7705 Service Aggregation Router Gen 2

Release 26.3.R1

Services Overview Guide

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Nokia is committed to diversity and inclusion. We are continuously reviewing our customer documentation and consulting with standards bodies to ensure that terminology is inclusive and aligned with the industry. Our future customer documentation will be updated accordingly.

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1 Getting started

1.1 About this guide

This guide describes subscriber services, and mirroring support provided by the 7705 SAR Gen 2 and presents examples to configure and implement various protocols and services.

This guide is organized into functional chapters and provides concepts and descriptions of the implementation flow, as well as Command Line Interface (CLI) syntax and command usage.

Unless otherwise indicated, the topics and commands described in this guide apply only to the 7705 SAR Gen 2 platforms listed in Platforms and terminology.

Command outputs shown in this guide are examples only; actual displays may differ depending on supported functionality and user configuration.

Note: Unless otherwise indicated, CLI commands, contexts, and configuration examples in this guide apply for both the classic CLI and the MD-CLI.

The SR OS CLI trees and command descriptions can be found in the following guides:

- *7705 SAR Gen 2 Classic CLI Command Reference Guide*
- *7705 SAR Gen 2 Clear, Monitor, Show, Tools CLI Command Reference Guide* (for both the MD-CLI and classic CLI)
- *7705 SAR Gen 2 MD-CLI Command Reference Guide*

Note: This guide generically covers Release 26.*x*.R*x* content and may contain some content that will be released in later maintenance loads. See the *SR OS R26.x.Rx Software Release Notes*, part number 3HE 29176 000*x* TQZZA, for information about features supported in each load of the Release 26.*x*.R*x* software. For a list of features and CLI commands that are present in SR OS but not supported on the 7705 SAR Gen 2 platforms, see "SR OS Features not Supported on SAR Gen 2" in the *SR OS R26.x.Rx Software Release Notes*.

1.2 Platforms and terminology

Note:
Unless explicitly noted otherwise, this guide uses the terminology defined in the following table to collectively designate the specified platforms.

Table 1: Platforms and terminology

Platform	Collective platform designation
7705 SAR-Hx	7705 SAR Gen 2
7705 SAR-Mx	

Platform	Collective platform designation
7705 SAR-1	

1.3 Conventions

This section describes the general conventions used in this guide.

1.3.1 Precautionary and information messages

The following information symbols are used in the documentation.

DANGER: Danger warns that the described activity or situation may result in serious personal injury or death. An electric shock hazard could exist. Before you begin work on this equipment, be aware of hazards involving electrical circuitry, be familiar with networking environments, and implement accident prevention procedures.

WARNING: Warning indicates that the described activity or situation may, or will, cause equipment damage, serious performance problems, or loss of data.

Caution: Caution indicates that the described activity or situation may reduce your component or system performance.

Note: Note provides additional operational information.

Tip: Tip provides suggestions for use or best practices.

1.3.2 Options or substeps in procedures and sequential workflows

Options in a procedure or a sequential workflow are indicated by a bulleted list. In the following example, at step 1, the user must perform the described action. At step 2, the user must perform one of the listed options to complete the step.

Example: Options in a procedure

1. User must perform this step.
2. This step offers three options. User must perform one option to complete this step.
   - This is one option.
   - This is another option.
   - This is yet another option.

Substeps in a procedure or a sequential workflow are indicated by letters. In the following example, at step 1, the user must perform the described action. At step 2, the user must perform two substeps (a. and b.) to complete the step.

Example: Substeps in a procedure

1. User must perform this step.
2. User must perform all substeps to complete this action.
   a. This is one substep.
   b. This is another substep.

Nested substeps within a procedure or a sequential workflow are indicated by roman numerals. In the following example, at step 1, the user must perform the described action. At step 2, the user must perform two substeps (a. and b.) to complete the step. At substep b, the user must perform two additional substeps (i. and ii.) to complete the step.

Example: Nested substeps in a procedure

1. User must perform this step.
2. User must perform all substeps to complete this action.
   a. This is one substep.
   b. User must perform all nested substeps to complete this action.
      i. This is a nested substep.
      ii. This is another nested substep.

2 Introduction

A service is a globally unique entity that refers to a type of connectivity service for either Internet or VPN connectivity. Each service is uniquely identified by a service ID and an optional service name within a service area. The Nokia service router model uses logical service entities to construct a service. In the service model, logical service entities provide a uniform, service-centric configuration, management, and billing model for service provisioning.

In the Nokia router services can provide Layer 2 bridged service or Layer 3 IP-routed connectivity between a service access point (SAP) on one router and another service access point (a SAP is where traffic enters and exits the service) on the same (local) router or another router (distributed). A distributed service spans more than one router.

Distributed services use service destination points (SDPs) to direct traffic to another Nokia router through a service tunnel. SDPs are created on each participating router, specifying the origination address (the router participating in the service communication) and the destination address of another router. SDPs are then bound to a specific customer service. Without the binding process, far-end router is not able to participate in the service (there is no service without associating an SDP with a service).

2.1 Service types

The Nokia routers offer the following types of subscriber services which are described in more detail in the referenced chapters:

- **Virtual Leased Line (VLL) service**
  - **Ethernet pipe (Epipe)**

    This is a Layer 2 point-to-point VLL service for Ethernet frames.

  See the *7705 SAR Gen 2 Layer 2 Services and EVPN Guide* for more information about VLL services.
- **Virtual Private LAN Service (VPLS)**

  This is a Layer 2 multipoint-to-multipoint VPN. VPLS includes Hierarchical VPLS (H-VPLS) which is an enhancement of VPLS which extends Martini-style signaled or static virtual circuit labeling outside the fully meshed VPLS core.

  See the *7705 SAR Gen 2 Layer 2 Services and EVPN Guide* for more information about VPLS.
- **Internet Enhanced Service (IES)**

  This is a direct Internet access service where the customer is assigned an IP interface for Internet connectivity.

  See the *7705 SAR Gen 2 Layer 3 Services Guide: IES and VPRN* for more information about IES.
- **Virtual Private Routed Network (VPRN)**

  This is a Layer 3 IP multipoint-to-multipoint VPN service as defined in RFC 2547bis.

  See the *7705 SAR Gen 2 Layer 3 Services Guide: IES and VPRN* for more information about VPRN services.

2.2 Service policies

Common to all Nokia service router connectivity services are policies that are assigned to the service. Policies are defined at a global level and then applied to a service on the router. Policies are used to define Nokia service router service enhancements. The types of policies that are common to the router's connectivity services are:

- **SAP Quality of Service (QoS) policies**

  SAP QoS policies allow for different classes of traffic within a service at SAP ingress and SAP egress. QoS ingress and egress policies determine the QoS characteristics for a SAP. A QoS policy applied to a SAP specifies the number of queues, queue characteristics (such as forwarding class, committed, and peak information rates, and so on) and the mapping of traffic to a forwarding class. A QoS policy must be created before it can be applied to a SAP. A single ingress and a single egress QoS policy can be associated with a SAP.

- **filter policies**

  Filter policies allow for selective blocking of traffic matching criteria from ingressing or egressing a SAP. Filter policies, also referred to as access control lists (ACLs), control the traffic allowed in or out of a SAP based on MAC or IP match criteria. Associating a filter policy on a SAP is optional. Filter policies are identified by a unique filter policy ID. A filter policy must be created before it can be applied to a SAP. A single ingress and single egress filter policy can be associated with a SAP.

- **scheduler policies**

  Scheduler policies define the hierarchy and operating options for virtual schedulers. Schedulers are divided into groups based on the tier each scheduler is created under. A tier is used to give structure to the schedulers within a policy and define rules for parent scheduler associations.

- **accounting policies**

  Accounting policies define how to count the traffic usage for a service for billing purposes. The routers provide a comprehensive set of service-related counters. Accounting data can be collected on a per-service, per-forwarding class basis, which enables network operators to accurately measure network usage and bill each customer for each individual service using any of a number of different billing models.

2.2.1 Multipoint shared queuing

Multipoint shared queuing is supported only on Nokia service router routers.

Multipoint shared queuing is supported to minimize the number of multipoint queues created for ingress VPLS, IES or VPRN SAPs or ingress subscriber SLA profiles. Normally, ingress multipoint packets are handled by multipoint queues created for each SAP or subscriber SLA profile instance. In some instances, the number of SAPs or SLA profile instances are sufficient for the in use multipoint queues to represent many thousands of queues on an ingress forwarding plane. If multipoint shared queuing is enabled for the SAPs or SLA profile instances on the forwarding plane, the multipoint queues are not created. Instead, the ingress multipoint packets are handled by the unicast queue mapped to the forwarding class of the multipoint packet.

Functionally, multipoint shared queuing is a superset of shared queuing. With shared queuing on a SAP or SLA profile instance, only unicast packets are processed twice, once for the initial service level queuing and a second time for switch fabric destination queuing. Shared queuing does not affect multipoint packet

handling. Multipoint packet handling in normal (service queuing) is the same as shared queuing. When multipoint shared queuing is enabled, shared queuing for unicast packets is automatically enabled.

2.2.1.1 Ingress queuing modes of operation

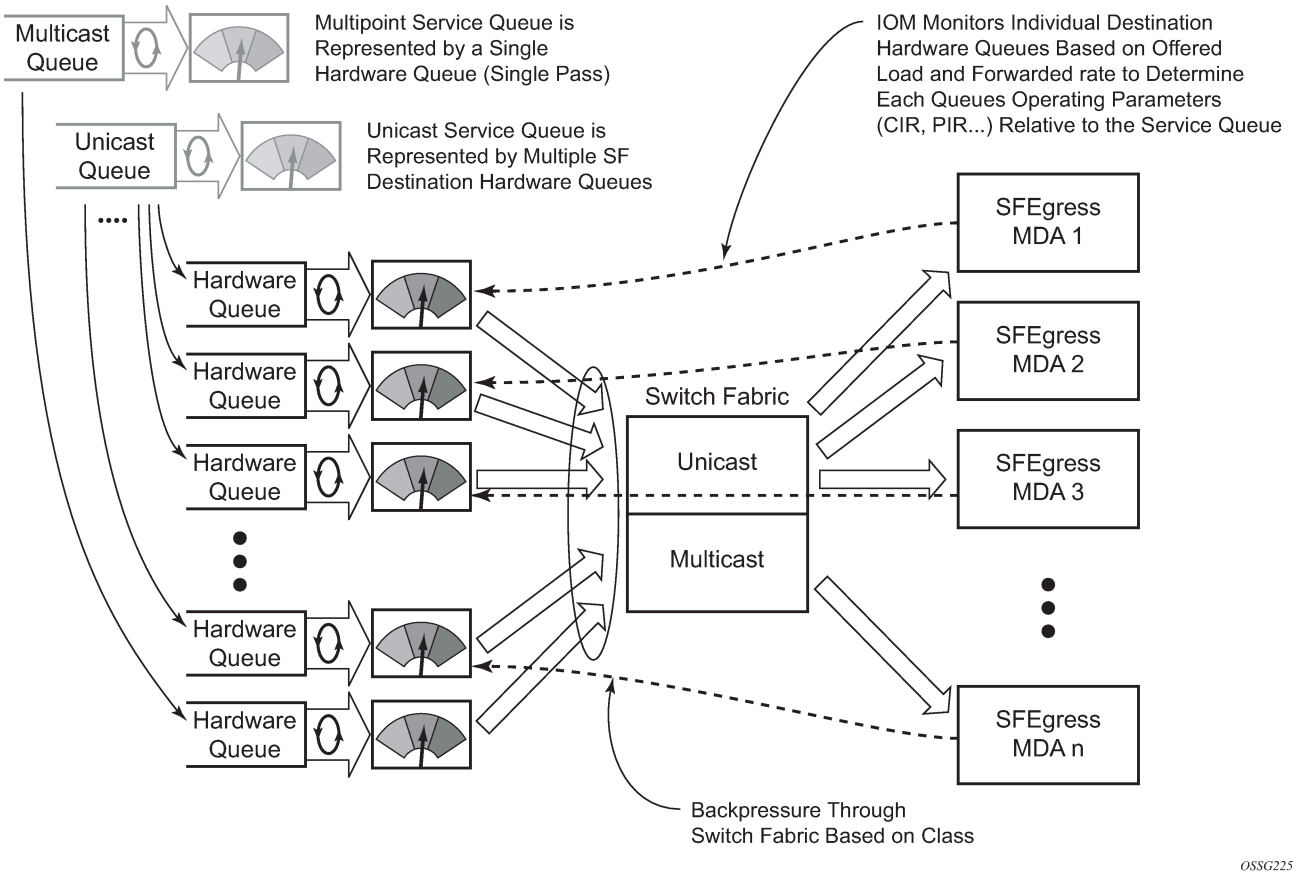
Three modes of ingress SAP queuing are supported for multipoint services (IES, VPLS and VPRN); service, shared, and multipoint shared. The same ingress queuing options are available for IES and VPLS subscriber SLA profile instance queuing.

2.2.1.2 Ingress service queuing

Normal or service queuing is the default mode of operation for SAP ingress queuing. Service queuing preserves ingress forwarding bandwidth by allowing a service queue defined in an ingress SAP QoS policy to be represented by a group of hardware queues. A hardware queue is created for each switch fabric destination to which the logical service queue must forward packets. For a VPLS SAP with two ingress unicast service queues, two hardware queues are used for each destination forwarding engine the VPLS SAP is forwarding to. If three switch fabric destinations are involved, six queues are allocated (two unicast service queues multiplied by three destination forwarding complexes equals six hardware queues). Figure 1: Unicast service queue mapping to multiple destination based hardware queues demonstrates unicast hardware queue expansion. Service multipoint queues in the ingress SAP QoS policy are not expanded to multiple hardware queues, each service multipoint queue defined on the SAP equates to a single hardware queue to the switch fabric.

When multiple hardware queues represent a single logical service queue, the system automatically monitors the offered load and forwarding rate of each hardware queue. Based on the monitored state of each hardware queue, the system imposes an individual CIR and PIR rate for each queue that provides an overall aggregate CIR and PIR reflective of what is provisioned on the service queue.

Figure 1: Unicast service queue mapping to multiple destination based hardware queues



2.2.1.3 Ingress shared queuing

To avoid the hardware queue expansion issues associated with normal service based queuing, the system allows an ingress logical service queue to map to a single hardware queue when shared queuing is enabled. Shared queuing uses two passes through the ingress forwarding plane to separate ingress per service queuing from the destination switch fabric queuing. In the case of shared queuing, ingress unicast service queues are created one-for-one relative to hardware queues. Each hardware queue representing a service queue is mapped to a special destination in the traffic manager that 'forwards' the packet back to the ingress forwarding plane allowing a second pass through the traffic manager. In the second pass, the packet is placed into a 'shared' queue for the destination forwarding plane. The shared queues are used by all services configured for shared queuing.

When the first SAP or SLA profile instance is configured for shared queuing on an ingress forwarding plane, the system allocates eight hardware queues per available destination forwarding plane, one queue per forwarding class. Twenty four hardware queues are also allocated for multipoint shared traffic. The shared queue command options that define the relative operation of the forwarding class queues are derived from the Shared Queue policy defined in the QoS CLI node. Figure 2: Unicast service queuing with shared queuing enabled demonstrates shared unicast queuing. SAP or SLA profile instance multipoint queuing is not affected by enabling shared queuing. Multipoint queues are still created as defined in the

ingress SAP QoS policy and ingress multipoint packets only traverse the ingress forwarding plane a single time, as demonstrated in Figure 3: Multipoint queue behavior with shared queuing enabled.

Enabling shared queuing may affect ingress performance because of double packet processing through the service and shared queues.

Figure 2: Unicast service queuing with shared queuing enabled

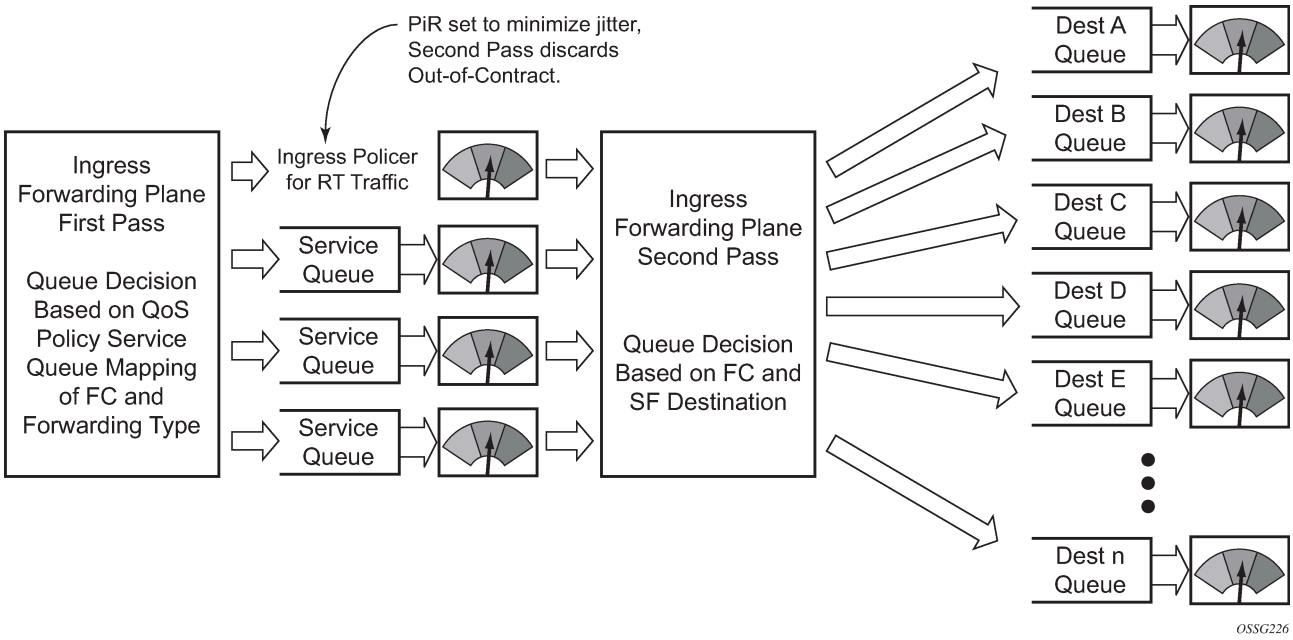
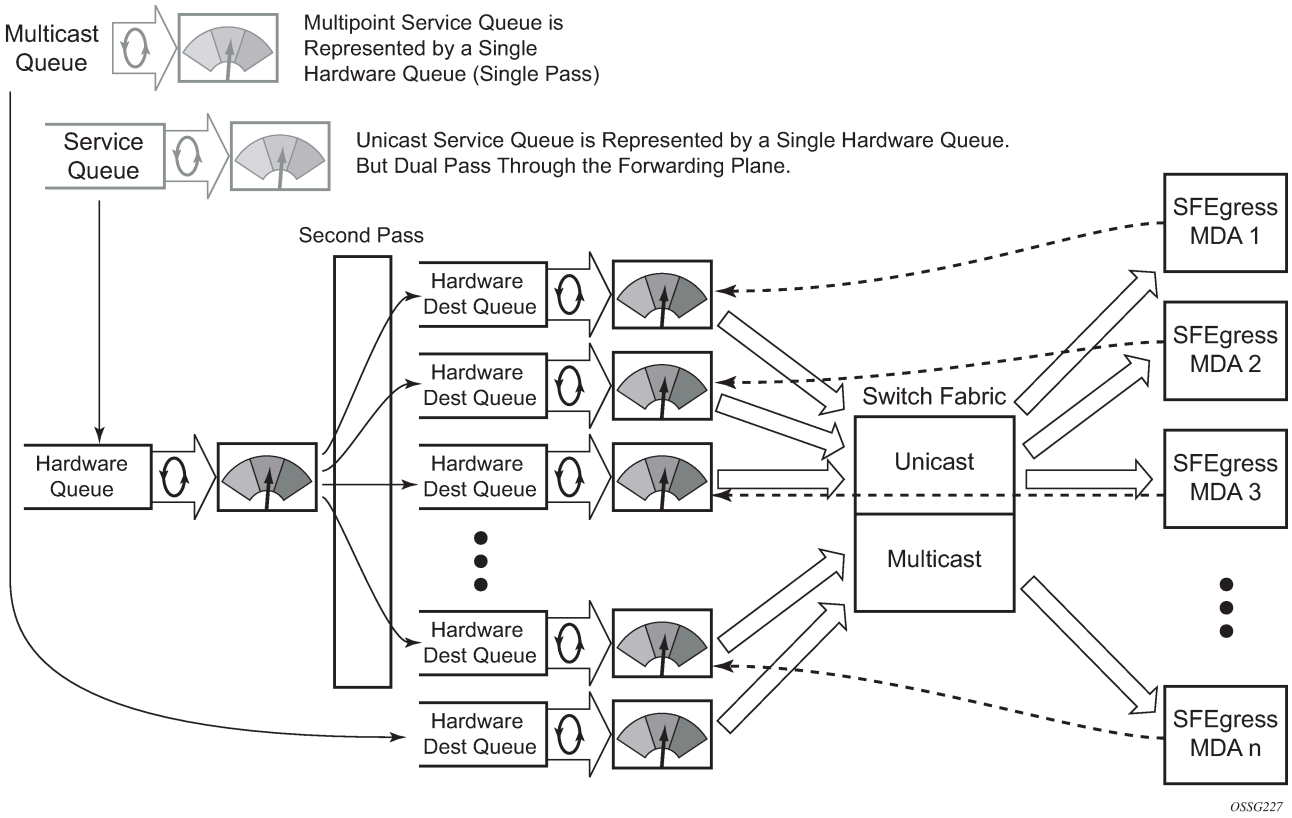


Figure 3: Multipoint queue behavior with shared queuing enabled



2.2.1.4 Ingress multipoint shared queuing

Ingress multipoint shared queuing is a variation to the unicast shared queuing defined in Ingress shared queuing. Ingress unicast service queues are mapped one-for-one with hardware queues and unicast packets traverse the ingress forwarding plane twice. In addition to the above, the multipoint queues defined in the ingress SAP QoS policy are not created. Instead, multipoint packets (broadcast, multicast and unknown unicast destined) are treated to the same dual pass ingress forwarding plane processing as unicast packets. In the first pass, the forwarding plane uses the unicast queue mappings for each forwarding plane. The second pass uses the multipoint shared queues to forward the packet to the switch fabric for special replication to all egress forwarding planes that need to process the packet.

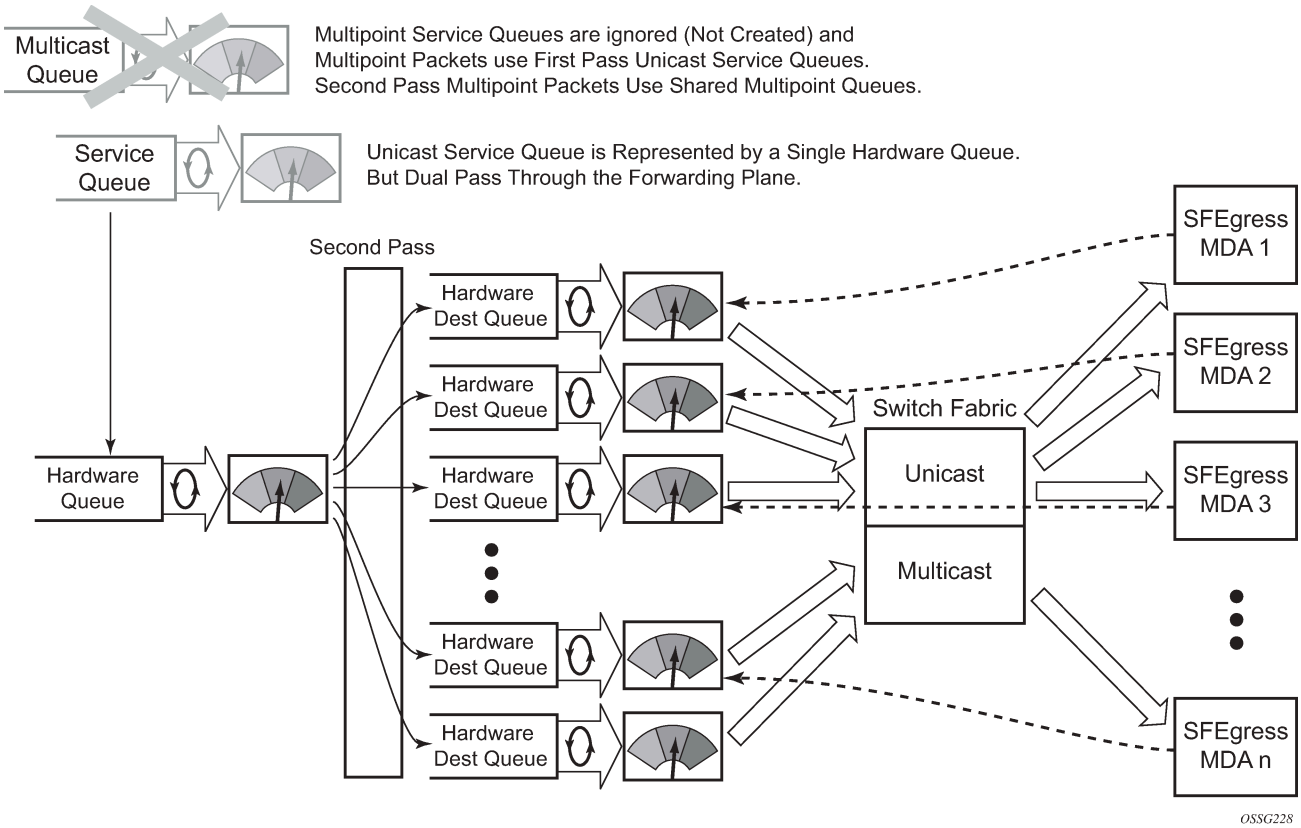
The benefit of defining multipoint shared queuing is the savings of the multipoint queues per service. By using the unicast queues in the first pass and then the aggregate shared queues in the second pass, per service multipoint queues are not required. The predominate scenario where multipoint shared queuing may be required is with subscriber managed QoS environments using a subscriber per SAP model. Usually, ingress multipoint traffic is minimal per subscriber and the extra multipoint queues for each subscriber reduces the overall subscriber density on the ingress forwarding plane. Multipoint shared queuing eliminates the multipoint queues sparing hardware queues for better subscriber density. Figure 4: Multipoint shared queuing using first pass unicast queues demonstrates multipoint shared queuing.

One disadvantage of enabling multipoint shared queuing is that multipoint packets are no longer managed per service (although the unicast forwarding queues may provide limited benefit in this area). Multipoint packets in a multipoint service (VPLS, IES and VPRN) use significant resources in the system, consuming

ingress forwarding plane multicast bandwidth and egress replication bandwidth. Usually, the per service unicast forwarding queues are not rate limited to a degree that allows adequate management of multipoint packets traversing them when multipoint shared queuing is enabled. It is possible to minimize the amount of aggregate multipoint bandwidth by setting restrictions on the multipoint queue command options in the QoS node's shared queue policy. Aggregate multipoint traffic can be managed per forwarding class for each of the three forwarding types (broadcast, multicast or unknown unicast – broadcast and unknown unicast are only used by VPLS).

A second disadvantage to multipoint shared queuing is the fact that multipoint traffic now consumes double the ingress forwarding plane bandwidth because of dual pass ingress processing.

Figure 4: Multipoint shared queuing using first pass unicast queues



3 Nokia service model

In the Nokia service model, the service edge routers are deployed at the provider edge. Services are provisioned on the service routers and transported across an IP or IP/MPLS provider core network, or both, in encapsulation tunnels created using generic router encapsulation (GRE) or MPLS label switched paths (LSPs).

The service model uses logical service entities to construct a service. The logical service entities are designed to provide a uniform, service-centric configuration, management, and billing model for service provisioning. Some benefits of this service-centric design include:

- Many services can be bound to a single customer.
- Many services can be bound to a single tunnel.
- Tunnel configurations are independent of the services they carry.
- Changes are made to a single logical entity instead of multiple ports on multiple devices. It is easier to change one tunnel instead of several services.
- The operational integrity of a logical entity (such as a service tunnel and service end points) can be verified instead of dozens of individual services improving management scaling and performance.
- On 7705 SAR Gen 2 SR OS, a failure in the network core can be correlated to specific subscribers and services.
- QoS policies, filter policies, and accounting policies are applied to each service instead of correlating command options and statistics from ports to customers to services.

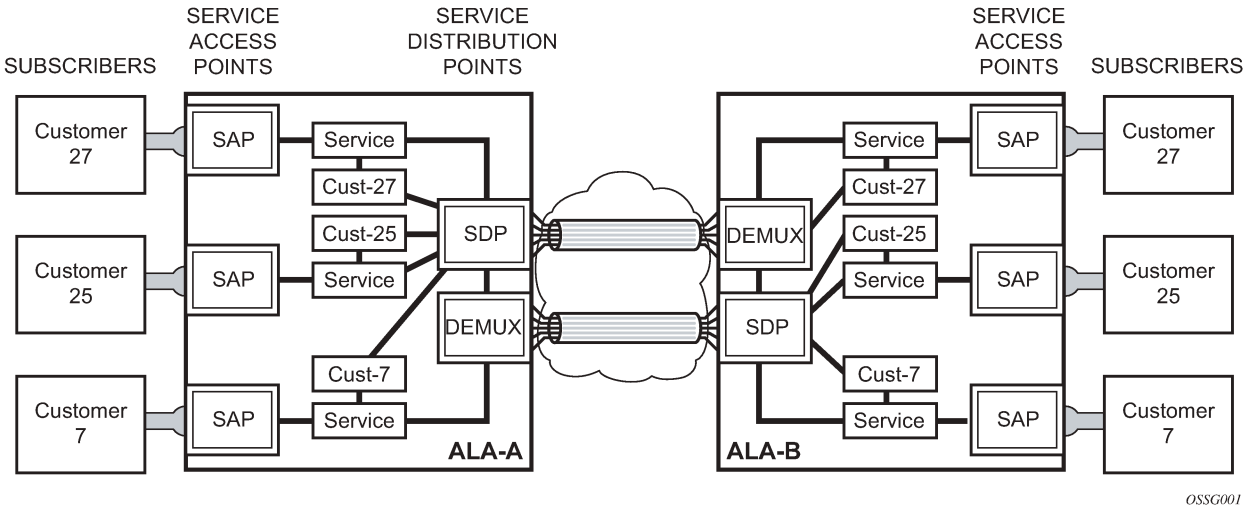
Service provisioning uses logical entities to provision a service where additional properties can be configured for bandwidth provisioning, QoS, security filtering, accounting/billing to the appropriate entity.

4 Service entities

The basic logical entities in the service model used to construct a service are:

- Customers
- SAPs
- Service destination points (for distributed services only)

Figure 5: Service entities



4.1 Customers

In this section, the terms customers and subscribers are used synonymously. The most basic required entity is the customer ID value which is assigned when the customer account is created. To provision a service, a customer ID must be associated with the service at the time of service creation.

4.2 SAPs

Each subscriber service type is configured with at least one service access point (SAP). A SAP identifies the customer interface point for a service on a router (for example Figure 6: 7705 SAR Gen 2 service access point (SAP)). The SAP configuration requires that slot, MDA, and port/channel information be specified. The slot, MDA, and port/channel must be configured before provisioning a service (see the "Cards, MDAs, and Ports" sections of the *7705 SAR Gen 2 Interface Configuration Guide*).

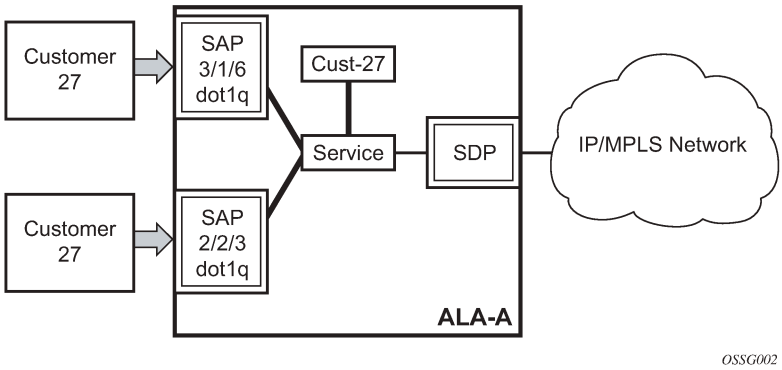
A SAP is a local entity to the router and is uniquely identified by:

- the physical Ethernet port or SONET/SDH port or TDM channel

- the encapsulation type
- the encapsulation identifier (ID)

Depending on the encapsulation, a physical port or channel can have more than one SAP associated with it. SAPs can only be created on ports or channels designated as "access" in the physical port configuration. SAPs cannot be created on ports designated as core-facing "network" ports as these ports have a different set of features enabled in software.

Figure 6: 7705 SAR Gen 2 service access point (SAP)



A SAP can also be associated with a pseudowire port instead of an access port. Such SAPs are called pseudowire SAPs. This is only applicable to IES, VPRN, and Epipe services.

4.2.1 SAP encapsulation types and identifiers

The encapsulation type is an access property of a service Ethernet port or SONET/SDH or TDM channel. The appropriate encapsulation type for the port or channel depends on the requirements to support multiple services on a single port or channel on the associated SAP and the capabilities of the downstream equipment connected to the port or channel. For example, a port can be tagged with IEEE 802.1Q (referred to as dot1q) encapsulation in which each individual tag can be identified with a service. A SAP is created on a specific port or channel by identifying the service with a specific encapsulation ID.

4.2.2 Ethernet encapsulations

The following lists encapsulation service options on Ethernet ports:

- **null**

  Null supports a single service on the port. For example, where a single customer with a single service customer edge (CE) device is attached to the port. The encapsulation ID is always 0 (zero).

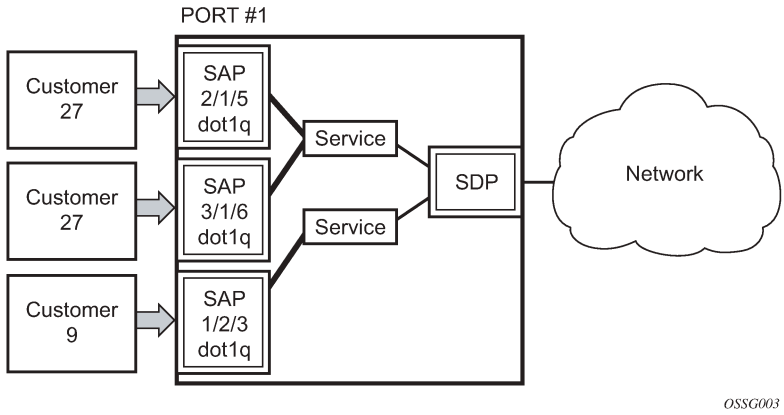
- **dot1q**

  Dot1q supports multiple services for one customer or services for multiple customers. For example, the port is connected to a multitenant unit (MTU) device with multiple downstream customers. The encapsulation ID used to distinguish an individual service is the VLAN ID in the IEEE 802.1Q header.

- **QinQ**

  The QinQ encapsulation type adds a IEEE 802.1Q tag to the 802.1Q tagged packets entering the network to expand the VLAN space by tagging tagged packets, producing a double tagged frame.

Figure 7: Multiple SAPs on a single port/channel



4.2.3 Default SAP on a dot1q port

On dot1q-encapsulated ports where a default SAP is configured, all packets with q-tags not matching any explicitly defined SAPs are assigned to this SAP. SAPs with default QinQ encapsulation are supported in VPLS, Epipe, IES and VPRN services. Both DHCP snooping and IGMP snooping are supported for QinQ SAPs. In this context, the character "*" indicates "default" which means "allow through". A 0 value allows the Q-tag to be missing.

One of the applications where this feature can be applicable is an access connection of a customer who uses the whole port to access Layer 2 services. The internal VLAN tags are transparent to the service provider. This can be provided by a null encapsulated port.

A dedicated VLAN (not used by the user) can be used to provide CPE management.

In this type of environment, logically two SAPs exist, a management SAP and a service SAP. The management SAP can be created by specifying a VLAN tag which is reserved to manage the CPE. The service SAP covers all other VLANs and behaves as a SAP on a null-encapsulated port.

There a few constraints related for the use of default SAP on a Dot1q-encapsulated port:

- This type of SAP is supported only on VPLS and Epipe services and cannot be created in IES and VPRN services as it cannot preserve VLAN tag markings.
- For VPLS SAPs with STP enabled, STP listens to untagged and null-tagged BPDUs only. All other tagged BPDUs are forwarded like other customer packets. This is the same behavior as null-encapsulated ports.
- IGMP snooping is not supported on a default SAP. This would require remembering VLAN tags per hosts. By not allowing IGMP snooping of this SAP, all IGMP packets are transparently forwarded.
- This type of SAP and a SAP defined by explicit null encapsulation (for example, 1/1/1:0) are mutually exclusive. This avoids conflict as to which SAP untagged frames should be associated.

In a Dot1q port SAP with a non-zero or non-default tag, the tag (referred to as service-delimiting tag) is stripped off on ingress and pushed on egress. For example, the tag is popped from frames received on SAP 1/1/1:10 with a tag that contains VID 10. A tag with VID 10 is pushed onto frames that are sent out of SAP 1/1/1:10.

In case of Dot1q port SAPs with a zero or default tag, no tag is stripped off on ingress, and no tag is pushed on egress. For instance, tags are not stripped off from frames entering 1/1/1:* or 1/1/1:0, and tags are not pushed either on frames egressing those SAPs.

4.2.4 QinQ SAPs

A QinQ SAP has the following format:

qinq <port-id | lag-id>:<qtag1 | cp-conn-prof-id>

Where:

- *qtag1* is the outer Q-tag value - [*, null, 0 to 4094]
- *qtag2* is the inner Q-tag value - [*, null, 0 to 4094]
- *cp:* keyword
- *conn-prof-id*: 1 to 8000

Regular QinQ SAPs have qtag1 and qtag2 values between 1 and 4094. In addition, QinQ Ethernet and LAG ports support the additional "default" SAPs. Use the following command to enable default SAPs for QinQ Ethernet and LAG ports:

- **MD-CLI**

```
configure service system extended-default-qinq-sap-lookup
```

- **classic CLI**

```
configure system ethernet new-qinq-untagged-sap
```

QinQ Ethernet and LAG ports support these additional "default" SAPs:

- '*.null' is defined as a default sap for singly-tagged frames in a QinQ port. This SAP accepts single tags in the range 0 to 4095 as well as untagged traffic. This SAP never pushes any tags on egress.
- '*.*' is defined as a default sap for doubly-tagged frames in a QinQ port. This SAP accepts untagged, singly tagged, and doubly tagged frames with tags in the range 0..4095. This SAP never pushes any tags on egress.
- 'null.null' is defined as a default SAP for untagged frames only in a QinQ port. This SAP accepts only untagged frames and never pushes any tags on egress. This SAP has higher priority than '*.null' or '*.*', or both, when configured on the same QinQ port, therefore it captures untagged frames even if '*.null' or '*.*' are configured.
- '0.*' can also be used as a default SAP and captures untagged frames, doubly-tagged frames with qtag1 0 (and any value on qtag2) and singly-tagged frames with Q-tag 0. SAP '0.*' and 'null.null' cannot be configured on the same QinQ port.
- In addition to the above-mentioned SAPs, qtag2 can also be '0' or '*' when qtag1 is an explicit value in the 1 to 4094 range, for instance: 1/1/1:10.0 or 1/1/1:10.*. Assuming qtag1 is the same value, qtag1.* and qtag1.0 are supported in the same QinQ port. The system never pushes any qtag2 on egress for 1/1/110.0 and 1/1/1:10.*, only qtag1 is pushed. The x.0 accepts only 0 as second tag or not tag (and nothing else), while x.* accepts anything as second tag or no tag.

A SAP lookup is performed when a new frame arrives to a QinQ port. This 'lookup' is based on the <outer-tag, inner-tag> values of the frame.

You can control the forwarding of packets on a QinQ X.0 access SAP to only accept frames with a single tag matching the SAP outer tag or frames with double tags where the outer tag matches the SAP outer tag and the inner tag is set to 0. Table 2: System/port settings (QinQ x.0 access SAP control enabled) shows the SAP lookup precedence order for incoming frames with <*qtag1.qtag2*> Q-tag values when this option is enabled.

Table 2: System/port settings (QinQ x.0 access SAP control enabled)

Incoming frame *qtag1.qtag2*	**SAP lookup precedence order**						
	:X.Y	**:X.0**	**:X.***	**:0.***	**:null.null**	**:*.null**	**:*.***
x.y	1st		2nd				3rd
x.0		1st	2nd				3rd
0.y				1st			2nd
0.0				1st			2nd
x		1st	2nd			3rd	4th
0				1st		2nd	3rd
<untagged>				1st	2nd	3rd	4th

The following considerations apply to the information described in Table 2: System/port settings (QinQ x.0 access SAP control enabled):

- All SAP types (:X.Y, :X.0, :X.*, :0.* or :null.null, :*.null and :*.*) are supported in the same QinQ port (with the exception of :0.* and :null.null being incompatible) and, in the table, they are ordered from the most specific (left side) to the least specific with the following VID matching ranges:
  - X or Y means <1 to 4094>
  - * means <0 to 4095> or untagged
  - null means 'no tag'
  - 0 means VID 0 or untagged
- On egress, the system pushes a tag with a VID value for X and Y, whereas no tag is pushed on egress for values 0, * or null. For example:
  - On SAP 1/1/1:10.20, the system pushes tags with VIDs 10 and 20 (outer and inner respectively) on egress.
  - On SAP 1/1/1:10.0 or 1/1/1:10.* the system pushes only one tag with VID 10 on egress.
  - On SAPs 1/1/1:0.*, 1/1/1:null.null, 1/1/1:*.null or 1/1/1:*.* the system never pushes any tags on egress.
- The user can decide the SAP types that are configured in a specific port. Not all SAP types must be configured in a port.
- Table 2: System/port settings (QinQ x.0 access SAP control enabled) shows the lookup behavior for ingress frames and priority across SAPs in case more than one can match a specific ingress frame. The SAP lookup result for a specific frame does not depend on the operational status of the SAP. For instance:

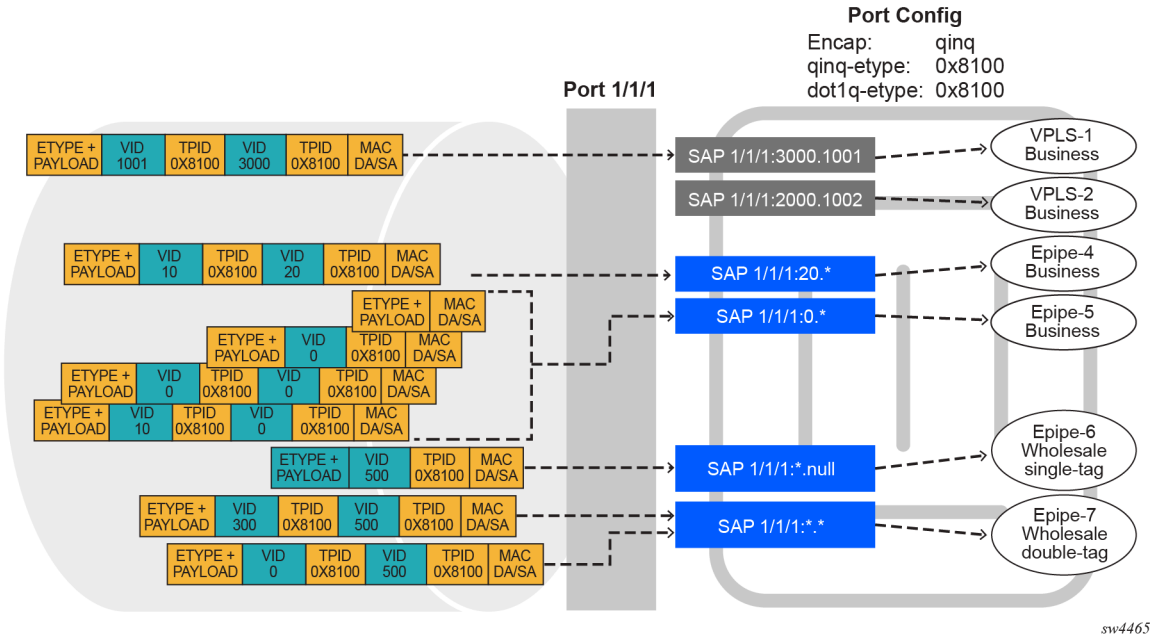
  - In a port with SAPs 1/1/1:0.* and 1/1/1:*.* defined, the SAP lookup for a specific frame with VIDs (0, 300) yields SAP 1/1/1:0.* regardless of its operational status.
  - The frame only matches SAP 1/1/1:*.* when the 0.* SAP is removed from the configuration.
- The following applies to VLAN tag handling:
  - The system does not strip-off any tags for frames entering the default SAPs (:0.*, :null.null, :*.null or :*.*).
  - No extra tags are added when the system transmits frames on the default SAPs (:0.*, :null.null, :*.null or :*.*).

The following examples illustrate the SAP classification QinQ ports. The examples assume that QinQ x.0 access SAP control is enabled.

As shown in Figure 8: Example 1 SAP classification QinQ ports, assuming that QinQ x.0 access SAP control is enabled, the following SAPs are defined on the same port:

- 1/1/1:3000.1001 - business customer - vpls-1
- 1/1/1:2000.1002 - business customer - vpls-2
- 1/1/1:20.* - business customer - epipe-4
- 1/1/1:0.* - business customer - epipe-5
- 1/1/1:*.null - wholesaling single tag - epipe-6
- 1/1/1:*.* - wholesaling double tag - epipe-7

Figure 8: Example 1 SAP classification QinQ ports



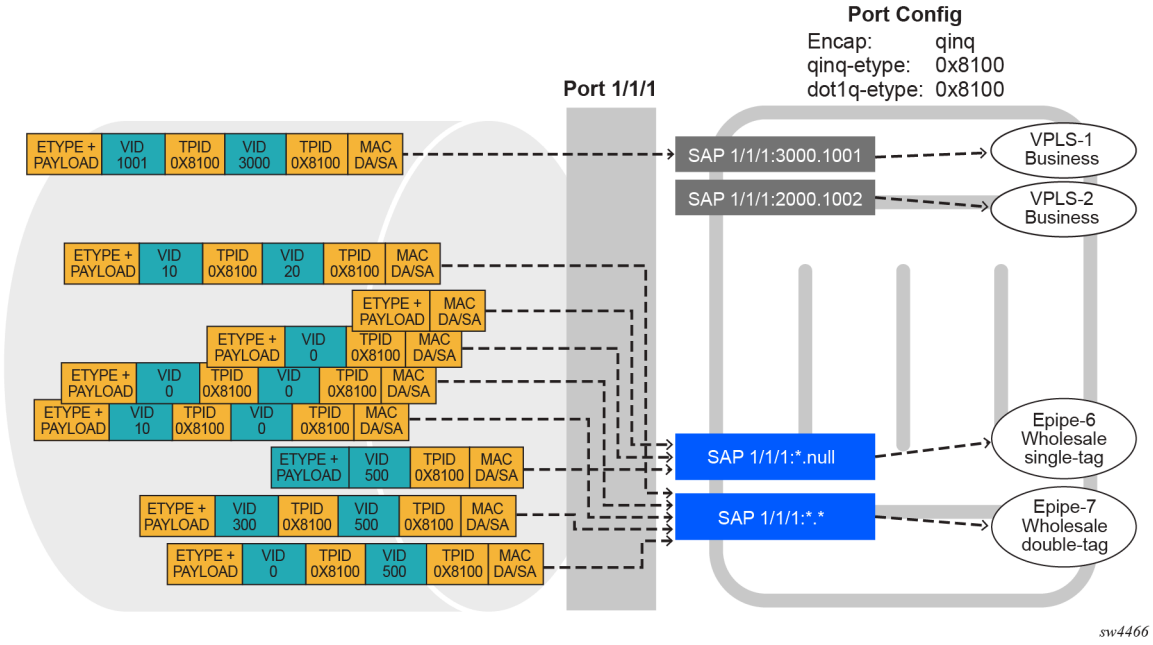
Based on the SAPs configuration described above, the incoming traffic is classified in the following way - notation (outer-VID, inner-VID):

- (3000, 1001) goes to vpls-1

- (20, 10) goes to epipe-4
- untagged, (0), (0, 0), and (0, 10) go to epipe-5
- (500) goes to wholesaling single tag (epipe-6)
- (500, 300) and (500, 0) go to wholesaling double tag (epipe-7)

Figure 9: Example 2 SAP classification QinQ ports highlights how untagged, VID=0 tagged frames and 20.X frames are classified in the absence of the 0.* and 20.* SAPs.

Figure 9: Example 2 SAP classification QinQ ports



As described in Figure 9: Example 2 SAP classification QinQ ports, assuming QinQ x.0 access SAP control is enabled, the following SAPs are defined on the same port:

- 1/1/1:3000.1001 - business customer - vpls-1
- 1/1/1:2000.1002 - business customer - vpls-2
- 1/1/1:*.null - wholesaling single tag - epipe-6
- 1/1/1:*.* - wholesaling double tag - epipe-7

Incoming traffic - notation (outer-VID, inner-VID)

- (3000, 1001) goes to vpls-1
- (20, 10) goes to wholesaling double tag (epipe-7)
- untagged and (0) go to wholesaling single tag (epipe-6)
- (500) goes to wholesaling single tag (epipe-6)
- (500, 300) and (500, 0) go to wholesaling double tag (epipe-7)
- (0,0), and (0,10) goes to wholesaling double tag (epipe-7)

Note: The system does not add service-delimiting tags with VID=0; however, tags with VID=0 are accepted and classified appropriately.

The following constraints must be considered when configuring default QinQ SAPs (:0.*, :null.null, :*.null, :*.*):

- Only supported in Ethernet ports or LAG.
- Only supported on Epipe, PBB-Epipe, VPLS and I-VPLS services. They are not supported on VPRN, IES, R-VPLS or B-VPLS services.
- Capture SAPs with encapsulation :*.* cannot coexist with a default :*.* SAP on the same port.
- Inverse-capture SAPs (*.x) are mutually-exclusive with :*.null SAPs.
- *.null SAPs are not supported for Open Flow matching and forwarding.
- The following applies to Eth-CFM:
  - Primary VLAN is not supported.
  - Eth-CFM extractions occur within the service after the packet lookup has determined which service the inbound packet belongs to.
  - All four SAPs (null.null, *.null, *.* and 0.*) are treated equally by ETH-CFM. Only untagged CFM PDUs are extracted by a local MEP or MIP. Additional tags in the header may match the service context but are not extracted by ETH-CFM for processing.
  - ETH-CFM PDU transmission encapsulation is based on the SAP configuration. This means that the ETH-CFM PDUs are transmitted out all four of these SAPs untagged. Care must be taken to ensure that there is no downstream service that may intercept the ETH-CFM PDUs that are not intended for that service. See Table 2: System/port settings (QinQ x.0 access SAP control enabled) for a description of the SAP lookup precedence order for incoming frames and to understand the potential consequences.
- Default QinQ SAPs do not support the following features:
  - PW-SAPs
  - Eth-tunnel or eth-ring SAPs
  - VLAN-translation *copy-outer*
  - E-Tree root-leaf-tag SAPs
  - BPDU-translation
  - Eth-tunnels
  - IGMP-snooping
  - MLD-snooping

4.2.5 Services and SAP encapsulations

The following table lists the services and SAP encapsulations.

Table 3: Service and SAP encapsulations

Port type	Encapsulation
Ethernet	Null
Ethernet	Dot1q
Ethernet	QinQ

4.2.6 SAP configuration considerations

When configuring a SAP, consider the following:

- A SAP is a local entity and only locally unique to a specific device. The same SAP ID value can be used on another Nokia router.
- There are no default SAPs. All SAPs in subscriber services must be created.
- The default administrative state for a SAP at creation time is administratively enabled.
- When a SAP is deleted, all configuration for the SAP is also deleted. For Internet Enhanced Service (IES), the IP interface must be shut down before the SAP on that interface may be removed.
- A SAP is owned by and associated with the service in which it is created in each router.
- A port or channel with a dot1q encapsulation type means the traffic for the SAP is identified based on a specific IEEE 802.1Q VLAN ID value. The VLAN ID is stripped off at SAP ingress and the appropriate VLAN ID placed on at SAP egress. As a result, VLAN IDs only have local significance, so the VLAN IDs for the SAPs for a service need not be the same at each SAP.
- If a port or channel is administratively shutdown, all SAPs on that port or channel are operationally out of service.
- A SAP cannot be deleted until it has been administratively disabled (shutdown).
- Each SAP can have one each of the following policies assigned:
  - ingress filter policy
  - egress filter policy
  - ingress QoS policy
  - egress QoS policy
  - accounting policy
  - ingress scheduler policy
  - egress scheduler policy

4.2.7 SAP bandwidth CAC

This feature provides a bandwidth Connection Admission Control (CAC) function per port or LAG based on an administrator bandwidth configured on a SAP and on the associated port or LAG. A booking factor is provided to allow overbooking or under booking of the sum of the SAP bandwidth compared to the port or LAG bandwidth.

The administrator bandwidth is a statically configured abstract value that could represent either the ingress or egress bandwidth, or both.

The goal of the CAC function is to ensure that the sum of the administrator SAP bandwidth on a port or LAG does not exceed the administrator bandwidth configured on that port or LAG.

This feature is supported on all service Ethernet SAPs, excluding PW SAPs, Ethernet tunnels and subscriber group interface SAPs. It is not supported in a VPLS or Epipe SAP template. It is applicable to both access and hybrid ports or LAGs; in the case of a hybrid port or LAG, the SAP CAC bandwidth only applies to the access operation.

By default, a SAP, port, or LAG has no administrator bandwidth configured, in which case it is excluded from the CAC function. Configuring an administrator bandwidth on a SAP enforces the CAC function.

An administrator bandwidth can only be configured on a SAP that is connected to a port or LAG on which an administrator bandwidth is already configured. When a LAG is configured, the administrator bandwidth and booking factor on its constituent ports are ignored.

The system tracks the requested and available bandwidth per port or LAG, where the available bandwidth is equal to the administrator bandwidth on the port or LAG, with the booking factor applied, minus the sum of administrator bandwidth configured on its SAPs. An attempt to increase a SAP's administrator bandwidth fails if there is insufficient available bandwidth on its port or LAG.

Use the following commands to configure the administrator bandwidth and booking factor for the port or LAG.

```
configure lag access bandwidth
configure lag access booking-factor

configure port ethernet access bandwidth
configure port ethernet access booking-factor

configure service {epipe | ipipe | vpls} sap bandwidth
configure service {ies | vprn} interface sap bandwidth
```

Dynamic changes in administrator bandwidth and booking factor are possible without having to disable the SAP, port, or LAG.

A SAP is allocated bandwidth on a port or LAG regardless of whether the SAP and port or LAG are administratively or operationally up or down. The administrator bandwidth must be removed from the SAP configuration to free up its bandwidth on the port or LAG. Actions such as clearing the card or MDA, power cycling the card, or removing and reinserting a card or MDA do not change the CAC state of the SAP and port or LAG.

4.2.7.1 CAC enforcement

The CAC is enforced when an administrator bandwidth is configured on a SAP, which may be when the administrator bandwidth is initially configured or when an existing administrator bandwidth value is modified.

The CAC enforcement is achieved by comparing the newly requested SAP administrator bandwidth (the incremental administrator bandwidth being configured above any currently assigned administrator bandwidth) with the available administrator bandwidth on its port or LAG.

The operation is as follows:

- If a SAP's admin bandwidth is increased and the incremental requested admin bandwidth is:

  - larger than the port or LAG available bandwidth then the command to increase the SAP admin bandwidth fails.
  - smaller or equal to the available port or LAG bandwidth then the incremental bandwidth is subtracted from the available port or LAG bandwidth.
- If a SAP's admin bandwidth is reduced then the available port or LAG bandwidth is increased accordingly.
- If the port or LAG admin bandwidth is increased, the available port or LAG bandwidth is increased accordingly.
- If the port or LAG admin bandwidth is decreased, the available port or LAG bandwidth is decreased accordingly. However, if the resulting available bandwidth would be less than the sum of the currently allocated SAP admin bandwidth on that port or LAG, then the command to decrease the admin bandwidth fails.
- If the port or LAG booking factor is decreased, the available port or LAG bandwidth is decreased accordingly. However, if the resulting available bandwidth would be less than the sum of the currently allocated SAP admin bandwidth on that port or LAG, then the command to decrease the booking factor fails.
- If the SAP admin bandwidth is removed, it is excluded from the SAP bandwidth CAC function. Its admin bandwidth is added to the related port or LAG available bandwidth.
- The port or LAG admin bandwidth can only be removed if all of its SAPs are excluded from the CAC function.

Output example

In the following example, a port is configured with an administrator bandwidth of 500 Mb/s, and a SAP on that port is configured with a bandwidth of 10 Mb/s. The **show** output displays these configured values together with the available and booked administrator bandwidth for the port.

```
===============================================================
Ethernet Interface
===============================================================
...

Access Bandwidth      : 500000 Booking Factor :100
Access Available BW  : 490000
Access Booked BW     : 10000

...
===============================================================
```

If an increase of the SAP administrator bandwidth to 600 Mb/s is attempted; the operation fails with the following error because of insufficient available administrator bandwidth on the port with the following error:

```
MINOR: SVCMGR #2664 Insufficient bandwidth available
```

If the booking factor for the port is increased to 200%, the increase of the SAP administrator bandwidth to 600 Mb/s is successful as the available administrator bandwidth for the port becomes 1 Gb/s. The booked administrator bandwidth for the port is 600 Mb/s and so the available administrator bandwidth for the port becomes 400 Mb/s.

```
===============================================================
Ethernet Interface
```

```
===============================================================
...

Access Bandwidth   : 500000                 Booking Factor : 200
Access Available BW: 400000
Access Booked BW   : 600000

...
===============================================================
```

4.3 Connection profile VLAN SAPs

The connection profile VLAN SAPs (CP SAPs) allow the association of a range of customer VIDs to a specific SAP. CP SAPs can be used to build Layer 2 services that are fully compatible with MEF 10.3 Bundling Service Attributes and RFC 7432 EVPN VLAN Bundle Service interfaces.

The following commands define the range of customer VIDs to be matched when the CP SAP is associated with a dot1q or QinQ SAP:

- **MD-CLI**

  ```
  configure connection-profile vlan qtag-range
  ```

- **classic CLI**

  ```
  configure connection-profile-vlan vlan-range
  ```

For VLAN manipulation, the CP SAP behavior is equivalent to the default SAP's (when the ingress VID falls into the range configured in the CP), where the range of VIDs included is not service-delimiting and therefore, the VIDs are not pushed/popped. The main differences between the CP SAPs and the default SAPs are:

- A default SAP consumes less resources; a default SAP consumes one SAP instance, whereas a CP SAP consumes SAP instances equal to the number of VLANs in the range. To check the number of SAP instances used by the system, run the following CLI command:

  ```
  tools dump resource-usage system
  ```

  See the *7705 SAR Gen 2 Clear, Monitor, Show, Tools CLI Command Reference Guide* for a complete description of the **tools dump resource-usage** commands:

Output example

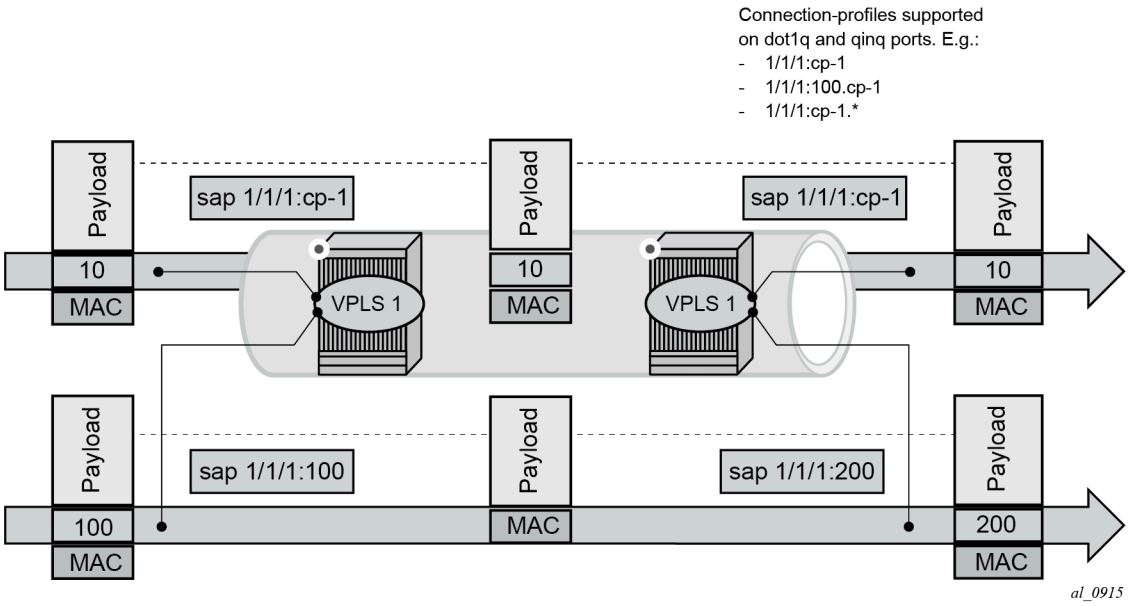
```
===============================================================================
Resource Usage Information for System
===============================================================================
                                                 Total   Allocated        Free
-------------------------------------------------------------------------------
<snip>
                               SAP Entries  |   262143           8      262135
===============================================================================

*A:Dut# tools dump resource-usage card 1 fp 1
===============================================================================
Resource Usage Information for Card Slot #1 FP #1
===============================================================================
```

```
                                                    Total   Allocated        Free
-------------------------------------------------------------------------------
<snip>
                                SAP Instances   |    63999         254       63745
<snip>
===============================================================================
```

- Unlike the default SAP, a CP SAP cannot coexist with a vlan SAP that is in the same range. For example, 1/1/1:* and 1/1/1:100 can coexist; in contrast, 2/1/1:cp-1 (cp-1 = vlan 1 to 200) and 2/1/1:100 cannot coexist.

Figure 10: VLAN tag handling shows customer VID processing by SAPs with service-delimiting VIDs of 1 to 50, and by CP SAPs. In this example, SAP 1/1/1:cp-1 does not strip off or push VID 10, whereas SAP 1/1/1:100 and SAP 1/1/1:200 do strip off and push the corresponding VID.

Figure 10: VLAN tag handling



A CP SAP allows the configuration of VLAN ranges with the following characteristics:

- A VLAN range can be defined as a single VID (for example, 101), or two VIDs delimiting the beginning and the end of the range (for example, 105 to 107).
- Discontinuous ranges are allowed.
- Overlapping ranges are not allowed within the same CP SAP configuration. Overlapping VLAN ranges can exist across different connection profiles if they are not applied to the same port (in the case of dot1q ports), or the same port and service-delimiting tag (in the case of QinQ ports). For example:
  - 1/1/1:x.cp-1 and 1/1/1:y.cp-2 can coexist on the same port, where cp-1 includes VIDs [10-20] and cp-2 includes VIDs [15-25]
  - if x=y, then the overlapping is not possible in the above case
- A CP SAP must have at least one range (with a single or multiple VIDs) before it can be associated with a SAP.
- A CP SAP cannot contain an explicitly defined SAP within any of the ranges when the explicit SAP is configured on the same port.

- The configured VLAN ranges cannot contain VIDs 0 or 4095.
- The CP SAPs are supported in Layer 2 services only. No IES or VPRN services can contain CP SAPs.
- CP SAPs are supported on access or hybrid ports but are not on network interfaces.
- CP SAPs are supported in (non-PBB) Epipe and VPLS services.
- CP SAPs support SAP based QoS policies. VID type MAC criteria can be used on CP SAPs to apply specific QoS on a VLAN within the connection-profile-vlan.
-
- In the classic CLI, the **mac-ping**, **mac-trace**, **mac-purge**, and **mac-populate** OAM commands are not supported for CP SAPs.

4.3.1 Using connection profile VLAN SAPs in dot1q ports

Table 4: SAP lookup matching order for dot1q ports describes the SAP lookup matching order that is applied when a CP SAP is used in dot1q ports.

Table 4: SAP lookup matching order for dot1q ports

Incoming frame Q-tag VID value	**SAP lookup precedence order (:0 and :* are mutually-exclusive on the same port)**			
	:X	**:CP**	**:0**	**:***
x (belongs to the CP range)	1st	1st		2nd
0			1st	1st
<untagged>			1st	1st

4.3.2 Using connection profile VLAN SAPs in QinQ ports

Table 5: SAP lookup matching order for QinQ ports (QinQ x.0 access SAP control enabled) describes the SAP lookup matching order that is applied when CP SAPs is used in QinQ ports.

Table 5: SAP lookup matching order for QinQ ports (QinQ x.0 access SAP control enabled)

Incoming frame *qtag1qtag2* **.**	**SAP lookup precedence order (assumption: X and Y are defined in CP ranges)**							
	:X.Y	**:X.0**	**:X.CP**	**:CP.***	**:X.***	**:0.***	**:*.null**	**:*.***
x.y	1st		1st	2nd	2nd			3rd
x.0		1st		2nd	2nd			3rd
0.y						1st		2nd
0.0						1st		2nd

Incoming frame *qtag1qtag2* .	SAP lookup precedence order (assumption: X and Y are defined in CP ranges)							
	:X.Y	**:X.0**	**:X.CP**	**:CP.***	**:X.***	**:0.***	**:*.null**	**:*.***
x		1st		2nd	2nd		3rd	4th
0						1st	2nd	3rd
<untagged>						1st	2nd	3rd

The following considerations apply when connection profile VLAN (CP VLAN) is used in QinQ ports:

- A CP can be defined for inner or outer tags but not both at the same time; for example, "":X.CP" and "":CP.*" are possible, but not "":CP.CP".
- It is important to note that "":CP:Y" is not allowed; for example, if a CP is defined at the outer VID, the inner VID can only be a "*" or a "0".
- "":0.CP" SAPs are not allowed; if the outer VID is 0, the inner VID cannot be a connection-profile-vlan value.
- A CP cannot contain a VID that is associated with an explicitly defined inner or outer tag in a specific port. For example, assuming that X and Y are tags defined in "CP", a specific port can be defined with ":X.CP" or ":Y.CP", but not with ":X.Y" and ":X.CP" or ":CP.*" and "X.*" in the same port.
- The following combinations are allowed:
  - :CP.0 (matches frames with outer tags contained in CP and inner tags 0 or null)
  - :CP.* (matches frames with outer tags contained in CP and any inner tags)
- In the case where a VLAN tag combination matches different SAPs, the highest priority SAP is picked, irrespective of its oper-status, as long as the SAP is still created. Therefore, if the SAP is down, the frames do not go to a different SAP. For example, suppose that ingress frames with VIDs 10.25 are classified as part of sap 10.cp-1. Only when sap 10.cp-1 is removed from the configuration do the frames with VIDs 10.25 go to sap cp-1.*.

4.4 Service destination points

A service destination point (SDP) acts as a logical way to direct traffic from one router to another through a unidirectional (one-way) service tunnel. The SDP terminates at the far-end device which directs packets to the correct service egress SAPs on that device. A distributed service consists of a configuration with at least one SAP on a local node, one SAP on a remote node, and an SDP binding the service to the service tunnel.

An SDP has the following characteristics:

- An SDP is locally unique to participating routers. The same SDP ID can appear on other Nokia routers.
- An SDP uses the system IP address to identify the far-end edge router.
- An SDP is not specific to any one service or any type of service. When an SDP is created, services are bound to the SDP. An SDP can also have more than one service type associated with it.
- All services mapped to an SDP use the same transport encapsulation type defined for the SDP (either GRE or MPLS).

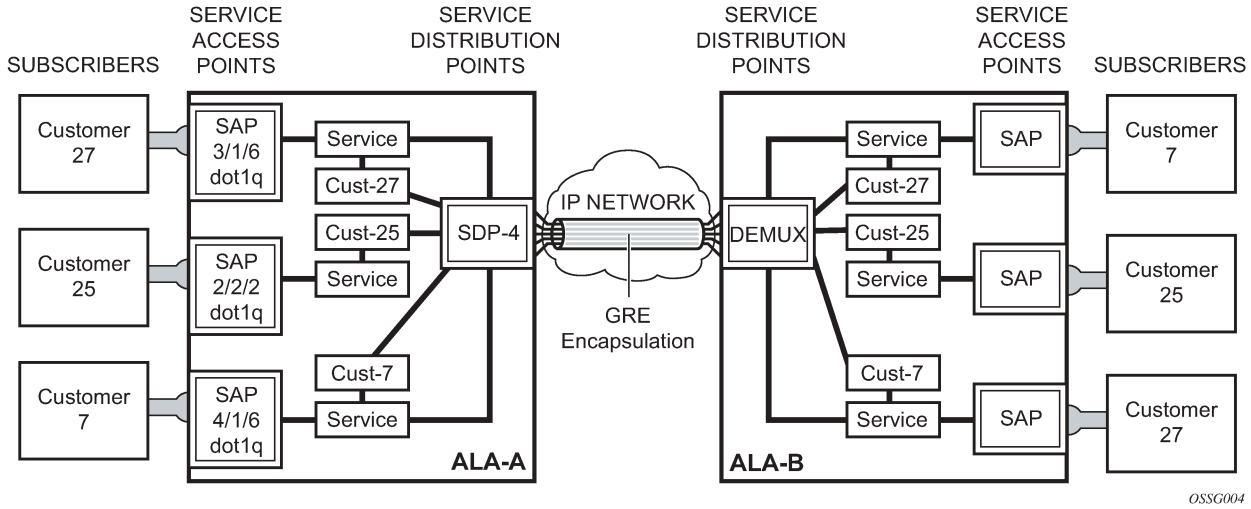
- An SDP is a management entity. Even though the SDP configuration and the services carried within are independent, they are related objects. Operations on the SDP affect all the services associated with the SDP. For example, the operational and administrative state of an SDP controls the state of services bound to the SDP.

An SDP from the local device to a far-end router requires a return path SDP from the far-end router back to the local router. Each device must have an SDP defined for every remote router to which it wants to provide service. SDPs must be created first, before a distributed service can be configured.

4.4.1 SDP binding

To configure a distributed service from ALA-A to ALA-B, the SDP ID (1) (shown in Figure 11: GRE SDP pointing from ALA-A to ALA-B) must be specified in the service creation process to "bind" the service to the tunnel (the SDP). Otherwise, service traffic is not directed to a far-end point and the far-end devices cannot participate in the service (there is no service). To configure a distributed service from ALA-B to ALA-A, the SDP ID (5) must be specified.

Figure 11: GRE SDP pointing from ALA-A to ALA-B



4.4.2 Spoke and mesh SDPs

When an SDP is bound to a service, it is bound as either a spoke SDP or a mesh SDP. The type of SDP indicates how flooded traffic is transmitted.

A spoke SDP is treated like the equivalent of a traditional bridge "port" where flooded traffic received on the spoke SDP is replicated on all other "ports" (other spoke and mesh SDPs or SAPs) and not transmitted on the port it was received.

All mesh SDPs bound to a service are logically treated like a single bridge "port" for flooded traffic where flooded traffic received on any mesh SDP on the service is replicated to other "ports" (spoke SDPs and SAPs) and not transmitted on any mesh SDPs.

4.4.3 SDP using BGP route tunnel

SDP is enhanced to use BGP route tunnel to extend inter-AS support for routes and services. An SDP can be configured based on service transport method (for example, GRE or MPLS tunnel). MPLS SDP support is enhanced to allow a BGP route tunnel to reach the far-end PE.

A single method of tunneling is allowed per SDP (for example, LDP, RSVP-TE LSP or BGP route tunnel).

For the inter-AS far-end PE, next-hop for BGP route tunnel must be one of the local ASBR. The LSP type selected to reach the local ASBR (BGP labeled route next-hop) must be configured under the BGP global context. LDP must be supported to provide transport LSP to reach the BGP route tunnel next-hop.

Only BGP route labels can be used to transition from ASBR to the next-hop ASBR. The global BGP route tunnel transport command option must be entered to select an LSP to reach the PE node from ASBR node. On the last BGP segment, both BGP and LDP and LDP routes may be available to reach the far-end PE from the ASBR node. LDP LSP must be preferred because of higher protocol priority. This leads to just one label besides other labels in stack to identify VC or VPN at far-end PE nodes.

4.4.4 SDP keepalives

SDP keepalives actively monitor the SDP operational state using periodic Nokia SDP ping echo requests and echo reply messages. Nokia SDP ping is a part of the Nokia suite of service diagnostics built on a Nokia service-level OAM protocol. When the SDP ping is used in the SDP keepalive application, the SDP echo requests and echo reply messages are a mechanism for exchanging the far-end SDP status.

Configuring SDP keepalives on an SDP is optional. SDP keepalives have the following configurable parameters:

- admin up/admin down state
- hello time
- message length
- max drop count
- hold down time

SDP keepalive echo request messages are only sent when the SDP is completely configured and administratively up, and SDP keepalives are administratively up. If the SDP is administratively down, keepalives for the SDP are disabled.

SDP keepalive echo request messages are sent out periodically based on the configured hello time. Message lengths for echo requests are configurable. If max drop count echo request messages do not receive an echo reply, the SDP immediately becomes operationally down.

If a keepalive response is received that indicates an error condition, the SDP immediately becomes operationally down.

When a response is received that indicates the error has cleared and the hold down time interval has expired, the SDP is eligible to be put into the operationally up state. If no other condition prevents the operational change, the SDP enters the operational state.

4.4.5 SDP selection rules

In the current SDP selection process, all provisioned SDPs with the correct far-end IP address, the correct tunnel-far-end IP address, and the correct service label signaling are considered. The SDP with the lowest admin metric is selected. If more than one SDP with the same lowest metric are found, then the SDP with the highest sdp-id is selected. The type of SDP, GRE or MPLS (BGP/RSVP/LDP) is not a criterion in this selection.

The selection rule with SDP admin groups is modified such that the following admin-group constraints are applied up front to prune SDPs that do not comply:

- If one or more SDP include statement is part of the PW template, then an SDP that is a member of one or more of the included groups is considered. With the **sdp-include** statement, there is no preference for an SDP that belongs to all included groups versus one that belongs to one or fewer of the included groups. All SDPs satisfying the admin-group constraint are considered and the selection above based on the lowest metric and highest SDP ID is applied.
- If one or more SDP exclude statement is part of the PW template, then an SDP that is a member of any of the excluded groups is not considered.

4.4.6 Class-based forwarding

4.4.6.1 Application of class-based forwarding over RSVP LSPs

Class-based forwarding over RSVP LSPs allows a service packet to be forwarded over a specific RSVP LSP, part of an SDP, based on its ingress determined forwarding class. The LSP selected depends on the operational status and load-balancing algorithms used for ECMP and LAG spraying.

Figure 12: Class-based forwarding over SDP LSPs

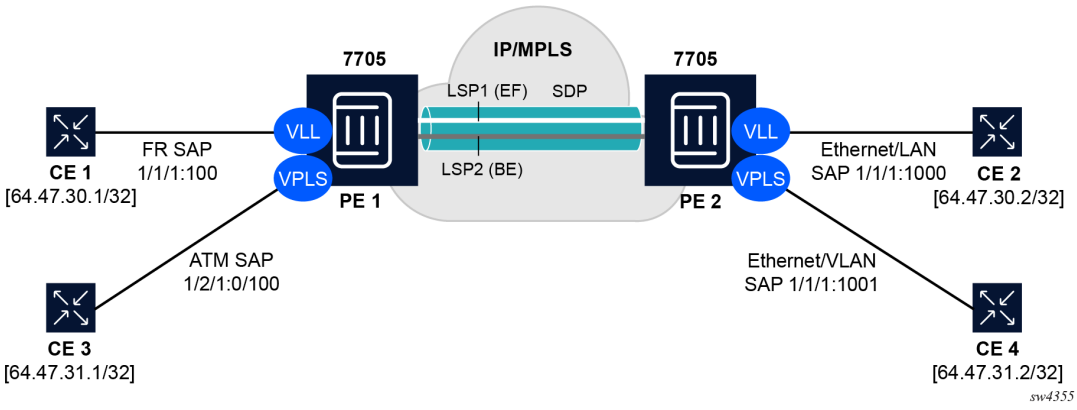


Figure 12: Class-based forwarding over SDP LSPs illustrates the use of class-based forwarding to direct packets of a service to specific RSVP or static LSPs that are part of the same SDP based on the packets' forwarding class. The forwarding class of the packet is the one assigned to the packet as a result of applying the ingress QoS policy to the service SAP. The VLL service packets are all classified into the **ef** forwarding class and those that are destined for PE2 are forwarded over LSP1. Multicast and broadcast are classified into the **be** class and are forwarded over LSP2.

This feature allows service providers to dedicate specific LSPs with a determined level of traffic engineering and protection to select service packets. For example, packets of a VoIP service are assigned the **ef** class to expedite their forwarding but are also sent over carefully traffic-engineered and FRR-protected LSP paths across the service provider network.

4.4.6.2 Operation of class-based forwarding over RSVP LSPs

The Nokia router's class-based forwarding feature applies to a set of LSPs that are part of the same SDP. Each LSP must be configured as part of an SDP specifying the forwarding classes it supports. A forwarding class can only be assigned to one LSP in a specific SDP, meaning that only one LSP within an SDP supports a specific class of service. However, multiple classes of services can be assigned to an LSP. Both RSVP and static LSPs are allowed. All subclasses are assigned to the same LSP as the parent forwarding class.

When a service packet is received at an ingress SAP, it is classified into one of the eight forwarding classes. If the packet leaves the SR on an SDP that is configured for class-based forwarding, the outgoing LSP is selected based on the packet's forwarding class. Each SDP has a default LSP. The default LSP is used to forward a received packet that was classified at the ingress SAP into a forwarding class for which the SDP does not have an explicitly-configured LSP association. It is also used to forward a received packet if the LSP supporting its forwarding class is down.

Note: The SDP goes down if the default LSP is down.

Class-based forwarding can be applied to all services supported by the Nokia routers. For VPLS services, explicit FC-to-LSP mappings are used for known unicast packets. Multicast and broadcast packets use the default LSP. There is a per-SDP user configuration that optionally overrides this behavior to specify an LSP to be used for multicast/broadcast packets.

VLL service packets are forwarded based on their forwarding class only if shared queuing is enabled on the ingress SAP. Shared queuing must be enabled on the VLL ingress SAP if class-forwarding is enabled on the SDP the service is bound to. Otherwise, the VLL packets are forwarded to the LSP which is the result of hashing the VLL service ID. Because there are eight entries in the ECMP table for an SDP, one LSP ID for each forwarding class, the resulting load balancing of VLL service ID is weighted by the number of times an LSP appears on that table. For instance, if there are eight LSPs, the result of the hashing is similar to when class based forwarding is disabled on the SDP. If there are fewer LSPs, then the LSPs which were mapped to more than one forwarding class, including the default LSP, have proportionally more VLL services forwarding to them.

Only user packets are forwarded based on their forwarding class. OAM packets are forwarded in the same way as an SDP with class-based forwarding disabled. In other words, LSP ping and LSP trace messages are queued in the queue corresponding to the forwarding class specified by the user and are forwarded over the LSP being tested. Service and SDP OAM packets, such as service ping, VCCV ping, and SDP ping are queued in the queue corresponding to the forwarding class specified by the user and forwarded over the first available LSP.

Class-based forwarding is not supported for protocol packets tunneled through an SDP. All packets are forwarded over the default LSP.

Class-based forwarding is not supported on a spoke SDP used for termination on an IES or VPRN service. All packets are forwarded over the default LSP.

4.4.7 Source IPv4 address configuration in GRE SDP and GRE tunnel

4.4.7.1 Introduction and feature configuration

When the GRE tunnel is used as part of a provisioned SDP, the following command is relaxed to allow the user to configure a source address for an GRE SDP:

```
configure service sdp local-end
```

The default value of the **local-end** command option is the primary IPv4 address of the system interface. To change the local-end address, the SDP must be shut down.

The primary IPv4 address of any local network IP interface, loopback or otherwise, may be used as the source address. The address does not need to match the primary address of an interface which has the MPLS-over-GRE termination subnet configured, unless a GRE SDP or tunnel from the far-end router terminates on this address.

The address of the following interfaces are not supported:

- unnumbered network IP interface
- IES interface
- VPRN interface
- CSC VPRN interface

The following rules apply when configuring the local end:

- You can configure a maximum of 15 distinct address values under the following contexts:
  - **GRE SDPs**

    ```
    configure service sdp local-end
    ```

  - **L2oGRE SDPs**

    ```
    configure service system gre-eth-bridged tunnel-termination
    ```

    The same source address cannot be used in both contexts because an address configured for a L2oGRE SDP matches an internally created interface which is not available to other applications.
- The local-end address of a GRE SDP, when different from system, need not match the primary address of an interface which has the MPLS-over-GRE termination subnet configured, unless a GRE SDP or tunnel from the far-end router terminates on this address.

The user must ensure that the local-end address is reachable from the far-end router that terminates the GRE SDP. To help ensure reachability, the interface for this address may be added to IGP or BGP, or a static route may be configured on the far-end router.

The following services can be bound to a GRE SDP when the local-end address is modified:

- VPRN or IES with a spoke-SDP interface
- VPLS with a provisioned spoke SDP
- BGP-AD VPLS with the provisioned SDP configured to use or prefer
- BGP-VPLS with the provisioned SDP configured to use or prefer

- Epipe with a provisioned spoke SDP
- Epipe with BGP-VPWS with the provisioned SDP configured to use or prefer

For services that support auto-binding to a GRE tunnel, the following command configures a single alternate source address per system.

```
configure service system vpn-gre-source-ip
```

The default value is the primary IPv4 address of the system interface.

A change to the value of the **vpn-gre-source-ip** command option can be performed without shutting down the service. After the new value is configured, the system address is not used in services that bind to the GRE tunnel.

The primary IPv4 address of any local network IP interface, loopback or otherwise, may be used.

The address of the following interfaces are not supported:

- unnumbered network IP interface
- IES interface
- VPRN interface
- CSC VPRN interface

The following rules apply to the **vpn-gre-source-ip** command option value:

- This single source address counts toward the maximum of 15 distinct address values per system that are used under the following contexts:
  - **GRE SDPs**

    ```
    configure service sdp local-end
    ```

  - **L2oGRE SDPs**

    ```
    configure service system gre-eth-bridged tunnel-termination
    ```

- The same source address can be used in both **vpn-gre-source-ip** and **configure service sdp local-end** contexts.
- The same source address cannot be used in both **vpn-gre-source-ip** and **configure service system gre-eth-bridged tunnel-termination** contexts because an address configured for a L2oGRE SDP matches an internally created interface that is not available to other applications.
- The **vpn-gre-source-ip** address, when different from system, need not match the primary address of an interface which has the MPLS-over-GRE termination subnet configured, unless a GRE SDP or tunnel from the far-end router terminates on this address.

The following contexts can use a GRE tunnel when the source IP address is modified:

- VPRN service with a SDP
- VPRN auto-bind-tunnel

The source address cannot be configured for the following services with auto-created GRE-SDP:

- BGP-AD VPLS
- BGP-VPLS
- VGP-VPWS

An alternative solution to bind any one of these services to its own specific GRE SDP with its own source IP address is to tag a pre-provisioned GRE SDP with a SDP admin-group (**sdp-group** command) and include the admin-group with the PW template binding of this service, as shown in the following command. The command provisioned SDP can also be set to prefer:

- **MD-CLI**

```
configure service provisioned-sdp sdp-include
```

- **classic CLI**

```
configure service pw-template use-provisioned-sdp sdp-include
```

4.4.7.2 Feature operation with T-LDP and BGP service label signaling

The origination function continues to operate as in previous releases. The only change is the ability to insert the user configured address in the source address field of the GRE/IPv4 header as described in Introduction and feature configuration.

Note: The service manager does not explicitly request from the LDP module that an SDP auto-generated T-LDP session for the MPLS-over-GRE SDP uses the source address configured with the following command:

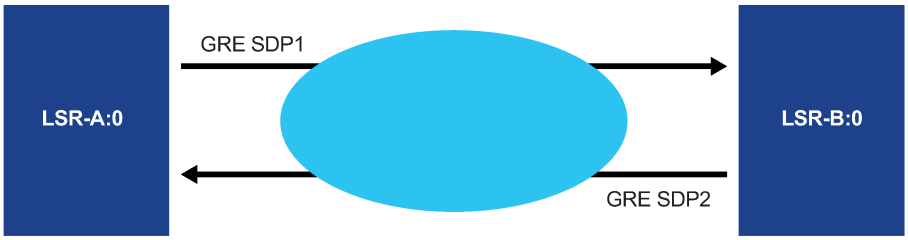
```
configure service sdp local-end
```

LDP ensures that either a user-configured T-LDP session, or a peer template based auto-created T-LDP session, exists and is connected to the far-end address of the SDP. LDP uses one of these sessions, or auto-creates one using the default local transport address of system.

Consequently, if the source transport address used by the T-LDP control plane session does not match the destination transport address set by the remote PE in the targeted LDP Hello messages, the T-LDP session does not come up.

For example, the setup in Figure 13: Mismatched T-LDP control plane configuration results in both GRE SDP1 and SDP2 to remain down because the targeted Hello adjacency and LDP session does not come up between the two LDP LSRs.

Figure 13: Mismatched T-LDP control plane configuration



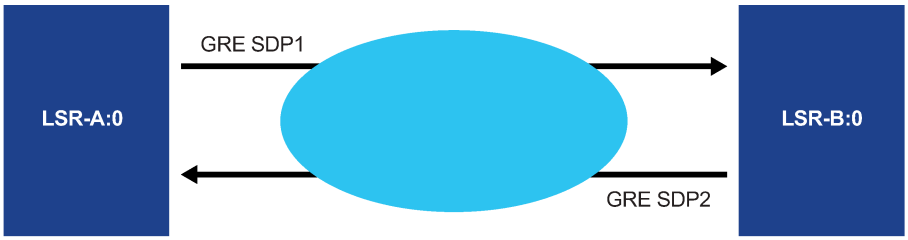
GRE SDP1:
• Local-end = A1
• Far-end = B1
T-LDP session (SDP auto-created):
• Local transport address = system1
• Peer transport address = B1

GRE SDP2:
• Local-end = B1
• Far-end = A1
T-LDP session (SDP auto-created):
• Local transport address = system2
• Peer transport address = A1

sw0628

The user must match the local transport address of the T-LDP session to the local-end address of the GRE SDP in both the local and remote PE routers. This can be achieved by manually configuring a T-LDP session to the peer, or by auto-creating a T-LDP session with the targeted peer template feature, and setting the local LSR ID to the address configured in the local-end address of the GRE SDP. In addition, the far-end address must be in a GRE termination subnet at the remote PE and be the primary address of an interface in order for T-LDP to use it as its local LSR ID at the remote PE. Figure 14: Proper setting of T-LDP control plane configuration shows an example of a correct configuration.

Figure 14: Proper setting of T-LDP control plane configuration



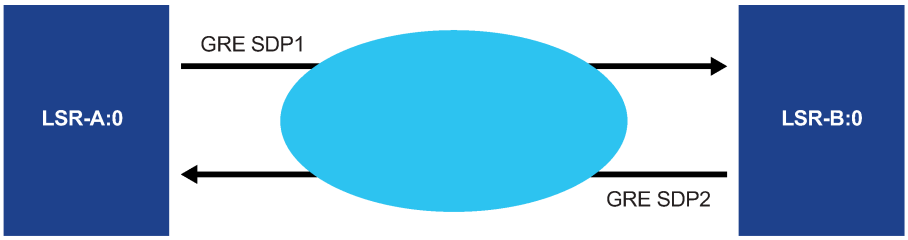
GRE SDP1:
• Local-end = A1
• Far-end = B1
T-LDP session (manually provisioned
or auto-created via peer template):
• Local transport address = A1
• Peer transport address = B1

GRE SDP2:
• Local-end = B1
• Far-end = A1
T-LDP session (manually provisioned
or auto-created via peer template):
• Local transport address = B1
• Peer transport address = A1

sw0629

The source address used by the GRE tunnel in the data plane can be different than the local transport address used by T-LDP in the control plane and the GRE SDPs still come up. For example, the setup in Figure 15: Source address mismatch between control and data planes uses at each end the system address for the T-LDP session but uses a loopback interface address as the source address of the GRE SDP.

Figure 15: Source address mismatch between control and data planes



GRE SDP1:
• Local-end = A1
• Far-end = system2
T-LDP session (SDP auto-created):
• Local transport address = system1
• Peer transport address = system2

GRE SDP2:
• Local-end = B1
• Far-end = system1
T-LDP session (SDP auto-created):
• Local transport address = system2
• Peer transport address = system1

sw0630

Note: The LDP uses a priority mechanism to select which provisioned options to use to instantiate a T-LDP session to the same far-end transport address. A manually provisioned T-LDP session overrides one that is signaled using the targeted peer template which overrides one that is auto-created by an SDP. This is done automatically by LDP by issuing, an ad-hoc update to the Hello message to the far-end with the new provisioned options. As long as the corresponding change is performed at the far-end router to match the local-end change (for example, changing the local transport address requires a change of the far-end transport address in the remote LSR to the same value) the T-LDP session remains up while the Hello adjacency is being synchronized by both LSRs.

The same recommendation applies when the SDP uses BGP for signaling the VC labels of the services. The user must configure the BGP session to the peer and set the local address under the BGP group context or under the neighbor context to the local-end address configured in the GRE SDP.

Replies to OAM messages such as an SDP keep-alive and sdp-ping are sent by the far-end PE using the MPLS-over-GRE encapsulation to the source address of the received OAM message. This means, the source transport address of the T-LDP control plane session or the BGP control plane session is used for the signaling of the VC-label in the local PE. Replies to OAM messages when the VC label is static are sent to the source address of the local PE. In all cases however, the system can properly extract them to the CPM as long as the subnet of that local interface is reachable.

4.4.8 GRE SDP tunnel fragmentation and reassembly

GRE SDP tunnel fragmentation and reassembly allows those services for which fragmentation is typically not available to make use of IP layer fragmentation and reassembly of GRE SDP tunnels that carry those services. It enables services that require larger MTUs to be carried over network segments where the MTU is less than the MTU of their respective GRE SDP tunnel packets. As a result, GRE SDP tunnel packets that require fragmentation are either fragmented at the source node or within the MTU restricted network, and reassembled on the GRE SDP terminating node.

4.4.8.1 GRE SDP tunnel fragmentation

The **allow-fragmentation** command enables GRE SDP tunnel fragmentation and can be configured under the following contexts:

- SDP with type GRE (MPLS tunnels are not supported)

```
configure service sdp allow-fragmentation
```

- PW template with the **auto-gre-sdp** command option set

```
configure service pw-template allow-fragmentation
```

The services that are supported with GRE SDP fragmentation and reassembly include the following:

- VPLS services using GRE SDP tunnels
- Epipe VLL services using GRE SDP tunnels
- BGP-VPLS services
- BGP-VPWS services

When enabled, GRE SDP tunnel fragmentation is applied to any generated GRE SDP tunnel packet where its size is greater than the MTU of the network interface needed to egress the node. The network interface chosen to egress the node is based on the SDP bindings for the service.

For GRE SDPs and SDP bindings using PW templates with the **auto-gre-sdp** command option configured, if a received SAP packet size is greater than the service MTU, the packet is dropped per normal SAP ingress processing.

If GRE-SDP tunnel fragmentation is enabled when configuring **allow-fragmentation**, the DF-bit is cleared for unfragmented and fragmented GRE SDP tunnel packets. This allows downstream routers to fragment the packets further if needed.

4.4.8.2 GRE SDP tunnel reassembly

To reassemble GRE SDP tunnel fragments on the node terminating the service carried in the GRE SDP tunnel, the vISA-BB application is used to receive fragments, reassemble them, and return the reassembled GRE SDP tunnel packet for regular ingress processing.

To enable reassembly of GRE SDP fragmented packets, the following items must be configured:

1. Use the commands in the **configure card mda** context to enable the ISA-BB application on the node.

   See the *7705 SAR Gen 2 Multiservice ISA and ESA Guide* for more information.

2. Use the following commands to configure an IP filter:

   - **MD-CLI**

```
configure filter ip-filter default-action accept
configure filter ip-filter entry match protocol gre
configure filter ip-filter entry match fragment true
configure filter ip-filter entry action reassemble
```

   - **classic CLI**

```
configure filter ip-filter default-action forward
```

```
configure filter ip-filter entry match protocol gre
configure filter ip-filter entry match fragment true
configure filter ip-filter entry action reassemble
```

3. Configure a NAT group using the following commands:
   - **MD-CLI**

     ```
     configure isa nat-group redundancy active-mda-limit 1
     configure isa nat-group mda mda-BB-ISA
     ```

   - **classic CLI**

     ```
     configure isa nat-group active-mda-limit 1
     configure isa nat-group mda mda-BB-ISA
     ```

4. Add the filter to the router interface or interfaces where GRE SDP packets and fragments are expected to be received.
5. Enable reassembly to base routing using the following command:
   - **MD-CLI**

     ```
     configure router reassembly to-base-network
     ```

   - **classic CLI**

     ```
     configure router reassembly-group to-base-network
     ```

The following example displays a GRE SDP tunnel reassembly configuration.

Example: GRE SDP tunnel reassembly configuration (MD-CLI)

```
[ex:/configure card 1]
A:admin@node-2# info
    card-type imm-2pac-fp3
    mda 1 {
        admin-state enable
        mda-type isa2-bb
    }
```

```
[ex:/configure filter]
A:admin@node-2# info
        ip-filter "10" {
        default-action accept
        entry 1 {
            match {
                protocol gre
                fragment true
            }
            action {
                reassemble
            }
        }
```

```
[ex:/configure isa]
A:admin@node-2# info
    nat-group 1 {
        admin-state enable
```

```
        redundancy {
            active-mda-limit 1
        }
        mda 1/2
    }
```

```
[ex:/configure router "Base"]
A:admin@node-2# info
    interface "system" {
        admin-state enable
        ipv4 {
            primary {
                address 91.91.91.91
                prefix-length 32
            }
        }
    }
    interface "to-PE2" {
           port 1/1/1
           gre-termination true
           ingress {
                filter {
                    ip "10"
                }
            }
            ipv4 {
                primary {
                    address 10.1.1.10
                    prefix-length 24
                }
            }
        }
```

Example: GRE SDP tunnel reassembly configuration (classic CLI)

```
A:node-2>config>card# info
----------------------------------------
        card-type imm-2pac-fp3
        mda 1
            mda-type isa2-bb
            no shutdown
        exit
----------------------------------------
```

```
A:node-2>config>filter# info
----------------------------------------------
    ...       ip-filter 10 name "10" create
            default-action forward
            entry 1 create
                match protocol gre
                    fragment true
                exit
                action
                    reassemble
                exit
            exit
         ...
----------------------------------------------
```

```
A:node-2>config>filter# info
----------------------------------------------
```

```
        ip-filter 10 name "10" create
            default-action forward
            entry 1 create
                match protocol gre
                    fragment true
                exit
                action
                    reassemble
                exit
            exit
-----------------------------------------
```

```
A:node-2>config>isa# info
----------------------------------------------
        ...
        nat-group 1 create
            no shutdown
            mda 1/2
            active-mda-limit 1
        exit
----------------------------------------------
```

```
A:node-2>config>router# info
----------------------------------------------
        interface "system"
            address 91.91.91.91/32
            no shutdown
        exit
        interface "to-PE2"
            address 10.1.1.10/24
            port 1/2/1
            ingress
                filter ip 10
            exit
            gre-termination
            no shutdown
        exit
-----------------------------------------
```

4.4.8.3 NGE considerations

GRE SDP tunnel fragmentation and reassembly is supported in conjunction with NGE. Encryption is applied to the GRE SDP (NGE) tunnel packet before fragmentation on egress and not to each fragment. Decryption occurs after the GRE SDP (NGE) tunnel packet is reassembled by the BB-ISA application and returned to base routing for processing.

GRE SDP tunnel reassembly is supported when the GRE SDP tunnel terminates on the router interface IP address. See GRE SDP termination on router interface IP address for information about GRE SDP termination on a router interface IP address.

4.4.9 GRE SDP termination on router interface IP address

Use the following command to terminate GRE SDP tunnel packets directly on a router interface IP address:

- **MD-CLI**

```
configure router interface gre-termination
```

- **classic CLI**

```
configure router interface address gre-termination
```

Services that support GRE SDP termination on the router interface IP address include the following:

- VPRN services (spoke SDP and auto-bind-tunnel)
- T-LDP signaled Ethernet VLL services
- T-LDP signaled VPLS services
- BGP-VPLS services
- BGP-VPWS services

Only GRE SDP tunnel packets that have a destination IP that is equal to the /31 value of the IP address configured on the router interface can terminate on the router interface. For example, if the address is set to 1.2.3.4/24, only the single /31 address 1.2.3.4 is used for the GRE SDP tunnel packet to terminate on. GRE SDP termination on router interface IP addresses is not supported on loopback interfaces.

When T-LDP is used to signal services, the local LSR ID command option must be set to the /31 value of the IP address of the router interface used to terminate the GRE SDP tunnel packets.

When BGP is used to advertise routes for services, the local address for BGP sessions must be set to the /31 value of the IP address of the router interface used to terminate the GRE-SDP tunnel packets.

4.5 SAP and MPLS binding loopback with MAC swap

SAPs and MPLS SDP bindings within Ethernet services, Epipe, and VPLS can be placed into a loopback mode, which allows packets to be looped back toward the source of the traffic. The feature is specific to the entity on which the loopback is configured and is non-disruptive to other SAPs and SDP bindings on the same port or LAG.

Epipe, PBB Epipe, VPLS, and I-VPLS service constructs support both ingress and egress loopbacks on Ethernet SAPs or MPLS SDP bindings.

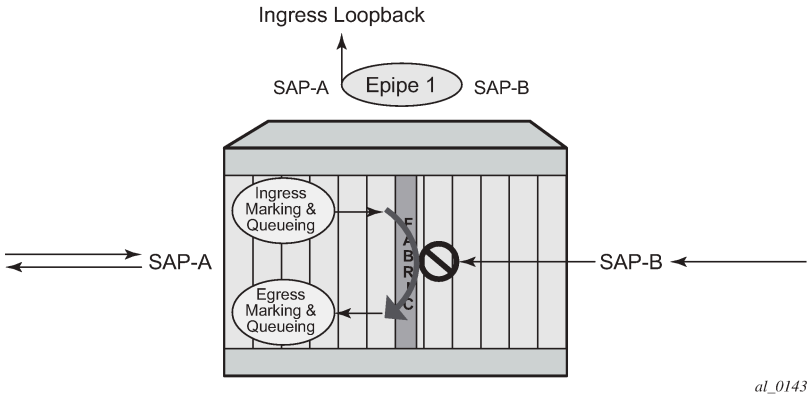
Note: Do not enable this functionality in the core PBB context because there is no ISID awareness. If this feature is enabled in the core PBB context all traffic that arrives on the B-SAP or B-MPLS binding is looped back into the PBB context, without regard for ISID or customer specific MAC headers.

An ingress loopback configured on the entity has the following effects on traffic forwarding on the entity:

- Traffic arriving on the entity is looped back to the same entity, via the fabric.
- Traffic attempting to egress that entity from another SAP or SDP binding within the service is blocked.

Essentially an ingress loopback function isolates the SAP or MPLS SDP binding from the rest of the service. Figure 16: Ingress loopback packet processing uses a simple Epipe service example to show the various touch points for a packet that is processed by an ingress loopback as it moves through the network element.

Figure 16: Ingress loopback packet processing



An egress loopback configured on the entity has the following effects on the traffic forwarding on the entity:

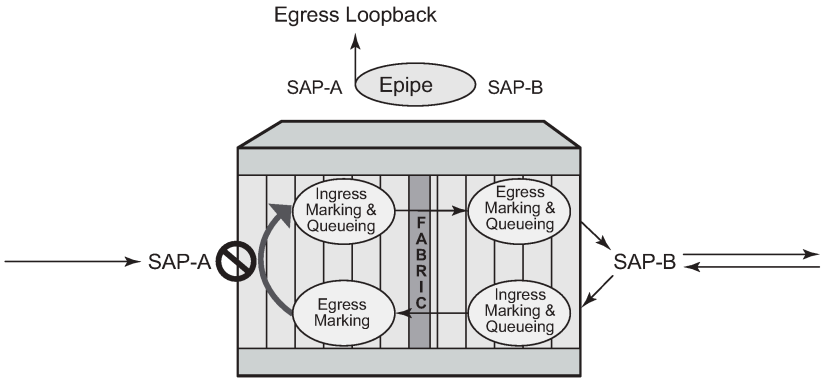
- Traffic arriving on any service SAP or SDP binding that is forwarded to an egress loopback is looped back into the service.
- Traffic attempting to gain access to the service from that entity (ingress the network element from the entity) is dropped.

In the case of the egress loopback, the SAP or MPLS SDP binding is not isolated from the rest of the service it remains part of the service and reflects traffic back into the service.

Note: Extreme care must be used when considering the application of an egress loopback in a VPLS or I-VPLS service. Because a VPLS service relies on MAC based forwarding, any packet that arrives at an egress loopback is reflected back into the service, which uses MAC based forwarding to apply the correct forwarding decision. In a live multipoint service with active endpoints this could have a major negative impact on the service and the clients connected to this service. Even if the forwarding database is primed, any arriving broadcast, unknown or multicast traffic arrives on the egress loopback and is reflected back into the service causing (at the very least) duplication of this type of traffic in the service.

Figure 17: Egress loopback packet processing uses a simple Epipe service to illustrate the various touch points for a packet that is processed by an egress loopback as it moves through the network element. Egress processing does not perform queuing functions on the egress; only functions of the forwarding plane like remarking are performed.

Figure 17: Egress loopback packet processing



The operational state of the SAP or MPLS SDP binding does not change as a result of the loopback function. This means a SAP or MPLS SDP binding that is operationally up does not change state strictly because the loopback started or stopped. Of course control protocols that are attempting to gain access via the entity that is not allowing packets to enter the service eventually time out.

Exercise caution when considering the use of control protocols in a service with enabled loopbacks. The operator must understand that control protocol interruptions can significantly impact the state of the SAP. When SAPs are dynamically created using a protocol or a protocol is required to maintain the operational state of the SAP, interrupting the control protocol causes the SAP to fail. Other SAPs linking their state to a failed SAP react to that failure as well. This loopback function is per Ethernet SAP or MPLS SDP binding. That is, all traffic that is extracted and sent to the CPM before the loopback process is looped back in the direction it was received, or in the case of VPLS, back into the service. All service based control protocols that are included with this service should be removed to ensure the loopback process is handling the packets and not some other function on the node that can extract the control protocol but never respond because the service is blocked. However, there may be instances where it is essential to continue running control protocols for the service during a loopback. For example, Down MEPs on an Ethernet SAP could continue to process ETH-CFM packets if the loopback is on the mate Ethernet SAP and was configured as an egress loopback.

By default, no MAC swap functions are performed. Options are available to support various MAC swap functions. Table 6: MAC-Swap configuration and options lists the actions and functions based on the configured **mac-swap** and associated options.

Table 6: MAC-Swap configuration and options

Configuration		**Reflection with inbound DA**			
Action	**Options**	**Unicast (learned)**	**Unicast (unknown)**	**Broadcast**	**Multicast**
MAC swap	no options	Swap SA to DA Swap DA to SA	Swap SA to DA Swap DA to SA	Drop	Drop
MAC swap	mac	Swap SA to DA Swap DA to SA	Swap SA to DA Swap DA to SA	Swap SA to DA Static MAC= SA	Swap SA to DA Static MAC= SA

Configuration		Reflection with inbound DA			
Action	**Options**	**Unicast (learned)**	**Unicast (unknown)**	**Broadcast**	**Multicast**
MAC swap	mac + all	Swap SA to DA Static MAC= SA	Swap SA to DA Static MAC= SA	Swap SA to DA Static MAC= SA	Swap SA to DA Static MAC= SA
none	none	No swapping	No swapping	No swapping	No swapping

Only the outer Layer 2 header can be manipulated.

In order for the loopback function to operate, the service must be operationally up, and the SAP, port, or LAG must be administratively up. In the case of a LAG, the LAG must have member ports that are administratively up. If any of these conditions are not met, the loopback function fails.

A SAP that is configured for egress loopback is not required to be operationally up, and the cabling does not need to be connected to the port. However, all necessary hardware must be installed in the network element for the ingress packets to be routed to the egress. Ghost ports do not support loopback operations.

An Epipe service enters an operationally down state when one of the SAPs is non-operational. The service state remains or is returned to an operational state if the following command is configured under the non-operational SAP.

```
configure service epipe sap ignore-oper-down
```

A VPLS service remains operational as long as one SAP in the service is operational. However, if the SAP is a VPLS is configured over a LAG, the SAP is removed from the forwarding table if it has a non-operational state, and, consequently, packets never reach the egress. Use the following command under the VPLS SAP over a LAG to allow the LAG SAP to be reached even with a non-operational SAP.

```
configure service vpls sap process-cpm-traffic-on-sap-down
```

If the service state is not operational or the egress SAP is not reachable via the forwarding plane, the traffic never arrives on the SAP to be looped.

MPLS SDP bindings must be operationally up or the loopback function fails.

Use the commands in the **tools** context to configure this functionality. In this specific case, the loopback tools supporting this functionality may be configured through CLI or through SNMP. However, these commands are never resident in the configuration. This means the loopback survives high availability events that cause one CPM to change from standby to active, as well as ISSU function or IOM resets (hard or soft). However the loopback function does not survive a complete node reboot.

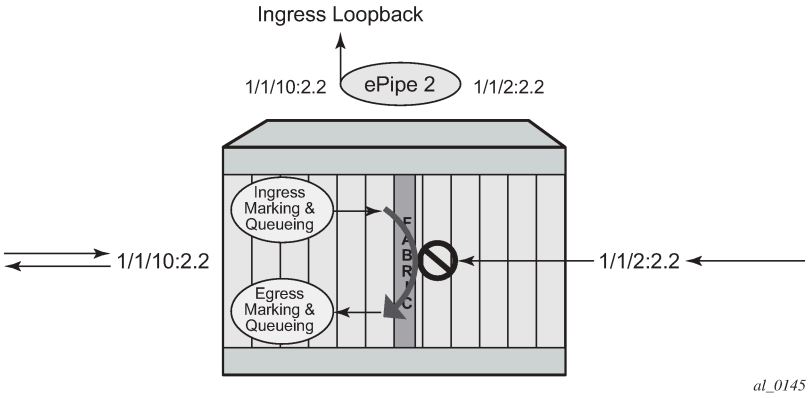
In the case on SNMP, it is possible to configure a static MAC address for the MAC swap function without actually invoking the MAC swap. This is not possible through the CLI.

This function requires a minimum of IOM/IMM.

This feature and functions that use mirroring are mutually exclusive.

Figure 18: Active loopback mode shows of sap 1/1/10:2.2 in service ID 2 (an Epipe) in an active loopback mode with a MAC swap for all broadcast and multicast destined packets.

Figure 18: Active loopback mode



The following example show output of the active loopback mode based on Figure 18: Active loopback mode.

Output example: Active loopback mode configuration

```
show service id 2 base
```

```
===============================================================================
Service Basic Information
===============================================================================
Service Id        : 2                   Vpn Id            : 0
Service Type      : Epipe
Name              : (Not Specified)
Description       : (Not Specified)
Customer Id       : 1                   Creation Origin   : manual
Last Status Change: 07/08/2013 09:57:02
Last Mgmt Change  : 07/08/2013 09:56:49
Admin State       : Up                  Oper State        : Up
MTU               : 1514
Vc Switching      : False
SAP Count         : 2                   SDP Bind Count    : 0
Per Svc Hashing   : Disabled
Force QTag Fwd    : Disabled
-------------------------------------------------------------------------------
Service Access & Destination Points
-------------------------------------------------------------------------------
Identifier                             Type         AdmMTU  OprMTU  Adm  Opr
-------------------------------------------------------------------------------
sap:1/1/2:2.2                          qinq         1522    1522    Up   Up
sap:1/1/10:2.2                         qinq         1522    1522    Up   Up
===============================================================================
tools perform service id 2 loopback eth sap 1/1/10:2.2 start ingress mac-swap mac
00:00:00:00:00:88 00:00:00:00:00:88
```

```
tools dump service loopback
```

```
===============================================================================
Service Ethernet Loopback Points
===============================================================================
Identifier                             Svc ID      Type  Swap    Swap    Oper
                                                         Unicast Mlt/Br
-------------------------------------------------------------------------------
```

```
SAP 1/1/10:2.2 qinq                    2           ingr  SA<->DA static  up
-------------------------------------------------------------------------------
No. of Service ethernet loopback points: 1
===============================================================================
```

```
tools dump service id 2 loopback sap 1/1/10:2.2
```

```
===============================================================================
Service ID 2 SAP 1/1/10:2.2 Loopback
===============================================================================
Identifier (SAP)      : 1/1/10:2.2 qinq
Service ID            : 2
Type                  : Ingress
MAC Swap
  Unicast             : SA<->DA
  Multicast/Broadcast : Static
  Static MAC          : 00:00:00:00:00:88
SAP Oper State        : Up
-------------------------------------------------------------------------------
Sap Statistics
-------------------------------------------------------------------------------
Last Cleared Time     : N/A

                        Packets                 Octets
CPM Ingress           : 491790                  46721290

Forwarding Engine Stats
Dropped               : 0                       0
Off. HiPrio           : 0                       0
Off. LowPrio          : 0                       0
Off. Uncolor          : 0                       0
Off. Managed          : 0                       0

Queueing Stats(Ingress QoS Policy 1)
Dro. HiPrio           : 0                       0
Dro. LowPrio          : 0                       0
For. InProf           : 0                       0
For. OutProf          : 0                       0

Queueing Stats(Egress QoS Policy 1)
Dro. InProf           : 0                       0
Dro. OutProf          : 0                       0
For. InProf           : 0                       0
For. OutProf          : 0                       0
-------------------------------------------------------------------------------
===============================================================================
```

Use a **stop** command to stop a loopback.

Example

```
tools perform service id 2 loopback eth sap 1/1/10:2.2 stop
```

5 Multiservice sites

A customer site can be designated a multiservice site where a single scheduler policy is applied to all SAPs associated with the site while retaining per-service and per-forwarding class shaping and policing. The SAPs associated with the multiservice site can be on a single port or on a single slot. The SAPs in a multiservice site cannot span slots.

Multiservice sites are anchor points to create an ingress and egress virtual scheduler hierarchy. When a site is created, it must be assigned to a chassis slot or port. When scheduler policies are defined for ingress and egress, the scheduler names contained in each policy are created according to the configuration defined in the policy. Multiservice customer sites exist for the sole purpose of creating a virtual scheduler hierarchy and making it available to queues on multiple Service Access Points (SAPs).

The scheduler policy association with the customer site normally prevents the scheduler policy from being deleted until after the scheduler policy is removed from the customer site.

When the multiservice customer site is created, an ingress and egress scheduler policy association does not exist. This does not prevent the site from being assigned to a chassis slot or prevent service SAP assignment. After the site has been created, the ingress and egress scheduler policy associations can be assigned or removed at any time.

Each customer site must have a unique name within the context of the customer. Modifications made to an existing site immediately affect all SAPs associated with the site. Changing a scheduler policy association can cause new schedulers to be created and existing policers and queues on the SAPs to no longer be orphaned. Existing schedulers on the site may cease to exist, causing queues relying on that scheduler to be orphaned.

6 Internal objects created for L2TP and NAT

Some services such as L2TP LNS (L2TP Network Server) and NAT (Network Address Translation) automatically create service objects for internal use. In particular, an IES service with ID 2147483648 is created. In that service, or in configured VPRN services, service objects such as interfaces, SAPs and related objects can be automatically created for internal use.

Named objects reserved for internal use have a name that starts with "_tmnx_". Objects with a numeric identifier created for internal use have an identifier from a reserved range.

The general rules for objects reserved for internal use:

- appear in CLI show commands and MIB walks output
- appear in the output of **info detail** commands but are never in the output of **admin save** or **admin save detail**

It may be possible to enter the CLI node of such an object, but it is not possible to change anything. It may also be possible to set the value of one of its objects to the current value with SNMP, but it is never possible to change any value.

7 Ethernet unnumbered interfaces

The ability to configure Ethernet Unnumbered interfaces has been added to support some service types for IPv4. The unnumbered interface capability has been available for other interface types on SR OS. Unnumbered Ethernet allows point-to-point interfaces to borrow the address from other interfaces such as system or loopback interfaces.

This feature enables unnumbered interfaces for some routing protocols (IS-IS and OSPF). Support for routing is dependent on the respective routing protocol and service. This feature also adds support for both dynamic and static ARP for unnumbered Ethernet interfaces to allow interworking with unnumbered interfaces that may not support dynamic ARP.

The use of unnumbered interface has no effect on IPv6 routes but the unnumbered command must only be used in cases where IPv4 is active (IPv4 only and mixed IPv4/IPv6 environments). When using an unnumbered interface for IPv4, the loopback address used for the unnumbered interface must have IPv4 address. Also, interface type for the unnumbered interface is automatically point-to-point.

8 ECMP and weighted ECMP for services using RSVP and SR-TE LSPs

ECMP over MPLS LSPs refers to spraying packets across multiple named RSVP and SR-TE LSPs within the same ECMP set. The ECMP-like spraying consists of hashing the relevant fields in the header of a labeled packet and selecting the next-hop tunnel based on the modulo operation of the output of the hash and the number of ECMP tunnels. Only LSPs with the same lowest LSP metric can be part of the ECMP set.

In weighted ECMP, the load-balancing weight of the LSP is normalized by the system and then used to bias the amount of traffic forwarded over each LSP. Weighted ECMP is supported where the service resolves directly to an ECMP set of RSVP or SR-TE LSPs with a configured load balancing weight, or where it resolves to a BGP tunnel and then uses an ECMP set of RSVP or SR-TE LSPs with a configured load balancing weight. Use the following commands to configure the weight for an LSP or LSP template.

```
configure router mpls lsp load-balancing-weight
configure router mpls lsp-template load-balancing-weight
```

If one or more LSPs in the ECMP set do not have **load-balancing-weight** configured, and the ECMP is set to a specific next hop, regular ECMP spraying is used.

Weighted ECMP is supported for VPRN Layer 3 services. See the *7705 SAR Gen 2 Layer 3 Services Guide: IES and VPRN* for more information.

Weighted ECMP is supported for the following Layer 2 services over RSVP-TE (including LDP over RSVP) and SR-TE tunnels:

- Epipe VLLs
- Ipipe VLLs
- LDP VPLS
- BGP-AD VPLS with provisioned SDPs

Class Based Forwarding (CBF) and weighted ECMP are mutually exclusive for VLL and VPLS services.

For services that use an explicitly configured SDP, use the following command to configure weighted ECMP under the SDP used by the service.

```
configure service sdp weighted-ecmp
```

By default, weighted ECMP is disabled.

For VLL and VPLS services that use a provisioned SDP on which weighted ECMP is configured, a path is selected based on the configured hash. Paths are then load-balanced across LSPs within an SDP according to the normalized LSP weights. Additional fields may be taken into account for VPLS services based on the commands configured in the following context.

```
configure service vpls load-balancing
configure service epipe load-balancing
```

Weighted ECMP is also supported for EVPN services. See the *7705 SAR Gen 2 Layer 2 Services and EVPN Guide* for more information.

9 NGE

This section provides information to configure Network Group Encryption (NGE).

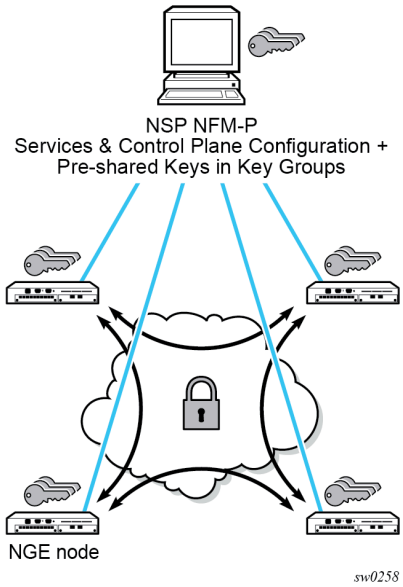
9.1 NGE overview

The Network Group Encryption (NGE) feature enables end-to-end encryption of MPLS services, Layer 3 user traffic, and IP/MPLS control traffic. NGE is an encryption method that uses a group-based keying security architecture, which removes the need to configure individual encryption tunnels to achieve network-wide encryption.

NGE relies on the NSP NFM-P to manage the network and apply encryption to specific MPLS services, Layer 3 user traffic, or control plane traffic depending on the security requirements of the network. Operators designate traffic types that require added security and then apply NGE to those traffic types using the NSP NFM-P. The NSP NFM-P also acts as the network-wide NGE key manager, downloading encryption and authentication keys to nodes and performing hitless rekeying of the network at operator-defined intervals. For more information about managing NGE within a network, see the *NSP NFM-P User Guide*.

Figure 19: NGE network with NSP NFM-P management shows an NGE network with NSP NFM-P services, control plane configuration, and key management.

Figure 19: NGE network with NSP NFM-P management



NGE provides five main types of encryption to secure an IP/MPLS network:

- **SDP encryption**

This is MPLS user plane encryption enabled on MPLS tunnels (SDPs) supporting VPRN or IES services using spoke SDPs, VPLS using spoke or mesh SDPs, routed VPLS into VPRN, Epipes, and Cpipes.

- **VPRN encryption**
  - **unicast VPRN**

    This is MP-BGP-based VPRN-level encryption using auto-bind of LDP, GRE, RSVP-TE, MPLS (LDP or RSVP-TE), or segment routing (SR-ISIS, SR-OSPF, and SR-TE) tunnels.
  - **multicast VPRN**

    NG-mVPN using mLDP with auto-discovery
- **router interface**

  This is Layer 3 user plane and control plane encryption.
- **WLAN-GW group interface**

  This is L2oMPLSoGRE level encryption from WLAN access points (APs) that support NGE.
- **PW template encryption**

  This is BGP-VPLS- and BGP-VPWS-based MPLS services encryption, which uses a PW template with **auto-gre-sdp** configured.

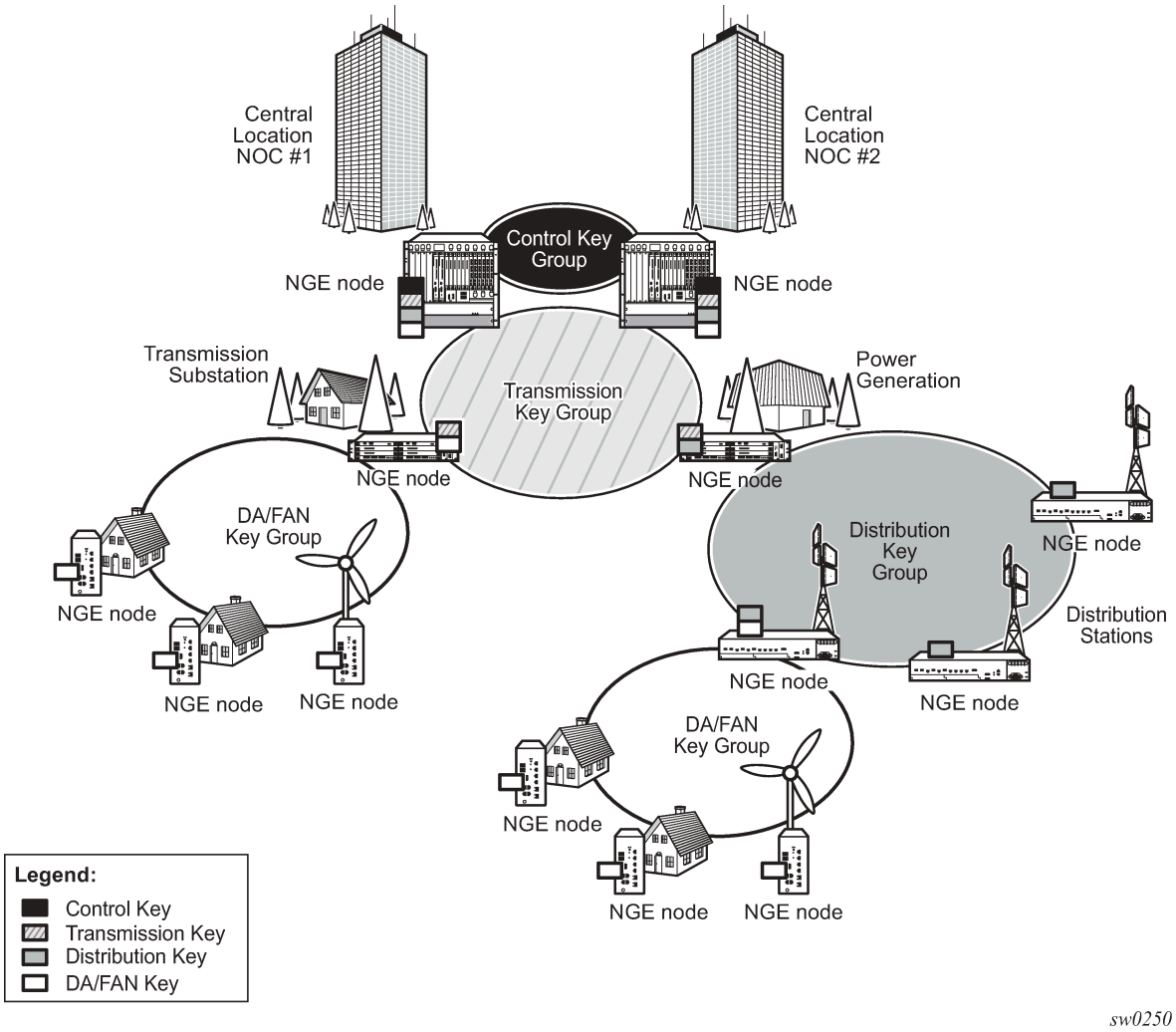
Note: See the *7705 SAR Gen 2 Router Configuration Guide* for information about configuring NGE on router interfaces.

9.1.1 NGE key groups and encryption partitions

NGE allows a tiered approach to managing encryption keys in a network using key groups by configuring services or router interfaces to use specific key groups, depending on security policies for the service and network topology.

Figure 20: Key group partitioning shows a typical application of NGE key group partitioning in which there are several critical levels (tiers) of security that need to be considered. In this example, the protection of Distribution Automation and Field Area Network (DA/FAN) equipment are less critical than the Transmission or Distribution Substation network equipment. Ensure that nodes more at risk of a security breach do not contain more critical information than is necessary. Therefore, encryption keys for the sensitive portions of the network (such as control center traffic) should not be available on nodes that are at risk. The NGE feature enables operators to partition and distribute encryption keys among different services, NGE domains, or nodal groups in a network. NGE partitions are enabled by configuring different key groups per security partition and applying those key groups as needed.

Figure 20: Key group partitioning



Another application of key group partitioning allows different parts of an organization to have their own method of end-to-end communication without the need to share encryption keys between each organization. If two partitions need to communicate between themselves, gateway nodes configured with both key groups allow inter-organization traffic flows between the key group partitions as needed.

9.1.2 Network services platform management

The NGE feature is tightly integrated with the NSP NFM-P. The following functions are provided by the NSP NFM-P:

- managing and synchronizing encryption and authentication keys within key groups on a network-wide basis
- configuring NGE on MPLS services and managing associated key groups
- configuring NGE on router interfaces and managing associated key groups

- coordinating network-wide rekeying of key groups

The NSP NFM-P acts as the key manager for NGE-enabled nodes and allocates the keys in key groups that are used to perform encryption and authentication. The NSP NFM-P ensures that all nodes in a key group are kept in synchronization and that only the key groups that are relevant to the associated nodes are downloaded with key information.

The NSP NFM-P performs network-wide hitless rekeying for each key group at the rekeying interval specified by the operator. Different key groups can be rekeyed at different times if needed, or all key groups can be rekeyed network-wide at the same time.

For more information about NSP NFM-P management, see the "Service Management" section in the *NSP NFM-P User Guide*.

9.2 Key groups

Users can partition the network based on security requirements by organizing encryption keys into distinct key groups. A key group contains the following elements:

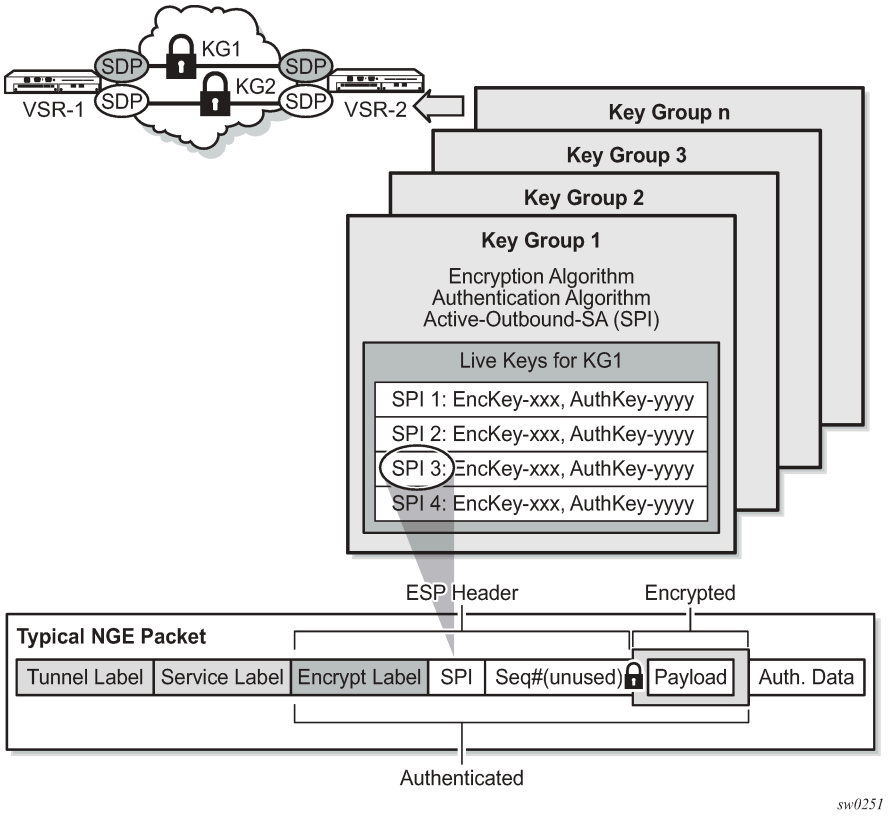
- an encryption algorithm (see Key group algorithms)
- an authentication algorithm (see Key group algorithms)
- a list of security associations (SAs) (see Security associations)
- an active outbound SA (see Active outbound SA)

Figure 21: Key groups and a typical NGE packet illustrates the use of key groups (KGs), SAs, and Security Parameter Indexes (SPIs). The VSR-1 and VSR-2 both have the same set of key groups configured. One path uses key group 1 (KG1) and the other uses key group 2 (KG2). Each key group contains the elements listed above. KG1 has four live keys, SPI_1 through SPI_4, and SPI_3 is the active outbound SA. The active outbound SA is identified by its SPI, and this SPI is embedded in the NGE packet.

Each SA listed in a key group, indexed by an SPI, specifies a single key for encryption and a single key for authentication. Packets transmitted or received that reference a particular SPI use the keys in the SA for that SPI when performing encryption and authentication.

Before enabling encryption, key groups must be configured on the node. Only after a key group is configured can it be assigned to an SDP or VPRN services.

Figure 21: Key groups and a typical NGE packet



9.2.1 Key group algorithms

All SAs configured in a key group share the same encryption algorithm and the same authentication algorithm. The size and values required by a particular key depend on the requirements of the algorithms selected (see lists below). One encryption algorithm and one authentication algorithm must be selected per key group.

Encryption algorithms available per key group include:

- AES128 (a 128-bit key, requiring a 32-digit ASCII hexadecimal string)
- AES256 (a 256-bit key, requiring a 64-digit ASCII hexadecimal string)

Authentication algorithms available per key group include:

- HMAC-SHA-256 (a 256-bit key, requiring a 64-digit ASCII hexadecimal string)
- HMAC-SHA-512 (a 512-bit key, requiring a 128-digit ASCII hexadecimal string)

Encryption and authentication strengths can be mixed depending on the requirements of the application. For example, 256-bit strength encryption can be used with 512-bit strength authentication.

The configured algorithms cannot be changed when there is an existing SA configured for the key group. All SAs in a key group must be deleted before a key group algorithm can be modified.

Key values are not visible in CLI or retrievable using SNMP. Each node calculates a 32-bit CRC checksum for the keys configured against the SPI. The CRC can be displayed in the CLI or read by SNMP. The

purpose of the CRC is to provide a tool to check consistency between nodes, thereby verifying that each node is set with the same key values while keeping the actual key values hidden.

9.2.1.1 Encapsulating security payload

The NGE feature uses the Encapsulating Security Payload (ESP) protocol according to IETF RFC 4303. ESP maintains data integrity, ensuring privacy and confidentiality for encrypted traffic.

The ESP protocol used by NGE relies on symmetric ciphers, meaning that the same key is used for encryption and decryption. The NGE node supports Cipher Block Chaining (CBC) encryption mode. Block ciphers used by NGE include:

- AES128 with a 128-bit key using 128-bit blocks
- AES256 with a 256-bit key using 128-bit blocks

For authentication, the integrity check value (ICV) size is as follows:

- HMAC-SHA-256 (16 bytes or 128 bits)
- HMAC-SHA-512 (32 bytes or 256 bits)

9.2.2 Security associations

Each key group has a list of up to four security associations (SAs). An SA is a reference to a pair of encryption and authentication keys that are used to decrypt and authenticate packets received by the node and to encrypt packets leaving the node.

For encrypted ingress traffic, any of the four SAs in the key group can be used for decryption if there is a match between the SPI in the traffic and the SPI in the SA. For egress traffic, only one of the SAs can be used for encryption and is designated as the active outbound SA. Figure 21: Key groups and a typical NGE packet illustrates these relationships.

As shown in Figure 21: Key groups and a typical NGE packet, each SA is referenced by an SPI value, which is included in packets during encryption and authentication. SPI values must be numerically unique throughout all SAs in all key groups. If an SPI value is configured in one key group and an attempt is made to configure the same SPI value in another key group, the configuration is blocked.

Note: Keys are entered in clear text using the **security-association** command. After configuration, they are never displayed in their original, clear text form. Keys are displayed in an encrypted form, which is indicated by the system-appended **crypto** keyword when you run an **info** command. The NGE node also includes the **crypto** keyword with an **admin save** operation, so that the NGE node can decrypt the keys when reloading a configuration database. For security reasons, keys encrypted on one node are not usable on other nodes (that is, keys are not exchangeable between nodes).

9.2.2.1 Active outbound SA

The active outbound SA is specified by the SPI referencing the specific SA used to encrypt and authenticate packets egressing the node for the SDP or service using the key group. The SPI value for the active outbound SA is included in the ESP header of packets being encrypted and authenticated.

9.3 Services encryption

NGE provides the ability to encrypt MPLS services using key groups that are configured against these services. These services include:

- VLL service (Epipe and Cpipe)
- VPRN service using Layer 3 spoke SDP termination
- IES service using Layer 3 spoke SDP termination
- VPLS service using spoke and mesh SDPs
- routed VPLS service into a VPRN or IES
- MP-BGP-based VPRNs
- BGP-VPLS and BGP-VPWS using a PW template with **auto-gre-sdp** configured
- NG-MVPN

For services that use SDPs, all tunnels may be either MPLS LSPs (RSVP-TE, LDP, or static LSP), or GRE or MPLSoUDP tunnels.

For MP-BGP services, resolving routes using spoke SDPs (**spoke-sdp**) or auto-bind SDPs (**auto-bind-tunnel**) is supported using LDP, GRE, RSVP-TE, or segment routing (SR-ISIS, SR-OSPF, or SR-TE).

9.3.1 Services encryption overview

NGE adds a global encryption label to the label stack for encrypting MPLS services. The global encryption label must be a unique network-wide label; in other words, the same label must be used on all nodes in the network that require NGE services. The label must be configured on individual nodes before NGE can become operational on those nodes.

The global encryption label is used to identify packets that have an NGE-encrypted payload and is added to the bottom of the stack. This allows network elements such as LSRs, ABRs, ASBRs, and RRs to forward NGE packets without needing to understand NGE or to know that the contents of these MPLS packets are encrypted. Only when a destination PE receives a packet that needs to be understood at the service layer does the PE check for an encryption label, and then decrypt the packet.

After the global encryption label is set, it should not be changed. If the label must be changed without impacting traffic, all key groups in the system should first be deleted. Next, the label should be changed, and then all key groups should be reconfigured.

The NSP NFM-P helps to coordinate the distribution of the global encryption label and ensures that all nodes in the network are using the same global encryption label.

Figure 22: NGE MPLS/GRE/MPLSoUDP label stack illustrates the NGE MPLS, GRE, or MPLSoUDP label stack.

Figure 22: NGE MPLS/GRE/MPLSoUDP label stack

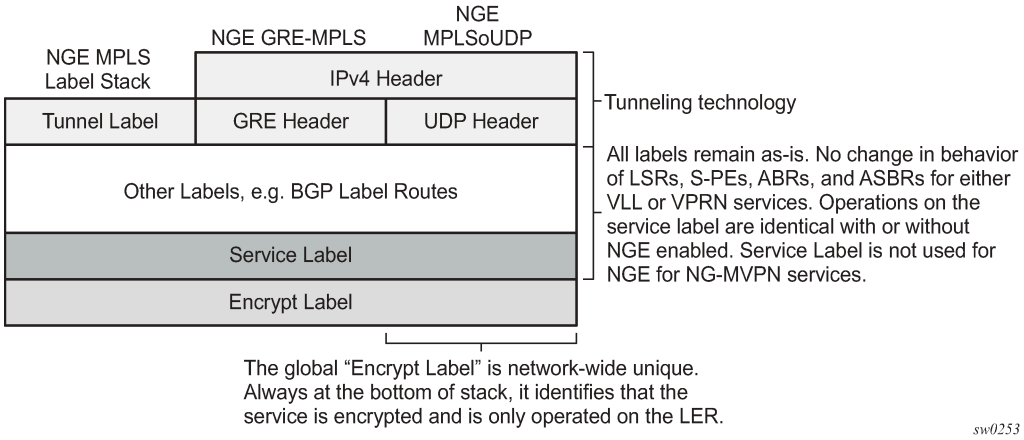
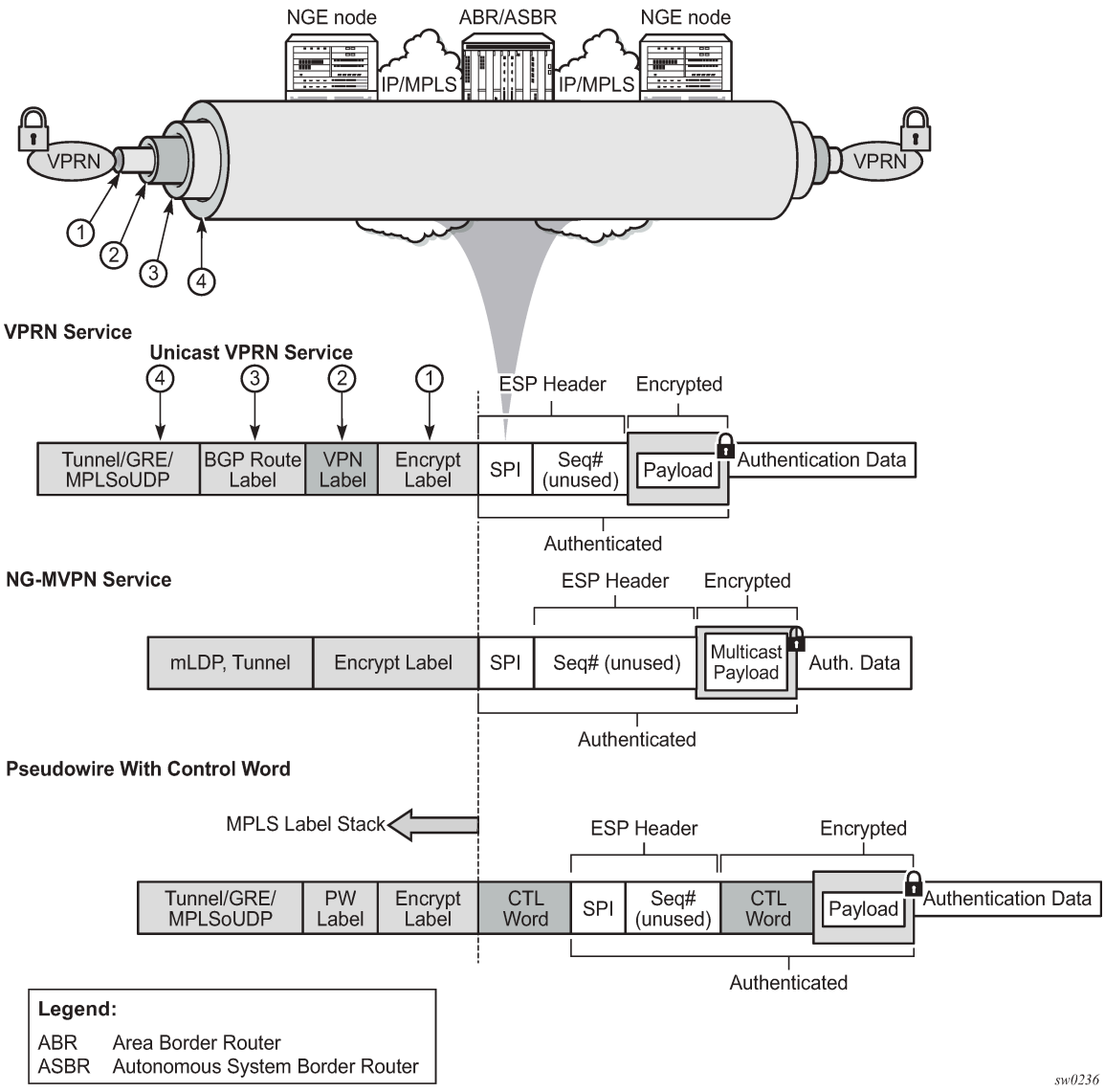


Figure 23: NGE and packet formats illustrates VPRN and PW (with control word) packet formats using NGE.

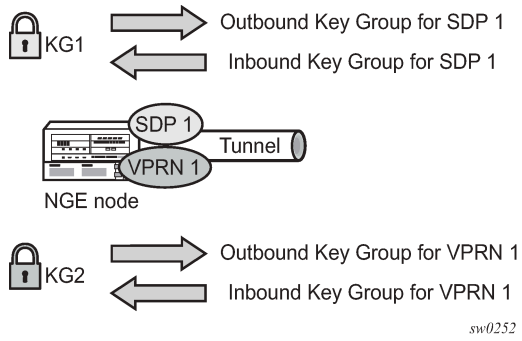
Figure 23: NGE and packet formats



9.3.2 Assigning key groups to services

Assigning key groups to services requires configuring an inbound and outbound key group for directional processing on a per-service basis (see Figure 24: Inbound and outbound key group assignments).

Figure 24: Inbound and outbound key group assignments



The outbound key group identifies which key group to use for traffic that egresses the node for the service. The inbound key group ensures that ingress traffic is using the correct key group for the service.

If the inbound key group is not set, the node ensures that packets are either unencrypted or are using one of the valid key groups configured in the system.

In most deployment scenarios, the inbound and outbound key groups are identical; however, it is possible to configure different key groups as the outbound and the inbound key groups, as this is not checked by the node.

Including an inbound and outbound direction when assigning key groups to services allows users to:

- gracefully enable and disable NGE for services
- move services from one key group domain to another domain without halting encryption

The NGE feature makes use of the NSP NFM-P to help manage the assignment of key groups to services on a network-wide basis. See the *NSP NFM-P User Guide* for more information.

9.3.3 VPRN Layer 3 spoke SDP encryption and MP-BGP-based VPRN encryption interaction

The encryption configured on an SDP used to terminate the Layer 3 spoke SDP of a VPRN always overrides any VPRN-level configuration for encryption.

- When VPRN encryption is enabled, all routes resolved using MP-BGP with spoke SDPs (**spoke-sdp**) or auto-bind SDPs (**auto-bind-tunnel**) are encrypted or decrypted using the VPRN key group.
- When Layer 3 spoke SDP encryption is enabled, all routes resolved using the Layer 3 interface are encrypted or decrypted using the SDP key group.

Some examples are as follows:

- If a VPRN is enabled for encryption while a Layer 3 spoke SDP for the same VPRN is using an SDP that is not enabled for encryption, then traffic egressing the spoke SDP is not encrypted.
- If a VPRN is disabled for encryption while a Layer 3 spoke SDP for the same VPRN is using an SDP that is enabled for encryption, then traffic egressing the spoke SDP is encrypted.
- If a VPRN is enabled for encryption using key group X, while a Layer 3 spoke SDP for the same VPRN is using key group Y, then traffic egressing the spoke SDP is encrypted using key group Y.

9.3.4 L2 service encryption using PW templates

NGE **encryption-keygroup** configuration is supported on PW templates to enable the encryption of MPLS services that are based on BGP-VPLS and BGP-VPWS and that have **auto-gre-sdp** enabled on the PW template. All services configured using the PW template that have both NGE and **auto-gre-sdp** enabled are encrypted. Use the commands in the following context to bind a key group to a PW template for inbound or outbound packet processing.

```
configure service pw-template encryption-keygroup
```

When changing the **encryption-keygroup** on a PW template, the change does not take effect immediately. Use the following command after each change to the **encryption-keygroup** command for it to take effect.

```
tools perform service eval-pw-template allow-service-impact
```

9.3.5 Pseudowire switching for NGE traffic

For VLL services, the NGE node supports PW switching of encrypted traffic from one PW to another. There are three scenarios that are supported with regard to PW switching of traffic:

- **PW switch using the same key group**

  When a PW is using an encrypted SDP, the PW may be switched to another PW that is also using an encrypted SDP, where both SDPs are in the same key group. In this case, to perform the PW switch, the NGE node leaves the encrypted payload unchanged and swaps the labels as needed for passing traffic between PWs.

- **PW switch using different key groups**

  When a PW is using an encrypted SDP, the PW may be switched to another PW that is also using an encrypted SDP, where both SDPs are in different key groups. In this case, the NGE node decrypts the traffic from the first SDP by using the configured key group for that SDP, and then re-encrypts the traffic by using the egress SDP's key group egress SPI ID.

- **PW switch between an encrypted and unencrypted PW**

  When traffic is switched from an encrypted PW to an unencrypted PW, the traffic is decrypted before it is sent. The converse occurs in the reverse direction (that is, traffic from an unencrypted PW to an encrypted PW gets encrypted before it is sent).

See "Pseudowire Switching" in the *7705 SAR Gen 2 OAM and Diagnostics Guide* for more information.

9.3.6 Pseudowire control word for NGE traffic

The control word is a configurable option for PWs and is included in PW packets when it is configured.

When the **control-word** command is enabled and NGE is used, the datapath creates two copies of the CW. One CW is both encrypted and authenticated, and is inserted after the ESP header. The other CW is not encrypted (clear form) and is inserted before the ESP header.

For cases where PW switching is configured, the NGE node ensures—in the CLI and with SNMP—that both segments of the PW have consistent configuration of the control word when encryption is being used.

9.3.7 NGE and RFC 8277

When RFC 8277 is enabled on the node and NGE traffic is crossing the Area Border Router (ABR) between two VPRN domains, the same key group must be used between the two domains.

Note: It is the responsibility of the network operator to ensure key group consistency across the (ABR).

9.3.8 NGE for NG-MVPN

NGE is supported for NG-MVPN services with multicast configurations that include:

- I-PMSI
- S-PMSI
- C-multicast signaling
- mLDP and RSVP-TE multicast tunnel LSPs

See the *7705 SAR Gen 2 Multicast Routing Protocols Guide* for information about Multicast VPN (MVPN).

When R-VPLS is configured for the VPRN, the source of an NG-MVPN multicast stream can originate within a VPLS service and can be NGE encrypted before entering the I-PMSI or S-PMSI. The receiver of an NG-MVPN multicast stream can be within a VPLS service and can be NGE decrypted before being sent over the VPLS service.

When NGE is enabled on a VPRN with NG-MVPN-based services, transit nodes (LSRs) have no knowledge that NGE is being employed, nor that the NGE encryption label is being used with an ESP header after the NGE label. Features that inspect packet contents to make further decisions are not supported and must be disabled for mLDP multicast paths that need to carry NG-MVPN traffic that is NGE encrypted.

These features include:

- ingress multicast path management
- IP-based LSR hashing

The above restriction includes any 3rd party routing function that inspects the contents after the mLDP or RVSP-TE transport label and expects a non-encrypted payload on which to make hashing decisions.

9.4 NGE packet overhead and MTU considerations

NGE adds overhead packets to services. Table 7: NGE overhead for MPLS shows the additional overhead for the worst-case scenario of MPLS services encryption. Table 8: NGE overhead for router interface shows the additional overhead for the worst-case scenario of router interface. Additional overhead depends on which encryption and authentication algorithms are chosen.

Table 7: NGE overhead for MPLS

Item	Number of bytes
Encryption label	4

Item	Number of bytes
ESP	24
ICV	32
Padding	17
Control word copy	4
Total	**81**

For MP-BGP-based VPRNs, the total is 77 bytes because the control word copy is not required.

Table 8: NGE overhead for router interface

Item	Number of bytes
ESP	24
ICV	32
Padding	17
Total	**73**

For Layer 3 packets for router interface encryption, the total is 73 bytes because the encryption label and control word copy are not required.

The overhead values in Table 7: NGE overhead for MPLS must be considered for services that are supported by NGE.

Note: Currently, the port MTU has a default value of 1572 bytes. This value is too low for outbound traffic when NGE is enabled. Users must configure new MTU values to adjust for the overhead associated with NGE, as described in Table 9: Accounting for NGE overhead SDP and service MTU — calculation examples for MPLS-based and GRE-based services. For details on configuring MTU, see the "MTU Configuration Guidelines" section in the *7705 SAR Gen 2 Interface Configuration Guide*.

The calculations in Table 9: Accounting for NGE overhead SDP and service MTU — calculation examples show how NGE overhead affects SDP MTU and service MTU values for MPLS-based, GRE-based, and VPRN-based services. The calculations are with and without NGE enabled.

Table 9: Accounting for NGE overhead SDP and service MTU — calculation examples

Service type	MTU values with and without NGE enabled
MPLS-based services	SDP MTU (MPLS): = 1572 (network port MTU) – 14 (Ethernet header) – 4 (outer label) – 4 (inner label) = 1550 bytes (without NGE enabled) => 1469 bytes (with NGE enabled)
	Service MTU (MPLS) considerations with NGE enabled:

Service type	MTU values with and without NGE enabled
	• Layer 3 spoke IP MTU (MPLS) = 1469 – 14 (inner Ethernet header) = 1455 bytes • PW spoke SDP MTU (MPLS) = SDP MTU = 1469 bytes
GRE-based services	SDP MTU (GRE): = 1572 (network port MTU) – 14 (Ethernet header) – 20 (IP header) – 4 (GRE header) – 4 (inner label) = 1530 bytes (without NGE enabled) => 1449 bytes (with NGE enabled)
	Service MTU (GRE) considerations with NGE enabled: • Layer 3 Spoke IP MTU (GRE) = 1449 – 14 (inner Ethernet header) = 1435 bytes • PW Spoke MTU (GRE) = SDP MTU = 1449 bytes
VPRN-based services	Each interface inherits its MTU from the SAP or spoke SDP to which it is bound and the MTU value can be manually changed using the **ip-mtu** command.
	MP-BGP-based VPRN services: The MTU of the egress IP interface is used. When NGE is enabled on a VPRN service, customers must account for the additional 77 bytes of overhead needed by NGE for any egress IP interface used by the VPRN service.

When an unencrypted Layer 3 packet ingresses the node and routing determines that the egress interface is a router interface NGE-enabled interface, the node calculates whether the packet size is greater than the MTU of the egress interface after the router interface NGE overhead is added. If the packet cannot be forwarded out from the network interface, an ICMP message is sent back to the sender and the packet is dropped. Users must configure new MTU values to adjust for the overhead associated with NGE.

If an IP exception ACL that matches the ingressing packet exists on the egress interface, the MTU check applied to the ingress packet includes the router interface NGE overhead. This is because the ingress interface cannot determine which IP exceptions are configured on the egress interface, and therefore the worst-case MTU check that includes the router interface NGE overhead is performed.

9.5 Statistics

Statistics specific to NGE are counted for the following main areas:

- key group
- SPI
- MDA
- service

9.6 Remote network monitoring support

Remote network Monitoring (RMON) can be used in conjunction with NGE statistics to provide event and alarm reporting. This can be used by customers to detect security breaches of NGE traffic flows and provide real-time reporting of such events.

Threshold crossing alerts and alarms using RMON are supported for SNMP MIB objects, including NGE.

9.7 Configuration notes

This section describes NGE configuration guidelines and restrictions. For more information about configuring NGE using the NSP NFM-P, see the *NSP NFM-P User Guide*.

Consider the following restrictions when performing NGE configuration tasks:

- The authentication and encapsulation keys must contain the exact number of hexadecimal characters required by the algorithm used. For example, using sha256 requires 64 hexadecimal characters.
- The key group bound to an SDP or service must be unbound from that SDP or service before the active outgoing SA for the key group can be removed.
- The active outgoing SA must be removed (deconfigured) before the SPI can be deleted from the SA list in the key group.
- The encryption or authentication algorithm for a key group cannot be changed if there are any SAs in the key group.
- The encryption configured on an SDP used to terminate the Layer 3 spoke SDP of a VPRN (enabled or disabled) always overrides any VPRN-level configuration for encryption. See section "VPRN Layer 3 Spoke-SDP Encryption and MP-BGP-based VPRN Encryption Interaction" in the *7705 SAR Gen 2 Layer 3 Services Guide: IES and VPRN* for more information.
- The NSP NFM-P provides command options that are not configurable using the CLI. See Network services platform management for more information.

9.7.1 Enabling NGE for an SDP or VPRN service

Procedure

Step 1. Install the outbound direction key group on each node for the service.

Step 2. Install the inbound direction key group on each node for the service.

9.7.2 Enabling NGE for a router interface

Procedure

Step 1. Enable **group-encryption** on the interface.

Step 2. Configure the outbound key group.

Step 3. Configure the inbound key group.

9.7.3 Changing NGE from one key group to another key group for an SDP or VPRN service

Procedure

Step 1. Remove the inbound direction key group from each node for the service.

Step 2. Change the outbound direction key group on each node for the service.

Step 3. Install the new inbound direction key group on each node for the service.

9.7.4 Changing NGE from one key group to another key group for a router interface

Procedure

Step 1. Remove the inbound key group.

Step 2. Configure the new outbound key group.

Step 3. Configure the new inbound key group.

9.7.5 Disabling NGE for an SDP or VPRN service

Procedure

Step 1. Remove the inbound direction key group from each node providing the service.

Step 2. Remove the outbound direction key group from each node for the service.

9.7.6 Disabling NGE for a router interface

Procedure

Step 1. Remove the inbound key group.

Step 2. Remove the outbound key group.

Step 3. Disable group encryption on the interface.

10 Raw socket IP transport service

Serial data transport using raw sockets over IP transport services is a method of transporting serial data, in character form, over an IP network using Layer 3-based services. This feature can help transport Supervisory control and data acquisition (SCADA) data from remote terminal units (RTUs) to front-end processors (FEPs) or SCADA masters.

The functionality provided by the IP transport service feature for serial raw sockets is summarized as follows:

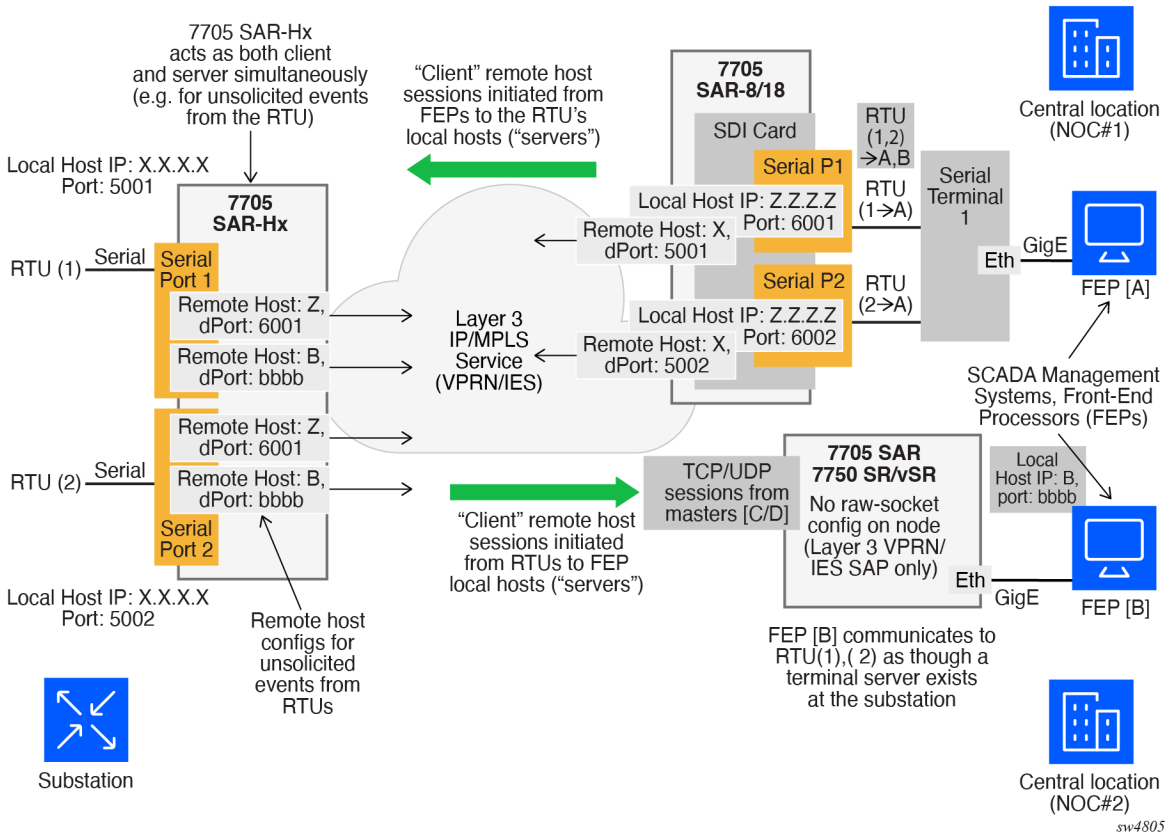
- IP transport local host (server) function, to listen to and open raw socket sessions from remote hosts
- IP transport remote host (client) function, to initiate and open new raw socket sessions to remote hosts
- both local host and remote host functions support for either TCP or UDP IP transport services
- IP transport over an IES or VPRN service
- enhanced QoS and queuing of sessions to ensure that collisions between sessions do not cause serial data to impact RTUs and end-user equipment

Figure 25: IP transport service shows a detailed view of the local host (server) and remote host (client) functionality that enables multiple communication streams to and from a serial port using raw socket IP transport.

The figure shows a three-node network: a 7705 SAR-Hx (left), a 7705 SAR-8 Shelf V2 or 7705 SAR-18 (top right) and a 7705 SAR-Hx node, 7705 SAR-8 Shelf V2/7705 SAR-18 node, or 7750 SR/VSR node (bottom right). There are two devices, RTU (1) and RTU (2) connected to the serial ports on the 7705 SAR-Hx. FEP server [A] can reach the RTUs via the socket sessions that originate from the 12-port Serial Data Interface card on the 7705 SAR-8 Shelf V2/7705 SAR-18 node. The bottom-right 7705 SAR or 7750 SR/VSR node is connected to the FEP server [B] directly using Ethernet. This FEP server reaches the RTUs via a Layer 3 IP/MPLS service, where raw socket sessions are processed directly on the FEP servers.

Through local host and remote host configurations on the 7705 SAR-Hx or 7705 SAR-8 Shelf V2/7705 SAR-18, serial raw socket IP transport sessions are established to carry serial data over a wireless IP/MPLS network. The source and destination IP addresses and port numbers for these sessions are derived directly from the local and remote host configurations associated with each serial port or master head-end server.

Figure 25: IP transport service



The 7705 SAR-Hx supports the ability to configure a raw socket IP transport interface for each serial port. This allows the raw socket IP transport to receive TCP or UDP session packets from multiple remote hosts when operating as a local host (server), or to create new multiple sessions to remote hosts to send and receive serial data when operating as a client.

There are two main configurations required for a serial raw socket IP transport service to be operational and to support the sending and receiving of serial data:

- **port-level configuration**

  This includes configuring rudimentary serial link parameters such as baud rate, start/stop values, and bits. Socket-level configuration is also required, such as configuring end-of-packet checking parameters (idle-time, length, special character) and the inter-sessions delay for transmitting session data over the serial link. For information about the required port-level configuration, see the *7705 SAR Gen 2 Classic CLI Command Reference Guide* and *7705 SAR Gen 2 MD-CLI Command Reference Guide*.

- **IP transport service-level configuration**

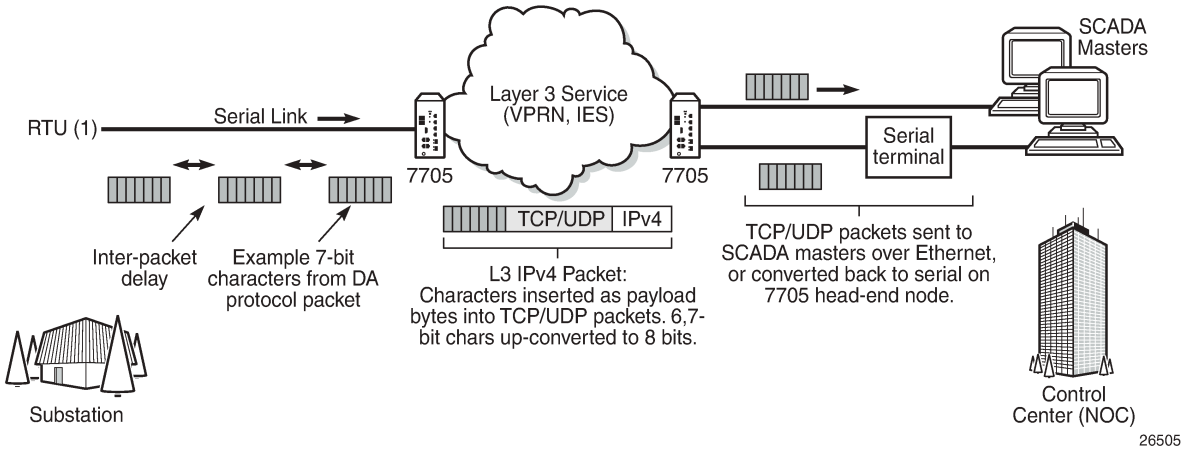
  This includes creating an IP transport subservice to associate the serial port within a Layer 3 IES/VPRN service, so that TCP/UDP encapsulated serial data can be routed within the corresponding Layer 3 service. The IP transport subservice ID is modeled and created in the same way that the SAP IDs are created under the same service types. IP transport configuration includes configuring IP transport local host items and remote host items, such as setting TCP timers and sessions controls. See the *7705 SAR Gen 2 Classic CLI Command Reference Guide*, *7705 SAR Gen 2 Clear, Monitor, Show,*

Tools CLI Command Reference Guide, and *7705 SAR Gen 2 MD-CLI Command Reference Guide* for the required commands.

The 7705 SAR-Hx supports the configuration of a raw socket IP transport service for each serial port. This allows each serial port's local host to listen to and open raw socket sessions from remote hosts that need to communicate over the serial port, and for each serial port's local host to initiate and open raw socket sessions to remote hosts when serial data needs to be sent to those remote hosts. The local and remote host functions support TCP or UDP sessions (but not both concurrently) over the IES/VPRN service.

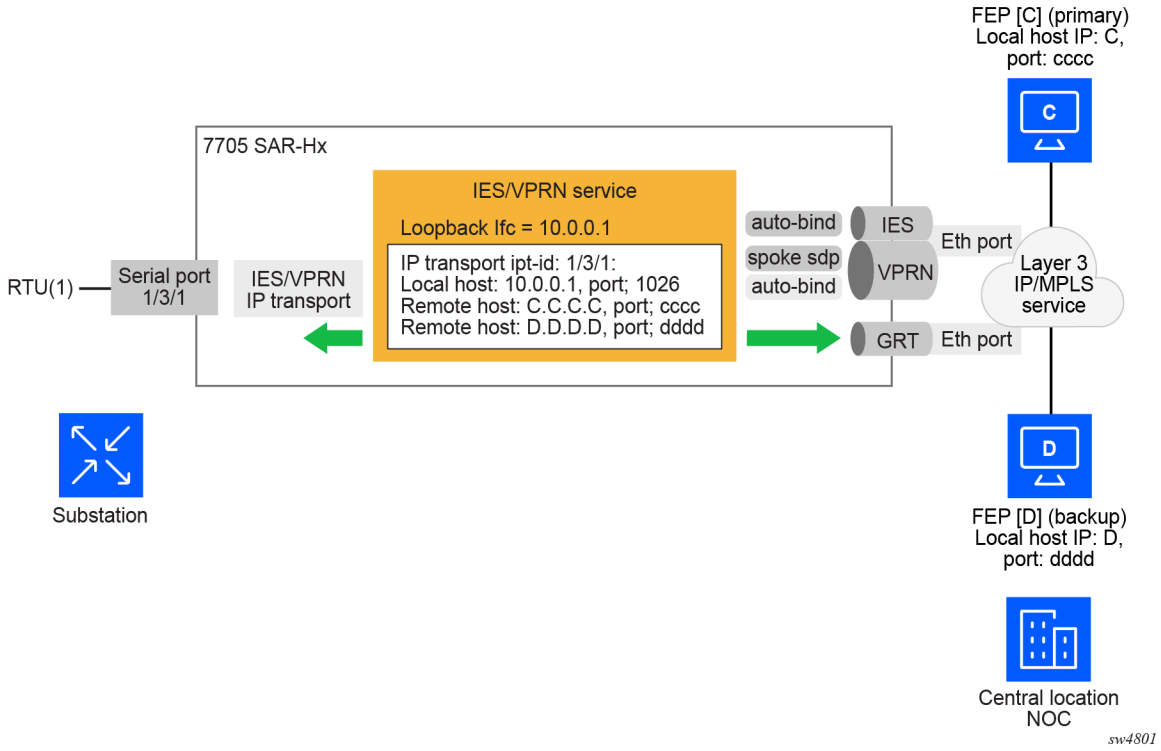
The serial data is received as characters that represent bytes in a packet. These bytes are packetized into Layer 3 TCP/UDP packets that are then transported or forwarded across the IP/MPLS network using the node's Layer 3 IES/VPRN service constructs for routing. The following figure shows how serial data is encapsulated into TCP/UDP packets and transported over IP/MPLS.

Figure 26: TCP/UDP packet transport over IP/MPLS



For raw socket packets to be routed within an IES/VPRN service, an IP transport subservice must be configured within an IES/VPRN context. The IP transport subservice context is where users configure local and remote host information, such as IP addresses and ports for establishing TCP/UDP sessions, and other per-session parameters. TCP/UDP encapsulated serial data is routed within the corresponding Layer 3 IES/VPRN service. The following figure shows this concept.

Figure 27: IES/VPRN IP transport service



To create an IP transport subservice, the following classic CLI command is used with the corresponding serial port as the IP transport ID to bind the serial port SAP to the IP transport subservice.

```
configure service vprn ip-transport ipt-id
configure service vprn ip-transport ipt-id
```

After the IP transport service is created, local host and remote host configurations can proceed. A local host must be configured before remote hosts can be configured.

Each local host uses a local address (from a loopback or local interface configured under the IES/VPRN service context) as the local host IP address of the IP transport subservice associated with the serial port. The local host IP address is the source IP address in the raw socket packets leaving the node within the IES/VPRN service. The local host is used to terminate TCP/UDP sessions from remote hosts. The local host can select either the TCP or UDP protocol for raw socket sessions, but not both concurrently.

Multiple remote hosts can be configured under the IP transport subservice associated with the serial port, so that each remote host receives the serial data received on the serial port. Each remote host has its own remote destination IP address and port value for establishing sessions. The configured remote hosts use the TCP or UDP protocol configured for the IP transport subservice.

Note: It is not necessary to configure remote hosts when the IP transport service is not originating sessions. If sessions are only established toward the IP transport local host (for example, remote servers polling the local host), the remote host configuration is not necessary. Remote host configurations may still be desirable when using the **filter-unknown-host** command.

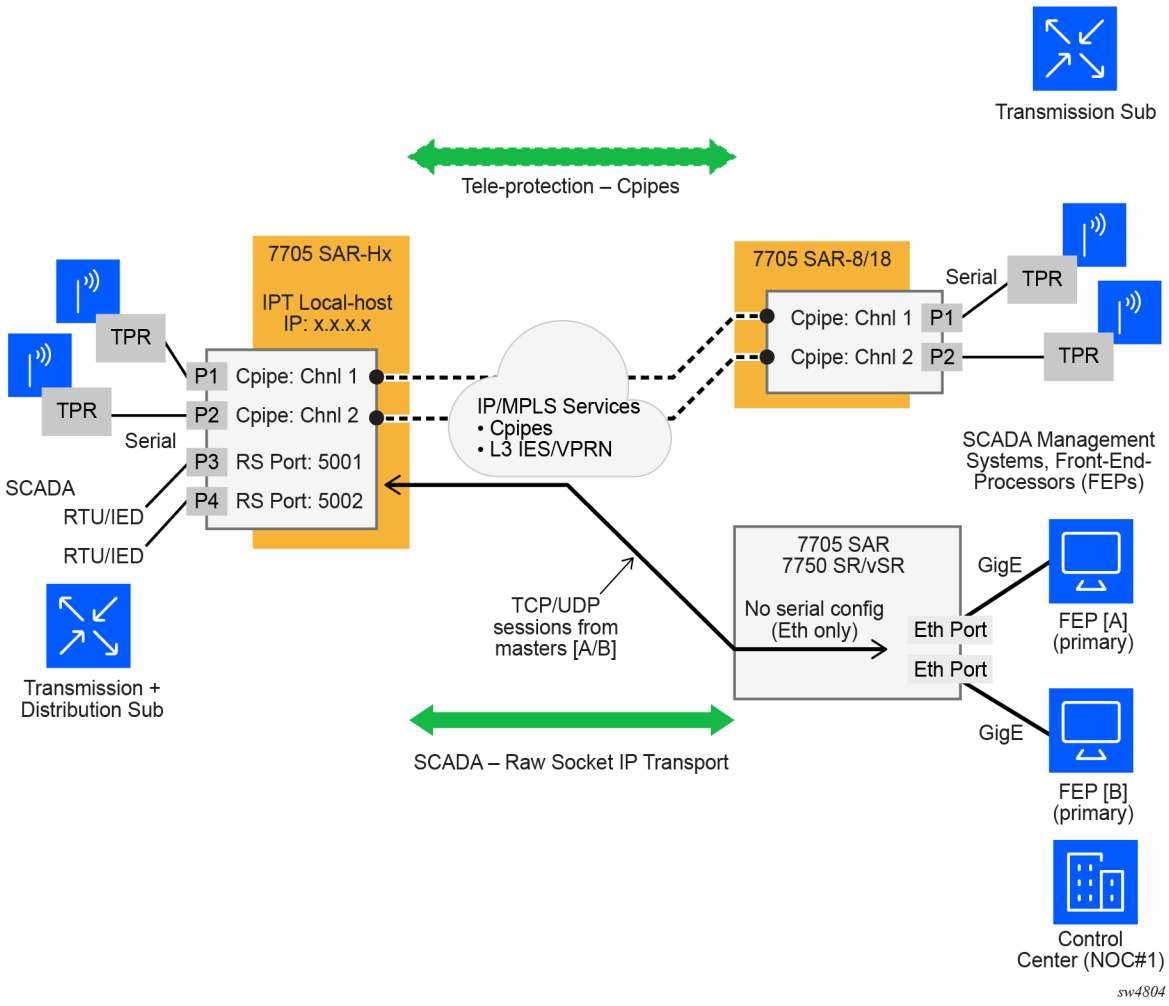
IP transport processing of TCP/UDP packets occurs on the CPM of the 7705 SAR-Hx. Filters configured for protecting the CPM must account for raw socket IP transport packets and ensure that the filter is not blocking associated IP transport sessions. For example, operators must ensure that interface IP addresses and ports configured on the node are not blocked and that remote host IP/port combinations are not blocked.

For IES/VPRN IP transport services, all tunnel types supported by the IES/VPRN service are also supported for the IP transport service. This includes all types of MPLS tunnels (such as RSVP-TE, LDP, autobind, and static LSP) and GRE tunnels.

Note: IP transport-to-IP transport raw socket data on the same node is not supported. If serial-to-serial communication is needed on the same node, customers must use Cpipes.

The 7705 SAR Gen 2 supports the concurrent operation of raw sockets and Cpipes, as shown in the following figure.

Figure 28: Raw socket and Cpipe support on the 7705 SAR Gen



2

10.1 Remote host manual TCP connection check

A manual TCP connection check can be performed for each remote host configured for a raw socket IP transport subservice. When executed by an operator, the TCP connection check attempts to establish a TCP session toward the configured remote host. Only one TCP connection check is attempted, with a fixed timeout of five seconds. If the attempt is successful, the session is torn down immediately, without sending any data.

The TCP connection check is initiated in the classic CLI using the following command.

```
tools perform service id ip-transport remote-host check-tcp
```

The result is displayed using the following classic CLI command.

```
tools dump service id ip-transport remote-host
```

Equivalent management is available using SNMP.

If a TCP connection to a remote host already exists because of serial traffic being transmitted, the check returns "successful" without impacting the existing TCP connection.

10.2 QoS requirements for IP transport

Serial raw socket data that is transported using an IP transport service can be DSCP marked at the source node. This allows the source node (local host) of the traffic to mark packets correctly so that downstream nodes prioritize them as needed, and to queue local traffic in the right egress queue based on the classification assigned to the IP transport service.

Additionally, the DSCP setting is assigned per IP transport subservice for all traffic from the local host and all traffic destined for each remote host. The DCSP setting is not set per remote host.

See the following DSCP commands in the *7705 SAR Gen 2 Classic CLI Command Reference Guide* for more information about configuring the QoS settings for an IES or VPRN IP transport subservice.

```
configure service ies ip-transport dscp
configure service vprn ip-transport dscp
```

10.3 Configuring serial raw socket transport within IES

Configure an IP transport subservice within an IES service to enable the transport of serial data using raw sockets.

Example: IP transport subservice within an IES service

```
A:node-2>config>service>ies>ipt$ info detail
----------------------------------------------
                shutdown
                no description
                dscp "ef"
                no filter-unknown-host
                local-host ip-addr 1.2.1.1 port-num 1026 protocol tcp
                remote-host 1 create ip-addr 1.1.1.1 port-num 1
                    no description
                    no name
                exit
                tcp
                    inactivity-timeout 30
                    max-retries 5
                    retry-interval 5
                exit
----------------------------------------------
```

The following example displays an IP transport subservice configuration output.

Example: IP transport subservice configuration

```
A:node-2>config>service>ies# info
----------------------------------------------
        configure
```

```
            service ies 20 create
                ip-transport 1/2/4.1 create
                description "ip-transport one"
                filter-unknown-host
                local-host ip-address 192.168.1.1 port-number 4000 protocol udp
                    exit
                remote-host 1 ip-address 192.168.1.7 port-number 4001 create
                    exit
                exit
                no-shutdown
-----------------------------------------------
A:ALU-B>config>service>ies#
```

10.4 Configuring serial raw socket transport within a VPRN

Configure an IP transport subservice within a VPRN service to enable the transport of serial data using raw sockets.

Example: IP transport subservice within a VPRN service

```
A:node-2>config>service>vprn>ipt$ info detail
----------------------------------------------
                shutdown
                no description
                dscp "ef"
                no filter-unknown-host
                local-host ip-addr 1.2.1.1 port-num 1026 protocol tcp
                remote-host 1 create ip-addr 1.1.1.1 port-num 1
                    no description
                    no name
                exit
                tcp
                    inactivity-timeout 30
                    max-retries 5
                    retry-interval 5
                exit
----------------------------------------------
```

The following example displays an IP transport subservice configuration output.

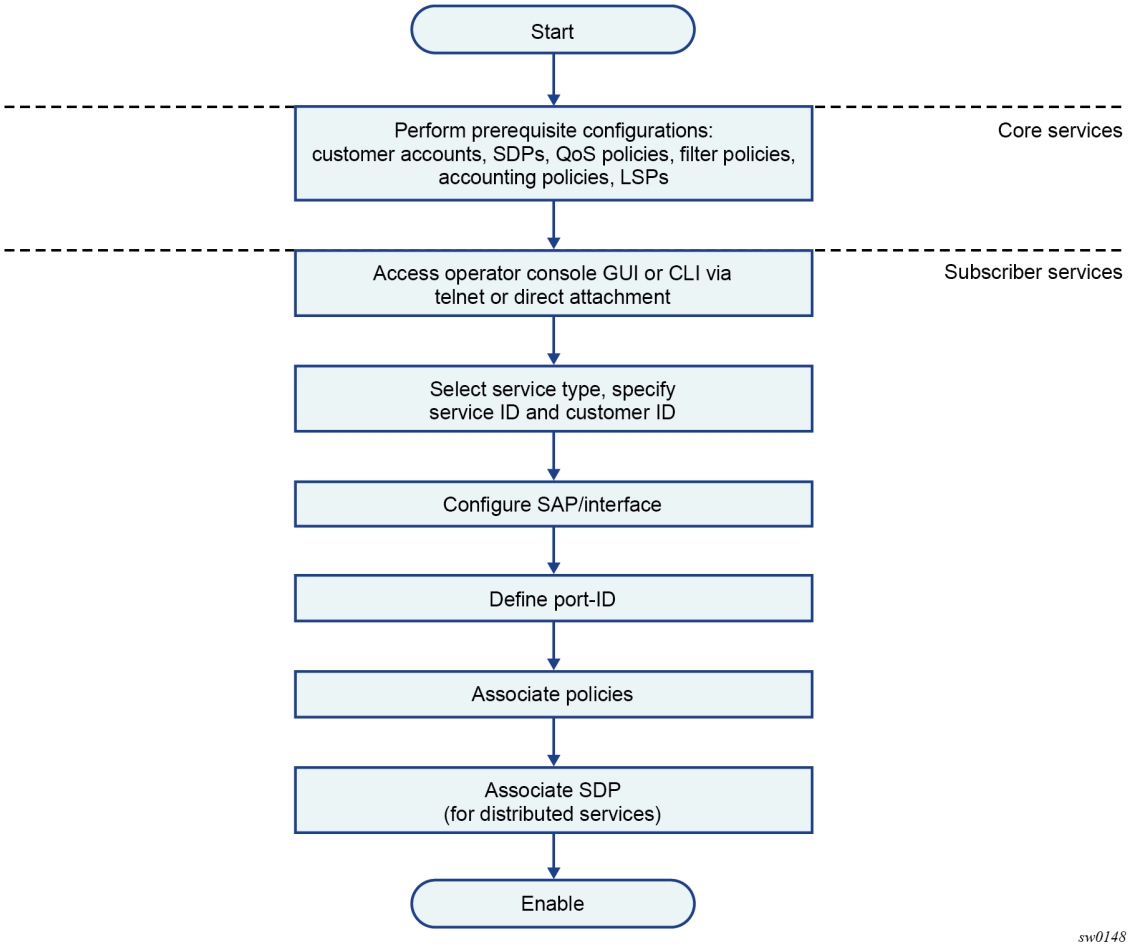
Example: IP transport subservice configuration

```
A:node-2>config>service>vprn# info
----------------------------------------------
        configure
            service vprn 100 create
                ip-transport 1/2/4.1 create
                description "ip-transport vprn"
                filter-unknown-host
                local-host ip-address 192.168.0.0 port-number 4000 protocol udp
                    exit
                remote-host 1 ip-address 192.168.0.1 port-number 4001 create
                    exit
                exit
                no-shutdown
----------------------------------------------
A:ALU-B>config>service>vprn
```

11 Service creation process overview

The following figure shows the overall process to provision core and subscriber services.

Figure 29: Service creation and implementation flow



12 Deploying and provisioning services

The service model provides a logical and uniform way of constructing connectivity services. The basic steps for deploying and provisioning services can be broken down into three phases.

12.1 Building the core network

About this task

The first phase of deploying and provisioning services is the core network construction.

Procedure

Step 1. Build the IP or IP/MPLS core network.

Step 2. Configure the routing protocols.

Step 3. Configure MPLS LSPs (if MPLS is used).

Step 4. Construct the core SDP service tunnel mesh for the services.

What to do next

Performing service administration

12.2 Performing service administration

Prerequisites

Perform the first phase for deploying and provisioning services, that is, building the core network.

About this task

The second phase of deploying and provisioning services is the service administration. The service administration includes preliminary policy and SDP configurations to control traffic flow, user access, and to manage fault conditions and alarm messages.

Procedure

Step 1. Configure group and user access privileges.

Step 2. Build templates for QoS, filter, or accounting policies needed to support the core services.

What to do next

Provisioning services

12.3 Provisioning services

Prerequisites

Perform the second phase for deploying and provisioning services, that is, performing service administration.

About this task

The third phase of deploying and provisioning services is the service provisioning.

Procedure

Step 1. Provision customer account information.

Step 2. If necessary, build any customer-specific QoS, filter, or accounting policies.

Step 3. Provision the services on the service edge routers by defining SAPs, binding policies to the SAPs, and binding the service to appropriate SDPs as necessary.

See Configuring customers and Configuring an SDP.

13 General configuration notes

Service provisioning tasks are typically performed before provisioning a subscriber service and can be logically separated into two main functional areas:

- core tasks
- subscriber tasks

The core tasks must be performed before the subscriber tasks.

Core tasks include the following:

- Create customer accounts.
- Create template QoS, filter, scheduler, and accounting policies.
- Create SDPs.

Subscriber tasks include the following:

1. Create Epipe, IES, VPLS, or VPRN services on the 7705 SAR Gen 2.
2. Bind SDPs.
3. Configure interfaces (where required) and SAPs.
4. Create exclusive QoS and filter policies.

14 Configuring global service entities with CLI

This section provides information to create subscriber (customer) accounts and configure SDPs using the command line interface.

14.1 Service model entities

The Nokia service model uses logical entities to construct a service. The service model contains four main entities to configure a service:

- subscribers (customers)
- SDPs
- services
  - **Ethernet Pipe (Epipe) services**

    See the *7705 SAR Gen 2 Layer 2 Services and EVPN Guide* for more information.
  - **Virtual Private LAN Service (VPLS)**

    See the *7705 SAR Gen 2 Layer 2 Services and EVPN Guide* for more information.
  - **Internet Enhanced Service (IES)**

    See the *7705 SAR Gen 2 Layer 3 Services Guide: IES and VPRN* for more information.
  - **Virtual Private Routed Network (VPRN) service**

    See the *7705 SAR Gen 2 Layer 3 Services Guide: IES and VPRN* for more information.
- Service Access Points (SAPs)
  - **Ethernet Pipe (Epipe) services**

    See the *7705 SAR Gen 2 Layer 2 Services and EVPN Guide* for more information.
  - **VPLS SAP**

    See the *7705 SAR Gen 2 Layer 2 Services and EVPN Guide* for more information.
  - **IES SAP**

    See the *7705 SAR Gen 2 Layer 3 Services Guide: IES and VPRN* for more information.
  - **VPRN Interface SAP**

    See the *7705 SAR Gen 2 Layer 3 Services Guide: IES and VPRN* for more information.

14.2 Basic configuration

The most basic service configuration must have the following:

- a customer ID
- a service type

- a service ID

  This is an optional service name that can be configured in addition to the service ID. Service names are optional. All services are required to assign a service ID to initially create a service. However, either the service ID or the service name can be used to identify and reference a specific service when it is initially created.
- a SAP identifying a port and encapsulation value
- an associated SDP for distributed services
- an interface (where required) identifying an IP address, IP subnet, and broadcast address
- for distributed services, an associated SDP

The commands in the following contexts provide nodes for basic configurations.

```
configure service customer
configure service sdp
configure service service type
```

14.3 Common configuration tasks

This section provides a brief overview of the tasks that must be performed to configure a customer account and an SDP.

14.3.1 Configuring customers

The most basic customer account must have a customer ID. Optional configurations include:

- description
- contact name
- telephone number
- multiservice site

14.3.1.1 Customer information

Use the following CLI syntax to create and input customer information.

```
A:node-2config>service# info
----------------------------------------
...
       customer 5
           description "Nokia Customer"
           contact "Technical Support"
           phone "650 555-1212"
       exit
...
----------------------------------------
```

14.3.1.2 Configuring multiservice-sites

Multiservice sites create a virtual scheduler hierarchy and making it available to queues and, at egress only, policers on multiple Service Access Points (SAPs). The **ingress** and **egress scheduler-policy** commands on the SAP are mutually exclusive with the SAP **multi-service-site** command. The multiservice customer site association must be removed from the SAP before local scheduler polices may be applied.

After a multiservice site is created, it must be assigned to a chassis slot or port.

Use the following CLI command to configure customer multiservice site information.

```
configure service customer multi-service-site
```

14.3.2 Configuring an SDP

The most basic SDP must have the following:

- a locally unique SDP identification (ID) number
- a system IP address of the far-end routers
- an SDP encapsulation type, either GRE or MPLS

14.3.2.1 SDP configuration tasks

About this task

This procedure provides a brief overview of the tasks that must be performed to configure a basic SPD.

Consider the following SDP characteristics:

- SDPs can be created as either GRE or MPLS.
- Each distributed service must have an SDP defined for every remote router to provide VLL, VPLS, and VPRN services.
- A distributed service must be bound to an SDP. By default, no SDP is associated with a service. After an SDP is created, services can be associated with that SDP.
- An SDP is not specific or exclusive to any one service or any type of service. An SDP can have more than one service bound to it.
- The SDP IP address must be an Nokia router system IP address.
- To configure an MPLS SDP, LSPs must be configured first and then the LSP-to-SDP association must be explicitly created.

  Auto-LSPs such as one-hop-p2p and mesh-p2p, and PCE initiated LSPs cannot be used by a configured MPLS SDP.
- In the SDP configuration, automatic ingress and egress labeling (targeted LDP) is enabled by default. Ingress and egress VC labels are signaled over a TLDP connection between two Nokia nodes.

Note: If signaling is disabled for an SDP, then services using that SDP must configure ingress and egress vc-labels manually.

Procedure

Step 1. Specify an originating node.

Step 2. Create an SDP ID.

Step 3. Specify an encapsulation type.

Step 4. Specify a far-end node.

14.3.2.2 Configuring a mixed-LSP SDP

Use the following command to configure an SDP with mixed LSP mode of operation:

- **MD-CLI**

```
configure service sdp delivery-type mpls mixed-lsp-mode
```

- **classic CLI**

```
configure service sdp mpls mixed-lsp-mode
```

The primary is backed up by the secondary. Two combinations are possible: primary of RSVP is backed up by LDP and primary of LDP is backed up by 8277 BGP.

The **no** form of this command disables the mixed LSP mode of operation. The user first has to remove one of the LSP types from the SDP configuration or the command fails.

The user can also configure the time the service manager must wait before it must revert the SDP to a higher priority LSP type when one becomes available by using the following command:

- **MD-CLI**

```
configure service sdp delivery-type mpls mixed-lsp-mode revert-time
```

- **classic CLI**

```
configure service sdp mpls mixed-lsp-mode revert-time
```

A special value of the timer dictates that the SDP must never revert to another higher priority LSP type unless the currently active LSP type is down:

- **MD-CLI**

```
configure service sdp delivery-type mpls mixed-lsp-mode revert-time never
```

- **classic CLI**

```
configure service sdp mpls mixed-lsp-mode revert-time infinite
```

The BGP LSP type is allowed. The **bgp-tunnel** command can be configured under the SDP with the **lsp** or **ldp** commands.

The mixed LSP SDP allows for a maximum of two LSP types to be configured within an SDP. A primary LSP type and a backup LSP type. An RSVP primary LSP type can be backed up by an LDP LSP type.

An LDP LSP can be configured as a primary LSP type which can then be backed up by a BGP LSP type.

At any time, the service manager programs only one type of LSP in the line card that activates it to forward service packets according to the following priority order:

With RSVP or LDP SDP, the service manager programs the NHLFEs for the active LSP type preferring the RSVP LSP type over the LDP LSP type. If no RSVP LSP is configured or all configured RSVP LSPs go down, the service manager reprograms the line card with the LDP LSP if available. If not, the SDP goes operationally down.

When a higher priority type LSP becomes available, the service manager reverts back to this LSP at the expiry of the revert time timer or the failure of the currently active LSP, whichever comes first. The service manager then re-programs the line card accordingly.

The SDP reverts to the highest priority type LSP only if the currently active LSP failed when the following commands were configured:

- **MD-CLI**

```
configure service sdp delivery-type mpls mixed-lsp-mode revert-time never
```

- **classic CLI**

```
configure service sdp mpls mixed-lsp-mode revert-time infinite
```

Note: LDP uses a tunnel down damp timer which is set to three seconds by default. When the LDP LSP fails, the SDP reverts to the RSVP LSP type after the expiry of this timer. For an immediate switchover this timer must be set to zero; use the **configure router ldp tunnel-down-damp-time** command.

If the value of the **revert-time** timer is changed, it takes effect only at the next use of the timer. Any timer which is outstanding at the time of the change is restarted with the new value.

If class based forwarding is enabled for this SDP, the forwarding of the packets over the RSVP LSPs is based on the FC of the packet as in current implementation. When the SDP activates the LDP LSP type, then packets are forwarded over the LDP ECMP paths using the regular hash routine.

With LDP/BGP SDP, the service manager prefers the LDP LSP type over the BGP LSP type. The service manager re-programs the line card with the BGP LSP if available otherwise it brings down the SDP operationally.

The following are differences in behavior between the LDP/BGP SDP and the RSVP/LDP SDP. For a specific /32 prefix, only a single route exists in the routing table: the IGP route or the BGP route. Therefore, either the LDP FEC or the BGP labeled route is active at any time. The impact of this is that the tunnel table needs to be re-programmed each time a route is deactivated and the other is activated. Furthermore, the SDP revert-time cannot be used because there is no situation where both LSP types are active for the same /32 prefix.

- **RSVP LSP type**
  Up to 16 RSVP LSPs can be entered by the user and programmed by the service manager in ingress line card to load balance service packets. This is the highest priority LSP type
- **LDP LSP type**
  One LDP FEC programmed by service manager but ingress line card can use up to 16 LDP ECMP paths for the FEC to load balance service packets when ECMP is enabled on the node.
- **BGP LSP type**
  One RFC 8277-labeled BGP prefix programmed by the service manager. The ingress line card can use more than one next-hop for the prefix.

15 Ethernet connectivity fault management (ETH-CFM)

The IEEE and the ITU-T have cooperated to define the protocols, procedures, and managed objects to support service-based fault management. Both the IEEE 802.1ag standard and the ITU-T Y.1731 recommendation support a common set of tools that allow users to deploy the necessary administrative constructs, management entities and functionality, and Ethernet Connectivity Fault Management (ETH-CFM). The ITU-T has also implemented a set of advanced ETH-CFM and performance management functions and features that build on the proactive and on-demand troubleshooting tools.

CFM uses Ethernet frames and is distinguishable by Ethertype 0x8902. In specific cases, the different functions use a reserved multicast Layer 2 MAC address that could also be used to identify specific functions at the MAC layer. The multicast MAC addressing is not used for every function or in every case. The Operational Code (OpCode) in the common CFM header is used to identify the PDU type carried in the CFM packet. CFM frames are only processed by IEEE MAC bridges.

IEEE 802.1ag and ITU-T Y.1731 functions that are implemented are available on the platforms

This section provides configuration examples for each of the functions. It also provides the various OAM command line options and **show** commands to operate the network. See the *7705 SAR Gen 2 MD-CLI Command Reference Guide* and *7705 SAR Gen 2 Classic CLI Command Reference Guide* for a detailed description of the CLI commands to build the necessary constructs and management points.

Note: 7705 SAR Gen 2 does not support ETH-CFM or EFM-OAM on PXC ports.

The following table lists and expands the acronyms used in this section.

Table 10: ETH-CFM acronym expansions

Acronym	Expansion	Supported platform
1DM	One-way Delay Measurement (Y.1731)	All
AIS	Alarm Indication Signal	All
CCM	Continuity Check Message	All
CFM	Connectivity Fault Management	All
CSF	Client Signal Fail (Receive)	All
DMM	Delay Measurement Message (Y.1731)	All
DMR	Delay Measurement Reply (Y.1731)	All
ED	Ethernet Defect (Y.1731 sub OpCode of MCC)	All
LBM	Loopback message	All
LBR	Loopback reply	All

Acronym	Expansion	Supported platform
LMM	(Frame) Loss Measurement message	Platform specific
LMR	(Frame) Loss Measurement response	Platform specific
LTM	Linktrace message	All
LTR	Linktrace reply	All
MCC	Maintenance Communication Channel (Y.1731)	All
ME	Maintenance Entity	All
MA	Maintenance Association	All
MD	Maintenance Domain	All
MEP	Maintenance Association Endpoint	All
MEP-ID	Maintenance Association Endpoint Identifier	All
MHF	MIP Half Function	All
MIP	Maintenance Domain Intermediate Point	All
OpCode	Operational Code	All
RDI	Remote Defect Indication	All
TST	Ethernet Test (Y.1731)	All
SLM	Synthetic Loss Message	All
SLR	Synthetic Loss Reply (Y.1731)	All
VSM	Vendor Specific Message (Y.1731)	All
VSR	Vendor Specific Reply (Y.1731)	All

15.1 Facility MEPs

Facility MEPs improve scalability, reduce operational overhead, and provide fate sharing without requiring service MEPs. This enables fault notification for Epipe services that share a common transport. Facility MEPs recognize failure based solely on ETH-CFM detection mechanisms.

The following facility MEPs exist, as described below:

- port (physical) – detects port failure where LOS may be hidden by some intervening network
- router IP interface (logical) – validates the Layer 2 connectivity between IP endpoints (troubleshooting only, no CCM functions)

In general, a facility MEP detects failure conditions using ETH-CFM at the Ethernet Transport Layer. The detection is based solely on the MEP entering a fault state as a result of ETH-CC. Conditions outside the scope of ETH-CFM have indirect influence on the state of the MEP. For example, after the failure of a port, CCM messages cannot reach the destination. This condition causes the MEP to enter a fault state after the 3.5 × interval expires, with the only exception being the acceptance of AIS on a Tunnel MEP. AIS received on all other facility MEPs is discarded silently when normal level matching targets the local facility MEP.

Facility MEPs are supported as part of a down MEP only. Facility MEPs validate the point-to-point Ethernet transport between two endpoints, which does not include validating switching functions outside this Ethernet transport. The service MEPs validate these additonal switching functions outside the point-to-point Ethernet transport.

A facility MEP allows for the scaling improvements using fate sharing and leveraging OAM mapping. The OAM mapping functions are part of the fault propagation functions and allow ETH-CFM to move from alarms only to network actions. Service-based MEPs are not required to generate AIS in reaction to a facility MEP fault. OAM mapping and generation of fault via fault-propagation means or the AIS function are only available for Epipe services. There is no equivalent AIS generation as part of the facility fault for VPLS. Service MEPs do not require the SAP transition in the VPLS service context. Normal SAP transition functions do not occur when these services are configured to accept the tunnel fault, or in reaction to a facility fault, where the underlying port or LAG transitions the SAP.

Note: Do not exceed the platform-specific scaling limits. A single facility fault may trigger the generation of many service-level faults. Ensure that the specific ETH-CFM processing power of the network element and any configured rate controlling features for the service are not exceeded. Exceeding the network element scaling properties may lead to OAM packet loss during processing and result in unwanted behavior.

Facility MEPs are created in the same manner as service MEPs, both related to the ETH-CFM domain and association. However, the association used to build the facility MEP does not include a bridge identifier. The CLI ensures that a bridge ID is not configured when the association is applied to a facility MEP.

Service MEPs and facility MEPs may communicate with each other, as long as all the matching criteria are met. Because facility MEPs use the standard ETH-CFM packets, there is nothing contained in the packet that would identify an ETH-CFM packet as a facility MEP or service MEP.

Facility MEPs are not supported on ports that are configured with Ethernet Tunnels (G.8031) and only facility MEPs of 1 second and above are supported on the ports that are involved in an Ethernet Ring (G.8032).

15.1.1 Common actionable failures

AIS operates independently from the **low-priority-defect** command option. The **low-priority-defect** command option affects only the ETH-CFM fault propagation and alarming outside the scope of AIS. By default, a fault in the CCM MEP state machine generates AIS when it is configured. Table 11: Defect conditions and priority settings summarizes the ETH-CC defect condition groups, configured **low-priority-defect** setting, priority, and defect as it applies to fault propagation. AIS maintains its own **low-priority-defect** command option, which can be used to exclude the CCM defect RDI from triggering the generation of AIS.

Table 11: Defect conditions and priority settings

Defect	Low priority defect	Description	Causes	Priority
DefNone	n/a	No faults in the association	Normal operations	n/a
DefRDICCM	allDef	Remote Defect Indication	Feedback mechanism to inform unidirectional faults exist. It provides the feedback loop to the node with the unidirectional failure conditions.	1
DefMACStatus (default)	macRemErrXcon	MAC Layer	Remote MEP is indicating a remote port or interface not operational.	2
DefRemoteCCM	remErrXon	No communication from remote peer	MEP is not receiving CCM from a configured peer. The timeout of CCM occurs at 3.5 x the local CC interval. As per the specification, this value is not configurable.	3
DefErrorCCM	errXcon	Remote and local configurations do not match the required configuration	Caused by different interval timer, domain-level issues (lower value arriving at a MEP configured with a higher value), MEP receiving CCM with its MEP-ID.	4
DefXconn	Xcon	Cross Connected Service	The service is receiving CCM packets from a different association. This could indicate that two services have merged or there is a configuration error on one of the SAP or bindings of the service, incorrect association identification.	5

A facility MEP may trigger two distinct actions as a result of fault. If they have been configured to do so, Epipe services generate AIS as a result of a failure. The level of the AIS is derived from the facility MEP. Multiple **client-meg-level** configurations can be configured under the facility MEP to allow for operational efficiency in the event a change is required. However, only the lowest AIS level is generated for all the linked and applicable services. VPLS SAPs transition the SAP state if they are configured to react to the facility MEP state. In addition, Epipe services may also take advantage of OAM and mapping functions.

Before implementing facility MEPs, it is important to understand the behavior of AIS and fault propagation. Nokia advises users to consider the following recommendations before enabling or altering the

configuration of any facility MEP. These steps must be tested on each individual network before building a maintenance operational procedure (MOP):

- Do not configure AIS on the facility MEP until the ETH-CCM has been verified. For example, when a local MEP is configured with AIS before the completion of the remote MEP, the AIS is immediately generated when the MEP enters a fault state for all services linked to that facility MEP.
- Disable the **client-meg-level** command when modifying existing functional facility MEPs for AIS. This stops the transmit function, but maintains the ability to receive and understand AIS conditions from the network.
- Set the **low-priority-defect** command to not report defects of DefXcon or lower, to prevent the MEP from entering a defect state and triggering SAP transitions and OAM mapping reactions.

Note: It is important to consider and select the types of fault conditions that cause the MEP to enter a faulty state when using fault propagation functions.

15.1.2 General detection, processing, and reaction

All facility MEPs that support CCM functions must have only one remote MEP peer. Facility MEPs validate point-to-point logical or physical Ethernet transports. Configure service MEPs if multipoint-service validation is required.

There are three distinct functions for a facility MEP:

- **general fault detection**

  This determines that a fault has occurred. In this case, the MEP performs its normal functions, such as: recognizing the fault condition, maintaining the local errors and reporting based on the low-priority setting, and taking no further action. This is the default.

- **fault processing**

  By default, there is no action taken as a result of a MEP state machine transition beyond alarming. To take action that may include a SAP operational state change, generation of AIS, or fault propagation and mapping, the appropriate **facility-fault** command must be configured and enabled. The general reaction to a fault is described as follows:

  – **port**

    This affects link operational status of the port. Facility failure changes the operational state to link operationally up. This indicates that the port has been brought down as a result of an OAM MEP fault. This operational state has the equivalent function to a port operationally down condition.

  – **router IP interface**

    This affects the operational status of the IP Interface.

- **propagation**

  Services appropriately linked to the facility MEP take the following service-specific actions:

  – Epipe generates AIS or uses fault propagation and OAM mappings.

  – VPLS does not propagate fault using AIS unless service-based MEPs are configured and contain MEP-specific AIS configuration. SAP transitions occur when the facility MEP failure is recognized by the service.

- **Enabling AIS command options**

  Epipe services support the following command under the SAP hierarchy level:

– **MD-CLI**

```
configure service epipe sap eth-cfm ais true
configure service epipe sap eth-cfm mep ais
```

– **classic CLI**

```
configure service epipe sap eth-cfm ais-enable
configure service epipe sap eth-cfm mep ais-enable
```

This structure, outside of the MEP context, creates a special link between the Epipe service SAP and the facility MEP. If a facility MEP enters a fault state, all Epipe service SAPs with this configuration generate lowest-level AIS at the level configured under the facility MEP. As with fault propagation, AIS generation is restricted to Epipe services only. The actions taken by the other services are described in more detail in the relevant facility MEP sections.

Note: Facility MEPs do not support the generation of AIS to an explicitly configured endpoint. An explicitly configured endpoint abstracts multiple endpoints within its context; for example, pseudowire (PW) redundancy. Although the linkage of a facility MEP to an Epipe, and AIS generation triggered as a result of the facility MEP failure can be configured, AIS generation is not supported and is unpredictable. When an explicit endpoint is configured, service-based MEPs are required when AIS generation is the needed behavior.

15.1.3 Port-based MEP

There is an increase in services sharing the same facilities, and service-based ETH-CFM, although very granular, comes at an operational and scalability cost. Configuring a MEP on a physical port allows ETH-CFM to detect Ethernet transport failures, raise a facility alarm, and perform local fault processing. A facility event is coordinated to the services or functions using the affected port.

The port-based MEP is intended to validate physical connectivity to the peer MEP, and provide on-demand and scheduled troubleshooting and performance management functions.

Port facility MEPs are advantageous in cases where port-to-port connectivity issues are obscured, similar to the deployment use cases for *IEEE 802.3 Clause 57 – Operation, Administration and Maintenance* (formerly 802.3ah). Clause 57 specification limits the transmit rate to 10 packets/s, or a send duration of 100 ms. All platform-specific requirements must be met for the needed interval. ETH-CFM and IEEE 802.3ah Clause 57 can influence the operational state of the port over which they are configured.

The 802.3ah and ETH-CFM protocols cannot simultaneously control the operational state of an individual port. Both protocols can be decoupled from the port operational state. The 802.3ah protocol defaults to influencing the port operational state. This can be modified by using the following command. When this command is configured, the ETH-OAM protocol does not impact the state of the port when there is a failure in the protocol state machine (discovery, configuration, timeout, loops, and so on). Only a protocol warning message is generated on the port.

Note: 7705 SAR Gen 2 does not support ETH-CFM or EFM-OAM on PXC ports.

- **MD-CLI**

```
configure port ethernet efm-oam ignore-efm-state true
```

- **classic CLI**

```
configure port ethernet efm-oam ignore-efm-state
```

The ETH-CFM protocol, ETH-CC, defaults to alarm only without influencing the port operational state. This can be modified by using the following command. When configured, the following command allows the facility MEP to move from just reporting the alarm condition to a network actionable function:

- **MD-CLI**

```
configure port ethernet eth-cfm mep facility-fault true
```

- **classic CLI**

```
configure port ethernet eth-cfm mep facility-fault
```

The 802.3ah and ETH-CFM protocol combinations that conflict with the single-port operational control rule are rejected with a configuration error. Port-level ETH-CFM PDUs are sent untagged because they are not specific to any service or VLAN. The ETH-CFM packets generated from a port-based facility MEP must use an ETH-CFM level of 0 or 1. Any ETH-CFM PDU that arrives untagged on a port matching the level for the port-based facility MEP is terminated and processed by the port-based MEP.

Do not use MEPs configured with level 0 to validate logical transport or services. Consider blocking all non-customer (5-7) levels at the network entry point.

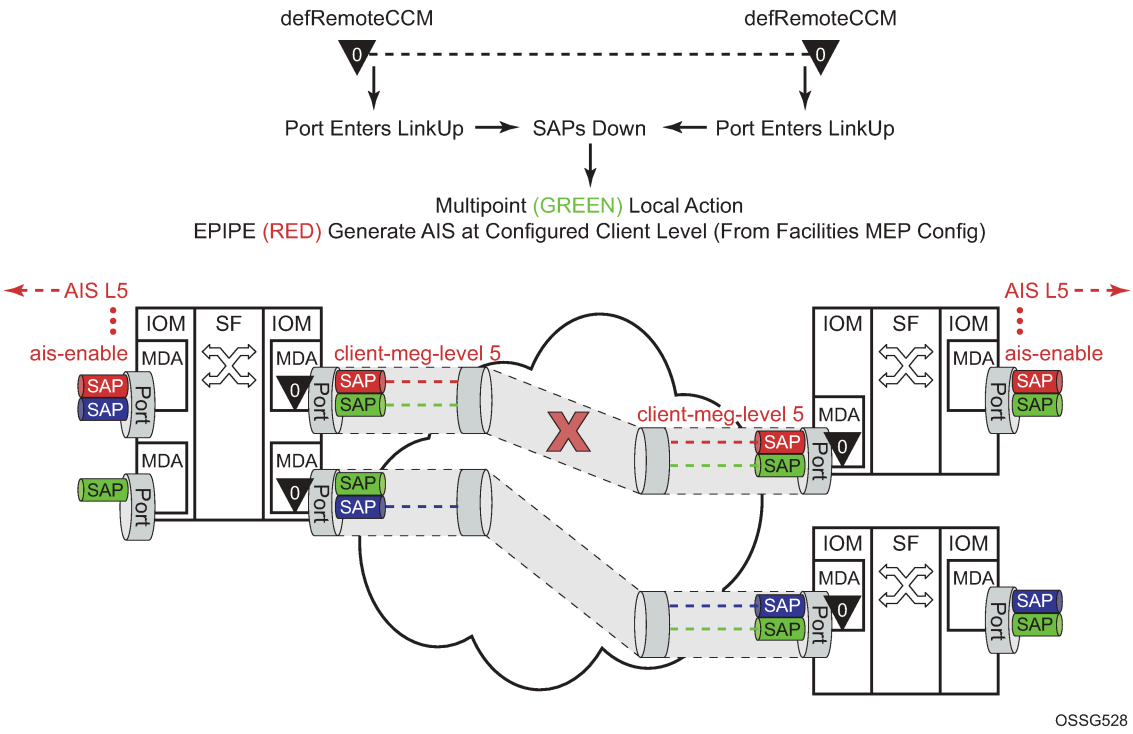
It is not expected that faults from other parts of the network are propagated and terminated on a port-based facility MEP. This type of facility MEP provides a one-to-one validation with a single remote MEP across on a physical port, allowing locally detected faults to be propagated to the endpoints of the network.

A physical port may only have a single port-based facility MEP. Because the purpose of the MEP is to control the port state, more than one is not required per port.

When a port enters the link-up operational state because of ETH-CFM, the MEP continues to transmit and receive to properly clear the condition. However, when the port fails for reasons that are not specific to ETH-CFM, it stops the transmit and receive functions until the condition is cleared. This differs from the behavior of a service MEP, because facility MEPs support only down MEPs, while some service-based MEPs support both up and down MEPs. In the case of up MEPs, a single port failure may not prevent all the CCMs from egressing the node. So the operational method for service-based MEPs remains the same, continuing to increase the counter for CCM transmit in the event of port failure, regardless of the cause.

The following figure shows how an ETH-CFM failure affects the various services that share that port. In this example, the green Epipe service generates AIS as a result of the port failure using the **client-meg-level** command configured on the port facility MEP. The multipoint service takes location-configured action when the SAP transitions to the down operational state. The blue Epipe service is not affected by the port link operationally up state as a result of the ETH-CFM fault.

Figure 30: Fault handling non-member port

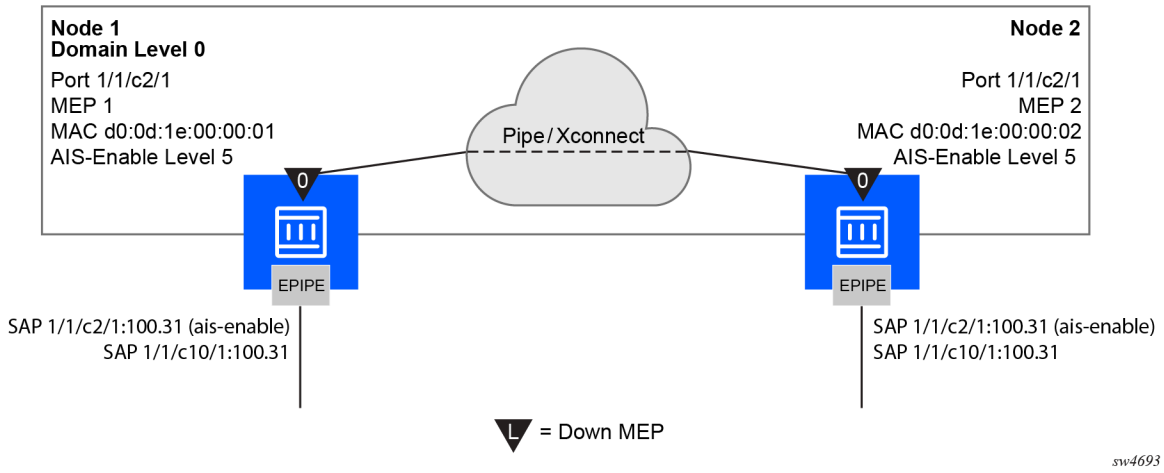


A debounce function has been implemented to prevent notifying every port state change if a port bounces multiple times within a window. Up to four notifications are accepted in a 3-second window. If the third port state is a down state change, the fourth is ignored. If the fourth port state change is a down state change, it is processed. After that, no further state changes are accepted for the duration of the 3-second timer. This helps ensure that the port is not artificially held in the operationally up state when it is not in operation. Following the processing of that last port state change, the third or fourth, the latest state change is held and processed at the expiration of the 3-second hold timer.

Port-based facility MEPs are not allowed on a port that is configured with G.8031 Ethernet tunnels.

The following figure shows how port-based MEPs and defect conditions translate into service awareness without service-based MEPs. In this example, the two nodes are aware that they are directly connected at the port level. However, they are unaware of the underlying cross-connections that enable this.

Figure 31: Port-Based MEP example



Use the following commands to configure port-based MEPs. When the MEP enters any defect state, an AIS is generated to any Epipe services that have AIS enabled under the **sap eth-cfm** hierarchy.

- **MD-CLI**

```
configure port ethernet eth-cfm mep facility-fault true
configure port ethernet eth-cfm mep ais client-meg-level
```

- **classic CLI**

```
configure port ethernet eth-cfm mep facility-fault
configure port ethernet eth-cfm mep ais-enable client-meg-level
```

Example: Node1 configuration (MD-CLI)

```
[ex:/configure eth-cfm]
A:admin@node-1# info
    domain "10" {
        level 0
        format none
        association "1" {
            icc-based "FacilityPort0"
            ccm-interval 1s
            remote-mep 2 {
            }
        }
    }

[ex:/configure port 1/1/c2/1]
A:admin@node-1# info
    admin-state enable
    ethernet {
        mode access
        encap-type qinq
        eth-cfm {
            mep md-admin-name "10" ma-admin-name "1" mep-id 1 {
                admin-state enable
                mac-address d0:0d:1e:00:00:01
                ccm true
```

```
                facility-fault true
                ais {
                    client-meg-level [5]
                }
            }
        }
    }
[ex:/configure service epipe "7"]
A:admin@node-1# info
    sap 1/1/c2/1:100.31 {
        eth-cfm {
            ais true
        }
    }
    sap 1/1/c10/1:100.31 {
    }
```

Example: Node1 configuration (classic CLI)

```
A:node-1>config>eth-cfm# info
----------------------------------------------
        domain 10 format none level 0
            association 1 format icc-based name "FacilityPort0"
                ccm-interval 1
                remote-mepid 2
            exit
        exit
----------------------------------------------

A:node-1>config>port# info
----------------------------------------------
        ethernet
            mode access
            encap-type qinq
            eth-cfm
                mep 1 domain 10 association 1
                    ais-enable
                        client-meg-level 5
                    exit
                    facility-fault
                    ccm-enable
                    mac-address d0:0d:1e:00:00:01
                    no shutdown
                exit
            exit
        exit
        no shutdown
----------------------------------------------

A:node-1>config>service>epipe# info
----------------------------------------------
            sap 1/1/c2/1:100.31 create
                eth-cfm
                    ais-enable
                exit
            exit
            sap 1/1/c10/1:100.31 create
            exit
            no shutdown
----------------------------------------------
```

Example: Node2 configuration (MD-CLI)

```
[ex:/configure eth-cfm]
A:admin@node-2# info
    domain "10" {
        level 0
        format none
        association "1" {
            icc-based "FacilityPort0"
            ccm-interval 1s
            remote-mep 1 {
            }
        }
    }
[ex:/configure port 1/1/c2/1]
A:admin@node-2# info
    admin-state enable
    ethernet {
        mode access
        encap-type qinq
        eth-cfm {
            mep md-admin-name "10" ma-admin-name "1" mep-id 2 {
                admin-state enable
                mac-address d0:0d:1e:00:00:02
                ccm true
                facility-fault true
                ais {
                    client-meg-level [5]
                }
            }
        }
    }
[ex:/configure service epipe "7"]
A:admin@node-2# info
    sap 1/1/c2/1:100.31 {
        eth-cfm {
            ais true
        }
    }
    sap 1/1/c10/1:100.31 {
    }
```

Example: Node2 configuration (classic CLI)

```
A:node-2>config>eth-cfm# info
----------------------------------------------
        domain 10 format none level 0
            association 1 format icc-based name "FacilityPort0"
                ccm-interval 1
                remote-mepid 1
            exit
        exit
----------------------------------------------

A:node-2>config>port# info
----------------------------------------------
        ethernet
            mode access
            encap-type qinq
            eth-cfm
                mep 2 domain 10 association 1
                    ais-enable
                        client-meg-level 5
```

```
                    exit
                    facility-fault
                    ccm-enable
                    mac-address d0:0d:1e:00:00:02
                    no shutdown
                exit
            exit
        exit
        no shutdown
----------------------------------------------

A:node-2>config>service>epipe# info
----------------------------------------------
            sap 1/1/c2/1:100.31 create
                eth-cfm
                    ais-enable
                exit
            exit
            sap 1/1/c10/1:100.31 create
            exit
            no shutdown
----------------------------------------------
```

There are two different fault levels to consider: Port State/Operational State driven by the **low-priority-defect** setting and the generation of AIS driven by the defect state for the MEP.

If the **low-priority-defect** is left at the default macRemErrXcon setting, port state may not match on both nodes. If a unidirectional failure is introduced for port-based MEPs, RDI is received on one of the nodes and the other node reports and reacts to RemoteCCM (timeout). As the RDI defect is below the default **low-priority-defect** in priority, the port and port state remains operationally up. The MEP that has timed out the peer MEP takes port-level action because this defect is higher in priority than the default **low-priority-defect**. The port state is recorded as Link Up and the port is operationally down with a "Reason Down: ethCfmFault". To avoid this inconsistency, set the **low-priority-defect** command to detect unidirectional failures using the allDef option.

The following **show** commands reveal the preceding condition within the network. In this example, Node 1 is receiving RDI and Node 2 has timed out its peer MEP.

Node1 outputs

The following outputs display information for the Node1 example configuration.

Use the following command to display port information.

```
show port
```

Output example: Node1 port output

```
===============================================================================
Ports on Slot 1
===============================================================================
Port        Admin Link Port    Cfg  Oper LAG/ Port Port Port   C/QS/S/XFP/
Id          State      State   MTU  MTU  Bndl Mode Encp Type   MDIMDX
-------------------------------------------------------------------------------
...
1/1/c2/1       Up    Yes  Up      1522 1522    - accs qinq xcme
...
```

Use the following command to display information for a specific port.

```
show port 1/1/c2/1
```

Output example: Node1 output for a specific port

```
===============================================================================
Ethernet Interface
===============================================================================
Description        : 10/100/Gig Ethernet SFP
Interface          : 1/1/c2/1                    Oper Speed       : 1 Gbps
Link-level         : Ethernet                  Config Speed     : 1 Gbps
Admin State        : up                        Oper Duplex      : full
Oper State         : up                        Config Duplex    : full
Physical Link      : Yes                       MTU              : 1522
...
```

Use the following command to display the maintenance endpoint, maintenance domain, and maintenance association information.

```
show eth-cfm mep 1 domain 10 association 1
```

Output example: Node1 MEP configuration information output

```
===============================================================================
Eth-Cfm MEP Configuration Information
===============================================================================
Md-index           : 10                        Direction         : Down
Ma-index           : 1                         Admin             : Enabled
MepId              : 1                         CCM-Enable        : Disabled
Port               : 1/1/c2/1              VLAN              : 0
Description        : (Not Specified)
FngState           : fngReset                  ControlMep        : False
LowestDefectPri    : macRemErrXcon             HighestDefect     : none
Defect Flags       : bDefRDICCM
Mac Address        : d0:0d:1e:00:00:01         ControlMep        : False
CcmLtmPriority     : 7
CcmTx              : 1481                      CcmSequenceErr    : 0
Fault Propagation  : disabled                  FacilityFault     : Notify
MA-CcmInterval     : 1                         MA-CcmHoldTime    : 0ms
Eth-1Dm Threshold  : 3(sec)                    MD-Level          : 0
Eth-Ais:           : Enabled                   Eth-Ais Rx Ais:   : No
Eth-Ais Tx Priorit*: 7                         Eth-Ais Rx Interv*: 1
Eth-Ais Tx Interva*: 1                         Eth-Ais Tx Counte*: 3019
Eth-Ais Tx Levels  : 5
Eth-Tst:           : Disabled
...
```

Use the following command to display ETH-CFM facility information.

```
show service sap-using eth-cfm facility
```

Output example: Node1 ETH-CFM facility information output

```
===============================================================================
Service ETH-CFM Facility Information
===============================================================================
SapId             SvcId                          SAP AIS  SAP Tunnel SVC Tunnel
                                                          Fault      Fault
```

```
-------------------------------------------------------------------------------
1/1/c2/1:100.31      100                           Enabled  Accept     Ignore
-------------------------------------------------------------------------------
No. of Facility SAPs: 1
===============================================================================
```

Node2 outputs

The following outputs display information for the Node2 example configuration.

Use the following command to display port information.

```
show port
```

Output example: Node2 port output

```
===============================================================================
Ports on Slot 1
===============================================================================
Port        Admin Link Port    Cfg  Oper LAG/ Port Port Port   C/QS/S/XFP/
Id          State      State   MTU  MTU  Bndl Mode Encp Type   MDIMDX
-------------------------------------------------------------------------------
...
1/1/c2/1       Up    Yes  Link Up 1522 1522    - accs qinq xcme
...
```

Use the following command to display information for a specific port.

```
show port 1/1/2
```

Output example: Node2 output for a specific port

```
===============================================================================
Ethernet Interface
===============================================================================
Description        : 10/100/Gig Ethernet SFP
Interface          : 1/1/c2/1                  Oper Speed       : N/A
Link-level         : Ethernet                  Config Speed     : 1 Gbps
Admin State        : up                        Oper Duplex      : N/A
Oper State         : down                      Config Duplex    : full
Reason Down        : ethCfmFault
Physical Link      : Yes                       MTU              : 1522
...
```

Use the following command to display information for the specified maintenance endpoint, maintenance domain, and maintenance association.

```
show eth-cfm mep 2 domain 10 association 1
```

Output example: Node2 MEP configuration information output

```
===============================================================================
Eth-Cfm MEP Configuration Information
===============================================================================
Md-index           : 10                      Direction         : Down
Ma-index           : 1                       Admin             : Enabled
MepId              : 2                       CCM-Enable        : Enabled
Port               : 1/1/c2/1                VLAN              : 0
```

```
Description        : (Not Specified)
FngState           : fngDefectReported       ControlMep        : False
LowestDefectPri    : macRemErrXcon           HighestDefect     : defRemoteCCM
Defect Flags       : bDefRemoteCCM
Mac Address        : d0:0d:1e:00:00:02       ControlMep        : False
CcmLtmPriority     : 7
CcmTx              : 5336                    CcmSequenceErr    : 0
Fault Propagation  : disabled                FacilityFault     : Notify
MA-CcmInterval     : 1                       MA-CcmHoldTime    : 0ms
Eth-1Dm Threshold  : 3(sec)                  MD-Level          : 0
Eth-Ais:           : Enabled                 Eth-Ais Rx Ais:   : No
Eth-Ais Tx Priorit*: 7                       Eth-Ais Rx Interv*: 1
Eth-Ais Tx Interva*: 1                       Eth-Ais Tx Counte*: 3515
Eth-Ais Tx Levels  : 5
Eth-Tst:           : Disabled
...
```

Use the following command to display ETH-CFM facility information.

```
show service sap-using eth-cfm facility
```

Output example: Node2 ETH-CFM facility information output

```
===============================================================================
Service ETH-CFM Facility Information
===============================================================================
SapId             SvcId                          SAP AIS  SAP Tunnel SVC Tunnel
                                                          Fault      Fault
-------------------------------------------------------------------------------
1/1/c2/1:100.31      100                            Enabled  Accept     Ignore
-------------------------------------------------------------------------------
No. of Facility SAPs: 1
===============================================================================
```

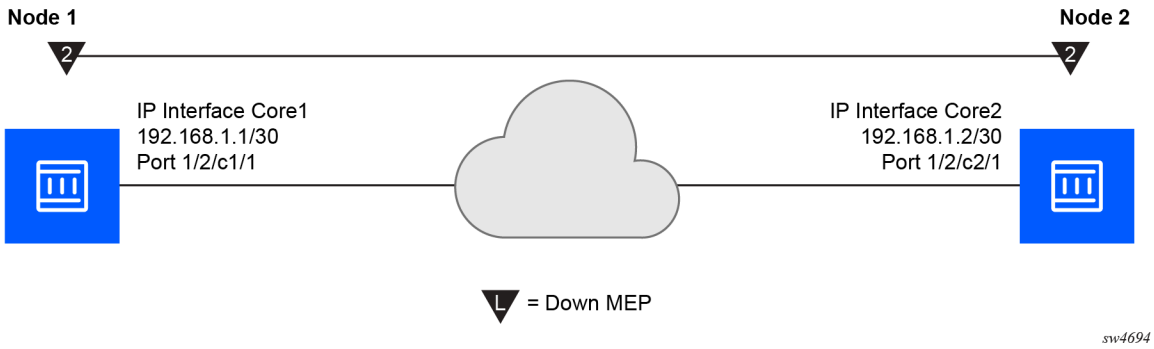
15.1.4 Router interface MEP

MEPs and associated on-demand troubleshooting functions act as router interfaces that are part of the base routing instance. This feature allows the user to verify Layer 2 transport that connects the Layer 3 interfaces.

Router interfaces MEPs are supported for all router interface instances (null port 1/1/1, dot1q port 1/1/3:vid, null LAG-lag-id and dot1q LAG-lag-id:vid).

The following figure shows how a router facility MEP can be configured on a routed interface in the base router instance.

Figure 32: Router MEP example



ETH-CFM tools for proactive management (ETH-CC), troubleshooting (Loopback, Linktrace, and so on), and profiling (Delay Measurement, and so on) are supported. The configuration and some ETH-CFM test commands are shown for Node1 (on the left in the preceding figure). Following the on-demand test output, the configuration for Node 2 is included for completeness, without repeating the on-demand tests.

Example: Node1 configuration (MD-CLI)

```
[ex:/configure port 1/2/c1/1]
A:admin@node-1# info
    admin-state enable

[ex:/configure eth-cfm]
A:admin@node-1# info
    domain "2" {
        level 2
        format none
        association "2" {
            icc-based "FacilityRtr01"
        }
    }

[ex:/configure router "Base"]
A:admin@node-1# info
    interface "Core1" {
        port 1/2/c1/1
        eth-cfm {
            mep md-admin-name "2" ma-admin-name "2" mep-id 1 {
                admin-state enable
                mac-address d0:0d:1e:00:00:01
            }
        }
        ipv4 {
            primary {
                address 192.168.1.1
                prefix-length 30
            }
        }
    }
```

Example: Node1 configuration (classic CLI)

```
A:node-1>config>port# info
----------------------------------------------
        ethernet
```

```
        exit
        no shutdown
-----------------------------------------------

A:node-1>config>eth-cfm# info
-----------------------------------------------
        domain 2 format none level 2
            association 2 format icc-based name "FacilityRtr01"
            exit
        exit
-----------------------------------------------

A:node-1>config>router# info
#--------------------------------------------------
echo "IP Configuration"
#--------------------------------------------------
        interface "Core1"
            address 192.168.1.1/30
            port 1/2/c1/1
            eth-cfm
                mep 1 domain 2 association 2
                    mac-address d0:0d:1e:00:00:01
                    no shutdown
                exit
            exit
        exit
        interface "system"
        exit
-----------------------------------------------
```

Use the following command to display CFM facility information stack information for all router interfaces.

```
show eth-cfm cfm-stack-table facility all-router-interfaces
```

Output example: CFM facility information output

```
===============================================================================
CFM Stack Table Defect Legend:
R = Rdi, M = MacStatus, C = RemoteCCM, E = ErrorCCM, X = XconCCM, A = AisRx

===============================================================================
CFM Facility Interface Stack Table
===============================================================================
Interface          Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
Core1                2 Down          2          2    1 d0:0d:1e:00:00:01 ------
===============================================================================
```

Use the following command to display CFM facility interface stack information for all router interfaces.

```
show eth-cfm cfm-stack-table facility all-router-interfaces
```

Output example: CFM facility interface stack information output

```
===============================================================================
CFM Stack Table Defect Legend:
R = Rdi, M = MacStatus, C = RemoteCCM, E = ErrorCCM, X = XconCCM, A = AisRx

===============================================================================
CFM Facility Interface Stack Table
===============================================================================
```

```
Interface          Lvl Dir  Md-index   Ma-index   MepId  Mac-address     Defect
-------------------------------------------------------------------------------
Core1                2 Down          2          2    1 d0:0d:1e:00:00:01 ------
===============================================================================

# oam eth-cfm loopback d0:0d:1e:00:00:02 mep 1 domain 2 association 2
 send-count 5
Eth-Cfm Loopback Test Initiated: Mac-Address: d0:0d:1e:00:00:02, out service: 0
Sent 5 packets, received 5 packets [0 out-of-order, 0 Bad Msdu]

# oam eth-cfm linktrace d0:0d:1e:00:00:02 mep 1 domain 2 association
2
Index Ingress Mac          Egress Mac           Relay      Action
----- -------------------- -------------------- ---------- ----------
1     D0:0D:1E:00:00:02    00:00:00:00:00:00    n/a        terminate
----- -------------------- -------------------- ---------- ----------
No more responses received in the last 6 seconds.

# oam eth-cfm two-way-delay-test d0:0d:1e:00:00:02 mep 1 domain 2 association 2
Two-Way-Delay-Test Response:
Delay 1130 microseconds        Variation 63 microseconds

# oam eth-cfm two-way-delay-test d0:0d:1e:00:00:02 mep 1 domain 2 association 2
Two-Way-Delay-Test Response:
Delay 1218 microseconds        Variation 88 microseconds
```

Example: Node2 configuration (MD-CLI)

```
[ex:/configure port 1/2/c2/1]
A:admin@node-2# info
    admin-state enable

[ex:/configure eth-cfm]
A:admin@node-2# info
    domain "2" {
        level 2
        format none
        association "2" {
            icc-based "FacilityRtr01"
        }
    }

[ex:/configure router "Base"]
A:admin@node-2# info
    interface "Core2" {
        port 1/2/c2/1
        eth-cfm {
            mep md-admin-name "2" ma-admin-name "2" mep-id 2 {
                admin-state enable
                mac-address d0:0d:1e:00:00:02
            }
        }
        ipv4 {
            primary {
                address 192.168.1.2
                prefix-length 30
            }
        }
    }
```

Example: Node2 configuration (classic CLI)

```
A:node-2>config>port# info
----------------------------------------------
        ethernet
        exit
        no shutdown
----------------------------------------------

A:node-2>config>eth-cfm# info
----------------------------------------------
        domain 2 format none level 2
            association 2 format icc-based name "FacilityRtr01"
            exit
        exit
----------------------------------------------

A:node-2>config>router# info
#--------------------------------------------------
echo "IP Configuration"
#--------------------------------------------------
        interface "Core2"
            address 192.168.1.2/30
            port 1/2/c2/1
            eth-cfm
                mep 2 domain 2 association 2
                    mac-address d0:0d:1e:00:00:02
                    no shutdown
                exit
            exit
        exit
        interface "system"
        exit
----------------------------------------------
```

15.2 ETH-CFM and MC-LAG

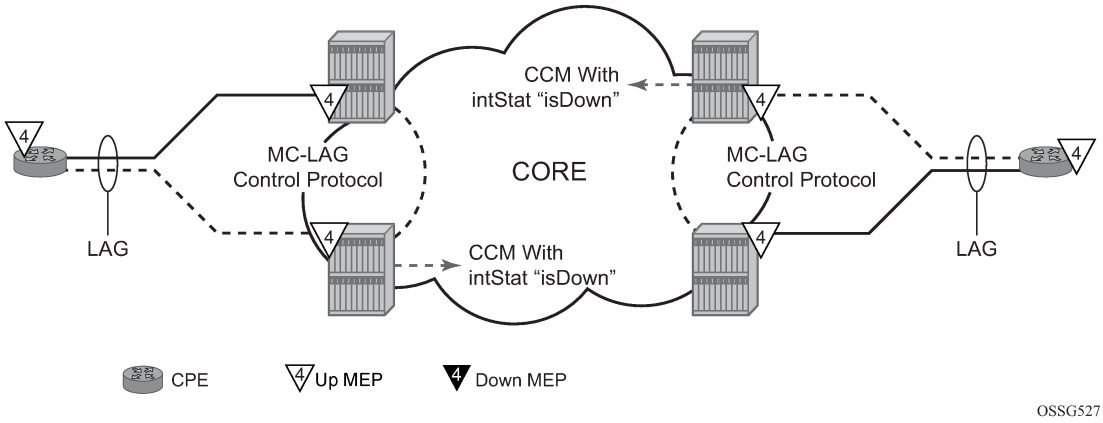
By default, ETH-CFM MEPs and MC-LAG operate independently. Nokia recommends users do not enable fault propagation when the default behavior is in use. A global command allows ETH-CFM to track the state of MC-LAG for MPs configured on MC-LAG ports. This feature does not allow MEPs to influence the MC-LAG state. Because the MP relies on the underlying MC-LAG construct, consider the correct MC-LAG design and deployment. The state of the MC-LAG can be reflected in the state of the MPs, which are configured on SAPs that are part MC-LAGs. For example, a SAP on a LAG that is part of an MC-LAG configuration can behave in a manner that more appropriately represents the MC-LAG.

15.2.1 ETH-CFM and MC-LAG default behavior

ETH-CFM MPs track the SAPs, bindings, and facility independently. Therefore, when an MP is configured on a SAP that is not operationally up because of an MC-LAG ETH-CFM defect, the system can raise alarms for conditions that could be considered normal.

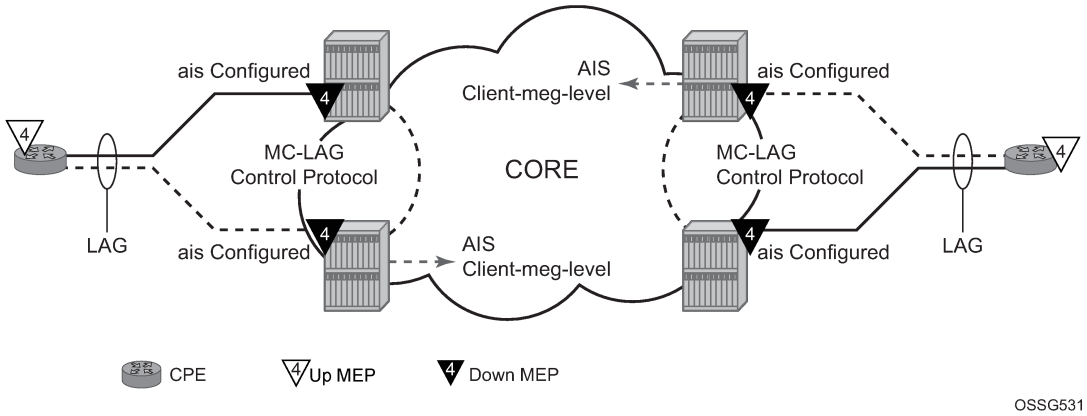
The following figure shows the default behavior for a point-to-point service, regardless of the MC-LAG. In the following case, the two up MEPs operating at level 4 on the affected SAPs set the Interface-Status-TLV bit in the ETH-CC header to represent the isDown condition, assuming ETH-CC is executing between the peer MEPs. This is the correct action based on the ETH-CFM perspective; SAPs are operationally down.

Figure 33: Independent processing up MEP example



A similar condition exists if a user configures down MEPs on the SAPs that are operationally down. The following figure shows how the same service configured with down MEPs would generate AIS, if enabled, toward the remote client at the configured **client-meg-level**, in the reverse direction of the MEP. This is also the correct behavior from the perspective of ETH-CFM.

Figure 34: Independent processing down MEP example



15.2.2 Linking ETH-CFM to MC-LAG state

There are benefits to allowing ETH-CFM to understand the state of MC-LAG and to adjust the behavior of the MP (MEP) accordingly.

MC-LAG represents the two upstream nodes as a single system to the node terminating in a standard LAG. Linking the ETH-CFM MPs to the state of the MC-LAG allows the user to configure MPs across the two nodes that appear the same. Under the default configuration, this introduces various defect conditions and event conditions. However, when ETH-CFM tracks the state of the MC-LAG, the MPs perform a role that represents the state of the resiliency mechanism.

Use the following system-wide command to enable MEPs to track the state of MC-LAG and allow MEPs on the standby MC-LAG to act administratively down:

- **MD-CLI**

```
configure system eth-cfm redundancy mc-lag standby-mep true
```

- **classic CLI**

```
configure eth-cfm redundancy mc-lag standby-mep-shutdown
```

When an MP is part of an active MC-LAG system, it performs as a normal MP and handles the following for all relevant ETH-CFM packets:

- terminating
- generating
- responding to
- processing

An MP that is on the standby MC-LAG node enters a pseudo-shutdown state. These MPs terminate all ETH-CFM packets that are part of the regular interception process, but do not process them. The router silently discards them. Also, an MP that exists on a standby MC-LAG system does not generate any ETH-CFM packets. The router blocks all proactive and on-demand functions on the standby MC-LAG node. When scheduled tests are executed through SAA, they still attempt to run, but fail as a result of the MEP state. These failures are not representative of the network.

This feature relies on the correct configuration, design, and deployment of the MC-LAG protocol. Numerous optimizations and command options are available as part of the MC-LAG functions. For example, by default, when a currently active MC-LAG port transitions to standby, by any means, including manual user intervention, the remote node terminating the standard LAG sees the LAG transition because all ports in the LAG are down for an instance in time. This is standard LAG behavior and does not change as a result of linking the MP state to the MC-LAG state. This transition causes the fault propagation for MEPs configured on that node.

ETH-CFM registers a fault propagation delay timer equal to the propagate hold time configured using the following command (default of 1s):

- **MD-CLI**

```
configure system eth-cfm redundancy mc-lag propagate-hold-time
```

- **classic CLI**

```
configure eth-cfm redundancy mc-lag propagate-hold-time
```

The fault propagation delay timer delays notification of an event that may be the result of an MC-LAG failover. This allows the system time to coordinate events and triggers that together represent the MC-LAG transition from active to standby.

A fixed timer value of 1-second delays an up MEP from announcing a SAP down condition, through the CCM Interface-Status-TLV bits. ETH-CFM maintains a status of last sent to the peer of the up MEPs. When the SAP transitions either up or down, that fault is held for the fixed 1-second interval, and the last Interface-Status-TLV bits are set based on the previous transmission. If the condition, different from the one sent previously, still exists at the end of the 1-second fixed timer, and when the next CCM interval expires, the representative value of the SAP is sent in the Interface-Status-TLV. These two timers help smooth out network transitions at the cost of propagation and fault clearing.

When a node with ETH-CFM linked to MC-LAG is transitioning from standby to active, ETH-CFM assumes no underlying conditions exist for any SAPs that are now part of the newly activated MC-LAG. The initial notification to an up MEP peer does not include any faults. It assumes that the transitioning SAPs are stabilizing as the switchover proceeds. The fixed 1-second timer starts, and a second CCM PDU (based on the up MEPs interval) is sent without any recognition of a potential fault on the SAP. However, after the expiration of the fixed timer, and on the next CCM interval, the Interface-Status-TLV represents the state of the SAP.

In scaled environments, configure the **propagation-hold-time** and the CCM intervals to achieve the needed goals. If these timers are set too aggressively, the router may generate fault and defect conditions during times of network stabilization. Carefully consider the use of fault propagation and AIS transmission in environments where MC-LAG protection mechanisms are deployed. Timer values do not guarantee that transitional state information is not propagated to the peer. The propagation of such states may be more taxing and disruptive than allowing the transmission states to complete. For example, if AIS generation is used, use a 60-second AIS interval to avoid advertising the transitional state.

AIS generation is paced in a first-come, first-served model not to exceed the system capability. The scale depends on the type of system. If AIS is configured in an MC-LAG solution, the user must ensure that the same MEPs on each system are configured to generate AIS, and this number does not exceed the maximum allowed. This requires the user to configure both nodes with the same MEPs that can generate AIS and not exceed the system capacity. If the nodes are configured differently or exceed the system scale, a transition may see a different set of MEPs outpace the AIS of the original set of MEPs. The AIS state is not synchronized across nodes.

Administrative functions, like administratively down, are special cases. When the administrative state changes from up to down, the timer is bypassed, and communication from ETH-CFM is immediate.

When an MP is configured in an MC-LAG environment, Nokia recommends that each aspect of the MP be configured the same, including MAC address. Also, both nodes participating in the MC-LAG, which require this functionality, should include the following global command to avoid unpredictable behavior:

- **MD-CLI**

```
configure system eth-cfm redundancy mc-lag standby-mep true
```

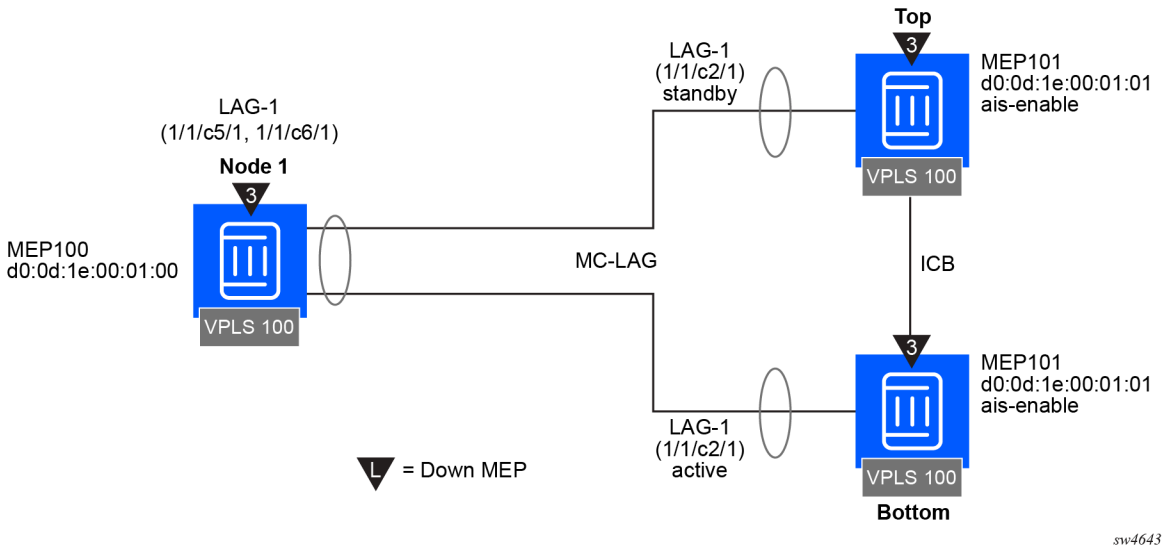
- **classic CLI**

```
configure eth-cfm redundancy mc-lag standby-mep-shutdown
```

In summary, a SAP that uses ETH-CFM to track MC-LAG represents the current state of the MC-LAG. MPs configured on the standby MC-LAG ports enter a state similar to being administratively disabled. MPs on the active MC-LAG ports perform all normal processing.

The following figure shows how MEPs can be linked to the MC-LAG state. In this example, a service MEP is created on the LAG SAP on NODE1 within service VPLS 100. The MEPs configured on the MC-LAG nodes within service 100 are identical on both nodes. Both MEPs use the same MEP-ID and the same MAC address.

Figure 35: ETH-CFM and MC-LAG example



Only one of the MEPs on the MC-LAG nodes is active for VPLS service 100. The other MEP is in a shutdown mode, so that even when the MC-LAG is in standby and the port state is link up, the MEP is in a pseudo-shutdown state.

The following configuration example is not meant to provide all possible MC-LAG configuration statements required to fine-tune each provider network. It provides a base configuration that demonstrates the ETH-CFM feature.

Example: Node1 configuration (MD-CLI)

```
[ex:/configure port 1/1/c5/1]
A:admin@node-1# info
    ethernet {
        autonegotiate limited
        mode access
        encap-type qinq
    }

[ex:/configure port 1/1/c6/1]
A:admin@node-1# info
    ethernet {
        autonegotiate limited
        mode access
        encap-type qinq
    }

[ex:/configure lag "lag-1"]
A:admin@node-1# info
    admin-state enable
    encap-type qinq
    mode access
    hold-time-down 10
    lacp {
        mode active
        administrative-key 32768
    }
    access {
```

```
        adapt-qos {
            mode link
        }
    }
    port 1/1/c5/1 {
    }
    port 1/1/c6/1 {
    }

[ex:/configure eth-cfm]
A:admin@node-1# info
...
    domain "3" {
        level 3
        format none
        association "1" {
            icc-based "03-0000000100"
            ccm-interval 1s
            bridge-identifier "100" {
            }
            remote-mep 101 {
            }
        }
    }
[ex:/configure service vpls "100"]
A:admin@node-1# info
...
    stp {
        admin-state disable
    }
    sap 1/1/c2/1:100.100 {
    }
    sap lag-1:100.100 {
        eth-cfm {
            mep md-admin-name "3" ma-admin-name "1" mep-id 100 {
                mac-address d0:0d:1e:00:01:00
                ccm true
            }
        }
    }
```

Example: Node1 configuration (classic CLI)

```
A:node-1>config>port# info (both ports)
----------------------------------------------
        ethernet
            mode access
            encap-type qinq
            autonegotiate limited
        exit
        no shutdown
----------------------------------------------

A:node-1>config>lag# info
----------------------------------------------
     mode access
        encap-type qinq
        access
            adapt-qos link
        exit
        port 1/1/c5/1
        port 1/1/c6/1
        lacp active administrative-key 32768
```

```
        hold-time down 10
        no shutdown
-----------------------------------------------

A:node-1>config>eth-cfm# info
-----------------------------------------------
        domain 3 format none level 3
            association 1 format icc-based name "03-0000000100"
                bridge-identifier bridge-name 100
                exit
            ccm-interval 1
            remote-mepid 101
            exit
        exit
-----------------------------------------------

A:node-1>config>service>vpls# info
-----------------------------------------------
            stp
                shutdown
            exit
            sap 1/1/c2/1:100.100 create
            exit
            sap lag-1:100.100 create
                eth-cfm
                    mep 100 domain 3 association 1
                        ccm-enable
                        mac-address d0:0d:1e:00:01:00
                        no shutdown
                    exit
                exit
            exit
            no shutdown
-----------------------------------------------
```

Example: Top (MC-LAG Standby) configuration (MD-CLI)

```
[ex:/configure port 1/1/c2/1]
A:admin@node-top# info
    ethernet {
        autonegotiate limited
        mode access
        encap-type qinq
    }

[ex:/configure lag "lag-1"]
A:admin@node-top# info
    admin-state enable
    encap-type qinq
    mode access
    hold-time-down 10
    lacp {
        mode active
        administrative-key 32768
    }
    access {
        adapt-qos {
            mode link
        }
    }
    port 1/1/c2/1 {
    }
```

```
[ex:/configure router "Base"]
A:admin@node-top# info
    interface "Core2" {
        port 1/1/c2/1
        ipv4 {
            primary {
                address 192.168.1.2
                prefix-length 30
            }
        }
    }

[ex:/configure redundancy]
A:admin@node-top# info
    synchronize boot-env
    multi-chassis {
        peer 192.168.1.1 {
            admin-state enable
            source-address 192.168.1.2
            mc-lag {
                admin-state enable
            lag "lag-1" {
                    lacp-key 1
                    system-id 00:00:00:00:00:01
                    system-priority 100
                }
            }
        }
    }

[ex:/configure eth-cfm]
A:admin@node-top# info
    domain "3" {
        level 3
        format none
        association "1" {
            icc-based "03-0000000100"
            ccm-interval 1s
            bridge-identifier "100" {
            }
            remote-mep 100 {
            }
        }
    }

[ex:/configure system eth-cfm]
A:admin@node-top# info
    redundancy {
        mc-lag {
            standby-mep true
        }
    }

[ex:/configure service vpls "100"]
A:admin@node-top# info
...
    stp {
        admin-state disable
    }
    sap lag-1:100.100 {
        eth-cfm {
            mep md-admin-name "3" ma-admin-name "1" mep-id 101 {
                mac-address d0:0d:1e:00:01:01
                ccm true
```

```
            }
        }
    }
```

Example: Top (MC-LAG Standby) configuration (classic CLI)

```
A:node-top>config>port# info
----------------------------------------------
        ethernet
            mode access
            encap-type qinq
            autonegotiate limited
        exit
        no shutdown
----------------------------------------------

A:node-top>config>lag# info
----------------------------------------------
        mode access
        encap-type qinq
        access
            adapt-qos link
        exit
        port 1/1/c2/1
        lacp active administrative-key 32768
        no shutdown
----------------------------------------------

A:node-top>config>router# info
#------------------------------------------------
echo "IP Configuration"
#------------------------------------------------
        interface "Core2"
            address 192.168.1.2/30
            port 1/1/c2/1
        exit
        interface "system"
        exit
----------------------------------------------

A:node-top>config>redundancy# info
----------------------------------------------
        multi-chassis
            peer 192.168.1.1 create
                source-address 192.168.1.2
                mc-lag
                    lag 1 lacp-key 1 system-id 00:00:00:00:00:01 system-priority
 100
                    no shutdown
                exit
                no shutdown
            exit
        exit
        synchronize boot-env
----------------------------------------------

A:node-top>config>eth-cfm# info
----------------------------------------------
        domain 3 format none level 3
            association 1 format icc-based name "03-0000000100"
                bridge-identifier bridge-name 100
                exit
                ccm-interval 1
```

```
                remote-mepid 100
            exit
        exit
        redundancy
            mc-lag
                standby-mep-shutdown
            exit
        exit
-----------------------------------------------

A:node-top>config>service>vpls# info
-----------------------------------------------
            stp
                shutdown
            exit
            sap lag-1:100.100 create
                eth-cfm
                    mep 101 domain 3 association 1
                        exit
                        ccm-enable
                        mac-address d0:0d:1e:00:01:01
                        no shutdown
                    exit
                exit
            exit
            no shutdown
-----------------------------------------------
```

Use the following command to display LAG information for the Top (standby) configuration.

```
show lag 1
```

Output example: Top (standby) LAG output

```
===============================================================================
Lag Data
===============================================================================
Lag-id         Adm     Opr     Port-Threshold   Up-Link-Count   MC Act/Stdby
-------------------------------------------------------------------------------
1              up      down    0                0               standby
===============================================================================
```

Use the following command to display port information.

```
show port
```

Output example: Top (standby) port output

```
===============================================================================
Ports on Slot 1
===============================================================================
Port        Admin Link Port    Cfg  Oper LAG/ Port Port Port   C/QS/S/XFP/
Id          State      State   MTU  MTU  Bndl Mode Encp Type   MDIMDX
-------------------------------------------------------------------------------
...
1/1/c2/1       Up    Yes  Link Up 1522 1522    1 accs qinq xcme
...
===============================================================================
```

Example: Bottom (MC-LAG Active) configuration (MD-CLI)

```
[ex:/configure port 1/1/c2/1]
A:admin@node-bottom# info
    ethernet {
        autonegotiate limited
        mode access
        encap-type qinq
    }

[ex:/configure lag "lag-1"]
A:admin@node-bottom# info
    admin-state enable
    encap-type qinq
    mode access
    lacp {
        mode active
        administrative-key 32768
    }
    access {
        adapt-qos {
            mode link
        }
    }
    port 1/1/c2/1 {
    }

[ex:/configure router "Base"]
A:admin@node-bottom# info
    interface "Core1" {
        port 1/1/c2/1
        ipv4 {
            primary {
                address 192.168.1.1
                prefix-length 30
            }
        }
    }

[ex:/configure redundancy]
A:admin@node-bottom# info
    synchronize boot-env
    multi-chassis {
        peer 192.168.1.2 {
            admin-state enable
            source-address 192.168.1.1
            mc-lag {
                admin-state enable
                lag "lag-1" {
                    lacp-key 1
                    system-id 00:00:00:00:00:01
                    system-priority 100
                }
            }
        }
    }

[ex:/configure eth-cfm]
A:admin@node-bottom# info
    domain "3" {
        level 3
        format none
        association "1" {
            icc-based "03-0000000100"
```

```
            ccm-interval 1s
            bridge-identifier "100" {
            }
            remote-mep 100 {
            }
        }
    }



[ex:/configure system eth-cfm]
A:admin@node-bottom# info
    redundancy {
        mc-lag {
            standby-mep true
        }
    }

[ex:/configure service vpls "100"]
A:admin@node-bottom# info
...
    stp {
        admin-state disable
    }
    sap lag-1:100.100 {
        eth-cfm {
            mep md-admin-name "3" ma-admin-name "1" mep-id 101 {
                mac-address d0:0d:1e:00:01:01
                ccm true
            }
        }
    }
```

Example: Bottom (MC-LAG Active) configuration (classic CLI)

```
A:node-bottom>config>port# info
----------------------------------------------
        ethernet
            mode access
            encap-type qinq
            autonegotiate limited
        exit
        no shutdown
----------------------------------------------

A:node-bottom>config>lag# info
----------------------------------------------
        mode access
        encap-type qinq
        access
            adapt-qos link
        exit
        port 1/1/c2/1
        lacp active administrative-key 32768
        no shutdown
----------------------------------------------

A:node-bottom>config>router# info
#------------------------------------------------
echo "IP Configuration"
#------------------------------------------------
        interface "Core1"
            address 192.168.1.1/30
```

```
            port 1/1/c2/1
        exit
        interface "system"
        exit
-----------------------------------------------

A:node-bottom>config>redundancy# info
-----------------------------------------------
        multi-chassis
            peer 192.168.1.2 create
                source-address 192.168.1.1
                mc-lag
                    lag 1 lacp-key 1 system-id 00:00:00:00:00:01 system-priority 100
                    no shutdown
                exit
                no shutdown
            exit
        exit
        synchronize boot-env
-----------------------------------------------

A:node-bottom>config>eth-cfm# info
-----------------------------------------------
        domain 3 format none level 3
            association 1 format icc-based name "03-0000000100"
                bridge-identifier bridge-name "100"
                exit
                ccm-interval 1
                remote-mepid 100
            exit
        exit
        redundancy
            mc-lag
                standby-mep-shutdown
            exit
        exit
-----------------------------------------------

A:node-bottom>config>service>vpls# info
-----------------------------------------------
            stp
                shutdown
            exit
            sap lag-1:100.100 create
                eth-cfm
                    mep 101 domain 3 association 1
                        exit
                        ccm-enable
                        mac-address d0:0d:1e:00:01:01
                        no shutdown
                    exit
                exit
            exit
            no shutdown
-----------------------------------------------
```

Use the following command to display LAG information.

```
show lag 1
```

Output example: Bottom (active) LAG output

```
===============================================================================
Lag Data
===============================================================================
Lag-id         Adm     Opr     Port-Threshold   Up-Link-Count   MC Act/Stdby
-------------------------------------------------------------------------------
1              up      up      0                1               active
===============================================================================
```

Use the following command to display port information.

```
show port
```

Output example: Bottom (active) LAG port output

```
===============================================================================
Ports on Slot 1
===============================================================================
Port        Admin Link Port    Cfg  Oper LAG/ Port Port Port   C/QS/S/XFP/
Id          State      State   MTU  MTU  Bndl Mode Encp Type   MDIMDX
-------------------------------------------------------------------------------
...
1/1/c2/1       Up    Yes  Up      1522 1522    1 accs qinq xcme
...
===============================================================================
```

15.3 Configuring ETH-CFM

Configuring ETH-CFM requires commands at two different CLI hierarchy levels.

The configuration under the **configure eth-cfm** context defines the domains, associations, and the applicable global configurations for each of those contexts, including the linkage to the service using the **bridge-identifier** command. After this configuration is complete, the Management Points (MPs) may be defined referencing the appropriate global context.

As described in the *7705 SAR OAM and Diagnostics Guide*, MEPs can be implemented at the service or the facility level. The following examples describe how the ETH-CFM MPs are configured within the service hierarchy level. However, because of the wide range of features that the ITU-T has defined in recommendation Y.1731 (*Fault Management, Performance Management and Protection Mechanisms*), the features may be applied to other features and hierarchies. For example, Ethernet Ring Protection (G.8032) also uses various ETH-CFM functions.

The following is an example of how domains and associations can be constructed, illustrating how the different services are linked to the contexts.

Example: Construction of domains and associations (MD-CLI)

```
[ex:/configure eth-cfm]
A:admin@node-2# info
    domain "3" {
        level 3
        format none
        association "1" {
            icc-based "03-0000000101"
            bridge-identifier "100" {
```

```
            }
        }
    }
    domain "4" {
        level 4
        format none
        association "1" {
            icc-based "04-0000000102"
            ccm-interval 60s
            bridge-identifier "100" {
            }
            remote-mep 200 {
            }
        }
    }
```

Example: Construction of domains and associations (classic CLI)

```
A:node-2>config>eth-cfm# info
----------------------------------------------
        domain 3 format none level 3
            association 1 format icc-based name "03-0000000101"
                bridge-identifier 100
                exit
            exit
        exit
        domain 4 format none level 4
            association 1 format icc-based name "04-0000000102"
                bridge-identifier 100
                remote-mepid 200
                ccm-interval 60
                exit
            exit
        exit
```

The following configuration examples illustrate how different services use the domain and association configuration. An Epipe and VPLS service are shown in this example.

Note: All of the following examples cannot be configured at the same time because the service ID 100 cannot be used across multiple services.

Example: Configuration of the domain and association in different services (MD-CLI)

```
[ex:/configure service epipe "100"]
A:admin@node-2# info
    admin-state enable
    customer "1"
    sap 1/1/c2/1:100.31 {
        admin-state enable
        eth-cfm {
            mep md-admin-name "3" ma-admin-name "1" mep-id 111 {
                admin-state enable
                direction down
                mac-address d0:0d:1e:00:01:11
            }
        }
    }
    sap 1/1/c10/1:100.31 {
        admin-state enable
        eth-cfm {
            mep md-admin-name "4" ma-admin-name "1" mep-id 101 {
```

```
                admin-state enable
                direction up
                mac-address d0:0d:1e:00:01:01
                ccm true
            }
        }
    }

[ex:/configure service vpls "100"]
A:admin@node-2# info
    admin-state enable
    customer "1"
    sap 1/1/c2/1:100.31 {
        eth-cfm {
            mep md-admin-name "3" ma-admin-name "1" mep-id 111 {
                admin-state enable
                direction down
                mac-address d0:0d:1e:00:01:11
            }
        }
    }
    sap 1/1/c10/1:100.31 {
        eth-cfm {
            mep md-admin-name "4" ma-admin-name "1" mep-id 101 {
                admin-state enable
                direction up
                mac-address d0:0d:1e:00:01:01
                ccm true
            }
        }
    }
```

Example: Configuration of the domain and association in different services (classic CLI)

```
A:node-2# configure service epipe 100 customer 1 create
A:node-2>config>service>epipe# info
----------------------------------------------
            sap 1/1/c2/1:100.31 create
                eth-cfm
                    mep 111 domain 3 association 1 direction down
                        no shutdown
                        mac-address d0:0d:1e:00:01:11
                    exit
                exit
                no shutdown
            exit
            sap 1/1/c10/1:100.31 create
                eth-cfm
                    mep 101 domain 4 association 1 direction up
                        ccm-enable
                        mac-address d0:0d:1e:00:01:01
                        no shutdown
                    exit
                exit
                no shutdown
            exit
            no shutdown
----------------------------------------------
A:node-2# configure service vpls 100 customer 1 create
A:node-2>config>service>vpls# info
----------------------------------------------
            sap 1/1/c2/1:100.31 create
                eth-cfm
```

```
                    mep 111 domain 3 association 1 direction down
                        mac-address d0:0d:1e:00:01:11
                        no shutdown
                    exit
                exit
            exit
            sap 1/1/c10/1:100.31 create
                eth-cfm
                    mep 101 domain 4 association 1 direction up
                        mac-address d0:0d:1e:00:01:01
                        ccm-enable
                        no shutdown
                    exit
                exit
            exit
            no shutdown
-----------------------------------------------
```

16 Configuring NGE with CLI

NGE is fully managed by the NSP NFM-P. The NSP NFM-P ensures correct network synchronization of key groups, services, and NGE domains. Managing NGE without the NSP NFM-P is not recommended. See the *NSP NFM-P User Guide* for more information.

This section provides information about configuring NGE using the command line interface.

16.1 Basic NGE configuration overview

About this task

This procedure configures NGE for an MPLS service or router interface.

Procedure

Step 1. Configure the group encryption label. The label must be unique, and the same label must be used on all nodes in the network group.

Step 2. Create a key group, duplicating this configuration on all nodes participating in this key group.

a. Configure the encryption and authentication algorithms for the group.

b. Configure a security association (SA) that contains the encryption and authentication keys.

c. Configure the active outbound SA for the group.

Step 3. Select the SDPs, VPRN services, or router interfaces that require encryption.

a. For each SDP, VPRN service, or router interface, configure the outbound direction key group.

b. For each SDP, VPRN service, or router interface, configure the inbound direction key group.

16.2 Configuring NGE components

Use the CLI syntax in the subsequent sections to configure NGE.

16.2.1 Configuring the global encryption label

The global encryption label is the network-wide, unique MPLS encryption label used for all nodes in the network group. The same encryption label must be configured on each node in the group.

Use the following command to configure the global encryption label.

```
configure group-encryption group-encryption-label
```

16.2.2 Configuring a key group

To configure a key group, set the following command options:

- encryption and authentication algorithms
- security association
- active outbound SA

The authentication and encapsulation keys must contain the exact number of hexadecimal characters required by the algorithm used. For example, using sha256 requires 64 hexadecimal characters.

Keys are entered in cleartext using the following command:

```
configure group-encryption encryption-keygroup security-association
```

Once entered, keys are never displayed in their original, clear text form. Keys are displayed in an encrypted form, which is indicated by the system-appended **crypto** keyword when an **info** command is run.

The NGE node also includes the **crypto** keyword with an **admin save** operation so that the NGE node can decrypt the keys when reloading a configuration database. For security reasons, keys encrypted on one node are not usable on other nodes (that is, keys are not exchangeable between nodes).

Use the commands in the following context to configure key group options.

```
configure group-encryption encryption-keygroup
```

The following example displays the key group configuration.

Example: MD-CLI

```
[ex:/configure group-encryption]
A:admin@node-2# info detail
    group-encryption-label 34
    encryption-keygroup 2 {
        description "Main_secure_KG"
        keygroup-name "KG1_secure"
        authentication-algorithm sha256
        encryption-algorithm aes128
        active-outbound-security-association 6
        security-association 2 {
            authentication-key "0XLyKVjy88fjyz0FGgpoklHAPB8344vN42vv6LMy5Zy1e08aiZe2CLa
LstrqXQaw" hash2
            encryption-key "bxYkRG2enIPs85zNMSDhX1BzGMaro8TAIFrwcysTRf8= hash2"
        }
        security-association 6 {
            authentication-key "RmzyeCJNICozfGXXQ4jfBQ1zRbW6nf5GcjTuCYSjQCAri1ufVhABj9No
Zqcmtwb8" hash2
            encryption-key "jWYIDREOTd3jeViBBprxGQ4Dixn87UypaM1dNosk7Iw= hash2"
        }
    }
```

Example: classic CLI

```
A:node-2>config>grp-encryp# info detail
----------------------------------------------
        group-encryption-label 34
        encryption-keygroup 2 create
```

```
            description "Main_secure_KG"
            keygroup-name "KG1_secure"
            esp-auth-algorithm sha256
            esp-encryption-algorithm aes128
            security-association spi 2 authentication-
key 0x78d9e66a6669bd17454fe3184 ee161315b67adb8912949ceda20b6b741eb63604abe17de478e2
4723a7d1d5f7b6ffafc encryption-
key 0x8d51db8f826239f672457442cecc73665f52cbe00aedfb4eda6166001247b4eb crypto
            security-association spi 6 authentication-key 0x7fb9fc5553630924ee29973f
7b0a48f801b0ae1cb38b7666045274476a268e8d694ab6aa7ea050b7a43cdf8d80977625 encryption-
key 0x72bd9b87841dbebcb2d114031367ab5d9153a41b7c79c8f889ac56b950d8fffa crypto
            active-outbound-sa 6
        exit
----------------------------------------------
```

16.2.3 Assigning a key group to an SDP, VPRN service, or PW template

A key group can be assigned to the following entities:

- SDPs
- VPRNs
- PW templates

Note: Key groups can only be assigned to SDPs or VPRNs using the classic CLI commands.

NGE supports encrypting the following services when key groups are assigned to an SDP, VPRN service, or PW template:

- VLL services (Epipe or BGP-VPWS)
- VPRN service using Layer 3 spoke-SDP termination
- IES service using Layer 3 spoke-SDP termination
- VPLS service using spoke and mesh SDPs
- routed VPLS service into a VPRN or IES
- MP-BGP-based VPRNs
- BGP-VPLS and BGP-VPWS with an auto-created GRE SDP

For services that use SDPs, all tunnels may be either MPLS LSPs (RSVP-TE, LDP, or static LSP), or GRE or MPLSoUDP tunnels.

For MP-BGP services, resolving routes using spoke SDPs or auto-bind SDPs is supported using LDP, GRE, RSVP-TE, or segment routing (SR-ISIS, SR-OSPF, or SR-TE).

Use the following commands to assign a key group to an SDP, VPRN service, or PW template:

- **MD-CLI**

```
configure service pw-template encryption-keygroup inbound
configure service pw-template encryption-keygroup outbound
configure service vprn subscriber-interface group-interface wlan-gw group-encryption
 encryption-keygroup-inbound
```

- **classic CLI**

```
configure service sdp encryption-keygroup direction {inbound | outbound}
configure service vprn encryption-keygroup direction {inbound | outbound}
configure service pw-template encryption-keygroup direction {inbound | outbound}
```

Note: After assigning a key group to the PW template, execute the following command:

```
tools perform service eval-pw-template allow-service-impact
```

17 Global service entity management tasks

This section describes global service entity management tasks.

17.1 Modifying customer accounts

To access a specific customer account, specify the customer ID.

Use the following command to display a list of customer IDs.

```
show service customer
```

Use the commands in the following context to edit customer information, such as description, contact, or phone number.

```
configure service customer
```

17.2 Deleting customers

Deleting a customer removes a customer ID and all associated information. All service references to the customer must be shut down and deleted before a customer account can be deleted.

Use the following command to delete a customer:

- **MD-CLI**

  ```
  configure service delete customer
  ```

- **classic CLI**

  ```
  configure service no customer
  ```

17.3 Modifying SDPs

To access a specific SDP, specify the SDP ID. Use the following command to display a list of SDPs.

```
show service sdp
```

Modify the SDP command options, such as **description** or **far-end** by entering the information in the following context:

Note: When created, the SDP encapsulation type cannot be modified.

```
configure service sdp
```

17.4 Deleting SDPs

Deleting an SDP removes an SDP ID and all associated information. Before an SDP can be deleted, the SDP must be shut down and removed (unbound) from all customer services where it is applied.

Use the following command to delete an SDP:

- **MD-CLI**

  ```
  configure service delete sdp
  ```

- **classic CLI**

  ```
  configure service no sdp
  ```

18 NGE management tasks

This section describes NGE management tasks.

18.1 Modifying a key group

Note: The following conditions apply for the classic CLI.

When modifying a key group, the user must adhere to the following conditions:

- The encryption or authentication algorithm for a key group cannot be changed if there are any SAs in the key group.
- The active outgoing SA must be removed (deconfigured) before the SPI can be deleted from the SA list in the key group.
- Before the outgoing SA can be deconfigured, the key group must be removed from all services on the node that uses the key group.

The following example displays the modification of a key group using the following steps:

1. In the classic CLI, the active outgoing SA is deconfigured.
2. In the classic CLI, the SAs are removed.
3. The encryption algorithm is changed.
4. The SAs are reconfigured.
5. The active outgoing SA is reconfigured.

Example: MD-CLI

```
*[ex:/configure group-encryption]
A:admin@node-2# encryption-keygroup 1

*[ex:/configure group-encryption encryption-keygroup 1]
A:admin@node-2# encryption-algorithm aes256

*[ex:/configure group-encryption encryption-keygroup 1]
A:admin@node-2# security-association 6 authentication-key
 0x66666666000000006666666600000000666666660000000066666666000000000

*[ex:/configure group-encryption encryption-keygroup 1]
A:admin@node-2# security-association 6 encryption-key
 0x66666666000000006666666600000000666666660000000066666666000000000

*[ex:/configure group-encryption encryption-keygroup 1]
A:admin@node-2# active-outbound-security-association 6
```

Example: classic CLI

```
*A:node-2>config>grp-encryp# encryption-keygroup 1
*A:node-2>config>grp-encryp>encryp-keygrp# no active-outbound-sa
```

```
*A:node-2>config>grp-encryp>encryp-keygrp# no security-association spi 6
*A:node-2>config>grp-encryp>encryp-keygrp# esp-encryption-algorithm aes256
*A:node-2>config>grp-encryp>encryp-keygrp# security-association spi 6 authentication-
key 0x66666666000000006666666600000000666666660000000066666666000000006
 0x66666666000000006666666600000000666666660000000066666666000000006
*A:node-2>config>grp-encryp>encryp-keygrp# active-outbound-sa 6
```

18.2 Removing a key group

Both inbound and outbound direction key groups must be deconfigured before the key group can be removed (unbound). The inbound and outbound key groups must be deconfigured individually. Specifying a *keygroup-id* is optional.

18.2.1 Removing a key group from an SDP, VPRN service, or PW template

Use the following commands to remove a key group from an SDP, VPRN service, or PW template:

Note: Key groups can only be assigned to SDPs or VPRNs using the classic CLI commands.

- **MD-CLI**

```
configure service pw-template delete encryption-keygroup inbound
configure service pw-template delete encryption-keygroup outbound
```

- **classic CLI**

```
configure service sdp no encryption-keygroup direction {inbound | outbound}
configure service vprn no encryption-keygroup direction {inbound | outbound}
configure service pw-template no encryption-keygroup direction {inbound | outbound}
```

Note: After removing a key group to the PW template, the following command must be executed.

```
tools perform service eval-pw-template allow-service-impact
```

18.3 Changing key groups

About this task

To change a key group requires a removal, a change, and an installation of the key group.

Procedure

Step 1. Remove the inbound direction key group.

Step 2. Change the outbound direction key group.

Step 3. Install the new inbound direction key group.

18.3.1 Changing the key group for an SDP, VPRN service, PW template, or WLAN-GW group interface

Changing key groups for an SDP, VPRN service, PW template, or WLAN-GW group interface must be performed on all nodes for the service.

To change the key group on an SDP, VPRN service, PW template, or WLAN-GW group interface, perform the task as described in: Changing key groups.

Note: Key groups can only be changed on SDPs and VPRNs using the classic CLI commands.

Note: For PW template changes, the following command must be executed after the changes are made.

```
tools perform service eval-pw-template allow-service-impact
```

18.4 Deleting a key group from an NGE node

To delete a key group from an NGE node, the key group must be removed (unbound) from all SDPs, VPRN services, PW templates, and router interfaces that use it.

Note: When deleting a key group from a PW template, the following command must be executed after the encryption keygroup changes are made.

```
tools perform service eval-pw-template allow-service-impact
```

Use the following command to locate the key group bindings.

```
show group-encryption encryption-keygroup
```

Use the following command to delete a key group:

- **MD-CLI**

  ```
  configure group-encryption delete encryption-keygroup
  ```

- **classic CLI**

  ```
  configure group-encryption no encryption-keygroup
  ```

19 Standards and protocol support

Note:
The information provided in this chapter is subject to change without notice and may not apply to all platforms.

Nokia assumes no responsibility for inaccuracies.

19.1 Bidirectional Forwarding Detection (BFD)

RFC 5880, *Bidirectional Forwarding Detection (BFD)*

RFC 5881, *Bidirectional Forwarding Detection (BFD) IPv4 and IPv6 (Single Hop)*

RFC 5882, *Generic Application of Bidirectional Forwarding Detection (BFD)*

19.2 Border Gateway Protocol (BGP)

draft-hares-idr-update-attrib-low-bits-fix-01, *Update Attribute Flag Low Bits Clarification*

draft-ietf-idr-add-paths-guidelines-08, *Best Practices for Advertisement of Multiple Paths in IBGP*

draft-ietf-idr-best-external-03, *Advertisement of the best external route in BGP*

draft-ietf-idr-bgp-gr-notification-01, *Notification Message support for BGP Graceful Restart*

draft-ietf-idr-bgp-optimal-route-reflection-10, *BGP Optimal Route Reflection (BGP-ORR)*

draft-ietf-idr-error-handling-03, *Revised Error Handling for BGP UPDATE Messages*

draft-ietf-idr-link-bandwidth-03, *BGP Link Bandwidth Extended Community*

RFC 1772, *Application of the Border Gateway Protocol in the Internet*

RFC 1997, *BGP Communities Attribute*

RFC 2385, *Protection of BGP Sessions via the TCP MD5 Signature Option*

RFC 2439, *BGP Route Flap Damping*

RFC 2545, *Use of BGP-4 Multiprotocol Extensions for IPv6 Inter-Domain Routing*

RFC 2858, *Multiprotocol Extensions for BGP-4*

RFC 2918, *Route Refresh Capability for BGP-4*

RFC 4271, *A Border Gateway Protocol 4 (BGP-4)*

RFC 4360, *BGP Extended Communities Attribute*

RFC 4364, *BGP/MPLS IP Virtual Private Networks (VPNs)*

RFC 4456, *BGP Route Reflection: An Alternative to Full Mesh Internal BGP (IBGP)*

RFC 4486, *Subcodes for BGP Cease Notification Message*

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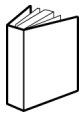

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