Routed CO

In This Chapter

This section provides information about Routed Central Office (Routed CO) configurations.

Topics in this section include:

Applicability

This example is applicable to the 7750 SR and SR-c series as well as the 7450 ESS series in mixed mode and was tested on SR-OS 11.0.R4. Chassis mode C or higher must be used.

Summary

In the Routed Central Office (Routed CO) model, subscriber management features are implemented on a Layer 3 subscriber interface, available in a VPRN or an IES service. Compared to regular Layer 3 interfaces, a subscriber-interface supports multiple SAP's, see later.

Customer originated traffic enters an Access Node (AN) and can be aggregated via either a Layer 2 or a Layer 3 aggregation network before being handled by a Broadband Network Gateway (BNG). Alternatively, an AN can be directly connected to the BNG.

Routed CO supports numbered, unnumbered and hybrid (combined numbered/unnumbered) subscriber interface configurations.

Enhanced Subscriber Management (ESM) is not mandatory for IPoEv4 in Routed CO, but is mandatory for PPPoE and all IPoEv6 scenarios.

The numbered and unnumbered scenarios in this example use an IES service with:

- Dual Stack IPoEv4 + IPoEv6
- Single stack PPPoEv4

General knowledge of Alcatel-Lucent's Triple Play Service Delivery Architecture is assumed throughout this section. Refer to the 7x50 SR OS Triple Play Guide.

Overview

The Routed CO model offers through the subscriber and group interface construct:

- Flexible subnet management
  → Subnets can be shared across multiple access nodes.
- Support for different deployment models, for example:
  → VLAN/service model.
  → VLAN/subscriber model.
  → VLAN/service/subscriber model.
  → VLAN/access node model.
- Per group-interface load balancing in multi-chassis redundancy configurations. Redundancy is out of the scope of this example.

The components needed in the Routed CO model are depicted in Figure 407.

For the Routed CO model two interface types are needed:

- First, one or more subscriber interfaces must be created.
- Second, one or more group interfaces must be created within the subscriber interface context.

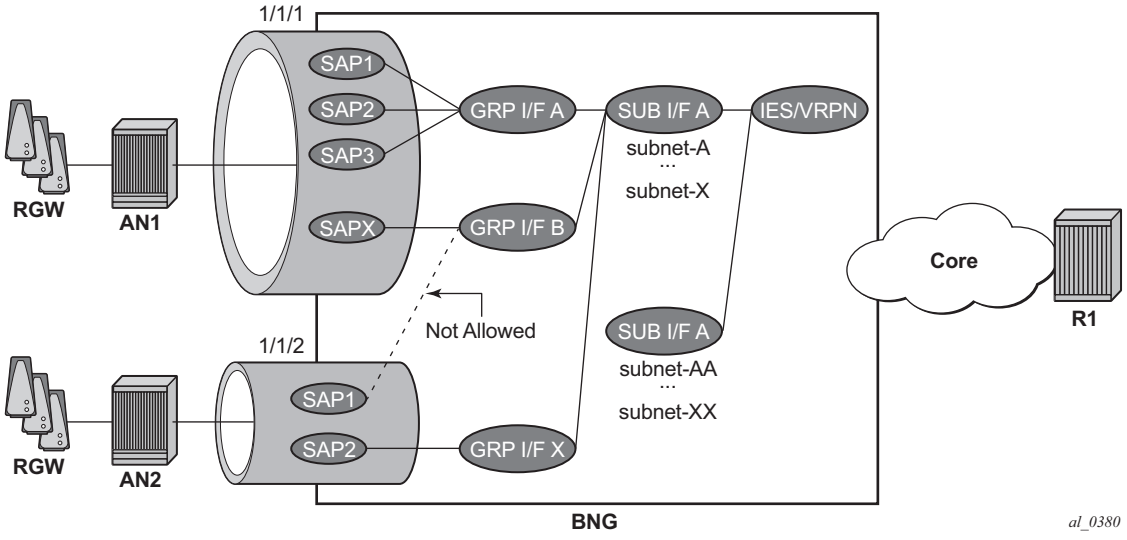

Figure 407: Components of the Routed CO Model

Subscriber Interface

A subscriber interface is a set of one or more group interfaces and identified by name.

A subscriber interface is created under an IES or VPRN service context, and supports up to 256 subnets (sum of IPv4 subnets and IPv6 prefixes).

Three types of subscriber interface configurations are available:

- Numbered subscriber interface.
- Unnumbered subscriber interface.
- Hybrid subscriber interface (numbered and unnumbered combined).

Subnet/Prefix Assignment

For the numbered scenario, the subscriber interface is configured with

- One or more IPv4 subnets.
- One or more IPv6 subscriber prefixes:
  - → For WAN-hosts, using the DHCPv6 Identity Association for Non-temporary Addresses (IA_NA) option or Stateless Address Auto Configuration (SLAAC) and the prefix length is /64.
  - → For Prefix Delegation-hosts (PD-hosts), using the DHCPv6 Identity Association for Prefix Delegation (IA_PD) option and the prefix length is defined by the Delegated Prefix Length (DPL).

This allows for subscriber-host address assignment in these subnets/prefixes only.

For the unnumbered scenario, the subscriber interface is configured with:

- IPv4:
  - → No IPv4 subnets.
  - → The keyword **unnumbered** plus an interface in the same routing instance (for example the system interface). The IP address of the interface referenced in the unnumbered command is used in IPCP negotiation.
- IPv6:
  - → No IPv6 prefixes.
  - → **allow-unmatching-prefixes**.

This allows for subscriber-host address assignment in any subnet/prefix. For IPv4, the keywords **unnumbered** and **allow-unmatching-subnets** are mutually exclusive.

For the hybrid scenario the subscriber interface is configured with:

- One or more IPv4 subnets and/or IPv6 subscriber prefixes.
- For IPv4: the keyword **allow-unmatching-subnets**.
- For IPv6: the keyword **allow-unmatching-prefixes**.

This allows for both subscriber-host address assignment within and outside of these subnets/prefixes.

Host IP Reachability

For the numbered scenario, host IP reachability requires:

- Adding the subscriber interfaces to the Interior Gateway Protocol (IGP).
- Or an export policy matching the subscriber interface subnets/prefixes.

For the unnumbered scenario, host IP reachability requires:

- An export policy matching the addresses of all individual subscriber hosts (from protocol sub-mgmt).

For the hybrid scenario, host IP reachability requires:

- An export policy matching both the subscriber interface subnets/prefixes as well as all individual subscriber hosts addresses.

Detailed examples of numbered/unnumbered/hybrid scenarios, including host IP reachability are included below.

Group Interface

A group interface is a set of one or more SAPs belonging to the same port and identified by name.

Configuration

This section covers:

- The definition of subscriber and group interfaces.
- A description of the numbered, unnumbered and hybrid scenarios.
- Options ensuring host IP reachability throughout the network.

Subscriber Interface

The configuration of the subscriber interface appears as follows.

```
configure
    service
        ies 1
            subscriber-interface "sub-int-1" create
                address 10.1.1.254/24
                address 10.1.2.254/24
                ipv6
                    delegated-prefix-len 56
                    link-local-address FE80::EA:48:FF
                    subscriber-prefixes
                        prefix 2001:DB8:101::/48 wan-host
                        prefix 2001:DB8:102::/48 pd
                        prefix 2001:DB8:F101::/48 wan-host
                        prefix 2001:DB8:F102::/48 pd
                    exit
                exit
            exit
            subscriber-interface "sub-int-2" create
                address 10.2.1.254/24
                address 10.2.2.254/24
                ipv6
                    delegated-prefix-len 56
                    link-local-address FE80::EA:48:FF
                    subscriber-prefixes
                        prefix 2001:DB8:201::/48 wan-host
                        prefix 2001:DB8:202::/48 pd
                        prefix 2001:DB8:F201::/48 wan-host
                        prefix 2001:DB8:F202::/48 pd
                    exit
                exit
            exit
```

Notice that once a subnet/prefix is assigned to a subscriber interface, the subnet/prefix is tied to that interface, meaning that the same subnet/prefix cannot be used on another subscriber interface or regular interface in the same routing instance. When using VPRN for the Routed CO model, overlapping subnets/prefixes are allowed when on different VPRN services.

As long as no group interfaces are configured within the subscriber interface context, the subscriber interfaces are in the operationally down state as shown in the following output. The subscriber-interfaces, sub-int-1 and sub-int-2, are operational down since no group-interfaces have been assigned at this stage.

```
*A:BNG# show router "Base" interface
===============================================================================
Interface Table (Router: Base)
===============================================================================
Interface-Name                   Adm          Opr(v4/v6)  Mode    Port/SapId
   IP-Address                                                    PfxState
-------------------------------------------------------------------------------
sub-int-1                        Up           Down/Down   IES Sub subscriber
   10.1.1.254/24                                                 n/a
   10.1.2.254/24                                                 n/a
   2001:DB8:101::/48                                             INACCESSIBLE
   2001:DB8:102::/48                                             INACCESSIBLE
   2001:DB8:F101::/48                                            INACCESSIBLE
   2001:DB8:F102::/48                                            INACCESSIBLE
   FE80::EA:48:FF/64                                             INACCESSIBLE
sub-int-2                        Up           Down/Down   IES Sub subscriber
   10.2.1.254/24                                                 n/a
   10.2.2.254/24                                                 n/a
   2001:DB8:201::/48                                             INACCESSIBLE
   2001:DB8:202::/48                                             INACCESSIBLE
   2001:DB8:F201::/48                                            INACCESSIBLE
   2001:DB8:F202::/48                                            INACCESSIBLE
   FE80::EA:48:FF/64                                             INACCESSIBLE
system                           Up           Up/Up       Network system
   192.0.2.75/32                                                 n/a
   2001:DB8::75/128                                              PREFERRED
toDHCP-1                         Up           Up/Up       Network loopback
   10.11.11.1/32                                                 n/a
   2001:DB8::11/128                                              PREFERRED
   FE80::E84B:FFFF:FE00:0/64                                     PREFERRED
toRADIUS-1                       Up           Up/Down     Network 1/1/10
   192.168.202.75/24                                             n/a
-------------------------------------------------------------------------------
Interfaces : 5
===============================================================================
*A:BNG#
```

The corresponding IPv4 routing table looks as follows.

```
*A:BNG# show router "Base" route-table ipv4
===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                            Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
10.11.11.1/32                                 Local   Local     00h30m12s  0
       toDHCP-1                                                       0
192.0.2.75/32                                 Local   Local     00h30m12s  0
       system                                                         0
192.168.202.0/24                              Local   Local     00h29m54s  0
       toRADIUS-1                                                     0
```

```
-------------------------------------------------------------------------------
No. of Routes: 3
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
*A:BNG#
```

The corresponding IPv6 routing table looks as follows.

```
*A:BNG# show router "Base" route-table ipv6
===============================================================================
IPv6 Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
2001:DB8::11/128                                Local   Local     00h30m19s  0
       toDHCP-1                                                        0
2001:DB8::75/128                                Local   Local     00h30m21s  0
       system                                                          0
-------------------------------------------------------------------------------
No. of Routes: 2
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
*A:BNG#
```

No subscriber interface subnets/prefixes are present in the IPv4 and the IPv6 routing table as the subscriber interfaces are operational down.

Group Interface

A group interface is created under the subscriber-interface hierarchy.

```
configure
    service
        ies 1
            subscriber-interface "sub-int-1" create
                group-interface "grp-int-1-1" create
                    ipv6
                    exit
                    sap 1/1/1:111 create
                    exit
                    sap 1/1/1:112 create
                    exit
                exit
                group-interface "grp-int-1-2" create
                    ipv6
                    exit
                    sap 1/1/1:121 create
                    exit
                exit
            exit
            subscriber-interface "sub-int-2" create
                group-interface "grp-int-2-1" create
                    ipv6
                    exit
                    sap 1/1/2:211 create
                    exit
                exit
                group-interface "grp-int-2-2" create
                    ipv6
                    exit
                    sap 1/1/3:221 create
                    exit
                    sap 1/1/3:222 create
                    exit
                exit
            exit
        exit
```

Static SAPs are created manually under the group-interface context. Managed SAPs (MSAPs) are dynamically created when a trigger packet (DHCP, DHCPv6, ARP, PPPoE) is successfully authenticated, which eliminates the provisioning of static SAPs. The creation and use of capture and managed SAPs (MSAPs) is explained in the example on Managed SAPs with Routed CO on page 2511.

A group interface is operationally up when at least one of its statically configured SAPs is operationally up or when no static SAPs are configured while the parameter **oper-up-while-empty** under the group-interface context is enabled. The following output shows all group interfaces are operationally up.

```
*A:BNG# show router "Base" interface ipv4
===============================================================================
Interface Table (Router: Base)
===============================================================================
Interface-Name                   Adm          Opr(v4/v6)  Mode    Port/SapId
   IP-Address                                                    PfxState
-------------------------------------------------------------------------------
grp-int-1-1                      Up           Up/Up       IES Grp 1/1/1
grp-int-1-2                      Up           Up/Up       IES Grp 1/1/1
grp-int-2-1                      Up           Up/Up       IES Grp 1/1/2
grp-int-2-2                      Up           Up/Up       IES Grp 1/1/3
sub-int-1                        Up           Up/Up       IES Sub subscriber
   10.1.1.254/24                                                 n/a
   10.1.2.254/24                                                 n/a
sub-int-2                        Up           Up/Up       IES Sub subscriber
   10.2.1.254/24                                                 n/a
   10.2.2.254/24                                                 n/a
system                           Up           Up/Up       Network system
   192.0.2.75/32                                                 n/a
toDHCP-1                         Up           Up/Up       Network loopback
   10.11.11.1/32                                                 n/a
toRADIUS-1                       Up           Up/Down     Network 1/1/10
   192.168.202.75/24                                             n/a
-------------------------------------------------------------------------------
Interfaces : 9
===============================================================================
*A:BNG#
```

The IPv4 routing table includes the subnets configured on the subscriber-interfaces.

```
*A:BNG# show router "Base" route-table ipv4
===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
10.1.1.0/24                                     Local   Local     00h25m32s  0
       sub-int-1                                                        0
10.1.2.0/24                                     Local   Local     00h25m32s  0
       sub-int-1                                                        0
10.2.1.0/24                                     Local   Local     00h25m32s  0
       sub-int-2                                                        0
10.2.2.0/24                                     Local   Local     00h25m32s  0
       sub-int-2                                                        0
10.11.11.1/32                                   Local   Local     01h01m53s  0
       toDHCP-1                                                         0
192.0.2.75/32                                   Local   Local     01h01m53s  0
       system                                                           0
192.168.202.0/24                                Local   Local     01h01m36s  0
       toRADIUS-1                                                       0
```

```
-------------------------------------------------------------------------------
No. of Routes: 7
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
*A:BNG#
```

For IPv6, the interface table looks as follows.

```
*A:BNG# show router "Base" interface ipv6
===============================================================================
Interface Table (Router: Base)
===============================================================================
Interface-Name                   Adm          Opr(v4/v6)  Mode    Port/SapId
   IP-Address                                                    PfxState
-------------------------------------------------------------------------------
grp-int-1-1                      Up           Up/Up       IES Grp 1/1/1
grp-int-1-2                      Up           Up/Up       IES Grp 1/1/1
grp-int-2-1                      Up           Up/Up       IES Grp 1/1/2
grp-int-2-2                      Up           Up/Up       IES Grp 1/1/3
sub-int-1                        Up           Up/Up       IES Sub subscriber
   2001:DB8:101::/48                                               PREFERRED
   2001:DB8:102::/48                                               PREFERRED
   2001:DB8:F101::/48                                              PREFERRED
   2001:DB8:F102::/48                                              PREFERRED
   FE80::EA:48:FF/64                                               PREFERRED
sub-int-2                        Up           Up/Up       IES Sub subscriber
   2001:DB8:201::/48                                               PREFERRED
   2001:DB8:202::/48                                               PREFERRED
   2001:DB8:F201::/48                                              PREFERRED
   2001:DB8:F202::/48                                              PREFERRED
   FE80::EA:48:FF/64                                               PREFERRED
system                           Up           Up/Up       Network system
   2001:DB8::75/128                                                PREFERRED
toDHCP-1                         Up           Up/Up       Network loopback
   2001:DB8::11/128                                                PREFERRED
   FE80::E84B:FFFF:FE00:0/64                                       PREFERRED
toRADIUS-1                       Up           Up/Down     Network 1/1/10
   -                                                               -
-------------------------------------------------------------------------------
Interfaces : 9
===============================================================================
*A:BNG# #
```

The IPv6 routing table includes the prefixes configured on the subscriber interfaces.

```
*A:BNG# show router "Base" route-table ipv6
===============================================================================
IPv6 Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
2001:DB8::11/128                                Local   Local     14d04h08m  0
       toDHCP-1                                                       0
2001:DB8::75/128                                Local   Local     14d04h08m  0
```

```
       system                                                       0
2001:DB8:101::/48                      Local   Local     14d03h10m  0
       sub-int-1                                                    0
2001:DB8:102::/48                      Local   Local     14d03h10m  0
       sub-int-1                                                    0
2001:DB8:201::/48                      Local   Local     14d03h08m  0
       sub-int-2                                                    0
2001:DB8:202::/48                      Local   Local     14d03h08m  0
       sub-int-2                                                    0
2001:DB8:F101::/48                     Local   Local     14d03h10m  0
       sub-int-1                                                    0
2001:DB8:F102::/48                     Local   Local     14d03h10m  0
       sub-int-1                                                    0
2001:DB8:F201::/48                     Local   Local     14d03h08m  0
       sub-int-2                                                    0
2001:DB8:F202::/48                     Local   Local     14d03h08m  0
       sub-int-2                                                    0
-------------------------------------------------------------------------------
No. of Routes: 10
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
*A:BNG#
```

Numbered Scenario

Figure 408 depicts the numbered scenario outlined below, including the connecting subscribers and subscriber hosts. Subscribers sub-11 and sub-44 are using PPPv4 hosts, and subscribers sub-22 and sub-33 are using dual stack DHCP hosts. Their VLANs and the MAC addresses are shown, as are the IP addresses and prefixes assigned once they are connected.

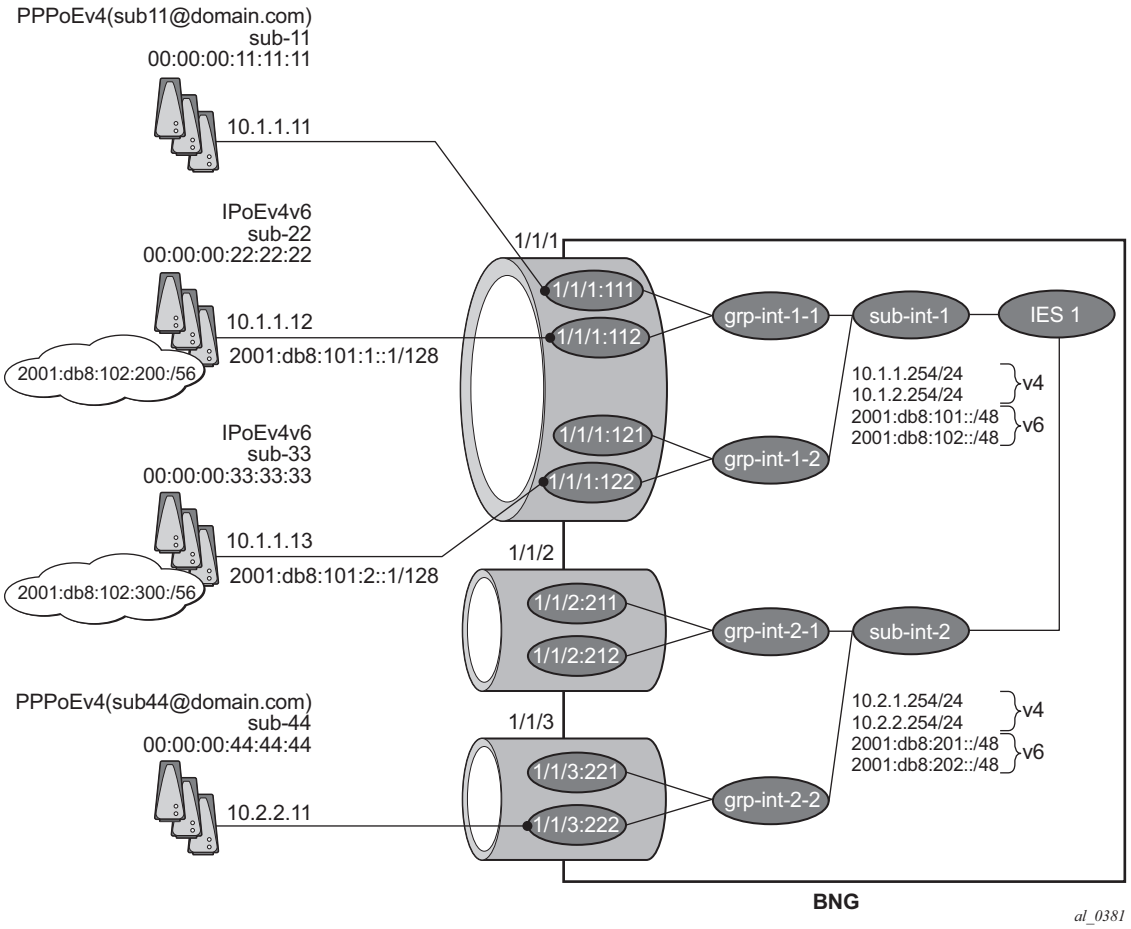

Figure 408: Numbered Scenario For IES 1

The configuration for the numbered scenario is shown below. Only the configuration items specific to the numbered scenario are shown.

In the numbered scenario the subscriber interfaces have following configuration:

- IPv4
  - → Subnets.
  - → **no allow-unmatching-subnets.**
  - → **no unnumbered.**
- IPv6
  - → A delegated prefix length.
  - → subscriber prefixes.
  - → **no allow-unmatching-prefixes.**

```
configure
    service
        ies 1
            subscriber-interface "sub-int-1" create
                address 10.1.1.254/24
                address 10.1.2.254/24
                ipv6
                    delegated-prefix-len 56
                    link-local-address FE80::EA:4B:FF
                    subscriber-prefixes
                        prefix 2001:DB8:101::/48 wan-host
                        prefix 2001:DB8:102::/48 pd
                    exit
                exit
                group-interface "grp-int-1-1" create
                    ipv6
                        --- snip ---
                    exit
                    arp-populate
                    dhcp
                        --- snip ---
                        lease-populate 100
                        no shutdown
                    exit
                    authentication-policy "auth-pol-1"
                    local-proxy-arp
                    sap 1/1/1:111 create
                        anti-spoof ip-mac
                        sub-sla-mgmt
                        --- snip ---
                        exit
                    exit
                    sap 1/1/1:112 create
                        anti-spoof ip-mac
                        sub-sla-mgmt
                        --- snip ---
                        exit
```

```
            exit
            pppoe
                --- snip ---
                no shutdown
            exit
        exit
        group-interface "grp-int-1-2" create
            ipv6
                --- snip ---
            exit
            arp-populate
            dhcp
                --- snip ---
                lease-populate 100
                no shutdown
            exit
            authentication-policy "auth-pol-1"
            local-proxy-arp
            sap 1/1/1:121 create
                anti-spoof ip-mac
                sub-sla-mgmt
                --- snip ---
                exit
            exit
            sap 1/1/1:122 create
                anti-spoof ip-mac
                sub-sla-mgmt
                --- snip ---
                exit
            exit
            pppoe
                --- snip ---
                no shutdown
            exit
        exit
    exit
    subscriber-interface "sub-int-2" create
        address 10.2.1.254/24
        address 10.2.2.254/24
        ipv6
            delegated-prefix-len 56
            link-local-address FE80::EA:4B:FF
            subscriber-prefixes
                prefix 2001:DB8:201::/48 wan-host
                prefix 2001:DB8:202::/48 pd
            exit
        exit
        group-interface "grp-int-2-1" create
            ipv6
                --- snip ---
            exit
            arp-populate
            dhcp
                --- snip ---
                lease-populate 100
                no shutdown
            exit
            authentication-policy "auth-pol-1"
            local-proxy-arp
```

```
            sap 1/1/2:211 create
                anti-spoof ip-mac
                sub-sla-mgmt
                --- snip ---
                exit
            exit
            sap 1/1/2:212 create
                anti-spoof ip-mac
                sub-sla-mgmt
                --- snip ---
                exit
            exit
            pppoe
                --- snip ---
                no shutdown
            exit
        exit
        group-interface "grp-int-2-2" create
            ipv6
                --- snip ---
            exit
            arp-populate
            dhcp
                --- snip ---
                lease-populate 100
                no shutdown
            exit
            authentication-policy "auth-pol-1"
            local-proxy-arp
            sap 1/1/3:221 create
                anti-spoof ip-mac
                sub-sla-mgmt
                --- snip ---
                exit
            exit
            sap 1/1/3:222 create
                anti-spoof ip-mac
                sub-sla-mgmt
                --- snip ---
                exit
            exit
            pppoe
                --- snip ---
                no shutdown
            exit
        exit
    exit
    no shutdown
```

The following parameters are mandatory for the routed CO model:

- **lease-populate** — DHCPv4 lease state population is enabled by default on a group-interface with DHCPv4 configured as **no shutdown**. The number of leases allowed on each SAP of the group-interface must be configured. By default one single DHCPv4 host is allowed on each SAP. This parameter enables the creation of an ESM host table entry for each DHCPv4 lease. For DHCPv6 the ESM host table entry creation is implicit: no CLI parameter is required.
- **arp-populate** — The ARP table is populated with dynamically learned entries from the DHCP lease state table or static entries from the static host table. The BNG does not send downstream ARPs for those managed ARP table entries.
- **local-proxy-arp** — Enables user to user traffic in a split-horizon environment. The BNG responds with its own MAC address to ARP requests targeting subnets configured on the subscriber interface. If the ARP request is targeting a host of the same subscriber on the same SAP, the ARP request is silently discarded. This prevents traffic within a single bridged home to be attracted to the BNG. Local-proxy-arp is enabled by default.
- **anti-spoof** — Checks the source MAC and/or source IP of the upstream subscriber traffic. This parameter is configured at the SAP level with values **ip-mac** (default), **ip** or **nh-mac**. With ESM enabled, anti-spoof must include the source mac (values **ip-mac** or **nh-mac**).

Optional settings are:

- **description** — Can be used to assign a descriptive text to the item and used for administrative reasons.
- **delayed-enable** — To be used in redundant configurations. It is expressed in seconds and defines the additional time the BNG waits before the interface is enabled.

Verification

The interfaces on the BNG are listed using following command. Notice that all subscriber and group interfaces are operational up for IPv4 and IPv6.

```
A:BNG# show router "Base" interface
===============================================================================
Interface Table (Router: Base)
===============================================================================
Interface-Name                   Adm         Opr(v4/v6)  Mode    Port/SapId
   IP-Address                                                    PfxState
-------------------------------------------------------------------------------
grp-int-1-1                      Up          Up/Up       IES Grp 1/1/1
grp-int-1-2                      Up          Up/Up       IES Grp 1/1/1
grp-int-2-1                      Up          Up/Up       IES Grp 1/1/2
grp-int-2-2                      Up          Up/Up       IES Grp 1/1/3
sub-int-1                        Up          Up/Up       IES Sub subscriber
   10.1.1.254/24                                                 n/a
   10.1.2.254/24                                                 n/a
   2001:DB8:101::/48                                             PREFERRED
   2001:DB8:102::/48                                             PREFERRED
   FE80::EA:48:FF/64                                             PREFERRED
sub-int-2                        Up          Up/Up       IES Sub subscriber
   10.2.1.254/24                                                 n/a
   10.2.2.254/24                                                 n/a
   2001:DB8:201::/48                                             PREFERRED
   2001:DB8:202::/48                                             PREFERRED
   FE80::EA:48:FF/64                                             PREFERRED
system                           Up          Up/Up       Network system
   192.0.2.75/32                                                 n/a
   2001:DB8::75/128                                              PREFERRED
toDHCP-1                         Up          Up/Up       Network loopback
   10.11.11.1/32                                                 n/a
   2001:DB8::11/128                                              PREFERRED
   FE80::E84B:FFFF:FE00:0/64                                     PREFERRED
toR1                             Up          Up/Up       Network 1/1/12
   192.168.12.1/24                                               n/a
   2001:DEAD::1/64                                               PREFERRED
   FE80::E84B:FFFF:FE00:0/64                                     PREFERRED
toRADIUS-1                       Up          Up/Down     Network 1/1/10
   192.168.202.75/24                                             n/a
-------------------------------------------------------------------------------
Interfaces : 10
===============================================================================
A:BNG#
```

Successfully created hosts have forwarding state Fwding. Hosts not in the Fwding state cannot forward any data.

```
A:BNG# show service id 1 subscriber-hosts
===============================================================
Subscriber Host table
===============================================================
Sap                    Subscriber
  IP Address
```

```
    MAC Address          PPPoE-SID Origin       Fwding State
-------------------------------------------------------------
1/1/1:111              sub-11
  10.1.1.11
    00:00:00:11:11:11    1         IPCP         Fwding
1/1/1:112              sub-22
  10.1.1.12
    00:00:00:22:22:22    N/A       DHCP         Fwding
1/1/1:112              sub-22
  2001:DB8:101:1::1/128
    00:00:00:22:22:22    N/A       IPoE-DHCP6   Fwding
1/1/1:112              sub-22
  2001:DB8:102:200::/56
    00:00:00:22:22:22    N/A       IPoE-DHCP6   Fwding
1/1/1:122              sub-33
  10.1.1.13
    00:00:00:33:33:33    N/A       DHCP         Fwding
1/1/1:122              sub-33
  2001:DB8:101:2::1/128
    00:00:00:33:33:33    N/A       IPoE-DHCP6   Fwding
1/1/1:122              sub-33
  2001:DB8:102:300::/56
    00:00:00:33:33:33    N/A       IPoE-DHCP6   Fwding
1/1/3:222              sub-44
  10.2.2.11
    00:00:00:44:44:44    1         IPCP         Fwding
-------------------------------------------------------------
Number of subscriber hosts : 8
=============================================================
A:BNG#
```

The list of active subscribers can be displayed as follows.

```
A:BNG# show service active-subscribers
===============================================================================
Active Subscribers
===============================================================================
-------------------------------------------------------------------------------
Subscriber sub-11 (sub-prof-1)
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
(1) SLA Profile Instance sap:1/1/1:111 - sla:sla-prof-1
-------------------------------------------------------------------------------
IP Address
                MAC Address       PPPoE-SID Origin
-------------------------------------------------------
10.1.1.11
                00:00:00:11:11:11 1         IPCP
-------------------------------------------------------------------------------
Subscriber sub-22 (sub-prof-1)
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
(1) SLA Profile Instance sap:1/1/1:112 - sla:sla-prof-1
-------------------------------------------------------------------------------
IP Address
                MAC Address       PPPoE-SID Origin
-------------------------------------------------------
10.1.1.12
```

```
                00:00:00:22:22:22 N/A       DHCP
2001:DB8:101:1::1/128
                00:00:00:22:22:22 N/A       IPoE-DHCP6
2001:DB8:102:200::/56
                00:00:00:22:22:22 N/A       IPoE-DHCP6
-------------------------------------------------------------------------------
Subscriber sub-33 (sub-prof-1)
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
(1) SLA Profile Instance sap:1/1/1:122 - sla:sla-prof-1
-------------------------------------------------------------------------------
IP Address
                MAC Address       PPPoE-SID Origin
-------------------------------------------------------
10.1.1.13
                00:00:00:33:33:33 N/A       DHCP
2001:DB8:101:2::1/128
                00:00:00:33:33:33 N/A       IPoE-DHCP6
2001:DB8:102:300::/56
                00:00:00:33:33:33 N/A       IPoE-DHCP6
-------------------------------------------------------------------------------
Subscriber sub-44 (sub-prof-1)
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
(1) SLA Profile Instance sap:1/1/3:222 - sla:sla-prof-1
-------------------------------------------------------------------------------
IP Address
                MAC Address       PPPoE-SID Origin
-------------------------------------------------------
10.2.2.11
                00:00:00:44:44:44 1         IPCP
-------------------------------------------------------------------------------
Number of active subscribers : 4
-------------------------------------------------------------------------------
A:BNG#
```

Manually cross-referencing the SAPs from this output with the actual configuration shows the following for IPv4, and is depicted in Figure 408.

- Sub-11 and sub-22 are connected to the same subscriber and group interface (sub-int-1 and grp-int-1-1) but via different SAPs (1/1/1:111 and 1/1/1:112) and are sharing the same IPv4 subnet.
- Sub-33 is also connected to the same subscriber interface (sub-int-1) but via a different group-interface (grp-int-1-2). Sub-33 shares the same IPv4 subnet as sub-11 and sub-12, showing that the same subnet is shared across multiple group-interfaces.
- Sub-44 is connected to a different subscriber and group interface, and does not share a subnet with the other subscribers.

An alternative way to find where, for example, subscriber sub-33 is connected is shown below.

```
*A:BNG# show service active-subscribers subscriber "sub-33" detail
===============================================================================
Active Subscribers
===============================================================================
-------------------------------------------------------------------------------
Subscriber sub-11 (sub-prof-1)
-------------------------------------------------------------------------------
I. Sched. Policy : N/A

   ---  snip ---

Oper-Rate-Limit  : Maximum
* indicates that the corresponding row element may have been truncated.
-------------------------------------------------------------------------------
(1) SLA Profile Instance
    - sap:1/1/1:112 (IES 1 - grp-int-1-2)
    - sla:sla-prof-1
-------------------------------------------------------------------------------
Description          : (Not Specified)

   ---  snip ---
```

An alternative to find where, for example, IP address 10.1.1.13 is connected is shown below.

```
*A:BNG# show service id 1 dhcp lease-state ip-address 10.1.1.13 detail
===============================================================================
DHCP lease states for service 1
===============================================================================
Service ID           : 1
IP Address           : 10.1.1.13
Client HW Address    : 00:00:00:33:33:33
Subscriber-interface : sub-int-1
Group-interface      : grp-int-1-2
SAP                  : 1/1/1:122

--- snip ---

Sub-Ident            : "sub-33"
Sub-Profile-String   : "sub-prof-1"
SLA-Profile-String   : "sla-prof-1"
App-Profile-String   : ""

--- snip ---

DHCP Server Addr     : 10.11.11.1
Radius User-Name     : "00:00:00:33:33:33"
-------------------------------------------------------------------------------
Number of lease states : 1
===============================================================================
*A:BNG#
```

For IPv6, the situation is as follows:

- Sub-22 and sub-33 are connected to the same subscriber interface (sub-int-1) but to different group interfaces. Both subscribers share the same IPv6 prefix for prefix-delegation (PD) and wan-host.

With these subscriber hosts connected, the IPv4 routing table (RIB) for the base router looks as follows.

```
*A:BNG# show router "Base" route-table ipv4
===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
10.1.1.0/24                                     Local   Local     02h25m15s  0
       sub-int-1                                                       0
10.1.1.11/32                                    Remote  Sub Mgmt  02h25m10s  0
       [grp-int-1-1]                                                   0
10.1.1.12/32                                    Remote  Sub Mgmt  00h49m52s  0
       [grp-int-1-1]                                                   0
10.1.1.13/32                                    Remote  Sub Mgmt  00h47m40s  0
       [grp-int-1-2]                                                   0
10.1.2.0/24                                     Local   Local     02h25m15s  0
       sub-int-1                                                       0
10.2.1.0/24                                     Local   Local     02h25m15s  0
       sub-int-2                                                       0
10.2.2.0/24                                     Local   Local     02h25m15s  0
       sub-int-2                                                       0
10.2.2.11/32                                    Remote  Sub Mgmt  02h25m10s  0
       [grp-int-2-2]                                                   0
10.11.11.1/32                                   Local   Local     02h25m33s  0
       toDHCP-1                                                        0
192.0.2.75/32                                   Local   Local     02h25m33s  0
       system                                                          0
192.0.2.76/32                                   Remote  ISIS      02h24m43s  15
       192.168.12.2                                                    10
192.168.12.0/24                                 Local   Local     02h25m15s  0
       toR1                                                            0
192.168.202.0/24                                Local   Local     02h25m15s  0
       toRADIUS-1                                                      0
-------------------------------------------------------------------------------
No. of Routes: 13
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
*A:BNG#
```

The IPv6 routing table (RIB) for the base router displays as follows.

```
*A:BNG# show router "Base" route-table ipv6
===============================================================================
IPv6 Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
```

```
      Next Hop[Interface Name]                                    Metric
-------------------------------------------------------------------------------
2001:DB8::11/128                          Local   Local     02h27m23s  0
       toDHCP-1                                                    0
2001:DB8::75/128                          Local   Local     02h27m24s  0
       system                                                      0
2001:DB8::76/128                          Remote  ISIS      02h26m32s  15
       FE80::E84C:FFFF:FE00:0-"toR1"                               10
2001:DB8:101::/48                         Local   Local     02h27m06s  0
       sub-int-1                                                   0
2001:DB8:101:1::1/128                     Remote  Sub Mgmt  01h13m43s  0
       [grp-int-1-1]                                               0
2001:DB8:101:2::1/128                     Remote  Sub Mgmt  01h13m25s  0
       [grp-int-1-2]                                               0
2001:DB8:102::/48                         Local   Local     02h27m06s  0
       sub-int-1                                                   0
2001:DB8:102:200::/56                     Remote  Sub Mgmt  01h13m43s  0
       [grp-int-1-1]                                               0
2001:DB8:102:300::/56                     Remote  Sub Mgmt  01h13m25s  0
       [grp-int-1-2]                                               0
2001:DB8:201::/48                         Local   Local     02h27m06s  0
       sub-int-2                                                   0
2001:DB8:202::/48                         Local   Local     02h27m06s  0
       sub-int-2                                                   0
2001:DEAD::/64                            Local   Local     02h27m05s  0
       toR1                                                        0
-------------------------------------------------------------------------------
No. of Routes: 12
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
*A:BNG#
```

The corresponding IPv4 FIB on card 1 looks as follows.

```
*A:BNG# show router "Base" fib 1 ipv4
===============================================================================
FIB Display
===============================================================================
Prefix                                                      Protocol
    NextHop
-------------------------------------------------------------------------------
10.1.1.0/24                                                 LOCAL
    10.1.1.0 (sub-int-1)
10.1.2.0/24                                                 LOCAL
    10.1.2.0 (sub-int-1)
10.2.1.0/24                                                 LOCAL
    10.2.1.0 (sub-int-2)
10.2.2.0/24                                                 LOCAL
    10.2.2.0 (sub-int-2)
10.11.11.1/32                                               LOCAL
    10.11.11.1 (toDHCP-1)
192.0.2.75/32                                               LOCAL
    192.0.2.75 (system)
192.0.2.76/32                                               ISIS
    192.168.12.2 (toR1)
192.168.12.0/24                                             LOCAL
    192.168.12.0 (toR1)
```

```
192.168.202.0/24                                                LOCAL
    192.168.202.0 (toRADIUS-1)
-------------------------------------------------------------------------------
Total Entries : 9
-------------------------------------------------------------------------------
===============================================================================
*A:BNG#
```

The corresponding IPv6 FIB on card 1 is as follows.

```
*A:BNG# show router "Base" fib 1 ipv6
===============================================================================
FIB Display
===============================================================================
Prefix                                                          Protocol
    NextHop
-------------------------------------------------------------------------------
2001:DB8::11/128                                                LOCAL
    2001:DB8::11 (toDHCP-1)
2001:DB8::75/128                                                LOCAL
    2001:DB8::75 (system)
2001:DB8::76/128                                                ISIS
    FE80::E84C:FFFF:FE00:0 (toR1)
2001:DB8:101::/48                                               LOCAL
    2001:DB8:101:: (sub-int-1)
2001:DB8:102::/48                                               LOCAL
    2001:DB8:102:: (sub-int-1)
2001:DB8:201::/48                                               LOCAL
    2001:DB8:201:: (sub-int-2)
2001:DB8:202::/48                                               LOCAL
    2001:DB8:202:: (sub-int-2)
2001:DEAD::/64                                                  LOCAL
    2001:DEAD:: (toR1)
-------------------------------------------------------------------------------
Total Entries : 8
-------------------------------------------------------------------------------
===============================================================================
*A:BNG#
```

The addresses of the individual subscriber hosts show up in the RIB but they do not show up in the FIB.

- /32 for IPv4-hosts.
- /DPL (Delegated Prefix Length) for IPv6 DP hosts, /56 in this example.
- /128 or /64 for IPv6 wan host.

Downstream traffic is forwarded based on a subscriber host table lookup. For specific network designs, subscriber host IPv4 addresses can optionally be included in the FIB with the populate-host-routes statement added to the subnet configuration. This is out of scope of this example.

Unnumbered Scenario

Figure 409 depicts the unnumbered scenario outlined below, including the connecting subscribers and subscriber hosts. Sub-11 and sub-44 are using single stack PPPoEv4 hosts, and sub-22 and sub-33 are using dual stack DHCP hosts. Their VLANs and the MAC addresses are shown, as are the IP addresses and prefixes assigned once they are connected.

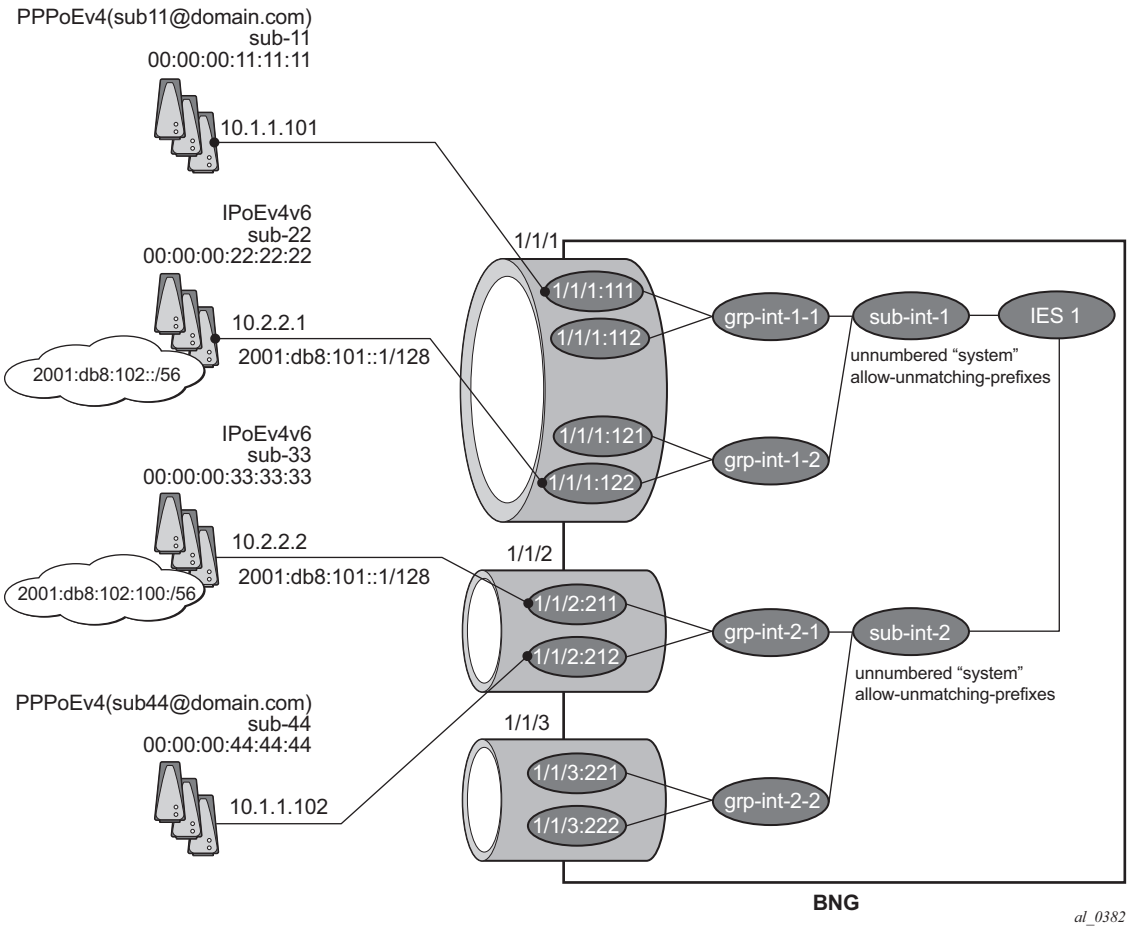

Figure 409: Unnumbered Scenario for IES 1

The configuration for the unnumbered scenario is show below. Only the configuration items specific to the unnumbered scenario are shown.

In the unnumbered scenario the subscriber interfaces have following properties:

- IPv4:
  - → No subnets configured.
  - → **unnumbered**, with an IPv4 interface or an IPv4 address used for IPCP negotiation.
  - → **no allow-unmatching-subnets.**
- IPv6:
  - → No subscriber prefixes configured.
  - → **allow-unmatching-prefixes.**

```
configure
    service
        ies 1
            subscriber-interface "sub-int-1" create
                unnumbered "system"
                ipv6
                    delegated-prefix-len 56
                    allow-unmatching-prefixes
                    link-local-address FE80::EA:4B:FF
                exit
                group-interface "grp-int-1-1" create
                    ipv6
                        --- snip ---
                    exit
                    arp-populate
                    dhcp
                        --- snip ---
                        lease-populate 100
                        no shutdown
                    exit
                    authentication-policy "auth-pol-1"
                    sap 1/1/1:111 create
                        anti-spoof ip-mac
                        sub-sla-mgmt
                            --- snip ---
                        exit
                    exit
                    sap 1/1/1:112 create
                        anti-spoof ip-mac
                        sub-sla-mgmt
                            --- snip ---
                        exit
                    exit
                    pppoe
                        --- snip ---
                        no shutdown
                    exit
                exit
                group-interface "grp-int-1-2" create
                    ipv6
                        --- snip ---
                    exit
                    arp-populate
                    dhcp
```

```
                --- snip ---
                lease-populate 100
                no shutdown
            exit
            authentication-policy "auth-pol-1"
            sap 1/1/1:121 create
                anti-spoof ip-mac
                sub-sla-mgmt
                    --- snip ---
                exit
            exit
            sap 1/1/1:122 create
                anti-spoof ip-mac
                sub-sla-mgmt
                    --- snip ---
                exit
            exit
            pppoe
                --- snip ---
                no shutdown
            exit
        exit
    exit
    subscriber-interface "sub-int-2" create
        unnumbered "system"
        ipv6
            delegated-prefix-len 56
            allow-unmatching-prefixes
            link-local-address FE80::EA:4B:FF
        exit
        group-interface "grp-int-2-1" create
            ipv6
                --- snip ---
            exit
            arp-populate
            dhcp
                --- snip ---
                lease-populate 100
                no shutdown
            exit
            authentication-policy "auth-pol-1"
            sap 1/1/2:211 create
                anti-spoof ip-mac
                sub-sla-mgmt
                    --- snip ---
                exit
            exit
            sap 1/1/2:212 create
                anti-spoof ip-mac
                sub-sla-mgmt
                    --- snip ---
                exit
            exit
            pppoe
                --- snip ---
                no shutdown
            exit
        exit
        group-interface "grp-int-2-2" create
```

```
            ipv6
                --- snip ---
            exit
            arp-populate
            dhcp
                --- snip ---
                lease-populate 100
                no shutdown
            exit
            authentication-policy "auth-pol-1"
            sap 1/1/3:221 create
                anti-spoof ip-mac
                sub-sla-mgmt
                    --- snip ---
                exit
            exit
            sap 1/1/3:222 create
                sub-sla-mgmt
                anti-spoof ip-mac
                sub-sla-mgmt
                    --- snip ---
                exit
                exit
            exit
            pppoe
                --- snip ---
                no shutdown
            exit
        exit
    exit
    no shutdown
```

The same mandatory and optional settings as for the numbered scenario apply.

Verification

The interfaces on the BNG are listed using following command. Notice that all subscriber and group interfaces are operational up for IPv4 and IPv6.

```
A:BNG# show router "Base" interface
===============================================================================
Interface Table (Router: Base)
===============================================================================
Interface-Name                   Adm         Opr(v4/v6)  Mode    Port/SapId
   IP-Address                                                    PfxState
-------------------------------------------------------------------------------
grp-int-1-1                      Up          Up/Up       IES Grp 1/1/1
grp-int-1-2                      Up          Up/Up       IES Grp 1/1/1
grp-int-2-1                      Up          Up/Up       IES Grp 1/1/2
grp-int-2-2                      Up          Up/Up       IES Grp 1/1/3
lb-pool4-1                       Up          Up/Down     Network loopback
   10.1.1.254/24                                                 n/a
lb-pool4-2                       Up          Up/Down     Network loopback
   10.1.2.254/24                                                 n/a
lb-pool4-3                       Up          Up/Down     Network loopback
   10.2.1.254/24                                                 n/a
lb-pool4-4                       Up          Up/Down     Network loopback
   10.2.2.254/24                                                 n/a
sub-int-1                        Up          Up/Up       IES Sub subscriber
   Unnumbered If[system]                                         n/a
   FE80::EA:4B:FF/64                                             PREFERRED
sub-int-2                        Up          Up/Up       IES Sub subscriber
   Unnumbered If[system]                                         n/a
   FE80::EA:4B:FF/64                                             PREFERRED
system                           Up          Up/Up       Network system
   192.0.2.75/32                                                 n/a
   2001:DB8::75/128                                              PREFERRED
toDHCP-1                         Up          Up/Up       Network loopback
   10.11.11.1/32                                                 n/a
   2001:DB8::11/128                                              PREFERRED
   FE80::E84B:FFFF:FE00:0/64                                     PREFERRED
toR1                             Up          Up/Down     Network 1/1/12
   192.168.12.1/24                                               n/a
toRADIUS-1                       Up          Up/Down     Network 1/1/10
   192.168.202.75/24                                             n/a
-------------------------------------------------------------------------------
Interfaces : 14
===============================================================================
A:BNG#
```

Successfully created hosts have forwarding state Fwding. Hosts not in the Fwding state cannot forward any data.

```
*A:BNG# show service id 1 subscriber-hosts
===============================================================
Subscriber Host table
===============================================================
Sap                    Subscriber
  IP Address
    MAC Address          PPPoE-SID Origin       Fwding State
---------------------------------------------------------------
1/1/1:111              sub-11
  10.1.1.101
    00:00:00:11:11:11    1         IPCP         Fwding
1/1/1:122              sub-22
  10.2.2.1
    00:00:00:22:22:22    N/A       DHCP         Fwding
1/1/1:122              sub-22
  2001:DB8:101::1/128
    00:00:00:22:22:22    N/A       IPoE-DHCP6   Fwding
1/1/1:122              sub-22
  2001:DB8:102::/56
    00:00:00:22:22:22    N/A       IPoE-DHCP6   Fwding
1/1/2:211              sub-33
  10.2.2.2
    00:00:00:33:33:33    N/A       DHCP         Fwding
1/1/2:211              sub-33
  2001:DB8:101:1::1/128
    00:00:00:33:33:33    N/A       IPoE-DHCP6   Fwding
1/1/2:211              sub-33
  2001:DB8:102:100::/56
    00:00:00:33:33:33    N/A       IPoE-DHCP6   Fwding
1/1/2:212              sub-44
  10.1.1.102
    00:00:00:44:44:44    1         IPCP         Fwding
---------------------------------------------------------------
Number of subscriber hosts : 8
===============================================================
*A:BNG#
```

A variant of the show service active-subscribers command shows the subscriber hierarchy.

```
*A:BNG# show service active-subscribers hierarchy
===============================================================================
Active Subscriber hierarchy
===============================================================================
-- sub-11 (sub-prof-1)
   |
   |-- sap:1/1/1:111 - sla:sla-prof-1
   |   |
   |   |-- 10.1.1.101
   |   |   00:00:00:11:11:11 - 1 (IPCP)
   |   |

-- sub-22 (sub-prof-1)
   |
```

```
   |-- sap:1/1/1:122 - sla:sla-prof-1
   |   |
   |   |-- 10.2.2.1
   |   |   00:00:00:22:22:22 - N/A (DHCP)
   |   |
   |   |-- 2001:DB8:101::1/128
   |   |   00:00:00:22:22:22 - N/A (IPoE-DHCP6)
   |   |
   |   |-- 2001:DB8:102::/56
   |   |   00:00:00:22:22:22 - N/A (IPoE-DHCP6)
   |   |

-- sub-33 (sub-prof-1)
   |
   |-- sap:1/1/2:211 - sla:sla-prof-1
   |   |
   |   |-- 10.2.2.2
   |   |   00:00:00:33:33:33 - N/A (DHCP)
   |   |
   |   |-- 2001:DB8:101:1::1/128
   |   |   00:00:00:33:33:33 - N/A (IPoE-DHCP6)
   |   |
   |   |-- 2001:DB8:102:100::/56
   |   |   00:00:00:33:33:33 - N/A (IPoE-DHCP6)
   |   |

-- sub-44 (sub-prof-1)
   |
   |-- sap:1/1/2:212 - sla:sla-prof-1
   |   |
   |   |-- 10.1.1.102
   |   |   00:00:00:44:44:44 - 1 (IPCP)
   |   |
===============================================================================
*A:BNG#
```

Manually cross-referencing the SAPs from this output with the actual configuration shows the following for IPv4, and is represented in Figure 409.

- Sub-11 and sub-44 share the same IPv4 subnet even though they are connected to different subscriber interfaces.
- Sub-22 and sub-33 share the same subnet even though they are connected to different subscriber interfaces.

For IPv6 the situation is as follows:

- Sub-22 and sub-33 are in different subscriber interfaces and do not share IPv6 prefixes in this example.

With these subscriber hosts are connected, the IPv4 RIB for the base router looks as follows.

```
A:BNG# show router "Base" route-table ipv4
===============================================================================
Route Table (Router: Base)
===============================================================================
```

```
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
10.1.1.0/24                                     Local   Local     00h49m42s  0
       lb-pool4-1                                                      0
10.1.1.101/32                                   Remote  Sub Mgmt  00h23m24s  0
       [grp-int-1-1]                                                   0
10.1.1.102/32                                   Remote  Sub Mgmt  00h02m32s  0
       [grp-int-2-1]                                                   0
10.1.2.0/24                                     Local   Local     00h49m42s  0
       lb-pool4-2                                                      0
10.2.1.0/24                                     Local   Local     00h49m42s  0
       lb-pool4-3                                                      0
10.2.2.0/24                                     Local   Local     00h49m42s  0
       lb-pool4-4                                                      0
10.2.2.1/32                                     Remote  Sub Mgmt  00h27m18s  0
       [grp-int-1-2]                                                   0
10.2.2.2/32                                     Remote  Sub Mgmt  00h27m10s  0
       [grp-int-2-1]                                                   0
10.11.11.1/32                                   Local   Local     00h49m42s  0
       toDHCP-1                                                        0
192.0.2.75/32                                   Local   Local     00h49m42s  0
       system                                                          0
192.0.2.76/32                                   Remote  ISIS      00h41m48s  15
       192.168.12.2                                                    10
192.168.12.0/24                                 Local   Local     00h49m24s  0
       toR1                                                            0
192.168.202.0/24                                Local   Local     00h49m24s  0
       toRADIUS-1                                                      0
-------------------------------------------------------------------------------
No. of Routes: 13
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
A:BNG#
```

The IPv6 RIB for the base router looks as follows.

```
.A:BNG# show router "Base" route-table ipv6
===============================================================================
IPv6 Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
2001:DB8::11/128                                Local   Local     01h03m27s  0
       toDHCP-1                                                        0
2001:DB8::75/128                                Local   Local     00h06m34s  0
       system                                                          0
2001:DB8:101::1/128                             Remote  Sub Mgmt  00h36m12s  0
       [grp-int-1-2]                                                   0
2001:DB8:101:1::1/128                           Remote  Sub Mgmt  00h35m58s  0
       [grp-int-2-1]                                                   0
2001:DB8:102::/56                               Remote  Sub Mgmt  00h36m12s  0
       [grp-int-1-2]                                                   0
2001:DB8:102:100::/56                           Remote  Sub Mgmt  00h35m58s  0
       [grp-int-2-1]                                                   0
-------------------------------------------------------------------------------
```

```
No. of Routes: 6
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
A:BNG# #
```

The corresponding IPv4 FIB on card 1 looks as follows.

```
A:BNG# show router "Base" fib 1 ipv4
===============================================================================
FIB Display
===============================================================================
Prefix                                                          Protocol
    NextHop
-------------------------------------------------------------------------------
10.1.1.0/24                                                     LOCAL
    10.1.1.0 (lb-pool4-1)
10.1.1.101/32                                                   LOCAL
    10.1.1.101 (sub-int-1)
10.1.1.102/32                                                   LOCAL
    10.1.1.102 (sub-int-2)
10.1.2.0/24                                                     LOCAL
    10.1.2.0 (lb-pool4-2)
10.2.1.0/24                                                     LOCAL
    10.2.1.0 (lb-pool4-3)
10.2.2.0/24                                                     LOCAL
    10.2.2.0 (lb-pool4-4)
10.2.2.1/32                                                     LOCAL
    10.2.2.1 (sub-int-1)
10.2.2.2/32                                                     LOCAL
    10.2.2.2 (sub-int-2)
10.11.11.1/32                                                   LOCAL
    10.11.11.1 (toDHCP-1)
192.0.2.75/32                                                   LOCAL
    192.0.2.75 (system)
192.0.2.76/32                                                   ISIS
    192.168.12.2 (toR1)
192.168.12.0/24                                                 LOCAL
    192.168.12.0 (toR1)
192.168.202.0/24                                                LOCAL
    192.168.202.0 (toRADIUS-1)
-------------------------------------------------------------------------------
Total Entries : 13
-------------------------------------------------------------------------------
===============================================================================
A:BNG#
```

The corresponding IPv6 FIB on card 1 looks as follows:

```
A:BNG# show router "Base" fib 1 ipv6
===============================================================================
FIB Display
===============================================================================
Prefix                                                      Protocol
    NextHop
-------------------------------------------------------------------------------
2001:DB8::11/128                                            LOCAL
    2001:DB8::11 (toDHCP-1)
2001:DB8::75/128                                            LOCAL
    2001:DB8::75 (system)
2001:DB8:101::1/128                                         LOCAL
    2001:DB8:101::1 (sub-int-1)
2001:DB8:101:1::1/128                                       LOCAL
    2001:DB8:101:1::1 (sub-int-2)
2001:DB8:102::/56                                           LOCAL
    2001:DB8:102:: (sub-int-1)
2001:DB8:102:100::/56                                       LOCAL
    2001:DB8:102:100:: (sub-int-2)
-------------------------------------------------------------------------------
Total Entries : 6
-------------------------------------------------------------------------------
===============================================================================
A:BNG#
```

The addresses of the individual subscriber hosts appear in the RIB and the FIB, which is the main difference with the numbered model. The forwarding plane here needs the individual addresses to forward the traffic towards the individual subscriber hosts.

Hybrid Scenario

An alternative to the scenarios described above does exist in the form of a mixed numbered/ unnumbered (hybrid) scenario as depicted in Figure 410.

The subscriber interface is configured with

- One or more IPv4 subnets and/or IPv6 subscriber prefixes.
- For IPv4: the keyword **allow-unmatching-subnets**.
- For IPv6: the keyword **allow-unmatching-prefixes**.

No explicit configuration is shown as it is a mix of the numbered and the unnumbered scenario described above, and as such the behavior is mixed.

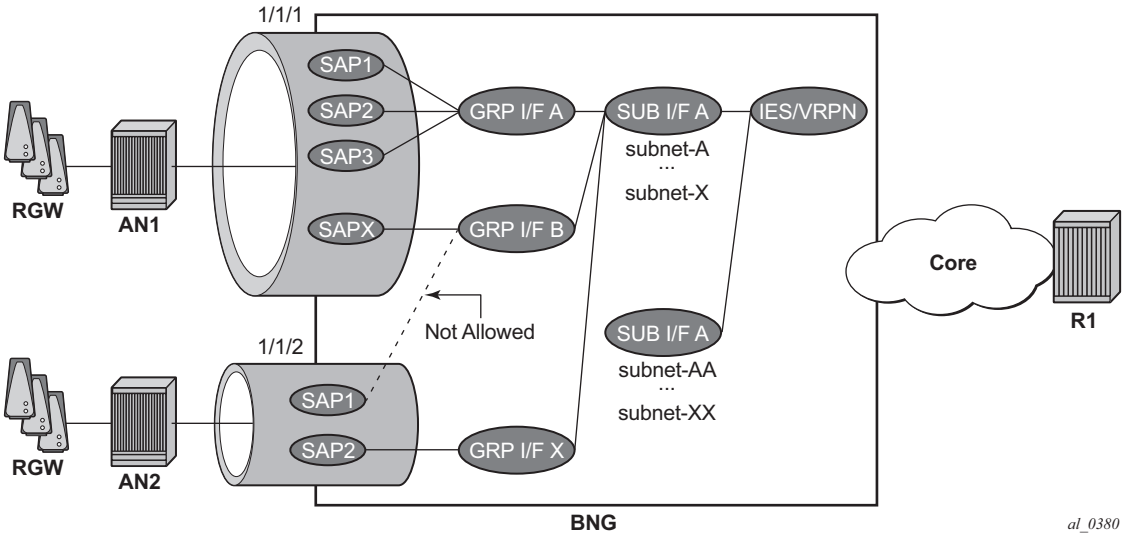

Figure 410: Hybrid Configuration

Host IP Reachability

To ensure reachability to the individual subscriber hosts, the subnets and prefixes of the subscriber interfaces/subscriber hosts need to be distributed to other routers in the network.

Three options are available:

- Without an export policy.
- With an export policy using, for example, from protocol direct.
- With an export policy using, for example, from protocol sub-mgmt.

Option 1 – No Export Policy

The key properties for the first option are:

- Subscriber interface subnets and prefixes are distributed into the network by adding the subscriber interfaces as passive interfaces to the routing protocol.
- It is used in combination with IGP based route distribution.
- It works with the numbered model only.

In this option the BNG uses IS-IS as IGP and no export policy is needed.

```
configure
    router
       isis
            area-id 48.0001
            multi-topology
                ipv6-unicast
            exit
            interface "system"
                no shutdown
            exit
            interface "sub-int-1"
                passive
                no shutdown
            exit
            interface "sub-int-2"
                passive
                no shutdown
            exit
            interface "toR1"
                interface-type point-to-point
                no shutdown
            exit
            no shutdown
        exit
```

The corresponding IPv4 RIB on router R1 (from Figure 407) lists the subscriber-interface subnets, not the individual subscriber host addresses.

```
A:R1# show router "Base" route-table ipv4
===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
10.1.1.0/24                                     Remote  ISIS      00h14m11s  15
       192.168.12.1                                                    20
10.1.2.0/24                                     Remote  ISIS      00h14m11s  15
       192.168.12.1                                                    20
10.2.1.0/24                                     Remote  ISIS      00h14m05s  15
       192.168.12.1                                                    20
10.2.2.0/24                                     Remote  ISIS      00h14m05s  15
       192.168.12.1                                                    20
192.0.2.75/32                                   Remote  ISIS      00h14m17s  15
       192.168.12.1                                                    10
192.0.2.76/32                                   Local   Local     62d21h22m  0
       system                                                          0
192.168.12.0/24                                 Local   Local     05d04h43m  0
       toBNG                                                           0
-------------------------------------------------------------------------------
No. of Routes: 7
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
A:R1#
```

The corresponding IPv6 RIB on router R1 lists the subscriber-interface prefixes, not the individual subscriber host addresses/prefixes.

```
A:R1# show router "Base" route-table ipv6
===============================================================================
IPv6 Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
2001:DB8::75/128                                Remote  ISIS      00h04m25s  15
       FE80::E84B:FFFF:FE00:0-"toBNG"                                  10
2001:DB8::76/128                                Local   Local     02d05h54m  0
       system                                                          0
2001:DB8:101::/48                               Remote  ISIS      00h04m25s  15
       FE80::E84B:FFFF:FE00:0-"toBNG"                                  20
2001:DB8:102::/48                               Remote  ISIS      00h04m25s  15
       FE80::E84B:FFFF:FE00:0-"toBNG"                                  20
2001:DB8:201::/48                               Remote  ISIS      00h04m25s  15
       FE80::E84B:FFFF:FE00:0-"toBNG"                                  20
2001:DB8:202::/48                               Remote  ISIS      00h04m25s  15
       FE80::E84B:FFFF:FE00:0-"toBNG"                                  20
2001:DEAD::/64                                  Local   Local     01h42m18s  0
       toBNG                                                           0
-------------------------------------------------------------------------------
No. of Routes: 7
```

```
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
A:R1#
```

Alternatively the same result can be achieved with OSPF/OSPFv3.

Option 2 – Export Policy (from protocol direct)

The key properties for the second option are:

- Subscriber interface subnets and prefixes are distributed into the network by applying an export policy.
- It is most typically used in combination with BGP based route distribution.
- It works with the numbered model only.

The following export policy is used for this example.

```
configure
    router
        policy-options
            policy-statement "local-subnets-out"
                entry 10
                    from
                        protocol direct
                    exit
                    action accept
                    exit
                exit
            exit
```

In this option the BNG relies on BGP using the policy local-subnets-out as an export policy. The neighbor address is the IPv4 system address of router R1.

```
configure
    router
        autonomous-system 65536
        bgp
            group "grp-1"
                family ipv4 ipv6
                export "local-subnets-out"
                peer-as 65536
                neighbor 192.0.2.76
                    advertise-label ipv6
                exit
            exit
            no shutdown
        exit
```

The following command shows the IPv4 routes advertised by applying the local-subnets-out policy. The subscriber interface subnets are advertised, as are some other local subnets.

```
*A:BNG# show router bgp neighbor 192.0.2.76 advertised-routes ipv4
===============================================================================
 BGP Router ID:192.0.2.75       AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
 Origin codes  : i - IGP, e - EGP, ? - incomplete, > - best, b - backup
===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                              LocalPref   MED
      Nexthop                                              Path-Id     Label
      As-Path
-------------------------------------------------------------------------------
i     10.1.1.0/24                                          100         None
      192.0.2.75                                           None        -
      No As-Path
i     10.1.2.0/24                                          100         None
      192.0.2.75                                           None        -
      No As-Path
i     10.2.1.0/24                                          100         None
      192.0.2.75                                           None        -
      No As-Path
i     10.2.2.0/24                                          100         None
      192.0.2.75                                           None        -
      No As-Path
i     10.11.11.1/32                                        100         None
      192.0.2.75                                           None        -
      No As-Path
i     192.0.2.75/32                                        100         None
      192.0.2.75                                           None        -
      No As-Path
i     192.168.12.0/24                                      100         None
      192.0.2.75                                           None        -
      No As-Path
i     192.168.202.0/24                                     100         None
      192.0.2.75                                           None        -
      No As-Path
-------------------------------------------------------------------------------
Routes : 8
===============================================================================
*A:BNG#
```

The same applies for IPv6.

```
*A:BNG# show router bgp neighbor 192.0.2.76 advertised-routes ipv6
===============================================================================
 BGP Router ID:192.0.2.75       AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
 Origin codes  : i - IGP, e - EGP, ? - incomplete, > - best, b - backup
===============================================================================
BGP IPv6 Routes
```

```
===============================================================================
Flag  Network                                          LocalPref   MED
      Nexthop                                          Path-Id     Label
      As-Path
-------------------------------------------------------------------------------
i     2001:DB8::11/128                                 100         None
      ::FFFF:C000:24B                                  None        2
      No As-Path
i     2001:DB8::75/128                                 100         None
      ::FFFF:C000:24B                                  None        2
      No As-Path
i     2001:DB8:101::/48                                100         None
      ::FFFF:C000:24B                                  None        2
      No As-Path
i     2001:DB8:102::/48                                100         None
      ::FFFF:C000:24B                                  None        2
      No As-Path
i     2001:DB8:201::/48                                100         None
      ::FFFF:C000:24B                                  None        2
      No As-Path
i     2001:DB8:202::/48                                100         None
      ::FFFF:C000:24B                                  None        2
      No As-Path
i     2001:DEAD::/64                                   100         None
      ::FFFF:C000:24B                                  None        2
      No As-Path
-------------------------------------------------------------------------------
Routes : 7
===============================================================================
*A:BNG#
```

The corresponding IPv4 RIB on router R1 lists the subscriber-interface subnets, not the individual subscriber host addresses. Notice the list also includes other routes local to the BNG.

```
*A:R1# show router "Base" route-table ipv4
===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                             Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
10.1.1.0/24                                    Remote  BGP       00h13m34s  170
       192.168.12.1                                                0
10.1.2.0/24                                    Remote  BGP       00h13m34s  170
       192.168.12.1                                                0
10.2.1.0/24                                    Remote  BGP       00h13m34s  170
       192.168.12.1                                                0
10.2.2.0/24                                    Remote  BGP       00h13m34s  170
       192.168.12.1                                                0
10.11.11.1/32                                  Remote  BGP       00h13m34s  170
       192.168.12.1                                                0
192.0.2.75/32                                  Remote  ISIS      00h15m38s  15
       192.168.12.1                                                10
192.0.2.76/32                                  Local   Local     03h11m54s  0
       system                                                      0
192.168.12.0/24                                Local   Local     03h11m25s  0
       toBNG                                                       0
```

```
192.168.202.0/24                                Remote  BGP       00h13m34s  170
       192.168.12.1                                                     0
-------------------------------------------------------------------------------
No. of Routes: 9
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
*A:R1#
```

The corresponding IPv6 RIB on router R1 lists the subscriber-interface prefixes, not the individual subscriber host addresses/prefixes. They are tunneled through the IPv4 core.

```
*A:R1# show router "Base" route-table ipv6
===============================================================================
IPv6 Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                     Metric
-------------------------------------------------------------------------------
2001:DB8::11/128                                Remote  BGP       00h00m49s  170
       192.0.2.75 (tunneled)                                            0
2001:DB8::75/128                                Remote  ISIS      00h54m05s  15
       FE80::E84B:FFFF:FE00:0-"toBNG"                                   10
2001:DB8::76/128                                Local   Local     05h18m12s  0
       system                                                           0
2001:DB8:101::/48                               Remote  BGP       00h00m49s  170
       192.0.2.75 (tunneled)                                            0
2001:DB8:102::/48                               Remote  BGP       00h00m49s  170
       192.0.2.75 (tunneled)                                            0
2001:DB8:201::/48                               Remote  BGP       00h00m49s  170
       192.0.2.75 (tunneled)                                            0
2001:DB8:202::/48                               Remote  BGP       00h00m49s  170
       192.0.2.75 (tunneled)                                            0
2001:DEAD::/64                                  Local   Local     05h17m42s  0
       toBNG                                                            0
-------------------------------------------------------------------------------
No. of Routes: 8
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
*A:R1# #
```

The same export policy can be used in combination with IGP based route distribution. However, when IGP based route distribution is needed option 1 is the preferred method.

Option 3 – Export Protocol (from protocol sub-mgmt)

The key properties for the third option are:

- Host addresses and prefixes are distributed into the network by applying an export policy.
- It is most typically used in combination with BGP based route distribution, as IGP based route distribution does not scale for a large number of subscribers.
- It is most typically used for the unnumbered model, and in some cases for the numbered model.

The following export policy is used for this option.

```
configure
    router
        policy-options
            policy-statement "subsc-hosts-out"
                entry 10
                    from
                        protocol sub-mgmt
                    exit
                    action accept
                    exit
                exit
            exit
```

In this option the BNG relies on BGP using the policy subsc-hosts-out as an export policy.

```
configure
    router
        autonomous-system 65536
        bgp
            group "grp-1"
                family ipv4 ipv6
                export "subsc-hosts-out"
                peer-as 65536
                neighbor 192.0.2.76
                    advertise-label ipv6
                exit
            exit
            no shutdown
        exit
```

The following command shows the IPv4 routes advertised by applying the subsc-hosts-out policy. Now the subscriber host addresses are advertised individually.

```
*A:BNG# show router bgp neighbor 192.0.2.76 advertised-routes ipv4
===============================================================================
 BGP Router ID:192.0.2.75       AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
 Origin codes  : i - IGP, e - EGP, ? - incomplete, > - best, b - backup
===============================================================================
BGP IPv4 Routes
===============================================================================
Flag  Network                                              LocalPref   MED
      Nexthop                                              Path-Id     Label
      As-Path
-------------------------------------------------------------------------------
?     10.1.1.101/32                                        100         0
      192.0.2.75                                           None        -
      No As-Path
?     10.1.1.102/32                                        100         0
      192.0.2.75                                           None        -
      No As-Path
?     10.2.2.1/32                                          100         0
      192.0.2.75                                           None        -
      No As-Path
?     10.2.2.2/32                                          100         0
      192.0.2.75                                           None        -
      No As-Path
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
*A:BNG#
```

For IPv6, the host addresses and prefixes are advertised.

```
*A:BNG# show router bgp neighbor 192.0.2.76 advertised-routes ipv6
===============================================================================
 BGP Router ID:192.0.2.75       AS:65536       Local AS:65536
===============================================================================
 Legend -
 Status codes  : u - used, s - suppressed, h - history, d - decayed, * - valid
 Origin codes  : i - IGP, e - EGP, ? - incomplete, > - best, b - backup
===============================================================================
BGP IPv6 Routes
===============================================================================
Flag  Network                                              LocalPref   MED
      Nexthop                                              Path-Id     Label
      As-Path
-------------------------------------------------------------------------------
?     2001:DB8:101::1/128                                  100         0
      ::FFFF:C000:24B                                      None        2
      No As-Path
?     2001:DB8:101:1::1/128                                100         0
      ::FFFF:C000:24B                                      None        2
      No As-Path
```

```
?     2001:DB8:102::/56                                 100         0
      ::FFFF:C000:24B                                   None        2
      No As-Path
?     2001:DB8:102:100::/56                             100         0
      ::FFFF:C000:24B                                   None        2
      No As-Path
-------------------------------------------------------------------------------
Routes : 4
===============================================================================
*A:BNG#
```

The corresponding IPv4 RIB on router R1 looks as follows. Notice the individual host addresses do appear.

```
A:R1# show router route-table ipv4
===============================================================================
Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
10.1.1.101/32                                   Remote  BGP       00h40m49s  170
       192.168.12.1                                                    0
10.1.1.102/32                                   Remote  BGP       00h19m53s  170
       192.168.12.1                                                    0
10.2.2.1/32                                     Remote  BGP       00h44m49s  170
       192.168.12.1                                                    0
10.2.2.2/32                                     Remote  BGP       00h44m17s  170
       192.168.12.1                                                    0
192.0.2.75/32                                   Remote  ISIS      00h59m41s  15
       192.168.12.1                                                    10
192.0.2.76/32                                   Local   Local     01h22m11s  0
       system                                                          0
192.168.12.0/24                                 Local   Local     01h21m42s  0
       toBNG                                                           0
-------------------------------------------------------------------------------
No. of Routes: 7
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
A:R1#
```

The corresponding IPv6 RIB on router R1 looks as follows. Notice the individual host addresses and prefixes are distributed in this case.

```
A:R1# show router route-table ipv6
===============================================================================
IPv6 Route Table (Router: Base)
===============================================================================
Dest Prefix[Flags]                              Type    Proto     Age        Pref
      Next Hop[Interface Name]                                      Metric
-------------------------------------------------------------------------------
2001:DB8::76/128                                Local   Local     01h22m16s  0
       system                                                          0
2001:DB8:101::1/128                             Remote  BGP       00h36m40s  170
       192.0.2.75 (tunneled)                                           0
```

```
2001:DB8:101:1::1/128                          Remote  BGP       00h36m40s  170
       192.0.2.75 (tunneled)                                          0
2001:DB8:102::/56                              Remote  BGP       00h36m40s  170
       192.0.2.75 (tunneled)                                          0
2001:DB8:102:100::/56                          Remote  BGP       00h36m40s  170
       192.0.2.75 (tunneled)                                          0
2001:DEAD::/64                                 Local   Local     01h21m47s  0
       toBNG                                                          0
-------------------------------------------------------------------------------
No. of Routes: 6
Flags: L = LFA nexthop available    B = BGP backup route available
       n = Number of times nexthop is repeated
===============================================================================
A:R1#
```

Conclusion

This example explains how to configure and use the Routed CO model. The subscriber and the group interfaces were configured for the numbered, unnumbered and hybrid scenario, showing the flexibility of the Routed CO model in terms of subnet/prefix assignment as well as the impact on the forwarding and the reachability to and from the subscriber hosts.