7450 Ethernet Service Switch
7750 Service Router
7950 Extensible Routing System
Virtualized Service Router

Releases up to 24.10.R2

Unicast Routing Protocols Advanced Configuration Guide for MD CLI

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Table of contents

List of tables

List of figures

Preface

About This Guide

Each Advanced Configuration Guide is organized alphabetically and provides feature and configuration explanations, CLI descriptions, and overall solutions. The Advanced Configuration Guide chapters are written for and based on several Releases, up to 24.10.R2. The Applicability section in each chapter specifies on which release the configuration is based.

The Advanced Configuration Guides supplement the user configuration guides listed in the *7450 ESS, 7750 SR, and 7950 XRS Guide to Documentation*.

Audience

This manual is intended for network administrators who are responsible for configuring the routers. It is assumed that the network administrators have a detailed understanding of networking principles and configurations.

Advertising IPv4 NLRI with IPv6 Next-Hop

This chapter describes Advertising IPv4 NLRI with IPv6 Next-Hop.

Topics in this chapter include:

Applicability

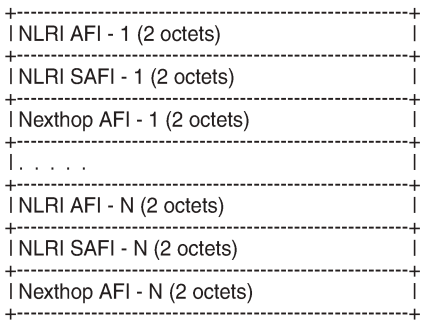
The information and configuration in this chapter are based on SR OS Release 24.3.R1. Advertising IPv4 Network Layer Reachability Information (NLRI) with IPv6 next-hop is supported in SR OS Release 19.5.R1 and later.

Overview

In networks where the routers are interconnected by IPv6-only links, SR OS routers can advertise and receive BGP routes that convey reachability to IPv4-unicast destinations that are reachable through IPv6 next-hops. Advertising and receiving IPv4 routes with IPv6 next-hops is useful in networks or regions with IPv6-only interfaces, such as data center deployments where leaf, spine, and aggregation routers are interconnected by IPv6-only links that carry a mix of unencapsulated IPv4 and IPv6 packets.

This feature requires the Extended Next Hop encoding BGP capability which is described in RFC 5549, *Advertising IPv4 Network Layer Reachability Information with an IPv6 Next Hop*. BGP capabilities are advertised between peers. For the Extended Next Hop encoding capability, the capability code field must be set to 5, the capability length field set to the length of the capability value field, and a capability value field with the format shown in Figure 1: Capability value field format:

Figure 1: Capability value field format



Each triplet (NLRI AFI, NLRI SAFI, Nexthop AFI) indicates that NLRI AFI/SAFI may be advertised with a next-hop address belonging to the network-layer protocol of "Nexthop AFI".

By default, IPv4-unicast routes are advertised with IPv4 next-hops. However, on IPv6-only TCP transport sessions, IPv4-unicast routes can be advertised with IPv6 next-hops if the **advertise-ipv6-next-hops** command with the **ipv4 true** option applies to the session. The **advertise-ipv6-next-hops** command can be enabled for several address families, as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            advertise-ipv6-next-hops ?

 advertise-ipv6-next-hops

 evpn                  - Advertise EVPN route with IPv6 next-hop address
 ipv4                  - Advertise IPv4 route with IPv6 next-hop address
 label-ipv4            - Advertise label IPv4 route with IPv6 next-hop address
 label-ipv6            - Advertise label IPv6 route with IPv6 next-hop address
 vpn-ipv4              - Advertise VPN IPv4 route with IPv6 next-hop address
 vpn-ipv6              - Advertise VPN IPv6 route with IPv6 next-hop address
```

For receiving IPv4-unicast routes with IPv6 next-hop addresses, the **extended-nh-encoding** command with the **ipv4 true** option must be applied to the session. This advertises the RFC 5549 capability to the peer for the different address families. The **extended-nh-encoding** command can be configured for several address families, as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            extended-nh-encoding ?

 extended-nh-encoding

 ipv4                  - Advertise encoding capability for IPv4 routes
 label-ipv4            - Advertise encoding capability for label-IPv4 routes
 vpn-ipv4              - Advertise encoding capability for VPN-IPv4 routes
```

When the BGP session is established, the BGP peers advertise the capability to each other, and the Extended Next Hop encoding capability is both a local and a remote capability, as in the following example between BGP peers 2001:db8::12:1 and 2001:db8::12:2:

```
[/]
A:admin@PE-1# show router bgp neighbor "2001:db8::12:2" | match "Capability" post-lines 1
Local Capability     : RtRefresh MPBGP 4byte ASN ExtNhEncoding
Remote Capability    : RtRefresh MPBGP 4byte ASN ExtNhEncoding
---snip---
```

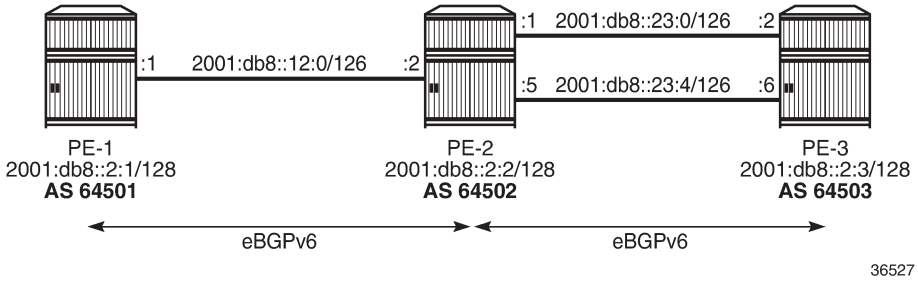
When **next-hop-self true** applies to the BGP session and the neighbor address is IPv6, an IPv4-unicast route that is advertised or re-advertised gets the following as next-hop:

- The IPv6 local address used for peering, if the peer opened the BGP session by advertising an extended next-hop encoding capability with NLRI AFI=1, SAFI=1, and nexthop AFI=2, and the session is associated with an **advertise-ipv6-next-hops ipv4 true** command.
- The IPv4 system interface address in all other cases.

Configuration

Figure 2: Example topology with IPv6 interfaces shows the example topology with three nodes with IPv6-only interfaces in different Autonomous Systems (ASs).

Figure 2: Example topology with IPv6 interfaces

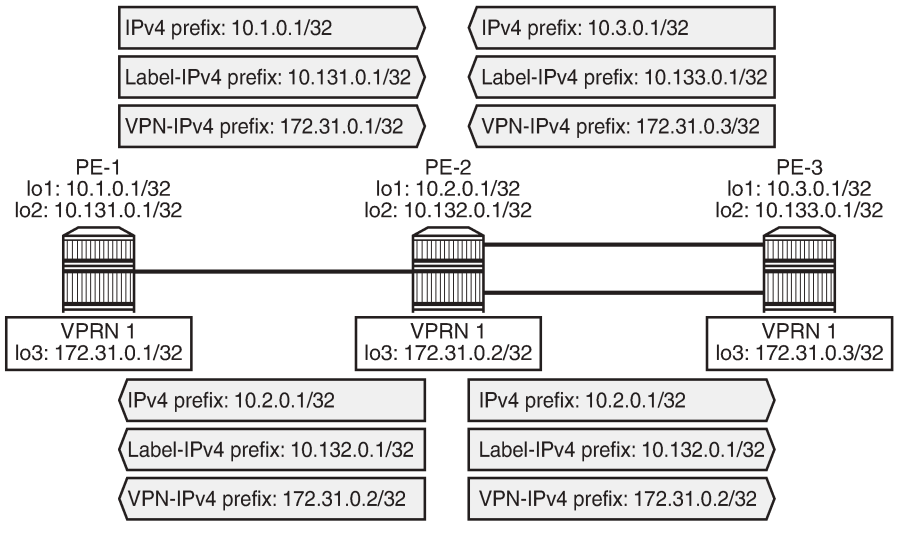


The initial configuration includes:

- Cards, MDAs, ports
- Router interfaces with IPv6 addresses

In the example, IPv4, label-IPv4, and VPN-IPv4 routes are advertised with an IPv6 next-hop. On PE-1, loopback interfaces lo1 (10.1.0.1/32) and lo2 (10.131.0.1/32) are configured; lo1 is advertised as an IPv4 route and lo2 as a label-IPv4 route. VPRN 1 is configured on all nodes with loopback interface lo3, and prefix 172.31.0.1/32 is advertised as a VPN-IPv4 route on PE-1. PE-2 and PE-3 have similar loopback interfaces. Figure 3: Loopback addresses and advertised IPv4, label-IPv4, and VPN-IPv4 routes shows the loopback addresses and the advertised routes.

Figure 3: Loopback addresses and advertised IPv4, label-IPv4, and VPN-IPv4 routes



On PE-2, the interface configuration is as follows:

```
# on PE-2:
configure {
    router "Base" {
        interface "int-PE-2-PE-1" {
            port 1/1/c2/1
            ipv6 {
                address 2001:db8::12:2 {
                    prefix-length 126
                }
            }
        }
        interface "int-PE-2-PE-3-0" {
            port 1/1/c1/1
            ipv6 {
                address 2001:db8::23:1 {
                    prefix-length 126
                }
            }
        }
        interface "int-PE-2-PE-3-4" {
            port 1/1/c3/1
            ipv6 {
                address 2001:db8::23:5 {
                    prefix-length 126
                }
            }
        }
        interface "lo1" {
            loopback
            ipv4 {
                primary {
                    address 10.2.0.1
                    prefix-length 32
                }
            }
            ipv6 {
                address 2001:db8::10:2:0:1 {
                    prefix-length 128
                }
            }
        }
        interface "lo2" {
            loopback
            ipv4 {
                primary {
                    address 10.132.0.1
                    prefix-length 32
                }
            }
            ipv6 {
                address 2001:db8::10:132:0:1 {
                    prefix-length 128
                }
            }
        }
        interface "system" {
            ipv4 {
                primary {
                    address 192.0.2.2
                    prefix-length 32
                }
            }
```

```
            ipv6 {
                address 2001:db8::2:2 {
                    prefix-length 128
                }
            }
        }
    }
}
```

The interface configuration on PE-1 and on PE-3 is similar.

On PE-2, the VPRN configuration is as follows:

```
# on PE-2:
configure {
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            ecmp 2
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64502:1"
                    vrf-target {
                        community "target:1:1"
                    }
                    auto-bind-tunnel {
                        resolution filter
                    }
                }
            }
            interface "lo3" {
                loopback true
                ipv4 {
                    primary {
                        address 172.31.0.2
                        prefix-length 32
                    }
                }
                ipv6 {
                    address 2001:db8::172:31:0:2 {
                        prefix-length 128
                    }
                }
            }
        }
    }
}
```

The VPRN configuration on PE-1 and on PE-3 is similar.

On PE-2, eBGP is configured toward three IPv6 neighbors with **next-hop-self true** enabled. For each of the BGP neighbors, **extended-nh-encoding** and **advertise-ipv6-next-hops** are configured for different address families. The BGP configuration is as follows:

```
# on PE-2:
configure {
    router "Base" {
        autonomous-system 64502
        ecmp 2
        bgp {
```

```
            inter-as-vpn true
            ebgp-default-reject-policy {
                import false
                export false
            }
            multipath {
                max-paths 2
                ebgp 2
            }
            group "eBGP-IPv6" {
                loop-detect discard-route
                next-hop-self true
                split-horizon true
                family {
                    ipv4 true
                    vpn-ipv4 true
                    ipv6 true
                    vpn-ipv6 true
                    label-ipv4 true
                    label-ipv6 true
                }
                local-as {
                    as-number 64502
                }
                import {
                    policy ["import-1:1-3:3"]
                }
                export {
                    policy ["export-10.2" "export-10.132"]
                }
                extended-nh-encoding {
                    vpn-ipv4 true
                    label-ipv4 true
                    ipv4 true
                }
                advertise-ipv6-next-hops {
                    vpn-ipv6 true
                    label-ipv6 true
                    vpn-ipv4 true
                    label-ipv4 true
                    ipv4 true
                }
            }
            neighbor "2001:db8::12:1" {
                group "eBGP-IPv6"
                peer-as 64501
            }
            neighbor "2001:db8::23:2" {
                group "eBGP-IPv6"
                peer-as 64503
            }
            neighbor "2001:db8::23:6" {
                group "eBGP-IPv6"
                peer-as 64503
            }
        }
    }
}
```

where configurations that apply for all neighbors are moved to the BGP group to which they belong. The BGP configuration on PE-1 and on PE-3 is similar.

Import and export policies tailor the information that the BGP neighbors exchange. On PE-2, the policies are configured as follows:

```
# on PE-2:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        community "2:2" {
            member "2:2" { }
        }
        community "3:3" {
            member "3:3" { }
        }
        prefix-list "10.2.0.0/16" {
            prefix 10.2.0.0/16 type longer { }
        }
        prefix-list "10.132.0.0/16" {
            prefix 10.132.0.0/16 type longer { }
        }
        prefix-list "2001:db8::10:2:0:0/96" {
            prefix 2001:db8::10:2:0:0/96 type longer { }
        }
        prefix-list "2001:db8::10:132:0:0/96" {
            prefix 2001:db8::10:132:0:0/96 type longer { }
        }
        policy-statement "export-10.2" {
            entry 10 {
                from {
                    prefix-list ["10.2.0.0/16"]
                }
                to {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    community {
                        add ["2:2"]
                    }
                }
            }
            entry 20 {
                from {
                    prefix-list ["2001:db8::10:2:0:0/96"]
                }
                to {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    community {
                        add ["2:2"]
                    }
                }
            }
        }
        policy-statement "export-10.132" {
            entry 10 {
```

```
                from {
                    prefix-list ["10.132.0.0/16"]
                }
                to {
                    protocol {
                        name [bgp-label]
                    }
                }
                action {
                    action-type accept
                    community {
                        add ["2:2"]
                    }
                }
            }
            entry 20 {
                from {
                    prefix-list ["2001:db8::10:132:0:0/96"]
                }
                to {
                    protocol {
                        name [bgp-label]
                    }
                }
                action {
                    action-type accept
                    community {
                        add ["2:2"]
                    }
                }
            }
        }
        policy-statement "import-1:1-3:3" {
            entry 10 {
                from {
                    community {
                        name "1:1"
                    }
                }
                action {
                    action-type accept
                }
            }
            entry 20 {
                from {
                    community {
                        name "3:3"
                    }
                }
                action {
                    action-type accept
                }
            }
        }
    }
}
```

The policies on PE-1 and on PE-3 are similar.

The BGP summary on PE-1 shows that for each of the configured address families, one route is advertised and two routes are received and accepted:

```
[/]
```

```
A:admin@PE-1# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
2001:db8::12:2
Def. Inst       64502      34    0 00h04m59s 2/2/1 (IPv4)
                           28    0           2/2/1 (IPv6)
                                             2/2/1 (VpnIPv4)
                                             2/2/1 (VpnIPv6)
                                             2/2/1 (Lbl-IPv4)
                                             2/2/1 (Lbl-IPv6)

-------------------------------------------------------------------------------
```

On PE-1, the following IPv4 routes with IPv6 next-hop are received and used: route 10.2.0.1/32 originates from PE-2 and route 10.3.0.1/32 from PE-3. Both routes have next-hop 2001:db8::12:2 because **next-hop-self true** is enabled, as follows:

```
[/]
A:admin@PE-1# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.1        AS:64501       Local AS:64501
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.2.0.1/32                                      None        None
      2001:db8::12:2                                   None        0
      64502                                                        -
u*>i  10.3.0.1/32                                      None        None
      2001:db8::12:2                                   None        0
      64502 64503                                                  -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

On PE-2, the following VPN-IPv4 routes with different IPv6 next-hops are received and used:

```
[/]
A:admin@PE-2# show router bgp routes vpn-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64502       Local AS:64502
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
```

```
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64501:1:172.31.0.1/32                            None        None
      2001:db8::12:1                                   None        0
      64501                                                        524283
u*>i  64503:1:172.31.0.3/32                            None        None
      2001:db8::23:2                                   None        0
      64503                                                        524281
u*>i  64503:1:172.31.0.3/32                            None        None
      2001:db8::23:6                                   None        0
      64503                                                        524281
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

On PE-3, the following label-IPv4 routes with IPv6 next-hop are received and used. Route 10.131.0.1/32 originates from PE-1 and is re-advertised by PE-2 on two eBGP paths, with next-hop addresses 2001:db8::23:1 and 2001:db8::23:5. Route 10.132.0.1/32 originates from PE-2 and is also advertised over these two eBGP paths.

```
[/]
A:admin@PE-3# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.3        AS:64503       Local AS:64503
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.131.0.1/32                                    None        None
      2001:db8::23:1                                   None        0
      64502 64501                                                  524286
u*>i  10.131.0.1/32                                    None        None
      2001:db8::23:5                                   None        0
      64502 64501                                                  524286
u*>i  10.132.0.1/32                                    None        None
      2001:db8::23:1                                   None        0
      64502                                                        524287
u*>i  10.132.0.1/32                                    None        None
      2001:db8::23:5                                   None        0
      64502                                                        524287
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

The route table on PE-3 includes BGP IPv4 and label-IPv4 routes with IPv6 next-hops, as follows:

```
[/]
A:admin@PE-3# show router route-table

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
10.1.0.1/32                                     Remote  BGP       00h07m07s  170
       2001:db8::23:1                                               0
10.1.0.1/32                                     Remote  BGP       00h07m07s  170
       2001:db8::23:5                                               0
10.2.0.1/32                                     Remote  BGP       00h07m07s  170
       2001:db8::23:1                                               0
10.2.0.1/32                                     Remote  BGP       00h07m07s  170
       2001:db8::23:5                                               0
10.3.0.1/32                                     Local   Local     00h15m16s  0
       lo1                                                          0
10.131.0.1/32                                   Remote  BGP_LABEL 00h07m07s  170
       2001:db8::23:1                                               0
10.131.0.1/32                                   Remote  BGP_LABEL 00h07m07s  170
       2001:db8::23:5                                               0
10.132.0.1/32                                   Remote  BGP_LABEL 00h07m07s  170
       2001:db8::23:1                                               0
10.132.0.1/32                                   Remote  BGP_LABEL 00h07m07s  170
       2001:db8::23:5                                               0
10.133.0.1/32                                   Local   Local     00h15m16s  0
       lo2                                                          0
192.0.2.3/32                                    Local   Local     00h15m16s  0
       system                                                       0
-------------------------------------------------------------------------------
No. of Routes: 11
---snip---
===============================================================================
```

The tunnel table on PE-3 shows four BGP tunnels with IPv6 next-hops, as follows:

```
[/]
A:admin@PE-3# show router tunnel-table

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
10.131.0.1/32         bgp       MPLS  262146    12     2001:db8::23:1 1000
10.131.0.1/32         bgp       MPLS  262146    12     2001:db8::23:5 1000
10.132.0.1/32         bgp       MPLS  262145    12     2001:db8::23:1 1000
10.132.0.1/32         bgp       MPLS  262145    12     2001:db8::23:5 1000
-------------------------------------------------------------------------------
---snip---
===============================================================================
```

The route table for VPRN 1 on PE-3 includes BGP VPN-IPv4 routes with IPv6 next-hops, as follows:

```
[/]
A:admin@PE-3# show router "1" route-table
```

```
===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
172.31.0.1/32                                   Remote  BGP VPN   00h05m28s  170
       2001:db8::23:1                                               0
172.31.0.1/32                                   Remote  BGP VPN   00h05m28s  170
       2001:db8::23:5                                               0
172.31.0.2/32                                   Remote  BGP VPN   00h05m28s  170
       2001:db8::23:1                                               0
172.31.0.2/32                                   Remote  BGP VPN   00h05m28s  170
       2001:db8::23:5                                               0
172.31.0.3/32                                   Local   Local     00h05m32s  0
       lo3                                                          0
-------------------------------------------------------------------------------
No. of Routes: 5
---snip---
===============================================================================
```

The reachability between source address 172.31.0.3 and destination 172.31.0.1 can be verified, but the following traceroute does not display any address for the intermediate node:

```
[/]
A:admin@PE-3# traceroute 172.31.0.1 router-instance "VPRN 1" numeric source-address 172.31.0.3
traceroute to 172.31.0.1 from 172.31.0.3, 30 hops max, 40 byte packets
  1  0.0.0.0  * * *
  2  172.31.0.1    3.42 ms  3.29 ms  3.62 ms
```

However, the following traceroute from lo1 on PE-3 to lo1 on PE-1 fails:

```
[/]
A:admin@PE-3# traceroute 10.1.0.1 numeric source-address 10.3.0.1
traceroute to 10.1.0.1 from 10.3.0.1, 30 hops max, 40 byte packets
  1  0.0.0.0  * * *
  2  0.0.0.0  * * *
  3  0.0.0.0  * * *
  4  0.0.0.0  * * *
  5  0.0.0.0  * * *
  6  0.0.0.0  * ^C
traceroute aborted by user
```

In an IPv6-only network, the IPv4 interfaces are down, as follows:

```
[/]
A:admin@PE-2# show router interface

===============================================================================
Interface Table (Router: Base)
===============================================================================
Interface-Name                   Adm       Opr(v4/v6)  Mode    Port/SapId
   IP-Address                                                   PfxState
-------------------------------------------------------------------------------
int-PE-2-PE-1                    Up        Down/Up     Network 1/1/c2/1
   2001:db8::12:2/126                                           PREFERRED
   fe80::60e:1ff:fe01:b/64                                      PREFERRED
int-PE-2-PE-3-0                  Up        Down/Up     Network 1/1/c1/1
   2001:db8::23:1/126                                           PREFERRED
   fe80::60e:1ff:fe01:1/64                                      PREFERRED
int-PE-2-PE-3-4                  Up        Down/Up     Network 1/1/c3/1
   2001:db8::23:5/126                                           PREFERRED
```

```
   fe80::60e:1ff:fe01:15/64                                    PREFERRED
lo1                           Up        Up/Up       Network loopback
   10.2.0.1/32                                                 n/a
   2001:db8::10:2:0:1/128                                      PREFERRED
   fe80::202:feff:fe00:0/64                                    PREFERRED
lo2                           Up        Up/Up       Network loopback
   10.132.0.1/32                                               n/a
   2001:db8::10:132:0:1/128                                    PREFERRED
   fe80::202:feff:fe00:0/64                                    PREFERRED
system                        Up        Up/Up       Network system
   192.0.2.2/32                                                n/a
   2001:db8::2:2/128                                           PREFERRED
-------------------------------------------------------------------------------
Interfaces : 6
===============================================================================
```

To allow CPM-originated or terminated packets, such as IPv4 ping or traceroute traffic, the **forward-ipv4-packets** command is configured in the **ipv6** context of these interfaces, as follows:

```
# on PE-2:
configure {
    router "Base" {
        interface "int-PE-2-PE-1" {
            ipv6 {
                forward-ipv4-packets true
            }
        }
        interface "int-PE-2-PE-3-0" {
            ipv6 {
                forward-ipv4-packets true
            }
        }
        interface "int-PE-2-PE-3-4" {
            ipv6 {
                forward-ipv4-packets true
            }
        }
    }
}
```

The configuration on PE-1 and on PE-3 is similar.

The connectivity between the lo1 and lo2 interfaces can now be verified from PE-3, as follows:

```
[/]
A:admin@PE-3# traceroute 10.1.0.1 numeric source-address 10.3.0.1
traceroute to 10.1.0.1 from 10.3.0.1, 30 hops max, 40 byte packets
  1  10.2.0.1    2.36 ms  2.81 ms  2.94 ms
  2  10.1.0.1    3.97 ms  3.45 ms  3.65 ms
```

```
[/]
A:admin@PE-3# traceroute 10.2.0.1 numeric source-address 10.3.0.1
traceroute to 10.2.0.1 from 10.3.0.1, 30 hops max, 40 byte packets
  1  10.2.0.1    2.57 ms  2.98 ms  3.02 ms
```

```
[/]
A:admin@PE-3# traceroute 10.131.0.1 numeric source-address 10.133.0.1
traceroute to 10.131.0.1 from 10.133.0.1, 30 hops max, 40 byte packets
  1  10.2.0.1    2.56 ms  2.67 ms  2.86 ms
```

```
  2  10.131.0.1    3.70 ms  3.85 ms  3.60 ms
```

```
[/]
A:admin@PE-3# traceroute 10.132.0.1 numeric source-address 10.133.0.1
traceroute to 10.132.0.1 from 10.133.0.1, 30 hops max, 40 byte packets
  1  10.132.0.1    2.37 ms  2.93 ms  6.76 ms
```

With the **forward-ipv4-packets** command, the IOM is instructed by the CPM to consider the IPv4 operational state of the interface as up when the IPv6 interface is operationally up. IPv4 packets can be sent and received on the interface when the IPv6 interface is up, even when the IPv4 interface is operationally down.

PE-1 does not accept IPv4, VPN-IPv4 and label-IPv4 BGP routes that have an IPv6 next-hop, when **extended-nh-encoding** is not configured on PE-1 for the BGP neighbor on PE-2, as follows:

```
[/]
A:admin@PE-1# show router bgp neighbor "2001:db8::12:2" | match "Capability" post-lines 1
Local Capability     : RtRefresh MPBGP 4byte ASN
Remote Capability    : RtRefresh MPBGP 4byte ASN ExtNhEncoding
---snip---

[/]
A:admin@PE-2# show router bgp neighbor "2001:db8::12:1" | match "Capability" post-lines 1
Local Capability     : RtRefresh MPBGP 4byte ASN ExtNhEncoding
Remote Capability    : RtRefresh MPBGP 4byte ASN
---snip---
```

This is verified as follows:

```
[/]
A:admin@PE-1# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
2001:db8::12:2
Def. Inst       64502      24    0 00h01m44s 2/0/1 (IPv4)
                           18    0           2/2/1 (IPv6)
                                             2/0/1 (VpnIPv4)
                                             2/2/1 (VpnIPv6)
                                             2/0/1 (Lbl-IPv4)
                                             2/2/1 (Lbl-IPv6)

-------------------------------------------------------------------------------
```

PE-1 does not install the corresponding routes in its route tables.

- When **overextending true** is configured on PE-1:
  - the PE-1 route table has BGP routes to lo1 on PE-2, lo1 on PE-3, lo2 on PE-2, and lo2 on PE-3, via an IPv6 next-hop as follows:

    ```
    [/]
    ```

```
A:admin@PE-1# show router route-table ipv4

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                                Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
10.1.0.1/32                                       Local   Local     00h15m41s  0
       lo1                                                            0
10.2.0.1/32                                       Remote  BGP       00h07m12s  170
       2001:db8::12:2                                                 0
10.3.0.1/32                                       Remote  BGP       00h06m43s  170
       2001:db8::12:2                                                 0
10.131.0.1/32                                     Local   Local     00h15m41s  0
       lo2                                                            0
10.132.0.1/32                                     Remote  BGP_LABEL 00h07m12s  170
       2001:db8::12:2                                                 0
10.133.0.1/32                                     Remote  BGP_LABEL 00h06m43s  170
       2001:db8::12:2                                                 0
192.0.2.1/32                                      Local   Local     00h15m41s  0
       system                                                         0
-------------------------------------------------------------------------------
No. of Routes: 7
---snip---
===============================================================================
```

– the VPRN 1 route table on PE-1 has BGP routes to lo3 on PE-2 and lo3 on PE-3, via an IPv6 next-hop as follows:

```
[/]
A:admin@PE-1# show router "1" route-table ipv4

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                                Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
172.31.0.1/32                                     Local   Local     00h05m54s  0
       lo3                                                            0
172.31.0.2/32                                     Remote  BGP VPN   00h05m33s  170
       2001:db8::12:2                                                 0
172.31.0.3/32                                     Remote  BGP VPN   00h04m34s  170
       2001:db8::12:2                                                 0
-------------------------------------------------------------------------------
No. of Routes: 3
---snip---
===============================================================================
```

– the tunnel table on PE-1 has tunnels to lo2 on PE-2 and lo2 on PE-3, as follows:

```
[/]
A:admin@PE-1# show router tunnel-table

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
10.132.0.1/32         bgp       MPLS  262145    12     2001:db8::12:2 1000
10.133.0.1/32         bgp       MPLS  262146    12     2001:db8::12:2 1000
```

```
-------------------------------------------------------------------------------
---snip---
===============================================================================
```

- When **extended-nh-encoding** is not configured on PE-1:
  - those BGP routes and tunnels are missing, as follows:

```
[/]
A:admin@PE-1# show router route-table ipv4

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
10.1.0.1/32                                     Local   Local     00h30m32s  0
       lo1                                                          0
10.131.0.1/32                                   Local   Local     00h30m32s  0
       lo2                                                          0
192.0.2.1/32                                    Local   Local     00h30m32s  0
       system                                                       0
-------------------------------------------------------------------------------
No. of Routes: 3
---snip---
===============================================================================
```

```
[/]
A:admin@PE-1# show router "1" route-table ipv4

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
172.31.0.1/32                                   Local   Local     00h20m21s  0
       lo3                                                          0
-------------------------------------------------------------------------------
No. of Routes: 1
---snip---
===============================================================================
```

```
[/]
A:admin@PE-1# show router tunnel-table

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
No Matching Entries.
-------------------------------------------------------------------------------
---snip---
===============================================================================
```

  - and there is no connectivity from and to PE-1. This is verified as follows:

```
# on PE-1, towards PE-2 and PE-3
```

```
[/]
A:admin@PE-1# ping 10.2.0.1 source-address 10.1.0.1 count 5
PING 10.2.0.1 56 data bytes
---snip---
---- 10.2.0.1 PING Statistics ----
5 packets transmitted, 0 packets received, 100% packet loss

[/]
A:admin@PE-1# ping 10.3.0.1 source-address 10.1.0.1 count 5
PING 10.3.0.1 56 data bytes
---snip---
---- 10.3.0.1 PING Statistics ----
5 packets transmitted, 0 packets received, 100% packet loss

[/]
A:admin@PE-1# ping 10.132.0.1 source-address 10.131.0.1 count 5
PING 10.132.0.1 56 data bytes
---snip---
---- 10.132.0.1 PING Statistics ----
5 packets transmitted, 0 packets received, 100% packet loss

[/]
A:admin@PE-1# ping 10.133.0.1 source-address 10.131.0.1 count 5
PING 10.133.0.1 56 data bytes
---snip---
---- 10.133.0.1 PING Statistics ----
5 packets transmitted, 0 packets received, 100% packet loss

[/]
A:admin@PE-1# ping 172.31.0.2 router-instance "VPRN 1" source-address 172.31.0.1 count 5
PING 172.31.0.2 56 data bytes
---snip---
---- 172.31.0.2 PING Statistics ----
5 packets transmitted, 0 packets received, 100% packet loss

[/]
A:admin@PE-1# ping 172.31.0.3 router-instance "VPRN 1" source-address 172.31.0.1 count 5
PING 172.31.0.3 56 data bytes
---snip---
---- 172.31.0.3 PING Statistics ----
5 packets transmitted, 0 packets received, 100% packet loss
```

```
# on PE-3, towards PE-1 (similar on PE-2 towards PE-1):
[/]
A:admin@PE-3# ping 10.1.0.1 source-address 10.3.0.1 count 5
PING 10.1.0.1 56 data bytes
---snip---
---- 10.1.0.1 PING Statistics ----
5 packets transmitted, 0 packets received, 100% packet loss

---snip---

[/]
A:admin@PE-3# ping 10.131.0.1 source-address 10.133.0.1 count 5
PING 10.131.0.1 56 data bytes
---snip---
---- 10.131.0.1 PING Statistics ----
5 packets transmitted, 0 packets received, 100% packet loss

---snip---

[/]
A:admin@PE-3# ping 172.31.0.1 router-instance "VPRN 1" source-address 172.31.0.3 count 5
```

```
PING 172.31.0.1 56 data bytes
---snip---
---- 172.31.0.1 PING Statistics ----
5 packets transmitted, 0 packets received, 100% packet loss

---snip---
```

Conclusion

SR OS routers can advertise and receive BGP routes for IPv4 destinations with IPv6 next-hops. This feature requires the Extended Next Hop encoding BGP capability in RFC 5549 and is useful in IPv6-only networks or regions.

Associating Communities with Static and Aggregate Routes

This chapter provides information about associating communities with static and aggregate routes configurations.

Topics in this chapter include:

Applicability

This chapter was initially written for SR OS Release 11.0.R3, but the MD-CLI in this edition corresponds to SR OS Release 20.7.R2. There are no prerequisites for this configuration.

Introduction

Border gateway protocol (BGP) communities are optional, transitive attributes attached to BGP route prefixes to carry more information about that route prefix. Multiple route prefixes can have the same community attached such that it can be matched by a route policy. As a result, the presence of a community value can be used to influence and control route policies.

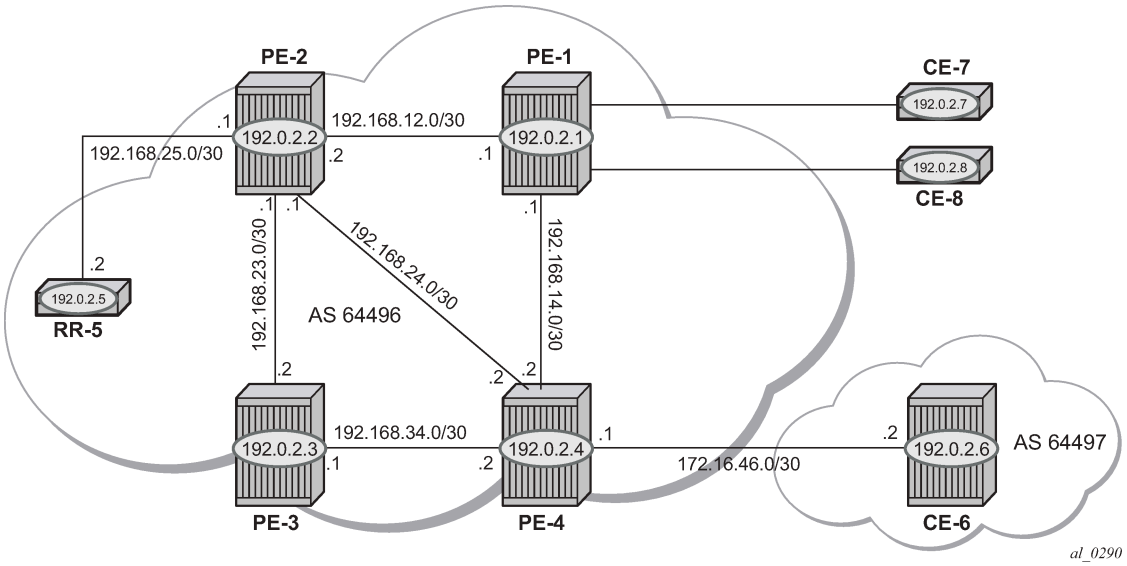
A BGP community is a 32-bit value that is written as two 16-bit numbers separated by a colon. The first number usually represents the autonomous system (AS) number that defines or originates the community while the second is set by the network administrator.

Knowledge of RFC 4271 (BGP-4) and RFC 1997 (BGP Communities Attribute) is assumed throughout this document, as well as knowledge of multi-protocol BGP (MP-BGP) and RFC 4364 (BGP/MPLS IP VPNs).

Overview

Figure 4: Example topology shows the example topology with 7750 Server Router nodes. PE-1 to PE-4 and the Route Reflector (RR-5) are located in the same Autonomous System (AS): AS 64496. CE-6 is in a separate AS 64497 and peers using eBGP with its directly connected neighbor, PE-4.

Figure 4: Example topology



The objectives are:

- To configure static routes in a VPRN in PE-1 with various community values—including well-known communities—export them to other PEs within the same AS, and then via eBGP to CE-6. During this process, the community values for each route will be examined to ensure that the transitive nature of the attribute is maintained.
- To associate a community with an aggregate route that represents a larger number of composite prefixes. The aggregate will be advertised in place of the composite prefixes.

The following configuration tasks should be completed as a prerequisite:

- Full mesh IS-IS or OSPF between all of the PE routers and the RR.
- iBGP between the RR and all PEs.
- eBGP between PE-4 and CE-6.
- Link-layer LDP between all PEs.

Associating communities with static and aggregate routes

It is possible to add a single community value to a static and aggregate route without using a route policy.

The community value can be in the 4-byte format comprising of a 2-byte AS value, followed by a 2-byte decimal value, separated by a colon. It can also be the name of a well-known standard community, such as: no-export, no-advertise, no-export-subconfed.

Any community added can be matched using a route policy.

The purpose of this example is to provision static and aggregate IPv4 route prefixes and associate a community with each route. These routes are then redistributed into the BGP protocol and advertised to other BGP speakers.

This is shown for IPv4 routes within a VPRN. Well-known, standard communities will also be configured to show that the correct behavior is observed.

Configuration

The first step is to configure an iBGP session between each of the PEs and the Route Reflector (RR). The address family negotiated between peers is VPN-IPv4.

The following BGP configuration is identical for all PEs:

```
# on all PEs:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            group "internal" {
                peer-as 64496
                family {
                    vpn-ipv4 true
                }
            }
            neighbor "192.0.2.5" {
                group "internal"
            }
```

The IP addresses can be derived from Figure 4: Example topology.

The BGP configuration for RR-5 is as follows:

```
# on RR-5:
configure {
 router "Base" {
        autonomous-system 64496
        bgp {
            cluster {
                cluster-id 0.0.0.1
            }
            group "RR-clients" {
                peer-as 64496
                family {
                    vpn-ipv4 true
                }
            }
            neighbor "192.0.2.1" {
                group "RR-clients"
            }
            neighbor "192.0.2.2" {
                group "RR-clients"
            }
            neighbor "192.0.2.3" {
                group "RR-clients"
            }
            neighbor "192.0.2.4" {
                group "RR-clients"
            }
```

The following BGP summary on RR-5 shows that BGP sessions with each PE are established for the VPN-IPv4 address family:

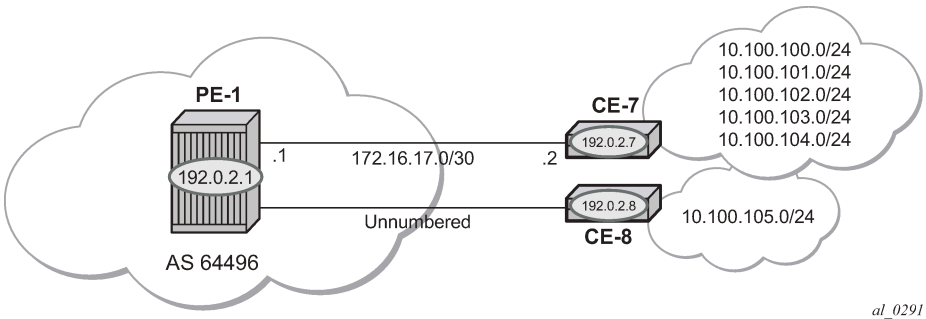
```
[]
A:admin@RR-5# show router bgp summary all
```

```
===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.1
Def. Instance  64496        3    0 00h00m11s 0/0/0 (VpnIPv4)
                            3    0
192.0.2.2
Def. Instance  64496        3    0 00h00m11s 0/0/0 (VpnIPv4)
                            3    0
192.0.2.3
Def. Instance  64496        3    0 00h00m11s 0/0/0 (VpnIPv4)
                            3    0
192.0.2.4
Def. Instance  64496        3    0 00h00m11s 0/0/0 (VpnIPv4)
                            3    0

-------------------------------------------------------------------------------
```

VPRN: IPv4

Figure 5: CE connections for next-hops shows the Customer Edge (CE) routers connected to PE-1.

Figure 5: CE connections for next-hops



The VPRN configuration for PE-1 is as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            route-distinguisher "64496:1"
            vrf-target {
                community "target:64496:1"
            }
            auto-bind-tunnel {
                resolution filter
                resolution-filter {
```

```
                ldp true
            }
        }
        interface "int-PE-1-CE-7" {
            ipv4 {
                primary {
                    address 172.16.17.1
                    prefix-length 30
                }
            }
            sap 1/2/1:1.0 {
            }
        }
        interface "int-PE-1-CE-8" {
            ipv4 {
                unnumbered {
                    ip-int-name "loop1"
                }
            }
            sap 1/2/2:1.0 {
            }
        }
        interface "loop1" {
            loopback true
            ipv4 {
                primary {
                    address 192.0.2.100
                    prefix-length 32
                }
            }
        }
```

For unnumbered interfaces, an IP address is borrowed from a loopback interface, see "Unnumbered Interfaces in RSVP-TE and LDP" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR MPLS Advanced Configuration Guide for Classic CLI*.

LDP is used as the label-switching protocol for next-hop resolution.

PE-4 is configured with an interface toward CE-6 that supports eBGP. The following export policy is configured:

```
# on PE-4:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        policy-statement "BGP-VPN-accept" {
            entry 10 {
                from {
                    protocol {
                        name [bgp-vpn]
                    }
                }
                action {
                    action-type accept
                    community {
                        add ["1:1"]
                    }
                }
            }
        }
```

The configuration of the VPRN service "VPRN 1" on PE-4 is as follows:

```
# on PE-4:
configure {
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            autonomous-system 64496
            route-distinguisher "64496:1"
            vrf-target {
                community "target:64496:1"
            }
            auto-bind-tunnel {
                resolution filter
                resolution-filter {
                    ldp true
                }
            }
            bgp {
                group "VPRN1-external" {
                    peer-as 64497
                    export {
                        policy ["BGP-VPN-accept"]
                    }
                    import {
                        policy ["1:1"]
                    }
                }
                neighbor "172.16.46.2" {
                    group "VPRN1-external"
                }
            }
            interface "int-PE-4-CE-6" {
                ipv4 {
                    primary {
                        address 172.16.46.1
                        prefix-length 30
                    }
                }
                sap 1/2/1:1 {
                }
            }
```

Static routes with communities

A static route has multiple next-hop options: direct connected IP address, black-hole, indirect IP address, and interface-name.

Figure 5: CE connections for next-hops shows a pair of CE routers connected to PE-1. The link to CE-7 is a numbered link. The link to CE-8 is an unnumbered link. The loopback interface address is used as a reference address for the unnumbered Ethernet interface.

Beyond CE-7 are several /24 subnets. Static routes to these individual subnets are created on PE-1 using a static route with a next-hop type of "interface address" or an "indirect address". The indirect address is learned using a static route.

Beyond CE-8 is a single /24 subnet. A static route to this subnet is created with an interface-name as the next-hop.

There are several well-known, standard communities:

- **no-export**: the route is not advertised to any external peer. This route should be present in the route tables of all BGP speakers in the originating AS, but not in those in neighboring ASs.
- **no-advertise**: the route is not advertised to any peer. This route should not be present in any router as BGP-learned route.

The requirement for each subnet is:

- 10.100.100.0/24 must not be advertised outside of the AS. This must be associated with the standard, well-known community **no-export**. The community value is encoded as 65535:65281 (0xFFFFFF01), but the CLI requires the keyword **no-export**.

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            static-routes {
                route 10.100.100.0/24 route-type unicast {
                    next-hop "172.16.17.2" {
                        admin-state enable
                        community "no-export"
                    }
                }
```

- 10.100.101.0/24 must be advertised with a community of 64496:101

```
                route 10.100.101.0/24 route-type unicast {
                    next-hop "172.16.17.2" {
                        admin-state enable
                        community "64496:101"
                    }
                }
```

- 10.100.102.0/24 must not be advertised to any BGP peer. This must be associated with the standard, well-known community **no-advertise**. The community value is encoded as 65535:65282 (0xFFFFFF02), but the CLI requires the keyword **no-advertise**.

```
                route 10.100.102.0/24 route-type unicast {
                    next-hop "172.16.17.2" {
                        admin-state enable
                        community "no-advertise"
                    }
                }
```

- 10.100.103.0/24 must be advertised with a community of 64496:103 and a route tag of 10.

```
                route 10.100.103.0/24 route-type unicast {
                    next-hop "172.16.17.2" {
                        admin-state enable
                        tag 10
                        community "64496:103"
                    }
                }
```

- 10.100.104.0/24 must be advertised with a community of 64496:104. It is reachable via 192.0.2.7 which, in turn, is reachable via 172.16.17.2. This is using a static route which does not need to be advertised, therefore, it is associated with the **no-advertise** community.

```
route 10.100.104.0/24 route-type unicast {
    indirect 192.0.2.7 {
        admin-state enable
        community "64496:104"
    }
}
route 192.0.2.7/32 route-type unicast {
    next-hop "172.16.17.2" {
        admin-state enable
        community "no-advertise"
    }
}
```

- 10.100.105.0/24 must be advertised with a community of 64496:105. It is reachable via the unnumbered interface to CE-8.

```
route 10.100.105.0/24 route-type unicast {
    interface "int-PE-1-CE-8" {
        admin-state enable
        community "64496:105"
    }
}
```

On PE-1, static routes are configured that match the static routes from Figure 5: CE connections for next-hops, and the preceding conditions.

The default behavior of a VPRN is to export all static and connected routes into a BGP labeled route with the appropriate route-target extended community configured in the VRF-target statement. A single community string can be added using the preceding static-route community commands. If multiple communities are required, then a VRF-export policy should be used, but this is outside the scope of this chapter.

The following BGP table on PE-1 shows which VPN-IPv4 routes have been exported correctly to RR-5:

```
[]
A:admin@PE-1# show router bgp neighbor 192.0.2.5 advertised-routes vpn-ipv4
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
i     64496:1:10.100.100.0/24                          100         None
      192.0.2.1                                        None        n/a
      No As-Path                                                   524283
i     64496:1:10.100.101.0/24                          100         None
      192.0.2.1                                        None        n/a
      No As-Path                                                   524283
```

```
i     64496:1:10.100.103.0/24                                 100         None
      192.0.2.1                                               None        n/a
      No As-Path                                                          524283
i     64496:1:10.100.104.0/24                                 100         None
      192.0.2.1                                               None        n/a
      No As-Path                                                          524283
i     64496:1:10.100.105.0/24                                 100         None
      192.0.2.1                                               None        n/a
      No As-Path                                                          524283
i     64496:1:172.16.17.0/30                                  100         None
      192.0.2.1                                               None        n/a
      No As-Path                                                          524283
i     64496:1:192.0.2.100/32                                  100         None
      192.0.2.1                                               None        n/a
      No As-Path                                                          524283
-------------------------------------------------------------------------------
Routes : 7
===============================================================================
```

There are only seven exported routes. The route prefixes associated with the **no-advertise** community are not present, as expected.

Examining the BGP table of PE-4 shows the presence of the expected routes, with the correct community values.

The prefix 10.100.100.0/24 is a member of community **no-export**. This is correctly advertised to PE-4, as follows:

```
[]
A:admin@PE-4# show router bgp routes 10.100.100.0/24 vpn-ipv4 detail
===============================================================================
 BGP Router ID:192.0.2.4        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Original Attributes

Network        : 10.100.100.0/24
Nexthop        : 192.0.2.1
Route Dist.    : 64496:1                VPN Label      : 524283
Path Id        : None
From           : 192.0.2.5
Res. Nexthop   : n/a
Local Pref.    : 100                    Interface Name : int-PE-4-PE-1
Aggregator AS  : None                   Aggregator     : None
Atomic Aggr.   : Not Atomic             MED            : None
AIGP Metric    : None                   IGP Cost       : 10
Connector      : None
Community      : no-export target:64496:1
Cluster        : 0.0.0.1
Originator Id  : 192.0.2.1              Peer Router Id : 192.0.2.5
Fwd Class      : None                   Priority       : None
Flags          : Used  Valid  Best  IGP
Route Source   : Internal
AS-Path        : No As-Path
Route Tag      : 0
Neighbor-AS    : n/a
```

```
Orig Validation: N/A
Source Class   : 0                     Dest Class     : 0
Add Paths Send : Default
Last Modified  : 01h16m07s
VPRN Imported  :  1
---snip---
```

The following command shows all members of the community **no-export**:

```
[]
A:admin@PE-4# show router bgp routes vpn-ipv4 community no-export
===============================================================================
 BGP Router ID:192.0.2.4        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64496:1:10.100.100.0/24                          100         None
      192.0.2.1                                        None        10
      No As-Path                                                   524283
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Because the community no-export is encoded as community 65535:65281, the same output can be retrieved as follows:

```
[]
A:admin@PE-4# show router bgp routes vpn-ipv4 community 65535:65281
===============================================================================
 BGP Router ID:192.0.2.4        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64496:1:10.100.100.0/24                          100         None
      192.0.2.1                                        None        10
      No As-Path                                                   524283
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The prefix 10.100.101.0/24 is a member of community 64496:101. This is correctly advertised to PE-4.

```
[]
A:admin@PE-4# show router bgp routes 10.100.101.0/24 vpn-ipv4 detail
===============================================================================
 BGP Router ID:192.0.2.4        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Original Attributes

Network        : 10.100.101.0/24
Nexthop        : 192.0.2.1
Route Dist.    : 64496:1                VPN Label      : 524283
Path Id        : None
From           : 192.0.2.5
Res. Nexthop   : n/a
Local Pref.    : 100                    Interface Name : int-PE-4-PE-1
Aggregator AS  : None                   Aggregator     : None
Atomic Aggr.   : Not Atomic             MED            : None
AIGP Metric    : None                   IGP Cost       : 10
Connector      : None
Community      : 64496:101 target:64496:1
Cluster        : 0.0.0.1
Originator Id  : 192.0.2.1              Peer Router Id : 192.0.2.5
Fwd Class      : None                   Priority       : None
Flags          : Used  Valid  Best  IGP
Route Source   : Internal
AS-Path        : No As-Path
Route Tag      : 0
Neighbor-AS    : n/a
Orig Validation: N/A
Source Class   : 0                      Dest Class     : 0
Add Paths Send : Default
Last Modified  : 01h34m23s
VPRN Imported  :  1
---snip---
```

The prefix 10.100.103.0/24 is a member of community 64496:103. This is correctly advertised to PE-4, as follows:

```
[]
A:admin@PE-4# show router bgp routes 10.100.103.0/24 vpn-ipv4 detail
===============================================================================
 BGP Router ID:192.0.2.4        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Original Attributes

Network        : 10.100.103.0/24
```

```
Nexthop         : 192.0.2.1
Route Dist.     : 64496:1                VPN Label      : 524283
Path Id         : None
From            : 192.0.2.5
Res. Nexthop    : n/a
Local Pref.     : 100                    Interface Name : int-PE-4-PE-1
Aggregator AS   : None                   Aggregator     : None
Atomic Aggr.    : Not Atomic             MED            : None
AIGP Metric     : None                   IGP Cost       : 10
Connector       : None
Community       : 64496:103 target:64496:1
Cluster         : 0.0.0.1
Originator Id   : 192.0.2.1              Peer Router Id : 192.0.2.5
Fwd Class       : None                   Priority       : None
Flags           : Used  Valid  Best  IGP
Route Source    : Internal
AS-Path         : No As-Path
Route Tag       : 0
Neighbor-AS     : n/a
Orig Validation: N/A
Source Class    : 0                      Dest Class     : 0
Add Paths Send : Default
Last Modified   : 01h26m24s
VPRN Imported   :  1
---snip---
```

The prefix 10.100.104.0/24 is a member of community 64496:104. This is correctly advertised to PE-4, as follows:

```
[]
A:admin@PE-4# show router bgp routes 10.100.104.0/24 vpn-ipv4 detail
===============================================================================
 BGP Router ID:192.0.2.4        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Original Attributes

Network         : 10.100.104.0/24
Nexthop         : 192.0.2.1
Route Dist.     : 64496:1                VPN Label      : 524283
Path Id         : None
From            : 192.0.2.5
Res. Nexthop    : n/a
Local Pref.     : 100                    Interface Name : int-PE-4-PE-1
Aggregator AS   : None                   Aggregator     : None
Atomic Aggr.    : Not Atomic             MED            : None
AIGP Metric     : None                   IGP Cost       : 10
Connector       : None
Community       : 64496:104 target:64496:1
Cluster         : 0.0.0.1
Originator Id   : 192.0.2.1              Peer Router Id : 192.0.2.5
Fwd Class       : None                   Priority       : None
Flags           : Used  Valid  Best  IGP
Route Source    : Internal
AS-Path         : No As-Path
Route Tag       : 0
```

```
Neighbor-AS    : n/a
Orig Validation: N/A
Source Class   : 0                     Dest Class     : 0
Add Paths Send : Default
Last Modified  : 01h20m45s
VPRN Imported  :  1
---snip---
```

The prefix 10.100.105.0/24 is a member of community 64496:105. This is correctly advertised to PE-4.

```
[]
A:admin@PE-4# show router bgp routes 10.100.105.0/24 vpn-ipv4 detail
===============================================================================
 BGP Router ID:192.0.2.4        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Original Attributes

Network        : 10.100.105.0/24
Nexthop        : 192.0.2.1
Route Dist.    : 64496:1               VPN Label      : 524283
Path Id        : None
From           : 192.0.2.5
Res. Nexthop   : n/a
Local Pref.    : 100                   Interface Name : int-PE-4-PE-1
Aggregator AS  : None                  Aggregator     : None
Atomic Aggr.   : Not Atomic            MED            : None
AIGP Metric    : None                  IGP Cost       : 10
Connector      : None
Community      : 64496:105 target:64496:1
Cluster        : 0.0.0.1
Originator Id  : 192.0.2.1             Peer Router Id : 192.0.2.5
Fwd Class      : None                  Priority       : None
Flags          : Used  Valid  Best  IGP
Route Source   : Internal
AS-Path        : No As-Path
Route Tag      : 0
Neighbor-AS    : n/a
Orig Validation: N/A
Source Class   : 0                     Dest Class     : 0
Add Paths Send : Default
Last Modified  : 01h18m11s
VPRN Imported  :  1
---snip---
```

The following route table of VPRN 1 on PE-4 shows that these seven BGP-learned routes are present as valid routes.

```
[]
A:admin@PE-4# show router 1 route-table protocol bgp-vpn

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
```

```
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.100.100.0/24                          Remote  BGP VPN   01h54m30s  170
       192.0.2.1 (tunneled)                                        0
10.100.101.0/24                          Remote  BGP VPN   01h46m55s  170
       192.0.2.1 (tunneled)                                        0
10.100.103.0/24                          Remote  BGP VPN   01h37m47s  170
       192.0.2.1 (tunneled)                                        0
10.100.104.0/24                          Remote  BGP VPN   01h30m18s  170
       192.0.2.1 (tunneled)                                        0
10.100.105.0/24                          Remote  BGP VPN   01h26m58s  170
       192.0.2.1 (tunneled)                                        0
172.16.17.0/30                           Remote  BGP VPN   01h54m30s  170
       192.0.2.1 (tunneled)                                        0
192.0.2.100/32                           Remote  BGP VPN   01h54m30s  170
       192.0.2.1 (tunneled)                                        0
-------------------------------------------------------------------------------
No. of Routes: 7
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The following route table on CE-6 shows six valid BGP-learned routes, as expected:

```
[]
A:admin@CE-6# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                       Type    Proto     Age        Pref
      Next Hop[Interface Name]                                 Metric
-------------------------------------------------------------------------------
10.100.101.0/24                          Remote  BGP       00h04m31s  170
       172.16.46.1                                                 0
10.100.103.0/24                          Remote  BGP       00h04m31s  170
       172.16.46.1                                                 0
10.100.104.0/24                          Remote  BGP       00h04m31s  170
       172.16.46.1                                                 0
10.100.105.0/24                          Remote  BGP       00h04m31s  170
       172.16.46.1                                                 0
172.16.17.0/30                           Remote  BGP       00h04m31s  170
       172.16.46.1                                                 0
192.0.2.100/32                           Remote  BGP       00h04m31s  170
       172.16.46.1                                                 0
-------------------------------------------------------------------------------
No. of Routes: 6
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The prefix 10.100.100.0/24 is not received from PE-4 because it is a member of the **no-export** community.

```
[]
A:admin@CE-6# show router bgp routes 10.100.100.0/24 detail

===============================================================================
 BGP Router ID:192.0.2.6        AS:64497       Local AS:64497
===============================================================================
```

```
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
No Matching Entries Found
===============================================================================
```

Static route 10.100.101.0/24 is received on CE-6 with the correct community 64496:101, as follows:

```
[]
A:admin@CE-6# show router bgp routes community 64496:101
===============================================================================
 BGP Router ID:192.0.2.6        AS:64497       Local AS:64497
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.100.101.0/24                                  None        None
      172.16.46.1                                      None        0
      64496                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Static route 10.100.103.0/24 is received on CE-6 with the correct community 64496:103, as follows:

```
[]
A:admin@CE-6# show router bgp routes community 64496:103
===============================================================================
 BGP Router ID:192.0.2.6        AS:64497       Local AS:64497
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.100.103.0/24                                  None        None
      172.16.46.1                                      None        0
      64496                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Static route 10.100.104.0/24 is received on CE-6 with the correct community 64496:104, as follows:

```
[]
A:admin@CE-6# show router bgp routes community 64496:104
===============================================================================
 BGP Router ID:192.0.2.6        AS:64497       Local AS:64497
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.100.104.0/24                                  None        None
      172.16.46.1                                      None        0
      64496                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Static route 10.100.105.0/24 is received on CE-6 with the correct community 64496:105.

```
[]
A:admin@CE-6# show router bgp routes community 64496:105
===============================================================================
 BGP Router ID:192.0.2.6        AS:64497       Local AS:64497
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.100.105.0/24                                  None        None
      172.16.46.1                                      None        0
      64496                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Aggregate routes with communities

An aggregate route can be configured to represent a larger number of prefixes. For example, a set of prefixes 10.101.0.0/24 to 10.101.7.0/24 can be represented as a single aggregate prefix of 10.101.0.0/21.

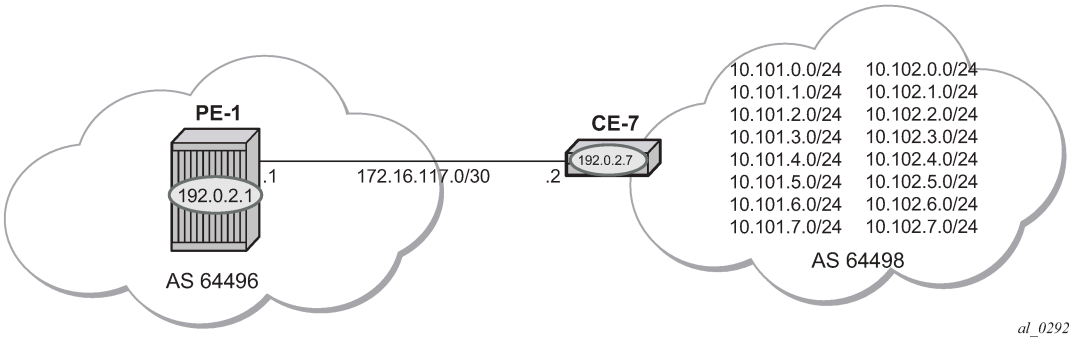
This is because the third octet in the range 0 to 7 can be represented by the 8 bits 00000000 to 00000111. The first 5 bits of this octet are common, along with the previous 2 octets, giving a prefix where the first 21 bits are common. Therefore, the aggregate can be written as 10.101.0.0/21.

To illustrate the configuration of an aggregate, consider following.

Figure 6: CE-7 connectivity shows a CE router (CE-7), in AS 64498, that advertises a series of contiguous prefixes via BGP.

- 10.101.0.0/24 to 10.101.7.0/24
- 10.102.0.0/24 to 10.102.7.0/24

Figure 6: CE-7 connectivity



Instead of advertising all these prefixes out of the VPRN toward an external CE individually, an aggregate route can be configured that summarizes each set of eight prefixes and a community can be directly associated with each aggregate route.

The configuration for VPRN service "VPRN 2" on PE-1, including the external BGP configuration is as follows:

```
# on PE-1:
configure {
    policy-options {
        community "1:2" {
            member "1:2" { }
        }
        policy-statement "1:2" {
            entry 10 {
                from {
                    community {
                        name "1:2"
                    }
                }
                action {
                    action-type accept
                }
            }
        }
    }
    service {
        vprn "VPRN 2" {
            admin-state enable
            service-id 2
            customer "1"
            autonomous-system 64496
            route-distinguisher "64496:2"
```

```
            vrf-target {
                community "target:64496:2"
            }
            auto-bind-tunnel {
                resolution filter
                resolution-filter {
                    ldp true
                }
            }
            bgp {
                group "external" {
                    peer-as 64498
                    import {
                        policy ["1:2"]
                    }
                    export {
                        policy ["1:2"]
                    }
                }
                neighbor "172.16.117.2" {
                    group "external"
                }
            }
            interface "int-PE-1-CE-7_2nd" {
                ipv4 {
                    primary {
                        address 172.16.117.1
                        prefix-length 30
                    }
                }
                sap 1/2/1:2.0 {
                }
            }
```

The BGP neighbor relationship on PE-1 shows the following:

```
[]
A:admin@PE-1# show router 2 bgp neighbor

===============================================================================
BGP Neighbor
===============================================================================
-------------------------------------------------------------------------------
Peer                 : 172.16.117.2
Description          : (Not Specified)
Group                : external
-------------------------------------------------------------------------------
Peer AS              : 64498           Peer Port           : 179
Peer Address         : 172.16.117.2
Local AS             : 64496           Local Port          : 50195
Local Address        : 172.16.117.1
Peer Type            : External        Dynamic Peer        : No
State                : Established     Last State          : Active
Last Event           : recvOpen
Last Error           : Unrecognized Error
Local Family         : IPv4
Remote Family        : IPv4
Hold Time            : 90              Keep Alive          : 30
Min Hold Time        : 0
Active Hold Time     : 90              Active Keep Alive   : 30
Cluster Id           : None
Preference           : 170             Num of Update Flaps : 0
Input Queue          : 0               Output Queue        : 0
```

```
Input Messages       : 7                Output Messages      : 7
Input Octets         : 247              Output Octets        : 232
Input Updates        : 1                Output Updates       : 1
Input RtRefresh      : 0                Output RtRefresh     : 0
TTL Security         : Disabled         Min TTL Value        : n/a
Graceful Restart     : Disabled         Stale Routes Time    : n/a
Restart Time         : n/a
Long-Lived GR        : Disabled
Advertise Inactive   : Disabled         Peer Tracking        : Disabled
Auth key chain       : n/a
Disable Cap Nego     : Disabled         Bfd Enabled          : Disabled
Default Route Tgt    : Disabled
Aigp Metric          : Disabled         Split Horizon        : Disabled
Damp Peer Oscillatio*: Disabled         Update Errors        : 0
GR Notification      : Disabled         Fault Tolerance      : Disabled
Rem Idle Hold Time   : 00h00m00s
Next-Hop Unchanged   : None
sel-lbl-ipv4-install : Disabled
Local Capability     : RtRefresh MPBGP 4byte ASN
Remote Capability    : RtRefresh MPBGP 4byte ASN
Routes Resolve To St*: Disabled
Local AddPath Capabi*: Disabled
Remote AddPath Capab*: Send - None
                     : Receive - None
Import Policy        : 1:2
                     : Default Reject
Export Policy        : 1:2
                     : Default Reject
---snip---
-------------------------------------------------------------------------------
Neighbors shown : 1
===============================================================================
* indicates that the corresponding row element may have been truncated.
```

The following output shows the 16 received BGP routes on PE-1:

```
[]
A:admin@PE-1# show router 2 bgp routes
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  10.101.0.0/24                                     None        None
      172.16.117.2                                      None        0
      64498                                                         -
u*>i  10.101.1.0/24                                     None        None
      172.16.117.2                                      None        0
      64498                                                         -
u*>i  10.101.2.0/24                                     None        None
      172.16.117.2                                      None        0
      64498                                                         -
u*>i  10.101.3.0/24                                     None        None
```

```
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.101.4.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.101.5.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.101.6.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.101.7.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.102.0.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.102.1.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.102.2.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.102.3.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.102.4.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.102.5.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.102.6.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
u*>i  10.102.7.0/24                                         None        None
      172.16.117.2                                          None        0
      64498                                                             -
-------------------------------------------------------------------------------
Routes : 16
===============================================================================
```

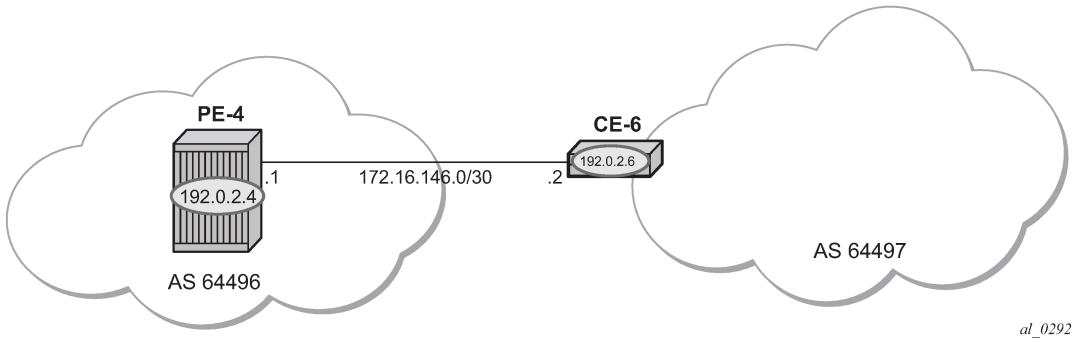
PE-4 also has a VPRN 2 instance configured, so that it will receive the imported BGP routes. The service configuration for “VPRN 2” on PE-4 is as follows:

```
# on PE-4:
configure {
    service {
        vprn "VPRN 2" {
            admin-state enable
            service-id 2
            customer "1"
            autonomous-system 64496
            route-distinguisher "64496:2"
            vrf-target {
                community "target:64496:2"
            }
            auto-bind-tunnel {
                resolution filter
                resolution-filter {
                    ldp true
                }
            }
```

```
            bgp {
                group "VPRN2-external" {
                    peer-as 64497
                    import {
                        policy ["1:2"]
                    }
                    export {
                        policy ["1:2"]
                    }
                }
                neighbor "172.16.146.2" {
                    group "VPRN2-external"
                }
            }
            interface "int-PE-4-CE-6_2nd" {
                ipv4 {
                    primary {
                        address 172.16.146.1
                        prefix-length 30
                    }
                }
                sap 1/2/1:2 {
                }
            }
```

Figure 7: CE-6 connectivity shows the connectivity between PE-4 and CE-6. PE-4 will only forward a summarizing aggregate route toward CE-6.

Figure 7: CE-6 connectivity



PE-4 receives labeled BGP route prefixes from PE-1 via the route reflector and installs them in the FIB for router instance 2, as follows:

```
[]
A:admin@PE-4# show router 2 route-table

===============================================================================
Route Table (Service: 2)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.101.0.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.101.1.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.101.2.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
```

```
10.101.3.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.101.4.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.101.5.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.101.6.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.101.7.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.102.0.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.102.1.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.102.2.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.102.3.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.102.4.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.102.5.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.102.6.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
10.102.7.0/24                                   Remote  BGP VPN   00h01m07s  170
       192.0.2.1 (tunneled)                                          0
172.16.117.0/30                                 Remote  BGP VPN   00h02m41s  170
       192.0.2.1 (tunneled)                                          0
172.16.146.0/30                                 Local   Local     00h02m42s  0
       int-PE-4-CE-6_2nd                                             0
-------------------------------------------------------------------------------
No. of Routes: 18
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

On CE-6, an additional interface is configured toward PE-4, as follows:

```
# on CE-6:
configure {
    service {
        ies "IES 2" {
            admin-state enable
            service-id 2
            customer "1"
            interface "int-CE-6-PE-4_2nd" {
                sap 1/1/1:2 {
                }
                ipv4 {
                    primary {
                        address 172.16.146.2
                        prefix-length 30
                    }
                }
            }
```

The BGP configuration of CE-6 is as follows:

```
# on CE-6:
configure {
    router "Base" {
```

```
        bgp {
            group "external-toVPRN2onPE-4" {
                peer-as 64496
                import {
                    policy ["1:2"]
                }
                export {
                    policy ["1:2"]
                }
            }
            neighbor "172.16.146.1" {
                group "external-toVPRN2onPE-4"
            }
        }
```

The BGP neighbor state for PE-4 is as follows:

```
[]
A:admin@PE-4# show router 2 bgp neighbor 172.16.146.2

===============================================================================
BGP Neighbor
===============================================================================
-------------------------------------------------------------------------------
Peer                 : 172.16.146.2
Description          : (Not Specified)
Group                : VPRN2-external
-------------------------------------------------------------------------------
Peer AS              : 64497            Peer Port            : 179
Peer Address         : 172.16.146.2
Local AS             : 64496            Local Port           : 50683
Local Address        : 172.16.146.1
Peer Type            : External         Dynamic Peer         : No
State                : Established      Last State           : Active
Last Event           : recvOpen
Last Error           : Unrecognized Error
Local Family         : IPv4
Remote Family        : IPv4
Hold Time            : 90               Keep Alive           : 30
Min Hold Time        : 0
Active Hold Time     : 90               Active Keep Alive    : 30
Cluster Id           : None
Preference           : 170              Num of Update Flaps  : 0
Input Queue          : 0                Output Queue         : 0
Input Messages       : 25               Output Messages      : 20
Input Octets         : 750              Output Octets        : 387
Input Updates        : 5                Output Updates       : 0
Input RtRefresh      : 0                Output RtRefresh     : 0
TTL Security         : Disabled         Min TTL Value        : n/a
Graceful Restart     : Disabled         Stale Routes Time    : n/a
Restart Time         : n/a
Long-Lived GR        : Disabled
Advertise Inactive   : Disabled         Peer Tracking        : Disabled
Auth key chain       : n/a
Disable Cap Nego     : Disabled         Bfd Enabled          : Disabled
Default Route Tgt    : Disabled
Aigp Metric          : Disabled         Split Horizon        : Disabled
Damp Peer Oscillatio*: Disabled         Update Errors        : 0
GR Notification      : Disabled         Fault Tolerance      : Disabled
Rem Idle Hold Time   : 00h00m00s
Next-Hop Unchanged   : None
sel-lbl-ipv4-install : Disabled
Local Capability     : RtRefresh MPBGP 4byte ASN
```

```
Remote Capability    : RtRefresh MPBGP 4byte ASN
Routes Resolve To St*: Disabled
Local AddPath Capabi*: Disabled
Remote AddPath Capab*: Send - None
                     : Receive - None
Import Policy        : 1:2
                     : Default Reject
Export Policy        : 1:2
                     : Default Reject
---snip---

-------------------------------------------------------------------------------
Neighbors shown : 1
===============================================================================
* indicates that the corresponding row element may have been truncated.
```

To advertise a summarizing aggregate route with an associated community string, an aggregate route is required. In this case, the 10.101.x.0/24 group of prefixes will be associated with community 64496:101. The 10.102.x.0/24 group of prefixes will be associated with the standard community **no-export**, so that it will not be advertised to any external peer. These aggregate routes are configured in VPRN 2 on PE-4, as follows:

```
# on PE-4:
configure {
    service {
        vprn "VPRN 2" {
            aggregates {
                aggregate 10.101.0.0/21 {
                    community ["64496:101"]
                }
                aggregate 10.102.0.0/21 {
                    community ["no-export"]
                }
            }
        }
```

The following export policy is required on PE-4 to allow the advertising of the aggregate route. No community is applied using this policy.

```
# on PE-4:
configure {
    policy-options {
        policy-statement "PE-4-VPN-Agg" {
            entry 10 {
                from {
                    protocol {
                        name [aggregate]
                    }
                }
                action {
                    action-type accept
                    community {
                        add ["1:2"]
                    }
                }
            }
        }
```

This is applied as an export policy within the group context of the BGP configuration of the VPRN, as follows:

```
# on PE-4:
configure {
    service {
        vprn "VPRN 2" {
            bgp {
                group "VPRN2-external" {
                    export {
                        policy ["PE-4-VPN-Agg"]
                    }
                }
            }
```

The aggregate route 10.101.0.0/21 is received at CE-6 via BGP. The community that was associated with this prefix is seen: 64496:101. The route is seen as an aggregate, with PE-4 as the aggregating router (192.0.2.4). The "Atomic Aggregate" attribute is present, meaning that PE-4 has not advertised any details of the AS Paths of the composite routes.

```
[]
A:admin@CE-6# show router bgp routes 10.101.0.0/21 hunt
===============================================================================
 BGP Router ID:192.0.2.6        AS:64497       Local AS:64497
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 10.101.0.0/21
Nexthop        : 172.16.146.1
Path Id        : None
From           : 172.16.146.1
Res. Protocol  : LOCAL                  Res. Metric    : 0
Res. Nexthop   : 172.16.146.1
Local Pref.    : None                   Interface Name : int-CE-6-PE-4_2nd
Aggregator AS  : 64496                  Aggregator     : 192.0.2.4
Atomic Aggr.   : Atomic                 MED            : None
AIGP Metric    : None                   IGP Cost       : 0
Connector      : None
Community      : 64496:101
Cluster        : No Cluster Members
Originator Id  : None                   Peer Router Id : 192.0.2.4
Fwd Class      : None                   Priority       : None
Flags          : Used  Valid  Best  IGP
Route Source   : External
AS-Path        : 64496
Route Tag      : 0
Neighbor-AS    : 64496
Orig Validation: NotFound
Source Class   : 0                      Dest Class     : 0
Add Paths Send : Default
Last Modified  : 00h02m07s
---snip---
```

The aggregate route 10.102.0.0/21 is not received at CE-6, because PE-4 does not advertise it, due to the fact that it is associated with the "no-export" community.

```
[]
A:admin@CE-6# show router bgp routes 10.102.0.0/21 hunt
===============================================================================
 BGP Router ID:192.0.2.6        AS:64497       Local AS:64497
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
No Matching Entries Found
===============================================================================
```

Conclusion

Community strings can be added to static and aggregate routes. This example shows the configuration of communities with both static and aggregate routes, together with the associated show outputs which can be used to verify and troubleshoot them.

BGP Add-Path

This chapter provides information about BGP Add-Path.

Topics in this chapter include:

Applicability

The chapter was initially written for SR OS Release 14.0.R7, but the MD-CLI in the current edition is based on SR OS Release 22.2.R2.

Overview

When a BGP router learns multiple paths for the same prefix, it selects one route as its best path and advertises only this route to its BGP peers. The BGP add-path feature allows advertising the best n paths for the same prefix, where n is configurable. If the set of n paths includes multiple paths with the same BGP next hop, only the best route with a specific next hop is advertised and the other paths are suppressed.

The BGP add-path feature increases path visibility in the Autonomous System (AS), because more routes are stored in the Routing Information Base (RIB). BGP add-path has the following benefits:

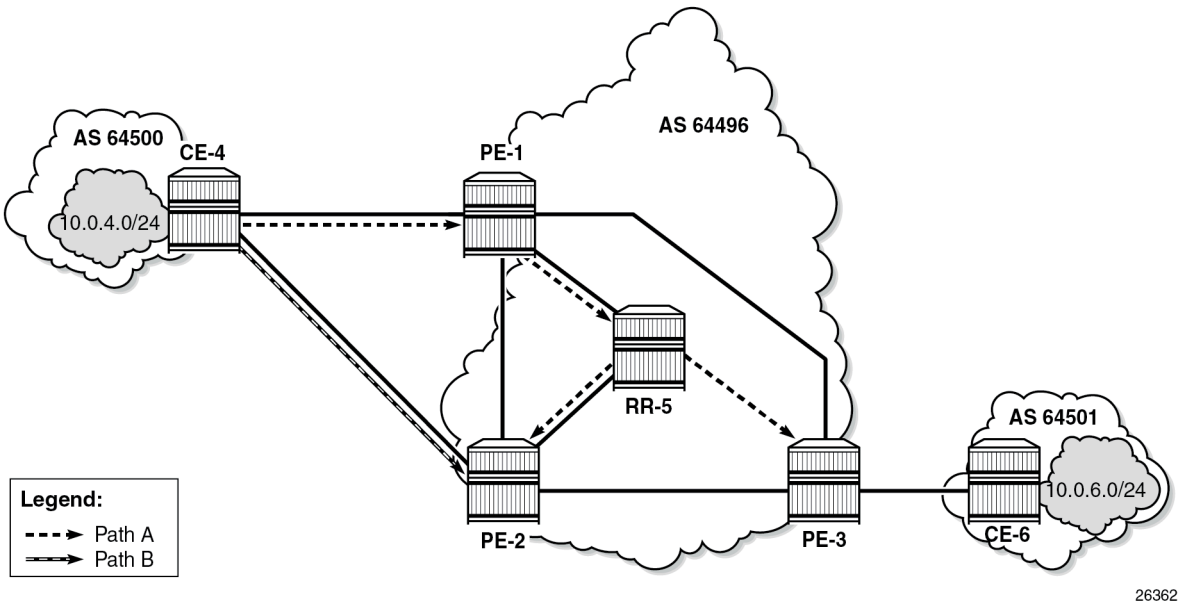
- Faster convergence after failure
- Enhanced load-sharing
- Reduced routing churn

These benefits are described in the following sections.

Faster convergence after failure

Figure 8: RR advertises best path only – path A preferred over path B shows a network that does not support add-path. CE-4 advertises two paths for prefix 10.0.4.0/24 to its EBGP neighbors: PE-1 and PE-2. PE-1 has an import policy that sets the local preference (LP) of path A to 200; PE-2 has an import policy that keeps the default LP of 100 for path B. Therefore, path A that is advertised to PE-1 is preferred in AS 64496. The route reflector RR-5 advertises the preferred path A to PE-2 and PE-3. PE-2 suppresses the advertisement of its external path (B) to RR-5, because path A is preferred. Traffic from CE-6 to CE-4 is sent via PE-3 and PE-1.

Figure 8: RR advertises best path only – path A preferred over path B

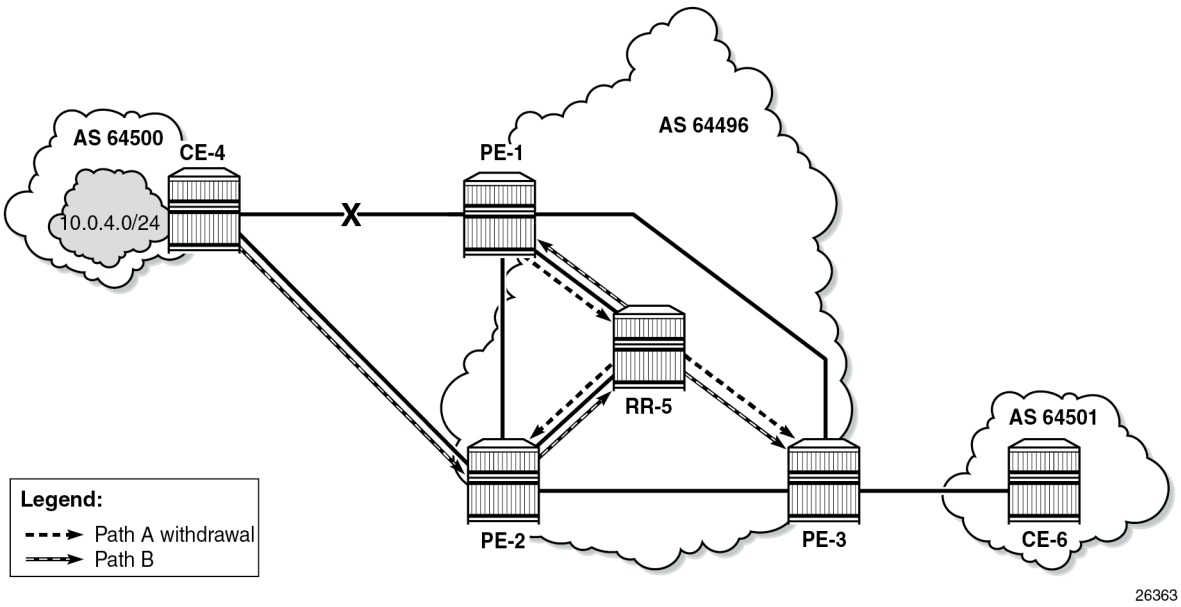


When the link between CE-4 and PE-1 fails, the following steps take place for reconvergence:

1. PE-1 sends a BGP update withdrawing path A to RR-5.
2. RR-5 receives and propagates the withdrawal to its other clients: PE-2 and PE-3.
3. PE-2 receives the withdrawal of path A and reruns the BGP decision process. PE-2 selects path B as its best route and advertises path B to RR-5.
4. RR-5 receives the BGP update for path B and reruns its BGP decision process. RR-5 selects path B as its best path and advertises path B to its other clients: PE-1 and PE-3.
5. PE-1 and PE-3 rerun their BGP decision process and determine that path B is the best path. Traffic can flow from CE-6 to CE-4 via PE-3 and PE-2.

Figure 9: Reconvergence after path failure (without add-path) shows the BGP updates sent to withdraw path A and advertise path B.

Figure 9: Reconvergence after path failure (without add-path)



If the propagation time of a BGP update message between RR-5 and any of its clients is X, the convergence time is four times X, plus processing, transmission, and queuing delays.

With the use of add-path on all BGP routers in AS 64496, the convergence time can be reduced considerably, because PE-3 has more than one path for prefix 10.0.4.0/24 in its RIB-IN before the failure takes place. When there are no failures, PE-2 decides that path A is best, and PE-2 also advertises its second-best path (B)—which is its best external path—to RR-5. With add-path enabled, the RR has knowledge of two paths for prefix 10.0.4.0/24 and advertises both to its clients. PE-3 receives two routes for prefix 10.0.4.0/24, reruns the BGP decision process, and updates its forwarding table based on the results. The following options are possible:

- Path A is the best path, whereas path B is maintained in the RIB-IN. The FIB entry for destination 10.0.4.0/24 points at path {A} only.
- When BGP FRR is enabled as described in chapter BGP Fast Reroute, path A is the best path and path B is the second-best path. The FIB entry for destination 10.0.4.0/24 points to path {A,B}. If path A is available, it is used for all traffic to the destination; if path A is unavailable but path B is available, then all traffic to the destination is directed to path B. In this case, path B is effectively a pre-computed, pre-installed backup path for the destination.
- When Equal Cost Multi-Path (ECMP) and BGP multipath are enabled and the paths have an equal cost, both paths A and B represent the best path. The FIB entry for destination 10.0.4.0/24 points to multipath entry {A,B}. When both paths are available, traffic to the destination is load-shared across paths A and B. If only one path is available, traffic is directed to that available path.

Figure 10: Advertised paths when BGP add-path is enabled in PEs and RR shows the BGP update messages prior to any failures. RR-5 receives path A from PE-1 and path B from PE-2, whereas it advertises path B to PE-1, path A to PE-2, and both path A and path B to PE-3. Path B has the default LP 100, whereas path A gets LP 200 as per import policy on PE-1. However, in case of ECMP, both paths keep the default LP 100.

Figure 10: Advertised paths when BGP add-path is enabled in PEs and RR

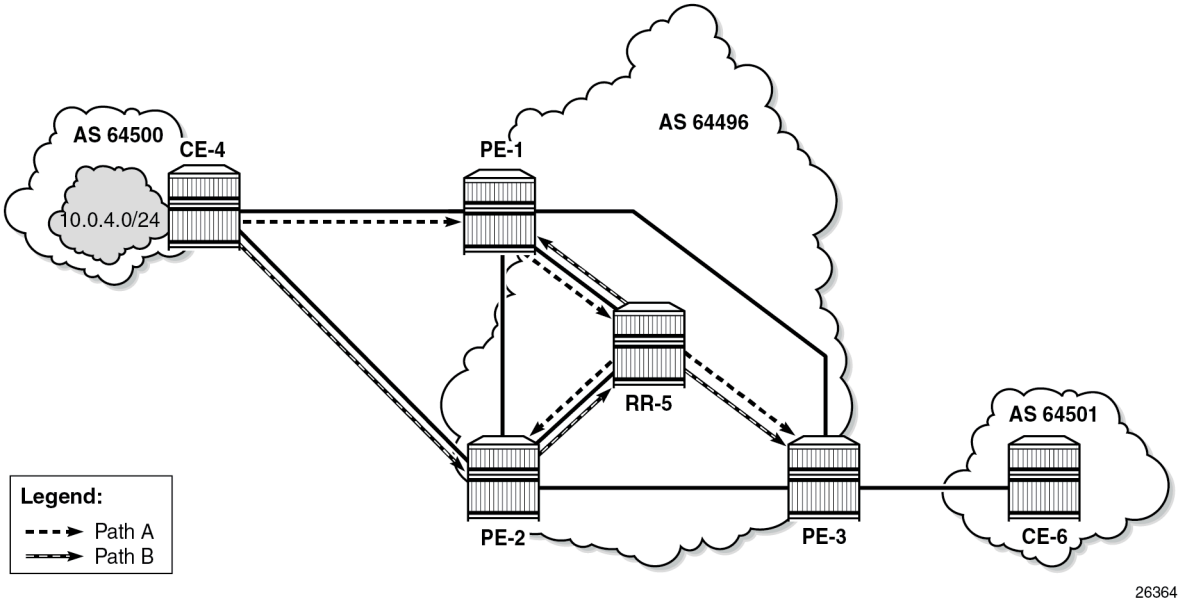
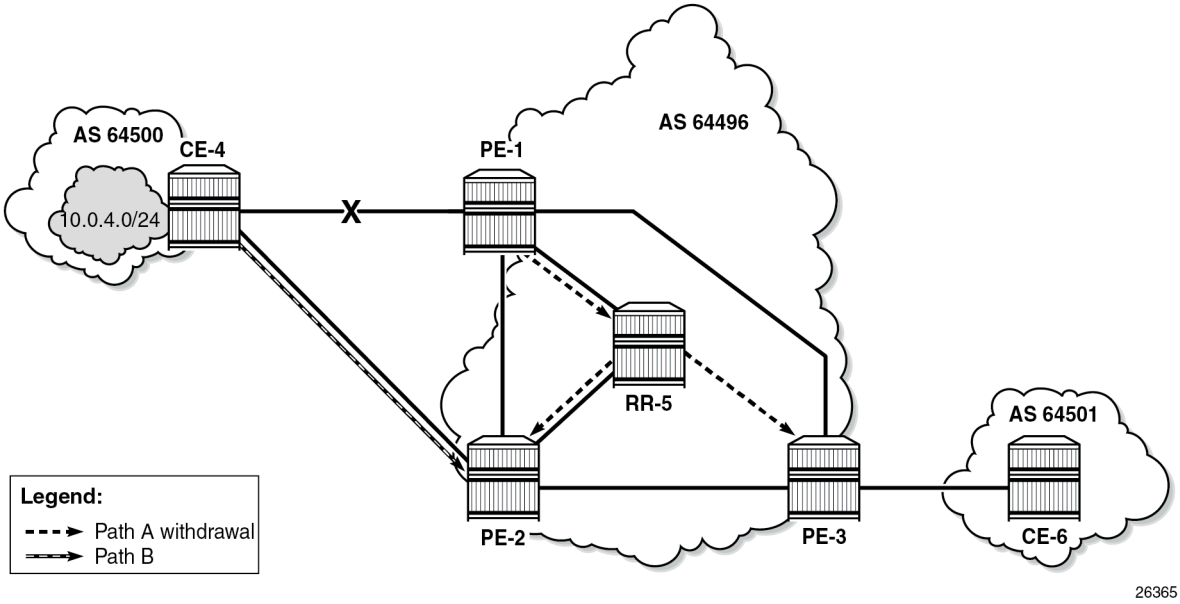


Figure 11: Reconvergence after path failure when BGP add-path is enabled shows the BGP update messages that are sent after a link failure between CE-4 and PE-1. With add-path, fewer steps are required for convergence:

1. PE-1 sends a BGP update message withdrawing path A.
2. RR-5 receives the withdrawal and propagates it to its clients PE-2 and PE-3.
3. PE-2 and PE-3 receive the withdrawal, rerun the BGP decision process, and update the forwarding entry for destination 10.0.4.0/24: path B is best.

Figure 11: Reconvergence after path failure when BGP add-path is enabled



The convergence time with add-path is much shorter than without add-path. If X is the propagation time of a BGP update message between RR and any of the PEs, then the convergence time is the time required for the BGP update from PE-1 to RR-5 (X) plus the time required for the BGP update propagation from RR-5 to the other PEs (X), in addition to delays for processing, transmission, and queuing. The convergence with add-path is twice as fast as without add-path.

For some types of failures, the convergence can be even faster:

- When PE-1 becomes unreachable, the next-hop tracking by PE-3 will invalidate path A before the BGP withdrawal message is received from RR-5.
- If PE-3 implements BGP FRR and path A has been marked as unusable, PE-3 can switch traffic destined to 10.0.4.0/24 to path B.
- When Bidirectional Forwarding Detection (BFD) is enabled on the EBGP sessions and on the IGP protocol, the failure is detected faster and BGP convergence can be sped up when BGP FRR is enabled.

Enhanced load-sharing

When paths A and B are equal in cost or preference, and ECMP and BGP multipath are enabled on all PEs, load-sharing can be done for traffic with destination 10.0.4.0/24. With BGP add-path, both paths A and B are advertised to the PEs. PE-3 runs the BGP decision process and determines that paths A and B are both best paths to destination 10.0.4.0/24, so paths A and B are combined into one multipath forwarding entry: {A,B}.

The benefits of load-sharing for traffic to destination 10.0.4.0/24 are the following:

- More even bandwidth utilization of the links in AS 64496
- More even bandwidth utilization for traffic across peering points PE-1 and PE-2 with AS 64500

- Faster reaction to some failures; for example, the BGP next hop for one of the paths becomes unreachable in the IGP and next hop tracking is enabled.

Reduced routing churn

Routing churn refers to repeated advertisements and withdrawals of a prefix and path. Some degree of routing churn is normal and expected in most networks. However, it should be contained as much as possible to avoid overloading router CPUs. Routing churn can be caused by:

- Flapping links (links that repeatedly transition between up and down state)
- Route oscillation (networks that use RRs or AS confederations and BGP path selection relies on Multi Exit Discriminator (MED) and IGP cost comparisons)

Add-path helps to reduce routing churn by constraining the effect of some failures to the local AS where they occur. For example, the link between CE-4 and PE-1 could repeatedly cycle up and down due to a misconfiguration. When the link goes down, a BGP withdrawal message is sent by PE-1 to RR-5 and from RR-5 to the other RR clients (PE-2 and PE-3). PE-3 will withdraw and advertise path A to its EBGP peer CE-6 in AS 64501, but path B is constantly advertised to CE-6 (when add-path has been negotiated between PE-3 and CE-6).

Without add-path, PE-2 would be affected by the instability in AS 64496 and there would be periods of time when AS 64501 has no paths to destination 10.0.4.0/24 (between the withdrawal of path A and the advertisement of path B).

Add-path implementation

BGP **add-path** is configured in the base routing instance, for IBGP or EBGP, per address family at different levels: in the global **bgp** context, per **group**, and per **neighbor**. The following address families are supported:

```
[ex:/configure router "Base" bgp]
A:admin@PE-1# add-paths ?

 add-paths

 evpn                  + Enter the evpn context
 ipv4                  + Enter the ipv4 context
 ipv6                  + Enter the ipv6 context
 label-ipv4            + Enter the label-ipv4 context
 label-ipv6            + Enter the label-ipv6 context
 mcast-vpn-ipv4        + Enter the mcast-vpn-ipv4 context
 mcast-vpn-ipv6        + Enter the mcast-vpn-ipv6 context
 mvpn-ipv4             + Enter the mvpn-ipv4 context
 mvpn-ipv6             + Enter the mvpn-ipv6 context
 vpn-ipv4              + Enter the vpn-ipv4 context
 vpn-ipv6              + Enter the vpn-ipv6 context
```

Up to 16 paths are configurable per address family per peer (send-limit):

```
*[ex:/configure router "Base" bgp add-paths ipv4]
A:admin@PE-1# ?

 receive               - Receive multiple routes per unlabeled IPv4 prefix
 send                  - Max paths advertised per unlabeled IPv4 unicast prefix
```

Only the number of advertised routes per prefix is controlled, not the number of received routes. All routes advertised by an add-path peer are accepted; otherwise, routing loops might occur. If a BGP speaker is configured with **send** *n*, but has more than n paths available in the LOC-RIB, it selects the *n* best paths with unique BGP next hops following the Add-*n* path selection algorithm described in *draft-ietf-idr-add-paths-guidelines*. Also, the send limit n can be overridden, for specific prefixes, using route policies.

When BGP add-path is configured for an address family, the BGP capability will be announced to the BGP peer as part of the BGP open message, as follows:

```
# Enable debugging for BGP open messages on PE-1 (in classic CLI):
//debug router bgp open
```

```
23 2022/05/06 15:58:35.200 CEST MINOR: DEBUG #2001 Base BGP
"BGP: OPEN
Peer 1: 172.16.14.2 - Send (Active) BGP OPEN: Version 4
   AS Num 64496: Holdtime 90: BGP_ID 192.0.2.1: Opt Length 26 (ExtOpt F)
   Opt Para: Type CAPABILITY: Length = 24: Data:
     Cap_Code GRACEFUL-RESTART: Length 2
       Bytes: 0x0 0x78
     Cap_Code MP-BGP: Length 4
       Bytes: 0x0 0x1 0x0 0x1
     Cap_Code ROUTE-REFRESH: Length 0
     Cap_Code 4-OCTET-ASN: Length 4
       Bytes: 0x0 0x0 0xfb 0xf0
     Cap_Code ADD-PATH: Length 4
       Bytes: 0x0 0x1 0x1 0x3
"
```

The BGP add-path capability code value typically consists of one or more blocks of four bytes; two octets for the Address Family Identifier (AFI), one octet for the Subsequent Address Family Identifier (SAFI), and one octet for send/receive. In this example, AFI/SAFI bytes point to an IPv4 address family and send/receive value "3" means that the sender is able to receive and send multiple paths from/to its BGP peer.

In BGP update messages, a 4-octet path identifier (ID) is added to the Network Layer Reachability Information (NLRI) field. The combination of both prefix and path ID identifies a BGP path. SR OS allocates path IDs sequentially on a per address family basis, not per prefix. The path ID is only locally significant, which means that when a BGP speaker re-advertises a route with path IDs, it must generate its own path ID.

```
# Enable debugging for BGP UPDATE messages on RR-5 (in classic CLI):
//debug router bgp update
```

RR-5 received the following BGP update for prefix 10.0.4.0/24 with path ID.

```
44 2022/05/06 15:59:37.463 CEST MINOR: DEBUG #2001 Base Peer 1: 192.0.2.2
"Peer 1: 192.0.2.2: UPDATE
Peer 1: 192.0.2.2 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 27
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 6 AS Path:
        Type: 2 Len: 1 < 64500 >
    Flag: 0x40 Type: 3 Len: 4 Nexthop: 192.0.2.2
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    NLRI: Length = 8
        10.0.4.0/24 Path-ID 1
```

"

When routers have negotiated to advertise (and receive) routes with path identifiers, all BGP updates (advertisements or withdrawals) without path identifier will be rejected. There will be an NLRI parsing error —because the BGP update has an incorrect length—and a notification will be sent.

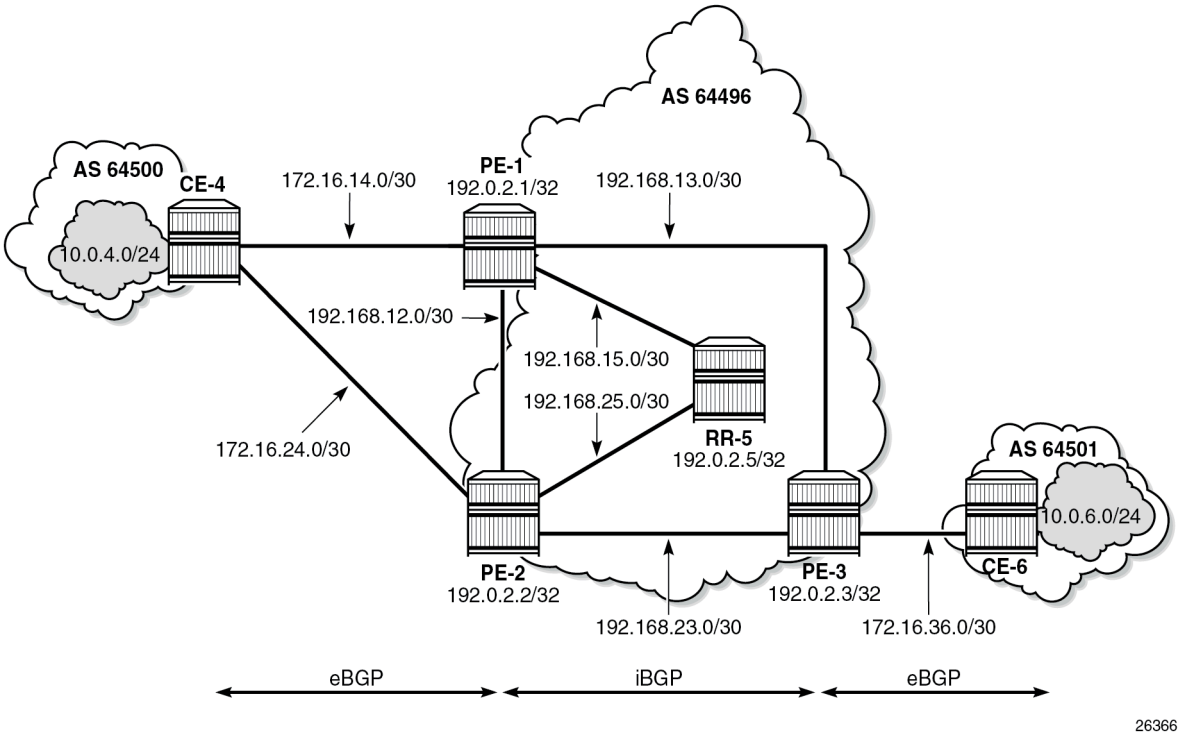
Configuration

The following configuration examples are in this section:

- BGP without add-path
- BGP with add-path for address family IPv4: no BGP FRR, no ECMP
- BGP with add-path for address family IPv4 and BGP FRR enabled
- BGP with add-path for address family IPv4 and ECMP enabled
- BGP with add-path for address family VPN-IPv4 and BGP FRR enabled
- BGP with add-path for address family VPN-IPv4 and ECMP enabled

Figure 12: Example topology shows the example topology with CE-4 in AS 64500 advertising route 10.0.4.0/24 to its EBGP peers PE-1 and PE-2 in AS 64496. PE-1 has an import policy that sets the LP for this route to 200, whereas PE-2 has an import policy that keeps the default local preference of 100. RR-5 is RR for all PEs in AS 64496. CE-6 in AS 64501 peers with PE-3 in AS 64496 and can send traffic to CE-4 in AS 64500.

Figure 12: Example topology



Initial configuration

The initial configuration on all nodes includes:

- Cards, MDAs, ports
- Router interfaces
- IS-IS as IGP on all interfaces within AS 64496 (alternatively, OSPF can be used)
- LDP on all interfaces between the PEs in AS 64496, but not toward RR-5

BGP is configured on all the nodes. CE-4 peers with PE-1 and PE-2 and exports prefix 10.0.4.0/24 to both EBGP peers, as follows:

```
# on CE-4:
configure {
    policy-options {
        prefix-list "10.0.0.0/8" {
            prefix 10.0.0.0/8 type longer {
            }
        }
        prefix-list "10.0.4.0/24" {
            prefix 10.0.4.0/24 type exact {
            }
        }
        policy-statement "import-bgp-10.x" {
            entry 10 {
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                }
            }
        }
        policy-statement "export-bgp-10.0.4.x" {
            entry 10 {
                from {
                    prefix-list ["10.0.4.0/24"]
                }
                action {
                    action-type accept
                }
            }
        }
    }
    router "Base" {
        autonomous-system 64500
        bgp {
            rapid-withdrawal true
            split-horizon true
            group "EBGP" {
                peer-as 64496
                import {
                    policy ["import-bgp-10.x"]
                }
                export {
                    policy ["export-bgp-10.0.4.x"]
                }
            }
            neighbor "172.16.14.1" {
                group "EBGP"
```

```
            }
            neighbor "172.16.24.1" {
                group "EBGP"
            }
```

The BGP configuration on CE-6 is similar.

PE-1 peers with CE-4 in AS 64500 and RR-5 in AS 64496. An import policy is configured to set the LP to 200 for all routes received from CE-4, as follows:

```
# on PE-1:
configure {
    policy-options {
        prefix-list "10.0.0.0/8" {
            prefix 10.0.0.0/8 type longer {
            }
        }
        policy-statement "export-bgp-10.x" {
            entry 10 {
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                }
            }
        }
        policy-statement "import-bgp-LP200" {
            entry 10 {
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                    local-preference 200
                }
            }
        }
    }
    router "Base" {
        autonomous-system 64496
        bgp {
            rapid-withdrawal true
            split-horizon true
            group "EBGP" {
                peer-as 64500
                import {
                    policy ["import-bgp-LP200"]
                }
                export {
                    policy ["export-bgp-10.x"]
                }
            }
            group "IBGP" {
                next-hop-self true
                peer-as 64496
            }
            neighbor "172.16.14.2" {
                group "EBGP"
            }
            neighbor "192.0.2.5" {
                group "IBGP"
            }
```

```
        }
```

The BGP configuration on PE-2 and PE-3 is similar, but with an import policy that does not set the LP, so the default LP of 100 applies.

The BGP configuration on RR-5 is as follows:

```
# on RR-5:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            rapid-withdrawal true
            split-horizon true
            group "IBGP" {
                peer-as 64496
                cluster {
                    cluster-id 192.0.2.5
                }
            }
            neighbor "192.0.2.1" {
                group "IBGP"
            }
            neighbor "192.0.2.2" {
                group "IBGP"
            }
            neighbor "192.0.2.3" {
                group "IBGP"
            }
```

PE-1 advertises a route for prefix 10.0.4.0/24 with LP 200 to RR-5. RR-5 propagates this route to its other clients: PE-2 and PE-3. When PE-2 learns this route, it does not advertise its own route for 10.0.4.0/24 with LP 100 to RR-5 anymore. PE-3 only learns the route for prefix 10.0.4.0/24 with LP 200, as follows:

```
[/]
A:admin@PE-3# show router bgp routes 10.0.4.0/24
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.0.4.0/24                                      200         None
      192.0.2.1                                        None        10
      64500                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Reconvergence without add-path

A failure of the link between CE-4 and PE-1 is simulated as follows:

```
# on CE-4:
configure {
    router "Base" {
        interface "int-CE-4-PE-1" {
            admin-state disable
            commit
```

The following four BGP update messages are received or sent by RR-5.

RR-5 receives the following withdrawal message from PE-1:

```
# on RR-5:
15 2022/05/06 15:53:26.491 CEST MINOR: DEBUG #2001 Base Peer 1: 192.0.2.1
"Peer 1: 192.0.2.1: UPDATE
Peer 1: 192.0.2.1 - Received BGP UPDATE:
    Withdrawn Length = 4
        10.0.4.0/24
    Total Path Attr Length = 0
"
```

RR-5 propagates this withdrawal to its other clients, for example to PE-2, as follows:

```
# on RR-5:
16 2022/05/06 15:53:26.491 CEST MINOR: DEBUG #2001 Base Peer 1: 192.0.2.2
"Peer 1: 192.0.2.2: UPDATE
Peer 1: 192.0.2.2 - Send BGP UPDATE:
    Withdrawn Length = 4
        10.0.4.0/24
    Total Path Attr Length = 0
"
```

When PE-2 receives this withdrawal, it reruns the BGP decision process and decides that its route for prefix 10.0.4.0/24 with LP 100 is the best route. PE-2 advertises this route to RR-5; it is received by RR-5 as follows:

```
# on RR-5:
18 2022/05/06 15:53:49.540 CEST MINOR: DEBUG #2001 Base Peer 1: 192.0.2.2
"Peer 1: 192.0.2.2: UPDATE
Peer 1: 192.0.2.2 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 27
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 6 AS Path:
        Type: 2 Len: 1 < 64500 >
    Flag: 0x40 Type: 3 Len: 4 Nexthop: 192.0.2.2
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    NLRI: Length = 4
        10.0.4.0/24
"
```

RR-5 propagates this message to its other clients: PE-1 and PE-3. The following BGP update is sent to PE-3:

```
# on RR-5:
```

```
20 2022/05/06 15:53:56.479 CEST MINOR: DEBUG #2001 Base Peer 1: 192.0.2.3
"Peer 1: 192.0.2.3: UPDATE
Peer 1: 192.0.2.3 - Send BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 41
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 6 AS Path:
        Type: 2 Len: 1 < 64500 >
    Flag: 0x40 Type: 3 Len: 4 Nexthop: 192.0.2.2
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0x80 Type: 9 Len: 4 Originator ID: 192.0.2.2
    Flag: 0x80 Type: 10 Len: 4 Cluster ID:
        192.0.2.5
    NLRI: Length = 4
        10.0.4.0/24
"
```

Again, PE-3 has only one route for prefix 10.0.4.0/24, but this time with next hop 192.0.2.2, as follows:

```
[/]
A:admin@PE-3# show router bgp routes 10.0.4.0/24
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.0.4.0/24                                      100         None
      192.0.2.2                                        None        10
      64500                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The configuration is restored as follows:

```
# on CE-4:
configure {
    router "Base" {
        interface "int-CE-4-PE-1" {
            admin-state enable
            commit
```

Add-path enabled: no BGP FRR, no ECMP

Before add-path is enabled, the following information is displayed on PE-1 for BGP neighbor RR-5:

```
[/]
A:admin@PE-1# show router bgp neighbor 192.0.2.5 | match "Local AddPath" post-lines 2
Local AddPath Capabi*: Disabled
```

```
Remote AddPath Capab*: Send - None
                     : Receive - None
```

Add-path is enabled on PE-1 and PE-2 with a send path limit of two for groups "EBGP" and "IBGP"; the **receive true** option implies that the add-path receive capability is negotiated, so IPv4 routes without path ID will be rejected:

```
# on PE-1. PE-2:
configure {
    router "Base" {
        bgp {
            group "EBGP" {
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            group "IBGP" {
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
```

When the preceding **show** command is repeated on PE-1 or PE-2, the local BGP add-path capabilities are specified for address family IPv4: a maximum of two paths can be sent for a specific IPv4 prefix. The remote peer RR-5 does not have add-path enabled yet.

```
[/]
A:admin@PE-1# show router bgp neighbor 192.0.2.5 | match "Local AddPath" post-lines 3
Local AddPath Capabi*: Send - ipv4 (2)
                     : Receive - ipv4
Remote AddPath Capab*: Send - None
                     : Receive - None
```

Initially, add-path remains disabled on PE-3. On the RR, add-path is enabled for neighbors 192.0.2.1 and 192.0.2.2, but not for 192.0.2.3 yet. For neighbor 192.0.2.1, the **receive false** option implies that the add-path receive capability is not negotiated.

```
# on RR-5:
configure {
    router "Base" {
        bgp {
            neighbor 192.0.2.1 {
                add-paths {
                    ipv4 {
                        send 2
                        receive false
                    }
                }
            }
            neighbor 192.0.2.2 {
                add-paths {
                    ipv4 {
                        send 2
                        receive true
```

```
                    }
                }
            }
```

The following output shows that add-path is enabled locally on RR-5 and remotely on PE-1 for address family IPv4. RR-5 can send a maximum of two paths for a specific prefix toward PE-1 and PE-2; toward PE-3, add-path remains disabled.

```
[/]
A:admin@RR-5# show router bgp neighbor 192.0.2.1 | match "Local AddPath" post-lines 3
Local AddPath Capabi*: Send - ipv4 (2)
                     : Receive - None
Remote AddPath Capab*: Send - ipv4
                     : Receive - ipv4
```

```
[/]
A:admin@RR-5# show router bgp neighbor 192.0.2.2 | match "Local AddPath" post-lines 3
Local AddPath Capabi*: Send - ipv4 (2)
                     : Receive - ipv4
Remote AddPath Capab*: Send - ipv4
                     : Receive - ipv4
```

```
[/]
A:admin@RR-5# show router bgp neighbor 192.0.2.3 | match "Local AddPath" post-lines 2
Local AddPath Capabi*: Disabled
Remote AddPath Capab*: Send - None
                     : Receive - None
```

The **receive false** option indicates that RR-5 does not negotiate the add-path receive capability with its peer. PE-1 knows that peer 192.0.2.5 may send IPv4 routes with a path ID, but has no information about what this peer will receive:

```
[/]
A:admin@PE-1# show router bgp neighbor 192.0.2.5 | match "Local AddPath" post-lines 3
Local AddPath Capabi*: Send - ipv4 (2)
                     : Receive - ipv4
Remote AddPath Capab*: Send - ipv4
                     : Receive - None
```

With BGP add-path enabled, PE-2 will advertise its second-best route for prefix 10.0.4.0/24 with LP 100 to RR-5. PE-1, PE-2, and RR-5 will have two routes for prefix 10.0.4.0/24 in their RIB-IN, but only the route with LP 200 will be used. The following output shows the BGP routes on RR-5, but it resembles the output on PE-1 and PE-2:

```
[/]
A:admin@RR-5# show router bgp routes 10.0.4.0/24
===============================================================================
 BGP Router ID:192.0.2.5        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
```

```
      Nexthop (Router)                                      Path-Id     IGP Cost
      As-Path                                                           Label
-------------------------------------------------------------------------------
u*>i  10.0.4.0/24                                           200         None
      192.0.2.1                                             None        10
      64500                                                             -
*i    10.0.4.0/24                                           100         None
      192.0.2.2                                             1           10
      64500                                                             -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

Even though RR-5 has two routes for this prefix, it only advertises its best route to PE-3, because add-path is not enabled for this BGP session. Therefore, PE-3 only has the route for 10.0.4.0/24 with LP 200, as follows:

```
[/]
A:admin@PE-3# show router bgp routes 10.0.4.0/24
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  10.0.4.0/24                                       200         None
      192.0.2.1                                         None        10
      64500                                                         -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

When add-path is enabled on the session between PE-3 and RR-5, the second route will also be advertised, as follows:

```
# on PE-3:
configure {
    router "Base" {
        bgp {
            group "IBGP" {
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
```

```
# on RR-5:
configure {
    router "Base" {
        bgp {
```

```
            neighbor 192.0.2.3 {
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
```

```
[/]
A:admin@PE-3# show router bgp routes 10.0.4.0/24
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  10.0.4.0/24                                       200         None
      192.0.2.1                                         13          10
      64500                                                         -
*i    10.0.4.0/24                                       100         None
      192.0.2.2                                         14          10
      64500                                                         -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

BGP add-path is enabled, but BGP FRR and ECMP are disabled. The routing table on PE-3 only contains one entry for prefix 10.0.4.0/24:

```
[/]
A:admin@PE-3# show router route-table 10.0.4.0/24

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.0.4.0/24                                   Remote  BGP       00h06m44s  170
       192.168.13.1                                                 10
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

Reconverge with add-path: no BGP FRR, no ECMP

A link failure between CE-4 and PE-1 is simulated as follows:

```
# on CE-4:
configure {
    router "Base" {
        interface "int-CE-4-PE-1" {
            admin-state disable
            commit
```

PE-1 sends a withdrawal message for route 10.0.4.0/24 with LP 200 to RR-5 and reruns the BGP decision process. RR-5 propagates this withdrawal message to its other clients that rerun the BGP decision process. As a result, the route for prefix 10.0.4.0/24 with LP 100 will be used on all nodes; for example, on PE-3:

```
[/]
A:admin@PE-3# show router bgp routes 10.0.4.0/24
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.0.4.0/24                                      100         None
      192.0.2.2                                        14          10
      64500                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The routing table contains a route to 10.0.4.0/24 with PE-2 as next hop, as follows:

```
[/]
A:admin@PE-3# show router route-table 10.0.4.0/24

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.0.4.0/24                                   Remote  BGP       00h04m07s  170
       192.168.23.1                                                 10
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
```

```
===============================================================================
```

The convergence with add-path enabled is twice as fast as without BGP add-path. With BGP add-path disabled, four sequential messages are sent:

1. PE-1 sends a withdrawal to RR-5.
2. RR-5 propagates withdrawal.
3. PE-2 advertises its route.
4. RR-5 propagates the route.

In the scenario with add-path, the last two messages are already sent before the failure happened. During convergence, only two withdrawal messages are sent: PE-1 sends a withdrawal to RR-5; RR-5 propagates this to its clients.

Add-path and BGP FRR

The convergence time can be further reduced by enabling BGP FRR, where the BGP decision process runs for the best route and the backup path before any failure happens, as described in chapter BGP Fast Reroute. On all PEs, BGP FRR is enabled for the IPv4 address family, as follows:

```
# on all PEs:
configure {
    router "Base" {
        bgp {
            backup-path {
                ipv4 true
            }
```

Each PE has two routes for prefix 10.0.4.0/24 and when BGP FRR is enabled, both are used, but one is used as backup, indicated by the "b"-flag in the following output:

```
[/]
A:admin@PE-3# show router bgp routes 10.0.4.0/24
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.0.4.0/24                                      200         None
      192.0.2.1                                        20          10
      64500                                                        -
ub*i  10.0.4.0/24                                      100         None
      192.0.2.2                                        14          10
      64500                                                        -
-------------------------------------------------------------------------------
Routes : 2
```

```
===============================================================================
```

The following routing table on PE-3 shows the active route for 10.0.4.0/24 and adds an indication "B", indicating that a BGP backup route is available:

```
[/]
A:admin@PE-3# show router route-table 10.0.4.0/24

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.0.4.0/24 [B]                                 Remote  BGP       00h01m48s  170
       192.168.13.1                                                 10
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The following output shows both the active and the backup route for prefix 10.0.4.0/24:

```
[/]
A:admin@PE-3# show router route-table 10.0.4.0/24 alternative

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
      Alt-NextHop                                                  Alt-
                                                                   Metric
-------------------------------------------------------------------------------
10.0.4.0/24                                     Remote  BGP       00h01m48s  170
       192.168.13.1                                                 10
10.0.4.0/24 (Backup)                            Remote  BGP       00h01m48s  170
       192.168.23.1                                                 10
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       Backup = BGP backup route
       LFA = Loop-Free Alternate nexthop
       S = Sticky ECMP requested
===============================================================================
```

In case of link failure between CE-4 and PE-1, the same BGP withdrawals will be sent from PE-1 to RR-5 and from RR-5 to PE-2 and PE-3. When PE-2 and PE-3 receive the withdrawal, the BGP decision process need not run again. The backup path is promoted to active immediately.

BGP FRR is disabled on the PEs:

```
# on all PEs”
configure {
    router "Base" {
        bgp {
            delete backup-path
```

Add-path and ECMP

To have paths with equal cost, the import policy "import-bgp-10.x" on PE-1 does not set the LP:

```
# on PE-1:
configure {
    policy-options {
        prefix-list "10.0.0.0/8" {
            prefix 10.0.0.0/8 type longer {
            }
        }
        policy-statement "import-bgp-10.x" {
            entry 10 {
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                }
            }
        }
    }
    router "Base" {
        bgp {
            group "EBGP" {
                delete import
                import {
                    policy ["import-bgp-10.x"]
                }
```

On all PEs, ECMP is enabled with a value of 2 and BGP multipath is configured with the maximum number of paths equal to 2 in the **bgp** context, as follows:

```
# on all PEs:
configure {
    router "Base" {
        ecmp 2
        bgp {
            multipath {
                max-paths 2
            }
```

For more information about BGP multipath, see chapter BGP Multipath.

All PEs have two routes for prefix 10.0.4.0/24 and both are active when ECMP is enabled; for example, for PE-3, as follows:

```
[/]
A:admin@PE-3# show router bgp routes 10.0.4.0/24
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
```

```
Flag  Network                                              LocalPref   MED
      Nexthop (Router)                                     Path-Id     IGP Cost
      As-Path                                                          Label
-------------------------------------------------------------------------------
u*>i  10.0.4.0/24                                          100         None
      192.0.2.1                                            20          10
      64500                                                            -
u*>i  10.0.4.0/24                                          100         None
      192.0.2.2                                            14          10
      64500                                                            -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

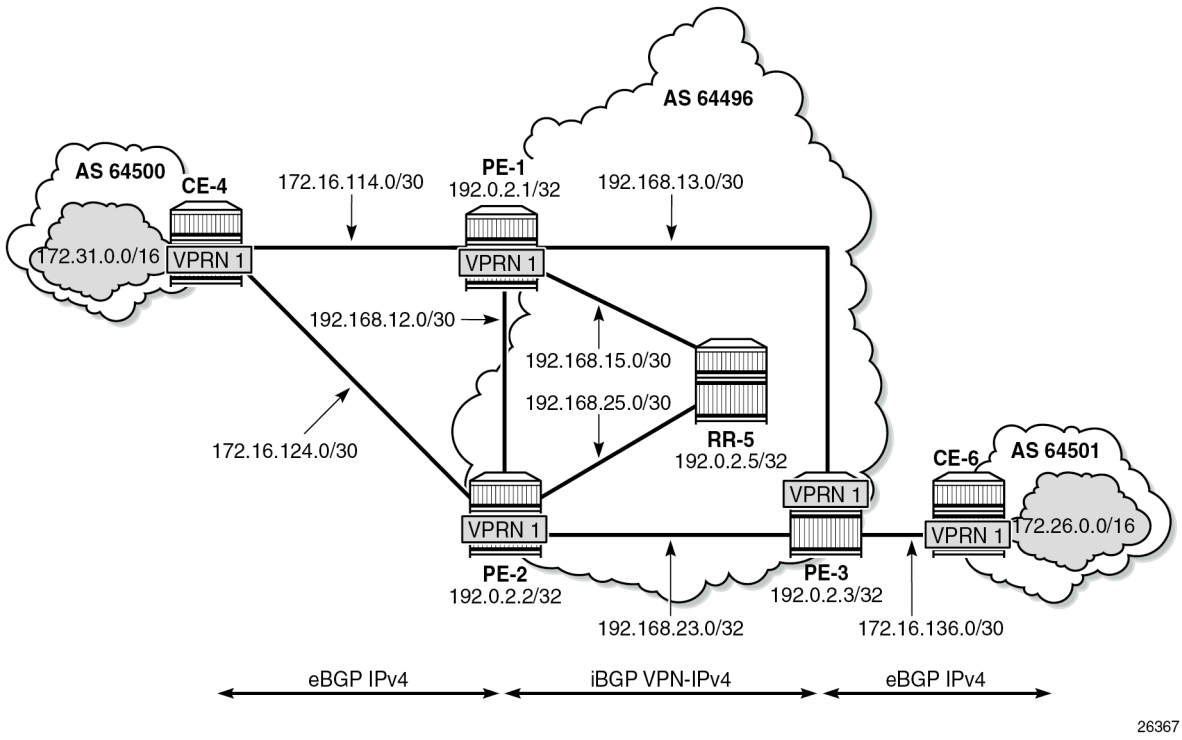
```
[/]
A:admin@PE-3# show router route-table 10.0.4.0/24

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.0.4.0/24                                   Remote  BGP       00h02m33s  170
       192.168.13.1                                                 10
10.0.4.0/24                                   Remote  BGP       00h02m33s  170
       192.168.23.1                                                 10
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

Traffic flows with destination 10.0.4.0/24 will be sprayed over the two active paths.

Add-path for family VPN-IPv4 with BGP FRR

Figure 13: Example topology with VPRNs shows the example topology with VPRN1 configured on the PEs in AS 64496. CE-4 exports prefix 172.31.0.0/16 to VPRN 1 on PE-1 and PE-2.

Figure 13: Example topology with VPRNs



VPRN 1 is configured on all PEs in AS 64496, but not on the RR. BGP FRR is enabled in the VPRN with the **bgp-vpn-backup>ipv4 true** option. The configuration of VPRN 1 is similar on all PEs; for example, for PE-1, the VPRN configuration is as follows:

```
# on PE-1:
configure {
    policy-options {
        prefix-list "172.16.0.0/12" {
            prefix 172.16.0.0/12 type longer {
            }
        }
        policy-statement "import-bgp-vprn-LP200" {
            entry 10 {
                from {
                    prefix-list ["172.16.0.0/12"]
                }
                action {
                    action-type accept
                    local-preference 200
                }
            }
        }
        policy-statement "export-bgp-vprn" {
            entry 10 {
                from {
                    protocol {
                        name [bgp-vpn]
                    }
                }
                to {
```

```
                protocol {
                    name [bgp]
                }
            }
            action {
                action-type accept
            }
        }
    }
}
service {
    vprn "VPRN 1" {
        admin-state enable
        service-id 1
        customer "1"
        autonomous-system 64496
        export-inactive-bgp true      # BGP best-external in VPRN
        bgp-ipvpn {
            mpls {
                admin-state enable
                route-distinguisher "64496:1"
                vrf-target {
                    community "target:64496:1"
                }
                auto-bind-tunnel {
                    resolution any
                }
            }
        }
        bgp {
            split-horizon true
            group "EBGP_1" {
                next-hop-self true
                peer-as 64500
                import {
                    policy ["import-bgp-vprn-LP200"]
                }
                export {
                    policy ["export-bgp-vprn"]
                }
            }
            neighbor "172.16.114.2" {
                group "EBGP_1"
            }
        }
        interface "int-PE-1-CE-4_VPRN1" {
            ipv4 {
                primary {
                    address 172.16.114.1
                    prefix-length 30
                }
            }
            sap 1/1/3:1 {
            }
        }
        bgp-vpn-backup {        # BGP-FRR
            ipv4 true
        }
    }
```

The import policy sets the LP to 200 for the routes received from CE-4. The configuration on PE-2 is similar, but with an import policy that does not set the LP. Therefore, the path via PE-1 will be preferred over the path via PE-2.

The **export-inactive-bgp true** option must be configured on PE-2, because the route for prefix 172.31.0.0/16 received by PE-2 from CE-4 is inactive, but should still be advertised as BGP VPN-IPv4 route to RR-5; see chapter "BGP Best External in a VPRN" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Layer 3 Services Advanced Configuration Guide for Classic CLI*. In this example, the **export-inactive-bgp true** option is configured on all PEs.

On the CEs, the configuration is either in the base routing instance—with additional router interfaces and BGP neighbors—or in a VPRN. In this example, the following VPRN is configured on CE-4:

```
# on CE-4:
configure {
    policy-options {
        prefix-list "172.16.0.0/12" {
            prefix 172.16.0.0/12 type longer {
            }
        }
        prefix-list "172.31.0.0/16" {
            prefix 172.31.0.0/16 type longer {
            }
        }
        policy-statement "import-bgp-vprn" {
            entry 10 {
                from {
                    prefix-list ["172.16.0.0/12"]
                }
                action {
                    action-type accept
                }
            }
        }
        policy-statement "export_172.31.0.0/16" {
            entry 10 {
                from {
                    prefix-list ["172.31.0.0/16"]
                }
                action {
                    action-type accept
                }
            }
        }
    }
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            autonomous-system 64500
            bgp {
                split-horizon true
                group "EBGP_1" {
                    peer-as 64496
                    import {
                        policy ["import-bgp-vprn"]
                    }
                    export {
                        policy ["export_172.31.0.0/16"]
                    }
                }
                neighbor "172.16.114.1" {
                    group "EBGP_1"
                }
                neighbor "172.16.124.1" {
                    group "EBGP_1"
```

```
            }
        }
        interface "int-CE-4-PE-1_VPRN1" {
            ipv4 {
                primary {
                    address 172.16.114.2
                    prefix-length 30
                }
            }
            sap 1/1/1:1 {
            }
        }
        interface "int-CE-4-PE-2_VPRN1" {
            ipv4 {
                primary {
                    address 172.16.124.2
                    prefix-length 30
                }
            }
            sap 1/1/2:1 {
            }
        }
        interface "test_connectedNW" {
            loopback true
            ipv4 {
                primary {
                    address 172.31.0.1
                    prefix-length 16
                }
            }
        }
    }
```

The configuration on CE-6 is similar.

For all BGP speakers in AS 64496, BGP must be configured for address family VPN-IPv4 as well as for IPv4. BGP add-path cannot be enabled in the **bgp** context within a VPRN. However, BGP add-path can be enabled in the base routing instance for address family VPN-IPv4. This is done on all PEs at group level with the following command:

```
# on PE-1, PE-2, PE-3:
configure {
    router "Base" {
        bgp {
            group "IBGP" {
                family {
                    ipv4 true
                    vpn-ipv4 true
                }
                add-paths {
                    vpn-ipv4 {
                        send 2
                        receive true
                    }
                }
```

In this example, BGP add-path is enabled at neighbor level on RR-5, as follows:

```
# on RR-5:
configure {
    router "Base" {
        bgp {
```

```
            group "IBGP" {
                family {
                    ipv4 true
                    vpn-ipv4 true
                }
            }
            neighbor 192.0.2.1 {
                add-paths {
                    vpn-ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            neighbor 192.0.2.2 {
                add-paths {
                    vpn-ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            neighbor 192.0.2.3 {
                add-paths {
                    vpn-ipv4 {
                        send 2
                        receive true
                    }
                }
            }
```

The BGP configuration for group "IBGP" on PE-1 is as follows:

```
[ex:/configure router "Base" bgp group "IBGP"]
A:admin@PE-1# info
    next-hop-self true
    peer-as 64496
    family {
        ipv4 true
        vpn-ipv4 true
    }
    add-paths {
        ipv4 {
            send 2
            receive true
        }
        vpn-ipv4 {
            send 2
            receive true
        }
    }
```

With add-path enabled for address family VPN-IPv4, PE-1 and PE-2 will advertise their route for prefix 172.31.0.0/16 as VPN-IPv4 route to RR-5. RR-5 will advertise both routes to its other RR clients. PE-3 receives two VPN-IPv4 routes for prefix 172.31.0.0/16, as follows:

```
[/]
A:admin@PE-3# show router bgp routes 172.31.0.0/16 vpn-ipv4
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
```

```
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64496:1:172.31.0.0/16                            200         None
      192.0.2.1                                        15          10
      64500                                                        524283
ub*i  64496:1:172.31.0.0/16                            100         None
      192.0.2.2                                        17          10
      64500                                                        524284
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

Both routes are used: the route via PE-1 is the active route and the route via PE-2 is used as a backup, as indicated by the "b" flag.

The routing table for VPRN 1 on PE-3 shows that there is a backup route for prefix 172.31.0.0/16, as indicated by "B" as follows:

```
[/]
A:admin@PE-3# show router 1 route-table 172.31.0.0/16

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
172.31.0.0/16 [B]                              Remote  BGP VPN   00h01m13s  170
       192.0.2.1 (tunneled)                                          10
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The active route and the alternative (backup) route are shown in the following output:

```
[/]
A:admin@PE-3# show router 1 route-table 172.31.0.0/16 alternative

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
      Alt-NextHop                                                  Alt-
                                                                   Metric
-------------------------------------------------------------------------------
172.31.0.0/16                                  Remote  BGP VPN   00h01m13s  170
       192.0.2.1 (tunneled)                                          10
172.31.0.0/16 (Backup)                         Remote  BGP VPN   00h01m13s  170
```

```
       192.0.2.2 (tunneled)                                          10
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       Backup = BGP backup route
       LFA = Loop-Free Alternate nexthop
       S = Sticky ECMP requested
===============================================================================
```

BGP FRR is disabled in VPRN 1 on the PEs, as follows:

```
# on PE-1, PE-2, PE-3:
configure {
    service {
        vprn "VPRN 1" {
            delete bgp-vpn-backup
```

Add-path for family VPN-IPv4 with ECMP

A different import policy is configured in VPRN 1 on PE-1 to make the cost of the paths via PE-1 and PE-2 equal, as follows:

```
# on PE-1:
configure {
    policy-options {
        prefix-list "172.16.0.0/12" {
            prefix 172.16.0.0/12 type longer {
            }
        }
        policy-statement "import-bgp-vprn" {
            entry 10 {
                from {
                    prefix-list ["172.16.0.0/12"]
                }
                action {
                    action-type accept
                }
            }
        }
    }
    service {
        vprn "VPRN 1" {
            bgp {
                group "EBGP_1" {
                    delete import
                    import {
                        policy ["import-bgp-vprn"]
                    }
                }
```

ECMP is enabled in VPRN 1 on all PEs, as follows:

```
# on PE-1, PE-2, PE-3:
configure {
    service {
        vprn "VPRN 1" {
            ecmp 2
```

BGP multipath needs to be enabled in the base routing context, but that already happened.

With ECMP enabled, the two routes that are received on PE-3 from RR-5 are both active, as follows:

```
[/]
A:admin@PE-3# show router bgp routes 172.31.0.0/16 vpn-ipv4
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64496:1:172.31.0.0/16                            100         None
      192.0.2.1                                        15          10
      64500                                                        524283
u*>i  64496:1:172.31.0.0/16                            100         None
      192.0.2.2                                        17          10
      64500                                                        524283
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

ECMP is enabled with a value of two, so traffic flows in VPRN 1 on PE-3 with destination 172.31.0.0/16 are distributed over two paths: one via PE-1 and another via PE-2, as follows:

```
[/]
A:admin@PE-3# show router 1 route-table 172.31.0.0/16

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
172.31.0.0/16                                  Remote  BGP VPN   00h02m22s  170
       192.0.2.1 (tunneled)                                           10
172.31.0.0/16                                  Remote  BGP VPN   00h02m22s  170
       192.0.2.2 (tunneled)                                           10
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

Conclusion

BGP add-path allows BGP speakers to advertise multiple distinct paths for the same prefix. The potential benefits of BGP add-path include reduced routing churn, faster convergence, and better load-sharing.

BGP Add-Path Policy Control

This chapter provides information about BGP add-path policy control.

Topics in this chapter include:

Applicability

This chapter was initially based on SR OS Release 15.0.R4, but the CLI in the current edition corresponds to SR OS Release 22.10.R2.

Overview

BGP add-path allows for advertising multiple paths per prefix for faster convergence, load sharing, and reduction of routing churn. See the BGP Add-Path chapter for more information.

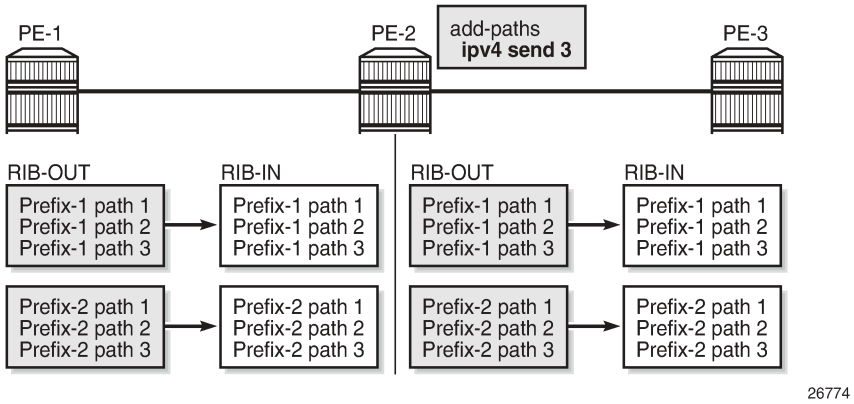
The BGP add-path policy control feature extends the functionality of BGP add-path, which was able to control the number of advertised paths per prefix per address family. This meant that all prefixes that belonged to an address family (such as IPv4, IPv6, and so on) were subject to the same sending limit imposed by the **send** <*number*|*keyword*> command configured at the BGP instance, group, or neighbor level.

BGP add-path policy control adds the capability to configure the number of advertised paths on a per-prefix basis. The **add-paths-send-limit** route policy action allows overriding the sending limit in the **bgp** context for selected prefixes. This adds finer granularity to BGP add-path, where a global path limit is defined at the relevant BGP level and specific limits can be defined for exceptional prefixes at an import policy level.

A value between 1 and 16 is configurable for **add-paths-send-limit**.

Figure 14: BGP add-paths before policy control shows a topology for BGP add-paths before policy control.

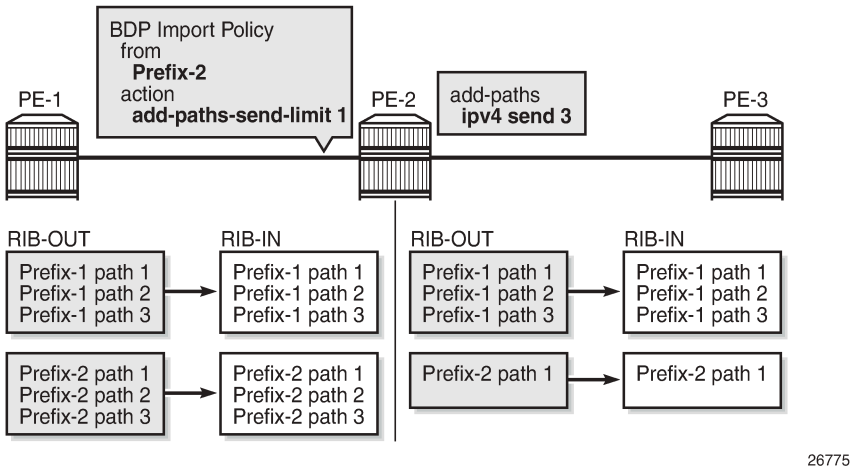
Figure 14: BGP add-paths before policy control



In Figure 14: BGP add-paths before policy control, PE-2 receives two prefixes with three diverse paths from PE-1. PE-2 has a sending limit with a value of 3 configured at a BGP level that is applicable to PE-3. Therefore, PE-2 sends both prefixes with three different path IDs to PE-3.

Figure 15: BGP add-paths after policy control shows a topology for BGP add-paths after policy control.

Figure 15: BGP add-paths after policy control



In Figure 15: BGP add-paths after policy control, a BGP-import policy is applied on PE-2. The policy selectively applies a sending limit of 1 on the paths received for Prefix-2. Therefore, PE-2 sends only one path for Prefix-2 to PE-3, while the BGP level sending limit of 3 still applies for Prefix-1.

The policy action is only applicable for BGP-import policy and has no effect on BGP-export policy, VRF-import policy, or VRF-export policy. The reason for this is that the policy needs to be applied on the routes accepted into the RIB-IN, otherwise two or more paths may not be present.

The BGP-import policy does not match VPN-IP routes unless the **vpn-apply-import** *true* command is configured in the BGP global base, group, or neighbor level.

Note:
The route policy only controls the number of advertised paths, not the set of paths.

Configuration

The following configuration examples are in this section:

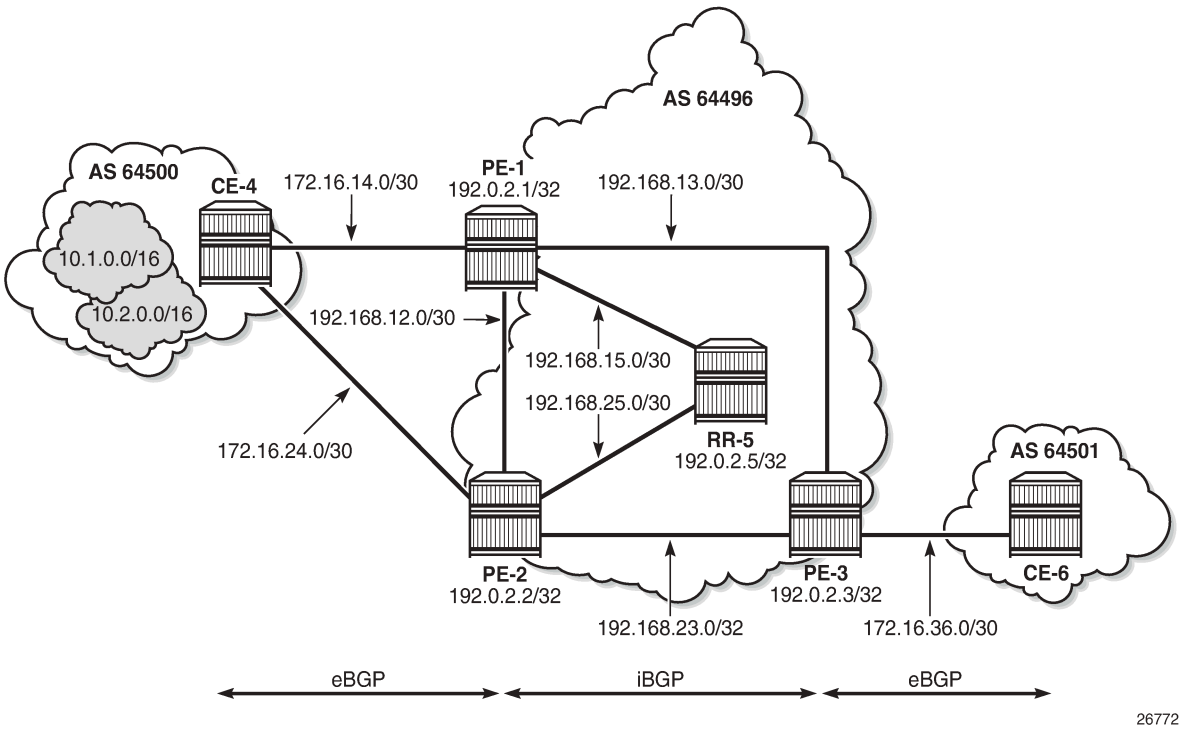
- BGP add-path for address family IPv4 without policy control
- BGP add-path for address family IPv4 with policy control
- BGP add-path for address family VPN-IPv4 with policy control

Example topology

Figure 16: Example topology - IPv4 shows the example topology used for the BGP add-path policy control feature for the IPv4 address family. The topology used is similar to the one in the BGP Add-Path chapter, with the following characteristics:

- CE-4 in AS 64500 advertises both prefixes 10.1.0.0/16 and 10.2.0.0/16 to its eBGP peers PE-1 and PE-2 in AS 64496.
- RR-5 is route reflector for all PEs in AS 64496.
- add-path is configured on all PE routers and RR-5 with a sending limit of 2.
- CE-6 in AS 64501 peers with PE-3 in AS 64496 and can send traffic to CE-4 in 64500.

Figure 16: Example topology - IPv4



Initial configuration

The initial configuration on all nodes includes:

- Cards, MDAs, ports
- Router interfaces
- IS-IS as IGP on all interfaces within AS 64496 (alternatively, OSPF can be used)
- LDP on all interfaces between the PEs in AS 64496, but not toward RR-5. LDP is used to create the transport tunnels that bind to the VPRN services in the VPN-IPv4 address family section.

BGP is configured on all the nodes. CE-4 peers with PE-1 and PE-2 and exports prefixes 10.1.0.0/16 and 10.2.0.0/16 to both eBGP peers, as follows:

```
# on CE-4:
configure {
    router "Base" {
        autonomous-system 64500
        bgp {
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "eBGP" {
                peer-as 64496
```

```
                export {
                    policy ["export-bgp"]
                }
            }
            neighbor "172.16.14.1" {
                group "eBGP"
            }
            neighbor "172.16.24.1" {
                group "eBGP"
            }
        }
        interface "int-loopback-1" {
            loopback
            ipv4 {
                primary {
                    address 10.1.1.1
                    prefix-length 16
                }
            }
        }
        interface "int-loopback-2" {
            loopback
            ipv4 {
                primary {
                    address 10.2.1.1
                    prefix-length 16
                }
            }
        }
    }
    policy-options {
        prefix-list "10.1.0.0/16" {
            prefix 10.1.0.0/16 type longer {
            }
        }
        prefix-list "10.2.0.0/16" {
            prefix 10.2.0.0/16 type longer {
            }
        }
        policy-statement "export-bgp" {
            entry 10 {
                from {
                    prefix-list ["10.1.0.0/16"]
                }
                action {
                    action-type accept
                }
            }
            entry 20 {
                from {
                    prefix-list ["10.2.0.0/16"]
                }
                action {
                    action-type accept
                }
            }
        }
    }
}
```

The BGP configuration on CE-6 is similar, except for the export policy.

PE-1 peers with CE-4 in AS 64500 and RR-5 in AS 64496. The BGP configuration on PE-1 is as follows:

```
# on PE-1:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "eBGP" {
                peer-as 64500
            }
            group "iBGP" {
                next-hop-self true
                peer-as 64496
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            neighbor "172.16.14.2" {
                group "eBGP"
            }
            neighbor "192.0.2.5" {
                group "iBGP"
            }
        }
    }
}
```

The BGP configuration on PE-2 and PE-3 is similar to that of PE-1.

RR-5 acts as a route reflector to all the PEs in AS 64500 with a cluster ID of 5.5.5.5. The configuration on RR-5 is as follows:

```
# on RR-5:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "iBGP" {
                peer-as 64496
                cluster {
                    cluster-id 5.5.5.5
                }
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
```

```
            }
            neighbor "192.0.2.1" {
                group "iBGP"
            }
            neighbor "192.0.2.2" {
                group "iBGP"
            }
            neighbor "192.0.2.3" {
                group "iBGP"
            }
        }
    }
}
```

BGP add-path for address family IPv4 without policy control

RR-5 receives both the 10.1.0.0/16 and 10.2.0.0/16 prefixes with two paths from PE-1 and PE-2:

```
[/]
A:admin@RR-5# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.5        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  10.1.0.0/16                                       100         None
      192.0.2.1                                         2           10
      64500                                                         -
*i    10.1.0.0/16                                       100         None
      192.0.2.2                                         2           10
      64500                                                         -
u*>i  10.2.0.0/16                                       100         None
      192.0.2.1                                         1           10
      64500                                                         -
*i    10.2.0.0/16                                       100         None
      192.0.2.2                                         1           10
      64500                                                         -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

RR-5 propagates these updates to its clients, for example to PE-3, as follows:

```
12 2023/01/26 12:57:20.218 CET MINOR: DEBUG #2001 Base Peer 1: 192.0.2.3
"Peer 1: 192.0.2.3: UPDATE
Peer 1: 192.0.2.3 - Send BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 41
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 6 AS Path:
```

```
        Type: 2 Len: 1 < 64500 >
    Flag: 0x40 Type: 3 Len: 4 Nexthop: 192.0.2.1
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0x80 Type: 9 Len: 4 Originator ID: 192.0.2.1
    Flag: 0x80 Type: 10 Len: 4 Cluster ID:
        5.5.5.5
    NLRI: Length = 14
        10.1.0.0/16 Path-ID 11
        10.2.0.0/16 Path-ID 12
"
```

```
3 2023/01/26 12:56:53.218 CET MINOR: DEBUG #2001 Base Peer 1: 192.0.2.3
"Peer 1: 192.0.2.3: UPDATE
Peer 1: 192.0.2.3 - Send BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 41
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 6 AS Path:
        Type: 2 Len: 1 < 64500 >
    Flag: 0x40 Type: 3 Len: 4 Nexthop: 192.0.2.2
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0x80 Type: 9 Len: 4 Originator ID: 192.0.2.2
    Flag: 0x80 Type: 10 Len: 4 Cluster ID:
        5.5.5.5
    NLRI: Length = 14
        10.1.0.0/16 Path-ID 1
        10.2.0.0/16 Path-ID 2
"
```

PE-3 receives both prefixes in its BGP routing table with two different paths (also, optionally, has ECMP and BGP multipath enabled as described in the BGP Add-Path chapter):

```
# on PE-3:
configure {
    router "Base" {
        ecmp 2
        bgp {
            multipath {
                max-paths 2
            }
        }
    }
}
```

```
[/]
A:admin@PE-3# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
```

```
u*>i  10.1.0.0/16                                       100         None
      192.0.2.1                                         11          10
      64500                                                         -
u*>i  10.1.0.0/16                                       100         None
      192.0.2.2                                         1           10
      64500                                                         -
u*>i  10.2.0.0/16                                       100         None
      192.0.2.1                                         12          10
      64500                                                         -
u*>i  10.2.0.0/16                                       100         None
      192.0.2.2                                         2           10
      64500                                                         -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

BGP add-path for address family IPv4 with policy control

The following policy is enabled on RR-5, which limits the number of advertised paths for prefix 10.2.0.0/16 to one:

```
# on RR-5
configure {
    policy-options {
        prefix-list "10.2.0.0/16" {
            prefix 10.2.0.0/16 type longer {
            }
        }
        policy-statement "import-add-path" {
            entry 10 {
                from {
                    prefix-list ["10.2.0.0/16"]
                }
                action {
                    action-type accept
                    add-paths-send-limit 1
                }
            }
        }
    }
    router "Base" {
        bgp {
            group "iBGP" {
                import {
                    policy ["import-add-path"]
                }
            }
        }
    }
}
```

RR-5 sends the following withdrawal message to PE-3:

```
13 2023/01/26 13:03:13.218 CET MINOR: DEBUG #2001 Base Peer 1: 192.0.2.3
"Peer 1: 192.0.2.3: UPDATE
Peer 1: 192.0.2.3 - Send BGP UPDATE:
    Withdrawn Length = 7
        10.2.0.0/16 Path-ID 2
    Total Path Attr Length = 0
"
```

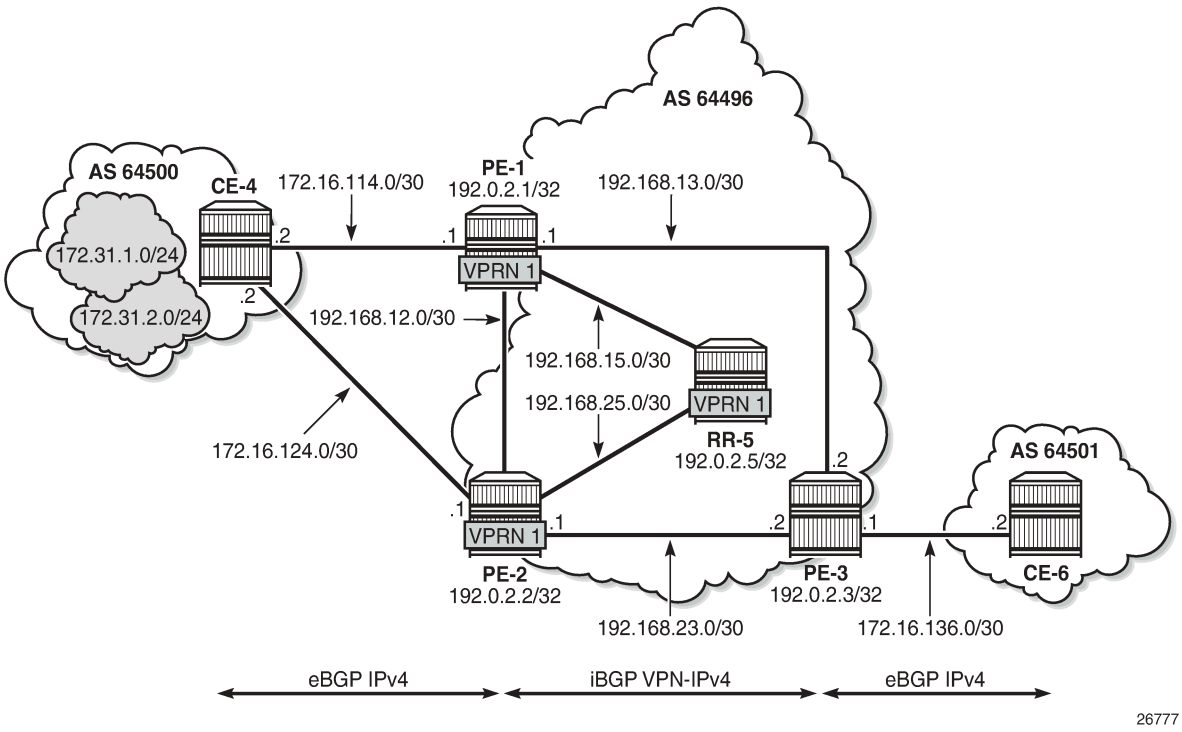
PE-3 deletes the route with Path-ID 12 for prefix 10.2.0.0/16:

```
[/]
A:admin@PE-3# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.0.0/16                                      100         None
      192.0.2.1                                        11          10
      64500                                                        -
u*>i  10.1.0.0/16                                      100         None
      192.0.2.2                                        1           10
      64500                                                        -
u*>i  10.2.0.0/16                                      100         None
      192.0.2.1                                        12          10
      64500                                                        -
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

BGP add-path for address family VPN-IPv4 with policy control

Figure 17: Example topology - VPN-IPv4 shows the example topology used for the BGP add-path policy control feature for VPN-IPv4 route family. The topology used is similar to the one used in the BGP Add-Path chapter. CE-4 exports both prefixes 172.31.1.0/24 and 172.31.2.0/24 to VPRN 1 on PE-1 and PE-2.

Figure 17: Example topology - VPN-IPv4



VPRN 1 is configured on all PEs in AS 64496. The configuration of VPRN 1 is similar on all PEs; for example, for PE-1, the VPRN configuration is as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            autonomous-system 64496
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64496:1"
                    vrf-target {
                        community "target:64496:1"
                    }
                    auto-bind-tunnel {
                        resolution any
                    }
                }
            }
            bgp {
                split-horizon true
                ebgp-default-reject-policy {
                    import false
                    export false
                }
                group "eBGP-1" {
                    peer-as 64500
```

```
                }
                neighbor "172.16.114.2" {
                    group "eBGP-1"
                }
            }
            interface "int-PE-1-CE-4-VPRN1" {
                ipv4 {
                    primary {
                        address 172.16.114.1
                        prefix-length 30
                    }
                }
                sap 1/1/c1/2:1 {
                }
            }
        }
    }
}
```

On the CEs, the configuration is either in the base routing instance, with additional router interfaces and BGP neighbors, or in a VPRN. In this example, the following VPRN is configured on CE-4:

```
# on CE-4:
configure {
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            autonomous-system 64500
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64500:1"
                }
            }
            bgp {
                split-horizon true
                ebgp-default-reject-policy {
                    import false
                    export false
                }
                group "eBGP-1" {
                    peer-as 64496
                    export {
                        policy ["export-VPRN1"]
                    }
                }
                neighbor "172.16.114.1" {
                    group "eBGP-1"
                }
                neighbor "172.16.124.1" {
                    group "eBGP-1"
                }
            }
            interface "int-CE-4-PE-1-VPRN1" {
                ipv4 {
                    primary {
                        address 172.16.114.2
                        prefix-length 30
                    }
                }
                sap 1/1/c1/1:1 {
```

```
                }
            }
            interface "int-CE-4-PE-2-VPRN1" {
                ipv4 {
                    primary {
                        address 172.16.124.2
                        prefix-length 30
                    }
                }
                sap 1/1/c1/2:1 {
                }
            }
            interface "loopback1-VPRN1" {
                loopback true
                ipv4 {
                    primary {
                        address 172.31.1.1
                        prefix-length 24
                    }
                }
            }
            interface "loopback2-VPRN1" {
                loopback true
                ipv4 {
                    primary {
                        address 172.31.2.1
                        prefix-length 24
                    }
                }
            }
        }
    }
}
```

The export policy to export prefixes 172.31.1.0/24 and 172.31.2.0/24 is defined as follows:

```
# on CE-4:
configure {
     policy-options {
        prefix-list "172.31.0.0/16" {
            prefix 172.31.0.0/16 type longer {
            }
        }
        policy-statement "export-VPRN1" {
            entry 10 {
                from {
                    prefix-list ["172.31.0.0/16"]
                }
                action {
                    action-type accept
                }
            }
        }
    }
}
```

The configuration on CE-6 is similar, but no prefix is exported from CE-6.

For all BGP speakers in AS 64496, BGP must be configured for address family VPN-IPv4 as well as for IPv4, as follows:

```
# on PE-1, PE-2, PE-3, RR-5:
configure {
```

```
    router "Base" {
        bgp {
            group "iBGP" {
                family {
                    ipv4 true
                    vpn-ipv4 true
                }
            }
        }
    }
}
```

BGP add-path cannot be enabled in the **bgp** context within a VPRN. However, it can be enabled in the base routing instance for address family VPN-IPv4. This is done on all PEs and RR-5 at group level with the following configuration:

```
# on PE-1, PE-2, PE-3, RR-5:
configure exclusive
    router "Base" {
        bgp {
            group "iBGP" {
                add-paths {
                    vpn-ipv4 {
                        send 2
                        receive true
                    }
                }
            }
        }
    }
}
```

The BGP configuration on PE-1 is as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "eBGP" {
                peer-as 64500
            }
            group "iBGP" {
                next-hop-self true
                peer-as 64496
                family {
                    ipv4 true
                    vpn-ipv4 true
                }
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                    vpn-ipv4 {
                        send 2
                        receive true
```

```
                    }
                }
            }
            neighbor "172.16.14.2" {
                group "eBGP"
            }
            neighbor "192.0.2.5" {
                group "iBGP"
            }
        }
    }
}
```

With add-path enabled for address family VPN-IPv4, PE-1 and PE-2 advertise their routes for prefixes 172.31.1.0/24 and 172.31.2.0/24 as VPN-IPv4 routes to RR-5. RR-5 advertises both routes to its other RR clients. PE-3 receives two VPN-IPv4 routes for each of the prefixes 172.31.1.0/24 and 172.31.2.0/24, as follows:

```
[/]
A:admin@PE-3# show router bgp routes 172.31.0.0/16 vpn-ipv4 longer
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64496:1:172.31.1.0/24                            100         None
      192.0.2.1                                        21          10
      64500                                                        524283
u*>i  64496:1:172.31.1.0/24                            100         None
      192.0.2.2                                        9           10
      64500                                                        524283
u*>i  64496:1:172.31.2.0/24                            100         None
      192.0.2.1                                        20          10
      64500                                                        524283
u*>i  64496:1:172.31.2.0/24                            100         None
      192.0.2.2                                        10          10
      64500                                                        524283
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

All routes are used because of the ECMP setting in VPRN 1:

```
# on PE-3:
configure {
    service {
        vprn "VPRN 1" {
            ecmp 2
        }
    }
}
```

Alternatively, BGP FRR can be enabled for VPRN 1, as described in the BGP Add-Path chapter.

To limit the advertisement of prefix 172.31.2.0/24 to a single path, the following route policy is configured on RR-5:

```
# on RR-5:
configure {
    policy-options {
        prefix-list "172.31.2.0/24" {
            prefix 172.31.2.0/24 type longer {
            }
        }
        policy-statement "import-add-path" {
            entry 20 {
                from {
                    prefix-list ["172.31.2.0/24"]
                }
                action {
                    action-type accept
                    add-paths-send-limit 1
                }
            }
        }
    }
}
```

The policy entry for prefix 172.31.2.0/24 can be configured in a new policy-statement or be added to an existing BGP policy (used for the previous IPv4 add-path policy section, for example).

If this is a new policy-statement, apply the policy in the **group "iBGP"** context on RR-5:

```
# on RR-5:
configure {
    router "Base" {
        bgp {
            group "iBGP" {
                import {
                    policy ["import-add-path"]
                }
            }
        }
    }
}
```

At this point, PE-3 still has two paths for each of the prefixes:

```
[/]
A:admin@PE-3# show router bgp routes 172.31.0.0/16 vpn-ipv4 longer
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
```

```
-------------------------------------------------------------------------------
u*>i  64496:1:172.31.1.0/24                           100         None
      192.0.2.1                                       21          10
      64500                                                       524283
u*>i  64496:1:172.31.1.0/24                           100         None
      192.0.2.2                                       9           10
      64500                                                       524283
u*>i  64496:1:172.31.2.0/24                           100         None
      192.0.2.1                                       20          10
      64500                                                       524283
u*>i  64496:1:172.31.2.0/24                           100         None
      192.0.2.2                                       10          10
      64500                                                       524283
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

The following configuration is applied on RR-5 to make the BGP policy effective for VPN-IPV4 routes:

```
# on RR-5:
configure {
    router "Base" {
        bgp {
            vpn-apply-import true
        }
    }
}
```

Upon application of this configuration, RR-5 sends the following withdrawal to PE-3:

```
57 2023/01/26 13:14:03.218 CET MINOR: DEBUG #2001 Base Peer 1: 192.0.2.3
"Peer 1: 192.0.2.3: UPDATE
Peer 1: 192.0.2.3 - Send BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 26
    Flag: 0x90 Type: 15 Len: 22 Multiprotocol Unreachable NLRI:
        Address Family VPN_IPV4
        172.31.2.0/24 RD 64496:1 Label 0 (Raw label 0x1) Path-ID 10
"
```

PE-3 now has a single route for prefix 172.31.2.0/24 in its BGP routing table:

```
[/]
A:admin@PE-3# show router bgp routes 172.31.0.0/16 vpn-ipv4 longer
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                         LocalPref   MED
      Nexthop (Router)                                Path-Id     IGP Cost
      As-Path                                                     Label
-------------------------------------------------------------------------------
u*>i  64496:1:172.31.1.0/24                           100         None
      192.0.2.1                                       21          10
      64500                                                       524283
```

```
u*>i  64496:1:172.31.1.0/24                              100         None
      192.0.2.2                                          9           10
      64500                                                          524283
u*>i  64496:1:172.31.2.0/24                              100         None
      192.0.2.1                                          20          10
      64500                                                          524283
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

PE-3 has installed a single route for prefix 172.31.2.0/24 in its VPRN route table:

```
[/]
A:admin@PE-3# show router 1 route-table 172.31.0.0/16 longer

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
172.31.1.0/24                                 Remote  BGP VPN   00h06m31s  170
       192.0.2.1 (tunneled)                                         10
172.31.1.0/24                                 Remote  BGP VPN   00h06m31s  170
       192.0.2.2 (tunneled)                                         10
172.31.2.0/24                                 Remote  BGP VPN   00h01m26s  170
       192.0.2.1 (tunneled)                                         10
-------------------------------------------------------------------------------
No. of Routes: 3
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

Conclusion

The BGP add-path policy control feature allows BGP speakers to advertise multiple distinct paths for the same prefix. The potential benefits of using BGP add-path policy control are increased granularity and flexibility in advertising multiple paths to BGP neighbors.

BGP Autonomous System Override

This chapter describes BGP Autonomous System Override.

Topics in this chapter include:

Applicability

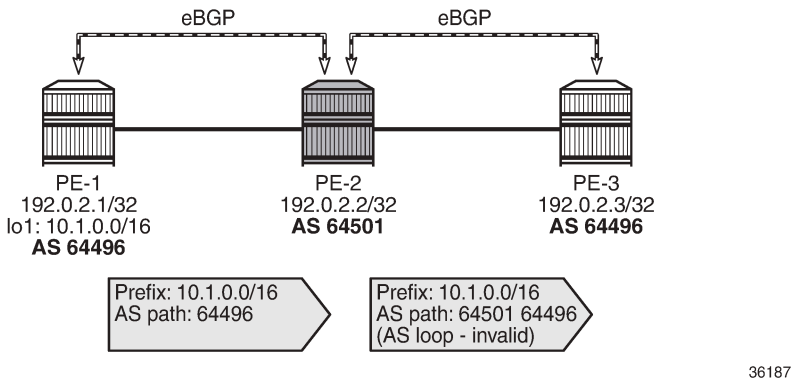
The information and configuration in this chapter are based on SR OS Release 20.5.R1. In SR OS releases earlier than 19.7.R1, BGP Autonomous System (AS) override is only supported in VPRN BGP instances; BGP AS override in the base router is supported in SR OS Release 19.7.R1 and later.

Overview

In some network designs, the same Autonomous System Number (ASN) is reused at different sites or regions that are interconnected by a common service or backbone. This can occur when an enterprise buys an IP VPN service to connect various sites that, in the past, were operated as a single ASN. This can also occur when a service provider builds a common backbone to interconnect regional networks that, for simplicity, reuse the same ASN.

This type of interconnectivity creates a problem because a BGP route originated by one of the sites and propagated through the backbone will appear as an AS path loop when advertised into another site. Routes with an AS loop are invalid; Figure 18: PE-2 detects AS-path loop and advertises the route to PE-3 as invalid shows an example. PE-2 in AS 64501 receives a BGP route from PE-1 in AS 64496. PE-2 detects that the ASN 64496 in the BGP AS-path attribute equals the ASN of its peer PE-3, so it detects an AS loop and advertises this route to PE-3 as an invalid route.

Figure 18: PE-2 detects AS-path loop and advertises the route to PE-3 as invalid

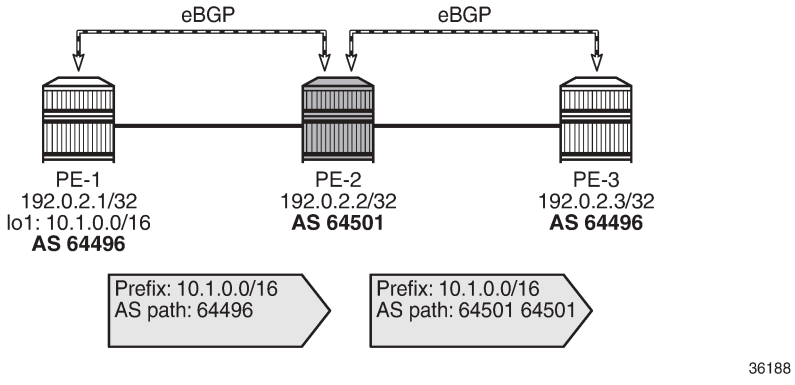


There are different solutions to this problem:

- Use different ASNs per site or region. From an operational point of view, this is a major change in an existing network.
- Disable AS path loop detection within each region. This is not encouraged in case you have external peering to the outside world. Any loops formed between these paths would be undetected.
- Configure the base router or the VPRN instance with BGP AS override.

Most operators prefer to use BGP AS override. A router configured to use BGP AS override on a BGP session monitors outbound routes toward that peer. Whenever a route has the ASN of the peer in its AS-path, all occurrences of this ASN are replaced by the local ASN of the router (or its confederation ID, if the peer is outside the confederation). Figure 19: BGP AS override replaces the peer ASN in the AS-path with the local ASN shows that PE-2 has replaced ASN 64496 in the AS-path attribute of the BGP route toward PE-3 with its own ASN 64501.

Figure 19: BGP AS override replaces the peer ASN in the AS-path with the local ASN



BGP AS override applies to all supported address families and is supported whether the session is confed-EBGP or EBGP.

The **as-override** command is configurable in the BGP group or neighbor context, both for the base router and the VPRNs.

In SR OS, AS path loop detection is enabled by default. Several actions can be configured when detecting an AS path loop, but those actions are out of the scope of this chapter:

```
configure router bgp / group / neighbor loop-detect
                                          {drop-peer|ignore-loop|off|discard-route}
```

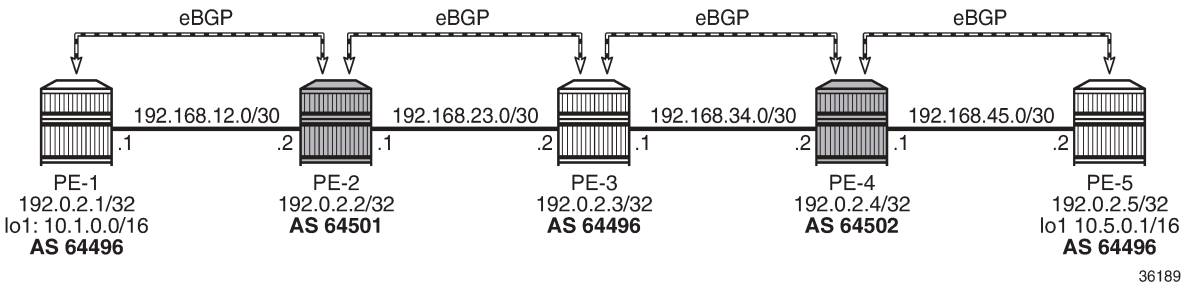
```
configure service vprn bgp / group / neighbor loop-detect
                                          {drop-peer|ignore-loop|off|discard-route}
```

With the **ignore-loop** parameter configured, the BGP routes are ignored when having an AS-loop flag but BGP peering remains established.

Configuration

Figure 20: Example topology shows the example topology with five routers: PE-1, PE-3, and PE-5 in AS 64496, PE-2 in AS 64501, and PE-4 in AS 64502.

Figure 20: Example topology



The initial configuration includes:

- Cards, MDAs, ports
- Router interfaces
- EBGP sessions between the nodes

The initial BGP configuration on PE-2 is as follows.

```
# on PE-2:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        policy-statement "1:1" {
            entry 10 {
                from {
                    community {
                        name "1:1"
                    }
                }
                action {
                    action-type accept
                }
```

```
            }
        }
    }
    router "Base" {
        autonomous-system 64501
        bgp {
            split-horizon true
            group "eBGP" {
                family {
                    ipv4 true
                }
                import {
                    policy ["1:1"]
                }
                export {
                    policy ["1:1"]
                }
            }
            neighbor "192.168.12.1" {
                group "eBGP"
                peer-as 64496
            }
            neighbor "192.168.23.2" {
                group "eBGP"
                peer-as 64496
            }
        }
```

The BGP configuration on the other nodes is similar.

In this chapter, two examples are shown:

- BGP AS override in the base router
- BGP AS override in a VPRN

Default: BGP AS override disabled in base router

By default, BGP AS override is not configured for a BGP group or BGP neighbor; this is verified on PE-2 as follows:

```
[]
A:admin@PE-2# show router bgp neighbor 192.168.12.1 detail | match "AS Override"
Multihop             : 0 (Default)      AS Override          : Disabled
```

```
[]
A:admin@PE-2# show router bgp neighbor 192.168.23.2 detail | match "AS Override"
Multihop             : 0 (Default)      AS Override          : Disabled
```

PE-1 exports BGP route 10.1.0.0/16, defined as a loopback interface in the base routing instance. The configuration is as follows:

```
# on PE-1:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        prefix-list "10.1.0.0/16" {
            prefix 10.1.0.0/16 type longer {
```

```
            }
        }
        policy-statement "export-prefix_10.1" {
            entry 10 {
                from {
                    prefix-list ["10.1.0.0/16"]
                }
                to {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    community {
                        add ["1:1"]
                    }
                }
            }
        }
        policy-statement "1:1" {
            entry 10 {
                from {
                    community {
                        name "1:1"
                    }
                }
                action {
                    action-type accept
                }
            }
        }
    }
    router "Base" {
        autonomous-system 64496
        bgp {
            split-horizon true
            group "eBGP" {
                peer-as 64501
                family {
                    ipv4 true
                }
                import {
                    policy ["1:1"]
                }
            }
            neighbor "192.168.12.2" {
                group "eBGP"
                export {
                    policy ["export-prefix_10.1"]
                }
            }
        }
```

PE-2 receives the BGP route from PE-1 with AS-path 64496, as follows:

```
[]
A:admin@PE-2# show router bgp neighbor 192.168.12.1 received-routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64501       Local AS:64501
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
```

```
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.0.0/16                                      None        None
      192.168.12.1                                     None        0
      64496                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

PE-2 detects that the ASN 64496 in the AS-path equals the ASN of the peer AS of PE-3, so an AS loop is detected and PE-2 advertises this route to PE-3 as an invalid route:

```
[]
A:admin@PE-2# show router bgp neighbor 192.168.23.2 advertised-routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
i     10.1.0.0/16                                      n/a         None
      192.168.23.1                                     None        0
      64501 64496                                                  -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

PE-3 receives this route with the following flags:

```
[]
A:admin@PE-3# show router bgp routes hunt | match Flags
Flags          : Invalid IGP AS-Loop
```

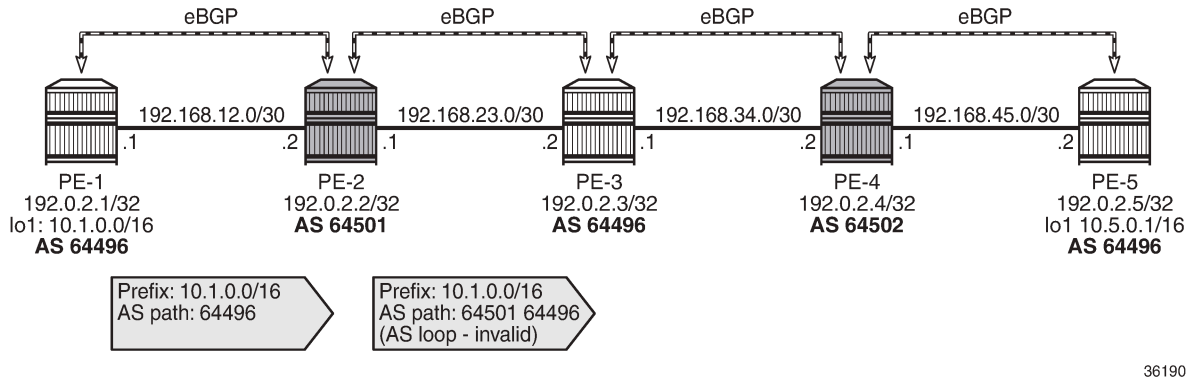
Normal BGP rules do not allow invalid routes to be advertised, so PE-3 does not advertise any route to PE-4, as follows:

```
[]
A:admin@PE-3# show router bgp neighbor 192.168.34.2 advertised-routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
```

```
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
No Matching Entries Found.
===============================================================================
```

Figure 21: PE-2 detects AS loop and advertises a route to PE-3 as invalid shows the BGP routes advertised by PE-1 and PE-2 with the corresponding AS-path.

Figure 21: PE-2 detects AS loop and advertises a route to PE-3 as invalid



BGP AS override in base router

On PE-2 and PE-4, the following command configures BGP AS override in the group "eBGP":

```
# on PE-2, PE-4:
configure {
    router "Base" {
        bgp {
            group "eBGP" {
                as-override true
            }
        }
```

With this configuration, BGP AS override is configured for both BGP neighbors, as follows:

```
[]
A:admin@PE-2# show router bgp neighbor 192.168.12.1 detail | match "AS Override"
Multihop             : 0 (Default)      AS Override          : Enabled
```

```
[]
A:admin@PE-2# show router bgp neighbor 192.168.23.2 detail | match "AS Override"
Multihop             : 0 (Default)      AS Override          : Enabled
```

PE-2 receives the route from PE-1 with ASN 64496, as follows:

```
[]
A:admin@PE-2# show router bgp routes 10.1.0.0/16
===============================================================================
 BGP Router ID:192.0.2.2        AS:64501       Local AS:64501
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.0.0/16                                      None        None
      192.168.12.1                                     None        0
      64496                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Instead of advertising a route with an AS loop, PE-2 will now replace ASN 64496 in the AS-path attribute with its own ASN 64501, so PE-3 receives the following valid route:

```
[]
A:admin@PE-3# show router bgp routes 10.1.0.0/16
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.0.0/16                                      None        None
      192.168.23.1                                     None        0
      64501 64501                                                  -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

PE-4 receives the following BGP route:

```
[]
A:admin@PE-4# show router bgp routes 10.1.0.0/16
===============================================================================
 BGP Router ID:192.0.2.4        AS:64502       Local AS:64502
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
```

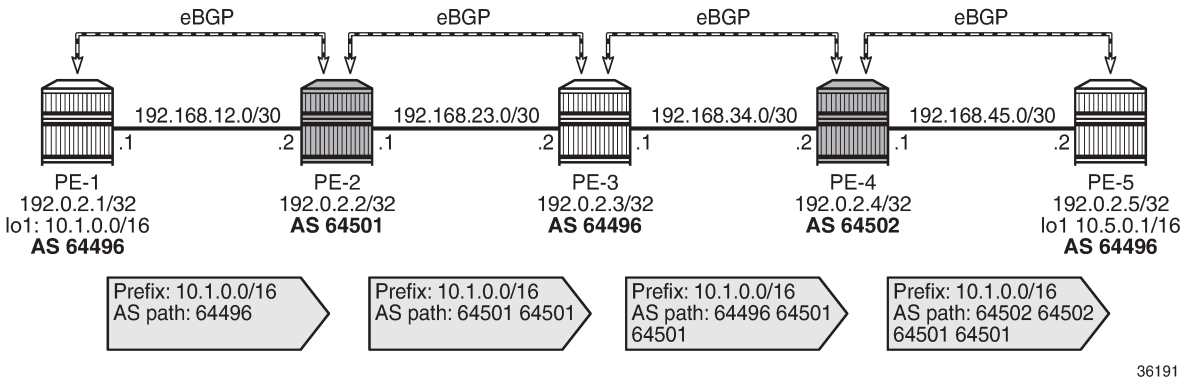
```
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.0.0/16                                      None        None
      192.168.34.1                                     None        0
      64496 64501 64501                                            -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

PE-4 detects an AS loop when advertising this route to its peer PE-5 in AS 64496, so it replaces ASN 64496 in the AS-path with its own ASN 64502. PE-5 receives the following valid route from PE-4:

```
[]
A:admin@PE-5# show router bgp routes 10.1.0.0/16
===============================================================================
 BGP Router ID:192.0.2.5        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.0.0/16                                      None        None
      192.168.45.1                                     None        0
      64502 64502 64501 64501                                      -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Figure 22: No AS loop when BGP AS override is enabled for group "eBGP" on PE-2 and PE-4 shows the BGP routes advertised by the PEs with the corresponding AS-path.

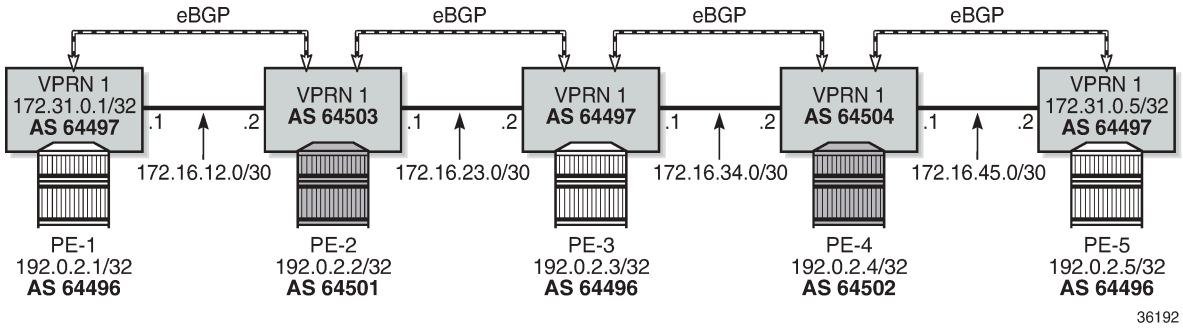
Figure 22: No AS loop when BGP AS override is enabled for group "eBGP" on PE-2 and PE-4



Default: BGP AS override disabled in VPRN

Figure 23: Example topology with VPRN 1 on all PEs shows the example topology with VPRN 1 configured on all PEs.

Figure 23: Example topology with VPRN 1 on all PEs



On PE-2, VPRN 1 is configured as follows. By default, **as-override** is not configured for any BGP group or BGP neighbor.

```
# on PE-2:
configure {
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            autonomous-system 64503
            router-id 172.31.0.2
            route-distinguisher "64503:1"
            vrf-target {
                community "target:1:1"
            }
            bgp {
```

```
                split-horizon true
                group "eBGP" {
                    peer-as 64497
                    local-as {
                        as-number 64503
                    }
                    import {
                        policy ["1:1"]
                    }
                    export {
                        policy ["1:1"]
                    }
                }
                neighbor "172.16.12.1" {
                    group "eBGP"
                }
                neighbor "172.16.23.2" {
                    group "eBGP"
                }
            }
            interface "int-VPRN1-PE-2-PE-1" {
                ipv4 {
                    primary {
                        address 172.16.12.2
                        prefix-length 30
                    }
                }
                sap 1/1/2:1 {
                }
            }
            interface "int-VPRN1-PE-2-PE-3" {
                ipv4 {
                    primary {
                        address 172.16.23.1
                        prefix-length 30
                    }
                }
                sap 1/1/1:1 {
                }
            }
            interface "system" {
                loopback true
                ipv4 {
                    primary {
                        address 172.31.0.2
                        prefix-length 32
                    }
                }
            }
```

The service configuration on the other nodes is similar. The IP addresses and ASNs are shown in Figure 23: Example topology with VPRN 1 on all PEs.

VPRN 1 on PE-1 exports BGP route 172.31.0.1/32, defined as a loopback interface within the VPRN 1 routing instance. The configuration is as follows:

```
# on PE-1:
configure {
    policy-options {
        prefix-list "172.31.0.0/16" {
            prefix 172.31.0.0/16 type longer {
            }
        }
```

```
        policy-statement "export-prefix_172.31" {
            entry 10 {
                from {
                    prefix-list ["172.31.0.0/16"]
                    protocol {
                        name [direct]
                    }
                }
                to {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    community {
                        add ["1:1"]
                    }
                }
            }
        }
    }
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            autonomous-system 64497
            router-id 172.31.0.1
            route-distinguisher "64497:1"
            vrf-target {
                community "target:1:1"
            }
            bgp {
                split-horizon true
                group "eBGP" {
                    peer-as 64503
                    local-as {
                        as-number 64497
                    }
                    import {
                        policy ["1:1"]
                    }
                }
                neighbor "172.16.12.2" {
                    group "eBGP"
                    export {
                        policy ["export-prefix_172.31"]
                    }
                }
            }
            interface "int-VPRN1-PE-1-PE-2" {
                ipv4 {
                    primary {
                        address 172.16.12.1
                        prefix-length 30
                    }
                }
                sap 1/1/1:1 {
                }
            }
            interface "system" {
                loopback true
                ipv4 {
```

```
                    primary {
                        address 172.31.0.1
                        prefix-length 32
                    }
                }
            }
```

VPRN 1 on PE-1 exports route 172.31.0.1/32 with ASN 64497 to VPRN 1 on PE-2. On PE-2, the following route is received in VPRN 1:

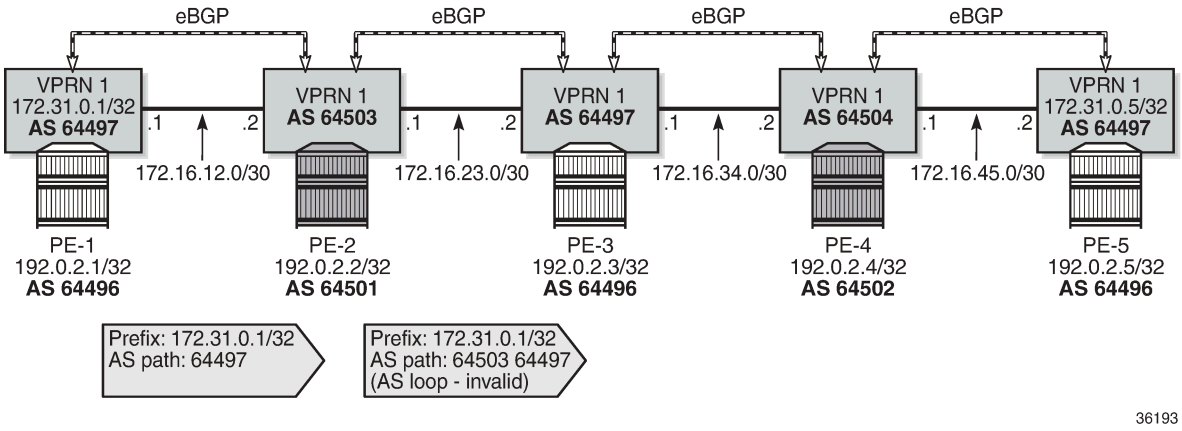
```
[]
A:admin@PE-2# show router 1 bgp neighbor 172.16.12.1 received-routes
===============================================================================
 BGP Router ID:172.31.0.2       AS:64503       Local AS:64503
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  172.31.0.1/32                                    n/a         None
      172.16.12.1                                      None        0
      64497                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

ASN 64497 equals the peer AS of PE-3, so an AS loop is detected, and the following route is advertised to VPRN 1 on PE-3 as invalid:

```
[]
A:admin@PE-2# show router 1 bgp neighbor 172.16.23.2 advertised-routes
===============================================================================
 BGP Router ID:172.31.0.2       AS:64503       Local AS:64503
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
i     172.31.0.1/32                                    n/a         None
      172.16.23.1                                      None        0
      64503 64497                                                  -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Figure 24: AS loop when BGP AS override is not configured in VPRN 1 on PE-2 shows the routes sent by VPRN 1 on PE-1 and PE-2. PE-3 receives an invalid route with an AS loop that is not re-advertised.

Figure 24: AS loop when BGP AS override is not configured in VPRN 1 on PE-2



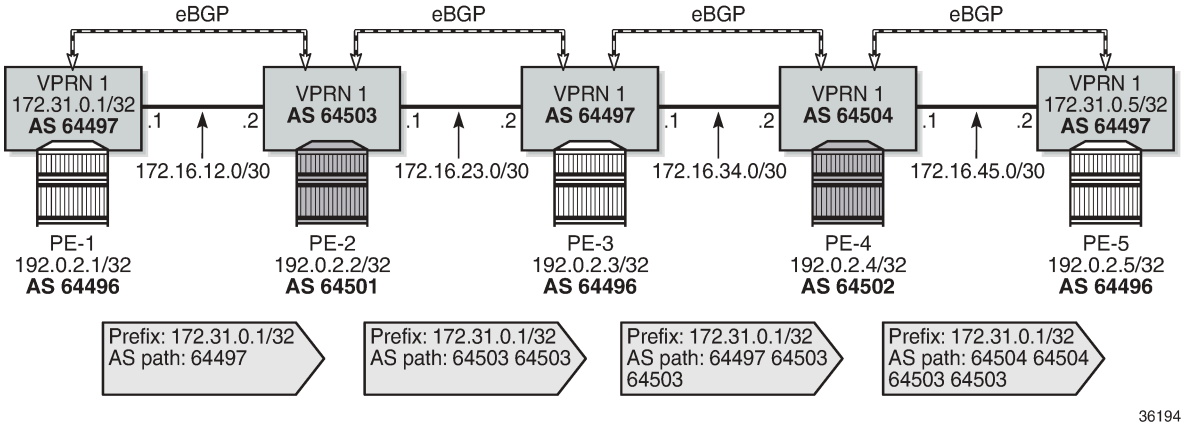
BGP AS override in VPRN

On PE-2 and PE-4, **as-override** is enabled in VPRN 1 for group "eBGP", as follows:

```
# on PE-2, PE-4:
configure {
    service {
        vprn "VPRN 1" {
            bgp {
                group "eBGP" {
                    as-override true
                }
            }
```

Figure 25: Routes advertised when BGP AS override is enabled in VPRN 1 on the PEs shows the routes advertised in VPRN 1 on the PEs when BGP AS override is enabled on PE-2 and PE-4.

Figure 25: Routes advertised when BGP AS override is enabled in VPRN 1 on the PEs



VPRN 1 on PE-2 receives the route with ASN 64497:

```
[]
A:admin@PE-2# show router 1 bgp routes 172.31.0.1/32
===============================================================================
 BGP Router ID:172.31.0.2       AS:64503       Local AS:64503
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  172.31.0.1/32                                    None        None
      172.16.12.1                                      None        0
      64497                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

With AS override enabled, VPRN 1 on PE-3 receives the following valid route where ASN 64497 is replaced by ASN 64503:

```
[]
A:admin@PE-3# show router 1 bgp routes 172.31.0.1/32
===============================================================================
 BGP Router ID:192.0.2.3        AS:64497       Local AS:64497
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
```

```
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  172.31.0.1/32                                    None        None
      172.16.23.1                                      None        0
      64503 64503                                                  -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

VPRN 1 on PE-4 receives the following route:

```
[]
A:admin@PE-4# show router 1 bgp routes 172.31.0.1/32
===============================================================================
 BGP Router ID:172.31.0.4       AS:64504       Local AS:64504
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  172.31.0.1/32                                    None        None
      172.16.34.1                                      None        0
      64497 64503 64503                                            -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

VPRN 1 on PE-4 replaces ASN 64497 with its own ASN 64504, so PE-5 receives the following valid route with AS-path <64504 64504 64503 64503>:

```
[]
A:admin@PE-5# show router 1 bgp routes 172.31.0.1/32
===============================================================================
 BGP Router ID:172.31.0.5       AS:64497       Local AS:64497
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  172.31.0.1/32                                    None        None
      172.16.45.1                                      None        0
      64504 64504 64503 64503                                      -
-------------------------------------------------------------------------------
```

```
Routes : 1
===============================================================================
```

Conclusion

BGP AS override can prevent AS loops in network designs where different sites or regions are interconnected by a common service or backbone. BGP AS override can be enabled for BGP groups or BGP neighbors, both in the base router and in VPRNs.

BGP Conditional Route Advertisement

This chapter provides information about BGP Conditional Route Advertisement.

Topics in this chapter include:

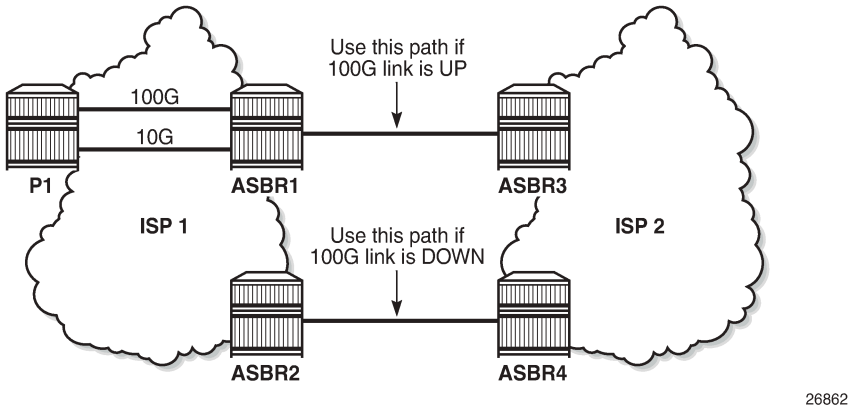
Applicability

The information and configuration in this chapter was originally based on SR OS Release 15.0.R4. The CLI in the current edition is based on SR OS Release 23.3.R2.

Overview

The BGP conditional route advertisement feature allows a router to control the advertisement of routes based on predetermined routes in the route table. Figure 26: Conditional BGP Route Advertisement - ISP Peering shows an example in which this feature can bring flexibility in an ISP peering scenario.

Figure 26: Conditional BGP Route Advertisement - ISP Peering



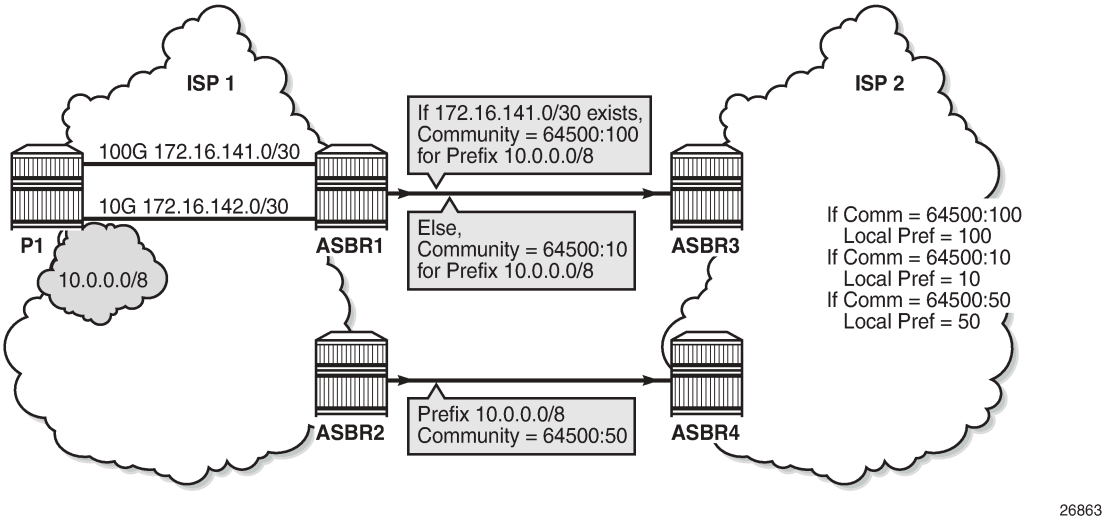
ISP 1 and ISP 2 have two peering points; a first between ASBR1 and ASBR3, and a second between ASBR2 and ASBR4. For redundancy, ISP 1 has two links between ASBR1 and the internal P1 router, one with 100 Gb/s and the other with 10 Gb/s capacity. According to the service agreement, ISP 1 instructs ISP 2 to send traffic using the upper path (between ASBR1 and ASBR3) only if the 100 Gb/s link between P1 and ASBR1 is up. If this is not the case, ISP 2 uses the lower path.

To implement the BGP conditional route advertisement feature, a conditional route policy entry is used. The route policy is as follows:

- Within a **policy-statement** entry, a conditional expression is created.
- The conditional expression tests for active IPv4 or IPv6 routes defined in a prefix list.
- If the expression is true, the **action** commands of the **policy** entry are applied.
- If the expression is false, the entire **policy** entry is skipped and processing continues with the next **policy** entry.
- Conditional expressions are only applicable when the route policy is used as a BGP export policy or a VRF export policy.

Figure 27: Conditional BGP Route Advertisement Implementation Example shows the implementation using the example in Figure 26: Conditional BGP Route Advertisement - ISP Peering.

Figure 27: Conditional BGP Route Advertisement Implementation Example



The prefix of the 100G interface between ASBR1 and P1 is 172.16.141.0/30. ASBR1 receives prefix 10.0.0.0/8 from P1 via BGP. Under standard conditions, the 100G interface is up and 172.16.141.0/30 exists in the route table and ASBR1 advertises 10.0.0.0/8 with a community value of 64500:100. ASBR2 advertises the same prefix with a community value of 64500:50. ASBR3 and ASBR4 in ISP 2 use an import policy that applies local preference values of 100 and 50 on the routes advertised by ASBR1 and ASBR2, respectively. As a result, the routers in ISP 2 prefer ASBR3 as an exit point for traffic flowing toward ISP 1.

If the 100G interface goes down, the prefix 172.16.141.0/30 is withdrawn from the route table and, as a result, ASBR1 starts advertising 10.0.0.0/8 with a community value of 64500:10. ASBR3 and ASBR4 adjust the local preference value for ASBR1 to 10 and, therefore, ASBR4 becomes the preferred exit point for routers in ISP 2.

The only conditional expression that can be contained in a **policy-statement** entry is a route-existence test defined by the **route-exists** keyword in the CLI. The command accepts two parameters: **all** and **none**:

- If neither the **all** nor the **none** parameter is used, the match logic is **any** - that is, the conditional expression is true if any exact match entry in the referenced prefix list has an active route in the route table associated with the policy.

- **all** - the conditional expression is true only if all the exact match entries in the referenced prefix list have an active route in the route table associated with the policy.
- **none** - the conditional expression is true only if none of the exact match entries in the referenced prefix list have an active route in the route table associated with the policy.

Configuration

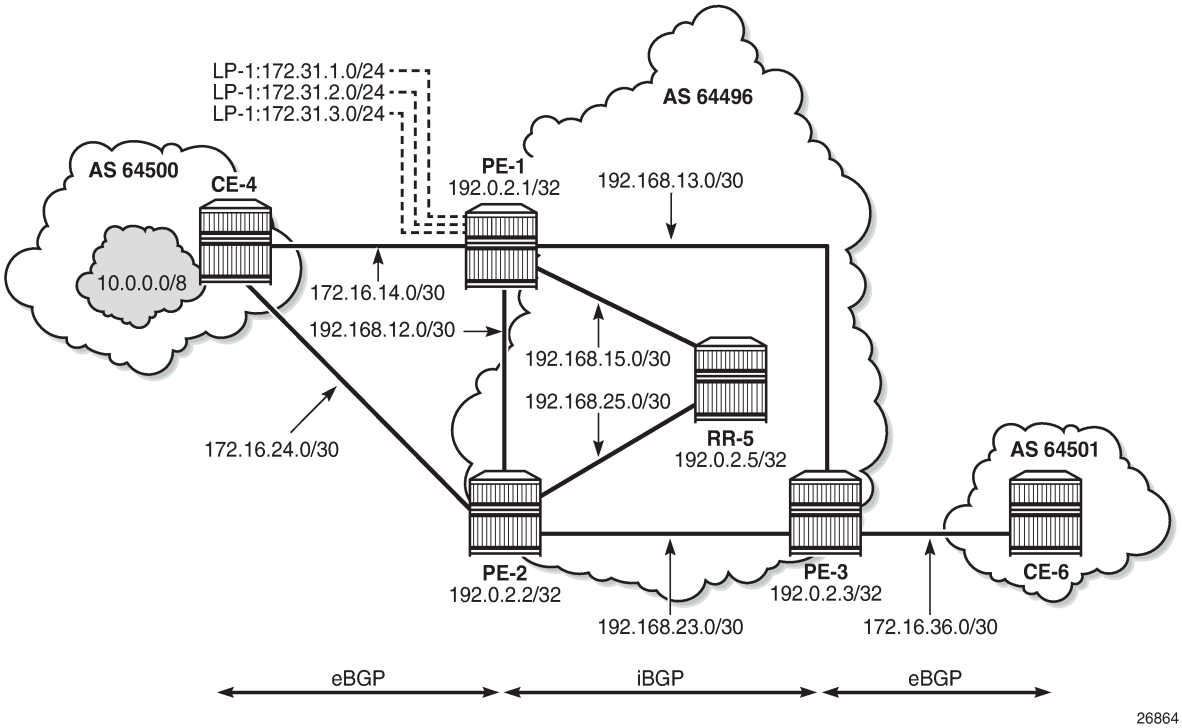
The following configuration examples are covered in this section:

- BGP Conditional Route Advertisement Using "any" Prefix List Match
- BGP Conditional Route Advertisement Using "all" Prefix List Match
- BGP Conditional Route Advertisement Using "none" Prefix List Match

Figure 28: Example Topology shows the example topology for BGP conditional route advertisement with the following characteristics:

- CE-4 in AS 64500 advertises prefix 10.0.0.0/8 to its eBGP peers PE-1 and PE-2 in AS 64496.
- PE-1 has three loopback interfaces configured to demonstrate the use of conditional route advertisement: LP-1, LP-2, and LP-3.
- RR-5 is route reflector for all PEs in AS 64496.
- CE-6 in AS 64501 peers with PE-3 in AS 64496 and can send traffic to CE-4 in 64500.

Figure 28: Example Topology



Initial Configuration

The initial configuration on all nodes includes:

- Cards, MDAs, ports
- LAG configured for the link between CE-4 and PE-1 with two member links
- Router interfaces
- IS-IS as IGP on all interfaces within AS 64496 (alternatively, OSPF can be used)

BGP is configured on all the nodes. CE-4 peers with PE-1 and PE-2 and exports the prefix 10.0.0.0/8 to both eBGP peers, which includes the address of the *int-loopback-1* interface, as follows:

```
# On CE-4:
configure {
    policy-options {
        prefix-list "10.0.0.0/8" {
            prefix 10.0.0.0/8 type longer {
            }
        }
        policy-statement "policy-export-bgp" {
            entry 10 {
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                }
            }
        }
    }
    router "Base" {
        autonomous-system 64500
        interface "int-loopback-1" {
            loopback
            ipv4 {
                primary {
                    address 10.1.1.1
                    prefix-length 8
                }
            }
        }
        bgp {
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "eBGP" {
                peer-as 64496
                export {
                    policy ["policy-export-bgp"]
                }
            }
            neighbor "172.16.14.1" {
                group "eBGP"
            }
            neighbor "172.16.24.1" {
                group "eBGP"
            }
```

```
        }
    }
}
```

The BGP configuration on CE-6 is identical, except for the loopback interface and export policy.

PE-1 peers with CE-4 in AS 65400 and RR-5 in AS 64496. The BGP configuration on PE-1 is as follows:

```
# On PE-1:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "eBGP" {
                peer-as 64500
            }
            neighbor "172.16.14.2" {
                group "eBGP"
            }
            group "iBGP" {
                next-hop-self true
                peer-as 64496
            }
            neighbor "192.0.2.5" {
                group "iBGP"
            }
        }
    exit all
```

The BGP configuration on PE-2 and PE-3 is similar to that of PE-1.

RR-5 is the route reflector to all the PEs in AS 64500 with a cluster ID of 5.5.5.5. The configuration on RR-5 is as follows:

```
# On RR-5:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "iBGP" {
                cluster {
                    cluster-id 5.5.5.5
                }
                peer-as 64496
            }
            neighbor "192.0.2.1" {
                group "iBGP"
            }
            neighbor "192.0.2.2" {
                group "iBGP"
            }
```

```
            neighbor "192.0.2.3" {
                group "iBGP"
            }
        }
    exit all
```

Three loopback interfaces are configured in PE-1 to be used for route existence tests:

```
# On PE-1:
configure {
    router "Base" {
        interface "int-loopback-1" {
            admin-state enable
            loopback
            ipv4 {
                primary {
                    address 172.31.1.1
                    prefix-length 24
                }
            }
        }
        interface "int-loopback-2" {
            admin-state enable
            loopback
            ipv4 {
                primary {
                    address 172.31.2.1
                    prefix-length 24
                }
            }
        }
        interface "int-loopback-3" {
            admin-state enable
            loopback
            ipv4 {
                primary {
                    address 172.31.3.1
                    prefix-length 24
                }
            }
        }
    exit all
```

BGP Conditional Route Advertisement Using "any" Prefix List Match

In the initial condition, RR-5 receives the prefix 10.0.0.0/8 from PE-1 and PE-2 with no community values and the default local preference value of 100:

```
[/]
A:admin@RR-5# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.1
Local Pref.    : 100                    Interface Name : int-RR-5-PE-1
Community      : No Community Members
Nexthop        : 192.0.2.2
Local Pref.    : 100                    Interface Name : int-RR-5-PE-2
Community      : No Community Members
```

The following policy is configured on PE-1 that adds the community 64500:100 to the 10.0.0.0/8 prefix advertised to RR-5 if any of the conditional prefixes in the prefix list are active in the route table:

```
# On PE-1:
configure {
    policy-options {
        community "64500:10" {
            member "64500:10" { }
        }
        community "64500:100" {
            member "64500:100" { }
        }
        prefix-list "10.0.0.0/8" {
            prefix 10.0.0.0/8 type longer {
            }
        }
        prefix-list "prefix-conditional-routes" {
            prefix 172.31.1.0/24 type longer {
            }
            prefix 172.31.2.0/24 type longer {
            }
            prefix 172.31.3.0/24 type longer {
            }
        }
        policy-statement "policy-bgp-community" {
            entry 10 {
                conditional-expression {
                    route-exists "[prefix-conditional-routes]"
                }
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                    community {
                        add ["64500:100"]
                    }
                }
            }
            entry 20 {
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                    community {
                        add ["64500:10"]
                    }
                }
            }
        }
    exit all
```

Special attention is required on the policy syntax. The square brackets […] in the expression of the **route-exists** command are very important.

The following policy is configured on PE-2 that adds the community 64500:50 to the 10.0.0.0/8 prefix advertised to RR-5 without any conditions:

```
# On PE-2:
configure {
    policy-options {
```

```
        community "64500:50" {
            member "64500:50" { }
        }
        prefix-list "10.0.0.0/8" {
            prefix 10.0.0.0/8 type longer {
            }
        }
        policy-statement "policy-bgp-community" {
            entry 10 {
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                    community {
                        add ["64500:50"]
                    }
                }
            }
        }
    exit all
```

The policy is applied to the iBGP group on PE-1 and PE-2:

```
# On PE-1 and on PE-2:
configure {
    router "Base" {
        bgp {
            group "iBGP" {
                export {
                    policy ["policy-bgp-community"]
                exit all
```

The prefix 10.0.0.0/8 is received on RR-5 with the respective community values and still with the default local preference values:

```
[/]
A:admin@RR-5# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.1
Local Pref.    : 100                    Interface Name : int-RR-5-PE-1
Community      : 64500:100
Nexthop        : 192.0.2.2
Local Pref.    : 100                    Interface Name : int-RR-5-PE-2
Community      : 64500:50
```

The following policy is configured on RR-5 to apply different local preference values based on the corresponding community value:

```
# On RR-5:
configure {
    policy-options {
        community "64500:10" {
            member "64500:10" { }
        }
        community "64500:100" {
            member "64500:100" { }
        }
        community "64500:50" {
            member "64500:50" { }
        }
        policy-statement "policy-bgp-preference" {
```

```
            entry 10 {
                from {
                    community {
                        name "64500:100"
                    }
                }
                action {
                    action-type accept
                    local-preference 100
                }
            }
            entry 20 {
                from {
                    community {
                        name "64500:50"
                    }
                }
                action {
                    action-type accept
                    local-preference 50
                }
            }
            entry 30 {
                from {
                    community {
                        name "64500:10"
                    }
                }
                action {
                    action-type accept
                    local-preference 10
                }
            }
        }
    exit all
```

The policy is applied on RR-5:

```
# On RR-5:
configure {
    router "Base" {
        bgp {
            group "iBGP" {
                import {
                    policy ["policy-bgp-preference"]
                exit all
```

The following command output shows that the correct local preference values are applied on the routes received from PE-1 and PE-2:

```
[/]
A:admin@RR-5# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.1
Local Pref.    : 100                    Interface Name : int-RR-5-PE-1
Community      : 64500:100
Nexthop        : 192.0.2.2
Local Pref.    : 50                     Interface Name : int-RR-5-PE-2
Community      : 64500:50
TieBreakReason : LocalPref
```

RR-5 advertises the route with local preference of 100 to PE-3, with next hop PE-1:

```
[/]
A:admin@PE-3# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.1
Local Pref.    : 100                    Interface Name : int-PE-3-PE-1
Community      : 64500:100
```

The first loopback interface is shutdown on PE-1, which results in the withdrawal of prefix 172.31.1.0/24 from the route table on PE-1:

```
# On PE-1:
configure {
    router "Base" {
        interface "int-loopback-1" {
            admin-state disable
        exit all
```

PE-1 still advertises the prefix 10.0.0.0/8 with the community 64500:100:

```
[/]
A:admin@RR-5# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.1
Local Pref.    : 100                    Interface Name : int-RR-5-PE-1
Community      : 64500:100
Nexthop        : 192.0.2.2
Local Pref.    : 50                     Interface Name : int-RR-5-PE-2
Community      : 64500:50
TieBreakReason : LocalPref
```

The second loopback interface is shutdown on PE-1, which results in the withdrawal of prefix 172.31.2.0/24 from the route on PE-1:

```
# On PE-1:
configure {
    router "Base" {
        interface "int-loopback-2" {
            admin-state disable
        exit all
```

PE-1 still advertises the prefix 10.0.0.0/8 with the community 64500:100:

```
[/]
A:admin@RR-5# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.1
Local Pref.    : 100                    Interface Name : int-RR-5-PE-1
Community      : 64500:100
Nexthop        : 192.0.2.2
Local Pref.    : 50                     Interface Name : int-RR-5-PE-2
Community      : 64500:50
TieBreakReason : LocalPref
```

The third and the last loopback interface is shutdown on PE-1, which results in the withdrawal of prefix 172.31.3.0/24 from the route table on PE-1:

```
# On PE-1:
configure {
    router "Base" {
        interface "int-loopback-3" {
```

```
            admin-state disable
        exit all
```

PE-1 now starts advertising the prefix 10.0.0.0/8 with the community 64500:10 and RR-5 applies local preference 10 for this route:

```
[/]
A:admin@RR-5# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.2
Local Pref.    : 50                     Interface Name : int-RR-5-PE-2
Community      : 64500:50
Nexthop        : 192.0.2.1
Local Pref.    : 10                     Interface Name : int-RR-5-PE-1
Community      : 64500:10
TieBreakReason : LocalPref
```

RR-5 advertises prefix 10.0.0.0/8 to PE-3 with the next-hop address of PE-2:

```
[/]
A:admin@PE-3# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.2
Local Pref.    : 50                     Interface Name : int-PE-3-PE-2
Community      : 64500:50
```

BGP Conditional Route Advertisement Using "all" Prefix List Match

The loopback interfaces on PE-1 are re-enabled:

```
# On PE-1:
configure {
    router "Base" {
        interface "int-loopback-1" {
            admin-state enable
        }
        interface "int-loopback-2" {
            admin-state enable
        }
        interface "int-loopback-3" {
            admin-state enable
        }
    exit all
```

The policy on PE-1 is changed so that the prefix 10.0.0.0/8 is advertised with community 64500:100 only if all the prefixes in the prefix list are active:

```
# On PE-1:
configure {
    policy-options {
        policy-statement "policy-bgp-community" {
            entry 10 {
                conditional-expression {
                    route-exists "[prefix-conditional-routes] all"
                exit all
```

The first loopback interface is shutdown on PE-1, which results in the withdrawal of prefix 172.31.1.0/24 from the route table on PE-1:

```
# On PE-1:
configure {
    router "Base" {
        interface "int-loopback-1" {
            admin-state disable
        exit all
```

PE-1 now advertises the prefix 10.0.0.0/8 with the community 64500:10:

```
[/]
A:admin@RR-5# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.2
Local Pref.    : 50                    Interface Name : int-RR-5-PE-2
Community      : 64500:50
Nexthop        : 192.0.2.1
Local Pref.    : 10                    Interface Name : int-RR-5-PE-1
Community      : 64500:10
TieBreakReason : LocalPref
```

RR-5 advertises prefix 10.0.0.0/8 to PE-3 with the next-hop address of PE-2:

```
[/]
A:admin@PE-3# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.2
Local Pref.    : 50                    Interface Name : int-PE-3-PE-2
Community      : 64500:50
```

BGP Conditional Route Advertisement Using "none" Prefix List Match

The loopback interfaces on PE-1 are re-enabled:

```
# On PE-1:
configure {
    router "Base" {
        interface "int-loopback-1" {
            admin-state enable
        }
        interface "int-loopback-2" {
            admin-state enable
        }
        interface "int-loopback-3" {
            admin-state enable
        }
    exit all
```

The policy on PE-1 is changed so that the prefix 10.0.0.0/8 is advertised with community 64500:100 only if none of the prefixes in the prefix list are active:

```
# On PE-1:
configure {
    policy-options {
        policy-statement "policy-bgp-community" {
            entry 10 {
                conditional-expression {
```

```
                    route-exists "[prefix-conditional-routes] none"
                exit all
```

PE-1 advertises the prefix 10.0.0.0/8 with the community 64500:10, because all loopback interface prefixes are active:

```
[/]
A:admin@RR-5# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.2
Local Pref.    : 50                     Interface Name : int-RR-5-PE-2
Community      : 64500:50
Nexthop        : 192.0.2.1
Local Pref.    : 10                     Interface Name : int-RR-5-PE-1
Community      : 64500:10
TieBreakReason : LocalPref
```

The loopback interfaces are shut down one by one or together using a range with the following command on PE-1:

```
# On PE-1:
configure {
    router "Base" {
        interface "int-loopback-1" {
            admin-state disable
        }
        interface "int-loopback-2" {
            admin-state disable
        }
        interface "int-loopback-3" {
            admin-state disable
        }
    exit all
```

PE-1 now advertises the prefix 10.0.0.0/8 with the community 64500:100:

```
[/]
A:admin@RR-5# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.1
Local Pref.    : 100                    Interface Name : int-RR-5-PE-1
Community      : 64500:100
Nexthop        : 192.0.2.2
Local Pref.    : 50                     Interface Name : int-RR-5-PE-2
Community      : 64500:50
TieBreakReason : LocalPref
```

RR-5 advertises prefix 10.0.0.0/8 to PE-3 with the next-hop address of PE-1:

```
[/]
A:admin@PE-3# show router bgp routes 10.0.0.0/8 hunt brief | match '^Nexthop|^Community|Pref'
Nexthop        : 192.0.2.1
Local Pref.    : 100                    Interface Name : int-PE-3-PE-1
Community      : 64500:100
```

Conclusion

BGP conditional route advertisement allows the control of BGP updates based on routes in the route table. A conditional policy entry can be created that tests whether any, all, or none of the prefixes in a prefix list are active and executes the related policy actions.

BGP Convergence — Delayed Route Advertisement

This chapter describes BGP Convergence — Delayed Route Advertisement.

Topics in this chapter include:

Applicability

The information and MD-CLI configuration in this chapter are based on SR OS Release 20.7.R2. BGP Delayed Route Advertisement is supported in SR OS Release 19.7.R1 and later.

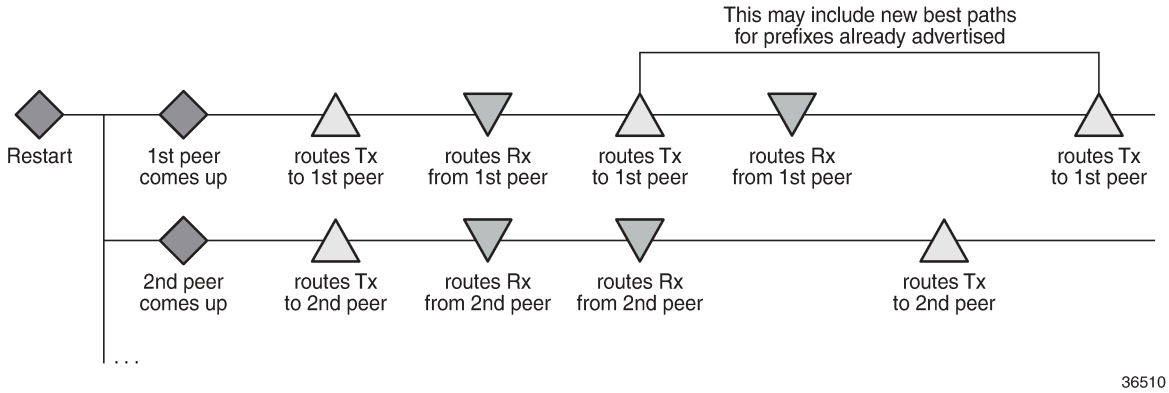
Overview

When the BGP process on a router is starting up or restarting, BGP convergence is finished after the restarting router completes the following actions:

- Reestablish the sessions with configured and discovered BGP neighbors.
- Relearn BGP routes advertised by the direct BGP neighbors (their best paths plus potentially some additional paths).
- Advertise to its direct neighbors the locally originated BGP routes plus the received routes from its set of best paths.

By default, the preceding steps are executed in parallel. After the first BGP session is reestablished, the restarting router starts advertising its own best paths to the BGP neighbor, even though it is still learning BGP routes and rebuilding its RIB-IN database. When more BGP sessions come up and more routes are learned, it is possible that routes previously considered best are no longer best, leading to multiple route advertisements for the same prefix, as shown in Figure 29: Default SR OS behavior when the BGP process restarts.

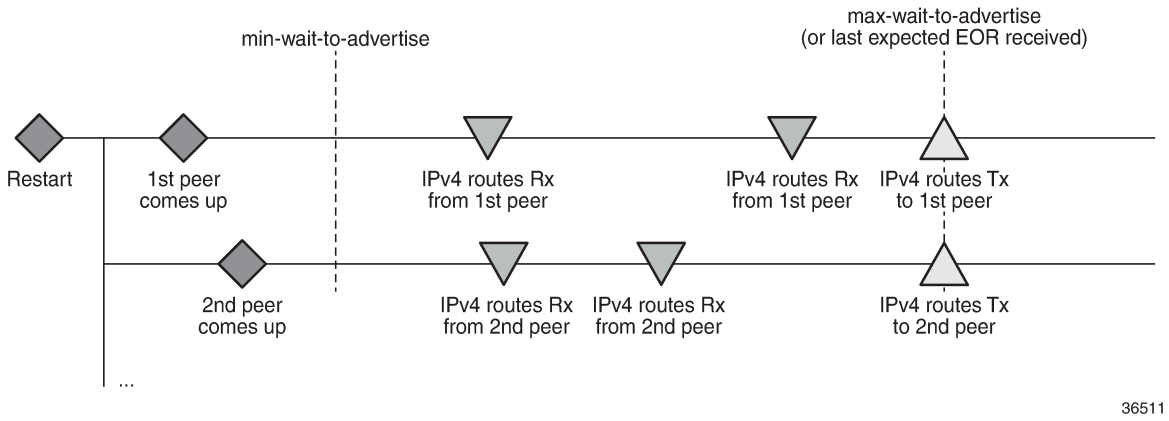
Figure 29: Default SR OS behavior when the BGP process restarts



Multiple route advertisements increase the processing workload on the restarting router and on its BGP neighbors. This lengthens the overall convergence time and it can cause short-term inefficiencies in traffic forwarding.

The BGP delayed route advertisement feature provides the following two convergence timers to offer the operator more control on the BGP convergence process when BGP is starting up or restarting: **min-wait-to-advertise** and **max-wait-to-advertise**. This feature applies to IPv4 unicast and IPv6 unicast routes of the base router BGP instance and VPRN BGP instances. BGP convergence tuning allows different timers in the base router and the VPRNs. Also, the **max-wait-to-advertise** timer can be different for IPv4 and IPv6 address families. Figure 30: BGP convergence tuning with delayed route advertisement shows the BGP convergence tuning.

Figure 30: BGP convergence tuning with delayed route advertisement



When a BGP peer has advertised all its routes for a specific address family, it sends an End of RIB (EOR) marker for each address family; for example, peer 192.0.2.4 sent the following EOR for IPv4:

```
171 2020/10/06 13:53:07.312 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.2.4
"Peer 1: 192.0.2.4: UPDATE
Peer 1: 192.0.2.4 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 0
      End-of-Rib marker (IPV4)
```

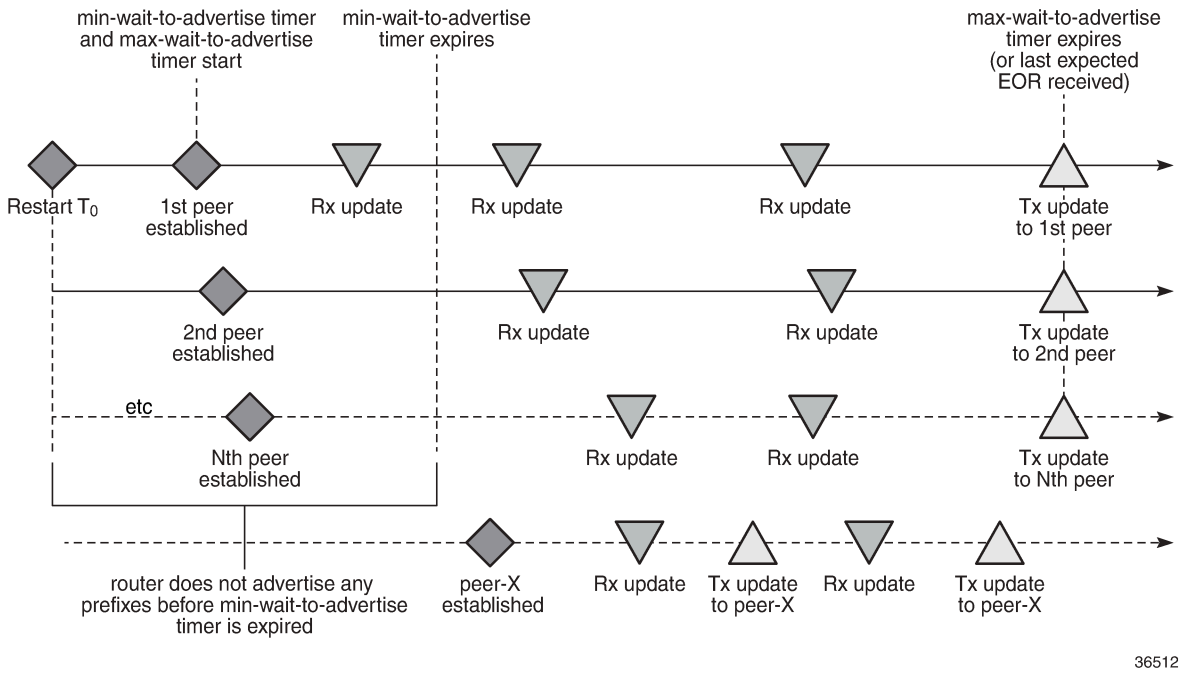
"

The restarting node will never advertise routes before the **min-wait-to-advertise** timer has expired. In Figure 30: BGP convergence tuning with delayed route advertisement, no routes were received at that time, but it is possible. Each peer advertises its routes followed by an EOR message per address family. When the restarting node receives all the expected EOR messages (and after the **min-wait-to-advertise** timer expires), it starts advertising its best routes. However, if the **max-wait-to-advertise** timer for the address family expires before all expected EORs have been received, it also starts advertising its best routes.

Note:
The timer values must be chosen well, because it is possible that the convergence degrades instead of improves with unsuitable timer values. The timer values depend on the BGP topology (number of peers, number of prefixes per peer, and BGP activeness of the peers). Timer values can be optimized by trial and error, and may have to be reviewed in case of network changes.

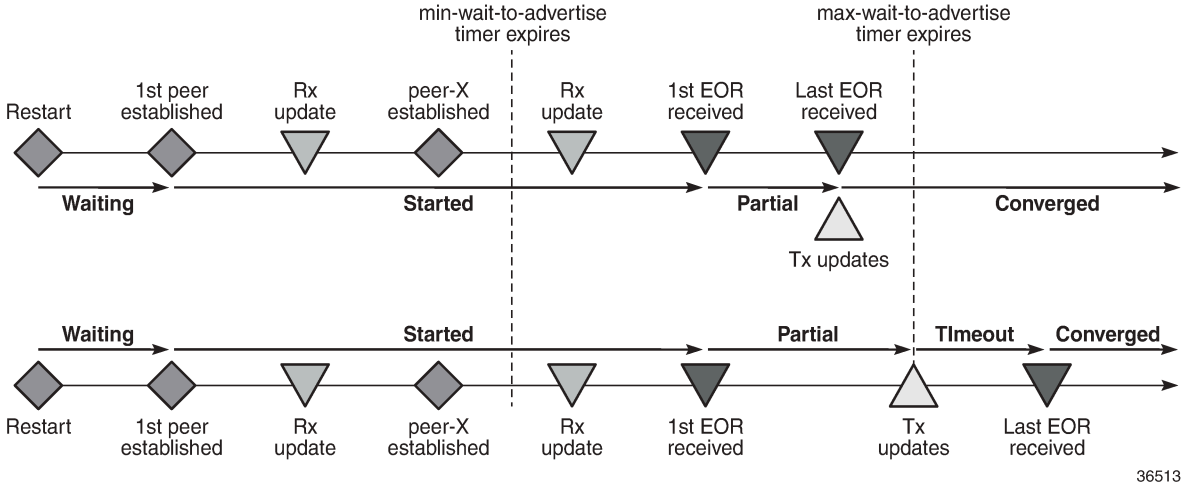
Figure 31: BGP convergence timers shows that the **min-wait-to-advertise** timer starts when the BGP process starts up or restarts, whereas the **max-wait-to-advertise** timer starts when the first peer (dynamic or configured) is established. It also shows that BGP convergence tuning does not apply to a new peer (peer-X) that is established after the **min-wait-to-advertise** timer has expired.

Figure 31: BGP convergence timers



The BGP convergence process can be monitored with the **show router bgp convergence** command. Figure 32: BGP convergence states shows the different BGP convergence states.

Figure 32: BGP convergence states



The BGP convergence states are:

- **Waiting**: when BGP convergence timers are configured and no peer has reconnected yet.
- **Started**: when the first peer (dynamic or configured) is established.
- **Partial**: when the first EOR is received from a neighbor for a specific address family.
- **Converged**: when the last EOR for an address family is received. If that occurs before the max-time-to-advertise timer expires, the restarting node starts advertising its RIB-OUT.
- **Timeout**: when the max-wait-to-advertise timer expires before the last EOR for an address family is received. The restarting node advertises its RIB-OUT when the timer expires.

When the feature is implemented, BGP maintains information about the convergence process associated with the last startup.

Configuration

The following example shows the principles of SR OS BGP convergence, whereas real-life examples have much larger numbers of BGP sessions and routes. Figure 33: Example topology shows the example topology with one node in Autonomous System (AS) 64501 and three nodes in AS 64500. On all four nodes, VPRN 1 is configured in AS 64496.

Figure 33: Example topology

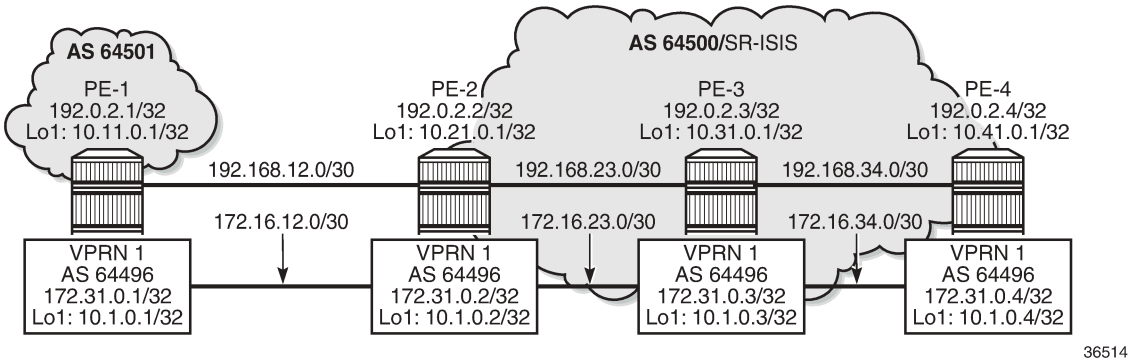


Figure 33: Example topology only shows the IPv4 addresses, but all interfaces also have IPv6 addresses.

The initial configuration on the nodes includes:

- Cards, MDAs, ports
- Router interfaces, with IPv4 and IPv6 addresses
- SR-ISIS in the base router on the three nodes in AS 64500
- IS-IS in VPRN 1 on all four nodes in AS 64496

In the base router, an eBGP session is established between PE-1 in AS 64501 and PE-2 in AS 64500. For the iBGP sessions in AS 64500, PE-2 acts as a Route Reflector (RR). The BGP configuration in the base router on PE-2 is as follows:

```
# on PE-2:
configure {
    router "Base" {
        autonomous-system 64500
        bgp {
            split-horizon true
            group "eBGP" {
                peer-as 64501
                local-address "int-PE-2-PE-1"
                local-as {
                    as-number 64500
                }
                import {
                    policy ["1:1"]
                }
            }
            group "iBGP-IPv4" {
                peer-as 64500
                family {
                    ipv4 true
                }
                cluster {
                    cluster-id 192.0.2.2
                }
            }
            group "iBGP-IPv6" {
                peer-as 64500
                family {
                    ipv6 true
                }
```

```
                cluster {
                    cluster-id 192.0.2.2
                }
            }
            neighbor "192.0.2.3" {
                group "iBGP-IPv4"
                next-hop-self true
                export {
                    policy ["export-10.21"]
                }
            }
            neighbor "192.0.2.4" {
                group "iBGP-IPv4"
                next-hop-self true
                export {
                    policy ["export-10.21"]
                }
            }
            neighbor "192.168.12.1" {
                group "eBGP"
                next-hop-self true
                family {
                    ipv4 true
                }
                export {
                    policy ["export-10.21" "1:1"]
                }
            }
            neighbor "2001:db8::2:3" {
                group "iBGP-IPv6"
                next-hop-self true
                export {
                    policy ["export-10:21"]
                }
            }
            neighbor "2001:db8::2:4" {
                group "iBGP-IPv6"
                next-hop-self true
                export {
                    policy ["export-10:21"]
                }
            }
            neighbor "2001:db8::12:1" {
                group "eBGP"
                next-hop-self true
                family {
                    ipv6 true
                }
                export {
                    policy ["export-10:21" "1:1"]
                }
            }
        }
```

The policies are the following:

```
# on PE-2:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        prefix-list "10.21.0.0/16" {
```

```
            prefix 10.21.0.0/16 type longer {
            }
        }
        prefix-list "_::10:21_" {
            prefix 2001:db8::10:21:0:0/120 type longer {
            }
        }
        policy-statement "1:1" {
            entry 10 {
                from {
                    community {
                        name "1:1"
                    }
                }
                action {
                    action-type accept
                }
            }
        }
        policy-statement "export-10.21" {
            entry 10 {
                from {
                    prefix-list ["10.21.0.0/16"]
                }
                action {
                    action-type accept
                    community {
                        add ["1:1"]
                    }
                }
            }
        }
        policy-statement "export-10:21" {
            entry 10 {
                from {
                    prefix-list ["_::10:21_"]
                }
                action {
                    action-type accept
                    community {
                        add ["1:1"]
                    }
                }
            }
        }
```

The BGP configuration in the base router is similar on the other PEs, with similar export policies.

BGP is also configured in VPRN 1, with similar export policies. On RR PE-2, the BGP configuration in VPRN 1 is as follows:

```
# on PE-2
configure {
    service {
        vprn "VPRN 1" {
            autonomous-system 64496
            bgp {
                router-id 172.31.0.2
                split-horizon true
                group "iBGP-VPRN1" {
                    peer-as 64496
                    cluster {
                        cluster-id 172.31.0.2
```

```
                }
            }
            neighbor "172.31.0.1" {
                group "iBGP-VPRN1"
                local-address 172.31.0.2
                family {
                    ipv4 true
                }
                export {
                    policy ["export-10.1"]
                }
            }
            neighbor "172.31.0.3" {
                group "iBGP-VPRN1"
                local-address 172.31.0.2
                family {
                    ipv4 true
                }
                export {
                    policy ["export-10.1"]
                }
            }
            neighbor "172.31.0.4" {
                group "iBGP-VPRN1"
                local-address 172.31.0.2
                family {
                    ipv4 true
                }
                export {
                    policy ["export-10.1"]
                }
            }
            neighbor "2001:db8::31:0:1" {
                group "iBGP-VPRN1"
                family {
                    ipv6 true
                }
                export {
                    policy ["export-10:1"]
                }
            }
            neighbor "2001:db8::31:0:3" {
                group "iBGP-VPRN1"
                family {
                    ipv6 true
                }
                export {
                    policy ["export-10:1"]
                }
            }
            neighbor "2001:db8::31:0:4" {
                group "iBGP-VPRN1"
                family {
                    ipv6 true
                }
                export {
                    policy ["export-10:1"]
                }
            }
        }
```

The configuration is similar on the other nodes.

The following BGP summary on PE-2 shows the different sessions where PE-2 receives one IPv4 or IPv6 route per neighbor and advertises three IPv4 or IPv6 routes per neighbor, both in the base router (Def. Instance) and in VPRN 1 (Svc: 1):

```
[]
A:admin@PE-2# show router bgp summary all
===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.3
Def. Instance  64500        8    0 00h01m56s 1/1/3 (IPv4)
                           11    0
192.0.2.4
Def. Instance  64500        8    0 00h01m43s 1/1/3 (IPv4)
                           11    0
192.168.12.1
Def. Instance  64501        9    0 00h02m20s 1/1/3 (IPv4)
                           11    0
2001:db8::2:3
Def. Instance  64500        8    0 00h01m56s 1/1/3 (IPv6)
                           11    0
2001:db8::2:4
Def. Instance  64500        8    0 00h01m43s 1/1/3 (IPv6)
                           11    0
2001:db8::12:1
Def. Instance  64501        9    0 00h02m14s 1/1/3 (IPv6)
                           11    0
172.31.0.1
Svc: 1         64496        9    0 00h02m01s 1/1/3 (IPv4)
                           12    0
172.31.0.3
Svc: 1         64496        9    0 00h02m02s 1/1/3 (IPv4)
                           12    0
172.31.0.4
Svc: 1         64496        8    0 00h01m50s 1/1/3 (IPv4)
                           10    0
2001:db8::31:0:1
Svc: 1         64496        8    0 00h01m50s 1/1/3 (IPv6)
                           10    0
2001:db8::31:0:3
Svc: 1         64496        8    0 00h01m50s 1/1/3 (IPv6)
                           10    0
2001:db8::31:0:4
Svc: 1         64496        8    0 00h01m50s 1/1/3 (IPv6)
                           10    0
-------------------------------------------------------------------------------
```

By default, BGP does not delay route advertisement. The following **show** command on PE-2 shows that no **min-wait-to-advertise** timer and no **max-wait-to-advertise** timer is configured (the default value is 0). The number of established peers is 3 for IPv4 and IPv6 in the base router.

```
[]
A:admin@PE-2# show router bgp convergence

===============================================================================
```

```
BGP IPv4 Convergence
===============================================================================
Min wait advertise timer                    : 0
Established peers at min wait timer expiry  : N/A
Current established peers                   : 3
First session established time              : N/A
Last session established time               : N/A
Max Wait advertise timer                    : 0
Converged peers                             : N/A
Converged state                             : N/A
Converged time                              : N/A
===============================================================================

===============================================================================
BGP IPv6 Convergence
===============================================================================
Min wait advertise timer                    : 0
Established peers at min wait timer expiry  : N/A
Current established peers                   : 3
First session established time              : N/A
Last session established time               : N/A
Max Wait advertise timer                    : 0
Converged peers                             : N/A
Converged state                             : N/A
Converged time                              : N/A
===============================================================================
```

A similar command can be launched for VPRN 1: **show router 1 bgp convergence**. The output is similar, but not shown here.

On PE-2, BGP delayed route advertisement is configured with **min-wait-to-advertise** equal to 20 seconds in the base router and **min-wait-to-advertise** equal to 60 seconds in VPRN 1. For both cases, the **max-wait-to-advertise** is three times as long as the **min-wait-to-advertise**, but it is possible to have different **max-wait-to-advertise** timers for IPv4 and IPv6.

In this example, BGP delayed route advertisement is only configured on PE-2, while the other nodes keep advertising their routes immediately after the BGP session is reestablished. PE-2 will accept these routes, but it will only advertise them after receiving the last expected EOR for IPv4 or IPv6 (for the base router or VPRN 1) and **min-wait-to-advertise** timer expires. If the **max-wait-to-advertise** timer expires before the last expected EOR is received for IPv4 or IPv6, PE-2 will start advertising the received routes.

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            convergence {
                min-wait-to-advertise 20
                family ipv4 {
                    max-wait-to-advertise 30
                }
                family ipv6 {
                    max-wait-to-advertise 30
                }
            }
        }
    }
    service {
        vprn "VPRN 1" {
            bgp {
                convergence {
                    min-wait-to-advertise 60
                    family ipv4 {
```

```
                    max-wait-to-advertise 180
                }
                family ipv6 {
                    max-wait-to-advertise 180
                }
            }
        }
    }
```

With this configuration, the BGP converged state on PE-2 changes to "waiting", because no BGP sessions are reestablished yet, so no BGP convergence tuning has taken place.

```
[]
A:admin@PE-2# show router bgp convergence

===============================================================================
BGP IPv4 Convergence
===============================================================================
Min wait advertise timer                    : 20
Established peers at min wait timer expiry  : 0
Current established peers                   : 3
First session established time              : 00h00m00s
Last session established time               : 00h00m00s
Max Wait advertise timer                    : 30
Converged peers                             : 3
Converged state                             : waiting
Converged time                              : N/A
===============================================================================

===============================================================================
BGP IPv6 Convergence
===============================================================================
Min wait advertise timer                    : 20
Established peers at min wait timer expiry  : 0
Current established peers                   : 3
First session established time              : 00h00m00s
Last session established time               : 00h00m00s
Max Wait advertise timer                    : 30
Converged peers                             : 3
Converged state                             : waiting
Converged time                              : N/A
===============================================================================
```

The **show router 1 bgp convergence** command shows a similar output for VPRN 1, but is not shown here.

The following **clear** command on PE-2 causes BGP to restart:

```
# on PE-2:
clear router bgp protocol
clear router 1 bgp protocol
```

When BGP restarts, the converged state remains "waiting" until the first peer is established.

With the first peer established, the converged state changes to "started", as follows:

```
[]
A:admin@PE-2# show router bgp convergence

===============================================================================
BGP IPv4 Convergence
===============================================================================
```

```
Min wait advertise timer                    : 20
Established peers at min wait timer expiry  : 0
Current established peers                   : 3
First session established time              : 00h00m01s
Last session established time               : 00h00m01s
Max Wait advertise timer                    : 30
Converged peers                             : 0
Converged state                             : started
Converged time                              : N/A
===============================================================================

===============================================================================
BGP IPv6 Convergence
===============================================================================
Min wait advertise timer                    : 20
Established peers at min wait timer expiry  : 0
Current established peers                   : 3
First session established time              : 00h00m01s
Last session established time               : 00h00m01s
Max Wait advertise timer                    : 30
Converged peers                             : 0
Converged state                             : started
Converged time                              : N/A
===============================================================================
```

The **show router 1 bgp convergence** command shows a similar output for VPRN 1, but is not shown here.

After a few seconds, PE-2 receives IPv4 and IPv6 routes from PE-3 and PE-4, both in the base router and VPRN 1, as follows:

```
[]
A:admin@PE-2# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.3
Def. Instance  64500        5    0 00h00m01s 1/1/0 (IPv4)
                            4    0
192.0.2.4
Def. Instance  64500        5    0 00h00m01s 1/1/0 (IPv4)
                            4    0
192.168.12.1
Def. Instance  64501        3    0 00h00m00s 0/0/0 (IPv4)
                            4    0
2001:db8::2:3
Def. Instance  64500        5    0 00h00m01s 1/1/0 (IPv6)
                            4    0
2001:db8::2:4
Def. Instance  64500        5    0 00h00m01s 1/1/0 (IPv6)
                            4    0
2001:db8::12:1
Def. Instance  64501        3    0 00h00m00s 0/0/0 (IPv6)
                            4    0
172.31.0.1
```

```
Svc: 1         64496        3    0 00h00m00s 0/0/0 (IPv4)
                            3    0
172.31.0.3
Svc: 1         64496        5    0 00h00m01s 1/1/0 (IPv4)
                            4    0
172.31.0.4
Svc: 1         64496        5    0 00h00m01s 1/1/0 (IPv4)
                            4    0
2001:db8::31:0:1
Svc: 1         64496        3    0 00h00m00s 0/0/0 (IPv6)
                            3    0
2001:db8::31:0:3
Svc: 1         64496        5    0 00h00m01s 1/1/0 (IPv6)
                            4    0
2001:db8::31:0:4
Svc: 1         64496        5    0 00h00m01s 1/1/0 (IPv6)
                            4    0
-------------------------------------------------------------------------------
```

PE-2 accepts the received routes, but does not advertise the routes because the **min-wait-to-advertise** timer has not expired yet, and PE-2 only received IPv4 and IPv6 routes and EORs from PE-3 and PE-4, not from PE-1, so the converged state is "partial", as follows:

```
[]
A:admin@PE-2# show router bgp convergence

===============================================================================
BGP IPv4 Convergence
===============================================================================
Min wait advertise timer                    : 20
Established peers at min wait timer expiry  : 0
Current established peers                   : 3
First session established time              : 00h00m01s
Last session established time               : 00h00m02s
Max Wait advertise timer                    : 30
Converged peers                             : 2
Converged state                             : partial
Converged time                              : N/A
===============================================================================

===============================================================================
BGP IPv6 Convergence
===============================================================================
Min wait advertise timer                    : 20
Established peers at min wait timer expiry  : 0
Current established peers                   : 3
First session established time              : 00h00m01s
Last session established time               : 00h00m02s
Max Wait advertise timer                    : 30
Converged peers                             : 2
Converged state                             : partial
Converged time                              : N/A
===============================================================================
```

The **show router 1 bgp convergence** command shows a similar output for VPRN 1, but is not shown here.

After a few seconds, all IPv4 and IPv6 routes have been received in the base router. PE-2 has received an EOR message from each neighbor in the base router. The following BGP summary shows that PE-2 has

received and advertised all IPv4 and IPv6 routes in the base router, whereas it only received IPv4 and IPv6 routes from two neighbors in VPRN 1, not yet from PE-1:

```
[]
A:admin@PE-2# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.3
Def. Instance  64500        5    0 00h00m12s 1/1/3 (IPv4)
                            7    0
192.0.2.4
Def. Instance  64500        5    0 00h00m11s 1/1/3 (IPv4)
                            7    0
192.168.12.1
Def. Instance  64501        5    0 00h00m14s 1/1/3 (IPv4)
                            5    0
2001:db8::2:3
Def. Instance  64500        5    0 00h00m12s 1/1/3 (IPv6)
                            7    0
2001:db8::2:4
Def. Instance  64500        5    0 00h00m11s 1/1/3 (IPv6)
                            7    0
2001:db8::12:1
Def. Instance  64501        5    0 00h00m13s 1/1/3 (IPv6)
                            5    0
172.31.0.1
Svc: 1         64496        4    0 00h00m13s 0/0/0 (IPv4)
                            4    0
172.31.0.3
Svc: 1         64496        5    0 00h00m12s 1/1/0 (IPv4)
                            4    0
172.31.0.4
Svc: 1         64496        5    0 00h00m11s 1/1/0 (IPv4)
                            4    0
2001:db8::31:0:1
Svc: 1         64496        4    0 00h00m13s 0/0/0 (IPv6)
                            4    0
2001:db8::31:0:3
Svc: 1         64496        5    0 00h00m12s 1/1/0 (IPv6)
                            4    0
2001:db8::31:0:4
Svc: 1         64496        5    0 00h00m11s 1/1/0 (IPv6)
                            4    0
-------------------------------------------------------------------------------
```

As a result of this, BGP is in the "converged" state in the base router, both for IPv4 and IPv6, as follows:

```
[]
A:admin@PE-2# show router bgp convergence

===============================================================================
BGP IPv4 Convergence
===============================================================================
Min wait advertise timer                   : 20
```

```
Established peers at min wait timer expiry  : 3
Current established peers                   : 3
First session established time              : 00h00m01s
Last session established time               : 00h00m03s
Max Wait advertise timer                    : 30
Converged peers                             : 3
Converged state                             : converged
Converged time                              : 00h00m20s
===============================================================================

===============================================================================
BGP IPv6 Convergence
===============================================================================
Min wait advertise timer                    : 20
Established peers at min wait timer expiry  : 3
Current established peers                   : 3
First session established time              : 00h00m01s
Last session established time               : 00h00m03s
Max Wait advertise timer                    : 30
Converged peers                             : 3
Converged state                             : converged
Converged time                              : 00h00m20s
===============================================================================
```

The converged time is only applicable in the "converged" state and is measured relative to BGP instance restart at time T=0.

BGP is still in the "partial" state within the VPRN 1 context, both for IPv4 and IPv6, as follows:

```
[]
A:admin@PE-2# show router 1 bgp convergence

===============================================================================
BGP IPv4 Convergence
===============================================================================
Min wait advertise timer                    : 60
Established peers at min wait timer expiry  : 0
Current established peers                   : 3
First session established time              : 00h00m01s
Last session established time               : 00h00m03s
Max Wait advertise timer                    : 180
Converged peers                             : 3
Converged state                             : partial
Converged time                              : N/A
===============================================================================

===============================================================================
BGP IPv6 Convergence
===============================================================================
Min wait advertise timer                    : 60
Established peers at min wait timer expiry  : 0
Current established peers                   : 3
First session established time              : 00h00m01s
Last session established time               : 00h00m03s
Max Wait advertise timer                    : 180
Converged peers                             : 3
Converged state                             : partial
Converged time                              : N/A
===============================================================================
```

After a while, PE-1 also advertises its routes for VPRN 1, followed by EORs for IPv4 and IPv6. BGP converges for VPRN 1, as follows:

```
[]
A:admin@PE-2# show router 1 bgp convergence

===============================================================================
BGP IPv4 Convergence
===============================================================================
Min wait advertise timer                    : 60
Established peers at min wait timer expiry  : 3
Current established peers                   : 3
First session established time              : 00h00m01s
Last session established time               : 00h00m03s
Max Wait advertise timer                    : 180
Converged peers                             : 3
Converged state                             : converged
Converged time                              : 00h01m00s
===============================================================================

===============================================================================
BGP IPv6 Convergence
===============================================================================
Min wait advertise timer                    : 60
Established peers at min wait timer expiry  : 3
Current established peers                   : 3
First session established time              : 00h00m01s
Last session established time               : 00h00m03s
Max Wait advertise timer                    : 180
Converged peers                             : 3
Converged state                             : converged
Converged time                              : 00h01m00s
===============================================================================
```

Conclusion

With BGP convergence tuning (by means of delaying route advertisements using two timers), less path churn and fewer advertisements can result in faster convergence. BGP convergence is mainly important in scaled environments (high number of BGP sessions and routes). As a result, the advertised paths are more optimal. The BGP convergence process can be monitored using a **show** command.

BGP Default Route Origination

This chapter describes BGP Default Route Origination.

Topics in this chapter include:

Applicability

The information and MD-CLI configuration in this chapter are based on SR OS Release 20.7.R1. Advertising artificially generated IPv4 and IPv6 default routes is supported in SR OS Release 19.7.R1 and later.

Overview

It is common practice for a BGP router to send an IPv4 and/or IPv6 default route to certain peers rather than a number of more specific routes.

In SR OS releases earlier than 19.7.R1, a BGP router only advertises a default route that is installed in the Forwarding Information Base (FIB). This default route is either received from a BGP peer and re-advertised, or the default route is configured locally as a static route, with black-hole next-hop. The attributes of this default route can be modified by an export policy. The drawback of depending on a default route installed in the FIB is that when the BGP peer withdraws or modifies the default route, the BGP router must withdraw or re-advertise the default route.

In SR OS Release 19.7.R1 and later, the **send-default** command allows BGP routers to advertise artificially generated IPv4 (0.0.0.0/0) and/or IPv6 (::/0) default routes. These artificially generated default routes are unrelated to possible default routes installed in the FIB of the local router. If the local FIB contains a default route and a BGP export policy allows that installed default route to be advertised, the **send-default** command overrides the advertisement of the installed default route. If the default route in the FIB is withdrawn or modified, the artificially generated default route continues to be advertised.

The **send-default** command can be configured in the general BGP context, in the BGP group context, or in the BGP neighbor context, in both base router instance and VPRN router instances. The command can be used for IPv4, IPv6, or both. An optional send-default export policy can modify the attributes of the artificially generated default routes. Only the **default-action** part of this send-default export policy is parsed and applied, as follows:

```
*[ex:configure router "Base" bgp]
A:admin@PE-1# send-default

 send-default
```

```
export-policy         - Export policy name
ipv4                  - Enable IPv4 family type
ipv6                  - Enable IPv6 family type
```

Before modification by a send-default export policy, the properties of the artificially generated default route are as follows:

- The origin is set to Incomplete.
- When advertised to an iBGP peer, the AS_PATH is empty.
- When advertised to an eBGP peer, the global Autonomous System Number (ASN) and/or local AS are prepended. If the send-default export policy specifies an **as-path-prepend** action, these modifications are made before prepending the ASN and/or local AS.
- The BGP next-hop is the local address used with the receiving peer or the local router ID (if the Network Layer Reachability Information (NLRI) is IPv6, and the local address is an IPv4 address or it refers to an IPv4-only interface).
- No Multi-Exit Discriminator (MED) attribute is added.
- When advertised to an iBGP peer, a local preference attribute is added and its value is taken from the configuration of the **local-preference** command or the value 100, the implicit default.
- No standard or large communities are attached. When a send-default export policy is applied to change this, confirm that **disable-communities** is not set.

Configuration

Figure 34: Example topology with IPv4 addresses shows the example topology with two routers. An eBGP session is established between the base routers (PE-1 in AS 64501 and PE-2 in AS 64500) and an iBGP session is established within VPRN 1 in AS 64496.

Figure 34: Example topology with IPv4 addresses

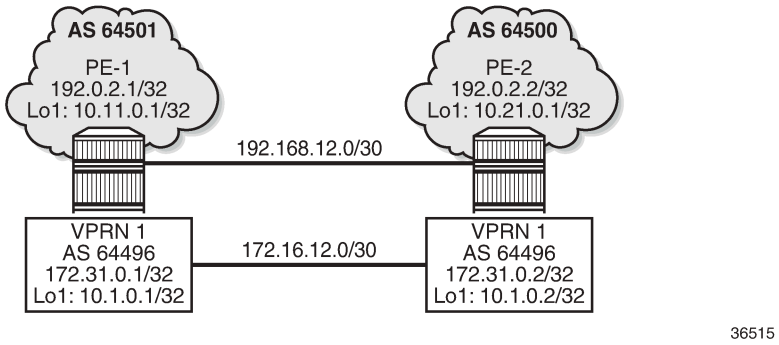
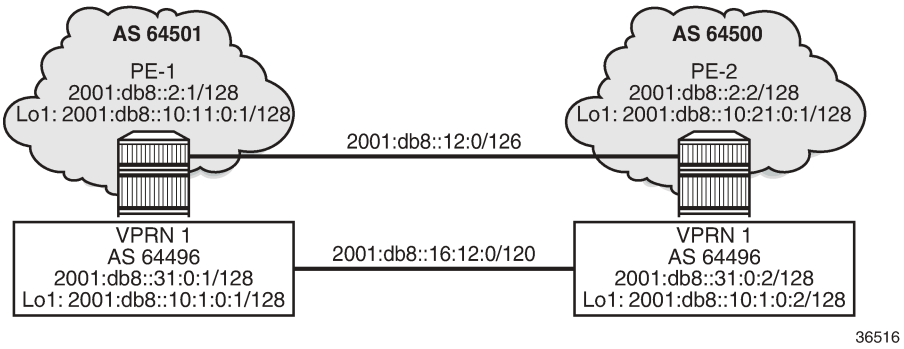


Figure 35: Example topology with IPv6 addresses shows the same example topology with IPv6 addresses.

Figure 35: Example topology with IPv6 addresses



The initial configuration includes:

- Cards, MDAs, ports
- Router interfaces

On PE-1, the BGP configuration in the base router is as follows:

```
# on PE-1:
configure {
    router "Base" {
        autonomous-system 64501
        bgp {
            router-id 192.0.2.1
            split-horizon true
            group "eBGP" {
                peer-as 64500
                local-as {
                    as-number 64501
                }
                import {
                    policy ["1:0"]        # accepts routes with community "1:0"
                }
            }
            neighbor "192.168.12.2" {
                group "eBGP"
                local-address "int-PE-1-PE-2"
                send-communities {
                    large false           # no large communities sent to 192.168.12.2
                }
                family {
                    ipv4 true
                }
            }
            neighbor "2001:db8::12:2" {
                group "eBGP"
                local-address 2001:db8::12:1
                family {
                    ipv6 true
                }
            }
        }
```

On PE-1, the BGP configuration in VPRN 1 is as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            autonomous-system 64496
            ---snip---
            bgp
                router-id 172.31.0.1
                split-horizon true
                group "iBGP-VPRN1" {
                    type internal
                }
                neighbor "172.31.0.2" {
                    group "iBGP-VPRN1"
                    local-address 172.31.0.1
                    send-communities {
                        large false       # no large communities sent to 172.31.0.2
                    }
                    family {
                        ipv4 true
                    }
                }
                neighbor "2001:db8::31:0:2" {
                    group "iBGP-VPRN1"
                    family {
                        ipv6 true
                    }
                }
            }
            ---snip---
```

The configuration is similar on PE-2.

No export policies are applied in BGP, so no routes will be advertised. The following BGP sessions are established on PE-2:

```
[]
A:admin@PE-2# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.168.12.1
Def. Instance  64501        8    0 00h01m45s 0/0/0 (IPv4)
                            9    0
2001:db8::12:1
Def. Instance  64501        7    0 00h01m39s 0/0/0 (IPv6)
                            7    0

172.31.0.1
Svc: 1         64496        7    0 00h01m33s 0/0/0 (IPv4)
                            7    0
2001:db8::31:0:1
Svc: 1         64496        6    0 00h01m24s 0/0/0 (IPv6)
```

```
                            6    0
-------------------------------------------------------------------------------
```

Initially, no default routes are installed in the route table of the base router or the VPRN; for example, on PE-2, as follows:

```
[]
A:admin@PE-2# show router route-table 0.0.0.0/0

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
No. of Routes: 0
```

```
[]
A:admin@PE-2# show router 1 route-table ipv6 ::/0

===============================================================================
IPv6 Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
No. of Routes: 0
```

The following use cases are shown in the following subsections:

- Advertise default routes that are installed in the FIB
- Advertise artificially generated default routes

Advertise default routes that are installed in the FIB

PE-1 has not received default routes from any other BGP peer, so black-holed default routes for IPv4 and IPv6 are configured locally in the base router and in VPRN 1 routing instances, as follows:

```
# on PE-1:
configure {
    router "Base" {
        static-routes {
            route 0.0.0.0/0 route-type unicast {
                blackhole {
                    admin-state enable
                }
            }
            route ::/0 route-type unicast {
                blackhole {
                    admin-state enable
                }
            }
        }
    }
    service {
        vprn "VPRN 1" {
```

```
            static-routes {
                route 0.0.0.0/0 route-type unicast {
                    blackhole {
                        admin-state enable
                    }
                }
                route ::/0 route-type unicast {
                    blackhole {
                        admin-state enable
                    }
                }
            }
```

The following export policies are configured for prefixes 0.0.0.0/0 and ::/0.

```
# on PE-1:
configure {
    policy-options {
        community "1:0" {
            member "1:0" { }
        }
        prefix-list "route_0/0" {
            prefix 0.0.0.0/0 type exact {
            }
        }
        prefix-list "route_::/0" {
            prefix ::/0 type exact {
            }
        }
        policy-statement "export-route_0/0" {
            entry 10 {
                from {
                    prefix-list ["route_0/0"]
                }
                action {
                    action-type accept
                    community {
                        add ["1:0"]
                    }
                    origin igp
                }
            }
        }
        policy-statement "export-route_::/0" {
            entry 10 {
                from {
                    prefix-list ["route_::/0"]
                }
                action {
                    action-type accept
                    community {
                        add ["1:0"]
                    }
                    origin igp
                }
            }
        }
```

These export policies are applied in BGP group "eBGP" in the base router, as follows:

```
# on PE-1:
configure {
    router "Base" {
```

```
        bgp {
            group "eBGP" {
                export {
                    policy ["export-route_0/0" "export-route_::/0"]
                }
            }
        }
```

The same export policies are applied in the general **bgp** context in VPRN 1, as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            bgp {
                export {
                    policy ["export-route_0/0" "export-route_::/0"]
                }
            }
```

No default routes are configured on PE-2.

The following BGP summary on PE-2 shows that in each BGP session one BGP route is received and active:

```
[]
A:admin@PE-2# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.168.12.1
Def. Instance  64501       22    0 00h08m21s 1/1/0 (IPv4)
                           22    0
2001:db8::12:1
Def. Instance  64501       21    0 00h08m15s 1/1/0 (IPv6)
                           20    0

172.31.0.1
Svc: 1         64496       21    0 00h08m10s 1/1/0 (IPv4)
                           20    0
2001:db8::31:0:1
Svc: 1         64496       21    0 00h08m00s 1/1/0 (IPv6)
                           20    0
-------------------------------------------------------------------------------
```

The following BGP route is received in the base router:

```
[]
A:admin@PE-2# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
```

```
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  0.0.0.0/0                                        100         None
      192.168.12.1                                     None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Also, a BGP-IPv6 route for ::/0 is received in the base router, and VPRN 1 receives BGP-IPv4 route 0.0.0.0/0 and BGP-IPv6 route ::/0, as follows:

```
[]
A:admin@PE-2# show router 1 bgp routes ipv6
===============================================================================
 BGP Router ID:172.31.0.2       AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv6 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  ::/0                                             100         None
      2001:db8::31:0:1                                 None        10
      No As-Path                                                   -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The default route 0.0.0.0/0 is installed in the route table for the base router, as follows:

```
[]
A:admin@PE-2# show router route-table 0.0.0.0/0
===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
0.0.0.0/0                                     Remote  BGP       00h02m48s  170
       192.168.12.1                                                  0
-------------------------------------------------------------------------------
No. of Routes: 1
```

Similarly, the default route ::/0 is installed in the IPv6 route table for the base router (not shown here). For VPRN 1, default route 0.0.0.0/0 is installed in the IPv4 route table (not shown here), whereas default route ::/0 is installed in the IPv6, as follows:

```
[]
A:admin@PE-2# show router 1 route-table ipv6 ::/0
===============================================================================
IPv6 Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
::/0                                          Remote  BGP       00h02m52s  170
       fe80::21:88ab:d904:706f-"int-VPRN1-PE-2-PE-1"                10
-------------------------------------------------------------------------------
No. of Routes: 1
```

Advertise artificially generated default routes

With the **send-default** command, no default routes need to be installed in the FIB. However, the following example shows that both static default routes in PE-1 remain, but that this static default route will not be advertised anymore. With the **send-default** command, an artificially generated default route is advertised and overrules the static default route.

The following **send-default** command is configured on PE-1 and PE-2:

```
# on PE-1, PE-2:
configure {
    router "Base" {
        bgp {
            group "eBGP" {
                send-default {
                    ipv4 true
                    ipv6 true
                }
            }
        }
    }
    service {
        vprn "VPRN 1" {
            bgp {
                send-default {
                    ipv4 true
                    ipv6 true
                }
            }
        }
```

The following BGP summary on PE-2 shows that in each iBGP session (VPRN 1 in AS 64496), one route is received and active, and one route is advertised. The BGP sessions in the base router are eBGP sessions. In MD-CLI, the default behavior is compliant with RFC 8212, so all BGP routes are rejected when no export policies are configured.

```
[]
A:admin@PE-2# show router bgp summary all

===============================================================================
BGP Summary
```

```
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.168.12.1
Def. Instance  64501       13    0 00h03m50s 0/0/0 (IPv4)
                           14    0
2001:db8::12:1
Def. Instance  64501       12    0 00h03m44s 0/0/0 (IPv6)
                           12    0
172.31.0.1
Svc: 1         64496       12    0 00h03m40s 1/1/1 (IPv4)
                           13    0
2001:db8::31:0:1
Svc: 1         64496       12    0 00h03m40s 1/1/1 (IPv6)
                           12    0
-------------------------------------------------------------------------------
```

Because no send-default export policy is configured to modify the attributes, the origin will remain Incomplete, which also proves that the received routes in VPRN 1 on PE-2 are different from the ones received before the **send-default** command was configured, as follows:

```
[]
A:admin@PE-2# show router 1 bgp routes
===============================================================================
 BGP Router ID:172.31.0.2       AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>?  0.0.0.0/0                                        100         None
      172.31.0.1                                       None        10
      No As-Path                                                   -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The following shows the details of the received and advertised BGP-IPv6 route ::/0 in VPRN 1 on PE-2:

```
[]
A:admin@PE-2# show router 1 bgp routes ::/0 hunt
===============================================================================
 BGP Router ID:172.31.0.2       AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete
```

```
===============================================================================
BGP IPv6 Routes
===============================================================================
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : ::/0
Nexthop        : 2001:db8::31:0:1
Path Id        : None
From           : 2001:db8::31:0:1
Res. Protocol  : ISIS                  Res. Metric    : 10
Res. Nexthop   : fe80::21:88ab:d904:706f
Local Pref.    : 100                   Interface Name : int-VPRN1-PE-2-PE-1
Aggregator AS  : None                  Aggregator     : None
Atomic Aggr.   : Not Atomic            MED            : None
AIGP Metric    : None                  IGP Cost       : 10
Connector      : None
Community      : No Community Members
Cluster        : No Cluster Members
Originator Id  : None                  Peer Router Id : 172.31.0.1
Fwd Class      : None                  Priority       : None
Flags          : Used Valid Best Incomplete
Route Source   : Internal
AS-Path        : No As-Path
Route Tag      : 0
Neighbor-AS    : n/a
Orig Validation: NotFound
Source Class   : 0                     Dest Class     : 0
Add Paths Send : Default
RIB Priority   : Normal
Last Modified  : 00h01m07s

-------------------------------------------------------------------------------
RIB Out Entries
-------------------------------------------------------------------------------
Network        : ::/0
Nexthop        : 2001:db8::31:0:2
Path Id        : None
To             : 2001:db8::31:0:1
Res. Protocol  : INVALID               Res. Metric    : 0
Res. Nexthop   : n/a
Local Pref.    : 100                   Interface Name : NotAvailable
Aggregator AS  : None                  Aggregator     : None
Atomic Aggr.   : Not Atomic            MED            : None
AIGP Metric    : None                  IGP Cost       : 10
Connector      : None
Community      : No Community Members
Cluster        : No Cluster Members
Originator Id  : None                  Peer Router Id : 172.31.0.1
Origin         : Incomplete
AS-Path        : No As-Path
Route Tag      : 0
Neighbor-AS    : n/a
Orig Validation: NotFound
Source Class   : 0                     Dest Class     : 0

-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

The origin attribute can be modified by the following export policy that sets the origin to IGP, the MED value to 50, and adds the communities "64496:1:1" and "1:0":

```
# on PE-1, PE-2:
configure {
    policy-options {
        community "1:0" {
            member "1:0" { }
        }
        community "large1" {
            member "64496:1:1" { }
        }
        policy-statement "1:0" {                    # import policy for eBGP sessions (base)
            entry 10 {
                from {
                    community {
                        name "1:0"
                    }
                }
                action {
                    action-type accept
                }
            }
        }
        policy-statement "export-default" {         # send-default export policy
            default-action {
                action-type accept
                origin igp
                bgp-med {
                    set 50
                }
                community {
                    add ["large1" "1:0"]
                }
            }
        }
```

The export policy is included in the **send-default** command, as follows:

```
# on PE-1, PE-2:
configure {
    router "Base" {
        bgp {
            group "eBGP" {
                send-default {
                    ipv4 true
                    ipv6 true
                    export-policy "export-default"
                }
                import {
                    policy ["1:0"]
                }
            }
        }
    }
    service {
        vprn "VPRN 1" {
            bgp {
                send-default {
                    ipv4 true
                    ipv6 true
                    export-policy "export-default"
                }
```

```
            }
```

The export policy sets the origin to IGP, sets the MED to a value of 50, and adds communities "large1" and "1:0". The import policy in the base router accepts routes with community "1:0". PE-2 receives and accepts the BGP-IPv4 default route with origin IGP and MED 50, as follows:

```
[]
A:admin@PE-2# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  0.0.0.0/0                                        None        50
      192.168.12.1                                     None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

```
[]
A:admin@PE-2# show router bgp routes 0.0.0.0/0 hunt | match Flags
Flags          : Used Valid Best IGP
```

The other artificially generated default routes also have origin IGP and MED 50. In this example, the **send-communities large false** command is configured on PE-1 and PE-2 for the IPv4 neighbors in the base router and in VPRN 1, so no large community is sent for IPv4; only for IPv6. On PE-2, the default IPv4 routes in the RIB-IN and the RIB-OUT of the base router only contain community "1:0", not the large community "64496:1:1", as follows:

```
[]
A:admin@PE-2# show router bgp routes 0.0.0.0/0 hunt | match Community
Community      : 1:0        # RIB-IN
Community      : 1:0        # RIB-OUT
```

On PE-2, the details of the received default IPv6 route ::/0 in VPRN 1 are as follows:

```
[]
A:admin@PE-2# show router 1 bgp routes ::/0 hunt
===============================================================================
 BGP Router ID:172.31.0.2       AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv6 Routes
```

```
===============================================================================
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : ::/0
Nexthop        : 2001:db8::31:0:1
Path Id        : None
From           : 2001:db8::31:0:1
Res. Protocol  : ISIS                    Res. Metric    : 10
Res. Nexthop   : fe80::10:1ff:fe01:1
Local Pref.    : 100                     Interface Name : int-VPRN1-PE-2-PE-1
Aggregator AS  : None                    Aggregator     : None
Atomic Aggr.   : Not Atomic              MED            : 50
AIGP Metric    : None                    IGP Cost       : 10
Connector      : None
Community      : 1:0 64496:1:1
Cluster        : No Cluster Members
Originator Id  : None                    Peer Router Id : 172.31.0.1
Fwd Class      : None                    Priority       : None
Flags          : Used Valid Best IGP
Route Source   : Internal
AS-Path        : No As-Path
Route Tag      : 0
Neighbor-AS    : n/a
Orig Validation: NotFound
Source Class   : 0                       Dest Class     : 0
Add Paths Send : Default
RIB Priority   : Normal
Last Modified  : 00h02m50s
---snip---
```

The artificially generated default routes are only modified by the send-default export policy, not involving other export BGP policies.

Conclusion

With the **send-default** command, BGP routers can advertise artificially generated default routes for IPv4, IPv6, or both. The artificially generated default routes are always advertised, regardless of the presence of default routes installed in the local FIB.

BGP Fast Reroute

This chapter provides information about BGP Fast Reroute.

Topics in this chapter include:

Applicability

This chapter was initially written for SR OS Release 14.0.R7, but the MD-CLI in the current edition is based on SR OS Release 20.10.R1.

Overview

Border Gateway Protocol (BGP) is a key protocol for ISPs, supporting inter-Autonomous System (inter-AS) and intra-Autonomous System (intra-AS) applications with many address families. Additionally, ISPs need to maintain the service level agreements with their customers, even in case of network failures.

MPLS Fast Reroute (FRR) is often used to provide resiliency to intra-AS services, and relies on alternate label switched paths being established through the network. Traffic is switched to the alternate path in case of a failure of the primary path.

However, the traffic for inter-AS services crosses the boundaries of multiple ASs, so to provide resiliency, BGP FRR can be used. Before a network failure occurs, multiple paths must be received for a prefix to take advantage of this feature. When a prefix has a backup path and its primary paths fail, the affected traffic is rapidly diverted to the backup path without waiting for the control plane to reconverge. When many prefixes share the same primary paths, and in some cases also the same backup path, the time to divert traffic to the backup path is independent of the number of prefixes; this is also known as Prefix Independent Convergence (PIC). The traffic goes back to the primary paths when those paths are restored. Multiple primary paths can be active simultaneously when Equal Cost Multi Path (ECMP) applies.

Within SR OS, two BGP FRR functions are supported: Core PIC and Edge PIC. Core PIC describes a scenario where a link or node on the path to the BGP next-hop fails, but the BGP next-hop remains reachable; see Figure 36: Core PIC. Edge PIC describes a scenario where an edge node or edge link fails, which results in a change of the BGP next-hop; see Figure 37: Edge PIC.

Figure 36: Core PIC

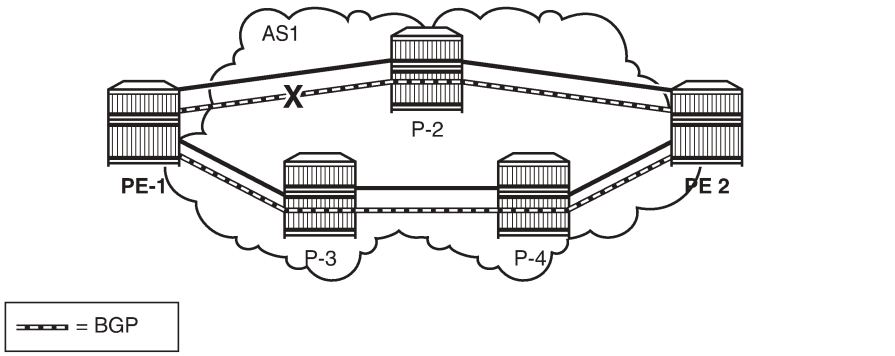
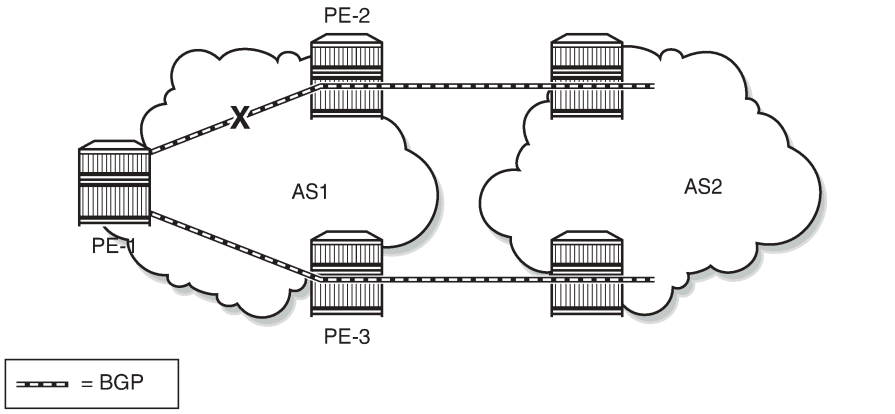


Figure 37: Edge PIC



Within SR OS, Core PIC is enabled by default and cannot be disabled. Therefore, this chapter will describe the use of Edge PIC.

BGP FRR is supported for different BGP address families in the **base router** context or within a specific **vprn** context. This chapter will focus on the IPv4 address family within the base router context.

The following SR OS supported features can be used to allow BGP to maintain multiple paths through an autonomous system:

- BGP best external
- BGP add-paths

Convergence goes through several phases, which also apply to BGP:

- detect the network failure
- distribute updated routing information, and update the network topology
- calculate new routes, and optionally change next-hops
- update the forwarding plane

Several mechanisms are available to enhance BGP network convergence, such as:

- Bidirectional Forwarding Detection (BFD)
- Minimum Router Advertisement Interval (MRAI)
- BGP peer tracking

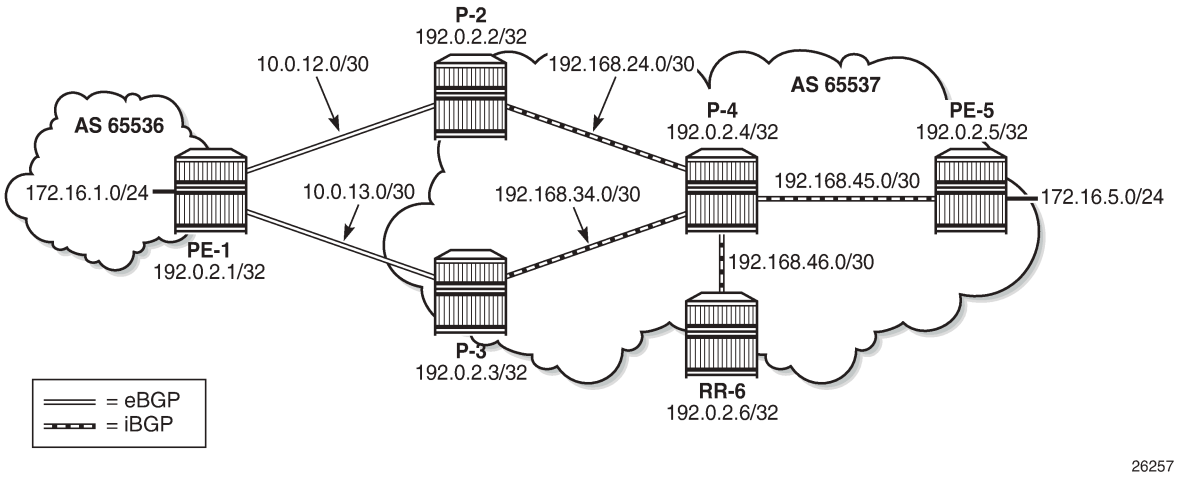
This chapter describes the use of BFD and MRAI for faster network convergence.

Configuration

The example topology used in this chapter is shown in Figure 38: BGP FRR topology, and has the following characteristics:

- iBGP sessions are established between AS 65537 routers using RR-6 as route reflector with P-2, P-3, P-4, and PE-5 as route reflector clients.
- eBGP sessions are established between P-2 and P-3 of AS 65537 and PE-1 of AS 65536.
- PE-1 advertises a BGP route for prefix 172.16.1.0/24 with community "1:0" to P-2 and P-3.
- P-2 changes the local preference to 150 for the route advertised to its route reflector RR-6. Import policy "Import_LP150" on P-2 accepts routes with community "1:0" and modifies the local preference to 150; import policy "1:0" on P-3 accepts routes with community "1:0" without modifications.
- PE-5 advertises a BGP route for prefix 172.16.5.0/24 with community "1:0" to RR-6. This route is re-advertised to the other RR clients and eventually, by P-2 and P-3 to PE-1.

Figure 38: BGP FRR topology



These characteristics enforce traffic for destination 172.16.1.0/24 to leave AS 65537 via P-2. P-2 (and also PE-5) learns the destination and the local preference via route reflector RR-6. But because P-3's own local preference is lower (default LP=100), it stops advertising prefix 172.16.1.0/24 toward RR-6, so that P-4 is aware of the path via P-2 only.

The objective is for P-4 to receive multiple copies of the 172.16.1.0/24 prefix with redundant next-hops, to provide for faster convergence under failure. Considering the characteristics previously listed for the topology, two features contribute for achieving this goal:

1. Using BGP best external

2. Using BGP add-paths

The BGP add-paths feature is required in scenarios with route-reflectors, possibly combined with the BGP best external feature. The BGP best external feature can be used without BGP add-paths in scenarios when the BGP peers are in a full mesh.

As a result, multiple exit paths for prefix 172.16.1.0/24 leaving AS 65537 are available, improving convergence time on the iBGP peers because they only need to update their FIBs if they lose the primary route.

BGP best external

P-3 is configured with the BGP best external feature, as follows:

```
# on P-3:
configure {
    router "Base" {
        autonomous-system 65537
        bgp {
            loop-detect discard-route
            advertise-inactive true
            split-horizon true
            advertise-external {
                ipv4 true
            }
            group "eBGP_AS65536" {
                peer-as 65536
                import {
                    policy ["1:0"]
                }
                export {
                    policy ["1:0"]
                }
            }
            group "iBGP_AS65537" {
                next-hop-self true
                peer-as 65537
            }
            neighbor "10.0.13.1" {
                group "eBGP_AS65536"
            }
            neighbor "192.0.2.6" {
                group "iBGP_AS65537"
            }
```

In this output, advertise-external is activated for the IPv4 address family only. It can also be activated for the IPv6, label-IPv4, and label-IPv6 address families.

Although it is not necessary to also enable BGP best external on P-2, it is not uncommon to also configure this feature on other autonomous system border routers.

P-3 advertises prefix 172.16.1.0/24 toward the route reflector RR-6, as follows:

```
[]
A:admin@P-3# show router bgp neighbor 192.0.2.6 advertised-routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:65537       Local AS:65537
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
```

```
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
i     172.16.1.0/24                                    100         None
      192.0.2.3                                        None        0
      65536                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The BGP best external feature is sufficient for providing alternate paths in a fully meshed autonomous system, and could be used in conjunction with the BGP add-paths feature. The BGP add-paths feature is a requirement in scenarios with route reflectors.

BGP add-paths

P-2, P-3, P-4 and RR-6 are configured with the BGP add-paths feature. PE-5 does not require the add-paths feature, because the alternate path to 172.16.1.0/24 starts in P-4.

```
# on P-2, P-3, P-4, RR-6:
configure {
    router "Base" {
        bgp {
            group "iBGP_AS65537" {
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
```

The BGP configuration on P-2 is as follows:

```
# on P-2:
configure {
    router "Base" {
        bgp {
            loop-detect discard-route
            advertise-inactive true
            split-horizon true
            group "eBGP_AS65536" {
                peer-as 65536
                import {
                    policy ["Import_LP150"]
                }
                export {
                    policy ["1:0"]
                }
            }
            group "iBGP_AS65537" {
                next-hop-self true
                peer-as 65537
```

```
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            neighbor "10.0.12.1" {
                group "eBGP_AS65536"
            }
            neighbor "192.0.2.6" {
                group "iBGP_AS65537"
            }
        }
```

The BGP configuration for P-3 and P-4 is very similar and is not shown here.

The BGP configuration on RR-6 then is as follows:

```
# on RR-6:
configure {
    router "Base" {
        autonomous-system 65537
        bgp {
            loop-detect discard-route
            split-horizon true
            group "iBGP_AS65537" {
                peer-as 65537
                advertise-inactive true
                cluster {
                    cluster-id 6.6.6.6
                }
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            neighbor "192.0.2.2" {
                group "iBGP_AS65537"
            }
            neighbor "192.0.2.3" {
                group "iBGP_AS65537"
            }
            neighbor "192.0.2.4" {
                group "iBGP_AS65537"
            }
            neighbor "192.0.2.5" {
                group "iBGP_AS65537"
            }
```

The default behavior of a route reflector is to only consider the best path. By enabling the add-paths feature on RR-6, multiple paths are considered.

Both P-2 and P-3 advertise route 172.16.1.0/24 to RR-6, as follows:

```
[]
A:admin@P-2# show router bgp neighbor 192.0.2.6 advertised-routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:65537       Local AS:65537
===============================================================================
 Legend -
```

```
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
i     172.16.1.0/24                                     150         None
      192.0.2.2                                         1           0
      65536                                                         -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

```
[]
A:admin@P-3# show router bgp neighbor 192.0.2.6 advertised-routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:65537       Local AS:65537
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
i     172.16.1.0/24                                     100         None
      192.0.2.3                                         1           0
      65536                                                         -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

For more examples of the BGP add-paths feature, see BGP Add-Path and BGP Multipath in this guide.

Backup path

P-4 is the place in the topology where an alternate path is created. The data plane part of the Edge PIC configuration is performed by enabling the **backup-path** command within the **bgp** context. In the following, backup-paths are considered for the IPv4 address family only, but the IPv6, label-IPv4, and label-IPv6 address families are allowed too.

```
# on PE-1, P-4:
configure {
    router "Base" {
        bgp {
            backup-path {
                ipv4 true
            }
```

In this way, BGP considers all alternate paths which are present through the BGP best external and BGP add-paths feature. The BGP configuration on P-4 is as follows:

```
# on P-4:
configure {
    router "Base" {
        autonomous-system 65537
        bgp {
            loop-detect discard-route
            split-horizon true
            backup-path {
                ipv4 true
            }
            group "iBGP_AS65537" {
                peer-as 65537
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            neighbor "192.0.2.6" {
                group "iBGP_AS65537"
            }
```

In the default BGP behavior, without the **backup-path** command, two BGP routes exist. Both routes are valid, but only the first one is the best path (indicated by ">"), as follows:

```
[]
A:admin@P-4# show router bgp routes 172.16.1.0/24
===============================================================================
 BGP Router ID:192.0.2.4        AS:65537       Local AS:65537
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  172.16.1.0/24                                    150         None
      192.0.2.2                                        4           10
      65536                                                        -
*i    172.16.1.0/24                                    100         None
      192.0.2.3                                        5           10
      65536                                                        -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

The routing table then is as follows:

```
[]
A:admin@P-4# show router route-table protocol bgp

===============================================================================
```

```
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
172.16.1.0/24                                 Remote  BGP       00h17m19s  170
       192.168.24.1                                                 0
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

With the **backup-path** command, again both BGP routes are valid; the first route is the best path, and now the second route is explicitly marked to be a backup path (indicated by "b"), as follows:

```
[]
A:admin@P-4# show router bgp routes 172.16.1.0/24
===============================================================================
 BGP Router ID:192.0.2.4        AS:65537       Local AS:65537
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  172.16.1.0/24                                    150         None
      192.0.2.2                                        4           10
      65536                                                        -
ub*i  172.16.1.0/24                                    100         None
      192.0.2.3                                        5           10
      65536                                                        -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

Now the routing table is as follows. The "B" flag indicates that a BGP backup path is available.

```
[]
A:admin@P-4# show router route-table protocol bgp
===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
172.16.1.0/24 [B]                             Remote  BGP       00h00m16s  170
       192.168.24.1                                                 0
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
```

```
       S = Sticky ECMP requested
===============================================================================
```

To show both routes, use the following command:

```
[]
A:admin@P-4# show router route-table protocol bgp alternative
===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
      Alt-NextHop                                                Alt-
                                                                 Metric
-------------------------------------------------------------------------------
172.16.1.0/24                                 Remote  BGP       00h01m36s  170
       192.168.24.1                                                 0
172.16.1.0/24 (Backup)                        Remote  BGP       00h01m36s  170
       192.168.34.1                                                 0
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       Backup = BGP backup route
       LFA = Loop-Free Alternate nexthop
       S = Sticky ECMP requested
===============================================================================
```

The currently active next-hop in the forwarding path is 192.168.24.1, as follows:

```
[]
A:admin@P-4# show router fib 1 ip-prefix-prefix-length 172.16.1.0/24 all
===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                Protocol            Installed
  NextHop
-------------------------------------------------------------------------------
172.16.1.0/24                                 BGP                 Y
  192.168.24.1 (int-P-4-P-2)
-------------------------------------------------------------------------------
Total Entries : 1
-------------------------------------------------------------------------------
===============================================================================
```

The active and standby next-hops are also programmed into the forwarding path, as follows:

```
[]
A:admin@P-4#  show router fib 1 ip-prefix-prefix-length 172.16.1.0/24 extensive
===============================================================================
FIB Display (Router: Base)
===============================================================================
Dest Prefix             : 172.16.1.0/24
  Protocol              : BGP
  Installed             : Y
  Indirect Next-Hop     : 192.0.2.2
    QoS                 : Priority=n/c, FC=n/c
    Source-Class        : 0
    Dest-Class          : 0
    ECMP-Weight         : 1
    Resolving Next-Hop  : 192.168.24.1
      Interface         : int-P-4-P-2
      ECMP-Weight       : 1
```

```
  Indirect Next-Hop     : 192.0.2.3
    QoS                 : Priority=n/c, FC=n/c
    Source-Class        : 0
    Dest-Class          : 0
    ECMP-Weight         : 1
    Backup-Path         : Yes
    Resolving Next-Hop  : 192.168.34.1
      Interface         : int-P-4-P-3
      ECMP-Weight       : 1
===============================================================================
Total Entries : 1
===============================================================================
```

In summary, two paths are available out of P-4 and leading to 172.16.1.0/24 in the remote AS, but only one is installed in the forwarding plane. The active route is P-4-P-2-PE-1; the backup route is P-4-P-3-PE-1. A **traceroute** command confirms the active path, as follows:

```
[]
A:admin@PE-5# traceroute 172.16.1.1 source-address 172.16.5.1 numeric
traceroute to 172.16.1.1 from 172.16.5.1, 30 hops max, 40 byte packets
  1  192.168.45.1    0.722 ms  0.662 ms  0.646 ms
  2  192.168.24.1    1.22 ms  1.21 ms  1.21 ms
  3  172.16.1.1    3.09 ms  1.78 ms  1.74 ms
```

Faster convergence through BFD

As already described, BFD can help speed up BGP convergence, mainly when detecting network failure. In the following, BFD is enabled on the eBGP sessions, and on the IS-IS protocol.

The BFD parameters are defined at interface level, enabling BFD for an application is done in the application context. Because PE-1 only has eBFD sessions toward P-2 and P-3, it is enabled at the global BGP level, but it can also be enabled at the group or neighbor level.

```
# on PE-1:
configure {
    router "Base" {
        interface "int-PE-1-P-2" {
            ipv4 {
                bfd {
                admin-state enable
                }
            }
        }
        interface "int-PE-1-P-3" {
            ipv4 {
                bfd {
                admin-state enable
                }
            }
        }
        bgp {
            bfd-liveness true
        }
```

Because the BFD configuration for P-2 and P-3 is very similar, it is only shown for P-2, as follows:

```
# for P-2:
configure {
```

```
    router "Base" {
        interface "int-P-2-PE-1" {
            ipv4 {
                bfd {
                    admin-state enable
                }
            }
        }
        interface "int-P-2-P-4" {
            ipv4 {
                bfd {
                    admin-state enable
                }
            }
        }
```

BFD is enabled for group eBGP_AS65536 only, at group level, as follows:

```
# on P-2:
configure {
    router "Base" {
        bgp {
            group "eBGP_AS65536" {
            bfd-liveness true
            }
        }
```

BFD for IS-IS is enabled at the IS-IS interface level, and is enabled for IPv4 only, as follows.

```
# on P-2:
configure {
    router "Base" {
        isis 0 {
            interface "int-P-3-P-4" {
                bfd-liveness {
                    ipv4 {
                    }
                }
            }
```

Faster convergence through MRAI

Adjusting the BGP MRAI also can help speed up network convergence, using the following command:

```
*[ex:configure router "Base" bgp]
A:admin@P-2# min-route-advertisement

 min-route-advertisement <number>
 <number>  - <1..255>
 Default   - 30

    Minimum time before a prefix can be advertised to peer
```

Lowering the MRAI puts a higher load on the CPM, so a trade-off must be made between convergence time and processing load.

Switchover

To demonstrate a switchover scenario, a failure is introduced by disabling port 1/1/1 on PE-1, as follows:

```
# on PE-1:
configure {
    port 1/1/1 {
        admin-state disable
```

The path through the network is PE-5-P-4-P-3-PE-1, as follows:

```
[]
A:admin@PE-5# traceroute 172.16.1.1 source-address 172.16.5.1 numeric
traceroute to 172.16.1.1 from 172.16.5.1, 30 hops max, 40 byte packets
  1  192.168.45.1    0.698 ms  0.695 ms  0.698 ms
  2  192.168.34.1    1.21 ms  1.21 ms  1.15 ms
  3  172.16.1.1    1.73 ms  1.71 ms  1.70 ms
```

On P-4, traffic is now diverted to P-3, and the BGP routes are as follows:

```
[]
A:admin@P-4# show router bgp routes 172.16.1.0/24
===============================================================================
 BGP Router ID:192.0.2.4        AS:65537       Local AS:65537
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  172.16.1.0/24                                    100         None
      192.0.2.3                                        1           10
      65536                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The route table is as follows:

```
[]
A:admin@P-4# show router route-table protocol bgp
===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
172.16.1.0/24                                 Remote  BGP       00h01m41s  170
       192.168.34.1                                                  0
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
```

```
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The forwarding plane is reprogrammed to send traffic for the 172.16.1.0/24 subnet to P-3, as follows:

```
[]
A:admin@P-4# show router fib 1 ip-prefix-prefix-length 172.16.1.0/24 extensive
===============================================================================
FIB Display (Router: Base)
===============================================================================
Dest Prefix             : 172.16.1.0/24
  Protocol              : BGP
  Installed             : Y
  Indirect Next-Hop     : 192.0.2.3
    QoS                 : Priority=n/c, FC=n/c
    Source-Class        : 0
    Dest-Class          : 0
    ECMP-Weight         : 1
    Resolving Next-Hop  : 192.168.34.1
      Interface         : int-P-4-P-3
      ECMP-Weight       : 1
===============================================================================
Total Entries : 1
===============================================================================
```

Bringing port 1/1/1 on PE-1 up again will result in the path PE-5-P-4-P-2-PE-1 being reactivated. Switchback takes longer, because the external BGP session needs to be re-established, and routes have to be relearned.

Conclusion

BGP FRR provides ISPs the means to offer backup paths with fast switchover times when used in combination with short failure detection times and short advertisement intervals. By guaranteeing service in case of network failures, ISPs can provide enhanced service offerings to their customers.

BGP Fast Reroute Policy Control

This chapter provides information about BGP Fast Reroute Policy Control.

Topics in this chapter include:

Applicability

This chapter was initially based on SR OS Release 15.0.R4, but the CLI in the current edition is based on SR OS Release 22.10.R2.

Overview

BGP Fast Reroute (FRR) allows for precomputing multiple redundant BGP paths in the control plane and installing backup routes in the forwarding plane via indirection techniques. See the BGP Fast Reroute chapter for more information.

The BGP FRR Policy Control feature allows for selectively applying FRR for designated BGP prefixes. This allows an operator to develop separate service and redundancy models for different customers or services. It also allows for using data path resources required for BGP FRR in a more efficient way.

The BGP FRR policy control feature includes the **install-backup-path** policy action command. This command is supported in the following configuration contexts:

```
[/]
A:admin@PE-3# tree flat detail | match install-backup-path
configure groups group <string> policy-options policy-statement <string> default-action
 install-backup-path <boolean>
configure groups group <string> policy-options policy-statement <string> entry <string |
 number> action install-backup-path <boolean>
configure groups group <string> policy-options policy-statement <string> named-entry <string>
 action install-backup-path <boolean>
configure policy-options policy-statement <string> default-action install-backup-path <boolean>
configure policy-options policy-statement <string> entry <number> action install-backup-path
 <boolean>
configure policy-options policy-statement <string> named-entry <string> action install-backup-
path <boolean>
```

The **install-backup-path** command is effective when configured in BGP-import or VRF-import policies. In cases where this command is configured in an import policy applied in the global **bgp** context, the command applies to the following types of routes:

- IPv4

- IPv6
- Label-IPv4
- 6PE
- VPN-IPv4 (only if **vpn-apply-import** is configured in BGP)
- VPN-IPv6 (only if **vpn-apply-import** is configured in BGP)

Figure 39: Community addition on PE-1 and PE-2 shows an example of community addition. Two prefixes, 10.1.0.0/16 and 10.2.0.0/16, are advertised by CE-4 to both of its peers, PE-1 and PE-2. The administrator of AS 64496 wants to apply FRR only for the 10.2.0.0/16 prefix that will eventually be advertised to and used on PE-3, and not for 10.1.0.0/16. To facilitate this procedure, an import policy is applied on both PE-1 and PE-2 for routes advertised by CE-4 in AS 64500. The import policy selects and adds a community value of "1:1" to the 10.2.0.0/16 prefix. No community is applied to 10.1.0.0/16.

Figure 39: Community addition on PE-1 and PE-2

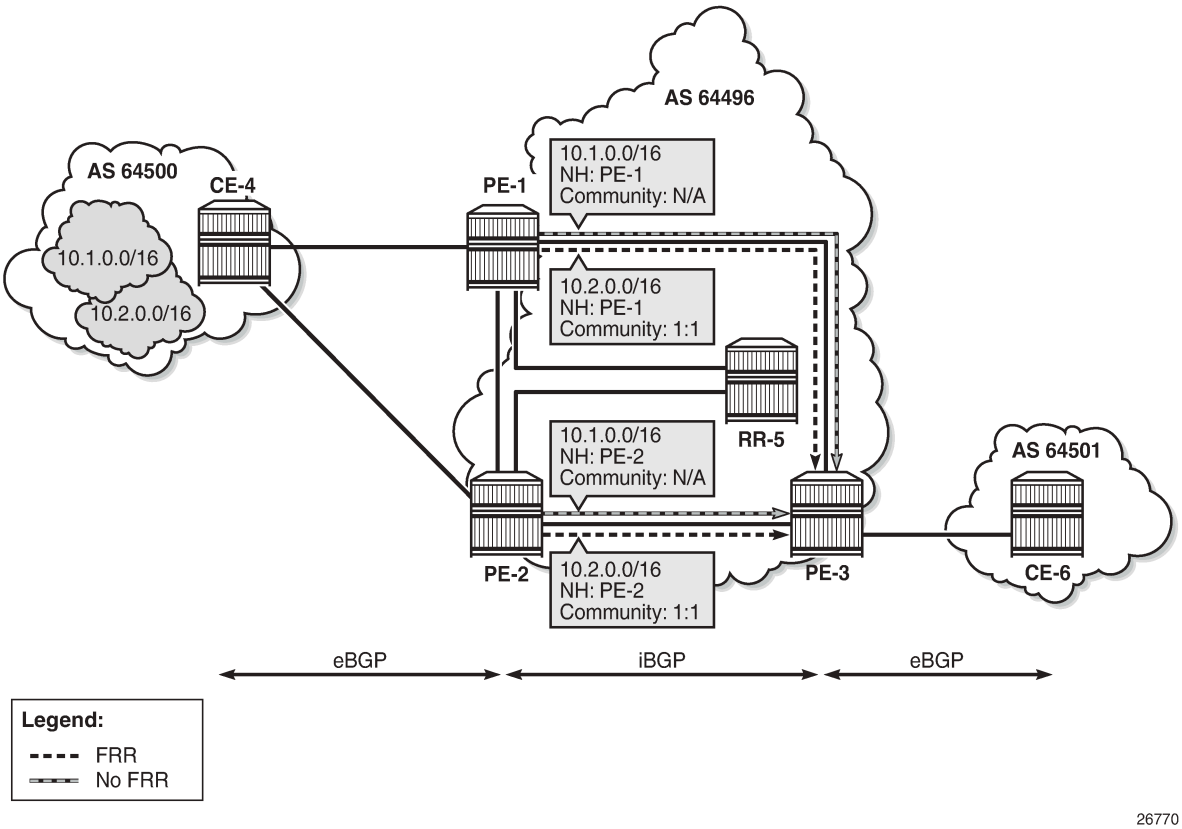
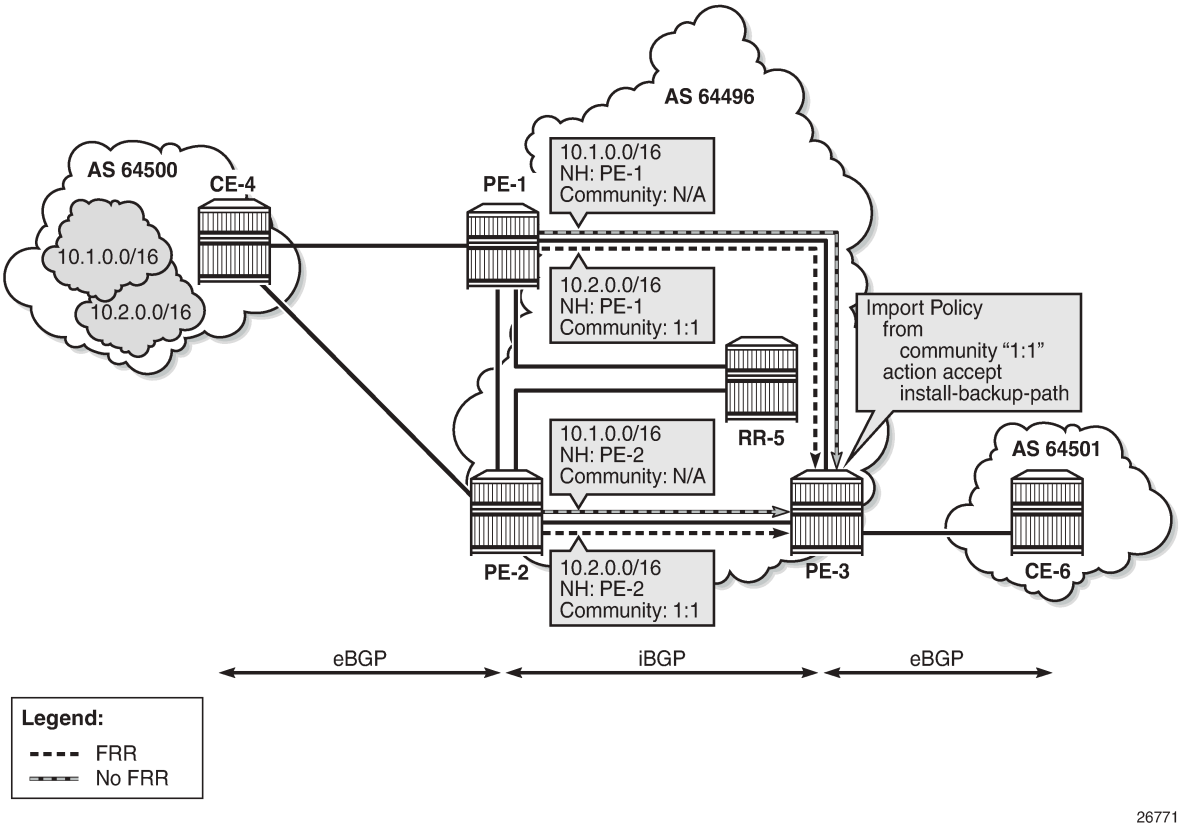


Figure 40: FRR policy on PE-3 shows the FRR import policy applied on PE-3 for the routes received from PE-1 and PE-2. The policy matches routes with a community value of "1:1" and instructs the router to calculate and install a backup path for those matching routes.

Figure 40: FRR policy on PE-3



Configuration

The following configuration examples are in this section:

- BGP FRR for address family IPv4 without FRR policy
- BGP FRR for address family IPv4 with FRR policy
- BGP with FRR policy for address family VPN-IPv4 using global BGP policy and **vpn-apply-import**
- BGP with FRR policy for address family VPN-IPv4 using VRF-import policy

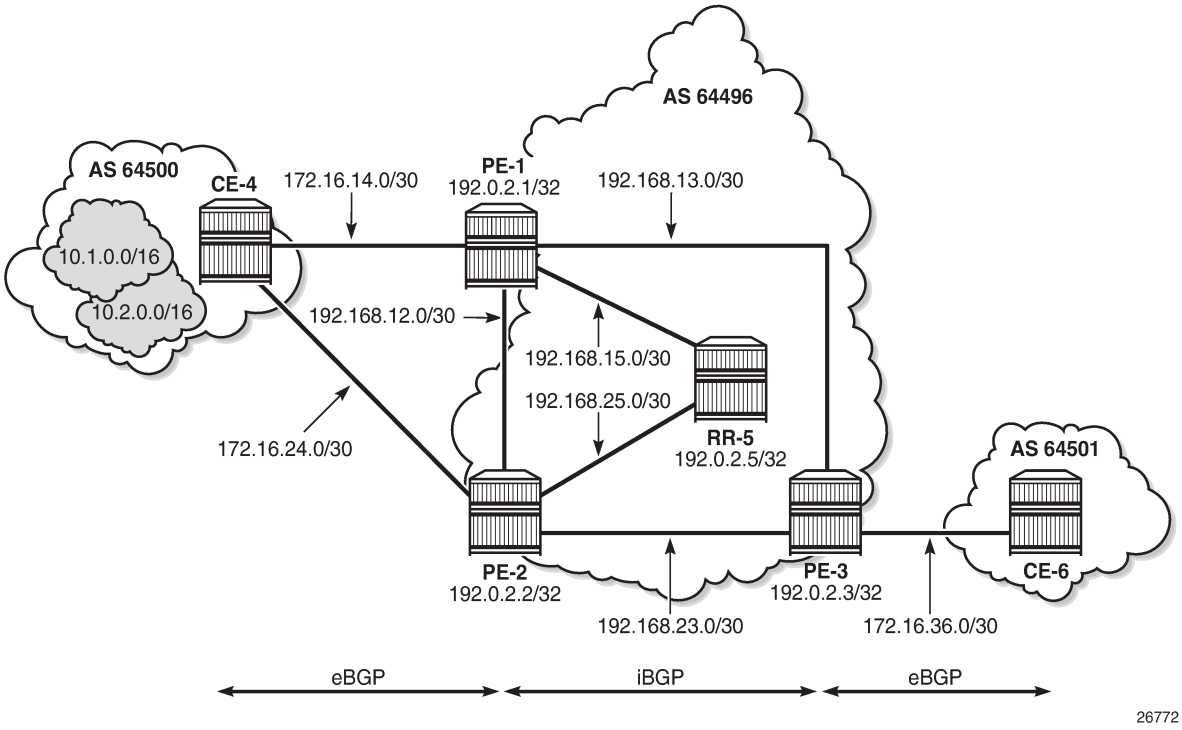
BGP FRR policy control feature for address family IPv4

Figure 41: Example topology - IPv4 shows the example topology used for the BGP FRR Policy Control feature for the IPv4 address family. The topology is similar to the one in the BGP Add-Path chapter, with the following characteristics:

- CE-4 in AS 64500 advertises both prefixes 10.1.0.0/16 and 10.2.0.0/16 to its eBGP peers PE-1 and PE-2 in AS 64496.
- RR-5 is route reflector for all PEs in AS 64496.

- Add-path is configured on all PE routers and RR-5 with a sending limit of 2.
- CE-6 in AS 64501 peers with PE-3 in AS 64496 and can send traffic to CE-4 in 64500.

Figure 41: Example topology - IPv4



Initial configuration

The initial configuration on all nodes includes:

- Cards, MDAs, ports
- Router interfaces
- IS-IS as IGP on all interfaces within AS 64496 (alternatively, OSPF can be used)
- LDP on all interfaces between the PEs in AS 64496, but not toward RR-5. LDP is used to create the transport tunnels that are bound to the VPRN services in the VPN-IPv4 address family section.

BGP is configured on all the nodes. CE-4 peers with PE-1 and PE-2 and exports prefixes 10.1.0.0/16 and 10.2.0.0/16 to both eBGP peers, as follows:

```
# on CE-4:
configure {
    policy-options {
        prefix-list "10.1.0.0/16" {
            prefix 10.1.0.0/16 type longer {
            }
        }
        prefix-list "10.2.0.0/16" {
            prefix 10.2.0.0/16 type longer {
            }
```

```
        }
        policy-statement "export-bgp" {
            entry 10 {
                from {
                    prefix-list ["10.1.0.0/16"]
                }
                action {
                    action-type accept
                }
            }
            entry 20 {
                from {
                    prefix-list ["10.2.0.0/16"]
                }
                action {
                    action-type accept
                }
            }
        }
    }
    router "Base" {
        autonomous-system 64500
        bgp {
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "eBGP" {
                export {
                    policy ["export-bgp"]
                }
                peer-as 64496
            }
            neighbor "172.16.14.1" {
                group "eBGP"
            }
            neighbor "172.16.24.1" {
                group "eBGP"
            }
        }
    }
```

CE-4 also has configured the following loopback interfaces:

```
# on CE-4:
configure {
    router "Base" {
        interface "int-loopback-1" {
            ipv4 {
                primary {
                    address 10.1.1.1
                    prefix-length 16
                }
            }
            loopback
        }
        interface "int-loopback-2" {
            ipv4 {
                primary {
                    address 10.2.1.1
                    prefix-length 16
```

```
                }
            }
            loopback
        }
```

The BGP configuration on CE-6 is similar, except for the export policy.

PE-1 peers with CE-4 in AS 65400 and RR-5 in AS 64496. The BGP configuration on PE-1 is as follows:

```
# on PE-1:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "eBGP" {
                peer-as 64500
            }
            neighbor "172.16.14.2" {
                group "eBGP"
            }
            group "iBGP" {
                next-hop-self true
                peer-as 64496
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            neighbor "192.0.2.5" {
                group "iBGP"
            }
```

The BGP configuration on PE-2 and PE-3 is similar to PE-1.

RR-5 acts as a route reflector to all the PEs in AS 64500 with a cluster ID of 5.5.5.5. The BGP configuration on RR-5 is as follows:

```
# on RR-5:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "iBGP" {
                cluster {
                    cluster-id 5.5.5.5
                }
                peer-as 64496
                add-paths {
                    ipv4 {
```

```
                        send 2
                        receive true
                    }
                }
            }
            neighbor "192.0.2.1" {
                group "iBGP"
            }
            neighbor "192.0.2.2" {
                group "iBGP"
            }
            neighbor "192.0.2.3" {
                group "iBGP"
            }
```

BGP FRR for address family IPv4 without FRR policy

PE-3 receives both prefixes from PE-1 and PE-2 via RR-5, but only uses the one from PE-1 (Nexthop: 192.0.2.1).

```
[/]
A:admin@PE-3# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.0.0/16                                      100         None
      192.0.2.1                                        10          10
      64500                                                        -
*i    10.1.0.0/16                                      100         None
      192.0.2.2                                        3           10
      64500                                                        -
u*>i  10.2.0.0/16                                      100         None
      192.0.2.1                                        11          10
      64500                                                        -
*i    10.2.0.0/16                                      100         None
      192.0.2.2                                        4           10
      64500                                                        -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

The following configuration is applied on PE-3 to enable BGP FRR:

```
# on PE-3:
configure {
    router "Base" {
        bgp {
            backup-path ipv4
```

PE-3 calculates and marks BGP routes from PE-2 as backup routes in the BGP routing table:

```
[/]
A:admin@PE-3# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.0.0/16                                      100         None
      192.0.2.1                                        10          10
      64500                                                        -
ub*i  10.1.0.0/16                                      100         None
      192.0.2.2                                        3           10
      64500                                                        -
u*>i  10.2.0.0/16                                      100         None
      192.0.2.1                                        11          10
      64500                                                        -
ub*i  10.2.0.0/16                                      100         None
      192.0.2.2                                        4           10
      64500                                                        -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

PE-3 installs BGP routes from PE-2 as backup routes in its route table:

```
[/]
A:admin@PE-3# show router route-table 10.0.0.0/8 longer alternative

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
      Alt-NextHop                                                 Alt-
                                                                  Metric
-------------------------------------------------------------------------------
10.1.0.0/16                                   Remote  BGP       00h02m47s  170
       192.168.13.1                                               10
10.1.0.0/16 (Backup)                          Remote  BGP       00h02m47s  170
       192.168.23.1                                               10
10.2.0.0/16                                   Remote  BGP       00h02m47s  170
       192.168.13.1                                               10
10.2.0.0/16 (Backup)                          Remote  BGP       00h02m47s  170
       192.168.23.1                                               10
-------------------------------------------------------------------------------
No. of Routes: 4
Flags: n = Number of times nexthop is repeated
       Backup = BGP backup route
       LFA = Loop-Free Alternate nexthop
       S = Sticky ECMP requested
```

```
===============================================================================
```

BGP FRR for address family IPv4 with FRR policy

The global BGP FRR activation command enabled on PE-3 in the previous step is removed from the configuration:

```
# on PE-3:
configure {
    router "Base" {
        bgp {
            backup-path delete ipv4
```

The following command output on PE-3 shows no community values attached to the prefix 10.2.0.0/16 advertised by PE-1 and PE-2:

```
[/]
A:admin@PE-3# show router bgp routes 10.2.0.0/16 detail | match '^Nexthop|Community'
Nexthop        : 192.0.2.1
Community      : No Community Members
Nexthop        : 192.0.2.1
Community      : No Community Members
Nexthop        : 192.0.2.2
Community      : No Community Members
Nexthop        : 192.0.2.2
Community      : No Community Members
```

The following policy is configured on PE-1 and PE-2 to add the BGP community "1:1" to the prefix 10.2.0.0/16 advertised by CE-4:

```
# on PE-1 and PE-2:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        prefix-list "10.2.0.0/16" {
            prefix 10.2.0.0/16 type longer {
            }
        }
        policy-statement "add-bgp-community" {
            entry 10 {
                from {
                    prefix-list ["10.2.0.0/16"]
                }
                action {
                    action-type accept
                    community {
                        add ["1:1"]
                    }
                }
            }
        }
```

The policy is applied as a BGP-import policy on PE-1 and PE-2 for the eBGP group:

```
# on PE-1, PE-2:
configure {
```

```
    router "Base" {
        bgp {
            group "eBGP" {
                import {
                    policy ["add-bgp-community"]
```

PE-3 now shows the community value associated with prefix 10.2.0.0/16 as applied and advertised by PE-1 and PE-2:

```
[/]
A:admin@PE-3# show router bgp routes 10.2.0.0/16 detail | match '^Nexthop|Community'
Nexthop        : 192.0.2.1
Community      : 1:1
Nexthop        : 192.0.2.1
Community      : 1:1
Nexthop        : 192.0.2.2
Community      : 1:1
Nexthop        : 192.0.2.2
Community      : 1:1
```

The following policy is configured on PE-3 to selectively install a backup path only for prefixes with a community value equal to "1:1":

```
# on PE-3:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        policy-statement "policy-bgp-frr-import" {
            entry 10 {
                from {
                    community {
                        name "1:1"
                    }
                }
                action {
                    action-type accept
                    install-backup-path true
                }
            }
        }
```

The policy is applied on PE-3 to selectively install a backup path only for prefixes with a community value equal to "1:1":

```
# on PE-3:
configure {
    router "Base" {
        bgp {
            group "iBGP" {
                import {
                    policy ["policy-bgp-frr-import"]
```

The following command output shows PE-3 has calculated a BGP FRR path only for prefix 10.2.0.0/16 indicated by the "b" (backup) flag:

```
[/]
A:admin@PE-3# show router bgp routes
===============================================================================
```

```
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.0.0/16                                      100         None
      192.0.2.1                                        10          10
      64500                                                        -
*i    10.1.0.0/16                                      100         None
      192.0.2.2                                        3           10
      64500                                                        -
u*>i  10.2.0.0/16                                      100         None
      192.0.2.1                                        11          10
      64500                                                        -
ub*i  10.2.0.0/16                                      100         None
      192.0.2.2                                        4           10
      64500                                                        -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

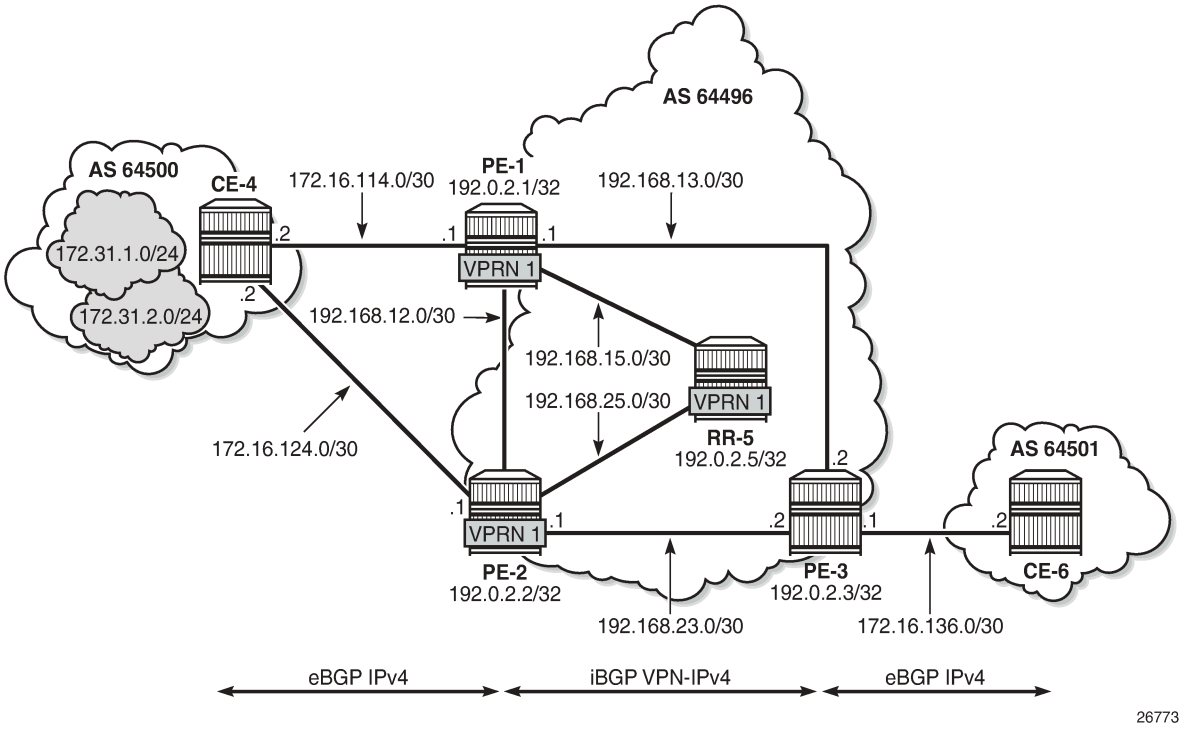
The following command output shows PE-3 has installed a backup route only for prefix 10.2.0.0/16 in its route table:

```
[/]
A:admin@PE-3# show router route-table 10.0.0.0/8 longer alternative

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
      Alt-NextHop                                                 Alt-
                                                                  Metric
-------------------------------------------------------------------------------
10.1.0.0/16                                    Remote  BGP       00h09m48s  170
       192.168.13.1                                                 10
10.2.0.0/16                                    Remote  BGP       00h01m12s  170
       192.168.13.1                                                 10
10.2.0.0/16 (Backup)                           Remote  BGP       00h01m12s  170
       192.168.23.1                                                 10
-------------------------------------------------------------------------------
No. of Routes: 3
Flags: n = Number of times nexthop is repeated
       Backup = BGP backup route
       LFA = Loop-Free Alternate nexthop
       S = Sticky ECMP requested
===============================================================================
```

BGP with FRR policy for address family VPN-IPv4 using global BGP policy

Figure 42: Example topology - VPN-IPv4 shows the example topology used to illustrate the BGP FRR policy control feature for the VPN-IPv4 route family. CE-4 exports both prefixes 172.31.1.0/24 and 172.31.2.0/24 to VPRN 1 on PE-1 and PE-2.

Figure 42: Example topology - VPN-IPv4



VPRN 1 is configured on all PEs in AS 64496. The configuration of VPRN 1 is similar on all PEs; for example, for PE-1, the VPRN configuration is as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            customer "1"
            service-id 1
            autonomous-system 64496
            interface "int-PE-1-CE-4-VPRN1" {
                ipv4 {
                    primary {
                        address 172.16.114.1
                        prefix-length 30
                    }
                }
                sap 1/1/c1/2:1 {
                }
            }
            bgp {
                split-horizon true
```

```
                ebgp-default-reject-policy {
                    import false
                    export false
                }
                group "eBGP-1" {
                    peer-as 64500
                }
                neighbor "172.16.114.2" {
                    group "eBGP-1"
                }
            }
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64496:1"
                    vrf-target {
                        community "target:64496:1"
                    }
                    auto-bind-tunnel {
                        resolution any
                    }
                }
            }
            admin-state enable
```

On the CEs, the configuration is either in the base routing instance, with additional router interfaces and BGP neighbors, or in a VPRN. In this example, the following VPRN is configured on CE-4:

```
# on CE-4:
    service {
        vprn "VPRN 1" {
            customer "1"
            service-id 1
            autonomous-system 64500
            interface "int-CE-4-PE-1-VPRN1" {
                ipv4 {
                    primary {
                        address 172.16.114.2
                        prefix-length 30
                    }
                }
                sap 1/1/c1/1:1 {
                }
            }
            interface "int-CE-4-PE-2-VPRN1" {
                ipv4 {
                    primary {
                        address 172.16.124.2
                        prefix-length 30
                    }
                }
                sap 1/1/c1/2:1 {
                }
            }
            interface "loopback1-VPRN1" {
                ipv4 {
                    primary {
                        address 172.31.1.1
                        prefix-length 24
                    }
                }
                loopback true
            }
```

```
            interface "loopback2-VPRN1" {
                ipv4 {
                    primary {
                        address 172.31.2.1
                        prefix-length 24
                    }
                }
                loopback true
            }
            bgp {
                split-horizon true
                ebgp-default-reject-policy {
                    import false
                    export false
                }
                group "eBGP-1" {
                    export {
                        policy ["export-VPRN1"]
                    }
                    peer-as 64496
                }
                neighbor "172.16.114.1" {
                    group "eBGP-1"
                }
                neighbor "172.16.124.1" {
                    group "eBGP-1"
                }
            }
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64500:1"
                }
            }
            admin-state enable
```

The export policy to export prefixes 172.31.1.0/24 and 172.31.2.0/24 is defined as follows:

```
# on CE-4:
configure {
    policy-options {
        prefix-list "172.31.0.0/16" {
            prefix 172.31.0.0/16 type longer {
            }
        }
        policy-statement "export-VPRN1" {
            entry 10 {
                from {
                    prefix-list ["172.31.0.0/16"]
                }
                action {
                    action-type accept
                }
            }
        }
```

The VPRN configuration on CE-6 is similar, but no prefix is exported from CE-6.

For all BGP speakers in AS 64496, BGP must be configured for address family VPN-IPv4 as well as for IPv4, as follows:

```
# on PE-1, PE-2, PE-3, RR-5:
configure {
```

```
    router "Base" {
        bgp {
            group "iBGP" {
                family {
                    ipv4 true
                    vpn-ipv4 true
                }
```

BGP add-path cannot be enabled in the **bgp** context within a VPRN. However, it can be enabled in the base routing instance for address family VPN-IPv4. This is done on all PEs and RR-5 at group level with the following command:

```
# on PE-1, PE-2, PE-3, RR-5:
configure {
    router "Base" {
        bgp {
            group "iBGP" {
                add-paths {
                    vpn-ipv4 {
                        send 2
                        receive true
                    }
```

The BGP configuration on PE-1 is as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "eBGP" {
                peer-as 64500
                import {
                    policy ["add-bgp-community"]
                }
            }
            group "iBGP" {
                next-hop-self true
                peer-as 64496
                family {
                    ipv4 true
                    vpn-ipv4 true
                }
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                    vpn-ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            neighbor "172.16.14.2" {
                group "eBGP"
            }
```

```
            neighbor "192.0.2.5" {
                group "iBGP"
            }
```

With add-path enabled for address family VPN-IPv4, PE-1 and PE-2 will advertise their routes for prefixes 172.31.1.0/24 and 172.31.2.0/24 as VPN-IPv4 routes to RR-5. RR-5 will advertise both routes to its other RR clients. PE-3 receives two VPN-IPv4 routes for each of the prefixes 172.31.1.0/24 and 172.31.2.0/24, as follows:

```
[/]
A:admin@PE-3# show router bgp routes 172.31.0.0/16 vpn-ipv4 longer
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64496:1:172.31.1.0/24                            100         None
      192.0.2.1                                        21          10
      64500                                                        524283
*>i   64496:1:172.31.1.0/24                            100         None
      192.0.2.2                                        9           10
      64500                                                        524283
u*>i  64496:1:172.31.2.0/24                            100         None
      192.0.2.1                                        20          10
      64500                                                        524283
*>i   64496:1:172.31.2.0/24                            100         None
      192.0.2.2                                        10          10
      64500                                                        524283
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

The following policy is configured on PE-1 and PE-2 to include the community value "1:1" to prefix 172.31.2.0/24, as well as to the VPRN route target 64496:1 within entry 10. All the other routes are tagged with only the VPRN route target 64496:1 in entry 20.

```
# on PE-1 and PE-2:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        community "target:64496:1" {
            member "target:64496:1" { }
        }
        prefix-list "172.31.2.0/24" {
            prefix 172.31.2.0/24 type longer {
            }
        }
        policy-statement "policy-export-VPRN1" {
            entry 10 {
```

```
                from {
                    prefix-list ["172.31.2.0/24"]
                }
                action {
                    action-type accept
                    community {
                        add ["1:1" "target:64496:1"]
                    }
                }
            }
            entry 20 {
                from {
                }
                action {
                    action-type accept
                    community {
                        add ["target:64496:1"]
                    }
                }
            }
        }
```

The policy is applied as a VRF-export policy in VPRN 1 on PE-1 and PE-2:

```
# on PE-1, PE-2:
configure {
    service {
        vprn "VPRN 1" {
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    vrf-export {
                        policy ["policy-export-VPRN1"]
```

On PE-3, prefix 172.31.1.0/24 is received with the community value of the VPRN route target only:

```
[/]
A:admin@PE-3# show router bgp routes 172.31.1.0/24 vpn-ipv4 hunt | match "Community"
Community      : target:64496:1
Community      : target:64496:1
```

However, prefix 172.31.2.0/24 is received with both community values "1:1" and "target:64496:1" from PE-1 and PE-2:

```
[/]
A:admin@PE-3# show router bgp routes 172.31.2.0/24 vpn-ipv4 hunt | match "Community"
Community      : 1:1 target:64496:1
Community      : 1:1 target:64496:1
```

The following command is applied on PE-3 to make the policy named "policy-bgp-frr-import", configured in the previous section for IPv4 routes, effective also on VPN-IPv4 routes:

```
# on PE-3:
configure {
    router "Base" {
        bgp {
            vpn-apply-import true
```

PE-3 now has a BGP backup path only for prefix 172.31.2.0/24, as indicated by the "b" (backup) flag:

```
[/]
A:admin@PE-3# show router bgp routes 172.31.0.0/16 vpn-ipv4 longer
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64496:1:172.31.1.0/24                            100         None
      192.0.2.1                                        21          10
      64500                                                        524283
*>i   64496:1:172.31.1.0/24                            100         None
      192.0.2.2                                        9           10
      64500                                                        524283
u*>i  64496:1:172.31.2.0/24                            100         None
      192.0.2.1                                        20          10
      64500                                                        524283
ub*>i 64496:1:172.31.2.0/24                            100         None
      192.0.2.2                                        10          10
      64500                                                        524283
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

PE-3 has installed a backup route only for prefix 172.31.2.0/24 in its VPRN route table:

```
[/]
A:admin@PE-3# show router 1 route-table 172.31.0.0/16 longer alternative

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                          Type    Proto     Age        Pref
      Next Hop[Interface Name]                                 Metric
      Alt-NextHop                                              Alt-
                                                               Metric
-------------------------------------------------------------------------------
172.31.1.0/24                               Remote  BGP VPN   00h01m47s  170
       192.0.2.1 (tunneled)                                        10
172.31.2.0/24                               Remote  BGP VPN   00h01m47s  170
       192.0.2.1 (tunneled)                                        10
172.31.2.0/24 (Backup)                      Remote  BGP VPN   00h01m47s  170
       192.0.2.2 (tunneled)                                        10
-------------------------------------------------------------------------------
No. of Routes: 3
Flags: n = Number of times nexthop is repeated
       Backup = BGP backup route
       LFA = Loop-Free Alternate nexthop
       S = Sticky ECMP requested
===============================================================================
```

BGP with FRR policy for address family VPN-IPv4 using VRF-import policy

The **vpn-apply-import** command enabled in the previous section is removed from the BGP configuration on PE-3:

```
# on PE-3:
configure {
    router "Base" {
        bgp {
            delete vpn-apply-import
```

PE-3 removes the backup path for prefix 172.31.2.0/24:

```
[/]
A:admin@PE-3# show router 1 route-table 172.31.0.0/16 longer alternative

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
      Alt-NextHop                                                 Alt-
                                                                  Metric
-------------------------------------------------------------------------------
172.31.1.0/24                                 Remote  BGP VPN   00h01m36s  170
       192.0.2.1 (tunneled)                                          10
172.31.2.0/24                                 Remote  BGP VPN   00h01m36s  170
       192.0.2.1 (tunneled)                                          10
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       Backup = BGP backup route
       LFA = Loop-Free Alternate nexthop
       S = Sticky ECMP requested
===============================================================================
```

The following policy is configured to selectively apply FRR for prefixes with a matching community value equal to "1:1" and "target:64496:1" on PE-3:

```
# on PE-3:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        community "target:64496:1" {
            member "target:64496:1" { }
        }
        policy-statement "policy-import-VPRN1" {
            entry 10 {
                from {
                    community {
                        expression "[target:64496:1] AND [1:1]"
                    }
                }
                action {
                    action-type accept
                    install-backup-path true
                }
            }
```

```
            default-action {
                action-type accept
            }
        }
```

The policy is applied as a VRF-import policy in VPRN 1 on PE-3:

```
# on PE-3:
configure {
    service {
        vprn "VPRN 1" {
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    vrf-import {
                        policy ["policy-import-VPRN1"]
```

PE-3 again installs a backup path only for prefix 172.31.2.0/24 and not for 172.31.1.0/24:

```
[/]
A:admin@PE-3# show router 1 route-table 172.31.0.0/16 longer alternative

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
      Alt-NextHop                                                 Alt-
                                                                  Metric
-------------------------------------------------------------------------------
172.31.1.0/24                                 Remote  BGP VPN   00h01m42s  170
       192.0.2.1 (tunneled)                                         10
172.31.2.0/24                                 Remote  BGP VPN   00h01m42s  170
       192.0.2.1 (tunneled)                                         10
172.31.2.0/24 (Backup)                        Remote  BGP VPN   00h01m42s  170
       192.0.2.2 (tunneled)                                         10
-------------------------------------------------------------------------------
No. of Routes: 3
Flags: n = Number of times nexthop is repeated
       Backup = BGP backup route
       LFA = Loop-Free Alternate nexthop
       S = Sticky ECMP requested
===============================================================================
```

Conclusion

The BGP FRR policy control feature allows for selectively applying FRR for designated prefixes. The feature brings more flexibility and granularity to the BGP FRR implementation.

BGP FlowSpec for IPv4 and IPv6

This chapter provides information about BGP FlowSpec for IPv4 and IPv6.

Topics in this chapter include:

Applicability

The configuration and information in this chapter are based on SR OS Release 22.7.R1.

Overview

The base BGP Flow Specification (FlowSpec) is defined in RFC 5575 (Flow Specification) and describes a method of encoding IPv4 flow specification information into Network Layer Reachability Information (NLRI). RFC 8955 updates RFC 5575 and RFC 8956 includes the IPv6 address family. The flow specification is an n-tuple consisting of one or more matching criteria, which can be applied to IP traffic. The FlowSpec NLRI is encoded into Multiprotocol BGP using MP_REACH_NLRI and MP_UNREACH_NLRI attributes.

As well as the flow specification defining match criteria, extended community attributes are defined to provide traffic filtering actions for the specified flow specification. Therefore, a FlowSpec route (MP_REACH_NLRI) contains a description of the traffic to be matched (using FlowSpec NLRI), and the filtering action to be taken with that traffic (using traffic filtering action extended communities). RFC 7674 provided an update to the original RFC 5575 specification to clarify the formatting of some of these traffic actions, notably redirect to VRF.

The use of FlowSpec is to dynamically distribute traffic filtering rules for mitigating distributed denial of service (DDoS) attacks. A router receiving a FlowSpec update can dynamically create IP filters to mitigate both intra-AS and inter-AS DDoS attacks. Mitigation is implemented by dropping traffic at the ingress point of the network (or nearest possible point toward the source of the DDoS attack) or by redirecting traffic to a separate routing context for forwarding (off-ramping) to a traffic-cleansing device. The ability to redirect traffic led to FlowSpec being considered for software defined networking (SDN)-driven applications or network re-optimization tools. In those cases, a subset of traffic needs to be forced (redirected) into a specific routing context or tunnel/label switched path (LSP) for network capacity optimization or to meet a service level agreement (SLA).

BGP FlowSpec uses AFI 1 (IPv4) or AFI 2 (IPv6) with SAFI 133 (IPv4 dissemination of flow specification rules) or SAFI 134 (VPNv4 dissemination of flow specification rules). SR OS supports IPv4 and IPv6. In SR OS Release 22.7.R1 and later, VPN-IPv4 and VPN-IPv6 are also supported.

The FlowSpec NLRI may consist of several components that form the flow specification. A packet only matches the flow specification when it matches all of the components in the NLRI. In the *BGP FlowSpec*

section of the *7450 ESS, 7750 SR, 7950 XRS, and VSR Unicast Routing Protocols Guide*, tables *Subcomponents of FlowSpec IPv4 and FlowSpec-VPN IPv4 NLRI* and *Subcomponents of FlowSpec IPv6 and FlowSpec-VPN IPv6 NLRI* list the component types that are currently defined, their type values, and their support in SR OS. Flow specification components must follow strict ordering. If present in the specification, a component must precede any other component of higher type value.

The traffic filtering action for a flow specification uses a number of extended community attributes. The attributes standardized in RFC 5575 are listed in the tables *IPv4 FlowSpec actions* and *IPv6 FlowSpec actions* in the *BGP FlowSpec* section of the *7450 ESS, 7750 SR, 7950 XRS, and VSR Unicast Routing Protocols Guide*. The traffic rate extended community specifies the rate in bytes per second, where a rate of zero specifies a drop action. The traffic action extended community consists of six bytes; only the two least significant bits of the last byte are currently defined. The terminal action (T-bit), when set to 1, indicates that subsequent filtering rules should be applied (like a next-entry action). When this bit is set to zero, and this action is applied, the evaluation of the traffic filter stops. The sample bit (S-bit), when set to 1, enables traffic sampling and logging for this flow specification. The **redirect-to-vrf** and mark traffic class extended communities are self-explanatory, with a route-target value being used to define the target redirect VRF.

FlowSpec routes are typically originated and contained within the administrative domain of an operator; particularly when used for DDoS mitigation purposes. This approach means applying ingress filters at the point where traffic enters the autonomous system (AS), such as an external peering point.

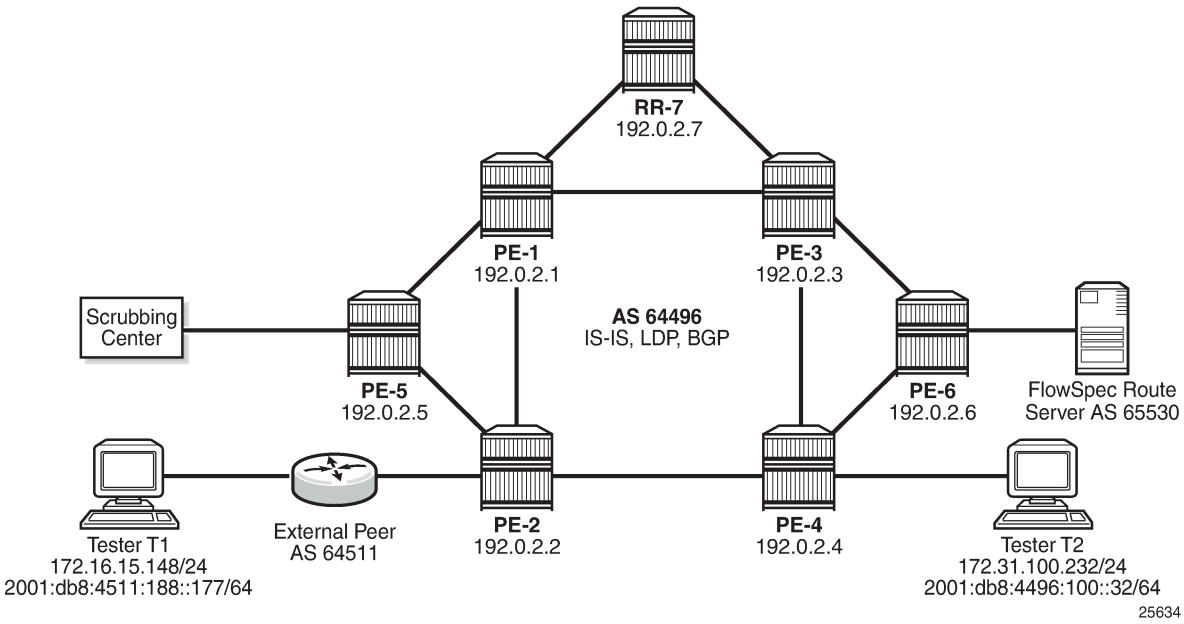
These filters should be instantiated as close as possible to the source of the attack traffic, even if that means applying filters within another operator's domain. This means that FlowSpec routes must be exchanged between ASs, requiring a trust relationship between the ASs, and a method for validating FlowSpec routes exchanged across AS boundaries. This is covered in the BGP FlowSpec Route Validation chapter.

Example topology

The example topology used in this chapter is shown in Figure 43: Example topology. PE-1 through PE-6 and RR-7 participate in IS-IS Level-2 and LDP. All these devices are part of network AS 64496, with all PE routers peering in IBGP with the Route Reflector RR-7 for address families IPv4, IPv6, VPN-IPv4, VPN-IPv6, Label-IPv4, Label-IPv6, Flow-IPv4, and Flow-IPv6.

By including the Label-IPv4 and Label-IPv6 address families, generating labeled routes, and resolving these labeled routes to LDP tunnels on all PEs in the topology, IPv4 and IPv6 traffic is tunneled in MPLS.

Figure 43: Example topology



To demonstrate FlowSpec, the following items are connected to AS 64496:

- PE-2 is connected to an external peer in AS 64511, which advertises the IPv4 prefix 172.16.0.0/20 and the IPv6 prefix 2001:db8:4511::/48 in EBGP. Both prefixes are advertised within AS 64496 by PE-2 as labeled routes.
- PE-4 advertises IPv4 prefix 172.31.100.0/24 and IPv6 prefix 2001:db8:4496::/48 into IBGP, which PE-2 subsequently advertises in EBGP to AS 64511.
- Tester T1 is connected to the external peer in AS 64511 and sources and sinks traffic from IPv4 address 172.16.15.148 and IPv6 address 2001:db8:4511:188::177. Tester T2 is connected to PE-4 and sources and sinks traffic from IPv4 address 172.31.100.232 and IPv6 address 2001:db8:4496:100:32.
- PE-6 externally peers with a FlowSpec route server belonging to AS 65530.
- PE-5 connects to a DDoS scrubbing center with two interfaces:
  - A "dirty" interface for forwarding of mitigated traffic toward the scrubbing center for cleansing. This interface is connected to an off-ramp VPRN configured on PE-5 and PE-2. PE-5 has static IPv4/IPv6 default routes toward the scrubbing center, which are subsequently advertised into the off-ramp VPRN. This provides sufficient routing information to attract redirected traffic from PE-2 toward the scrubbing center for cleansing.
  - A "clean" interface for traffic received from the scrubbing center after it has been cleansed. This interface is connected to an IES service and is therefore routed toward its destination using the Global Routing Table (GRT).

Configuration

As an example of FlowSpec configuration, the following output shows the BGP configuration on PE-1. Similar configurations are applied to all other PE routers. All PE routers within AS 64496 peer as clients

with RR-7 for the address families IPv4, IPv6, VPN-IPv4, VPN-IPv6, Label-IPv4, Label-IPv6, Flow-IPv4, and Flow-IPv6. The Label-IPv4 and Label-IPv6 address families are required for labeled routes, and the resolution filter enables IPv4 and IPv6 traffic to pass through the MPLS/LDP transport tunnels. The Flow-IPv4 and Flow-IPv6 address families are required for propagating the FlowSpec routes, and represent the only part of the BGP configuration required by FlowSpec.

```
A:admin@PE-1# admin show configuration /configure router bgp
    admin-state enable
    path-mtu-discovery false
    split-horizon true
    group "IBGP" {
        type internal
        family {
            ipv4 true
            vpn-ipv4 true
            ipv6 true
            vpn-ipv6 true
            flow-ipv4 true
            flow-ipv6 true
            label-ipv4 true
            label-ipv6 true
        }
    }
    neighbor "192.0.2.7" {
        admin-state enable
        group "IBGP"
    }
```

PE-2 peers with AS 64511 through an IES service interface using the IPv4 and IPv6 address families, with a dedicated BGP session for each family. This external peering point is the point where the IPv4 and IPv6 filters embedding the flowspec filters are applied. In the following output, these filters are applied in the SAP ingress context, to enable FlowSpec for IPv4 and IPv6, respectively. Such filters can also be enabled on spoke-SDPs within routed interfaces, and is supported within the base and VPRN routing instances.

```
A:admin@PE-2# admin show configuration /configure service ies 10
    admin-state enable
    description "Flowspec-test"
    customer "1"
    interface "to-AS64511" {
        sap 1/1/c4/1:10 {
            ingress {
                filter {
                    ip "104"
                    ipv6 "106"
                }
            }
        }
        ipv4 {
            primary {
                address 192.168.2.1
                prefix-length 30
            }
        }
        ipv6 {
            address 2001:db8:1b0c:2121::2 {
                prefix-length 127
            }
        }
    }
```

FlowSpec operation

With FlowSpec enabled and configured as in previous section, FlowSpec routes can be advertised to dynamically trigger the instantiation of embedded filters. When valid FlowSpec routes are received, the FlowSpec filters are created. These FlowSpec filters must be referenced from the operator-defined IPv4 or IPv6 filters, for example as follows. These operator-defined filters must be applied to the interfaces in the ingress context for FlowSpec to work.

```
A:admin@PE-2# admin show configuration /configure filter
    ip-filter "104" {
        default-action accept
        embed {
            flowspec offset 10000 {
                router-instance "Base"
            }
        }
    }
    ipv6-filter "106" {
        default-action accept
        embed {
            flowspec offset 10000 {
                router-instance "Base"
            }
        }
    }
```

This section demonstrates the use of FlowSpec for traffic black-holing and traffic redirection for both IPv4 and IPv6.

IPv4 FlowSpec

To validate the instantiation of ingress filters based on IPv4 FlowSpec routes, a bidirectional traffic stream is started between T1 (172.16.15.148) in AS 64511 and T2 (172.31.100.232) in AS 64496. In the T1 to T2 direction, the destination port is TCP port 4191.

An IPv4 FlowSpec route is generated to black-hole/drop traffic with a source address of 172.16.15.148 (T1) and a destination address of 172.31.100.232 (T2), for any destination ports in the range 4191-4198. The following output shows the route as received at PE-2.

```
<timestamp> MINOR: DEBUG #2001 Base Peer 1: 192.0.2.7
"Peer 1: 192.0.2.7: UPDATE
Peer 1: 192.0.2.7 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 77
    Flag: 0x90 Type: 14 Len: 28 Multiprotocol Reachable NLRI:
        Address Family FLOW_IPV4
        NLRI len: 22
          dest_pref   172.31.100.232/32
          src_pref    172.16.15.148/32
          ip_proto    [ == 6 ]
          dest_port   [ >4190 ] and [ <4199 ]
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 6 AS Path:
        Type: 2 Len: 1 < 65530 >
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0x80 Type: 9 Len: 4 Originator ID: 192.0.2.6
    Flag: 0x80 Type: 10 Len: 4 Cluster ID:
```

```
        192.0.2.7
    Flag: 0xc0 Type: 16 Len: 8 Extended Community:
        rate-limit: 0 kbps
"
```

The route is shown as an MP_REACH_NLRI for address family Flow-IPv4 (AFI 1 SAFI 133). The NLRI uses the source and destination prefixes, the IP protocol, and the destination-port components to describe the flow and create the filter match criteria. The traffic rate extended community is then used to define a rate of 0, which is the filter drop action.

Unlike other address families, there is no strict requirement for the Next-Hop attribute to be present in the MP_REACH_NLRI. The Length of Next-Hop in the Address field can optionally be set to zero and should be ignored on receipt.

The received FlowSpec route can also be verified in the RIB, which provides a concise output of the flow attributes and traffic filtering function, as follows:

```
A:admin@PE-2# /show router bgp routes flow-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP FLOW IPV4 Routes
===============================================================================
Flag  Network             Nexthop                 LocalPref       MED
      As-Path                                                     IGP Cost
-------------------------------------------------------------------------------
u*>?  --                  0.0.0.0                 100             None
      65530

      Community Action:  redirect-to-vrf:64496:2
      Flowspec Components:
      Dest Pref : 172.31.100.232/32
      Src Pref  : 172.16.15.148/32
      Ip Proto  : [ == 6 ]
      Port      : [ >4190 ] or [ <4199 ]
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The dynamically created FlowSpec IPv4 ingress filter is identified as *fSpec-0*, as follows. The origin indicates entry 256 has been added by BGP Flowspec.

```
A:admin@PE-2# /show filter ip "fSpec-0" detail

===============================================================================
IP Filter
===============================================================================
Filter Id           : fSpec-0
Scope               : Embedded
Type                : Normal
Shared Policer      : Off
Entries             : 1 (insert By Bgp)
Sub-Entries         : 4 (insert By Bgp)
Description         : IPv4 BGP FlowSpec filter for the Base router
-------------------------------------------------------------------------------
```

```
Filter Match Criteria : IP
-------------------------------------------------------------------------------
Entry               : 256
Origin              : Inserted by BGP FlowSpec
Description         : (Not Specified)
Log Id              : n/a
Src. IP             : 172.16.15.148/32
Dest. IP            : 172.31.100.232/32
Port                : port-list "_tmnx_fSpec_ipv4_14_both"
Protocol            : 6
Dscp                : Undefined
ICMP Type           : Undefined                   ICMP Code      : Undefined
Fragment            : Off                         Src Route Opt  : Off
Sampling            : Off                         Int. Sampling  : On
IP-Option           : 0/0                         Multiple Option: Off
Tcp-flag            : (Not Specified)
Option-pres         : Off
Egress PBR          : Disabled
Primary Action      : Drop
Ing. Matches        : 0 pkts
Egr. Matches        : 0 pkts

-------------------------------------------------------------------------------
Filter Match IP Prefix Lists
-------------------------------------------------------------------------------
No IP Prefix Lists
-------------------------------------------------------------------------------
Filter Match Port Lists
-------------------------------------------------------------------------------
Port list "_tmnx_fSpec_ipv4_14_both"
    0-4198      4191-65535
    NUM ports/ranges: 2

    References:
        IP-filter 104 entry 10256 (Both)
        IP-filter fSpec-0 entry 256 (Both)
        NUM references: 2

NUM Port Lists: 1
-------------------------------------------------------------------------------
Filter Match Protocol Lists
-------------------------------------------------------------------------------
No Protocol Lists
===============================================================================
```

The configuration of filter 104 (embedding the *fSpec-0* filter) is as follows, and shows a count of ingress matches, which are dropped. This is verified with the loss of traffic in the direction from T1 to T2, but not in the reverse direction.

```
A:admin@PE-2# /show filter ip 104 detail

===============================================================================
IP Filter
===============================================================================
Filter Id           : 104                         Applied        : Yes
Scope               : Template                    Def. Action    : Forward
Type                : Normal
Shared Policer      : Off
System filter       : Unchained
Radius Ins Pt       : n/a
CrCtl. Ins Pt       : n/a
RadSh. Ins Pt       : n/a
PccRl. Ins Pt       : n/a
```

```
Entries             : 0/0/0/1 (Fixed/Radius/Cc/Embedded)
Sub-Entries         : 0/0/0/4
Description         : (Not Specified)
Filter Name         : 104
-------------------------------------------------------------------------------
Filter Match Criteria : IP
-------------------------------------------------------------------------------
Entry               : 10256
Origin              : Inserted by embedded filter fSpec-0 entry 256
Description         : (Not Specified)
Log Id              : n/a
Src. IP             : 172.16.15.148/32
Dest. IP            : 172.31.100.232/32
Port                : port-list "_tmnx_fSpec_ipv4_14_both"
Protocol            : 6
Dscp                : Undefined
ICMP Type           : Undefined                   ICMP Code      : Undefined
Fragment            : Off                         Src Route Opt  : Off
Sampling            : Off                         Int. Sampling  : On
IP-Option           : 0/0                         Multiple Option: Off
Tcp-flag            : (Not Specified)
Option-pres         : Off
Egress PBR          : Disabled
Primary Action      : Drop
Ing. Matches        : 0 pkts
Egr. Matches        : 0 pkts

-------------------------------------------------------------------------------
Filter Match IP Prefix Lists
-------------------------------------------------------------------------------
No IP Prefix Lists
-------------------------------------------------------------------------------
Filter Match Port Lists
-------------------------------------------------------------------------------
Port list "_tmnx_fSpec_ipv4_14_both"
    0-4198      4191-65535
    NUM ports/ranges: 2

    References:
        IP-filter 104 entry 10256 (Both)
        IP-filter fSpec-0 entry 256 (Both)
        NUM references: 2

NUM Port Lists: 1
-------------------------------------------------------------------------------
Filter Match Protocol Lists
-------------------------------------------------------------------------------
No Protocol Lists
===============================================================================
```

When the route is withdrawn and PE-2 receives an MP_UNREACH_NLRI for the same FlowSpec NLRI, the dynamically created filter entries are removed and all associated hardware resources (TCAM entries) are released.

Instead of dropping traffic at the ingress point to the network, an alternative option is to redirect the mitigated traffic to a traffic-cleansing device, if this infrastructure exists. FlowSpec has the redirect-to-vrf extended community for this purpose, with the process of forwarding traffic toward a scrubbing center frequently referred to as off-ramping. At PE-2, a VPRN is configured to off-ramp traffic toward the scrubbing center connected to PE-5, as shown in the following output.

In the case of FlowSpec, traffic redirection is half-duplex. That is, traffic is forwarded from PE-2 toward PE-5, but not from PE-5 toward PE-2. This is because when the traffic has been cleansed, it re-enters the

network at PE-5 within an IES, and is therefore routed toward its destination using the GRT. This process is frequently referred to as on-ramping. As a result of this half-duplex traffic flow, only a vrf-target import statement is required. There is no requirement to export any routes from PE-2.

```
A:admin@PE-2# admin show configuration /configure service vprn "2"
    admin-state enable
    description "FlowSpec-OffRamp-VRF"
    customer "1"
    bgp-ipvpn {
        mpls {
            admin-state enable
            route-distinguisher "64496:2"
            vrf-target {
                import-community "target:64496:2"
            }
            auto-bind-tunnel {
                resolution any
            }
        }
    }
```

Off-ramping traffic also requires a VPRN service instance in PE-5 with a single SAP toward the scrubbing center, as shown in the following output. Static IPv4 and IPv4 default routes are configured with next hops of the scrubbing center and these are advertised into VPN-IPv4/VPN-IPv6 using route-policy. There is no requirement for PE-5 to import any BGP-VPN routes.

```
A:admin@PE-5# admin show configuration /configure service vprn "2"
    admin-state enable
    description "FlowSpec-OffRamp-VRF"
    customer "1"
    bgp-ipvpn {
        mpls {
            admin-state enable
            route-distinguisher "64496:2"
            vrf-export {
                policy ["vrf2-export"]
            }
        }
    }
    interface "OffRamp-to-Scrubbing-Center" {
        ipv4 {
            primary {
                address 192.168.2.5
                prefix-length 30
            }
        }
        sap 1/1/c3/1:10 {
        }
        ipv6 {
            address 2001:db8:1b0c:2121::4 {
                prefix-length 127
            }
        }
    }
    static-routes {
        route 0.0.0.0/0 route-type unicast {
            next-hop "192.168.2.6" {
                admin-state enable
            }
        }
        route ::/0 route-type unicast {
            next-hop "2001:db8:1b0c:2121::5" {
```

```
                admin-state enable
            }
        }
    }
```

On-ramping the traffic back onto the network after cleansing the traffic is via IES 3, which is configured as follows. This way the cleansed traffic re-enters the network and is forwarded toward its destination using the GRT.

```
A:admin@PE-5# admin show configuration /configure service ies "3"
    admin-state enable
    description "FlowSpec-OnRamp-IES"
    customer "1"
    interface "OnRamp-from-Scrubbing-Center" {
        sap 1/1/c3/1:11 {
        }
        ipv4 {
            primary {
                address 192.168.2.6
                prefix-length 30
            }
        }
        ipv6 {
            address 2001:db8:1b0c:2121::5 {
                prefix-length 127
            }
        }
    }
```

To validate the instantiation of the redirection filter, the same bidirectional traffic stream is started between T1 (172.16.15.148) in AS 64511 and T2 (172.31.100.232) in AS 64496. In the T1 to T2 direction, the destination port is TCP port 4191. When the IPv4 FlowSpec route is received at PE-2, the NLRI shows the same traffic match criteria previously used for the black-hole/drop scenario. The extended community has changed to **redirect-to-vrf** with a route-target value of *64496:2*, as shown in the following output.

```
<timestamp> MINOR: DEBUG #2001 Base Peer 1: 192.0.2.7
"Peer 1: 192.0.2.7: UPDATE
Peer 1: 192.0.2.7 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 77
    Flag: 0x90 Type: 14 Len: 28 Multiprotocol Reachable NLRI:
        Address Family FLOW_IPV4
        NLRI len: 22
          dest_pref   172.31.100.232/32
          src_pref    172.16.15.148/32
          ip_proto    [ == 6 ]
          dest_port   [ >4190 ] and [ <4199 ]
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 6 AS Path:
        Type: 2 Len: 1 < 65530 >
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0x80 Type: 9 Len: 4 Originator ID: 192.0.2.6
    Flag: 0x80 Type: 10 Len: 4 Cluster ID:
        192.0.2.7
    Flag: 0xc0 Type: 16 Len: 8 Extended Community:
        redirect-to-vrf:64496:2
"
```

The dynamically created FlowSpec IPv4 ingress filter is identified as *fSpec-0*, as follows. The filter match criteria for entry 256 indicate the primary action is *forward (VRF)*, and the forwarding router/service ID is service ID 2 (the off-ramp VPRN).

```
A:admin@PE-2# /show filter ip "fSpec-0" detail

===============================================================================
IP Filter
===============================================================================
Filter Id           : fSpec-0
Scope               : Embedded
Type                : Normal
Shared Policer      : Off
Entries             : 1 (insert By Bgp)
Sub-Entries         : 4 (insert By Bgp)
Description         : IPv4 BGP FlowSpec filter for the Base router
-------------------------------------------------------------------------------
Filter Match Criteria : IP
-------------------------------------------------------------------------------
Entry               : 256
Origin              : Inserted by BGP FlowSpec
Description         : (Not Specified)
Log Id              : n/a
Src. IP             : 172.16.15.148/32
Dest. IP            : 172.31.100.232/32
Port                : port-list "_tmnx_fSpec_ipv4_11_both"
Protocol            : 6
Dscp                : Undefined
ICMP Type           : Undefined                   ICMP Code      : Undefined
Fragment            : Off                         Src Route Opt  : Off
Sampling            : Off                         Int. Sampling  : On
IP-Option           : 0/0                         Multiple Option: Off
Tcp-flag            : (Not Specified)
Option-pres         : Off
Egress PBR          : Disabled
Primary Action      : Forward (VRF)
  Router            : 2
  Extended Action   : None
PBR Down Action     : Drop (entry-default)
Ing. Matches        : 4 pkts (328 bytes)
Egr. Matches        : 0 pkts

-------------------------------------------------------------------------------
Filter Match IP Prefix Lists
-------------------------------------------------------------------------------
No IP Prefix Lists
-------------------------------------------------------------------------------
Filter Match Port Lists
-------------------------------------------------------------------------------
Port list "_tmnx_fSpec_ipv4_11_both"
    0-4198      4191-65535
    NUM ports/ranges: 2

    References:
        IP-filter 104 entry 10256 (Both)
        IP-filter fSpec-0 entry 256 (Both)
        NUM references: 2

NUM Port Lists: 1
-------------------------------------------------------------------------------
Filter Match Protocol Lists
-------------------------------------------------------------------------------
No Protocol Lists
```

```
===============================================================================
```

The configuration of filter 1 (embedding the *fSpec-0* filter) shows a count of ingress matches, and is as follows:

```
A:admin@PE-2# /show filter ip 104

===============================================================================
IP Filter
===============================================================================
Filter Id           : 104                          Applied        : Yes
Scope               : Template                     Def. Action    : Forward
Type                : Normal
Shared Policer      : Off
System filter       : Unchained
Radius Ins Pt       : n/a
CrCtl. Ins Pt       : n/a
RadSh. Ins Pt       : n/a
PccRl. Ins Pt       : n/a
Entries             : 0/0/0/1 (Fixed/Radius/Cc/Embedded)
Sub-Entries         : 0/0/0/4
Description         : (Not Specified)
Filter Name         : 104
-------------------------------------------------------------------------------
Filter Match Criteria : IP
-------------------------------------------------------------------------------
Entry               : 10256
Origin              : Inserted by embedded filter fSpec-0 entry 256
Description         : (Not Specified)
Log Id              : n/a
Src. IP             : 172.16.15.148/32
Dest. IP            : 172.31.100.232/32
Port                : port-list "_tmnx_fSpec_ipv4_12_both"
Protocol            : 6
Dscp                : Undefined
ICMP Type           : Undefined                    ICMP Code      : Undefined
Fragment            : Off                          Src Route Opt  : Off
Sampling            : Off                          Int. Sampling  : On
IP-Option           : 0/0                          Multiple Option: Off
Tcp-flag            : (Not Specified)
Option-pres         : Off
Egress PBR          : Disabled
Primary Action      : Forward (VRF)
  Router            : 2
  Extended Action   : None
PBR Down Action     : Drop (entry-default)
Ing. Matches        : 4 pkts (328 bytes)
Egr. Matches        : 0 pkts

-------------------------------------------------------------------------------
Filter Match IP Prefix Lists
-------------------------------------------------------------------------------
No IP Prefix Lists
-------------------------------------------------------------------------------
Filter Match Port Lists
-------------------------------------------------------------------------------
Port list "_tmnx_fSpec_ipv4_13_both"
    0-4198      4191-65535
    NUM ports/ranges: 2

    References:
        IP-filter 104 entry 10256 (Both)
        IP-filter fSpec-0 entry 256 (Both)
```

```
        NUM references: 2

NUM Port Lists: 1
-------------------------------------------------------------------------------
Filter Match Protocol Lists
-------------------------------------------------------------------------------
No Protocol Lists
===============================================================================
```

Traffic is correctly received in the T1 to T2 direction, and also in the reverse direction. However, traffic in the T1 to T2 direction is redirected by PE-2 toward the scrubbing center attached to PE-5, before being forwarded to its destination at PE-4.

IPv6 FlowSpec

To validate the instantiation of ingress filters based on IPv6 FlowSpec routes, a bidirectional traffic stream is commenced between T1 (2001:db8:4511:188::177) in AS 64511 and T2 (2001:db8:4496:100::32) in AS 64496. In the T1 to T2 direction, the destination port is TCP port 4191.

An IPv6 FlowSpec route is generated to black-hole/drop traffic with a source address of 2001:db8:4511:188::177 (T1) and a destination address of 2001:db8:4496:100::32 (T2), for any destination ports in the range 4191-4198. The following output shows the route as received at PE-2.

```
<timestamp> MINOR: DEBUG #2001 Base Peer 1: 192.0.2.7
"Peer 1: 192.0.2.7: UPDATE
Peer 1: 192.0.2.7 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 103
    Flag: 0x90 Type: 14 Len: 54 Multiprotocol Reachable NLRI:
        Address Family FLOW_IPV6
        NLRI len: 48
          dest_pref   2001:db8:4496:100::32/128 offset 0
          src_pref    2001:db8:4511:188::177/128 offset 0
          ip_proto    [ == 6 ]
          dest_port   [ >4190 ] and [ <4199 ]
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 6 AS Path:
        Type: 2 Len: 1 < 65530 >
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0x80 Type: 9 Len: 4 Originator ID: 192.0.2.6
    Flag: 0x80 Type: 10 Len: 4 Cluster ID:
        192.0.2.7
    Flag: 0xc0 Type: 16 Len: 8 Extended Community:
        rate-limit: 0 kbps
"
```

The route is shown as an MP_REACH_NLRI for address family Flow-IPv6 (AFI 2 SAFI 133). As with the FlowSpec IPv4 example, the NLRI uses the source and destination prefixes, the IP protocol, and the destination-port components to describe the flow and create the filter match criteria. The traffic rate extended community is then used to define a rate of 0, which is equivalent to a filter drop action.

The dynamically created FlowSpec IPv6 ingress filter is identified as *fSpec-0*, as follows. The description indicates entry 256 has been added through BGP Flowspec.

```
A:admin@PE-2# show filter ipv6 "fSpec-0" detail

===============================================================================
IPv6 Filter
```

```
===============================================================================
Filter Id           : fSpec-0
Scope               : Embedded
Type                : Normal
Shared Policer      : Off
Entries             : 1 (insert By Bgp)
Sub-Entries         : 4 (insert By Bgp)
Description         : IPv6 BGP FlowSpec filter for the Base router
-------------------------------------------------------------------------------
Filter Match Criteria : IPv6
-------------------------------------------------------------------------------
Entry               : 256
Origin              : Inserted by BGP FlowSpec
Description         : (Not Specified)
Log Id              : n/a
Src. IP             : 2001:db8:4511:188::177/128
Dest. IP            : 2001:db8:4496:100::32/128
Port                : port-list "_tmnx_fSpec_ipv6_14_both"
Next Header         : 6
Dscp                : Undefined
ICMP Type           : Undefined                    ICMP Code      : Undefined
Sampling            : Off                          Int. Sampling  : On
Tcp-flag            : (Not Specified)
Fragment            : Off
HopByHop Opt        : Off                          Routing Type0  : Off
Auth Hdr            : Off                          ESP header     : Off
Flow-label          : n/a                          Flow-label Mask: n/a
Egress PBR          : Disabled
Primary Action      : Drop
Ing. Matches        : 0 pkts
Egr. Matches        : 0 pkts

-------------------------------------------------------------------------------
Filter Match IPv6 Prefix Lists
-------------------------------------------------------------------------------
No IPv6 Prefix Lists
-------------------------------------------------------------------------------
Filter Match Port Lists
-------------------------------------------------------------------------------
Port list "_tmnx_fSpec_ipv6_14_both"
    0-4198      4191-65535
    NUM ports/ranges: 2

    References:
        IPv6-filter 106 entry 10256 (Both)
        IPv6-filter fSpec-0 entry 256 (Both)
        NUM references: 2

NUM Port Lists: 1
-------------------------------------------------------------------------------
Filter Match Protocol Lists
-------------------------------------------------------------------------------
No Protocol Lists
===============================================================================
```

The configuration of filter 106 (embedding the *fSpec-0* filter) is as follows, and shows a count of ingress matches, which are dropped (primary action is drop). This is observed with the loss of traffic in the direction from T1 to T2, but not in the reverse direction.

```
A:admin@PE-2# /show filter ipv6 106 detail

===============================================================================
IPv6 Filter
```

```
===============================================================================
Filter Id           : 106                          Applied        : Yes
Scope               : Template                     Def. Action    : Forward
Type                : Normal
Shared Policer      : Off
System filter       : Unchained
Radius Ins Pt       : n/a
CrCtl. Ins Pt       : n/a
RadSh. Ins Pt       : n/a
PccRl. Ins Pt       : n/a
Entries             : 0/0/0/1 (Fixed/Radius/Cc/Embedded)
Sub-Entries         : 0/0/0/4
Description         : (Not Specified)
Filter Name         : 106
-------------------------------------------------------------------------------
Filter Match Criteria : IPv6
-------------------------------------------------------------------------------
Entry               : 10256
Origin              : Inserted by embedded filter fSpec-0 entry 256
Description         : (Not Specified)
Log Id              : n/a
Src. IP             : 2001:db8:4511:188::177/128
Dest. IP            : 2001:db8:4496:100::32/128
Port                : port-list "_tmnx_fSpec_ipv6_14_both"
Next Header         : 6
Dscp                : Undefined
ICMP Type           : Undefined                    ICMP Code      : Undefined
Sampling            : Off                          Int. Sampling  : On
Tcp-flag            : (Not Specified)
Fragment            : Off
HopByHop Opt        : Off                          Routing Type0  : Off
Auth Hdr            : Off                          ESP header     : Off
Flow-label          : n/a                          Flow-label Mask: n/a
Egress PBR          : Disabled
Primary Action      : Drop
Ing. Matches        : 0 pkts
Egr. Matches        : 0 pkts

-------------------------------------------------------------------------------
Filter Match IPv6 Prefix Lists
-------------------------------------------------------------------------------
No IPv6 Prefix Lists
-------------------------------------------------------------------------------
Filter Match Port Lists
-------------------------------------------------------------------------------
Port list "_tmnx_fSpec_ipv6_14_both"
    0-4198      4191-65535
    NUM ports/ranges: 2

    References:
        IPv6-filter 106 entry 10256 (Both)
        IPv6-filter fSpec-0 entry 256 (Both)
        NUM references: 2

NUM Port Lists: 1
-------------------------------------------------------------------------------
Filter Match Protocol Lists
-------------------------------------------------------------------------------
No Protocol Lists
===============================================================================
```

The FlowSpec IPv6 route with the drop action is subsequently withdrawn, restoring the traffic flow between T1 and T2.

To off-ramp IPv6 traffic toward the scrubbing center, the same redirect infrastructure is used as in the IPv4 example:

- PE-2 and PE-5 use the same off-ramp VPRN (VPRN 2), which transports both VPN-IPv4 and VPN-IPv6 traffic.
- PE-5 uses the same on-ramp (IES). When traffic is returned from the scrubbing center, PE-5 routes packets toward their destination using the GRT.

An IPv6 FlowSpec route with a **redirect-to-vrf** extended community is then sourced by the FlowSpec route generator. When the route is received at PE-2, the NLRI shows the same traffic match criteria previously used for the IPv6 black-hole/drop scenario. The extended community has changed to **redirect-to-vrf** with a route-target value of *64496:2*, as shown in the following output.

```
<timestamp> CEST MINOR: DEBUG #2001 Base Peer 1: 192.0.2.7
"Peer 1: 192.0.2.7: UPDATE
Peer 1: 192.0.2.7 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 103
    Flag: 0x90 Type: 14 Len: 54 Multiprotocol Reachable NLRI:
        Address Family FLOW_IPV6
        NLRI len: 48
          dest_pref   2001:db8:4496:100::32/128 offset 0
          src_pref    2001:db8:4511:188::177/128 offset 0
          ip_proto    [ == 6 ]
          dest_port   [ >4190 ] and [ <4199 ]
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 6 AS Path:
        Type: 2 Len: 1 < 65530 >
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0x80 Type: 9 Len: 4 Originator ID: 192.0.2.6
    Flag: 0x80 Type: 10 Len: 4 Cluster ID:
        192.0.2.7
    Flag: 0xc0 Type: 16 Len: 8 Extended Community:
        redirect-to-vrf:64496:2
"
```

The dynamically created FlowSpec IPv4 ingress filter is identified as *fSpec-0*, as follows. The filter match criteria for entry 256 indicate the primary action is *forward (VRF)*, and the forwarding router/service ID is service ID 2 (the off-ramp VPRN).

```
A:admin@PE-2# /show filter ipv6 "fSpec-0" detail

===============================================================================
IPv6 Filter
===============================================================================
Filter Id           : fSpec-0
Scope               : Embedded
Type                : Normal
Shared Policer      : Off
Entries             : 1 (insert By Bgp)
Sub-Entries         : 4 (insert By Bgp)
Description         : IPv6 BGP FlowSpec filter for the Base router
-------------------------------------------------------------------------------
Filter Match Criteria : IPv6
-------------------------------------------------------------------------------
Entry               : 256
Origin              : Inserted by BGP FlowSpec
Description         : (Not Specified)
Log Id              : n/a
Src. IP             : 2001:db8:4511:188::177/128
Dest. IP            : 2001:db8:4496:100::32/128
```

```
Port                : port-list "_tmnx_fSpec_ipv6_15_both"
Next Header         : 6
Dscp                : Undefined
ICMP Type           : Undefined                    ICMP Code      : Undefined
Sampling            : Off                          Int. Sampling  : On
Tcp-flag            : (Not Specified)
Fragment            : Off
HopByHop Opt        : Off                          Routing Type0  : Off
Auth Hdr            : Off                          ESP header     : Off
Flow-label          : n/a                          Flow-label Mask: n/a
Egress PBR          : Disabled
Primary Action      : Forward (VRF)
  Router            : 2
  Extended Action   : None
PBR Down Action     : Drop (entry-default)
Ing. Matches        : 0 pkts
Egr. Matches        : 0 pkts

-------------------------------------------------------------------------------
Filter Match IPv6 Prefix Lists
-------------------------------------------------------------------------------
No IPv6 Prefix Lists
-------------------------------------------------------------------------------
Filter Match Port Lists
-------------------------------------------------------------------------------
Port list "_tmnx_fSpec_ipv6_15_both"
    0-4198      4191-65535
    NUM ports/ranges: 2

    References:
        IPv6-filter 106 entry 10256 (Both)
        IPv6-filter fSpec-0 entry 256 (Both)
        NUM references: 2

NUM Port Lists: 1
-------------------------------------------------------------------------------
Filter Match Protocol Lists
-------------------------------------------------------------------------------
No Protocol Lists
===============================================================================
```

The configuration of IPv6 filter 106 (embedding the *fSpec-0* filter) shows a count of ingress matches, and is as follows:

```
A:admin@PE-2# /show filter ipv6 106 detail

===============================================================================
IPv6 Filter
===============================================================================
Filter Id           : 106                          Applied        : Yes
Scope               : Template                     Def. Action    : Forward
Type                : Normal
Shared Policer      : Off
System filter       : Unchained
Radius Ins Pt       : n/a
CrCtl. Ins Pt       : n/a
RadSh. Ins Pt       : n/a
PccRl. Ins Pt       : n/a
Entries             : 0/0/0/1 (Fixed/Radius/Cc/Embedded)
Sub-Entries         : 0/0/0/4
Description         : (Not Specified)
Filter Name         : 106
-------------------------------------------------------------------------------
```

```
Filter Match Criteria : IPv6
-------------------------------------------------------------------------------
Entry               : 10256
Origin              : Inserted by embedded filter fSpec-0 entry 256
Description         : (Not Specified)
Log Id              : n/a
Src. IP             : 2001:db8:4511:188::177/128
Dest. IP            : 2001:db8:4496:100::32/128
Port                : port-list "_tmnx_fSpec_ipv6_15_both"
Next Header         : 6
Dscp                : Undefined
ICMP Type           : Undefined                   ICMP Code      : Undefined
Sampling            : Off                         Int. Sampling  : On
Tcp-flag            : (Not Specified)
Fragment            : Off
HopByHop Opt        : Off                         Routing Type0  : Off
Auth Hdr            : Off                         ESP header     : Off
Flow-label          : n/a                         Flow-label Mask: n/a
Egress PBR          : Disabled
Primary Action      : Forward (VRF)
  Router            : 2
  Extended Action   : None
PBR Down Action     : Drop (entry-default)
Ing. Matches        : 799 pkts (102272 bytes)
Egr. Matches        : 0 pkts

-------------------------------------------------------------------------------
Filter Match IPv6 Prefix Lists
-------------------------------------------------------------------------------
No IPv6 Prefix Lists
-------------------------------------------------------------------------------
Filter Match Port Lists
-------------------------------------------------------------------------------
Port list "_tmnx_fSpec_ipv6_15_both"
    0-4198      4191-65535
    NUM ports/ranges: 2

    References:
        IPv6-filter 106 entry 10256 (Both)
        IPv6-filter fSpec-0 entry 256 (Both)
        NUM references: 2

NUM Port Lists: 1
-------------------------------------------------------------------------------
Filter Match Protocol Lists
-------------------------------------------------------------------------------
No Protocol Lists
===============================================================================
```

Traffic is correctly received in the T1 to T2 direction, and also in the reverse direction. However, traffic in the T1 to T2 direction is redirected by PE-2 toward the scrubbing center attached to PE-5, before being forwarded to its destination at PE-4.

Resource consumption

Similar to static filters consuming hardware resources, dynamically instantiated FlowSpec filters consume hardware resources (TCAM entries) on the associated line cards. Therefore, resources must be checked and monitored to ensure that the system operates within its scaling boundaries.

Before the activation of any FlowSpec routes, there are two ingress ACL/QoS entries consumed for IPv4 and another two entries for IPv6, as shown in the following output.

```
A:admin@PE-2# /tools dump resource-usage system all | match 'Usage|Free|ACL Entries'
Resource Usage Information for System
                                                Total   Allocated        Free
Resource Usage Information for Card Slot #1
                                                Total   Allocated        Free
Resource Usage Information for Card Slot #1 FP #1
                                                  Total  Allocated       Free
               Ingress ACL Entries (IPv4/v6) |      98304          2      98302
                Egress ACL Entries (IPv4/v6) |      49152          2      49150
Resource Usage Information for Card Slot #1 MDA #1
                                                Total   Allocated        Free
Resource Usage Information for Card Slot #1 MDA #2
                                                Total   Allocated        Free
```

When a FlowSpec IPv4 rule matching on a source/destination IP address is dynamically instantiated, one additional ACL entry is consumed in hardware, as shown in the following output.

```
A:admin@PE-2# /tools dump resource-usage system all | match 'Usage|Free|ACL Entries'
Resource Usage Information for System
                                                Total   Allocated        Free
Resource Usage Information for Card Slot #1
                                                Total   Allocated        Free
Resource Usage Information for Card Slot #1 FP #1
                                                  Total  Allocated       Free
               Ingress ACL Entries (IPv4/v6) |      98304          3      98301
                Egress ACL Entries (IPv4/v6) |      49152          2      49150
Resource Usage Information for Card Slot #1 MDA #1
                                                Total   Allocated        Free
Resource Usage Information for Card Slot #1 MDA #2
                                                Total   Allocated        Free
```

TCAM entries are not consumed on a per-interface basis. When TCAM entries are consumed on a line card for a FlowSpec NLRI match criteria, the same criteria can be used for filtering across multiple IP interfaces on the same line card without consuming additional TCAM entries.

Conclusion

FlowSpec IPv4 and IPv6 provide a dynamic way to activate (and tear down) ingress filters to mitigate against DDoS attacks. SR OS supports a wide range of match criteria (FlowSpec NLRI) coupled with the ability to either drop or redirect mitigated traffic. This offers flexibility not only in what traffic is matched, but also in traffic treatment, depending on the availability of a traffic-cleansing infrastructure.

The ability of FlowSpec to dynamically create and remove filters has some immediate benefits:

- Reduces the likelihood of configuration errors on one or more devices
- Allows for temporary use of hardware resources, which are released when the threat has passed
- Allows for a push configuration from a single point to a potentially large number of network devices, without having to visit each one to configure filters manually.

BGP Multipath

This chapter provides information about BGP Multipath.

Topics in this chapter include:

Applicability

This chapter was initially written for SR OS Release 14.0.R4, but the MD-CLI in the current edition is based on SR OS Release 21.10.R1. Configurable BGP multipath parameters per address family and selective BGP multipath is supported in SR OS Release 19.5.R1, and later.

Overview

When BGP multipath is enabled, traffic can be forwarded to an IP prefix destination over multiple BGP paths that are considered equal by the BGP decision process. BGP multipath is supported in base router and VPRNs, both for iBGP and eBGP. The **multipath** command specifies the maximum number of BGP paths that each BGP RIB can submit to the route table for an IP prefix. The equal cost multipath (ECMP) limit defines how many paths are selected for installation in the forwarding information base (FIB). Traffic in the data path that matches the IP prefix is load-balanced across the ECMP next hops on a per-packet hash calculation.

Note:
As described in chapter Separate BGP RIBs for Labeled Routes, labeled routes and unlabeled routes do not mix.

BGP multipath can be configured as follows:

1. The **multipath** commands present in the base router and VPRN **bgp** contexts are configurable on a global level or more specific, within an address family context (**ipv4**, **ipv6**, **label-ipv4**, and **label-ipv6**). Following parameters are possible:

```
[ex:configure router "Base" bgp multipath]
A:admin@PE-5#             multipath ?

 multipath

 ebgp                   - Maximum multipaths per prefix for EBGP learned routes
 family                 + Enter the family list instance
 ibgp                   - Maximum multipaths per prefix for IBGP learned routes
 max-paths              - Maximum multipaths per prefix
 restrict               - AS path restriction for the non-best path
```

```
 unequal-cost          - Ignore differences in the next-hop cost for multipath
```

```
[ex:/configure router "Base" bgp multipath]
A:admin@PE-5#                max-paths ?

 max-paths <number>
 <number>  - <1..64>
 Default   - 1

    Maximum multipaths per prefix
```

```
[ex:/configure router "Base" bgp multipath]
A:admin@PE-5#                restrict ?

 restrict <keyword>
 <keyword>  - (same-as-path-length|same-neighbor-as|exact-as-path)
 Default    - same-as-path-length

    AS path restriction for the non-best path
```

- multipath configuration per address family overrules the generic max-paths configuration.
- *max-paths* is the default maximum number of paths. It is overruled by ebgp-max-paths and ibgp-max-paths. However, if there is no maximum set for the number of eBGP paths or iBGP paths, then the maximum number of paths is set by max-paths.
- *ebgp-max-paths* specifies the maximum number of paths that can be used when the best path is eBGP. If configured, *ebgp-max-paths* overrides the configured *max-paths* for eBGP paths.
- *ibgp-max-paths* specifies the maximum number of paths that can be used when the best path is iBGP. If configured, *ibgp-max-paths* overrides the configured *max-paths* for iBGP paths.
- **restrict same-neighbor-as** forces multipaths to have the same (shortest) AS path length (unless **as-path-ignore** is configured) and, for the paths with that length, the same neighbor AS.
- **restrict exact-as-path** forces multipaths to have the exact same AS paths.
- **unequal-cost** allows to use routes with different next-hop costs in multipath ECMP sets.

2. The **ebgp-ibgp-equal** command is added to the **best-path-selection** contexts in base router and VPRN **bgp** contexts. When this command is configured, as follows, the BGP decision process skips the step that prefers eBGP over iBGP. This enables load-balancing between eBGP and iBGP paths.

```
[ex:/configure router "Base" bgp]
A:admin@PE-5#             best-path-selection ?

 best-path-selection

 always-compare-med    + Enter the always-compare-med context
 as-path-ignore        + Enter the as-path-ignore context
 compare-origin-       - Compare RPKI origin validation state of usable routes
  validation-state
 d-path-length-ignore  - Enable D-PATH length ignore
 deterministic-med     - Group paths based on AS before MED attribute comparison
 ebgp-ibgp-equal       + Enter the ebgp-ibgp-equal context
 ignore-nh-metric      - Ignore next-hop distance in best path selection
 ignore-router-id      + Enable the ignore-router-id context
 origin-invalid-       - Deem invalid routes unusable for best-path selection
  unusable
```

Note:
The ebgp-ibgp-equal command is not to be confused with the eibgp-loadbalance command in a VPRN, that is used to provide ECMP over BGP-VPN (imported routes) and BGP routes. It is called eibgp-loadbalance because, in such scenarios, BGP-VPN is typically used between iBGP peers and BGP is used between eBGP peers. However, this is not always the case, so the name can be misleading.

Entire BGP groups or a selection of BGP neighbors can be configured as multipath-eligible. If a route is learned for an IPv4, IPv6, label-IPv4, or label-IPv6 prefix, and the associated maximum number of paths is N (which can depend on the address family and whether the best path was received from an eBGP or iBGP peer), then one of the following three rules applies:

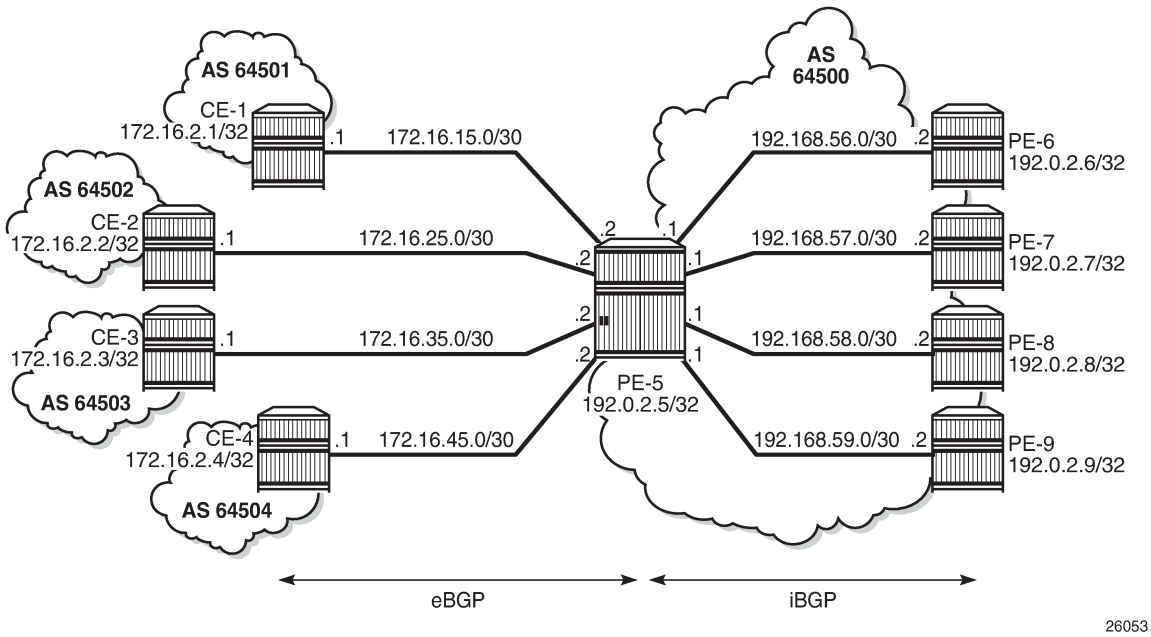
- If the best path came from a neighbor marked as **multipath-eligible**, then only paths marked as multipath-eligible are candidates for the BGP multipath and the best N are chosen for installation as ECMP next-hops.
- If none of the paths from the set of all possible multipaths came from a neighbor marked as **multipath-eligible**, the best N are chosen.
- If the best path did not come from a neighbor marked as **multipath-eligible** and at least one path from the set of all possible multipaths came from a multipath-eligible peer, then only the best path is chosen and all other paths are eliminated.

Configuration

The examples in this section show the multipath BGP configuration in the base router. For BGP multipath in a VPRN, the configuration is similar.

Figure 44: Example topology shows the example configuration with the used IP addresses. PE-5 has eBGP sessions with CEs in different autonomous systems (ASs) and iBGP sessions with PE-6, PE-7, PE-8, and PE-9.

Figure 44: Example topology



The initial configuration includes:

- Cards, MDAs, ports
- Router interfaces
- IS-IS in AS 64500
- LDP in AS 64500
- BGP on all nodes (eBGP between CEs and PE-5; iBGP between PEs)
- Export policy "export-bgp" accepting routes from protocol direct on all nodes

The BGP configuration on CE-1 is as follows:

```
# on CE-1:
configure {
    router "Base" {
        autonomous-system 64501
        bgp {
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "eBGP" {
                peer-as 64500
                export {
                    policy ["export-bgp"]
                }
            }
            neighbor "172.16.15.2" {
                group "eBGP"
            }
```

```
        }
```

The BGP configuration on the other nodes that advertise routes to PE-5 is similar.

The BGP configuration on PE-5 is as follows:

```
# on PE-5:
configure {
    router "Base" {
        autonomous-system 64500
        bgp {
            split-horizon true
            group "eBGP" {
                ebgp-default-reject-policy {
                    import false
                    export false
                }
            }
            group "iBGP" {
                peer-as 64500
            }
            neighbor "172.16.15.1" {
                group "eBGP"
                peer-as 64501
            }
            neighbor "172.16.25.1" {
                group "eBGP"
                peer-as 64502
            }
            neighbor "172.16.35.1" {
                group "eBGP"
                peer-as 64503
            }
            neighbor "172.16.45.1" {
                group "eBGP"
                peer-as 64504
            }
            neighbor "192.0.2.6" {
                group "iBGP"
            }
            neighbor "192.0.2.7" {
                group "iBGP"
            }
            neighbor "192.0.2.8" {
                group "iBGP"
            }
            neighbor "192.0.2.9" {
                group "iBGP"
            }
        }
```

The following will be configured and verified:

- BGP multipath with different eBGP and iBGP path limits
- BGP multipath with equal eBGP and iBGP path treatment
- BGP multipath restricted to the same neighbor AS
- BGP multipath restricted to the exact AS path
- BGP multipath per address family
- Selective BGP multipath

BGP multipath with different eBGP and iBGP path limits

On PE-5, BGP multipath is configured as follows:

```
# on PE-5:
configure {
    router "Base" {
        bgp {
            multipath {
                max-paths 8
                ebgp 2
                ibgp 3
            }
```

The **max-paths** limit is only used when no limits are configured for eBGP or iBGP. It is allowed to specify a lower value for **max-paths** than for either eBGP or iBGP because the configured number of paths for eBGP and iBGP overrule the max-paths limitation, as follows:

```
# on PE-5:
configure {
    router "Base" {
        bgp {
            multipath {
                max-paths 1
                ebgp 2
                ibgp 3
            }
```

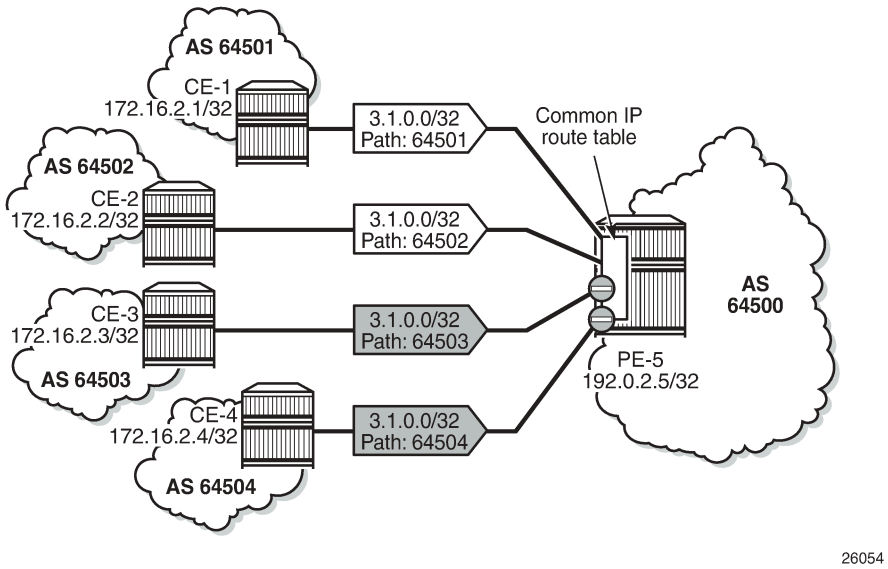
With this configuration, regardless of the value of max-paths, there can be two eBGP routes for the same prefix and three iBGP routes for the same prefix. If the best route is eBGP, the *ebgp-max-paths* value is 2; if the best route is iBGP, the *ibgp-max-paths* value is 3. The value for max-paths (1) is never used when limits for both eBGP and iBGP are configured.

```
# on PE-5:
configure {
    router "Base" {
        bgp {
            multipath {
                max-paths 3
                ebgp 2
            }
```

With this configuration, there can be two eBGP routes for the same prefix and three iBGP routes for the same prefix. If the best route is eBGP, the *ebgp-max-paths* value is 2, and if the best route is iBGP, the *max-paths* value is 3.

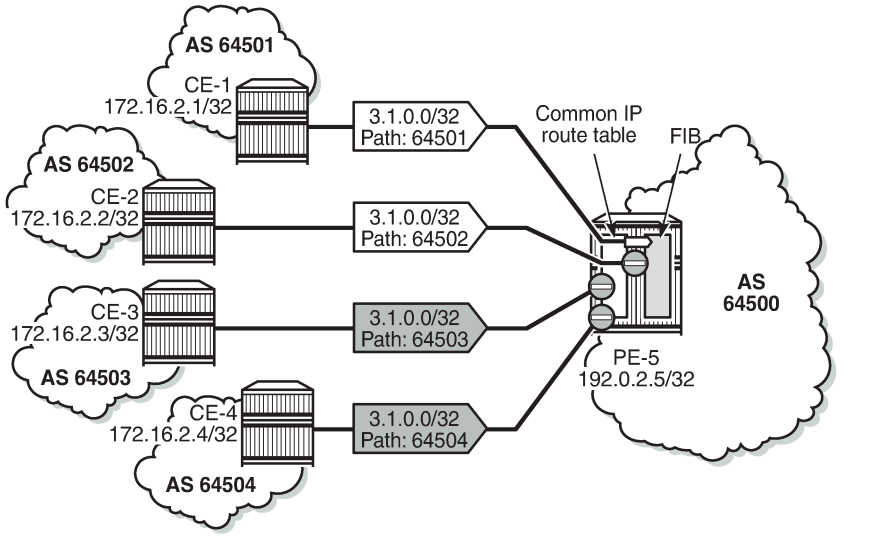
In the following example, all four eBGP neighbors advertise prefix 3.1.0.0/32 to PE-5 and all four iBGP neighbors advertise prefix 3.2.0.0/32 to PE-5. PE-5 receives four eBGP routes for prefix 3.1.0.0/32, but only two are added to the common IP route table, as shown in Figure 45: BGP multipath with eBGP limit 2.

Figure 45: BGP multipath with eBGP limit 2



These routes can only be added to the FIB if ECMP is configured to a value at least equal to the number of routes allowed in BGP multipath. By default, ECMP is disabled and only one route is added to the FIB, as shown in Figure 46: eBGP multipath with limit 2 and ECMP disabled.

Figure 46: eBGP multipath with limit 2 and ECMP disabled



With ECMP disabled, only one of the four paths is used for prefix 3.1.0.0/32, as follows:

```
[/]
A:admin@PE-5# show router bgp routes 3.1.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
```

```
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.1.0.0/32                                       None        None
      172.16.15.1                                      None        0
      64501                                                        -
*i    3.1.0.0/32                                       None        None
      172.16.25.1                                      None        0
      64502                                                        -
*i    3.1.0.0/32                                       None        None
      172.16.35.1                                      None        0
      64503                                                        -
*i    3.1.0.0/32                                       None        None
      172.16.45.1                                      None        0
      64504                                                        -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

In the remainder of the chapter, ECMP is configured with a value of eight, implying that the routes added to the common IP route table will be added to the FIB as well. ECMP is configured on PE-5 as follows:

```
# on PE-5:
configure {
    router "Base" {
        ecmp 8
    }
```

With ECMP configured with a limit of eight, two eBGP paths are used for prefix 3.1.0.0/32.

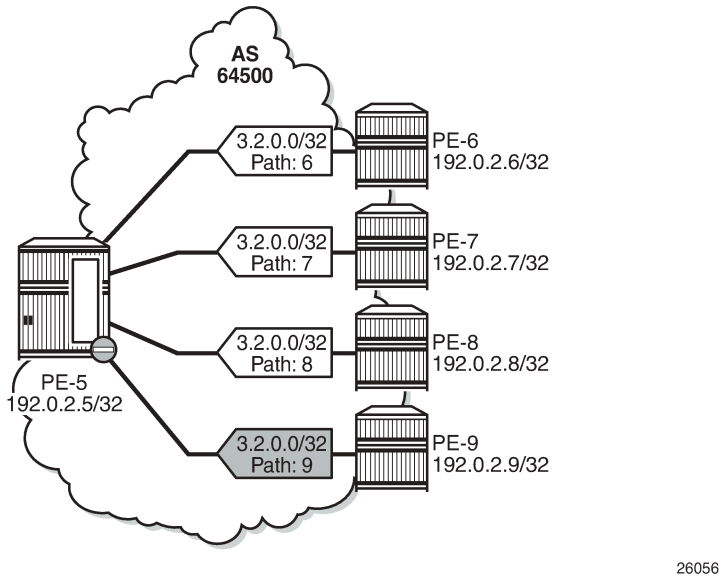
The first two of the following BGP routes for prefix 3.1.0.0/32 are used on PE-5:

```
[/]
A:admin@PE-5# show router bgp routes 3.1.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.1.0.0/32                                       None        None
      172.16.15.1                                      None        0
      64501                                                        -
u*>i  3.1.0.0/32                                       None        None
```

```
      172.16.25.1                                          None        0
      64502                                                            -
*>i   3.1.0.0/32                                          None        None
      172.16.35.1                                          None        0
      64503                                                            -
*>i   3.1.0.0/32                                          None        None
      172.16.45.1                                          None        0
      64504                                                            -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

The four iBGP neighbors of PE-5 advertise prefix 3.2.0.0/32 to PE-5. BGP multipath has a limit of three for iBGP routes. Consequently, three BGP routes are added to the common IP route table and to the FIB, as shown in Figure 47: BGP multipath with iBGP limit 3 and ECMP limit 8.

Figure 47: BGP multipath with iBGP limit 3 and ECMP limit 8



Three iBGP paths are used for prefix 3.2.0.0/32, as follows:

```
[/]
A:admin@PE-5# show router bgp routes 3.2.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.2.0.0/32                                       100         None
```

```
      192.0.2.6                                                 None        10
      6                                                                     -
u*>i  3.2.0.0/32                                                100         None
      192.0.2.7                                                 None        10
      7                                                                     -
u*>i  3.2.0.0/32                                                100         None
      192.0.2.8                                                 None        10
      8                                                                     -
*>i   3.2.0.0/32                                                100         None
      192.0.2.9                                                 None        10
      9                                                                     -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

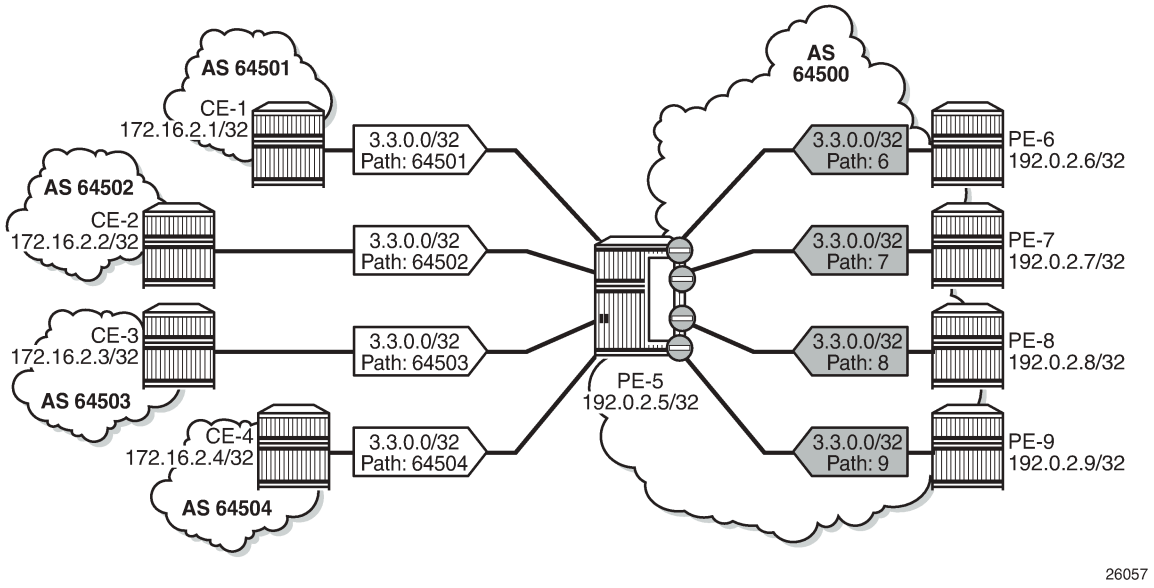
BGP multipath with equal eBGP and iBGP path treatment

It is optional to specify limits for eBGP and iBGP; an overall multipath limitation is sufficient, such as:

```
# on PE-5:
configure {
    router "Base" {
        bgp {
            multipath {
                max-paths 6
            }
```

With this configuration, there can be six routes for the same prefix. These routes can be eBGP or iBGP routes. By default, eBGP routes are preferred and, therefore, only the four eBGP routes are imported in the common IP route table, as shown in Figure 48: BGP multipath with limit 6 and eBGP preferred.

Figure 48: BGP multipath with limit 6 and eBGP preferred



Only the four eBGP paths are used, as follows:

```
[/]
A:admin@PE-5# show router bgp routes 3.3.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  3.3.0.0/32                                        None        None
      172.16.15.1                                       None        0
      64501                                                         -
u*>i  3.3.0.0/32                                        None        None
      172.16.25.1                                       None        0
      64502                                                         -
u*>i  3.3.0.0/32                                        None        None
      172.16.35.1                                       None        0
      64503                                                         -
u*>i  3.3.0.0/32                                        None        None
      172.16.45.1                                       None        0
      64504                                                         -
*i    3.3.0.0/32                                        100         None
      192.0.2.6                                         None        10
      6                                                             -
*i    3.3.0.0/32                                        100         None
      192.0.2.7                                         None        10
      7                                                             -
*i    3.3.0.0/32                                        100         None
      192.0.2.8                                         None        10
      8                                                             -
*i    3.3.0.0/32                                        100         None
      192.0.2.9                                         None        10
      9                                                             -
-------------------------------------------------------------------------------
Routes : 8
===============================================================================
```

The BGP decision process prefers eBGP over iBGP, but this step can be skipped by configuring the following:

```
# on PE-5:
configure {
    router "Base" {
        bgp {
             best-path-selection {
                 ebgp-ibgp-equal {
                     ipv4 true
                 }
             }
```

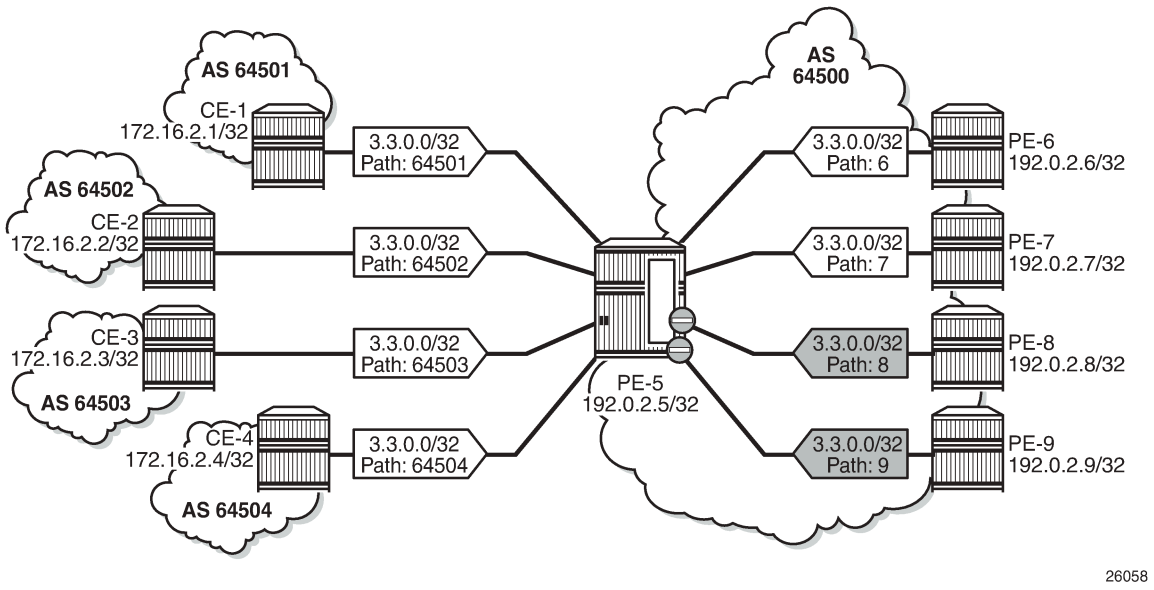
This configuration only skips one step in the BGP decision process. If the best route is still eBGP, the eBGP multipath limit applies; if the best route is iBGP, the iBGP multipath limit applies.

Optionally, other best path selection criteria can also be configured, such as ignore-nh-metric. However, the multipath configuration can also be configured with the unequal-cost option. This allows to ignore the next-hop cost in BGP multipath ECMP sets, while preserving the next-hop option in the BGP decision process.

```
# on PE-5:
configure {
    router "Base" {
        bgp {
            multipath
                max-paths 6
                unequal-cost true
            }
```

When all other path options are identical (such as local preference, MED, IGP cost, and other criteria from the BGP decision process), or when the best-path-selection is configured to ignore specific path options, and the only differentiator is an originator ID, the remaining steps in the BGP decision process do not exclude any routes. In that case, six of the eight eligible BGP paths are included in the BGP multipath, as shown in Figure 49: BGP multipath with limit 6, eBGP equal to iBGP, and other path options identical.

Figure 49: BGP multipath with limit 6, eBGP equal to iBGP, and other path options identical



From the eight advertised BGP routes for prefix 3.3.0.0/32, six paths are used, as follows:

```
[/]
A:admin@PE-5# show router bgp routes 3.3.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
```

```
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.3.0.0/32                                       None        None
      172.16.15.1                                      None        0
      64501                                                        -
u*>i  3.3.0.0/32                                       None        None
      172.16.25.1                                      None        0
      64502                                                        -
u*>i  3.3.0.0/32                                       None        None
      172.16.35.1                                      None        0
      64503                                                        -
u*>i  3.3.0.0/32                                       None        None
      172.16.45.1                                      None        0
      64504                                                        -
u*>i  3.3.0.0/32                                       100         None
      192.0.2.6                                        None        10
      6                                                            -
u*>i  3.3.0.0/32                                       100         None
      192.0.2.7                                        None        10
      7                                                            -
*>i   3.3.0.0/32                                       100         None
      192.0.2.8                                        None        10
      8                                                            -
*>i   3.3.0.0/32                                       100         None
      192.0.2.9                                        None        10
      9                                                            -
-------------------------------------------------------------------------------
Routes : 8
===============================================================================
```

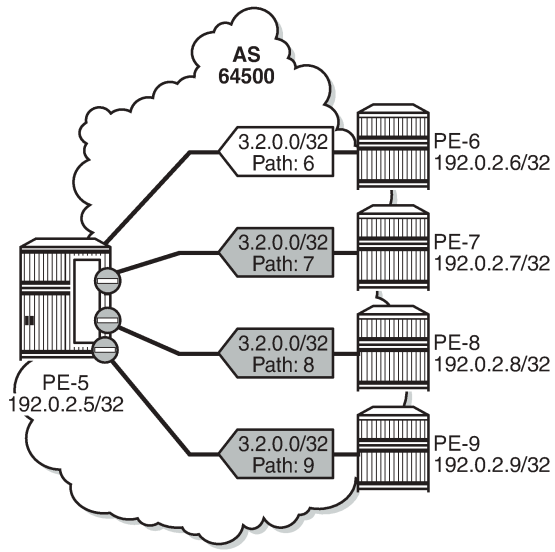
BGP multipath restricted to the same neighbor AS

BGP multipath can be configured with the restriction that the neighbor AS must be the same for all the used paths. When all routes have a different neighbor AS, only one path is used. This can be shown for prefix 3.2.0.0/32 that is advertised by the iBGP neighbors. The BGP multipath configuration on PE-5 is as follows:

```
# on PE-5:
configure {
    router "Base" {
        bgp {
            multipath {
                max-paths 8
                ebgp 2
                ibgp 3
                restrict same-neighbor-as
            }
```

Figure 50: BGP multipath configured with restriction to the same neighbor AS shows that with the restriction to the same neighbor AS, only one path is used because all BGP routes have a different neighbor AS.

Figure 50: BGP multipath configured with restriction to the same neighbor AS

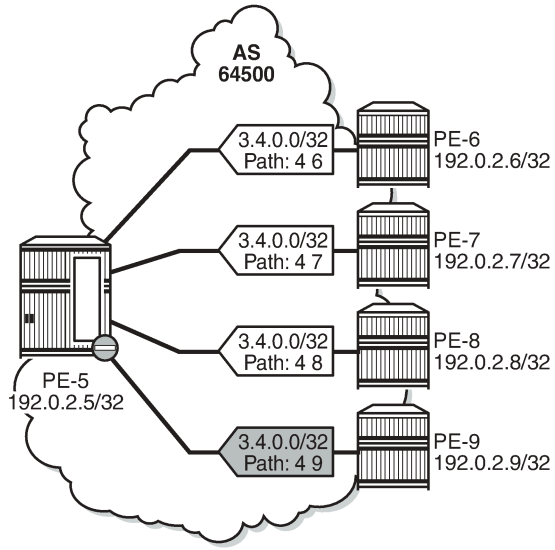


Only one BGP path is used, because all the other routes have a different neighbor AS, as follows:

```
[/]
A:admin@PE-5# show router bgp routes 3.2.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                              LocalPref   MED
      Nexthop (Router)                                     Path-Id     IGP Cost
      As-Path                                                          Label
-------------------------------------------------------------------------------
u*>i  3.2.0.0/32                                           100         None
      192.0.2.6                                            None        10
      6                                                                -
*>i   3.2.0.0/32                                           100         None
      192.0.2.7                                            None        10
      7                                                                -
*>i   3.2.0.0/32                                           100         None
      192.0.2.8                                            None        10
      8                                                                -
*>i   3.2.0.0/32                                           100         None
      192.0.2.9                                            None        10
      9                                                                -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

Figure 51: BGP multipath restricted to the same neighbor AS: AS paths with same length shows that the iBGP neighbors also advertise prefix 3.4.0.0/32 with a different AS path, but the AS path is equally long and the neighbor AS is the same. Three of these BGP paths are used.

Figure 51: BGP multipath restricted to the same neighbor AS: AS paths with same length



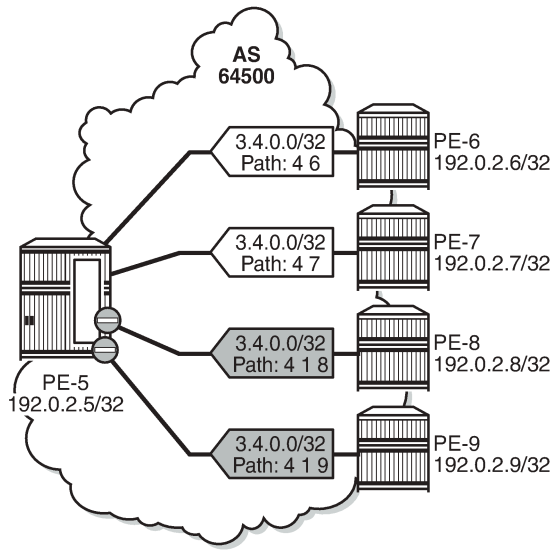
All iBGP neighbors have the same neighbor AS and an AS path of equal length. Three of the iBGP paths for prefix 3.4.0.0/32 are used, as follows:

```
[/]
A:admin@PE-5# show router bgp routes 3.4.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                              LocalPref   MED
      Nexthop (Router)                                     Path-Id     IGP Cost
      As-Path                                                          Label
-------------------------------------------------------------------------------
u*>i  3.4.0.0/32                                           100         None
      192.0.2.6                                            None        10
      4 6                                                              -
u*>i  3.4.0.0/32                                           100         None
      192.0.2.7                                            None        10
      4 7                                                              -
u*>i  3.4.0.0/32                                           100         None
      192.0.2.8                                            None        10
      4 8                                                              -
*>i   3.4.0.0/32                                           100         None
      192.0.2.9                                            None        10
      4 9                                                              -
```

```
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

The restriction that the neighbor AS must be the same does not overrule the BGP selection criterion that the shorter AS path is preferred. When the AS path is longer for the routes advertised by neighbors 192.0.2.8 and 192.0.2.9, only the BGP paths with the shorter AS path are used, as shown in Figure 52: BGP multipath restricted to the same neighbor AS: AS paths of different lengths.

Figure 52: BGP multipath restricted to the same neighbor AS: AS paths of different lengths



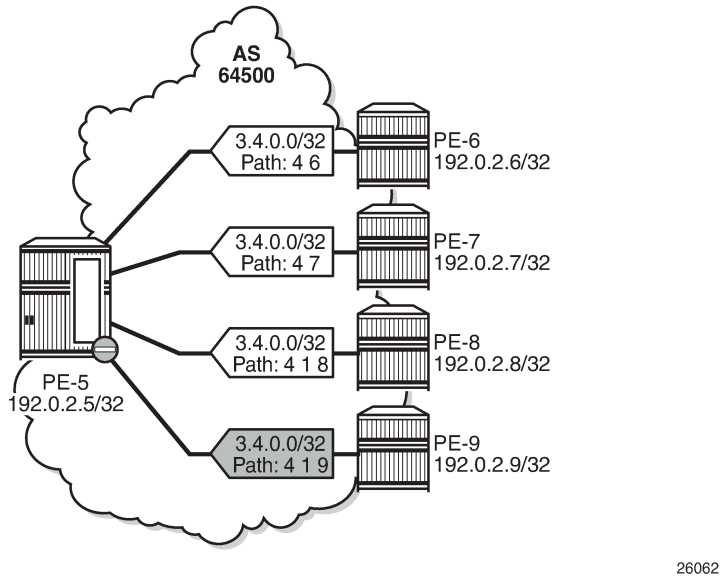
All BGP routes advertised by the iBGP neighbors have the same neighbor AS, but the AS path is longer for neighbors 192.0.2.8 and 192.0.2.9. The routes advertised by these neighbors will not be selected as best path and will not be added to the route table. Only the two BGP routes with the shorter AS path are used, as follows:

```
[/]
A:admin@PE-5# show router bgp routes 3.4.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.4.0.0/32                                       100         None
      192.0.2.6                                        None        10
      4 6                                                          -
u*>i  3.4.0.0/32                                       100         None
```

```
      192.0.2.7                                          None        10
      4 7                                                            -
*i    3.4.0.0/32                                         100         None
      192.0.2.8                                          None        10
      4 1 8                                                          -
*i    3.4.0.0/32                                         100         None
      192.0.2.9                                          None        10
      4 1 9                                                          -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

When the best path selection is configured to ignore the AS path, three paths are used again, as shown in Figure 53: BGP multipath restricted to the same neighbor AS: AS paths of different lengths, AS path ignored.

Figure 53: BGP multipath restricted to the same neighbor AS: AS paths of different lengths, AS path ignored



The best path selection is reconfigured as follows:

```
# on PE-5:
configure {
    router "Base" {
        bgp {
            best-path-selection {
                as-path-ignore {
                    ipv4 true
                }
            }
```

Three of the four eligible BGP routes are used, as follows:

```
[/]
A:admin@PE-5# show router bgp routes 3.4.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
```

```
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.4.0.0/32                                       100         None
      192.0.2.6                                        None        10
      4 6                                                          -
u*>i  3.4.0.0/32                                       100         None
      192.0.2.7                                        None        10
      4 7                                                          -
u*>i  3.4.0.0/32                                       100         None
      192.0.2.8                                        None        10
      4 1 8                                                        -
*>i   3.4.0.0/32                                       100         None
      192.0.2.9                                        None        10
      4 1 9                                                        -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

The best selection path settings are restored as follows:

```
# on PE-5:
configure {
    router "Base" {
        bgp {
            delete best-path-selection
```

BGP multipath restricted to the exact AS path

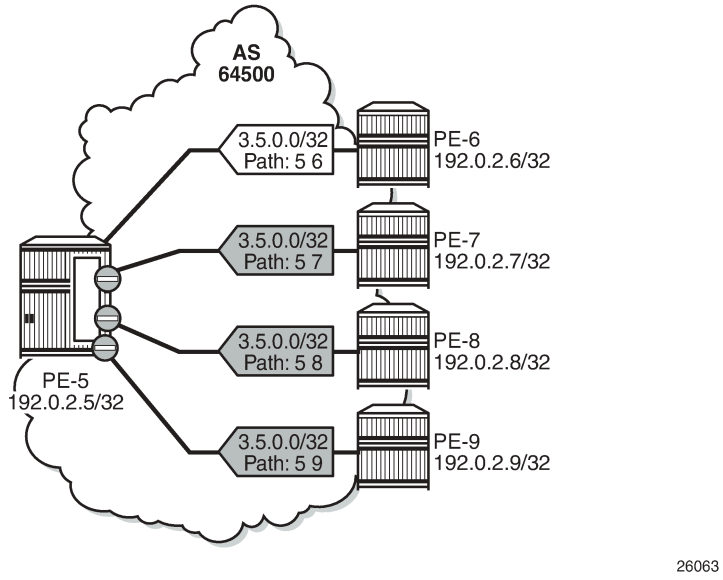
The BGP multipath configuration on PE-5 restricts BGP to only use identical AS paths, as follows:

```
# on PE-5:
configure {
    router "Base" {
        bgp {
            multipath {
                max-paths 8
                ebgp 2
                ibgp 3
                restrict exact-as-path
            }
```

The four iBGP neighbors advertise prefixes 3.5.0.0/32 and 3.6.0.0/32 to PE-5, see Figure 54: BGP multipath restricted to exact same AS. All AS paths are different. and Figure 55: BGP multipath restricted to exact same AS. All AS paths are identical. The AS paths for prefix 3.5.0.0/32 are not identical, but the neighbor AS is the same, and the AS path is of equal length. The AS paths for prefix 3.6.0.0/32 are identical.

The BGP multipath configuration specifies that the AS paths must be identical, which is not the case for the received BGP routes for prefix 3.5.0.0/32. Only one BGP route is imported in the route table, as shown in Figure 54: BGP multipath restricted to exact same AS. All AS paths are different..

Figure 54: BGP multipath restricted to exact same AS. All AS paths are different.



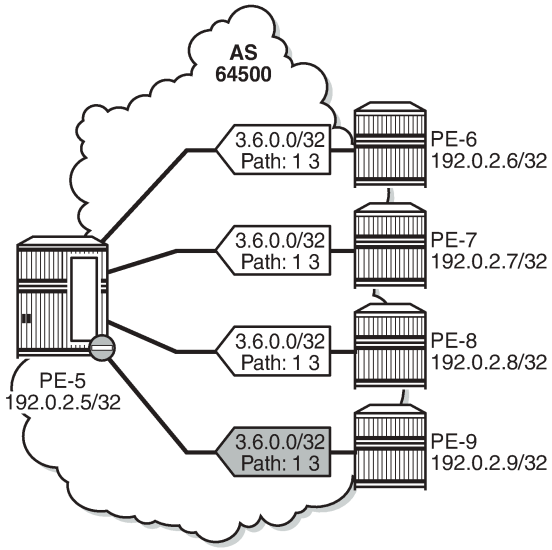
All the BGP routes for prefix 3.5.0.0/32 have a different AS path. Only the BGP route advertised by neighbor 192.0.2.6 is used, as follows:

```
[/]
A:admin@PE-5# show router bgp routes 3.5.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                              LocalPref   MED
      Nexthop (Router)                                     Path-Id     IGP Cost
      As-Path                                                          Label
-------------------------------------------------------------------------------
u*>i  3.5.0.0/32                                           100         None
      192.0.2.6                                            None        10
      5 6                                                              -
*>i   3.5.0.0/32                                           100         None
      192.0.2.7                                            None        10
      5 7                                                              -
*>i   3.5.0.0/32                                           100         None
      192.0.2.8                                            None        10
      5 8                                                              -
*>i   3.5.0.0/32                                           100         None
      192.0.2.9                                            None        10
      5 9                                                              -
```

```
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

However, all the received BGP routes for prefix 3.6.0.0/32 have the same AS path. Three of these BGP paths are used, as shown in Figure 55: BGP multipath restricted to exact same AS. All AS paths are identical.

Figure 55: BGP multipath restricted to exact same AS. All AS paths are identical



Three of the four received BGP routes for prefix 3.6.0.0/32 are used, as follows:

```
[/]
A:admin@PE-5# show router bgp routes 3.6.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.6.0.0/32                                       100         None
      192.0.2.6                                        None        10
      1 3                                                          -
u*>i  3.6.0.0/32                                       100         None
      192.0.2.7                                        None        10
      1 3                                                          -
u*>i  3.6.0.0/32                                       100         None
      192.0.2.8                                        None        10
      1 3                                                          -
```

```
*>i   3.6.0.0/32                                          100         None
      192.0.2.9                                           None        10
      1 3                                                             -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

BGP multipath per address family

On PE-6, PE-7, PE-8, and PE-9, the address families IPv4, label-IPv4, and label-IPv6 are configured in the context of iBGP neighbor 192.0.2.5. Prefix 3.7.0.0/32 is exported as IPv4 route, whereas prefix 3.8.0.0/32 is exported as label-IPv4 route, and prefix 2001:db8::3:8:0:0/32 as label-IPv6 route.

On PE-5, the address families IPv4, label-IPv4, and label-IPv6 are configured in the context of the "iBGP" group, each with a different *max-paths* setting: maximum two IPv4 paths, maximum three label-IPv4 paths, and maximum four label-IPv6 paths:

```
# on PE-5:
configure {
    router "Base" {
        bgp {
            multipath {
                family ipv4 {
                    max-paths 2
                    ibgp 2
                }
                family label-ipv4 {
                    max-paths 3
                    ibgp 3
                }
                family label-ipv6 {
                    max-paths 4
                    ibgp 4
                }
            }
            group "iBGP" {
                peer-as 64500
                family {
                    ipv4 true
                    label-ipv4 true
                    label-ipv6 true
                }
            }
```

In this example, only iBGP routes are received. Two of the four received IPv4 routes for prefix 3.7.0.0/32 are used:

```
[/]
A:admin@PE-5# show router bgp routes 3.7.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
```

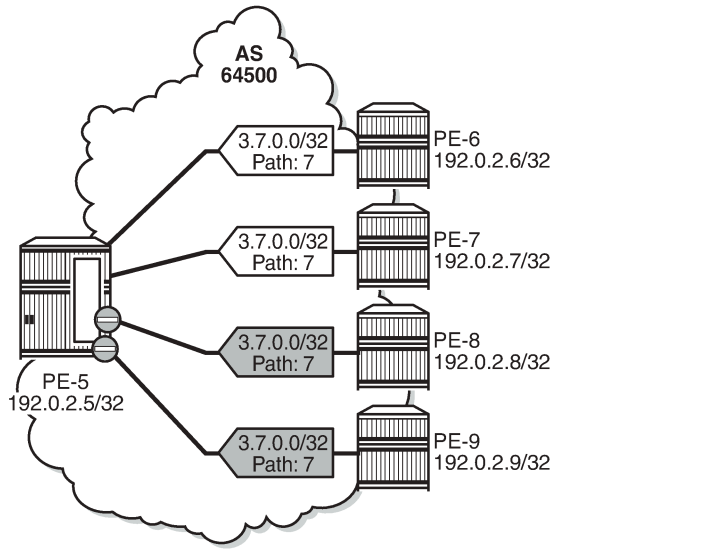
```
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.7.0.0/32                                       100         None
      192.0.2.6                                        None        10
      7                                                            -
u*>i  3.7.0.0/32                                       100         None
      192.0.2.7                                        None        10
      7                                                            -
*>i   3.7.0.0/32                                       100         None
      192.0.2.8                                        None        10
      7                                                            -
*>i   3.7.0.0/32                                       100         None
      192.0.2.9                                        None        10
      7                                                            -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

The last two IPv4 routes from PE-8 and PE-9 are not used because the maximum number of IPv4 iBGP paths (2) is exceeded:

```
[/]A:admin@PE-5# show router bgp routes 3.7.0.0/32 hunt | match "MP Exc. Reason"
TieBreakReason : PeerRouterID           MP Exc. Reason : MaxPathsExceeded
TieBreakReason : PeerRouterID           MP Exc. Reason : MaxPathsExceeded
```

Figure 56: BGP multipath for the IPv4 address family shows that two of the four received IPv4 routes are used.

Figure 56: BGP multipath for the IPv4 address family



Three of the four received label-IPv4 routes for prefix 3.8.0.0/32 are used:

```
[/]
A:admin@PE-5# show router bgp routes 3.8.0.0/32 label-ipv4
```

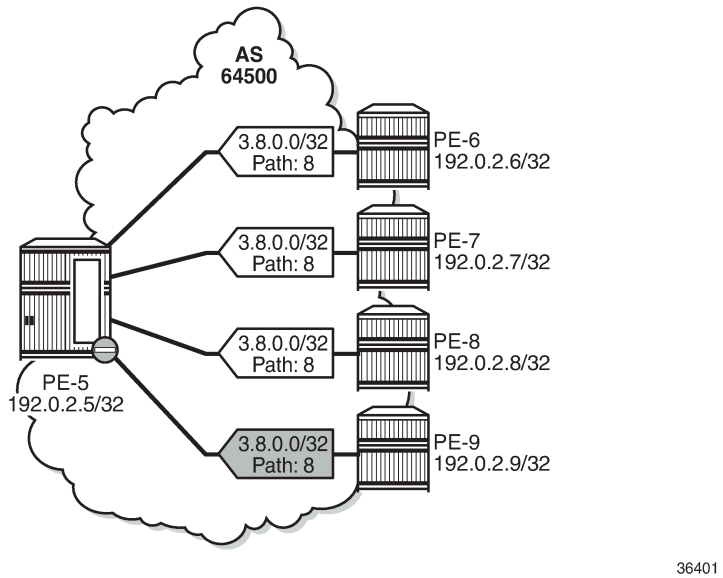
```
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.8.0.0/32                                       100         None
      192.0.2.6                                        None        10
      8                                                            524282
u*>i  3.8.0.0/32                                       100         None
      192.0.2.7                                        None        10
      8                                                            524282
u*>i  3.8.0.0/32                                       100         None
      192.0.2.8                                        None        10
      8                                                            524282
*>i   3.8.0.0/32                                       100         None
      192.0.2.9                                        None        10
      8                                                            524282
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

The last label-IPv4 route from PE-9 is not used because the maximum number of label-IPv4 paths (3) is exceeded:

```
[/]
A:admin@PE-5# show router bgp routes 3.8.0.0/32 label-ipv4 hunt | match "MP Exc. Reason"
TieBreakReason : PeerRouterID           MP Exc. Reason : MaxPathsExceeded
```

Figure 57: BGP multipath for the label-IPv4 address family shows that three of the received label-IPv4 routes are used.

Figure 57: BGP multipath for the label-IPv4 address family

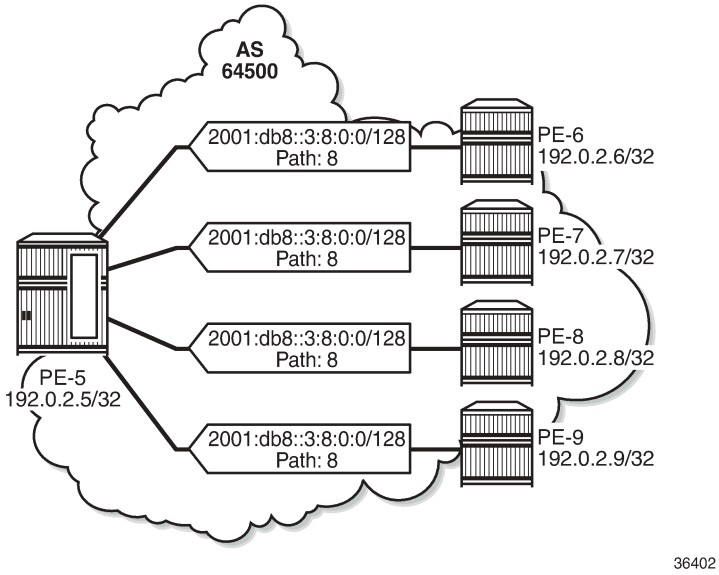


All four received label-IPv6 routes for prefix 2001:db8::3:8:0:0/128 are used:

```
[/]
A:admin@PE-5# show router bgp routes 2001:db8::3:8:0:0/128 label-ipv6
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV6 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  2001:db8::3:8:0:0/128                             100         None
      ::ffff:192.0.2.6                                  None        10
      8                                                             2
u*>i  2001:db8::3:8:0:0/128                             100         None
      ::ffff:192.0.2.7                                  None        10
      8                                                             2
u*>i  2001:db8::3:8:0:0/128                             100         None
      ::ffff:192.0.2.8                                  None        10
      8                                                             2
u*>i  2001:db8::3:8:0:0/128                             100         None
      ::ffff:192.0.2.9                                  None        10
      8                                                             2
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

Figure 58: BGP multipath for the label-IPv6 address family shows that all four received label-IPv6 routes are used.

Figure 58: BGP multipath for the label-IPv6 address family



Selective BGP multipath

Entire BGP groups or a selection of BGP neighbors can be configured as **multipath-eligible**. In all preceding examples, all BGP groups and BGP neighbors are—by default—marked as 'not multipath-eligible'. In a scenario where all paths originate from neighbors that are not marked as multipath-eligible, the N best routes are chosen.

For prefixes 3.7.0.0/32, 3.8.0.0/32, and 2001:db8::3:8:0:0/128, the best path is the path originating from neighbor 192.0.2.6, based on the (lowest) router ID.

In the following example, only neighbors 192.0.2.7 and 192.0.2.8 are configured as **multipath-eligible**:

```
# on PE-5:
configure {
    router "Base"
        bgp {
            multipath {
                family ipv4 {
                    max-paths 2
                    ibgp 2
                }
                family label-ipv4 {
                    max-paths 3
                    ibgp 3
                }
                family label-ipv6 {
                    max-paths 4
                    ibgp 4
                }
            }
            neighbor "192.0.2.6" {
```

```
                group "iBGP"
            }
            neighbor "192.0.2.7" {
                multipath-eligible true
                group "iBGP"
            }
            neighbor "192.0.2.8" {
                multipath-eligible true
                group "iBGP"
            }
            neighbor "192.0.2.9" {
                group "iBGP"
            }
```

When the best path originates from a neighbor that is not multipath-eligible (default), while at least one path originates from a neighbor that is marked as **multipath-eligible**, only the best path is used (no multipath in this scenario):

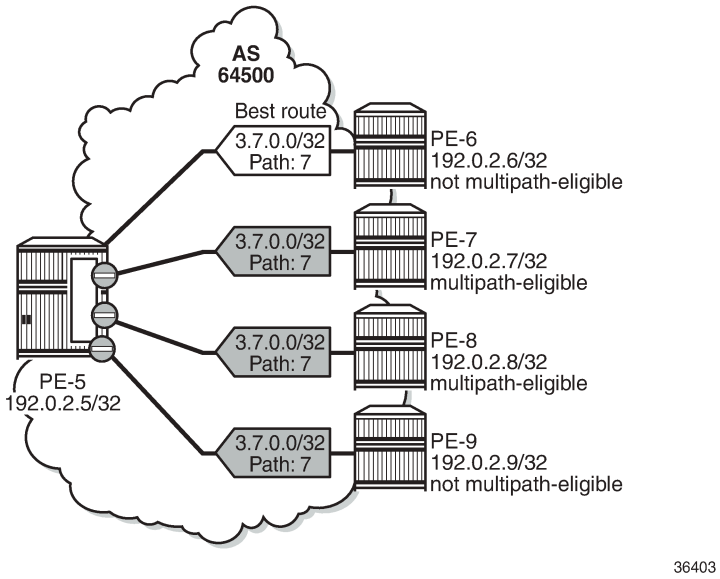
```
[/]
A:admin@PE-5# show router bgp routes 3.7.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.7.0.0/32                                       100         None
      192.0.2.6                                        None        10
      7                                                            -
*>i   3.7.0.0/32                                       100         None
      192.0.2.7                                        None        10
      7                                                            -
*>i   3.7.0.0/32                                       100         None
      192.0.2.8                                        None        10
      7                                                            -
*>i   3.7.0.0/32                                       100         None
      192.0.2.9                                        None        10
      7                                                            -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

The routes originating from PE-7, PE-8, and PE-9 are not used because the best BGP path toward 3.7.0.0/32 originates from PE-6, which is not multipath-eligible:

```
[/]
A:admin@PE-5# show router bgp routes 3.7.0.0/32 hunt | match "MP Exc. Reason"
TieBreakReason : PeerRouterID           MP Exc. Reason : NotMultipathEligible
TieBreakReason : PeerRouterID           MP Exc. Reason : NotMultipathEligible
TieBreakReason : PeerRouterID           MP Exc. Reason : NotMultipathEligible
```

Figure 59: Best IPv4 path originates from a non-multipath-eligible BGP neighbor shows that only the best IPv4 route is used when the best path originates from a non-multipath-eligible BGP neighbor.

Figure 59: Best IPv4 path originates from a non-multipath-eligible BGP neighbor



Also, for the label-IPv4 and label-IPv6 routes, only the best path is used and the other routes are not included in the multipath because the best path is not multipath-eligible.

In the following example, BGP neighbors 192.0.2.6, 192.0.2.8, and 192.0.2.9 are configured as multipath-eligible:

```
# on PE-5:
configure {
    router "Base" {
        bgp {
            multipath {
                family ipv4 {
                    max-paths 2
                    ibgp 2
                }
                family label-ipv4 {
                    max-paths 3
                    ibgp 3
                }
                family label-ipv6 {
                    max-paths 4
                    ibgp 4
                }
            }
            neighbor "192.0.2.6" {
                multipath-eligible true
                group "iBGP"
            }
            neighbor "192.0.2.7" {
                delete multipath-eligible    # restore default
                group "iBGP"
            }
            neighbor "192.0.2.8" {
```

```
                multipath-eligible true
                group "iBGP"
            }
            neighbor "192.0.2.9" {
                multipath-eligible true
                group "iBGP"
            }
```

The best path originates from neighbor 192.0.2.6 that is marked as multipath-eligible. In this case, only paths marked as multipath-eligible are candidates for the BGP multipath algorithm and the best N multipath-eligible routes will be chosen (if available): two IPv4 paths, three label-IPv4 paths, and four label-IPv6 paths.

On PE-5, two IPv4 routes are used for prefix 3.7.0.0/32: the best path from neighbor 192.0.2.6 and a path from neighbor 192.0.2.8:

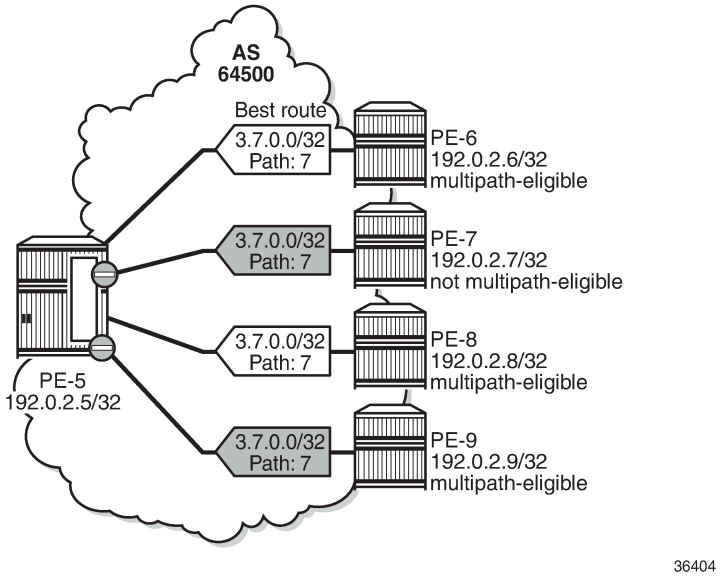
```
[/]
A:admin@PE-5# show router bgp routes 3.7.0.0/32
===============================================================================
 BGP Router ID:192.0.2.5        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.7.0.0/32                                       100         None
      192.0.2.6                                        None        10
      7                                                            -
*>i   3.7.0.0/32                                       100         None
      192.0.2.7                                        None        10
      7                                                            -
u*>i  3.7.0.0/32                                       100         None
      192.0.2.8                                        None        10
      7                                                            -
*>i   3.7.0.0/32                                       100         None
      192.0.2.9                                        None        10
      7                                                            -
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
```

IPv4 route from neighbor 192.0.2.7 is not used because it is not multipath-eligible; IPv4 route from neighbor 192.0.2.9 is not used because the maximum number of IPv4 paths is exceeded, as follows:

```
[/]
A:admin@PE-5# show router bgp routes 3.7.0.0/32 hunt | match "MP Exc. Reason"
TieBreakReason : PeerRouterID           MP Exc. Reason : NotMultipathEligible
TieBreakReason : PeerRouterID           MP Exc. Reason : MaxPathsExceeded
```

Figure 59: Best IPv4 path originates from a non-multipath-eligible BGP neighbor shows that two IPv4 routes from multipath-eligible peers are used: the best path originating from PE-6 and the second best path originating from PE-8.

Figure 60: Two IPv4 paths from multipath-eligible BGP peers are used



Conclusion

BGP multipath allows the IP routing table to have multiple BGP paths to the same destination. Different path limits can be applied for eBGP and iBGP paths and per address family. It is possible to treat eBGP and iBGP routes as equal. Restrictions can be imposed related to AS path. Specific BGP neighbors or entire BGP groups can be marked as multipath-eligible, resulting in selective BGP multipath behavior.

BGP Optimal Route Reflection for Hierarchical Networks

This chapter provides information about BGP optimal route reflection for hierarchical networks.

Topics in this chapter include:

Applicability

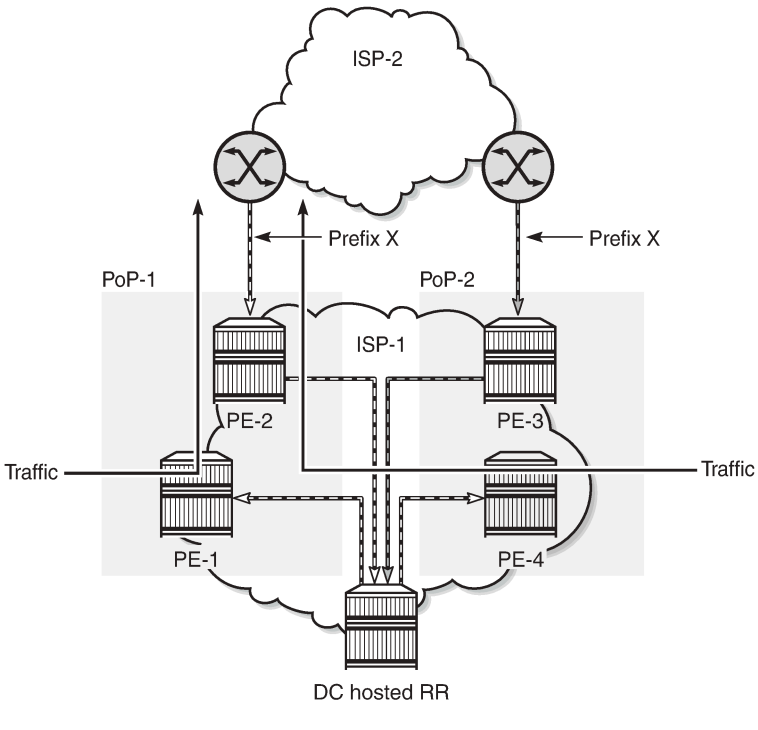
This chapter was initially written based on SR OS Release 15.0.R4, but the MD-CLI in the current edition corresponds to SR OS Release 23.7.R2.

Overview

BGP route reflectors are used in many networks. They improve network scalability by eliminating or reducing the need for a full-mesh of IBGP sessions.

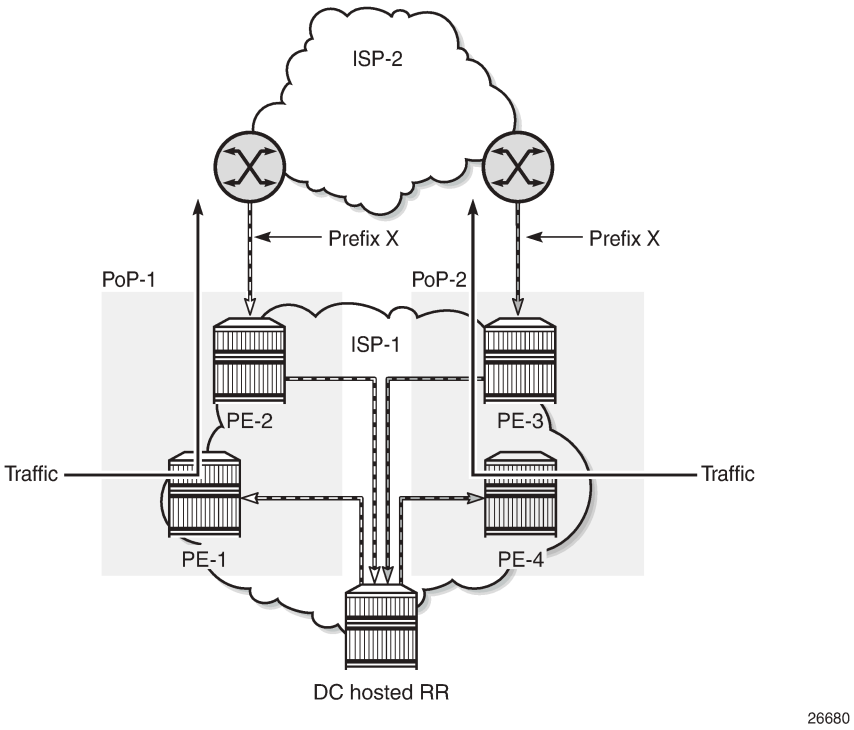
When a BGP route reflector receives multiple paths for the same IP destination, it normally selects and reflects a single best path in its routing domain to all clients in that domain, based on its own location in the domain. In Figure 61: Centralized route reflection, the centralized route reflector RR for ISP-1 is located in the datacenter (DC), and receives prefix X from ISP-2 through PE-2 in point of presence PoP-1 and also through PE-3 in PoP-2. RR selects and reflects PE-2 as the best path to the remaining route reflector clients because RR is closer to PoP-1 than it is to PoP-2, so the traffic to destination X flows as indicated. Therefore, sending traffic to another autonomous system (AS) through the closest possible exit point from the local AS, known as hot-potato routing, cannot be achieved.

Figure 61: Centralized route reflection



Hot-potato routing can be achieved using a route reflector selecting and reflecting multiple best paths, for different subdomains and from the point of view of a client in a subdomain, as outlined in RFC 9107 *BGP optimal route reflection* (ORR), and requires the route reflector to know the topology of each subdomain. In Figure 62: Centralized route reflection with ORR, the route reflector calculates the best path for PoP-1 and reflects that to the clients in PoP-1 (PE-1), and it also calculates the best path for PoP-2 and reflects that to the clients in PoP-2 (PE-4).

Figure 62: Centralized route reflection with ORR



If the routing domain is non-hierarchical, the route reflector is part of the routing domain and thus has a view on the entire topology through the interior gateway protocol (IGP). See the BGP Optimal Route Reflection for Non-Hierarchical Networks chapter if the network topology is non-hierarchical.

If the routing domain is hierarchical, the route reflector needs to extract the link state database (LSDB) from the subdomains it is not part of, which is achieved through BGP link state (BGP-LS). The use of BGP-LS allows the route reflector to learn the IGP topology information for OSPF areas and IS-IS levels in which the route reflector is not a direct participant.

ORR CLI commands

The BGP **optimal-route-reflection** context defines the shortest path first (SPF) parameters, and multiple locations.

```
*[ex:/configure router "Base" bgp]
A:admin@RR-5# optimal-route-reflection ?

 optimal-route-reflection

 location              + Enter the location list instance
 spf-wait              + Enter the spf-wait context
```

The SPF calculation is configurable with the **spf-wait** command. **Initial-wait** and **second-wait** are optional arguments. These timers define when to initiate the first, second, and subsequent SPF runs after a topology change occurs.

```
*[ex:/configure router "Base" bgp optimal-route-reflection]
A:admin@RR-5# spf-wait ?

 spf-wait

 initial-wait          - Initial SPF calculation delay after a topology change
 max-wait              - Maximum interval between consecutive SPF calculations
 second-wait           - Delay between first and second SPF calculation
```

Multiple locations can be created in the **optimal-route-reflection** context, as follows. Each location is identified through a location ID [1..255], and contains a primary IP address and, optionally, a secondary IP address and a tertiary IP address, for redundancy reasons. These addresses must correspond to loopback or system IP addresses of routers participating in the IGP protocols, and are used as the starting point (or seed) for the SPF calculation. Because all clients in the same location receive the same optimal path for that location, these addresses must be close to the clients in that part of the network.

```
*[ex:/configure router "Base" bgp optimal-route-reflection location 1]
A:admin@RR-5# ?

 apply-groups          - Apply a configuration group at this level
 apply-groups-exclude  - Exclude a configuration group at this level
 primary-ip-address    - Primary IPv4 address of the reference location for ORR
 primary-ipv6-address  - Primary IPv6 address of the reference location for ORR
 secondary-ip-address  - Secondary IPv4 address of reference location for ORR
 secondary-ipv6-       - Secondary IPv6 address of reference location for ORR
  address
 tertiary-ip-address   - Tertiary IPv4 address of the reference location for ORR
 tertiary-ipv6-        - Tertiary IPv6 address of the reference location for ORR
  address
```

The locations are then referred to with the **cluster** command (residing in the BGP group or neighbor context) through the **orr-location** argument, as follows.

```
*[ex:/configure router "Base" bgp group "IBGP-1"]
A:admin@RR-5# cluster ?

 cluster

 allow-local-fallback  - Allow fallback to RR topology location
 cluster-id            - Route reflector cluster ID
 orr-location          - Optimal route reflection location for the cluster


*[ex:/configure router "Base" bgp neighbor "192.0.2.3"]
A:admin@RR-5# cluster ?

 cluster

 allow-local-fallback  - Allow fallback to RR topology
 cluster-id            - Route reflector cluster ID
 orr-location          - Optimal route reflection location for the cluster
```

The location ID is referred to in the **orr-location** argument of the **cluster** command. Typically, the **cluster** command applies to a BGP peer group; all neighbors in that group share the same location ID, unless the **cluster** command applies at a neighbor level. The **allow-local-fallback** option allows the RR to advertise

the best reachable BGP path using its own location, but only when no BGP routes are reachable for some location. Otherwise, no path would be advertised to the clients in that location.

Properties

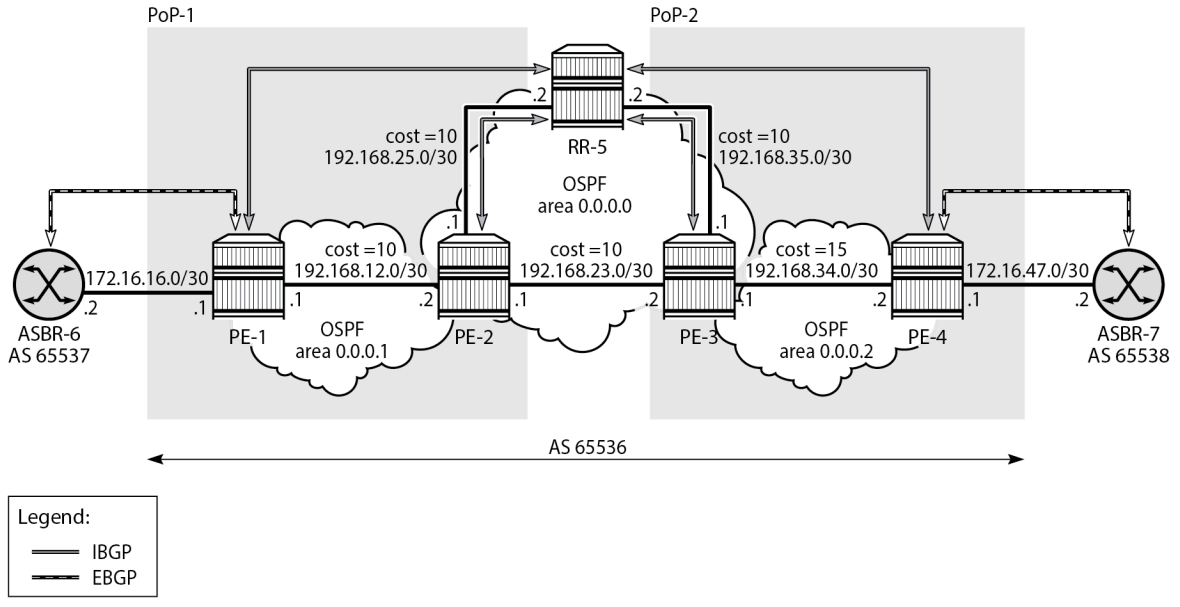
The following properties apply to ORR in SR OS:

- ORR is supported in the Base router BGP instance.
- ORR is supported for the IPv4, label-IPv4, label-IPv6, VPN-IPv4, and VPN-IPv6 address families.
- ORR is supported with add-paths, meaning that add-paths advertised to ORR clients are also ORR location-based.

Configuration

Figure 63: Example hierarchical networking using OSPF shows the example topology. OSPF is used as the IGP for AS 65536, with RR-5 taking the role of the route reflector for clients PE-1 to PE-4. The OSPF backbone area is area 0.0.0.0, connecting routers PE-2, PE-3, and RR-5. Area 0.0.0.1 is a stub area interconnecting PE-1 and PE-2; area 0.0.0.2 is a stub area interconnecting PE-3 and PE-4. Both PE-2 and PE-3 are area border routers (ABRs). Additionally, ASBR-6 in AS 65537 peers with PE-1, and ASBR-7 in AS 65538 peers with PE-4.

Figure 63: Example hierarchical networking using OSPF



The initial configuration on all nodes includes:

- Cards, MDAs, and ports
- Router interfaces

- OSPF as IGP on all interfaces within AS 65536, with multiple non-backbone areas (alternatively, IS-IS can be used), and traffic engineering enabled

The following shows the OSPF configuration on ABR PE-3 with some interfaces in backbone area 0.0.0.0 and other interfaces in stub area 0.0.0.2. The metric on the interfaces is 10, except for the interface between PE-3 and PE-4 with metric 15 in stub area 0.0.0.2.

```
# on PE-3:
configure {
    router "Base" {
        ospf 0 {
            admin-state enable
            traffic-engineering true
            area 0.0.0.0 {
                interface "int-PE-3-PE-2" {
                    interface-type point-to-point
                    metric 10
                }
                interface "int-PE-3-RR-5" {
                    interface-type point-to-point
                    metric 10
                }
                interface "system" {
                }
            }
            area 0.0.0.2 {
                stub {
                }
                interface "int-LB-BGP" {
                }
                interface "int-PE-3-PE-4" {
                    interface-type point-to-point
                    metric 15
                }
            }
        }
```

Route reflection without ORR

RR-5 peers with clients PE-1 to PE-4, and because RR-5 is the route reflector, the **cluster** command is added, defining the cluster ID attribute value to use. The configuration for RR-5 is as follows:

```
# on RR-5:
configure {
    router "Base" {
        autonomous-system 65536
        bgp {
            loop-detect discard-route
            split-horizon true
            group "IBGP" {
                peer-as 65536
                cluster {
                    cluster-id 192.0.2.5
                }
            }
            neighbor "192.0.2.1" {
                group "IBGP"
            }
            neighbor "192.0.2.2" {
                group "IBGP"
```

```
            }
            neighbor "192.0.2.3" {
                group "IBGP"
            }
            neighbor "192.0.2.4" {
                group "IBGP"
            }
        }
```

PE-1 belongs to the cluster defined in the route reflector, so it does not need to be fully meshed with the other routers in the area; peering with the route reflectors in the area is sufficient for PE-1 to receive updates. Typically, two route reflectors are provisioned for redundancy, but that does not apply in this example. PE-1 also peers with ASBR-6 in AS 65537 through EBGP, so the PE-1 configuration is as follows:

```
# on PE-1:
configure {
    router "Base" {
        autonomous-system 65536
        bgp {
            loop-detect discard-route
            split-horizon true
            group "EBGP" {
            }
            group "IBGP" {
                next-hop-self true
                peer-as 65536
            }
            neighbor "172.16.16.2" {
                group "EBGP"
                peer-as 65537
                ebgp-default-reject-policy {
                    import false
                }
            }
            neighbor "192.0.2.5" {
                group "IBGP"
            }
        }
```

PE-2 and PE-3 only peer with the route reflector. Their configuration is the same:

```
# on PE-2, PE-3:
configure {
    router "Base" {
        autonomous-system 65536
        bgp {
            loop-detect discard-route
            split-horizon true
            group "IBGP" {
                peer-as 65536
            }
            neighbor "192.0.2.5" {
                group "IBGP"
            }
        }
```

PE-4 also belongs to the IBGP cluster defined in the route reflector and PE-4 peers with ASBR-7 in AS 65538. The PE-4 configuration is similar to the configuration of PE-1.

Loopback address 10.1.11.1/24 is configured on ASBR-8 in AS 65540 (not shown in the example topology). ASBR-8 exports prefix 10.1.11.0/24 to its EBGP peers ASBR-6 in AS 65537 and ASBR-7 in AS 65538. ASBR-6 advertises prefix 10.1.11.0/24 to router PE-1; ASBR-7 advertises the same prefix to router PE-4.

RR-5 receives IBGP updates from PE-1 and PE-4, and selects the best path based on its own position in the topology. The IGP cost from RR-5 to PE-1 is 20, and the cost from RR-5 to PE-4 is 25, so RR-5 selects the BGP path with next hop 192.0.2.1.

```
[/]
A:admin@RR-5# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.5        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                     100         None
      192.0.2.1                                        None        20
      65537 65540                                                  -
*i    10.1.11.0/24                                     100         None
      192.0.2.4                                        None        25
      65538 65540                                                  -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

RR-5 reflects the path with next hop 192.0.2.1 to all clients except PE-1, because PE-1 is the client where the path was learned from).

For prefix 10.1.11.0/24, PE-1 received an EBGP route from ASBR-6 in AS 65537 with next hop 172.16.16.2 and no IBGP route from RR-5:

```
[/]
A:admin@PE-1# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.1        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                     None        None
      172.16.16.2                                      None        0
      65537 65540                                                  -
```

```
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

As a result, traffic offered to PE-1 for destination 10.1.11.0/24 is routed to ASBR-6, as follows:

```
[/]
A:admin@PE-1# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.1.11.0/24                                  Remote  BGP       00h04m15s  170
       172.16.16.2                                                 0
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

PE-2 received an IBGP route for prefix 10.1.11.0/24 with next hop 192.0.2.1 from RR-5:

```
[/]
A:admin@PE-2# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                     100         None
      192.0.2.1                                        None        10
      65537 65540                                                  -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Traffic offered to PE-2 for destination 10.1.11.0/24 is routed to PE-1, as follows:

```
[/]
A:admin@PE-2# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
```

```
10.1.11.0/24                                  Remote  BGP       00h03m22s  170
       192.168.12.1                                                  10
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

Likewise, PE-3 received an IBGP route for prefix 10.1.11.0/24 with next hop 192.0.2.1 from RR-5:

```
[/]
A:admin@PE-3# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                     100         None
      192.0.2.1                                        None        20
      65537 65540                                                  -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Traffic offered to PE-3 for destination 10.1.11.0/24 is routed via the interface address 192.168.23.1 on PE-2, as follows:

```
[/]
A:admin@PE-3# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.1.11.0/24                                  Remote  BGP       00h03m20s  170
       192.168.23.1                                                  20
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

For prefix 10.1.11.0/24, PE-4 received an EBGP route from ASBR-7 with next hop 172.16.47.2 and an IBGP route from RR-5 with next hop 192.0.2.1, as follows. EBGP routes are preferred over IBGP routes.

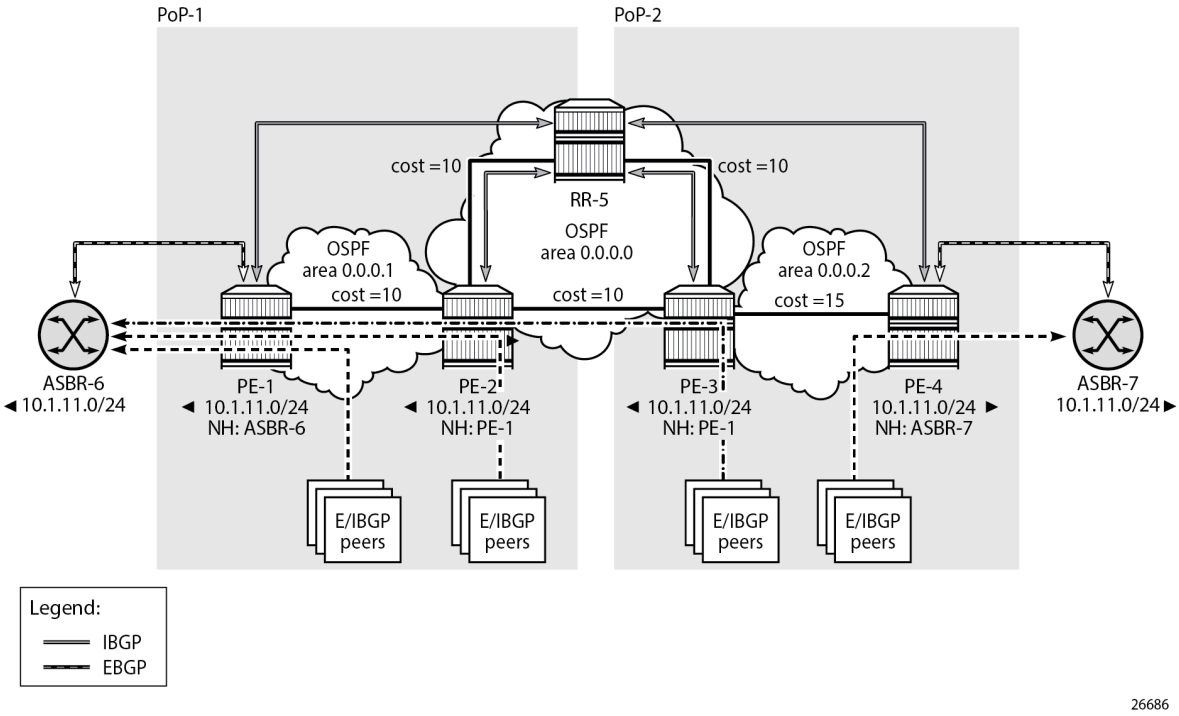
```
[/]
A:admin@PE-4# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.4        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                     None        None
      172.16.47.2                                      None        0
      65538 65540                                                  -
*i    10.1.11.0/24                                     100         None
      192.0.2.1                                        None        35
      65537 65540                                                  -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

The used route is the EBGP route from ASBR-7, so the traffic offered to PE-4 for destination 10.1.11.0/24 is routed to ASBR-7, as follows:

```
[/]
A:admin@PE-4# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.1.11.0/24                                  Remote  BGP       00h03m59s  170
       172.16.47.2                                                 0
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

This is summarized in Figure 64: Suboptimal route reflection. Ultimately, PE-1 only has one path, and so do PE-2 and PE-3. PE-4 has two paths, but by default prefers the EBGP learned path over the IBGP learned path. The routing is suboptimal on PE-3, where the IGP cost to PE-1 is 20 and the IGP cost to PE-4 is 15.

Figure 64: Suboptimal route reflection



Route reflection with ORR

Implementing ORR using the hierarchical topology from Figure 64: Suboptimal route reflection requires changes in the non-backbone OSPF areas as well as changes to the route reflector.

Because the route reflector is part of the backbone area, and ABRs do not pass the link state advertisements (LSAs) describing the topology and the traffic engineering data for the non-backbone areas, that data must be extracted from the non-backbone areas and copied to the route reflector. This is achieved using BGP-LS, with additional support from OSPF.

In this example, BGP-LS is activated in PE-1, PE-4, and RR-5. PE-1 in area 0.0.0.1 has the BGP-LS address family configured. The BGP option **link-state-import-enable** is needed for PE-1 to advertise the LSDB and traffic engineering database (TED) to the route reflector. On the same router PE-1, OSPF is instructed to provide the **bgp-ls-identifier 1** using the **database-export** command. The configuration for PE-1 is as follows:

```
# on PE-1:
configure {
    router "Base" {
        ospf 0 {
            admin-state enable
            traffic-engineering true
            database-export {
                igp-identifier 1
                bgp-ls-identifier {
                    value 1
                }
```

```
            }
            area 0.0.0.1 {
                stub {
                }
                interface "int-PE-1-PE-2" {
                    interface-type point-to-point
                    metric 10
                }
                interface "system" {
                }
            }
        }
        bgp {
            loop-detect discard-route
            split-horizon true
            link-state-route-import true
            group "EBGP" {
                peer-as 65537
            }
            group "IBGP" {
                next-hop-self true
                peer-as 65536
                family {
                    ipv4 true
                    bgp-ls true
                }
            }
            neighbor "172.16.16.2" {
                group "EBGP"
                peer-as 65537
                ebgp-default-reject-policy {
                    import false
                }
            }
            neighbor "192.0.2.5" {
                group "IBGP"
            }
        }
```

The configuration on PE-4 is similar, and there the **bgp-ls-identifier** is set to 2. Routers PE-2 and PE-3 do not need to be reconfigured.

RR-5 in the backbone area also has BGP-LS activated with the **family** command, and **link-state-export-enable true** is required for accepting and storing the LSDB and TED. No reconfiguration of OSPF is required in RR-5.

For implementing ORR using the hierarchical topology shown in Figure 69: Suboptimal route reflection, the route reflector RR-5 defines two locations in the **optimal-route-reflection** context. The primary IP address for location 1 is the PE-1 system IP address 192.0.2.1; the primary IP address for location 2 is loopback address 192.0.2.44 on PE-4 and the secondary IP address is loopback address 192.0.2.33 on PE-3. These addresses are used as the starting point for the SPF run. The ORR locations 1 and 2 are then referred to from within the group definitions through the **cluster** command. Because RR-5 is not on the data path, there is no need for implementing the routes into the FIB, which is achieved through the **route-table-install false** command. The overall BGP configuration of RR-5 is as follows:

```
# on RR-5:
configure {
    router "Base" {
        autonomous-system 65536
        bgp {
            loop-detect discard-route
```

```
            route-table-install false
            split-horizon true
            link-state-route-export true
            family {
                bgp-ls true
            }
            optimal-route-reflection {
                spf-wait {
                    max-wait 1
                    initial-wait 1
                    second-wait 1
                }
                location 1 {
                    primary-ip-address 192.0.2.1
                }
                location 2 {
                    primary-ip-address 192.0.2.44      # loopback address on PE-4
                    secondary-ip-address 192.0.2.33    # loopback address on PE-3
                }
            }
            group "IBGP-1" {
                peer-as 65536
                cluster {
                    cluster-id 192.0.2.5
                    orr-location 1
                    allow-local-fallback true
                }
            }
            group "IBGP-2" {
                peer-as 65536
                cluster {
                    cluster-id 192.0.2.5
                    orr-location 2
                    allow-local-fallback true
                }
            }
            neighbor "192.0.2.1" {
                group "IBGP-1"
            }
            neighbor "192.0.2.2" {
                group "IBGP-1"
            }
            neighbor "192.0.2.3" {
                group "IBGP-2"
            }
            neighbor "192.0.2.4" {
                group "IBGP-2"
            }
        }
```

With these changes applied, the following command can be used for verification of the BGP sessions:

```
[/]
A:admin@RR-5# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
```

```
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.1
Def. Inst       65536      20    0 00h03m56s 1/0/0 (IPv4)
                           19    0           18/0/18 (LinkState)
192.0.2.2
Def. Inst       65536      11    0 00h03m56s 0/0/1 (IPv4)
                           12    0
192.0.2.3
Def. Inst       65536      11    0 00h03m56s 0/0/1 (IPv4)
                           12    0
192.0.2.4
Def. Inst       65536      20    0 00h03m56s 1/0/0 (IPv4)
                           19    0           18/0/18 (LinkState)

-------------------------------------------------------------------------------
```

ASBR-6 advertises prefix 10.1.11.0/24 to router PE-1; ASBR-7 advertises the same prefix to router PE-4. RR-5 receives the updates from PE-1 and PE-4, and now performs two SPF runs because two locations are used. The first SPF run uses the 192.0.2.1 address of PE-1 as the starting point for the first location, selects the path via PE-1 as the best path, and reflects that path to the remaining peers in the first location. The second SPF run uses the 192.0.2.44 loopback address of PE-4 as the starting point for the second location, selects the path via PE-4 as the best path, and reflects that path to the remaining peers in the second location.

In comparison with the previous scenario, there only is a change in the routing for this prefix on PE-3. RR-5 reflects the route with next hop 192.0.2.4 to PE-3.

```
[/]
A:admin@PE-3# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                     100         None
      192.0.2.4                                        None        15
      65538 65540                                                  -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

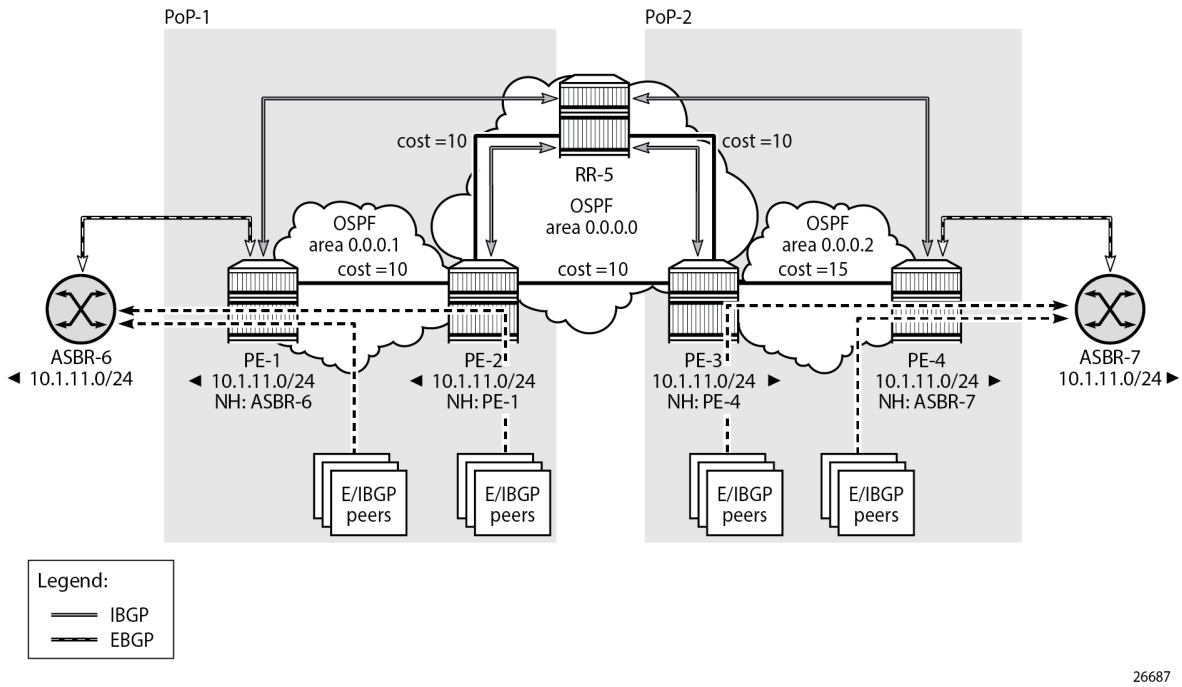
Traffic offered to PE-3 for destination 10.1.11.0/24 has next hop PE-4 and is routed via the interface address 192.168.34.2 on PE-4, as follows:

```
[/]
A:admin@PE-3# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
```

```
Dest Prefix[Flags]                                Type    Proto     Age        Pref
      Next Hop[Interface Name]                                        Metric
-------------------------------------------------------------------------------
10.1.11.0/24                                      Remote  BGP       00h04m56s  170
       192.168.34.2                                                     15
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

This is summarized in Figure 65: Optimal route reflection.

Figure 65: Optimal route reflection



The following command provides the IGP distances for the configured reference points to all available BGP peers and all detected BGP next hops on the route reflector.

```
[/]
A:admin@RR-5# show router bgp optimal-route-reflection bgp-nh-info

===============================================================================
ORR BGP-NH Table (Router: Base)
===============================================================================
Location 1:
    Primary        : 192.0.2.1 [active]
    Secondary      : -
    Tertiary       : -
    Primary-ipv6   : -
    Secondary-ipv6 : -
    Tertiary-ipv6  : -
Location 2:
```

```
    Primary        : 192.0.2.44 [active]
    Secondary      : 192.0.2.33
    Tertiary       : -
    Primary-ipv6   : -
    Secondary-ipv6 : -
    Tertiary-ipv6  : -

Age          : 00h05m43s
Spf wait     : 1
Initial wait : 1
Second wait  : 1

-------------------------------------------------------------------------------
Next Hop
   Loc    Dest-Prefix
                              DB-Source  Type         Proto     Metric    Pref
-------------------------------------------------------------------------------

192.0.2.1
    1     192.0.2.1/32
                              BGP-LS     Local        Local     0           0
    2     192.0.2.1/32
                              BGP-LS     Remote       OSPFv2    35         10

192.0.2.4
    1     192.0.2.4/32
                              BGP-LS     Remote       OSPFv2    35         10
    2     192.0.2.4/32
                              BGP-LS     Local        Local     0           0
-------------------------------------------------------------------------------
No. of BGP-NHs: 2
===============================================================================
```

Conclusion

BGP optimal route reflection allows operators to optimize traffic streams through their network, even when the route reflector is placed out-of-path, for example in datacenters, thereby reducing the OPEX and CAPEX of route reflector deployment.

BGP Optimal Route Reflection for Non-Hierarchical Networks

This chapter provides information about BGP optimal route reflection for non-hierarchical networks.

Topics in this chapter include:

Applicability

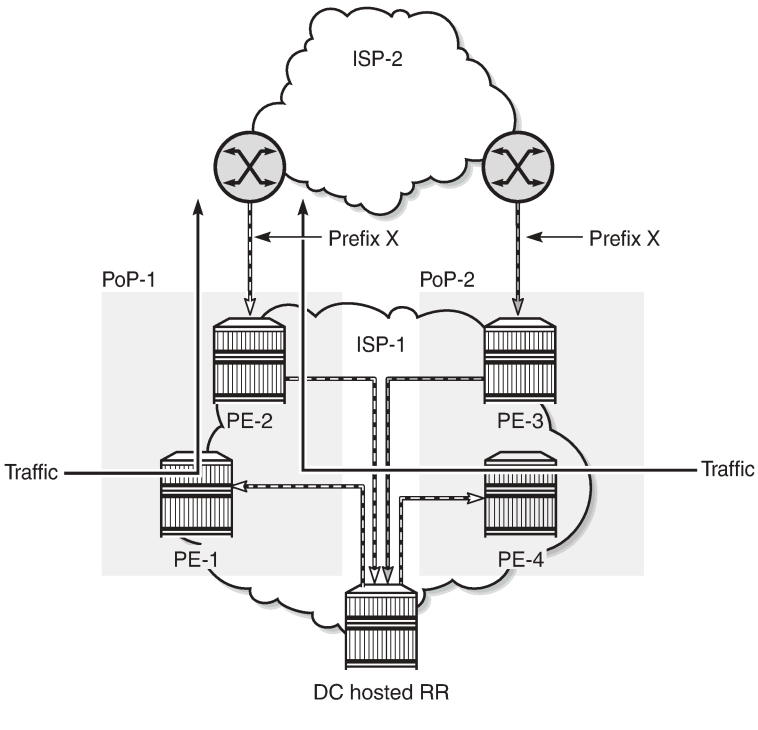
This chapter was initially written based on SR OS Release 15.0.R4, but the MD-CLI in the current edition corresponds to SR OS Release 23.7.R2.

Overview

BGP route reflectors are used in many networks. They improve network scalability by eliminating or reducing the need for a full-mesh of IBGP sessions.

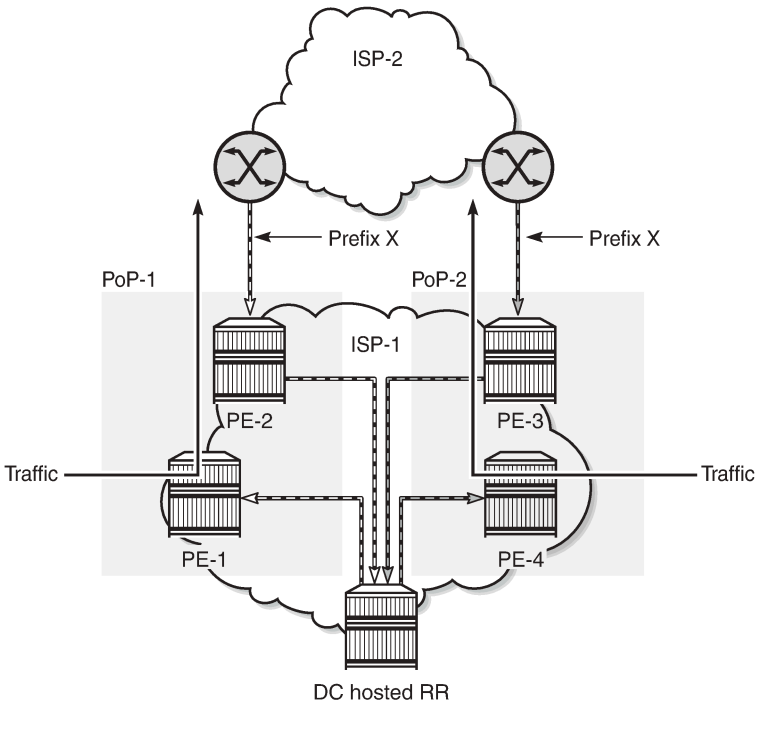
When a BGP route reflector receives multiple paths for the same IP destination, it normally selects and reflects a single best path in its routing domain to all clients in that domain, based on its own location in the domain. In Figure 66: Centralized route reflection, the centralized route reflector RR for ISP-1 is located in the datacenter (DC), and receives prefix X from ISP-2 through PE-2 in point of presence PoP-1 and also through PE-3 in PoP-2. RR selects and reflects PE-2 as the best path to the remaining route reflector clients because RR is closer to PoP-1 than it is to PoP-2, so the traffic to destination X flows as indicated. Therefore, sending traffic to another autonomous system (AS) through the closest possible exit point from the local AS, known as hot-potato routing, cannot be achieved.

Figure 66: Centralized route reflection



Hot-potato routing can be achieved using a route reflector selecting and reflecting multiple best paths, for different subdomains and from the point of view of a client in a subdomain, as outlined in RFC 9107 *BGP optimal route reflection* (ORR), and requires the route reflector to know the topology of each subdomain. In Figure 67: Centralized route reflection with ORR, the route reflector calculates the best path for PoP-1 and reflects that to the clients in PoP-1 (PE-1), and it also calculates the best path for PoP-2 and reflects that to the clients in PoP-2 (PE-4).

Figure 67: Centralized route reflection with ORR



If the routing domain is non-hierarchical, the route reflector is part of the routing domain and thus has a view on the entire topology through the interior gateway protocol (IGP).

If the routing domain is hierarchical, the route reflector needs to extract the link state database (LSDB) from the subdomain it is not part of, which is achieved through BGP link state (BGP-LS). The use of BGP-LS allows the route reflector to learn the IGP topology information for OSPF areas and IS-IS levels in which the route reflector is not a direct participant. See the BGP Optimal Route Reflection for Hierarchical Networks chapter if the network topology is hierarchical.

ORR CLI commands

The BGP **optimal-route-reflection** context defines the shortest path first (SPF) parameters, and multiple locations.

```
*[ex:/configure router "Base" bgp]
A:admin@RR-5# optimal-route-reflection ?

 optimal-route-reflection

 location              + Enter the location list instance
 spf-wait              + Enter the spf-wait context
```

The SPF calculation is configurable with the **spf-wait** command. **Initial-wait** and **second-wait** are optional arguments. These timers define when to initiate the first, second, and subsequent SPF runs after a topology change occurs.

```
*[ex:/configure router "Base" bgp optimal-route-reflection]
A:admin@RR-5# spf-wait ?

 spf-wait

 initial-wait          - Initial SPF calculation delay after a topology change
 max-wait              - Maximum interval between consecutive SPF calculations
 second-wait           - Delay between first and second SPF calculation
```

Multiple locations can be created in the **optimal-route-reflection** context, as follows. Each location is identified through a location ID [1..255], and contains a primary IP address and, optionally, a secondary IP address and a tertiary IP address, for redundancy reasons. These addresses must correspond to loopback or system IP addresses of routers participating in the IGP protocols, and are used as the starting point (or seed) for the SPF calculation. Because all clients in the same location receive the same optimal path for that location, these addresses must be close to the clients in that part of the network.

```
*[ex:/configure router "Base" bgp optimal-route-reflection location 1]
A:admin@RR-5# ?

 apply-groups          - Apply a configuration group at this level
 apply-groups-exclude  - Exclude a configuration group at this level
 primary-ip-address    - Primary IPv4 address of the reference location for ORR
 primary-ipv6-address  - Primary IPv6 address of the reference location for ORR
 secondary-ip-address  - Secondary IPv4 address of reference location for ORR
 secondary-ipv6-       - Secondary IPv6 address of reference location for ORR
  address
 tertiary-ip-address   - Tertiary IPv4 address of the reference location for ORR
 tertiary-ipv6-        - Tertiary IPv6 address of the reference location for ORR
  address
```

The locations are then referred to with the **cluster** command (residing in the BGP group or neighbor context) through the **orr-location** argument, as follows.

```
*[ex:/configure router "Base" bgp group "IBGP-1"]
A:admin@RR-5# cluster ?

 cluster

 allow-local-fallback  - Allow fallback to RR topology location
 cluster-id            - Route reflector cluster ID
 orr-location          - Optimal route reflection location for the cluster


*[ex:/configure router "Base" bgp neighbor "192.0.2.3"]
A:admin@RR-5# cluster ?

 cluster

 allow-local-fallback  - Allow fallback to RR topology
 cluster-id            - Route reflector cluster ID
 orr-location          - Optimal route reflection location for the cluster
```

The location ID is referred to in the **orr-location** argument of the **cluster** command. Typically, the **cluster** command applies to a BGP peer group; all neighbors in that group share the same location ID, unless the **cluster** command applies at a neighbor level. The **allow-local-fallback** option allows the RR to advertise

the best reachable BGP path using its own location, but only when no BGP routes are reachable for some location. Otherwise, no path would be advertised to the clients in that location.

Properties

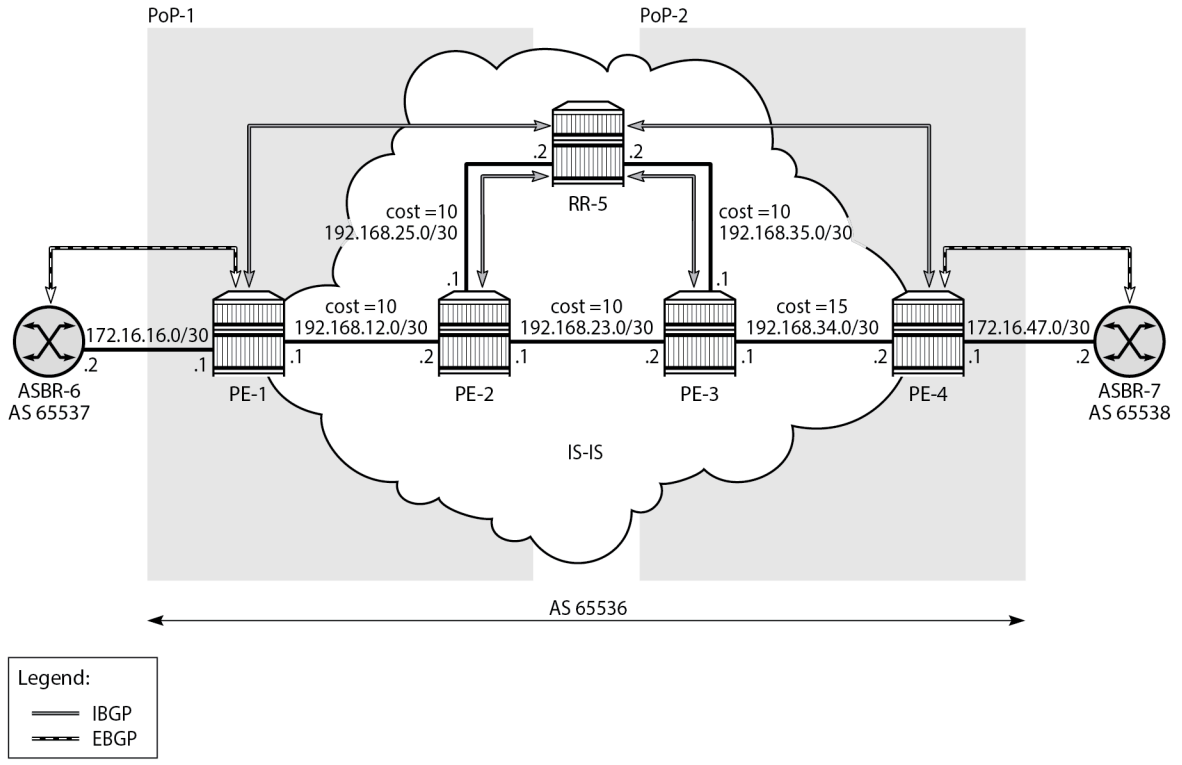
The following properties apply to ORR in SR OS:

- ORR is supported in the Base router BGP instance.
- ORR is supported for the IPv4, label-IPv4, label-IPv6, VPN-IPv4, and VPN-IPv6 address families.
- ORR is supported with add-paths, meaning that add-paths advertised to ORR clients are also ORR location-based.

Configuration

Figure 68: Example non-hierarchical networking using IS-IS shows the example topology. IS-IS is used as the IGP for AS 65536, with RR-5 taking the role of the route reflector for clients PE-1 to PE-4. Additionally, ASBR-6 in AS 65537 peers with PE-1, and ASBR-7 in AS 65538 peers with PE-4.

Figure 68: Example non-hierarchical networking using IS-IS



The initial configuration on all nodes includes:

- Cards, MDAs, and ports

- Router interfaces
- IS-IS as IGP on all interfaces within AS 65536, in a non-hierarchical way (alternatively, OSPF can be used), and traffic engineering enabled

The basic IS-IS configuration is very similar for all routers, including the route reflector. The RR-5 configuration is as follows:

```
# on RR-5:
configure {
    router "Base" {
        isis 0 {
            admin-state enable
            traffic-engineering true
            area-address [49.0001]
            interface "int-RR-5-PE-2" {
                interface-type point-to-point
            }
            interface "int-RR-5-PE-3" {
                interface-type point-to-point
            }
            interface "system" {
            }
        }
```

Route reflection without ORR

RR-5 peers with clients PE-1 to PE-4, and because RR-5 is the route reflector, the **cluster** command is added, defining the cluster ID attribute value to use. The configuration for RR-5 is as follows:

```
# on RR-5:
configure {
    router "Base" {
        autonomous-system 65536
        bgp {
            loop-detect discard-route
            split-horizon true
            group "IBGP" {
                peer-as 65536
                cluster {
                    cluster-id 192.0.2.5
                }
            }
            neighbor "192.0.2.1" {
                group "IBGP"
            }
            neighbor "192.0.2.2" {
                group "IBGP"
            }
            neighbor "192.0.2.3" {
                group "IBGP"
            }
            neighbor "192.0.2.4" {
                group "IBGP"
            }
        }
```

PE-1 belongs to the cluster defined in the route reflector, so it does not need to be fully meshed with the other routers in the area; peering with the route reflectors in the area is sufficient for PE-1 to receive

updates. Typically, two route reflectors are provisioned for redundancy, but that does not apply in this example. PE-1 also peers with ASBR-6 in AS 65537 through EBGP, so the PE-1 configuration is as follows:

```
# on PE-1:
configure {
    router "Base" {
        autonomous-system 65536
        bgp {
            loop-detect discard-route
            split-horizon true
            group "EBGP" {
            }
            group "IBGP" {
                next-hop-self true
                peer-as 65536
            }
            neighbor "172.16.16.2" {
                group "EBGP"
                peer-as 65537
                ebgp-default-reject-policy {
                    import false
                }
            }
            neighbor "192.0.2.5" {
                group "IBGP"
            }
        }
```

PE-2 and PE-3 only peer with the route reflector. Their configuration is the same:

```
# on PE-2, PE-3:
configure {
    router "Base" {
        autonomous-system 65536
        bgp {
            loop-detect discard-route
            split-horizon true
            group "IBGP" {
                peer-as 65536
            }
            neighbor "192.0.2.5" {
                group "IBGP"
            }
        }
```

PE-4 also belongs to the IBGP cluster defined in the route reflector and PE-4 peers with ASBR-7 in AS 65538. The PE-4 configuration is similar to the configuration of PE-1.

Loopback address 10.1.11.1/24 is configured on ASBR-8 in AS 65540 (not shown in the example topology). ASBR-8 exports prefix 10.1.11.0/24 to its EBGP peers ASBR-6 in AS 65537 and ASBR-7 in AS 65538. ASBR-6 advertises prefix 10.1.11.0/24 to router PE-1; ASBR-7 advertises the same prefix to router PE-4.

RR-5 receives IBGP updates from PE-1 and PE-4, and selects the best path based on its own position in the topology. The IGP cost from RR-5 to PE-1 is 20, and the cost from RR-5 to PE-4 is 25, so RR-5 selects the BGP path with next hop 192.0.2.1.

```
[/]
A:admin@RR-5# show router bgp routes
===============================================================================
```

```
 BGP Router ID:192.0.2.5        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                     100         None
      192.0.2.1                                        None        20
      65537 65540                                                  -
*i    10.1.11.0/24                                     100         None
      192.0.2.4                                        None        25
      65538 65540                                                  -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

RR-5 reflects the path with next hop 192.0.2.1 to all clients except PE-1, because PE-1 is the client where the path was learned from).

For prefix 10.1.11.0/24, PE-1 received an EBGP route from ASBR-6 in AS 65537 with next hop 172.16.16.2 and no IBGP route from RR-5:

```
[/]
A:admin@PE-1# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.1        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                     None        None
      172.16.16.2                                      None        0
      65537 65540                                                  -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

As a result, traffic offered to PE-1 for destination 10.1.11.0/24 is routed to ASBR-6, as follows:

```
[/]
A:admin@PE-1# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
```

```
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.1.11.0/24                                    Remote  BGP       00h04m15s  170
       172.16.16.2                                                  0
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

PE-2 received an IBGP route for prefix 10.1.11.0/24 with next hop 192.0.2.1 from RR-5:

```
[/]
A:admin@PE-2# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                     100         None
      192.0.2.1                                        None        10
      65537 65540                                                  -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Traffic offered to PE-2 for destination 10.1.11.0/24 is routed to PE-1, as follows:

```
[/]
A:admin@PE-2# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.1.11.0/24                                    Remote  BGP       00h17m22s  170
       192.168.12.1                                                 10
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

Likewise, PE-3 received an IBGP route for prefix 10.1.11.0/24 with next hop 192.0.2.1 from RR-5:

```
[/]
A:admin@PE-3# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                     100         None
      192.0.2.1                                        None        20
      65537 65540                                                  -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Traffic offered to PE-3 for destination 10.1.11.0/24 is routed via the interface address 192.168.23.1 on PE-2, as follows:

```
[/]
A:admin@PE-3# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
10.1.11.0/24                                   Remote  BGP       00h10m26s  170
       192.168.23.1                                                20
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

For prefix 10.1.11.0/24, PE-4 received an EBGP route from ASBR-7 with next hop 172.16.47.2 and an IBGP route from RR-5 with next hop 192.0.2.1, as follows. EBGP routes are preferred over IBGP routes.

```
[/]
A:admin@PE-4# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.4        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
```

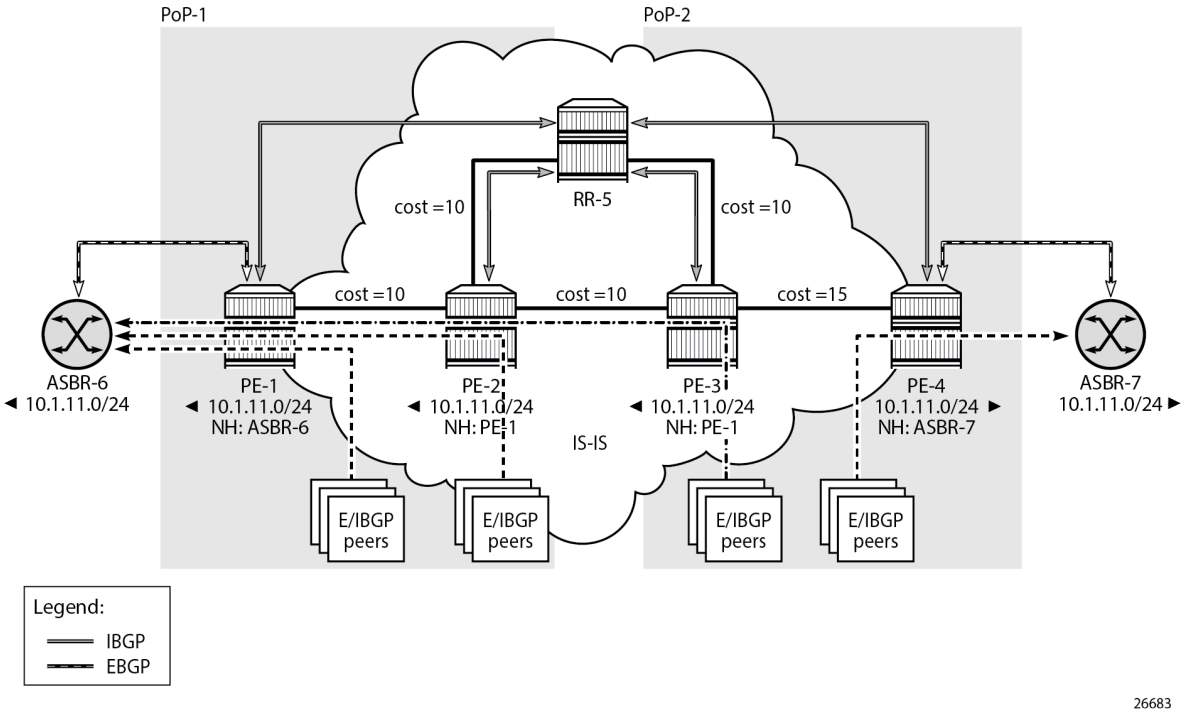
```
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                     None        None
      172.16.47.2                                      None        0
      65538 65540                                                  -
*i    10.1.11.0/24                                     100         None
      192.0.2.1                                        None        35
      65537 65540                                                  -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

The used route is the EBGP route from ASBR-7, so the traffic offered to PE-4 for destination 10.1.11.0/24 is routed to ASBR-7, as follows:

```
[/]
A:admin@PE-4# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.1.11.0/24                                  Remote  BGP       00h18m08s  170
       172.16.47.2                                                 0
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

This is summarized in Figure 69: Suboptimal route reflection. Ultimately, PE-1 only has one path, and so do PE-2 and PE-3. PE-4 has two paths, but by default prefers the EBGP learned path over the IBGP learned path. The routing is suboptimal on PE-3, where the IGP cost to PE-1 is 20 and the IGP cost to PE-4 is 15.

Figure 69: Suboptimal route reflection



Route reflection with ORR

For implementing ORR using the non-hierarchical topology from Figure 69: Suboptimal route reflection the route reflector RR-5 defines two locations in the **optimal-route-reflection** context. The primary IP address for location 1 is the PE-1 system IP address 192.0.2.1; the primary IP address for location 2 is loopback address 192.0.2.44 on PE-4 and the secondary IP address is loopback address 192.0.2.33 on PE-3. These addresses are used as the starting point for the SPF run. The ORR locations 1 and 2 are then referred to from within the group definitions through the **cluster** command. The overall BGP configuration of RR-5 is as follows:

```
# on RR-5
configure {
    router "Base" {
        autonomous-system 65536
        bgp {
            loop-detect discard-route
            split-horizon true
            optimal-route-reflection {
                spf-wait {
                    max-wait 1
                    initial-wait 1
                    second-wait 1
                }
                location 1 {
                    primary-ip-address 192.0.2.1
                }
                location 2 {
```

```
                    primary-ip-address 192.0.2.44      # loopback address on PE-4
                    secondary-ip-address 192.0.2.33    # loopback address on PE-3
                }
            }
            group "IBGP-1" {
                peer-as 65536
                cluster {
                    cluster-id 192.0.2.5
                    orr-location 1
                    allow-local-fallback true
                }
            }
            group "IBGP-2" {
                peer-as 65536
                cluster {
                    cluster-id 192.0.2.5
                    orr-location 2
                    allow-local-fallback true
                }
            }
            neighbor "192.0.2.1" {
                group "IBGP-1"
            }
            neighbor "192.0.2.2" {
                group "IBGP-1"
            }
            neighbor "192.0.2.3" {
                group "IBGP-2"
            }
            neighbor "192.0.2.4" {
                group "IBGP-2"
            }
        }
```

No changes are required in the BGP clients.

ASBR-6 advertises prefix 10.1.11.0/24 to router PE-1; ASBR-7 advertises the same prefix to router PE-4. RR-5 receives the updates from PE-1 and PE-4, and now performs two SPF runs because two locations are used. The first SPF run uses the 192.0.2.1 address of PE-1 as the starting point for the first location, selects the path via PE-1 as the best path, and reflects that path to the remaining peers in the first location. The second SPF run uses the 192.0.2.44 loopback address of PE-4 as the starting point for the second location, selects the path via PE-4 as the best path, and reflects that path to the remaining peers in the second location.

In comparison with the previous scenario, there only is a change in the routing for this prefix on PE-3. RR-5 reflects the route with next hop 192.0.2.4 to PE-3.

```
[/]
A:admin@PE-3# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
```

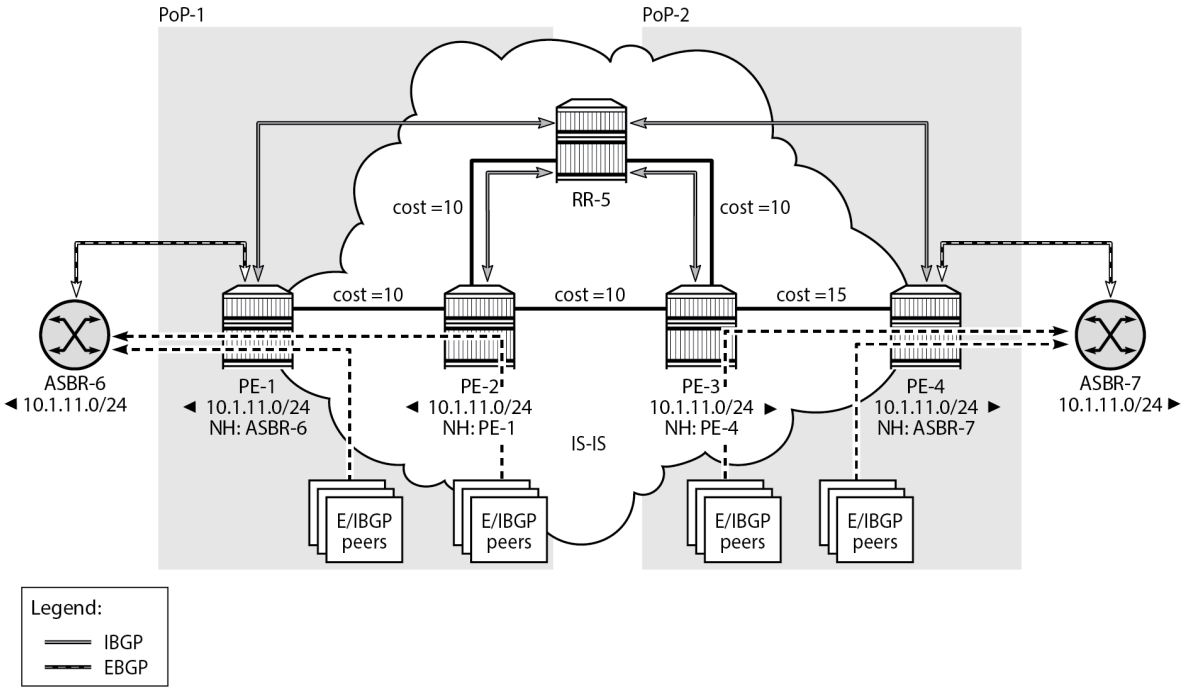
```
      As-Path                                                          Label
-------------------------------------------------------------------------------
u*>i  10.1.11.0/24                                    100         None
      192.0.2.4                                       None        15
      65538 65540                                                 -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Traffic offered to PE-3 for destination 10.1.11.0/24 has next hop PE-4 and is routed via the interface address 192.168.34.2 on PE-4, as follows:

```
[/]
A:admin@PE-3# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.1.11.0/24                                  Remote  BGP       00h02m06s  170
       192.168.34.2                                                 15
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

This is summarized in Figure 70: Optimal route reflection.

Figure 70: Optimal route reflection



The following command provides the IGP distances for the configured reference points to all available BGP peers and all detected BGP next hops on the route reflector.

```
[/]
A:admin@RR-5# show router bgp optimal-route-reflection bgp-nh-info

===============================================================================
ORR BGP-NH Table (Router: Base)
===============================================================================
Location 1:
    Primary        : 192.0.2.1 [active]
    Secondary      : -
    Tertiary       : -
    Primary-ipv6   : -
    Secondary-ipv6 : -
    Tertiary-ipv6  : -
Location 2:
    Primary        : 192.0.2.44 [active]
    Secondary      : 192.0.2.33
    Tertiary       : -
    Primary-ipv6   : -
    Secondary-ipv6 : -
    Tertiary-ipv6  : -

Age          : 00h02m55s
Spf wait     : 1
Initial wait : 1
Second wait  : 1

-------------------------------------------------------------------------------
Next Hop
```

```
   Loc    Dest-Prefix
                               DB-Source  Type         Proto     Metric    Pref
-------------------------------------------------------------------------------

192.0.2.1
    1     192.0.2.1/32
                               IGP        Local        Local     0           0
    2     192.0.2.1/32
                               IGP        Remote       ISIS      35         18

192.0.2.4
    1     192.0.2.4/32
                               IGP        Remote       ISIS      35         18
    2     192.0.2.4/32
                               IGP        Local        Local     0           0
-------------------------------------------------------------------------------
No. of BGP-NHs: 2
===============================================================================
```

Conclusion

BGP optimal route reflection allows operators to optimize traffic streams through their network, even when the route reflector is placed out-of-path, for example in datacenters, thereby reducing the OPEX and CAPEX of route reflector deployment.

BGP Prefix Limit per Address Family

This chapter provides information about BGP prefix limit per address family.

Topics in this chapter include:

Applicability

This chapter was initially written based on SR OS Release 15.0.R1, but the MD-CLI in the current edition is based on SR OS Release 22.10.R1.

Overview

A BGP per address family prefix limit can be defined to control the number of prefixes learned per neighbor or per group of neighbors in the base router or in a VPRN. This feature allows ISPs to secure their network from misbehaving or misconfigured peers. This feature can also be used to enforce the terms of a service contract.

Table 1: Supported address families for BGP prefix limit lists the address families for which a prefix limit can be defined in the base router and in VPRNs.

Table 1: Supported address families for BGP prefix limit

Address family	Base router	VPRN
ipv4	X	X
ipv6	X	X
mcast-ipv4	X	X
mcast-ipv6	X	X
flow-ipv4	X	X
flow-ipv6	X	X
label-ipv4	X	X
label-ipv6	X	–
vpn-ipv4	X	–

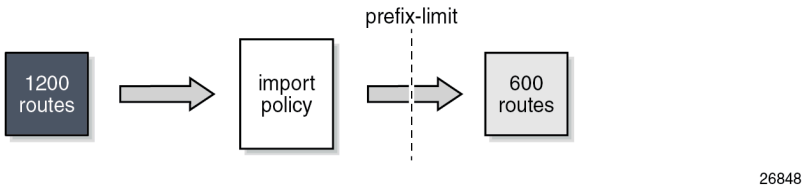
Address family	Base router	VPRN
vpn-ipv6	X	–
mvpn-ipv4	X	–
mvpn-ipv6	X	–
mcast-vpn-ipv4	X	–
mcast-vpn-ipv6	X	–
flow-vpn-ipv4	X	–
flow-vpn-ipv6	X	–
sr-policy-ipv4	X	–
sr-policy-ipv6	X	–
l2-vpn	X	–
mdt-safi	X	–
ms-pw	X	–
route-target	X	–
evpn	X	–
bgp-ls	X	–

If the number of received routes from a peer exceeds a defined per address family limit, the BGP session is torn down, the state is changed to disabled, the routes learned from that peer are deleted, and the RIB and FIB are recalculated. With the **log-only** option enabled, the BGP session is not torn down and no routes are deleted. An SNMP trap message is issued when exceeding the per address family threshold (default: 90%), and the per address family prefix limit.

Re-establishing the BGP session with the peer requires a manual intervention, or use of the **idle-timeout** option. The idle-timeout option defines the time in minutes after which the system attempts to re-establish the BGP session.

The **post-import** option indicates that the limit should be applied only to the routes accepted by import policies, as shown in Figure 71: Post-import option. A route rejected by an import policy will not be counted when checking against the prefix limit. Not specifying the post-import option results in routes being counted and verified against the prefix limit when they are received, before the import policy is executed, and might lead to BGP sessions being torn down unexpectedly.

Figure 71: Post-import option



BGP sessions will be torn down as soon as one of the address family prefix limits is exceeded, even when the limit for the other address family is not yet exceeded. In cases where this is important, consider defining two BGP sessions between two peers; the first using IPv4 for its transport, and the second using IPv6. In this way, an IPv4 limit being exceeded will not lead to IPv6 prefixes being affected.

Note: A VPN route carrying a route-target (for example, VPN-IPv4, VPN-IPv6, L2-VPN, MVPN-IPV4, MVPN-IPv6) might not be retained in the RIB-IN if it is not imported by any service. If a VPN route is not stored in the RIB-IN, it is not counted and not checked against the prefix limit for its associated address family. If **mp-bgp-keep true** is configured, or the router is a route reflector (using the **cluster** command) or an ASBR in an inter-AS VPRN model B, then the VPN-IP route is always stored.

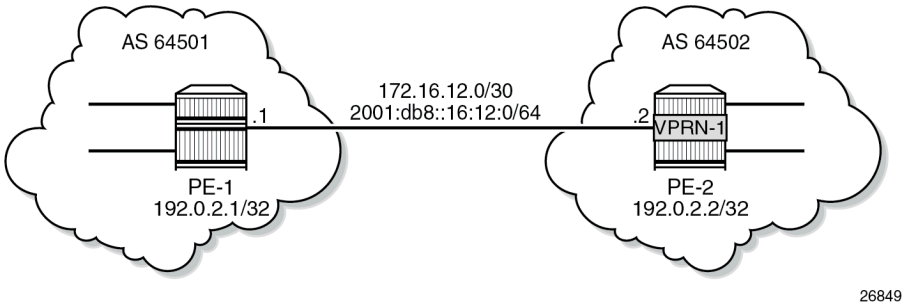
Configuration

Figure 72: Example topology shows the example topology. PE-1 in AS 64501 peers with VPRN-1 hosted by PE-2 in AS 64502.

Two scenarios are considered:

- Prefix limit without post-import option
- Prefix limit with post-import option

Figure 72: Example topology



Prefix limit without post-import option

PE-1 peers with VPRN-1 on PE-2, where IP prefix limit is configured in the BGP group toward PE-1: the IPv4 prefix limit is 10, the threshold is 50%, and the idle-timeout is 1 minute; the IPv6 prefix limit is 10, the threshold 80%, and the idle-timeout is 4 minutes, as follows:

```
# on PE-2:
configure {
    service {
        vprn "VPRN-1" {
            admin-state enable
            description "VPRN with BGP prefix limit"
            service-id 1
            customer "1"
            autonomous-system 64502
            bgp-ipvpn {
```

```
                mpls {
                    admin-state enable
                    route-distinguisher "64502:1"
                }
            }
            bgp {
                loop-detect discard-route
                split-horizon true
                group "EBGP-IPv4" {
                    peer-as 64501
                    family {
                        ipv4 true
                    }
                    import {
                        policy ["import-10.1-ranges"]
                    }
                    prefix-limit ipv4 {
                        maximum 10
                        threshold 50
                        idle-timeout 1
                    }
                }
                group "EBGP-IPv6" {
                    peer-as 64501
                    family {
                        ipv6 true
                    }
                    import {
                        policy ["import-ipv6-88-ranges"]
                    }
                    prefix-limit ipv6 {
                        maximum 10
                        threshold 80
                        idle-timeout 4
                    }
                }
                neighbor "172.16.12.1" {
                    group "EBGP-IPv4"
                }
                neighbor "2001:db8::16:12:1" {
                    group "EBGP-IPv6"
                }
            }
            interface "int-VPRN-1onPE-2-PE-1" {
                ipv4 {
                    primary {
                        address 172.16.12.2
                        prefix-length 30
                    }
                }
                sap 1/1/c2/1:1 {
                }
                ipv6 {
                    address 2001:db8::16:12:2 {
                        prefix-length 126
                    }
                }
            }
        }
```

The debug configuration (in classic CLI) is as follows:

```
# on PE-2:
```

```
debug
    router service-name "VPRN-1"
        bgp
            packets neighbor 172.16.12.1
            events neighbor 172.16.12.1
        exit
    exit
```

The debug output is sent to the log with log-id "log-1", as follows:

```
# on PE-2:
configure {
    log {
        log-id "log-1" {
            source {
                debug true
            }
            destination {
                memory {
                }
            }
```

Initially, the number of IPv4 routes received from PE-1 is below the threshold, and PE-1 gradually injects more IPv4 routes into VPRN-1 on PE-2. The following is a snapshot where three IPv4 routes and four IPv6 routes are received and active in PE-2:

```
[/]
A:admin@PE-2# show router 1 bgp summary
===============================================================================
 BGP Router ID:192.0.2.2        AS:64502       Local AS:64502
===============================================================================
BGP Admin State         : Up          BGP Oper State              : Up
Total Peer Groups       : 2           Total Peers                 : 2
Current Internal Groups : 2           Max Internal Groups         : 2
Total BGP Paths         : 7           Total Path Memory           : 2480

Total IPv4 Remote Rts   : 3           Total IPv4 Rem. Active Rts  : 3
Total IPv6 Remote Rts   : 4           Total IPv6 Rem. Active Rts  : 4
Total IPv4 Backup Rts   : 0           Total IPv6 Backup Rts       : 0
Total LblIpv4 Rem Rts   : 0           Total LblIpv4 Rem. Act Rts  : 0
Total LblIpv6 Rem Rts   : 0           Total LblIpv6 Rem. Act Rts  : 0
Total LblIpv4 Bkp Rts   : 0           Total LblIpv6 Bkp Rts       : 0
Total Supressed Rts     : 0           Total Hist. Rts             : 0
Total Decay Rts         : 0

Total McIPv4 Remote Rts : 0           Total McIPv4 Rem. Active Rts: 0
Total McIPv6 Remote Rts : 0           Total McIPv6 Rem. Active Rts: 0

Total FlowIpv4 Rem Rts  : 0           Total FlowIpv4 Rem Act Rts  : 0
Total FlowIpv6 Rem Rts  : 0           Total FlowIpv6 Rem Act Rts  : 0
Total FlowVpnv4 Rem Rts : 0           Total FlowVpnv4 Rem Act Rts : 0
Total FlowVpnv6 Rem Rts : 0           Total FlowVpnv6 Rem Act Rts : 0
Total Link State Rem Rts: 0           Total Link State Rem Act Rts: 0
Total SrPlcyIpv4 Rem Rts: 0           Total SrPlcyIpv4 Rem Act Rts: 0
Total SrPlcyIpv6 Rem Rts: 0           Total SrPlcyIpv6 Rem Act Rts: 0

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
```

```
Description
                   AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
172.16.12.1
                64501       8    0 00h01m54s 3/3/0 (IPv4)
                            7    0
2001:db8::16:12:1
                64501       8    0 00h01m45s 4/4/0 (IPv6)
                            7    0
-------------------------------------------------------------------------------
```

The following three BGP IPv4 routes are received by VPRN-1 on PE-2 and they are all active:

```
[/]
A:admin@PE-2# show router 1 bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64502       Local AS:64502
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  10.1.0.0/24                                       None        None
      172.16.12.1                                       None        0
      64501                                                         -
u*>i  10.1.1.0/24                                       None        None
      172.16.12.1                                       None        0
      64501                                                         -
u*>i  10.1.2.0/24                                       None        None
      172.16.12.1                                       None        0
      64501                                                         -
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

When the sixth BGP IPv4 route is received, the threshold value (50% of 10 is 5) is exceeded, and a message is generated and sent to log "99", as follows:

```
[/]
A:admin@PE-2# show log log-id "99"

===============================================================================
Event Log 99 log-name 99
===============================================================================
Description : Default System Log
Memory Log contents  [size=500   next event=110  (not wrapped)]

109 2022/11/25 15:49:27.411 CET MINOR: BGP #2035 vprn1 Peer 2: 172.16.12.1
"(ASN 64501) VR 2: Group EBGP-IPv4: Peer 172.16.12.1: number of routes learned has exceeded 50
 percentage of the configured maximum (10) for ipv4 family"
```

Likewise, when the nineth IPv6 route is received, the threshold value (80% of 10 is 8) is exceeded, the following message is added to log 99:

```
[/]
A:admin@PE-2# show log log-id "99"
---snip---

110 2022/11/25 15:50:04.412 CET MINOR: BGP #2035 vprn1 Peer 2: 2001:db8::16:12:1
"(ASN 64501) VR 2: Group EBGP-IPv6: Peer 2001:db8::16:12:1: number of routes learned has
 exceeded 80 percentage of the configured maximum (10) for ipv6 family"
```

When the eleventh BGP IPv4 route is received, the configured maximum number of BGP routes for IPv4 is exceeded. The BGP session state changes from *established* to *idle* and the peer is notified, as indicated in the following debug log:

```
[/]
A:admin@PE-2# show log log-id "log-1"

===============================================================================
Event Log 1 log-name log-1
===============================================================================
Description : (Not Specified)
Memory Log contents  [size=100   next event=65  (not wrapped)]

64 2022/11/25 15:53:59.417 CET MINOR: DEBUG #2001 vprn1 Peer 2: 172.16.12.1
"Peer 2: 172.16.12.1: NOTIFICATION
Peer 2: 172.16.12.1 - Send BGP NOTIFICATION: Code = 6 (CEASE) Subcode = 1 (Maximum prefixed
 reached)
  Data Length = 7  Data: 0x0 0x1 0x1 0x0 0x0 0x0 0xa
"

63 2022/11/25 15:53:59.417 CET MINOR: DEBUG #2001 vprn1 BGP
"BGP: STATE
Peer 2: 172.16.12.1 - Change State from ESTABLISHED to IDLE due to MAXPREFIX_EXCEEDED
"

62 2022/11/25 15:53:59.417 CET MINOR: DEBUG #2001 vprn1 Peer 2: 172.16.12.1
"Peer 2: 172.16.12.1: UPDATE
Peer 2: 172.16.12.1 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 20
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 6 AS Path:
        Type: 2 Len: 1 < 64501 >
    Flag: 0x40 Type: 3 Len: 4 Nexthop: 172.16.12.1
    NLRI: Length = 44
        10.1.0.0/24
        10.1.1.0/24
        10.1.10.0/24
        10.1.2.0/24
        10.1.3.0/24
        10.1.4.0/24
        10.1.5.0/24
        10.1.6.0/24
        10.1.7.0/24
        10.1.8.0/24
        10.1.9.0/24
"
```

The BGP session is torn down and the corresponding state is disabled, as follows:

```
[/]
A:admin@PE-2# show router 1 bgp summary
===============================================================================
 BGP Router ID:192.0.2.2        AS:64502       Local AS:64502
===============================================================================
BGP Admin State         : Up          BGP Oper State              : Up
Total Peer Groups       : 2           Total Peers                 : 2
Current Internal Groups : 1           Max Internal Groups         : 2
Total BGP Paths         : 6           Total Path Memory           : 2120

Total IPv4 Remote Rts   : 0           Total IPv4 Rem. Active Rts  : 0
Total IPv6 Remote Rts   : 10          Total IPv6 Rem. Active Rts  : 10
Total IPv4 Backup Rts   : 0           Total IPv6 Backup Rts       : 0
Total LblIpv4 Rem Rts   : 0           Total LblIpv4 Rem. Act Rts  : 0
Total LblIpv6 Rem Rts   : 0           Total LblIpv6 Rem. Act Rts  : 0
Total LblIpv4 Bkp Rts   : 0           Total LblIpv6 Bkp Rts       : 0
Total Supressed Rts     : 0           Total Hist. Rts             : 0
Total Decay Rts         : 0

Total McIPv4 Remote Rts : 0           Total McIPv4 Rem. Active Rts: 0
Total McIPv6 Remote Rts : 0           Total McIPv6 Rem. Active Rts: 0

Total FlowIpv4 Rem Rts  : 0           Total FlowIpv4 Rem Act Rts  : 0
Total FlowIpv6 Rem Rts  : 0           Total FlowIpv6 Rem Act Rts  : 0
Total FlowVpnv4 Rem Rts : 0           Total FlowVpnv4 Rem Act Rts : 0
Total FlowVpnv6 Rem Rts : 0           Total FlowVpnv6 Rem Act Rts : 0
Total Link State Rem Rts: 0           Total Link State Rem Act Rts: 0
Total SrPlcyIpv4 Rem Rts: 0           Total SrPlcyIpv4 Rem Act Rts: 0
Total SrPlcyIpv6 Rem Rts: 0           Total SrPlcyIpv6 Rem Act Rts: 0

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
                   AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
172.16.12.1
                64501       0    0 00h00m10s Disabled
                            0    0
2001:db8::16:12:1
                64501      25    0 00h09m11s 10/10/0 (IPv6)
                           22    0
-------------------------------------------------------------------------------
```

Also, this event is recorded in the system logs, as follows:

```
[/]
A:admin@PE-2# show log log-id "99"
---snip---

137 2022/11/25 15:55:32.424 CET WARNING: BGP #2012 vprn1 Peer 2: 172.16.12.1
"(ASN 64501) Peer 2: 172.16.12.1: Closing connection: VR 2: Group EBGP-IPv4: Peer 172.16.12.1
 not enabled or not in configuration"

136 2022/11/25 15:55:32.418 CET WARNING: BGP #2005 vprn1 Peer 2: 172.16.12.1
"(ASN 64501) VR 2: Group EBGP-IPv4: Peer 172.16.12.1: sending notification: code CEASE subcode
 MAX_PFX_RCHD"
```

```
135 2022/11/25 15:55:32.418 CET WARNING: BGP #2039 vprn1 Peer 2: 172.16.12.1
"(ASN 64501) VR 2: Group EBGP-IPv4: Peer 172.16.12.1: moved from higher state ESTABLISHED to
 lower state IDLE due to event MAXPREFIX_EXCEEDED"
```

When the idle-timeout expires, in this case, after one minute, the system tries to re-establish the session. With the BGP session re-established, the peer starts re-advertising its routes. As long as the number of received routes in VPRN-1 on PE-2 is lower than or equal to the limit, the session is maintained. In this example, the maximum number of received IPv4 routes is 10 and the maximum number of received IPv6 routes is 10.

Prefix limit with post-import option

Use caution when using the prefix limit in combination with import policies. By default, the routes are counted when receiving them, that is, before the import policy is enforced. To postpone the prefix limit check, the **post-import** option must be used.

The BGP configuration for VPRN-1 on PE-2 has **post-import** enabled, as follows:

```
# on PE-2:
configure {
    service {
        vprn "VPRN-1" {
            admin-state enable
            description "VPRN with BGP prefix limit"
            service-id 1
            customer "1"
            autonomous-system 64502
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64502:1"
                }
            }
            bgp {
                loop-detect discard-route
                split-horizon true
                group "EBGP-IPv4" {
                    peer-as 64501
                    import {
                        policy ["import-10.1-ranges"]
                    }
                    prefix-limit ipv4 {
                        maximum 10
                        threshold 50
                        idle-timeout 1
                        post-import true
                    }
                }
                group "EBGP-IPv6" {
                    peer-as 64501
                    family {
                        ipv6 true
                    }
                    import {
                        policy ["import-ipv6-88-ranges"]
                    }
                    prefix-limit ipv6 {
                        maximum 10
                        threshold 80
```

```
                        idle-timeout 4
                    }
                }
                neighbor "172.16.12.1" {
                    group "EBGP-IPv4"
                }
                neighbor "2001:db8::16:12:1" {
                    group "EBGP-IPv6"
                }
            }
            interface "int-VPRN-1onPE-2-PE-1" {
                ipv4 {
                    primary {
                        address 172.16.12.2
                        prefix-length 30
                    }
                }
                sap 1/1/c2/1:1 {
                }
                ipv6 {
                    address 2001:db8::16:12:2 {
                        prefix-length 126
                    }
                }
            }
        }
```

The *import-10.1-ranges* policy is defined as follows:

```
# on PE-2:
configure {
    policy-options {
        prefix-list "pfx-10.1-ranges" {
            prefix 10.1.0.0/16 type longer {
            }
        }
        policy-statement "import-10.1-ranges" {
            entry 10 {
                from {
                    prefix-list ["pfx-10.1-ranges"]
                }
                action {
                    action-type accept
                }
            }
            default-action {
                action-type reject
            }
        }
```

When twelve IPv4 routes are received over this BGP session, six in the 10.1.0.0/16 range and six in the 10.2.0.0/16 range, then only the six routes in the 10.1.0.0/16 range are accepted and active in the routing table, as follows:

```
[/]
A:admin@PE-2# show router 1 route-table protocol bgp

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
```

```
-------------------------------------------------------------------------------
10.1.0.0/24                                 Remote  BGP       00h02m07s  170
       172.16.12.1                                              0
10.1.1.0/24                                 Remote  BGP       00h02m07s  170
       172.16.12.1                                              0
10.1.2.0/24                                 Remote  BGP       00h02m07s  170
       172.16.12.1                                              0
10.1.3.0/24                                 Remote  BGP       00h02m07s  170
       172.16.12.1                                              0
10.1.4.0/24                                 Remote  BGP       00h02m07s  170
       172.16.12.1                                              0
10.1.5.0/24                                 Remote  BGP       00h02m07s  170
       172.16.12.1                                              0
-------------------------------------------------------------------------------
No. of Routes: 6
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The BGP session remains established with twelve received routes and six of these being active, as follows:

```
[/]
A:admin@PE-2# show router 1 bgp summary
===============================================================================
 BGP Router ID:192.0.2.2        AS:64502       Local AS:64502
===============================================================================
BGP Admin State         : Up          BGP Oper State              : Up
Total Peer Groups       : 2           Total Peers                 : 2
Current Internal Groups : 2           Max Internal Groups         : 2
Total BGP Paths         : 7           Total Path Memory           : 2480

Total IPv4 Remote Rts   : 12          Total IPv4 Rem. Active Rts  : 6
Total IPv6 Remote Rts   : 10          Total IPv6 Rem. Active Rts  : 10
Total IPv4 Backup Rts   : 0           Total IPv6 Backup Rts       : 0
Total LblIpv4 Rem Rts   : 0           Total LblIpv4 Rem. Act Rts  : 0
Total LblIpv6 Rem Rts   : 0           Total LblIpv6 Rem. Act Rts  : 0
Total LblIpv4 Bkp Rts   : 0           Total LblIpv6 Bkp Rts       : 0
Total Supressed Rts     : 0           Total Hist. Rts             : 0
Total Decay Rts         : 0

Total McIPv4 Remote Rts : 0           Total McIPv4 Rem. Active Rts: 0
Total McIPv6 Remote Rts : 0           Total McIPv6 Rem. Active Rts: 0

Total FlowIpv4 Rem Rts  : 0           Total FlowIpv4 Rem Act Rts  : 0
Total FlowIpv6 Rem Rts  : 0           Total FlowIpv6 Rem Act Rts  : 0
Total FlowVpnv4 Rem Rts : 0           Total FlowVpnv4 Rem Act Rts : 0
Total FlowVpnv6 Rem Rts : 0           Total FlowVpnv6 Rem Act Rts : 0
Total Link State Rem Rts: 0           Total Link State Rem Act Rts: 0
Total SrPlcyIpv4 Rem Rts: 0           Total SrPlcyIpv4 Rem Act Rts: 0
Total SrPlcyIpv6 Rem Rts: 0           Total SrPlcyIpv6 Rem Act Rts: 0

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
                   AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
```

```
172.16.12.1
                64501      18    0 00h06m14s 12/6/0 (IPv4)
                           17    0
2001:db8::16:12:1
                64501      39    0 00h16m14s 10/10/0 (IPv6)
                           36    0
-------------------------------------------------------------------------------
```

Without the **post-import** option, the session is torn down as soon as the number of received routes exceeds the configured prefix limit.

Conclusion

The BGP prefix limit per address family feature allows ISPs to protect their network from misbehaving or misconfigured peers, and can also be used to enforce the terms of a service contract.

BGP Remove-Private ASN

This chapter describes BGP Remove-Private ASN.

Topics in this chapter include:

Applicability

The information and configuration in this chapter are based on SR OS Release 22.10.R2.

Overview

In some networks, the network operator may need to assign a private Autonomous System Number (ASN) to the BGP speakers in a region or domain. These private ASNs are taken from the following ranges defined by IANA:

- 64512 to 65534 inclusive, for 2-octet ASNs
- 4200000000 to 4294967294 inclusive, for 4-octet ASNs

In SR OS, the ASN numbers 65535 and 4294967295, which are reserved values, are also treated as private ASNs.

The **remove-private** command is required when routes originated by a BGP speaker with a private ASN need to be advertised into a public domain, such as the Internet, where private ASNs may not be unique. The functionality of the **remove-private** command in SR OS is as follows:

- When the **remove-private** command is configured for neighbor X, the stripping of private ASNs applies only to outbound routes advertised to neighbor X.
- The **remove-private** command supports the following three options, which can be configured standalone or combined:
  - The **limited true** option causes BGP to remove only the private ASNs until the first public ASN.
  - The **skip-peer-as true** option causes BGP to not remove a private ASN from the AS path attribute if that ASN is the same as the BGP peer ASN.
  - The **replace true** option replaces the private ASN with the ASN of the router, as configured in:
    - **local-as** if the router advertises routes to a peer covered by such a command, and not configured as **private**
    - **configure router autonomous-system** if there is no applicable **local-as** configuration in BGP and the router is not part of a confederation

- **configure router bgp confederation** if the router advertises routes to an eBGP peer outside the confederation

Note:
The use of the **remove-private** command without the **replace true** option can make the AS path attribute shorter. This makes the route more preferable for the BGP decision process, which may not be the wanted outcome.

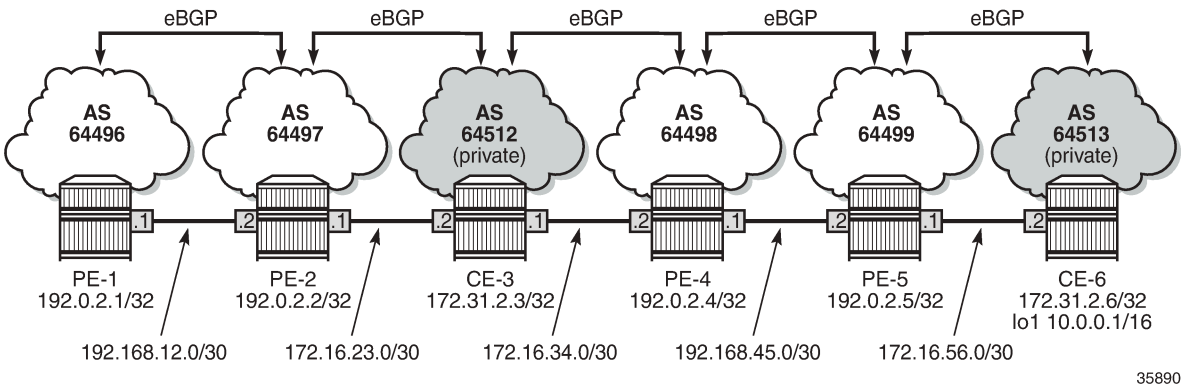
Note:
When **as-override** is enabled in the same session as **remove-private**, processing related to **remove-private** occurs first, followed by the processing related to **as-override**.

Configuration

Use case 1: Initial example topology

Figure 73: Use case 1 topology shows the initial example topology with six nodes in different ASs: CE-3 and CE-6 have a private ASN, whereas PE-1, PE-2, PE-4, and PE-5 have a public ASN.

Figure 73: Use case 1 topology



The initial configuration on the nodes includes:

- Cards, MDAs, ports
- Router interfaces
- eBGP between adjacent nodes for the IPv4 address family

The initial BGP configuration on PE-2 is as follows:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "eBGP" {
                family {
                    ipv4 true
```

```
                }
            }
            neighbor "172.16.23.2" {
                group "eBGP"
                peer-as 64512
            }
            neighbor "192.168.12.1" {
                group "eBGP"
                peer-as 64496
            }
        }
```

CE-6 exports prefix 10.0.0.0/16. The configuration is as follows:

```
# on CE-6:
configure {
    policy-options {
        prefix-list "10.0.0.0/16" {
            prefix 10.0.0.0/16 type longer {
            }
        }
        policy-statement "export-prefix" {
            entry 10 {
                from {
                    prefix-list ["10.0.0.0/16"]
                }
                action {
                    action-type accept
                }
            }
        }
    }
    router "Base" {
        autonomous-system 64513
        interface "int-CE-6-PE-5" {
            port 1/1/c1/2:100
            ipv4 {
                primary {
                    address 172.16.56.2
                    prefix-length 30
                }
            }
        }
        interface "lo1" {
            loopback
            ipv4 {
                primary {
                    address 10.0.0.1
                    prefix-length 16
                }
            }
        }
        interface "system" {
            ipv4 {
                primary {
                    address 172.31.2.6
                    prefix-length 32
                }
            }
        }
        bgp {
            split-horizon true
            group "eBGP" {
```

```
                family {
                    ipv4 true
                }
            }
            neighbor "172.16.56.1" {
                group "eBGP"
                peer-as 64499
                export {
                    policy ["export-prefix"]
                }
            }
        }
```

PE-2 receives the following BGP route for prefix 10.0.0.0/16 with public and private ASNs in the AS path: 64512 (private ASN of CE-3) – 64498 (public ASN of PE-4) – 64499 (public ASN of PE-5) – 64513 (private ASN of CE-6).

```
[/]
A:admin@PE-2# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:192.0.2.2        AS:64497       Local AS:64497
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.0.0.0/16                                      None        None
      172.16.23.2                                      None        0
      64512 64498 64499 64513                                      -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

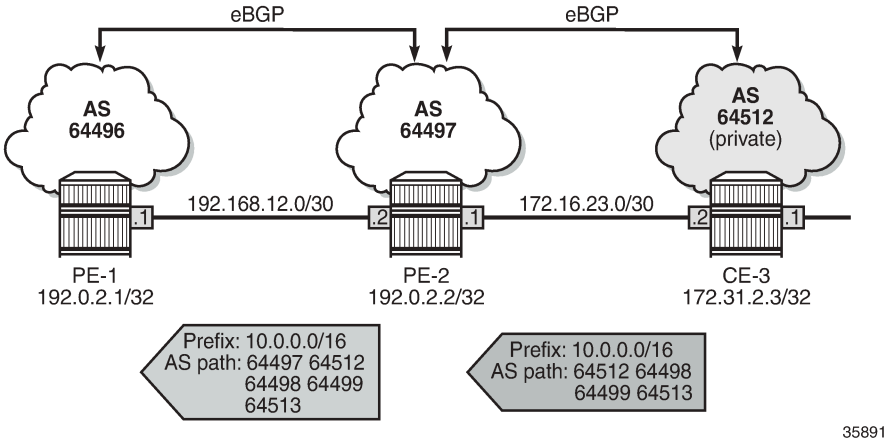
PE-2 adds its own public ASN (64497) to the AS path when it sends the BGP route to its neighbor PE-1. The following BGP route is received by PE-1:

```
[/]
A:admin@PE-1# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.0.0.0/16                                      None        None
```

```
      192.168.12.2                                          None        0
      64497 64512 64498 64499 64513                                     -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Figure 74: PE-2 adds its ASN and keeps all ASNs in the AS path (default) shows the BGP routes for prefix 10.0.0.0/16 received by PE-2 and PE-1:

Figure 74: PE-2 adds its ASN and keeps all ASNs in the AS path (default)



In the following examples, different **remove-private** ASN configurations are demonstrated: first without **replace true** and afterward with **replace true**.

- **remove-private** ASN without any extra option (= default setting)
- **remove-private** ASN with **limited true** option
- **remove-private** ASN with **skip-peer-as true** option

Remove all private ASNs

On PE-2, the **remove-private** command is configured for neighbor 192.168.12.1, as follows:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "eBGP" {
                family {
                    ipv4 true
                }
            }
            neighbor "172.16.23.2" {
                group "eBGP"
                peer-as 64512
            }
            neighbor "192.168.12.1" {
                group "eBGP"
                peer-as 64496
                remove-private {
```

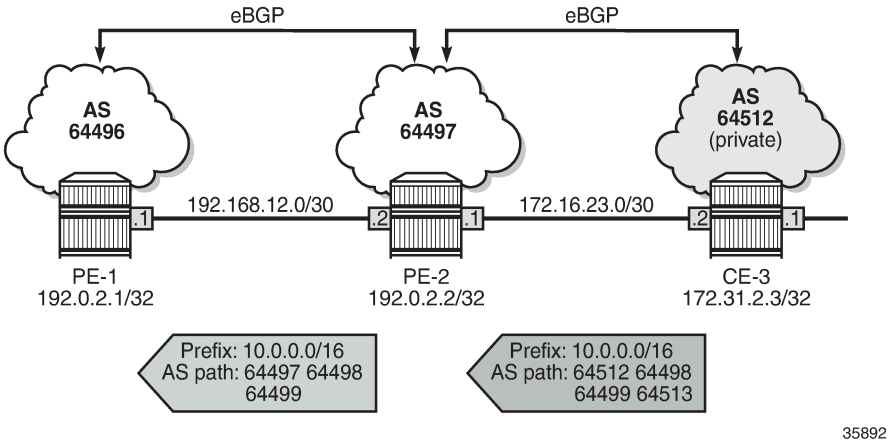
```
                    skip-peer-as false
                }
            }
        }
```

PE-2 removes all private ASNs (64512 from CE-3 and 64513 from CE-6) from the AS path, which makes the AS path shorter. PE-1 receives the following BGP route for prefix 10.0.0.0/16:

```
[/]
A:admin@PE-1# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                              LocalPref   MED
      Nexthop (Router)                                     Path-Id     IGP Cost
      As-Path                                                          Label
-------------------------------------------------------------------------------
u*>i  10.0.0.0/16                                          None        None
      192.168.12.2                                         None        0
      64497 64498 64499                                                -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Figure 75: PE-2 adds its own ASN and removes all private ASNs shows the AS path of the BGP routes for prefix 10.0.0.0/16 received by PE-2 and PE-1:

Figure 75: PE-2 adds its own ASN and removes all private ASNs



Replace all private ASNs

On PE-2, the **remove-private** command is configured with the **replace true** option for neighbor 192.168.12.1, as follows:

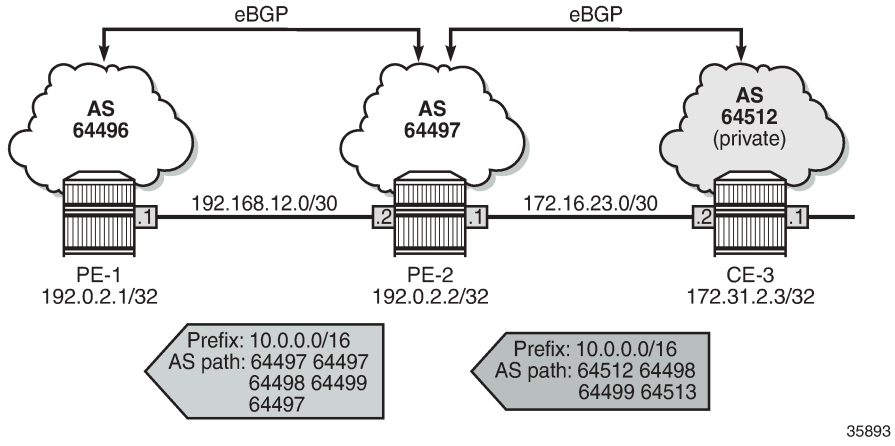
```
# on PE-2:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "eBGP" {
                family {
                    ipv4 true
                }
            }
            neighbor "172.16.23.2" {
                group "eBGP"
                peer-as 64512
            }
            neighbor "192.168.12.1" {
                group "eBGP"
                peer-as 64496
                remove-private {
                    skip-peer-as false
                    replace true
                }
            }
        }
```

PE-2 adds its ASN 64497 and replaces the private ASNs 64512 and 64513 with its own public ASN 64497 (in bold), so ASN 64497 occurs three times in the AS path, as follows:

```
[/]
A:admin@PE-1# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.0.0.0/16                                      None        None
      192.168.12.2                                     None        0
      64497 64497 64498 64499 64497                                -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Figure 76: PE-2 adds its own ASN and replaces all private ASNs with its own ASN shows the BGP routes for prefix 10.0.0.0/16 received by PE-2 and PE-1.

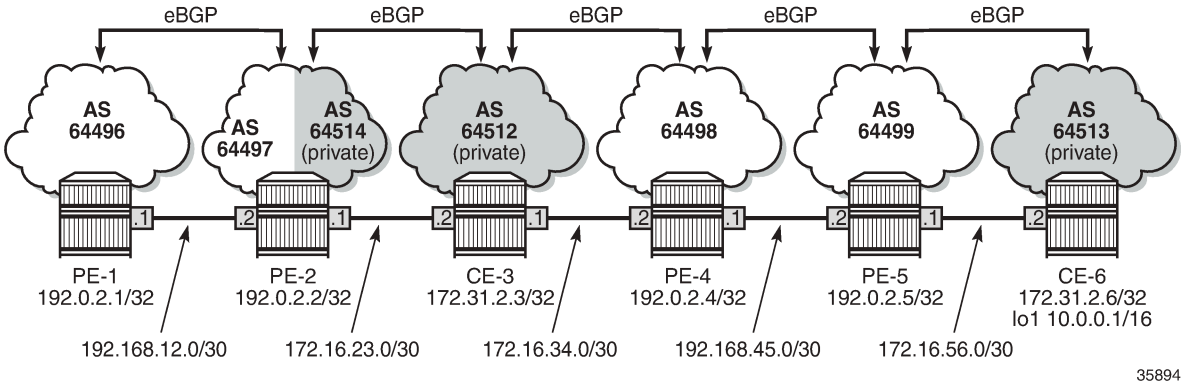
Figure 76: PE-2 adds its own ASN and replaces all private ASNs with its own ASN



Use case 2: Local private ASN in PE-2

Figure 77: Use case 2 topology shows the example topology that is modified with local private ASN 64514 configured on PE-2 for the neighbor 172.16.23.2. On CE-3, the peering with neighbor 172.16.23.1 is configured with private ASN 64514.

Figure 77: Use case 2 topology



Initially (without **remove-private** command), the private ASN is kept. The BGP configuration on PE-2 is as follows:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "eBGP" {
                family {
                    ipv4 true
                }
            }
```

```
            neighbor "172.16.23.2" {
                group "eBGP"
                peer-as 64512
                local-as {
                    as-number 64514
                }
            }
            neighbor "192.168.12.1" {
                group "eBGP"
                peer-as 64496
                delete remove-private
            }
        }
```

The BGP configuration on CE-3 is modified as follows:

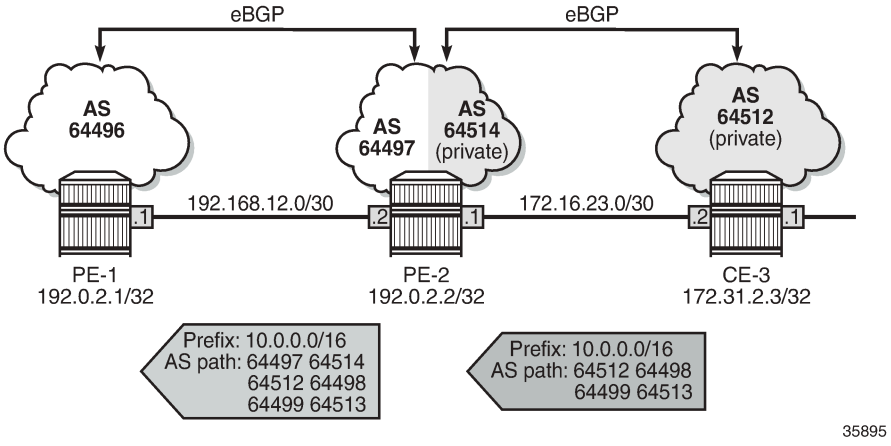
```
# on CE-3:
configure {
    router "Base" {
        bgp {
            neighbor "172.16.23.1" {
                group "eBGP"
                peer-as 64514
            }
```

On PE-2, the received BGP route for prefix 10.0.0.0/16 is the same as before. With the preceding BGP configuration, PE-2 adds two ASNs: private ASN 64514 and public ASN 64497. PE-1 receives the following BGP route for prefix 10.0.0.0/16:

```
[/]
A:admin@PE-1# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  10.0.0.0/16                                       None        None
      192.168.12.2                                      None        0
      64497 64514 64512 64498 64499 64513                           -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Figure 78: PE-2 adds its own private ASN and its public ASN (default) shows the AS path of the BGP routes received by PE-2 and PE-1.

Figure 78: PE-2 adds its own private ASN and its public ASN (default)



When the local ASN is explicitly configured as private, the local ASN is not added to the AS path attribute. The local address configuration on PE-2 is modified with the **private** option, as follows:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            neighbor "172.16.23.2" {
                group "eBGP"
                peer-as 64512
                local-as {
                    as-number 64514
                    private true
                }
            }
```

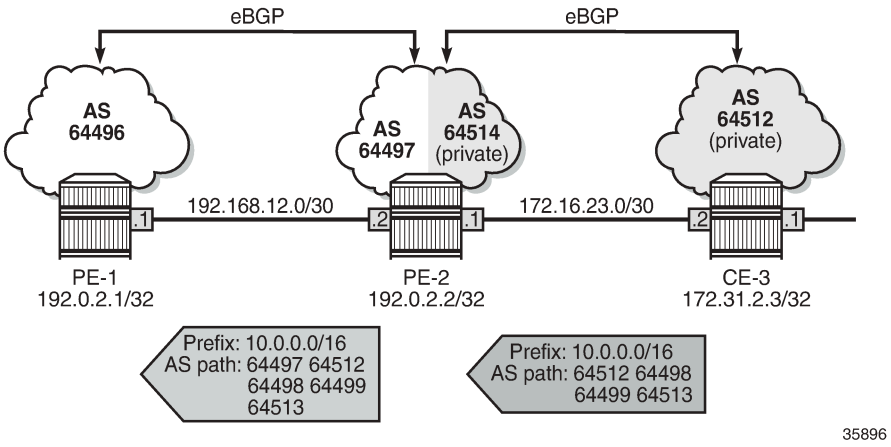
PE-1 receives the BGP route for prefix 10.0.0.0/16 with an AS path that does not include the private ASN 64514 anymore, as follows:

```
[/]
A:admin@PE-1# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.0.0.0/16                                      None        None
      192.168.12.2                                     None        0
      64497 64512 64498 64499 64513                                -
-------------------------------------------------------------------------------
```

```
Routes : 1
===============================================================================
```

Figure 79: PE-2 adds only its own public ASN when local ASN is configured as private shows the AS paths in the BGP routes received by PE-2 and PE-1.

Figure 79: PE-2 adds only its own public ASN when local ASN is configured as private



Remove private ASNs until the first public ASN

On PE-2, the **remove-private** command is configured with the **limited true** option, as follows:

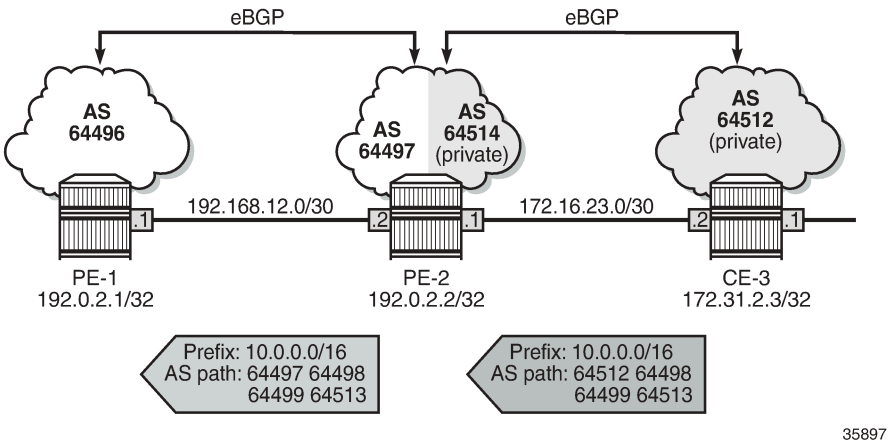
```
# on PE-2:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "eBGP" {
                family {
                    ipv4 true
                }
            }
            neighbor "172.16.23.2" {
                group "eBGP"
                peer-as 64512
                local-as {
                    as-number 64514
                    private true
                }
            }
            neighbor "192.168.12.1" {
                group "eBGP"
                peer-as 64496
                remove-private {
                    limited true
                    skip-peer-as false
                }
            }
```

The first ASN in the AS path is private (64512) and is removed by PE-2. The next ASN in the AS path is public (64498), so the rest of the AS path is preserved. PE-1 receives the following BGP route for prefix 10.0.0.0/16:

```
[/]
A:admin@PE-1# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                              LocalPref   MED
      Nexthop (Router)                                     Path-Id     IGP Cost
      As-Path                                                          Label
-------------------------------------------------------------------------------
u*>i  10.0.0.0/16                                          None        None
      192.168.12.2                                         None        0
      64497 64498 64499 64513                                          -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Figure 80: PE-2 removes the private ASNs until the first public ASN shows the BGP routes received by PE-2 and PE-1.

Figure 80: PE-2 removes the private ASNs until the first public ASN



Replace private ASNs until the first public ASN

On PE-2, the **replace true** option is added to the **remove-private** settings:

```
# on PE-2:
configure {
    router "Base" {
```

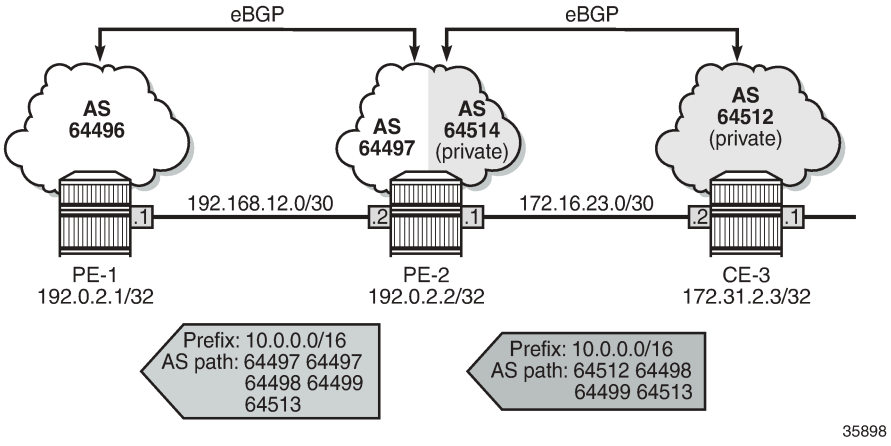
```
        bgp {
            split-horizon true
            group "eBGP" {
                family {
                    ipv4 true
                }
            }
            neighbor "172.16.23.2" {
                group "eBGP"
                peer-as 64512
                local-as {
                    as-number 64514
                    private true
                }
            }
            neighbor "192.168.12.1" {
                group "eBGP"
                peer-as 64496
                remove-private {
                    limited true
                    skip-peer-as false
                    replace true
                }
            }
```

Instead of removing the private ASN 64512, PE-2 replaces it with its own public ASN 64497, so PE-1 receives the following BGP route for prefix 10.0.0.0/16:

```
[/]
A:admin@PE-1# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.0.0.0/16                                      None        None
      192.168.12.2                                     None        0
      64497 64497 64498 64499 64513                                -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

This route is shown in Figure 81: PE-2 replaces the private ASNs until the first public ASN.

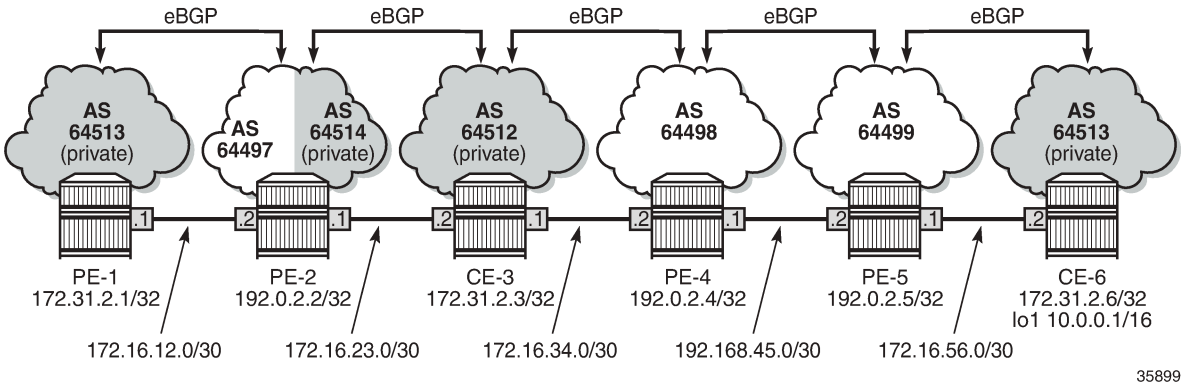
Figure 81: PE-2 replaces the private ASNs until the first public ASN



Use case 3: CE-1 and CE-6 in the same private AS

Figure 82: Use case 3 topology with private ASN 64513 on CE-1 and CE-6 shows the Use case 3 topology where PE-1 is replaced by CE-1 with a private ASN 64513, equal to the private ASN of CE-6.

Figure 82: Use case 3 topology with private ASN 64513 on CE-1 and CE-6



On PE-2, the peer ASN for neighbor 172.16.12.1 is 64513. Initially, no private ASNs are removed. The BGP configuration is as follows:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "eBGP" {
                family {
                    ipv4 true
                }
            }
            neighbor "172.16.23.2" {
```

```
                group "eBGP"
                peer-as 64512
                local-as {
                    as-number 64514
                    private true
                }
            }
            neighbor "172.16.12.1" {
                group "eBGP"
                peer-as 64513
            }
```

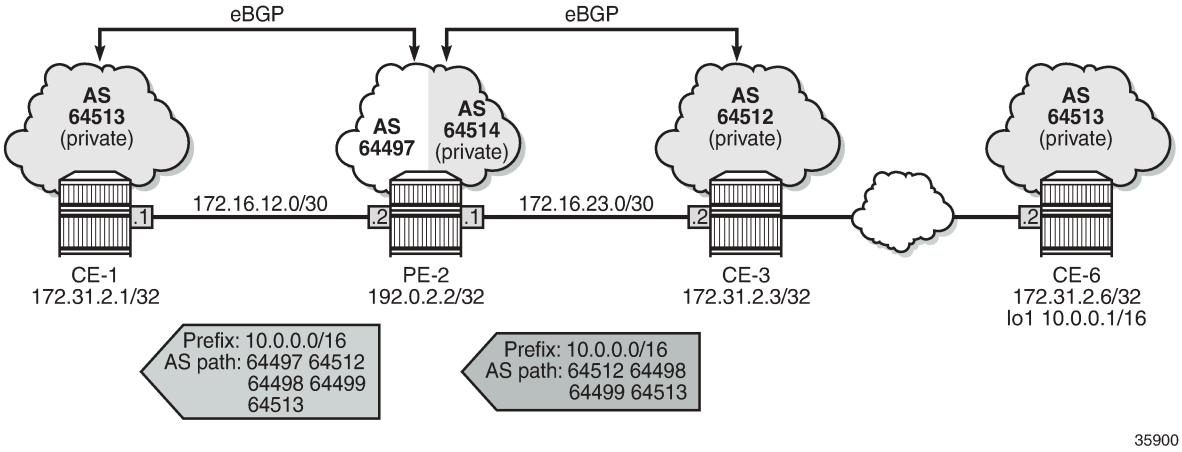
On CE-1, the received route for prefix 10.0.0.0/16 is invalid, because CE-1 detects its own ASN in the AS path attribute, which is considered an AS loop:

```
[/]
A:admin@CE-1# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:172.31.2.1       AS:64513       Local AS:64513
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
i     10.0.0.0/16                                      None        None
      172.16.12.2                                      None        0
      64497 64512 64498 64499 64513                                -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

```
[/]
A:admin@CE-1# show router bgp routes 10.0.0.0/16 detail | match Flags
Flags          : Invalid IGP AS-Loop      # Original Attributes
Flags          : Invalid IGP AS-Loop      # Modified Attributes
```

Figure 83: PE-2 adds its public ASN to the AS path shows the BGP routes received by PE-2 and CE-1.

Figure 83: PE-2 adds its public ASN to the AS path



Remove private ASNs except peer AS 64513

On PE-2, the **remove-private** command is configured with the **skip-peer-as true** option, as follows:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "eBGP" {
                family {
                    ipv4 true
                }
            }
            neighbor "172.16.23.2" {
                group "eBGP"
                peer-as 64512
                local-as {
                    as-number 64514
                    private true
                }
            }
            neighbor "172.16.12.1" {
                group "eBGP"
                peer-as 64513
                remove-private {
                    skip-peer-as true
                }
            }
        }
```

On PE-2, for neighbor 172.16.12.1, the peer ASN is 64513, so this private ASN is not removed; only private ASN 64512 (from CE-3) is removed. As a result, CE-1 receives the following BGP route:

```
[/]
A:admin@CE-1# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:172.31.2.1       AS:64513       Local AS:64513
```

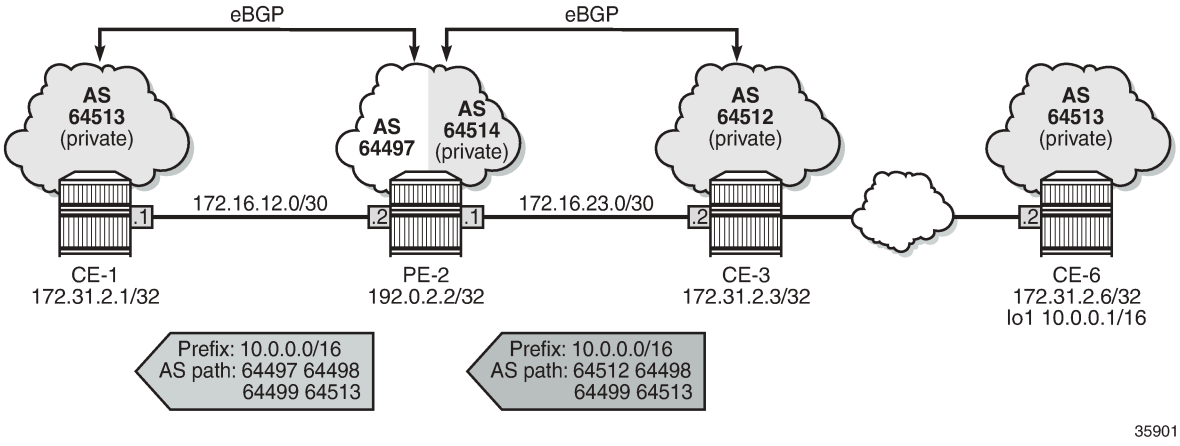
```
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
i     10.0.0.0/16                                       None        None
      172.16.12.2                                       None        0
      64497 64498 64499 64513                                       -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Again, this route is invalid because of the AS loop, as indicated by the flags:

```
[/]
A:admin@CE-1# show router bgp routes 10.0.0.0/16 detail | match Flags
Flags          : Invalid IGP AS-Loop      # Original Attributes
Flags          : Invalid IGP AS-Loop      # Modified Attributes
```

Figure 84: PE-2 removes the private ASNs except peer ASN 64513 shows the BGP routes received by PE-2 and CE-1.

Figure 84: PE-2 removes the private ASNs except peer ASN 64513



Replace private ASNs except peer AS 64513

On PE-2, the **remove-private** command is modified with the **replace true** option, as follows:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
```

```
            split-horizon true
            group "eBGP" {
                family {
                    ipv4 true
                }
            }
            neighbor "172.16.23.2" {
                group "eBGP"
                peer-as 64512
                local-as {
                    as-number 64514
                    private true
                }
            }
            neighbor "172.16.12.1" {
                group "eBGP"
                peer-as 64513
                remove-private {
                    skip-peer-as true
                    replace true
                }
            }
        }
```

The following BGP route for prefix 10.0.0.0/16 is received on CE-1. PE-2 has replaced the private ASN 64512 in the AS path with its own public ASN 64497, while the private ASN 64513 is preserved.

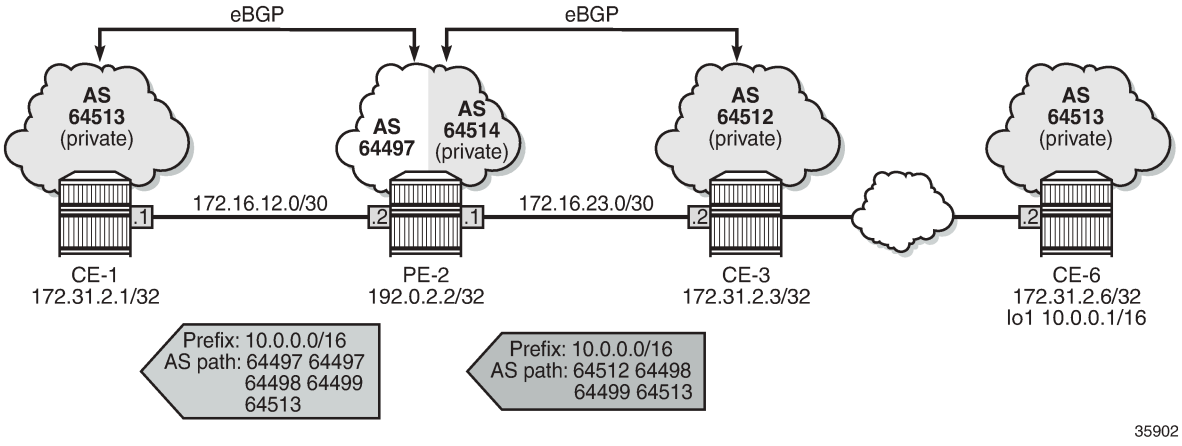
```
[/]
A:admin@CE-1# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:172.31.2.1       AS:64513       Local AS:64513
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
i     10.0.0.0/16                                      None        None
      172.16.12.2                                      None        0
      64497 64497 64498 64499 64513                                -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Again, the route is invalid because of the AS loop, as indicated by the flags:

```
[/]
A:admin@CE-1# show router bgp routes 10.0.0.0/16 detail | match Flags
Flags          : Invalid IGP AS-Loop      # Original Attributes
Flags          : Invalid IGP AS-Loop      # Modified Attributes
```

Figure 85: PE-2 replaces the private ASNs except peer ASN 64513 shows the received BGP routes on PE-2 and CE-1.

Figure 85: PE-2 replaces the private ASNs except peer ASN 64513



Loop-detect threshold N

If the received AS path has a local AS number of the router, the route is considered a loop if the number of occurrences is greater than the configured value N. By default, the loop-detect threshold in BGP is zero, meaning that any route with at least one occurrence of the local ASN is considered a loop and therefore invalid. The loop-detect threshold can be configured in the general **bgp** context, the **bgp group** context, or the **bgp neighbor** context.

On CE-1 and CE-6, the loop-detect threshold is configured with the value of 1 for group "eBGP", as follows:

```
# on CE-1 and CE-6:
configure {
    router "Base" {
        bgp {
            group "eBGP" {
                loop-detect-threshold 1
            }
```

Note:
Loop-detect thresholds are only applicable for newly learned prefixes. Existing loop states remain unchanged.

After the BGP session with peer PE-2 has been bounced (disabled and re-enabled), the prefix is learned again. The route is valid, because the local ASN only occurs once in the AS path attribute, so the loop-detect threshold is not violated on CE-1.

```
# Bounce BGP group "eBGP" on CE-1 and CE-6:
configure {
    router "Base" {
        bgp {
            group "eBGP" {
                admin-state disable
                commit
                admin-state enable
                commit
```

```
            }
```

```
[/]
A:admin@CE-1# show router bgp routes 10.0.0.0/16
===============================================================================
 BGP Router ID:172.31.2.1       AS:64513       Local AS:64513
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.0.0.0/16                                      None        None
      172.16.12.2                                      None        0
      64497 64497 64498 64499 64513                                -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

Note:
The loop-detect threshold is not reflected in the **show** commands.

Conclusion

Network operators may assign private ASNs to the BGP speakers in a region or domain. These private ASNs may not be unique when advertised into a public domain. In such cases, the **remove-private** command can either remove one or more private ASNs or replace the private ASNs with its public ASN.

BGP Route Leaking

This chapter provides information about BGP route leaking.

Topics in this chapter include:

Applicability

This chapter was initially written based on SR OS Release 14.0.R4. The MD-CLI in the current edition corresponds to SR OS Release 22.2.R2.

Overview

Route leaking refers to the process of copying a route from one router context to another.

Network administrators may need to leak routes between routing instances in the same SR OS router. BGP route leaking is an alternative to using import and export policies based on communities to exchange routes between Virtual Router and Forwarders (VRFs).

It is possible to leak a copy of a BGP route (including all its path attributes) from one routing instance to another in the same SR OS router. This BGP route leaking capability applies to IPv4, IPv6, and label-IPv4 routes. Leaking is supported from the GRT to a VPRN, from one VPRN to another VPRN, and from a VPRN to the GRT.

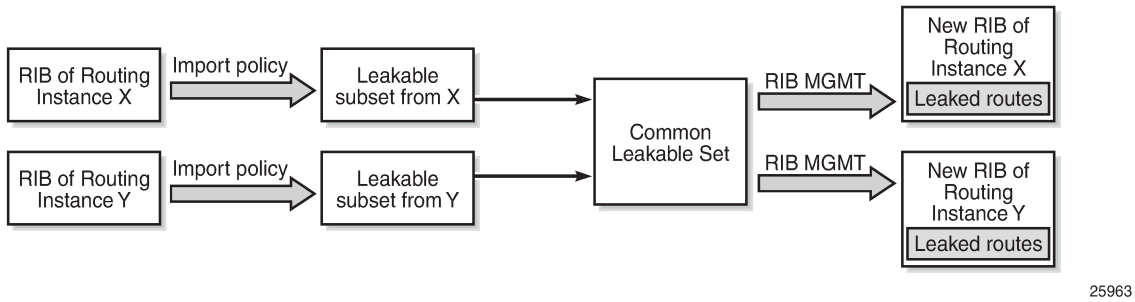
Any BGP route for an IPv4 or IPv6 prefix can be leaked. A BGP route does not have to be the best path or used for forwarding in the source instance in order to be leaked. In SR OS releases earlier than 19.10.R1, the BGP route had to be valid (that is, the next-hop must be resolved; the AS PATH must not exhibit a loop, for example). In SR OS Release 19.10.R1, and later, BGP in the base router can be configured to allow unresolved route leaking, as described in the *Unresolved Route Leaking from Base Router to VPRN* chapter in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Unicast Routing Protocols Advanced Configuration Guide for Classic CLI*.

An IPv4 or IPv6 BGP route becomes a candidate for leaking to another instance when it is specially marked by a BGP import policy. This marking is achieved by accepting the route with a **bgp-leak** action in the route policy. Routes that are candidates for leaking to other instances show a **leakable** flag in the output of various **show router bgp** commands.

To copy a leakable BGP route from a source instance into the BGP RIB of a target instance, the target instance must be configured with a leak-import policy that matches and accepts the leakable route. There are separate leak-import policies for IPv4 and IPv6 routes. Up to 15 leak-import policies can be chained together for more complex examples. In the target instance, the **show router bgp routes** command displays leaked BGP RIB-IN routes in addition to direct RIB-IN routes learned from neighbors of the routing

instance. A **leaked** flag is added to the leaked RIB-IN entries. Figure 86: BGP route leaking process shows the process of BGP route leaking.

Figure 86: BGP route leaking process



Leaked BGP routes can be advertised to BGP neighbors (peers) of the target routing instance. The BGP next hop of a leaked route is automatically reset to self whenever it is advertised to a peer of the target instance. Normal route advertisement rules apply: by default, the leaked route is advertised if it is the overall best path that is used as the active route to the destination and it is not blocked by the IBGP-to-IBGP split-horizon rule.

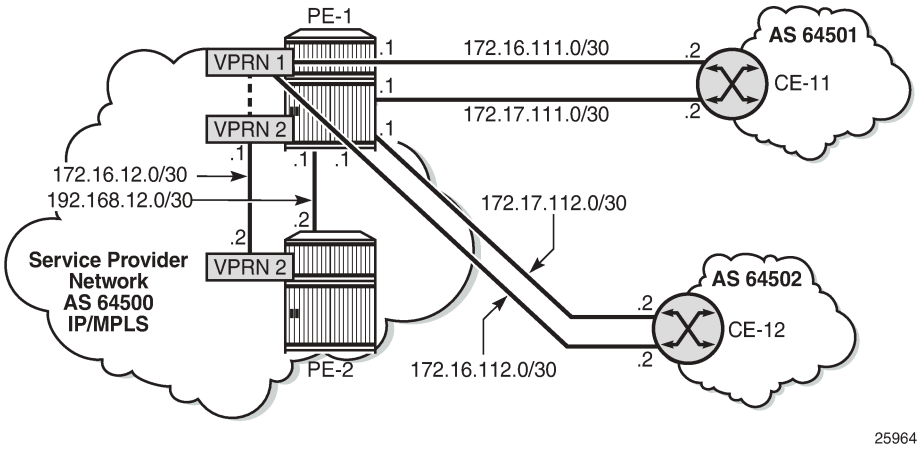
A BGP route leaked into a VPRN can be exported from the VPRN as a VPN-IPv4/v6 route if it matches the VRF export policy. Normal VPN export rules apply: by default, the leaked route is exported if it is the overall best path and it is used as the active route to the destination.

This chapter describes BGP route leaking only. For other routes, such as IS-IS, OSPF, RIP, and static routes, VPRN route leaking mechanisms apply that are protocol independent, see chapter *Traffic Leaking from VPRN to GRT* in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Unicast Routing Protocols Advanced Configuration Guide for Classic CLI*.

Configuration

Figure 87: Example topology shows the example topology used in this chapter, including the IPv4 addresses. For each of the examples, a dedicated figure will show the specific topology, which is a subset of the topology in Figure 87: Example topology. The interfaces also have IPv6 addresses, which will be shown in Figure 91: BGP IPv6 route leaking between VPRNs and Figure 92: BGP IPv6 route leaking from GRT and VPRN to VPRN. VPRN 2 also has CEs attached, but for simplicity, these are not shown on the figures and no CLI will be shown for any CE.

Figure 87: Example topology



The following examples will be explained:

- Example 1 - BGP IPv4 route leaking between VPRNs. Global BGP policy
- Example 2 - BGP IPv4 route leaking between VPRNs per neighbor
- Example 3 - BGP IPv4 route leaking from VPRN to GRT per BGP group
- Example 4 - BGP IPv4 route leaking from GRT to VPRN per neighbor
- Example 5 - BGP IPv6 route leaking between VPRNs. Global VPRN BGP configuration
- Example 6 - BGP IPv6 route leaking from GRT to VPRN and from VPRN to VPRN

Initial configuration

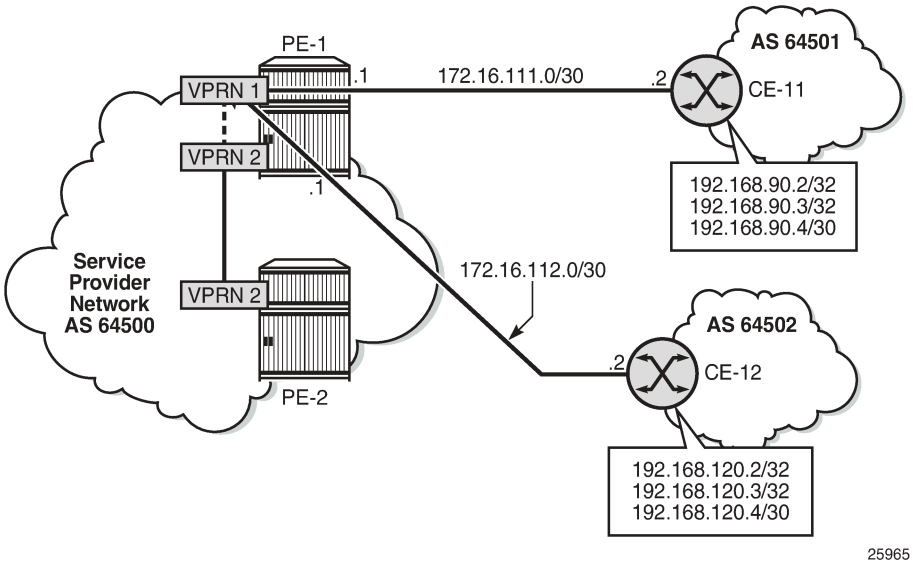
The nodes in the example topology have the following initial configuration:

- Cards, MDAs, ports
- Router interfaces
- IGP (IS-IS or OSPF) between the PEs
- LDP between the PEs
- VPRN "VPRN 1" on PE-1; VPRN "VPRN 2" on PE-1 and PE-2
- BGP (IBGP between the PEs; EBGP between PE-1 and the CEs)
  - On the PEs, BGP is configured in the base router and in the VPRNs.
- Loopback addresses and black-hole static routes in the CEs. Different routes are exported to GRT and VPRN 1 on PE-1

Example 1 - BGP IPv4 route leaking between VPRNs. Global BGP policy

Figure 88: BGP IPv4 route leaking between VPRNs shows the topology for this example. CE-11 exports routes such as 192.168.90.2/32 to VPRN 1 on PE-1, and CE-12 exports routes such as 192.168.120.2/32 to VPRN 1 on PE-1.

Figure 88: BGP IPv4 route leaking between VPRNs



In MD-CLI, all EBGP routes are by default rejected unless policies are configured. The following import policy accepts all BGP routes and is applied in VPRN 1.

```
# on PE-1:
configure {
    policy-options {
        policy-statement "import-bgp" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                }
            }
        }
    }
    service {
        vprn "VPRN 1" {
            bgp {
                import {
                    policy ["import-bgp"]
                }
            }
```

The routing table for VPRN 1 on PE-1 includes routes that are learned from CE-11 and CE-12, as follows:

```
[/]
A:admin@PE-1# show router 1 route-table

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
```

```
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
172.16.1.1/32                              Local   Local     00h04m46s  0
       system                                                     0
172.16.111.0/30                            Local   Local     00h04m46s  0
       int-PE-1-CE-11                                             0
172.16.112.0/30                            Local   Local     00h04m46s  0
       int-PE-1-CE-12                                             0
192.168.90.2/32                            Remote  BGP       00h00m21s  170
       172.16.111.2                                               0
192.168.90.3/32                            Remote  BGP       00h00m21s  170
       172.16.111.2                                               0
192.168.90.4/30                            Remote  BGP       00h00m21s  170
       172.16.111.2                                               0
192.168.120.2/32                           Remote  BGP       00h00m36s  170
       172.16.112.2                                               0
192.168.120.3/32                           Remote  BGP       00h00m36s  170
       172.16.112.2                                               0
192.168.120.4/32                           Remote  BGP       00h00m36s  170
       172.16.112.2                                               0
-------------------------------------------------------------------------------
No. of Routes: 9
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

These BGP routes are not leakable, by default, as follows:

```
[/]
A:admin@PE-1# show router 1 bgp routes ipv4 leakable
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
No Matching Entries Found.
===============================================================================
```

The routing table for VPRN 2 does not include any of these routes because BGP route leaking is disabled by default:

```
[/]
A:admin@PE-1# show router 2 route-table

===============================================================================
Route Table (Service: 2)
===============================================================================
Dest Prefix[Flags]                         Type    Proto     Age        Pref
      Next Hop[Interface Name]                                  Metric
-------------------------------------------------------------------------------
```

```
172.16.2.1/32                                   Local   Local     00h04m46s  0
       system                                                         0
172.16.2.2/32                                   Remote  BGP VPN   00h03m52s  170
       192.0.2.2 (tunneled)                                           0
172.16.12.0/30                                  Local   Local     00h04m46s  0
       int-PE-1-PE-2_VPN2                                             0
-------------------------------------------------------------------------------
No. of Routes: 3
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

To configure BGP route leaking, an import policy with **action>bgp-leak true** is required in VPRN 1. The BGP route leaking policy is configured on PE-1, as follows:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "BGP-Leak" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    bgp-leak true
                }
            }
        }
```

By adding **action>action-type accept** and **action>bgp-leak true**, BGP routes are imported and marked as BGP-leakable, meaning they are available to be copied—with their complete set of BGP path attributes—to the BGP RIB-IN of another routing instance.

In this example, the BGP route leaking policy replaces the import policy applied in VPRN 1 in the general BGP configuration, but the route leaking policy can also be configured in the group context, or per neighbor:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            bgp {
                delete import
                import {
                    policy ["BGP-Leak"]
                }
            }
```

With the preceding configuration, SR OS is marking all the BGP routes imported into the VPRN as leakable. The BGP routes originate from CE-11 or CE-12 in this example.

The following command shows which BGP routes in VPRN 1 are marked as leakable:

```
[/]
A:admin@PE-1# show router 1 bgp routes ipv4 leakable
===============================================================================
```

```
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  192.168.90.2/32                                  None        None
      172.16.111.2                                     None        0
      64501                                                        -
u*>i  192.168.90.3/32                                  None        None
      172.16.111.2                                     None        0
      64501                                                        -
u*>i  192.168.90.4/30                                  None        None
      172.16.111.2                                     None        0
      64501                                                        -
u*>i  192.168.120.2/32                                 None        None
      172.16.112.2                                     None        0
      64502                                                        -
u*>i  192.168.120.3/32                                 None        None
      172.16.112.2                                     None        0
      64502                                                        -
u*>i  192.168.120.4/32                                 None        None
      172.16.112.2                                     None        0
      64502                                                        -
-------------------------------------------------------------------------------
Routes : 6
===============================================================================
```

The routes learned from CE-11 and CE-12 are leakable. The following detailed output for one of the routes in the preceding list shows the flag "Leakable". The route source is external because the routes are imported (from CE-11 or CE-12):

```
[/]
A:admin@PE-1# show router 1 bgp routes 192.168.90.2/32 detail
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Original Attributes

Network        : 192.168.90.2/32
Nexthop        : 172.16.111.2
Path Id        : None
From           : 172.16.111.2
Res. Protocol  : LOCAL                 Res. Metric    : 0
Res. Nexthop   : 172.16.111.2
Local Pref.    : n/a                   Interface Name : int-PE-1-CE-11
---snip---
```

```
Originator Id  : None                  Peer Router Id : 172.16.0.11
Fwd Class      : None                  Priority       : None
Flags          : Used Valid Best IGP Leakable In-RTM
Route Source   : External
AS-Path        : 64501
---snip---
```

BGP leakable routes can be imported into another VPRN. Prefix lists can be used to filter specific routes for BGP leaking, but that is not configured in this example. The following import policy is configured on PE-1 to import BGP leakable routes:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "Import-Leakable-Routes" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                }
            }
        }
```

In each of the examples, the same import policy will be used. The import policy to import BGP leakable routes is applied in the VPRN 2 on PE-1 as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 2" {
            bgp {
               rib-management {
                   ipv4 {
                        leak-import {
                           policy ["Import-Leakable-Routes"]
                        }
                   }
               }
            }
```

The following command shows that VPRN 2 imported leaked BGP routes from VPRN 1. The status code "l" indicates that the route is leaked.

```
[/]
A:admin@PE-1# show router 2 bgp routes ipv4 leaked
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
```

```
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>li 192.168.90.2/32                                  100         None
      172.16.111.2 (VPRN 1)                            None        0
      64501                                                        -
u*>li 192.168.90.3/32                                  100         None
      172.16.111.2 (VPRN 1)                            None        0
      64501                                                        -
u*>li 192.168.90.4/30                                  100         None
      172.16.111.2 (VPRN 1)                            None        0
      64501                                                        -
u*>li 192.168.120.2/32                                 100         None
      172.16.112.2 (VPRN 1)                            None        0
      64502                                                        -
u*>li 192.168.120.3/32                                 100         None
      172.16.112.2 (VPRN 1)                            None        0
      64502                                                        -
u*>li 192.168.120.4/32                                 100         None
      172.16.112.2 (VPRN 1)                            None        0
      64502                                                        -
-------------------------------------------------------------------------------
Routes : 6
===============================================================================
```

The flags in the detailed output for a particular leaked BGP route from the preceding list include the flag "Leaked". The route source for this leaked route is VPRN 1 and all BGP attributes are preserved, as follows:

```
[/]
A:admin@PE-1# show router 2 bgp routes 192.168.90.2/32 detail
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Original Attributes

Network        : 192.168.90.2/32
Nexthop        : 172.16.111.2 (VPRN 1)
Path Id        : None
From           : BGP VPRN 1
Res. Protocol  : LOCAL                  Res. Metric    : 0
Res. Nexthop   : 172.16.111.2
Local Pref.    : 100                    Interface Name : int-PE-1-CE-11
Aggregator AS  : None                   Aggregator     : None
Atomic Aggr.   : Not Atomic             MED            : None
AIGP Metric    : None                   IGP Cost       : 0
Connector      : None
Community      : No Community Members
Cluster        : No Cluster Members
Originator Id  : None                   Peer Router Id : 0.0.0.0
Fwd Class      : None                   Priority       : None
Flags          : Used Valid Best IGP Leaked In-RTM
Route Source   : Leaked from VPRN 1
AS-Path        : 64501
```

```
Route Tag      : 0
Neighbor-AS    : 64501
Orig Validation: NotFound
Source Class   : 0                     Dest Class     : 0
Add Paths Send : Default
RIB Priority   : Normal
Last Modified  : 00h00m36s
---snip---
```

The route table for VPRN 2 in the neighbor PE-2 contains the leaked routes, as follows:

```
[/]
A:admin@PE-2# show router 2 route-table

===============================================================================
Route Table (Service: 2)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
172.16.2.1/32                                  Remote  BGP VPN   00h12m14s  170
       192.0.2.1 (tunneled)                                          0
172.16.2.2/32                                  Local   Local     00h12m59s  0
       system                                                        0
172.16.12.0/30                                 Local   Local     00h12m59s  0
       int-PE-2-PE-1_VPN2                                            0
192.168.90.2/32                                Remote  BGP       00h03m22s  170
       172.16.12.1                                                   0
192.168.90.3/32                                Remote  BGP       00h03m22s  170
       172.16.12.1                                                   0
192.168.90.4/30                                Remote  BGP       00h03m22s  170
       172.16.12.1                                                   0
192.168.120.2/32                               Remote  BGP       00h03m22s  170
       172.16.12.1                                                   0
192.168.120.3/32                               Remote  BGP       00h03m22s  170
       172.16.12.1                                                   0
192.168.120.4/32                               Remote  BGP       00h03m22s  170
       172.16.12.1                                                   0
-------------------------------------------------------------------------------
No. of Routes: 9
```

Example 2 - BGP IPv4 route leaking between VPRNs per neighbor

The topology used for this example is the same as for Example 1; see Figure 88: BGP IPv4 route leaking between VPRNs. Both CEs export the same routes as in the preceding example, and the BGP route leaking policy is identical:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "BGP-Leak" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    bgp-leak true
```

```
                }
            }
        }
```

In the preceding example, the BGP route leaking policy was applied in the global **bgp** context in VPRN 1 and consequently, it applied to routes from all neighbors. In this example, the BGP route leaking policy is applied in VPRN 1 for neighbor CE-11 only, as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            bgp {
                delete import
                neighbor "172.16.111.2" {
                    import {
                        policy ["BGP-Leak"]
                    }
                }
            }
```

This import policy implies that only routes learned from CE-11 will be leakable. The following command shows all the BGP routes learned in VPRN 1 on PE-1.

```
[/]
A:admin@PE-1# show router 1 bgp routes
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  192.168.90.2/32                                  None        None
      172.16.111.2                                     None        0
      64501                                                        -
u*>i  192.168.90.3/32                                  None        None
      172.16.111.2                                     None        0
      64501                                                        -
u*>i  192.168.90.4/30                                  None        None
      172.16.111.2                                     None        0
      64501                                                        -
i     192.168.120.2/32                                 None        None
      172.16.112.2                                     None        0
      64502                                                        -
i     192.168.120.3/32                                 None        None
      172.16.112.2                                     None        0
      64502                                                        -
i     192.168.120.4/32                                 None        None
      172.16.112.2                                     None        0
      64502                                                        -
-------------------------------------------------------------------------------
Routes : 6
```

```
===============================================================================
```

Only the routes imported from CE-11 are accepted and leakable. The following command shows which IPv4 BGP routes are marked as leakable in VPRN 1 on PE-1:

```
[/]
A:admin@PE-1# show router 1 bgp routes ipv4 leakable
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  192.168.90.2/32                                   None        None
      172.16.111.2                                      None        0
      64501                                                         -
u*>i  192.168.90.3/32                                   None        None
      172.16.111.2                                      None        0
      64501                                                         -
u*>i  192.168.90.4/30                                   None        None
      172.16.111.2                                      None        0
      64501                                                         -
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

The BGP leakable routes can be imported into another VPRN instance. The import policy is the same as for Example 1:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "Import-Leakable-Routes" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                }
            }
        }
```

This import policy is applied in VPRN 2 in the same way as in example 1:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 2" {
            bgp {
```

```
                rib-management {
                    ipv4 {
                        leak-import {
                            policy ["Import-Leakable-Routes"]
                        }
                    }
                }
            }
```

The following command shows the leaked routes in VPRN 2. Each of these routes is leaked from VPRN 1, as indicated between brackets in the following output. Only routes learned from CE-11 in VPRN 1 are leaked to VPRN 2.

```
[/]
A:admin@PE-1# show router 2 bgp routes ipv4 leaked
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>li 192.168.90.2/32                                  100         None
      172.16.111.2 (VPRN 1)                            None        0
      64501                                                        -
u*>li 192.168.90.3/32                                  100         None
      172.16.111.2 (VPRN 1)                            None        0
      64501                                                        -
u*>li 192.168.90.4/30                                  100         None
      172.16.111.2 (VPRN 1)                            None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

The detailed output for any of these BGP routes shows that the flag "Leaked" is set and that the route source corresponds to VPRN 1, as follows for route 192.168.90.2/32:

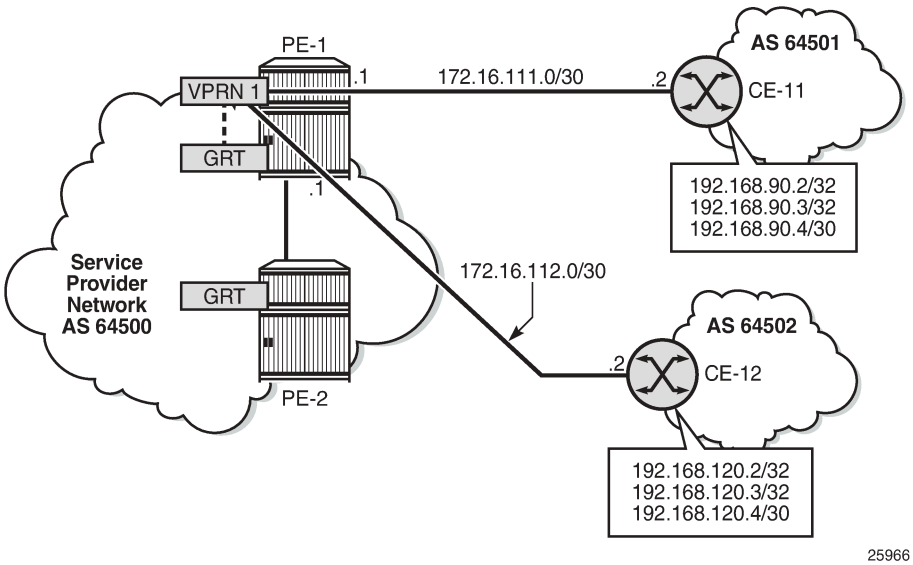
```
[/]
A:admin@PE-1# show router 2 bgp routes 192.168.90.2/32 detail
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Original Attributes

Network        : 192.168.90.2/32
```

```
Nexthop         : 172.16.111.2 (VPRN 1)
Path Id         : None
From            : BGP VPRN 1
Res. Protocol   : LOCAL                 Res. Metric    : 0
Res. Nexthop    : 172.16.111.2
Local Pref.     : 100                   Interface Name : int-PE-1-CE-11
Aggregator AS   : None                  Aggregator     : None
Atomic Aggr.    : Not Atomic            MED            : None
AIGP Metric     : None                  IGP Cost       : 0
Connector       : None
Community       : No Community Members
Cluster         : No Cluster Members
Originator Id   : None                  Peer Router Id : 0.0.0.0
Fwd Class       : None                  Priority       : None
Flags           : Used Valid Best IGP Leaked In-RTM
Route Source    : Leaked from VPRN 1
AS-Path         : 64501
---snip---
```

Example 3 - BGP IPv4 route leaking from VPRN to GRT per BGP group

Figure 89: BGP IPv4 route leaking from VPRN to GRT shows the topology for this example. CE-11 and CE-12 export the same routes to VPRN 1. The routes originating from CE-11 will be accepted, marked as leakable, and leaked to the GRT.

Figure 89: BGP IPv4 route leaking from VPRN to GRT



The import policy is the same as in the preceding examples:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "BGP-Leak" {
            entry 10 {
                from {
                    protocol {
```

```
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    bgp-leak true
                }
            }
        }
```

This policy is applied for BGP group "EBGP_64500to64501_IPv4", so the routes from CE-11 will be accepted and marked as leakable:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            bgp {
                group "EBGP_64500to64501_IPv4" {
                    import {
                        policy ["BGP-Leak"]
                    }
                }
            }
```

The routing table for VPRN 1 in PE-1 contains the BGP routes exported by CE-11, as follows:

```
[/]
A:admin@PE-1# show router 1 route-table

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
172.16.1.1/32                                   Local   Local     00h14m37s  0
       system                                                          0
172.16.111.0/30                                 Local   Local     00h14m37s  0
       int-PE-1-CE-11                                                  0
172.16.112.0/30                                 Local   Local     00h14m37s  0
       int-PE-1-CE-12                                                  0
192.168.90.2/32                                 Remote  BGP       00h01m45s  170
       172.16.111.2                                                    0
192.168.90.3/32                                 Remote  BGP       00h01m45s  170
       172.16.111.2                                                    0
192.168.90.4/30                                 Remote  BGP       00h01m45s  170
       172.16.111.2                                                    0
-------------------------------------------------------------------------------
No. of Routes: 6
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The routing table of the base router does not include any of the BGP routes exported by the CEs, as follows:

```
[/]
A:admin@PE-1# show router route-table
```

```
===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
172.17.111.0/30                                 Local   Local     00h14m37s  0
       int-PE-1-CE-11                                               0
172.17.112.0/30                                 Local   Local     00h14m37s  0
       int-PE-1-CE-12                                               0
192.0.2.1/32                                    Local   Local     00h14m37s  0
       system                                                       0
192.0.2.2/32                                    Remote  ISIS      00h14m13s  15
       192.168.12.2                                                 10
192.168.12.0/30                                 Local   Local     00h14m37s  0
       int-PE-1-PE-2                                                0
-------------------------------------------------------------------------------
No. of Routes: 5
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The following command shows the leakable BGP routes in VPRN 1:

```
[/]
A:admin@PE-1# show router 1 bgp routes ipv4 leakable
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  192.168.90.2/32                                   None        None
      172.16.111.2                                      None        0
      64501                                                         -
u*>i  192.168.90.3/32                                   None        None
      172.16.111.2                                      None        0
      64501                                                         -
u*>i  192.168.90.4/30                                   None        None
      172.16.111.2                                      None        0
      64501                                                         -
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

The leakable BGP routes in VPRN 1 can be imported into the GRT. The import policy is identical to the import policy in the preceding examples, as follows:

```
# on PE-1:
configure {
```

```
    policy-options {
        policy-statement "Import-Leakable-Routes" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                }
            }
        }
```

This import policy is applied in the base router, as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            rib-management {
                ipv4 {
                    leak-import {
                        policy ["Import-Leakable-Routes"]
                    }
                }
            }
```

As a result, the leakable BGP routes in VPRN 1 are leaked to the GRT, as follows:

```
[/]
A:admin@PE-1# show router bgp routes ipv4 leaked
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>li 192.168.90.2/32                                  100         None
      172.16.111.2 (VPRN 1)                            None        0
      64501                                                        -
u*>li 192.168.90.3/32                                  100         None
      172.16.111.2 (VPRN 1)                            None        0
      64501                                                        -
u*>li 192.168.90.4/30                                  100         None
      172.16.111.2 (VPRN 1)                            None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

The detailed information for any of these leaked routes shows that the flag "Leaked" is present and that the route source is VPRN 1, as follows:

```
[/]
A:admin@PE-1# show router bgp routes 192.168.90.2/32 detail
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Original Attributes

Network        : 192.168.90.2/32
Nexthop        : 172.16.111.2 (VPRN 1)
Path Id        : None
From           : BGP VPRN 1
Res. Protocol  : LOCAL                  Res. Metric    : 0
Res. Nexthop   : 172.16.111.2
Local Pref.    : 100                    Interface Name : int-PE-1-CE-11
Aggregator AS  : None                   Aggregator     : None
Atomic Aggr.   : Not Atomic             MED            : None
AIGP Metric    : None                   IGP Cost       : 0
Connector      : None
Community      : No Community Members
Cluster        : No Cluster Members
Originator Id  : None                   Peer Router Id : 0.0.0.0
Fwd Class      : None                   Priority       : None
Flags          : Used Valid Best IGP Leaked In-RTM
Route Source   : Leaked from VPRN 1
AS-Path        : 64501
---snip---
```

The GRT includes the leaked routes, as follows:

```
[/]
A:admin@PE-1# show router route-table

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
172.17.111.0/30                                 Local   Local     00h16m10s  0
       int-PE-1-CE-11                                               0
172.17.112.0/30                                 Local   Local     00h16m10s  0
       int-PE-1-CE-12                                               0
192.0.2.1/32                                    Local   Local     00h16m10s  0
       system                                                       0
192.0.2.2/32                                    Remote  ISIS      00h15m47s  15
       192.168.12.2                                                 10
192.168.12.0/30                                 Local   Local     00h16m10s  0
       int-PE-1-PE-2                                                0
192.168.90.2/32                                 Remote  BGP       00h00m36s  170
       172.16.111.2                                                 0
192.168.90.3/32                                 Remote  BGP       00h00m36s  170
       172.16.111.2                                                 0
```

```
192.168.90.4/30                                 Remote  BGP       00h00m36s  170
       172.16.111.2                                                    0
-------------------------------------------------------------------------------
No. of Routes: 8
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

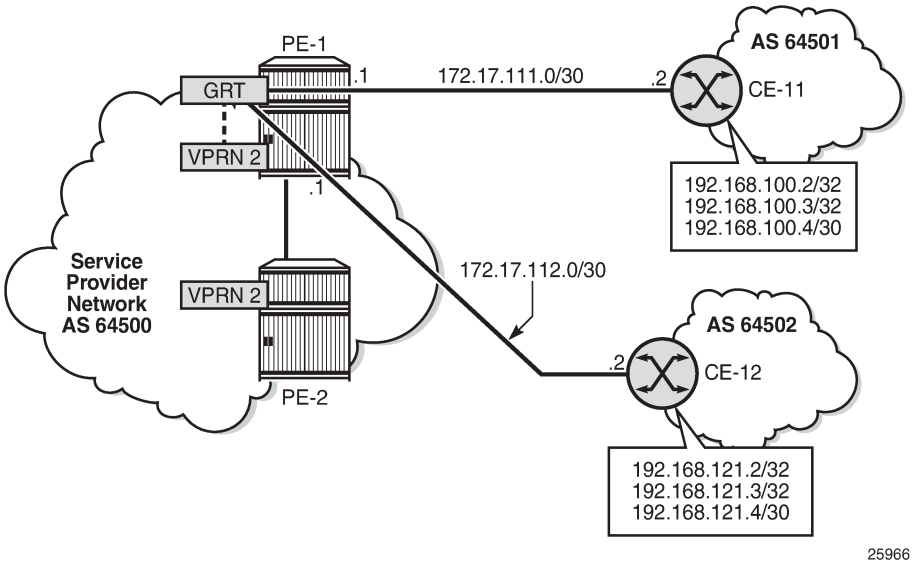
The GRT on neighbor PE-2 also includes the leaked routes, as follows:

```
[/]
A:admin@PE-2# show router route-table

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
192.0.2.1/32                                    Remote  ISIS      00h15m47s  15
       192.168.12.1                                                    10
192.0.2.2/32                                    Local   Local     00h15m55s  0
       system                                                          0
192.168.12.0/30                                 Local   Local     00h15m55s  0
       int-PE-2-PE-1                                                   0
192.168.90.2/32                                 Remote  BGP       00h00m07s  170
       192.168.12.1                                                    10
192.168.90.3/32                                 Remote  BGP       00h00m07s  170
       192.168.12.1                                                    10
192.168.90.4/30                                 Remote  BGP       00h00m07s  170
       192.168.12.1                                                    10
-------------------------------------------------------------------------------
No. of Routes: 6
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

Example 4 - BGP IPv4 route leaking from GRT to VPRN per neighbor

Figure 90: BGP IPv4 route leaking from GRT to VPRN shows the topology for this example, and the corresponding IP addresses. CE-11 exports routes such as 192.168.100.2/32 to the base router and CE-12 exports routes such as 192.168.121.2/32 to the base router. The routes will be leaked from the base router to VPRN 2 if matched by an import policy in the base router of PE-1.

Figure 90: BGP IPv4 route leaking from GRT to VPRN



On PE-1, the following import policy accepts BGP routes and marks them as leakable:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "BGP-Leak" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    bgp-leak true
                }
            }
        }
```

This import policy is applied for neighbor 172.17.111.2 in the base router, as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            neighbor "172.17.111.2" {
                group "EBGP_64500to64501_IPv4"
                import {
                    policy ["BGP-Leak"]
                }
            }
        }
```

The policy is not applied for neighbor 172.17.112.2 on CE-12, so only the routes from CE-11 will be accepted and marked as leakable:

```
[/]
A:admin@PE-1# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  192.168.100.2/32                                 None        None
      172.17.111.2                                     None        0
      64501                                                        -
u*>i  192.168.100.3/32                                 None        None
      172.17.111.2                                     None        0
      64501                                                        -
u*>i  192.168.100.4/30                                 None        None
      172.17.111.2                                     None        0
      64501                                                        -
i     192.168.121.2/32                                 None        None
      172.17.112.2                                     None        0
      64502                                                        -
i     192.168.121.3/32                                 None        None
      172.17.112.2                                     None        0
      64502                                                        -
i     192.168.121.4/30                                 None        None
      172.17.112.2                                     None        0
      64502                                                        -
-------------------------------------------------------------------------------
Routes : 6
===============================================================================
```

The GRT in PE-1 includes BGP routes learned from CE-11, as follows:

```
[/]
A:admin@PE-1# show router route-table

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
172.17.111.0/30                               Local   Local     00h21m08s  0
       int-PE-1-CE-11                                               0
172.17.112.0/30                               Local   Local     00h21m08s  0
       int-PE-1-CE-12                                               0
192.0.2.1/32                                  Local   Local     00h21m08s  0
       system                                                       0
192.0.2.2/32                                  Remote  ISIS      00h20m48s  15
       192.168.12.2                                                 10
192.168.12.0/30                               Local   Local     00h21m08s  0
       int-PE-1-PE-2                                                0
```

```
192.168.100.2/32                                Remote  BGP       00h01m21s  170
       172.17.111.2                                                    0
192.168.100.3/32                                Remote  BGP       00h01m21s  170
       172.17.111.2                                                    0
192.168.100.4/30                                Remote  BGP       00h01m21s  170
       172.17.111.2                                                    0
-------------------------------------------------------------------------------
No. of Routes: 8
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The following command shows that only the routes imported from neighbor CE-11 are marked as leakable in the GRT:

```
[/]
A:admin@PE-1# show router bgp routes ipv4 leakable
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  192.168.100.2/32                                  None        None
      172.17.111.2                                      None        0
      64501                                                         -
u*>i  192.168.100.3/32                                  None        None
      172.17.111.2                                      None        0
      64501                                                         -
u*>i  192.168.100.4/30                                  None        None
      172.17.111.2                                      None        0
      64501                                                         -
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

The leakable BGP routes in the GRT can be imported into VPRN 2. The import policy is identical to the import policy in the preceding examples, as follows:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "Import-Leakable-Routes" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
```

```
                }
            }
        }
```

This import policy is applied in VPRN 2, as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 2" {
            bgp {
                rib-management {
                    ipv4 {
                        leak-import {
                            policy ["Import-Leakable-Routes"]
                        }
                    }
                }
```

The following command shows the imported leaked BGP routes in VPRN 2. The source of these leaked routes is the base router, not a VPRN.

```
[/]
A:admin@PE-1# show router 2 bgp routes ipv4 leaked
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>li 192.168.100.2/32                                 100         None
      172.17.111.2 (Base)                              None        0
      64501                                                        -
u*>li 192.168.100.3/32                                 100         None
      172.17.111.2 (Base)                              None        0
      64501                                                        -
u*>li 192.168.100.4/30                                 100         None
      172.17.111.2 (Base)                              None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

Any of these leaked BGP routes has the flag "leaked", and the route source is the base router (leaked from base), as follows:

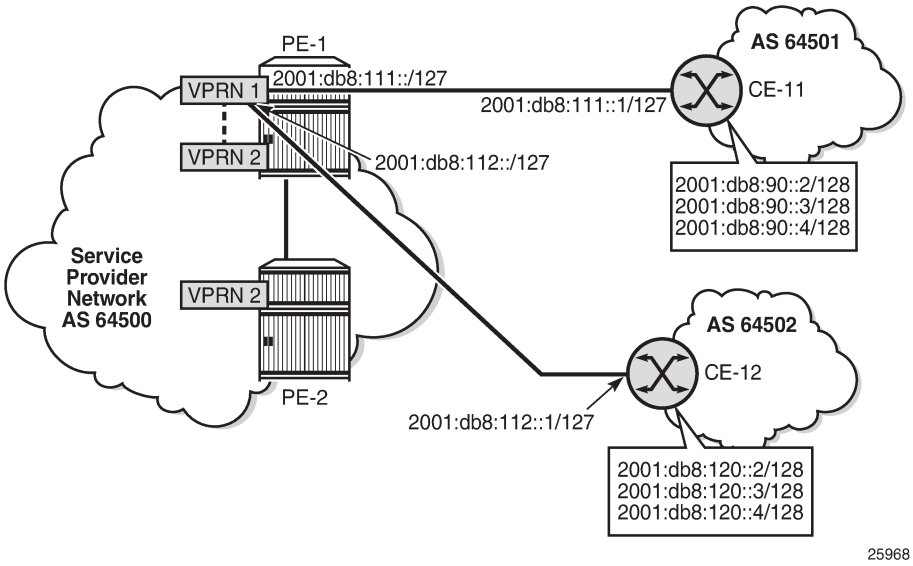
```
[/]
A:admin@PE-1# show router 2 bgp routes 192.168.100.2/32 detail
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
```

```
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Original Attributes

Network        : 192.168.100.2/32
Nexthop        : 172.17.111.2 (Base)
Path Id        : None
From           : BGP Base
Res. Protocol  : LOCAL                  Res. Metric    : 0
Res. Nexthop   : 172.17.111.2
Local Pref.    : 100                    Interface Name : int-PE-1-CE-11
Aggregator AS  : None                   Aggregator     : None
Atomic Aggr.   : Not Atomic             MED            : None
AIGP Metric    : None                   IGP Cost       : 0
Connector      : None
Community      : No Community Members
Cluster        : No Cluster Members
Originator Id  : None                   Peer Router Id : 0.0.0.0
Fwd Class      : None                   Priority       : None
Flags          : Used Valid Best IGP Leaked In-RTM
Route Source   : Leaked from Base
AS-Path        : 64501
---snip---
```

Example 5 - BGP IPv6 route leaking between VPRNs. Global VPRN BGP configuration

Figure 91: BGP IPv6 route leaking between VPRNs shows the topology and the IP addresses used for this example. CE-11 exports routes such as 2001:db8:90::2/128 to VPRN 1 on PE-1, and CE-12 exports routes such as 2001:db8:120::2/128 to VPRN 1 on PE-1.

Figure 91: BGP IPv6 route leaking between VPRNs



The following policy imports BGP routes and marks them as leakable:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "BGP-Leak" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    bgp-leak true
                }
            }
        }
```

This import policy is applied in the general **bgp** context in VPRN 1:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            bgp {
                import {
                    policy ["BGP-Leak"]
                }
            }
```

The following route table includes three BGP routes exported by CE-11 and three BGP routes exported by CE-12:

```
[/]
```

```
A:admin@PE-1# show router 1 route-table family ipv6

===============================================================================
IPv6 Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
2001:db8::1:1/128                             Local   Local     00h25m40s  0
       system                                                        0
2001:db8:90::2/128                            Remote  BGP       00h01m22s  170
       2001:db8:111::1                                               0
2001:db8:90::3/128                            Remote  BGP       00h01m22s  170
       2001:db8:111::1                                               0
2001:db8:90::4/126                            Remote  BGP       00h01m22s  170
       2001:db8:111::1                                               0
2001:db8:111::/127                            Local   Local     00h25m40s  0
       int-PE-1-CE-11                                                0
2001:db8:112::/127                            Local   Local     00h25m40s  0
       int-PE-1-CE-12                                                0
2001:db8:120::2/128                           Remote  BGP       00h01m04s  170
       2001:db8:112::1                                               0
2001:db8:120::3/128                           Remote  BGP       00h01m04s  170
       2001:db8:112::1                                               0
2001:db8:120::4/126                           Remote  BGP       00h01m04s  170
       2001:db8:112::1                                               0
-------------------------------------------------------------------------------
No. of Routes: 9
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

All the routes imported into the VPRN using BGP are marked as leakable. The following command shows which BGP IPv6 routes are marked as leakable in VPRN 1:

```
[/]
A:admin@PE-1# show router 1 bgp routes ipv6 leakable
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv6 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  2001:db8:90::2/128                               None        None
      2001:db8:111::1                                  None        0
      64501                                                        -
u*>i  2001:db8:90::3/128                               None        None
      2001:db8:111::1                                  None        0
      64501                                                        -
u*>i 2001:db8:90::4/126                                None        None
      2001:db8:111::1                                  None        0
      64501                                                        -
```

```
u*>i  2001:db8:120::2/128                                None        None
      2001:db8:112::1                                    None        0
      64502                                                          -
u*>i  2001:db8:120::3/128                                None        None
      2001:db8:112::1                                    None        0
      64502                                                          -
u*>i 2001:db8:120::4/126                                 None        None
      2001:db8:112::1                                    None        0
      64502                                                          -
-------------------------------------------------------------------------------
Routes : 6
===============================================================================
```

The BGP leakable routes can be imported into VPRN 2 when the following import policy is configured and applied in VPRN 2:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "Import-Leakable-Routes" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                }
            }
        }
```

The only difference from IPv4 routes is that the policy is applied to the IPv6 context of the RIB management:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 2" {
            bgp {
                rib-management {
                    ipv6 {
                        leak-import {
                            policy ["Import-Leakable-Routes"]
                        }
                    }
```

The following command shows that the VPRN is importing the leaked BGP IPv6 routes from another VPRN instance:

```
[/]
A:admin@PE-1# show router 2 bgp routes ipv6 leaked
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
```

```
BGP IPv6 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>li 2001:db8:90::2/128                               100         None
      2001:db8:111::1 (VPRN 1)                         None        0
      64501                                                        -
u*>li 2001:db8:90::3/128                               100         None
      2001:db8:111::1 (VPRN 1)                         None        0
      64501                                                        -
u*>li 2001:db8:90::4/126                               100         None
      2001:db8:111::1 (VPRN 1)                         None        0
      64501                                                        -
u*>li 2001:db8:120::2/128                              100         None
      2001:db8:112::1 (VPRN 1)                         None        0
      64502                                                        -
u*>li 2001:db8:120::3/128                              100         None
      2001:db8:112::1 (VPRN 1)                         None        0
      64502                                                        -
u*>li 2001:db8:120::4/126                              100         None
      2001:db8:112::1 (VPRN 1)                         None        0
      64502                                                        -
-------------------------------------------------------------------------------
Routes : 6
===============================================================================
```

The BGP routes have the flag "leaked" and the route source is VPRN 1, as follows:

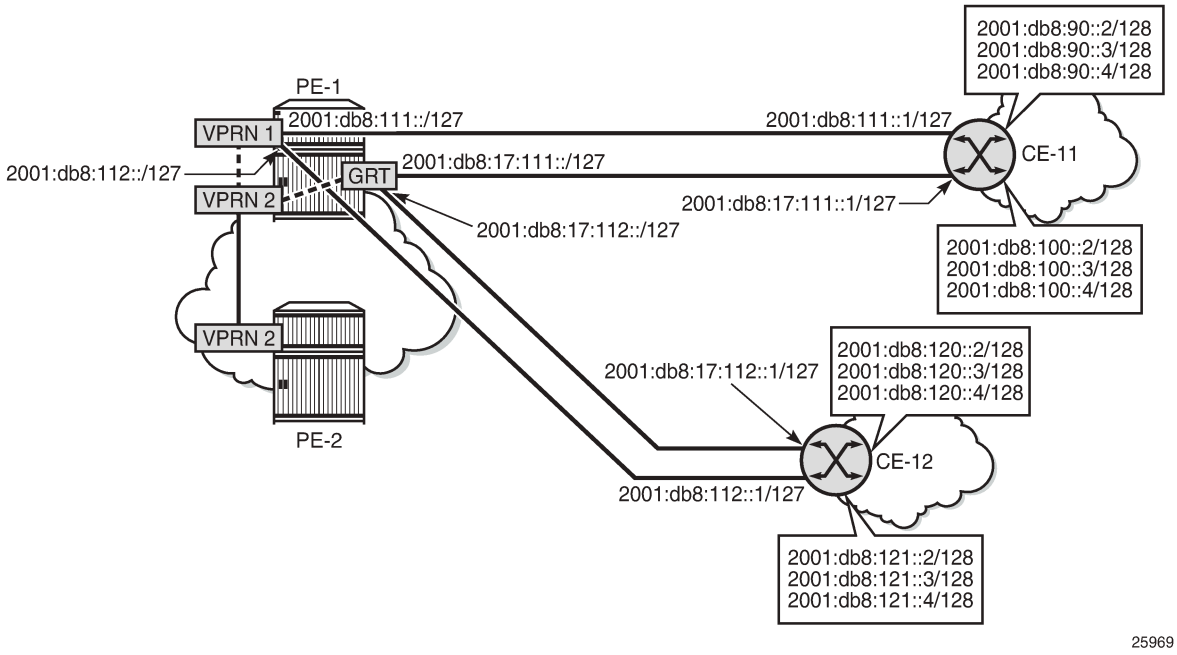
```
[/]
A:admin@PE-1# show router 2 bgp routes 2001:db8:90::2/128 detail
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv6 Routes
===============================================================================
Original Attributes

Network        : 2001:db8:90::2/128
Nexthop        : 2001:db8:111::1 (VPRN 1)
Path Id        : None
From           : BGP VPRN 1
Res. Protocol  : LOCAL                  Res. Metric    : 0
Res. Nexthop   : 2001:db8:111::1
Local Pref.    : 100                    Interface Name : int-PE-1-CE-11
Aggregator AS  : None                   Aggregator     : None
Atomic Aggr.   : Not Atomic             MED            : None
AIGP Metric    : None                   IGP Cost       : 0
Connector      : None
Community      : No Community Members
Cluster        : No Cluster Members
Originator Id  : None                   Peer Router Id : 0.0.0.0
Fwd Class      : None                   Priority       : None
Flags          : Used Valid Best IGP Leaked In-RTM
Route Source   : Leaked from VPRN 1
AS-Path        : 64501
```

```
---snip---
```

Example 6 - BGP IPv6 route leaking from GRT to VPRN and from VPRN to VPRN

Figure 92: BGP IPv6 route leaking from GRT and VPRN to VPRN shows the topology and the IPv6 addresses used in this example. CE-11 exports IPv6 routes such as 2001:db8:90::2/128 to VPRN 1 and IPv6 routes such as 2001:db8:100::2/128 to the GRT. CE-12 exports IPv6 routes such as 2001:db8:120::2/128 to VPRN 1 and IPv6 routes such as 2001:db8:121::2/128 to the GRT.

Figure 92: BGP IPv6 route leaking from GRT and VPRN to VPRN



The policy to mark imported BGP routes as leakable can be identical to the policy used in the preceding examples. However, in this case, prefix-lists are added as a filter. VPRN 1 may accept routes such as 2001:db8:90::2/128 and 2001:db8:120::2/128.

```
# on PE-1:
configure {
    policy-options {
        prefix-list "2001:db8:120::" {
            prefix 2001:db8:120::/100 type longer {
            }
        }
        prefix-list "2001:db8:90::" {
            prefix 2001:db8:90::/100 type longer {
            }
        }
        policy-statement "BGP-Leak-VPRN1_90_120" {
            entry 10 {
                from {
                    prefix-list ["2001:db8:90::"]
                    protocol {
                        name [bgp]
```

```
                    }
                }
                action {
                    action-type accept
                    bgp-leak true
                }
            }
            entry 20 {
                from {
                    prefix-list ["2001:db8:120::"]
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    bgp-leak true
                }
            }
        }
```

This import policy is applied in the general BGP settings for VPRN 1, as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            bgp {
                import {
                    policy ["BGP-Leak-VPRN1_90_120"]
                }
            }
```

In a similar way, the base router may accept routes such as 2001:8db:100::2/128 and 2001:8db:121::2/128:

```
# on PE-1:
configure {
    policy-options {
        prefix-list "2001:db8:100::" {
            prefix 2001:db8:100::/100 type longer {
            }
        }
        prefix-list "2001:db8:121::" {
            prefix 2001:db8:121::/100 type longer {
            }
        }
        policy-statement "BGP-Leak-Base_100_121" {
            entry 10 {
                from {
                    prefix-list ["2001:db8:100::"]
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    bgp-leak true
                }
            }
            entry 20 {
                from {
```

```
                    prefix-list ["2001:db8:121::"]
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    bgp-leak true
                }
            }
        }
```

This policy is applied in the base router for BGP neighbor 2001:db8:17:111::1 (CE-11), as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            neighbor "2001:db8:17:111::1" {
                import {
                    policy ["BGP-Leak-Base_100_121"]
                }
            }
```

The import policy in the base router is not applied for BGP neighbor 2001:db8::112::1 (CE-12), so only the routes exported by CE-11 will be accepted and marked as leakable. The IPv6 routing table in the base router is as follows:

```
[/]
A:admin@PE-1# show router route-table family ipv6

===============================================================================
IPv6 Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
2001:db8::1/128                                 Local   Local     00h31m24s  0
       system                                                         0
2001:db8::2/128                                 Remote  ISIS      00h31m04s  15
       fe80::b:1ff:fe01:1-"int-PE-1-PE-2"                            10
2001:db8:12::/126                               Local   Local     00h31m23s  0
       int-PE-1-PE-2                                                  0
2001:db8:17:111::/127                           Local   Local     00h31m22s  0
       int-PE-1-CE-11                                                 0
2001:db8:17:112::/127                           Local   Local     00h31m23s  0
       int-PE-1-CE-12                                                 0
2001:db8:100::2/128                             Remote  BGP       00h01m18s  170
       2001:db8:17:111::1                                             0
2001:db8:100::3/128                             Remote  BGP       00h01m18s  170
       2001:db8:17:111::1                                             0
2001:db8:100::4/126                             Remote  BGP       00h01m18s  170
       2001:db8:17:111::1                                             0
-------------------------------------------------------------------------------
No. of Routes: 8
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The IPv6 routing table for VPRN 1 contains routes exported by CE-11 and CE-12, as follows:

```
[/]
A:admin@PE-1# show router 1 route-table family ipv6

===============================================================================
IPv6 Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
2001:db8::1:1/128                               Local   Local     00h31m22s  0
       system                                                        0
2001:db8:90::2/128                              Remote  BGP       00h02m03s  170
       2001:db8:111::1                                               0
2001:db8:90::3/128                              Remote  BGP       00h02m03s  170
       2001:db8:111::1                                               0
2001:db8:90::4/126                              Remote  BGP       00h02m03s  170
       2001:db8:111::1                                               0
2001:db8:111::/127                              Local   Local     00h31m22s  0
       int-PE-1-CE-11                                                0
2001:db8:112::/127                              Local   Local     00h31m21s  0
       int-PE-1-CE-12                                                0
2001:db8:120::2/128                             Remote  BGP       00h02m03s  170
       2001:db8:112::1                                               0
2001:db8:120::3/128                             Remote  BGP       00h02m03s  170
       2001:db8:112::1                                               0
2001:db8:120::4/126                             Remote  BGP       00h02m03s  170
       2001:db8:112::1                                               0
-------------------------------------------------------------------------------
No. of Routes: 9
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The following command shows which routes are marked as leakable in the GRT:

```
[/]
A:admin@PE-1# show router bgp routes ipv6 leakable
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv6 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  2001:db8:100::2/128                               None        None
      2001:db8:17:111::1                                None        0
      64501                                                         -
u*>i  2001:db8:100::3/128                               None        None
      2001:db8:17:111::1                                None        0
      64501                                                         -
u*>i  2001:db8:100::4/126                               None        None
```

```
      2001:db8:17:111::1                                    None        0
      64501                                                             -
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

The following command shows which routes are marked as leakable in VPRN 1:

```
[/]
A:admin@PE-1# show router 1 bgp routes ipv6 leakable
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv6 Routes
===============================================================================
Flag  Network                                               LocalPref   MED
      Nexthop (Router)                                      Path-Id     IGP Cost
      As-Path                                                           Label
-------------------------------------------------------------------------------
u*>i  2001:db8:90::2/128                                    None        None
      2001:db8:111::1                                       None        0
      64501                                                             -
u*>i  2001:db8:90::3/128                                    None        None
      2001:db8:111::1                                       None        0
      64501                                                             -
u*>i  2001:db8:90::4/126                                    None        None
      2001:db8:111::1                                       None        0
      64501                                                             -
u*>i  2001:db8:120::2/128                                   None        None
      2001:db8:112::1                                       None        0
      64502                                                             -
u*>i  2001:db8:120::3/128                                   None        None
      2001:db8:112::1                                       None        0
      64502                                                             -
u*>i  2001:db8:120::4/126                                   None        None
      2001:db8:112::1                                       None        0
      64502                                                             -
-------------------------------------------------------------------------------
Routes : 6
===============================================================================
```

On PE-1, a policy is created to import the BGP leakable routes (the same as in the preceding examples), as follows:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "Import-Leakable-Routes" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
```

```
                }
            }
        }
```

This import policy is configured for IPv6 routes in VPRN 2, as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 2" {
            bgp {
                rib-management {
                    ipv6 {
                        leak-import {
                            policy ["Import-Leakable-Routes"]
                        }
                    }
                }
```

The following command shows the leaked IPv6 routes in VPRN 2:

```
[/]
A:admin@PE-1# show router 2 bgp routes ipv6 leaked
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv6 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>li 2001:db8:90::2/128                                100         None
      2001:db8:111::1 (VPRN 1)                          None        0
      64501                                                         -
u*>li 2001:db8:90::3/128                                100         None
      2001:db8:111::1 (VPRN 1)                          None        0
      64501                                                         -
u*>li 2001:db8:90::4/126                                100         None
      2001:db8:111::1 (VPRN 1)                          None        0
      64501                                                         -
u*>li 2001:db8:100::2/128                               100         None
      2001:db8:17:111::1 (Base)                         None        0
      64501                                                         -
u*>li 2001:db8:100::3/128                               100         None
      2001:db8:17:111::1 (Base)                         None        0
      64501                                                         -
u*>li 2001:db8:100::4/126                               100         None
      2001:db8:17:111::1 (Base)                         None        0
      64501                                                         -
u*>li 2001:db8:120::2/128                               100         None
      2001:db8:112::1 (VPRN 1)                          None        0
      64502                                                         -
u*>li 2001:db8:120::3/128                               100         None
      2001:db8:112::1 (VPRN 1)                          None        0
      64502                                                         -
u*>li 2001:db8:120::4/126                               100         None
```

```
      2001:db8:112::1 (VPRN 1)                          None        0
      64502                                                         -
-------------------------------------------------------------------------------
Routes : 9
===============================================================================
```

Some of these routes are leaked from the base router and some routes are leaked from VPRN 1. The detailed information for any of these leaked routes shows that the flag "Leaked" is present. For route 2001:db8:100::2/128, the route source is the base router, as follows:

```
[/]
A:admin@PE-1# show router 2 bgp routes 2001:db8:100::2/128 detail
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv6 Routes
===============================================================================
Original Attributes

Network        : 2001:db8:100::2/128
Nexthop        : 2001:db8:17:111::1 (Base)
Path Id        : None
From           : BGP Base
Res. Protocol  : LOCAL                  Res. Metric    : 0
Res. Nexthop   : 2001:db8:17:111::1
Local Pref.    : 100                    Interface Name : int-PE-1-CE-11
Aggregator AS  : None                   Aggregator     : None
Atomic Aggr.   : Not Atomic             MED            : None
AIGP Metric    : None                   IGP Cost       : 0
Connector      : None
Community      : No Community Members
Cluster        : No Cluster Members
Originator Id  : None                   Peer Router Id : 0.0.0.0
Fwd Class      : None                   Priority       : None
Flags          : Used Valid Best IGP Leaked In-RTM
Route Source   : Leaked from Base
AS-Path        : 64501
---snip---
```

For route 2001:db8:90::2/128, the route source is VPRN 1, as follows:

```
[/]
A:admin@PE-1# show router 2 bgp routes 2001:db8:90::2/128 detail
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv6 Routes
===============================================================================
Original Attributes
```

```
Network        : 2001:db8:90::2/128
Nexthop        : 2001:db8:111::1 (VPRN 1)
Path Id        : None
From           : BGP VPRN 1
Res. Protocol  : LOCAL                  Res. Metric    : 0
Res. Nexthop   : 2001:db8:111::1
Local Pref.    : 100                    Interface Name : int-PE-1-CE-11
Aggregator AS  : None                   Aggregator     : None
Atomic Aggr.   : Not Atomic             MED            : None
AIGP Metric    : None                   IGP Cost       : 0
Connector      : None
Community      : No Community Members
Cluster        : No Cluster Members
Originator Id  : None                   Peer Router Id : 0.0.0.0
Fwd Class      : None                   Priority       : None
Flags          : Used Valid Best IGP Leaked In-RTM
Route Source   : Leaked from VPRN 1
AS-Path        : 64501
---snip---
```

Conclusion

BGP provides many ways to manipulate routes. In this example, IPv4/IPv6 routes learned from BGP neighbors could be marked as "leakable" and imported into other routing instances (VPRN to VPRN, VPRN to GRT, GRT to VPRN) without the use of communities in the network policy.

BGP Route Refresh

This chapter describes BGP Route Refresh.

Topics in this chapter include:

Applicability

The information and configuration in this chapter are based on SR OS Release 20.5.R2. The option to manually trigger BGP ROUTE_REFRESH messages to a BGP peer is supported in SR OS Release 19.7.R1, and later.

In SR OS releases earlier than 19.7.R1, only the automatic route refresh mechanism for VPN routes that carry Route Target extended communities, such as VPN-IPv4, VPN-IPv6, L2-VPN, MVPN-IPv4, or MVPN-IPv6 routes, is supported.

In SR OS releases earlier than 19.7.R1, soft reconfiguration inbound is supported for all non-VPN and VPN address families, using a **clear** command with **soft-inbound** option. With soft reconfiguration inbound, incoming routes are continuously retained in memory (RIB-IN), exactly as they were originally received from a BGP peer. Therefore, when an import policy change happens, the reevaluation of these routes can happen locally. There is no need to involve the peer node, because no route-refresh is involved. The disadvantage is the extra resource consumption to retain a copy of all original routes in memory, even if they are not needed at the current time.

Overview

RFC 2918, *Route Refresh Capability for BGP-4*, describes the BGP ROUTE_REFRESH message type and capability for BGP-4. When BGP router PE-1 sends a route refresh message for a specific address family to its BGP peer PE-2, PE-2 re-advertises all its RIB-OUT routes for PE-1 belonging to that address family. Manually-triggered BGP route refresh can be used for any BGP address family. However, if PE-2 did not advertise the route refresh capability in the BGP OPEN message to PE-1, then PE-2 ignores the incoming ROUTE_REFRESH message from PE-1.

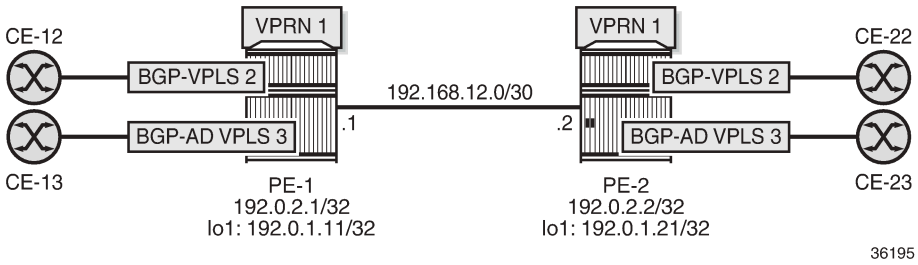
In this chapter, the following use cases are shown:

- Automatic route refresh for VPN-IP and L2-VPN routes after an import policy is modified
- Block automatic route refresh for VPN-IP routes (**mp-bgp-keep** option)
- Manual route refresh for BGP routes for different address families (**soft-route-refresh** option in **clear** command)

Configuration

Figure 93: Example topology shows the example topology with two nodes.

Figure 93: Example topology



The initial configuration on the nodes includes:

- Cards, MDAs, ports
- Router interfaces
- SR-ISIS

The following route policies are configured on PE-1; the policies on PE-2 are similar.

```
# on PE-1:
configure {
    policy-options {
        community "target:64500:1" {
            member "target:64500:1" { }
        }
        community "target:64500:2" {
            member "target:64500:2" { }
        }
        prefix-list "192.0.1.0/24" {
            prefix 192.0.1.0/24 type range {
                start-length 32
                end-length 32
            }
        }
        policy-statement "export-VPLS2" {
            entry 10 {
                action {
                    action-type accept
                    community {
                        add ["target:64500:2"]
                    }
                }
            }
        }
        policy-statement "export-VPRN1" {
            entry 10 {
                action {
                    action-type accept
                    next-hop 192.0.1.11
                    community {
                        add ["target:64500:1"]
                    }
```

```
                }
            }
        }
        policy-statement "export-bgp" {
            entry 10 {
                from {
                    prefix-list ["192.0.1.0/24"]
                }
                action {
                    action-type accept
                }
            }
        }
        policy-statement "import-VPLS2" {
            entry 10 {
                from {
                    family [l2-vpn]
                    community {
                        name "target:64500:2"
                    }
                }
                action {
                    action-type accept
                }
            }
            default-action {
                action-type reject
            }
        }
        policy-statement "import-VPRN1" {
            entry 10 {
                from {
                    community {
                        name "target:64500:1"
                    }
                    protocol {
                        name [bgp-vpn]
                    }
                }
                action {
                    action-type accept
                }
            }
            default-action {
                action-type reject
            }
        }
```

Two BGP groups are configured: one for the VPN-IPv4 and Label-IPv4 address families and another for the L2-VPN address family. The BGP configuration for the base router on PE-1 is as follows:

```
# on PE-1:
configure {
    router "Base" {
        autonomous-system 64500
        bgp {
            split-horizon true
            next-hop-resolution {
                labeled-routes {
                    transport-tunnel {
                        family label-ipv4 {
                            resolution-filter {
                                ldp false
```

```
                                sr-isis true
                            }
                        }
                    }
                }
            }
            group "iBGP-L2" {
                type internal
                local-address 192.0.1.11
                family {
                    l2-vpn true
                }
            }
            group "iBGPv4" {
                peer-as 64500
                family {
                    vpn-ipv4 true
                    label-ipv4 true
                }
            }
            neighbor "192.0.1.21" {
                group "iBGP-L2"
            }
            neighbor "192.0.2.2" {
                group "iBGPv4"
                export {
                    policy ["export-bgp"]
                }
            }
        }
```

The service configuration on PE-1 is as follows:

```
# on PE-1:
configure {
    service {
        pw-template "PW1" {
            pw-template-id 1
        }
        vpls "BGP-AD VPLS 3" {
            admin-state enable
            service-id 3
            customer "1"
            bgp 1 {
                route-distinguisher "64500:3"
                route-target {
                    export "target:64500:3"
                    import "target:64500:3"
                }
                pw-template-binding "PW1" {
                }
            }
            bgp-ad {
                admin-state enable
                vpls-id "64500:3"
                vsi-id-prefix 192.0.1.11
            }
            sap 1/2/1:3 {
            }
        }
        vpls "BGP-VPLS 2" {
            admin-state enable
            service-id 2
```

```
            customer "1"
            bgp 1 {
                route-distinguisher "64500:2"
                vsi-import ["import-VPLS2"]
                vsi-export ["export-VPLS2"]
                route-target {
                    export "target:64500:2"
                    import "target:64500:2"
                }
                pw-template-binding "PW1" {
                    import-rt ["target:64500:2"]
                }
            }
            bgp-vpls {
                admin-state enable
                maximum-ve-id 100
                ve {
                    name "PE-1"
                    id 1
                }
            }
            sap 1/2/1:2 {
            }
        }
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            route-distinguisher "64500:1"
            vrf-target {
                community "target:64500:1"
            }
            vrf-import {
                policy ["import-VPRN1"]
            }
            vrf-export {
                policy ["export-VPRN1"]
            }
            auto-bind-tunnel {
                resolution filter
            }
            bgp {
                next-hop-resolution {
                    use-bgp-routes true
                }
            }
            interface "lo1" {
                loopback true
                ipv4 {
                    primary {
                        address 172.31.1.1
                        prefix-length 32
                    }
                }
            }
        }
```

The following BGP OPEN message sent by PE-1 includes the route refresh capability for two BGP address families:

```
1 2020/06/23 09:03:58.168 UTC MINOR: DEBUG #2001 Base BGP
"BGP: OPEN
Peer 1: 192.0.2.2 - Send (Passive) BGP OPEN: Version 4
```

```
   AS Num 64500: Holdtime 90: BGP_ID 192.0.2.1: Opt Length 26 (ExtOpt F)
   Opt Para: Type CAPABILITY: Length = 24: Data:
     Cap_Code GRACEFUL-RESTART: Length 2
       Bytes: 0x0 0x78
     Cap_Code MP-BGP: Length 4
       Bytes: 0x0 0x1 0x0 0x80                # AFI / SAFI ; 1 / 128 ; vpn-ipv4
     Cap_Code MP-BGP: Length 4
       Bytes: 0x0 0x1 0x0 0x4                 # AFI / SAFI ; 1 / 4 ; label-ipv4
     Cap_Code ROUTE-REFRESH: Length 0
     Cap_Code 4-OCTET-ASN: Length 4
       Bytes: 0x0 0x0 0xfb 0xf4
"
```

The BGP session between PE-1 and PE-2 includes the route refresh capability, as follows. No route refresh messages have been triggered manually yet.

```
[]
A:admin@PE-1# show router bgp neighbor 192.0.2.2 | match RtRefresh
Input RtRefresh      : 0               Output RtRefresh     : 0
Local Capability     : RtRefresh MPBGP 4byte ASN
Remote Capability    : RtRefresh MPBGP 4byte ASN
```

PE-1 receives the following BGP Labeled Unicast (BGP-LU) route:

```
[]
A:admin@PE-1# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  192.0.1.21/32                                    100         None
      192.0.2.2                                        None        10
      No As-Path                                                   524274
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

PE-1 receives the following VPN-IPv4 route for VPRN 1:

```
[]
A:admin@PE-1# show router bgp routes vpn-ipv4
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
```

```
===============================================================================
Flag  Network                                       LocalPref   MED
      Nexthop (Router)                              Path-Id     IGP Cost
      As-Path                                                   Label
-------------------------------------------------------------------------------
u*>i  64500:1:172.31.1.2/32                         100         None
      192.0.1.21                                    None        0
      No As-Path                                                524286
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

PE-1 receives one L2-VPN route for BGP-VPLS 2 and one L2-VPN route for BGP-AD VPLS 3:

```
[]
A:admin@PE-1# show router bgp routes l2-vpn
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP L2VPN Routes
===============================================================================
Flag  RouteType                   Prefix                          MED
      RD                          SiteId                          Label
      Nexthop                     VeId                  BlockSize LocalPref
      As-Path                     BaseOffset            vplsLabelBa
                                                        se
-------------------------------------------------------------------------------
u*>i  VPLS                        -                     -         0
      64500:2                     -                               -
      192.0.1.21                  2                     8         100
      No As-Path                  1                     524278
u*>i  AutoDiscovery               192.0.1.21            -         0
      64500:3                     -                               -
      192.0.1.21                  -                     -         100
      No As-Path                  -                     -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

Automatic route refresh for VPN-IP and L2-VPN routes

The following import policy is modified on PE-1; the "import-VPRN1" policy action sets the local preference to a value of 200:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "import-VPRN1" {
            entry 10 {
                from {
                    community {
                        name "target:64500:1"
                    }
                    protocol {
```

```
                        name [bgp-vpn]
                    }
                }
                action {
                    action-type accept
                    local-preference 200
                }
            }
            default-action {
                action-type reject
            }
        }
```

When one or more import policies are modified after the VPN-IP and L2-VPN routes have been received, the node automatically generates route refresh messages for VPN-IP and L2-VPN routes to its peers. In this case, PE-1 sends one route refresh message for VPN-IPv4 routes and one route refresh message for L2-VPN routes to its BGP peer PE-2. When debugging is enabled for BGP route refresh messages, the following debug messages are logged on PE-1:

```
18 2020/06/23 09:14:47.611 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.2.2
"Peer 1: 192.0.2.2: ROUTE REFRESH
Peer 1: 192.0.2.2 - Send BGP ROUTE REFRESH:
Address Family AFI_IPV4: Sub AFI SAFI_VPN
"

19 2020/06/23 09:14:47.611 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.1.21
"Peer 1: 192.0.1.21: ROUTE REFRESH
Peer 1: 192.0.1.21 - Send BGP ROUTE REFRESH:
Address Family AFI_L2VPN: Sub AFI SAFI_VPLS
"
```

The first route refresh message triggers VPN-IPv4 routes to be re-advertised by the peer, while the second route refresh message triggers L2-VPN routes to be re-advertised. With these BGP route refresh messages, all VPN-IPv4 and L2-VPN routes are refreshed, even for services without an import policy, such as BGP-AD VPLS 3. The first of the following routes is related to VPRN 1 (with route-target target:64500:1), the second to BGP-VPLS 2 (with route-target target:64500:2), and the third to BGP-AD VPLS 3 (with route-target target:64500:3):

```
20 2020/06/23 09:14:47.614 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.2.2
"Peer 1: 192.0.2.2: UPDATE
Peer 1: 192.0.2.2 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 62
    Flag: 0x90 Type: 14 Len: 33 Multiprotocol Reachable NLRI:
        Address Family VPN_IPV4
        NextHop len 12 NextHop 192.0.1.21
        172.31.1.2/32 RD 64500:1 Label 524286
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 0 AS Path:
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0xc0 Type: 16 Len: 8 Extended Community:
        target:64500:1
"
```

```
21 2020/06/23 09:14:47.614 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.1.21
"Peer 1: 192.0.1.21: UPDATE
Peer 1: 192.0.1.21 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 72
```

```
    Flag: 0x90 Type: 14 Len: 28 Multiprotocol Reachable NLRI:
        Address Family L2VPN
        NextHop len 4 NextHop 192.0.1.21
     [VPLS/VPWS] preflen 17, veid: 2, vbo: 1, vbs: 8, label-base: 524278, RD 64500:2
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 0 AS Path:
    Flag: 0x80 Type: 4 Len: 4 MED: 0
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0xc0 Type: 16 Len: 16 Extended Community:
        target:64500:2
        l2-vpn/vrf-imp:Encap=19: Flags=none: MTU=1514: PREF=0
"
```

```
22 2020/06/23 09:14:47.614 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.1.21
"Peer 1: 192.0.1.21: UPDATE
Peer 1: 192.0.1.21 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 67
    Flag: 0x90 Type: 14 Len: 23 Multiprotocol Reachable NLRI:
        Address Family L2VPN
        NextHop len 4 NextHop 192.0.1.21
        [AD] 192.0.1.21/32, RD 64500:3
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 0 AS Path:
    Flag: 0x80 Type: 4 Len: 4 MED: 0
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0xc0 Type: 16 Len: 16 Extended Community:
        target:64500:3
        l2-vpn/vrf-imp:64500:3
"
```

Block automatic route refresh for VPN-IP routes

When the VPN-IP routes do not need to be re-advertised when an import policy is modified, the **mp-bgp-keep** option can be configured in the generic **bgp** context of the base router, as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            mp-bgp-keep true
```

Change the import policy back to the original configuration, as follows:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "import-VPRN1" {
            entry 10 {
                from {
                    community {
                        name "target:64500:1"
                    }
                    protocol {
                        name [bgp-vpn]
                    }
                }
                action {
                    action-type accept
```

```
                    delete local-preference # do not modify LP
                }
            }
            default-action {
                action-type reject
            }
        }
```

The **mp-bgp-keep true** option blocks the route refresh message for the VPN-IP routes, but not for the L2-VPN routes. The following route refresh message is sent by PE-1:

```
35 2020/06/23 09:21:33.951 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.1.21
"Peer 1: 192.0.1.21: ROUTE REFRESH
Peer 1: 192.0.1.21 - Send BGP ROUTE REFRESH:
 Address Family AFI_L2VPN: Sub AFI SAFI_VPLS
"
```

Therefore, PE-1 receives the following refreshed L2-VPN routes from PE-2:

```
36 2020/06/23 09:21:33.954 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.1.21
"Peer 1: 192.0.1.21: UPDATE
Peer 1: 192.0.1.21 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 67
    Flag: 0x90 Type: 14 Len: 23 Multiprotocol Reachable NLRI:
        Address Family L2VPN
        NextHop len 4 NextHop 192.0.1.21
        [AD] 192.0.1.21/32, RD 64500:3
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 0 AS Path:
    Flag: 0x80 Type: 4 Len: 4 MED: 0
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0xc0 Type: 16 Len: 16 Extended Community:
        target:64500:3
        l2-vpn/vrf-imp:64500:3
"
```

```
37 2020/06/23 09:21:33.954 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.1.21
"Peer 1: 192.0.1.21: UPDATE
Peer 1: 192.0.1.21 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 72
    Flag: 0x90 Type: 14 Len: 28 Multiprotocol Reachable NLRI:
        Address Family L2VPN
        NextHop len 4 NextHop 192.0.1.21
     [VPLS/VPWS] preflen 17, veid: 2, vbo: 1, vbs: 8, label-base: 524278, RD 64500:2
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 0 AS Path:
    Flag: 0x80 Type: 4 Len: 4 MED: 0
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0xc0 Type: 16 Len: 16 Extended Community:
        target:64500:2
        l2-vpn/vrf-imp:Encap=19: Flags=none: MTU=1514: PREF=0
"
```

Manually-triggered route refresh for any BGP address family

A manual route refresh can be triggered by the **soft-route-refresh** option using the **clear** operation. This command can be launched for any address family. The command will look like the following:

```
[]
A:admin@PE-1# clear router bgp neighbor {<ip-address>|as <as-number>|external|all}
 soft-route-refresh [<family>]

<family>             : ipv4|vpn-ipv4|ipv6|mcast-ipv4|vpn-ipv6|l2-vpn|mvpn-ipv4|mdt-safi|flow-
ipv4|ms-pw|route-target|mcast-vpn-ipv4|mvpn-ipv6|flow-ipv6|evpn|mcast-ipv6|label-ipv4|label-
ipv6|mcast-vpn-ipv6|bgp-ls|sr-policy-ipv4
```

For example, the following command on PE-1 clears the BGP-LU routes from PE-1:

```
[]
A:admin@PE-1# clear router bgp neighbor 192.0.2.2 soft-route-refresh label-ipv4
```

The preceding command triggers the following route refresh message for the BGP-LU routes:

```
38 2020/06/23 09:23:48.951 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.2.2
"Peer 1: 192.0.2.2: ROUTE REFRESH
Peer 1: 192.0.2.2 - Send BGP ROUTE REFRESH:
Address Family AFI_IPV4: Sub AFI SAFI_MPLS_LABEL
"
```

The following BGP-LU route is received by PE-1:

```
39 2020/06/23 09:23:48.954 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.2.2
"Peer 1: 192.0.2.2: UPDATE
Peer 1: 192.0.2.2 - Received BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 35
    Flag: 0x90 Type: 14 Len: 17 Multiprotocol Reachable NLRI:
        Address Family LBL-IPV4
        NextHop len 4 NextHop 192.0.2.2
        192.0.1.21/32 Label 524274
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 0 AS Path:
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
"
```

The following command on PE-1 shows that one output route refresh message is sent:

```
[]
A:admin@PE-1# show router bgp neighbor 192.0.2.2 | match RtRefresh
Input RtRefresh      : 0               Output RtRefresh     : 1
Local Capability     : RtRefresh MPBGP 4byte ASN
Remote Capability    : RtRefresh MPBGP 4byte ASN
```

A similar command on PE-2 shows that one input route refresh message has been received:

```
[]
A:admin@PE-2# show router bgp neighbor 192.0.2.1 | match RtRefresh
Input RtRefresh      : 1               Output RtRefresh     : 0
Local Capability     : RtRefresh MPBGP 4byte ASN
Remote Capability    : RtRefresh MPBGP 4byte ASN
```

When the **soft-route-refresh** option is executed without a specific address family, the BGP routes are refreshed for all negotiated address families with that neighbor:

```
[]
A:admin@PE-1# clear router bgp neighbor 192.0.2.2 soft-route-refresh
                                                                  # BGP- LU, BGP-VPN

[]
A:admin@PE-1# clear router bgp neighbor 192.0.1.21 soft-route-refresh   # L2-VPN
```

The preceding **clear** commands trigger the following BGP ROUTE_REFRESH messages:

```
42 2020/06/23 09:39:53.836 CEST MINOR: DEBUG #2001 Base Peer 1: 192.0.1.21
"Peer 1: 192.0.1.21: ROUTE REFRESH
Peer 1: 192.0.1.21 - Send BGP ROUTE REFRESH:
Address Family AFI_L2VPN: Sub AFI SAFI_VPLS
"
```

```
43 2020/06/23 09:39:53.836 CEST MINOR: DEBUG #2001 Base Peer 1: 192.0.2.2
"Peer 1: 192.0.2.2: ROUTE REFRESH
Peer 1: 192.0.2.2 - Send BGP ROUTE REFRESH:
Address Family AFI_IPV4: Sub AFI SAFI_VPN
"
```

```
44 2020/06/23 09:39:53.836 CEST MINOR: DEBUG #2001 Base Peer 1: 192.0.2.2
"Peer 1: 192.0.2.2: ROUTE REFRESH
Peer 1: 192.0.2.2 - Send BGP ROUTE REFRESH:
Address Family AFI_IPV4: Sub AFI SAFI_MPLS_LABEL
"
```

Conclusion

The **soft-route-refresh** option in the **clear router bgp neighbor** command keeps a BGP session up and sends one or more ROUTE_REFRESH messages to the peer, each requesting the peer to resend all RIB-OUT routes for a specific address family (or for all established address families for a BGP neighbor). This option can be used to debug and troubleshoot route advertisement issues.

BGP Unresolved Route Leaking from Base Router to VPRN

This chapter describes BGP unresolved route leaking from base router to VPRN.

Topics in this chapter include:

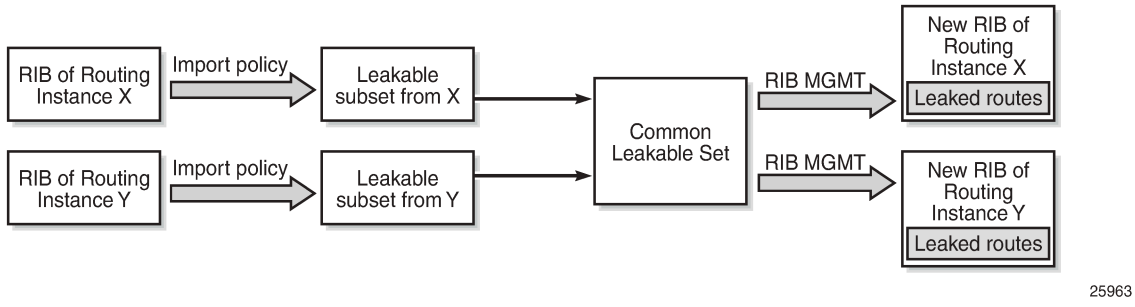
Applicability

The information and configuration in this chapter are based on SR OS Release 22.10.R2. BGP resolved route leaking between BGP routing instances is supported in SR OS Release 12.0.R7, and later; BGP unresolved route leaking from base router to VPRN is supported in SR OS Release 19.10.R1, and later.

Overview

The BGP Route Leaking chapter describes how BGP resolved routes can be leaked from one BGP routing instance to other BGP routing instances; for example, from the base router to a VPRN, from one VPRN to another VPRN, or from a VPRN to the base router. The first BGP routing instance (source) makes selected BGP routes in its RIB-IN leakable, so that these routes are available for import by BGP in other routing instances (destinations). Figure 94: BGP route leaking process between BGP routing instances X and Y shows the BGP route leaking process between BGP routing instances.

Figure 94: BGP route leaking process between BGP routing instances X and Y



In SR OS Releases earlier than 19.10.R1, a BGP route is leakable if it meets the following conditions:

- It must have been received from a BGP neighbor and matched by a BGP import policy that accepts the route with a **bgp-leak true** action.

- It must have a BGP next-hop that is resolved by a route or tunnel belonging to the source routing instance.

Those leakable BGP routes can be imported into other destination BGP routing instances. A BGP RIB imports a leakable BGP route when it has a **leak-import** policy that matches and accepts the route.

Leaked BGP routes are compared to other (leaked and non-leaked) BGP routes for the same prefix to come up with the best path, Equal Cost Multi-Path (ECMP), backup path, and so on. A leaked route can be advertised to BGP peers of the importing BGP instance. A leaked route imported into a VPRN BGP instance can even be re-advertised as a VPN-IP route subject to the **vrf-export** policies of the VPRN.

The following use cases require that unresolved BGP routes are leaked from base router to VPRN. To avoid per-VPRN BGP sessions, a Route Reflector (RR) advertises BGP routes toward a PE over a single BGP session with the base router, even though some of the routes belong to VPRNs of the PE. The PE can determine the VPRN owner of a route from an attached community value. The BGP routes that belong to VPRNs can be marked as leakable in the base router, then imported into the correct VPRN based on community matching in the **leak-import** policies.

When the RR advertises a BGP route intended for a VPRN, the BGP next-hop of the route is resolvable in the VPRN instance, but not in the base router. The **allow-unresolved-leaking true** command must be added to the **BGP next-hop-resolution** context for the base router to allow any leakable route to be imported into any VPRN, even when the BGP next-hop is unresolved. The BGP next-hop is resolved as follows:

- If the next-hop of a valid BGP route is resolvable in the base router, any VPRN that imports the route uses the next-hop resolution result of the base router, even if that VPRN is also able to resolve the BGP next-hop using its own routing table.
- If the next-hop of a valid BGP route is unresolvable in the base router and **allow-unresolved-leaking** is set to true, any VPRN can import the route. A VPRN that imports the route then uses its own routing table to resolve the BGP next-hop:
  - By default, the importing VPRN can only use IGP routes, such as OSPFv2, OSPFv3, IS-IS, RIP, RIPng, and static routes to resolve the BGP next-hop of the leaked route.
  - If **use-bgp-routes true** is configured in the **BGP next-hop-resolution** context, the importing VPRN can also use BGP and BGP-VPN routes to resolve the BGP next-hop of the leaked route.

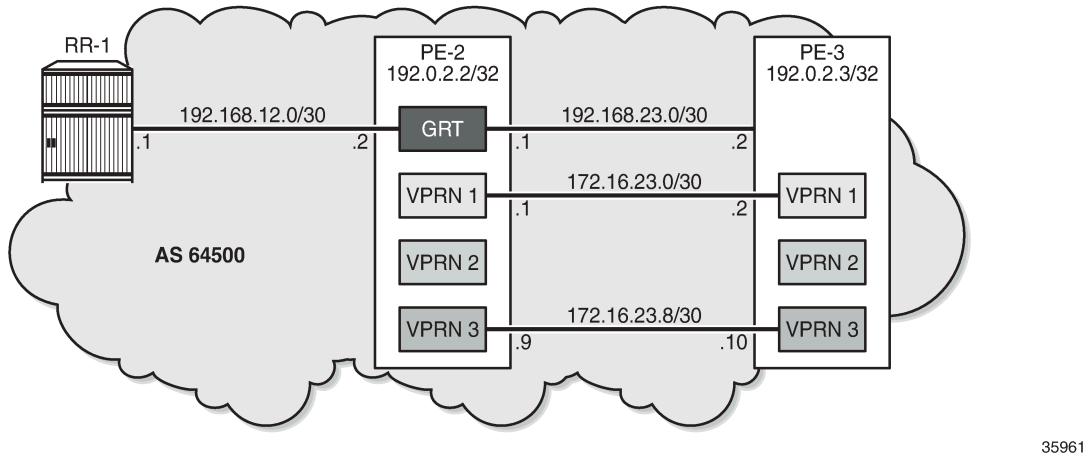
If a leaked BGP route is resolved by a VPRN, the VPRN can re-advertise the route to VPRN BGP peers or export the route as a VPN-IP route. However, if a leaked route is resolved over a BGP-VPN route, it can only be exported as a VPN-IP route if **allow-bgp-vpn-export** is enabled in the VPRN.

If a BGP route is invalid in the base router for reasons other than next-hop reachability, it is not leakable into any VPRN, regardless of the **allow-unresolved-leaking** setting.

Configuration

Figure 95: Example topology shows the example topology with an RR and two PEs.

Figure 95: Example topology



The initial configuration on the PEs includes the following:

- Cards, MDAs, ports
- Router interfaces
- SR-ISIS

The initial configuration on PE-2 is as follows:

```
# on PE-2:
configure {
    router "Base" {
        autonomous-system 64500
        interface "int-PE-2-PE-3" {
            port 1/1/c1/1:100
            ipv4 {
                primary {
                    address 192.168.23.1
                    prefix-length 30
                }
            }
        }
        interface "int-PE-2-RR-1" {
            port 1/1/c1/3:100
            ipv4 {
                primary {
                    address 192.168.12.2
                    prefix-length 30
                }
            }
        }
        interface "system" {
            ipv4 {
                primary {
                    address 192.0.2.2
                    prefix-length 32
                }
            }
        }
        mpls-labels {
            sr-labels {
```

```
                start 32000
                end 32999
            }
        }
        isis 0 {
            admin-state enable
            advertise-router-capability area
            area-address [49.0001]
            segment-routing {
                admin-state enable
                prefix-sid-range {
                    global
                }
            }
            interface "int-PE-2-PE-3" {
                interface-type point-to-point
            }
            interface "system" {
                ipv4-node-sid {
                    index 2
                }
            }
        }
    }
}
```

A BGP session is established between RR-1 and the base router on PE-2. The BGP configuration on PE-2 is as follows:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "iBGP" {
                peer-as 64500
                family {
                    ipv4 true
                }
            }
            neighbor "192.168.12.1" {
                group "iBGP"
            }
        }
    }
}
```

RR-1 advertises BGP routes with different communities for the different VPRNs on PE-2:

- prefix 10.14.0.0/16 with community "target:64501:1" for VPRN 1
- prefix 10.24.0.0/16 with community "target:64501:2" for VPRN 2
- prefix 10.34.0.0/16 with community "target:64501:3" for VPRN 3

PE-2 receives the following BGP routes from RR-1:

```
[/]
A:admin@PE-2# show router bgp neighbor 192.168.12.1 received-routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
```

```
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
i     10.14.0.0/16                                     100         None
      10.13.0.1                                        None        0
      64501                                                        -
i     10.24.0.0/16                                     100         None
      10.23.0.1                                        None        0
      No As-Path                                                   -
i     10.34.0.0/16                                     100         None
      10.33.0.1                                        None        0
      64503                                                        -
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

These routes are invalid in the base router because the next-hop is unresolved, as indicated by the flags in the BGP route details:

```
[/]
A:admin@PE-2# show router bgp routes hunt | match Flags
Flags          : Invalid IGP Nexthop-Unresolved
Flags          : Invalid IGP Nexthop-Unresolved
Flags          : Invalid IGP Nexthop-Unresolved
```

On PE-2, the following import policy is created to make the prefixes leakable:

```
# on PE-2:
configure {
    policy-options {
        prefix-list "10.0.0.0/8" {
            prefix 10.0.0.0/8 type longer {
            }
        }
        policy-statement "leak-10.x" {
            entry 10 {
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                    bgp-leak true
                }
            }
        }
    }
    router "Base" {
        bgp {
            group "iBGP" {
                peer-as 64500
                family {
                    ipv4 true
                }
            }
```

```
            neighbor "192.168.12.1" {
                group "iBGP"
                import {
                    policy ["leak-10.x"]
                }
            }
        }
    }
}
```

The routes are now marked as leakable:

```
[/]
A:admin@PE-2# show router bgp routes hunt | match Flags
Flags          : Invalid IGP Nexthop-Unresolved Leakable
Flags          : Invalid IGP Nexthop-Unresolved Leakable
Flags          : Invalid IGP Nexthop-Unresolved Leakable
```

```
[/]
A:admin@PE-2# show router bgp routes ipv4 leakable
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
i     10.14.0.0/16                                      100         None
      10.13.0.1                                         None        0
      64501                                                         -
i     10.24.0.0/16                                      100         None
      10.23.0.1                                         None        0
      No As-Path                                                    -
i     10.34.0.0/16                                      100         None
      10.33.0.1                                         None        0
      64503                                                         -
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

Even though the routes are marked as leakable, these BGP routes with unresolved next-hop are only leaked from the base router to a **VPRN** context when the command **allow-unresolved-leaking true** is configured in the **BGP next-hop-resolution** context of the base router, as shown later in the examples.

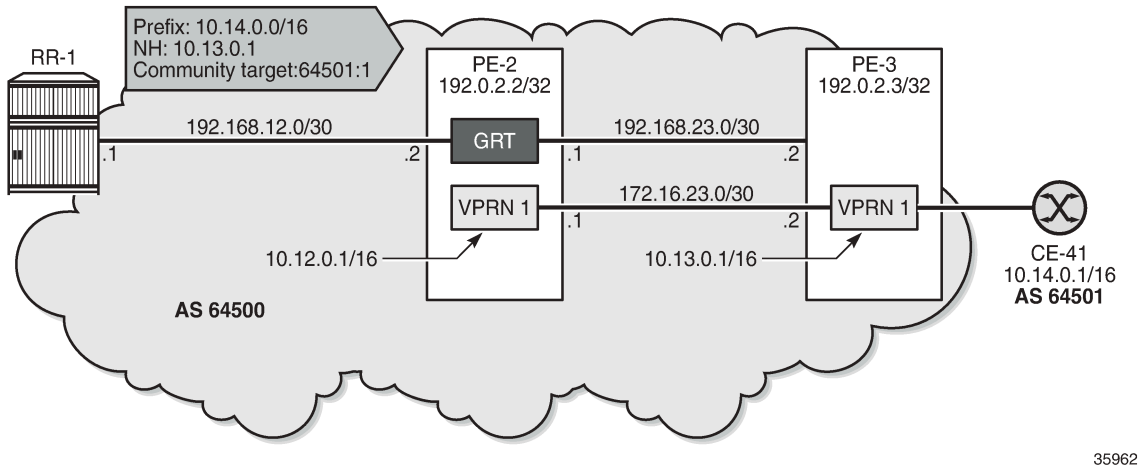
The following use cases are shown:

- BGP route 10.14.0.0/16 leaked to VPRN 1 with BGP next-hop resolved using IS-IS
- BGP route 10.24.0.0/16 leaked to VPRN 2 with BGP next-hop resolved using VPN-IP
- BGP route 10.34.0.0/16 leaked to VPRN 3 with BGP next-hop resolved using eBGP

Use case 1: BGP route leaked to VPRN 1 with next-hop resolved using IS-IS

Figure 96: Leaked route 10.14.0.0/16 with next-hop resolved in VPRN 1 using IS-IS shows that RR-1 advertises prefix 10.14.0.0/16 with next-hop 10.13.0.0/16, which is unresolvable in the base router of PE-2, but can be resolved in VPRN 1.

Figure 96: Leaked route 10.14.0.0/16 with next-hop resolved in VPRN 1 using IS-IS



On PE-3, VPRN 1 has a loopback interface "lo1" configured with IP address 10.13.0.1/32. IS-IS on PE-3 is only enabled on the loopback interface and on the interface facing VPRN 1 on PE-2, not on the interface toward CE-41. VPRN 1 is configured as follows:

```
# on PE-3:
configure {
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            autonomous-system 64500
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64500:1"
                    vrf-target {
                        community "target:64500:1"
                    }
                }
            }
            interface "int-VPRN1-PE-3-PE-2" {
                ipv4 {
                    primary {
                        address 172.16.23.2
                        prefix-length 30
                    }
                }
                sap 1/1/c1/2:1 {
                }
            }
            interface "int-VPRN3-PE-3-CE-41" {
```

```
                ipv4 {
                    primary {
                        address 172.16.34.1
                        prefix-length 30
                    }
                }
                sap 1/1/c1/1:1 {
                }
            }
            interface "lo1" {
                loopback true
                ipv4 {
                    primary {
                        address 10.13.0.1
                        prefix-length 32
                    }
                }
            }
            static-routes {
                route 10.14.0.0/16 route-type unicast {
                    next-hop "172.16.34.2" {
                        admin-state enable
                    }
                }
            }
            isis 0 {
                admin-state enable
                area-address [49.0001]
                interface "int-VPRN1-PE-3-PE-2" {
                    interface-type point-to-point
                }
                interface "lo1" {
                    interface-type point-to-point
                }
            }
        }
    }
}
```

On PE-2, the route table for VPRN 1 shows the following IS-IS route for prefix 10.13.0.1/32:

```
[/]
A:admin@PE-2# show router 1 route-table

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.12.0.1/32                                  Local   Local     00h10m07s  0
       lo1                                                          0
10.13.0.1/32                                  Remote  ISIS      00h09m34s  15
       172.16.23.2                                                  10
172.16.23.0/30                                Local   Local     00h10m07s  0
       int-VPRN1-PE-2-PE-3                                          0
-------------------------------------------------------------------------------
No. of Routes: 3
---snip---
===============================================================================
```

PE-2 receives the following BGP route from RR-1 in the base routing instance with community "target 64500:1":

```
[/]
A:admin@PE-2# show router bgp routes community target:64500:1
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
i     10.14.0.0/16                                     100         None
      10.13.0.1                                        None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

This route is leakable:

```
[/]
A:admin@PE-2# show router bgp routes community target:64500:1 hunt | match Flags
Flags          : Invalid IGP Nexthop-Unresolved Leakable
```

On PE-2, the following **leak-import** policy is configured in VPRN 1 to import the leakable routes with community "target:64500:1":

```
# on PE-2:
configure {
    policy-options
        community "target:64500:1" {
            member "target:64500:1" { }
        }
        policy-statement "leak-import-1" {
            entry 10 {
                from {
                    community {
                        name "target:64500:1"
                    }
                }
                action {
                    action-type accept
                }
            }
            default-action {
                action-type reject
            }
        }
    }
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
```

```
            customer "1"
            autonomous-system 64500
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64500:1"
                    vrf-target {
                        community "target:64500:1"
                    }
                }
            }
            bgp {
                rib-management {
                    ipv4 {
                        leak-import {
                            policy ["leak-import-1"]
                        }
                    }
                }
            }
        }
    }
}
```

By default, the base router does not leak unresolved routes, so the list of leaked BGP routes in VPRN 1 remains empty:

```
[/]
A:admin@PE-2# show router 1 bgp routes ipv4 leaked
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
No Matching Entries Found.
===============================================================================
```

The **allow-unresolved-leaking true** command in the **BGP next-hop resolution** context of the base router allows unresolved BGP routes to be leaked:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            next-hop-resolution {
                allow-unresolved-leaking true
            }
        }
    }
}
```

When routes with unresolved BGP next-hop in the base router are leaked, VPRN 1 receives the BGP route for prefix 10.14.0.0/16, and the next-hop can be resolved in the VPRN, so the leaked route is valid, best, and used:

```
[/]
A:admin@PE-2# show router 1 bgp routes ipv4 leaked
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>li 10.14.0.0/16                                     100         None
      10.13.0.1 (Base)                                 None        10
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

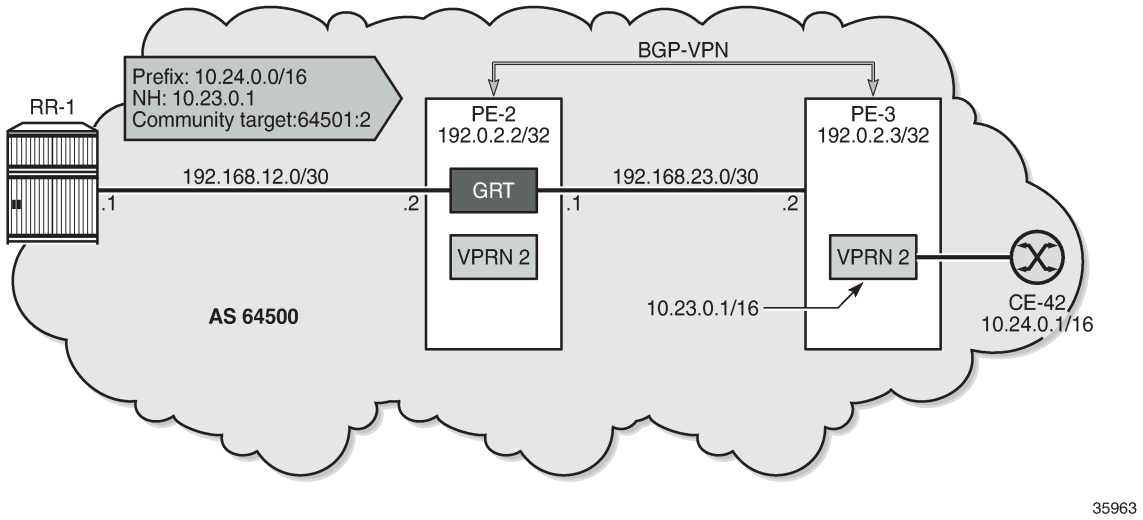
The route table for VPRN 1 includes a BGP route for prefix 10.14.0.0/16 with next-hop 172.16.23.2:

```
[/]
A:admin@PE-2# show router 1 route-table

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
10.12.0.1/32                                   Local   Local     00h16m47s  0
       lo1                                                           0
10.13.0.1/32                                   Remote  ISIS      00h16m14s  15
       172.16.23.2                                                   10
10.14.0.0/16                                   Remote  BGP       00h00m17s  170
       172.16.23.2                                                   10
172.16.23.0/30                                 Local   Local     00h16m47s  0
       int-VPRN1-PE-2-PE-3                                           0
-------------------------------------------------------------------------------
No. of Routes: 4
---snip---
===============================================================================
```

Use case 2: BGP route leaked to VPRN 2 with next-hop resolved using VPN-IP

Figure 97: Leaked route 10.24.0.0/16 with next-hop resolved in VPRN 2 using VPN-IP shows that RR-1 advertises prefix 10.24.0.0/16 with next-hop 10.23.0.1 while PE-3 advertises prefix 10.23.0.1/32 in a VPN-IP route to PE-2.

Figure 97: Leaked route 10.24.0.0/16 with next-hop resolved in VPRN 2 using VPN-IP



On PE-3, VPRN 2 has a loopback interface "lo1" configured with IP address 10.23.0.1/32, which is the BGP next-hop of the leakable route received from RR-1. VPRN 2 is configured with auto-bind-tunnel with resolution to SR-ISIS tunnels.

```
# on PE-3:
configure {
    service {
        vprn "VPRN 2" {
            admin-state enable
            service-id 2
            customer "1"
            autonomous-system 64500
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64500:2"
                    vrf-target {
                        community "target:64500:2"
                    }
                    auto-bind-tunnel {
                        resolution filter
                        resolution-filter {
                            sr-isis true
                        }
                    }
                }
            }
            interface "lo1" {
                loopback true
                ipv4 {
                    primary {
                        address 10.23.0.1
                        prefix-length 32
                    }
                }
            }
        }
    }
```

```
}
```

Prefix 10.23.0.1/32 is advertised in a VPN-IPv4 route to PE-2. On PE-3, the BGP configuration is as follows:

```
# on PE-3:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "iBGP-VPN" {
                peer-as 64500
                family {
                    vpn-ipv4 true
                }
            }
            neighbor "192.0.2.2" {
                group "iBGP-VPN"
            }
        }
    }
}
```

When the prefix 10.23.0.1/32 is advertised by PE-3, the route table for VPRN 2 on PE-2 is as follows:

```
[/]
A:admin@PE-2# show router 2 route-table

===============================================================================
Route Table (Service: 2)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.22.0.1/32                                  Local   Local     00h19m19s  0
       lo1                                                        0
10.23.0.1/32                                  Remote  BGP VPN   00h17m59s  170
       192.0.2.3 (tunneled:SR-ISIS:524290)                        10
-------------------------------------------------------------------------------
No. of Routes: 2
---snip---
===============================================================================
```

RR-1 advertises the following BGP route for prefix 10.24.0.0/16 with next-hop 10.23.0.1 and community "target:64500:2":

```
[/]
A:admin@PE-2# show router bgp routes community target:64500:2
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
```

```
      As-Path                                                                 Label
------------------------------------------------------------------------------------
i     10.24.0.0/16                                          100         None
      10.23.0.1                                             None        0
      No As-Path                                                        -
------------------------------------------------------------------------------------
Routes : 1
====================================================================================
```

This route is not resolved in BGP, as indicated by the flags:

```
[/]
A:admin@PE-2# show router bgp routes community target:64500:2 hunt | match Flags
Flags          : Invalid IGP Nexthop-Unresolved Leakable
```

The route is leakable and, by configuration, routes with unresolved next-hop can be leaked. The following **leak-import** policy is configured on PE-2 to import routes with community "target:64500:2":

```
# on PE-2:
configure {
    policy-options {
        community "target:64500:2" {
            member "target:64500:2" { }
        }
        policy-statement "leak-import-2" {
            entry 10 {
                from {
                    community {
                        name "target:64500:2"
                    }
                }
                action {
                    action-type accept
                }
            }
            default-action {
                action-type reject
            }
        }
    }
    service {
        vprn "VPRN 2" {
            admin-state enable
            service-id 2
            customer "1"
            autonomous-system 64500
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64500:2"
                    vrf-target {
                        community "target:64500:2"
                    }
                    auto-bind-tunnel {
                        resolution filter
                        resolution-filter {
                            sr-isis true
                        }
                    }
                }
            }
            bgp {
```

```
                rib-management {
                    ipv4 {
                        leak-import {
                            policy ["leak-import-2"]
                        }
                    }
                }
            }
        }
    }
}
```

The route is now leaked even though the next-hop is not only unresolved in the base router, but also unresolved in VPRN 2:

```
[/]
A:admin@PE-2# show router 2 bgp routes ipv4 leaked
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
li    10.24.0.0/16                                     100         None
      10.23.0.1 (Base)                                 None        0
      No As-Path                                                   -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

```
[/]
A:admin@PE-2# show router 2 bgp routes hunt | match Flags
Flags          : Invalid IGP Nexthop-Unresolved Leaked
```

By default, the BGP next-hop in the VPRN is resolved using IGP or static routes, but in this example, the route for 10.23.0.1/23 is resolved using the BGP VPN-IPv4 address family. Therefore, the **BGP next-hop resolution** context in VPRN 2 must be configured to allow the use of BGP routes:

```
# on PE-2:
configure {
    service {
        vprn "VPRN 2" {
            admin-state enable
            service-id 2
            customer "1"
            autonomous-system 64500
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64500:2"
                    vrf-target {
                        community "target:64500:2"
```

```
                    }
                    auto-bind-tunnel {
                        resolution filter
                        resolution-filter {
                            sr-isis true
                        }
                    }
                }
            }
            bgp {
                next-hop-resolution {
                    use-bgp-routes true     # for BGP and BGP-VPN routes
                }
                rib-management {
                    ipv4 {
                        leak-import {
                            policy ["leak-import-2"]
                        }
                    }
                }
            }
        }
    }
}
```

When the next-hop can be resolved using a VPN-IPv4 route, the leaked route becomes used, valid, and best in VPRN 2:

```
[/]
A:admin@PE-2# show router 2 bgp routes ipv4 leaked
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>li 10.24.0.0/16                                     100         None
      10.23.0.1 (Base)                                 None        10
      No As-Path                                                   -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

```
[/]
A:admin@PE-2# show router 2 bgp routes hunt | match Flags
Flags          : Used Valid Best IGP Leaked In-RTM
```

The route table for VPRN 2 on PE-2 now includes a BGP route for prefix 10.24.0.0/16:

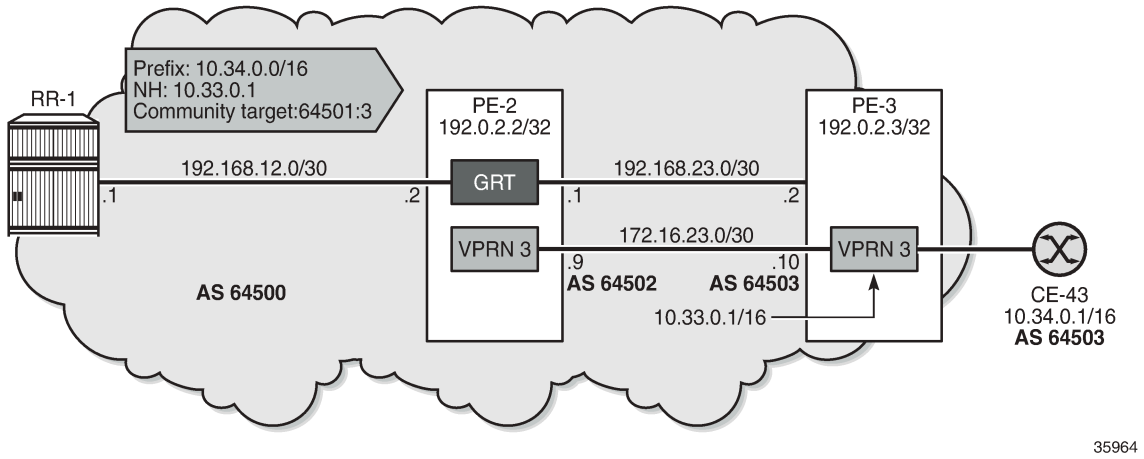
```
[/]
A:admin@PE-2# show router 2 route-table
```

```
===============================================================================
Route Table (Service: 2)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
10.22.0.1/32                                    Local   Local     00h25m07s  0
       lo1                                                          0
10.23.0.1/32                                    Remote  BGP VPN   00h23m46s  170
       192.0.2.3 (tunneled:SR-ISIS:524290)                          10
10.24.0.0/16                                    Remote  BGP       00h00m22s  170
       192.0.2.3 (tunneled:SR-ISIS:524290)                          10
-------------------------------------------------------------------------------
No. of Routes: 3
---snip---
===============================================================================
```

Use case 3: BGP route leaked to VPRN 3 with next-hop resolved using eBGP

Figure 98: Leaked route 10.34.0.0/16 with next-hop resolved in VPRN 2 using eBGP shows that RR-1 advertises prefix 10.34.0.0/16 with next-hop 10.33.0.1. A BGP session is established within VPRN 3 on PE-2 and PE-3.

Figure 98: Leaked route 10.34.0.0/16 with next-hop resolved in VPRN 2 using eBGP



On PE-3, VPRN 3 has a loopback Interface "lo1" configured with IP address 10.33.0.1/32, which is the BGP next-hop of the leakable route received from RR-1. Prefix 10.33.0.0/16 is advertised by BGP in VPRN 3.

```
# on PE-3:
configure {
    policy-options {
        prefix-list "10.33.0.0/16" {
            prefix 10.33.0.0/16 type longer {
            }
        }
        policy-statement "export_10.33" {
            entry 10 {
                from {
```

```
                    prefix-list ["10.33.0.0/16"]
                }
                to {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                }
            }
        }
    }
    service {
        vprn "VPRN 3" {
            admin-state enable
            service-id 3
            customer "1"
            autonomous-system 64503
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64503:3"
                    vrf-target {
                        community "target:64500:3"
                    }
                }
            }
            bgp {
                router-id 10.33.0.1
                split-horizon true
                group "eBGP" {
                    peer-as 64502
                }
                neighbor "172.16.23.9" {
                    group "eBGP"
                    export {
                        policy ["export_10.33"]
                    }
                }
            }
            interface "int-VPRN3-PE-3-CE-43" {
                ipv4 {
                    primary {
                        address 172.16.34.9
                        prefix-length 30
                    }
                }
                sap 1/1/c1/1:3 {
                }
            }
            interface "int-VPRN3-PE-3-PE-2" {
                ipv4 {
                    primary {
                        address 172.16.23.10
                        prefix-length 30
                    }
                }
                sap 1/1/c1/2:3 {
                }
            }
            interface "lo1" {
                loopback true
                ipv4 {
```

```
                    primary {
                        address 10.33.0.1
                        prefix-length 32
                    }
                }
            }
            static-routes {
                route 10.34.0.0/16 route-type unicast {
                    next-hop "172.16.34.10" {
                        admin-state enable
                    }
                }
            }
        }
    }
}
```

The route table for VPRN 3 on PE-2 contains the loopback address from VPRN 3 on PE-3:

```
[/]
A:admin@PE-2# show router 3 route-table

===============================================================================
Route Table (Service: 3)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.32.0.1/32                                    Local   Local     00h26m59s  0
       lo1                                                          0
10.33.0.1/32                                    Remote  BGP       00h25m56s  170
       172.16.23.10                                                 0
172.16.23.8/30                                  Local   Local     00h26m59s  0
       int-VPRN3-PE-2-PE-3                                          0
-------------------------------------------------------------------------------
No. of Routes: 3
---snip---
===============================================================================
```

PE-2 receives the following BGP route with community "target:64500:3" from RR-1:

```
[/]
A:admin@PE-2# show router bgp routes community target:64500:3
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
i     10.34.0.0/16                                      100         None
      10.33.0.1                                         None        0
      64503                                                         -
-------------------------------------------------------------------------------
Routes : 1
```

```
===============================================================================
```

This route is leakable, but the next-hop 10.33.0.1 cannot be resolved in the base router of PE-2:

```
[/]
A:admin@PE-2# show router bgp routes community target:64500:3 hunt | match Flags
Flags          : Invalid IGP Nexthop-Unresolved Leakable
```

The only BGP route used in VPRN 3 on PE-2 is for prefix 10.33.0.1/32:

```
[/]
A:admin@PE-2# show router 3 bgp routes
===============================================================================
 BGP Router ID:10.32.0.1        AS:64502       Local AS:64502
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  10.33.0.1/32                                      None        None
      172.16.23.10                                      None        0
      64503                                                         -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The following **leak-import** policy is configured on PE-2 to import leakable BGP routes with community "64500:3":

```
# on PE-2:
configure {
    policy-options {
        community "target:64500:3" {
            member "target:64500:3" { }
        }
        policy-statement "leak-import-3" {
            entry 10 {
                from {
                    community {
                        name "target:64500:3"
                    }
                }
                action {
                    action-type accept
                }
            }
            default-action {
                action-type reject
            }
        }
    }
}
```

This **leak-import** policy is applied in VPRN 3 and the **BGP next-hop-resolution** is configured as **use-bgp-routes true**:

```
# on PE-2:
configure {
    service {
        vprn "VPRN 3" {
            admin-state enable
            service-id 3
            customer "1"
            autonomous-system 64502
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "64502:3"
                    vrf-target {
                        community "target:64500:3"
                    }
                }
            }
            bgp {
                next-hop-resolution {
                    use-bgp-routes true     # for BGP and BGP-VPN routes
                }
                rib-management {
                    ipv4 {
                        leak-import {
                            policy ["leak-import-3"]
                        }
                    }
                }
            }
        }
    }
}
```

With this configuration, the received RR-1 route for prefix 10.34.0.0/16 is leaked to VPRN 3 and the next-hop is resolved using a BGP route. The BGP routes in VPRN 3 on PE-2 are the following:

```
[/]
A:admin@PE-2# show router 3 bgp routes
===============================================================================
 BGP Router ID:10.32.0.1        AS:64502       Local AS:64502
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.33.0.1/32                                     None        None
      172.16.23.10                                     None        0
      64503                                                        -
u*>li 10.34.0.0/16                                     100         None
      10.33.0.1 (Base)                                 None        0
      64503                                                        -
```

```
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

The route table for VPRN 3 on PE-2 now includes a route for prefix 10.34.0.0/16:

```
[/]
A:admin@PE-2# show router 3 route-table

===============================================================================
Route Table (Service: 3)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.32.0.1/32                                  Local   Local     00h32m42s  0
       lo1                                                          0
10.33.0.1/32                                  Remote  BGP       00h31m38s  170
       172.16.23.10                                                 0
10.34.0.0/16                                  Remote  BGP       00h00m09s  170
       172.16.23.10                                                 0
172.16.23.8/30                                Local   Local     00h32m42s  0
       int-VPRN3-PE-2-PE-3                                          0
-------------------------------------------------------------------------------
No. of Routes: 4
---snip---
===============================================================================
```

Conclusion

BGP routes can be leaked from the base router to a VPRN routing instance, even when the next-hop is unresolved in the base router. This feature reduces the number of BGP sessions toward an RR, because all VPRN-related routes can now be leaked from the base router using a single BGP session. The VPRNs distinguish the routes based on the community value.

BGP Weighted ECMP

This chapter provides information about BGP weighted ECMP.

Topics in this chapter include:

Applicability

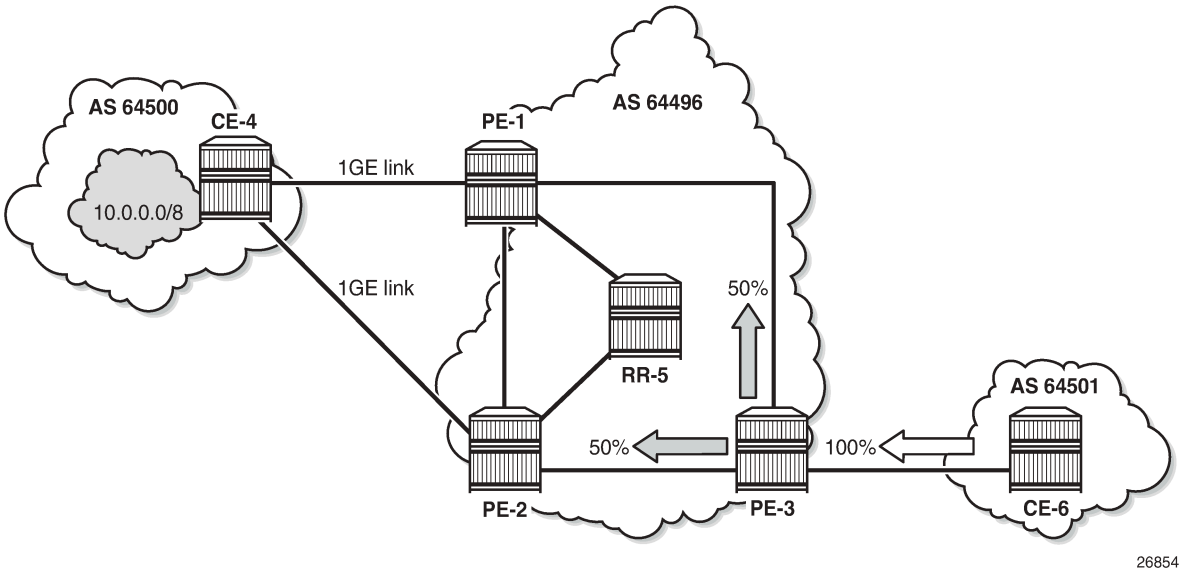
The information and configuration in this chapter was originally based on SR OS Release 15.0.R4. The CLI in the current edition is based on SR OS Release 23.3.R2.

Overview

Equal-cost multipath (ECMP) is a routing strategy that allows the installation of multiple next hops for an IP destination in the routing table. When used in conjunction with BGP multipath, the ingress router can forward traffic to an IP prefix destination in a load-balanced fashion across the available ECMP next hops. For more information about the implementation, see the BGP Multipath chapter.

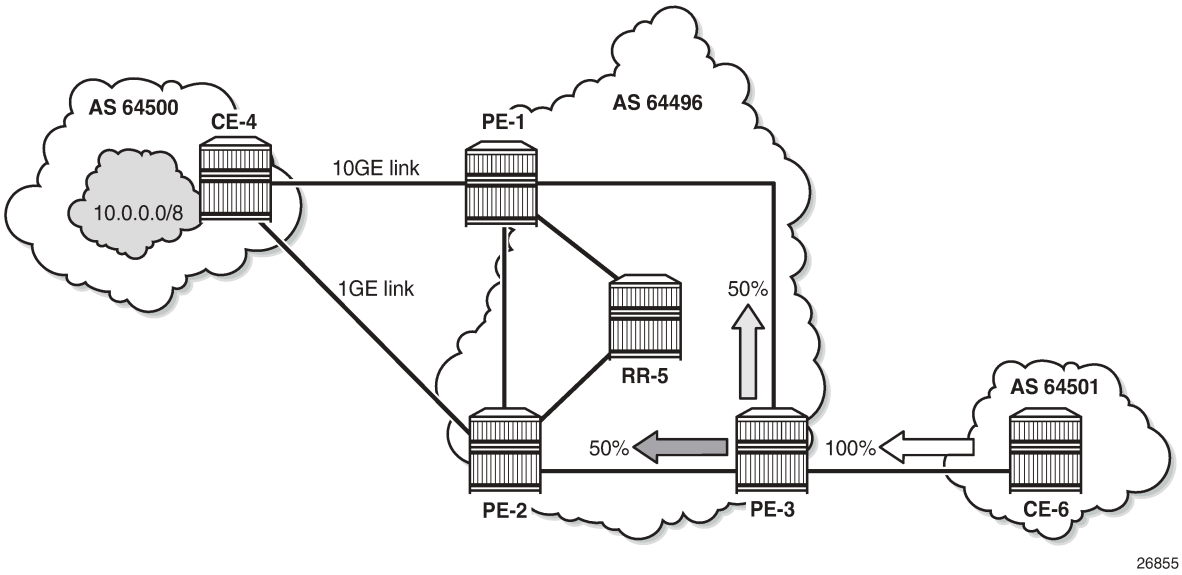
In the standard implementation, ECMP distributes traffic as evenly as possible across all the ECMP next hops. Figure 99: Standard ECMP - Equal Bandwidth Links shows an example scenario where CE-4 is dual-homed to two PE routers and advertises the prefix 10.0.0.0/8. This prefix is then advertised within AS 64496 and received by PE-3, which in turn advertises it to CE-6 in AS 64501. PE-3 has BGP multipath and ECMP enabled, so the traffic toward destinations in 10.0.0.0/8 sent by CE-6 is load-balanced toward PE-1 and PE-2 as evenly as possible.

Figure 99: Standard ECMP - Equal Bandwidth Links



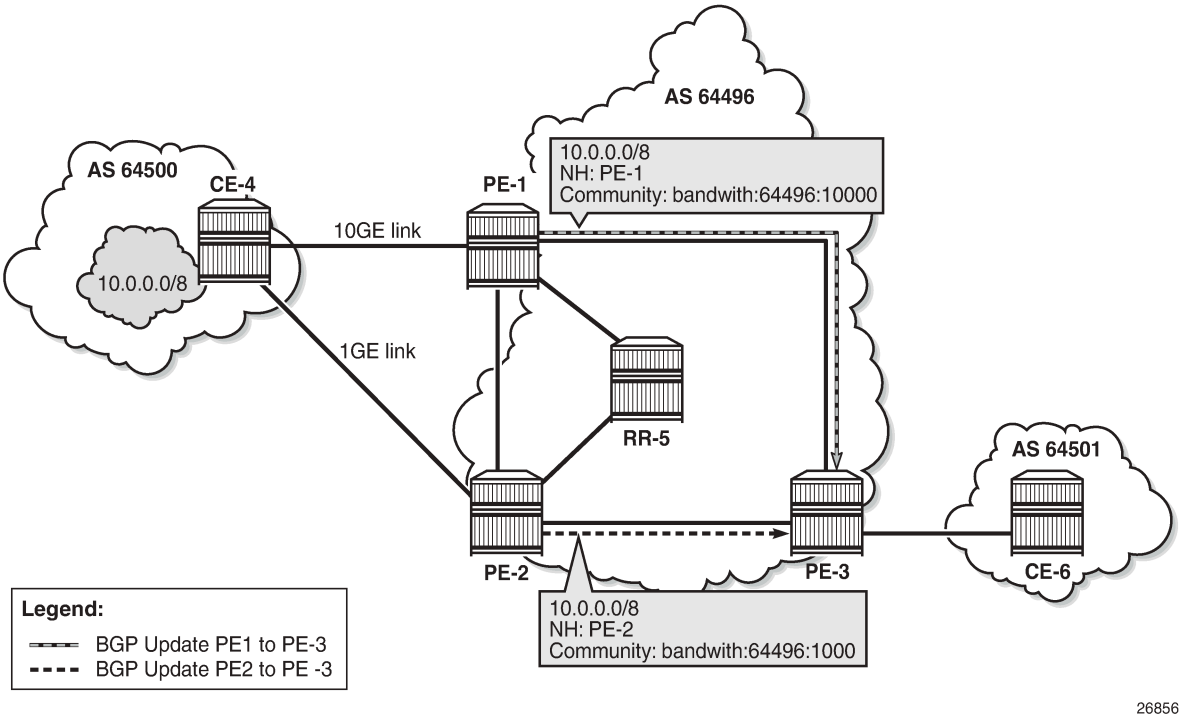
The behavior of equally distributing across the ECMP next hops may not be suitable under specific circumstances. Consider the same topology with the connection between CE-4 and PE-1 replaced with a 10GE link, while the CE-4 to PE-2 connection still is a 1GE link, as shown in Figure 100: Standard ECMP - Unequal Bandwidth Links. In standard ECMP operation, when PE-3 sends 50% of traffic to PE-1 and 50% to PE-2, this may result in an under-utilization of the link between CE-4 and PE-1 or an over-utilization of the link between CE-4 and PE-2.

Figure 100: Standard ECMP - Unequal Bandwidth Links



BGP Weighted ECMP, also known as Unequal-Cost Multipath (UCMP), allows for the distribution of traffic in proportion to the relative bandwidth of each equal-cost path. This feature uses a BGP community called the Link Bandwidth Extended Community. Figure 101: Link Bandwidth Extended Community Advertisement shows that PE-1 and PE-2, with this functionality, can add a Link Bandwidth Extended Community to the BGP routes advertised toward other routers within AS 64496 that indicates the bandwidth of their PE-CE link.

Figure 101: Link Bandwidth Extended Community Advertisement



PE-3 can use the information in the Link Bandwidth Extended Community to distribute the traffic according to the relative bandwidth, or the "weight" of each path. Figure 102: Weighted ECMP - Unequal Bandwidth Links shows that 91% of traffic is sent toward PE-1 with the 10GE link and 9% is sent toward PE-2 with the 1GE link.

Figure 102: Weighted ECMP - Unequal Bandwidth Links

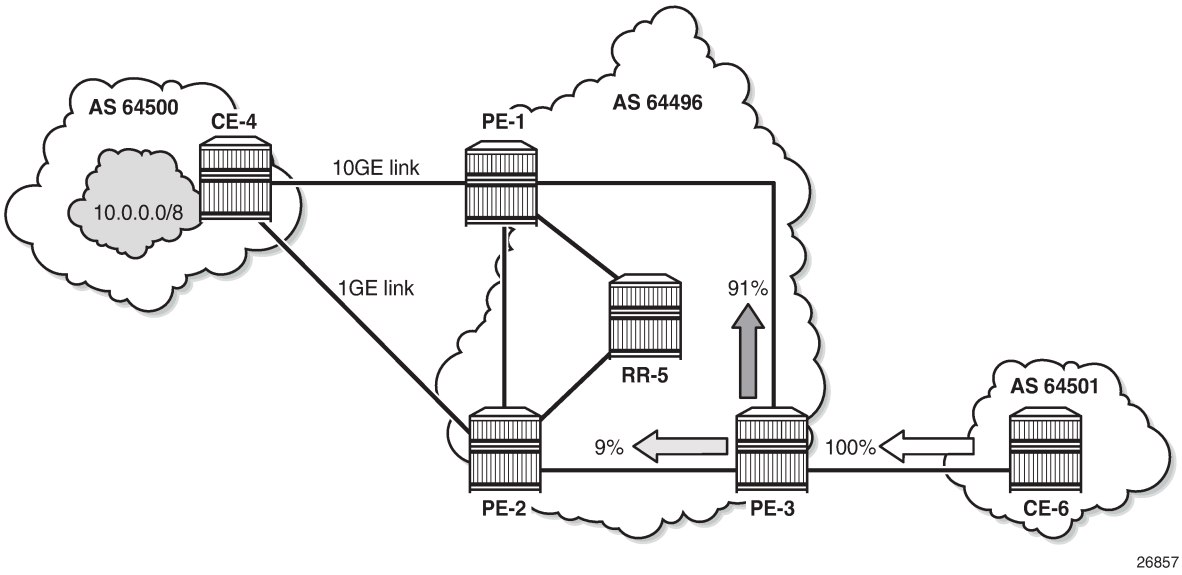


Figure 103: Weighted ECMP - Link Aggregation Group shows another example where the CE-4-to-PE-1 link is composed of four 1GE links that are part of a Link Aggregation Group (LAG) and the CE-4-to-PE-2 link is 1GE. Weighted ECMP can be used here to achieve an 80% to 20% distribution of traffic sent from PE-3 to PE-1 and PE-2, respectively.

Figure 103: Weighted ECMP - Link Aggregation Group

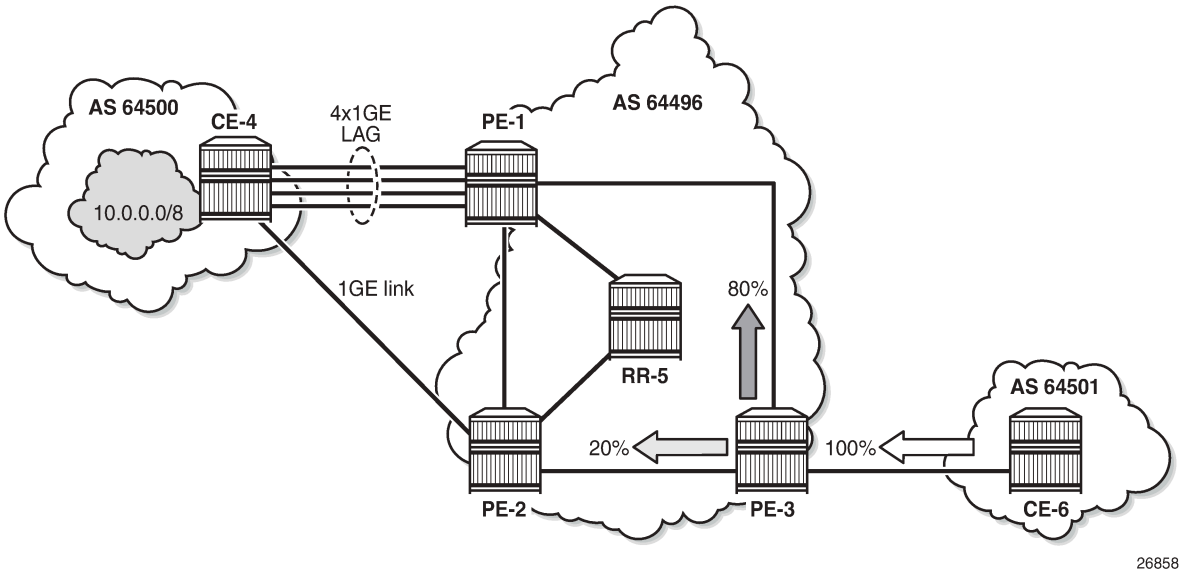


Figure 104: Standard ECMP - Unequal Bandwidth Links with eBGP shows an example where PE-1 is connected to two eBGP routers in neighbor AS 64500. Using the weighted ECMP functionality, 91% of traffic is sent to CE-4 and 9% to CE-5, according to the relative bandwidth values.

Figure 104: Standard ECMP - Unequal Bandwidth Links with eBGP

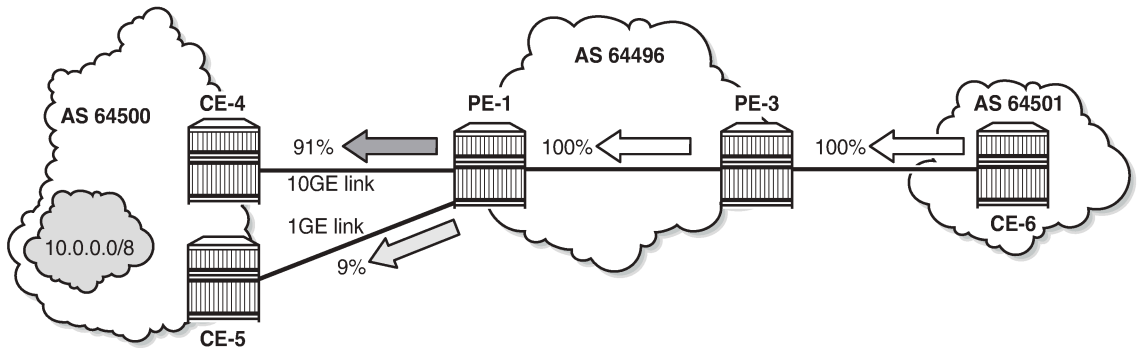
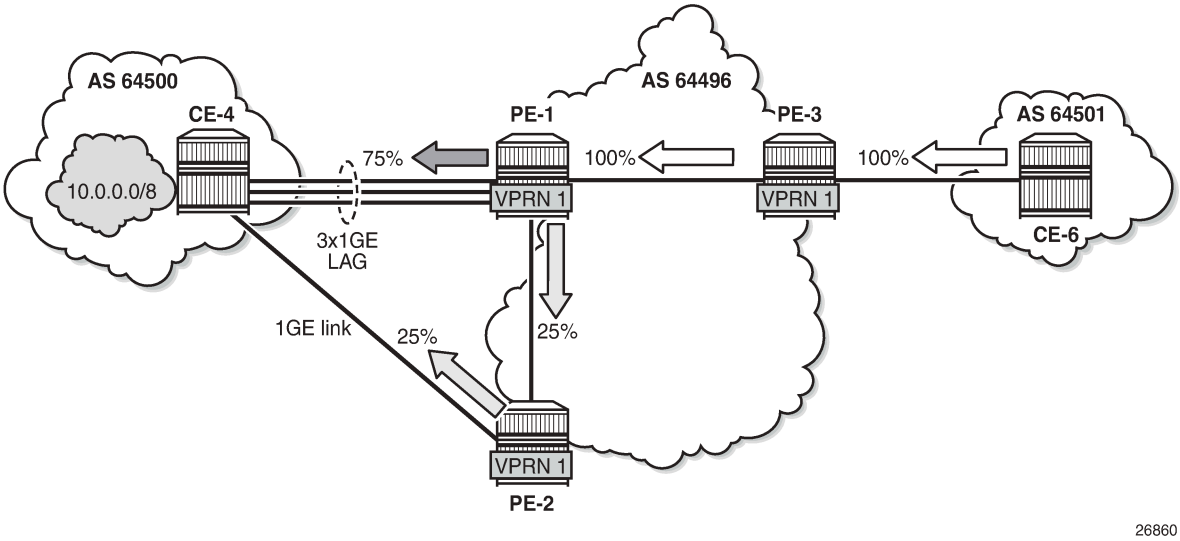


Figure 105: Weighted ECMP - Unequal Bandwidth Links with VPRN shows an example with a Layer 3 VPRN service. PE-1 receives prefix 10.0.0.0/8 from CE-4 via eBGP, and also from PE-2 via iBGP. PE-1 sets the Link Bandwidth Extended Community indicating 3GE on the route received from CE-4. PE-2 sets the community value indicating 1GE on the route it advertises to PE-1. With Exterior Interior Border Gateway Protocol (EIBGP) multipath (described in the BGP Multipath chapter) and ECMP within the VPRN, PE-1 can send 75% of traffic on the direct LAG link to CE-4 and 25% to PE-2, which then forwards that traffic to CE-4.

Figure 105: Weighted ECMP - Unequal Bandwidth Links with VPRN



Link Bandwidth Extended Community is defined in *draft-ietf-idr-link-bandwidth-06* and has the following characteristics:

- Signals the link bandwidth of a BGP path
- Has the following format: bandwidth:<as-number>:<value>
  - bandwidth is the community type
  - <as-number> is the local AS number

  - <value> is a fixed/static bandwidth in Mb/s (converted to IEEE floating point format in a BGP Update message)
- Optional and non-transitive attribute (not sent to other eBGP peers upon receipt)
- If a router changes the route next hop, it does not propagate the Link Bandwidth Extended Community
- A route can only have a single Link Bandwidth Extended Community
- SR OS routers automatically perform weighted load balancing if all the BGP updates received for a destination contain the Link Bandwidth Extended Community

Link Bandwidth Extended Community can be added to a BGP route with the following methods:

- **link-bandwidth** command
- BGP import policy action
- VRF import policy action
- BGP export policy action

The **link-bandwidth** command has the following characteristics:

- Configurable per BGP group or neighbor in base router or VPRN
- Adds a Link Bandwidth Extended Community to all (IPv4, IPv6, VPN-IPv4, VPN-IPv6, label-IPv4, label-IPv6) routes received from directly connected EBGP peers
- Bandwidth value is based on the speed of port or active LAG members
- Bandwidth is automatically adjusted for LAG interfaces based on the number of active LAG member ports

SR OS uses the following rules when BGP paths are received with Link Bandwidth Extended Communities:

1. If BGP multipath and ECMP are configured and all the eligible multipaths have a Link Bandwidth Extended Community, then weighted ECMP is performed on the relative bandwidth of each path.
2. If EIBGP multipath and ECMP are enabled in a VPRN and all the eligible next hops have a Link Bandwidth Extended Community, then weighted ECMP is performed based on the relative bandwidth of each path.
3. The Link Bandwidth Extended Community is not used as a criterion for two or more paths to be considered equal for BGP/EIBGP multipath purposes.

Configuration

The following configuration examples for BGP weighted ECMP are covered in this chapter:

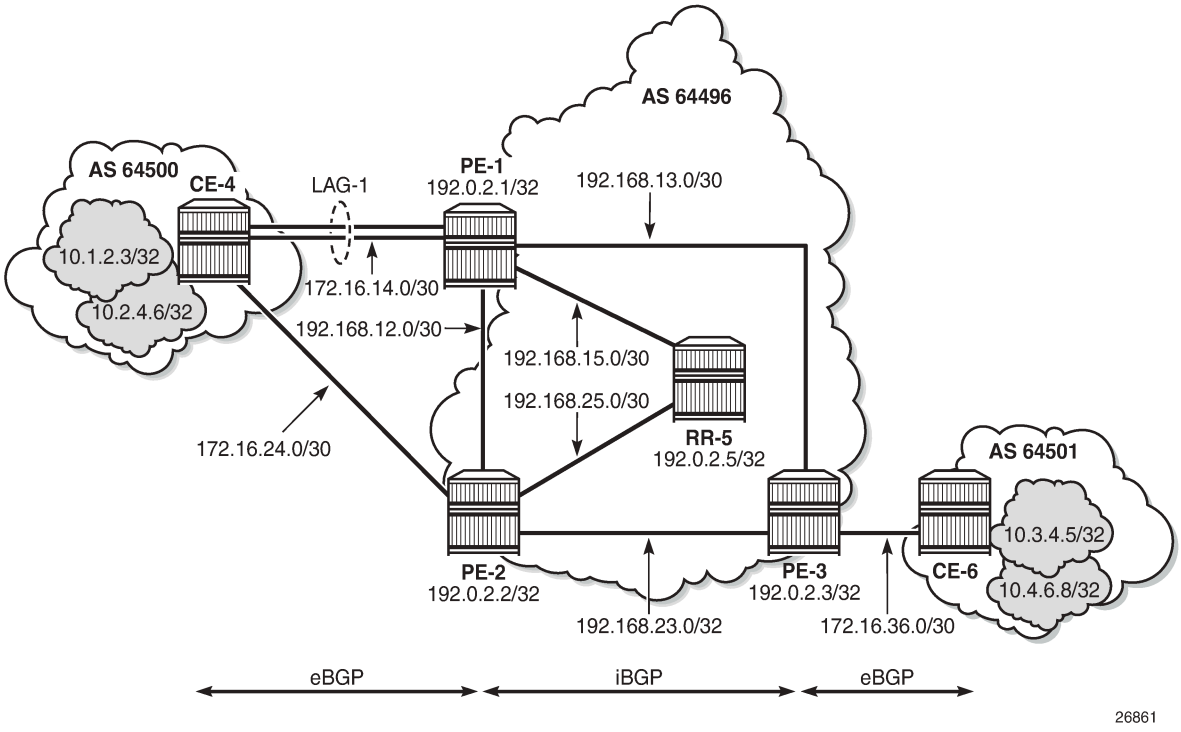
- BGP Weighted ECMP for IPv4 Family using the link-bandwidth command
- BGP Weighted ECMP for IPv4 Family using BGP Import Policy

Figure 106: Example Topology - BGP Weighted ECMP for IPv4 Family shows the example topology for BGP Weighted ECMP for IPv4 family with the following characteristics:

- CE-4 in AS 64500 advertises both prefixes 10.1.2.3/32 and 10.2.4.6/32 to its eBGP peers PE-1 and PE-2 in AS 64496.
- RR-5 is route reflector for all PEs in AS 64496.
- **add-paths** is configured on all PE routers and RR-5 with a **send** limit of *2*.

- CE-6 in AS 64501 advertises both prefixes 10.3.4.5/32 and 10.4.6.8/32 to its eBGP peer PE-3 in AS 64496.

Figure 106: Example Topology - BGP Weighted ECMP for IPv4 Family



Initial Configuration

The initial configuration on all nodes includes:

- Cards, MDAs, ports
- LAG configured for the link between CE-4 and PE-1 with two member links
- Router interfaces
- IS-IS as IGP on all interfaces within AS 64496 (alternatively, OSPF can be used)

BGP is configured on all the nodes. CE-4 peers with PE-1 and PE-2 and exports the 10.1.2.3/32 and 10.2.4.6/32 loopback prefixes to both eBGP peers, as follows:

```
# on CE-4:
configure {
    router "Base" {
        interface "int-loopback-1" {
            loopback
            ipv4 {
                primary {
                    address 10.1.2.3
                    prefix-length 32
                }
            }
```

```
        }
        interface "int-loopback-2" {
            loopback
            ipv4 {
                primary {
                    address 10.2.4.6
                    prefix-length 32
                }
            }
        }
        autonomous-system 64500
        bgp {
            admin-state enable
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "eBGP" {
                peer-as 64496
                export {
                    policy ["policy-export-bgp"]
                }
            }
            neighbor "172.16.14.1" {
                group "eBGP"
            }
            neighbor "172.16.24.1" {
                group "eBGP"
            }
        }
    }
    policy-options {
        prefix-list "10.0.0.0/8" {
            prefix 10.0.0.0/8 type longer {
            }
        }
        policy-statement "policy-export-bgp" {
            entry 10 {
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                }
            }
        }
    }
}
```

The BGP configuration on CE-6 is identical, except for the loopback interface addresses.

PE-1 peers with CE-4 in AS 65400 and RR-5 in AS 64496. **add-paths** is enabled on the iBGP group to advertise redundant BGP paths to the route reflector. The BGP configuration on PE-1 is as follows:

```
# on PE-1:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            admin-state enable
            rapid-withdrawal true
```

```
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "eBGP" {
                peer-as 64500
            }
            neighbor "172.16.14.2" {
                group "eBGP"
            }
            group "iBGP" {
                family {
                    ipv4 true
                }
                next-hop-self true
                peer-as 64496
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            neighbor "192.0.2.5" {
                group "iBGP"
            }
        }
    exit all
```

The BGP configuration on PE-2 and PE-3 is similar to that on PE-1.

RR-5 acts as a route reflector to all the PEs in AS 64496 with a cluster ID of 5.5.5.5. **add-paths** is enabled to advertise redundant BGP paths to the PEs. The configuration on RR-5 is as follows:

```
# on RR-5:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            admin-state enable
            rapid-withdrawal true
            split-horizon true
            ebgp-default-reject-policy {
                import false
                export false
            }
            group "iBGP" {
                family {
                    ipv4 true
                }
                cluster {
                    cluster-id 5.5.5.5
                }
                peer-as 64496
                add-paths {
                    ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            neighbor "192.0.2.1" {
```

```
                group "iBGP"
            }
            neighbor "192.0.2.2" {
                group "iBGP"
            }
            neighbor "192.0.2.3" {
                group "iBGP"
            }
        }
    }
}
```

BGP Weighted ECMP for IPv4 Family using the link-bandwidth command

PE-3 receives the prefixes 10.1.2.3/32 and 10.2.4.6/32 from PE-1 and PE-2 via the route reflector and indicates the ones received from PE-1 as the "used" or active routes, as follows:

```
[/]
A:admin@PE-3# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.2.3/32                                      100         None
      192.0.2.1                                        7           10
      64500                                                        -
*i    10.1.2.3/32                                      100         None
      192.0.2.2                                        8           10
      64500                                                        -
u*>i  10.2.4.6/32                                      100         None
      192.0.2.1                                        9           10
      64500                                                        -
*i    10.2.4.6/32                                      100         None
      192.0.2.2                                        10          10
      64500                                                        -
u*>i  10.3.4.5/32                                      None        None
      172.16.36.2                                      None        0
      64501                                                        -
u*>i  10.4.6.8/32                                      None        None
      172.16.36.2                                      None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 6
===============================================================================
```

ECMP and BGP multipath are enabled on PE-3 with the following commands:

```
# on PE-3:
configure {
```

```
    router "Base" {
        ecmp 2
        bgp {
            multipath {
                max-paths 2
            }
        }
    }
}
```

As a result, PE-3 installs the routes from PE-2 as active, in addition to those from PE-1:

```
[/]
A:admin@PE-3# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.2.3/32                                      100         None
      192.0.2.1                                        7           10
      64500                                                        -
u*>i  10.1.2.3/32                                      100         None
      192.0.2.2                                        8           10
      64500                                                        -
u*>i  10.2.4.6/32                                      100         None
      192.0.2.1                                        9           10
      64500                                                        -
u*>i  10.2.4.6/32                                      100         None
      192.0.2.2                                        10          10
      64500                                                        -
u*>i  10.3.4.5/32                                      None        None
      172.16.36.2                                      None        0
      64501                                                        -
u*>i  10.4.6.8/32                                      None        None
      172.16.36.2                                      None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 6
===============================================================================
```

The multiple next hops are also visible in the route table of PE-3:

```
[/]
A:admin@PE-3# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.1.2.3/32                                   Remote  BGP       00h00m55s  170
```

```
       192.168.13.1                                                    10
10.1.2.3/32                                 Remote  BGP       00h00m55s  170
       192.168.23.1                                                    10
10.2.4.6/32                                 Remote  BGP       00h00m55s  170
       192.168.13.1                                                    10
10.2.4.6/32                                 Remote  BGP       00h00m55s  170
       192.168.23.1                                                    10
10.3.4.5/32                                 Remote  BGP       00h02m47s  170
       172.16.36.2                                                     0
10.4.6.8/32                                 Remote  BGP       00h02m47s  170
       172.16.36.2                                                     0
-------------------------------------------------------------------------------
No. of Routes: 6
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The following command shows that the routes received on PE-3 have no community added (string within single quotes in the match statement to indicate that it is an expression).

```
[/]
A:admin@PE-3# show router bgp routes 10.1.2.3/32 hunt brief | match '^Nexthop|Community'
Nexthop        : 192.0.2.1
Community      : No Community Members
Nexthop        : 192.0.2.2
Community      : No Community Members
```

The following command output shows the ECMP-weight outputs assigned to next hops 192.0.2.1 and 192.0.2.2. Both have a value of 1.

```
[/]
A:admin@PE-3# show router fib 1 ip-prefix-prefix-length 10.1.2.3/32 extensive

===============================================================================
FIB Display (Router: Base)
===============================================================================
Dest Prefix             : 10.1.2.3/32
  Protocol              : BGP
  Installed             : Y
  Indirect Next-Hop     : 192.0.2.1
    QoS                 : Priority=n/c, FC=n/c
    Source-Class        : 0
    Dest-Class          : 0
    ECMP-Weight         : 1
    Resolving Next-Hop  : 192.168.13.1
      Interface         : int-PE-3-PE-1
      ECMP-Weight       : 1
  Indirect Next-Hop     : 192.0.2.2
    QoS                 : Priority=n/c, FC=n/c
    Source-Class        : 0
    Dest-Class          : 0
    ECMP-Weight         : 1
    Resolving Next-Hop  : 192.168.23.1
      Interface         : int-PE-3-PE-2
      ECMP-Weight       : 1
===============================================================================
Total Entries : 1
===============================================================================
```

The following command is executed on both PE-1 and PE-2 to automatically add a Link Bandwidth Extended Community on routes received from their eBGP neighbor CE-4:

```
# on PE-1 and on PE-2:
configure {
    router "Base" {
        bgp {
            group "eBGP" {
                link-bandwidth {
                    add-to-received-ebgp ipv4
                exit all
```

PE-3 now receives the routes from PE-1 and PE-2 with Link Bandwidth Extended Communities corresponding to the interface bandwidth for each CE-PE link:

```
[/]
A:admin@PE-3# show router bgp routes 10.1.2.3/32 hunt brief | match '^Nexthop|Community'
Nexthop        : 192.0.2.1
Community      : bandwidth:64496:200000
Nexthop        : 192.0.2.2
Community      : bandwidth:64496:100000
```

The following command output now shows that the ECMP-Weight value assigned to next hop 192.0.2.1 is 2, relative to its two member interfaces in the LAG, whereas the ECMP-Weight value of 192.0.2.2 is still 1, because it has a single interface to CE-4:

```
[/]
A:admin@PE-3# show router fib 1 ip-prefix-prefix-length 10.1.2.3/32 extensive

===============================================================================
FIB Display (Router: Base)
===============================================================================
Dest Prefix             : 10.1.2.3/32
  Protocol              : BGP
  Installed             : Y
  Indirect Next-Hop     : 192.0.2.1
    QoS                 : Priority=n/c, FC=n/c
    Source-Class        : 0
    Dest-Class          : 0
    ECMP-Weight         : 2
    Resolving Next-Hop  : 192.168.13.1
      Interface         : int-PE-3-PE-1
      ECMP-Weight       : 1
  Indirect Next-Hop     : 192.0.2.2
    QoS                 : Priority=n/c, FC=n/c
    Source-Class        : 0
    Dest-Class          : 0
    ECMP-Weight         : 1
    Resolving Next-Hop  : 192.168.23.1
      Interface         : int-PE-3-PE-2
      ECMP-Weight       : 1
===============================================================================
Total Entries : 1
===============================================================================
```

If a tester tool is available, it can be used to test the traffic load-balancing behavior by using it to replace CE-4 and CE-6 in the topology. This would be the preferred option to get better results in observing the effect of weighted ECMP. Multiple flows (preferably a couple of hundred or thousands) should be created and sent between the tester ports. For a simple test, the SR OS rapid ping tool can be used to create traffic between the loopback interfaces of CE-6 and CE-4.

At least three flows need to be created to see traffic distributed over the two LAG links between CE-4 and PE-1 and the single link between CE-4 and PE-2. The loopback IP addresses on CE-4 and CE-6 have been specifically chosen to demonstrate the expected load balancing. The behavior may be different if different loopback IP addresses are used, because it affects the load-balancing algorithm.

To facilitate the test, two more Telnet or SSH sessions are initiated to CE-6 (three in total) and the following commands are executed in each separate session:

First session:

```
[/]
A:admin@CE-6# ping 10.1.2.3 source-address 10.3.4.5 size 1200 count 100000 interval 1
```

Second session:

```
[/]
A:admin@CE-6# ping 10.1.2.3 source-address 10.3.4.5 size 1200 count 100000 interval 1
```

Third session:

```
[/]
A:admin@CE-6# ping 10.1.2.3 source-address 10.4.6.8 size 1200 count 100000 interval 1
```

The **monitor** command outputs on PE-1 and PE-2 show the traffic from CE-6 to CE-4 is being distributed over the two LAG links on PE-1 and the single link on PE-2. In the ideal case, PE-1 would receive 67% and PE-2 would receive 33% of total traffic; however, it may not be possible to observe this effectively with only three ICMP flows.

On the PE-1 LAG link to CE-4, the following traffic is monitored. In each interval of 3 seconds, the number of output bytes is 250000 (or more if other traffic is sent in parallel).

```
[/]
A:admin@PE-1# monitor lag 1 interval 3 repeat 999 rate

===============================================================================
Monitor statistics for LAG ID 1
===============================================================================
Port-id         Input packets                    Output packets
                Input bytes                      Output bytes
                Input errors [Input util %]      Output errors [Output util %]
-------------------------------------------------------------------------------
----snip---
-------------------------------------------------------------------------------
At time t = 6 sec (Mode: Rate)
-------------------------------------------------------------------------------
1/1/c2/1        4                                3
                3878                             2628
                0                         ~0.00  0                         ~0.00
1/1/c5/1        1                                1
                128                              128
                0                         ~0.00  0                         ~0.00
-------------------------------------------------------------------------------
Totals          5                                4
                4006                             2756
                0                         ~0.00  0                         ~0.00

-------------------------------------------------------------------------------
At time t = 9 sec (Mode: Rate)
-------------------------------------------------------------------------------
1/1/c2/1        4                                3
```

```
                3878                                2628
                0                         ~0.00     0                         ~0.00
1/1/c5/1        1                                   1
                128                                 128
                0                         ~0.00     0                         ~0.00
-------------------------------------------------------------------------------
Totals          5                                   4
                4006                                2756
                0                         ~0.00     0                         ~0.00
```

On the PE-2 to CE-4 link, the following traffic is monitored. In each interval of 3 seconds, the number of output bytes is 125000 (or more if other traffic is sent in parallel):

```
[/]
A:admin@PE-2# monitor port 1/1/c1/1 interval 3 repeat 999 rate

===============================================================================
Monitor statistics for Port 1/1/c1/1
===============================================================================
                                                    Input                 Output
-------------------------------------------------------------------------------
---snip---
-------------------------------------------------------------------------------
At time t = 6 sec (Mode: Rate)
-------------------------------------------------------------------------------
Octets                                                 0                  1250
Packets                                                0                     1
Errors                                                 0                     0
Bits                                                   0                 10000
Utilization (% of port capacity)                    0.00                 ~0.00

-------------------------------------------------------------------------------
At time t = 9 sec (Mode: Rate)
-------------------------------------------------------------------------------
Octets                                                 0                  1250
Packets                                                0                     1
Errors                                                 0                     0
Bits                                                   0                 10000
Utilization (% of port capacity)                    0.00                 ~0.00
```

BGP Weighted ECMP for IPv4 Family using BGP Import Policy

The **link-bandwidth** command, which was enabled in the previous step, is removed on PE-1 and PE-2:

```
# on PE-1 and on PE-2:
configure {
    router "Base" {
        bgp {
            group "eBGP" {
                link-bandwidth {
                    delete add-to-received-ebgp
                exit all
```

The following policy is configured on PE-1 to manually add the Link Bandwidth Extended Community "bandwidth:64500:4000" to routes received from CE-4:

```
# on PE-1:
configure {
    policy-options {
```

```
        prefix-list "10.0.0.0/8" {
            prefix 10.0.0.0/8 type longer {
            }
        }
        community "bandwidth-4G" {
            member "bandwidth:64500:4000" { }
        }
        policy-statement "policy-import-bandwidth-4G" {
            entry 10 {
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                    community {
                        add ["bandwidth-4G"]
                    }
                }
            }
        }
    }
}
```

The policy is applied on PE-1 for the eBGP group in the import direction:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            group "eBGP" {
                import {
                    policy ["policy-import-bandwidth-4G"]
                exit all
```

The following policy is configured on PE-2 to manually add the Link Bandwidth Extended Community "bandwidth:64500:2000" to routes received from CE-4:

```
# on PE-2:
configure {
    policy-options {
        prefix-list "10.0.0.0/8" {
            prefix 10.0.0.0/8 type longer {
            }
        }
        community "bandwidth-2G" {
            member "bandwidth:64500:2000" { }
        }
        policy-statement "policy-import-bandwidth-2G" {
            entry 10 {
                from {
                    prefix-list ["10.0.0.0/8"]
                }
                action {
                    action-type accept
                    community {
                        add ["bandwidth-2G"]
                    }
                }
            }
        }
    }
}
```

The policy is applied on PE-2 for the eBGP group in the import direction:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            group "eBGP" {
                import {
                    policy ["policy-import-bandwidth-2G"]
                exit all
```

PE-3 receives the routes from PE-1 and PE-2 with Link Bandwidth Extended Communities as configured in the previous step:

```
[/]
A:admin@PE-3# show router bgp routes 10.1.2.3/32 hunt brief | match '^Nexthop|Community'
Nexthop        : 192.0.2.1
Community      : bandwidth:64500:4000
Nexthop        : 192.0.2.2
Community      : bandwidth:64500:2000
```

Again, the following command output shows that the ECMP-weight output assigned to next hop 192.0.2.1 has become 2:

```
[/]
A:admin@PE-3# show router fib 1 ip-prefix-prefix-length 10.1.2.3/32 extensive

===============================================================================
FIB Display (Router: Base)
===============================================================================
Dest Prefix             : 10.1.2.3/32
  Protocol              : BGP
  Installed             : Y
  Indirect Next-Hop     : 192.0.2.1
    QoS                 : Priority=n/c, FC=n/c
    Source-Class        : 0
    Dest-Class          : 0
    ECMP-Weight         : 2
    Resolving Next-Hop  : 192.168.13.1
      Interface         : int-PE-3-PE-1
      ECMP-Weight       : 1
  Indirect Next-Hop     : 192.0.2.2
    QoS                 : Priority=n/c, FC=n/c
    Source-Class        : 0
    Dest-Class          : 0
    ECMP-Weight         : 1
    Resolving Next-Hop  : 192.168.23.1
      Interface         : int-PE-3-PE-2
      ECMP-Weight       : 1
===============================================================================
Total Entries : 1
===============================================================================
```

Note:
Any dynamic changes to the Link Bandwidth Extended Community upon failure or bandwidth change of a LAG link are not possible with the policy functionality, as opposed to using the **link-bandwidth** command.

Similar tests can be run using the rapid ping facility or an external tester tool as described in the previous section to check the packet forwarding behavior.

Conclusion

BGP Weighted ECMP allows modification of the standard load-balancing behavior to accommodate the relative link bandwidth values of different BGP next hops. This allows better utilization of the links in the network with different capacities. The bandwidth values are advertised by edge routers and carried within a BGP community called the Link Bandwidth Extended Community. SR OS routers automatically perform load balancing if all the BGP routes to a destination contain this community.

Dynamic BGP Peers

This chapter provides information about dynamic BGP peers.

Topics in this chapter include:

Applicability

This chapter was initially written for SR OS Release 14.0.R7, but the MD-CLI in the current edition corresponds to SR OS Release 20.7.R1.

Overview

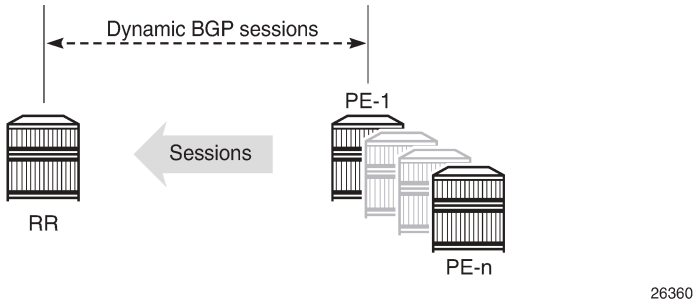
SR OS supports static and dynamic BGP sessions, where the static sessions are initiated toward explicitly configured non-passive neighbors, which are identified through an IPv4 or IPv6 address.

Neighbors must be part of a BGP peer group, and all neighbors in the same group share the same characteristics unless more specific characteristics are defined at the neighbor level.

SR OS will initiate TCP sessions toward explicitly configured non-passive neighbors, and listen for incoming TCP connections on port 179 for these configured neighbors. Sessions established with explicitly configured neighbors are considered static BGP sessions.

Dynamic BGP sessions can be established without explicitly configured neighbors; see Figure 107: Establishing dynamic BGP sessions. The source address of a dynamic peer should match one of the configured IPv4 or IPv6 prefixes for the allowed peer Autonomous Systems (ASs). SR OS will only listen for incoming TCP connections on port 179 for these prefixes (which defines passive mode). SR OS will never initiate connections toward dynamic peers. This is consistent with RFC 4271, which allows a BGP speaker to accept connections from unconfigured BGP peers.

Figure 107: Establishing dynamic BGP sessions



Dynamic BGP peering is also supported for ESM-routed subscriber hosts to improve deployment flexibility, but this is out of the scope of this chapter.

Characteristics

In SR OS, BGP groups and dynamic BGP peers have the following characteristics:

- A BGP group can support static and dynamic peers simultaneously.
- To support dynamic, unconfigured peers, multiple prefixes (IPv4/IPv6) in multiple allowed peer ASs can be associated with a group.
- A dynamic peer will be associated with a group, based on the source IP address of an incoming TCP connection. If multiple overlapping prefixes match, the prefix with the longest prefix length is used.
- A maximum number of dynamic peers can be configured per group and for the entire BGP instance. Whenever an incoming connection for a new dynamic session would cause either a group limit or the overall BGP limit to be exceeded, the connection attempt is rejected with a BGP Notification message.
- Dynamic peers are supported in the base router as well as in VPRN BGP instances.

Behavior

When a dynamic session is established, the following behavior will be observed when changes are made:

- If a new **prefix** entry is added to a group and this entry will become the longest prefix match for the IP address, then the session remains up, without interruption, if the new entry belongs to the same group as the one previously used to set up the dynamic session.
- If a new **prefix** entry is added to a group and this entry becomes the longest prefix match for the IP address, then the session is torn down immediately if the new entry belongs to a different group from the one previously used to set up the dynamic session. When the remote end attempts to reestablish the session, the parameters used locally are inherited from the new group.
- If a **neighbor** command is added to any group and its IP address matches the source IP address of an established dynamic session, then the dynamic session is torn down and the new session that is established inherits its local parameters from the **neighbor** configuration.

Using dynamic BGP peers can reduce the configuration file size of an SR OS router considerably, and is mainly used on route reflectors.

Configuration

In this section, the following two examples are shown:

- Dynamic BGP peers on a route reflector in an AS
- Dynamic BGP peers in multiple ASs

Dynamic BGP peers on a route reflector in an AS

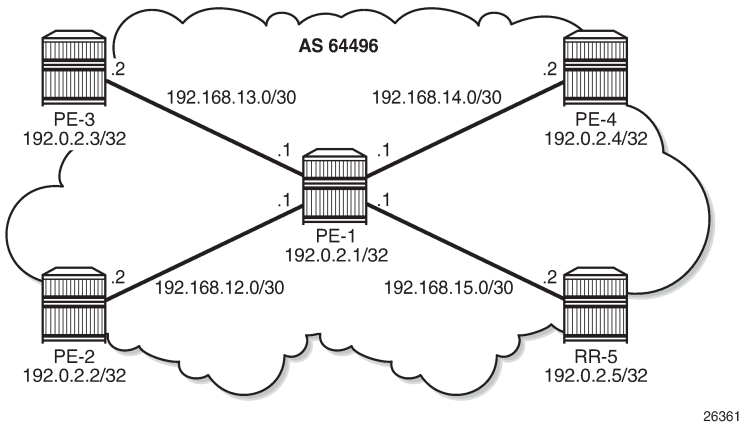
Figure 108: Dynamic BGP peers shows the example topology, and has the following characteristics:

- All nodes are part of AS 64496.
- BGP sessions are established between the routers of AS 64496, using RR-5 as route reflector with PE-1, PE-2, PE-3, and PE-4 being the route reflector clients.

The initial configuration on the nodes includes:

- cards, MDAs, and ports
- router interfaces
- IS-IS between the routers

Figure 108: Dynamic BGP peers



BGP is configured between the route reflector clients and the route reflector for the IPv4 address family. The configuration on PE-1 is as follows:

```
# on PE-1:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            loop-detect discard-route
            split-horizon true
            group "iBGP" {
                peer-as 64496
```

```
            }
            neighbor "192.0.2.5" {
                group "iBGP"
            }
```

The BGP configuration on PE-2 is as follows. The BGP configuration on PE-3 and PE-4 is similar, but the prefix-lists are different.

```
# on PE-2:
configure {
    policy-options {
        prefix-list "local-lb" {
            prefix 172.31.2.0/24 type exact {
            }
        }
        policy-statement "exp-local-lb" {
            entry 10 {
                from {
                    prefix-list ["local-lb"]
                }
                action {
                    action-type accept
                }
            }
        }
    }
    router "Base" {
        autonomous-system 64496
        bgp {
            loop-detect discard-route
            split-horizon true
            group "iBGP" {
                peer-as 64496
                export {
                    policy ["exp-local-lb"]
                }
            }
            neighbor "192.0.2.5" {
                group "iBGP"
            }
```

The initial route reflector RR-5 BGP configuration is as follows:

```
# on RR-5:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            loop-detect discard-route
            split-horizon true
            dynamic-neighbor-limit 20
            group "iBGP" {
                peer-as 64496
                dynamic-neighbor-limit 10
                cluster {
                    cluster-id 5.5.5.5
                }
                dynamic-neighbor {
                    match {
                        prefix 192.0.2.0/24 {
                            allowed-peer-as ["64496"]
                        }
```

```
                }
            }
        }
```

Dynamic neighbors are shown with the "D" flag, as follows:

```
[]
A:admin@RR-5# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.1(D)
Def. Instance  64496       64    0 00h30m53s 0/0/3 (IPv4)
                           67    0
192.0.2.2(D)
Def. Instance  64496       66    0 00h31m11s 1/1/2 (IPv4)
                           67    0
192.0.2.3(D)
Def. Instance  64496       67    0 00h31m49s 1/1/2 (IPv4)
                           68    0
192.0.2.4(D)
Def. Instance  64496       65    0 00h30m47s 1/1/2 (IPv4)
                           66    0

-------------------------------------------------------------------------------
```

The details for neighbor PE-2 show that the session is dynamic, as follows:

```
[]
A:admin@RR-5# show router bgp neighbor 192.0.2.2

===============================================================================
BGP Neighbor
===============================================================================
-------------------------------------------------------------------------------
Peer                : 192.0.2.2
Description         : (Not Specified)
Group               : iBGP
-------------------------------------------------------------------------------
Peer AS             : 64496           Peer Port           : 49704
Peer Address        : 192.0.2.2
Local AS            : 64496           Local Port          : 179
Local Address       : 192.0.2.5
Peer Type           : Internal        Dynamic Peer        : Yes
State               : Established     Last State          : Established
Last Event          : recvOpen
Last Error          : Cease (Connection Collision Resolution)
Local Family        : IPv4
Remote Family       : IPv4
Hold Time           : 90              Keep Alive          : 30
Min Hold Time       : 0
Active Hold Time    : 90              Active Keep Alive   : 30
Cluster Id          : 5.5.5.5
---snip---
```

```
-------------------------------------------------------------------------------
Neighbors shown : 1
===============================================================================
* indicates that the corresponding row element may have been truncated.
```

The BGP configuration on route reflector RR-5 is modified with static BGP neighbor PE-1, as follows:

```
# on RR-5:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            loop-detect discard-route
            split-horizon true
            dynamic-neighbor-limit 20
            group "iBGP" {
                peer-as 64496
                dynamic-neighbor-limit 10
                cluster {
                    cluster-id 5.5.5.5
                }
                dynamic-neighbor {
                    match {
                        prefix 192.0.2.0/24 {
                            allowed-peer-as ["64496"]
                        }
                    }
                }
            }
            neighbor "192.0.2.1" {      # defines PE-1 as a static neighbor
                group "iBGP"
                keepalive 20
                hold-time {
                    seconds 60
                }
            }
```

Therefore, the properties of BGP group iBGP are as follows:

```
[]
A:admin@RR-5# show router bgp group "iBGP"

===============================================================================
BGP Group : iBGP
===============================================================================
Group            : iBGP
Description      : (Not Specified)
Group Type       : No Type              State            : Up
Peer AS          : 64496                Local AS         : 64496
Local Address    : n/a                  Loop Detect      : Discard
Import Policy    : None Specified - Default Reject
Export Policy    : None Specified - Default Reject
Hold Time        : 90                   Keep Alive       : 30
Min Hold Time    : 0
Cluster Id       : 5.5.5.5              Client Reflect   : Enabled
NLRI             : Unicast              Preference       : 170
TTL Security     : Disabled             Min TTL Value    : n/a
Graceful Restart : Disabled             Stale Routes Time: n/a
Restart Time     : n/a
Auth key chain   : n/a
Bfd Enabled      : Disabled             Disable Cap Nego : Disabled
Creation Origin  : manual
Flowspec Validate: Disabled
```

```
Default Route Tgt: Disabled
Aigp Metric      : Disabled
Split Horizon    : Enabled
Damp Peer Oscill*: Disabled
GR Notification  : Disabled            Fault Tolerance  : Disabled
Next-Hop Unchang*: None
Routes Resolve T*: Disabled

List of Static Peers
- 192.0.2.1 :

List of Dynamic Peers
- 192.0.2.2
- 192.0.2.3
- 192.0.2.4

Total Peers      : 4                   Established      : 4
-------------------------------------------------------------------------------
Peer Groups : 1
===============================================================================
* indicates that the corresponding row element may have been truncated.
```

The BGP session toward PE-1 is static. The short session time is an indication that the BGP session toward PE-1 has been reestablished, as follows:

```
[]
A:admin@RR-5# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.1
Def. Instance  64496       95    0 00h01m33s 0/0/3 (IPv4)
                           16    0
192.0.2.2(D)
Def. Instance  64496        7    0 00h47m44s 1/1/2 (IPv4)
                            8    0
192.0.2.3(D)
Def. Instance  64496       94    0 00h45m04s 1/1/2 (IPv4)
                           99    0
192.0.2.4(D)
Def. Instance  64496       92    0 00h44m02s 1/1/2 (IPv4)
                           97    0

-------------------------------------------------------------------------------
```

Reestablishment of the BGP session is also indicated in log 99, as follows:

```
76 2020/08/19 16:41:37.265 CEST MINOR: BGP #2038 Base Peer 1: 192.0.2.1
"(ASN 64496) VR 1: Group iBGP: Peer 192.0.2.1: moved into established state"

75 2020/08/19 16:41:37.255 CEST WARNING: BGP #2011 Base Peer 1: 192.0.2.1
"(ASN 64496) VR 1: Group iBGP: Peer 192.0.2.1: remote end closed connection"

74 2020/08/19 16:41:37.255 CEST WARNING: BGP #2005 Base Peer 1: 192.0.2.1
```

```
"(ASN 64496) VR 1: Group iBGP: Peer 192.0.2.1: sending notification: code CEASE
subcode CONN_COLL_RES"

73 2020/08/19 16:41:37.234 CEST WARNING: BGP #2039 Base Peer 1: 192.0.2.1
"(ASN 64496) VR 1: Group iBGP: Peer 192.0.2.1: sending notification: code CEASE subcode CONFIG_
CHG"

72 2020/08/19 16:41:37.225 CEST WARNING: BGP #2011 Base Peer 1: 192.0.2.1
"(ASN 64496) VR 1: Group iBGP: Peer 192.0.2.1: moved from higher state ESTABLISHED to lower
 state IDLE due to event CONFIG_CHG"
```

New and more specific settings apply to static neighbor PE-1, as follows:

```
[]
A:admin@RR-5# show router bgp neighbor 192.0.2.1

===============================================================================
BGP Neighbor
===============================================================================
-------------------------------------------------------------------------------
Peer                 : 192.0.2.1
Description          : (Not Specified)
Group                : iBGP
-------------------------------------------------------------------------------
Peer AS              : 64496            Peer Port            : 49436
Peer Address         : 192.0.2.1
Local AS             : 64496            Local Port           : 179
Local Address        : 192.0.2.5
Peer Type            : Internal         Dynamic Peer         : No
State                : Established      Last State           : Established
Last Event           : recvOpen
Last Error           : Cease (Connection Collision Resolution)
Local Family         : IPv4
Remote Family        : IPv4
Hold Time            : 60               Keep Alive           : 20
Min Hold Time        : 0
Active Hold Time     : 60               Active Keep Alive    : 20
Cluster Id           : 5.5.5.5
---snip---
```

The properties of all dynamic peers can be displayed using a single command, as follows:

```
[]
A:admin@RR-5# show router bgp neighbor dynamic

===============================================================================
BGP Neighbor
===============================================================================
-------------------------------------------------------------------------------
Peer                 : 192.0.2.2
Description          : (Not Specified)
Group                : iBGP
-------------------------------------------------------------------------------
Peer AS              : 64496            Peer Port            : 49704
Peer Address         : 192.0.2.2
Local AS             : 64496            Local Port           : 179
Local Address        : 192.0.2.5
Peer Type            : Internal         Dynamic Peer         : Yes
State                : Established      Last State           : Established
---snip---
-------------------------------------------------------------------------------
Peer                 : 192.0.2.3
Description          : (Not Specified)
```

```
Group                : iBGP
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
Peer AS              : 64496           Peer Port           : 49636
Peer Address         : 192.0.2.3
Local AS             : 64496           Local Port          : 179
Local Address        : 192.0.2.5
Peer Type            : Internal        Dynamic Peer        : Yes
State                : Established     Last State          : Established
---snip---
-------------------------------------------------------------------------------
Peer                 : 192.0.2.4
Description          : (Not Specified)
Group                : iBGP
-------------------------------------------------------------------------------
Peer AS              : 64496           Peer Port           : 49840
Peer Address         : 192.0.2.4
Local AS             : 64496           Local Port          : 179
Local Address        : 192.0.2.5
Peer Type            : Internal        Dynamic Peer        : Yes
State                : Established     Last State          : Established
---snip---
-------------------------------------------------------------------------------
Neighbors shown : 3
===============================================================================
* indicates that the corresponding row element may have been truncated.
```

Lowering the dynamic peer limit will not tear down any existing BGP sessions, as follows:

```
# on RR-5:
configure {
    router "Base" {
        bgp {
            group "iBGP" {
                dynamic-neighbor-limit 2
            }
```

A hard reset of a running BGP session will result in that BGP session being torn down, as follows:

```
[]
A:admin@RR-5# clear router bgp neighbor 192.0.2.4 hard
```

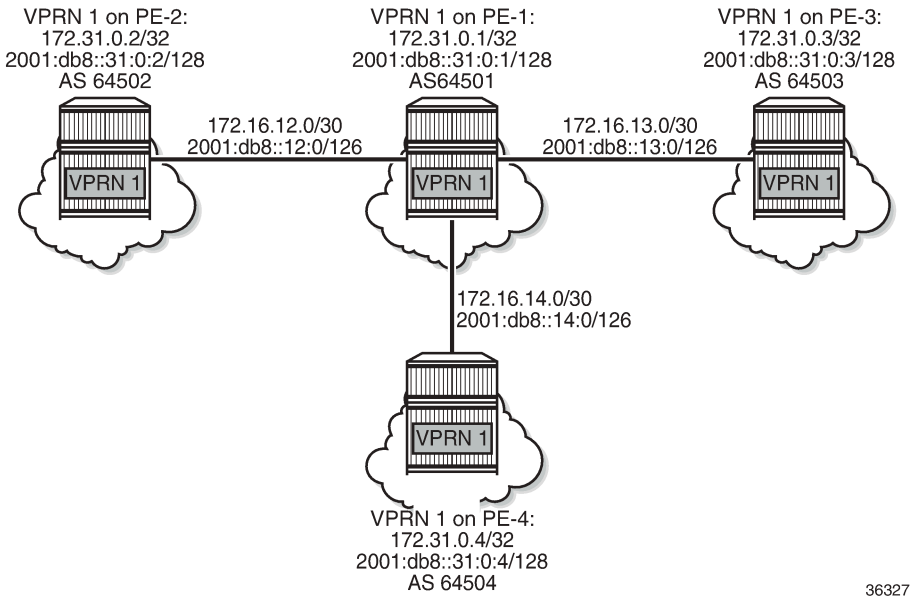
The BGP peer fails to reconnect to the route reflector, because the peer limit has been reached, as follows:

```
80 2020/08/19 17:12:39.585 CEST MINOR: BGP #2037 Base VR 1: Group iBGP
"192.0.2.4: Closing connection: reached dynamic peer limit (2) for BGP group iBGP"

79 2020/08/19 17:12:39.574 CEST WARNING: BGP #2005 Base Peer 1: 192.0.2.4
"(ASN 64496) VR 1: Group iBGP: Peer 192.0.2.4: sending notification: code CEASE
subcode HARD_RESET"

78 2020/08/19 17:12:39.574 CEST WARNING: BGP #2039 Base Peer 1: 192.0.2.4
"(ASN 64496) VR 1: Group iBGP: Peer 192.0.2.4: moved from higher state ESTABLISHED
to lower state IDLE due to event ADMIN_RESET_HARD"

77 2020/08/19 17:12:39.562 CEST INDETERMINATE: LOGGER #2010 Base Clear BGP
"Clear function clearRtrBgpNbr has been run with parameters: rtr-name="Base"
neighbor="192.0.2.4" type="hard".  The completion result is: success.
Additional error text, if any, is: "
```

Dynamic BGP peers in multiple ASs

In SR OS Release 19.5.R1 and later, dynamic BGP sessions associated with a single BGP peer group can belong to different peer Autonomous Systems (ASs), both in the base router and in VPRNs. Figure 109: Example topology with VPRN 1 in different ASs shows the example topology with VPRN 1 configured in different ASs. Each interface in VPRN 1 has an IPv4 and an IPv6 address.

Figure 109: Example topology with VPRN 1 in different ASs



EBGP sessions are established between VPRN 1 on PE-1 and VPRN 1 on the other nodes. In VPRN 1 on PE-2, PE-3, and PE-4, static BGP neighbors are configured. The VPRN configuration on PE-2 is as follows:

```
# on PE-2:
configure  {
    service  {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            autonomous-system 64502
            router-id 172.31.0.2
            route-distinguisher "1:1"
            vrf-target {
                community "target:1:1"
            }
            bgp {
                router-id 172.31.0.2
                split-horizon true
                group "eBGPv4" {
                    next-hop-self true
                    peer-as 64501
                    family {
                        ipv4 true
                    }
```

```
                }
                group "eBGPv6" {
                    next-hop-self true
                    peer-as 64501
                    family {
                        ipv6 true
                    }
                }
                neighbor "172.16.12.1" {
                    group "eBGPv4"
                    export {
                        policy ["exp-vprn-1-v4"]
                    }
                }
                neighbor "2001:db8::12:1" {
                    group "eBGPv6"
                    export {
                        policy ["exp-vprn-1-v6"]
                    }
                }
            }
            interface "int-VPRN1-PE-2-PE-1" {
                ipv4 {
                    primary {
                        address 172.16.12.2
                        prefix-length 30
                    }
                }
                sap 1/1/1:1 {
                }
                ipv6 {
                    address 2001:db8::12:2 {
                        prefix-length 126
                    }
                }
            }
            interface "system" {
                loopback true
                ipv4 {
                    primary {
                        address 172.31.0.2
                        prefix-length 32
                    }
                }
                ipv6 {
                    address 2001:db8::31:0:2 {
                        prefix-length 128
                    }
                }
            }
        }
```

In VPRN 1 on PE-1, dynamic BGP peering is configured for IPv4 prefixes matching 172.16.0.0/16 in AS 64502 (PE-2) or AS 64504 (PE-4) and IPv6 prefixes matching 2001:db8::/107 ASN range from 64502 (PE-2) to 64503 (PE-3). The BGP configuration in VPRN 1 on PE-1 is as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            bgp {
                router-id 172.31.0.1
                split-horizon true
```

```
                group "eBGPv4" {
                    next-hop-self true
                    dynamic-neighbor-limit 10
                    family {
                        ipv4 true
                    }
                    import {
                        policy ["1:1"]
                    }
                    export {
                        policy ["exp-vprn-1-v4" "1:1"]
                    }
                    dynamic-neighbor {
                        match {
                            prefix 172.16.0.0/16 {
                                allowed-peer-as ["64502" "64504"]
                            }
                        }
                    }
                }
                group "eBGPv6" {
                    next-hop-self true
                    dynamic-neighbor-limit 10
                    family {
                        ipv6 true
                    }
                    export {
                        policy ["exp-vprn-1-v6" "1:1"]
                    }
                    import {
                        policy ["1:1"]
                    }
                    dynamic-neighbor {
                        match {
                            prefix 2001:db8::/107 {
                                allowed-peer-as ["64502..64503"]
                            }
                        }
                    }
                }
            }
```

A dynamic BGP session can be rejected if receiving neighbor BGP OPEN message does not report an AS number in an allowed list: in the "eBGPv4" group, AS 64503 is not allowed and in the "eBGPv6" group, AS 64504 is not allowed. PE-1 sends a notification message with code OPEN and subcode INCORRECT_AS to PE-3 in AS 64503 and the following notification is logged in log 99:

```
14 2020/08/19 16:55:19.697 CEST WARNING: BGP #2005 vprn1 Peer 2: 172.16.13.2

"(ASN 0) VR 2: Group eBGPv4: Peer 172.16.13.2: sending notification: code OPEN subcode
 INCORRECT_AS"
```

When debugging is enabled for BGP OPEN messages and BGP notifications, the following messages are logged on PE-1: a BGP OPEN message received from PE-3 in AS 64503 and a BGP notification with code OPEN and subcode Bad Peer AS.

```
7 2020/08/19 16:55:19.697 CEST MINOR: DEBUG #2001 vprn1 Peer 2: 172.16.13.2

"Peer 2: 172.16.13.2: NOTIFICATION
Peer 2: 172.16.13.2 - Send BGP NOTIFICATION: Code = 2 (OPEN) Subcode = 2 (Bad Peer AS)
"
```

```
6 2020/08/19 16:55:19.697 CEST MINOR: DEBUG #2001 vprn1 BGP
"BGP: OPEN
Peer 2: 172.16.13.2 - Received BGP OPEN: Version 4
   AS Num 64503: Holdtime 90: BGP_ID 172.31.0.3: Opt Length 20 (ExtOpt F)
   Opt Para: Type CAPABILITY: Length = 18: Data:
     Cap_Code GRACEFUL-RESTART: Length 2
       Bytes: 0x0 0x78
     Cap_Code MP-BGP: Length 4
       Bytes: 0x0 0x1 0x0 0x1
     Cap_Code ROUTE-REFRESH: Length 0
     Cap_Code 4-OCTET-ASN: Length 4
       Bytes: 0x0 0x0 0xfb 0xf7            # AS 64503
"
```

The following BGP summary on PE-1 shows four dynamic BGP neighbors: 172.16.12.2 (in AS 64502), 172.16.14.2 (in AS 64504), 2001:db8::12:2 (in AS 64502), and 2001:db8::13:2 (in AS 64503):

```
[]
A:admin@PE-1# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.5
Def. Instance  64496       19    0 00h04m34s 2/2/0 (IPv4)
                           17    0

172.16.12.2(D)
Svc: 1         64502        8    0 00h01m36s 1/1/2 (IPv4)
                            9    0
172.16.14.2(D)
Svc: 1         64504        8    0 00h01m56s 1/1/2 (IPv4)
                            9    0
2001:db8::12:2(D)
Svc: 1         64502        8    0 00h01m54s 1/1/2 (IPv6)
                            9    0
2001:db8::13:2(D)
Svc: 1         64503        8    0 00h01m57s 1/1/2 (IPv6)
                            9    0
-------------------------------------------------------------------------------
```

The following command shows that BGP group "eBGPv4" has two dynamic peers (172.16.12.2 and 172.16.14.2) and group "eBGPv6" has two dynamic peers (2001:db8::12:2 and 2001:db8::13:2):

```
[]
A:admin@PE-1# show router 1 bgp group

===============================================================================
BGP Group
===============================================================================
Group             : eBGPv4
Description       : (Not Specified)
Group Type        : No Type              State           : Up
Peer AS           : n/a                  Local AS        : 64501
Local Address     : n/a                  Loop Detect     : Ignore
```

```
Import Policy    : 1:1
                 : Default Reject
Export Policy    : exp-vprn-1-v4
                 : 1:1
                 : Default Reject
---snip---

List of Static Peers

List of Dynamic Peers
- 172.16.12.2
- 172.16.14.2

Total Peers      : 2                   Established      : 2
Group            : eBGPv6
Description      : (Not Specified)
Group Type       : No Type             State            : Up
Peer AS          : n/a                 Local AS         : 64501
Local Address    : n/a                 Loop Detect      : Ignore
Import Policy    : 1:1
                 : Default Reject
Export Policy    : exp-vprn-1-v6
                 : 1:1
                 : Default Reject
---snip---

List of Static Peers

List of Dynamic Peers
- 2001:db8::12:2
- 2001:db8::13:2

Total Peers      : 2                   Established      : 2
-------------------------------------------------------------------------------
Peer Groups : 2
===============================================================================
* indicates that the corresponding row element may have been truncated.
```

Conclusion

The use of dynamic BGP peers provides ISPs the means to reduce the configuration file size for routers. This reduces the number of configuration changes to be made to the network over time, which lowers the operational cost of running the network.

EBGP Default Reject Policy

This chapter describes EBGP Default Reject Policy.

Topics in this chapter include:

Applicability

The information and MD-CLI configuration in this chapter are based on SR OS Release 20.7.R2. The eBGP default reject policy is supported in SR OS Release 19.5.R1 and later.

Overview

To improve security and reliability of Internet routing in the base router and in VPRN routing instances, a default eBGP reject policy rejects all BGP routes when no import or export policies are configured. This policy prevents accidental route leaks. In MD-CLI, the implicit **ebgp-default-reject-policy** is used by default for import and export, which is compliant with RFC 8212, *Default External BGP (EBGP) Route Propagation Behavior without Policies*.

The **ebgp-default-reject-policy** command can be configured in the general **bgp** context, in the BGP **group** context, and in the BGP **neighbor** context. It can be enabled for import direction only, for export direction only, or for both directions. The syntax of the command is as follows:

```
[ex:configure router "Base" bgp group "eBGP"]
A:admin@PE-2# ebgp-default-reject-policy

 ebgp-default-reject-policy

 export                - Enable default reject export policy for external peers
 import                - Enable default reject import policy for external peers
```

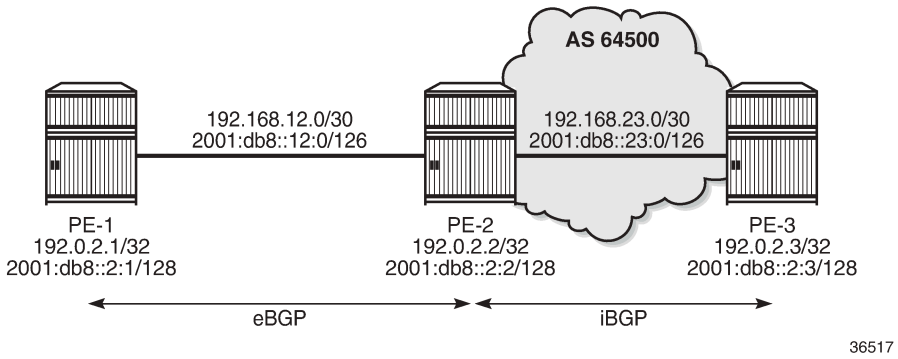
The eBGP default reject policy is the last policy in a policy chain.

Note:
In MD-CLI, the default behavior is compliant with RFC 8212 (**ebgp-default-reject-policy import/export true**). However, when BGP was initially configured in classic CLI and afterward converted to MD-CLI, the insecure behavior remains for backward compatibility (**ebgp-default-reject-policy import/export false**).

Configuration

Figure 110: Example topology shows the example topology with three nodes. An eBGP session is established between PE-1 and PE-2; an iBGP session between PE-2 and PE-3.

Figure 110: Example topology



The initial configuration includes:

- Cards, MDAs, ports
- Router interfaces
- SR-ISIS on PE-2 and PE-3 in AS 64500

On PE-1, BGP is configured as follows:

```
# on PE-1:
configure {
    router "Base" {
        autonomous-system 64501
        bgp {
            split-horizon true
            group "eBGP" {
                peer-as 64500
                local-as {
                    as-number 64501
                }
            }
            neighbor "192.168.12.2" {
                group "eBGP"
                family {
                    ipv4 true
                    ipv6 true
                    label-ipv4 true
                    label-ipv6 true
                }
                export {
                    policy ["export-10.1" "export-10.2" "export-10.131" "export-10.132"]
                }
            }
        }
```

On PE-2, BGP is configured as follows:

```
# on PE-2:
configure {
    router "Base" {
        autonomous-system 64500
        bgp {
            split-horizon true
            next-hop-resolution {
                labeled-routes {
                    transport-tunnel {
                        family label-ipv4 {
                            resolution-filter {
                                ldp false
                                sr-isis true
                            }
                        }
                    }
                }
            }
            group "eBGP" {
                peer-as 64501
                local-as {
                    as-number 64500
                }
            }
            group "iBGP-IPv4" {
                peer-as 64500
                family {
                    ipv4 true
                    label-ipv4 true
                }
            }
            group "iBGP-IPv6" {
                peer-as 64500
                family {
                    ipv6 true
                    label-ipv6 true
                }
            }
            neighbor "192.0.2.3" {
                group "iBGP-IPv4"
                next-hop-self true
            }
            neighbor "192.168.12.1" {
                group "eBGP"
                family {
                    ipv4 true
                    ipv6 true
                    label-ipv4 true
                    label-ipv6 true
                }
                export {
                    policy ["export-bgp"]
                }
            }
            neighbor "2001:db8::2:3" {
                group "iBGP-IPv6"
                next-hop-self true
            }
        }
```

Figure 111: Advertised BGP and BGP-LU IPv4 routes and Figure 112: Advertised BGP and BGP-LU IPv6 routes show the advertised BGP and BGP Labeled Unicast (BGP-LU) routes between PE-1 and PE-2:

Figure 111: Advertised BGP and BGP-LU IPv4 routes

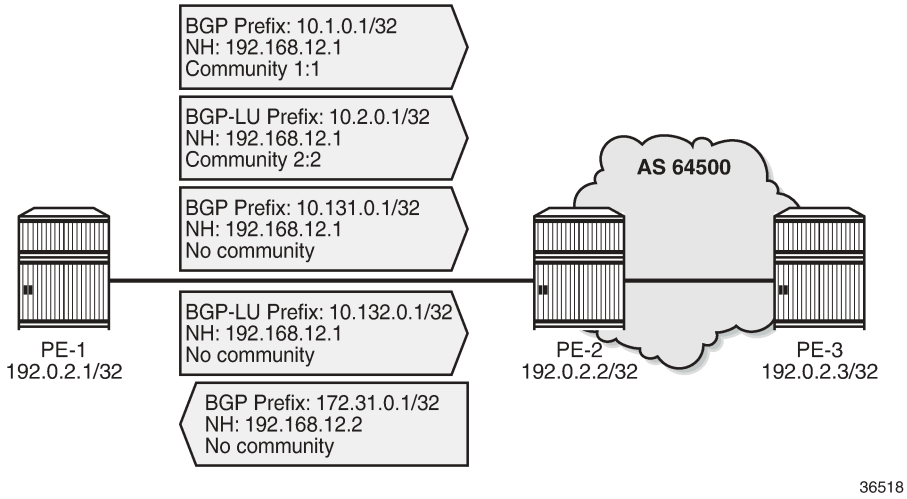
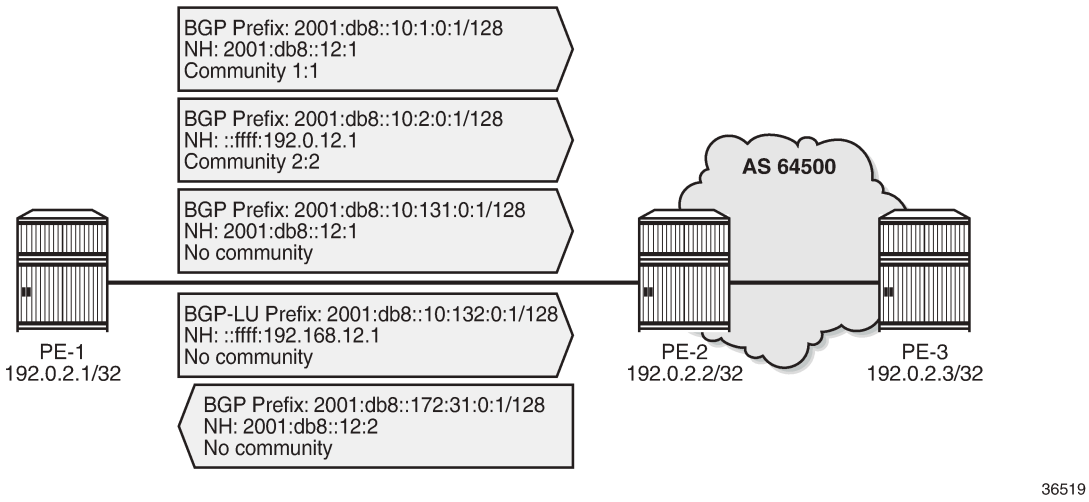


Figure 112: Advertised BGP and BGP-LU IPv6 routes



In this example, an export policy is configured toward eBGP peer 192.168.12.1 on PE-2:

```
[]
A:admin@PE-2# show router bgp neighbor 192.168.12.1 | match "Export Policy"
Export Policy        : export-bgp
```

By default, in MD-CLI, the eBGP default reject policy is used. When no eBGP import-policy is configured on PE-2, any route received from an eBGP peer is rejected, as follows:

```
[]
A:admin@PE-2# show router bgp neighbor 192.168.12.1 | match "Import Policy"
```

```
Import Policy        : None Specified - Default Reject
```

This behavior only applies to eBGP sessions. For iBGP sessions, the reverse is true and the default behavior is to accept. When no iBGP export-policy is configured on PE-2, any received eBGP route is advertised to the iBGP peer (PE-3 in this example), as follows:

```
[]
A:admin@PE-2# show router bgp neighbor 192.0.2.3 | match "Export Policy"
Export Policy        : None Specified - Default Accept
```

The BGP default reject policy is implicitly used for import and export. There is no need to configure it explicitly. Both on PE-1 and PE-2, export policies are configured, so the corresponding routes are advertised. However, no import policies are configured, so any route received from an eBGP peer is rejected. The BGP summary on PE-2 shows that for each of the address families, two routes are received from eBGP peer 192.168.12.1, but these routes are rejected:

```
[]
A:admin@PE-2# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.3
Def. Instance  64500        7    0 00h01m34s 0/0/0 (IPv4)
                           12    0           0/0/0 (Lbl-IPv4)
192.168.12.1
Def. Instance  64501       16    0 00h01m55s 2/0/1 (IPv4)
                           11    0           2/0/1 (IPv6)
                                             2/0/0 (Lbl-IPv4)
                                             2/0/0 (Lbl-IPv6)

2001:db8::2:3
Def. Instance  64500        7    0 00h01m34s 0/0/0 (IPv6)
                           12    0           0/0/0 (Lbl-IPv6)

-------------------------------------------------------------------------------
```

The following output shows that the received BGP routes are invalid:

```
[]
A:admin@PE-2# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
```

```
      Nexthop (Router)                                      Path-Id     IGP Cost
      As-Path                                                           Label
------------------------------------------------------------------------------
i     10.1.0.1/32                                           None        None
      192.168.12.1                                          None        0
      64501                                                             -
i     10.131.0.1/32                                         None        None
      192.168.12.1                                          None        0
      64501                                                             -
------------------------------------------------------------------------------
Routes : 2
==============================================================================
```

The status of the IPv6, BGP-LU IPv4, and BGP-LU IPv6 routes is the same. The flags for the received routes for the different address families include the 'Rejected' flag:

```
[]A:admin@PE-2# show router bgp routes hunt | match Flags
Flags          : Invalid IGP Rejected
Flags          : Invalid IGP Rejected
```

```
[]
A:admin@PE-2# show router bgp routes ipv6 hunt | match Flags
Flags          : Invalid IGP Rejected
Flags          : Invalid IGP Rejected
```

```
[]
A:admin@PE-2# show router bgp routes label-ipv4 hunt | match Flags
Flags          : Invalid IGP Rejected
Flags          : Invalid IGP Rejected
```

```
[]
A:admin@PE-2# show router bgp routes label-ipv6 hunt | match Flags
Flags          : Invalid IGP Rejected
Flags          : Invalid IGP Rejected
```

Import policy

When an import policy is configured, it is possible that some of these routes are accepted. The following import policy on PE-2 accepts incoming routes with communities "1:1" or "2:2":

```
# on PE-2:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        community "2:2" {
            member "2:2" { }
        }
        policy-statement "import-1:1-2:2" {
            entry 10 {
                from {
                    community {
                        name "1:1"
                    }
                }
                action {
```

```
                    action-type accept
                }
            }
            entry 20 {
                from {
                    community {
                        name "2:2"
                    }
                }
                action {
                    action-type accept
                }
            }
        }
    }
    router "Base" {
        bgp {
            group "eBGP" {
                peer-as 64501
                local-as {
                    as-number 64500
                }
                import {
                    policy ["import-1:1-2:2"]
                }
            }
        }
```

PE-2 accepts BGP route 10.1.0.1/32 with community "1:1", but it rejects route 10.131.0.1/32 because this route has no communities:

```
[]
A:admin@PE-2# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.0.1/32                                      None        None
      192.168.12.1                                     None        0
      64501                                                        -
i     10.131.0.1/32                                    None        None
      192.168.12.1                                     None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

The BGP summary on PE-2 shows that one route is accepted and one route is rejected for the IPv4, IPv6, BGP-LU IPv4, and BGP-LU IPv6 address families:

```
[]
```

```
A:admin@PE-2# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.3
Def. Instance  64500       81    0 00h38m35s 0/0/1 (IPv4)
                           94    0           0/0/1 (Lbl-IPv4)
192.168.12.1
Def. Instance  64501       90    0 00h38m56s 2/1/1 (IPv4)
                           85    0           2/1/1 (IPv6)
                                             2/1/0 (Lbl-IPv4)
                                             2/1/0 (Lbl-IPv6)
2001:db8::2:3
Def. Instance  64500       81    0 00h38m35s 0/0/1 (IPv6)
                           96    0           0/0/1 (Lbl-IPv6)
-------------------------------------------------------------------------------
```

The following shows that the routes with communities "1:1" or "2:2" are accepted while the other routes are rejected. For each of the address families, there are two routes in the RIB-IN: a first one with community "1:1" or "2:2" (with flags "Used Valid Best IGP") and second one with "No community members" (with flags "Invalid IGP Rejected"), as follows:

```
[]
A:admin@PE-2# show router bgp routes hunt | match expression "Comm|Flags"
Community      : 1:1
Flags          : Used Valid Best IGP
Community      : No Community Members
Flags          : Invalid IGP Rejected
Community      : 1:1                        # RIB-OUT
Community      : No Community Members       # RIB-OUT (172.31.0.1/32)
```

```
[]
A:admin@PE-2# show router bgp routes ipv6 hunt | match expression "Comm|Flags"
Community      : 1:1
Flags          : Used Valid Best IGP
Community      : No Community Members
Flags          : Invalid IGP Rejected
Community      : 1:1                        # RIB-OUT
Community      : No Community Members       # RIB-OUT (172.31.0.1/32)
```

```
[]
A:admin@PE-2# show router bgp routes label-ipv4 hunt | match expression "Comm|Flags"
Community      : 2:2
Flags          : Used Valid Best IGP
Community      : No Community Members
Flags          : Invalid IGP Rejected
Community      : 2:2                        # RIB-OUT
```

```
[]
A:admin@PE-2# show router bgp routes label-ipv6 hunt | match expression "Comm|Flags"
Community      : 2:2
Flags          : Used Valid Best IGP
```

```
Community      : No Community Members
Flags          : Invalid IGP Rejected
Community      : 2:2                       # RIB-OUT
```

Conclusion

The eBGP default reject policy is used to improve the security and reliability of Internet routing. The eBGP default reject policy can be combined with other policies and is always evaluated last in the list of policies.

EBGP Route Resolution to a Static Route

This chapter provides information about EBGP route resolution to a static route.

Topics in this chapter include:

Applicability

This chapter was initially written for SR OS Release 14.0.R7, but the MD-CLI in the current edition is based on SR OS Release 20.10.R1. EBGP route resolution to a static route is supported in SR OS Release 14.0.R1, and later.

Overview

The configuration in this chapter resembles the configuration in chapter "Inter-AS VPRN Model C" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Layer 3 Services Advanced Configuration Guide for Classic CLI*, but in this chapter, the eBGP peering between the ASBRs is using loopback addresses instead of interface addresses.

Typically, service providers use interface IP addresses in eBGP sessions toward an Autonomous System Border Router (ASBR) of an untrusted ISP, but it is possible to use loopback addresses, such as system IP addresses. This requires the ASBRs to provide visibility on each other's loopback address; for example, by defining static routes. EBGP route resolution to a static route only works for ASBRs that are directly connected. As an alternative, MPLS (for example, RSVP-TE or LDP) can be configured on the interfaces between the ASBRs, which is the only viable solution when the peering ASBRs are multiple hops away.

Configuring MPLS on the interface toward an ASBR of an untrusted ISP is considered insecure. For directly connected ASBRs, EBGP route resolution to a static route mitigates these security issues. On each ASBR, static routes are configured toward the loopback address of the peer ASBR. Additionally, the following command enables labeled routes to be resolved via a static route:

```
configure {
    router "Base" {
        bgp {
            next-hop-resolution {
                labeled-routes {
                    allow-static true
                }
            }
```

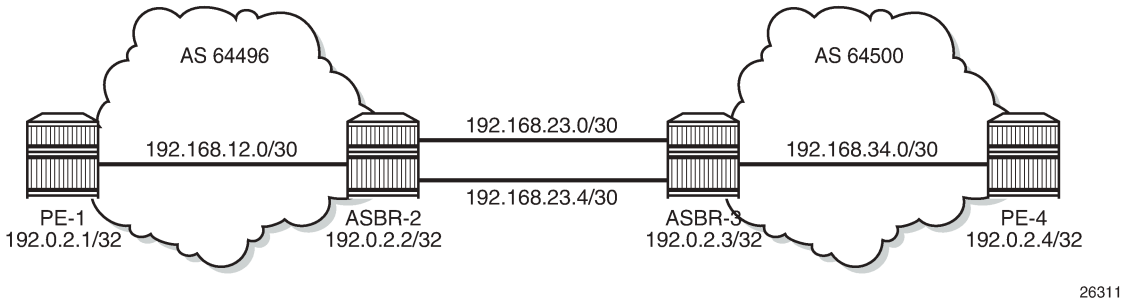
Even with this feature enabled, the system will first try to resolve the BGP next-hop to LDP or RSVP LSPs before the IP route table is attempted. The option is supported for the following address families:

- Labeled IPv4 routes
- VPN-IPv4 and VPN-IPv6 routes

Configuration

Figure 113: Example topology shows the example topology with four routers in two different ASs. ASBR-2 and ASBR-3 are connected via two links, which implies that there will be multiple next-hops configured for the static route entry toward the loopback IP address of the eBGP peer. Also, Equal Cost Multi-Path (ECMP) and BGP multipath need to be enabled between these ASBRs.

Figure 113: Example topology



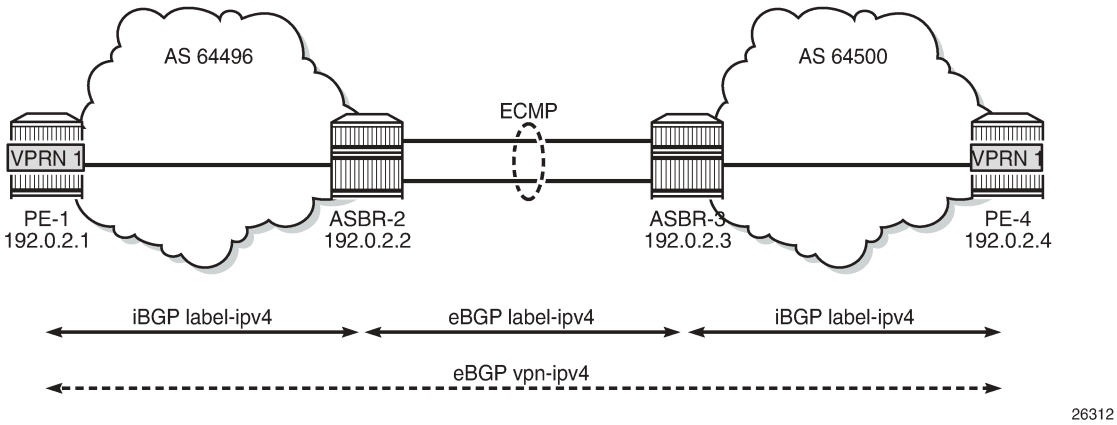
The initial configuration on the nodes includes the following:

- Cards, MDAs, ports
- Router interfaces
- IS-IS as IGP on the interfaces within an AS (alternatively, OSPF could be used)
- LDP on the interfaces within an AS

Figure 114: BGP peering shows the BGP sessions to be configured:

- iBGP sessions for address family labeled IPv4 between the PEs within each AS
- eBGP sessions for address family labeled IPv4 between ASBR-2 and ASBR-3
- a multi-hop eBGP session for address family VPN-IPv4 between PE-1 and PE-4

Figure 114: BGP peering



On PE-1, iBGP is configured for address family labeled IPv4, as follows. The configuration on PE-4 is similar.

```
# on PE-1:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            split-horizon true
            group "iBGP" {
                peer-as 64496
            }
            neighbor "192.0.2.2" {
                export {
                    policy "export-bgp"
                }
                group "iBGP"
                family {
                    label-ipv4 true
                }
            }
```

The following export policy exports the loopback IP prefixes from PE-1 to ASBR-2 (and from PE-4 to ASBR-3):

```
# on PE-1, PE-4:
configure {
    policy-options {
        community "1:0" {
            member "1:0" { }
        }
        prefix-list "PE-sys" {
            prefix 192.0.2.0/28 type longer {
            }
        }
        policy-statement "export-bgp" {
            entry 10 {
                from {
                    prefix-list ["PE-sys"]
                    protocol {
                        name [direct]
```

```
                }
            }
            action {
                action-type accept
                community {
                    add ["1:0"]
                }
            }
        }
    }
```

On ASBR-2, iBGP and eBGP are configured for address family labeled IPv4, as follows. Two links are connecting ASBR-2 to ASBR-3 and, therefore, ECMP and BGP multipath are enabled. For more information about BGP multipath, see chapter BGP Multipath. The BGP configuration on ASBR-3 is similar.

```
# on ASBR-2:
configure {
    policy-options {
        community "1:0" {
            member "1:0" { }
        }
        policy-statement "1:0" {
            entry 10 {
                from {
                    community {
                        name "1:0"
                    }
                }
                action {
                    action-type accept
                }
            }
        }
    }
    router "Base" {
        autonomous-system 64496
        ecmp 2
        bgp {
            split-horizon true
            multipath {
                max-paths 2
                ebgp 2
            }
            group "eBGP" {
                peer-as 64500
                import {
                    policy "1:0"
                }
                export {
                    policy "1:0"
                }
            }
            group "iBGP" {
                peer-as 64496
            }
            neighbor "192.0.2.1" {
                group "iBGP"
                family {
                    label-ipv4 true
                }
            }
            neighbor "192.0.2.3" {
                advertise-inactive true
```

```
                group "eBGP"
                family {
                    label-ipv4 true
                }
            }
```

On eBGP sessions, routes are by default rejected unless import and export policies are defined (RFC 8212). In this example, the policy “1:0” accepts routes with community “1:0”.

On the ASBRs, the BGP routes with the loopback IP addresses of the local AS PEs are not active because IGP routes are preferred. The **advertise-inactive true** option ensures that the ASBRs will also advertise these inactive routes to each other. ASBR-2 advertises prefix 192.0.2.1/32 to ASBR-3; ASBR-3 advertises prefix 192.0.2.4/32 to ASBR-2.

However, no prefixes can be exchanged between the ASBRs because the eBGP session is not in the established state yet; they still lack routing to each other's loopback IP address.

Eventually, the labeled IPv4 routes for prefixes PE-1 and PE-4 will be exchanged between ASBRs and forwarded to the PEs in the peer AS. PE-1 will have a route toward PE-4 in its routing table, and PE-4 will have a route toward PE-1. Both PEs can then set up a multi-hop eBGP session to each other for address family VPN-IPv4; for example, on PE-1, as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            group "eBGP_multihop" {
                peer-as 64500
                local-address "192.0.2.1"
                family {
                    vpn-ipv4 true
                }
            }
            neighbor 192.0.2.4 {
                group "eBGP_multihop"
                multihop 10
                ebgp-default-reject-policy {
                    import false
                    export false
                }
            }
```

The **ebgp-default-reject-policy export/import false** command allows to advertise to and receive routes from eBGP peer 192.0.2.4 when no export or import policies are defined.

On PE-1, VPRN 1 is configured with loopback address 10.1.1.1/32, as follows:

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            route-distinguisher "64496:1"
            vrf-target {
                import-community "target:64500:1"
                export-community "target:64496:1"
            }
            auto-bind-tunnel {
                resolution filter
```

```
                resolution-filter {
                    ldp true
                }
            }
            interface "loopback" {
                loopback true
                ipv4 {
                    primary {
                        address 10.1.1.1
                        prefix-length 32
                    }
                }
            }
```

The configuration of PE-4 resembles the configuration of PE-1, whereas the configuration of ASBR-3 resembles that of ASBR-2.

This configuration is almost identical to the configuration in chapter "Inter-AS VPRN Model C" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Layer 3 Services Advanced Configuration Guide for Classic CLI*, with the difference that the eBGP session between the ASBRs does not use interface IP addresses, but loopback addresses. The problem is that the ASBRs cannot reach each other's loopback IP address, so the eBGP session between the ASBRs cannot be established, which can be verified in the BGP summary, as follows:

```
[]
A:admin@ASBR-2# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.1
Def. Instance  64496       14    0 00h04m49s 1/0/0 (Lbl-IPv4)
                           14    0
192.0.2.3
Def. Instance  64500        0    0 00h04m49s Connect
                            1    0
-------------------------------------------------------------------------------
```

The state of the BGP session toggles between Active and Connect. The last event is an openFail, as follows:

```
[]
A:admin@ASBR-2# show router bgp neighbor 192.0.2.3 detail | match "BGP Neighbor"
                                                                  post-lines 15
BGP Neighbor
===============================================================================
-------------------------------------------------------------------------------
Peer                 : 192.0.2.3
Description          : (Not Specified)
Group                : eBGP
-------------------------------------------------------------------------------
Peer AS              : 64500           Peer Port           : 0
Peer Address         : 192.0.2.3
Local AS             : 64496           Local Port          : 0
```

```
Local Address        : 0.0.0.0
Peer Type            : External         Dynamic Peer         : No
State                : Active           Last State           : Connect
Last Event           : openFail
Last Error           : Cease (Other Configuration Change)
Local Family         : LABEL-IPv4
```

When the eBGP session between the ASBRs is not established, no IP prefixes will be learned from the peer AS. This implies that PE-1 will not have a route toward PE-4 in its routing table. Therefore, no multi-hop eBGP session can be established between PE-1 and PE-4, which can be shown as follows:

```
[]
A:admin@PE-1# show router route-table

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
192.0.2.1/32                                    Local   Local     00h10m50s  0
       system                                                          0
192.0.2.2/32                                    Remote  ISIS      00h10m40s  15
       192.168.12.2                                                    10
192.168.12.0/30                                 Local   Local     00h10m50s  0
       int-PE-1-ASBR-2                                                   0
-------------------------------------------------------------------------------
No. of Routes: 3
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

```
[]
A:admin@PE-1# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.2
Def. Instance  64496       10    0 00h03m19s 0/0/1 (Lbl-IPv4)
                           12    0
192.0.2.4
Def. Instance  64500        0    0 00h02m42s Connect
                            0    0

-------------------------------------------------------------------------------
```

The state of the multi-hop eBGP session toggles between Active and Connect. The last event is openFail, as follows:

```
[]
A:admin@PE-1# show router bgp neighbor 192.0.2.4 detail | match "BGP Neighbor" post-lines 15
```

```
BGP Neighbor
===============================================================================
-------------------------------------------------------------------------------
Peer                : 192.0.2.4
Description         : (Not Specified)
Group               : eBGP_multihop
-------------------------------------------------------------------------------
Peer AS             : 64500           Peer Port           : 0
Peer Address        : 192.0.2.4
Local AS            : 64496           Local Port          : 0
Local Address       : 0.0.0.0
Peer Type           : External        Dynamic Peer        : No
State               : Connect         Last State          : Active
Last Event          : openFail
Last Error          : Unrecognized Error
Local Family        : VPN-IPv4
```

The loopback IP addresses of the ASBRs can be made reachable by configuring static routes on each ASBR to the loopback IP address of the peer ASBR. This will be sufficient to establish the eBGP session between the ASBRs, but no BGP labeled IPv4 routes will be advertised to PE-1 and PE-4 yet. ASBR-2 and ASBR-3 are connected by two links and the static route entry contains two next-hops; for example, for ASBR-2, as follows. The configuration is similar for ASBR-3.

```
# on ASBR-2:
configure {
    router "Base" {
        static-routes {
            route 192.0.2.3/32 route-type unicast {
                next-hop "192.168.23.2" {
                    admin-state enable
                }
                next-hop "192.168.23.6" {
                    admin-state enable
                }
            }
```

The routing table in ASBR-2 contains two routes toward ASBR-3, as follows:

```
[]
A:admin@ASBR-2# show router route-table 192.0.2.3/32

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
192.0.2.3/32                                    Remote  Static    00h00m13s  5
       192.168.23.2                                                  1
192.0.2.3/32                                    Remote  Static    00h00m13s  5
       192.168.23.6                                                  1
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The eBGP session between the ASBRs is established; for example, on ASBR-2, as follows:

```
[]
A:admin@ASBR-2# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.1
Def. Instance  64496       40    0 00h17m38s 1/0/0 (Lbl-IPv4)
                           40    0
192.0.2.3
Def. Instance  64500        5    0 00h00m58s 1/0/1 (Lbl-IPv4)
                            6    0
-------------------------------------------------------------------------------
```

However, the multi-hop eBGP session between PE-1 and PE-4 is not established yet. The state of the multi-hop eBGP session toggles between active and connect and the following output from PE-1 shows that the last event was openFail:

```
[]
A:admin@PE-1# show router bgp neighbor 192.0.2.4 detail | match "BGP Neighbor"
                                                                    post-lines 15
BGP Neighbor
===============================================================================
-------------------------------------------------------------------------------
Peer                 : 192.0.2.4
Description          : (Not Specified)
Group                : eBGP_multihop
-------------------------------------------------------------------------------
Peer AS              : 64500            Peer Port           : 0
Peer Address         : 192.0.2.4
Local AS             : 64496            Local Port          : 0
Local Address        : 0.0.0.0
Peer Type            : External         Dynamic Peer        : No
State                : Connect          Last State          : Active
Last Event           : openFail
Last Error           : Unrecognized Error
Local Family         : VPN-IPv4
```

ASBR-2 advertised an inactive route for prefix 192.0.2.1/32 to ASBR-3 and received from ASBR-3 an inactive route for prefix 192.0.2.4/32. The following output shows that the route for prefix 192.0.2.4/32 is not valid on ASBR-2:

```
[]
A:admin@ASBR-2# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete
```

```
===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
*i    192.0.2.1/32                                     100         None
      192.0.2.1                                        None        10
      No As-Path                                                   524285
i     192.0.2.4/32                                     None        None
      192.0.2.3                                        None        0
      64500                                                        524285
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

Consequently, ASBR-2 does not advertise this invalid route to its iBGP peer PE-1 and PE-1 will not have a route toward PE-4 in its routing table, as follows:

```
[]
A:admin@PE-1# show router route-table

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
192.0.2.1/32                                   Local   Local     00h23m51s  0
       system                                                        0
192.0.2.2/32                                   Remote  ISIS      00h23m41s  15
       192.168.12.2                                                  10
192.168.12.0/30                                Local   Local     00h23m51s  0
       int-PE-1-ASBR-2                                               0
-------------------------------------------------------------------------------
No. of Routes: 3
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

PE-1 and PE-4 cannot set up a multi-hop eBGP session to one another to exchange routes for VPRN 1. This problem can be solved in two different ways:

1. Enable MPLS (in this example, LDP) on the interfaces between the ASBRs.
2. Enable the following option: **configure router bgp next-hop-resolution labeled-routes allow-static**.

It is risky to enable MPLS toward a peer ASBR belonging to an untrusted ISP, but it is required between distant ASBRs if loopback addresses are used in eBGP peering.

In the following section, the first solution is described (LDP is enabled on the interfaces between the ASBRs); the section after that describes how to enable eBGP route resolution to a static route.

Enable LDP toward peer ASBR

LDP is configured on the interfaces between the ASBRs; for example, on ASBR-2, as follows. The configuration is similar on ASBR-3.

```
# on ASBR-2:
configure {
    router "Base" {
        ldp {
            interface-parameters {
                interface "int-ASBR-2-ASBR-3_1st" {
                    ipv4 {
                    }
                }
                interface "int-ASBR-2-ASBR-3_2nd" {
                    ipv4 {
                    }
                }
            }
```

ASBR-2 now has a valid, best, and used route for prefix 192.0.2.4/32, as follows:

```
[]
A:admin@ASBR-2# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
*i    192.0.2.1/32                                     100         None
      192.0.2.1                                        None        10
      No As-Path                                                   524285
u*>i  192.0.2.4/32                                     None        None
      192.0.2.3                                        None        1
      64500                                                        524285
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

PE-1 has a valid route for prefix 192.0.2.4/32, as follows:

```
[]
A:admin@PE-1# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete
```

```
===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  192.0.2.4/32                                     100         None
      192.0.2.2                                        None        10
      64500                                                        524282
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The following routing table shows that PE-1 has a BGP labeled route toward PE-4:

```
[]
A:admin@PE-1# show router route-table

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                          Type    Proto     Age        Pref
      Next Hop[Interface Name]                                Metric
-------------------------------------------------------------------------------
192.0.2.1/32                                Local   Local     00h43m23s  0
       system                                                   0
192.0.2.2/32                                Remote  ISIS      00h43m13s  15
       192.168.12.2                                             10
192.0.2.4/32                                Remote  BGP_LABEL 00h17m57s  170
       192.0.2.2 (tunneled)                                     10
192.168.12.0/30                             Local   Local     00h43m23s  0
       int-PE-1-ASBR-2                                          0
-------------------------------------------------------------------------------
No. of Routes: 4
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

A multi-hop eBGP session is established for address family VPN-IPv4 between PE-1 and PE-4, as follows:

```
[]
A:admin@PE-1# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.2
Def. Instance  64496       93    0 00h44m01s 1/1/1 (Lbl-IPv4)
                           94    0
192.0.2.4
Def. Instance  64500       46    0 00h21m06s 1/1/1 (VpnIPv4)
                           47    0
```

```
-------------------------------------------------------------------------------
```

The loopback address defined in VPRN 1 on PE-4 (10.2.2.2/32) is advertised as VPN-IPv4 route in this multi-hop eBGP session on PE-1, as follows:

```
[]
A:admin@PE-1# show router bgp routes vpn-ipv4
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64500:1:10.2.2.2/32                              None        None
      192.0.2.4                                        None        0
      64500                                                        524284
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The routing table for VPRN 1 on PE-1 includes a BGP-VPN route to PE-4, as follows:

```
[]
A:admin@PE-1# show router 1 route-table

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
10.1.1.1/32                                    Local   Local     00h44m02s  0
       loopback                                                    0
10.2.2.2/32                                    Remote  BGP VPN   00h23m23s  170
       192.0.2.4 (tunneled:BGP)                                    0
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

To restore the configuration, LDP is disabled on the interfaces between the ASBRs, as follows for ASBR-2. The configuration is similar on ASBR-3.

```
# on ASBR-2:
configure {
    router "Base" {
        ldp {
            interface-parameters {
                delete interface "int-ASBR-2-ASBR-3_1st" {
```

```
                }
                delete interface "int-ASBR-2-ASBR-3_2nd" {
                }
            }
```

EBGP route resolution to a static route

The static routes are already configured on both ASBRs and the eBGP session between the ASBRs is established.

Multi-hop EBGP labeled IPv4 route resolution to a static route needs to be enabled on ASBR-2 and ASBR-3 using the following command:

```
# on ASBR-2, ASBR-3:
configure {
    router "Base" {
        bgp {
            next-hop-resolution {
                labeled-routes {
                    allow-static true
                }
            }
```

On ASBR-2, the labeled IPv4 route for prefix 192.0.2.4/32 is now valid, best, and used, as follows:

```
[]
A:admin@ASBR-2# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
*i    192.0.2.1/32                                     100         None
      192.0.2.1                                        None        10
      No As-Path                                                   524285
u*>i  192.0.2.4/32                                     None        None
      192.0.2.3                                        None        1
      64500                                                        524285
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

PE-1 learns the following BGP labeled IPv4 route for prefix 192.0.2.4/32 from ASBR-2:

```
[]
A:admin@PE-1# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
```

```
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  192.0.2.4/32                                     100         None
      192.0.2.2                                        None        10
      64500                                                        524284
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The routing table on PE-1 contains a BGP labeled IPv4 route to 192.0.2.4/32:

```
[]
A:admin@PE-1# show router route-table

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
192.0.2.1/32                                   Local   Local     01h23m40s  0
       system                                                         0
192.0.2.2/32                                   Remote  ISIS      01h23m30s  15
       192.168.12.2                                                   10
192.0.2.4/32                                   Remote  BGP_LABEL 00h06m39s  170
       192.0.2.2 (tunneled)                                           10
192.168.12.0/30                                Local   Local     01h23m40s  0
       int-PE-1-ASBR-2                                                0
-------------------------------------------------------------------------------
No. of Routes: 4
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The multi-hop eBGP session between PE-1 in AS 64496 and PE-4 in AS 64500 is established, as follows:

```
[]
A:admin@PE-1# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.2
Def. Instance  64496      164    0 01h18m54s 1/1/1 (Lbl-IPv4)
```

```
                          163    0
192.0.2.4
Def. Instance  64500       57    0 00h01m25s 1/1/1 (VpnIPv4)
                           11    0

------------------------------------------------------------------------------
```

The loopback address defined in VPRN 1 on PE-4 (10.2.2.2/32) is advertised as VPN-IPv4 route in this multi-hop eBGP session on PE-1, as follows:

```
[]
A:admin@PE-1# show router bgp routes vpn-ipv4
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64500:1:10.2.2.2/32                              None        None
      192.0.2.4                                        None        0
      64500                                                        524284
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The routing table for VPRN 1 on PE-1 includes the following BGP-VPN route to 10.2.2.2/32:

```
[]
A:admin@PE-1# show router 1 route-table

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
10.1.1.1/32                                    Local   Local     01h20m41s  0
       loopback                                                      0
10.2.2.2/32                                    Remote  BGP VPN   00h05m26s  170
      192.0.2.4 (tunneled:BGP)                                       0
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The results are similar on PE-4 and PE-1, and on ASBR-3 and ASBR-2.

For directly connected ASBRs, inter-AS VPRN model C can be configured using loopback addresses on the ASBRs without the need to enable MPLS between the ASBRs.

Conclusion

Most service providers use interface IP addresses in eBGP sessions, in which case this feature is not needed. However, some providers build directly connected eBGP sessions based on loopback interfaces. The system interface of the peer ASBR must be reachable and the labeled IPv4 routes for the remote AS PEs must be advertised to the local AS PEs. This advertisement can be achieved by configuring static routes on the ASBRs to the loopback address of their eBGP peer and enabling the eBGP route resolution to a static route. Enabling eBGP route resolution to a static route is much more secure than enabling MPLS on the interface to the peer ASBR of an untrusted ISP. However, when the ASBRs are distant and loopback addresses are used for the eBGP peering, MPLS must be enabled between the ASBRs.

Flexible Algorithm for IS-IS

This chapter describes Flexible Algorithm for IS-IS.

Topics in this chapter include:

Applicability

The information in this chapter is based on SR OS Release 20.7.R1. The MD-CLI configuration in the current edition is based on SR OS Release 20.10.R1.

Overview

By default, an IGP-computed path is based on the shortest IGP metric, but frequently these paths are accompanied by traffic-engineered paths that are used to meet the requirements of the network. These traffic-engineered paths are facilitated by RSVP-TE or SR-TE, both of which perform source routing based on a set of metrics and constraints. In many networks this works well, but for some operators the overhead of traffic engineering in this manner is perceived as complex or costly.

Flexible Algorithm (or Flex-Algorithm) — as described in *draft-ietf-lsr-flex-algo* —provides a way for IGPs to compute constraint-based paths across a domain. Flex-Algorithm uses extensions to IS-IS and OSPF to advertise TLVs containing one or more Flexible Algorithm Definitions (FADs). Each FAD is associated with a numeric identifier and identifies a set of metrics and constraints to calculate the best path along the constrained topology.

When used with Segment Routing (SR), one or more Prefix Node-SIDs can be associated with a Flex-Algorithm identifier, thereby providing a level of traffic engineering without any associated control plane overhead or additional label stack imposition. The classic SPF technology used for shortest path calculation is referred to as algorithm 0. In SR OS Release 20.7.R1, up to five additional flexible algorithms can be supported.

This chapter provides an overview of the operation of Flex-Algorithm with IS-IS and how it is applicable to SR; specifically, SR-MPLS.

Flexible Algorithm Definition

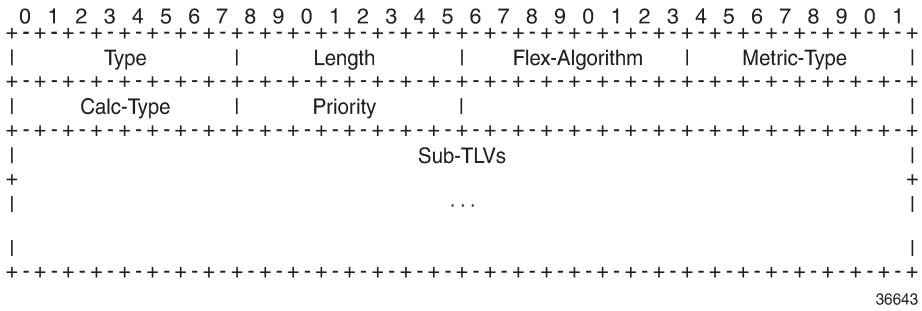
A FAD is the construct that identifies how a path for a Flex-Algorithm will be computed, and consists of three components:

- A calculation type

- A metric type
- A set of constraints, such as include or exclude statements

To guarantee loop-free forwarding for paths computed with a Flex-Algorithm, all routers that participate in that Flex-Algorithm must receive the definition of it. In IS-IS, the definition of the Flex-Algorithm is advertised using the FAD sub-TLV, which is a sub-TLV of the Router Capability TLV and has area scope, as shown in Figure 115: IS-IS FAD sub-TLV.

Figure 115: IS-IS FAD sub-TLV



The Type and Length fields are self-explanatory. The Flex-Algorithm field contains a numeric identifier in the range 128 to 255 that is associated with the FAD through configuration. The Metric-Type field contains one of IGP metric (0), Min Unidirectional Link Delay (1), or TE Default Metric (2). The Calc-Type field contains a value from 0 to 127, identifying the IGP algorithm type, such as shortest path (0). One or more sub-TLV fields may be present to specify "colors" that are used to include or exclude links during the Flex-Algorithm path computation. These are encoded using Exclude Admin Group, Include-any Admin Group, Include-all Admin-Group, and Exclude SRLG sub-TLVs.

The Sub-TLV field may also contain a Flags sub-TLV. In *draft-ietf-lsr-flex-algo*, only the M-flag (Prefix Metric) is defined. The M-flag indicates that the Flex-Algorithm Prefix Metric (FAPM) sub-TLV must be advertised with the prefix. The FAPM is not a sub-TLV of the FAD, but rather a sub-TLV of the Extended IP Reachability TLV, and is intended to assist with inter-area and inter-domain Flex-Algorithm path calculations.

Any IGP shortest-path tree calculation is limited to a single area, and the same applies to Flex-Algorithm. To allow for inter-area or inter-domain Flex-Algorithm calculations, the FAPM sub-TLV can be attached to Extended IP Reachability TLVs that are advertised between areas or domains. The FAPM sub-TLV contains the metric equivalent to the metric of the redistributing router to reach the prefix. If the FAD Flags sub-TLV has the M-flag set, the FAPM must be used when calculating prefix reachability for inter-area and inter-domain prefixes.

Only a subset of the routers participating in each Flex-Algorithm need to advertise the definition of the Flex-Algorithm. However, every router that is part of the intended Flex-Algorithm topology must be configured to participate in the Flex-Algorithm. If a router is not configured to participate in a specific Flex-Algorithm, it ignores FAD sub-TLV advertisements for that Flex-Algorithm.

Application-specific link attributes

Advertisement of link attributes for the purpose of traffic engineering was initially introduced by RFC 5305, which included a number of sub-TLVs encoded within the Extended IS Reachability TLV, such as admin group, TE default metric, maximum link bandwidth, and unreserved bandwidth.

RFC 7308 updated RFC 5305 by increasing the size of the admin group sub-TLV, thereby allowing for advertisement of more than the standard 32 admin groups per link. RFC 5305 was again updated by RFC 8570, which proposed the use of metric extensions, adding additional sub-TLVs to the Enhanced IS Reachability TLV, such as unidirectional link delay, unidirectional link loss, and unidirectional available bandwidth. These traffic-engineering extensions have been widely deployed for RSVP-TE purposes.

Other applications that also make use of traffic-engineering link attributes have been defined, such as SR, Loopfree Alternates (LFAs), and Flex-Algorithm. If these applications coexist, it may be advisable to unambiguously indicate which traffic-engineering attributes apply to which application. Their requirements may differ on a link-to-link basis, or two applications may not be fully congruent; for example, SR may not be fully deployed network-wide. For these reasons, Flex-Algorithm specifies the use of Application-Specific Link Attributes (ASLAs), from *draft-ietf-isis-te-app*, which defines two new code points for IS-IS ASLA advertisements:

- ASLA sub-TLV for Extended IS Reachability and Neighbor Link Attributes TLVs (TLVs 22, 23, 25, 141, 222, and 223)
- Application-Specific Shared Risk Link Group (SRLG) TLV

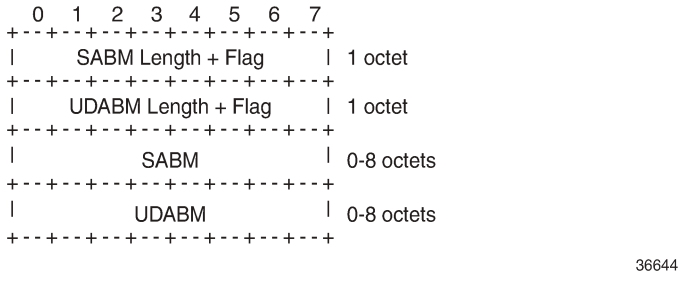
The ASLA sub-TLV contains Link Attribute sub-sub-TLVs, the format of which matches the existing formats defined in RFC 5305, RFC 7308, and RFC 8570. The Application-Specific SRLG TLV encodes link identifier sub-TLVs, such as IPv4/IPv6 Interface address, IPv4/IPv6 Neighbor address, and Link Local/Remote Identifiers. SR OS will advertise Application-Specific SRLG TLVs, but does not use SRLG TLVs for computing SRLG-diverse paths in Release 20.7.R1. Support for LFA (primary/backup) SRLG diversity for Flex-Algorithm is provided using locally configured LFA policies.

Each of the ASLA sub-TLV and Application-Specific SRLG TLV advertisements are coupled with an Application Identifier Bit Mask that identifies the applications associated with an advertisement. Two bit masks are available for use:

- the Standard Applications Bit Mask (SABM)is used for applications, where the definition of each bit is controlled by IANA.
- the User-Defined Applications Bit Mask (UDABM) allows for future non-standard extensibility.

The encoding shown in Figure 116: Application Identifier Bit Mask is used by both the ASLA sub-TLV and the Application-Specific SRLG TLV.

Figure 116: Application Identifier Bit Mask



The SABM Length + Flag field contains a single L-flag, known as the "Legacy" flag. When the L-flag is set in the Application Identifier Bit Mask, all the applications specified in the bit mask must use the legacy traffic-engineering advertisements for the corresponding link. That is, link attributes should be carried as sub-TLVs of the Extended IS Reachability TLV rather than sub-sub-TLVs of the ASLA sub-TLV. This allows for a level of backward compatibility such that legacy advertisements may continue to be used if:

- Only RSVP-TE is deployed

- Only SR /LFA is deployed
- A combination of RSVP-TE and SR/LFA is deployed, but the set of links that each application uses are fully congruent.

The UDABM Length + Flag field contains a single R-flag, which is reserved for future use.

The SABM field defines four bits to identify applications:

- The R-bit (bit 0) specifies RSVP-TE
- The S-bit (bit 1) specifies SR
- The F-Bit (bit 2) specifies LFA
- The X-bit (bit 3) specifies Flex-Algorithm

Applicability of Flex-Algorithm to SR

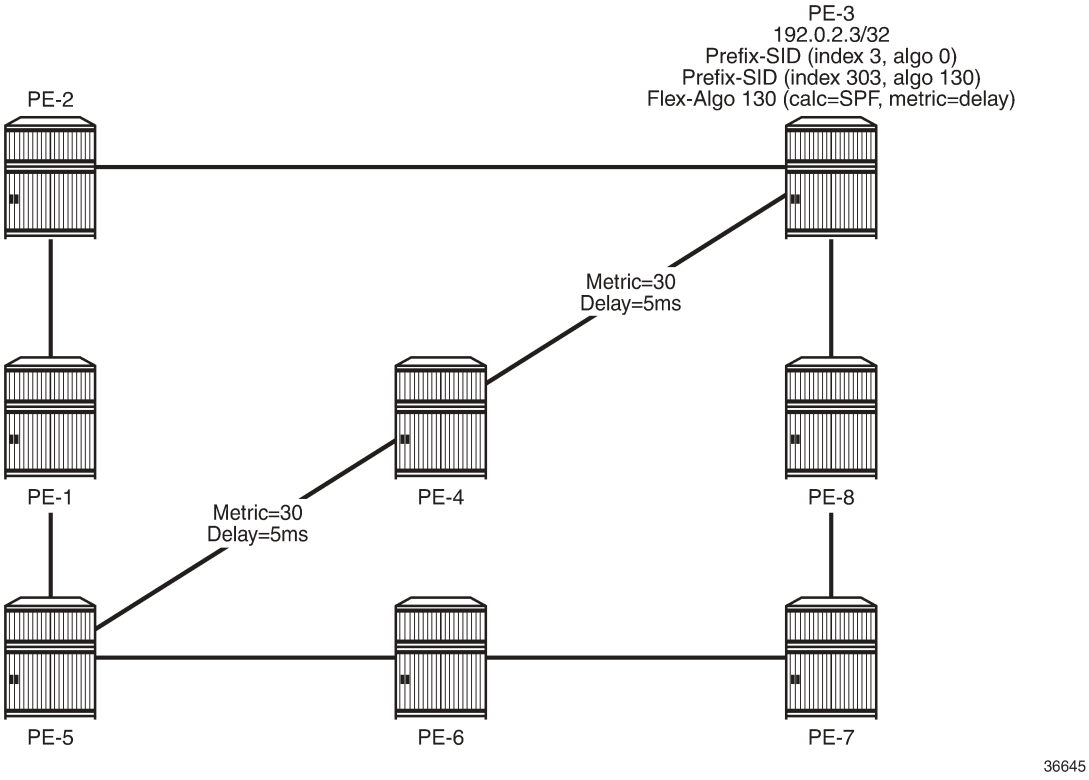
A router may use various algorithms when calculating reachability to other nodes or prefixes attached to those nodes. RFC 8667 — *IS-IS extensions for SR* — describes the use of the SR-Algorithm sub-TLV (carried as part of the Router Capabilities TLV) to advertise the algorithms that the router can support. By default, an SR router will signal support for algorithm 0 (metric-based SPF). To advertise participation for a specific Flex-Algorithm for SR, the Flex-Algorithm value must also be advertised in the SR-Algorithm sub-TLV.

When an SR router advertises a Prefix SID, it includes an SR-algorithm, so it is possible to associate a Prefix SID with a specific algorithm. For example, a router may advertise prefix P1 with Prefix SID {index=1, algorithm=0} and prefix P2 with Prefix SID {index=2, algorithm=128}. This indicates to other SR routers that to reach prefix P1, the default metric-based SPF should be used to calculate the best path, and to reach prefix P2, Flex-Algorithm 128 (and whatever that algorithm dictates) should be used.

Equally, in an SR-MPLS environment with an SR Global Block (SRGB) of {1000-1999}, a router may advertise prefix P1 with Prefix SID {index=1, algorithm=0}, and also Prefix SID {index=101, algorithm=129}. This indicates to other SR routers that when label 1001 is the active label to reach prefix P1, the default metric-based SPF should be used to calculate the best path, and when label 1101 is the active label, Flex-Algorithm 129 should be used.

Figure 117: Flexible Algorithm example in an SR-MPLS domain shows an SR-MPLS domain where all links have metric 10 except for links PE-5-PE-4 and PE-4-PE-3, which both have metric 30. All links have a unidirectional link latency of 10 ms, except for links PE-5-PE-4 and PE-4-PE-3, which both have a unidirectional latency of 5 ms. All routers use an SRGB of {1000-1999}.

Figure 117: Flexible Algorithm example in an SR-MPLS domain

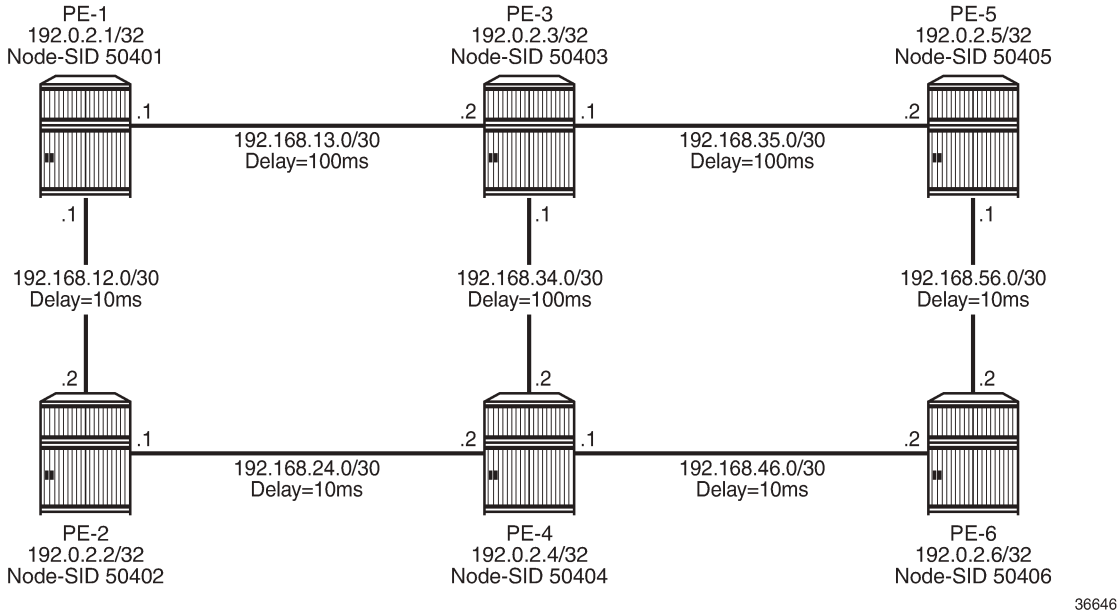


In addition to the default algorithm 0 (metric-based SPF), all routers participate in Flex-Algorithm 130 with FAD {calc-type=SPF, metric=delay, constraints=none}. Router PE-3 advertises prefix 192.0.2.3/32 with Prefix SID {index=3, algorithm=0} and Prefix SID {index=303, algorithm=130}. Router PE-5 has an SR-TE LSP provisioned with a destination of PE-3 (192.0.2.3) and a top (active) label of 1003. As a result, it is associated with algorithm 0 and uses the shortest path IGP metric PE-5-PE-1-PE-2-PE-3 to reach its destination. Router PE-5 is also provisioned with a second SR-TE LSP, again with a destination of PE-3 (192.0.2.3), but this time with a top (active) label of 1303. This second LSP is associated with Flex-Algorithm 130 and uses the shortest path delay metric PE-5-PE-4-PE-3 to reach its destination.

Example topology

Figure 118: Example topology shows the example topology used in this chapter. All routers within the example topology form part of Autonomous System 64496 and belong to the same IS-IS Level-2 area. All IGP link metrics are 100 and are symmetric. Unidirectional link delay is also configured, and all links have a delay of 10 ms, with the exception of links PE-1-PE-3, PE-3-PE-5, and PE-3-PE-4, which have a delay of 100 ms. SR is enabled within the domain, and the associated Node-SIDs used as a baseline are shown (Adj-SIDs are not shown for the purpose of clarity). The SRGB in use is {50000-54999}.

Figure 118: Example topology



An additional step is required if a Flex-Algorithm uses a metric-type of delay. Before the delay metric can be advertised, a value for that metric needs to be derived. There are various methods available to do this (including OAM probes and so on), but currently the only method that SR OS supports is static configuration. The following output provides an example of static configuration of delay metric at PE-1. The delay is entered as an if-attribute under each interface and is expressed in microseconds. As per Figure 118: Example topology, the link PE-1-PE-2 has a delay metric of 10 ms, while the link PE-1-PE-3 has a delay metric of 100 ms.

```
# on PE-1:
configure {
    router "Base" {
        interface "int-PE-1-PE-2" {
            if-attribute {
                delay {
                    static 10000
                }
            }
        }
        interface "int-PE-1-PE-3" {
            if-attribute {
                delay {
                    static 100000
                }
            }
        }
```

Configuration

The following steps are required to configure and enable the use of Flex-Algorithm:

- Enable the use of ASLAs
- Configure and advertise the FAD
- Configure Flex-Algorithm participation
- Configure a Flex-Algorithm Prefix Node-SID
- Configure traffic steering using Flex-Algorithm

These steps are described in the following subsections.

Enable the use of ASLAs

Flex-Algorithm specifies the use of ASLAs for advertisement of traffic-engineering information. If not already enabled, enable these under the IS-IS context for all routers in the domain, as follows:

```
# on all PEs:
configure {
    router "Base" {
        isis 0 {
            traffic-engineering-options {
                application-link-attributes {
                }
            }
```

For backward compatibility, the **application-link-attributes** command has an optional **legacy** argument, which allows link attributes to be encoded in the legacy manner as sub-TLVs of the Extended IS Reachability TLV, rather than being encoded as (sub-)sub-TLVs of the ASLA sub-TLV.

The following output shows how ASLAs are advertised as sub-TLVs of the Extended IS Reachability TLV. The output is taken at PE-1 and is truncated to include only the IS neighbor PE-3. Within the Extended IS Reachability TLV, there are three ASLA sub-TLVs:

- The first is non-legacy (L-bit is not set) and has an SABM field that has the R-bit and S-bit set, indicating that these attributes are specific to RSVP-TE and SR, respectively. The link attributes include Max Link Bandwidth and TE Metric.
- The second is non-legacy and has an SABM field with R-bit set, indicating that the intended application is RSVP-TE, and contains reservable and unreserved bandwidth link attributes.
- The third ASLA sub-TLV is non-legacy and has the X-bit set, indicating that this is specific only to Flex-Algorithm. This sub-TLV contains the Delay and TE Metric link attributes.

```
[]
A:admin@PE-1# show router isis database PE-1.00-00 detail

===============================================================================
Rtr Base ISIS Instance 0 Database (detail)
===============================================================================

Displaying Level 2 database
-------------------------------------------------------------------------------
LSP ID    : PE-1.00-00                                  Level     : L2
Sequence  : 0x114                 Checksum  : 0xe884    Lifetime  : 38293
Version   : 1                     Pkt Type  : 20        Pkt Ver   : 1
Attributes: L1L2                  Max Area  : 3         Alloc Len : 1492
SYS ID    : 1920.0000.2001        SysID Len : 6         Used Len  : 607
  ---snip---
  TE IS Nbrs   :
```

```
    Nbr   : PE-3.00
    Default Metric  : 100
    Sub TLV Len     : 103
    IF Addr   : 192.168.13.1
    Nbr IP    : 192.168.13.2
    TE APP LINK ATTR    :
      SABML-flag:Non-Legacy SABM-flags:R S
        MaxLink BW: 10000000 kbps
        TE Metric : 100
    TE APP LINK ATTR    :
      SABML-flag:Non-Legacy SABM-flags:R
        Resvble BW: 10000000 kbps
        Unresvd BW:
            BW[0] : 10000000 kbps
            BW[1] : 10000000 kbps
            BW[2] : 10000000 kbps
            BW[3] : 10000000 kbps
            BW[4] : 10000000 kbps
            BW[5] : 10000000 kbps
            BW[6] : 10000000 kbps
            BW[7] : 10000000 kbps
    TE APP LINK ATTR    :
      SABML-flag:Non-Legacy SABM-flags:   X      # when FAD is defined and applied
        Delay     : 100000
        TE Metric : 100
    Adj-SID: Flags:v4VLP Weight:0 Label:150013
    Adj-SID: Flags:v6VL Weight:0 Label:524272
  ---snip---
```

Configure FAD and participation

To define the FAD, the following example uses a metric-type of delay with no other constraints. As previously described, not all participating routers need to advertise the FAD; only their participation in it. Therefore, in this example, PE-1 and PE-5 are used to advertise the FAD and the following configuration is applied to both routers.

First, the FAD is created with a name under the **flexible-algorithm-definitions** context. After the flex-algo context has been created, the metric-type (IGP, TE metric, delay) and any other constraints (include-all, include-any, exclude) can be configured within it. It is also possible to configure a priority value for the flex-algo in the range 0 to 255. If multiple FAD advertisements are received, the highest priority will be selected. If priorities are equal, the FAD advertised by the highest router ID is selected. The default priority is 100.

```
# on PE-1, PE-5:
configure {
    routing-options {
        flexible-algorithm-definitions {
            flex-algo "FlexAlgo-128" {
                admin-state enable
                description "FlexAlgo-128-Delay-Metric"
                metric-type delay
            }
        }
```

After the FAD has been defined, it can be advertised into IS-IS. This is done under the flexible-algorithms context within the IS-IS instance. The Flex-Algorithm must initially be assigned a numeric identifier in the range 128 to 255, after which the **advertise** command is used to advertise the previously configured FAD "FlexAlgo-128". The **participate** command is used to configure participation for the specific Flex-Algorithm and must be enabled on all routers that are part of this Flex-Algorithm topology. Finally, LFA may

be enabled. If it is, the LFA SPF will use the same Flex-Algorithm topology as that used to calculate the primary path. Also, LFA settings (such as TI-LFA, Remote-LFA) within a Flex-Algorithm are inherited from the base IS-IS/LFA configuration.

PE-1 and PE-5 both advertise and participate in the Flex-Algorithm, as follows:

```
# on PE-1, PE-5:
configure {
    router "Base" {
        isis 0 {
            flexible-algorithms {
                admin-state enable
                flex-algo 128 {
                    participate true
                    advertise "FlexAlgo-128"
                    loopfree-alternate { }
                }
            }
        }
```

What remains is to configure all other routers in the domain to participate in the same Flex-Algorithm, as in the following output. This is essentially the same configuration as applied to PE-1 and PE-5, with the exception of the advertise statement.

```
# on PE-2, PE-3, PE-4, PE-6:
configure {
    router "Base" {
        isis 0 {
            flexible-algorithms
                admin-state enable
                flex-algo 128 {
                    participate true
                    loopfree-alternate { }
                }
            }
        }
```

After the FAD with Flex-Algorithm identifier 128 has been advertised and all routers have signaled that they participate in this Flex-Algorithm, it can be validated with router outputs. The following output shows the relevant parts of the IS-IS LSP advertised by PE-1. Within the Router Capabilities TLV, there are two notable additions. The SR-Algorithm sub-TLV shows the default metric-based SPF (algorithm 0), but now includes algorithm 128, showing its participation in this algorithm. There is also a FAD sub-TLV containing the definition of Flex-Algorithm 128 with metric-type of delay. The FAD has a Flags sub-TLV with the M-flag set, indicating that the FAPM must be used when calculating prefix reachability for inter-area and inter-domain prefixes.

```
[]
A:admin@PE-1# show router isis database PE-1.00-00 detail

===============================================================================
Rtr Base ISIS Instance 0 Database (detail)
===============================================================================

Displaying Level 2 database
-------------------------------------------------------------------------------
LSP ID    : PE-1.00-00                                  Level     : L2
Sequence  : 0x114                Checksum  : 0xe884   Lifetime  : 49976
Version   : 1                    Pkt Type  : 20       Pkt Ver   : 1
Attributes: L1L2                 Max Area  : 3        Alloc Len : 1492
SYS ID    : 1920.0000.2001       SysID Len : 6        Used Len  : 607
```

```
  ---snip---
  Router Cap : 192.0.2.1, D:0, S:0
    TE Node Cap : B E M  P
    SR Cap: IPv4 MPLS-IPv6
       SRGB Base:50000, Range:5000
    SR Alg: metric based SPF, 128
    Node MSD Cap: BMI : 12 ERLD : 15
    FAD Sub-Tlv:
        Flex-Algorithm   : 128
        Metric-Type      : delay
        Calculation-Type : 0
        Priority         : 100
        Flags: M
   ---snip---
```

Configure a Flex-Algorithm Prefix Node-SID

At each egress node, a Prefix Node-SID must be assigned to each Flex-Algorithm in use. This will be advertised as a Prefix SID sub-TLV that will contain (among other things) the algorithm to be used to reach the associated Prefix Node-SID. The Node-SID is taken from the generic SRGB; no special or dedicated label space is required. In the following example, PE-5 is the egress router and the relevant configuration is shown in the following output. Under the IS-IS system interface context, the Node-SID label assigned to algorithm 0 is 50405 and is generic SR configuration. Within the same context, a sub-context is created for flex-algo 128 for which a Prefix SID label of 54405 is assigned.

```
# on PE-5:
configure {
    router "Base" {
        isis 0 {
            interface "system" {
                passive true
                level-capability 2
                ipv4-node-sid {
                    label 50405
                }
                flex-algo 128 {
                    ipv4-node-sid {
                        label 54405
                    }
                }
            }
```

When configured, the additional Prefix SID advertisement can be viewed in the PE-5 advertised IS-IS LSP.

```
[]
A:admin@PE-5# show router isis database PE-5.00-00 detail

===============================================================================
Rtr Base ISIS Instance 0 Database (detail)
===============================================================================

Displaying Level 2 database
-------------------------------------------------------------------------------
LSP ID    : PE-5.00-00                                 Level     : L2
Sequence  : 0x101                Checksum  : 0x9c1c   Lifetime  : 53986
Version   : 1                    Pkt Type  : 20       Pkt Ver   : 1
Attributes: L1L2                 Max Area  : 3        Alloc Len : 1492
SYS ID    : 1920.0000.2005       SysID Len : 6        Used Len  : 650
```

```
  ---snip---
    TE IP Reach   :
    Default Metric  : 0
    Control Info:   S, prefLen 32
    Prefix   : 192.0.2.5
    Sub TLV   :
      Prefix-SID Index:405, Algo:0, Flags:NnP
      Prefix-SID Index:4405, Algo:128, Flags:NnP
  ---snip---
```

The Flex-Algorithm Prefix SID can also be viewed using the **show router prefix-sids** command with the relevant flex-algo extension. The index is 4405 and with an SRGB start-label of 50000, this equates to the configured label value of 54405.

```
[]
A:admin@PE-1# show router isis prefix-sids algo 128

===============================================================================
Rtr Base ISIS Instance 0 Prefix/SID Table
===============================================================================
Prefix                          SID        Lvl/Typ    SRMS   AdvRtr
                                            Algo       MT     Flags
-------------------------------------------------------------------------------
192.0.2.5/32                    4405       2/Int.      N     PE-5
                                               128        0      NnP
-------------------------------------------------------------------------------
No. of Prefix/SIDs:  (1 unique)
-------------------------------------------------------------------------------
SRMS : Y/N  = prefix SID advertised by SR Mapping Server (Y) or not (N)
       S    = SRMS prefix SID is selected to be programmed
Flags: R    = Re-advertisement
       N    = Node-SID
       nP   = no penultimate hop POP
       E    = Explicit-Null
       V    = Prefix-SID carries a value
       L    = value/index has local significance
===============================================================================
```

After the Prefix Node-SID has been correctly advertised by PE-5 with algorithm 128, it is possible to use the tunnel table to verify the Flex-Algorithm path toward the destination prefix. The following output shows the tunnel table at PE-1 for PE-5 (192.0.2.5/32). In this output, there are two entries. The first entry (tunnel ID 524296) is the default SR-ISIS tunnel calculated using algorithm 0. This has a next-hop of PE-3 (192.168.13.2) and metric of 200 representing the IGP cost of the path PE-1-PE-3-PE-5. The second entry (tunnel ID 524198) is calculated using Flex-Algorithm 128. It has a next-hop of PE-2 (192.168.12.2) and a metric of 40000 representing the accumulative delay metric (40msec) for the path PE-1-PE-2-PE-4-PE-6-PE-5.

```
[]
A:admin@PE-1# show router tunnel-table 192.0.2.5/32 protocol isis

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
192.0.2.5/32 [L]      isis (0)  MPLS  524296    11     192.168.13.2   200
192.0.2.5/32 [L]      isis (0)  MPLS  524298    11     192.168.12.2   40000
-------------------------------------------------------------------------------
Flags: B = BGP or MPLS backup hop available
```

```
       L = Loop-Free Alternate (LFA) hop available
       E = Inactive best-external BGP route
       k = RIB-API or Forwarding Policy backup hop
===============================================================================
```

Traffic steering using Flex-Algorithm

To statically steer traffic into a Flex-Algorithm LSP, the **static-route-entry** allows for indirect next-hops to configure a Flex-Algorithm identifier in addition to a resolution-filter specifying SR-ISIS. This uses the specified Flex-Algorithm to construct a tunnel toward the indirect next-hop. In the following example, a static-route for prefix 172.16.0.1/32 is configured at PE-1 toward PE-5 (192.0.2.5) using a resolution-filter of SR-ISIS and flex-algo 128. Note that if no tunnel exists in the tunnel table for the referenced Flex-Algorithm identifier that the static-route will not become active.

```
# on PE-1:
configure {
    router "Base" {
        static-routes {
            route 172.16.0.1/32 route-type unicast {
                indirect 192.0.2.5 {
                    admin-state enable
                    tunnel-next-hop {
                        resolution filter
                        flex-algo 128
                        resolution-filter {
                            sr-isis true
                        }
                    }
                }
            }
```

From the prefix in the route-table, the next-hop is PE-5 (192.0.2.5) and the next-hop is resolved to an SR-ISIS tunnel with tunnel ID 524298, which is the tunnel ID of the Flex-Algorithm LSP.

```
[]
A:admin@PE-1# show router route-table 172.16.0.1/32

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
172.16.0.1/32                                   Remote  Static    01h29m00s  5
       192.0.2.5 (tunneled:SR-ISIS:524298)                          1
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

Flex-Algorithm LSPs can also be used for BGP next-hop resolution and/or service next-hop resolution wherever an SR-TE or SR Policy path contains one or more Prefix Node-SIDs and the auto-bind-tunnel resolution-filter is configured appropriately. The following output provides an example of an SR-TE LSP configured at PE-1 toward PE-5. The LSP references a primary path named "FlexAlgo-128", where that

path has a single hop containing the label 54405. This is the label value that was previously allocated to Flex-Algorithm 128 at PE-5.

```
# on PE-1:
configure {
    router "Base" {
        mpls {
            path "FlexAlgo-128" {
                admin-state enable
                hop 1 {
                    sid-label 54405
                }
            }
            lsp "PE-1-PE-5-SR-TE-FlexAlgo128" {
                admin-state enable
                type p2p-sr-te
                to 192.0.2.5
                max-sr-labels {
                    label-stack-size 1
                    additional-frr-labels 2
                }
                primary "FlexAlgo-128" {
                }
            }
```

First, verification is obtained that the SR-TE LSP is administratively and operationally up.

```
[]
A:admin@PE-1# show router mpls sr-te-lsp "PE-1-PE-5-SR-TE-FlexAlgo128"

===============================================================================
MPLS SR-TE LSPs (Originating)
===============================================================================
LSP Name                                            Tun     Protect   Adm  Opr
  To                                                Id      Path
-------------------------------------------------------------------------------
PE-1-PE-5-SR-TE-FlexAlgo128                         1       N/A       Up   Up
  192.0.2.5
-------------------------------------------------------------------------------
LSPs : 1
===============================================================================
```

The same SR-TE LSP is also present in the tunnel table with tunnel ID 655362.

```
[]
A:admin@PE-1# show router tunnel-table 192.0.2.5/32 protocol sr-te

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
192.0.2.5/32          sr-te     MPLS  655362    8      192.0.2.5      16777215
-------------------------------------------------------------------------------
Flags: B = BGP or MPLS backup hop available
       L = Loop-Free Alternate (LFA) hop available
       E = Inactive best-external BGP route
       k = RIB-API or Forwarding Policy backup hop
===============================================================================
```

A VPRN is configured with PE-1 and PE-5 as members. At PE-1, the **auto-bind-tunnel** context has the **resolution-filter** set to SR-TE such that it can use the SR-TE LSP containing the Flex-Algorithm Prefix Node-SID for next-hop resolution.

```
# on PE-1:
configure {
    service {
         vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            route-distinguisher "64496:1"
            vrf-target {
                community "target:64496:1"
            }
            auto-bind-tunnel {
                resolution filter
                resolution-filter {
                    sr-te true
                }
            }
        }
```

VPN-IPv4 prefix 172.31.5.0/24 is advertised by PE-5 with the relevant Route-Target value such that it is imported at PE-1. The following output shows that prefix 172.31.5.0/24 is imported to the VPRN and uses an SR-TE LSP with tunnel ID 655362 in order to resolve the next-hop.

```
[]
A:admin@PE-1# show router 1 route-table 172.31.5.0/24

===============================================================================
Route Table (Service: 1)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
172.31.5.0/24                                 Remote  BGP VPN   00h22m08s  170
       192.0.2.5 (tunneled:SR-TE:655362)                          16777215
-------------------------------------------------------------------------------
No. of Routes: 1
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

Flex-Algorithm with admin group constraint

The configuration example used so far in this chapter employed a metric-type of delay. For completeness, the following section contains a second example using admin groups as a constraint.

When admin groups are used as a constraint, the first step is to apply the required admin groups to the relevant links. For the purpose of this example, the link PE-1-PE-3 is associated with admin group "blue". Initially, the admin group is configured as an if-attribute in the base router context and assigned an integer value in the range 0 to 31. The configuration of the admin group “blue” is as follows:

```
# on all PEs:
configure {
```

```
    routing-options {
        if-attribute {
            admin-group "blue" {
                value 10
            }
```

The admin group is then assigned to each required interface as an if-attribute in the same way that delay was previously configured. The following output is taken from PE-1 with a similar configuration applied at PE-3.

```
# on PE-1:
configure {
    router "Base"{
        interface "int-PE-1-PE-3" {
            if-attribute {
                  admin-group ["blue"]
                delay {
                    static 100000
                }
            }
```

Note:
draft-etf-isis-te-app permits the use of admin groups and Extended Admin Groups (EAGs). Admin groups (RFC 5305) contain a 4-octet bit mask, where each set bit corresponds to a single admin group, allowing for support of 32 admin groups. EAGs (RFC 7308) have no fixed limit. SR OS only supports advertisement of admin groups, not EAGs. For backward compatibility, if EAGs are used by another vendor they must use only the first 32 colors in the EAG.

The next step is to configure the FAD and participation. First, the FAD is configured to exclude the admin group "blue"; the metric-type remains the default IGP metric. The following configuration is applied at PE-1 and PE-5.

```
# on PE-1, PE-5:
configure {
    routing-options {
        flexible-algorithm-definitions {
            flex-algo "FlexAlgo-129" {
                admin-state enable
                description "FlexAlgo-129-AG-Blue"
                exclude {
                     admin-group "blue" { }
                }
            }
        }
```

In addition to the exclude admin-group constraint, there are options for include-any and include-all admin-groups:

- Include-any means that any link not configured with any of the specified admin-groups will be pruned.
- Include-all means that any link not configured with all of the specified admin-groups will be pruned.

The following step is to advertise the FAD and indicate the participation in the Flex-Algorithm. Again, the following configuration is applied at PE-1 and PE-5, who both participate and advertise in Flex-Algorithm 129. Similar configuration is applied to the other routers in the example topology, but without the **advertise**

command because they only have a requirement to participate in the Flex-Algorithm and not advertise its definition.

```
# on PE-1,PE-5:
configure {
    router "Base" {
        isis 0 {
            flexible-algorithms {
                flex-algo 129 {
                    participate true
                    advertise "FlexAlgo-129"
                    loopfree-alternate { }
                }
            }
```

Finally, a Prefix Node-SID is assigned to the Flex-Algorithm at the egress nodes. In the following example, PE-5 is the egress router and label 54415 is assigned to Flex-Algorithm 129.

```
# on PE-5:
configure {
    router "Base" {
        isis 0 {
            interface "system" {
                passive true
                level-capability 2
                ipv4-node-sid {
                    label 50405
                }
                flex-algo 129 {
                    ipv4-node-sid {
                        label 54415
                    }
                }
```

The Prefix SID and associated Flex-Algorithm advertised by PE-5 is learned at PE-1. As before, the SID 4415 is advertised as an index and, with an SRGB of {50000-54999}, represents label 54415.

```
[]
A:admin@PE-1# show router isis prefix-sids algo 129

===============================================================================
Rtr Base ISIS Instance 0 Prefix/SID Table
===============================================================================
Prefix                          SID        Lvl/Typ    SRMS   AdvRtr
                                            Algo       MT     Flags
-------------------------------------------------------------------------------
192.0.2.5/32                    4415       2/Int.      N     PE-5
                                               129        0      NnP
-------------------------------------------------------------------------------
No. of Prefix/SIDs: 1 (1 unique)
-------------------------------------------------------------------------------
SRMS : Y/N  = prefix SID advertised by SR Mapping Server (Y) or not (N)
       S    = SRMS prefix SID is selected to be programmed
Flags: R    = Re-advertisement
       N    = Node-SID
       nP   = no penultimate hop POP
       E    = Explicit-Null
       V    = Prefix-SID carries a value
       L    = value/index has local significance
===============================================================================
```

The tunnel table is also used to verify the Flex-Algorithm path toward the destination prefix. The following output shows the tunnel table at PE-1 for PE-5 (192.0.2.5/32). In this output, there are two entries. The first entry (tunnel ID 524296) is the default SR-ISIS tunnel calculated using algorithm 0. This has a next-hop of PE-3 (192.168.13.2) and metric of 200 representing the IGP cost of the path PE-1-PE-3-PE-5. The second entry (tunnel ID 524299) is calculated using Flex-Algorithm 129. It has a next-hop of PE-2 (192.168.12.2), avoiding the PE-1-PE-3 link, and a metric of 400 representing the IGP metric for the path PE-1-PE-2-PE-4-PE-6-PE-5.

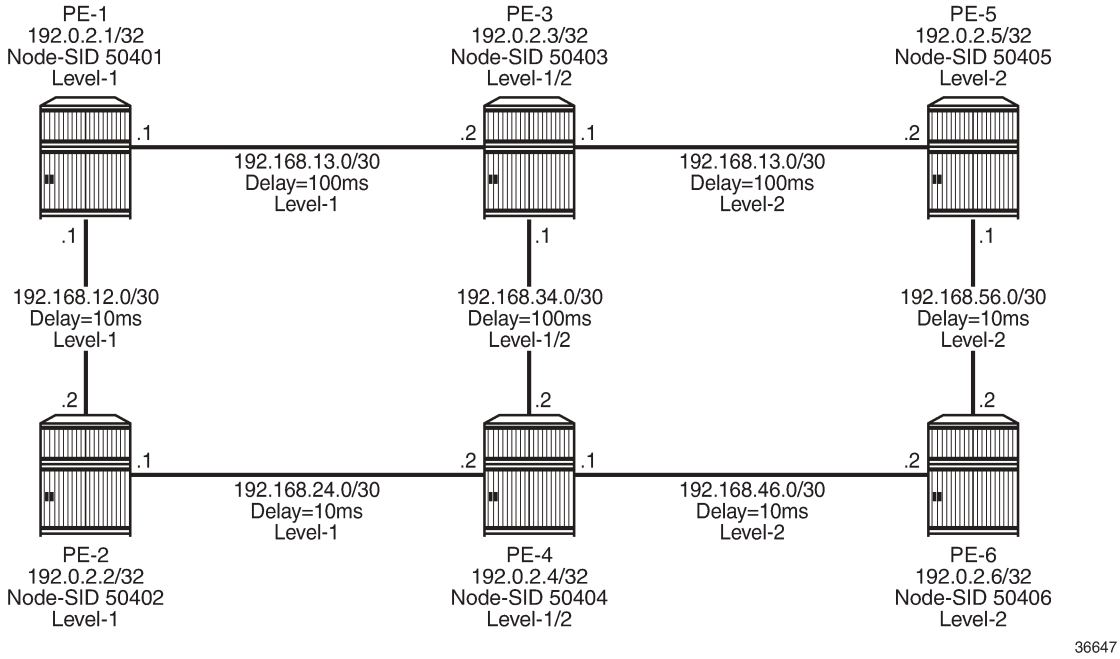
```
[]
A:admin@PE-1# show router tunnel-table 192.0.2.5/32 protocol isis

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
192.0.2.5/32 [L]      isis (0)  MPLS  524296    11     192.168.13.2   200
192.0.2.5/32          isis (0)  MPLS  524299    11     192.168.12.2   400
-------------------------------------------------------------------------------
Flags: B = BGP or MPLS backup hop available
       L = Loop-Free Alternate (LFA) hop available
       E = Inactive best-external BGP route
       k = RIB-API or Forwarding Policy backup hop
===============================================================================
```

The Prefix Node-SID for Flex-Algorithm 129 is now available for carrying traffic. Methods for traffic steering into Flex-Algorithm LSPs have previously been described in this chapter and are therefore not repeated here.

Inter-area Flex-Algorithm

To validate the use of Flex-Algorithm in an inter-area environment, the example topology in Figure 119: Example topology with modified IS-IS Level-1/2 capabilities is modified such that PE-1 and PE-2 are IS-IS Level-1 routers, while PE-3 and PE-4 are IS-IS Level-1/2 routers. PE-5 and PE-6 remain Level-2 only routers.

Figure 119: Example topology with modified IS-IS Level-1/2 capabilities



The previously configured Flex-Algorithm 128 (metric-type of delay) and Flex-Algorithm 129 (exclude admin-group blue) are again used, to show inter-area Flex-Algorithm path computations. Because PE-1 and PE-5 both advertise the FADs for these algorithms, this Level-1/2 inter-area scenario is affected because FAD sub-TLVs only have area scope; they are not redistributed between areas. In this scenario, PE-1 advertises the FAD within the Level-1 area, while PE-5 advertises the FAD within the Level-2 area.

As previously described, when a FAD includes the M-flag (Prefix Metric), an L1/L2 router (or ASBR) must include the FAPM sub-TLV when advertising a prefix within an Extended IP Reachability TLV between areas, levels, or domains. The advertised metric needs to be equal to the metric to reach the prefix for a Flex-Algorithm in the source area or domain. This allows a router in a different area/level/domain to include the FAPM when calculating prefix reachability for inter-area/domain prefixes and provides an optimal end-to-end path for a specific Flex-Algorithm.

In the example topology, both PE-5 and PE-6 are assigned Node-SID labels for Flex-Algorithms 128 and 129. PE-5 is assigned label 54405 for algorithm 128 and 54415 for algorithm 129, while PE-6 is assigned label 54406 for algorithm 128 and 54416 for algorithm 129.

The following output shows the PE-3 IS-IS Level-1 LSP as received by PE-1, truncated to show only the Extended IP Reachability TLV for PE-5 (192.0.2.5) and PE-6 (192.0.2.6). Each of these two prefixes has a Prefix SID sub-TLV for algorithm 0, algorithm 128, and algorithm 129. Flex-Algorithms 128 and 129 also have a FAPM sub-TLV containing the relevant metric for PE-3 to reach the destination prefix.

```
[]
A:admin@PE-1# show router isis database PE-3.00-00 detail

===============================================================================
Rtr Base ISIS Instance 0 Database (detail)
===============================================================================

Displaying Level 1 database
-------------------------------------------------------------------------------
```

```
LSP ID    : PE-3.00-00                                  Level     : L1
Sequence  : 0x58                  Checksum  : 0x4ec6   Lifetime  : 54000
Version   : 1                     Pkt Type  : 18       Pkt Ver   : 1
Attributes: L1L2                  Max Area  : 3        Alloc Len : 482
SYS ID    : 1920.0000.2003        SysID Len : 6        Used Len  : 482

TLVs :
  ---snip---
  TE IP Reach   :
    Default Metric  : 100
    Control Info: D S, prefLen 32
    Prefix   : 192.0.2.5
    Sub TLV   :
      Prefix-SID Index:405, Algo:0, Flags:RNnP
      Prefix-SID Index:4405, Algo:128, Flags:RNnP
      Prefix-Metric-FlexAlg Algo:128, Metric:100000
      Prefix-SID Index:4415, Algo:129, Flags:RNnP
      Prefix-Metric-FlexAlg Algo:129, Metric:100
    Default Metric  : 200
    Control Info: D S, prefLen 32
    Prefix   : 192.0.2.6
    Sub TLV   :
      Prefix-SID Index:406, Algo:0, Flags:RNnP
      Prefix-SID Index:4406, Algo:128, Flags:RNnP
      Prefix-Metric-FlexAlg Algo:128, Metric:110000
      Prefix-SID Index:4416, Algo:129, Flags:RNnP
      Prefix-Metric-FlexAlg Algo:129, Metric:200
  ---snip---
```

The information from the FAPM sub-TLV advertised by PE-3 and PE-4 (Level-1/2 routers) allows the routers in the Level-1 area to construct optimal end-to-end paths with accumulative metrics. The following output shows the tunnel table at PE-1 for PE-5 (192.0.2.5). The first entry is the SR-ISIS LSP calculated with algorithm 0 and showing an IGP metric of 200 for the path PE-1-PE-3-PE-5. The second entry is the SR-ISIS LSP calculated with Flex-Algorithm 129, which excludes the PE-1-PE-3 link, and therefore has an IGP metric of 400 for the path PE-1-PE-2-PE-4-PE-6-PE-5. The final entry is the SR-ISIS LSP calculated with Flex-Algorithm 128 using a metric-type of delay. This entry has a metric of 40000 representing the delay metric for the path PE-1-PE-2-PE-4-PE-6-PE-5.

```
[]
A:admin@PE-1# show router tunnel-table 192.0.2.5/32 protocol isis

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
192.0.2.5/32 [L]      isis (0)  MPLS  524414    11     192.168.13.2   200
192.0.2.5/32          isis (0)  MPLS  524418    11     192.168.12.2   400
192.0.2.5/32 [L]      isis (0)  MPLS  524416    11     192.168.12.2   40000
-------------------------------------------------------------------------------
Flags: B = BGP or MPLS backup hop available
       L = Loop-Free Alternate (LFA) hop available
       E = Inactive best-external BGP route
       k = RIB-API or Forwarding Policy backup hop
===============================================================================
```

Therefore, the optimal end-to-end paths can be calculated by redistributing prefixes with the FAPM sub-TLV and including that metric in the calculation for inter-area/domain prefixes.

Conclusion

With extensions to IS-IS, Flex-Algorithm provides a way to achieve a level of traffic engineering without the requirement for a centralized controller, and without the requirement to impose a deep label stack to represent the path; a single Node-SID is all that is required. Although the traffic engineering capabilities of Flex-Algorithm are limited compared to those available when using a centralized controller, it represents a reasonable trade-off between objective and complexity.

IS-IS Link Bundling

This chapter provides information about IS-IS link bundling.

Topics in this chapter include:

Applicability

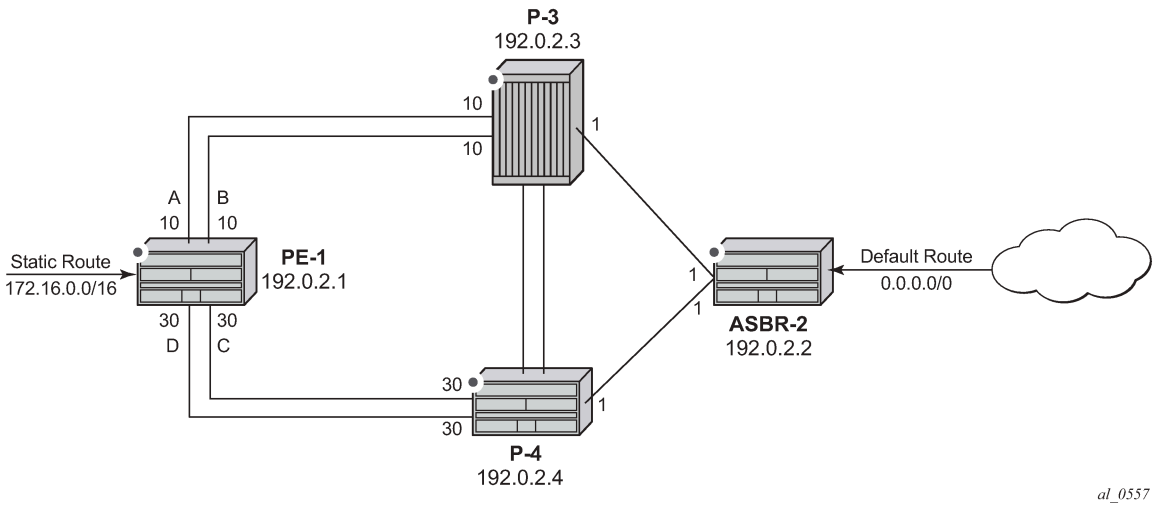
The chapter was initially written for SR OS Release 11.0.R6. The configuration in the current edition is based on MD-CLI in SR OS Release 20.7.R2.

Overview

Intermediate System to Intermediate System (IS-IS) Link Bundling allows for the grouping of a number of IS-IS interfaces into a single virtual link, called an IS-IS link group. It is used in conjunction with Equal Cost Multipath (ECMP) to dynamically change the metric of parallel IS-IS links if one or more links fail or suffer some sort of performance degradation.

Consider the network in Figure 120: Link bundle schematic, where a Provider Edge router PE-1 connects to a core network comprised of two Provider (P) routers and a single Autonomous System Border Router (ASBR).

Figure 120: Link bundle schematic



The links between PE-1 and P-3, and PE-1 and P-4 are 10 Gigabit Ethernet links. The links between ASBR-2 and P-3 and P-4 are both 100 Gigabit links. The link metrics are as shown in Figure 120: Link bundle schematic.

In order to maximize the use of link bandwidth, ECMP is enabled on all routers and set to a value of 2, so that IP traffic flowing between PE1 and P-3, and PE-1 and P-4, is load balanced across the two links.

A default route is injected into the ASBR-2 router and redistributed via a policy statement into IS-IS, so that traffic flowing from PE-1 to the ASBR is resolved by this route. Traffic flows between PE-1 and ASBR-2, using the path with the lowest IS-IS metric, via P-3 with a metric of 11. The second path PE-1 to ASBR-2 via P-4 has the same bandwidth, but a higher IS-IS metric of 31.

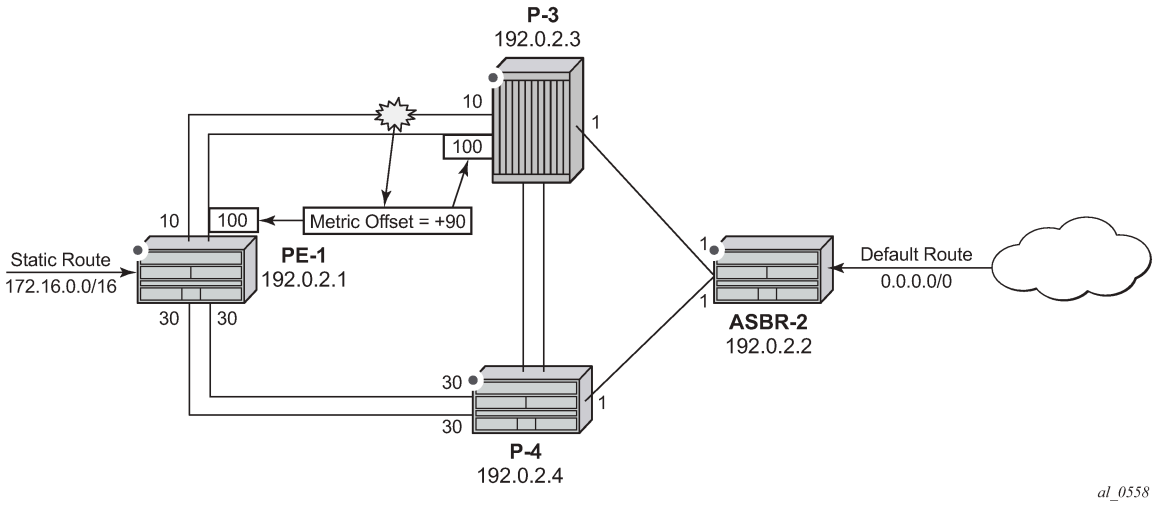
Traffic in the reverse direction flows toward a user subnet described by a static route configured on PE-1, which is redistributed into IS-IS using a policy statement. Once again, the shortest path between ASBR-2 and PE-1 is via P-3, so the bi-directional traffic flow is symmetric.

If one of the links between PE-1 and P-3 fails, traffic still flows via P-3, because the IS-IS metric is unchanged, but this now has less bandwidth than the second path via P-4. It is desirable to make use of the additional bandwidth of the second path, but this requires a change in metric. This can be achieved using IS-IS link bundling.

IS-IS link bundling allows for the creation of a group of IS-IS links, where the failure of a member link allows the metric of the remaining members of the link group to be increased by an offset value.

Using Figure 121: Effect of single link failure on bundle group as an example, the links between PE-1 and P-3 are included in a bundle group.

Figure 121: Effect of single link failure on bundle group



To illustrate the change in metrics, a default static route is configured on ASBR-2 and redistributed into IS-IS, and the path to this route is monitored at PE-1. Similarly, a static route to subnet 172.16.0.0/16 is configured on PE-1 and redistributed into IS-IS and viewed on ASBR-2.

Should one of the links between PE-1 and P-3 fail, the metric of the remaining members can be increased by an offset, for example 90, so that the metric of the remaining link becomes 10 + 90 = 100. The IS-IS metric between PE-1 and ASBR-2 via P-3 is now 101. The metric offset is applied to each remaining IS-IS interface individually and is advertised within the IS-IS database as the default cost in the TE-IS neighbors Type Length Variable (TLV).

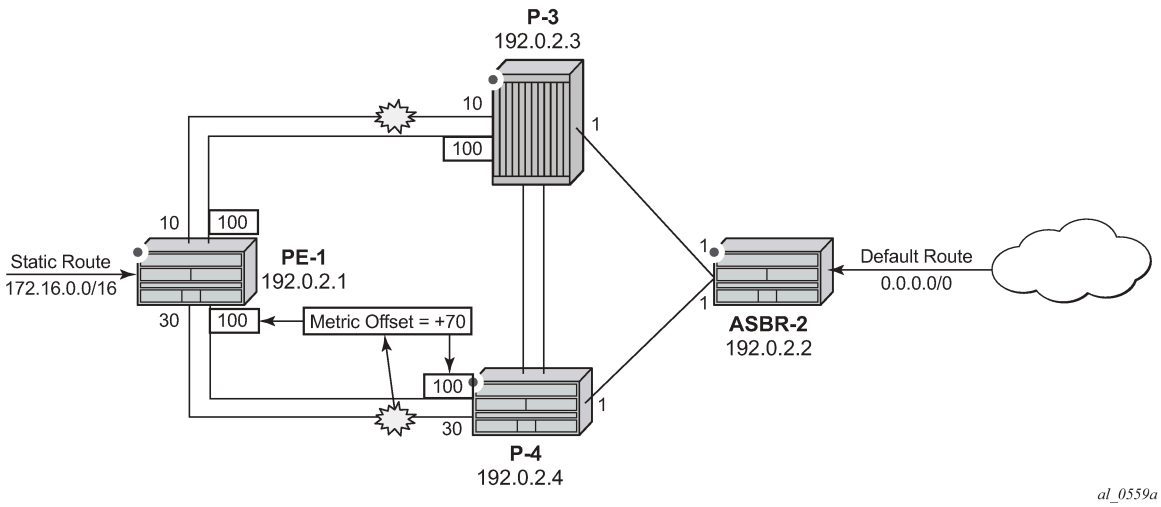
The path between PE-1 and ASBR-2 via P-4 now has the lowest IS-IS metric, and any affected routers within the IS-IS area will try and reroute the traffic based on the new metric.

The fundamentals of this feature are:

- The treatment of all member links in a link group bundle as a single virtual interface.
- The increase in metric by a specific offset value of each remaining individual link within the group when a failure of one or more links occurs.
  - The application of the offset occurs when the number of active links drops below a configured threshold.
  - The offset is removed when the number of active links within the link group bundle reaches the configured reversion threshold.
  - A link bundle is required on a router for the thresholds and offsets to apply.

Consider a second and subsequent failure where a link between PE-1 and P-4 also fails, so that there is only one active IS-IS interface between PE-1 and each of its neighboring P routers. This is shown in Figure 122: Double link failure .

Figure 122: Double link failure



In this case, the metric for the remaining link between PE-1 and P-4 can be increased by an offset value of +70 so that the IS-IS metric PE-1 to P-4 becomes 100, the same as that between PE-1 and P-3 when a link has failed.

PE-1 now sees two equal cost paths to the default route—one via P-3 and one via P-4, so there are still two 10Gigabit Ethernet links across which the traffic can be load shared.

This can be summarized using the following table, where ABCD are the 4 links as per Figure 120: Link bundle schematic and link status is Up (U) or Down (D).

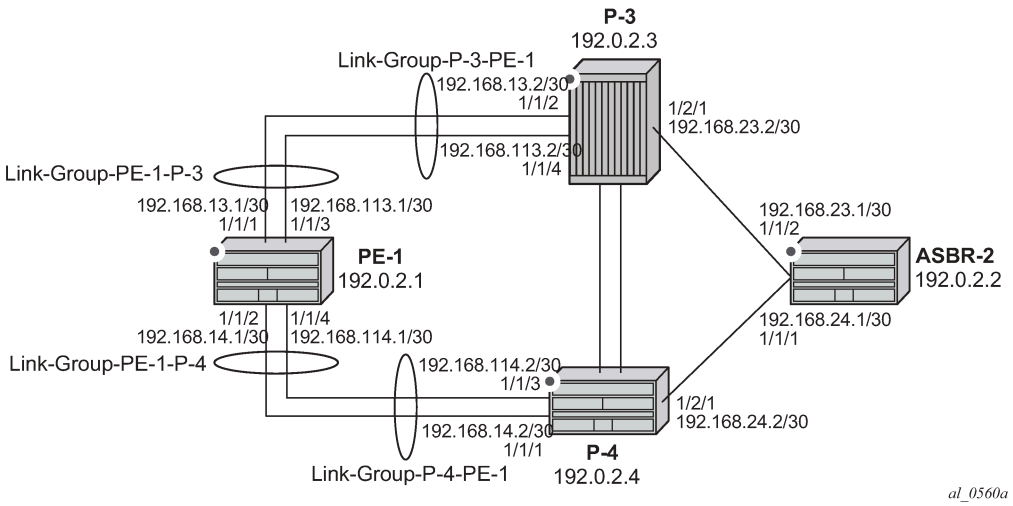
Table 2: Status of the links A, B, C, and D

ABCD Status	A (metric,status)	B (metric,status)	C (metric,status)	D (metric,status)
UUUU	10 Transmit	10 Transmit	30 Idle	30 Idle
UDUU	100 Idle	Down	30 Transmit	30 Transmit
UDUD	100 Transmit	Down	100 Transmit	Down
UUUD	10 Transmit	10 Transmit	100 Idle	Down

Configuration

The example topology is shown in Figure 123: Example topology.

Figure 123: Example topology



On PE-1, ECMP is set to a value of 2 and the following router interfaces are configured:

```
# on PE-1:
configure {
    router "Base" {
        ecmp 2
        interface "int-PE-1-P-3-1" {
            port 1/1/1
            ipv4 {
                primary {
                    address 192.168.13.1
                    prefix-length 30
                }
            }
        }
        interface "int-PE-1-P-3-2" {
            port 1/1/3
            ipv4 {
                primary {
                    address 192.168.113.1
                    prefix-length 30
                }
            }
        }
        interface "int-PE-1-P-4-1" {
            port 1/1/2
            ipv4 {
                primary {
                    address 192.168.14.1
                    prefix-length 30
                }
            }
        }
        interface "int-PE-1-P-4-2" {
            port 1/1/4
            ipv4 {
                primary {
```

```
                    address 192.168.114.1
                    prefix-length 30
                }
            }
        }
        interface "system" {
            ipv4 {
                primary {
                    address 192.0.2.1
                    prefix-length 32
                }
            }
        }
```

The IP router configuration for the remaining routers can be derived from Figure 123: Example topology.

The IS-IS network is a level 1 network.

The IS-IS configuration for PE-1, including the interface metrics is as follows:

```
# on PE-1:
configure {
    router "Base" {
        isis 0 {
            admin-state enable
            advertise-passive-only true
            level-capability 1
            area-address [49.0001]
            interface "int-PE-1-P-3-1" {
                interface-type point-to-point
                level 1 {
                    metric 10
                }
            }
            interface "int-PE-1-P-3-2" {
                interface-type point-to-point
                level 1 {
                    metric 10
                }
            }
            interface "int-PE-1-P-4-1" {
                interface-type point-to-point
                level 1 {
                    metric 30
                }
            }
            interface "int-PE-1-P-4-2" {
                interface-type point-to-point
                level 1 {
                    metric 30
                }
            }
            interface "system" {
                passive true
            }
            level 1 {
                wide-metrics-only true
            }
        }
```

The IS-IS configuration for the remaining routers can be derived from Figure 123: Example topology.

The following configuration is for the static route and export policy on ASBR-2. The configuration of the static route on PE-1 is similar.

```
# on ASBR-2:
configure {
    router "Base" {
        static-routes {
            route 0.0.0.0/0 route-type unicast {
                blackhole {
                    admin-state enable
                }
            }
```

```
# on PE-1, ASBR-2:
configure {
    policy-options {
        policy-statement "STATIC-ISIS" {
            entry 10 {
                from {
                    protocol {
                        name [static]
                    }
                }
                to {
                    level 1
                }
                action {
                    action-type accept
                    metric {
                        set "@igp@"
                    }
                }
            }
        }
    }
    router "Base" {
        isis 0 {
            export-policy ["STATIC-ISIS"]
        }
```

Link group configuration

PE-1 contains 2 link groups. The first link group contains the IS-IS interfaces toward P-3. The second contains the interfaces toward P-4.

Each link-group is configured using a unique name, which is unique per router, and the IS-IS interface names are configured within the group as group members.

The metric offset value is the amount by which the IS-IS metric of active member links is increased when the number of links drops below a configured threshold.

The IS-IS link group configuration for PE-1 for the interfaces toward P-3 is as follows:

```
# on PE-1:
configure {
    router "Base" {
        isis 0 {
            link-group "Link-Group-PE-1-P-3" {
                level 1 {
```

```
                    ipv4-unicast-metric-offset 90
                    oper-members 2
                    revert-members 2
                    member "int-PE-1-P-3-1" { }
                    member "int-PE-1-P-3-2" { }
                }
            }
```

Similarly, the IS-IS link group for PE-1 for the interfaces toward P-4 is:

```
            link-group "Link-Group-PE-1-P-4" {
                level 1 {
                    ipv4-unicast-metric-offset 70
                    oper-members 2
                    revert-members 2
                    member "int-PE-1-P-4-1" { }
                    member "int-PE-1-P-4-2" { }
                }
            }
```

Within the link-group, two thresholds are configured:

- oper-members threshold
- revert-members threshold

If the number of operational links in the link-group drops below the **oper-members** value, then all interfaces associated with that IS-IS link group have their interface metric increased by the configured offset value. As a result, IS-IS then tries to reroute traffic over lower cost paths.

If the number of operational links in the link-group equals the **revert-members** threshold value, then all interfaces associated with that IS-IS link group have their interface metric decreased by the configured offset value.

In this configuration, there is a requirement to increase the metric of each interface within a link group when a single interface fails. This means that the oper-members value is set to 2. In normal working circumstances, when both interfaces are active, the metric used is the configured interface metric. This means that the revert-members value must also be set to 2.

It is not possible to set the oper-members threshold to a value higher than that of the revert-members.

For completeness, the IS-IS configuration the P-routers is as follows.

```
# on P-3:
configure {
    router "Base" {
        isis 0 {
            admin-state enable
            advertise-passive-only true
            level-capability 1
            area-address [49.0001]
            interface "int-P-3-ASBR-2" {
                interface-type point-to-point
                level 1 {
                    metric 1
                }
            }
            interface "int-P-3-PE-1-1" {
                interface-type point-to-point
                level 1 {
                    metric 10
                }
```

```
            }
            interface "int-P-3-PE-1-2" {
                interface-type point-to-point
                level 1 {
                    metric 10
                }
            }
            interface "system" {
                passive true
            }
            level 1 {
                wide-metrics-only true
            }
            link-group "Link-Group-P-3-PE-1" {
                level 1 {
                    ipv4-unicast-metric-offset 90
                    oper-members 2
                    revert-members 2
                    member "int-P-3-PE-1-1" { }
                    member "int-P-3-PE-1-2" { }
                }
            }
```

```
# on PE-4:
configure {
    router "Base" {
        isis 0 {
            admin-state enable
            advertise-passive-only true
            level-capability 1
            area-address [49.0001]
            interface "int-P-4-ASBR-2" {
                interface-type point-to-point
                level 1 {
                    metric 1
                }
            }
            interface "int-P-4-PE-1-1" {
                interface-type point-to-point
                level 1 {
                    metric 30
                }
            }
            interface "int-P-4-PE-1-2" {
                interface-type point-to-point
                level 1 {
                    metric 30
                }
            }
            interface "system" {
                passive true
            }
            level 1 {
                wide-metrics-only true
            }
            link-group "Link-Group-P-4-PE-1" {
                level 1 {
                    ipv4-unicast-metric-offset 70
                    oper-members 2
                    revert-members 2
                    member "int-P-4-PE-1-1" { }
                    member "int-P-4-PE-1-2" { }
                }
```

```
            }
        }
```

An overview of all link groups can be shown using the following commands, in this case on node PE-1.

The link group status on PE-1 is as follows:

```
[]
A:admin@PE-1# show router isis link-group-status

===============================================================================
Rtr Base ISIS Instance 0 Link-Group Status
===============================================================================
Link-group              Mbrs   Oper   Revert Active Level   State
                               Mbr     Mbr    Mbr
-------------------------------------------------------------------------------
Link-Group-PE-1-P-3     2      2      2      2      L1      normal
Link-Group-PE-1-P-4     2      2      2      2      L1      normal
===============================================================================
```

The output for the individual link group members on PE-1 is as follows:

For "Link-Group-PE-1-P-3" at PE-1:

```
[]
A:admin@PE-1# show router isis link-group-member-status "Link-Group-PE-1-P-3"

===============================================================================
Rtr Base ISIS Instance 0 Link-Group Member
===============================================================================
Link-group            I/F name               Level      State
-------------------------------------------------------------------------------
Link-Group-PE-1-P-3   int-PE-1-P-3-1          L1         Up
Link-Group-PE-1-P-3   int-PE-1-P-3-2          L1         Up
-------------------------------------------------------------------------------
Legend: BER = bitErrorRate
===============================================================================
```

For "Link-Group-PE-1-P-4" at PE-1:

```
[]
A:admin@PE-1# show router isis link-group-member-status "Link-Group-PE-1-P-4"
===============================================================================
Rtr Base ISIS Instance 0 Link-Group Member
===============================================================================
Link-group            I/F name               Level      State
-------------------------------------------------------------------------------
Link-Group-PE-1-P-4   int-PE-1-P-4-1          L1         Up
Link-Group-PE-1-P-4   int-PE-1-P-4-2          L1         Up
-------------------------------------------------------------------------------
Legend: BER = bitErrorRate
===============================================================================
```

For P-3, the link group status is as follows:

```
[]
A:admin@P-3# show router isis link-group-status

===============================================================================
Rtr Base ISIS Instance 0 Link-Group Status
===============================================================================
```

```
Link-group              Mbrs   Oper   Revert Active Level   State
                               Mbr     Mbr    Mbr
-------------------------------------------------------------------------------
Link-Group-P-3-PE-1     2      2      2      2      L1      normal
===============================================================================
```

For P-3, the link group member status is as follows:

```
[]
A:admin@P-3# show router isis link-group-member-status "Link-Group-P-3-PE-1"

===============================================================================
Rtr Base ISIS Instance 0 Link-Group Member
===============================================================================
Link-group            I/F name                Level      State
-------------------------------------------------------------------------------
Link-Group-P-3-PE-1   int-P-3-PE-1-1          L1         Up
Link-Group-P-3-PE-1   int-P-3-PE-1-2          L1         Up
-------------------------------------------------------------------------------
Legend: BER = bitErrorRate
===============================================================================
```

Routing table PE-1

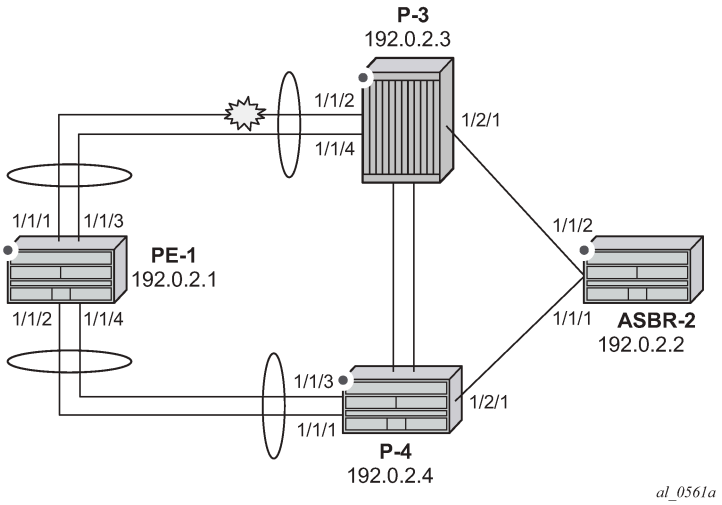
In a normal working state, the routing table for PE-1 contains the default route for forwarding traffic toward ASBR-2. Because ECMP is set to a value of 2, two entries are available with next-hops pointing toward P-3, as follows. The metric for each path is 11.

```
[]
A:admin@PE-1# show router route-table 0.0.0.0/0

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
0.0.0.0/0                                       Remote  ISIS      00h02m27s  15
       192.168.13.2                                                 11
0.0.0.0/0                                       Remote  ISIS      00h02m27s  15
       192.168.113.2                                                11
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

Failure of link member PE-1 to P-3

Figure 124: Link failure shows that one of the links in the active link group between PE-1 and P-3 fails.

Figure 124: Link failure



One of the links between PE-1 and P-3 is put into a failed state by disabling port 1/1/2 on P-3, as follows:

```
# on P-3:
configure {
    port 1/1/2 {
        admin-state disable
    }
```

The route-table on PE-1 shows that the metric for the default route prefix, 0.0.0.0/0, has increased from 11 to 31, and the next-hops are now interface addresses on P-4, as follows:

```
[]
A:admin@PE-1# show router route-table 0.0.0.0/0

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
0.0.0.0/0                                       Remote  ISIS      00h01m14s  15
       192.168.14.2                                                 31
0.0.0.0/0                                       Remote  ISIS      00h01m14s  15
       192.168.114.2                                                31
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The link-group status shows that the number of active members has fallen below the oper-members threshold and as a result, the metric offset has been applied.

```
[]
A:admin@PE-1# show router isis link-group-status
```

```
===============================================================================
Rtr Base ISIS Instance 0 Link-Group Status
===============================================================================
Link-group              Mbrs   Oper   Revert Active Level   State
                               Mbr     Mbr    Mbr
-------------------------------------------------------------------------------
Link-Group-PE-1-P-3     2      2      2      1      L1      Offset-Applied
Link-Group-PE-1-P-4     2      2      2      2      L1      normal
===============================================================================
```

Finally, the status of an individual link group member is as follows:

```
[]
A:admin@PE-1# show router isis link-group-member-status "Link-Group-PE-1-P-3"

===============================================================================
Rtr Base ISIS Instance 0 Link-Group Member
===============================================================================
Link-group            I/F name               Level      State
-------------------------------------------------------------------------------
Link-Group-PE-1-P-3   int-PE-1-P-3-1          L1         If-Down
Link-Group-PE-1-P-3   int-PE-1-P-3-2          L1         Up
-------------------------------------------------------------------------------
Legend: BER = bitErrorRate
===============================================================================
```

The following IS-IS database on PE-1 shows that the link metric (TE-IS neighbor) toward P-3 has a metric of 100, comprised of the original metric of 10 plus the offset of 90.

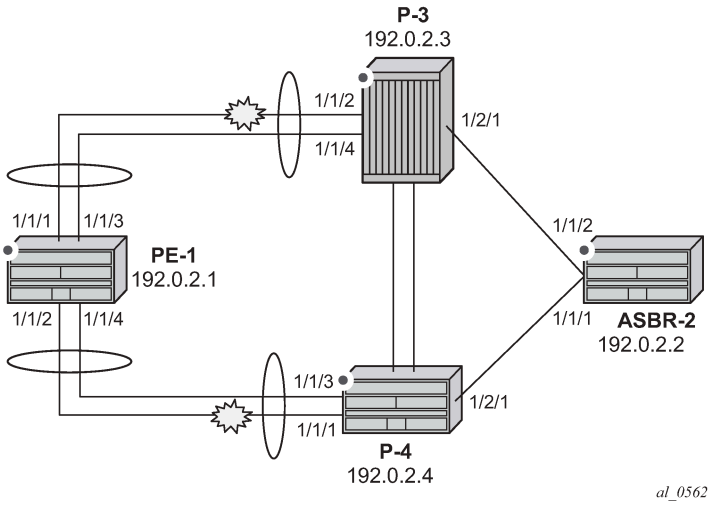
```
[]
A:admin@PE-1# show router isis database PE-1 detail

===============================================================================
Rtr Base ISIS Instance 0 Database (detail)
===============================================================================


Displaying Level 1 database
-------------------------------------------------------------------------------
LSP ID    : PE-1.00-00                                  Level     : L1
Sequence  : 0x7                   Checksum  : 0x3c96   Lifetime  : 1099
Version   : 1                     Pkt Type  : 18       Pkt Ver   : 1
Attributes: L1                    Max Area  : 3        Alloc Len : 1492
SYS ID    : 1920.0000.2001        SysID Len : 6        Used Len  : 163

TLVs :
  Area Addresses:
    Area Address : (3) 49.0001
  Supp Protocols:
    Protocols     : IPv4
  IS-Hostname   : PE-1
  Router ID   :
    Router ID   : 192.0.2.1
  I/F Addresses :
    I/F Address   : 192.0.2.1
    I/F Address   : 192.168.13.1
    I/F Address   : 192.168.14.1
    I/F Address   : 192.168.113.1
    I/F Address   : 192.168.114.1
  TE IS Nbrs   :
    Nbr   : P-3.00
```

```
    Default Metric  : 100
    Sub TLV Len     : 12
    IF Addr   : 192.168.113.1
    Nbr IP    : 192.168.113.2
  TE IS Nbrs   :
    Nbr   : P-4.00
    Default Metric  : 30
    Sub TLV Len     : 12
    IF Addr   : 192.168.14.1
    Nbr IP    : 192.168.14.2
  TE IS Nbrs   :
    Nbr   : P-4.00
    Default Metric  : 30
    Sub TLV Len     : 12
    IF Addr   : 192.168.114.1
    Nbr IP    : 192.168.114.2
  TE IP Reach   :
    Default Metric  : 1
    Control Info:    , prefLen 16
    Prefix   : 172.16.0.0
    Default Metric  : 0
    Control Info:    , prefLen 32
    Prefix   : 192.0.2.1

Level (1) LSP Count : 1

---snip---
```

Failure of link member PE-1 to P-4:

Figure 125: Second link failure shows that all link groups only have one active link instead of two.

Figure 125: Second link failure



If a link between PE-1 and P-4 now fails, simulated by disabling port 1/1/1 on P-4, then the metric offset is applied to the link groups on PE-1 and P-4 as the number of active links has dropped below the oper-members threshold for the link groups Link-Group-PE-1-P-4 on PE-1 and Link-Group-P-4-PE-1 on P-4.

```
# on P-4:
configure {
    port 1/1/1 {
```

```
        admin-state disable
    }
```

The routing table for PE-1 now shows that there are still two equal cost paths for the default route prefix advertised by ASBR-2, as follows:

```
[]
A:admin@PE-1# show router route-table 0.0.0.0/0

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
0.0.0.0/0                                       Remote  ISIS      00h01m16s  15
       192.168.113.2                                        101
0.0.0.0/0                                       Remote  ISIS      00h01m16s  15
       192.168.114.2                                        101
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

The metric for each routing table entry is 101, comprising of a cost of 100 for the PE-1 to P router link, where the link-group offset has been applied, and the cost of 1 for the P router to ASBR-2 router link.

By examining the IS-IS database on the PE-1 router, the updated metric for the link to neighbors P-3 and P-4 can be seen with the offset applied. These are seen in the “TE-IS Nbrs” TLV in the following output.

```
[]
A:admin@PE-1# show router isis database PE-1 detail

===============================================================================
Rtr Base ISIS Instance 0 Database
===============================================================================

Displaying Level 1 database
-------------------------------------------------------------------------------
LSP ID    : PE-1.00-00                                  Level     : L1
Sequence  : 0x8                  Checksum  : 0x3e0a   Lifetime  : 1129
Version   : 1                    Pkt Type  : 18       Pkt Ver   : 1
Attributes: L1                   Max Area  : 3        Alloc Len : 1492
SYS ID    : 1920.0000.2001       SysID Len : 6        Used Len  : 138

TLVs :
  Area Addresses:
    Area Address : (3) 49.0001
  Supp Protocols:
    Protocols     : IPv4
  IS-Hostname   : PE-1
  Router ID   :
    Router ID   : 192.0.2.1
  I/F Addresses :
    I/F Address   : 192.0.2.1
    I/F Address   : 192.168.13.1
    I/F Address   : 192.168.14.1
    I/F Address   : 192.168.113.1
    I/F Address   : 192.168.114.1
```

```
  TE IS Nbrs   :
    Nbr   : P-3.00
    Default Metric  : 100
    Sub TLV Len     : 12
    IF Addr   : 192.168.113.1
    Nbr IP    : 192.168.113.2
  TE IS Nbrs   :
    Nbr   : P-4.00
    Default Metric  : 100
    Sub TLV Len     : 12
    IF Addr   : 192.168.114.1
    Nbr IP    : 192.168.114.2
  TE IP Reach   :
    Default Metric  : 1
    Control Info:    , prefLen 16
    Prefix   : 172.16.0.0
    Default Metric  : 0
    Control Info:    , prefLen 32
    Prefix   : 192.0.2.1

Level (1) LSP Count : 1

---snip---
```

Conclusion

IS-IS link bundling allows service providers to configure multiple IS-IS interfaces as a single link group for ECMP purposes and allow link metric increases if an interface within the bundle group fails. This example provides the configuration for IS-IS link bundling, together with the associated commands and outputs which can be used for verifying and troubleshooting.

Next-Hop Resolution for Labeled BGP Routes

This chapter describes Next-Hop Resolution for Labeled BGP Routes.

Topics in this chapter include:

Applicability

This chapter was initially written for SR OS Release 15.0.R7, but the CLI in the current edition is based on SR OS Release 22.10.R3.

Overview

BGP routes with the VPN-IPv4, VPN-IPv6, labeled IPv4, and labeled IPv6 address families are BGP routes whose Network Layer Reachability Information (NLRI) contains an MPLS label that is mapped to the route. BGP advertises labels that subsequently are used in the data plane for MPLS forwarding. BGP labeled routes are fundamental to IP VPN services, 6PE services, inter-AS connectivity, and seamless MPLS network segmentation. When a BGP speaker receives a BGP labeled route, it has the following options for resolving the next hop (NH) of the route:

- It can resolve the NH to an MPLS tunnel, such as an LDP or RSVP tunnel. In this case, the router pushes a transport label on top of the BGP label and allows the BGP labeled packet to be transported to the NH router over a set of intermediate routers that lack context for forwarding using the BGP label.
- It can resolve the NH to a local interface if the NH is an address on a local subnet. No additional labels need to be pushed onto the top of the label stack.
- It can resolve the NH using a static route and no additional label needs to be pushed. BGP NH resolution using a static route is useful in the following cases:
  - The static route has a blackhole NH in an intentional Remotely Triggered Blackhole (RTBH) scenario. Blackholed static routes are used for BGP NH resolution even when the configuration does not allow BGP NH resolution using static routes.
  - The static route has a NH address of a loopback interface of a directly connected peer. By default, this option is disabled.
- It can resolve the NH using the Longest Prefix Match (LPM) in the route table with static routes, OSPF, IS-IS, and RIP routes. This is applicable for route reflectors (RRs) that are not in the data path, so they do not need to have tunnels. By default, this option is disabled.

NH resolution of BGP routes using tunnels is the same for eBGP and iBGP routes, and for VPN IP routes and label-unicast routes. The common NH resolution logic uses the following routes in order of preference:

1. Local or direct routes
2. Non-default static routes
   - Blackholed static routes
   - Non-blackholed non-default static routes, if allowed
3. Route Table Manager (RTM) routes (including static, OSPF, IS-IS, and RIP), if allowed—only for RRs
   - When enabled, no routes are installed in the Forwarding Information Base (FIB) and no tunnels can be used.
4. Tunnels

NH resolution using a local (interface) or direct route

If possible, the BGP NH is resolved to a local interface route.

If the BGP NH is an IPv4-mapped IPv6 address in ::ffff:a.b.c.d format, the system first tries to find a local route matching the IPv6 address. When no match is found, the system tries to find a local route matching the extracted IPv4 address a.b.c.d.

NH resolution using a non-default static route

If the BGP NH is an IPv4 address, the system looks for the non-default IPv4 static route that is the LPM of the address.

- If the LPM static route is blackholed, this static route is used, regardless of the **allow-static** command configuration.
- If the LPM static route is not blackholed, the static route is only used when the **allow-static true** command is configured.

If the BGP NH is an IPv4-mapped IPv6 address in the ::ffff:a.b.c.d format, the system first tries to find the non-default static route that is the LPM of the full IPv6 address.

If no matching IPv6 static route is found, the system tries to find the non-default IPv4 route that is the LPM of the extracted IPv4 address a.b.c.d.

NH resolution using any type of route in the RTM—only on RR

This is only applicable for RRs that are not in the data path and configured with the **rr-use-route-table** and **route-table-install** commands. The considered routes in the RTM can be static, OSPF, IS-IS, or RIP.

If the BGP NH is an IPv4 address, the system searches the IPv4 RTM route that is the LPM of the address.

If the BGP NH is an IPv4-mapped IPv6 address in ::ffff:a.b.c.d format, the system first searches for the IPv6 route that is the LPM of the full IPv6 address. If no match is found, the system searches for an RTM route matching the extracted IPv4 address a.b.c.d.

NH resolution using a tunnel in the Tunnel Table Manager (TTM)

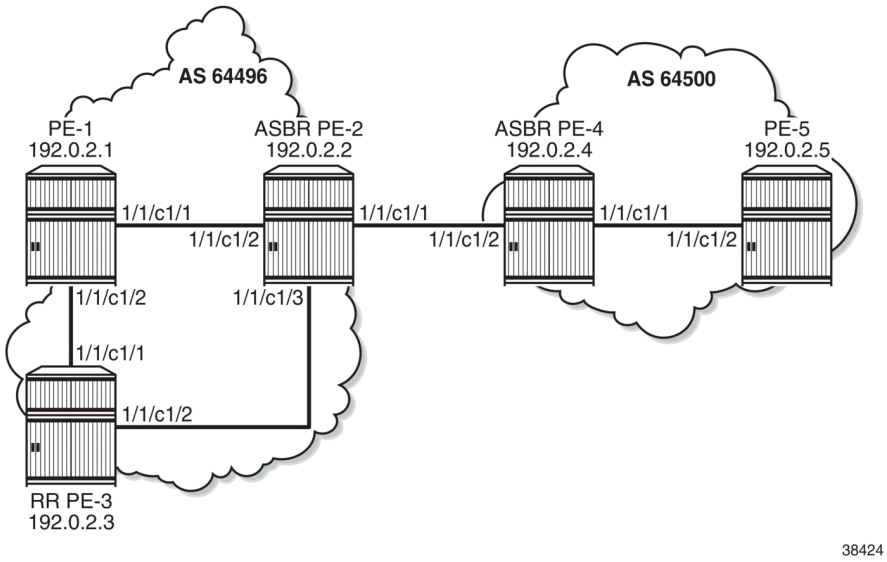
If the BGP NH is an IPv4 address, the TTM selects the tunnel table entry that matches the address prefix with the lowest preference and allowed by the applicable resolution filter. If the preference is the same, the tunnel table entry with the best metric is chosen, and so on.

If the BGP NH is an IPv4-mapped IPv6 address in ::ffff:a.b.c.d format, the system searches the most preferred TTM tunnel matching the extracted IPv4 address a.b.c.d that is allowed by the applicable resolution filter.

Configuration

Figure 126: Example topology shows the example topology with three routers in AS 64496 and two routers in AS 64500.

Figure 126: Example topology



The initial configuration includes the following:

- Cards, MDAs, ports
- Router interfaces between the PEs
- IS-IS as IGP between the PEs within an AS, not between ASBRs PE-2 and PE-4
- LDP between the PE-1 and PE-2 in AS 64496 (not to the RR PE-3) and between PE-4 and PE-5 in AS 64500

The following scenarios are configured in the following sections:

- NH resolution for labeled IPv4 routes
- NH resolution for iBGP VPN-IPv4/v6 routes
- NH resolution for inter-AS VPRN model B

- NH resolution for inter-AS VPRN model C

NH resolution for labeled IPv4 routes

In the NH resolution for inter-AS VPRN model C section, inter-AS VPRNs are configured, as described in the *VPRN Inter-AS VPRN Model C* chapter. Within each AS, the PEs advertise their system addresses (192.0.2.x) as labeled IPv4 routes. The configuration of the export policy is as follows:

```
# on all PEs:
configure {
    policy-options {
        prefix-list "PE-sys" {
            prefix 192.0.2.0/28 type range {
                start-length 32
                end-length 32
            }
        }
        policy-statement "export-bgp" {
            entry 10 {
                from {
                    prefix-list ["PE-sys"]
                    protocol {
                        name [direct]
                    }
                }
                to {
                    protocol {
                        name [bgp-label]
                    }
                }
                action {
                    action-type accept
                }
            }
        }
    }
}
```

Within each AS, BGP group "iBGP" is configured for the VPN-IPv4, VPN-IPv6, and label-IPv4 address families. In AS 64496, PE-3 is configured as RR. The initial BGP configuration on PE-3 is as follows:

```
# on PE-3:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "iBGP" {
                peer-as 64496
                advertise-inactive true
                cluster {
                    cluster-id 192.0.2.3
                }
            }
            neighbor "192.0.2.1" {
                group "iBGP"
                family {
                    vpn-ipv4 true
                    vpn-ipv6 true
                    label-ipv4 true
                }
```

```
            }
            neighbor "192.0.2.2" {
                group "iBGP"
                family {
                    label-ipv4 true
                }
            }
        }
    }
}
```

Between the Autonomous System Border Routers (ASBRs) PE-2 and PE-4, BGP is configured for the label-IPv4 address family only. The initial configuration for the eBGP peering uses the interface address of the remote ASBR (such as 192.168.24.2), which is the standard way for eBGP peering between ASBRs. However, for demonstration purposes, loopback addresses are configured later.

The BGP labeled routes for the system IP addresses are not used within an AS because IGP routes are preferred by the RTM, so they are inactive. However, BGP exports these inactive routes to the ASBR peer in the remote AS (**advertise-inactive true**) where these routes are used. The initial BGP configuration on PE-2 is as follows:

```
# on PE-2:
configure {
    router {
        bgp {
            split-horizon true
            group "iBGP" {
                peer-as 64496
                family {
                    label-ipv4 true
                }
                advertise-inactive true
            }
            neighbor "192.0.2.3" {
                group "iBGP"
            }
            group "eBGP4_local" {
                family {
                    label-ipv4 true
                }
                advertise-inactive true
            }
            neighbor "192.168.24.2" {
                group "eBGP4_local"
                peer-as 64500
            }
        }
    }
}
```

The default BGP NH resolution does not allow static routes and the only transport tunnel type that can be used for labeled IPv4 routes is LDP:

```
[/]
A:admin@PE-2# configure {
    router "Base" {
        bgp {
            next-hop-resolution
                labeled-routes
                    info detail | match "allow-static"
                    info detail | match "family label-ipv4" post-lines 17
```

```
[ex:/configure router "Base" bgp next-hop-resolution labeled-routes]
A:admin@PE-2#                     info detail | match "allow-static"
    allow-static false

[ex:/configure router "Base" bgp next-hop-resolution labeled-routes]
A:admin@PE-2#                     info detail | match "family label-ipv4" post-lines 17
        family label-ipv4 {
         ---snip---
            resolution-filter {
                bgp false
                ldp true
                ---snip---
```

Labeled IPv4 BGP NH resolved to local route

The route table on PE-2 shows that the route to 192.0.2.5 on PE-5 is a BGP labeled IPv4 route with NH 192.168.24.2:

```
[/]
A:admin@PE-2# show router route-table 192.0.2.5/32

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
192.0.2.5/32                                  Remote  BGP_LABEL 00h06m11s  170
       192.168.24.2                                                 0
-------------------------------------------------------------------------------
No. of Routes: 1
---snip---
===============================================================================
```

To verify that BGP NH resolution prefers local routes over static routes (if **allow-static true** is configured), the following is configured on the ASBRs. For the following static routes between PE-2 and PE-4, additional loopback addresses and a static route to the loopback address on the eBGP peer are configured. The configuration on ASBR PE-2 is as follows:

```
# on PE-2:
configure {
    router "Base" {
        interface "loopback" {
            loopback
            ipv4 {
                primary {
                    address 10.0.0.2
                    prefix-length 32
                }
            }
        static-routes {
            route 10.0.0.4/32 route-type unicast {
                next-hop "192.168.24.2" {
                    admin-state enable
                }
            }
        }
    }
```

```
}
```

On PE-2, the following additional eBGP group for the label IPv4 address family is configured and the BGP NH resolution for labeled routes is configured to allow static routes. The eBGP peer is only one hop away, so a **multihop** command is not required.

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            next-hop-resolution {
                labeled-routes {
                    allow-static true
                }
            }
            group "eBGP4_static" {
                admin-state enable
            }
            neighbor "10.0.0.4" {
                peer-as 64500
                group "eBGP4_static"
                family {
                    label-ipv4 true
                }
                advertise-inactive true
                local-address 10.0.0.2
            }
        }
    }
}
```

Another static route is configured to the system IP address of the eBGP peer with preference 25 to ensure that this static route is not preferred over the preceding static route with default preference 5. LDP is enabled on the interface between the ASBRs, such as "int-PE-2-PE-4" on PE-2. This makes it possible to resolve the BGP NH to an LDP tunnel. Also, an additional BGP group is configured for the labeled IPv4 address family to the system IP address of the eBGP peer, such as 192.0.2.4. The configuration on PE-2 is as follows:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            group "eBGP4_tunnel" {
                admin-state enable
            }
            neighbor "192.0.2.4" {
                peer-as 64500
                group "eBGP4_tunnel"
                family {
                    label-ipv4 true
                }
                advertise-inactive true
            }
        }
        ldp {
            interface-parameters {
                interface "int-PE-2-PE-4" {
                    ipv4 {
                    }
                }
            }
```

```
        }
        static-routes {
            route 192.0.2.4/32 route-type unicast {
                next-hop "192.168.24.2" {
                    admin-state enable
                    preference 25
                }
            }
        }
    }
}
```

This additional configuration does not result in a BGP NH resolution to an LDP tunnel, because the destination can also be reached via a static route, which is preferred. In the Labeled IPv4 BGP NH resolved to tunneled route section, the configuration is modified to exclude static routes from the NH resolution.

The following FIB on PE-2 shows that a labeled BGP route with resolved NH 192.168.24.2 is used for prefix 192.0.2.5/32. The BGP NH is not resolved to a tunnel.

```
[/]
A:admin@PE-2# show router fib 1 ip-prefix-prefix-length 192.0.2.5/32

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                                  Protocol
  NextHop
-------------------------------------------------------------------------------
192.0.2.5/32                                                    BGP_LABEL
  192.168.24.2 (int-PE-2-PE-4)
-------------------------------------------------------------------------------
Total Entries : 1
-------------------------------------------------------------------------------
===============================================================================
```

PE-2 has three labeled IPv4 BGP routes for prefix 192.0.2.5/32: the first route with local NH 192.168.24.2 (which is best and used), the second route with NH 10.0.0.4/32 (which can be reached via a static route), and the third route with NH 192.0.2.4 (which can be reached via a less preferred static route):

```
[/]
A:admin@PE-2# show router bgp routes 192.0.2.5/32 label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  192.0.2.5/32                                     None        None
      192.168.24.2                                     None        0
      64500                                                        524285
*i    192.0.2.5/32                                     None        None
```

```
      10.0.0.4                                                  None        1
      64500                                                                 524285
*i    192.0.2.5/32                                              None        None
      192.0.2.4                                                 None        1
      64500                                                                 524285
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

Table 3: Default preferences in route table shows the default preferences in a route table. These preferences are configurable, except for the direct attached routes, which always have preference 0.

Table 3: Default preferences in route table

Route type	Preference
Direct Attached	0
Static	5
OSPF Internal	10
IS-IS Level 1 Internal	15
IS-IS Level 2 Internal	18
RIP	100
OSPF External	150
IS-IS Level 1 External	160
IS-IS Level 2 External	165
BGP	170

The following shows the BGP NHs with the resolving prefix and the resolved NH. On PE-2, all three NHs of the labeled IPv4 routes for prefix 192.0.2.5/32 have resolved NH 192.168.24.2. NH 192.168.24.2 has owner local and preference 0; NH 10.0.0.4 has owner static and default preference 5; NH 192.0.2.4 has owner static and preference 25 by configuration.

```
[/]
[/]
A:admin@PE-2# show router bgp next-hop
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================

===============================================================================
BGP Next Hop
===============================================================================
Next Hop                                                  Pref     Owner
   Resolving Prefix                                       FibProg  Metric
   Resolved Next Hop                                      Colored  Ref. Count
   Admin-tag-policy                                       FlexAlgo Last Mod.
-------------------------------------------------------------------------------
10.0.0.4                                                  5        STATIC
   10.0.0.4/32                                            N        1
```

```
   192.168.24.2                                                  N        0
   --                                                            --       00h04m53s
192.0.2.3                                                        15       ISIS
   192.0.2.3/32                                                  N        10
   192.168.23.2                                                  N        0
   --                                                            --       00h16m55s
192.0.2.4                                                        25       STATIC
   192.0.2.4/32                                                  N        1
   192.168.24.2                                                  N        0
   --                                                            --       00h04m15s
192.168.24.2                                                     0        LOCAL
   192.168.24.0/30                                               N        0
   192.168.24.2                                                  N        0
   --                                                            --       00h16m55s
-------------------------------------------------------------------------------
Next Hops : 4
===============================================================================
```

Labeled IPv4 BGP NH resolved to non-default static route

When the BGP group "eBGP4_local" is disabled, the BGP NH can no longer be resolved to a local route. On the ASBRs PE-2 and PE-4, the following command disables the BGP group:

```
# on PE-2, PE-4:
configure {
    router "Base" {
        bgp {
            group "eBGP4_local" {
                admin-state disable
            }
        }
    }
}
```

The FIB on PE-2 shows that the route to prefix 192.0.2.5/32 is a labeled BGP route with resolved NH 192.168.24.2. This looks identical to the preceding output for the FIB when the BGP NH could be resolved to a local route, but in this case, the BGP NH is resolved to a non-default static route, as is shown later.

```
[/]
A:admin@PE-2# show router fib 1 ip-prefix-prefix-length 192.0.2.5/32

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                                   Protocol
  NextHop
-------------------------------------------------------------------------------
192.0.2.5/32                                                     BGP_LABEL
  192.168.24.2 (int-PE-2-PE-4)
-------------------------------------------------------------------------------
Total Entries : 1
-------------------------------------------------------------------------------
===============================================================================
```

PE-2 now has only two valid labeled IPv4 BGP routes instead of three: the best and used route has NH 10.0.0.4 and the less preferred route has NH 192.0.2.4:

```
[/]
A:admin@PE-2# show router bgp routes 192.0.2.5/32 label-ipv4
```

```
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  192.0.2.5/32                                     None        None
      10.0.0.4                                         None        1
      64500                                                        524285
*i    192.0.2.5/32                                     None        None
      192.0.2.4                                        None        1
      64500                                                        524285
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

On PE-2, NH 10.0.0.4 and NH 192.0.2.4 are both resolved to NH 192.168.24.2. NH 10.0.0.4 has preference 5, which is better than the configured preference 25 for NH 192.0.2.4.

```
[/]
A:admin@PE-2# show router bgp next-hop
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================

===============================================================================
BGP Next Hop
===============================================================================
Next Hop                                                 Pref     Owner
   Resolving Prefix                                      FibProg  Metric
   Resolved Next Hop                                     Colored  Ref. Count
   Admin-tag-policy                                      FlexAlgo Last Mod.
-------------------------------------------------------------------------------
10.0.0.4                                                 5        STATIC
   10.0.0.4/32                                           N        1
   192.168.24.2                                          N        0
   --                                                    --       00h17m17s
192.0.2.3                                                15       ISIS
   192.0.2.3/32                                          N        10
   192.168.23.2                                          N        0
   --                                                    --       00h29m19s
192.0.2.4                                                25       STATIC
   192.0.2.4/32                                          N        1
   192.168.24.2                                          N        0
   --                                                    --       00h16m39s
-------------------------------------------------------------------------------
Next Hops : 3
===============================================================================
```

When the preferred static route with NH 10.0.0.4 becomes unavailable, the other static route takes over. The following command disables the static route with NH 10.0.0.4 on PE-2.

```
# on PE-2:
```

```
configure {
    router "Base" {
        static-routes {
            route 10.0.0.4/32 route-type unicast {
                next-hop "192.168.24.2" {
                    admin-state disable
                }
            }
        }
    }
}
```

The FIB on PE-2 shows a labeled BGP route with resolved NH 192.168.24.2. Again, this FIB entry looks identical. The BGP NH is not resolved to a tunnel.

```
[/]
A:admin@PE-2# show router fib 1 ip-prefix-prefix-length 192.0.2.5/32

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                          Protocol
  NextHop
-------------------------------------------------------------------------------
192.0.2.5/32                                            BGP_LABEL
  192.168.24.2 (int-PE-2-PE-4)
-------------------------------------------------------------------------------
Total Entries : 1
-------------------------------------------------------------------------------
===============================================================================
```

On PE-2, the best and used labeled BGP route for prefix 192.0.2.5/32 has NH 192.0.2.4. The BGP route for prefix 192.0.2.5/32 with NH 10.0.0.4 is not valid, because the static route to 10.0.0.4/32 is disabled.

```
[/]
A:admin@PE-2# show router bgp routes 192.0.2.5/32 label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  192.0.2.5/32                                      None        None
      192.0.2.4                                         None        1
      64500                                                         524285
i     192.0.2.5/32                                      None        None
      10.0.0.4                                          None        0
      64500                                                         524285
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

On PE-2, NH 10.0.0.4 is not resolved, because the static route is disabled. NH 192.0.2.4 has resolved NH 192.168.24.2:

```
[/]
A:admin@PE-2# show router bgp next-hop
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================

===============================================================================
BGP Next Hop
===============================================================================
Next Hop                                                  Pref     Owner
   Resolving Prefix                                       FibProg  Metric
   Resolved Next Hop                                      Colored  Ref. Count
   Admin-tag-policy                                       FlexAlgo Last Mod.
-------------------------------------------------------------------------------
10.0.0.4                                                  -        -
   Unresolved                                                      -
   --                                                              -
   --                                                              00h09m04s
192.0.2.3                                                 15       ISIS
   192.0.2.3/32                                           N        10
   192.168.23.2                                           N        0
   --                                                     --       00h42m47s
192.0.2.4                                                 25       STATIC
   192.0.2.4/32                                           N        1
   192.168.24.2                                           N        0
   --                                                     --       00h30m07s
-------------------------------------------------------------------------------
Next Hops : 3
===============================================================================
```

The configuration on ASBR PE-2 is restored as follows and the BGP NH is resolved to the static route to 10.0.0.4 again:

```
# on PE-2:
configure {
    router "Base" {
        static-routes {
            route 10.0.0.4/32 route-type unicast {
                next-hop "192.168.24.2" {
                    admin-state enable
                }
            }
        }
    }
}
```

Labeled IPv4 BGP NH resolved to tunneled route

When the system does not allow BGH NH resolution to static routes, the tunneled route is selected. The following command configures BGP NH resolution for labeled routes to its default setting:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            next-hop-resolution {
```

```
                labeled-routes {
                    delete allow-static
                }
            }
        }
    }
}
```

On PE-2, the route table shows that the BGP labeled IPv4 route to 192.0.2.5/32 has NH 192.0.2.4, which is resolved to a tunnel:

```
[/]
A:admin@PE-2# show router route-table 192.0.2.5/32

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
192.0.2.5/32                                  Remote  BGP_LABEL 00h01m49s  170
       192.0.2.4 (tunneled)                                          1
-------------------------------------------------------------------------------
No. of Routes: 1
---snip---
===============================================================================
```

On PE-2, the following FIB shows that the BGP labeled route uses an LDP tunnel to the NH 192.0.2.4:

```
[/]
A:admin@PE-2# show router fib 1 ip-prefix-prefix-length 192.0.2.5/32

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                                  Protocol
  NextHop
-------------------------------------------------------------------------------
192.0.2.5/32                                                    BGP_LABEL
  192.0.2.4 (Transport:LDP)
-------------------------------------------------------------------------------
Total Entries : 1
-------------------------------------------------------------------------------
===============================================================================
```

PE-2 has two labeled BGP routes to prefix 192.0.2.5/32: the route with NH 10.0.0.4 is not valid because it requires a static route, which is not allowed for BGP NH resolution; the best and used route has NH 192.0.2.4 (which is the NH that is reached by an LDP tunnel):

```
[/]
A:admin@PE-2# show router bgp routes 192.0.2.5/32 label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV4 Routes
```

```
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  192.0.2.5/32                                     None        None
      192.0.2.4                                        None        1
      64500                                                        524285
i     192.0.2.5/32                                     None        None
      10.0.0.4                                         None        0
      64500                                                        524285
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

On PE-2, the following BGP NH list shows that NH 192.0.2.4 is resolved using a static route with NH 192.168.24.2:

```
[/]
A:admin@PE-2# show router bgp next-hop
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================

===============================================================================
BGP Next Hop
===============================================================================
Next Hop                                                 Pref     Owner
   Resolving Prefix                                      FibProg  Metric
   Resolved Next Hop                                     Colored  Ref. Count
   Admin-tag-policy                                      FlexAlgo Last Mod.
-------------------------------------------------------------------------------
10.0.0.4                                                 5        STATIC
   10.0.0.4/32                                           N        1
   192.168.24.2                                          N        0
   --                                                    --       00h05m51s
192.0.2.3                                                15       ISIS
   192.0.2.3/32                                          N        10
   192.168.23.2                                          N        0
   --                                                    --       00h49m53s
192.0.2.4                                                25       STATIC
   192.0.2.4/32                                          N        1
   192.168.24.2                                          N        0
   --                                                    --       00h37m13s
-------------------------------------------------------------------------------
Next Hops : 3
===============================================================================
```

The configuration on the ASBRs is modified as follows and the BGP NH is resolved to the local route, to 192.168.24.2 again. Local routes prevail over tunneled routes.

```
# on PE-2, PE-4:
configure {
    router "Base" {
        bgp {
            group "eBGP4_local" {
                admin-state enable
            }
        }
    }
}
```

Labeled IPv4 BGP NH resolved to RTM route on RR

RR PE-3 is not in the data path and **next-hop-self** is disabled, which is the default setting. PE-3 does not have LDP tunnels to PE-1 and PE-2, so BGP NH resolution to RTM routes needs to be allowed, by configuring **rr-use-route-table true**. The following error is raised when attempting to configure **rr-use-route-table true** with **route-table-install true**:

```
[ex:/configure router "Base" bgp next-hop-resolution labeled-routes]
A:admin@PE-3#                     rr-use-route-table true
MINOR: BGP #12: configure router "Base" bgp route-table-install - Inconsistent Value error -
 route-table-install and rr-use-route-table cannot both be set to true
```

The command **route-table-install** allows an RR to reflect routes without installing them in its FIB. This way, an RR can reflect more routes than it can install in its FIB.

The following configuration on RR PE-3 allows the use of the route table for labeled routes:

```
# on PE-3:
configure {
    router "Base" {
        bgp {
            route-table-install false
            split-horizon true
            next-hop-resolution {
                labeled-routes {
                    rr-use-route-table true
                }
            }
            group "iBGP" {
                peer-as 64496
                family {
                    vpn-ipv4 true
                    vpn-ipv6 true
                    label-ipv4 true
                }
                advertise-inactive true
                cluster {
                    cluster-id 192.0.2.3
                }
            }
            neighbor "192.0.2.1" {
                group "iBGP"
            }
            neighbor "192.0.2.2" {
                group "iBGP"
            }
        }
    }
}
```

The following command on RR PE-3 shows that the labeled BGP route for 192.0.2.5/32 is not used. This is because the route is not installed in the FIB of the RR, which is allowed, because the RR is not in the data path and NHS is disabled.

```
[/]
A:admin@PE-3# show router bgp routes 192.0.2.5/32 label-ipv4
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
```

```
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
*>i   192.0.2.5/32                                     100         None
      192.0.2.2                                        None        10
      64500                                                        524284
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The following labeled BGP route has NH 192.0.2.2, which is resolved to an IS-IS route:

```
[/]
A:admin@PE-3# show router bgp next-hop 192.0.2.2
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================

===============================================================================
BGP Next Hop
===============================================================================
Next Hop                                                 Pref     Owner
   Resolving Prefix                                      FibProg  Metric
   Resolved Next Hop                                     Colored  Ref. Count
   Admin-tag-policy                                      FlexAlgo Last Mod.
-------------------------------------------------------------------------------
192.0.2.2                                                15       ISIS
   192.0.2.2/32                                          N        10
   192.168.23.1                                          N        0
   --                                                    --       00h59m37s
-------------------------------------------------------------------------------
Next Hops : 1
===============================================================================
```

RR PE-3 advertises this labeled BGP route to PE-1, which installs the route in its FIB, so it is used:

```
[/]
A:admin@PE-1# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  192.0.2.5/32                                     100         None
```

```
      192.0.2.2                                             None        10
      64500                                                             524284
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The tunnel table on PE-1 has a BGP tunnel to 192.0.2.5 with NH 192.0.2.2 and an LDP tunnel to 192.0.2.2 with NH 192.168.12.2:

```
[/]
A:admin@PE-1# show router tunnel-table

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
192.0.2.2/32          ldp       MPLS  65537     9      192.168.12.2   10
192.0.2.5/32          bgp       MPLS  262146    12     192.0.2.2      1000
-------------------------------------------------------------------------------
---snip---
===============================================================================
```

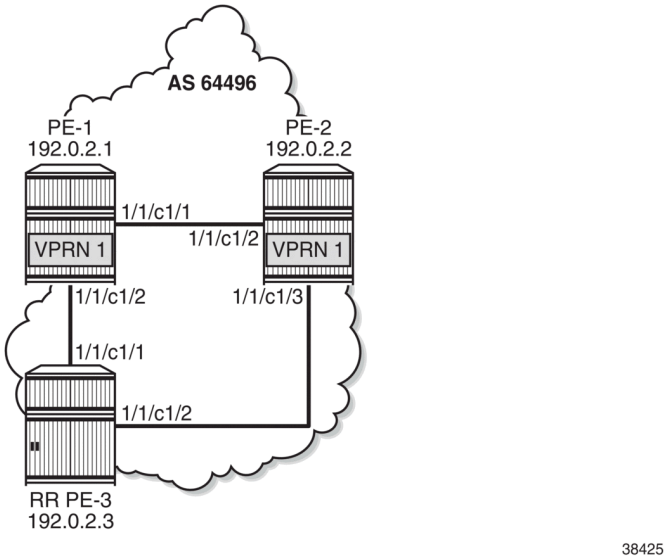
On PE-1, the BGP NH for route 192.0.2.5/32 is resolved to an LDP tunnel to PE-2:

```
[/]
A:admin@PE-1# show router fp-tunnel-table 1

===============================================================================
IPv4 Tunnel Table Display

Legend:
label stack is ordered from bottom-most to top-most
B - FRR Backup
===============================================================================
Destination                                Protocol         Tunnel-ID
  Lbl/SID
    NextHop                                               Intf/Tunnel
  Lbl/SID (backup)
    NextHop   (backup)
-------------------------------------------------------------------------------
192.0.2.2/32                               LDP               -
  524287
    192.168.12.2                                         1/1/c1/1:100
192.0.2.5/32                               BGP               -
  524284
    192.0.2.2                                            LDP
-------------------------------------------------------------------------------
Total Entries : 2
-------------------------------------------------------------------------------
===============================================================================
```

NH resolution for iBGP VPN-IPv4/v6 routes

Figure 127: VPRN 1 in AS 64496 shows that VPRN 1 is configured on PE-1 and PE-2 in AS 64496.

Figure 127: VPRN 1 in AS 64496



On both PE-1 and PE-2, the VPN-IPv4 and VPN-IPv6 address families are configured in group "iBGP":

```
# on PE-1, PE-2:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "iBGP" {
                peer-as 64496
                export {
                    policy ["export-bgp"]
                }
            }
            neighbor "192.0.2.3" {
                group "iBGP"
                family {
                    vpn-ipv4 true
                    vpn-ipv6 true
                }
            }
        }
    }
}
```

On PE-1, VPRN 1 is configured as follows. The configuration on PE-2 is similar.

```
# on PE-1:
configure {
    service {
        vprn "VPRN 1" {
            admin-state enable
            service-id 1
            customer "1"
            bgp-ipvpn {
                mpls {
                    admin-state enable
```

```
                    route-distinguisher "64496:1"
                    vrf-target {
                        community "target:64496:1"
                    }
                    auto-bind-tunnel {
                        resolution filter
                        resolution-filter {
                            ldp true
                        }
                    }
                }
            }
            interface "loopback1" {
                loopback true
                ipv4 {
                    primary {
                        address 1.1.1.1
                        prefix-length 32
                    }
                }
                ipv6 {
                    address 2001:db8::1:1:1:1 {
                        prefix-length 128
                    }
                }
            }
        }
    }
}
```

Even though only LDP is explicitly configured in the auto-bind tunnel resolution filter, the resolution filter allows LDP and BGP tunnels:

```
[/]
A:admin@PE-1# configure {
    service {
        vprn "VPRN 1" {
            info detail | match "auto-bind-tunnel" post-lines 20

*[ex:/configure service vprn "VPRN 1"]
A:admin@PE-1#             info detail | match "auto-bind-tunnel" post-lines 20
            auto-bind-tunnel {
                ---snip---
                resolution-filter {
                    bgp true
                    ---snip---
                    ldp true
                    ---snip---
```

VPRN 1 is only configured on nodes in AS 64496, so only LDP transport tunnels are used. The following tunnel table on PE-2 shows that an LDP tunnel toward PE-1 is available:

```
[/]
A:admin@PE-2# show router tunnel-table 192.0.2.1

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
192.0.2.1/32          ldp       MPLS  65537     9      192.168.12.1   10
```

```
-------------------------------------------------------------------------------
---snip---
===============================================================================
```

PE-2 receives the following BGP VPN-IPv4 route with route distinguisher (RD) 64496:1 used in VPRN 1:

```
[/]
A:admin@PE-2# show router bgp routes vpn-ipv4 rd 64496:1
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64496:1:1.1.1.1/32                               100         None
      192.0.2.1                                        None        10
      No As-Path                                                   524282
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

For iBGP VPN routes on a node that is not an RR, the NH can only be resolved using a tunnel in the TTM. If the BGP NH is an IPv4 address, the system uses the most preferred tunnel matching the address and allowed by the resolution filter. The resolution filter allows LDP and BGP, but within an AS, only LDP tunnels are used. The following FIB for VPRN 1 on PE-2 shows that the transport tunnel to NH 192.0.2.1 is an LDP tunnel:

```
[/]
A:admin@PE-2# show router 1 fib 1

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                           Protocol
  NextHop
-------------------------------------------------------------------------------
1.1.1.1/32                                               BGP_VPN
  192.0.2.1 (VPRN Label:524282 Transport:LDP)
2.2.2.1/32                                               LOCAL
  2.2.2.1 (loopback1)
-------------------------------------------------------------------------------
Total Entries : 2
-------------------------------------------------------------------------------
===============================================================================
```

The same is shown for BGP IPv6 routes:

```
[/]
A:admin@PE-2# show router bgp routes vpn-ipv6 rd 64496:1
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
```

```
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv6 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  64496:1:2001:db8::1:1:1:1/128                    100         None
      ::ffff:192.0.2.1                                 None        10
      No As-Path                                                   524282
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

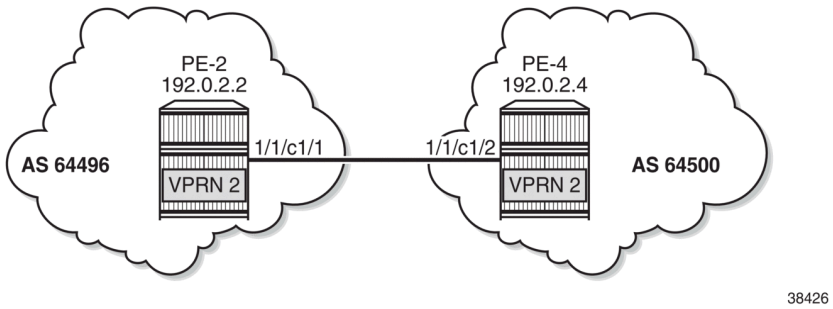
The following IPv6 FIB for VPRN 1 shows that a LDP tunnel is used to reach NH 192.0.2.1:

```
[/]
A:admin@PE-2# show router 1 fib 1 ipv6

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                           Protocol
  NextHop
-------------------------------------------------------------------------------
2001:db8::1:1:1:1/128                                    BGP_VPN
  192.0.2.1 (VPRN Label:524282 Transport:LDP)
2001:db8::2:2:2:1/128                                    LOCAL
  2001:db8::2:2:2:1 (loopback1)
-------------------------------------------------------------------------------
Total Entries : 2
-------------------------------------------------------------------------------
===============================================================================
```

NH resolution for inter-AS VPRN model B

Figure 128: VPRN 2 in AS 64496 and in AS 64500 shows that VPRN 2 is configured in AS 64496 and in AS 64500.

Figure 128: VPRN 2 in AS 64496 and in AS 64500



On PE-2, VPRN 2 is configured as follows. The service configuration on PE-4 is similar.

```
# on PE-2:
configure {
    service {
        vprn "VPRN 2" {
            admin-state enable
            service-id 2
            customer "1"
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "2:2"
                    vrf-target {
                        community "target:2:2"
                    }
                    auto-bind-tunnel {
                        resolution filter
                        resolution-filter {
                            ldp true
                        }
                    }
                }
            }
            interface "loopback2" {
                loopback true
                ipv4 {
                    primary {
                        address 2.2.2.2
                        prefix-length 32
                    }
                }
                ipv6 {
                    address 2001:db8::2:2:2:2 {
                        prefix-length 128
                    }
                }
            }
        }
    }
}
```

BGP is configured for the VPN IP address families and BGP NH can be resolved to static routes. Multiple eBGP neighbors are defined, with NHs that can be resolved to a local, static, or tunneled route. The BGP configuration on PE-2 is as follows. The BGP configuration on PE-4 is similar.

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            inter-as-vpn true
            split-horizon true
            rapid-update {
                vpn-ipv4 true
                vpn-ipv6 true
                label-ipv4 true
            }
            next-hop-resolution {
                labeled-routes {
                    allow-static true
                }
            }
```

```
            group "eBGP4_local" {
            }
            neighbor "192.168.24.2" {
                group "eBGP4_local"
                peer-as 64500
                family {
                    vpn-ipv4 true
                    vpn-ipv6 true
                }
            }
            group "eBGP4_static" {
            }
            neighbor "10.0.0.4" {
                peer-as 64500
                group "eBGP4_static"
                family {
                    vpn-ipv4 true
                    vpn-ipv6 true
                }
                local-address 10.0.0.2
            }
            group "eBGP4_tunnel" {
            }
            neighbor "192.0.2.4" {
                peer-as 64500
                group "eBGP4_tunnel"
                family {
                    vpn-ipv4 true
                    vpn-ipv6 true
                }
            }
        }
    }
}
```

VPN IP NH resolved to local route

PE-2 has three BGP VPN-IPv4 routes for prefix 4.4.4.2/32. The used route is NH 192.168.24.2, which is a local route.

```
[/]
A:admin@PE-2# show router bgp routes 4.4.4.2/32 vpn-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  2:2:4.4.4.2/32                                    None        None
      192.168.24.2                                      None        0
      64500                                                         524284
*i    2:2:4.4.4.2/32                                    None        None
```

```
      10.0.0.4                                                  None        1
      64500                                                                 524284
*i    2:2:4.4.4.2/32                                            None        None
      192.0.2.4                                                 None        1
      64500                                                                 524284
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

The IPv4 FIB on PE-2 shows prefix 4.4.4.2/32 with NH 192.168.24.2 on int-PE-2-PE-4. The NH is not resolved to a tunnel.

```
[/]
A:admin@PE-2# show router 2 fib 1

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                                  Protocol
  NextHop
-------------------------------------------------------------------------------
2.2.2.2/32                                                      LOCAL
  2.2.2.2 (loopback2)
4.4.4.2/32                                                      BGP_VPN
  192.168.24.2 (int-PE-2-PE-4)
-------------------------------------------------------------------------------
Total Entries : 2
-------------------------------------------------------------------------------
===============================================================================
```

In a similar way, the used VPN-IPv6 route on PE-2 has a NH resolved to a local route:

```
[/]
A:admin@PE-2# show router bgp routes 2001:db8::4:4:4:2/128 vpn-ipv6
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv6 Routes
===============================================================================
Flag  Network                                                   LocalPref   MED
      Nexthop (Router)                                          Path-Id     IGP Cost
      As-Path                                                               Label
-------------------------------------------------------------------------------
u*>i  2:2:2001:db8::4:4:4:2/128                                 None        None
      ::ffff:192.168.24.2                                       None        0
      64500                                                                 524284
*i    2:2:2001:db8::4:4:4:2/128                                 None        None
      ::ffff:10.0.0.4                                           None        1
      64500                                                                 524284
*i    2:2:2001:db8::4:4:4:2/128                                 None        None
      ::ffff:192.0.2.4                                          None        1
      64500                                                                 524284
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

VPN IP NH resolved to static route

When the eBGP session using the interface addresses is disabled, the next preferred NH resolution is static, which is allowed by configuration:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            group "eBGP4_local" {
                admin-state disable
            }
        }
    }
}
```

On PE-2, the static route with the best preference is toward 10.0.0.4:

```
[/]
A:admin@PE-2# show router bgp routes 4.4.4.2/32 vpn-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  2:2:4.4.4.2/32                                   None        None
      10.0.0.4                                         None        1
      64500                                                        524284
*>i   2:2:4.4.4.2/32                                   None        None
      192.0.2.4                                        None        1
      64500                                                        524284
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

On PE-2, NH 10.0.0.4 is resolved to 192.168.24.2:

```
[/]
A:admin@PE-2# show router bgp next-hop
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================

===============================================================================
BGP Next Hop
===============================================================================
Next Hop                                               Pref     Owner
   Resolving Prefix                                    FibProg  Metric
   Resolved Next Hop                                   Colored  Ref. Count
   Admin-tag-policy                                    FlexAlgo Last Mod.
```

```
-------------------------------------------------------------------------------
10.0.0.4                                                  5        STATIC
   10.0.0.4/32                                            N        1
   192.168.24.2                                           N        0
   --                                                     --       00h39m36s
192.0.2.4                                                 25       STATIC
   192.0.2.4/32                                           N        1
   192.168.24.2                                           N        0
   --                                                     --       01h10m58s
-------------------------------------------------------------------------------
Next Hops : 2
===============================================================================
```

This resolved NH 192.168.24.2 is the NH for prefix 4.4.4.2/32 in the FIB:

```
[/]
A:admin@PE-2# show router 2 fib 1

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                            Protocol
  NextHop
-------------------------------------------------------------------------------
2.2.2.2/32                                                LOCAL
  2.2.2.2 (loopback2)
4.4.4.2/32                                                BGP_VPN
  192.168.24.2 (int-PE-2-PE-4)
-------------------------------------------------------------------------------
Total Entries : 2
-------------------------------------------------------------------------------
===============================================================================
```

For IPv6 routes on PE-2, the used route toward 2001:db8::4:4:4:2/128 has NH ::ffff:10.0.0.4:

```
[/]
A:admin@PE-2# show router bgp routes 2001:db8::4:4:4:2/128 vpn-ipv6
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv6 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  2:2:2001:db8::4:4:4:2/128                        None        None
      ::ffff:10.0.0.4                                  None        1
      64500                                                        524284
*>i   2:2:2001:db8::4:4:4:2/128                        None        None
      ::ffff:192.0.2.4                                 None        1
      64500                                                        524284
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

VPN IP NH resolved to tunneled route

Note:
This scenario is only for demonstration purposes. In an operational service provider network, no LDP sessions are established to an untrusted AS (inter-AS VPRN model B is used for untrusted connections).

When the BGP configuration is changed to the default setting that static routes are not allowed for the NH resolution, the used BGP route toward 4.4.4.2/32 uses a tunnel toward the system address of the eBGP peer. The BGP configuration is modified as follows:

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            next-hop-resolution {
                labeled-routes {
                    delete allow-static
                }
            }
        }
    }
}
```

On PE-2, the used VPN-IPv4 route toward 4.4.4.2/32 has NH 192.0.2.4:

```
[/]
A:admin@PE-2# show router bgp routes 4.4.4.2/32 vpn-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  2:2:4.4.4.2/32                                   None        None
      192.0.2.4                                        None        1
      64500                                                        524284
*i    2:2:4.4.4.2/32                                   None        None
      10.0.0.4                                         None        1
      64500                                                        524284
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

The tunnel table on PE-2 shows that an LDP tunnel is available toward 192.0.2.4/32:

```
[/]
A:admin@PE-2# show router tunnel-table 192.0.2.4/32
```

```
===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref    Nexthop        Metric
   Color
-------------------------------------------------------------------------------
192.0.2.4/32          ldp       MPLS  65538     9       192.168.24.2   1
-------------------------------------------------------------------------------
---snip---
===============================================================================
```

The following FIB on PE-2 shows that an LDP tunnel is used toward NH 192.0.2.4 to reach prefix 4.4.4.2/32:

```
[/]
A:admin@PE-2# show router 2 fib 1

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                                  Protocol
  NextHop
-------------------------------------------------------------------------------
2.2.2.2/32                                                      LOCAL
  2.2.2.2 (loopback2)
4.4.4.2/32                                                      BGP_VPN
  192.0.2.4 (VPRN Label:524284 Transport:LDP)
-------------------------------------------------------------------------------
Total Entries : 2
-------------------------------------------------------------------------------
===============================================================================
```

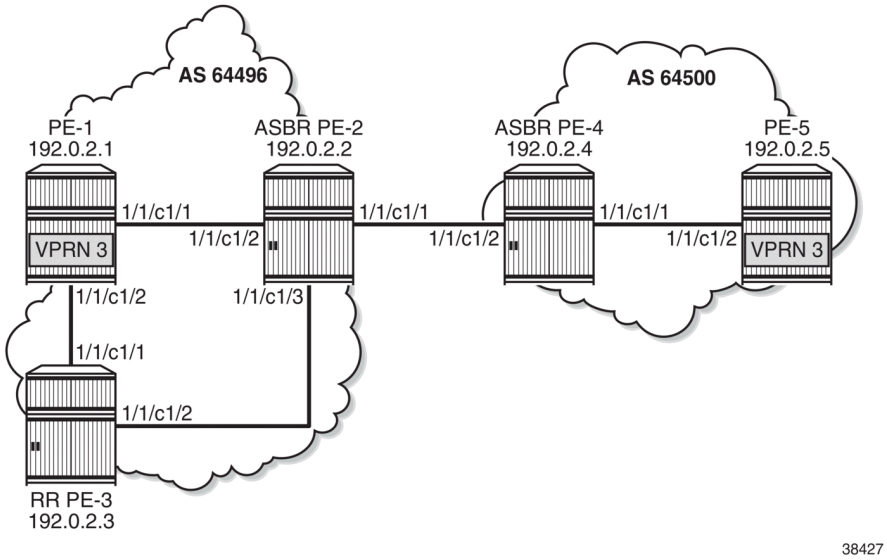
Similarly, the following IPv6 FIB on PE-2 shows that the same LDP tunnel is used toward NH 192.0.2.4 to reach prefix 2001:db8::4:4:4:2/128:

```
[/]
A:admin@PE-2# show router 2 fib 1 ipv6

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                                  Protocol
  NextHop
-------------------------------------------------------------------------------
2001:db8::2:2:2:2/128                                           LOCAL
  2001:db8::2:2:2:2 (loopback2)
2001:db8::4:4:4:2/128                                           BGP_VPN
  192.0.2.4 (VPRN Label:524284 Transport:LDP)
-------------------------------------------------------------------------------
Total Entries : 2
-------------------------------------------------------------------------------
===============================================================================
```

NH resolution for inter-AS VPRN model C

Figure 129: VPRN 3 - inter-AS VPRN model C shows the example topology with RR PE-3 in AS 64496. VPRN 3 is configured on PE-1 and PE-5.

Figure 129: VPRN 3 - inter-AS VPRN model C



A labeled IPv4 eBGP session is established between ASBRs PE-2 and PE-4, and a multi-hop eBGP session is established between PE-1 and PE-5 for the VPN-IPv4 and VPN-IPv6 address families. The following BGP configuration is configured on PE-1. The configuration on PE-5 is similar.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            split-horizon true
            rapid-update {
                vpn-ipv4 true
                vpn-ipv6 true
                label-ipv4 true
            }
            group "iBGP" {
                peer-as 64496
                export {
                    policy ["export-bgp"]
                }
            }
            neighbor "192.0.2.3" {
                group "iBGP"
                family {
                    vpn-ipv4 true
                    vpn-ipv6 true
                    label-ipv4 true
                }
            }
            group "eBGP_multihop" {
                peer-as 64500
            }
            neighbor "192.0.2.5" {
                group "eBGP_multihop"
                family {
                    vpn-ipv4 true
                    vpn-ipv6 true
                }
```

```
                local-address 192.0.2.1
                multihop 10
            }
        }
    }
}
```

The BGP configuration on RR PE-3 is as follows. The RR is configured with **route-table-install false**, so no routes are installed in the FIB; therefore, no eBGP multi-hop sessions can be established from the RR. The BGP NH is resolved using the RTM. Local routes would be preferred, but there are no candidates. BGP NH resolution to static routes is not allowed in this configuration.

```
# on PE-3:
configure {
    router "Base" {
        bgp {
            route-table-install false
            split-horizon true
            next-hop-resolution {
                labeled-routes {
                    rr-use-route-table true
                }
            }
            group "iBGP" {
                peer-as 64496
                advertise-inactive true
                cluster {
                    cluster-id 192.0.2.3
                }
            }
            neighbor "192.0.2.1" {
                group "iBGP"
                family {
                    vpn-ipv4 true
                    vpn-ipv6 true
                    label-ipv4 true
                }
            }
            neighbor "192.0.2.2" {
                group "iBGP"
                family {
                    label-ipv4 true
                }
            }
        }
    }
}
```

On the ASBRs, BGP is only configured for the labeled IPv4 address family. The BGP configuration on PE-2 is as follows. The configuration on PE-4 is similar.

```
# on PE-2:
configure {
    router "Base" {
        bgp {
            split-horizon true
            rapid-update {
                vpn-ipv4 true
                vpn-ipv6 true
                label-ipv4 true
            }
            group "iBGP" {
```

```
                peer-as 64496
                family {
                    label-ipv4 true
                }
                advertise-inactive true
            }
            neighbor "192.0.2.3" {
                group "iBGP"
            }
            group "eBGP4_local" {
                family {
                    label-ipv4 true
                }
                advertise-inactive true
            }
            neighbor "192.168.24.2" {
                group "eBGP4_local"
                peer-as 64500
            }
        }
    }
}
```

On PE-1, VPRN 3 is configured as follows. The configuration is similar on PE-5.

```
# on PE-1:
configure {
    service {
        vprn "VPRN 3" {
            admin-state enable
            service-id 3
            customer "1"
            bgp-ipvpn {
                mpls {
                    admin-state enable
                    route-distinguisher "3:3"
                    vrf-target {
                        community "target:3:3"
                    }
                    auto-bind-tunnel {
                        resolution filter
                        resolution-filter {
                            ldp true
                        }
                    }
                }
            }
            interface "loopback3" {
                loopback true
                ipv4 {
                    primary {
                        address 1.1.1.3
                        prefix-length 32
                    }
                }
                ipv6 {
                    address 2001:db8::1:1:1:3 {
                        prefix-length 128
                    }
                }
            }
        }
    }
```

```
}
```

With the preceding configuration, the resolution filter in VPRN 3 allows the use of LDP and BGP tunnels, which can be verified as follows. BGP tunnels are used for routes received from the peer AS.

```
[/]
A:admin@PE-1# configure {
    service {
        vprn "VPRN 3" {
            info detail | match "auto-bind-tunnel" post-lines 20

*[ex:/configure service vprn "VPRN 3"]
A:admin@PE-1#             info detail | match "auto-bind-tunnel" post-lines 20
            auto-bind-tunnel {
                ---snip---
                resolution-filter {
                    bgp true
                    ---snip---
                    ldp true
                    ---snip---
```

On PE-1, the VPN-IPv4 route for prefix 5.5.5.3/32 has NH 192.0.2.5 in the peer AS. Prefix 5.5.5.3/32 is the IP address of a loopback interface in VPRN 3 on PE-5.

```
[/]
A:admin@PE-1# show router bgp routes vpn-ipv4 rd 3:3
===============================================================================
 BGP Router ID:192.0.2.1        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  3:3:5.5.5.3/32                                    None        None
      192.0.2.5                                         None        0
      64500                                                         524283
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

On PE-1, the following tunnel table shows two tunnels: one LDP tunnel toward 192.0.2.2, and a BGP tunnel toward 192.0.2.5 in the remote AS.

```
[/]
A:admin@PE-1# show router tunnel-table

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
192.0.2.2/32          ldp       MPLS  65537     9      192.168.12.2   10
```

```
192.0.2.5/32          bgp       MPLS  262145    12     192.0.2.2      1000
-------------------------------------------------------------------------------
---snip---
===============================================================================
```

The following FIB for VPRN 3 on PE-1 shows that the BGP tunnel is used for prefix 5.5.5.3/32 with NH 192.0.2.5:

```
[/]
A:admin@PE-1# show router 3 fib 1

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                                  Protocol
  NextHop
-------------------------------------------------------------------------------
1.1.1.3/32                                                      LOCAL
  1.1.1.3 (loopback3)
5.5.5.3/32                                                      BGP_VPN
  192.0.2.5 (VPRN Label:524283 Transport:BGP)
-------------------------------------------------------------------------------
Total Entries : 2
-------------------------------------------------------------------------------
===============================================================================
```

On RR PE-3, the following VPN IP routes with NH 192.0.2.1 are reflected, but they are not installed in the FIB, so these are not used locally:

```
[/]
A:admin@PE-3# show router bgp routes vpn-ipv4 rd 3:3
===============================================================================
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP VPN-IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
*>i   3:3:1.1.1.3/32                                    100         None
      192.0.2.1                                         None        10
      No As-Path                                                    524283
*>i   3:3:5.5.5.3/32                                    100         None
      192.0.2.5                                         None        0
      64500                                                         524283
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

On RR PE-3, NH 192.0.2.1 is resolved using the RTM:

```
[/]
A:admin@PE-3# show router bgp next-hop
===============================================================================
```

```
 BGP Router ID:192.0.2.3        AS:64496       Local AS:64496
===============================================================================

===============================================================================
BGP Next Hop
===============================================================================
Next Hop                                                  Pref     Owner
   Resolving Prefix                                       FibProg  Metric
   Resolved Next Hop                                      Colored  Ref. Count
   Admin-tag-policy                                       FlexAlgo Last Mod.
-------------------------------------------------------------------------------
192.0.2.1                                                 15       ISIS
   192.0.2.1/32                                           N        10
   192.168.13.1                                           N        0
   --                                                     --       00h07m42s
192.0.2.2                                                 15       ISIS
   192.0.2.2/32                                           N        10
   192.168.23.1                                           N        0
   --                                                     --       00h07m42s
-------------------------------------------------------------------------------
Next Hops : 2
===============================================================================
```

Conclusion

The NH resolution of BGP routes using tunnels is consistent across different types of labeled route families (labeled IP and VPN-IP), both for eBGP and iBGP peering.

Policy Chaining and Logical Expressions

This chapter provides information about policy chaining and logical expressions.

Topics in this chapter include:

Applicability

This chapter was initially written for SR OS Release 14.0.R4, but the MD-CLI in the current edition is based on SR OS Release 21.7.R1. In SR OS releases earlier than 14.0.R1, only policy chaining was supported. SR OS Release 14.0.R1 introduced support for route policy logical expressions using the logical operators AND, OR, and NOT, and parentheses.

Overview

Multiple policies can be chained together for sequential evaluation. For more complex evaluation logic, logical expressions can be used with operators: AND, OR, and NOT, and with parentheses. A logical expression can be included in a larger policy chain. Route policy logical expressions are supported in the following contexts:

- BGP export
- BGP import
- BGP leak-import (RIB leaking)
- VRF import
- VRF export
- GRT export (GRT leaking)

Table 4: Policy chaining versus policy logical expressions shows a comparison between examples of policy chaining and policy logical expressions.

Table 4: Policy chaining versus policy logical expressions

Policy chaining example	Policy logical expressions example
configure router bgp import policy ["A" "B" "C"]	configure router bgp import policy "[A]OR[B]"

Policy chaining example	Policy logical expressions example
For each route, policy A is evaluated first. • If policy A matches the route with **action next-policy**, then apply any route modifications and continue to evaluate policy B, and so on. • When the route is matched in a policy with **action accept** or **reject**, the evaluation is completed.	Several logical operators can be used. This example shows an OR relationship between policy A and policy B. For each route, policy A is evaluated first. A true/false result is determined for policy A: • If true, the logical expression with operator OR is true already, and the evaluation is completed. • If false, then policy B is evaluated to determine the final true/false result. The final result is mapped back to a policy action (**accept**, **next-policy**, and so on).

To configure policy chaining that may or may not include a policy logical expression, the syntax is:

```
[ex:configure router "Base" bgp export]
A:admin@PE-1# policy

 policy <value>
 policy [<value>...] - 1..15 user-ordered values separated by spaces enclosed by
 brackets

 <value> - <string>
 <string> - <1..255 characters>

    Export policy name
```

When the **import/export policy** command has a single value, the value is either a policy or a logical expression. The **policy** may or may not be enclosed in double quotes. When enclosed in double quotes, all characters (including blanks) are considered part of the policy. The **logical expression** must be enclosed in double quotes. The logical expression accepts between 1 and 16 policies. In the logical expression:

- each policy must be enclosed in square brackets and must not be enclosed in double quotes.
- the operand may or may not be separated with spaces from the policies.
- the operand must be in uppercase (AND, OR, NOT).
- parentheses may be used to influence the logic. When used, nesting is limited to a maximum of 3 levels.

A policy is accepted with and without double quotes enclosing it.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy A
            }
(leads to: ["A"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy "A"
            }
(leads to: ["A"])
```

In a policy that is enclosed in double quotes, spaces before and after the policy are not allowed, as they are considered part of the policy name. The following message is raised when spaces are present before and after a policy that is enclosed in double quotes.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy " A "
            }
MINOR: MGMT_CORE #224: configure router "Base" bgp import policy - Entry does not exist -
 configure policy-options policy-statement " A "
```

A logical expression is accepted only when each policy is enclosed in square brackets and not in double quotes, while the logical expression itself is enclosed in double quotes.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy "[A]AND[B]"
            }
(leads to: ["[A]AND[B]"])
```

In a logical expression, spaces before and after the operand are allowed.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy "[A] AND [B]"
            }
```

```
(leads to: ["[A] AND [B]"])
```

In a logical expression, spaces before and after the square brackets that enclose a policy are allowed.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy " [A] AND [B] "
            }
(leads to: [" [A] AND [B] "])
```

In a logical expression, spaces inside the square brackets that enclose a policy are allowed.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy "[ A ]AND[ B ]"
            }
(leads to: ["[ A ]AND[ B ]"])
```

The following message is raised when the logical expression is not enclosed in double quotes.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [A]AND[B]
            }
A:admin@PE-1#         import policy [A]AND[B]
                                    ^^^
MINOR: MGMT_CORE #2201: Unknown element - 'AND'
```

The following message is raised when there are double quotes inside the square brackets that enclose a policy in a logical expression that is not enclosed in double quotes.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ["A"]AND["B"]
            }
A:admin@PE-1#         import policy ["A"]AND["B"]
                                      ^^^
MINOR: MGMT_CORE #2201: Unknown element - 'AND'
```

The following message is raised when a policy is enclosed in double quotes instead of square brackets in a logical expression that is not enclosed in double quotes.

```
# on PE-1:
configure {
```

```
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy "A"AND"B"
            }
A:admin@PE-1#         import policy "A"AND"B"
                                    ^^^
MINOR: MGMT_CORE #2201: Unknown element - 'AND'
```

The following message is raised when there are double quotes inside the square brackets that enclose a policy in a logical expression.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy "["A"]AND["B"]"
            }
A:admin@PE-1#         import policy "["A"]AND["B"]"
                                    ^
MINOR: MGMT_CORE #2201: Unknown element - 'A'
```

The following message is raised when a policy is enclosed in double quotes instead of square brackets in a logical expression.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ""A"AND"B""
            }
A:admin@PE-1#         import policy ""A"AND"B""
                                    ^
MINOR: MGMT_CORE #2301: Invalid element value - 'policy' expected string '<1..255 characters>'
 or reference '<1..64 characters>' (configure policy-options policy-statement <name>)
```

The operand in a logical expression must be in uppercase.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy "[A]AND[B]"
            }
(leads to: ["[A]AND[B]"])
```

The following message is raised when an operand in a logical expression is not in uppercase.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
```

```
            import {
                policy "[A]and[B]"
            }
A:admin@PE-1#         import policy "[A]and[B]"
                                    ^^^^^^^^^
MINOR: MGMT_CORE #2301: Invalid element value - 'policy' expected string '<1..255 characters>'
 or reference '<1..64 characters>' (configure policy-options policy-statement <name>)
```

A logical expression may use parentheses (nesting up to a maximum of 3 levels) to influence the logic.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy "((([P1]AND[P2])OR[P3])AND[P4])OR[P5]"
            }
(leads to: ["((([P1]AND[P2])OR[P3])AND[P4])OR[P5]"])
```

The following message is raised when the parentheses nesting exceeds 3 levels.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy "(((([P1]AND[P2])OR[P3])AND[P4])OR[P5])AND[P6]"
            }
A:admin@PE-1#         import policy "(((([P1]AND[P2])OR[P3])AND[P4])OR[P5])AND[P6]"
                                    ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
MINOR: MGMT_CORE #2301: Invalid element value - 'policy' expected string '<1..255 characters>'
 or reference '<1..64 characters>' (configure policy-options policy-statement <name>)
```

The following message is raised when the parentheses are not balanced.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy "((([P1]AND[P2])OR[P3])AND[P4]"
            }
A:admin@PE-1#         import policy "((([P1]AND[P2])OR[P3])AND[P4]"
                                    ^^^^^^^^^^^^^^^^^^^^^^^^^^^^
MINOR: MGMT_CORE #2301: Invalid element value - 'policy' expected string '<1..255 characters>'
 or reference '<1..64 characters>' (configure policy-options policy-statement <name>)
```

A logical expression accepts a maximum of 16 policies.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy
 "[P1]AND[P2]AND[P3]AND[P4]AND[P5]AND[P6]AND[P7]AND[P8]AND[P9]AND[P10]AND[P11]AND[P12]AND[P13]AND
[P14]AND[P15]AND[P16]"
```

```
            }
(leads to:
 ["[P1]AND[P2]AND[P3]AND[P4]AND[P5]AND[P6]AND[P7]AND[P8]AND[P9]AND[P10]AND[P11]AND[P12]AND[P13]
AND[P14]AND[P15]AND[P16]"])
```

The following message is raised when there are too many policies in the logical expression.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy
 "[P1]AND[P2]AND[P3]AND[P4]AND[P5]AND[P6]AND[P7]AND[P8]AND[P9]AND[P10]AND[P11]AND[P12]AND[P13]
AND[P14]AND[P15]AND[P16]AND[P17]"
            }
A:admin@PE-1#         import policy
 "[P1]AND[P2]AND[P3]AND[P4]AND[P5]AND[P6]AND[P7]AND[P8]AND[P9]AND[P10]AND[P11]AND[P12]AND[P13]
AND[P14]AND[P15]AND[P16]AND[P17]"

 ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
MINOR: MGMT_CORE #2301: Invalid element value - 'policy' expected string '<1..255 characters>'
 or reference '<1..64 characters>' (configure policy-options policy-statement <name>)
```

When the import/export policy command has multiple values, the values are separated with spaces and ordered in a **policy chain** that must be enclosed in square brackets. The policy chain accepts between 1 and 15 values. In the policy chain:

- each value is either a policy or a logical expression and must be formatted in the same way as the single value above.
- only 1 logical expression is allowed.
- policies and the logical expression may be repeated. Only the first occurrence of duplicate policies and duplicate logical expressions is retained in the resulting policy chain.
- a logical expression with a length that does not exceed 64 characters may be in any location. Otherwise, the logical expression with a length that does not exceed 255 characters must be in the first location.

A policy chain must be enclosed in square brackets.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [A]
            }
(leads to: ["A"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ["A"]
            }
```

```
(leads to: ["A"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [A B]
            }
(leads to: ["A" "B"])
```

The following message is raised when the policy chain is not enclosed in square brackets.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy A B
            }
A:admin@PE-1#         import policy A B
                                    ^
MINOR: MGMT_CORE #2201: Unknown element - 'B'
```

A policy chain is accepted with and without double quotes enclosing the policies.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [A]
            }
(leads to: ["A"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ["A"]
            }
(leads to: ["A"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [A B]
            }
(leads to: ["A" "B"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
```

```
            import {
                policy ["A" B]
            }
(leads to: ["A" "B"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [A "B"]
            }
(leads to: ["A" "B"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ["A" "B"]
            }
(leads to: ["A" "B"])
```

A policy chain can contain policies and a logical expression.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [A B "[C]OR[A]"]
            }
(leads to: ["A" "B" "[C]OR[A]"])
```

In a policy chain, policies and the logical expression may be repeated. Only the first occurrence of duplicate policies and duplicate logical expressions is retained in the resulting policy chain.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [A A "A"]
            }
(leads to: ["A"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [C A A C B A C B C A B C A]
            }
(leads to: ["C" "A" "B"])
```

```
configure {
    router "Base" {
```

```
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [C A "A" "C" B A C "B" "C" "A" B C A]
            }
(leads to: ["C" "A" "B"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ["[A]AND[B]" "[A]AND[B]"]
            }
(leads to: ["[A]AND[B]"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ["[A]AND[B]" C "[A]AND[B]"]
            }
(leads to: ["[A]AND[B]" "C"])
```

A policy chain accepts a maximum of 15 policies.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [P1 P2 P3 P4 P5 P6 P7 P8 P9 P10 P11 P12 P13 P14 P15]
            }
(leads to: ["P1" "P2" "P3" "P4" "P5" "P6" "P7" "P8" "P9" "P10" "P11" "P12" "P13" "P14" "P15"])
```

The following message is raised when there are too many policies in the policy chain.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [P1 P2 P3 P4 P5 P6 P7 P8 P9 P10 P11 P12 P13 P14 P15 P16]
            }
MINOR: MGMT_CORE #253: configure router "Base" bgp import policy - Reached maximum number of
 entries - number of entries must be between 1-15 but has 16
```

A policy chain has 1 logical expression at maximum. The following message is raised when the policy chain has more than 1 (different) logical expression.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ["[A]AND[B]" "[B]OR[C]"]
```

```
            }
MINOR: BGP #12: configure router "Base" bgp import policy - Inconsistent Value error - Policy
 chain exceeds maximum number of expressions - configure
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ["[A]AND[B]" C "[B]OR[C]"]
            }
MINOR: BGP #12: configure router "Base" bgp import policy - Inconsistent Value error - Policy
 chain exceeds maximum number of expressions - configure
```

A logical expression with a length that does not exceed 64 characters can be anywhere in the policy chain (but the result can be different).

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [A B "[C]AND[A]"]
            }
(leads to: ["A" "B" "[C]AND[A]"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [A "[C]AND[A]" B]
            }
(leads to: ["A" "[C]AND[A]" "B"])
```

```
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ["[C]AND[A]" A B]
            }
(leads to: ["[C]AND[A]" "A" "B"])
```

When the length of the logical expression exceeds 64 characters, the logical expression must be at the start of the policy chain.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ["[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]"
 A B]
            }
(leads to: ["[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]" "A" "B"])
```

The following message is raised when a logical expression with a length that exceeds 64 characters is not at the start of a policy chain.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy [A B
 "[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]"]
            }
MINOR: BGP #8: configure router "Base" bgp import policy - Wrong Length error - Policy entry 3
 exceeds maximum length (64) - configure
```

The following message is raised when a logical expression with a length that exceeds 255 characters is at the start of a policy chain.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import    # to remove already existing import policies
            import {
                policy ["[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AN
D[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AN
D[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AN
D[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]"
A B]
            }
A:admin@PE-1#         import policy ["[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]A
ND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]A
ND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]A
ND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]AND[A]AND[B]AND[C]"
A B]
                                      ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
MINOR: MGMT_CORE #2301: Invalid element value - 'policy' expected string '<1..255 characters>'
 or reference '<1..64 characters>' (configure policy-options policy-statement <name>)
```

Route policy logical expressions

Logical expressions are evaluated to be true or false. Table 5: Boolean values for the policy actions shows the mapping of policy actions to Boolean values.

Table 5: Boolean values for the policy actions

Policy action	Boolean value
Accept	True
Next-entry	True
Next-policy	True

Policy action	Boolean value
Reject	False

Table 6: Actions for the logical operators shows the evaluation actions for the logical operators NOT, OR, and AND.

Table 6: Actions for the logical operators

Logical operator	Action
NOT <expr>	Swaps the true/false result of the expression.
<expr1> OR <expr2>	If expr1 is true, the result is true and expr2 is not evaluated. If expr1 is false, expr2 must be evaluated. The final result is true if either expression is true; otherwise, it is false.
<expr1> AND <expr2>	If expr1 is false, the result is false and expr2 is not evaluated. If expr1 is true, expr2 must be evaluated. The final result is true only if both expressions are true.

Table 7: Mapping the final result of an expression to a policy action shows the mapping of the final result of an expression to a policy action. Routes are rejected when the entire expression is false.

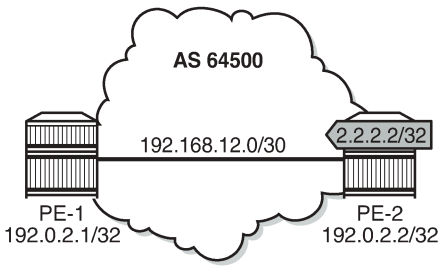
Table 7: Mapping the final result of an expression to a policy action

Final result	Action
True	**accept**, **next-entry**, or **next-policy** (depending on the last entry evaluated)
False	**reject**

Configuration

Figure 130: Example topology shows the example topology including the advertised route.

Figure 130: Example topology



The initial configuration of the routers includes:

- Cards, MDAs, ports
- Router interfaces
- IS-IS
- LDP
- BGP
- Export policy "export-bgp" accepting routes for prefix 2.2.2.2/32 on PE-2.

It is possible to configure VPRNs and assign policies to BGP in the VPRN, although in this chapter, all the examples are for BGP in the base router.

Policy chaining and policy logical expressions

In this section, three route policies are configured that will add a community and set the **local-preference** (LP): only policy C does not set LP. Policy C has **action next-policy**, and policies A and B have **action accept**. The configuration is:

```
# on PE-1, PE-2:
configure {
    policy-options {
        community "A" {
            member "1:1" { }
        }
        community "B" {
            member "2:2" { }
        }
        community "C" {
            member "3:3" { }
        }
        policy-statement "A" {
            entry 10 {
                action {
                    action-type accept
                    local-preference 110
                    community {
                        add ["A"]
                    }
                }
            }
        }
```

```
        policy-statement "B" {
            entry 10 {
                action {
                    action-type accept
                    local-preference 220
                    community {
                        add ["B"]
                    }
                }
            }
        }
        policy-statement "C" {
            entry 10 {
                action {
                    action-type next-policy
                    community {
                        add ["C"]
                    }
                }
            }
        }
```

Initially, policy chaining is configured without a logical expression. Subsequently, policy chaining is configured with only one policy logical expression and no other policies in the chain, as described in the following sections.

Policy chaining without logical expression

Policy chaining may include one logical expression, except in this example, there is no policy logical expression in the chain.

Policy chaining is configured on PE-1:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            import {
                policy ["C" "A" "B"]
            }
```

PE-1 receives route 2.2.2.2/32 from PE-2. For each route, PE-1 evaluates policy C first. This policy adds community C (3:3) and has **action next-policy**, which implies that the next policy must also be evaluated. Policy A adds community A (1:1) and sets the LP to a value of 110 (by default, the **local-preference** equals 100). Policy A has **action accept** and, therefore, the evaluation is completed. The local-preference and the community are shown in the following output:

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
```

```
===============================================================================
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
Path Id        : None
From           : 192.0.2.2
Res. Protocol  : ISIS                    Res. Metric    : 10
Res. Nexthop   : 192.168.12.2
Local Pref.    : 110                     Interface Name : int-PE-1-PE-2
Aggregator AS  : None                    Aggregator     : None
Atomic Aggr.   : Not Atomic              MED            : None
AIGP Metric    : None                    IGP Cost       : 10
Connector      : None
Community      : 1:1 3:3
---snip---
```

Policy logical expressions with two policies

In the following examples, the policy chain contains only a policy logical expression. When both policy A and policy B must be executed, the logical operator used is: AND. The sequence is important in this case, because both policies A and B set the LP and the last executed policy will set the final value for the LP. The following import policy expression is configured on PE-1:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["[A]AND[B]"]
            }
```

Policy A is evaluated first and it adds community A (1:1) and sets LP 110. Then, policy B is evaluated, which adds community B (2:2) and sets LP 220.

```
[/]
A:admin@PE-1# show router bgp routes hunt brief | match "Local Pref."
Local Pref.    : 220                     Interface Name : int-PE-1-PE-2
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief | match "Community"
Community      : 2:2 1:1
```

When the policy expression is [B]AND[A], the order is reversed. First, policy B sets LP 220, then policy A sets LP 110:

```
[/]
A:admin@PE-1# show router bgp routes hunt brief | match "Local Pref."
Local Pref.    : 110                     Interface Name : int-PE-1-PE-2
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief | match "Community"
Community      : 1:1 2:2
```

When the policy expression contains operator OR instead of AND, the first true expression results in a completed evaluation. Because both policy A and policy B result in a true expression, whichever policy is evaluated first is executed and the second one is skipped. For example, when policy A is evaluated first and the result is true, policy B is skipped. Therefore, the community is A (1:1) and the LP 110:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["[A]OR[B]"]
            }
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief | match "Local Pref."
Local Pref.    : 110                   Interface Name : int-PE-1-PE-2
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief | match "Community"
Community      : 1:1
```

Likewise, when policy B is evaluated first and the result is true, policy A is skipped. The added community is B (2:2) and the LP 220:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["[B]OR[A]"]
            }
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief | match "Local Pref."
Local Pref.    : 220                   Interface Name : int-PE-1-PE-2
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief | match "Community"
Community      : 2:2
```

The logical operator NOT swaps the result from true to false, and vice versa. When policy A is evaluated as true, NOT[A] is false. A false expression in an AND relationship leads to a false result. The next policy in the logical expression is not evaluated. No communities are added and no LP is set (the default value for LP is 100). The route is rejected as invalid:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["NOT[A]AND[B]"]
```

```
            }
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
---snip---
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 100                   Interface Name : int-PE-1-PE-2
---snip---
Community      : No Community Members
---snip---
Flags          : Invalid IGP Rejected
---snip---
```

However, a false NOT[A] expression in an OR relationship may still lead to the expression being evaluated to true:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["NOT[A]OR[B]"]
            }
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
---snip---
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 220                   Interface Name : int-PE-1-PE-2
---snip---
Community      : 2:2 1:1
---snip---
Flags          : Used Valid Best IGP In-RTM
---snip---
```

Policy B is evaluated as true for the route and, therefore, the entire logical expression "NOT[A]OR[B]" is true, and the route is accepted. Every policy in the expression that was evaluated, before the entire logical expression was recognized to be true, is executed, including policy A. This implies that policy A adds community A (1:1) to the route and sets LP to a value of 110. Then, policy B adds community B (2:2) to the route and overwrites the LP to a value of 220.

The import policy "[B] OR NOT[A]" is true after the first policy is evaluated as true. Only policy B is executed, the assigned community is B (2:2) and the LP is 220:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
```

```
            import {
                policy ["[B] OR NOT[A]"]
            }
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
---snip---
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 220                    Interface Name : int-PE-1-PE-2
---snip---
Community      : 2:2
---snip---
Flags          : Used Valid Best IGP In-RTM
---snip---
```

Table 8: Assigned LP and communities for the import logical expressions summarizes the results for these different scenarios.

Table 8: Assigned LP and communities for the import logical expressions

Import logical expression	Assigned LP	Assigned community
import "[A]AND[B]"	220	2:2 1:1
import "[B]AND[A]"	110	1:1 2:2
import "[A]OR[B]"	110	1:1
import "[B]OR[A]"	220	2:2
import "NOT[A]AND[B]"	None	None (Route rejected)
import "NOT[A]OR[B]"	220	2:2 1:1
Import "[B] OR NOT[A]"	220	2:2

Policy logical expressions with three policies

In policy chaining, the next policy in the chain is evaluated when the action is **next-policy**. In policy logical expressions, the next policy is evaluated depending on the logical operator and the Boolean value for the previous policies in the expression.

Policy C has **action next-policy** instead of **accept** and adds community C (3:3), but does not set the LP.

Several logical expressions can be made with policies A, B, and C. The following import policy has all three policies in an AND relationship. The expression is evaluated as true and all policies are executed: three communities are added and the LP is set.

```
# on PE-1:
configure {
    router "Base" {
```

```
        bgp {
            delete import
            import {
                policy ["[C]AND[A]AND[B]"]
            }
```

The first policy adds community C (3:3), the second policy adds community A (1:1) and sets LP 110, and the third policy adds community B (2:2) and sets LP 220:

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
---snip---
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 220                   Interface Name : int-PE-1-PE-2
---snip---
Community      : 2:2 1:1 3:3
---snip---
Flags          : Used Valid Best IGP In-RTM
---snip---
```

The import policy "[C]AND[A]OR[B]" results in the first two being executed. Policy C is evaluated as true, and the logical operation is AND. Therefore, the next policy must be evaluated too. Policy A is also evaluated as true and the next operation is OR. The final result is evaluated as true without evaluating policy B. The communities added are C and A (3:3 and later 1:1) and the LP is 110.

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["[C]AND[A]OR[B]"]
            }
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
---snip---
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 110                   Interface Name : int-PE-1-PE-2
---snip---
Community      : 1:1 3:3
---snip---
Flags          : Used Valid Best IGP In-RTM
---snip---
```

The import policy "[C]OR[A]OR[B]" is evaluated as true after the first policy is evaluated as true. Even though the action in policy C is **next-policy**, the next policy in this expression is not evaluated, because

the expression is already true. Only policy C is executed and it adds the community C (3:3), but does not configure the LP:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["[C]OR[A]OR[B]"]
            }
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
---snip---
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 100                    Interface Name : int-PE-1-PE-2
---snip---
Community      : 3:3
---snip---
Flags          : Used  Valid  Best  IGP
---snip---
```

However, if the policy chain contains not only a logical expression, but also single policies, the action next-policy ensures that a following policy in the chain is executed; for example, policy D in the following policy chain:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["[C]OR[A]OR[B]" "D"]
            }
```

The expression "[C]OR[A]OR[B]" is true after policy C has been evaluated, but policy C has **action next-policy** and policy D is the next policy to be evaluated.

The import policy "[C]OR[A]AND[B]" expression evaluates policy C as true. Policy C has an OR relationship with policy A in the logical expression "[C]OR[A]”, and therefore, policy A is not evaluated. There is an AND relationship with policy B and policy B is evaluated as true. Therefore, the entire logical expression "[C]OR[A]AND[B]" is true and the route is accepted. Both policy C and B are executed. First, policy C adds community C (3:3), then policy B adds community B (2:2) and sets LP 220:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["[C]OR[A]AND[B]"]
```

```
            }
```

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 220                    Interface Name : int-PE-1-PE-2
---snip---
Community      : 2:2 3:3
---snip---
Flags          : Used Valid Best IGP In-RTM
---snip---
```

Table 9: Assigned LP and communities for the import logical expressions summarizes the results for these different scenarios.

Table 9: Assigned LP and communities for the import logical expressions

Import logical expression	Assigned LP	Assigned community
import "[C]AND[A]AND[B]"	220	2:2 1:1 3:3
import "[C]AND[A]OR[B]"	110	1:1 3:3
import "[C]OR[A]OR[B]"	None	3:3
import "[C]OR[A]AND[B]"	220	2:2 3:3

Combinations of policy logical operations using brackets

For this section, the following communities and policies are configured on PE-1. All these policies have a **from** condition that matches a community (D, E, F, G). Besides these policies, there are also export policies on PE-2 that add one or more communities (D, E, F, G) to the advertised routes. On PE-1, incoming route 2.2.2.2/32 will have one or more communities that may or may not match the **from** condition in the following route policies.

```
# on PE-1 and PE-2:
configure {
    policy-options {
        community "D" {
            member "4:4" { }
        }
```

```
        community "E" {
            member "5:5" { }
        }
        community "F" {
            member "6:6" { }
        }
        community "G" {
            member "7:7" { }
        }
        policy-statement "D" {
            entry 10 {
                from {
                    community {
                        name "D"
                    }
                }
                action {
                    action-type accept
                    local-preference 4
                }
            }
            default-action {
                action-type reject
            }
        }
        policy-statement "E" {
            entry 10 {
                from {
                    community {
                        name "E"
                    }
                }
                action {
                    action-type accept
                    local-preference 5
                }
            }
            default-action {
                action-type reject
            }
        }
        policy-statement "F" {
            entry 10 {
                from {
                    community {
                        name "F"
                    }
                }
                action {
                    action-type accept
                    local-preference 6
                }
            }
            default-action {
                action-type reject
            }
        }
        policy-statement "G" {
            entry 10 {
                from {
                    community {
                        name "G"
                    }
                }
```

```
                action {
                    action-type accept
                    local-preference 7
                }
            }
            default-action {
                action-type reject
            }
        }
```

The received routes have community E (5:5) present. The following import policy is configured on PE-1:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["([D]AND[E])OR([F]AND[G])"]
            }
```

The first policy that is evaluated requires community D (4:4) to be present. This is not the case and the expression between brackets, ([D]AND[E]), is false. Policy E is not evaluated. The next policy to be evaluated is F and it requires community F (6:6), which is not present. The second expression between brackets, ([F]AND[G]), is therefore also false and policy G is not evaluated. The entire policy logical expression is false and the route is rejected.

The following commands show what policy evaluation caused the route to be rejected. For the entire logical expression "([D]AND[E])OR([F]AND[G])", the last policy that was evaluated, and that caused the route to be rejected, was policy F:

```
[/]
A:admin@PE-1# show router bgp policy-test plcy-or-long-expr "([D]AND[E])OR([F]AND[G])" family
 ipv4 prefix 0.0.0.0/0 longer display-rejects brief
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
      Network
-------------------------------------------------------------------------------
Rejected by Logical expression last policy F Default action
      2.2.2.2/32
-------------------------------------------------------------------------------
 Total Routes : 1 Routes rejected : 1
===============================================================================
```

For the logical expression "[D]AND[E]", the last policy that was evaluated, and that led to the conclusion that the expression was false, was policy D:

```
[/]
A:admin@PE-1# show router bgp policy-test plcy-or-long-expr "[D]AND[E]" family ipv4 prefix
 0.0.0.0/0 longer display-rejects brief
===============================================================================
```

```
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
      Network
-------------------------------------------------------------------------------
Rejected by Logical expression last policy D Default action
      2.2.2.2/32
-------------------------------------------------------------------------------
 Total Routes : 1 Routes rejected : 1
===============================================================================
```

For the logical expression "[F]AND[G]", the last policy that was evaluated, and that led to the conclusion that the expression was false, was policy F:

```
[/]
A:admin@PE-1# show router bgp policy-test plcy-or-long-expr "[F]AND[G]" family ipv4 prefix
 0.0.0.0/0 longer display-rejects brief
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
      Network
-------------------------------------------------------------------------------
Rejected by Logical expression last policy F Default action
      2.2.2.2/32
-------------------------------------------------------------------------------
 Total Routes : 1 Routes rejected : 1
===============================================================================
```

The logical expression "([D]AND[E])OR([F]AND[G])" is false and, therefore, the route is rejected. No LP is set. Community E (5:5) was already present in the incoming route.

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
---snip---
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 100                   Interface Name : int-PE-1-PE-2
---snip---
Community      : 5:5
---snip---
Flags          : Invalid IGP Rejected
---snip---
```

In the second example, the incoming route contains communities D (4:4) and E (5:5). The same policy logical expression "([D]AND[E])OR([F]AND[G])" is evaluated as true because both policy D and policy E are true. There is an OR relationship with the rest of the expression and, therefore, the entire logical expression is true. Policy E is the last policy to be evaluated:

```
[/]
A:admin@PE-1# show router bgp policy-test plcy-or-long-expr "([D]AND[E])OR([F]AND[G])" family
 ipv4 prefix 0.0.0.0/0 longer display-rejects brief
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
      Network
-------------------------------------------------------------------------------
Accepted by Logical expression last policy E Entry 10
      2.2.2.2/32
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The route is accepted as valid and gets LP 5. The communities D (4:4) and E (5:5) were already present for the incoming route. The first policy that was executed, was policy D and it set the LP to a value of 4. Policy E was the second and last policy that was executed and it set the LP to a value of 5:

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
---snip---
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 5                     Interface Name : int-PE-1-PE-2
---snip---
Community      : 5:5 4:4
Cluster        : No Cluster Members
Originator Id  : None                  Peer Router Id : 192.0.2.2
Fwd Class      : None                  Priority       : None
Flags          : Used Valid Best IGP In-RTM
---snip---
```

For the third example, the incoming route contains communities D (4:4) and E (5:5). The logical expression "([D]OR[E])AND([F]OR[G])" is evaluated as false and the route is rejected:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["([D]OR[E])AND([F]OR[G])"]
            }
```

First, policy D is evaluated as true because community D (4:4) is present. Policy D has an OR relationship with policy E, which is true without the need to evaluate policy E. The next policy to be evaluated is F. Policy F requires the community F (6:6) to be present, which is not the case. The logical expression "[F]OR[G]" can only be true if policy G is true. Policy G requires community G (7:7) to be present, which is false. The last policy that was evaluated before the route was rejected was policy G:

```
[/]
A:admin@PE-1# show router bgp policy-test plcy-or-long-expr "([D]OR[E])AND([F]OR[G])" family
 ipv4 prefix 0.0.0.0/0 longer display-rejects brief
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
      Network
-------------------------------------------------------------------------------
Rejected by Logical expression last policy G Default action
      2.2.2.2/32
-------------------------------------------------------------------------------
 Total Routes : 1 Routes rejected : 1
===============================================================================
```

The route was rejected and, therefore, no policy was executed. The LP kept its default value of 100:

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
---snip---
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 100                    Interface Name : int-PE-1-PE-2
---snip---
Community      : 5:5 4:4
---snip---
Flags          : Invalid IGP Rejected
---snip---
```

For the fourth example, the incoming route has communities E (5:5) and G (7:7). The logical expression "([D]OR[E])AND([F]OR[G])" is evaluated as true and the route is accepted. First, policy D is evaluated as false. Policy D has an OR relationship with policy E, which is evaluated as true. Consequently, the expression "[D]OR[E]" is true. This expression has an AND relationship with the expression "[F]OR[G]".

The next policy to be evaluated is F. Policy F requires the community F (6:6) to be present, which is false. The logical expression "[F]OR[G]" can only be true if policy G is true. Policy G requires community G (7:7) to be present, which is true. This makes [F]OR[G] true as well as the entire expression "([D]OR[E])AND([F]OR[G])".

The last policy that was evaluated before the route was accepted was policy G:

```
[/]
```

```
A:admin@PE-1# show router bgp policy-test plcy-or-long-expr "([D]OR[E])AND([F]OR[G])" family
 ipv4 prefix 0.0.0.0/0 longer display-rejects brief
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
      Network
-------------------------------------------------------------------------------
Accepted by Logical expression last policy G Entry 10
      2.2.2.2/32
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

The route was accepted and has the changes of all policies that were evaluated: initially, policy D set the LP to 4. This value was overwritten by policy E to 5, by policy F to 6, and finally by policy G to a value of 7:

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
---snip---
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 7                     Interface Name : int-PE-1-PE-2
---snip---
Community      : 5:5 7:7
---snip---
Flags          : Used Valid Best IGP In-RTM
---snip---
```

Table 10: Assigned LP for the import logical expressions summarizes the results for these different scenarios.

Table 10: Assigned LP for the import logical expressions

Ingress community	Import logical expression	Assigned LP
5:5	import "([D]AND[E])OR([F]AND[G])"	Prefix rejected
5:5 4:4	import "([D]AND[E])OR([F]AND[G])"	5
5:5 4:4	import "([D]OR[E])AND([F]OR[G])"	Prefix rejected
5:5 7:7	import "([D]OR[E])AND([F]OR[G])"	7

Modification of attributes while processing

During the policy evaluation process, some prefix attributes can be modified while processing, and these modified attributes can be used as criteria for other policies in the logical expression.

In the following example, two route policies are configured:

- Policy X adds a new community Y (11:11) to the incoming route update.
- Policy Y uses community Y (11:11) as the only match criterion and removes communities X and Y. Policy Y also sets the LP to a value of 9, which is used here as an indication that policy Y was executed.

An export policy on PE-2 adds community X (10:10) to prefix 2.2.2.2/32 (not shown here).

Route policies X and Y are configured on PE-1:

```
# on PE-1:
configure {
    policy-options {
        community "X" {
            member "10:10" { }
        }
        community "Y" {
            member "11:11" { }
        }
        policy-statement "X" {
            entry 10 {
                from {
                    community {
                        name "X"
                    }
                }
                action {
                    action-type accept
                    community {
                        add ["Y"]
                    }
                }
            }
        }
        policy-statement "Y" {
            entry 10 {
                from {
                    community {
                        name "Y"
                    }
                }
                action {
                    action-type accept
                    local-preference 9
                    community {
                        remove ["X" "Y"]
                    }
                }
            }
        }
```

When no import policy is applied on PE-1, the received route 2.2.2.2/32 has community 10:10 and the default LP:

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
---snip---
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 100                    Interface Name : int-PE-1-PE-2
---snip---
Community      : 10:10
---snip---
Flags          : Used Valid Best IGP In-RTM
---snip---
```

The import policy "[X]AND[Y]" is configured on PE-1:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            delete import
            import {
                policy ["[X]AND[Y]"]
            }
```

The route update contains community X (10:10) and policy X is evaluated as true. Policy X adds community Y (11:11) to the route. Policy Y requires this community and is evaluated as true. Therefore, the entire logical expression "[X]AND[Y]" is true and the route is accepted. Policy Y removes communities X (10:10) and Y (11:11), and sets the LP to a value of 9:

```
[/]
A:admin@PE-1# show router bgp routes hunt brief
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 2.2.2.2/32
Nexthop        : 192.0.2.2
---snip---
Local Pref.    : 9                      Interface Name : int-PE-1-PE-2
---snip---
Community      : No Community Members
---snip---
Flags          : Used Valid Best IGP In-RTM
---snip---
```

Conclusion

Route policy chaining and logical expressions allow complex route processing logic to be broken into smaller components. These policy components are reusable and facilitate the process of updating route control logic. Logical expressions offer more flexible combinations of policy statements.

Pop-Label for /32 Label-IPv4 BGP Routes

This chapter describes the pop-label for /32 label-IPv4 BGP routes.

Topics in this chapter include:

Applicability

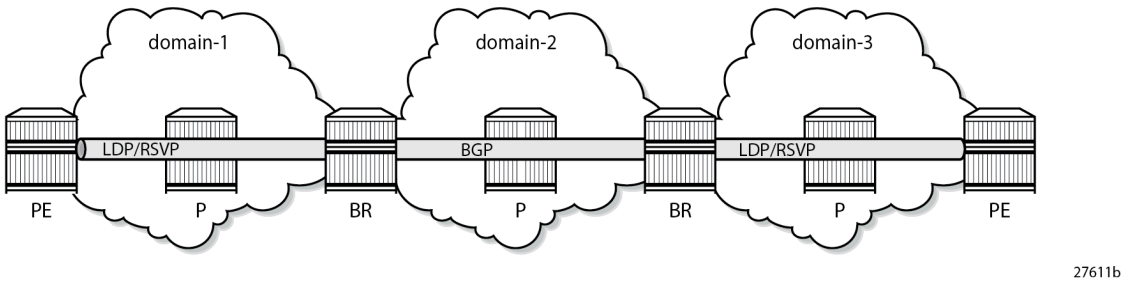
This chapter was initially written based on SR OS Release 15.0.R5, but the MD-CLI in the current edition is based on SR OS Release 23.7.R2.

Pop label for /32 label-IPv4 BGP routes is supported in SR OS Release 15.0.R1 and later.

Overview

Labeled IPv4 routes are used in seamless MPLS and in VPRN inter-AS model C scenarios. In these scenarios, transport tunnels run through multiple domains, where the area border routers (ABRs) or autonomous system border routers (ASBRs) effectively stitch LDP/RSVP tunnels to BGP tunnels. For inter-AS model C, the domain is an autonomous system (AS); for seamless MPLS, the domain is a part of an autonomous system. In either case, an end-to-end transport tunnel can be considered as a concatenation of multiple transport tunnels; as illustrated in Figure 131: Stitching RSVP/LDP tunnels to BGP tunnels.

Figure 131: Stitching RSVP/LDP tunnels to BGP tunnels



Pop-label for /32 label-IPv4 routes allows operators to save on resources used in the network (less swap ingress label mapping entries in the data path) and can be implemented at the border routers (ABR or ASBR) for /32 label-IPv4 BGP routes that are originated by exporting static, OSPF, or IS-IS routes from the route table into BGP.

Pop label for /32 label-IPv4 BGP routes provides a tighter coupling between the LDP/RSVP-TE and the BGP tunnels stitched at the ABR or ASBR, as follows:

1. By implementing an **accept** policy action (without the **advertise-label pop** modifier) for the /32 addresses in a **route-table-import** policy. The router advertises a /32 label-IPv4 route with a label that is swapped when an LDP/RSVP-TE is available, and withdrawn when the last LDP/RSVP-TE tunnel to that /32 prefix goes down. This applies to PEs with services, but should not be applied for route reflectors (RRs) when VPN addresses will be exchanged across EBGP sessions, because withdrawing labels for RRs would break the exchange of VPN routes. For the use of the **route-table-import** command, see the Separate BGP RIBs for Labeled Routes chapter.
2. By implementing the **accept** policy action with the **advertise-label pop** modifier for some system addresses in a **route-table-import** policy. The router advertises a /32 label-IPv4 route with a label that is popped rather than swapped, in case no LDP/RSVP-TE tunnel is available to that /32 prefix. This particularly applies to infrastructure nodes, for example off-data-path RRs, which do not participate in MPLS. RRs in different ASs, for example, still must be able to peer with each other through a multi-hop EBGP session, for the exchange of VPN routes belonging to the different services.

The **advertise-label pop** modifier can be used for the label-IPv4 redistribution of /32 prefixes of:

- OSPF and IS-IS routes
- Static routes:
  - Direct next-hop
  - Indirect next-hop
  - Blackhole

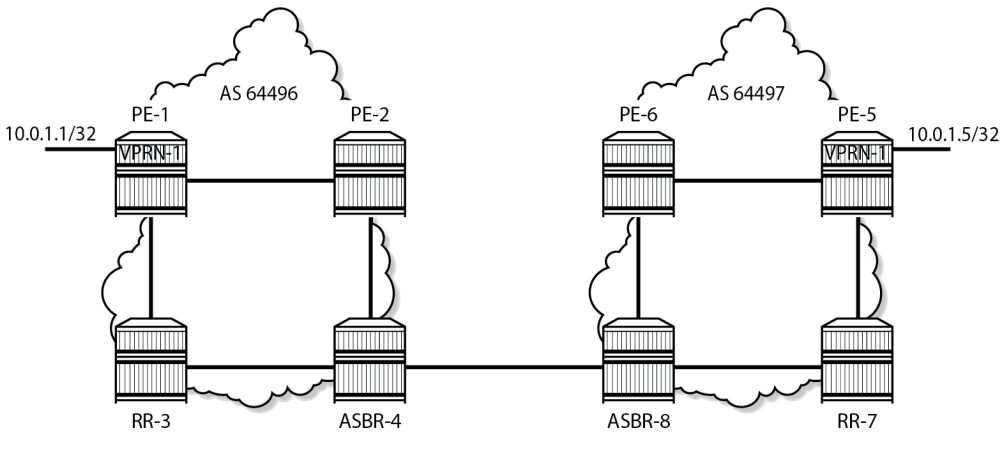
Redistributing /32 blackhole static routes does not require the **advertise-label pop** modifier; the label-IPv4 route is always advertised to the peer AS, and popped by the data plane.

The configuration in this chapter describes the redistribution of /32 prefixes for IS-IS routes. The redistribution of /32 routes for OSPF and the different static route types is similar.

Configuration

Figure 132: Example topology shows the example topology, depicting the inter-AS scenario also used in the "Inter-AS VPRN Model C" chapter. PE-1 and PE-5 host VPRN service "VPRN-1", with 10.0.1.1/32 and 10.0.1.5/32 being the loopback addresses for this service on PE-1 and PE-5, respectively. In AS 64496, RR-3 is the IPv4 VPN RR, and ASBR-4 is the label-IPv4 RR toward clients PE-1 and PE-2. In AS 64497, RR-7 is the IPv4 VPN RR, and ASBR-8 is the label-IPv4 RR toward clients PE-5 and PE-6. IS-IS is the IGP for AS 64496 and 64497, and ASBR-4 and ASBR-8 are their respective ASBRs. Additionally, and in support for model C, the RR-3 and RR-7 RRs require a multi-hop IPv4 VPN EBGP connection.

Figure 132: Example topology



The initial configuration includes:

1. Cards, MDAs, and ports.
2. Router interfaces.
3. IS-IS as IGP on all interfaces within AS 64496 and AS 64497 (alternatively, OSPF can be used).
4. LDP configured between PE-1, PE-2, and ASBR-4 in AS 64496, and between PE-5, PE-6, and ASBR-8 in AS 64497. The RR-3 and RR-7 RRs are off-data-path and do not have LDP enabled.

Base configuration

In this example topology, the PEs and the ASBRs generate labeled routes. The export policy configured on PE-1, PE-2, PE-5, and PE-6 advertises the system address 192.0.2.x/32. The export policy configured on the ASBRs advertises the system address of the RR. ASBR-4 and ASBR-8 advertise the system addresses of the PEs and the RRs to each other. The transport tunnels available in ASs 64496 and 64497 are LDP tunnels.

PE-1 and PE-2 peer with RR RR-3 for IPv4 VPN routes, and with RR ASBR-4 for label-IPv4 routes. This enables PE-1 and PE-2 to exchange service traffic with the PEs in the peer AS. Their internal BGP configuration is as follows:

```
# on PE-1, PE-2:
configure {
    policy-options {
        prefix-list "sys" {
            prefix 192.0.2.0/29 type range {
                start-length 32
                end-length 32
            }
        }
        policy-statement "exp-sys" {
            entry 10 {
                from {
                    prefix-list ["sys"]
                    protocol {
                        name [direct]
```

```
                }
            }
            action {
                action-type accept
            }
        }
    }
    router "Base" {
        autonomous-system 64496
        bgp {
            loop-detect discard-route
            split-horizon true
            group "IBGP" {
                peer-as 64496
            }
            neighbor "192.0.2.3" {
                group "IBGP"
                family {
                    vpn-ipv4 true
                }
            }
            neighbor "192.0.2.4" {
                group "IBGP"
                family {
                    label-ipv4 true
                }
                export {
                    policy ["exp-sys"]
                }
            }
        }
```

RR-3 is the IPv4 VPN RR for internal clients, using cluster ID 192.0.2.3, so it maintains IBGP sessions with PE-1 and PE-2. RR-3 also maintains a multi-hop EBGP session with RR-7, which is the RR for clients PE-5 and PE-6 in AS 64497. The **vpn-apply-import**, **vpn-apply-export**, and **import** and **export** commands can be used at **bgp**, **group**, or **neighbor** level for selectively exchanging dedicated VPN routes. The BGP configuration for RR-3 is as follows:

```
# on RR-3:
configure {
    policy-options {
        prefix-list "PE-pfxs" {
            prefix 192.0.2.1/32 type exact {
            }
            prefix 192.0.2.2/32 type exact {
            }
        }
        route-distinguisher-list "rd-123" {
            rd-entry "64497:1" { }
            rd-entry "64497:2" { }
            rd-entry "64497:3" { }
        }
        policy-statement "ebgp-exp-vpn" {
            entry 10 {
                from {
                    next-hop {
                        prefix-list "PE-pfxs"
                    }
                }
                action {
                    action-type accept
```

```
            }
        }
    }
    policy-statement "ebgp-imp-vpn" {
        entry 10 {
            from {
                route-distinguisher-list "rd-123"
            }
            action {
                action-type accept
            }
        }
    }
}
router "Base" {
    autonomous-system 64496
    bgp {
        loop-detect discard-route
        route-table-install false
        split-horizon true
        group "EBGP-VPN" {
            peer-as 64497
            local-address 192.0.2.3
            export {
                policy ["ebgp-exp-vpn"]
            }
            import {
                policy ["ebgp-imp-vpn"]
            }
        }
        group "IBGP-VPN" {
            peer-as 64496
            cluster {
                cluster-id 192.0.2.3
            }
        }
        neighbor "192.0.2.1" {
            group "IBGP-VPN"
            family {
                vpn-ipv4 true
            }
        }
        neighbor "192.0.2.2" {
            group "IBGP-VPN"
            family {
                vpn-ipv4 true
            }
        }
        neighbor "192.0.2.7" {
            group "EBGP-VPN"
            multihop 10
            vpn-apply-export true
            vpn-apply-import true
            family {
                vpn-ipv4 true
            }
        }
    }
```

On ASBR-4, the *RR-pfxs* prefix list is the exact /32 address of RR-3. The *imp-pfxs* policy in ASBR-4 matches the *RR-pfxs* prefix list in entry 10 with action accept and the **advertise-label pop** modifier; entry 20 matches the **PE-pfxs** prefix list with action accept without modifier. The *exp-sys* policy is used to advertise the RR prefix and the received label-IPv4 routes for the PE prefixes to the peer AS. The system

prefixes of PE-1 and PE-2 are advertised by the PEs as label-IPv4 routes. The policy configuration on ASBR-4 is as follows:

```
# on ASBR-4:
configure {
    policy-options {
        prefix-list "PE-pfxs" {
            prefix 192.0.2.1/32 type exact {
            }
            prefix 192.0.2.2/32 type exact {
            }
        }
        prefix-list "RR-pfxs" {
            prefix 192.0.2.3/32 type exact {
            }
        }
        policy-statement "exp-sys" {
            entry 10 {
                from {
                    prefix-list ["RR-pfxs"]
                }
                action {
                    action-type accept
                }
            }
            entry 20 {
                from {
                    protocol {
                        name [bgp-label]
                    }
                }
                action {
                    action-type accept
                }
            }
        }
        policy-statement "imp-sys" {
            entry 10 {
                from {
                    prefix-list ["RR-pfxs"]
                }
                action {
                    action-type accept
                    advertise-label pop
                }
            }
            entry 20 {
                from {
                    prefix-list ["PE-pfxs"]
                }
                action {
                    action-type accept
                }
            }
        }
```

ASBR-4 is the label-IPv4 RR for internal clients, using cluster ID 192.0.2.4, so it maintains IBGP sessions with PE-1 and PE-2. ASBR-4 imposes **next-hop-self** on the IBGP advertised label-IPv4 routes. ASBR-4 also maintains an EBGP session with ASBR-8, and requires the **advertise-inactive true** command. The reason for the **advertise-inactive** command is that the system IP addresses for PEs are advertised in IGP and in BGP. Because the IGP has a lower preference value than BGP, the BGP routes are rendered

inactive. By default, inactive BGP routes are not advertised to the peer AS, and the **advertise-inactive true** command bypasses this issue. The BGP configuration for ASBR-4 is as follows:

```
# on ASBR-4:
configure {
    router "Base" {
        autonomous-system 64496
        bgp {
            loop-detect discard-route
            split-horizon true
            rib-management {
                label-ipv4 {
                    route-table-import {
                        policy-name "imp-sys"
                    }
                }
            }
            group "EBGP-label" {
                advertise-inactive true
                ebgp-default-reject-policy {
                    import false
                }
                export {
                    policy ["exp-sys"]
                }
            }
            group "IBGP-label" {
                next-hop-self true
                peer-as 64496
                cluster {
                    cluster-id 192.0.2.4
                }
            }
            neighbor "192.0.2.1" {
                group "IBGP-label"
                family {
                    label-ipv4 true
                }
            }
            neighbor "192.0.2.2" {
                group "IBGP-label"
                family {
                    label-ipv4 true
                }
            }
            neighbor "192.168.48.2" {
                group "EBGP-label"
                peer-as 64497
                family {
                    label-ipv4 true
                }
            }
        }
```

Because RR-3 is deliberately placed off the data path, not participating in MPLS, an indirect static route is added to its configuration so that it can establish an EBGP session with RR-7, as follows:

```
# on RR-3:
configure {
    router "Base" {
        static-routes {
            route 192.0.2.7/32 route-type unicast {
```

```
                indirect 192.0.2.4 {
                    admin-state enable
                }
            }
        }
```

The configuration of the nodes in AS 64497 is similar to the nodes in AS 64496; see Figure 132: Example topology for the addresses required.

Redistributing IGP /32 routes to label-IPv4 routes

With the configuration as indicated in the previous section, ASBR-4 advertises the system addresses of PE-1, PE-2, and RR-3 in AS 64496 to ASBR-8 in the peer AS as label-IPv4 routes, as follows:

```
[/]
A:admin@ASBR-4# show router bgp neighbor 192.168.48.2 advertised-routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.4        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
i     192.0.2.1/32                                     n/a         20
      192.168.48.1                                     None        n/a
      64496                                                        524281
i     192.0.2.2/32                                     n/a         10
      192.168.48.1                                     None        n/a
      64496                                                        524282
i     192.0.2.3/32                                     n/a         10
      192.168.48.1                                     None        n/a
      64496                                                        524284
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

The label-IPv4 routes are accepted and put in the routing table of ASBR-8. The next hop for all the label-IPv4 routes is 192.168.48.1, as follows:

```
[/]
A:admin@ASBR-8# show router route-table 192.0.2.0/24 longer

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
192.0.2.1/32                                  Remote  BGP_LABEL 00h01m15s  170
       192.168.48.1                                                 0
192.0.2.2/32                                  Remote  BGP_LABEL 00h01m15s  170
       192.168.48.1                                                 0
```

```
192.0.2.3/32                                    Remote  BGP_LABEL 00h01m15s  170
       192.168.48.1                                                  0
192.0.2.5/32                                    Remote  ISIS      00h35m37s  18
       192.168.68.1                                                  20
192.0.2.6/32                                    Remote  ISIS      00h35m37s  18
       192.168.68.1                                                  10
192.0.2.7/32                                    Remote  ISIS      00h35m37s  18
       192.168.78.1                                                  10
192.0.2.8/32                                    Local   Local     00h35m38s  0
       system                                                        0
-------------------------------------------------------------------------------
No. of Routes: 7
Flags: n = Number of times nexthop is repeated
       B = BGP backup route available
       L = LFA nexthop available
       S = Sticky ECMP requested
===============================================================================
```

Also, ASBR-8 is advertising label-IPv4 routes to ASBR-4, so that ASBR-4 ultimately has LDP and BGP tunnels available to destinations in its own and its peer AS, respectively, as follows:

```
[/]
A:admin@ASBR-4# show router tunnel-table

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
192.0.2.1/32          ldp       MPLS  65538     9      192.168.24.1   20
192.0.2.2/32          ldp       MPLS  65537     9      192.168.24.1   10
192.0.2.5/32          bgp       MPLS  262147    12     192.168.48.2   1000
192.0.2.6/32          bgp       MPLS  262146    12     192.168.48.2   1000
192.0.2.7/32          bgp       MPLS  262145    12     192.168.48.2   1000
-------------------------------------------------------------------------------
Flags: B = BGP or MPLS backup hop available
       L = Loop-Free Alternate (LFA) hop available
       E = Inactive best-external BGP route
       k = RIB-API or Forwarding Policy backup hop
===============================================================================
```

The following shows the BGP inter-AS label mapping on ASBR-4:

```
[/]
A:admin@ASBR-4# show router bgp inter-as-label

===============================================================================
BGP Inter-AS labels
Flags: B - entry has backup, P - entry is promoted
===============================================================================
NextHop                       Received       Advertised     Label
                              Label          Label          Origin
-------------------------------------------------------------------------------
0.0.0.0                       0              524280         Edge
192.0.2.1                     524284         524284         Internal
192.0.2.2                     524284         524283         Internal
192.168.48.2                  524279         524279         External
192.168.48.2                  524281         524282         External
192.168.48.2                  524284         524281         External
-------------------------------------------------------------------------------
Total Labels allocated:   6
```

```
===============================================================================
```

The first entry in this table, with advertised label 524280, is used for tunnels for which ASBR-4 is the end-point, so that no label mapping is required. This is indicated by setting the next hop to 0.0.0.0, the received label to 0, and the label origin to Edge.

The second and third entries, with advertised labels 524284 and 524283, are used for tunnels to PE-1 and PE-2, respectively. Taking PE-2 as an example, label 524283 is swapped to label 524284.

The last three entries, with advertised labels 524279, 524282, and 524281, and received labels 524279, 524281, and 524284, respectively, are used for tunnels to the PEs and RR in the peer AS, which can be verified by displaying the label-IPv4 routes received by ASBR-4, as follows:

```
[/]
A:admin@ASBR-4# show router bgp neighbor 192.168.48.2 received-routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.4        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  192.0.2.5/32                                      n/a         None
      192.168.48.2                                      None        0
      64497                                                         524284
u*>i  192.0.2.6/32                                      n/a         None
      192.168.48.2                                      None        0
      64497                                                         524281
u*>i  192.0.2.7/32                                      n/a         10
      192.168.48.2                                      None        0
      64497                                                         524279
-------------------------------------------------------------------------------
Routes : 3
===============================================================================
```

Verifying the content of the RIB provides an alternative to check whether tunnels are stitched. A check is performed for PE-1, which has service "VPRN-1" defined, and for RR-3, which does not have any services.

On ASBR-4, the label-IPv4 route for the 192.0.2.1/32 prefix in the RIB-In contains the received label 524284 with next hop 192.0.2.1 resolved to an LDP tunnel; in the RIB-Out, the advertised BGP label to next hop 192.168.48.2 is 524284, and the label type is swap, as follows. This is consistent with the output from the previous commands. The label-IPv4 BGP route in RIB-In is valid, but not used on ASBR-4, because an IS-IS route is preferred between PE-1 and ASBR-4 in AS 64496 (TieBreakReason : RtmPref).

```
[/]
A:admin@ASBR-4# show router bgp routes 192.0.2.1/32 label-ipv4 hunt
===============================================================================
 BGP Router ID:192.0.2.4        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete
```

```
===============================================================================
BGP LABEL-IPV4 Routes
===============================================================================
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 192.0.2.1/32
Nexthop        : 192.0.2.1
Path Id        : None
From           : 192.0.2.1
Res. Nexthop   : 192.0.2.1 (LDP)
Local Pref.    : 100                    Interface Name : NotAvailable
Aggregator AS  : None                   Aggregator     : None
Atomic Aggr.   : Not Atomic             MED            : None
AIGP Metric    : None                   IGP Cost       : 20
Connector      : None
Community      : No Community Members
Cluster        : No Cluster Members
Originator Id  : None                   Peer Router Id : 192.0.2.1
Fwd Class      : None                   Priority       : None
IPv4 Label     : 524284
Flags          : Valid IGP
TieBreakReason : RtmPref
Route Source   : Internal
AS-Path        : No As-Path
Route Tag      : 0
Neighbor-AS    : n/a
DB Orig Val    : NotFound               Final Orig Val : NotFound
Source Class   : 0                      Dest Class     : 0
Add Paths Send : Default
RIB Priority   : Normal
Last Modified  : 00h10m05s

-------------------------------------------------------------------------------
RIB Out Entries
-------------------------------------------------------------------------------
Network        : 192.0.2.1/32
Nexthop        : 192.168.48.1
Path Id        : None
To             : 192.168.48.2
Res. Nexthop   : n/a
Local Pref.    : n/a                    Interface Name : NotAvailable
Aggregator AS  : None                   Aggregator     : None
Atomic Aggr.   : Not Atomic             MED            : None
AIGP Metric    : None                   IGP Cost       : 20
Connector      : None
Community      : No Community Members
Cluster        : No Cluster Members
Originator Id  : None                   Peer Router Id : 192.0.2.8
IPv4 Label     : 524284                 Label Type     : SWAP
Lbl Allocation : NEXT-HOP
Origin         : IGP
AS-Path        : 64496
Route Tag      : 0
Neighbor-AS    : 64496
DB Orig Val    : NotFound               Final Orig Val : N/A
Source Class   : 0                      Dest Class     : 0

-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

Checking for the 192.0.2.3/32 prefix in the ASBR-4 RIB shows that label 524280 is advertised to 192.168.48.2, and the label type is pop, as follows:

```
[/]
A:admin@ASBR-4# show router bgp routes 192.0.2.3/32 label-ipv4 hunt
===============================================================================
 BGP Router ID:192.0.2.4        AS:64496       Local AS:64496
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP LABEL-IPV4 Routes
===============================================================================
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------

-------------------------------------------------------------------------------
RIB Out Entries
-------------------------------------------------------------------------------
Network        : 192.0.2.3/32
Nexthop        : 192.168.48.1
Path Id        : None
To             : 192.168.48.2
Res. Nexthop   : n/a
Local Pref.    : n/a                    Interface Name : NotAvailable
Aggregator AS  : None                   Aggregator     : None
Atomic Aggr.   : Not Atomic             MED            : 10
AIGP Metric    : None                   IGP Cost       : n/a
Connector      : None
Community      : No Community Members
Cluster        : No Cluster Members
Originator Id  : None                   Peer Router Id : 192.0.2.8
IPv4 Label     : 524280                 Label Type     : POP
Lbl Allocation : NEXT-HOP
Origin         : IGP
AS-Path        : 64496
Route Tag      : 0
Neighbor-AS    : 64496
DB Orig Val    : N/A                    Final Orig Val : N/A
Source Class   : 0                      Dest Class     : 0

-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

RR-3 and RR-7 have a multi-hop EBGP session established and are exchanging VPN routes, as follows:

```
[/]
A:admin@RR-3# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId          AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                      PktSent OutQ
```

```
-------------------------------------------------------------------------------
192.0.2.1
Def. Inst       64496      29    0 00h11m17s 2/0/4 (VpnIPv4)
                           30    0
192.0.2.2
Def. Inst       64496      28    0 00h11m17s 1/0/5 (VpnIPv4)
                           31    0
192.0.2.7
Def. Inst       64497      13    0 00h03m22s 3/0/3 (VpnIPv4)
                           13    0

-------------------------------------------------------------------------------
```

Communication between VPRN-1 on PE-1 and on PE-5 is verified with a ping:

```
[/]
A:admin@PE-1# ping 10.0.1.5 router-instance "VPRN-1"
PING 10.0.1.5 56 data bytes
64 bytes from 10.0.1.5: icmp_seq=1 ttl=64 time=7.15ms.
64 bytes from 10.0.1.5: icmp_seq=2 ttl=64 time=6.57ms.
64 bytes from 10.0.1.5: icmp_seq=3 ttl=64 time=6.76ms.
64 bytes from 10.0.1.5: icmp_seq=4 ttl=64 time=6.62ms.
64 bytes from 10.0.1.5: icmp_seq=5 ttl=64 time=6.55ms.

---- 10.0.1.5 PING Statistics ----
5 packets transmitted, 5 packets received, 0.00% packet loss
round-trip min = 6.55ms, avg = 6.73ms, max = 7.15ms, stddev = 0.222ms
```

Disabling LDP on PE-1 results in ASBR-4 withdrawing the label-IPv4 route for prefix 192.0.2.1/32, as follows:

```
17 2023/09/27 08:23:26.963 UTC MINOR: DEBUG #2001 Base Peer 1: 192.168.48.2
"Peer 1: 192.168.48.2: UPDATE
Peer 1: 192.168.48.2 - Send BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 15
    Flag: 0x90 Type: 15 Len: 11 Multiprotocol Unreachable NLRI:
        Address Family LBL-IPV4
        192.0.2.1/32 Label 0
"
```

Conclusion

Implementing the **advertise-label pop** policy action in a **route-table-import** policy provides operators the means to save on resources used in the network.

Route Policy Action to Suppress BGP Route Installation

This chapter describes Route Policy Action to Suppress BGP Route Installation.

Topics in this chapter include:

Applicability

The information and MD-CLI configuration in this chapter are based on SR OS Release 20.5.R1. The route policy action to suppress BGP and BGP Labeled Unicast (BGP-LU) route installation in the route table and tunnel table associated with the BGP instance is supported in SR OS Release 19.10.R1and later.

Overview

In some deployments, a Route Reflector (RR) or PE router receives many BGP routes that must be re-advertised to other peers whereas these BGP routes do not need to be installed in the route table and Forwarding Information Base (FIB) of the RR or PE router. Network operators can suppress BGP route installation in the route table when they know that the router can forward the associated traffic anyway; for example, using a default or summary route. By suppressing BGP route installation, CPM memory is saved as well as FIB table space in the line cards.

The **route-table-install false** policy action only takes effect in BGP import policies and only for the IPv4, IPv6, label-IPv4, and label-IPv6 address families.

With this policy action in place, the following applies:

- when a BGP unlabeled IPv4 or IPv6 route is received from a base router or VPRN BGP peer, the route is:
  - not installed in the Route Table Manager (RTM)
  - not downloaded to the IOMs for installation in the FIB tables
  - not available for CPM routing (for example, for control plane traffic)
  - not available to resolve other routes
- when a BGP-LU IPv4 route is received from a base router or VPRN BGP peer, the route is:
  - not installed in the RTM and Tunnel Table Manager (TTM)
  - not downloaded to the IOMs for installation in the FIB tables
  - not available for CPM routing (for example, for control plane traffic)

  - not available as a tunnel to resolve other routes

Note:
If the BGP-LU IPv4 route is re-advertised with a new next-hop, the **route-table-install false** policy action does not prevent a new Incoming Label Map (ILM) label from being allocated for the route and programmed into the ILM tables of the line cards.

- when a BGP-LU IPv6 route is received from a base router BGP peer, the route is:
  - not installed in the RTM
  - not downloaded to the IOMs for installation in the FIB tables
  - not available for CPM routing (for example, for control plane traffic)
  - not available to resolve other routes

Usual BGP rules do not allow the advertising of inactive routes when **advertise-inactive** is not configured. However, routes marked by the **route-table-install false** policy action can be re-advertised, even if **advertise-inactive** is not configured toward the RIB-OUT peer and even if **next-hop-self true** is configured toward the RIB-OUT peer. Because of the latter, incorrect use of this feature can blackhole traffic.

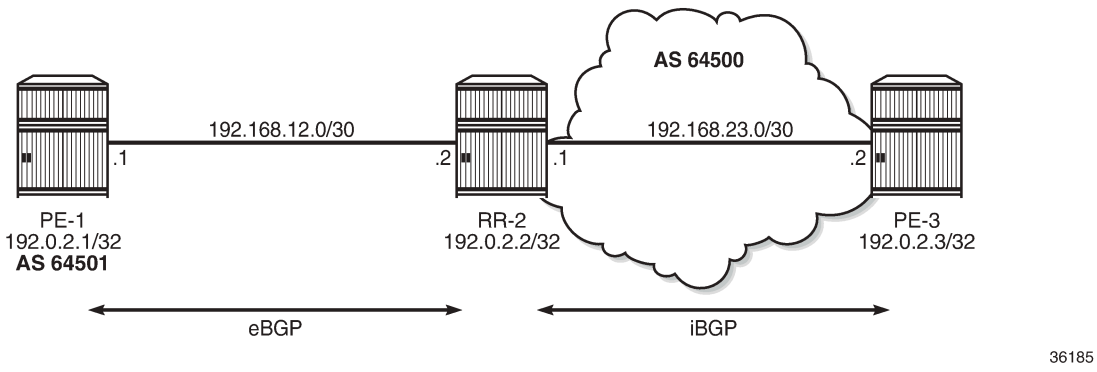
Note:
The **route-table-install false** command at the BGP instance level does not allow a route to be advertised under next-hop-self conditions.

The **route-table-install false** policy action overrides the effect of the **selective-label-ipv4-install true** command. Even if a /32 BGP-LU route should be installed in the route table and tunnel table because it has a dependent service, the **route-table-install false** policy action suppresses the installation.

Configuration

Figure 133: Example topology shows the example topology for this feature.

Figure 133: Example topology



The initial configuration on the nodes includes:

- Cards, MDAs, ports

- Router interfaces
- SR-ISIS (on RR-2 and PE-3 in AS 64500)

An eBGP session is established between PE-1 in AS 64501 and RR-2 in AS 64500, and an iBGP session between RR-2 and PE-3 in AS 64500 with **next-hop-self true**. The BGP configuration on RR-2 is as follows:

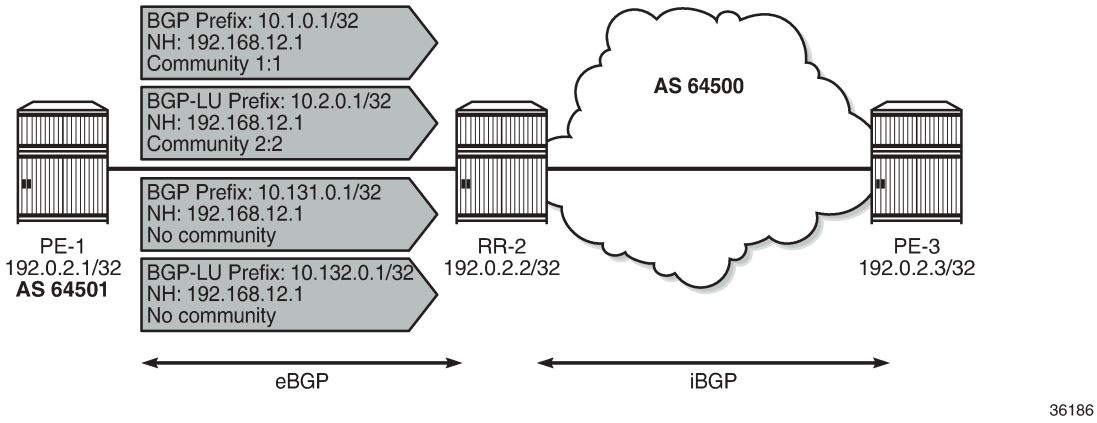
```
# on RR-2:
configure {
    router "Base" {
        bgp {
            split-horizon true
            ebgp-default-reject-policy {
                import true                # default
                export true                # default
            }
            next-hop-resolution {
                labeled-routes {
                    transport-tunnel {
                        family label-ipv4 {
                            resolution-filter {
                                ldp false
                                sr-isis true
                            }
                        }
                    }
                }
            }
            group "eBGP" {
                peer-as 64501
                local-as {
                    as-number 64500
                }
            }
            group "iBGP-IPv4" {
                peer-as 64500
                family {
                    ipv4 true
                    label-ipv4 true
                }
                cluster {
                    cluster-id 192.0.2.2
                }
            }
            neighbor "192.0.2.3" {
                group "iBGP-IPv4"
                next-hop-self true
            }
            neighbor "192.168.12.1" {
                group "eBGP"
                next-hop-self true
                family {
                    ipv4 true
                    label-ipv4 true
                }
            }
        }
```

Figure 134: PE-1 exports BGP IPv4 and BGP-LU IPv4 routes to RR-2 shows that PE-1 advertises two BGP IPv4 routes and two BGP-LU IPv4 routes to RR-2:

- BGP route 10.1.0.1/32 with community 1:1

- BGP-LU route 10.2.0.1/32 with community 2:2
- BGP route 10.131.0.1/32 without community
- BGP-LU route 10.132.0.1/32 without community

Figure 134: PE-1 exports BGP IPv4 and BGP-LU IPv4 routes to RR-2



On PE-1, the following export policies are applied for BGP neighbor 192.168.12.2:

```
# on PE-1:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        community "2:2" {
            member "2:2" { }
        }
        prefix-list "10.1.0.0/16" {
            prefix 10.1.0.0/16 type longer {
            }
        }
        prefix-list "10.131.0.0/16" {
            prefix 10.131.0.0/16 type longer {
            }
        }
        prefix-list "10.132.0.0/16" {
            prefix 10.132.0.0/16 type longer {
            }
        }
        prefix-list "10.2.0.0/16" {
            prefix 10.2.0.0/16 type longer {
            }
        }
        policy-statement "export-10.1" {
            entry 10 {
                from {
                    prefix-list ["10.1.0.0/16"]
                }
                to {
                    protocol {
                        name [bgp]
                    }
                }
```

```
                action {
                    action-type accept
                    community {
                        add ["1:1"]
                    }
                }
            }
        }
        policy-statement "export-10.131" {
            entry 10 {
                from {
                    prefix-list ["10.131.0.0/16"]
                }
                to {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                }
            }
        }
        policy-statement "export-10.132" {
            entry 10 {
                from {
                    prefix-list ["10.132.0.0/16"]
                }
                to {
                    protocol {
                        name [bgp-label]
                    }
                }
                action {
                    action-type accept
                }
            }
        }
        policy-statement "export-10.2" {
            entry 10 {
                from {
                    prefix-list ["10.2.0.0/16"]
                }
                to {
                    protocol {
                        name [bgp-label]
                    }
                }
                action {
                    action-type accept
                    community {
                        add ["2:2"]
                    }
                }
            }
        }
    }
    router "Base" {
        autonomous-system 64501
        bgp {
            split-horizon true
            group "eBGP" {
                peer-as 64500
                local-as {
```

```
                    as-number 64501
                }
            }
            neighbor "192.168.12.2" {
                group "eBGP"
                next-hop-self true
                family {
                    ipv4 true
                    label-ipv4 true
                }
                export {
                    policy ["export-10.1" "export-10.2" "export-10.131" "export-10.132"]
                }
            }
        }
```

Initially, RR-2 has no import policy matching any of these four routes. The following BGP routes are received on RR-2:

```
[]
A:admin@RR-2# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
i     10.1.0.1/32                                      None        None
      192.168.12.1                                     None        0
      64501                                                        -
i     10.131.0.1/32                                    None        None
      192.168.12.1                                     None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

By default, all eBGP routes are rejected because no import policy is configured (**ebgp-default-reject-policy import true**), so the routes get the flags "Invalid IGP Rejected”:

```
[]
A:admin@RR-2# show router bgp routes hunt | match "Flags"
Flags          : Invalid IGP Rejected
Flags          : Invalid IGP Rejected
```

The following BGP-LU routes are received on RR-2:

```
[]
A:admin@RR-2# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
```

```
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
i     10.2.0.1/32                                      None        None
      192.168.12.1                                     None        0
      64501                                                        524287
i     10.132.0.1/32                                    None        None
      192.168.12.1                                     None        0
      64501                                                        524287
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

These BGP-LU routes are also rejected, as follows:

```
[]
A:admin@RR-2# show router bgp routes label-ipv4 hunt | match "Flags"
Flags          : Invalid IGP Rejected
Flags          : Invalid IGP Rejected
```

None of these invalid routes is installed in the Routing Table Manager (RTM) and none of these routes will be re-advertised by RR-2 to PE-3.

route-table-install false policy action

On RR-2, an import policy is configured that only accepts and installs BGP routes with community "1:1" or "2:2"; all other routes match the policy **default-action accept route-table-install false**.

BGP IPv4 route 10.1.0.1/32 will be installed in the route table and the BGP-LU IPv4 route 10.131.0.1 will be installed in the route table and tunnel table. However, BGP IPv4 route 10.131.0.1/32 will not be installed in the route table and BGP-LU IPv4 route 10.132.0.1/32 will not be installed in the route table and tunnel table. Suppression of BGP route installation in the RTM and in the Tunnel Table Manager (TTM) can be done when the router has other ways of forwarding the associated traffic; in this example, via a static route 10.128.0.0/9.

```
# on RR-2:
configure {
    policy-options {
        community "1:1" {
            member "1:1" { }
        }
        community "2:2" {
            member "2:2" { }
        }
        policy-statement "bgp-install-1:1-2:2" {
            entry 10 {
                from {
                    community {
                        name "1:1"
                    }
```

```
                }
                action {
                    action-type accept
                }
            }
            entry 20 {
                from {
                    community {
                        name "2:2"
                    }
                }
                action {
                    action-type accept
                }
            }
            default-action {
                action-type accept
                route-table-install false
            }
        }
    }
    router "Base"
        bgp {
            group "eBGP" {
                peer-as 64501
                local-as {
                    as-number 64500
                }
            }
            neighbor "192.168.12.1" {
                group "eBGP"
                next-hop-self true
                family {
                    ipv4 true
                    label-ipv4 true
                }
                import {
                     policy ["bgp-install-1:1-2:2"]
                }
            }
        }
        static-routes {
            route 10.128.0.0/9 route-type unicast {
                next-hop "192.168.12.1" {
                    admin-state enable
                }
            }
        }
```

With this import policy, BGP route 10.1.0.1/32 is active, but route 10.131.0.1/32 is inactive, as follows:

```
[]
A:admin@RR-2# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
```

```
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.1.0.1/32                                      None        None
      192.168.12.1                                     None        0
      64501                                                        -
*>i   10.131.0.1/32                                    None        None
      192.168.12.1                                     None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

In a similar way, BGP-LU IPv4 route 10.2.0.1/32 is active, but route 10.132.0.1/32 is inactive:

```
[]
A:admin@RR-2# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  10.2.0.1/32                                      None        None
      192.168.12.1                                     None        0
      64501                                                        524287
*>i   10.132.0.1/32                                    None        None
      192.168.12.1                                     None        0
      64501                                                        524287
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

BGP route 10.131.0.1/32 and BGP-LU route 10.132.0.1/32 have the flag "Disable-RTM-Install" set, but both routes are advertised to the RIB-OUT peer PE-3, as follows:

```
[]
A:admin@RR-2# show router bgp routes hunt
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
-------------------------------------------------------------------------------
RIB In Entries
```

```
-------------------------------------------------------------------------------
Network        : 10.1.0.1/32
Nexthop        : 192.168.12.1
---snip---
Community      : 1:1
---snip---
Flags          : Used Valid Best IGP
---snip---

Network        : 10.131.0.1/32
Nexthop        : 192.168.12.1
---snip---
Community      : No Community Members
---snip---
Flags          : Valid Best IGP Disable-RTM-Install
---snip---
-------------------------------------------------------------------------------
RIB Out Entries
-------------------------------------------------------------------------------
Network        : 10.1.0.1/32
Nexthop        : 192.0.2.2
---snip---
Community      : 1:1
---snip---

Network        : 10.131.0.1/32
Nexthop        : 192.0.2.2
---snip---
Community      : No Community Members
---snip---
```

```
[]
A:admin@RR-2# show router bgp routes label-ipv4 hunt
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
-------------------------------------------------------------------------------
RIB In Entries
-------------------------------------------------------------------------------
Network        : 10.2.0.1/32
Nexthop        : 192.168.12.1
---snip---
Community      : 2:2
---snip---
Flags          : Used Valid Best IGP
---snip---

Network        : 10.132.0.1/32
Nexthop        : 192.168.12.1
---snip---
Community      : No Community Members
---snip---
Flags          : Valid Best IGP Disable-RTM-Install
---snip---
```

```
-------------------------------------------------------------------------------
RIB Out Entries
-------------------------------------------------------------------------------
Network        : 10.2.0.1/32
Nexthop        : 192.0.2.2
---snip---
Community      : 2:2
---snip---
Network        : 10.132.0.1/32
Nexthop        : 192.0.2.2
---snip---
Community      : No Community Members
---snip---
```

On RR-2, the route table only has one BGP route and one BGP-LU route, as follows:

```
[]
A:admin@RR-2# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.1.0.1/32                                   Remote  BGP       00h13m48s  170
       192.168.12.1                                                 0
-------------------------------------------------------------------------------
No. of Routes: 1
```

```
[]
A:admin@RR-2# show router route-table protocol bgp-label

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.2.0.1/32                                   Remote  BGP_LABEL 00h13m48s  170
       192.168.12.1                                                 0
-------------------------------------------------------------------------------
No. of Routes: 1
```

On RR-2, the FIB contains BGP route 10.1.0.1/32, BGP-LU route 10.2.0.1/32, and static route 10.128.0.0/9:

```
[]
A:admin@RR-2# show router fib 1 ip-prefix-prefix-length 10.0.0.0/8 longer

===============================================================================
FIB Display
===============================================================================
Prefix [Flags]                                                Protocol
  NextHop
-------------------------------------------------------------------------------
10.1.0.1/32                                                   BGP
  192.168.12.1 (int-RR-2-PE-1)
10.2.0.1/32                                                   BGP_LABEL
  192.168.12.1 (int-RR-2-PE-1)
```

```
10.128.0.0/9                                                    STATIC
  192.168.12.1 (int-RR-2-PE-1)
-------------------------------------------------------------------------------
Total Entries : 3
-------------------------------------------------------------------------------
===============================================================================
```

On RR-2, the tunnel table contains a BGP tunnel toward destination 10.2.0.1/32, but no tunnel toward destination 10.132.0.1/32, as follows:

```
[]
A:admin@RR-2# show router tunnel-table protocol bgp

===============================================================================
IPv4 Tunnel Table (Router: Base)
===============================================================================
Destination           Owner     Encap TunnelId  Pref   Nexthop        Metric
   Color
-------------------------------------------------------------------------------
10.2.0.1/32           bgp       MPLS  262145    12     192.168.12.1   1000
-------------------------------------------------------------------------------
Flags: B = BGP or MPLS backup hop available
       L = Loop-Free Alternate (LFA) hop available
       E = Inactive best-external BGP route
       k = RIB-API or Forwarding Policy backup hop
===============================================================================
```

RR-2 advertises both the active and the inactive/suppressed routes to RIB-OUT peer PE-3. The result is that, on PE-3, the route table contains both BGP routes and both BGP-LU routes:

```
[]
A:admin@PE-3# show router route-table protocol bgp

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.1.0.1/32                                   Remote  BGP       00h11m38s  170
       192.168.23.1                                               10
10.131.0.1/32                                 Remote  BGP       00h11m38s  170
       192.168.23.1                                               10
-------------------------------------------------------------------------------
No. of Routes: 2
```

```
[]
A:admin@PE-3# show router route-table protocol bgp-label

===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.2.0.1/32                                   Remote  BGP_LABEL 00h11m38s  170
       192.0.2.2 (tunneled:SR-ISIS:0)                             10
10.132.0.1/32                                 Remote  BGP_LABEL 00h11m38s  170
       192.0.2.2 (tunneled:SR-ISIS:0)                             10
-------------------------------------------------------------------------------
No. of Routes: 2
```

route-table-install false command

The **route-table-install false** command in the BGP global context is mainly used for off-path route reflectors that do not participate in traffic forwarding.

This section describes the **route-table-install false** command in the general **bgp** context, in combination with the **route-table-install false** parameter, which is part of the policy framework (**action** or **default-action**).

The **route-table-install false** command in the general BGP context is configured as follows:

```
# on RR-2:
configure {
    router "Base" {
        bgp {
            route-table-install false
        }
```

The rest of the BGP configuration (including import policy) remains unchanged.

This **route-table-install false** command applies to all received BGP routes, so none of the BGP and BGP-LU routes received from PE-1 will be installed in the RTM and TTM. Therefore, all BGP and BGP-LU routes are inactive (in this example, the second route was already inactive because of the import policy).

```
[]
A:admin@RR-2# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
*>i   10.1.0.1/32                                      None        None
      192.168.12.1                                     None        0
      64501                                                        -
*>i   10.131.0.1/32                                    None        None
      192.168.12.1                                     None        0
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

```
[]
A:admin@RR-2# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete
```

```
===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
*>i   10.2.0.1/32                                      None        None
      192.168.12.1                                     None        0
      64501                                                        524287
*>i   10.132.0.1/32                                    None        None
      192.168.12.1                                     None        0
      64501                                                        524287
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

When a BGP route is suppressed because of a **route-table-install false** general BGP command match, no flag is added. The "Disable-RTM-Install" flag is only present for the route when the **route-table-install false** policy action is matched. The following output shows that the first route did not get an additional flag:

```
[]
A:admin@RR-2# show router bgp routes hunt | match Flags
Flags          : Valid Best IGP                        #for BGP route 10.1.0.1/32
Flags          : Valid Best IGP Disable-RTM-Install    #for BGP-LU route 10.131.0.1/32
```

```
[]
A:admin@RR-2# show router bgp routes label-ipv4 hunt | match Flags
Flags          : Valid Best IGP                        #for BGP route 10.2.0.1/32
Flags          : Valid Best IGP Disable-RTM-Install    #for BGP-LU route 10.132.0.1/32
```

When the **route-table-install false** command is configured and **next-hop-self true** is configured toward the RIB-OUT peer, no BGP routes can be advertised for routes that are not installed in the RTM. In this example, the RIB-OUT toward PE-3 remains empty, as follows (the total number of routes equals the number of routes in the RIB-IN):

```
[]
A:admin@RR-2# show router bgp routes hunt | match "RIB Out Entries"
                                                    pre-lines 2 post-lines 50
-------------------------------------------------------------------------------
RIB Out Entries
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

```
[]
A:admin@RR-2# show router bgp routes label-ipv4 hunt | match "RIB Out Entries"
                                                   pre-lines 2 post-lines 50
-------------------------------------------------------------------------------
RIB Out Entries
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
Routes : 2
===============================================================================
```

Conclusion

The **route-table-install false** policy action in a BGP import policy allows the marking of a route with a "Disable-RTM-Install" flag and still re-advertises this route to RIB-OUT peers, even when **next-hop-self true** is configured. Other routers in the network can install these routes in the route table and FIB.

Separate BGP RIBs for Labeled Routes

This chapter provides information about separate border gateway protocol (BGP) route information bases (RIBs) for labeled-unicast routes.

Applicability

This chapter was initially written for SR OS Release 14.0.R4, but the MD-CLI in the current edition corresponds to SR OS Release 20.7.R2.

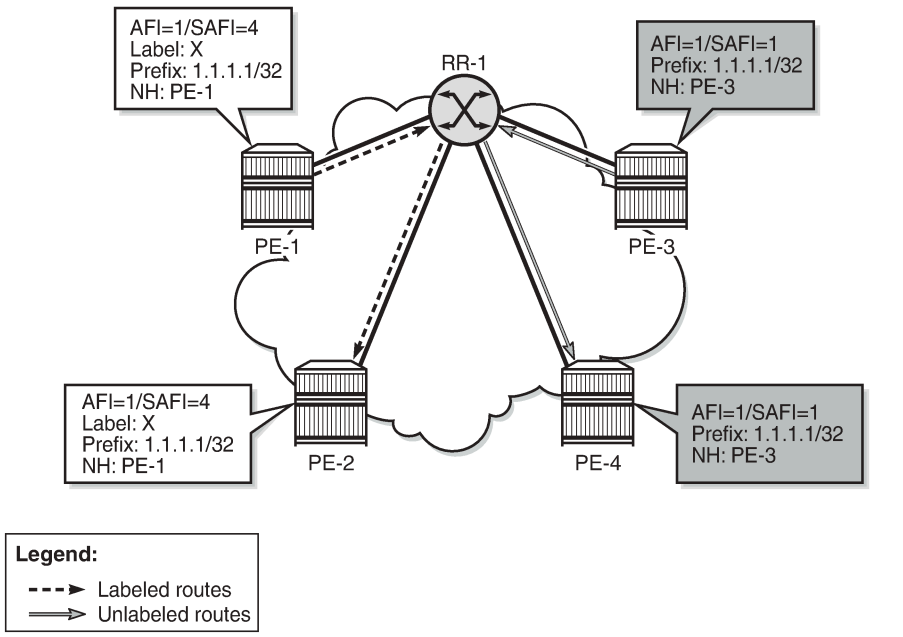
Release 14.0.R4 introduced separate BGP RIBs for labeled-unicast routes.

Overview

BGP separate labeled-IPv4 RIB implementation

Figure 135: RR-1 with separate labeled-IPv4 RIB implementation shows how RR-1 sends a labeled-IPv4 route to PE-2 with label X and next hop PE-1.

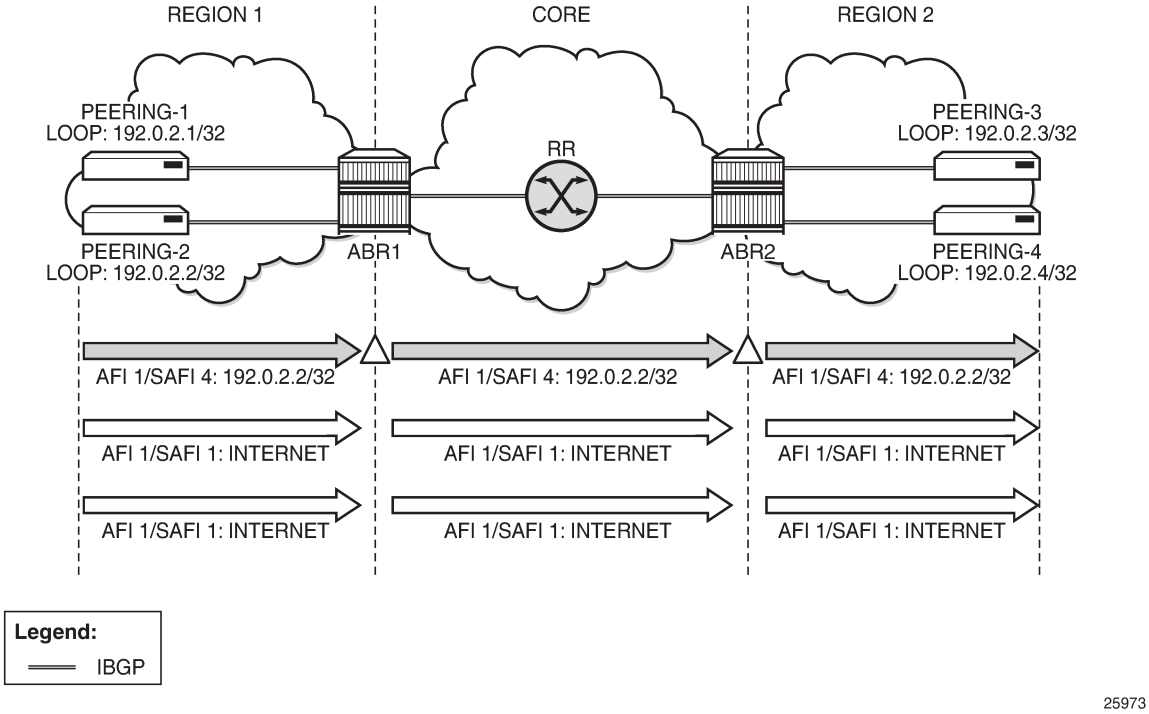
Figure 135: RR-1 with separate labeled-IPv4 RIB implementation



In SR OS Release 14.0.R4, and later, a separate RIB is used for labeled-IPv4 routes. With this implementation, client PE-2 learns the best labeled-IPv4 route and client PE-4 learns the best unlabeled IPv4 route. RR-1 does not need to set next-hop-self and traffic can be sent directly from PE-2 to PE-1 and from PE-4 to PE-3. The RR is used only for control traffic, as intended.

Figure 136: Seamless MPLS - Separate labeled-IPv4 implementation shows a seamless MPLS use case, which is a good example of the coexistence of labeled (AFI 1/SAFI 4) and unlabeled (AFI 1/SAFI 1) BGP sessions.

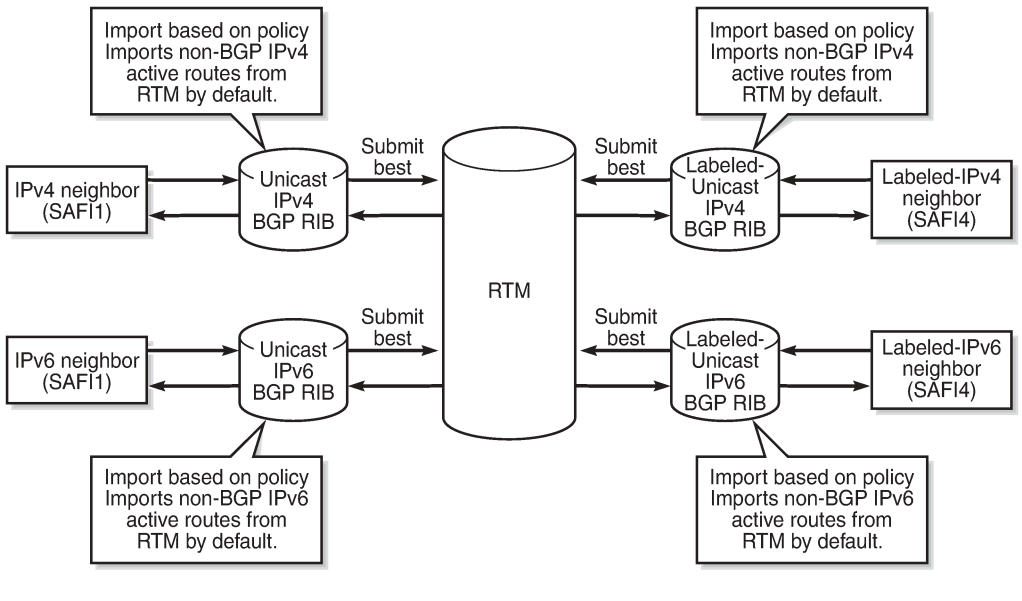
Figure 136: Seamless MPLS - Separate labeled-IPv4 implementation



RIB architecture

Figure 137: System architecture with separate RIBs for labeled-unicast and unlabeled routes shows the system architecture with four separate RIBs for IPv4 and IPv6 routes.

Figure 137: System architecture with separate RIBs for labeled-unicast and unlabeled routes



Labeled-unicast routes from peers are stored in a labeled RIB and unlabeled routes from the same or different peers are stored in a non-labeled RIB. Both labeled and unlabeled routes can be sent and received to and from the same peer. Different sets of routes can be advertised to labeled/unlabeled peers. Labeled and unlabeled BGP sessions are using the common equal cost multipath (ECMP) and multipath limit.

More user control is provided over the RTM route import process. By default, a RIB imports all non-BGP active routes from RTM, but a user-defined route policy can be applied. Route policies can be used to reduce BGP memory usage.

The address families mapped to the RIBs are: **ipv4, label-ipv4, ipv6, label-ipv6**. In route policies, protocol types **bgp** and **bgp-label** can be used.

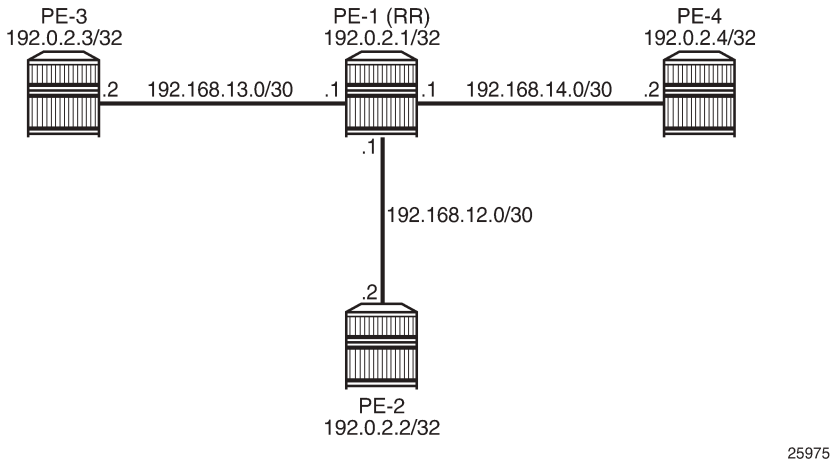
The default RTM preference for labeled IP routes is configurable (**label-preference**) in the **bgp** context of the base router or a VPRN. The default preference is 170.

Configuration

All the examples are based on labeled and unlabeled IPv4 addresses. For IPv6, the configuration is similar.

Figure 138: Example IPv4 topology shows the example topology using IPv4 addresses.

Figure 138: Example IPv4 topology



The initial configuration includes:

- Cards, MDAs, ports
- Router interfaces
- IS-IS in AS 64500 (PE-1, PE-2, PE-4)
- LDP in AS 64500
- Loopback addresses 3.3.3.3/32 in PE-3 and 4.4.4.4/32 in PE-4
- Export policy "export-bgp" accepting routes from protocol direct on all nodes
- Import policy "import-bgp" accepting BGP routes on PE-1

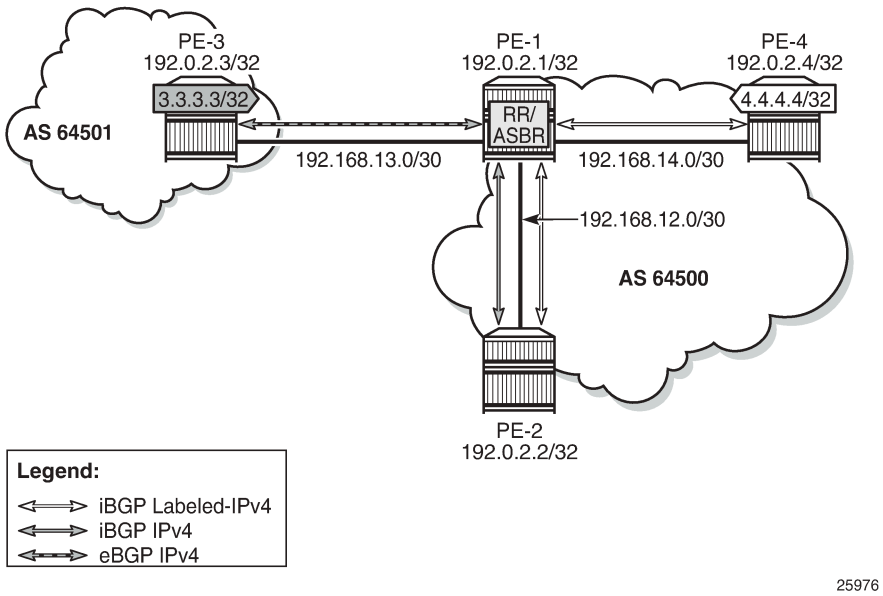
The following will be configured and verified:

1. Coexistence of labeled and unlabeled address families for BGP
2. Applying next-hop-self
3. Export policy to advertise route as labeled/unlabeled
4. Behavior of RR with a mix of labeled and unlabeled iBGP sessions

Coexistence of labeled and unlabeled address families for BGP

Figure 139: BGP sessions shows the eBGP and iBGP sessions that are established between the nodes and the routes advertised for the loopback addresses.

Figure 139: BGP sessions



PE-1 acts as RR for PE-2 and PE-4, and it is an autonomous system border router (ASBR) toward PE-3. PE-1 has two single-family connections: unlabeled IPv4 to PE-3 and labeled IPv4 to PE-4. PE-1 also has one dual-family connection to PE-2. The BGP configuration on PE-1 is as follows:

```
# on PE-1:
configure {
    router "Base" {
        autonomous-system 64500
        bgp {
            split-horizon true
            group "eBGP" {
                peer-as 64501
                import {
                    policy ["import-bgp"]
                }
            }
            group "iBGP" {
                peer-as 64500
                cluster {
                    cluster-id 192.0.2.1
                }
                export {
                    policy ["export-bgp"]
                }
            }
            neighbor "192.0.2.2" {
                group "iBGP"
                family {
                    ipv4 true
                    label-ipv4 true
                }
            }
            neighbor "192.168.13.2" {
                group "eBGP"
                family {
                    ipv4 true
```

```
                }
            }
            neighbor "192.0.2.4" {
                group "iBGP"
                family {
                    label-ipv4 true
                }
            }
```

The BGP configuration on PE-2 is as follows:

```
# on PE-2:
configure {
    router "Base" {
        autonomous-system 64500
        bgp {
            split-horizon true
            group "iBGP" {
                peer-as 64500
                export {
                    policy ["export-bgp"]
                }
            }
            neighbor "192.0.2.1" {
                group "iBGP"
                family {
                    ipv4 true
                    label-ipv4 true
                }
            }
```

The BGP configuration on PE-3 in AS 64501 is as follows:

```
# on PE-3:
configure {
    router "Base" {
        autonomous-system 64501
        bgp {
            split-horizon true
            export {
                policy ["export-bgp"]
            }
            group "eBGP" {
                peer-as 64500
            }
            neighbor "192.168.13.1" {
                group "eBGP"
                family {
                    ipv4 true
                }
            }
        }
```

The BGP configuration on PE-4 is as follows:

```
# on PE-4:
configure {
    router "Base" {
        autonomous-system 64500
        bgp {
            split-horizon true
            group "iBGP" {
```

```
                peer-as 64500
                export {
                    policy ["export-bgp"]
                }
            }
            neighbor "192.0.2.1" {
                group "iBGP"
                family {
                    label-ipv4 true
                }
            }
```

The BGP summary on PE-1 shows that there is a dual-family connection with PE-2: IPv4 and Lbl-IPv4. PE-1 has an Lbl-IPv4 connection with PE-4 and an IPv4 connection with PE-3.

```
[]
A:admin@PE-1# show router bgp summary all

===============================================================================
BGP Summary
===============================================================================
Legend : D - Dynamic Neighbor
===============================================================================
Neighbor
Description
ServiceId
                  AS PktRcvd InQ  Up/Down   State|Rcv/Act/Sent (Addr Family)
                     PktSent OutQ
-------------------------------------------------------------------------------
192.0.2.2
Def. Instance  64500        5    0 00h00m25s 2/0/6 (IPv4)
                            8    0           2/0/5 (Lbl-IPv4)
192.0.2.4
Def. Instance  64500        5    0 00h00m32s 3/1/4 (Lbl-IPv4)
                            7    0
192.168.13.2
Def. Instance  64501        5    0 00h00m43s 3/2/0 (IPv4)
                            5    0
-------------------------------------------------------------------------------
```

The unlabeled IPv4 routes on PE-1 include unlabeled routes imported from PE-2 and PE-3, including the loopback address 3.3.3.3/32 advertised by PE-3, as follows:

```
[]
A:admin@PE-1# show router bgp routes ipv4
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.3.3.3/32                                       None        None
      192.168.13.2                                     None        0
```

```
      64501                                                          -
*i    192.0.2.2/32                                        100        None
      192.0.2.2                                           None       10
      No As-Path                                                     -
u*>i  192.0.2.3/32                                        None       None
      192.168.13.2                                        None       0
      64501                                                          -
*i    192.168.12.0/30                                     100        None
      192.0.2.2                                           None       10
      No As-Path                                                     -
*i    192.168.13.0/30                                     None       None
      192.168.13.2                                        None       0
      64501                                                          -
-------------------------------------------------------------------------------
Routes : 5
===============================================================================
```

The labeled-unicast IPv4 routes on PE-1 include labeled routes imported from PE-2 and PE-4, including the loopback address 4.4.4.4/32 advertised by PE-4, as follows:

```
[]
A:admin@PE-1# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                             LocalPref   MED
      Nexthop (Router)                                    Path-Id     IGP Cost
      As-Path                                                         Label
-------------------------------------------------------------------------------
u*>i  4.4.4.4/32                                          100         None
      192.0.2.4                                           None        10
      No As-Path                                                      524284
*i    192.0.2.2/32                                        100         None
      192.0.2.2                                           None        10
      No As-Path                                                      524285
*i    192.0.2.4/32                                        100         None
      192.0.2.4                                           None        10
      No As-Path                                                      524284
*i    192.168.12.0/30                                     100         None
      192.0.2.2                                           None        10
      No As-Path                                                      524285
*i    192.168.14.0/30                                     100         None
      192.0.2.4                                           None        10
      No As-Path                                                      524284
-------------------------------------------------------------------------------
Routes : 5
===============================================================================
```

PE-2 imports the prefix 3.3.3.3/32 in its unlabeled RIB, as follows:

```
[]
A:admin@PE-2# show router bgp routes 3.3.3.3/32
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
```

```
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.3.3.3/32                                       100         None
      192.168.13.2                                     None        20
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

PE-2 imports the prefix 4.4.4.4/32 in its labeled RIB, as follows:

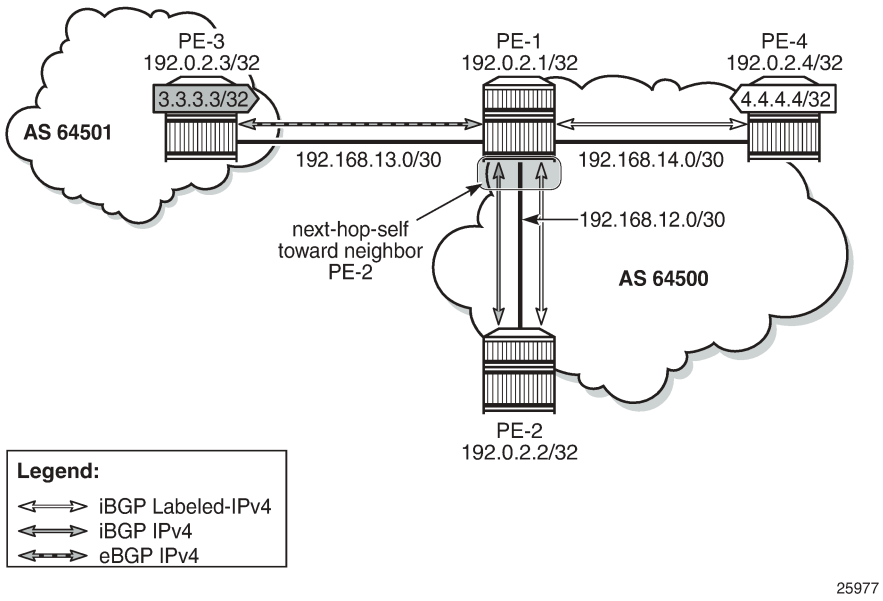
```
[]
A:admin@PE-2# show router bgp routes 4.4.4.4/32 label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  4.4.4.4/32                                       100         None
      192.0.2.4                                        None        20
      No As-Path                                                   524284
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

As expected, the prefixes from address family label-ipv4 are advertised independently from the prefixes from address family ipv4.

Applying next-hop-self

Figure 140: PE-1 applies next-hop-self toward neighbor PE-2 shows that PE-1 applies next-hop-self for BGP updates toward PE-2.

Figure 140: PE-1 applies next-hop-self toward neighbor PE-2



On PE-1, next-hop-self is enabled for neighbor PE-2 only, as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            neighbor 192.0.2.2 {
                next-hop-self true
            }
```

This applies to both address families. The next hop for unlabeled route 3.3.3.3/32 will be 192.0.2.1, as follows:

```
[]
A:admin@PE-2# show router bgp routes 3.3.3.3/32
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.3.3.3/32                                       100         None
      192.0.2.1                                        None        10
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 1
```

```
===============================================================================
```

The labeled-unicast route 4.4.4.4/32 also has next hop 192.0.2.1, as follows:

```
[]
A:admin@PE-2# show router bgp routes 4.4.4.4/32 label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete
===============================================================================
BGP Routes
===============================================================================
Flag  Network                                              LocalPref   MED
      Nexthop (Router)                                     Path-Id     IGP Cost
      As-Path                                                          Label
-------------------------------------------------------------------------------
u*>i  4.4.4.4/32                                           100         None
      192.0.2.1                                            None        10
      No As-Path                                                       524283
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

On PE-1, the next-hop-self configuration for neighbor PE-2 is removed as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            neighbor 192.0.2.2 {
                delete next-hop-self
            }
```

An export policy is configured to ensure that next-hop-self is only applied for address family ipv4. The route policy is configured as follows:

```
# on PE-1:
configure {
    policy-options {
        policy-statement "export-nhs" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                    next-hop self
                }
            }
            entry 20 {
                from {
                    protocol {
                        name [bgp-label]
                    }
                }
                action {
```

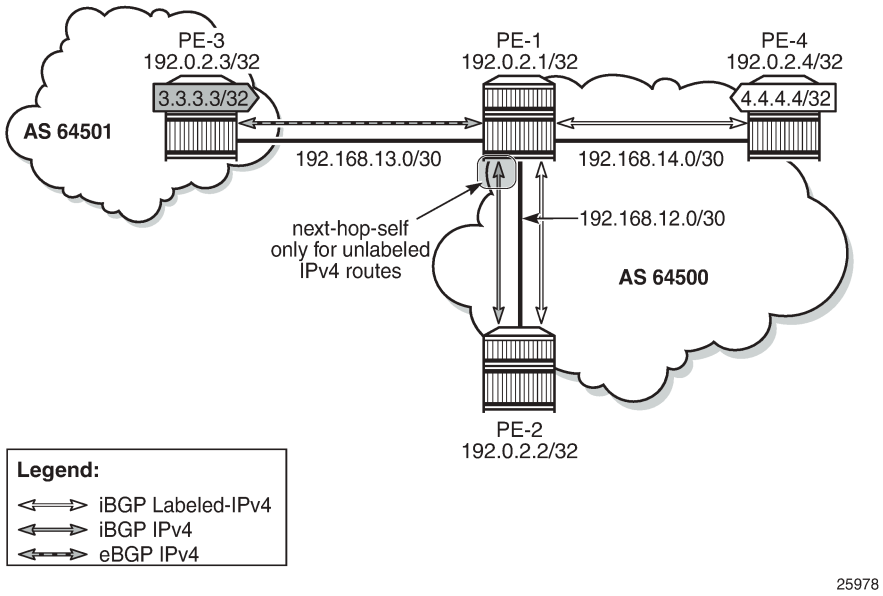
```
                    action-type accept
                }
            }
        }
```

On PE-1, the export policy "export-nhs" is configured for neighbor PE-2:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            neighbor "192.0.2.2" {
                export {
                    policy ["export-nhs"]
                }
            }
```

Figure 141: Applying next-hop-self to unlabeled IP-4 routes to neighbor PE-2 shows that next-hop-self is applied to unlabeled IPv4 routes only.

Figure 141: Applying next-hop-self to unlabeled IP-4 routes to neighbor PE-2



With this export policy, only the unlabeled route 3.3.3.3/32 will have next hop 192.0.2.1, while the labeled-unicast route 4.4.4.4/32 will have next hop 192.0.2.4, as follows:

```
[]
A:admin@PE-2# show router bgp routes 3.3.3.3/32
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
```

```
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  3.3.3.3/32                                       100         None
      192.0.2.1                                        None        10
      64501                                                        -
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

```
[]
A:admin@PE-2# show router bgp routes 4.4.4.4/32 label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete
===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  4.4.4.4/32                                       100         None
      192.0.2.4                                        None        20
      No As-Path                                                   524284
-------------------------------------------------------------------------------
Routes : 1
===============================================================================
```

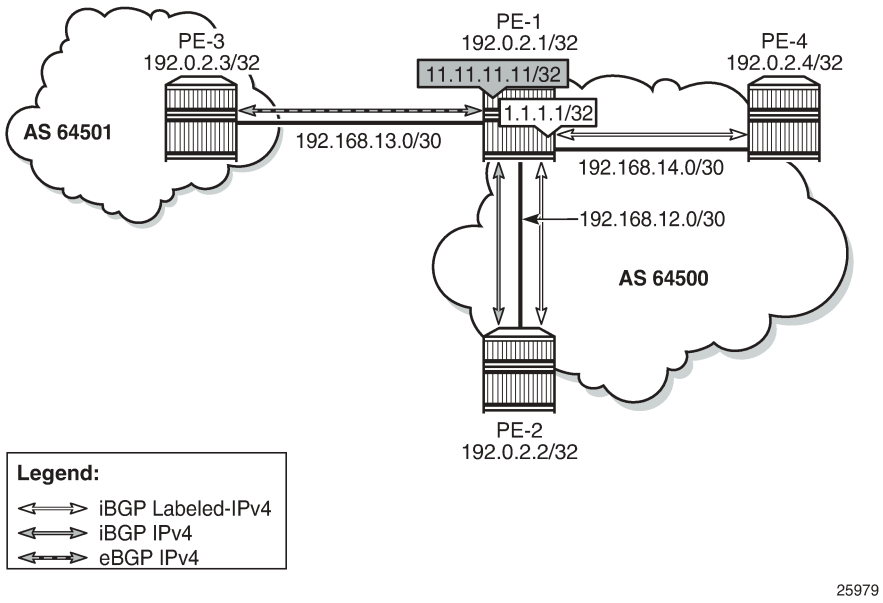
The export policy "export-nhs" toward neighbor PE-2 is removed as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            neighbor "192.0.2.2" {
                delete export
            }
```

Export policy to advertise route as labeled/unlabeled

Figure 142: PE-1 advertises prefixes 1.1.1.1/32 and 11.11.11.11/32 shows that two loopback addresses are configured in PE-1 to be advertised: prefix 1.1.1.1/32 and 11.11.11.11/32. Initially, there is no route policy applied for a selective export as labeled or unlabeled route.

Figure 142: PE-1 advertises prefixes 1.1.1.1/32 and 11.11.11.11/32



By default, these prefixes will be advertised as both labeled and unlabeled routes toward dual-family neighbor PE-2. On PE-2, the unlabeled IPv4 RIB contains prefixes 1.1.1.1/32 and 11.11.11.11/32, as follows:

```
[]
A:admin@PE-2# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
u*>i  1.1.1.1/32                                        100         None
      192.0.2.1                                         None        10
      No As-Path                                                    -
---snip---
u*>i  11.11.11.11/32                                    100         None
      192.0.2.1                                         None        10
      No As-Path                                                    -
---snip---
```

The labeled-IPv4 RIB on PE-2 also contains prefixes 1.1.1.1/32 and 11.11.11.11/32, as follows:

```
[]
A:admin@PE-2# show router bgp routes label-ipv4
```

```
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                              LocalPref   MED
      Nexthop (Router)                                     Path-Id     Label
      As-Path
-------------------------------------------------------------------------------
*>i   1.1.1.1/32                                           100         None
      192.0.2.1                                            None        10
      No As-Path                                                       524285
---snip---
*>i   11.11.11.11/32                                       100         None
      192.0.2.1                                            None        10
      No As-Path                                                       524285
---snip---
```

In many cases, it is not required to advertise both a labeled route and an unlabeled route. The following policy is configured to advertise prefix 1.1.1.1/32 as a labeled-IPv4 route and prefix 11.11.11.11/32 as an unlabeled IPv4 route:

```
# on PE-1:
configure {
    policy-options {
        prefix-list "1.1.1.1/32" {
            prefix 1.1.1.1/32 type exact {
            }
        }
        prefix-list "11.11.11.11/32" {
            prefix 11.11.11.11/32 type exact {
            }
        }
        policy-statement "export-bgp1" {
            entry 10 {
                from {
                    prefix-list ["1.1.1.1/32"]
                }
                to {
                    protocol {
                        name [bgp-label]
                    }
                }
                action {
                    action-type accept
                }
            }
            entry 20 {
                from {
                    prefix-list ["11.11.11.11/32"]
                }
                to {
                    protocol {
                        name [bgp]
                    }
                }
                action {
```

```
                    action-type accept
                }
            }
            default-action {
                action-type reject
            }
```

This policy is applied on PE-1 as an export policy for neighbor PE-2, as follows:

```
# on PE-1:
configure {
    router "Base" {
        bgp {
            neighbor 192.0.2.2 {
                export {
                    policy ["export-bgp1"]
                }
            }
```

Prefix 11.11.11.11/32 is received as an unlabeled route on PE-2 and stored in the unlabeled RIB, but prefix 1.1.1.1/32 is not, as follows:

```
[]
A:admin@PE-2# show router bgp routes
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  11.11.11.11/32                                   100         None
      192.0.2.1                                        None        10
      No As-Path                                                   -
-------------------------------------------------------------------------------
Routes : 1
```

On PE-2, prefix 1.1.1.1/32 is received as a labeled route and stored in the labeled-IPv4 RIB, but prefix 11.11.11.11/32 is not, as follows:

```
[]
A:admin@PE-2# show router bgp routes label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
```

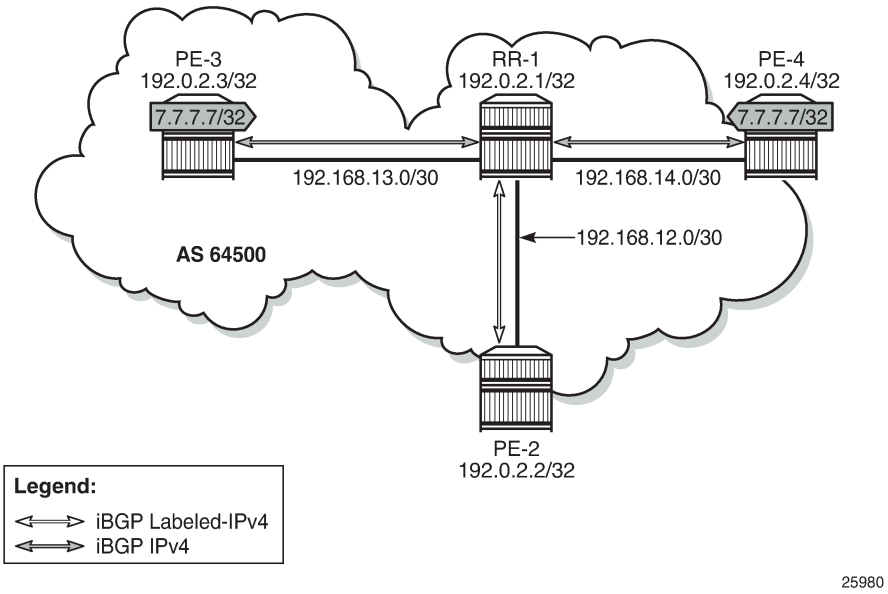
```
Flag  Network                                              LocalPref   MED
      Nexthop (Router)                                     Path-Id     IGP Cost
      As-Path                                                          Label
-------------------------------------------------------------------------------
u*>i  1.1.1.1/32                                           100         None
      192.0.2.1                                            None        10
      No As-Path                                                       524285
-------------------------------------------------------------------------------
Routes : 1
```

This selective route advertisement from PE-1 reduces the memory usage for the RIBs on PE-2.

RR behavior with a mix of labeled and unlabeled BGP sessions

Figure 143: RR with labeled and unlabeled BGP sessions shows a slightly different setup, with all PEs in the AS 64500 and RR-1 acting as the RR for all PEs. There are no dual-family connections. PE-3 and PE-4 have an unlabeled BGP session with RR-1 and PE-2 has a labeled BGP connection with RR-1. RR-1 has add-path=2 capability configured for neighbor PE-2. RR-1 receives the same prefix 7.7.7.7/32 from two neighbors: PE-3 and PE-4.

Figure 143: RR with labeled and unlabeled BGP sessions



On RR-1, BGP is configured as follows:

```
# on RR-1:
configure {
    router "Base" {
        bgp {
            split-horizon true
            group "iBGP" {
                peer-as 64500
                cluster {
                    cluster-id 192.0.2.1
                }
                export {
```

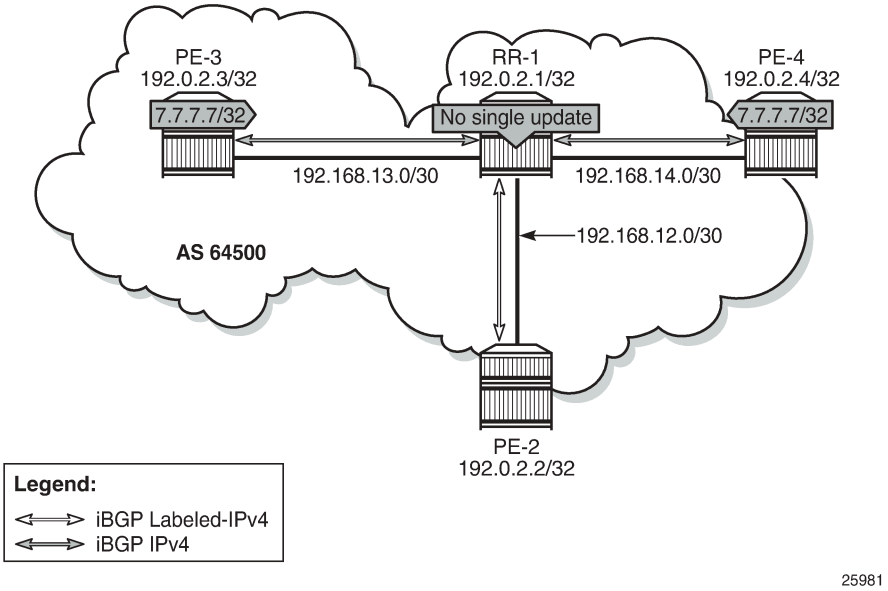
```
                    policy ["export-bgp"]
                }
            }
            neighbor "192.0.2.2" {
                group "iBGP"
                family {
                    label-ipv4 true
                }
                add-paths {
                    label-ipv4 {
                        send 2
                        receive true
                    }
                }
            }
            neighbor "192.0.2.3" {
                group "iBGP"
                family {
                    ipv4 true
                }
            }
            neighbor "192.0.2.4" {
                group "iBGP"
                family {
                    ipv4 true
                }
            }
```

RR-1 receives the prefix 7.7.7.7/32 from neighbors PE-3 and PE-4, as follows:

```
[]
A:admin@RR-1# show router bgp routes 7.7.7.7/32
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  7.7.7.7/32                                       100         None
      192.0.2.3                                        None        10
      No As-Path                                                   -
*i    7.7.7.7/32                                       100         None
      192.0.2.4                                        None        10
      No As-Path                                                   -
-------------------------------------------------------------------------------
Routes : 2
```

Both routes are unlabeled and BGP updates from unlabeled sessions are by default not exported to a labeled-IPv4 session, as shown in Figure 144: Updates from unlabeled sessions not propagated to labeled sessions (default).

Figure 144: Updates from unlabeled sessions not propagated to labeled sessions (default)



PE-2 will not receive prefix 7.7.7.7/32, neither as unlabeled route, nor as labeled route, as follows:

```
[]
A:admin@PE-2# show router bgp routes 7.7.7.7/32 ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
No Matching Entries Found
===============================================================================
```

```
[]
A:admin@PE-2# show router bgp routes 7.7.7.7/32 label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
```

```
      Nexthop (Router)                                    Path-Id     IGP Cost
      As-Path                                                         Label
-------------------------------------------------------------------------------
No Matching Entries Found
===============================================================================
```

A route policy is created on RR-1 to accept both labeled and unlabeled routes, as follows:

```
# on RR-1:
configure {
    policy-options {
        policy-statement "import-all" {
            entry 10 {
                from {
                    protocol {
                        name [bgp]
                    }
                }
                action {
                    action-type accept
                }
            }
            entry 20 {
                from {
                    protocol {
                        name [bgp-label]
                    }
                }
                action {
                    action-type accept
                }
            }
```

This policy accepts all routes, labeled and unlabeled. For route 7.7.7.7/32 to be advertised to the labeled peer PE-2, it is sufficient to have a policy with only entry 10 that says from protocol bgp action accept. However, the preceding policy can also be used to import labeled routes to be advertised to unlabeled peers.

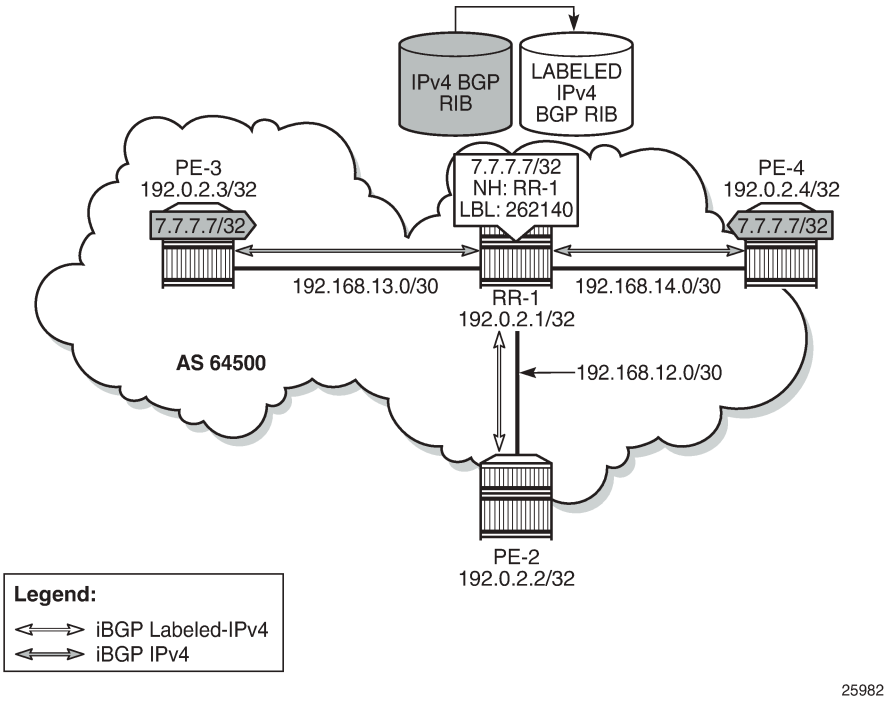
The following policy is applied as route-table-import policy in BGP RIB management, both for unlabeled IPv4 routes and labeled-IPv4 routes on RR-1:

```
# on RR-1:
configure {
    router "Base" {
        bgp {
            rib-management {
                ipv4 {
                    route-table-import {
                        policy-name "import-all"
                    }
                }
                label-ipv4 {
                    route-table-import {
                        policy-name "import-all"
                    }
                }
            }
```

For allowing unlabeled route 7.7.7.7/32 to be advertised on a labeled session, it is sufficient to have a route-table-import for labeled-IPv4 only. However, the configuration allows for RIB leaking in both ways: from unlabeled IPv4 BGP RIB to labeled-IPv4 BGP RIB and vice versa.

Figure 145: RIB leaking from IPv4 BGP RIB to labeled-IPv4 BGP RIB shows this RIB leaking process.

Figure 145: RIB leaking from IPv4 BGP RIB to labeled-IPv4 BGP RIB



After applying this RIB leaking, RR-1 will advertise prefix 7.7.7.7/32 to PE-2. Therefore, RR-1 needs to add a label to the route and RR-1 needs to set next-hop-self. RR-1 advertises only one labeled route for prefix 7.7.7.7/32, with next hop 192.0.2.1, as follows:

```
[]
A:admin@RR-1# show router bgp neighbor 192.0.2.2 label-ipv4 advertised-routes
===============================================================================
 BGP Router ID:192.0.2.1        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                           LocalPref   MED
      Nexthop (Router)                                  Path-Id     IGP Cost
      As-Path                                                       Label
-------------------------------------------------------------------------------
i     7.7.7.7/32                                        100         None
      192.0.2.1                                         None        n/a
      No As-Path                                                    524282
---snip---
```

The BGP update message is as follows:

```
4 2020/01/15 13:41:23.925 UTC MINOR: DEBUG #2001 Base Peer 1: 192.0.2.2
"Peer 1: 192.0.2.2: UPDATE
```

```
Peer 1: 192.0.2.2 - Send BGP UPDATE:
    Withdrawn Length = 0
    Total Path Attr Length = 49
    Flag: 0x90 Type: 14 Len: 17 Multiprotocol Reachable NLRI:
       Address Family LBL-IPV4
       NextHop len 4 NextHop 192.0.2.1
       7.7.7.7/32 Label 524282
    Flag: 0x40 Type: 1 Len: 1 Origin: 0
    Flag: 0x40 Type: 2 Len: 0 AS Path:
    Flag: 0x40 Type: 5 Len: 4 Local Preference: 100
    Flag: 0x80 Type: 9 Len: 4 Originator ID: 192.0.2.3
    Flag: 0x80 Type: 10 Len: 4 Cluster ID:
        192.0.2.1
"
```

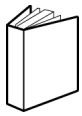
On PE-2, the following labeled BGP route is imported:

```
[]
A:admin@PE-2# show router bgp routes 7.7.7.7/32 label-ipv4
===============================================================================
 BGP Router ID:192.0.2.2        AS:64500       Local AS:64500
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
                 l - leaked, x - stale, > - best, b - backup, p - purge
 Origin codes  : i - IGP, e - EGP, ? - incomplete

===============================================================================
BGP Routes
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop (Router)                                 Path-Id     IGP Cost
      As-Path                                                      Label
-------------------------------------------------------------------------------
u*>i  7.7.7.7/32                                       100         None
         192.0.2.1                                        None        10
         No As-Path                                                   524282
-------------------------------------------------------------------------------
Routes : 1
```

Conclusion

The BGP RIB architecture with separate RIBs for unlabeled and labeled-unicast routes supports unlabeled sessions and labeled sessions in parallel. By default, labeled routes are not advertised to unlabeled sessions and vice versa. Route-table import policies for RIB management allow route leaking between separate RIBs: unlabeled BGP RIB and labeled-unicast BGP RIB.

Customer document and product support



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