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

Release 25.10.R1

Interface Configuration 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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1.1 About this guide

This guide describes system concepts and provides configuration examples to provision Input/Output modules (IOMs), XMA Control Modules (XCMs), also referred to as cards, Media Dependent Adapters (MDAs), XRS Media Adapters (XMAs), and ports.

Note: See the *7450 ESS, 7750 SR, 7950 XRS, and VSR Interface Configuration Advanced Configuration Guide for Classic CLI* for information about advanced configurations.
See the *7450 ESS, 7750 SR, 7950 XRS, and VSR Interface Configuration Advanced Configuration Guide for MD CLI* for information about advanced configurations.

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.

The topics and commands described in this guide apply to the:

- 7450 ESS
- 7750 SR
- 7950 XRS
- Virtualized Service Router (VSR)

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 MD-CLI and the classic CLI.

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

- *7450 ESS, 7750 SR, 7950 XRS, and VSR Classic CLI Command Reference Guide*
- *7450 ESS, 7750 SR, 7950 XRS, and VSR Clear, Monitor, Show, and Tools CLI Command Reference Guide* (for both the MD-CLI and the classic CLI)
- *7450 ESS, 7750 SR, 7950 XRS, and VSR MD-CLI Command Reference Guide*

Note: This guide generically covers Release 25.*x*.R*x* content and may contain some content that will be released in later maintenance loads. For information about features supported in each load of the Release 25.*x*.R*x* software or for a list of unsupported features by platform and chassis, see the *SR OS R25.x.Rx Software Release Notes*, part number 3HE 21562 000*x* TQZZA.

1.2 Conventions

This section describes the general conventions used in this guide.

1.2.1 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.

1.2.2 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.

2 Configuration overview

Note:

- This document uses the term "preprovisioning" in the context of preparing or preconfiguring entities such as chassis slots, cards, Media Dependent Adapters (MDAs), ports, and interfaces, before initialization. These entities can be installed while remaining administratively disabled (shutdown). When the entity is in a no shutdown state (administratively enabled), then the entity is considered to be provisioned.
- For consistency across platforms, XRS Media Adapters (XMAs) and Compact XMAs (C-XMAs) are modeled as MDAs.
- Unless specified otherwise:
  - The term "card" is used generically to refer to both Input Output Modules (IOMs) and XCMs.
  - The term "MDA" is used generically to refer to both MDAs and XMAs.

Nokia routers provide the capability to configure chassis slots to accept specific card and MDA types and set the relevant configurations before the equipment is actually installed. The preprovisioning capability allows you to plan your configurations as well as monitor and manage your router hardware inventory. Ports and interfaces can also be preprovisioned. When the functionality is needed, the cards can be inserted into the appropriate chassis slots when required.

2.1 Chassis slots and card slots

Depending on the chassis type, the relationship between the chassis slot and card slot varies. Chassis slots represent the physical slots in the chassis where modules can be installed. Card slots represent the reference used in management interfaces when provisioning the modules and then using resources of those modules (for example, port references). See the appropriate platform Installation Guide for more information.

To preprovision a card slot, the card type must be specified. Users can enter card type information for each slot. When a card is installed in a slot and enabled, the system verifies that the installed card type matches the provisioned card type. If the command options do not match, the card remains offline. A preprovisioned slot can remain empty without conflicting with populated slots.

The general syntax for the configuration of card slots is similar for all platforms, though the number of available slots varies by platform and chassis model. The supported card-types vary by chassis. See the appropriate platform Installation Guide for more information.

The 7950 XRS platforms accept XCMs in card slots. An XCM has two slots, each of which accept an XMA or C-XMA module. The C-XMA modules require a mechanical adapter to fit in an XMA slot.

Example: 7950 XRS card slot and XCM configuration (MD-CLI)

```
*[ex:/configure]
A:admin@node-2# card 1

*[ex:/configure card 1]
```

```
A:admin@cnode-2# card-type xcm-x20
```

Example: 7950 XRS card slot and XCM configuration (classic CLI)

```
*A:node-2>config# card 1
*A:node-2>config>card# card-type xcm-x20
```

The 7750 SR-2s/7s/14s platforms accept XCMs in card slots. The XCMs of the 7750 SR-2s/7s platforms have a single slot for an XMA or an XIOM module. The XCM of the 7750-14s have two slots for the XMA or XIOM modules.

The 7750 SR-1s platform supports a single XCM in a dedicated card slot. This XCM has a single XMA module. The type of XMA module is fixed based on the variant of 7750 SR-1s chassis. Both the XCM and the XMA must be provisioned.

The 7450 ESS-7/12, and 7750 SR-7/12, and 7750 SR-12e platforms accept either IMMs or IOMs in card slots. IOMs have two slots for pluggable MDAs. The IOM4-e and IOM4-e-B support MDA-e modules. The IOM5-e supports MDA-e-XP modules.

Example: 7450 ESS-7/12 card slot with an IOM configuration (MD-CLI)

```
*[ex:/configure]
A:admin@node-2# card 1

*[ex:/configure card 1]
A:admin@node-2# card-type iom4-e
```

Example: 7450 ESS-7/12 card slot with an IOM configuration (classic CLI)

```
*A:node-2>config# card 1
*A:node-2>config>card# card-type iom4-e
```

IMMs have integrated MDAs. The provisioning requirements depends on the generation of IMM that you use. See the IMM Installation Guide for more information.

The 7750 SR-a platforms support IOM-a cards in dedicated chassis slots. The 7750 SR-a4 supports one physical IOM-a in slot 3. This IOM-a is represented in the CLI as card 1. The 7750 SR-a8 supports two physical IOM-a cards, one in slot 3, the other in slot 6. These IOM-a cards are represented in the CLI as card 1 and card 2 respectively. The IOM-a does not have pluggable MDA slots. Each IOM-a can be configured to support up to four MDA-a or MDA-aXP modules. IOM-a cards are configured in the same manner as IOMs.

The 7750 SR-e platforms support the IOM-e modules in dedicated slots in the rear of each chassis. The 7750 SR-1e supports one physical IOM-e module. This IOM-e is represented in the CLI as card 1. The 7750 SR-2e supports two physical IOM-e cards. These IOM-e cards are represented in the CLI as card 1 and card 2 respectively. The 7750 SR-3e supports three physical IOM-e cards. These IOM-e cards are represented in the CLI as card 1, card 2, and card 3 respectively. The IOM-e does not have pluggable MDA slots. An IOM-e can be configured to support up to four MDA-e modules. IOM-e cards are configured in the same manner as IOMs.

2.2 XIOM modules

XIOM modules are modules that are used in 7750 SR-1s/2s/7s/14s platforms. These can be installed into an XCM instead of installing an XMA module. The XIOMs have two slots that support MDA-s modules (see MDA-a, MDA-aXP, MDA, MDA-e, and MDA-s modules).

The use of an XIOM introduces an additional index into the reference hierarchy. For example, a 7750 SR-14s with an XCM in card slot 1 can have an XMA in the first slot and an XIOM in the second slot.

The following example shows a 7750 SR-14s with an XCM in card with an XMA in the first slot and an XIOM in the second slot.

Example: MD-CLI

```
[ex:/configure card 1]
A:admin@node-2# info
    card-type xcm-14s
    mda 1 {
            mda-type s36-100gb-qsfp28
            level cr1600g
        }
        xiom "x2" {
            level cr1600g+
            xiom-type iom-s-3.0t
            mda 1 {
                mda-type ms2-400gb-qsfpdd+2-100gb-qsfp28
            }
            mda 2 {
                mda-type ms16-100gb-sfpdd+4-100gb-qsfp28
            }
        }
    }
```

Example: classic CLI

```
A:node-2>config>card# info
----------------------------------------------
        card-type xcm-14s
        xiom x2
            xiom-type iom-s-3.0t level cr1600g+
            mda 1
                mda-type ms2-400gb-qsfpdd+2-100gb-qsfp28
                no shutdown
            exit
            mda 2
                mda-type ms16-100gb-sfpdd+4-100gb-qsfp28
                no shutdown
            exit
            no shutdown
        exit
        mda 1
            mda-type s36-100gb-qsfp28 level cr1600g
            no shutdown
        exit
        no shutdown
----------------------------------------------
```

On the 7750 SR-1s/2s/7s/14s, the MDA-s modules are supported when an XIOM is installed into a slot within an XCM. Up to two MDA-s can be installed in an XIOM. MDA-s names in CLI start with the letters "ms" (for example, ms16-100g-sfpdd+4-100g-qsfp28).

2.3 MDA-a, MDA-aXP, MDA, MDA-e, and MDA-s modules

MDAs are pluggable adapter cards that provide physical interface connectivity. MDAs are available in a variety of interface and density configurations. MDA modules differ by chassis. See the individual chassis guide and the individual MDA installation guides for more information about specific MDAs.

On the 7450 ESS-7/12, 7750 SR-7/12, and 7750 SR-12e, MDAs plug into IOMs. (MDA-e modules plug into the IOM4-e and IOM4-e-B, MDA-e-XP modules plug into the IOM5-e). Up to two MDAs can be provisioned on an IOM.

IMMs are designed with fixed integrated media cards, which may require provisioning, depending on the generation of the IMM.

MDA-a and MDA-aXP modules are used in the 7750 SR-a and the MDA-e and ISA2 modules are used in the 7750 SR-e chassis. Up to four MDAs can be provisioned for each IOM.

In all cases, the card slot and IOM or IMM card-type must be provisioned before an MDA can be provisioned. A preprovisioned MDA slot can remain empty without interfering with services on populated equipment. When an MDA is installed and enabled, the system verifies that the MDA type matches the provisioned type. If the command options do not match, the MDA remains offline.

On the 7450 ESS-7/12, 7750 SR-7/12, and 7750 SR-12e platforms, MDA names in the CLI start with the letter 'm' (for example, m10-1gb-xp-sfp).

The following example displays the **card**, **card-type**, **mda**, and **mda-type** command usage in the 7750 SR-12.

Example: 7750 SR-12 configuration (MD-CLI)

```
*[ex:/configure]
A:admin@node-2# card 6

*[ex:/configure card 6]
A:admin@node-2# card-type iom4-e

*[ex:/configure card 6]
A:admin@node-2# mda 1

*[ex:/configure card 6 mda 1]
A:admin@node-2# mda-type me1-100gb-cfp2

*[ex:/configure card 6 mda 1]
A:admin@node-2# admin-state enable

*[ex:/configure card 6 mda 1]
A:admin@node-2# exit

*[ex:/configure card 6]
A:admin@node-2# mda 2

*[ex:/configure card 6 mda 2]
A:admin@node-2# mda-type me10-10gb-sfp+

*[ex:/configure card 6 mda 2]
A:admin@node-2# admin-state enable
```

```
*[ex:/configure card 6 mda 2]
A:admin@node-2# exit

*[ex:/configure card 6]
A:admin@node-2# admin-state enable
```

Example: 7750 SR-12 configuration output (MD-CLI)

```
[ex:/configure]
A:admin@node-2# info
...
 card 6 {
        admin-state enable
        card-type iom4-e
        mda 1 {
            admin-state enable
            mda-type me1-100gb-cfp2
        }
        mda 2 {
            admin-state enable
            mda-type me10-10gb-sfp+
        }
    }
```

Example: 7750 SR-12 configuration (classic CLI)

```
*A:node-2# configure card 6
*A:node-2>config>card# card-type "iom4-e"
*A:node-2>config>card# mda 1
*A:node-2>config>card>mda# mda-type me1-100gb-cfp2
*A:node-2>config>card>mda# no shutdown
*A:node-2>config>card>mda# exit
*A:node-2>config>card# mda 2
*A:node-2>config>card>mda# mda-type "me10-10gb-sfp+"
*A:node-2>config>card>mda# no shutdown
*A:node-2>config>card>mda# exit
*A:node-2>config>card# no shutdown
```

Example: 7750 SR-12 configuration output (classic CLI)

```
A:node-2>config>card# info
----------------------------------------------
        card-type iom4-e
        mda 1
            mda-type me1-100gb-cfp2
            no shutdown
        exit
        mda 2
            mda-type me10-10gb-sfp+
            no shutdown
        exit
        no shutdown
----------------------------------------------
```

The 7750 SR-a4 and 7750 SR-a8 support only MDA-a and MDA-aXP modules, which are identified in the CLI with an "ma" prefix (for example, ma4-10gb-sfp+), or "max" prefix (for example, maxp10-10gb-sfp+). Likewise, the 7750 SR-1e, 7750 SR-2e, and 7750 SR-3e support only MDA-e modules, which are identified in the CLI with an "me" prefix, such as me1-100gb-cfp2.

The following example shows the **card**, **card-type**, **mda**, and **mda-type** command usage in the 7750 SR-1e.

Example: 7750 SR-1e configuration (MD-CLI)

```
*[ex:/configure]
A:admin@node-2# card 1

[ex:/configure card 1]
A:admin@node-2# card-type iom-e

*[ex:/configure card 1]
A:admin@node-2# mda 1

*[ex:/configure card 1 mda 1]
A:admin@node-2# mda-type me10-10gb-sfp+

*[ex:/configure card 1 mda 1]
A:admin@node-2# exit

*[ex:/configure card 1]
A:admin@node-2# mda 4

*[ex:/configure card 1 mda 4]
A:admin@node-2# mda-type me1-100gb-cfp2

*[ex:/configure card 1 mda 4]
A:admin@node-2# exit
```

Example: 7750 SR-1e configuration output (MD-CLI)

```
[ex:/configure]
A:admin@node-2# info
    card 1 {
        card-type iom-e
        mda 1 {
            mda-type me10-10gb-sfp+
        }
        mda 4 {
            mda-type me1-100gb-cfp2
        }
    }
```

Example: 7750 SR-1e configuration (classic CLI)

```
*A:node-2# config# card 1
*A:node-2>config>card# card-type iom-e
*A:node-2>config>card# mda 1
*A:node-2>config>card>mda# mda-type me10-10gb-sfp+
*A:node-2>config>card>mda# exit
*A:node-2config>card# mda 4
*A:node-2>config>card>mda# mda-type me1-100gb-cfp2
*A:node-2config>card>mda# exit
```

Example: 7750 SR-1e configuration output (classic CLI)

```
A:node-2>config>card# info
----------------------------------------------
        card-type iom-e
        mda 1
            mda-type me10-10gb-sfp+
```

```
        exit
        mda 4
            mda-type me1-100gb-cfp2
        exit
    exit
```

2.4 XMAs/C-XMAs

Note: For consistency across platforms, XMAs are modeled in the system as MDAs, and unless specified otherwise, the term MDA is used generically in this document to refer to both MDAs and C-XMA/XMAs. When the term XMA is used, it refers to both XMAs and C-XMAs unless specified otherwise.

XMAs are supported on the 7750 SR-1s/2s/7s/14s and 7950 XRS platforms. XMAs plug into XCMs. XCMs must be provisioned before an XMA can be provisioned with a type.

The XMA information must be configured before ports can be configured. After you configure the XCM, use the following CLI commands to provision XMAs.

A maximum of two XMAs can be configured on an XCM. The following example displays the card slot, card type, MDA slot, and MDA type command usage.

Example: XMA configuration on an XCM (MD-CLI)

```
*[ex:/configure]
A:admin@node-2# card 1

*[ex:/configure card 1]
A:admin@node-2# card-type xcm-x20

*[ex:/configure card 1]
A:admin@node-2# mda 1

*[ex:/configure card 1 mda 1]
A:admin@node-2# mda-type x2-100g-tun

*[ex:/configure card 1 mda 1]
A:admin@node-2# power-priority-level 130

*[ex:/configure card 1 mda 1]
A:admin@node-2# exit

*[ex:/configure card 1]
A:admin@node-2# mda 2

*[ex:/configure card 1]
A:admin@node-2# mda-type x40-10g-sfp

*[ex:/configure card 1 mda 2]
A:admin@node-2# power-priority-level 135

*[ex:/configure card 1 mda 2]
A:admin@node-2# exit
```

Example: XMA configuration output (MD-CLI)

```
[ex:/configure]
A:admin@node-2# info
```

```
    card 1 {
        card-type xcm-x20
        mda 1 {
            mda-type x2-100g-tun
            power-priority-level 130
        }
        mda 2 {
            mda-type x40-10g-sfp
            power-priority-level 135
        }
    }
```

Example: XMA configuration on an XCM (classic CLI)

```
*A:node-2>config# card 1
*A:node-2>config>card# card-type xcm-x20
*A:node-2>config>card# mda 1
*A:node-2>config>card>mda# mda-type x2-100g-tun
*A:node-2>config>card>mda# power-priority-level 130
*A:node-2>config>card>mda# exit
*A:node-2>config>card# mda 2
*A:node-2>config>card>mda# mda-type x40-10g-sfp
*A:node-2>config>card>mda# power-priority-level 135
*A:node-2>config>card>mda# exit
```

Example: XMA configuration output (classic CLI)

```
A:node-2>config>card# info
----------------------------------------------
        card-type xcm-x20
        mda 1
            power-priority-level 130
            mda-type  x2-100g-tun
            no shutdown
        exit
        mda 2
            power-priority-level 135
            mda-type x40-10g-sfp
            no shutdown
        exit
        no shutdown
----------------------------------------------
```

On the 7950 XRS, the **show card state** output displays an "x" in the name of the XMA and "cx" in the name of a C-XMA. Use the following command to display the XMA and C-XMA information.

```
show card state
```

Output example

```
===============================================================================
Card State
===============================================================================
Slot/  Provisioned Type                  Admin Operational   Num   Num Comments
Id         Equipped Type (if different)  State State         Ports MDA
-------------------------------------------------------------------------------
1      xcm-x20                           up    up                 2
A      cpm2-x20                          up    up                    Active
B      cpm2-x20                          up    down                  Standby
===============================================================================
```

2.5 Hardware licensing

With the introduction of pay-as-you-grow licensing, level-based hardware assemblies (for example, FP4 and FP5 IOMs and XMAs) now include variants with license levels. These levels define the capacity and functionality of the assembly. The capacity controls aspects such as the number and types of connectors and breakout options that can be configured, as well as the total connector bandwidth. Licensing also controls the number of user (based on configuration) hardware egress queues and egress policers that are available per forwarding plane. For a more complete description of the levels available for a particular assembly, see the associated installation guide.

The license level must be provisioned for the assembly at the same time as the card type or MDA type is provisioned. Each assembly has a set of levels applicable to that particular IOM or XMA that are defined using mnemonic strings. For example, an assembly may have a level 'cr1200g' which refers to a functional level of 'core routing' and a capacity maximum bandwidth of 1.2 Tb/s. A second example of a license level is 'he2400g+', which refers to a functional level of 'high scale edge routing' and a capacity level of a bandwidth of 2.4 Tb/s but with Intelligent Aggregation (formerly known as Fan In/Out) to a higher bandwidth.

When an assembly is installed in the chassis, the license level encoded into the equipped assembly must match the value provisioned for the assembly. If they do not match, the assembly cannot become active in the chassis. The only exception is that a variant of the assembly with the maximum functional and capacity level is allowed to come up in a slot provisioned as any level; the restrictions in effect are at the provisioned level, but this allows this specific assembly to be used to replace any other level of that assembly if necessary.

The following example shows the provisioning of an XCM with two XMAs. The first XMA is a two complex, 2.4T 24-connector QSFP28 XMA with a license level of er2400g (edge routing, 2.4 Tb/s) and the second XMA is a two complex, 2.4T 6-connector CFP8 XMA with a license level of he1600g (high scale edge routing, 4 connector 1.2Tbps):

Example: XCM configuration with two XMAs (MD-CLI)

```
*[ex:/configure]
A:admin@node-2# card 4

*[ex:/configure card 4]
A:admin@node-2# card-type xcm-x20

*[ex:/configure card 4]
A:admin@node-2# mda 1

*[ex:/configure card 4 mda 1]
A:admin@node-2# mda-type x24-100g-qsfp28

*[ex:/configure card 4 mda 1]
A:admin@node-2# level er2400g

*[ex:/configure card 4 mda 1]
A:admin@node-2# exit

*[ex:/configure card 4]
A:admin@node-2# mda 2

*[ex:/configure card 4 mda 2]
A:admin@node-2# mda-type x6-400g-cfp8

*[ex:/configure card 4 mda 2]
```

```
A:admin@node-2# level he1600g
```

Example: XCM configuration with two XMAs (classic CLI)

```
*A:node-2# configure card 4 card-type "xcm2-x20"
*A:node-2# configure card 4 mda 1 mda-type "x24-100g-qsfp28" level "er2400g"
*A:node-2# configure card 4 mda 2 mda-type "x6-400g-cfp8" level "he1600g"
```

Use the following command to display the configuration information.

```
show mda
```

Output example

```
===============================================================================
MDA Summary
===============================================================================
Slot  Mda   Provisioned Type                          Admin     Operational
               Equipped Type (if different)           State     State
-------------------------------------------------------------------------------
4     1     x24-100g-qsfp28:er2400g                   up        up
      2     x6-400g-cfp8:he1600g                      up        up
===============================================================================
```

The **show card** and **show mda** output display both the type and level of the assembly and indicates when there is a difference between the provisioned and installed levels. In the following example, the first XMA has a provisioned value matching the installed assembly and the second XMA has a difference in the provisioned and installed assembly. Use the following command to show detailed XMA information.

```
show mda 4/1 detail
```

Output example

```
===============================================================================
MDA 4/1 detail
===============================================================================
Slot  Mda   Provisioned Type                          Admin     Operational
               Equipped Type (if different)           State     State
-------------------------------------------------------------------------------
4     1     x24-100g-qsfp28:er2400g                   up        up
MDA Licensing Data
    Licensed Level               : er2400g
    Description                  : 2.4T, 24c, Edge Routing
```

Use the following command to show detailed XMA information.

```
show mda 4/2 detail
```

Output example

```
===============================================================================
MDA 4/2 detail
===============================================================================
Slot  Mda   Provisioned Type                          Admin     Operational
               Equipped Type (if different)           State     State
-------------------------------------------------------------------------------
4     2     x6-400g-cfp8:he2400g                      up        provisioned
```

```
            x6-400g-cfp8:he1600g
MDA Licensing Data
    Licensed Level               : he1600g
    Description                  : 1.6T, 4c, High Scale Edge Routing
```

Use the following command to view the connector and bandwidth constraints of a card or MDA.

```
show licensing 1/1
```

Output example

```
===============================================================================
Connector           MAC  Licensed  Restrictions
-------------------------------------------------------------------------------
1/1/c1              1    Yes       None
1/1/c2              1    Yes       None
1/1/c3              1    Yes       None
1/1/c4              1    Yes       None
1/1/c5              1    No        No Breakout Allowed
1/1/c6              1    No        No Breakout Allowed
1/1/c7              2    Yes       None
1/1/c8              2    Yes       None
1/1/c9              2    Yes       None
1/1/c10             2    Yes       None
1/1/c11             2    No        No Breakout Allowed
1/1/c12             2    No        No Breakout Allowed
1/1/c13             3    Yes       None
...
```

Use the following command to display the number of hardware egress user queues and egress user policers (total, allocated, and free), which are dependent on the operational license level of the card, XIOM, or MDA containing the FP.

```
tools dump resource-usage card 1 fp 1
```

Output example

```
===============================================================================
Resource Usage Information for Card Slot #1 FP #1
===============================================================================
                                                    Total  Allocated       Free
-------------------------------------------------------------------------------
...
                         Egress User Queues |     131072        384     130688
...
                        Egress User Policers |     393215          0     393215
...
===============================================================================
```

The **tools dump resource-usage card fp** command also displays the number of hardware egress queues available on the related FP that is dependent on the configured allocation of the percentage of ingress queues.

2.6 Software license activation

The pay-as-you-grow licensing of the 7750 SR hardware platforms includes the ability to distribute software based licenses to operational systems in a live network. This is done by the creation of a license key file containing various individual licenses, making this file available to a system, and then activating that license key file on the system. Nokia provides the Configuration License Manager (CLM) tool to assist in this process. Normally, the CLM would perform all the steps in license distribution to a target system and only the assignment of individual licenses within a system itself need to be managed using the management mechanism for the system itself.

The license key file is a secure distribution mechanism for the licenses. Within the license key file, are one or more license keys. Each license key is assigned for a particular target system identified using a UUID. This UUID is tied to the chassis of the system and therefore the license key can only be validated on the system with that chassis. Each license key is also tied to a specific major software release of SR OS.

When a license key file is available to a target system and is activated it is first validated to ensure it is applicable for the specified target. For the license key of the SR OS hardware platform to be valid, the user must ensure that the:

- license is for a 7xxx platform
- UUID of the system matches the one encoded in the "UUID-locked" license key
- SR OS software version (the major release number) matches the one encoded in the license key
- license file is not expired

Validation or activation of the license key file results in zero or one license key that is valid for the running software on the target. If there is a valid license key, the records contained in that key are read and made available to the system (see Software license records).

There may be additional license keys in the file that are for the target system but for a different software release. This is the case when an upgrade of the system is planned. Those license keys shall be considered available however, the feature licenses contained within them are not available for use. Use the following command to see the feature licenses.

```
show system license available-licenses
```

Output example

```
===============================================================================
Available Licenses
===============================================================================
License name   : sr-regress@list.nokia.com
License uuid   : ab516e50-2413-44aa-9f7c-34b4e5b64d19
Machine uuid   : ab516e50-2413-44aa-9f7c-34b4e5b64d19
License desc   : 7xxx Platform
License prod   : 7xxx Platform
License sros   : TiMOS-[BC]-16.0.*
Current date   : FRI NOV 03 15:53:54 UTC 2017
Issue   date   : FRI SEP 22 20:55:14 UTC 2017
Start   date   : FRI SEP 15 00:00:00 UTC 2017
End     date   : THU MAR 15 00:00:00 UTC 2018
-------------------------------------------------------------------------------
License name   : sr-regress@list.nokia.com
License uuid   : ab516e50-2413-44aa-9f7c-34b4e5b64d19
Machine uuid   : ab516e50-2413-44aa-9f7c-34b4e5b64d19
License desc   : 7xxx Platform
```

```
License prod   : 7xxx Platform
License sros   : TiMOS-[BC]-17.0.*
Current date   : FRI NOV 03 15:53:54 UTC 2017
Issue   date   : FRI SEP 22 20:55:14 UTC 2017
Start   date   : FRI SEP 15 00:00:00 UTC 2017
End     date   : THU MAR 15 00:00:00 UTC 2018
-------------------------------------------------------------------------------
2 license(s) available.
===============================================================================
```

On a system boot, the license key file pointed to by the BOF is activated. If new license key files are activated on a system, the BOF should be updated to point to the new license key file. If there are active licenses in system that are in use and the node reboots and the license key file pointed to by the BOF either fails to validate or does not contain the in-use license records, the system is considered to be in unlicensed state. In this state, the node reboots every 60 minutes until the records are no longer in-use or a valid license key is provided that includes all the in use license records.

2.7 Software license records

The activate license key shall unlock a set of license records for use within the system. In Release 16.0, only Hardware Upgrade license records are distributed in the license keys. These can be used to upgrade the hardware capacity or the hardware functional level of a card or an XMA. These upgrades define a starting level and an upgraded level for the target assembly. Multiple instances of the same upgrade can be assigned to a system in the license key. Use the following command to check the list of license records, the number in use, and the number available.

```
show licensing entitlements
```

Output example

```
===============================================================================
License                              Available      In-Use       State
-------------------------------------------------------------------------------
...
MDA Upgrades
  cr1200g-cr1600g                          1           1        VALID
  cr1200g-er1200g                          1           0        VALID
  cr1600g-cr2400g                          1           0        VALID
  cr1600g-er1600g                          2           0        VALID
  cr2400g-er2400g                          1           0        VALID
  er1200g-er1600g                          4           2        VALID
  er1200g-he1200g                          1           0        VALID
  er1600g-er2400g                          1           0        VALID
  er1600g-he1600g                          1           0        VALID
  er2400g-he2400g                          1           0        VALID
  he1200g-he1600g                          1           0        VALID
  he1600g-he2400g                          1           0        VALID
===============================================================================
```

An upgrade can be assigned to a particular card or XMA using the **upgrade** command within the **configure card** or **configure card mda** context. Multiple upgrades can be assigned to the same card or XMA if needed to gradually augment the base card. In the following example, four upgrades have been applied in sequence to the base level of cr1600g to bring the XMA from CR to ER then ER to HE then to increase capacity first from 1600 Gb/s to 2400 Gb/s and then from 2400 Gb/s to 2400 Gb/s with aggregation to 3600 Gb/s.

Use the following command to show the upgraded configuration.

```
show mda 1/1 detail
```

Output example

```
===============================================================================
MDA 1/1 detail
===============================================================================
Slot  Mda   Provisioned Type                          Admin     Operational
              Equipped Type (if different)           State     State
-------------------------------------------------------------------------------
1     1     s36-100gb-qsfp28:cr1600g                 up        provisioned
              (not equipped)

MDA Licensing Data
    Licensed Level               : he2400g+
    Description                  : 2.4T /w agg to 3.6T, 36p, High Scale Edge
                                   Routing
    Upgrade 1                    : cr1600g-er1600g
    Upgrade 2                    : er1600g-he1600g
    Upgrade 3                    : he1600g-he2400g
    Upgrade 4                    : any2400g-2400g+
```

2.8 Oversubscribed Ethernet MDAs and Intelligent Aggregation

The 7750 SR and 7450 ESS support oversubscribed Ethernet MDAs. These have more bandwidth toward the user than the capacity between the MDA and IOM. This concept has continued with the MDA, IOM, XMA, XIOM, and MDA-s of the FP4 and FP5 generations, where it applies on assemblies labeled as using "Intelligent Aggregation".

A traffic management function is implemented on the MDA to control the data entering the IOM. This function consists of two parts:

- rate limiting
- packet classification and scheduling

2.8.1 Rate limiting

The oversubscribed MDA limits the rate at which traffic can enter the MDA on a per-port basis. If a port exceeds its configured limits then the excess traffic is discarded, and 802.3x flow control frames (pause frames) are generated.

2.8.2 Packet classification and scheduling

The classification and scheduling function implemented on the oversubscribed MDA, including assemblies using Intelligent Aggregation, ensures that traffic is correctly prioritized when the bus from the MDA to the IOM is overcommitted. This could occur if the policing command options configured are such that the sum of the traffic being admitted into the MDA is greater than the capacity between the MDA and the IOM.

The classification function uses the bits set in the DSCP or Dot1p fields of the customer packets to perform classification. It can also identify locally addressed traffic arriving on network ports as Network Control packets. This classification on the oversubscribed MDA uses the following rules:

- If the service QoS policy for the SAP (port or VLAN) uses the default classification policy, all traffic is classified as Best Effort (be).
- If the service QoS policy for the SAP contains a Dot1p classification, the Dot1p field in the customer packets is used for classification on the MDA.
- If the service QoS policy for the SAP contains a DSCP classification, the DSCP field in the customer packets is used for classification on the MDA.
- If a mix of Dot1p and DSCP classification definitions are present in the service QoS policy, then the field used to perform classification is the type used for the highest priority definition. For example, if High Priority 1 is the highest priority definition and it specifies that the DSCP field should be used, then the DSCP field is used for classification on the MDA and the Dot1p field is ignored.
- If the service QoS policy for the SAP specifies IP or MAC filters for forwarding class identification, then traffic is treated as Best Effort. Full MAC or IP classification is not possible on the MDA (but is possible on the IOM).
- The packet is classified into 16 classes. Typically, these are the eight forwarding classes and each packet is assigned one priority per forwarding class. After classification, the packet is offered to the queuing model. This queuing model is limited to three queues each having four thresholds. These thresholds define whether an incoming packet, after classification, is accepted in the queue or not. Table 1: Typical mapping of classes onto queues/threshold shows typical mapping of classes onto queues and thresholds.

Table 1: Typical mapping of classes onto queues/threshold

Counter	{Queue	Threshold	Traffic class}
0	{2	3	"fc-nc / in-profile"}
1	{2	2	"fc-nc / out-profile"}
2	{2	1	"fc-h1 / in-profile"}
3	{2	0	"fc-h1 / out-profile"}
4	{1	3	"fc-ef / in-profile"}
5	{1	2	"fc-ef / out-profile"}
6	{1	1	"fc-h2 / in-profile"}
7	{1	0	"fc-h2 / out-profile"}
8	{0	3	"fc-l1 / in-profile"}
9	{0	3	"fc-l1 / out-profile"}
10	{0	2	"fc-af / in-profile"}
11	{0	2	"fc-af / out-profile"}

Counter	{Queue	Threshold	Traffic class}
12	{0	1	"fc-l2 / in-profile"}
13	{0	1	"fc-l2 / out-profile"}
14	{0	0	"fc-be / in-profile"}
15	{0	0	"fc-be / out-profile"}

A counter is associated with each mapping. The above is an example and is dependent on the type of classification (such as dscp-exp, dot1p, and so on). When the threshold of a particular class is reached, packets belonging to that class are not accepted in the queue. The packets are dropped and the associated counter is incremented.

The scheduling of the three queues is done in a strict priority, highest priority basis is associated with queue 2. This means that scheduling is done at queue level, not on the class that resulted from the classification. As soon as a packet has been accepted by the queue there is no way to differentiate it from other packets in the same queue (for example, another classification result not exceeding its threshold). All packets queued in the same queue, have the same priority from a scheduling point of view.

2.9 FlexE interfaces

The Flex Ethernet (FlexE) implementation agreement from the Optical Integration Forum (OIF) supports the bonding of individual Ethernet interfaces into one large-capacity Ethernet interface. This is performed at the physical coding sublayer (PCS) and makes the full bandwidth of the bonded physical interfaces available for Ethernet traffic. For example, a FlexE group of four 400GE physical interfaces creates a single interface with the full 1.6 Tb/s bandwidth available to the router.

FlexE has an advantage over the use of LAG, because the LAG hashing algorithm can result in underutilized bandwidth. Some configurations of LAG result in the use of only 80 percent of the bandwidth available from the physical links.

The OIF-FlexE implementation agreement contains the following main parts:

- **bonding**

  This is the ability to group individual physical Ethernet ports together as a deployment alternative to LAG .

- **sub-rating**

  This is the ability to match a client or service to a lower-speed wavelength-division multiplexing (WDM) line without the use of a service definition.

- **channelization**

  This is a way of aggregating lower-rate interfaces onto a single higher-speed interface via the introduction of a TDM-like shim layer.

The SR OS FlexE implementation supports bonding but does not support sub-rating or channelization.

To understand how FlexE bonding works, consider a 400GBASE-LR8 interface, as defined in the IEEE 802.3. This interface uses 8 electrical lanes, each running at 26.5625 GBd and using PAM4 encoding. The 400 Gb/s Ethernet bitstream is spread across those 8 lanes. With FlexE bonding, one can consider this concept being extended to support the distribution of 800GE, 1200GE or even 1600GE bitstreams across the 16, 24, or 32 lanes of two, three or four 400GBASE-LR8 interfaces.

The FlexE implementation within SR OS is limited to the bonding of one, two, three, or four 400GE interfaces into one group. At that point, one single FlexE client consumes the entire bandwidth of the group. The 400GE interfaces must all reside on the same half of the E5 MAC chip. The relationship of the port to the E5 chip half is provided with a distinguisher in the **MAC Chip Num** column in the **show datapath** command. Both 400GE QSFP56-DD and the 400GE ports of a c2-400g-flex breakout QSFP112-DD transceiver are supported. The 400GE ZR DCO interfaces are allowed in a FlexE group but must be configured as c1-400g-flex breakout; other modes of operation are not supported. Multiple FlexE clients within one group are not supported.

Note: Hardware-specific bandwidth restrictions between components on the line cards may limit the achievable throughput for the FlexE group. See the specific hardware installation guide for information about these restrictions.

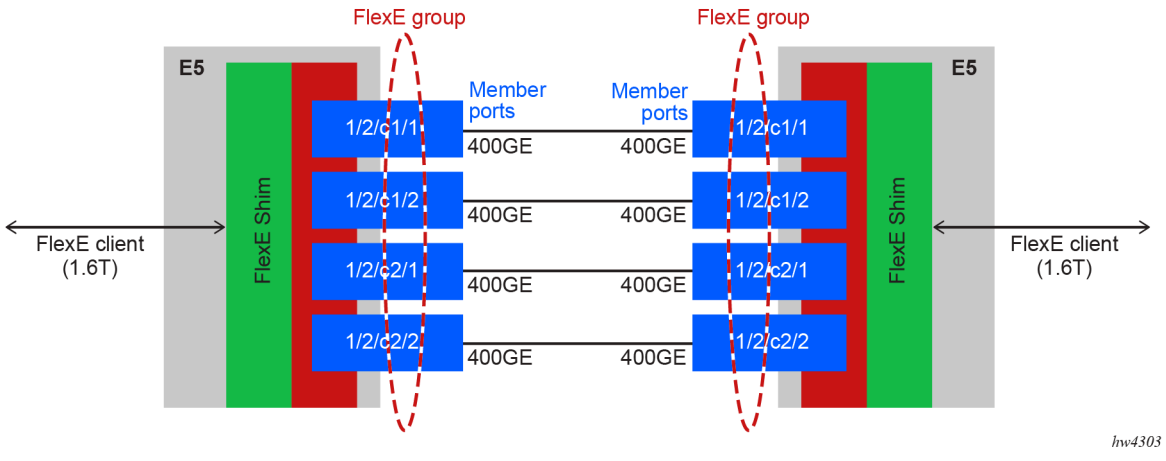
One important consideration with the use of FlexE groups with multiple 400GE PHYs is that the delays of the individual 400GE signals need to be kept within a tight range. The deskew buffer depth used on FP5-based MACs is 2400 nanoseconds. Recommendations to help ensure the difference in delays between the 400GE signals are the following:

- It is required to use the same part numbers for the transceivers for the FlexE member ports. Some modern transceivers have DSP in the data path and delays may differ depending on the vendor.
- For DCO transceivers, the compatibility mode must be the same across the ports.
- For DCO transceivers, the frequencies (channels) of the media signals should be adjacent. Frequencies travel at different speeds through fiber; the most extreme difference in frequencies can introduce a difference of 500 nanoseconds over 2000 km.
- The lengths of the fibers transporting the member signals should be equal.
- If using Optical Network transport, all member signal wavelengths must transit the same fiber.

In addition, intermediate OTN switching can introduce further skew and should be investigated to ensure the end-to-end deskew budget can be met.

The following figure shows a FlexE group between two SR OS systems that use four 400GE interfaces.

Figure 1: FlexE group between two SR OS systems using four 400GE interfaces



3 Digital Diagnostics Monitoring

Some Nokia SFPs, XFPs, QSFPs, CFPs and the MSA DWDM transponder have the Digital Diagnostics Monitoring (DDM) capability where the transceiver module maintains information about its working status in device registers including:

- temperature
- supply voltage
- transmit (TX) bias current
- TX output power
- received (RX) optical power

For QSFPs and CFPs, DDM Temperature and Supply voltage is available only at the Module level as shown in Table 3: DDM alarms and warnings.

See the Statistics collection section for details about the QSFP and CFP example DDM and DDM Lane information.

For the QSFPs and CFPs, the number of lanes is indicated by DDM attribute "Number of Lanes: 4".

Subsequently, each lane threshold and measured values are shown per lane.

If a lane entry is not supported by the specific QSFP or CFP specific model, then it is shown as "-" in the entry.

Use the following command to show QSFP and CFP lane information.

```
show port port-id detail
```

Output example

```
...
Transceiver Data
Transceiver Type   : QSFP+
Model Number       : 3HE06485AAAA01  ALU  IPUIBMY3AA
TX Laser Wavelength: 1310 nm                    Diag Capable     : yes
Number of Lanes    : 4
Connector Code     : LC                         Vendor OUI       : e4:25:e9
Manufacture date   : 2012/02/02                 Media            : Ethernet
Serial Number      : 12050188
Part Number        : DF40GELR411102A
Optical Compliance : 40GBASE-LR4
Link Length support: 10km for SMF
===============================================================================
Transceiver Digital Diagnostic Monitoring (DDM)
===============================================================================
                            Value High Alarm  High Warn   Low Warn  Low Alarm
-------------------------------------------------------------------------------
Temperature (C)              +35.6     +75.0      +70.0       +0.0       -5.0
Supply Voltage (V)            3.23      3.60       3.50       3.10       3.00
===============================================================================
===============================================================================
Transceiver Lane Digital Diagnostic Monitoring (DDM)
===============================================================================
                                High Alarm   High Warn    Low Warn   Low Alarm
```

```
Lane Tx Bias Current (mA)              78.0        75.0        25.0        20.0
Lane Rx Optical Pwr (avg dBm)          2.30        2.00      -11.02      -13.01
-------------------------------------------------------------------------------
Lane ID Temp(C)/Alm       Tx Bias(mA)/Alm   Tx Pwr(dBm)/Alm   Rx Pwr(dBm)/Alm
-------------------------------------------------------------------------------
    1              -              43.5                 -              0.42
    2              -              46.7                 -             -0.38
    3              -              37.3                 -              0.55
    4              -              42.0                 -             -0.52
===============================================================================


Transceiver Type   : CFP
Model Number       : 3HE04821ABAA01  ALU  IPUIBHJDAA
TX Laser Wavelength: 1294 nm                    Diag Capable     : yes
Number of Lanes    : 4
Connector Code     : LC                         Vendor OUI       : 00:90:65
Manufacture date   : 2011/02/11                 Media            : Ethernet
Serial Number      : C22CQYR
Part Number        : FTLC1181RDNL-A5
Optical Compliance : 100GBASE-LR4
Link Length support: 10km for SMF
===============================================================================
Transceiver Digital Diagnostic Monitoring (DDM)
===============================================================================
                             Value High Alarm  High Warn   Low Warn  Low Alarm
-------------------------------------------------------------------------------
Temperature (C)             +48.2     +70.0      +68.0       +2.0       +0.0
Supply Voltage (V)           3.24      3.46       3.43       3.17       3.13
===============================================================================
===============================================================================
Transceiver Lane Digital Diagnostic Monitoring (DDM)
===============================================================================
                                High Alarm   High Warn    Low Warn   Low Alarm
-------------------------------------------------------------------------------
Lane Temperature (C)                +55.0       +53.0       +27.0       +25.0
Lane Tx Bias Current (mA)           120.0       115.0        35.0        30.0
Lane Tx Output Power (dBm)           4.50        4.00       -3.80       -4.30
Lane Rx Optical Pwr (avg dBm)        4.50        4.00      -13.00      -16.00
-------------------------------------------------------------------------------
Lane ID Temp(C)/Alm       Tx Bias(mA)/Alm   Tx Pwr(dBm)/Alm   Rx Pwr(dBm)/Alm
-------------------------------------------------------------------------------
    1          +47.6              59.2              0.30            -10.67
    2          +43.1              64.2              0.27            -10.31
    3          +47.7              56.2              0.38            -10.58
    4          +51.1              60.1              0.46            -10.37
===============================================================================
```

The transceiver is programmed with warning and alarm thresholds for low and high conditions that can generate system events. These thresholds are programmed by the transceiver manufacturer.

There are no CLI commands required for DDM operations, however, the **show port** *port-id* **detail** command displays DDM information in the Transceiver Digital Diagnostics Monitoring output section.

DDM information is populated into the router's MIBs, so the DDM data can be retrieved by Network Management using SNMP. Also, RMON threshold monitoring can be configured for the DDM MIB variables to set custom event thresholds if the factory-programmed thresholds are not at the wanted levels.

The following are potential uses of the DDM data:

- **optics degradation monitoring**

With the information returned by the DDM-capable optics module, degradation in optical performance can be monitored and trigger events based on custom or the factory-programmed warning and alarm thresholds.

- **link or router fault isolation**

  With the information returned by the DDM-capable optics module, any optical problem affecting a port can be quickly identified or eliminated as the potential problem source.

Supported real-time DDM features are summarized in the following table.

Table 2: Real-time DDM information

Fields	User units	SFP/XFP units	SFP	XFP	MSA DWDM
Temperature	Celsius	C	✓	✓	✓
Supply Voltage	Volts	µV	✓	✓	
TX Bias Current	mA	µA	✓	✓	✓
TX Output Power	dBm (converted from mW)	mW	✓	✓	✓
RX Received Optical Power4	dBm (converted from dBm) (Avg Rx Power or OMA)	mW	✓	✓	✓
AUX1	option dependent (embedded in transceiver)			✓	
AUX2	option dependent (embedded in transceiver)			✓	

The factory-programmed DDM alarms and warnings that are supported are summarized in the following table.

Table 3: DDM alarms and warnings

Alarms and Warnings	SFP/XFP units	SFP	XFP	Required?	MSA DWDM
Temperature - High Alarm - Low Alarm - High Warning - Low Warning	C	Yes	Yes	Yes	Yes
Supply Voltage - High Alarm	µV	Yes	Yes	Yes	No

Alarms and Warnings	SFP/XFP units	SFP	XFP	Required?	MSA DWDM
- Low Alarm - High Warning - Low Warning					
TX Bias Current - High Alarm - Low Alarm - High Warning - Low Warning	µA	Yes	Yes	Yes	Yes
TX Output Power - High Alarm - Low Alarm - High Warning - Low Warning	mW	Yes	Yes	Yes	Yes
RX Optical Power - High Alarm - Low Alarm - High Warning - Low Warning	mW	Yes	Yes	Yes	Yes
AUX1 - High Alarm - Low Alarm - High Warning - Low Warning	option dependent (embedded in transceiver)	No	Yes	Yes	No
AUX2 - High Alarm - Low Alarm - High Warning - Low Warning	option dependent (embedded in transceiver)	No	Yes	Yes	No

3.1 SFPs and XFPs

The availability of the DDM real-time information and the warning and alarm status is based on the transceiver. It may or may not indicate that DDM is supported. Although some Nokia SFPs support DDM,

Nokia has not required DDM support in releases before Release 6.0. Non-DDM and DDM-supported SFPs are distinguished by a specific value in their EEPROM.

For SFPs that do not indicate DDM support in their EEPROM, DDM data is available although the accuracy of the information has not been validated or verified.

For non-Nokia transceivers, DDM information may be displayed, but Nokia is not responsible for formatting, accuracy, and so on.

3.2 Statistics collection

The DDM information and warnings and alarms are collected at one-minute intervals. As such, the minimum resolution for any DDM events when correlating with other system events is one minute.

In the Transceiver Digital Diagnostic Monitoring section of the **show port** *port-id* **detail** command output:

- If the present measured value is higher than either or both of the High Alarm and High Warn thresholds, an exclamation mark (!) displays along with the threshold value.
- If the present measured value is lower than either or both of the Low Alarm and Low Warn thresholds, an exclamation mark (!) displays along with the threshold value.

Use the following command to show Transceiver Digital Diagnostic Monitoring information.

```
show port 2/1/6 detail
```

Output example

```
...
===============================================================================
Transceiver Digital Diagnostic Monitoring (DDM)
===============================================================================
                             Value High Alarm  High Warn   Low Warn  Low Alarm
-------------------------------------------------------------------------------
Temperature (C)              +33.0     +98.0      +88.0      -43.0      -45.0
Supply Voltage (V)            3.31      4.12       3.60       3.00       2.80
===============================================================================

===============================================================================
Transceiver Lane Digital Diagnostic Monitoring (DDM)
===============================================================================
                                High Alarm   High Warn    Low Warn   Low Alarm
-------------------------------------------------------------------------------
...
Lane Tx Bias Current (mA)          60.0         50.0          0.1       10.0
Lane Tx Output Power (dBm)         0.00        -2.00       -10.50     -12.50
Lane Rx Optical Pwr (avg dBm)     -3.00!       -4.00       -19.51     -20.51

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

4 Ports

4.1 Port types

Before a port can be configured, the slot must be provisioned with a card type and MDA type.

Nokia routers support the following port types:

- **Ethernet**

  Supported Ethernet port types include:

  – Fast Ethernet (10/100BASE-T)
  – Gb Ethernet (1GbE, 1000BASE-T)
  – 10 Gb Ethernet (10GbE, 10GBASE-X)
  – 40 Gb Ethernet (40GbE)
  – 100 Gb Ethernet (100GbE)
  – 25 Gb Ethernet (25GBASE-R)
  – 50 Gb Ethernet (50GBASE-R)
  – 400 Gb Ethernet (400GBASE-R)
  – 800 Gb Ethernet (800GBASE-R)

  Router ports must be configured as either access, hybrid, or network. The default is network.

- **access**

  Access ports are configured for customer facing traffic on which services are configured. If a Service Access Port (SAP) is to be configured on the port or channel, it must be configured as an access port or channel. When a port is configured for access mode, the appropriate encapsulation type must be configured to distinguish the services on the port or channel. After a port has been configured for access mode, one or more services can be configured on the port or channel depending on the encapsulation value.

- **network**

  Network ports are configured for network-facing traffic. These ports participate in the service provider transport or infrastructure network. Dot1q is supported on network ports.

- **GNSS receiver**

  Some 7750 SR FP5 platforms are equipped with an integrated Global Navigation Satellite System (GNSS) receiver and GNSS radio frequency (RF) port for retrieval and recovery of GPS and Galileo signals.

  Note: Signal recovery must always be enabled in the system configuration when using the GNSS receiver.

  See the *7450 ESS, 7750 SR, 7950 XRS, and VSR Basic System Configuration Guide* for information about using a GNSS receiver as a timing source for the node.

- **hybrid**

  Hybrid ports are configured for access and network-facing traffic. While the default mode of an Ethernet port remains network, the mode of a port cannot be changed between the access, network, and hybrid values unless the port is shut down and the configured SAPs or interfaces are deleted. Hybrid ports allow a single port to operate in both access and network modes. The MTU of a port in hybrid mode is the same as in network mode, except for the 10/100 MDA. The default encapsulation for hybrid port mode is dot1q; it also supports QinQ encapsulation on the port level. Null hybrid port mode is not supported. After the port is changed to hybrid, the default MTU of the port is changed to match the value of 9212 bytes currently used in network mode (higher than an access port). This is to ensure that both SAP and network VLANs can be accommodated. The only exception is when the port is a 10/100 Fast Ethernet. In those cases, the MTU in hybrid mode is set to 1522 bytes, which corresponds to the default access MTU with QinQ, which is larger than the network dot1q MTU or access dot1q MTU for this type of Ethernet port. The configuration of all command options in **access** and **network** contexts continues to be done within the port using the same CLI hierarchy as in existing implementation. The difference is that a port configured in mode hybrid allows both ingress and egress contexts to be configured concurrently. An Ethernet port configured in hybrid mode can have two values of encapsulation type: dot1q and QinQ. The NULL value is not supported because a single SAP is allowed, and can be achieved by configuring the port in the access mode, or a single network IP interface is allowed, which can be achieved by configuring the port in network mode. Hybrid mode can be enabled on a LAG port when the port is part of a single chassis LAG configuration. When the port is part of a multichassis LAG configuration, it can only be configured to access mode because MC-LAG is not supported on a network port and consequently is not supported on a hybrid port. The same restriction applies to a port that is part of an MC-Ring configuration.

  For a hybrid port, use the following commands to split the amount of allocated port buffers in each ingress and egress equally between network and access contexts:

  – **MD-CLI**

    ```
    configure port hybrid-buffer-allocation ingress-weight access network
    configure port hybrid-buffer-allocation egress-weight access network
    ```

  – **classic CLI**

    ```
    configure port hybrid-buffer-allocation ing-weight access network
    configure port hybrid-buffer-allocation egr-weight access network
    ```

  Adapting the terminology in buffer-pools, the port’s access active bandwidth and network active bandwidth in each ingress and egress are derived as follows (egress formulas shown only):

  – total-hybrid-port-egress-weights = access-weight + network-weight

  – hybrid-port-access-egress-factor = access-weight / total-hybrid-port-egress-weights

  – hybrid-port-network-egress-factor = network-weight / total-hybrid-port-egress-weights

  – port-access-active-egress-bandwidth = port-active-egress-bandwidth x

  – hybrid-port-access-egress-factor

  – port-network-active-egress-bandwidth = port-active-egress-bandwidth x

  – hybrid-port-network-egress-factor

- **WAN PHY**

10 G Ethernet ports can be configured in WAN PHY mode. Use commands in the following context to configure 10 G Ethernet ports in WAN PHY mode.

```
configure port ethernet xgig
```

- **Link Aggregation (LAG)**

  LAG can be used to group multiple ports into one logical link. The aggregation of multiple physical links allows for load sharing and offers seamless redundancy. If one of the links fails, traffic is redistributed over the remaining links.

- **Optical Transport Network (OTN)**

  Including OTU2, OTU2e, OTU3, and OTU4. OTU2 encapsulates 10-Gigabit Ethernet WAN and adds FEC (Forward Error Correction). OTU2e encapsulates 10-Gigabit Ethernet LAN and adds FEC (Forward Error Correction). OTU4 encapsulates 100-Gigabit Ethernet and adds FEC.

- **connector**

  A QSFP28 (or QSFP-DD) connector that can accept transceiver modules including breakout connectors to multiple physical ports. For example, a QSFP28 connector can support ten 10 Gb Ethernet ports. The connectors themselves cannot be used as ports in other commands, however, the breakout ports can be used as any Ethernet port.

4.2 Port features

4.2.1 Port State and Operational State

There are two port attributes that are related and similar but have slightly different meanings: Port State and Operational State (or Operational Status).

The following descriptions are based on normal individual ports. Many of the same concepts apply to other objects that are modeled as ports in the router such as APS groups but the show output descriptions for these objects should be consulted for the details.

- **Port State**
  - Displayed in port summaries such as **show port** or **show port 1/1**
  - tmnxPortState in the TIMETRA-PORT-MIB
  - Values: None, Ghost, Down (linkDown), Link Up, Up
- **Operational State**
  - Displayed in the show output of a specific port such as **show port 2/1/3**
  - tmnxPortOperStatus in the TIMETRA-PORT-MIB
  - Values: Up (inService), Down (outOfService)

The behavior of Port State and Operational State are different for a port with link protocols configured (Eth OAM, Eth CFM or LACP for Ethernet ports, LCP for PPP/POS ports). A port with link protocols configured only transitions to the Up Port State when the physical link is up and all the configured protocols are up. A port with no link protocols configured transitions from Down to Link Up and then to Up immediately after the physical link layer is up.

The linkDown and linkUp log events (events 2004 and 2005 in the SNMP application group) are associated with transitions of the port Operational State. Note that these events map to the RFC 2863, *The Interfaces Group MIB*, (which obsoletes RFC 2233, *The Interfaces Group MIB using SMIv2*) linkDown and linkUp traps as mentioned in the SNMPv2-MIB.

An Operational State of Up indicates that the port is ready to transmit service traffic (the port is physically up and any configured link protocols are up). The relationship between port Operational State and Port State is shown in Table 4: Relationship of Port state and Oper state.

Table 4: Relationship of Port state and Oper state

Port state	**Operational state (Oper state or Oper status) (as displayed in "show port x/y/z")**	
Port State (as displayed in the **show port** summary)	For ports that have no link layer protocols configured	For ports that have link layer protocols configured (PPP, LACP, 802.3ah EFM, 802.1ag Eth-CFM)
Up	Up	Up
Link Up (indicates the physical link is ready)	Up	Down
Down	Down	Down

4.2.2 802.1x network access control

Nokia routers support network access control of client devices (PCs, STBs, and so on) on an Ethernet network using the IEEE. 802.1x standard. 802.1x is known as Extensible Authentication Protocol (EAP) over a LAN network or EAPOL.

4.2.2.1 802.1x modes

Nokia routers support port-based network access control for Ethernet ports only. Every Ethernet port can be configured to operate in one of three different operation modes, controlled by the **port-control** command:

- **force authorized**

  This mode disables 802.1x authentication and causes the port to transition to the authorized state without requiring any authentication exchange. The port transmits and receives normal traffic without requiring 802.1x-based host authentication. This is the default setting.

- **force unauthorized**

  This mode causes the port to remain in the unauthorized state, ignoring all attempts by the hosts to authenticate. The switch cannot provide authentication services to the host through the interface.

- **auto**

  This mode enables 802.1x authentication. The port starts in the unauthorized state, allowing only EAPOL frames to be sent and received through the port. Both the router and the host can initiate an authentication procedure as described below. The port remains in unauthorized state (no traffic except

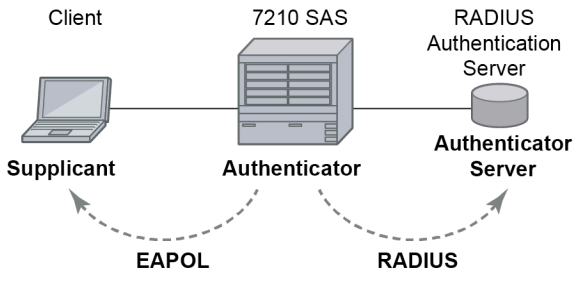
EAPOL frames is allowed) until the first client is authenticated successfully. After this, traffic is allowed on the port for all connected hosts.

4.2.2.2 802.1x basics

The IEEE 802.1x standard defines three participants in an authentication conversation (see Figure 2: 802.1x architecture that shows an example with the 7450 ESS).

the supplicant	the end-user device that requests access to the network
the authenticator	controls access to the network. Both the supplicant and the authenticator are referred to as Port Authentication Entities (PAEs).
the authentication server	performs the actual processing of the user information

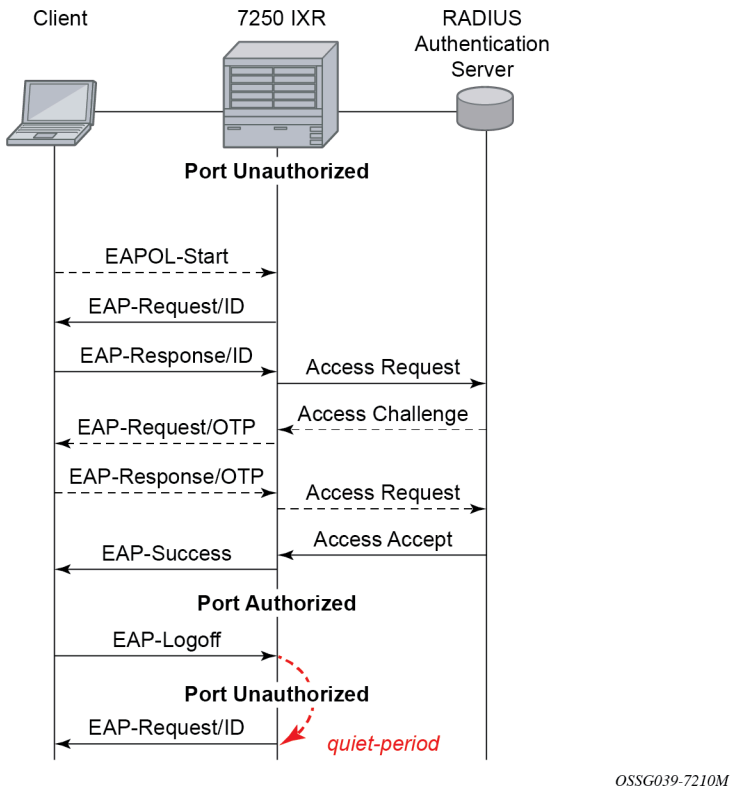
Figure 2: 802.1x architecture



The authentication exchange is carried out between the supplicant and the authentication server, the authenticator acts only as a bridge. The communication between the supplicant and the authenticator is done through the Extended Authentication Protocol (EAP) over LANs (EAPOL). On the back end, the communication between the authenticator and the authentication server is done with the RADIUS protocol. The authenticator is therefore a RADIUS client, and the authentication server a RADIUS server.

The messages involved in the authentication procedure are shown in Figure 3: 802.1x authentication scenario. The router initiates the procedure when the Ethernet port becomes operationally up, by sending a special PDU called EAP-Request/ID to the client. The client can also initiate the exchange by sending an EAPOL-start PDU, if it does not receive the EAP-Request/ID frame during bootup. The client responds on the EAP-Request/ID with a EAP-Response/ID frame, containing its identity (typically username + password).

Figure 3: 802.1x authentication scenario



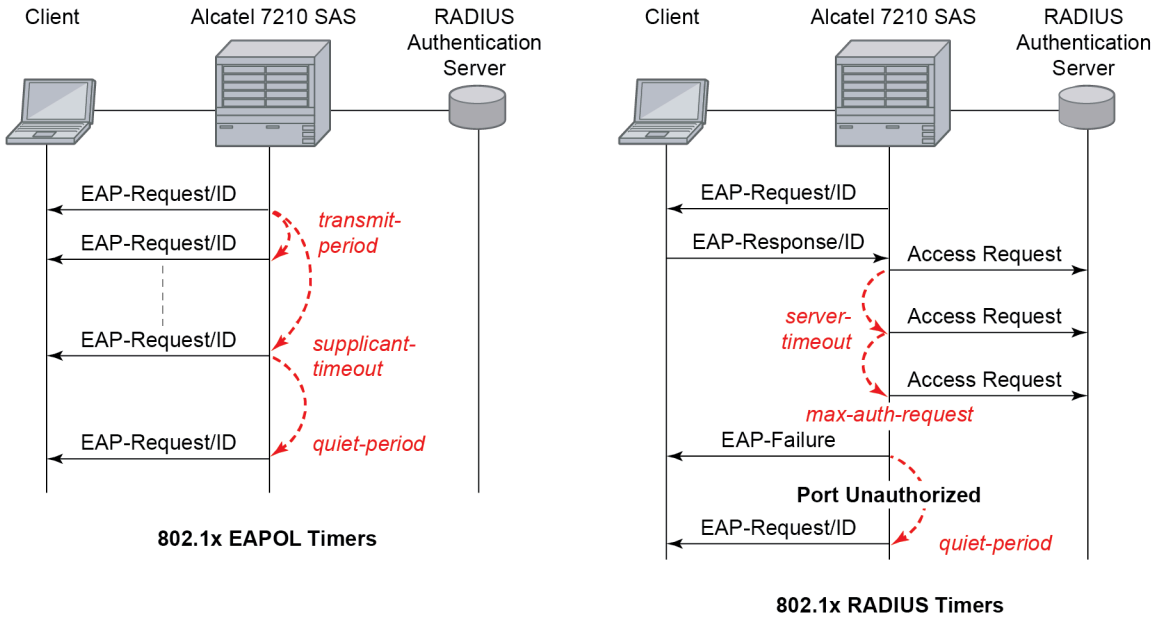
After receiving the EAP-Response/ID frame, the router encapsulates the identity information into a RADIUS AccessRequest packet, and sends it off to the configured RADIUS server.

The RADIUS server checks the supplied credentials, and if approved returns an Access Accept message to the router. The router notifies the client with an EAP-Success PDU and puts the port in authorized state.

4.2.2.3 802.1x timers

The 802.1x authentication procedure is controlled by a number of configurable timers and scalars. There are two separate sets, one for the EAPOL message exchange and one for the RADIUS message exchange. See Figure 4: 802.1x EAPOL timers (left) and RADIUS timers (right) for an example of the timers on the 7750 SR.

Figure 4: 802.1x EAPOL timers (left) and RADIUS timers (right)



EAPOL timers:

- **transmit-period**

  This timer indicates how many seconds the Authenticator listens for an EAP-Response/ID frame. If the timer expires, a new EAP-Request/ID frame is sent and the timer restarted. The default value is 60. The range is 1 to 3600 seconds.

- **supplicant-timeout**

  This timer is started at the beginning of a new authentication procedure (transmission of first EAP-Request/ID frame). If the timer expires before an EAP-Response/ID frame is received, the 802.1x authentication session is considered as having failed. The default value is 30. The range is 1 to 300.

- **quiet-period**

  This timer indicates number of seconds between authentication sessions. It is started after logout, after sending an EAP-Failure message or after expiry of the supplicant-timeout timer. The default value is 60. The range is 1 to 3600.

RADIUS timer and scalar:

- **maximum authentication requests**

  This scalar indicates the maximum number of times that the router sends an authentication request to the RADIUS server before the procedure is considered as having failed. The default value is value 2. The range is 1 to 10.

- **server timeout**

  This timer indicates how many seconds the authenticator waits for a RADIUS response message. If the timer expires, the access request message is sent again, up to maximum authentication request times. The default value is 60. The range is 1 to 3600 seconds.

The router can also be configured to periodically trigger the authentication procedure automatically. This is controlled by enabling re-authentication and re-authentication period. Re-authentication period indicates the period in seconds (since the last time that the authorization state was confirmed) before a new authentication procedure is started. The range of reauth-period is 1 to 9000 seconds (the default is 3600 seconds, one hour). Note that the port stays in an authorized state during the re-authentication procedure.

4.2.2.4 802.1x tunneling

Tunneling of untagged 802.1x frames received on a port is supported for both Epipe and VPLS service using either null or default SAPs (for example 1/1/1:*) when the following command is configured:

- **MD-CLI**

```
configure port ethernet dot1x port-control force-authorized
```

- **classic CLI**

```
configure port ethernet dot1x port-control force-auth
```

When tunneling is enabled on a port, untagged 802.1x frames are treated like user frames and are switched into Epipe or VPLS services which have a corresponding null SAP or default SAP on that port. In the case of a default SAP, it is possible that other non-default SAPs are also present on the port. Untagged 802.1x frames received on other service types, or on network ports, are dropped. Use the following command to enable tunneling on a port.

```
configure port port-id ethernet dot1x tunneling
```

When tunneling is required, it is expected that it is enabled on all ports into which 802.1x frames are to be received. The configuration of dot1x must be configured consistently across all ports in LAG as this is not enforced by the system.

Note that 802.1x frames are treated like user frames, that is, tunneled, by default when received on a spoke or mesh SDP.

4.2.2.5 Per-host authentication

Per-host authentication enables SR OS to authenticate each host individually and allows or disallows the PDUs from this host through the port. Per-host authentication is configurable using the CLI.

When dot1x tunneling is disabled, the port does not allow any PDUs to pass through, with the exception of dot1x packets, which are extracted.

When **per-host-authentication** is configured on the port for dot1x, each host is authenticated individually according to the RADIUS policy and host traffic is allowed or disallowed through the port. After the first successful host authentication, the behavior is the following:

- On downstream (that is, traffic from the network to the host), the port is authorized and allows all traffic to go through.
- On upstream (that is, traffic from the host to the network), the port is authorized, but allows through traffic from the authenticated hosts only. When the host is allowed through the port, all PDUs for that host are allowed to pass through the port, including untagged or tagged packets. The traffic from any unauthenticated host is disallowed.

For per-host authentication, EAPOL packets are sent to the RADIUS server using the RADIUS protocol. The calling station identifier is the source MAC address of the host and is usually present in the packet. The identifier is used to allow or disallow the host source MAC address based on the RADIUS success or failure answer.

The hosts are authenticated periodically. If a host is authenticated and placed on the allow list and a subsequent authentication fails, that host is removed from the allow list.

If a host authenticates unsuccessfully multiple times, that host is put on a disallow list for a specific amount of time. That is, enabling per-host authentication provides per-host (source MAC) DoS mitigation.

Duplicate MAC addresses are not allowed on the port.

All logs display per-host authentication.

4.2.2.5.1 Per-host authentication interaction with dot1x

When per-host authentication is first enabled, all MAC addresses on the port are denied. The user can allow MAC addresses using the static source MAC or dot1x host authentication. The following considerations apply when dot1x authentication is used.

- If the 802.1x authentication mode is configured as force authorized, any host that sends EAPOL frames is authenticated without requiring any exchange with the RADIUS server. Use the following command to configure force authorized:
  - **MD-CLI**

    ```
    configure port ethernet dot1x port-control force-authorized
    ```

  - **classic CLI**

    ```
    configure port ethernet dot1x port-control force-auth
    ```

- If **configure system security dot1x** is administratively disabled, the port behavior is the same as in the force authorized case:
  - **MD-CLI**

    ```
    configure port ethernet dot1x admin-state disable
    ```

  - **classic CLI**

    ```
    configure port ethernet dot1x shutdown
    ```

- If the 802.1x authentication mode is configured as **auto**, the hosts are authenticated using RADIUS. However, if **configure system security dot1x** is administratively disabled, the force authorized behavior takes effect.

4.2.2.5.2 Static allow source MAC

A host can be added to the Allow MAC list statically, without being authenticated using dot1x. In this case, the host source MAC address must be added manually using the CLI.

If the same host is added to the list using dot1x and the CLI, the static configuration takes precedence. If the host is added using the CLI, the host is placed on the Allow list. If the same host tries to authenticate

using RADIUS and the authentication fails, the host is still allowed through the port because it was statically added using the following command.

```
configure port ethernet dot1x per-host-authentication allowed-source-macs mac-address
```

4.2.2.5.3 Tagged dot1x authentication

Dot1x packets can arrive tagged or untagged on the authenticator port from the host. SR OS can be configured to tunnel or extract tagged dot1x packets. SR OS forwards tagged dot1x packets only.

The tunneling or extracting of tagged dot1x packets can be enabled for dot1q (**tunnel-dot1q**) and QinQ (**tunnel-qinq**) encapsulation types.

Each of the encapsulation types configured on the port can be configured to tunnel dot1x packets or extract dot1x packets to be authenticated using a configured RADIUS policy.

The extraction or tunneling of tagged packets applies to any tag value.

4.2.2.5.4 Dot1x and LAG

For dot1x authentication support, when the primary port member of the LAG is configured with dot1x, all members inherit the dot1x functionality. Dot1x packets can be extracted on any LAG member and sent to the RADIUS server for processing and authentication. After a successful authentication, the host is allowed on all LAG members. The host dot1x packets can be extracted on one LAG member, while the actual traffic traverses another LAG member. The following is the behavior of dot1x in a LAG bundle.

- When ports are added to the LAG member and dot1x is enabled, all ports inherit the same dot1x configuration as the primary port on the LAG member.
- If a host source address (SA) is authenticated through one of the LAG member ports, all ports on the LAG bundle are authorized and pass traffic.
- When a new port is added to the LAG member, if the LAG bundle has been authenticated and is authorized, the new member is authorized as well.
- Dot1x configuration changes are allowed on the primary LAG member only. A port can be added to a LAG only if its dot1x configuration aligns with that of the primary LAG member. If at least one LAG member is authorized, all LAG members are authorized.

  In an upgrade scenario, when an older configuration file (**admin save**) is executed on a new release, a warning is displayed instead of an error for a command that violates the dot1x configuration change behavior; the violating command is ignored.
- If a port is removed from the LAG bundle, the port becomes unauthorized and the EAP negotiation should authorize the port again. This is true for all ports in the LAG bundle, primary or not.
- When Random Early Discard (RED) updates are received during an ISSU on a LAG member in standby, the following updates are ignored:
  - enable dot1x on a LAG member
  - authorize a LAG member

  When a port is added to a LAG during ISSU, its dot1x configuration is reset to the default values.

4.2.2.5.5 SR host authentication behavior

SR allows the same MAC source address (MAC SA) on different ports if the MAC address is authenticated. Multiple hosts with the same MAC address can reside and get authenticated on different ports.

4.2.2.5.6 Authentication lists

The following authentication lists are supported:

- **authenticated host list**

  This list contains up to 1000 hosts. Only hosts that have been authenticated through RADIUS and are allowed through the port are included in this list.

- **unauthenticated host list**

  This list contains up to 2000 hosts. Only hosts that have failed authentication or are in the process of being authenticated are included in this list.

  If this list reaches the 2000-host limit and a new host is being authenticated, the new host bumps off the list the first host that has failed authentication. The following sequence shows an example:

Example

```
Unauthenticated list
Host 1 authenticating
Host 2 failed authentication
….
Host 2000 authenticating
Host 2001 just arrived, this host should bump Host 2 off in the list, not Host 1.
If all hosts are in authenticating state, the new Host 2001 is not allowed on the list.
```

4.2.2.6 802.1x configuration and limitations

Configuration of 802.1x network access control on the router consists of two parts:

- generic command options, which are configured under **configure system security dot1x**
- port-specific command options, which are configured under **configure port ethernet dot1x**

The following considerations apply:

- If per-host authentication is not configured, the authentication of any host on the port provides access to the port for any device, even if only a single client has been authenticated.
- 802.1x authentication can only be used to gain access to a pre-defined Service Access Point (SAP). It is not possible to dynamically select a service (such as a VPLS service) depending on the 802.1x authentication information.
- If 802.1x access control is enabled and a high rate of 802.1x frames are received on a port, that port is blocked for a period of 5 minutes as a DoS protection mechanism.

4.2.2.6.1 Disabling the 802.1x functionality on a port

By default, the 802.1x functionality consisting of packet extraction and processing on the CPM is enabled on each port.

Use the following command to administratively disable the 802.1x functionality on a port by not extracting the dot1x packets to the CPM.

- **MD-CLI**

```
configure port ethernet dot1x admin-state disable
```

- **classic CLI**

```
configure port ethernet dot1x shutdown
```

4.2.3 MACsec

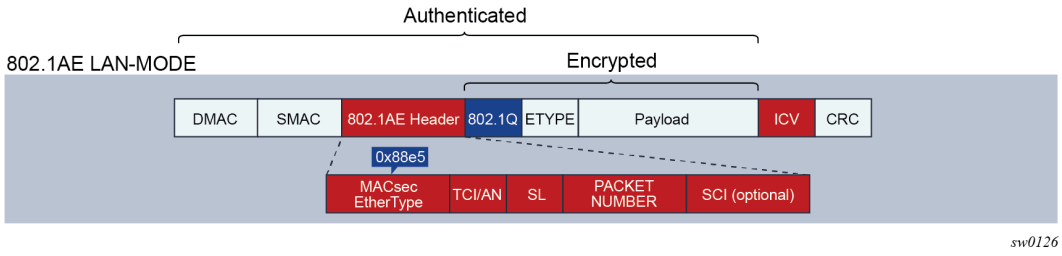
Media Access Control Security (MACsec) is an industry standard security technology that provides secure communication for almost all types of traffic on Ethernet links. MACsec provides point-to-point and point-to-multipoint security on Ethernet links between directly connected nodes or nodes connected via a Layer 2 cloud. MACsec can identify and prevent most security threats, including:

- denial of service
- intrusion
- man-in-the-middle
- masquerading
- passive wiretapping
- playback attacks

MACsec Layer 2 encryption is standardized in IEEE 802.1AE. MACsec encrypts anything from the 802.1AE header to the end of the payload, including 802.1Q; it leaves the DMAC and SMAC in clear text.

The following figure shows the 802.1AE LAN-Mode structure.

Figure 5: 802.1 AE LAN-MODE



The destination MAC address, which is in clear text, is used for MACsec packet forwarding.

4.2.3.1 MACsec 802.1AE header — security TAG

The MACsec 802.1AE header includes a security TAG (SecTAG) field that contains the following information:

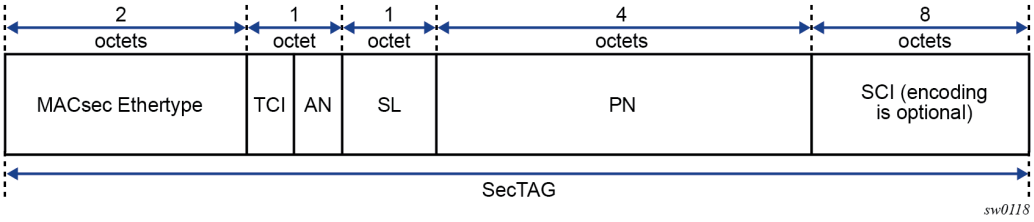
- association number within the channel
- packet number to provide a unique initialization vector for encryption and authentication algorithms, as well as protection against replay attack
- optional LAN-wide secure channel identifier

The SecTAG field, which is identified by the MACsec EtherType, conveys the following information:

- TAG Control Information (TCI)
- Association Number (AN)
- Short Length (SL)
- Packet Number (PN)
- Optionally-encoded Secure Channel Identifier (SCI)

The following figure shows the format of the SecTAG.

Figure 6: SecTAG format



4.2.3.2 MACsec encryption mode

The main modes of encryption in MACsec are:

- VLAN in clear text (WAN Mode)
- VLAN encrypted

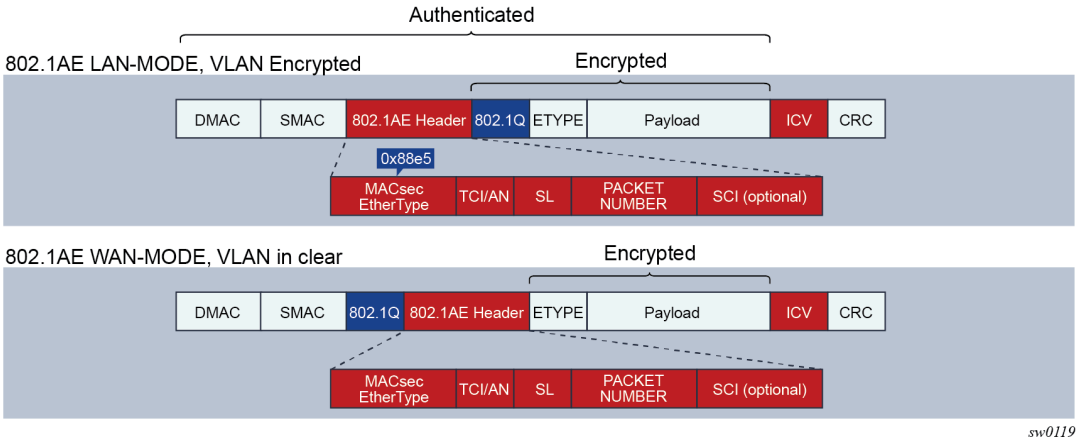
802.1AE dictates that the 802.1Q VLAN must be encrypted. Some vendors provide the option of configuring the MACsec on a port with VLAN in clear text.

SR OS supports both modes.

On the 7750 SR and 7450 ESS, 1/10 Gig cards support both mode of operation.

The following figure shows the encrypted VLAN and the VLAN in clear text.

Figure 7: 802.1 AE LAN and WAN modes and VLAN encrypted and clear



4.2.3.2.1 MACsec encryption per traffic flow encapsulation matching

In Release 16.0 and later, MACsec can be applied to a selected subset of the port traffic, based on the type and value of the packet encapsulation. The SR OS can be configured to match and encrypt the following traffic encapsulation types:

- all encap traffic arriving on port including untagged, single-tag, and double-tag. This is the default behavior of MACsec and the only option supported in releases before 16.0.
- untagged only traffic
- single-tag or dot1q traffic. In this mode, MACsec can apply to a specific tag or wild card tag where all single-tag traffic is matched.
- double-tag or QinQ traffic. In this mode, MACsec can apply to a specific service tag, a specific service and customer tag, or a wild card for any QinQ traffic.

MKA PDUs are generated specifically for the traffic encapsulation type that is being matched.

4.2.3.3 MACsec key management modes

The following table describes the main key management modes in MACsec.

Table 5: MACsec key management modes

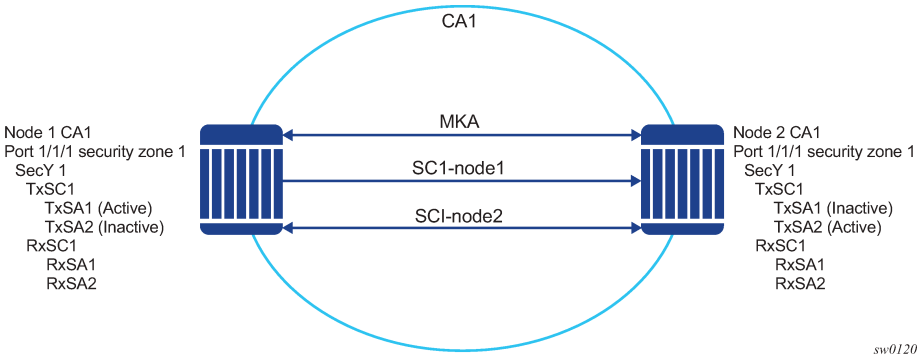
Keying	Explanation	SR OS support	Where used
Static SAK	Manually configures each node with a static SAK, SAM, or CLI		Switch to switch
Static CAK PRE SHARED KEY	Uses a dynamic MACsec Key Management (MKA) and a configured pre-shared key to drive the CAK. The CAK encrypts the SAK between two peers and authenticates the peers.	✓	Switch to switch

Keying	Explanation	SR OS support	Where used
Dynamic CAK EAP Authentication	Uses a dynamic MKA and an EAP Master System Key (MSK) to drive the CAK. The CAK encrypts the SAK between two peers and authenticates the peers.		Switch to switch
Dynamic CAK MSK distribution via RADIUS and EAP-TLS	Stores the MSKs in the Radius server and distributes to the hosts via EAP-TLS. This is typically used in the access networks where a large number of hosts use MACsec and connect to an access switch. MKA uses MSK to drive the CAK. The CAK encrypts the SAK between 2 peers and authenticates the peers.		Host to switch

4.2.3.4 MACsec terminology

The following figure shows some of the main concepts used in MACsec for the static-CAK scenario.

Figure 8: MACsec concepts for static-CAK



The following table describes MACsec terminology.

Table 6: MACsec terminology

MACsec term	Description
CA: Connectivity Association	Provides a security relationship, established and maintained by key agreement protocols (MKA), that comprises a fully connected subset of the SAPs in stations attached to a single LAN that are to be supported by MACsec.
MKA: MACsec Key Agreement Protocol	Provides a control protocol between MACsec peers, which is used for peer aliveness and encryption key distribution. MACsec Key Agreement is responsible for discovering, authenticating, and authorizing the potential participants in a CA.

MACsec term	Description
SecY: MAC Security Entity	Operates the MAC security protocol within a system. Manages and identifies the SC and corresponding active SA.
SC: Security Channel	Provides a unidirectional point-to-point or point-to-multipoint communication. Each SC contains a succession of SAs, and each SC has a different SAK.
SA: Security Association	In the cases of SR OS with two SAs per SC, each with a different SAK, each SC comprises a succession of SAs. Each SA is identified by the SC identifier, concatenated with a two-bit association number. The Secure Association Identifier (SAI) that is created allows the receiving SecY to identify the SA and the SAK used to decrypt and authenticate the received frame. The AN, and consequently the SAI, is only unique for the SAs that can be used or recorded by participating SecYs at any time. The MACsec Key Agreement creates and distributes SAKs to each of the Sec Ys in a CA. This key creation and distribution is independent of the cryptographic operation of each of the SecYs. The decision to replace one SA with its successor is made by the SecY that transmits using the SC, after the MKA has informed it that all the other SecYs are prepared to receive using that SA. No notification, other than receipt of a secured frame with a different SAI is sent to the receiver. A SecY must always be capable of storing SAKs for two SAs for each inbound SC, and of swapping from one SA to another without notice. Certain LAN technologies can reorder frames of different priority, so reception of frames on a single SC can use interleaved SA.
SAK: Security Association Key	Provides the encryption key used to encrypt the datapath of MACsec.

4.2.3.5 MACsec static CAK

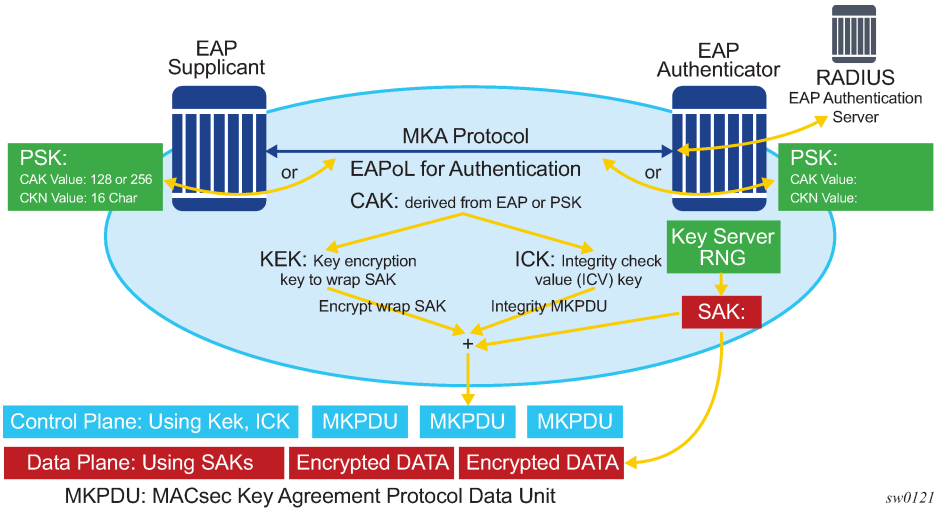
MACsec uses SAs to encrypt packets. SA is a security relationship that provides security guarantees for frames transmitted from one member of a CA to the others. Each SA contains a single secret key (SAK) with the cryptographic operations used to encrypt the datapath PDUs.

SAK is the secret key used by an SA to encrypt the channel.

When enabled, MACsec uses a static CAK security mode. Two security keys, a connectivity association key (CAK) that secures control plane traffic, and a randomly generated secure association key (SAK) that secures data plane traffic, are used to secure the point-to-point or point-to-multipoint Ethernet link. Both keys are regularly exchanged between both devices on each end of the Ethernet link to ensure link security.

The following figure shows MACsec generating the CAK.

Figure 9: MACsec generating the CAK



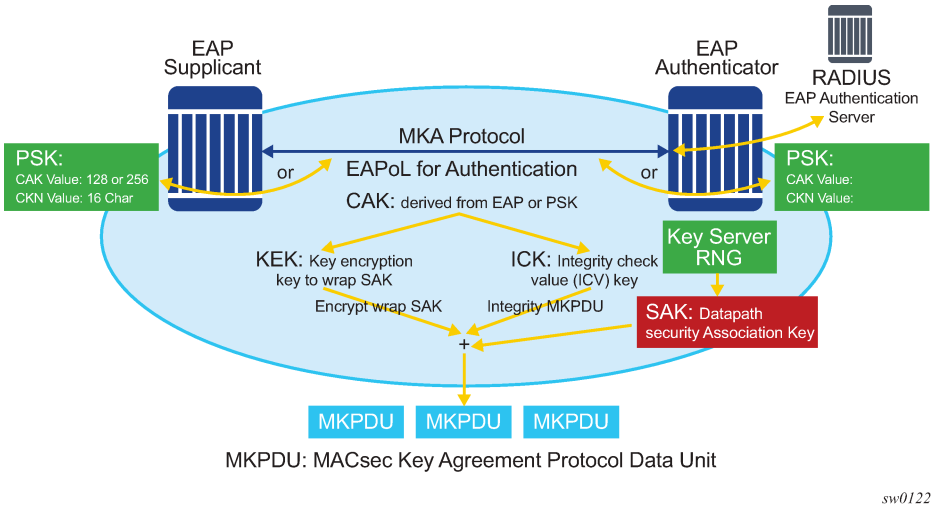
The node initially needs to secure the control plane communication to distribute the SAKs between two or more members of a CA domain.

The CAK is used to secure the control plane. The following main methods are used to generate the CAK:

- EAPoL (SR OS does not support EAPoL)
- pre-shared key (CAK and CKN values are configured manually using the CLI). The following CAK and CKN rules apply.
  - CAK has 32 hexadecimal characters for 128-bit key and 64 hexadecimal characters for 256-bit key depending on which algorithm is used for control plane encryption (for example, **aes-128-cmac** or **aes-256-cmac**).
  - CKN has 32 octets char (64 hex) and is the connectivity association key name which identifies the CAK. This allows each of the MKA participants to select which CAK to use to process a received MKPDU. MKA places no restriction on the format of the CKN, except that it must comprise an integral number of octets, between 1 and 32 (inclusive), and that all potential members of the CA use the same CKN.
  - CKN and CAK must match on peers to create a MACsec secure CA.

The following figure shows the MACsec control plane authentication and encryption.

Figure 10: MACsec control plane and encryption



A generated CAK can obtain the following additional keys:

- **Key Encryption Key (KEK)**

  This key is used to wrap and encrypt the SAKs.

- **Integrity Connection Value (ICV) Key (ICK)**

  This key is used for an integrity check of each MKPDU sent between two CAs.

The key server then creates a SAK, which is shared with the CAs of the security domain, and that SAK secures all data traffic traversing the link. The key server continues to periodically create and share a randomly created SAK over the point-to-point link for as long as MACsec is enabled.

The SAK is encrypted via the AES-CMAC, using the KEK as the encryption key, and ICK as the integration key.

4.2.3.6 SAK rollover

SR OS regenerates the SAK after the following events:

- when a new host has joined the CA domain and MKA hellos are received from this host
- when the sliding window is reaching the end of its 32-bit or 64-bit length
- when a new PSK is configured and a rollover of PSK is executed

4.2.3.7 MKA

Each MACsec peer operates the MKA. Each node can operate multiple MKAs based on the number of CAs the node belongs to. Each MKA instance is protected by a distinct secure CAK, which allows each PAE to ensure that information for an MKA instance is only accepted from other peers that also possess that CAK, which identifies the peers as members or potential members of the same CA. See MACsec static CAK for information about the CAK identification process performed via CKN.

4.2.3.7.1 MKA PDU generation

The following table describes the MKA PDUs generated for different traffic encapsulation matches.

Table 7: MKA PDU generation

Configuration	Configuration example (<s-tag>.<c-tag>)	MKA packet generation	Traffic pattern match/behavior

All-encap	**MD-CLI**
	`configure port ethernet dot1x macsec sub-port 10 ca-name 10 encap-match all-match true`
	classic CLI
	`configure port ethernet dot1x macsec sub-port 10 encap-match all-encap ca-name 10`
		untagged MKA packet	Matches all traffic on port, including untagged, single-tag, and double-tag. Default behavior; only available behavior in releases before 16.0.

UN-TAG	**MD-CLI**
	`configure port ethernet dot1x macsec sub-port 10 ca-name 2 encap-match untagged true`
	classic CLI
	`configure port ethernet dot1x macsec sub-port 10 encap-match untagged ca-name 2`
		untagged MKA packet	Matches only untagged traffic on port

802.1Q single S-TAG (specific S-TAG)	**MD-CLI**
	`configure port ethernet dot1x macsec sub-port 2 ca-name 3 encap-match single-tag 1`
	classic CLI
	`configure port ethernet dot1x macsec sub-port 2 encap-match single-tag 1 ca-name 3`
		MKA packet generated with S-TAG=1	Matches only single-tag traffic on port with tag ID of 1

802.1Q single S-TAG (any S-TAG)	**MD-CLI** `configure port ethernet dot1x macsec sub-port 3 ca-name 4 encap-match single-tag *`	untagged MKA packet	Matches any dot1q single-tag traffic on port

Configuration	Configuration example (<s-tag>.<c-tag>)	MKA packet generation	Traffic pattern match/behavior
	classic CLI `configure port ethernet dot1x macsec sub-port 3 encap-match single-tag * ca-name 4`		

802.1ad double tag (both tag have specific TAGs)	**MD-CLI**
	`configure port ethernet dot1x macsec sub-port 4 ca-name 4 encap-match double-tag 1.1`
	classic CLI
	`configure port ethernet dot1x macsec sub-port 4 encap-match double-tag 1.1 ca-name 4`
		MKA packet generated with S-tag=1 and C-TAG=1	Matches only double-tag traffic on port with service tag of 1 and customer tag of 1

802.1ad double tag (specific S-TAG, any C-TAG)	**MD-CLI**
	`configure port ethernet dot1x macsec sub-port 6 ca-name 7 encap-match double-tag 1.*`
	classic CLI
	`configure port ethernet dot1x macsec sub-port 6 encap-match double-tag 1.* ca-name 7`
		MKA packet generated with S-TAG=1	Matches only double-tag traffic on port with service tag of 1 and customer tag of any

802.1ad double tag (any S-TAG, any C-TAG)	**MD-CLI**
	`configure port ethernet dot1x macsec sub-port 7 ca-name 8 encap-match double-tag *.*`
	classic CLI
	`configure port ethernet dot1x macsec sub-port 7 encap-match double-tag *.* ca-name 8`
		untagged MKA packet	Matches any double-tag traffic on port

4.2.3.7.2 Tags in clear behavior by traffic encapsulation type

Table 8: Tags in clear behavior describes how single or double tags in clear configuration under a connectivity association affects different traffic flow encryptions.

By default, all tags are encrypted in CA. An MKA can be generated without any tags (un-tag), but the data being matched can be based on dot1q or QinQ.

Table 8: Tags in clear behavior

Configuration	Traffic pattern match/behavior	Sub-port CA configuration: no tag in clear text	Sub-port CA configuration: single-tag in clear text	Sub-port CA configuration: double-tag in clear text
PORT All-encap	Matches all traffic on port, including untagged, single-tag, double-tag (Release 15.0 default behavior)	MKA PDU: untagged Untagged traffic: encrypted Single-tag traffic: encrypted, no tag in clear Double-tag traffic: encrypted, no tag in clear	MKA PDU: untagged Untagged traffic: in clear Single-tag traffic: encrypted, single-tag in clear Double-tag traffic: encrypted, single-tag in clear	MKA PDU: untagged Untagged traffic: in clear Single-tag traffic: in clear Double-tag traffic: encrypted, double-tag in clear
untagged	Matches only untagged traffic on port	MKA PDU: untagged Untagged traffic: encrypted Single-tag traffic: not matched by this MACsec policy Double-tag traffic: not matched by this MACsec policy	N/A	N/A
802.1Q single tag (specific tag)	Matches only single-tag traffic on port with the configured tag value	MKA PDU: untagged Untagged traffic: not matched by this MACsec policy Single-tag traffic: tag is encrypted Double-tag traffic: not matched by this MACsec policy	MKA PDU: same tag as the one configured under **encap-match** Untagged traffic: not matched by this MACsec policy Single-tag traffic: tag is in clear Double-tag traffic: not matched by this MACsec policy	N/A
802.1Q single tag (any tag)	Matches all single-tag traffic on port	MKA PDU: untagged Untagged traffic: not matched by this MACsec policy Single-tag traffic: encrypted	MKA PDU: untagged Untagged traffic: not matched by this MACsec policy Single-tag traffic: encrypted with single tag in clear	N/A

Configuration	Traffic pattern match/behavior	Sub-port CA configuration: no tag in clear text	Sub-port CA configuration: single-tag in clear text	Sub-port CA configuration: double-tag in clear text
		Double-tag traffic: not matched by this MACsec policy	Double-tag traffic: not matched by this MACsec policy	
802.1ad double tag (both tag have specific values)	Matches only double-tag traffic on port with both configured tag values	MKA PDU: untagged Untagged traffic: not matched by this MACsec policy Single-tag traffic: not matched by this MACsec policy Double-tag traffic matching both configured tags: encrypted, no tag in clear	MKA PDU: single tag, equal to S-TAG Untagged traffic: not matched by this MACsec policy Single-tag traffic: not matched by this MACsec policy Double-tag traffic matching both configured tags: single S-TAG in clear	MKA PDU: double tag, equal to the values configured under the encap-match Untagged traffic: not matched by this MACsec policy Single-tag traffic: not matched by this MACsec policy Double-tag traffic matching both configured tags: encrypted, both tags in clear
802.1ad double tag (specific S-TAG, any C-TAG)	Matches only double-tag traffic on port with the configured S-TAG	MKA PDU: untagged Untagged traffic: not matched by this MACsec policy Single-tag traffic: not matched by this MACsec policy Double-tag traffic matching the configured S-TAG: encrypted, no tag in clear	MKA PDU: single tag, equal to S-TAG Untagged traffic: not matched by this MACsec policy Single-tag traffic: not matched by this MACsec policy Double-tag traffic matching the configured S-TAG: S-TAG tag in clear	MKA PDU: single tag, equal to S-TAG Untagged traffic: not matched by this MACsec policy Single-tag traffic: not matched by this MACsec policy Double-tag traffic matching the configured S-TAG: both tags in clear
802.1ad double tag (any S-TAG, any C-TAG	Matches all double-tag traffic on port	MKA PDU: untagged Untagged traffic: not matched by this MACsec policy Single-tag traffic: not matched by this MACsec policy	MKA PDU: untagged Untagged traffic: not matched by this MACsec policy Single-tag traffic: not matched by this MACsec policy Double-tag traffic: S-TAG tag in clear	MKA PDU: untagged Untagged traffic: not matched by this MACsec policy Single-tag traffic: not matched by this MACsec policy Double-tag traffic: both tags in clear

Configuration	Traffic pattern match/behavior	Sub-port CA configuration: no tag in clear text	Sub-port CA configuration: single-tag in clear text	Sub-port CA configuration: double-tag in clear text
		Double-tag traffic: encrypted, no tag in clear		

4.2.3.8 Pre-shared key

MKA protects the integrity of MKPDUs and secures the SAK using keys that are derived from the CAK. The CAK and CKN are configured as part of a PSK entry under the static CAK configuration.

SR OS supports the following methods for configuring a static CAK:

- **active PSK index**

  There are two PSK entries identified by indexes 1 and 2. The active PSK selects the PSK entry that is used for the MKA session. This method uses a single MKA session. Each time the active PSK is rotated, the CKN and the derived keys are replaced for the same MKA session. A new PSK does not instantiate a new MKA session.

- **a keychain where the SR OS keychain infrastructure is used**

  A keychain contains multiple key entries where each key entry corresponds to a PSK that is active from its configured begin time up to the next key entry's begin time plus a configurable tolerance. With this method, every key entry rotation (PSK rotation) instantiates a new MKA session that is named by the CKN and secured by keys derived from the CAK configured in the key entry (PSK). The previous MKA session bound to the old key entry is deleted when its key entry tolerance expires. See Keychain interaction with MACsec for more information about MACsec usage with keychains.

4.2.3.8.1 Active PSK configuration

With an active PSK, an MKA participant can support one or more PSKs. These PSKs secure the same MKA session; PSK rotation does not instantiate a new MKA session.

A PSK may be created by NSP or entered manually using the CLI.

Each PSK is configured with the following fields:

- CAK name (CKN)
- encryption type

The CKN must be unique per port for the configured sub-ports, and can be used to identify the key in subsequent management operations.

Each static CAK configuration can have two PSK entries for rollover. The active PSK index dictates which CAK is used to derive the keys for encrypting the SAKs and verifying the integrity of the MKPDUs.

NSP provides additional functionality to roll over and configure the PSK. The rollover using NSP can be based on a configured timer.

4.2.3.8.2 Keychain

With a keychain, up to 64 PSK entries (keys) can be configured. Each PSK creates a new dedicated MKA session, active for the duration of the key lifetime plus the configured tolerance.

The active PSK and keychain configurations do not operate simultaneously. When a keychain is configured, it takes precedence over the active PSK configuration. When a keychain is not configured, then the active PSK is used. To configure the active PSK or keychain, the CA must be administratively disabled first.

SR OS can use the keychain for MACsec PSK rotation. A new MACsec container holds the keychain's key entries, where the PSK CAK and CKN values can be configured as hexadecimal characters. A keychain contains multiple key entries. Each entry is activated at its begin time; and remains valid up to the begin time of the next key entry, plus its own tolerance time.

A MACsec keychain supports the same ciphers as an active PSK. The **aes-128-cmac** and **aes-256-cmac** ciphers can be configured per keychain key entry for MACsec.

The following MACsec container is used to configure the MACsec keychain entries:

- **MD-CLI**

```
configure system security keychains keychain macsec
```

- **classic CLI**

```
configure system security keychain macsec
```

When a keychain is configured with a MACsec key entry, other key entry types, such as bidirectional, received, or send, can no longer be added to the keychain. All MACsec key entries in the keychain must be removed to repurpose it for other key entry types. In addition, when a keychain is configured with any bidirectional, received, or send key entries, MACsec key entries can no longer be added. All other key entries in the keychain must be removed to repurpose it for MACsec use.

Only a keychain with at least one MACsec key entry can be assigned to a MACsec static CAK. When a keychain is assigned to a MACsec static CAK, the deletion of the MACsec key entry is rejected.

4.2.3.8.2.1 Transitioning from an active PSK to a keychain

For greenfield deployments, the user must choose between the use of an "active PSK" or "keychain" method for PSK rotation, as the two methods behave differently.

Users can upgrade from an active PSK implementation to a keychain. The following procedures are recommended when upgrading:

- To configure either a keychain or an active PSK, the CA must be administratively disabled first.
- Add the keychain after the CA is administratively disabled, and then administratively enable the CA.
- When the CA's static CAK contains a keychain, the keychain takes precedence over an active PSK configuration under the static CAK, even if the keychain key entries are not active or the MKA sessions for the keychain are not operationally up. In short, only one method is used at a time, with a keychain having precedence over an active PSK when configured.
- To remove the keychain, the CA has to be administratively disabled again.

Note: When a CA is administratively disabled, all MKA sessions using that CA are deleted.

4.2.3.8.2.2 Keychain interaction with MACsec

In other applications, the tolerance of a keychain key entry can be configured as 0, with a default tolerance value of 300 seconds. A minimum tolerance value of 20 seconds is required by the MACsec application; a 0 tolerance value is rejected if the key entry is a MACsec entry.

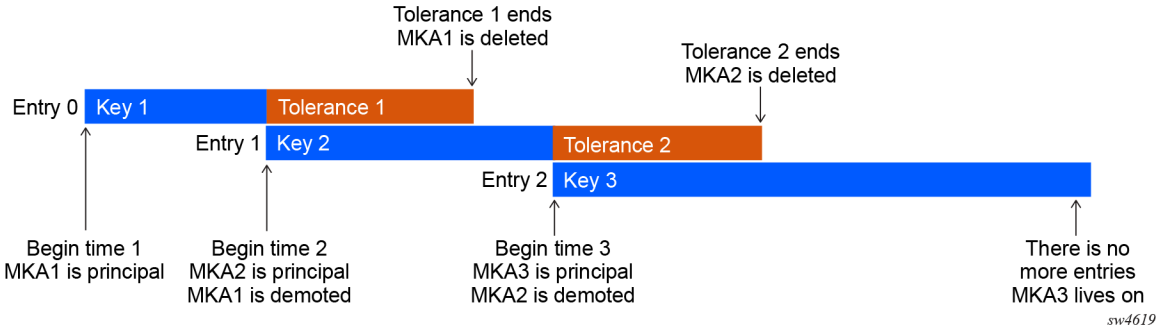
The MKA instance created by the first active key entry serves as the principal session from its begin time and remains functional until the end of its tolerance period. When the next key entry becomes active at its begin time, a new MKA instance is created. When the new MKA instance becomes operationally up, it becomes the principal session and the MKA instance created by the first key entry becomes the backup session until its tolerance timer expires. If the new MKA session does not become operationally up by the time the tolerance of the first key entry expires, the MACsec sub-port becomes operationally down because neither the first nor second key entry has an operational MKA instance.

4.2.3.8.2.3 Tolerance in a keychain

On SR OS, the default tolerance value for a MACsec key is 300 seconds (5 minutes). A tolerance value below 20 seconds is rejected.

The following figure shows an example of tolerance with three key entries.

Figure 11: Tolerance with three key entries



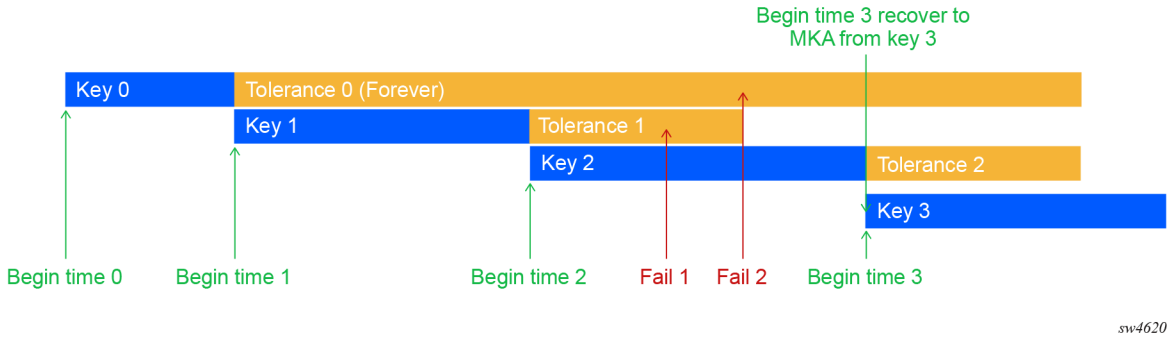
Note: SR OS supports a maximum of three[1] MKA sessions per sub-port at any one time. Therefore, the user must configure the begin times and tolerance periods of each entry in the keychain accordingly to ensure that no more than three MKA sessions exist at the same time.

4.2.3.8.2.3.1 Backup key

The following figure displays an example where key 0 is a backup key with the tolerance set to **forever**.

[1] One of the three concurrent MKA sessions must be from key entry 0 (backup key).

Figure 12: Backup key with the tolerance set to forever



In Figure 12: Backup key with the tolerance set to forever, the following also applies:

- The MKA session for Key 0 can live forever using the tolerance set to **forever**. This means the MKA session for Key 0 exchanges MKA hellos, but it is not the principal session.
- Only Key 0 is intended to be a long-lived backup key. To effectively use it as a backup key, its tolerance should be set to **forever**. However, no restrictions are placed on its begin time and tolerance values to allow flexibility in use cases. If a backup key is not required, it is recommended not to configure Key 0.
- If the MKA session of Key 1 or Key 2 fails, the MKA session of Key 0 takes over as the principal MKA session.
- At Fail 1 point of Key 2, the fallback is Key 1 because its tolerance has not expired.
- At Fail point 2 of Key 2, the fallback key is the Key 0 backup key entry.
- With the exception of Key 0, any configuration that results in more than two overlapping active keys (and therefore MKA sessions) are rejected.
- If at the end of Key 1, Tolerance 1 and Key 2 have not established a MKA session (for example, Key 2 has a mismatch in its CKN between the peers), the Key 0 MKA session takes over and becomes the principal MKA session. The switch from Key 1 to Key 0 after the tolerance of Key 1 expires is seamless.

4.2.3.8.2.4 Unique CKN per port

MACsec requires a unique CKN for each port. For consecutive keychain entries, identical CKNs are not allowed. Identical CKNs can be programmed on multiple keychains that are used for multiple subports on a MACsec port.

For example:

- Port 1/1/1, subport 1 is using keychain 1 and has one entry with CKN “1234”
- Port 1/1/1, subport 2 is using keychain 2 and also has one entry with CKN “1234”
- Port 1/1/1, subport 3 is using static CAK PSK 1 that has CKN “1234”

Note: Users must avoid configuring multiple keychains and static CAK PSKs with the same CKN on the same port.

4.2.3.9 MKA Hello timer

MKA uses a member identifier (MI) for each node in the CA domain.

A participant proves liveness to each of its peers by including its MI, together with an acceptably recent message number (MN), in an MKPDU.

To avoid a new participant having to respond to each MKPDU from each partner as it is received, or trying to delay its reply until it is likely that MI MN tuples have been received from all potential partners, each participant maintains and advertises both of the following:

- **live peers list**

  This list includes all the peers that have included the participant MI and a recent MN in a recent MKPDU.

- **potential peers list**

  This list includes all the other peers that have transmitted an MKPDU that was directly received by the participant or that were included in the live peers list of an MKPDU transmitted by a peer that has proved liveness.

Peers are removed from each list when an interval of between MKA Life Time and MKA Life Time plus MKA Hello Time has elapsed since the participant's recent MN was transmitted. This time is sufficient to ensure that two or more MKPDUs have been lost or delayed prior to the incorrect removal of a live peer.

Note: The specified use of the live and potential peers lists allows rapid removal of participants that are no longer active or attached to the LAN while reducing the number of MKPDUs transmitted during group formation; for example, a new participant is admitted to an established group after receiving, then transmitting, one MKPDU.

The following table describes the MKA participant timer values used on SR OS.

Table 9: MKA participant timer values

Timer use	Timeout (option)	Timeout (option)
Per participant periodic transmission, initialized for each transmission on expiry	MKA Hello Time or MKA Bounded Hello Time	2.0 0.5
Per peer lifetime, initialized when adding to or refreshing the potential peers list or live peers list; expiry causes removal from the list	MKA Life Time	6.0
Participant lifetime, initialized when participant created or following the receipt of an MKPDU; expiry causes the deletion of the participant		
Delay after last distributing a SAK, before the Key Server distributes a fresh SAK following a change in the live peer list while the potential peer list is still not empty		

4.2.3.10 MACsec Capability, Desire, and encryption offset

802.1x-2010 had identified the following fields in the MKA PDU:

- MACsec Capability
- Desire

MACsec Capability signals whether MACsec is capable of integrity and confidentiality. The following table describes the basic settings for MACsec Capability.

Table 10: MACsec basic settings

Setting	Description
0	MACsec is not implemented
1	Integrity without confidentiality
2	The following are supported: • Integrity without confidentiality • Integrity and confidentiality with a confidentiality offset of 0
3[2]	The following are supported: • Integrity without confidentiality • Integrity and confidentiality with a confidentiality offset of 0, 30, or 50

An encryption offset of 0, 30, or 50 starts from the byte after the SecTAG (802.1ae header). Ideally, the encryption offset should be configured for IPv4 (offset 30) and IPv6 (offset 50) to leave the IP header in clear text. This allows routers and switches to use the IP header for LAG or ECMP hashing.

4.2.3.11 Key server

The participants in an MKA instance agree on a Key Server and are responsible for the following:

- deciding on the use of MACsec
- cipher suite selection
- SAK generation and distribution
- SA assignment
- identifying the CA when two or more CAs merge

Each participant in an MKA instance uses the Key Server priority (an 8-bit integer) encoded in each MKPDU to agree on the Key Server. Each participant selects the live participant advertising the highest priority as its Key Server whenever the live peers list changes, provided that highest priority participant has not selected another as its Key Server or is unwilling to act as the Key Server. If a Key Server cannot be selected, SAKs are not distributed. In the event of a tie for the highest priority Key Server, the member with

[2] SR OS supports setting (3).

the highest priority SCI is chosen. For consistency with other uses of the SCI MAC address component as a priority, numerically lower values of the Key Server Priority and SCI are afforded the highest priority.

Note: For SCI, each SC is identified by an SCI that comprises a globally unique MAC address and a Port Identifier unique within the system that is allocated that address.

4.2.3.12 SA limits and network design

Each MACsec device supports 64 TX-SAs and 64 RX-SAs. An SA (Security Association) is the key to encrypt or decrypt the data.

In accordance with the IEEE 802.1AE standard, each SecY contains an SC (Security Channel), which is a unidirectional concept; for example, Rx-SC or Tx-SC. Each SC contains at least one SA for encryption on Tx-SC and decryption on Rx-SC. For extra security, each SC should be able to roll over the SA. The system allocates resources for two SAs on each SC for rollover purposes, as defined in the standard.

Each MACsec phy, referred to as a MACsec security zone, supports 64Tx-SAs and 64 RX-SAs. Assuming two SAs per SC for SA rollover, each security zone supports 32 RX-SC and 32 TX-SC.

The following table describes the port mapping to security zones.

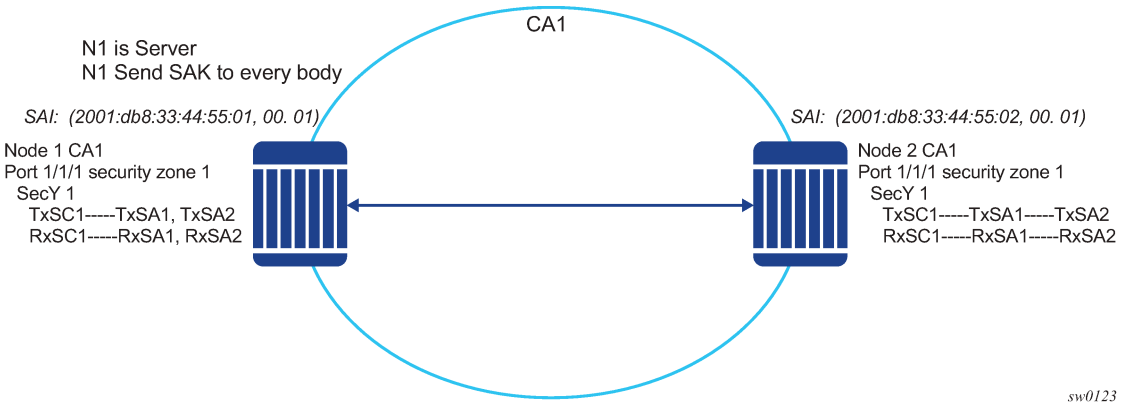
Table 11: Port mapping to security zone

MDA	Ports in security zone 1	Ports in security zone 2	Ports in security zone 3	SA limit per security zone
12-port SFP+/SFP MDA-e	Ports 1, 2, 3, 4	Ports 5, 6, 7, 8	Ports 9, 10, 11, 12	Rx-SA = 64 Tx-SA = 64

4.2.3.13 P2P (switch to switch) topology

In a point-to-point topology, each router needs a single security zone and single Tx-SC for encryption, and a single Rx-SC for decryption. Each SC has two SAs. In total, for point-to-point topology, four SAs are needed, two RxSA for RxSC1 and two TXSA for TxSC1. The following figure shows the P2P topology.

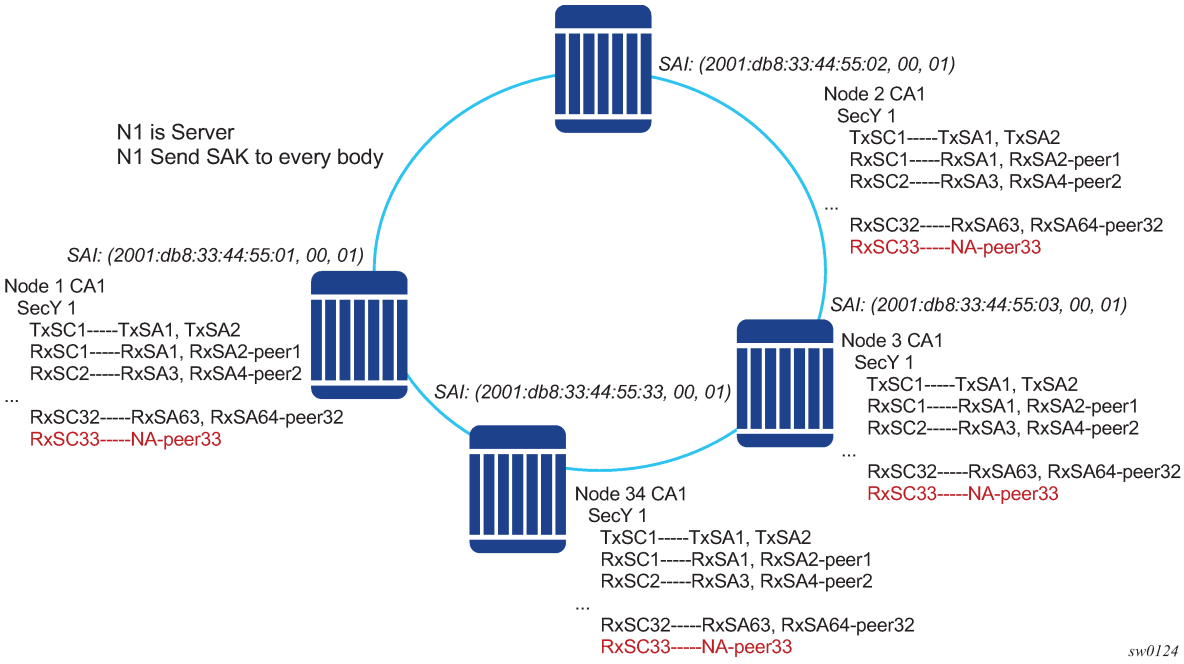
Figure 13: Switch point to switch point topology



4.2.3.14 P2MP (switch to switch) topology

In a multipoint topology with *N* nodes, each node needs a single TxSC and *N* RxSC, one for each of the peers. For example, 64 maximum RX-SAs per security zone translates to 32 Rx-SCs, which breaks down to only 32 peers (only 33 nodes in the multipoint topology per security zone, where each node has one TxSC and 32 RxSC).

Figure 14: Switch multipoint to switch multipoint topology



In the preceding figure, when the 34th node joins the multipoint topology, the other 33 nodes that are already part of this domain do not have SAs to create an RxSC for this 34th node. However, the 34th node has a TxSC and accepts 32 peers. The 34th node starts to transmit and encrypt the PDUs based on its TxSC. However, because the other nodes do not have an SC for this SAI, they drop all Rx PDUs.

To ensure that a multicast domain for a single security zone does not exceed 32 peers or the summation of all the nodes in a security zone CA domain, Nokia recommends not exceeding 33. This is the same as if a security zone has four CAs; the summation of all nodes in the four CAs must be 33 or less.

4.2.3.15 SA exhaustion behavior

SA limits and network design describes that a security zone has 64 RxSAs and 64 TxSAs. Two RxSAs are used for each RxSC for rollover purposes, and two TxSAs are used for TxSC for rollover purposes. This translates to 32 peers per security zone.

Under each port, users can configure the maximum number of peers allowed on that port.

Caution: Nokia strongly recommends that the user ensures the maximum peer value does not exceed the limit of maximum peers per security zone or maximum peers per port values in the following command:

- **MD-CLI**

```
configure port ethernet dot1x macsec sub-port max-peers
```

- **classic CLI**

```
configure port ethernet dot1x macsec sub-port max-peer
```

If the maximum peer is exceeded, the peer connectivity may be random in case of a node failure or packet loss. Peers may join the CA randomly, on a first-come first-served basis.

4.2.3.16 Clear tag mode

In most Layer 2 networks, MAC forwarding is performed via the destination MAC address. The 802.1AE standard dictates that any field after source and destination MAC address and after the SecTAG must be encrypted. This includes the 802.1Q tags. In some VLAN switching networks, it may be needed to leave the 802.1Q tag in clear text.

SR OS supports the configuration of 802.1Q tag, in clear text by placing the 802.1Q tag before the SecTAG, or encrypted text by placing it after the SecTAG.

The following table lists the MACsec encryption of 802.1Q tags when **clear-tag-mode** is configured on the SR OS.

Table 12: MACsec encryption of 802.1Q tags with clear-tag-mode configured

Unencrypted format	clear-tag-mode configuration	Pre-encryption (Tx)	Pre-decryption (Rx)
Single tag (dot1q)	Single-tag	DA, SA, TPID, VID, Etype	DA, SA, TPID, VID, SecTAG
Single tag (dot1q)	Double-tag	DA, SA, TPID, VID, Etype	DA, SA, TPID, VID, SecTAG
Double tag (QinQ)	Single-tag	DA, SA, TPID1, VID1, IPID2, VID2, Etype	DA, SA, TPID1, VID1, SecTAG
Double tag (QinQ)	Double-tag	DA, SA, TPID1, VID1, IPID2, VID2, Etype	DA, SA, TPID1, VID1, IPID2, VID2, SecTAG

4.2.3.17 802.1x tunneling and multihop MACsec

MACsec is an Ethernet packet and, as with any other Ethernet packet, can be forwarded through multiple switches via Layer 2 forwarding. The encryption and decryption of the packets is performed via 802.1x (MKA) capable ports.

To ensure that MKA is not terminated on any intermediate switch or router, the user can enable 802.1x tunneling on the corresponding port.

The following example shows how to check if tunneling is enabled.

Example: MD-CLI

```
[ex:/configure port 1/1/12 ethernet dot1x]
A:admin@node-2# info
```

```
    tunneling true
```

Example: classic CLI

```
A:node-2>config>port>ethernet>dot1x# info
----------------------------------------------
      tunneling
```

By enabling tunneling, the 802.1x MKA packets transit the port, without being terminated, therefore MKA negotiation does not occur on a port that has 802.1x tunneling enabled.

4.2.3.18 EAPoL destination address

The MKA packets are transported over EAPoL with a multicast destination MAC address. If it is required for the MKA have a point-to-point connection to a peer node over a Layer 2 multihop cloud, the EAPoL destination MAC address can be set to the peer MAC address. This forces the MKA to traverse multiple nodes and establish an MKA session with the specific peer.

4.2.3.19 Mirroring consideration

Mirroring is performed before the MACsec encryption engine. Therefore, if a port is MACsec-enabled and that port is mirrored, all the mirrored packets are in clear text.

4.2.4 K1 byte

The switch priority of a request is assigned as indicated by bits 1 through 4 of the K1 byte (as described in the rfc3498 APS-MIB); see Table 13: K1 byte, bits 1 to 4: type of request.

Table 13: K1 byte, bits 1 to 4: type of request

Bit 1234	Condition
1111	Lockout of protection
1110	Force switch
1101	SF – High priority
1100	SF – Low priority
1011	SD – High priority
1010	SD – Low priority
1001	(not used)
1000	Manual switch
0111	(not used)
0110	Wait-to-restore

Bit 1234	Condition
0101	(not used)
0100	Exercise
0011	(not used)
0010	Reverse request
0001	Do not revert
0000	No request

The channel requesting switch action is assigned by bits 5 through 8. When channel number 0 is selected, the condition bits show the received protection channel status. When channel number 1 is selected, the condition bits show the received working channel status. Channel values of 0 and 1 are supported.

Table 14: K1 byte, bits 5 to 8 (and K2 bits 1 to 4), channel number code assignments shows bits 5 to 8 of a K1 byte and K2 Bits 1 to 4 and the channel number code assignments.

Table 14: K1 byte, bits 5 to 8 (and K2 bits 1 to 4), channel number code assignments

Channel number Code	Channel and notes
0	Null channel. SD and SF requests apply to conditions detected on the protection line. For 1+1 systems, Forced and Request Switch requests apply to the protection line (for the 7750 SR only). Only code 0 is used with Lockout of Protection request.
1 to 14	Working channel. Only code 1 applies in a 1+1 architecture. Codes 1 through n apply in a 1:n architecture (for the 7750 SR only). SD and SF conditions apply to the corresponding working lines.
15	Extra traffic channel. May exist only when provisioned in a 1:n architecture. Only No Request is used with code 15.

4.2.5 K2 byte

The K2 byte indicates the bridging actions performed at the line-terminating equipment (LTE), the provisioned architecture and mode of operation.

The bit assignment for the K2 byte is listed in Table 15: K2 byte functions.

Table 15: K2 byte functions

Bits 1 to 8	Function
1 to 4	Channel number. The 7750 SR supports only values of 0 and 1.
5	0 Provisioned for 1+1 mode 1 Provisioned for 1:n mode
6 to 8	111 Line AIS 110 Line RDI 101 Provisioned for bidirectional switching 100 Provisioned for unidirectional switching 011 (reserved for future use) 010 (reserved for future use) 001 (reserved for future use) 000 (reserved for future use)

4.2.6 Failures indicated by K bytes

The following sections describe failures indicated by K bytes.

4.2.6.1 APS protection switching byte failure

An APS Protection Switching Byte (APS-PSB) failure indicates that the received K1 byte is either invalid or inconsistent. An invalid code defect occurs if the same K1 value is received for 3 consecutive frames (depending on the interface type (framer) used, the 7750 SR may not be able to strictly enforce the 3 frame check per GR-253 and G.783/G.841) and it is either an unused code or irrelevant for the specific switching operation. An inconsistent APS byte defect occurs when no three consecutive received K1 bytes of the last 12 frames are the same.

If the failure detected persists for 2.5 seconds, a Protection Switching Byte alarm is raised. When the failure is absent for 10 seconds, the alarm is cleared. This alarm can only be raised by the active port operating in bidirectional mode.

4.2.6.2 APS channel mismatch failure

An APS channel mismatch failure (APS-CM) identifies that there is a channel mismatch between the transmitted K1 and the received K2 bytes. A defect is declared when the received K2 channel number differs from the transmitted K1 channel number for more than 50 ms after three identical K1 bytes are sent. The monitoring for this condition is continuous, not just when the transmitted value of K1 changes.

If the failure detected persists for 2.5 seconds, a channel mismatch failure alarm is raised. When the failure is absent for 10 seconds, the alarm is cleared. This alarm can only be raised by the active port operating in a bidirectional mode.

4.2.6.3 APS mode mismatch failure

An APS mode mismatch failure (APS-MM) can occur for two reasons. The first is if the received K2 byte indicates that 1:N protection switching is being used by the far-end of the OC-N line, while the near end uses 1+1 protection switching. The second is if the received K2 byte indicates that unidirectional mode is being used by the far-end while the near-end uses bidirectional mode.

This defect is detected within 100 ms of receiving a K2 byte that indicates either of these conditions. If the failure detected persists for 2.5 seconds, a mode mismatch failure alarm is raised. However, it continues to monitor the received K2 byte, and should it ever indicate that the far-end has switched to a bidirectional mode the mode mismatch failure clearing process starts. When the failure is absent for 10 seconds, the alarm is cleared, and the configured mode of 1+1 bidirectional is used.

4.2.6.4 APS far-end protection line failure

An APS far-end protection line (APS-FEPL) failure corresponds to the receipt of a K1 byte in 3 consecutive frames that indicates a signal fail (SF) at the far end of the protection line. This forces the received signal to be selected from the working line.

If the failure detected persists for 2.5 seconds, a far-end protection line failure alarm is raised. When the failure is absent for 10 seconds, the alarm is cleared. This alarm can only be raised by the active port operating in a bidirectional mode.

4.2.7 Revertive switching

The APS implementation also provides the revertive and non-revertive modes with non-revertive switching as the default option. In revertive switching, the activity is switched back to the working port after the working line has recovered from a failure (or the manual switch is cleared). In non-revertive switching, a switch to the protection line is maintained even after the working line has recovered from a failure (or if the manual switch is cleared).

A revert-time is defined for revertive switching so frequent automatic switches as a result of intermittent failures are prevented. A change in this value takes effect upon the next initiation of the wait to restore (WTR) timer. It does not modify the length of a WTR timer that has already been started. The WTR timer of a non-revertive switch can be assumed to be infinite.

In case of failure on both working and the protection line, the line that has less severe errors on the line is active at any point in time. If there is signal degrade on both ports, the active port that failed last stays active. When there is signal failure on both ports, the working port is always active. The reason is that the signal failure on the protection line is of a higher priority than on the working line.

4.2.8 Bidirectional 1+1 switchover operation example

Table 16: Actions for the bidirectional protection switching process describes the steps that a bidirectional protection switching process goes through during a typical automatic switchover.

Table 16: Actions for the bidirectional protection switching process

Status	APS commands sent in K1 and K2 bytes on protection line		Action	
	B -> A	A -> B	At site B	At site A
No failure (Protection line is not in use).	No request	No request	No action	No action
Working line Degraded in direction A->B.	SD on working channel 1	No request	Failure detected,	No action

Status	APS commands sent in K1 and K2 bytes on protection line		Action	
	B -> A	A -> B	At site B	At site A
			notify A and switch to protection line	
Site A receives SD failure condition.	Same	Reverse request	No action	Remote failure detected, acknowledge and switch to protection line
Site B receives Reverse request.	Same	Same	No action	No action

4.2.9 Annex B (1+1 optimized) operation

Operation and behavior conferment with Annex B of ITU.T G.841 can be configured for an APS group. Characteristics of this mode include are the following:

- Annex B operates in non-revertive bidirectional switching mode only as defined in G.841.
- Annex B operates with 1+1 signaling, but 1:1 datapath whereby data is transmitted on the active link only.
- K bytes are transmitted on both circuits.

Because the request/reverse-request nature of an Annex B switchover, the data outage is longer than a typical (non Annex B single chassis) APS switchover. Nokia recommends using maintenance commands under the **tools perform aps** context for planned switchovers (not MDA or IOM shutdown) to minimize the outage.

4.2.9.1 Annex B APS outage reduction optimization

Typical standard Annex B behavior when a local SF is detected on the primary section (circuit), and this SF is the highest priority request on both the local side and from the remote side as per the APS specifications, is to send a request to the remote end and then wait until a reverse request is received before switching over to the secondary section. To reduce the recovery time for traffic, the router switches over to the secondary section immediately upon detecting the local SF on the primary section instead of waiting for the reverse request from the remote side. If the remote request is not received after a period of time then an “PSB Failure is declared” event is raised (Protection Switching Byte Failure – indicates an inconsistent or invalid Rx K1 Bytes), and the APS group on the local side switches back to the primary section.

When the remote side is in Lockout, and a local SF is detected then a reverse request is not received by the local side. In this case, the traffic no longer flows on the APS group because neither the primary nor secondary sections can carry traffic, and the outage reduction optimization causes a temporary switchover from the primary to the secondary and then back again (which causes no additional outage or traffic issue because neither section is usable). If this temporary switchover is not wanted then it is recommended to either perform Lockout from the router side, or to Lockout from both sides, which avoids the possibility of the temporary switchover.

Failures detected on the secondary section cause immediate switch over as per the Annex B specification. There is no outage reduction optimization in the router for this case as it is not needed.

Some examples of events that can cause a local SF to be detected include: a cable being cut, laser transmitter or receiver failure, a port administratively "shutdown", MDA failure or shutdown, IOM failure or shutdown.

Note: In Annex B operation, all switch requests are for a switch from the primary section to the secondary section. After a switch request clears normally, traffic is maintained on the section to which it was switched by making that section the primary section. The primary section may be working circuit 1 or working circuit 2 at any particular moment.

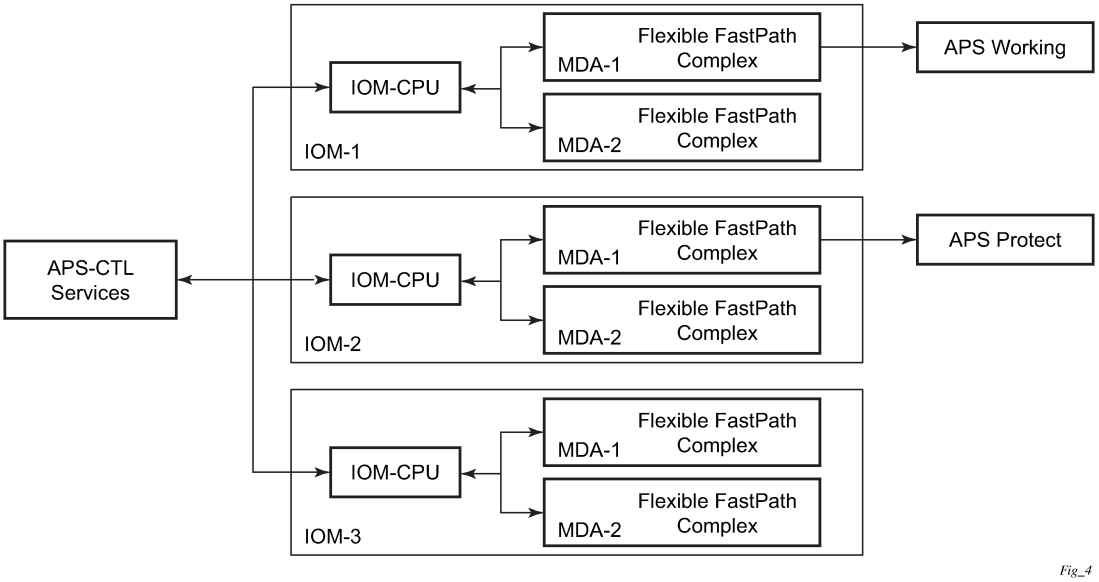
4.2.10 Protection of upper layer protocols and services

APS prevents upper layer protocols and services from being affected by the failure of the active circuit.

The following example with figures and description illustrate how services are protected during a single-chassis APS switchover.

Figure 15: APS working and protection circuit example shows an example in which the APS working circuit is connected to IOM-1/MDA-1 and the protection circuit is connected to IOM-2/MDA-1. In this example, assume that the working circuit is currently used to transmit and receive data.

Figure 15: APS working and protection circuit example



4.2.10.1 Switchover process for transmitted data

For packets arriving on all interfaces that need to be transmitted over APS protected interfaces, the next hop associated with all these interfaces are programmed in all Flexible Fast-Path complexes in each MDA with a logical next-hop index. This next hop-index identifies the actual next-hop information used to direct traffic to the APS working circuit on IOM-1/MDA-1.

All Flexible Fast-Path complexes in each MDA are also programmed with next hop information used to direct traffic to the APS protect circuit on IOM-2/MDA-1. When the transmitted data needs to be switched from the working to the protect circuit, only the relevant next hop indexes need to be changed to the pre-programmed next-hop information for the protect circuit on IOM-2/MDA-1.

Although the control CPM on the SF/CPM blade initiates the changeover between the working to protect circuit, the changeover is transparent to the upper layer protocols and service layers that the switchover occurs.

Physical link monitoring of the link is performed by the CPU on the relevant IOM for both working and protect circuits.

4.2.10.2 Switchover process for received data

The Flexible Fast-Path complexes for both working and protect circuits are programmed to process ingress. The inactive (protect) circuit however is programmed to ignore all packet data. To perform the switchover from working circuit to the protect circuit the Flexible Fast-Path complex for the working circuit is set to ignore all data while the Flexible Fast-Path complex of the protect circuit is changed to accept data.

The ADM or compatible head-end transmits a valid data signal to both the working and protection circuits. The signal on the protect line is ignored until the working circuit fails or degrades to the degree that requires a switchover to the protect circuit. When the switchover occurs all services including all their QoS and filter policies are activated on the protection circuit.

4.2.11 APS user-initiated requests

The following subsections describe APS user-initiated requests.

4.2.11.1 Lockout protection

The lockout of protection disables the use of the protection line. Because the **tools perform aps lockout** command has the highest priority, a failed working line using the protection line is switched back to itself even if it is in a fault condition. No switches to the protection line are allowed when locked out.

4.2.11.2 Request switch of active to protection

The request or manual switch of active to protection command switches the active line to use the protection line unless a request of equal or higher priority is already in effect. If the active line is already on the protection line, no action takes place.

4.2.11.3 Request switch of active to working

The request or manual switch of active to working command switches the active line back from the protection line to the working line unless a request of equal or higher priority is already in effect. If the active line is already on the working line, no action takes place.

4.2.11.4 Forced switching of active to protection

The forced switch of active to protection command switches the active line to the protection line unless a request of equal or higher priority is already in effect. When the forced switch of working to protection command is in effect, it may be overridden either by a lockout of protection or by detecting a signal failure on the protection line. If the active line is already on the protection line, no action takes place.

4.2.11.5 Forced switch of active to working

The forced switch of active to working command switches the active line back from the protection line to the working unless a request of equal or higher priority is already in effect.

4.2.11.6 Exercise command

The exercise command is only supported in the bidirectional mode of the 1+1 architecture. The exercise command is specified in the following context and exercises the protection line by sending an exercise request over the protection line to the tail-end and expecting a reverse request response back.

```
tools perform aps force exercise
```

The switch is not actually completed during the exercise routine.

4.2.12 E-LMI

The Ethernet Local Management Interface (E-LMI) protocol is defined in Metro Ethernet Forum (MEF) technical specification MEF16. This specification defines the protocol and procedures that convey the information for auto-configuration of a CE device and provides the means for EVC status notification. MEF16 does not include link management functions. In the Ethernet context that role is already accomplished with Clause 57 Ethernet OAM (formerly 802.3ah).

The SR OS currently implements the User Network Interface-Network (UNI-N) functions for status notification supported on Ethernet access ports with dot1q encapsulation type. Notification related to status change of the EVC and CE-VLAN ID to EVC mapping information is provided as a one to one between SAP and EVC.

The E-LMI frame encapsulation is based on IEEE 802.3 untagged MAC frame format using an ether-type of 0x88EE. The destination MAC address of the packet 01-80-C2-00-00-07 is dropped by any 802.1d compliant bridge that does not support or have the E-LMI protocol enabled. When the E-LMI protocol is not enable on the port, E-LMI packets are tunneled for Epipe services. However, these packets are discarded for VPLS services. This discard action in a VPLS service can be changed using the **configure service vpls tunnel-elmi** command.

Status information is sent from the UNI-N to the UNI-C, either because a status inquiry was received from the UNI-C or unsolicited. The Active and Not Active EVC status are supported. The Partially Active state is left for further study.

The bandwidth profile sub-information element associated with the EVC Status IE does not use information from the SAP QoS policy. A value of 0 is used in this release as MEF 16 indicates the bandwidth profile sub-IE is mandatory in the EVC Status IE. The EVC identifier is set to the description of the SAP and the

UNI identifier is set to the description configured on the port. Further, the implementation associates each SAP with an EVC. Currently, support exists for CE-VLAN ID/EVC bundling mode.

The E-LMI the UNI-N can participate in the OAM fault propagation functions. This is a unidirectional update from the UNI-N to the UNI-C and interacting with service manager of VLL, VPLS, VPRN and IES services.

4.2.13 LLDP

The IEEE 802.1ab Link Layer Discovery Protocol (LLDP) standard defines protocol and management elements that are suitable for advertising information to stations attached to the same IEEE 802 LAN (emulation) for the purpose of populating physical or logical topology and device discovery management information databases. The protocol facilitates the identification of stations connected by IEEE 802 LANs/MANs, their points of interconnection, and access points for management protocols.

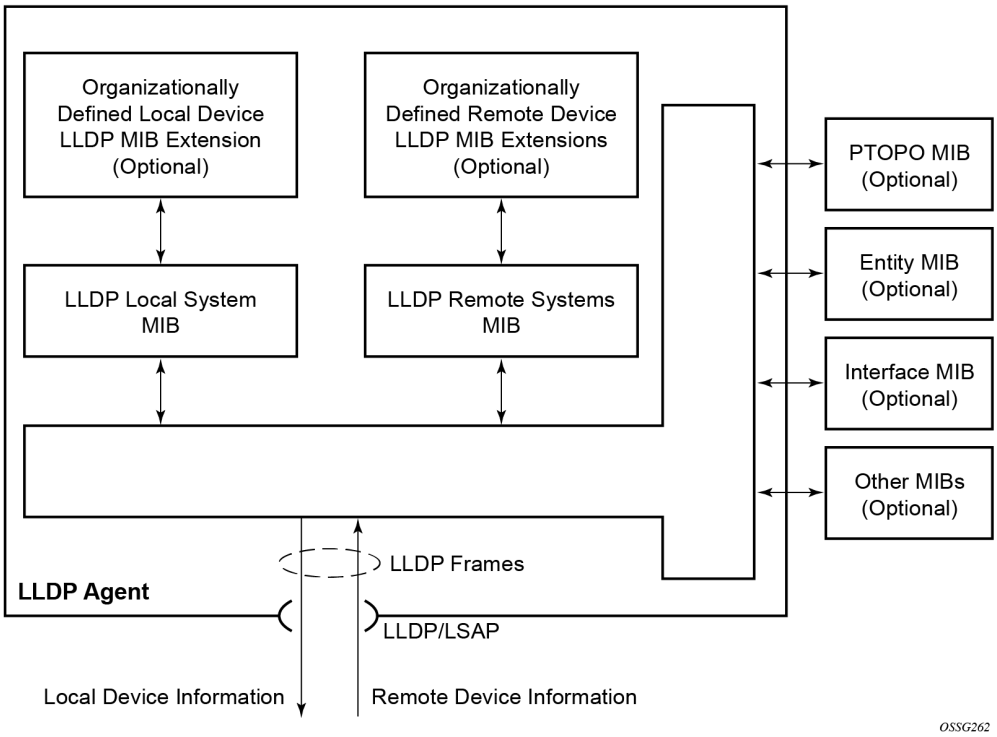
Note that LAN emulation and logical topology wording is applicable to customer bridge scenarios (enterprise/carrier of carrier) connected to a provider network offering a transparent LAN emulation service to their customers. It helps the customer bridges detect misconnection by an intermediate provider by offering a view of the customer topology where the provider service is represented as a LAN interconnecting these customer bridges.

The following lists the information included in the protocol defined by the IEEE 802.1ab standard:

- Advertises connectivity and management information about the local station to adjacent stations on the same IEEE 802 LAN.
- Receives network management information from adjacent stations on the same IEEE 802 LAN.
- Operates with all IEEE 802 access protocols and network media.
- Establishes a network management information schema and object definitions that are suitable for storing connection information about adjacent stations.
- Provides compatibility with several MIBs as shown in Figure 16: LLDP internal architecture for a network node.

The following figure shows the internal architecture for a network node.

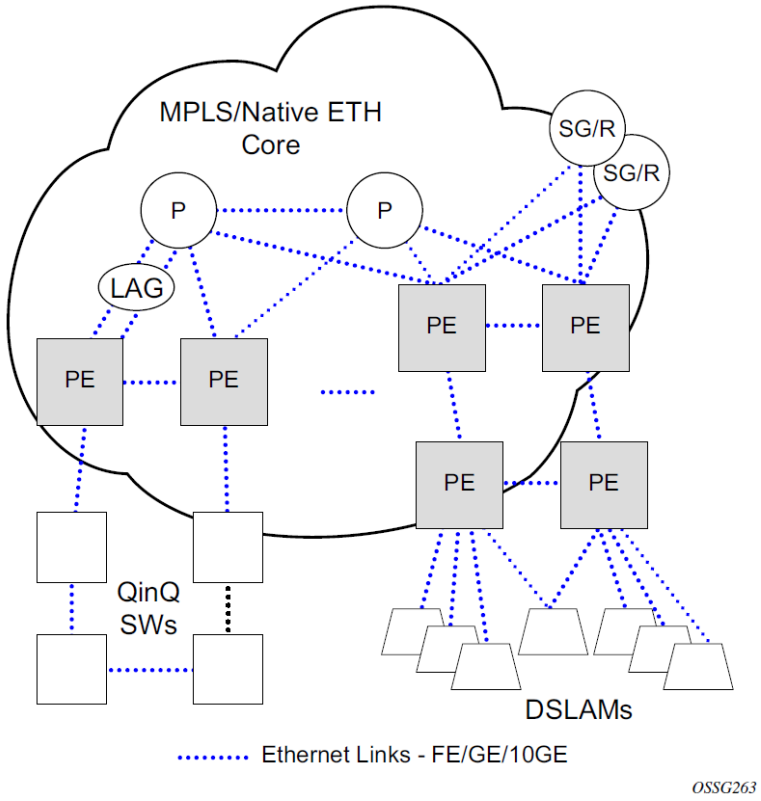
Figure 16: LLDP internal architecture for a network node



To detect and address network problems and inconsistencies in the configuration, the network operator can discover the topology information using LLDP. The standard-based tools address the complex network scenarios where multiple devices from different vendors are interconnected using Ethernet interfaces.

The following figure shows an example of an MPLS network that uses Ethernet interfaces in the core or as an access/handoff interface to connect to different kinds of Ethernet-enabled devices, such as service gateway/routers, QinQ switches, DSLAMs, or customer equipment.

Figure 17: Generic customer use case for LLDP



The topology information of the network in the preceding figure can be discovered if IEEE 802.1ab LLDP is running on each of the Ethernet interfaces in the network.

Users using IOM or IMM cards can tunnel the nearest-bridge at the port level using the following command.

```
configure port ethernet lldp dest-mac tunnel-nearest-bridge
```

The **dest-mac nearest-bridge** command must be disabled for tunneling to occur.

Use the following command to configure the tunneling of nearest-customer dest-mac on the port.

```
configure port ethernet lldp dest-mac tunnel-nearest-customer
```

Use the following command to configure the tunneling of LLDP nearest non-TPMR dest-mac on the port.

```
configure port ethernet lldp dest-mac tunnel-nearest-non-tpmr
```

Note: By default, tunneling is enabled for **tunnel-nearest-customer** and **tunnel-nearest-non-tpmr** if the protocol is not configured. Because of the mutually exclusive behavior of protocol and tunneling, the tunneling configuration must be disabled before enabling LLDP **tunnel-nearest-customer** or **tunnel-nearest-non-tpmr** for **dest-mac**.

4.2.13.1 LLDP protocol features

LLDP is a unidirectional protocol that uses the MAC layer to transmit specific information related to the capabilities and status of the local device. Separately from the transmit direction, the LLDP agent can also receive the same kind of information for a remote device that is stored in the related MIBs.

LLDP does not contain a mechanism for soliciting specific information from other LLDP agents, nor does it provide a specific means of confirming the receipt of information. LLDP allows the transmitter and the receiver to be separately enabled, making it possible to configure an implementation so that the local LLDP agent can either transmit only, receive only, or can transmit and receive LLDP information.

The information fields in each LLDP frame are contained in an LLDP Data Unit (LLDPDU) as a sequence of variable-length information elements, that each include type, length, and value fields (known as TLVs), where:

- Type identifies what kind of information is being sent.
- Length indicates the length of the information string in octets.
- Value is the information that must be sent (for example, a binary bit map or an alphanumeric string that can contain one or more fields).

Each LLDPDU contains four mandatory TLVs and can contain optional TLVs as selected by network management:

- Chassis ID TLV
- Port ID TLV
- Time To Live TLV
- Zero or more optional TLVs, as allowed by the maximum size of the LLDPDU
- End Of LLDPDU TLV

The chassis ID and the port ID values are concatenated to form a logical identifier that is used by the recipient to identify the sending LLDP agent/port. Both the chassis ID and port ID values can be defined in several forms. When selected, the chassis ID/port ID value combination remains the same if the port remains operable.

A non-zero value in the TTL field of the Time To Live TLV tells the receiving LLDP agent how long all information pertaining to this LLDPDU identifier is valid, so that the information can later be discarded by the receiving LLDP agent if the sender fails to update it in a timely manner. A zero value indicates that any information pertaining to this LLDPDU identifier is to be discarded immediately.

A TTL value of zero can be used, for example, to signal that the sending port has initiated a port shutdown procedure. The End Of LLDPDU TLV marks the end of the LLDPDU.

Use commands in the following context to configure LLDP for a port.

```
configure port ethernet lldp
```

The implementation defaults to setting the port ID field in the LLDP OAMPDU to **tx-local**. This encodes the port ID field as ifIndex (sub-type 7) of the associated port. Some network management systems use the ifIndex value to properly build the Layer Two Topology Network Map. However, this numerical value is difficult to interpret or readily identify the LLDP peer. Configuration options are available to control the encoding of the port ID information and the associated subtype using the following command.

```
configure port ethernet lldp dest-mac port-id-subtype
```

Three options are supported for the **port-id-subtype**:

- **tx-if-alias**

  This option transmits the ifAlias String (subtype 1) that describes the port as stored in the IFMIB, either as a user-configured description or the default entry (that is,10/100/Gig Ethernet SFP).

- **tx-if-name**

  This option transmits the ifName string (subtype 5) that describes the port as stored in the IFMIB, ifName info.

- **tx-local**

  This is the interface ifIndex value (subtype 7).

IPv6 (address subtype 2) and IPv4 (address subtype 1) LLDP system management addresses are supported. The IP addresses can be selected from the system IP addressing, the out-of-band management address (BOF), or both.

If the **port-desc** TLV is enabled it has a maximum of 255 byte limit. However, truncation of the port description information occurs if the combination of the port ID and the ifDesc (for example 1/1/c1/2, 10-Gig Ethernet) exceeds the 255-byte maximum. The truncation of the port description information is equal to the number of bytes required to include the ifDesc.

All the port level LLDP configuration options are also available at the LAG level using commands in the following context.

```
configure lag lldp-member-template
```

When this configuration is enabled, it is applied to all the member ports of that LAG. Though the LLDP template configuration option exists at the LAG level, the LLDP peer establishment happens only at the individual port level. When a port is removed from the LAG (with the LLDP template configuration), the LLDP configuration is completely removed for that port.

The following table describes the behavior for different combinations of port and LAG LLDP configurations.

Table 17: LLDP protocol or tunneling: port and LAG LLDP combinations

LAG LLDP template configuration	Port LLDP configuration	Behavior
Yes	No	All member ports inherit the LAG LLDP template configuration
Yes	Yes	Ports with the LLDP protocol or tunneling configuration at the port level cannot be added to LAG. The LLDP configuration at port level must be set to default (disabled) before it can be added to the LAG.
No	Yes	• LLDP protocol or tunneling can be enabled or disabled for individual member ports • The LAG LLDP template configuration cannot be enabled without removing the LLDP configuration from the member ports.

4.2.14 Exponential Port Dampening

Exponential Port Dampening (EPD) provides the ability to automatically block a port from reuse for a period of time after physical link-down and physical link-up events. If a series of down-up events occur close together, EPD keeps the port's operational state down for a longer period than if only one down-up event has occurred. The router avoids using that port if external events are causing the link state to fluctuate. The more events that occur, the longer the port is kept down and avoided by the routing protocols.

EPD behavior uses a fixed penalty amount per link-down event and a half-life decay equation to reduce these penalties over time. The following equation defines exponential decay:

$$N(t) = N_0\left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$$

sw0109

where:

$N(t)$ is the quantity that still remains after a time t

N_0 is the initial quantity

$t_{½}$ is the half-life

In dampening, N_0 refers to the starting penalties from the last link-down event. The quantity *N(t)* refers to the decayed penalties at a specific time, and is calculated starting from the last link-down event (that is, from the time when N_0 last changed).

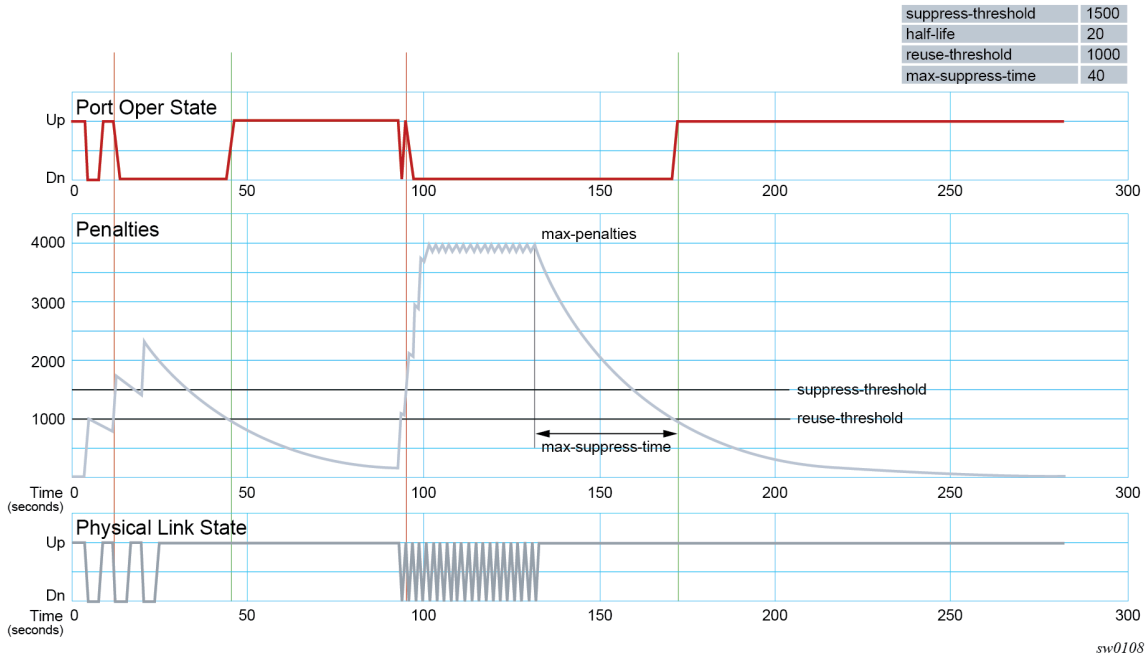
This equation can also be used on a periodic basis by updating the initial quantity value N_0 each period and then computing the new penalty over the period *(t)*.

Use commands in the following context to configure EPD for a port.

```
configure port ethernet dampening
```

The following figure shows an example usage of the EDP feature.

Figure 18: EPD example



At time (*t* = 0) in the preceding figure, the initial condition has the link up, the accumulated penalties are zero, the dampening state is idle, and the port operational state is up. The following series of events and actions occur.

1. *t* = 5: link-down event
   - the accumulated penalties are incremented by 1000
   - the accumulated penalties now equal 1000, which is less than the suppress threshold (of 1500), so the dampening state is idle
   - because the dampening state is idle, link-down is passed to the upper layer
   - link-down triggers the port operational state to down
2. *t* = 9: link-up event
   - the accumulated penalties equal 869, which is less than the suppress threshold, so the dampening state remains as idle
   - because the dampening state is idle, link-up is passed to the upper layer
   - link-up triggers the port operational state to up
3. *t* = 13: link-down event
   - the accumulated penalties are incremented by 1000
   - the accumulated penalties now equal 1755, which is greater than the suppress threshold, so the dampening state is changed to active
   - because the dampening state just transitioned to active, link-down is passed to the upper layer
   - link-down triggers the port operational state to down
4. *t* = 17: link-up event

- the accumulated penalties equal 1527, which is above the reuse threshold (of 1000) and greater than the suppress threshold, so the dampening state remains as active
- because the dampening state is active, link-up is not passed to the upper layer
- the port operational state remains down

5. *t* = 21: link-down event

- the accumulated penalties are incremented by 1000
- the accumulated penalties now equal 2327, which is above the reuse threshold, so the dampening state remains as active
- because the dampening state is active, link-down is not passed to the upper layer
- the port operational state remains down

6. *t* = 25: link-up event

- the accumulated penalties equal 2024, which is above the reuse threshold, so dampening state remains as active
- because the dampening state is active, link-up is not passed to the upper layer
- the port operational state remains down

7. *t* = 46: accumulated penalties drop below the reuse threshold

- the accumulated penalties drop below the reuse threshold, so the dampening state changes to idle
- because the dampening state is idle and the current link state is up, link-up is passed to the upper layer
- the port operational state changes to up

8. *t* = 94 to 133: link-down and link-up events every second

- similar to previous events, the accumulated penalties increment on every link-down event
- the dampening state transitions to active at *t* = 96, and link state events are not sent to the upper layer after that time
- the upper layer keeps the port operational state down after *t* = 96
- the accumulated penalties increment to a maximum of 4000

9. *t* = 133: final link event of link-up

- the accumulated penalties equal 3863
- the dampening state remains active and link state events are not sent to the upper layer
- the upper layer keeps the port operational state down

10. *t* = 172: accumulated penalties drop below the reuse threshold

- the accumulated penalties drop below the reuse threshold, so the dampening state changes to idle
- because the dampening state is idle and the current link state is up, link-up is passed to the upper layer
- the port operational state changes to up

4.3 Per port aggregate egress queue statistics monitoring

Monitoring the aggregate egress queue statistics per port provides in-profile, out-of-profile, and total statistics for both forwarded and dropped packets and octets on a specific port.

When enabled, all queues on the port are monitored, including SAP egress, network egress, subscriber egress, and egress queue group queues, as well as system queues which can be used, for example, to send port-related protocol packets (LACP, EFM, and so on).

Use the following command to enable monitoring of the aggregate egress queue statistics.

```
configure port monitor-agg-egress-queue-stats
```

When enabled, the line card polls the related queues to derive the aggregates which provide the delta of the queue statistics since turning on the monitoring. This means that the reported statistics are not reduced by those from a deleted queue and so the aggregates correctly represent the forwarded/dropped statistics since the start of monitoring.

The following example shows the configuration to enable monitoring of aggregate egress queue statistics on port 2/1/1.

Example: MD-CLI

```
*[ex:/configure]
A:node-2# port 2/1/1 monitor-agg-egress-queue-stats
```

Example: classic CLI

```
*A:node-2# configure port 2/1/1 monitor-agg-egress-queue-stats
```

Use the following command to show detailed information about the aggregates.

```
show port 2/1/1 statistics egress-aggregate detail
```

Output example

```
===============================================================================
Port 2/1/1 Egress Aggregate Statistics on Slot 2
===============================================================================
                        Forwarded               Dropped                 Total
-------------------------------------------------------------------------------
PacketsIn                     144                     0                   144
PacketsOut                      0                     0                     0
OctetsIn                    12353                     0                 12353
OctetsOut                       0                     0                     0
===============================================================================
```

To clear the aggregate statistics, the monitoring must be disabled and then re-enabled. The aggregate statistics are also cleared when the card is cleared (using a **clear card** *slot-number* command) or power-cycled (with the **tools perform card** *slot-id* command). Additionally, aggregate statistics related to MDA are cleared when the MDA is cleared (using the **clear mda** *mda-id* command) or the MDA is inserted into an IOM.

In MD-CLI, the aggregate statistics are not cleared when an **admin-state** is configured to **disable** or **enable** on the card or MDA.

In classic CLI, the aggregate statistics are not cleared when a **shutdown** or **no shutdown** is performed on the card or MDA.

There is no specific limit on the number of queues that can be monitored, but the amount of each line card's CPU resources allocated to the monitoring is bounded; consequently, when more queues on a card’s ports are monitored, the aggregate statistics are updated the less frequently.

Monitoring of aggregate statistics is supported on PXC sub-ports but not on a PXC physical port. It is also not supported on satellite ports.

4.4 Forward Error Correction

Users can use Forward Error Correction (FEC) on some ports to improve either the transmission reliability or reach, or both. FEC must always be used on some interface types while it is optional for other interface types. Also, some interface types allow more than one type of FEC. No matter what the setting of the FEC attributes, the transmitter and the receiver must have the same configuration, or the link will not work. The setting of FEC on a specific port is dependent on the interface type and the specific optical transceiver in use.

For coherent optics, the FEC (host and media) do not need to be configured and are automatically inherited and enabled based on the specific module and configured coherent mode of operation.

For 800G QSFP-DD and 400G QSFP-DD, the FEC from the host module is always enabled and no additional setting is required.

Contact your Nokia representative for information about the options based on the transceiver in use.

5 Datapath mapping

Use the following command to display the mapping between a card and its MDAs, FPs, MACs, connectors, and ports on hardware.

```
show datapath
```

Output example

```
===============================================================================
Card    [XIOM/]MDA  FP  TAP   MAC Chip Num   Connector      Port
-------------------------------------------------------------------------------
1       x1/1        1   N/A   1             c1
1       x1/1        1   N/A   1             c2
1       x1/1        1   N/A   1             c3
1       x1/1        1   N/A   2             c4
1       x1/1        1   N/A   2             c5
1       x1/1        1   N/A   2             c6
1       x2/1        5   N/A   1             c1
1       x2/1        5   N/A   1             c2
1       x2/1        5   N/A   1             c3
1       x2/1        5   N/A   1             c4
1       x2/1        5   N/A   1             c5
1       x2/1        5   N/A   1             c6
1       x2/1        5   N/A   2             c7
1       x2/1        5   N/A   2             c8
1       x2/1        5   N/A   2             c9
1       x2/1        5   N/A   2             c10
1       x2/1        5   N/A   2             c11
1       x2/1        5   N/A   2             c12
1       x2/1        5   N/A   3             c13
1       x2/1        5   N/A   3             c14
1       x2/1        5   N/A   3             c15
1       x2/1        5   N/A   3             c16
1       x2/1        5   N/A   3             c17
1       x2/1        5   N/A   3             c18
===============================================================================
```

6 Port Cross-Connect

6.1 PXC terminology

The following describes Port Cross-Connect (PXC) terminology:

- **Port Cross-Connect (PXC)**
  PXC is a software concept representing a pair of logical ports interconnecting egress and ingress forwarding paths within the same forwarding complex.

  The physical underpinning of a PXC can be either of the following:

  – **a faceplate (physical) port in a loopback mode**

    The PXC is referred to as a port-based PXC. Multiple PXCs can be created per a faceplate port.

  – **a loopback configuration in the MAC chip**

    The PXC is referred to as an internal or MAC-based PXC. Multiple PXCs can be created per MAC loopback.

- **PXC sub-port**

  PXC sub-port is a logical port that is created under the PXC. Two interconnected PXC sub-ports are created per PXC. This is further described in Port-based PXC.

- **Forwarding Complex (FC)**

  FC is a chipset connected to a set of faceplate ports that processes traffic in the ingress direction (the ingress path) and the egress direction (the egress path). A line card can contain multiple FCs for increased throughput, while the inverse is not true, a single FC cannot be distributed over multiple line cards.

  The terms cross-connect and loopback can be used interchangeably.

6.2 Overview

Note: See the "Overview" section of "Port Cross-Connect (PXC)" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Interface Configuration Advanced Configuration Guide for Classic CLI* for information about advanced configurations.
See the "Overview" section of "Port Cross-Connect (PXC)" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Interface Configuration Advanced Configuration Guide for MD CLI* for information about advanced configurations.

This section describes the Port Cross-Connect (PXC) feature implementation. PXC is a software concept representing a pair of logical ports interconnecting egress and ingress forwarding paths within the same forwarding complex (FC). In cross-connect functionality, an egress forwarding path is looped back to the ingress forwarding path on the same forwarding complex instead of leading out of the system. The FC is a chipset connected to a set of faceplate ports that processes traffic in the ingress direction (the ingress path) and the egress direction (the egress path). A line card can contain multiple FCs for increased throughput, but a single FC cannot be distributed over multiple line cards. The most common use for a cross-connect

configuration is to process traffic entering the node. In this case, traffic passes through the ingress path twice. The first ingress pass is always on the FC on which traffic enters the node (an ingress line card), while the second ingress pass, achieved through the cross-connect, can be on any forwarding complex. The user can select to co-locate the ingress line card and the line card hosting the cross-connect. In this co-located case, traffic is looped through the same ingress forwarding path twice.

The reasons for dual-stage ingress processing are related to the manipulation of multilayer headers in the frame within the service termination context. This operation is, in some instances, too complex to perform in a single stage. Feeding the traffic from the first ingress stage to the second through the cross-connect is shown in Figure 19: Traffic preprocessing using PXC. A cross-connect can be created in two ways:

- using a faceplate (physical) port in a loopback mode
- using a loopback configuration in the MAC chip, which does not require a faceplate port

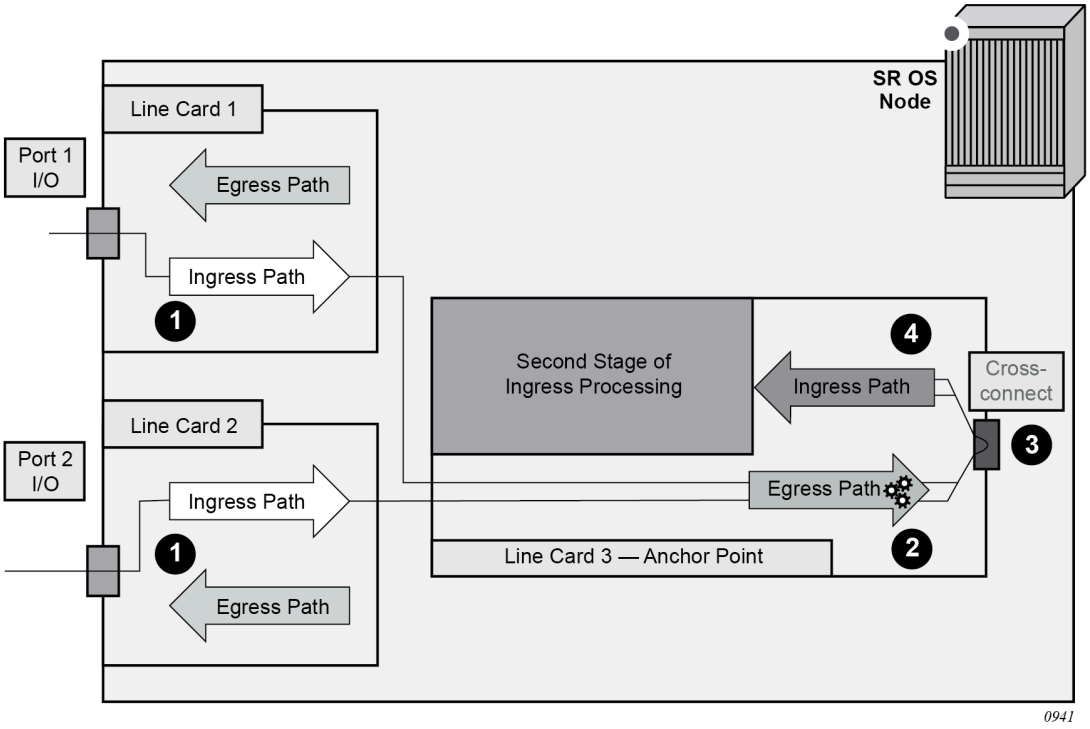
In both cases, the cross-connect is modeled in the system and in the CLI as a port, appropriately naming the feature Port Cross-Connect (PXC) software concept representing a pair of logical ports interconnecting egress and ingress forwarding paths within the same forwarding complex.

Conceptually, PXC functionality is similar to the functionality provided by two externally interconnected faceplate ports where traffic exits the system through one port (the egress path) and is immediately looped back into another port (the ingress path) through a cable.

Figure 19: Traffic preprocessing using PXC shows the traffic flow from the first to the second stage through a cross-connect in a system with PXC:

1. Traffic entering a node through a faceplate port is processed by the local ingress forwarding path (1) on the line cards 1 and 2. Traffic is then directed toward the PXC (3) on the line card 3.
2. The PXC (3) loops the traffic from the local egress path (2) into the local ingress forwarding path (4) where it is further processed.

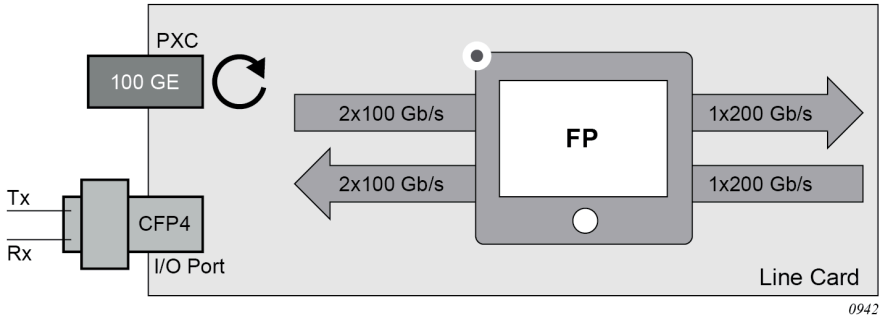
Figure 19: Traffic preprocessing using PXC



6.3 Port-based PXC

The concept of a port-based PXC (a PXC based on a faceplate port in loopback mode) is shown in Figure 20: Port-based PXC. This PXC does not require an optical transceiver.

Figure 20: Port-based PXC



Example: Place the faceplate port into a cross-connect mode (MD-CLI)

```
[ex:/configure]
A:admin@node-2# info
   port-xc {
        pxc 1 {
```

```
            admin-state enable
            port-id 1/x1/1/c1/1
        }
    }
```

Example: Place the faceplate port into a cross-connect mode (classic CLI)

```
A:node-2>config>port-xc# info
----------------------------------------------
        pxc 1 create
            port 1/x1/1/c1/1
            no shutdown
        exit
    exit
----------------------------------------------
```

Example: Multiple PXCs on the same underlying cross-connect configuration (MD-CLI)

```
[ex:/configure]
A:admin@node-2# info
    port-xc {
        pxc 1 {
            admin-state enable
            port-id 1/x1/1/c1/1
        }
        pxc 2 {
            admin-state enable
            port-id 1/x1/1/c1/1
        }
        pxc 3 {
            admin-state enable
            port-id 1/x1/1/c1/1
        }
    }
```

Example: Multiple PXCs on the same underlying cross-connect configuration (classic CLI)

```
A:node-2>config>port-xc# info
----------------------------------------------
        pxc 1 create
            port 1/x1/1/c1/1
            no shutdown
        exit
        pxc 2 create
            shutdown
            port 1/x1/1/c1/1
        exit
        pxc 3 create
            shutdown
            port 1/x1/1/c1/1
        exit
    exit
```

A faceplate port that has been placed in the loopback mode for PXC use, supports only hybrid mode of operation and dot1q encapsulation. The recommendation is that the MTU value be configured to the maximum value. dot1x tunneling is enabled and cannot be changed.

The pre-set dot1q Ethernet encapsulation on the faceplate port is irrelevant from the user's perspective and there is no need to change it. The relevant encapsulation carrying service tags defined on PXC subports and that encapsulation is configurable. For more information, see PXC sub-ports.

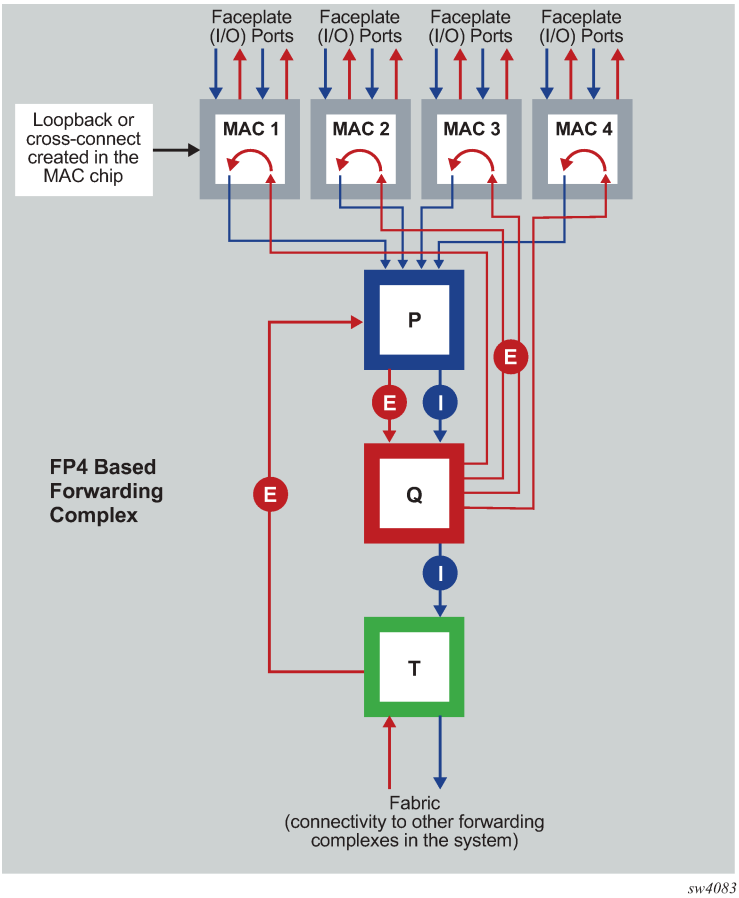
The following guidelines apply to a PXC configuration based on faceplate ports:

- Only unused faceplate ports (not associated with an interface or SAP) can be referenced within a PXC ID configuration.
- When the faceplate port is allocated to a PXC, it cannot be used outside of the PXC context. For example, an IP interface cannot use the faceplate port directly, or a SAP under a such port cannot be associated with an Epipe or VPLS service.

6.4 Internal PXC

With internal (or MAC-based) PXC, the egress path is cross-connected to the ingress path in the MAC chip, without the need to consume a faceplate port, as shown in Figure 21: Internal cross-connect (loopback) in a MAC chip. The number of the MAC chips on a line card varies with the line card type. The **show datapath** command shows the MAC chip related connectivity information in the datapath (forwarding complex). This information is essential for the correct configuration of the cross-connect.

Figure 21: Internal cross-connect (loopback) in a MAC chip



The following example shows the configuration of cross-connect in the MAC chip represented in the CLI as a loopback.

Example: MAC chip cross-connect configuration (MD-CLI)

```
[ex:/configure card 1]
A:admin@node-2# info
    mda 1 {
        mda-type s36-100gb-qsfp28
        xconnect {
            mac 1 {
                description "test description"
                loopback 1 {
                    description "loopback description"
                    bandwidth 100
                }
            }
        }
    }
```

Example: MAC chip cross-connect configuration (classic CLI)

```
A:node-2>config>card# info
----------------------------------------------
 ...
        mda 1
            mda-type s36-100gb-qsfp28
            xconnect
                mac 1 create
                    description "test description"
                    loopback 1 create
                        description "loopback description"
                        bandwidth 100
                    exit
                exit
            exit
            no shutdown
        exit
        no shutdown
----------------------------------------------
```

On the cards with IOM-s modules, an addition of xiom node is used:

Example: Cross-connect configuration on IOM-s modules (MD-CLI)

```
[ex:/configure card 1]
A:admin@node-2# info
...
    xiom "x2" {
        level cr1600g+
        xiom-type iom-s-3.0t
        mda 1 {
            mda-type ms2-400gb-qsfpdd+2-100gb-qsfp28
            xconnect {
                mac 1 {
                    description "test description"
                    loopback 1 {
                        description "loopback description"
                    }
                }
            }
        }
```

Example: Cross-connect configuration on IOM-s modules (classic CLI)

```
A:node-2>config>card# info
----------------------------------------------
...
        xiom x2
            xiom-type iom-s-3.0t level cr1600g+
            mda 1
                mda-type ms2-400gb-qsfpdd+2-100gb-qsfp28
                xconnect
                    mac 1 create
                        description "test description"
                        loopback 1 create
                            description "loopback description"
                        exit
                    exit
                exit
                no shutdown
            exit
        exit
```

The loopback created on the MAC chip at location **card**, **xiom, mda**, or **mac** is assigned a bandwidth in discrete steps. This is a Layer 2 bandwidth, which includes the Ethernet Layer 2 header, but excludes the 20 bytes of Ethernet preamble and the inter-packet gap.

The cross-connect cannot be used in this form, but instead, it must be represented as a port in the system so other software components, such as services, can access it.

In classic CLI, the port associated with the loopback is automatically created.

In MD-CLI, use the **configure port** command to manually create the port. Use the following format for the cross-connect port ID.

slotNum/*mdaNum*/m*MACchipNum*/*loopback-id*

slotNum
: the slot number

xiom
: the xiom-slot

mdaNum
: the MDA number

m
: the keyword indicating that this is a cross-connect type port created in a MAC chip

MACchipNum
: the MAC chip number, the physical location of the loopback on a forwarding complex

loopback-id
: the loopback ID

For example, a cross-connect (loopback) port 1 on the card 1, xiom 'x1', mda 1, MAC chip 1 is created with the following commands:

Example: Port configuration (MD-CLI only)

```
[ex:/configure]
A:admin@node-2# info
...
```

```
    port 1/x1/1/m1/1 {
        admin-state enable
    }
```

This port is ready to be used as a PXC, without having to reserve external ports. Multiple PXCs can be created on the same underlying cross-connect:

Example: Port configured as a PXC (MD-CLI)

```
[ex:/configure]
A:admin@node-2# info
    port-xc {
        pxc 1 {
            admin-state enable
            port-id 1/x1/1/m1/1
        }
        pxc 2 {
            admin-state enable
            port-id 1/x1/1/m1/1
        }
        pxc 3 {
            admin-state enable
            port-id 1/x1/1/m1/1
        }
    }
```

Example: Port configured as a PXC (classic CLI)

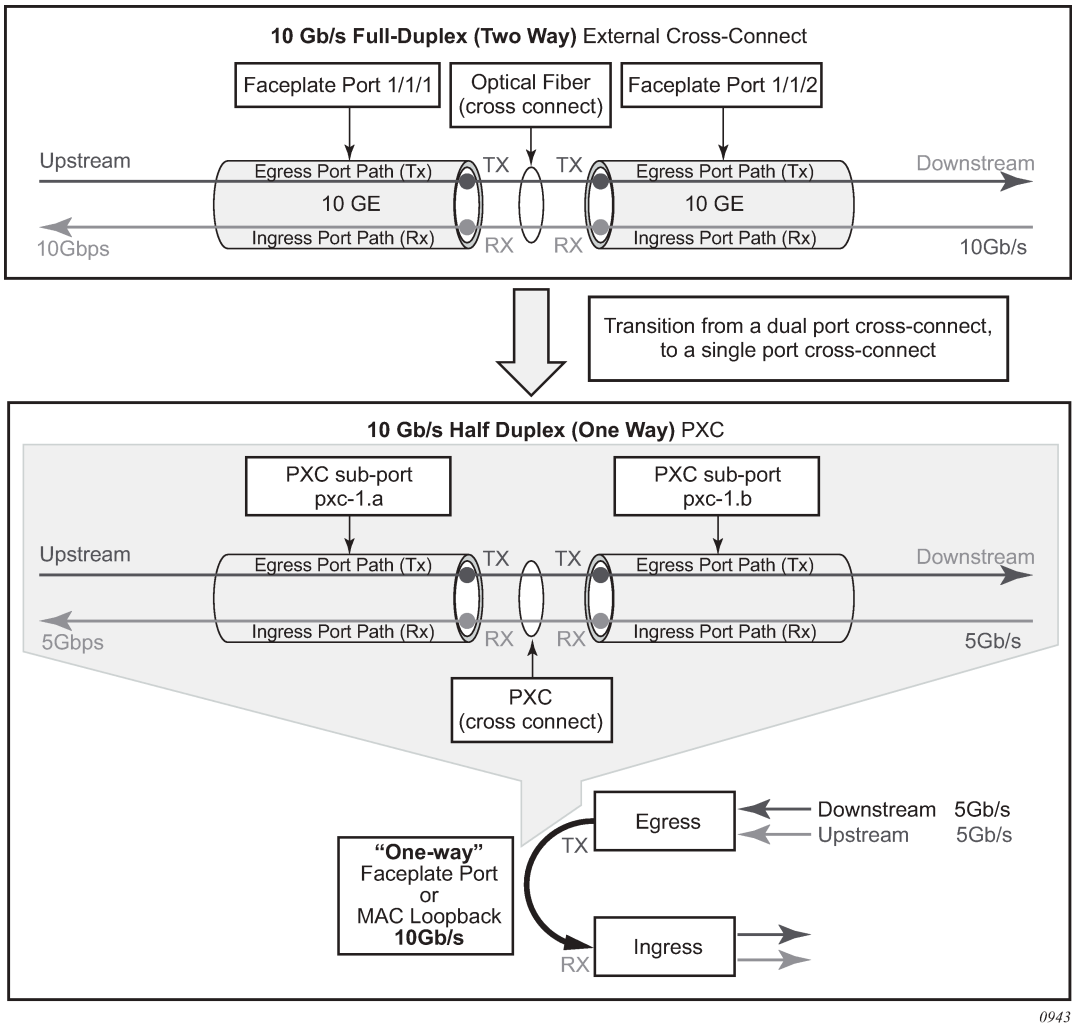
```
A:node-2>config>port-xc# info
----------------------------------------------
        pxc 1 create
            port 1/x1/1/m1/1
            no shutdown
        exit
        pxc 2 create
            shutdown
            port 1/x1/1/m1/1
        exit
        pxc 3 create
            shutdown
            port 1/x1/1/m1/1
        exit
    exit
```

The loopback created in the MAC chip does not have an administrative state, but the port created on top of it does have an administrative state.

6.5 PXC sub-ports

Figure 22: Two cross-connected external ports versus a single cross-connect displays the benefit of PXC sub-ports on top of the cross-connect, which is analogous to two distinct faceplate ports that are connected by a fiber cable.

Figure 22: Two cross-connected external ports versus a single cross-connect



Bidirectional connectivity provided by PXC requires two sub-ports, one in each direction. The router uses these PXC sub-ports as logical configurations to transmit traffic in both directions over a half-duplex (one-way) cross-connect created in the system. As a result, the total bandwidth capacity supported by the mated PXC sub-ports is limited by the bandwidth capacity of the underlying cross-connect (a single faceplate port or a MAC loopback).

For example, if a 10 Gb/s faceplate port is allocated for PXC functions, the sum of downstream and upstream traffic on the mated PXC sub-ports is always less than or equal to 10 Gb/s. The bandwidth distribution is flexible; it can be symmetric (5 Gb/s downstream and 5 Gb/s upstream), or asymmetric (9 Gb/s downstream and 1 Gb/s upstream, 8 Gb/s downstream and 2 Gb/s upstream, or any other downstream and upstream distribution combination). Therefore, the faceplate port speed from the PXC perspective is half-duplex.

Similar logic can be followed for MAC-based PXC, with two key differences:

- The bandwidth (for example, 100 Gb/s) is configured under the MAC loopback and there is no need to allocate an additional faceplate port.

- PXC traffic is not reserved as part of the faceplate port bandwidth, as it is in the port-based PXC where a faceplate port is reserved only for PXC traffic. Instead, the PXC traffic is added to the traffic from the faceplate ports even in situations where all faceplate ports are 100% used, potentially oversubscribing the forwarding complex.

After the faceplate port or the port based on MAC loopback is associated with a PXC ID, a pair of mated PXC sub-ports is automatically created in the classic CLI by the SR OS.

In MD-CLI, the user must manually create the sub-ports.

The sub-ports must be explicitly enabled. Use the following commands to enable the subports:

- **MD-CLI**

```
admin-state enable
```

- **classic CLI**

```
no shutdown
```

The two PXC sub-ports are distinguishable by ".a" and ".b" suffixes. They transmit traffic toward each other, simulating two ports that are interconnected.

Although, the most PXC sub-ports command options are configurable, specific command options are fixed and cannot be changed. For example, PXC sub-ports are created in a hybrid mode and this cannot be modified.

Each PXC sub-port is internally (within the system) represented by an internal four-byte VLAN tag which is not visible to the user. Therefore, traffic carried over the PXC contains four extra bytes, which must be accounted for in the QoS configured on PXC sub-ports.

Example: MD-CLI

```
[ex:/configure port-xc]
A:admin@node-2# info
    pxc 1 {
        admin-state enable
        port-id 1/1/1
    }
    pxc 2 {
        admin-state enable
        port-id 1/1/2
    }
```

Example: classic CLI

```
A:node-2>config>port-xc# info
----------------------------------------------
        pxc 1 create
            port 1/1/1
            no shutdown
        exit
        pxc 2 create
            port 1/1/2
            no shutdown
        exit
----------------------------------------------
```

The preceding configuration automatically creates the following PXC sub-ports. In the following example, the following ports are cross-connected:

- pxc-1.a is cross-connected with pxc-1.b
- pxc-1.b is cross-connected with pxc-1.a
- pxc-2.a is cross-connected with pxc-2.b
- pxc-2.b is cross-connected with pxc-2.a

Example: MD-CLI

```
[ex:/configure]
A:admin@node-2# info
...
    port pxc-1.a {
    }
    port pxc-1.b {
    }
    port pxc-2.a {
    }
    port pxc-2.b {
    }
```

Example: classic CLI

```
A:node-2# admin display-config
...
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
    port pxc-1.a
        exit
    exit
    port pxc-1.b
        exit
    exit
    port pxc-2.a
        exit
    exit
    port pxc-2.b
        exit
    exit
```

6.6 Bandwidth considerations and QoS

Note: See the "QoS continuity" section of "Port Cross-Connect (PXC)" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Interface Configuration Advanced Configuration Guide for Classic CLI* for information about advanced configurations.
See the "QoS continuity" section of "Port Cross-Connect (PXC)" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Interface Configuration Advanced Configuration Guide for MD CLI* for information about advanced configurations.

Bandwidth consumed by PXCs based on faceplate ports correlates with the faceplate's port capacity. Because each PXC allocates a faceplate port for exclusive use, the PXC capacity cannot exceed the card capacity that is already allocated for the faceplate ports. In other words, a PXC based on a faceplate port does not add any additional bandwidth to the forwarding complex. This is in contrast to the MAC-based PXCs, where bandwidth consumed on each PXC is added to the faceplate port capacity. If bandwidth is not carefully managed on cards with MAC- based PXC, extensive periods of oversubscription can occur.

Operating under extended periods of congestion is not recommended and should be avoided. Therefore, practical use of a MAC-based PXC makes sense in an environment where the utilization of faceplate ports is relatively low so the remaining bandwidth can be used for traffic flowing through the MAC-based PXC.

The bandwidth management in the PXC environment is performed through existing QoS mechanisms, and in addition, for MAC-based PXCs by careful selection of the MAC chip and in some instances in fabric taps. The user can control the selection of these entities.

6.6.1 Location selection for internal PXC

The following are general guidelines for MAC chip selection and the loopback naming:

- A suitable card candidate has lower actual traffic volumes through faceplate ports so the unused bandwidth in the forwarding complex can be used for PXC.
- A suitable MAC chip candidate is connected to the faceplate ports with lower bandwidth utilization.
- SR-s platforms with IOM-s cards (XIOM configuration), a loopback ID influences the selection of the fabric tap to which the PXC traffic is mapped. In these platforms, loopback should be distributed over the fabric taps in a way that avoids congestion. This is described in Internal PXC and source fabric taps.

Use the following command to show the connectivity layout between the MAC chips, faceplate ports, and fabric taps.

```
show datapath 1 detail
```

Output example

```
===============================================================================
Card    [XIOM/]MDA  FP  TAP   MAC Chip Num   Connector      Port
-------------------------------------------------------------------------------
1       x1/1        1   1     1             c1             1/x1/1/c1/1
1       x1/1        1   1     1             c1             1/x1/1/c1/2
1       x1/1        1   1     1             c2             1/x1/1/c2/1
1       x1/1        1   1     1             c2             1/x1/1/c2/2
1       x1/1        1   1     1             c3             1/x1/1/c3/1
1       x1/1        1   1     1             c3             1/x1/1/c3/2
1       x1/1        1   N/A   2             c4
1       x1/1        1   N/A   2             c5
1       x1/1        1   N/A   2             c6
1       x1/1        1   1     1             N/A            1/x1/1/m1/1
1       x1/2        2   1     1             c1             1/x1/2/c1/1
1       x1/2        2   1     1             c1             1/x1/2/c1/2
1       x1/2        2   1     1             c1             1/x1/2/c1/3
1       x1/2        2   1     1             c1             1/x1/2/c1/4
1       x1/2        2   1     1             c1             1/x1/2/c1/5
1       x1/2        2   1     1             c1             1/x1/2/c1/6
1       x1/2        2   1     1             c1             1/x1/2/c1/7
1       x1/2        2   1     1             c1             1/x1/2/c1/8
1       x1/2        2   1     1             c1             1/x1/2/c1/9
1       x1/2        2   1     1             c1             1/x1/2/c1/10
1       x1/2        2   N/A   1             c2
1       x1/2        2   N/A   1             c3
1       x1/2        2   N/A   1             c4
1       x1/2        2   N/A   1             c5
1       x1/2        2   N/A   1             c6
1       x1/2        2   N/A   2             c7
1       x1/2        2   N/A   2             c8
1       x1/2        2   N/A   2             c9
1       x1/2        2   2     2             c10            1/x1/2/c10/1
```

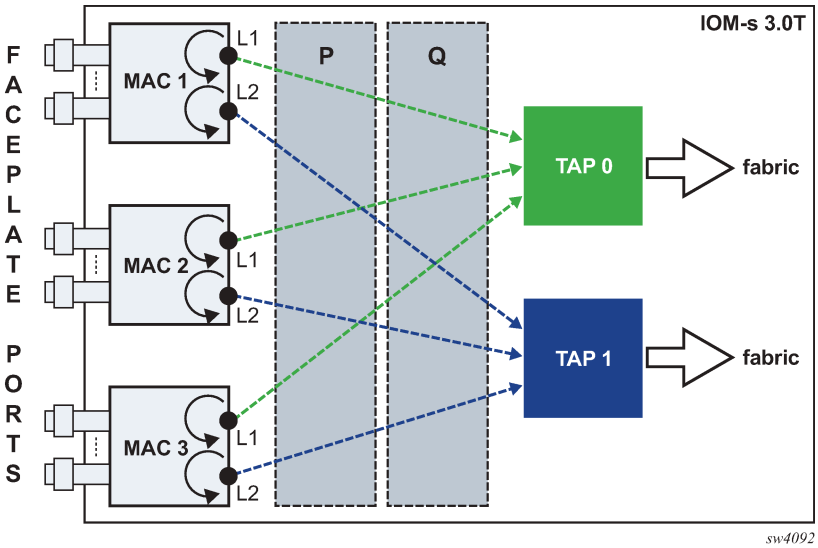
```
1       x1/2        2   2     2             c10           1/x1/2/c10/2
1       x1/2        2   2     2             c10           1/x1/2/c10/3
1       x1/2        2   2     2             c10           1/x1/2/c10/4
1       x1/2        2   2     2             c10           1/x1/2/c10/5
1       x1/2        2   2     2             c10           1/x1/2/c10/6
1       x1/2        2   2     2             c10           1/x1/2/c10/7
1       x1/2        2   2     2             c10           1/x1/2/c10/8
1       x1/2        2   2     2             c10           1/x1/2/c10/9
1       x1/2        2   2     2             c10           1/x1/2/c10/10
1       x1/2        2   N/A   2             c11
1       x1/2        2   N/A   2             c12
1       x1/2        2   N/A   3             c13
1       x1/2        2   N/A   3             c14
1       x1/2        2   N/A   3             c15
1       x1/2        2   N/A   3             c16
1       x1/2        2   N/A   3             c17
1       x1/2        2   N/A   3             c18
```

6.6.1.1 Internal PXC and source fabric taps

PXC traffic passing through the MAC loopback is mapped to a specific source fabric tap that moves the traffic from the local source forwarding complex into the fabric and toward the destination forwarding complex. A fabric tap represents a chip that connects a forwarding complex to the system fabric. Traffic that is on its way from an ingress port (any port, including a PXC port) to the destination port, is always mapped to the same fabric tap (source fabric tap) on the ingress forwarding complex. If the source forwarding complex has two fabric taps, the fabric tap selection plays a role in optimal bandwidth distribution. An example of these forwarding complexes can be found on IOM-s cards in SR-s platforms.

On IOM-s 3.0T, the source tap selection is based on the loopback ID. The mapping scheme is simple; loopbacks with even IDs are mapped to one source tap while loopbacks with odd IDs are mapped to the other. This is shown in Figure 23: Mapping of internal loopbacks to source taps. On IOM-s 1.5T, the mapping is based on the MDA number.

Figure 23: Mapping of internal loopbacks to source taps



6.6.1.2 Bandwidth configuration on the internal PXC

The bandwidth configured on the internal PXC sets the maximum achievable throughput for the PXC, provided sufficient bandwidth is available on the forwarding path.

This configuration does not reserve any bandwidth within the system. The bandwidth consumption of the PXC competes with that of faceplate ports on the forwarding path. If congestion arises, QoS mechanisms manage the traffic.

Use the following command to set the maximum bandwidth for the internal PXC.

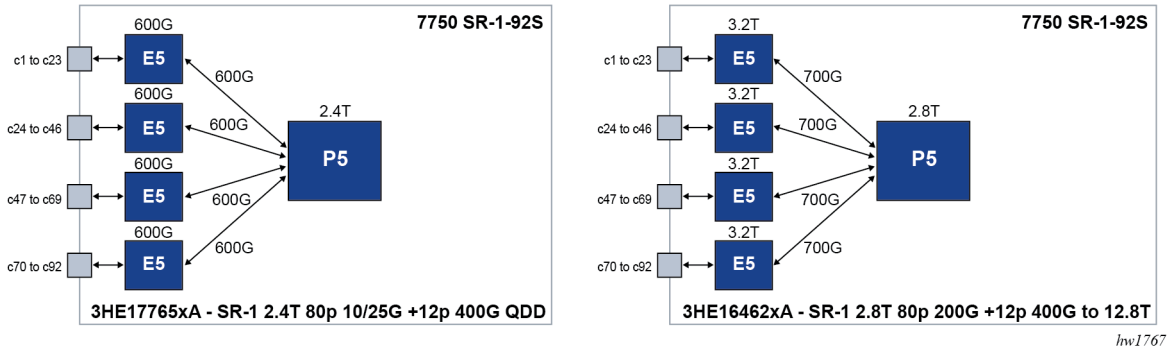
```
configure card xiom mda xconnect mac loopback bandwidth
```

Available bandwidth options are the following: 10G, 25G, 40G, 100G (default), 400G, and 800G. The suitability of the configured bandwidth depends on the capacity of the hardware, as the internal PXC is generated within the MAC chip. Users must verify that the connection of the MAC to the rest of the system supports the desired bandwidth.

Perform the following actions to confirm the correct configuration:

- See the Chassis Installation Guide for your specific hardware. This guide contains system diagrams specific to your equipment.

  Figure 24: 7750 SR-1-92S 2.4T 80p 10/25G +12p 400G QDD and 7750 SR-1-92S 2.8T 80p 200G +12p 400G to 12.8T connector layout



- Check the diagram for your specific hardware to ensure that the link capacity between critical points, such as E5 and P5, meets or exceeds the configured bandwidth for the PXC. For example, in the preceding figure, if a 600G link is shown between E5 and P5, setting the PXC bandwidth to 800G is ineffective.

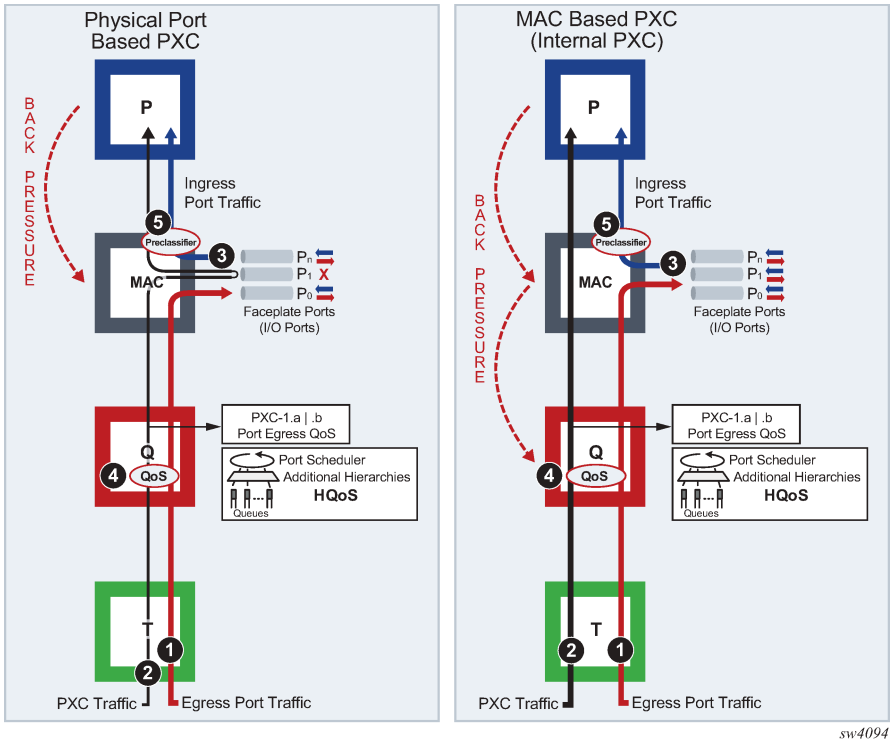
Note: The PXC bandwidth configures the maximum rate available for use and does not restrict other MAC capacities. The system does not check the bandwidth of the E-P link against the configured PXC bandwidth. For example, an 800G setting may be accepted even on a 600G link, which risks the PXC exceeding the MAC capacity and bypassing the QoS controls.

6.6.2 QoS

Interaction points between the PXC traffic and non-PXC traffic in the FC depends on the configured PXC type. Figure 25: Interaction between PXC and non-PXC traffic shows this interaction as the traffic enters

the egress forwarding path from the fabric tap (T). This traffic consists of non-PXC traffic (1) destined for the egress faceplate ports and PXC traffic (2) that is sent (cross-connected) to the ingress forwarding path (P) within the same forwarding complex. Regular ingress traffic from the faceplate ports (3) is added to the stream and merged into the same ingress forwarding path as the PXC traffic.

Figure 25: Interaction between PXC and non-PXC traffic



The physical port-based PXC configuration on the left side of Figure 25: Interaction between PXC and non-PXC traffic, shows interaction of the three traffic streams on the forwarding complex with a PXC based on the faceplate ports. To manage congestion, the user-configured input can be exserted in points 4 and 5.

Point 4 represents regular egress QoS in the traffic manager (Q) applied to an egress port. In this setup, the faceplate port P1 is reserved for PXC traffic which is represented by the two sub ports (PXC sub-ports **pxc**-*id*.*a* and **pxc**-*id*.*b*). Egress QoS is applied to each PXC subport.

Point 5 represents a pre-classifier in the MAC chip that manages ingress bandwidth if transient bursts occur in the ingress datapath (P), which then exserts back pressure toward the MAC. During congestion, the pre-classifier arbitrates between regular ingress traffic from the faceplate ports and the PXC traffic.

The MAC-based PXC configuration on the right side of Figure 25: Interaction between PXC and non-PXC traffic shows the traffic flow in the FC with the MAC-based PXC. Similar to the previous case, the existing egress QoS in the traffic manager (Q) in point 4 is applied to the egress ports. However, the egress port in the PXC case is not a faceplate port but instead it is represented by the configured loopback in the MAC chip. This loopback is configured with the maximum bandwidth using the following command.

```
configure card xiom mda xconnect mac loopback
```

The congestion management logic with internal PXC diverges from the previous scenario because the PXC traffic is moved through the MAC chip straight to the ingress datapath (P), bypassing the egress faceplate ports. Therefore, the pre-classifier in point 5 has no effect on PXC traffic. Any congestion in the

(P) and MAC is managed in the traffic manager (Q) at point 4, as a result of the back pressure from the (P) and MAC toward the (Q).

6.6.2.1 QoS on PXC sub-ports

The network user must understand the concept of the PXC sub-ports described in Port-based PXC for correct egress QoS configuration in the traffic manager (Q).

The following summarizes key points for the PXC sub ports:

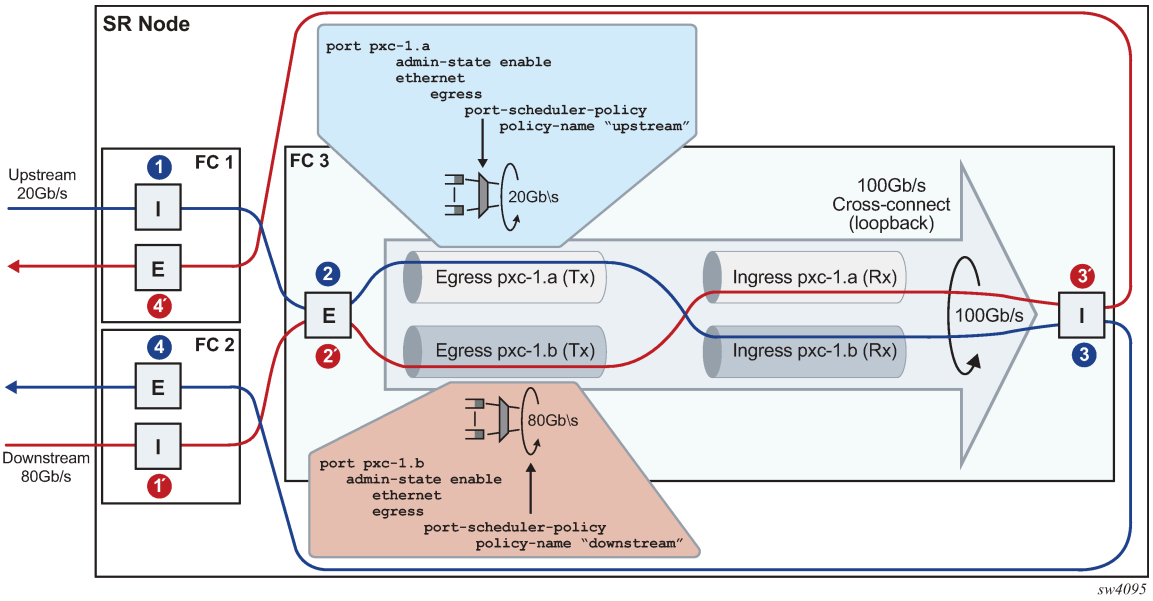
- Each subport (**pxc**-*id*.*a* and **pxc**-*id*.*b*) in a PXC is, in the context of egress QoS, treated as a separate port with its own port scheduler policy.
- Both sub-ports are created on top of the same loopback configuration (port- based or MAC-based). For faceplate ports, this bandwidth is determined by the port capabilities (for example, a 100 Gb\s port versus a 400 Gb\s port) and for the MAC loopback, this bandwidth is configurable.

Funneling traffic from two PXC sub-ports through the same loopback requires separate bandwidth management for each PXC sub-ports. The sum of the configured bandwidth caps for the Egress Port Scheduler (EPS) under the two PXC sub-ports should not exceed the bandwidth capacity of the underlying loopback. Figure 26: Bandwidth management on PXC sub-ports shows an example of this concept where each PXC sub-port is divided into two parts, the Tx or the egress part and the Rx or the ingress part. Figure 26: Bandwidth management on PXC sub-ports shows bidirectional traffic entering and exiting the SR node at forwarding complex 1 and 2, with PXC processing on forwarding complex 3. In the upstream direction, traffic enters SR node at the ingress forwarding complex 1 at point (1) and is redirected to the PXC for additional processing, points (2) and (3). From there, traffic is sent by the egress forwarding complex 2 out of the node, at point (4).

Similar logic can be followed in the downstream (opposite) direction where the traffic enters the ingress forwarding complex 2 at point (1’), it is redirected to the same PXC on forwarding complex 3 and exists the node on forwarding complex 1 at point (4’).

In this example with the maximum loopback bandwidth of 100 Gb\s, port-schedulers under the PXC egress subports must be configured to support their respective anticipated bandwidth in each direction (20 Gb\s upstream and 80 Gb\s downstream), for the total bandwidth of 100 Gb\s supported on the cross-connect.

Figure 26: Bandwidth management on PXC sub-ports



Traffic traversing PXC contains an overhead of 4 bytes per packet that are attributed to the internal VLAN tag used for PXC sub-port identification within the SR node. However, these 4 bytes are not accounted for in the configured QoS rates. Therefore, the user should take this into consideration when configuring rates on QoS objects under PXC ports.

6.6.3 Queue allocation on PXC sub-ports

PXC sub-ports are auto-configured in hybrid mode and this cannot be changed by configuration. The PXC sub-ports each have a set of queues on the network egress side and a set of queues on the access egress and ingress (per SAP or ESM subscriber). Queues on network ingress are shared per FP or per MDA, as they are on non-PXC ports in hybrid mode.

Queue groups are allocated per PXC sub-ports.

6.6.4 Pool allocations on PXC ports

Queue buffers are created in buffer pools and are used for traffic buffering when queues are congested. Buffer pools are allocated per forwarding complex or per cross-connect.

Each cross-connect has three associated buffer pools:

- access ingress
- access egress
- network egress

The network ingress pool is shared between all faceplate ports on a forwarding complex. The size of the buffer pools is automatically determined by the system based on the forwarding complex type and cross-connect configuration.

6.7 Operational states

A port under a PXC (for example, port 1/1/1 or port 1/x1/1/m1/1), the PXC itself (PXC ID represented by the cross-connect port configuration port-xc pxc 1), and PXC sub-ports (for example, port pxc-1.*a* and pxc-1.*b*) all have administrative and operational states.

For a port-based PXC, when all layers of a PXC (PXC port, PXC ID, and PXC sub-ports) are operationally up, the faceplate port status LED on the faceplate blinks amber. The port activity LED lights green in the presence of traffic on PXC ports and turns off in the absence of traffic on PXC ports. The presence of the optical transceiver on the PXC has no effect on its operational state. Traffic cannot be sent out through the transceiver or be received through the transceiver from the outside. However, the existing traps related to insertion or removal of a transceiver (SFF Inserted/Removed) are supported. The "Signal-Fail" alarm on the PXC is suppressed.

The operational state of the PXC ID is derived from its administrative state and the operational state of the sub-ports.

The operational state of the PXC sub-ports is dependent on the operational state of the underlying port (faceplate port or MAC loopback) and the administrative state of the corresponding PXC ID.

6.8 PXC statistics

Two types of statistics can be collected on a regular, non-PXC Ethernet port:

- Low-level port statistics which provide information about conditions on the data-link layer and physical port, for example, the aggregate number of forwarded and dropped octets or bytes on the data-link layer (Layer 2 MAC), FCS errors, number of collisions, and so on. These statistics can be viewed with the **show port** command.
- Network-level statistics provide information about forwarded and dropped octets or packets on a per-queue level on network ports. These statistics can be viewed with the **show port detail** command.

Statistics collection ability on the PXC port depends on whether the PXC is port-based or MAC-based (internal).

6.8.1 Statistics on faceplate PXC ports

The statistics on the faceplate PXC ports are maintained only on the data-link layer (Layer 2 MAC). The internal Q-tag used for PXC sub-port identification within the router is included in the displayed octet count. The collected statistics represent the combined upstream and downstream traffic carried by the corresponding PXC sub-ports.

For example, in port level statistics output for a faceplate PXC port, the output count represents the upstream and downstream traffic flowing out of the faceplate port while the input count represents the same looped traffic returning into the same port.

```
show port 1/1/1 detail
```

Output example

```
...
```

```
===============================================================================
Traffic Statistics
===============================================================================
                                                    Input                 Output
-------------------------------------------------------------------------------
Octets                                          290164703             290164703
Packets                                           2712661               2712661
Errors                                                  0                     0
```

Statistics are cleared when a faceplate port is added or removed from the PXC.

Statistics collection to a local file is not supported for faceplate PXC ports.

Queues are not instantiated on the faceplate PXC ports, therefore, the network level (queue) statistics are not maintained in that location.

6.8.2 Statistics collection on internal (MAC-based) PXC

Internal ports created in the MAC chip (for example port 1/x1/1/m1/1) do not have Layer 2 MAC addresses, therefore, statistics based on the data-link layer (Layer 2 MAC) are not available.

6.8.3 Statistics collection on PXC sub-ports and PXC LAG

PXC sub-ports (for example, pxc-1.a and pxc-1.b) provide aggregated network-level statistics (queue statistics). Physical-level statistics are not supported on PXC sub-ports because these ports do not relay on MAC statistics.

The statistics on a PXC sub-port are aggregated counts of all queues in each traffic direction for the following:

- forwarded packets
- forwarded octets
- dropped packets
- dropped octets

The statistics collection is triggered on demand at the time of executing either of the following commands.

```
show port pxc-1.a statistics queue-aggregate
monitor port pxc-1.a interval 30 0 aggregate-queue
```

The collected statistics are cached for 30 seconds. If multiple consecutive executions of these commands occur within the 30 second period, the statistics counters remains unchanged from the previous reads. Therefore, the minimum interval between two executions of the following command should be at least 30 seconds apart.

```
show port statistics queue-aggregate
```

Examples for PXC statistics on individual PXC sub-ports

Use the following command to display aggregate queue statistics.

```
show port pxc-1.a statistics aggregate-queue
```

Output example

```
===============================================================================
Port Statistics on Slot 1
===============================================================================
Port-id                  Ingress Packets Fwd   Ingress Octets Fwd
                        Ingress Packets Drop   Ingress Octets Drop
                          Egress Packets Fwd     Egress Octets Fwd
                         Egress Packets Drop     Egress Octets Drop
-------------------------------------------------------------------------------
pxc1.a                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
                                        55451          22144
===============================================================================
```

Use the following command to display aggregate queue statistics with the **interval** and **repeat** option.

```
monitor port pxc-1.a interval 30 repeat 10 aggregate-queue
```

Output example

```
===============================================================================
Monitor statistics for port pxc-1.a
===============================================================================
 Ingress Packets Fwd      Ingress Octets Fwd
Ingress Packets Drop      Ingress Octets Drop
  Egress Packets Fwd      Egress Octets Fwd
 Egress Packets Drop      Egress Octets Drop
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
At time t = 0 sec (Base Statistics)
-------------------------------------------------------------------------------
             4654649       94523288
               22544          99852
            98652214       65889554
               55451          22144
-------------------------------------------------------------------------------
At time t = 30 sec (Mode: Delta)
-------------------------------------------------------------------------------
             4654649       94523288
               22544          99852
            98652214       65889554
               55451          22144
 -------------------------------------------------------------------------------
At time t = 60 sec (Mode: Delta)
-------------------------------------------------------------------------------
             4654649       94523288
               22544          99852
            98652214       65889554
               55451          22144
-------------------------------------------------------------------------------
```

Use the following command to display aggregate queue statistics with the **interval**, **repeat**, and **rate** option.

```
monitor port pxc-1.a interval 30 repeat 10 rate aggregate-queue
```

Output example

```
===============================================================================
Monitor statistics for port pxc-1.a
===============================================================================
                                            Input                  Output
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
At time t = 0 sec (Base Statistics)
-------------------------------------------------------------------------------
Forwarded Packets                           454649        94288
Forwarded Bytes                             3343434      777998

-------------------------------------------------------------------------------
At time t = 30 sec
-------------------------------------------------------------------------------
Rate [kbps]                                 4654649      94288
Utilization (% of port capacity)            22.54        9.98

-------------------------------------------------------------------------------
At time t = 60 sec
-------------------------------------------------------------------------------
Rate [kbps]                                 4654649      94288
Utilization (% of port capacity)            22.54        9.98
-------------------------------------------------------------------------------
```

Examples for PXC statistics on PXC LAG

Use the following command to display aggregate queue statistics on PXC LAG.

```
show lag 1 statistics aggregate-queue
```

Output example

```
===============================================================================
LAG Statistics
===============================================================================
Description  : N/A

Port-id                  Ingress Packets Fwd   Ingress Octets Fwd
                        Ingress Packets Drop   Ingress Octets Drop
                          Egress Packets Fwd     Egress Octets Fwd
                         Egress Packets Drop     Egress Octets Drop
-------------------------------------------------------------------------------
pxc1.a                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
                                        55451          22144

pxc2.a                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
                                        55451          22144
-------------------------------------------------------------------------------
Totals                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
                                        55451          22144
===============================================================================
```

Use the following command to display aggregate queue statistics with the **interval** and **repeat** option.

```
monitor lag 1 interval 30 repeat 10 aggregate-queues
```

Output example

```
===============================================================================
Monitor statistics for LAG ID 1
===============================================================================

Port-id                  Ingress Packets Fwd   Ingress Octets Fwd
                        Ingress Packets Drop   Ingress Octets Drop
                          Egress Packets Fwd     Egress Octets Fwd
                         Egress Packets Drop     Egress Octets Drop
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
At time t = 0 sec (Base Statistics)
-------------------------------------------------------------------------------

pxc1.a                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
                                        55451          22144

pxc2.a                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
                                        55451          22144
-------------------------------------------------------------------------------
Totals                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
                                        55451          22144
-------------------------------------------------------------------------------

At time t = 30 sec (Mode: Delta)
-------------------------------------------------------------------------------
pxc1.a                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
                                        55451          22144

pxc2.a                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
                                        55451          22144
-------------------------------------------------------------------------------
Totals                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
                                        55451          22144
-------------------------------------------------------------------------------

At time t = 60 sec (Mode: Delta)
-------------------------------------------------------------------------------
pxc1.a                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
                                        55451          22144

pxc2.a                                4654649       94523288
                                        22544          99852
                                     98652214       65889554
```

```
                                        55451         22144
-------------------------------------------------------------------------------
Totals                                4654649       94523288
                                        22544          99852
                                      98652214       65889554
                                        55451          22144
```

Use the following command to display aggregate queue statistics with the **interval**, **repeat**, and **rate** option.

```
monitor lag 1 interval 30 repeat 10 rate aggregate-queues
```

Output example

```
===============================================================================
Monitor statistics for LAG ID 1
===============================================================================

Port-id                  Ingress Rate [kbps]   Egress Rate [kbps]
                        Ingress Utilization   Egress Utilization
                         % of port capacity)      (% of port capacity)

-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
At time t = 0 sec (Base Statistics)
-------------------------------------------------------------------------------
pxc1.a                                0                   0
                                      0                   0


pxc2.a                                0                   0
                                      0                   0

-------------------------------------------------------------------------------
Totals                                4654649       94523288
                                        22.44            17.52

-------------------------------------------------------------------------------

At time t = 30 sec (Mode: Delta)
-------------------------------------------------------------------------------
pxc1.a                                4654649       94523288
                                        25.44            10.85



pxc2.a                                4654649       94523288
                                        22.44            11.52

-------------------------------------------------------------------------------
Totals                                4654649       94523288
                                        22.44            17.52
-------------------------------------------------------------------------------

At time t = 60 sec (Mode: Delta)
-------------------------------------------------------------------------------
pxc1.a                                4654649       94523288
                                        25.44            10.85



pxc2.a                                4654649       94523288
```

```
                                        22.44          11.52

-------------------------------------------------------------------------------
Totals                                4654649       94523288
                                        22.44          17.52
```

6.8.3.1 MIBs

PXC sub-ports statistics are represented in a MIB table tmnxPortAggQueueStatsTable which is defined in TIMETRA-PORT-MIB.mib with the following entries.

```
TmnxPortAggQueueStatsEntry         ::= SEQUENCE
{
    tmnxPortAggQueueIngPktsFwd      Counter64,
    tmnxPortAggQueueIngOctsFwd      Counter64,
    tmnxPortAggQueueIngPktsDrop     Counter64,
    tmnxPortAggQueueIngOctsDrop     Counter64,
    tmnxPortAggQueueEgrPktsFwd      Counter64,
    tmnxPortAggQueueEgrOctsFwd      Counter64,
    tmnxPortAggQueueEgrPktsDrop     Counter64,
    tmnxPortAggQueueEgrOctsDrop     Counter64,
    tmnxPortLastClearedTime         TimeStamp,
    tmnxPortLastFetchedTime         TimeStamp

}
```

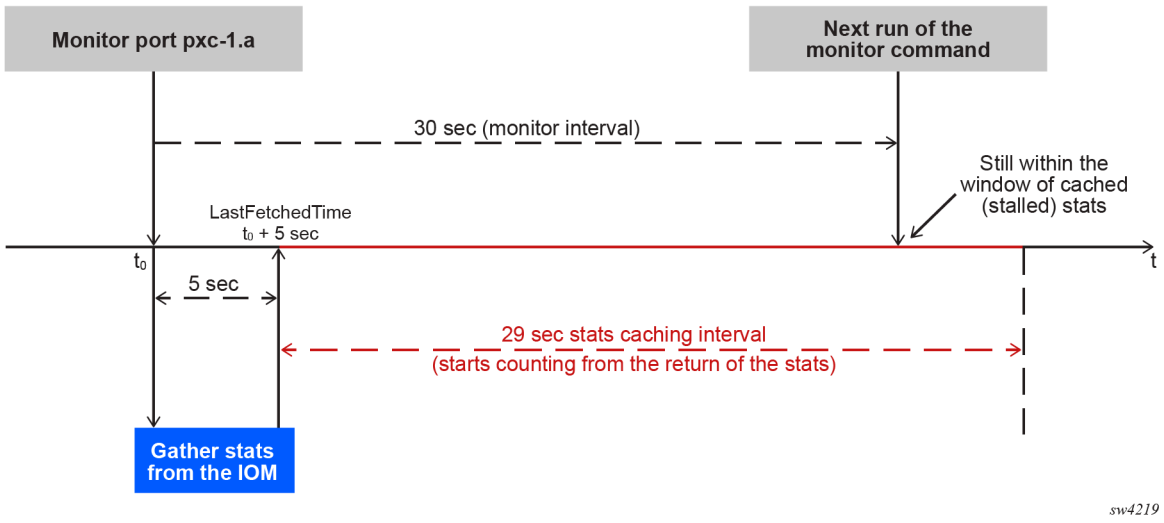
6.8.3.2 Restrictions

The following items describe monitor port restriction.

- Monitor port command allows monitoring of five simultaneous ports. Mixing of PXC and regular ports in the same monitor command is not supported.
- When monitoring ports with a large number of queues, it is possible that the longer time needed for statistics collection may lead to every other output of the monitor command displaying all zeros. This is particularly true at shorter monitoring intervals, such as the minimum of 30 seconds. To ensure consistent non-zero outputs, Nokia recommends gradually increasing the monitoring interval. The recommended monitoring interval with larger number of queues is 60 seconds.

  The following diagram illustrates this issue.

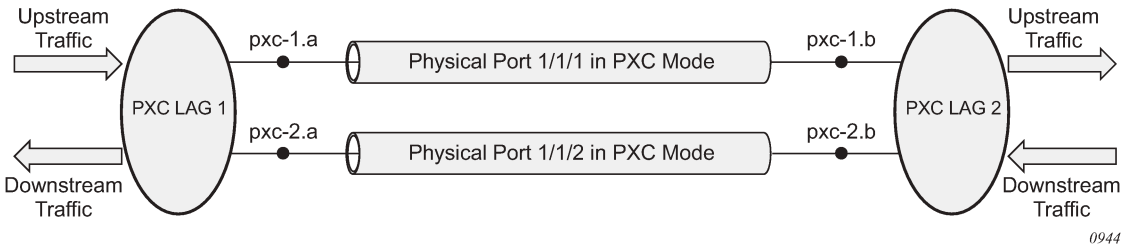
Figure 27: Monitor port interval issue



6.9 PXC LAG

PXC sub-ports can be aggregated into a PXC LAG for increased capacity and card redundancy. A logical concept of a PXC LAG is shown in Figure 28: Logical concept of a LAG on PXC ports.

Figure 28: Logical concept of a LAG on PXC ports



Although the configuration allows for a mix of port-based PXCs and MAC-based PXCs in a LAG, the configuration should be used in a production network only during a short migration period when transitioning from one type of PXC to the other. Outside of the migration, the PXCs in a LAG should be of the same type, for example, a LAG should contain only port-based PXCs or only MAC-based PXCs but not both.

The LAGs on PXC ports must be configured in pairs as shown in the following example.

Example: MD-CLI

```
[ex:/configure]
A:admin@node-2# info
...
    lag "lag-1" {
        description "lag in the up direction"
        port pxc-1.a {
```

```
        }
        port pxc-2.a {
        }
    }
    lag "lag-2" {
        description "lag in the down direction"
        port pxc-1.b {
        }
        port pxc-2.b {
        }
    }
```

Example: classic CLI

```
A:node-2# configure lag 1
A:node-2>config>lag$ info
----------------------------------------------
        description "lag in the up direction"
        port pxc-1.a
        port pxc-2.a
----------------------------------------------
A:node-2# configure lag 2
A:node-2>config>lag$ info
----------------------------------------------
        description "lag in the down direction"
        port pxc-1.b
        port pxc-2.b
        no shutdown
----------------------------------------------
```

Within the router, the two sides of the PXC LAG (LAG 1 and LAG 2 in the example configuration) are not aware of their interconnection. As a result, the operational state of one side of the PXC LAG is not influenced by the state of the PXC LAG on the other side.

PXC sub-ports in a LAG must have the same properties (such as the same speed). Mixing PXC sub-ports and non-PXC ports is not allowed. The first port added to a LAG determines the type of LAG (PXC or non-PXC).

Statistics in the output of the **show lag statistics** command represent combined traffic carried over the referenced LAG and its pair (lag 1 and lag 2 in the above example).

6.10 Basic PXC provisioning

The CLI configuration flow example shown in the following figure represents a PXC configuration based on the faceplate port. The oval marked "User" represents a configuration step that the user must perform. The block marked "Dynamic" represents a step that the system performs automatically without a user's assistance.

Figure 29: MD-CLI flow

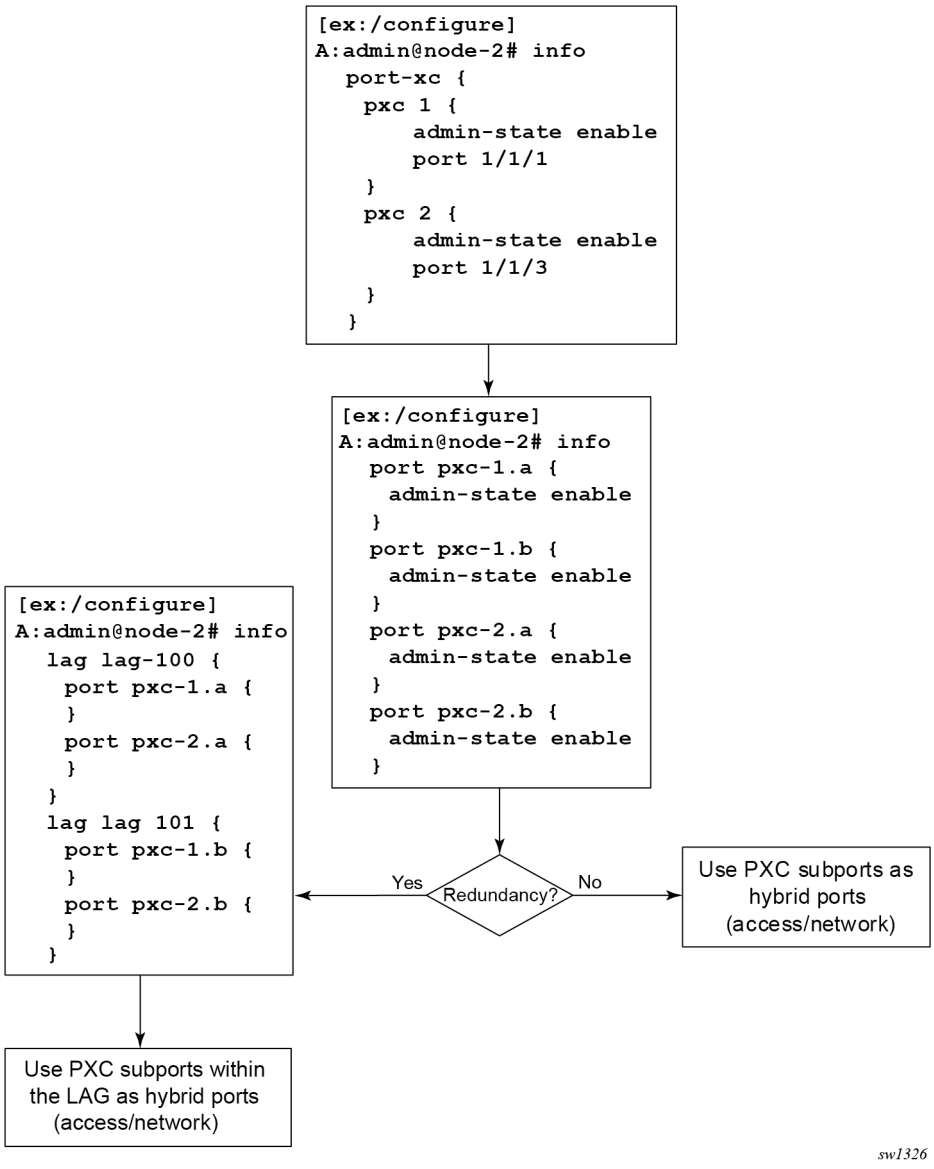


Figure 30: MD-CLI PXC configuration on internal loopback

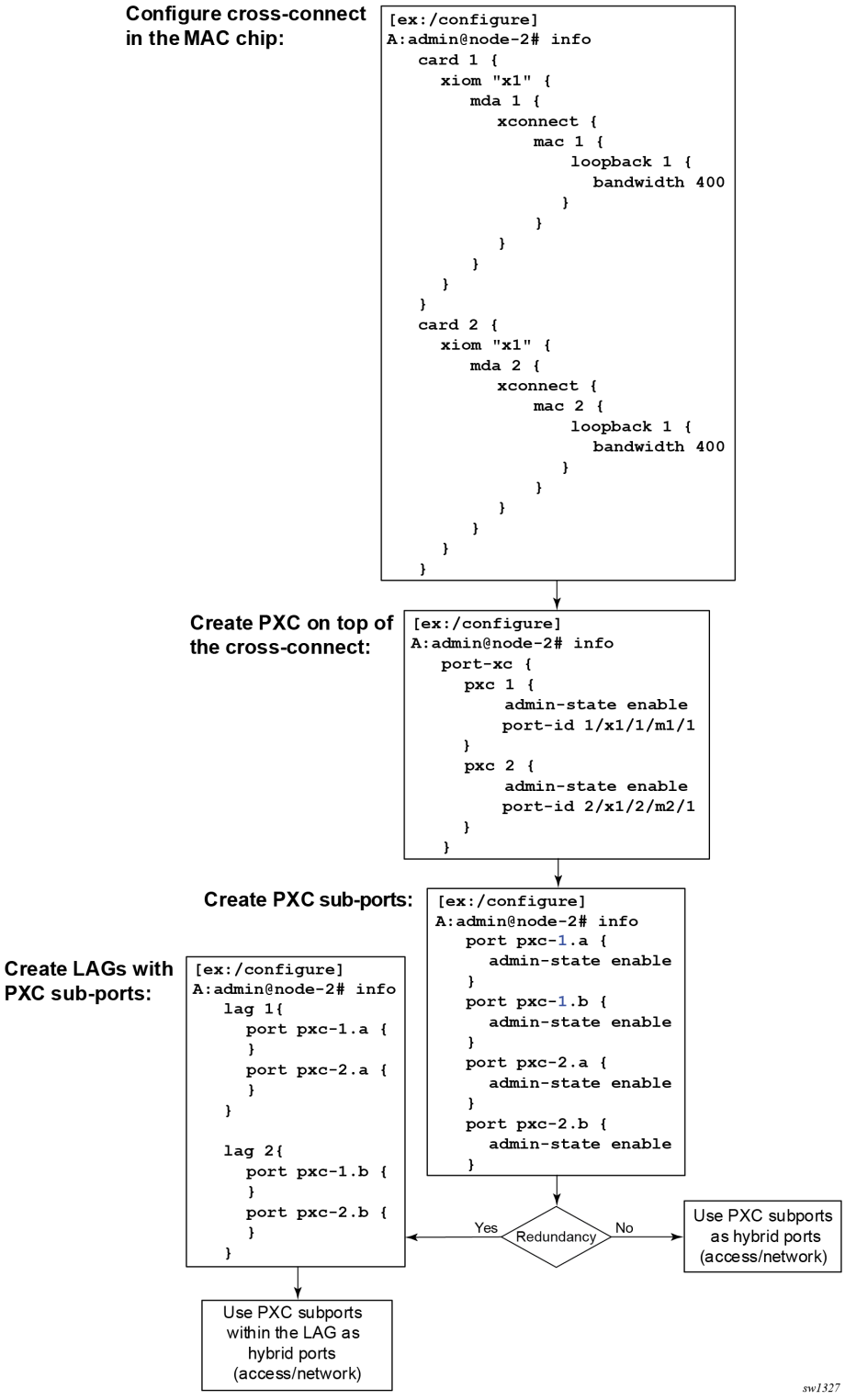


Figure 31: Classic CLI flow

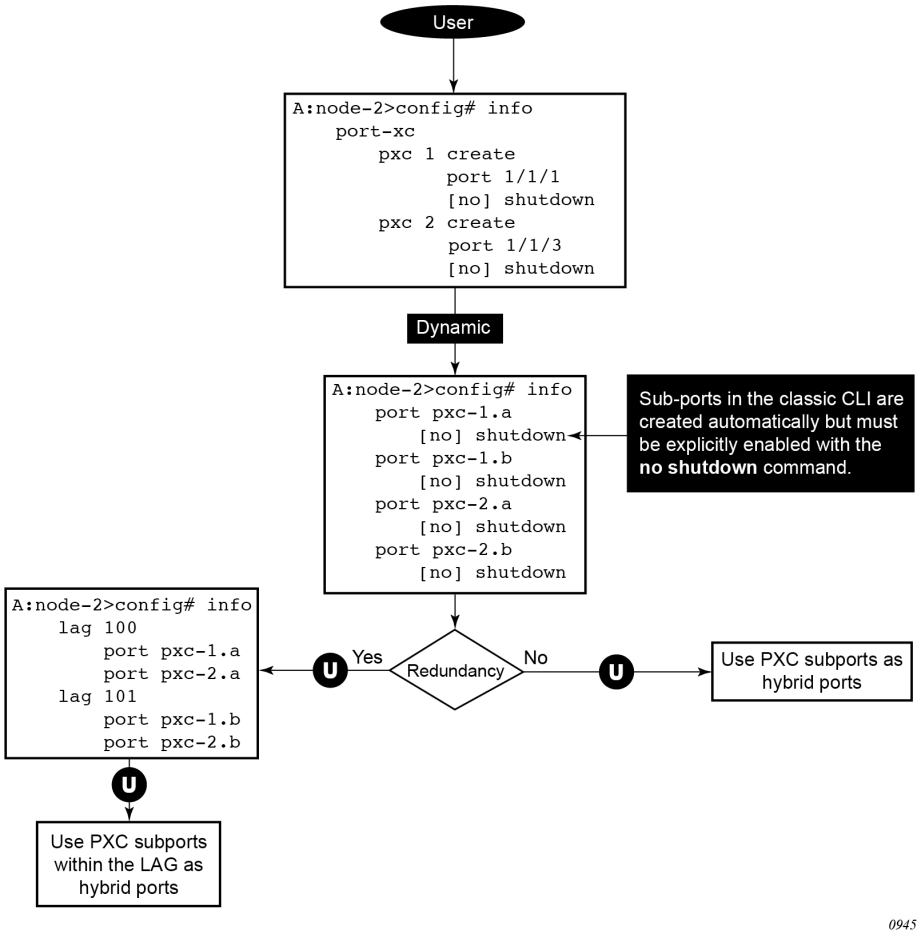
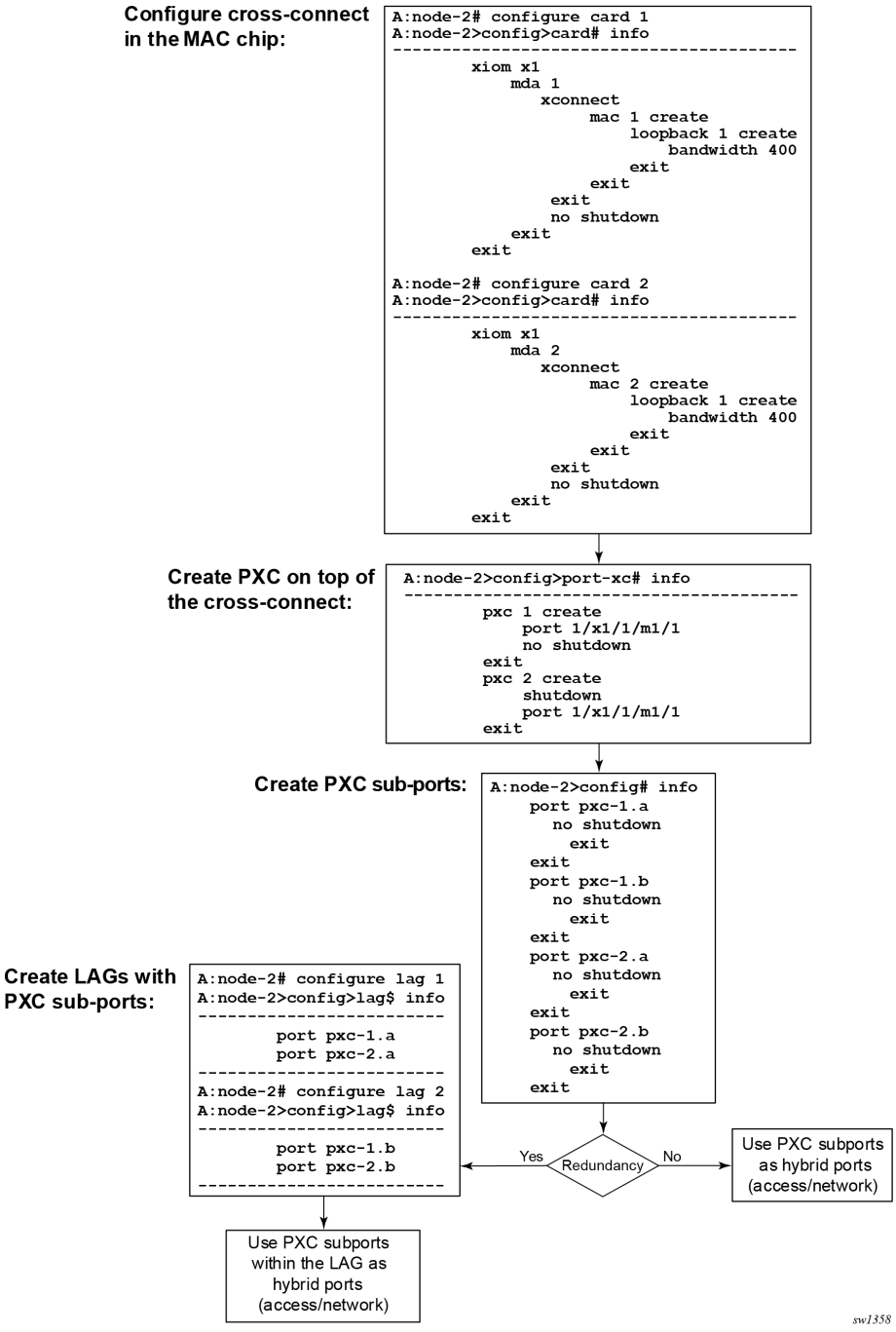


Figure 32: Classic CLI PXC configuration on internal loopback



6.11 PXC mirroring and LI

Traffic on a PXC sub-port can be mirrored or lawfully intercepted (LI). For example, subscriber "Annex1" traffic arriving on a PXC sub-port is mirrored if "Annex1" is configured as a mirror or LI source. A PXC sub-port can also be used to transmit mirror and LI traffic out from a mirror-destination service (such as a mirror-dest SAP or SDP can egress out a PXC sub-port, or a routable LI encapsulated packet can be forwarded and transmitted out a PXC sub-port).

A mirror destination can be configured to transmit mirrored and LI traffic out of a SAP on a PXC sub-port that is then cross connected into a VPLS service where a VXLAN encapsulation is added to the mirrored packets before transmission out of the node.

The internal Q-tag that represents the PXC sub-port within the system is included in the lawfully intercepted copy of the packet for traffic intercepted (mirrored) on the ingress side of a PXC sub-port, when the associate mirror-dest service is of type **ether** (the default) with routable lawful interception encapsulation in the following context.

Use the following command to configure a mirror destination to transmit mirrored and LI traffic from a SAP on a PXC sub-port.

```
configure mirror mirror-dest encap
```

See the *7450 ESS, 7750 SR, 7950 XRS, and VSR OAM and Diagnostics Guide* for information about LI.

6.12 Multichassis redundancy

Multichassis Synchronization (MCS) configuration is supported for entities using PXCs in the following context.

```
configure redundancy multi-chassis peer sync
```

However, MC-LAG is not supported directly on PXCs because PXCs are not directly connected to external equipment.

6.13 Health monitoring on the PXC

Health monitoring of the PXC sub-ports is based on EFM OAM where the Information OAMPDUs are transmitted by each peer (pxc sub-port) at the configured intervals. Their purpose is to perform keepalive and critical notification functions.

For PXCs with underlying faceplate ports, status monitoring can be enabled for either or both of the faceplate ports:

- crc-monitoring (link quality) on the RX side of the port using the following command

  ```
  configure port ethernet crc-monitor
  ```

- crc-monitoring (link quality) on the path from IOM toward MDA using the following command

```
configure port ethernet down-on-internal-error
```

The TX disable flag (disable remote laser on error) is not supported on PXC ports because PXC ports are looped. Use the following command to turn the flag off:

– **MD-CLI**

```
configure port ethernet down-on-internal-error tx-laser off
```

– **classic CLI**

```
configure port ethernet down-on-internal-error tx-disable
```

CRC monitoring on the RX side of the faceplate ports has the following characteristics:

- monitor ingress error conditions
- compare error counts against configurable thresholds
- CRC errors are only recorded if frames are transmitted
- crossing the signal degrade (SD) threshold raises log event
- crossing the signal failure (SF) threshold takes down the port's operational state
- error rate thresholds uses format m·10-n; both the threshold (n) and multiplier (m) are configurable

Health monitoring on the faceplate ports level is disabled by default.

In addition to the explicitly configured aforementioned health monitoring mechanisms, PXC operational state transitions are by default reported by a port UP/DOWN trap:

478 2015/10/22 14:08:15.86 UTC WARNING: SNMP #2004 Base pxc-1.b Interface pxc-1.b is not operational

478 2015/10/22 14:08:15.86 UTC WARNING: SNMP #2004 Base pxc-1.b Interface pxc-1.b is operational

6.14 Configuration example

Note: See the "Configuration" section of "Port Cross-Connect (PXC)" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Interface Configuration Advanced Configuration Guide for Classic CLI* for information about advanced configurations.
See the "Configuration" section of "Port Cross-Connect (PXC)" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Interface Configuration Advanced Configuration Guide for MD CLI* for information about advanced configurations.

The following example is based on a PXC on a faceplate port. Subscriber traffic with QinQ encapsulation arriving on two different line cards (3 and 4) is terminated on the PXC LAG on line cards 1 and 2. With this method, if one of the ingress line cards (3 or 4) fails, the subscriber traffic remains unaffected (continues to be terminated on line cards 1 and 2) provided that the correct protection mechanism is implemented in the access part of the network. This protection mechanism in the access part of the network must ensure that traffic arriving on card 3 can be rerouted to card 4 if card 3 fails. The opposite must be true as well (the path to card 4 must be protected by a path to card 3).

PXC can be on any card, independent of ingress ports.

Example: Faceplate (physical) port configuration on cards 3 and 4 (MD-CLI)

```
[ex:/configure port 3/1/1]
A:admin@node-2# info
        description "access I/O port on card 3; ecap is null which means that all
         VLAN tagged and untagged traffic will be accepted”
        ethernet {
          mode access
          encap-type null
       }

[ex:/configure port 4/1/1]
A:admin@node-2# info
        description "access I/O port on card 4; ecap is null which means that all
         VLAN tagged and untagged traffic will be accepted”
        ethernet {
          mode access
          encap-type null
       }
    }
```

Example: Faceplate (physical) port configuration on cards 3 and 4 (classic CLI)

```
A:node-2>config# port 3/1/1
A:node-2>config>port# info
----------------------------------------------
        description "access I/O port on card 3; ecap is null which means that all VLAN
 tagged and untagged traffic will be accepted"
        ethernet
            mode access
        exit
A:node-2>config>port# info detail
----------------------------------------------
...
        ethernet
...
            encap-type null
...
A:node-2>config# port 4/1/1
A:node-2>config>port# info
----------------------------------------------
        shutdown
        description "access I/O port on card 4; ecap is null which means that all VLAN
 tagged and untagged traffic will be accepted"
        ethernet
            mode access
        exit
A:node-2>config>port# info detail
----------------------------------------------
...
        ethernet
...
            encap-type null
...
```

Example: PXC configuration on cards 1 and 2 (MD-CLI)

```
[ex:/configure port-xc]
A:admin@node-2# info
    pxc 1 {
        admin-state enable
        description "PXC on card 1"
```

```
        port-id 1/1/1
    }
    pxc 2 {
        admin-state enable
        description "PXC on card 2"
        port-id 2/1/1
    }
```

Example: PXC configuration on cards 1 and 2 (classic CLI)

```
A:node-2>config>port-xc# info
----------------------------------------------
        pxc 1 create
            description "PXC on card 1"
            port 1/1/1
            no shutdown
        exit
        pxc 2 create
            description "PXC on card 2"
            port 2/1/1
            no shutdown
        exit
----------------------------------------------
```

The user must manually configure the sub-port encapsulation (the default is dot1q). PXC sub-ports transparently pass traffic with preserved QinQ tags from the .b side of the PXC to the .a side of the PXC where a *.* capture SAP is configured.

Example: Configuration of the sub-port encapsulation (MD-CLI)

```
[ex:/configure port pxc-2.b]
A:admin@Vnode-2# info
...
    port pxc-1.a {
        admin-state enable
        description "termination PXC side; *.* capture SAP will be configured here"
        ethernet {
            encap-type qinq
        }
    }
    port pxc-1.b {
        admin-state enable
        description "transit PXC side; all VLAN tags (*) will be transparently passed via
 this side"
        ethernet {
            encap-type qinq
        }
    }
    port pxc-2.a {
        admin-state enable
        description "together with pxc-1.a, this sub-port is a member of LAG 1"
        ethernet {
            encap-type qinq
        }
    }
    port pxc-2.b {
        admin-state enable
        description "together with pxc-1.b, this sub-port is a member of LAG 2"
        ethernet {
            encap-type qinq
        }
```

```
    }
```

Example: Configuration of the sub-port encapsulation (classic CLI)

```
A:node-2# admin display-config
...
#--------------------------------------------------
echo "Port Configuration"
#--------------------------------------------------
...
    port pxc-1.a
        description "termination PXC side; *.* capture SAP will be configured here"
        ethernet
            encap-type qinq
        exit
        no shutdown
    exit
    port pxc-1.b
        description "transit PXC side; all VLAN tags (*) will be transparently passed via
 this side"
        ethernet
            encap-type qinq
        exit
        no shutdown
    exit
    port pxc-2.a
        description "together with pxc-1.a, this sub-port is a member of LAG 1"
        ethernet
            encap-type qinq
        exit
        no shutdown
    exit
    port pxc-2.b
        description "together with pxc-1.b, this sub-port is a member of LAG 2"
        ethernet
            encap-type qinq
        exit
        no shutdown
    exit
```

Example: PXC LAG configuration (MD-CLI)

```
[ex:/configure]
A:admin@node-2# info
...
    lag "lag-1" {
        admin-state enable
        description "terminating side of the cross-connect"
        port pxc-1.a {
        }
        port pxc-2.a {
        }
    }
    lag "lag-2" {
        admin-state enable
        description "transient side of the cross-connect"
        port pxc-1.b {
        }
        port pxc-2.b {
        }
    }
```

Example: PXC LAG configuration (classic CLI)

```
A:node-2# configure lag 1
A:node-2>config>lag$ info
----------------------------------------------
        description "terminating side of the cross-connect"
        port pxc-1.a
        port pxc-2.a
        no shutdown
----------------------------------------------
A:node-2# configure lag 2
A:node-2>config>lag$ info
----------------------------------------------
        description "transient side of the cross-connect"
        port pxc-1.b
        port pxc-2.b
        no shutdown
----------------------------------------------
```

Passing traffic from the ingress side on access (ports 3/1/1 and 4/1/1) via the transient PXC sub-ports pxc-1.b and pxc-2.b to the termination side of the PXC is performed through VPLS.

Example: Passing traffic through VPLS (MD-CLI)

```
[ex:/configure service]
A:admin@node-2# info
    vpls "1" {
        admin-state enable
        description "stitching access side to the anchor"
        customer "1"
        split-horizon-group "access (I/O) side" {
        }
        sap 3/1/1 {
            admin-state enable
            description "I/O port"
            split-horizon-group "access"
        }
        sap 4/1/1 {
            admin-state enable
            description "I/O port"
            split-horizon-group "access"
        }
        sap lag-2:* {
            admin-state enable
            description "transit side of PXC"
        }
    }
```

Example: Passing traffic through VPLS (classic CLI)

```
A:node-2>config>service# info
----------------------------------------------
...
        vpls 1 name "1" customer 1 create
            description "stitching access side to the anchor"
            split-horizon-group "access I/O side" create
            exit
            sap 3/1/1 split-horizon-group "access" create
                description "I/O port"
                no shutdown
            exit
            sap 4/1/1 split-horizon-group "access" create
```

```
                description "I/O port"
                no shutdown
            exit
            sap lag-2:* create
                description "transit side of PXC"
                no shutdown
            exit
            no shutdown
        exit
----------------------------------------------
```

Example: Capture SAPs on the anchor (MD-CLI)

```
[ex:/configure service]
A:admin@node-2# info
    vpls "3" {
        admin-state enable
        description "VPLS with capture SAPs"
        customer "1"
        capture-sap lag-1:10.* {
            description "termination side of PXC; traffic with S-tag=10 will be extracted
 here"
            trigger-packet {
                dhcp true
                dhcp6 true
                pppoe true
            }
        }
        capture-sap lag-1:11.* {
            description "termination side of PXC; traffic with S-tag=11 will be extracted
 here"
        }
    }
```

Example: Capture SAPs on the anchor (classic CLI)

```
A:node-2>config>service# info
----------------------------------------------
        vpls 3 name "3" customer 1 create
            description "VPLS with capture SAPs"
            sap lag-1:10.* capture-sap create
                description "termination side of PXC; traffic with S-tag=10 will be
 extracted here"
                trigger-packet dhcp dhcp6 pppoe
                no shutdown
            exit
            sap lag-1:11.* capture-sap create
                description "termination side of PXC; traffic with S-tag=11 will be
 extracted here"
                no shutdown
            exit
            no shutdown
        exit
----------------------------------------------
```

7 FPE

Certain applications in the SR OS require extra traffic processing in the forwarding plane. Such additional traffic processing is facilitated by an internal cross-connect that uses PXC ports (described in the Port Cross-Connect). Application-specific use of the cross-connect is built on the common premise that the traffic must be steered from the input ports to the PXC ports where the traffic can be looped for additional processing in the forwarding plane. To shield the user from the intricacies involved when configuring application-specific cross-connect attributes, a CLI construct referred to as Forwarding Path Extensions (FPE) simplifies provisioning of various applications which rely on PXC functionality. The following are examples of applications that rely on PXC and FPE:

- anchored PW-ports where PW payload termination in Layer 3 services is disjointed from I/O ports in the system
- VXLAN termination on non-system IPv4 addresses and VXLAN IPv6 underlay
- origination or termination of a service with an SRv6 tunnel
- GTP-U tunnel termination for Fixed Wireless Access (FWA)

Application-specific uses of PXC ports and FPEs are described in the respective service guides which may include, but are not limited to the *7450 ESS, 7750 SR, and VSR Triple Play Service Delivery Architecture Guide* and *7450 ESS, 7750 SR, 7950 XRS, and VSR Layer 2 Services and EVPN Guide*.

The FPE configuration provides information to the SR OS node necessary to associate the application with the PXC (paired PXC sub-ports, multipath PXC sub-ports, or PXC based LAG IDs). Consequently, the SR OS node sets up the internal logic using PXC as required by the application.

The following figure displays an example of FPE provisioning:

- The first three steps in the classic CLI example are applicable to PXC port provisioning. In MD-CLI, the user must explicitly create sub-ports as described in Port Cross-Connect.
- Association between the application and the PXC is performed in steps 4 and 5. These applications require internal configuration of SDPs and their IDs are allocated from the user configurable range. To prevent conflict between the user-provisioned SDP IDs and internally configured SDP IDs in FPE case, a range of SDP IDs that are used by FPE is reserved by the **sdp-id-range** commands under **configure fwd-path-ext**.
- Application-specific configuration is performed in step 6, partially by the user and partially by the system. This is described in the application-specific user guides.

Figure 33: FPE – MD-CLI provisioning steps

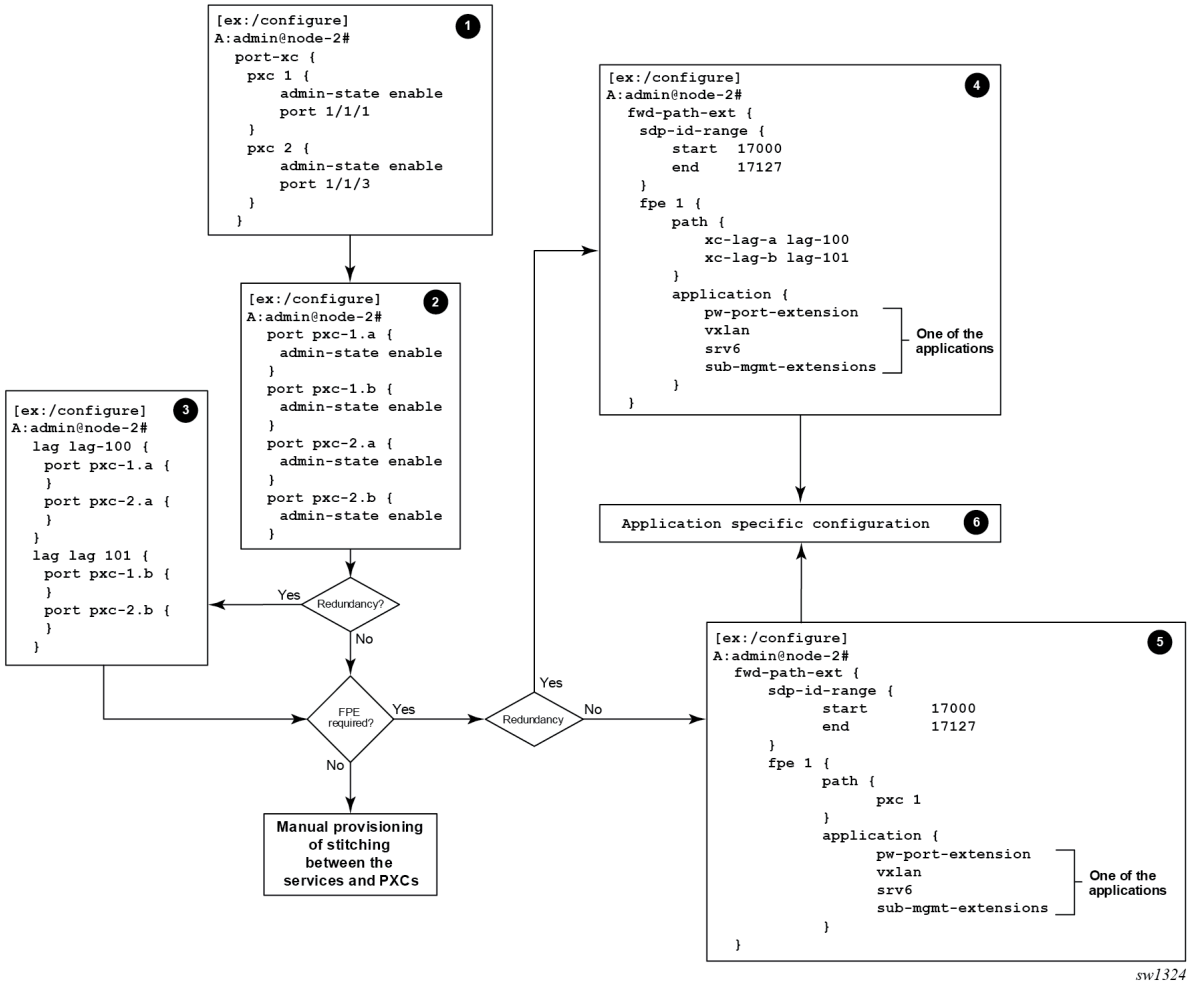
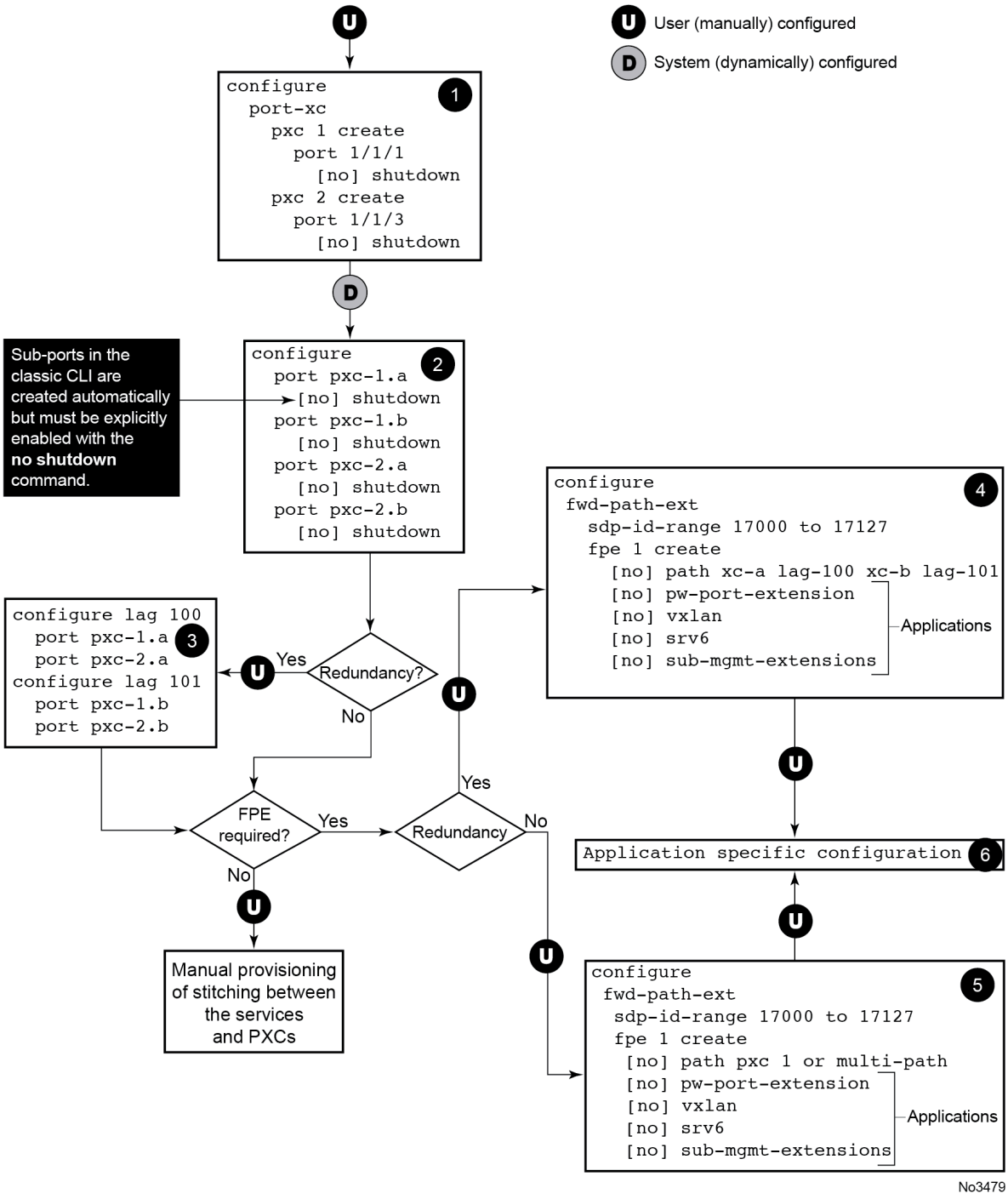


Figure 34: FPE – classic CLI provisioning steps



After the PXC sub-port or LAG is associated with an FPE object, the user cannot use CLI to create IP interfaces manually and SAPs under these PXC sub-ports or LAGs. Only the SR OS system is allowed to reference these PXC sub-ports or LAGs in internal IP interfaces and SAPs, as required by each application.

The user can modify PXC sub-port and LAG command options (QoS, LAG profiles, and so on). To remove PXC sub-ports or LAGs from the FPE object, they must not be associated with an application.

Multipath FPE

Some applications require load balancing over multiple PXC ports or LAGs of PXC ports; for example, the subscriber management application has limited forwarding and QoS resources per line card. To optimize resource usage, Nokia recommends load-balance sessions over multiple line cards. However, the subscriber-management application cannot use a LAG of PXCs for load balancing because a LAG reserves subscriber-management resources on each line card that has LAG members. Use the following command to solve this issue by configuring an FPE with multiple paths, each of which can be a PXC port or a LAG of PXC ports.

```
configure fwd-path-ext fpe multi-path
```

Support for multipath FPEs is application specific.

8 LAG

A Link Aggregation Group (LAG), based on the IEEE 802.1ax standard (formerly 802.3ad), increases the bandwidth available between two network devices by grouping multiple ports to form one logical interface.

Traffic forwarded to a LAG by the router is load balanced between all active ports in the LAG. The hashing algorithm deployed by Nokia routers ensures that packet sequencing is maintained for individual sessions. Load balancing for packets is performed by the hardware, which provides line rate forwarding for all port types.

LAGs can be either statically configured or formed dynamically with Link Aggregation Control Protocol (LACP). A LAG can consist of same-speed ports or mixed-speed ports.

All ports within a LAG must be of the same Ethernet type (access, network, or hybrid) and have the same encapsulation type (dot1q, QinQ, or null).

The following is an example of static LAG configuration using dot1q access ports.

Example: MD-CLI

```
[ex:/configure lag "lag-1"]
A:admin@node-2# info
    admin-state enable
    encap-type dot1q
    mode access
    port 1/1/1 {
    }
    port 1/1/2 {
    }
```

Example: classic CLI

```
A:node-2>config>lag# info
----------------------------------------------
        mode access
        encap-type dot1q
        port 1/1/1
        port 1/1/2
        no shutdown
----------------------------------------------
```

8.1 LACP

The LACP control protocol, defined by the IEEE 802.3ad standard, specifies the method by which two devices establish and maintain LAGs. When LACP is enabled, SR OS automatically associates LACP-compatible ports into a LAG.

The following is an example of LACP LAG configuration using network ports and a default null encapsulation type.

Example: MD-CLI

```
[ex:/configure lag "lag-2"]
A:admin@node-2# info
    admin-state enable
    mode network
    lacp {
        mode active
        administrative-key 32768
    }
    port 1/1/3 {
    }
    port 1/1/4 {
    }
```

Example: classic CLI

```
A:node-2>config>lag# info
----------------------------------------------
        mode network
        port 1/1/3
        port 1/1/4
        lacp active administrative-key 32768
        no shutdown
----------------------------------------------
```

8.1.1 LACP multiplexing

The router supports two modes of multiplexing RX/TX control for LACP: coupled and independent.

In coupled mode (default), both RX and TX are enabled or disabled at the same time whenever a port is added or removed from a LAG group.

In independent mode, RX is first enabled when a link state is UP. LACP sends an indication to the far-end that it is ready to receive traffic. Upon the reception of this indication, the far-end system can enable TX. Therefore, in independent RX/TX control, LACP adds a link into a LAG only when it detects that the other end is ready to receive traffic. This minimizes traffic loss that may occur in coupled mode if a port is added into a LAG before notifying the far-end system or before the far-end system is ready to receive traffic. Similarly, on link removals from LAG, LACP turns off the distributing and collecting bit and informs the far-end about the state change. This allows the far-end side to stop sending traffic as soon as possible.

Independent control provides for lossless operation for unicast traffic in most scenarios when adding new members to a LAG or when removing members from a LAG. It also reduces loss for multicast and broadcast traffic.

Note that independent and coupled mode are interoperable (connected systems can have either mode set).

Independent and coupled modes are supported when using PXC ports, however, independent mode is recommended as it provides significant performance improvements.

8.1.2 LACP tunneling

LACP tunneling is supported on Epipe and VPLS services. In a VPLS, the Layer 2 control frames are sent out of all the SAPs configured in the VPLS. This feature should only be used when a VPLS emulates an

end-to-end Epipe service (an Epipe configured using a three-point VPLS, with one access SAP and two access-uplink SAP/SDPs for redundant connectivity). The use of LACP tunneling is not recommended if the VPLS is used for multipoint connectivity. When a Layer 2 control frame is forwarded out of a dot1q SAP or a QinQ SAP, the SAP tags of the egress SAP are added to the packet.

The following SAPs can be configured for tunneling the untagged LACP frames (the corresponding protocol tunneling needs to be enabled on the port).

- If the port encapsulation is null, a null SAP can be configured on a port to tunnel these packets.
- If the port encapsulation is dot1q, either a dot1q explicit null SAP (for example, 1/1/10:0) or a dot1q default SAP (for example, 1/1/11:*) can be used to tunnel these packets.
- If the port encapsulation is QinQ, a 0.* SAP (for example, 1/1/10:0.*) can be used to tunnel these packets.

LAG port states may be impacted if LACP frames are lost because of incorrect prioritization and congestion in the network carrying the tunnel.

8.1.3 LACP fallback

LACP fallback allows one or more designated links of an LACP-controlled LAG to go into forwarding mode if LACP is not yet operational after a configured timeout period.

SR OS supports LACP fallback in static mode. In static mode, a single designated LAG member goes into forwarding mode if LACP is not operational after the timeout period.

Use the following commands to configure LACP fallback by selecting the mode and fallback timeout (in seconds):

- **MD-CLI**

```
configure lag lacp fallback mode static
configure lag lacp fallback timeout
```

- **classic CLI**

```
configure lag lacp-fallback mode timeout
```

Note:
The LACP-fallback feature is not supported for MC-LAG.

When the LACP transmit interval (**lacp-xmit-interval**) is set to **slow**, if SNMP is used to enable LACP fallback, both the **mode** and the **timeout** with a value greater than 90 must be sent in the same SNMP request. An SNMP request with only the **mode** or only the **timeout** fails.

Nokia recommends configuring the **lacp-xmit-interval** command to **fast** and the fallback **timeout** value to 4 seconds.

If the LAG receives no PDUs and the timeout period expires, the configured fallback mode is enabled. If any member link in the LAG receives a PDU, the fallback mode is immediately disabled.

The following example displays the configuration to enable LACP fallback mode for a LAG, which allows a single designated LAG member to go into forwarding mode if LACP is not operational after the timeout period.

Example: Enable LACP fallback mode for a LAG (MD-CLI)

```
[ex:/configure lag "lag-1"]
A:admin@node-2# info
    lacp {
        fallback {
            mode static
            timeout 30
        }
    }
```

Example: Enable LACP fallback mode for a LAG (classic CLI)

```
A:node-2>config>lag$ info
----------------------------------------------
        lacp-fallback mode static timeout 30
----------------------------------------------
```

8.2 LAG sub-group

LAG can provide active/standby redundancy by logically dividing LAG into sub-groups. The LAG is divided into sub-groups by either assigning each LAG's ports to an explicit sub-group (1 by default), or by automatically grouping all LAG's ports residing on the same line card into a unique sub-group (**auto-iom**) or by automatically grouping all LAG's ports residing on the same MDA into a unique sub-group (**auto-mda**).

When a LAG is divided into sub-groups, only a single sub-group is elected as active. Which sub-group is selected depends on the LAG selection criteria.

The standby state of a port in the LAG is communicated to the remote end using the LAG standby signaling, which can be either **lacp** for LACP LAG or **best-port** for static LAG. The following applies for standby state communication:

- **lacp**

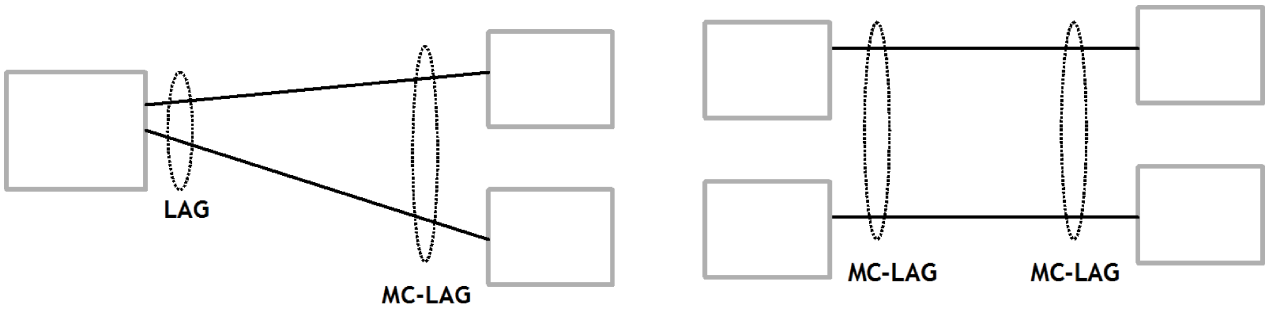
  The standby state of a port is communicated to the remote system using the LACP protocol.

- **best-port**

  The standby state of a port is communicated by switching the transmit laser off. This requires the LAG to be configured using **selection-criteria best-port** and **standby-signaling power-off**.

Figure 35: Active/standby LAG operation deployment examples shows how LAG in active/standby mode can be deployed toward a DSLAM access using sub-groups with auto-iom sub-group selection. LAG links are divided into two sub-groups (one per line card).

Figure 35: Active/standby LAG operation deployment examples



In case of a link failure, as shown in Figure 36: LAG on access interconnection and Figure 37: LAG on access failure switchover, the switch over behavior ensures that all LAG-members connected to the same IOM as failing link become standby and LAG-members connected to other IOM become active. This way, QoS enforcement constraints are respected, while the maximum of available links is used.

Figure 36: LAG on access interconnection

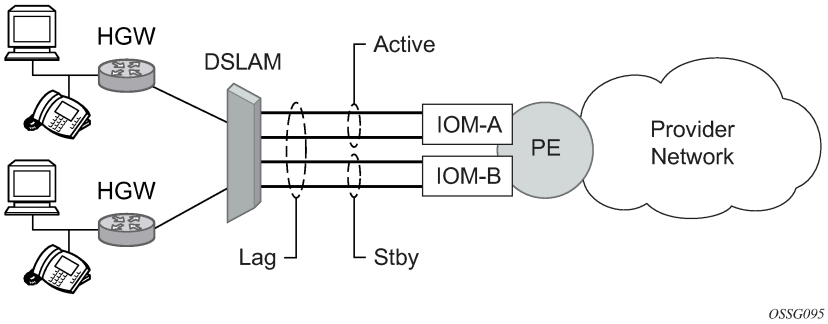
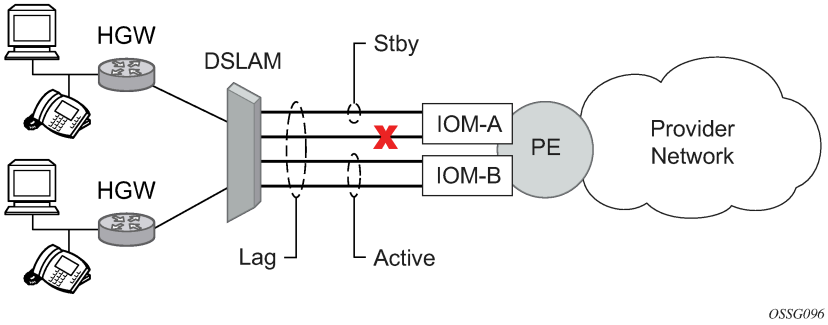


Figure 37: LAG on access failure switchover



8.3 Traffic load balancing options

When a requirement exists to increase the available bandwidth for a logical link that exceeds the physical bandwidth or add redundancy for a physical link, typically one of two methods is applied: equal cost multi-

path (ECMP) or Link Aggregation (LAG). A system can deploy both at the same time using ECMP of two or more Link Aggregation Groups (LAG) or single links, or both.

Different types of hashing algorithms can be employed to achieve one of the following objectives:

- ECMP and LAG load balancing should be influenced solely by the offered flow packet. This is referred to as *per-flow* hashing.
- ECMP and LAG load balancing should maintain consistent forwarding within a specific service. This is achieved using *consistent per-service* hashing.
- LAG load balancing should maintain consistent forwarding on egress over a single LAG port for a specific network interface, SAP, and so on. This is referred as *per link* hashing (including explicit per-link hashing with LAG link map profiles). Note that if multiple ECMP paths use a LAG with per-link hashing, the ECMP load balancing is done using either *per flow* or *consistent per service* hashing.

These hashing methods are described in the following subsections. Although multiple hashing options may be configured for a specific flow at the same time, only one method is selected to hash the traffic based on the following decreasing priority order:

For ECMP load balancing:

1. Consistent per-service hashing
2. Per-flow hashing

For LAG load balancing:

1. LAG link map profile
2. Per-link hash
3. Consistent per-service hashing
4. Per-flow hashing

8.3.1 Per-flow hashing

Per-flow hashing uses information in a packet as an input to the hash function ensuring that any specific flow maps to the same egress LAG port/ECMP path. Note that because the hash uses information in the packet, traffic for the same SAP/interface may be sprayed across different ports of a LAG or different ECMP paths. If this is not wanted, other hashing methods described in this section can be used to change that behavior. Depending on the type of traffic that needs to be distributed into an ECMP or LAG, or both, different variables are used as input to the hashing algorithm that determines the next hop selection. The following describes default per-flow hashing behavior for those different types of traffic:

- VPLS known unicast traffic is hashed based on the IP source and destination addresses for IP traffic, or the MAC source and destination addresses for non-IP traffic. The MAC SA/DA are hashed and then, if the Ethertype is IPv4 or IPv6, the hash is replaced with one based on the IP source address/destination address.
- VPLS multicast, broadcast and unknown unicast traffic.
  - Traffic transmitted on SAPs is not sprayed on a per-frame basis, but instead, the service ID selects ECMP and LAG paths statically.
  - Traffic transmitted on SDPs is hashed on a per packet basis in the same way as VPLS unicast traffic. However, per packet hashing is applicable only to the distribution of traffic over LAG ports, as the ECMP path is still chosen statically based on the service ID.

Data is hashed twice to get the ECMP path. If LAG and ECMP are performed on the same frame, the data is hashed again to get the LAG port (three hashes for LAG). However, if only LAG is performed, then hashing is only performed twice to get the LAG port.

  - Multicast traffic transmitted on SAPs with IGMP snooping enabled is load-balanced based on the internal multicast ID, which is unique for every (s,g) record. This way, multicast traffic pertaining to different streams is distributed across different LAG member ports.
  - The hashing procedure that used to be applied for all VPLS BUM traffic would result in PBB BUM traffic being sent out on BVPLS SAP to follow only a single link when MMRP was not used. Therefore, traffic flooded out on egress BVPLS SAPs is now load spread using the algorithm described above for VPLS known unicast.

- Unicast IP traffic routed by a router is hashed using the IP SA/DA in the packet.
- MPLS packet hashing at an LSR is based on the whole label stack, along with the incoming port and system IP address. Note that the EXP/TTL information in each label is not included in the hash algorithm. This method is referred to as *Label-Only Hash* option and is enabled by default, or can be re-instated in CLI by entering the lbl-only option. A few options to further hash on the headers in the payload of the MPLS packet are also provided.
- VLL traffic from a service access point is not sprayed on a per-packet basis, but as for VPLS flooded traffic, the service ID selects one of the ECMP/LAG paths. The exception to this is when shared-queuing is configured on an Epipe SAP, or Ipipe SAP, or when H-POL is configured on an Epipe SAP. In those cases, traffic spraying is the same as for VPLS known unicast traffic. Packets of the above VLL services received on a spoke SDP are sprayed the same as for VPLS known unicast traffic.
- Note that Cpipe VLL packets are always sprayed based on the service-id in both directions.
- Multicast IP traffic is hashed based on an internal multicast ID, which is unique for every record similar to VPLS multicast traffic with IGMP snooping enabled.

If the ECMP index results in the selection of a LAG as the next hop, then the hash result is hashed again and the result of the second hash is input to the modulo like operation to determine the LAG port selection.

When the ECMP set includes an IP interface configured on a spoke SDP (IES/VPRN spoke interface), or a Routed VPLS spoke SDP interface, the unicast IP packets—which is sprayed over this interface—is not further sprayed over multiple RSVP LSPs/LDP FEC (part of the same SDP), or GRE SDP ECMP paths. In this case, a single RSVP LSP, LDP FEC next-hop or GRE SDP ECMP path is selected based on a modulo operation of the service ID. In case the ECMP path selected is a LAG, the second round of the hash, hashes traffic based on the system, port or interface load-balancing settings.

In addition to the above described per-flow hashing inputs, the system supports multiple options to modify default hash inputs.

8.3.1.1 LSR hashing

By default, the LSR hash routine operates on the label stack only. However, the system also offers the ability to hash on the IP header fields of the packet for the purpose of spraying labeled IP packets over ECMP paths in an LSP or over multiple links of a LAG group.

The LSR hashing options can be selected using the following system-wide command.

```
configure system load-balancing lsr-load-balancing
```

LSR label-only hash

The system hashes the packet using the labels in the MPLS stack and the incoming port (**port-id**). In the presence of entropy label, the system uses only the entropy label and does not use the incoming port (**port-id**) for the hash calculation.

The net result is used to select which LSP next hop to send the packet to using a modulo operation of the hash result with the number of next hops.

This same result feeds to a second round of hashing if there is LAG on the egress port where the selected LSP has its NHLFE programmed.

Use the following command to enable the label-only hash option.

```
configure system load-balancing lsr-load-balancing lbl-only
```

LSR label-IP hash

In the first hash round for ECMP, the algorithm parses down the label stack and after it reaches the bottom, it checks the next nibble. If the nibble value is 4, it assumes it is an IPv4 packet. If the nibble value is 6, it assumes it is an IPv6 packet. In both cases, the result of the label hash is fed into another hash along with source and destination address fields in the IP packet header. Otherwise, the algorithm uses the label stack hash already calculated for the ECMP path selection.

Note: Enable the control word for Layer 2 services to avoid hashing based on incorrect parameters in cases where the ETH header in the ETHoMPLS packets ingressing at the LSR has the first nibble set to 4 or 6.

The second round of hashing for LAG re-uses the net result of the first round of hashing.

Use the following command to enable the label-IP hash option.

```
configure system load-balancing lsr-load-balancing lbl-ip
```

LSR IP-only hash

This option behaves like the label-IP hash option, except that when the algorithm reaches the bottom of the label stack in the ECMP round and finds an IP packet, it throws the outcome of the label hash and only uses the source and destination address fields in the IP packet header.

Use the following command to enable the IP-only hash option.

```
configure system load-balancing lsr-load-balancing ip-only
```

LSR Ethernet encapsulated IP hash

This option behaves like LSR IP-only hash, except for how the IP SA/DA information is found.

After the bottom of the MPLS stack is reached, the hash algorithm verifies that what follows is an Ethernet II untagged or tagged frame. For untagged frames, the system determines the value of Ethertype at the expected packet location and checks whether it contains an Ethernet-encapsulated IPv4 (0x0800) or IPv6 (0x86DD) value. The system also supports Ethernet II tagged frames with up to two 802.1Q tags, provided that the Ethertype value for the tags is 0x8100.

When the Ethertype verification passes, the first nibble of the expected IP packet location is then verified to be 4 (IPv4) or 6 (IPv6).

Use the following command to enable the LSR Ethernet encapsulated IP hash option.

```
configure system load-balancing lsr-load-balancing eth-encap-ip
```

LSR label, IP, L4, TEID hash

This option hashes the packet based on the MPLS labels and IP header fields IP source and destination address, TCP/UDP source and destination ports, and GTP TEID if the packet is IPv4 or IPv6 by checking the next nibble after the bottom of the label stack.

For Layer 2 service traffic (Ethernet header following MPLS label stack), if an IPv4 or IPv6 header is found immediately after the MPLS label stack, the hashing includes label stack, source and destination IP addresses, TCP/UDP port numbers, and, if present, TEID values. If an IPv4 or IPv6 header is not found immediately after the MPLS label stack, the data plane searches for a valid Ethertype value for IPv4 and IPv6 payload. If a valid EtherType is found and an IP header follows the Ethernet header, hashing includes the source and destination IP addresses, TCP/UDP port numbers, and, if present, TEID values. In all other cases, hashing falls back to MPLS label-only hashing.

Use the following command to enable the LSR label, IP, L4, TEID hash option.

```
configure system load-balancing lsr-load-balancing lbl-ip-l4-teid
```

LSR hashing of MPLS-over-GRE encapsulated packet

When the router removes the GRE encapsulation, pops one or more labels and then swaps a label, it acts as an LSR. The LSR hashing for packets of a MPLS-over-GRE SDP or tunnel follows a different procedure, which is enabled automatically and overrides the LSR hashing option enabled on the incoming network IP interface.

On a packet-by-packet basis, the new hash routine parses through the label stack and the new hash routine hashes on the SA/DA fields and the Layer 4 SRC/DST Port fields of the inner IPv4/IPv6 header.

Note:

- If the GRE header and label stack sizes are such that the Layer4 SRC/DST Port fields are not read, it hashes on the SA/DA fields of the inner IPv4/IPv6 header.
- If the GRE header and label stack sizes are such that the SA/DA fields of the inner IPv4/IPv6 header are not read, it hashes on the SA/DA fields of the outer IPv4/IPv6 header.

LSR hashing when an Entropy Label is present in the packet's label stack

The LSR hashing procedures are modified as follows:

- If the **lbl-only** hashing command option is enabled, or if one of the other LSR hashing options are enabled but an IPv4 or IPv6 header is not detected below the bottom of the label stack, the LSR hashes on the Entropy Label (EL) only.
- If the **lbl-ip** hashing command option is enabled, the LSR hashes on the EL and the IP headers.
- If the **ip-only** or **eth-encap-ip** hashing command option is enabled, the LSR hashes on the IP headers only.

8.3.1.2 Layer 4 load balancing

Users can enable Layer 4 load balancing to include TCP/UDP source/destination port numbers in addition to source/destination IP addresses in per-flow hashing of IP packets. By including the Layer 4 information, a SA/DA default hash flow can be subdivided into multiple finer-granularity flows if the ports used between a specific SA/DA vary.

Note: For fragmented traffic, Layer 4 information is not included for load balancing.

Layer 4 load balancing can be enabled or disabled at the system or interface level to improve load balancing distribution by including the TCP or UDP source and destination port of the packet to the hash function.

Use the following command to enable layer 4 load balancing at the system level.

```
configure system load-balancing l4-load-balancing
```

This setting applies to unicast traffic, to apply to multicast traffic the following command also needs to be enabled.

```
configure system load-balancing mc-enh-load-balancing
```

Note: This option does not affect LSR load balancing.

8.3.1.3 System IP load balancing

This option, when enabled, enhances all per-flow load balancing by adding the system IP address to the hash calculation. This capability avoids polarization of flows when a packet is forwarded through multiple routers with a similar number of ECMP/LAG paths.

Note: The system IP address is not added to the hash calculation for packets load balanced based on service ID.

Use the following command to enable system IP address load balancing.

```
configure system load-balancing system-ip-load-balancing
```

8.3.1.4 TEID hash for GTP-encapsulated traffic

Use the **teid-load-balancing** command to enable TEID hashing on Layer 3 interfaces and VPLS services. The hash algorithm identifies GTP-C or GTP-U by looking at the UDP destination port (2123 or 2152) of an IP packet to be hashed. If the value of the port matches, the packet is assumed to be GTP-U/C. For GTPv1 packets, the TEID value from the expected header location is then included in hash. For GTPv2 packets, the TEID flag value in the expected header is additionally checked to verify whether the TEID is present. If TEID is present, it is included in the hash algorithm inputs. The TEID is used in addition to GTP tunnel IP hash inputs: SA/DA and SPort/DPort (if Layer 4 load balancing is enabled). If a non-GTP packet is received on the GTP UDP ports above, the packets are hashed as GTP.

The **teid-load-balancing** command is used under Layer 3 interfaces to enable TEID hashing for load balancing.

Use the following command to enable VPLS services to use TEID hash.

```
configure service vpls load-balancing teid-load-balancing
```

Note:

- If the VPRN interface TEID hash is configured, traffic terminating on an R-VPLS interface will use per VPRN interface TEID hash. The Layer 3 interface TEID hash overrides the VPLS service TEID hash configuration.
- This option does not affect LSR load balancing.

8.3.1.5 Source-only/destination-only hash inputs

A user can include only the **source** command option or only the **destination** command option in the hash for inputs that have **source**/**destination** context (such as IP address and Layer 4 port). Command options that do not have source/destination context (such as TEID or System IP, for example) are also included in hash as per applicable hash configuration. The functionality ensures that both upstream and downstream traffic hash to the same ECMP path/LAG port on system egress when traffic is sent to a hair-pinned appliance (by configuring source-only hash for incoming traffic on upstream interfaces and destination-only hash for incoming traffic on downstream interfaces).

Note: The **source** or **destination** options do not affect LSR load balancing.

Use the **source** and **destination** command options in the following commands to enable source-only or destination-only hash inputs in load balancing at the Layer 3 interface (**service** or **router**) level:

- **MD-CLI**

```
configure router interface load-balancing ip-load-balancing
configure service vprn interface load-balancing ip-load-balancing
configure service ies interface load-balancing ip-load-balancing
```

- **classic CLI**

```
configure router interface load-balancing egr-ip-load-balancing
configure service vprn interface load-balancing egr-ip-load-balancing
configure service ies interface load-balancing egr-ip-load-balancing
```

8.3.1.6 Enhanced multicast load balancing

Enhanced multicast load balancing allows users to replace the default multicast per-flow hash input (internal multicast ID) with information from the packet. When enabled, multicast traffic for Layer 3 services (such as IES, VPRN, r-VPLS) and ng-MVPN (multicast inside RSVP-TE, LDP LSPs) are hashed using information from the packet. Which inputs are chosen depends on which per-flow hash inputs options are enabled based on the following:

- **IP replication**

The hash algorithm for multicast mimics unicast hash algorithm using SA/DA by default and optionally TCP/UDP ports (Layer 4 load balancing enabled) and/or system IP (System IP load balancing enabled) and/or source/destination command options only (Source-only/Destination-only hash inputs).

- **MPLS replication**

  The hash algorithm for multicast mimics unicast hash algorithm is described in the LSR hashing section.

Use the following command to enable enhanced multicast load balancing.

```
configure system load-balancing mc-enh-load-balancing
```

Note: Enhanced multicast load balancing is not supported with Layer 2 and ESM services. It is supported on all platforms except the 7450 ESS in standard mode.

8.3.1.7 SPI load balancing

IPsec tunneled traffic transported over a LAG typically falls back to IP header hashing only. For example, in LTE deployments, TEID hashing cannot be performed because of encryption, and the system performs IP-only tunnel-level hashing. Because each SPI in the IPsec header identifies a unique SA, and therefore flow, these flows can be hashed individually without impacting packet ordering. In this way, SPI load balancing provides a mechanism to improve the hashing performance of IPsec encrypted traffic.

The system allows enabling SPI hashing per Layer 3 interface (this is the incoming interface for hash on system egress)/Layer 2 VPLS service. When enabled, an SPI value from ESP/AH header is used in addition to any other IP hash input based on per-flow hash configuration: source/destination IPv6 addresses, Layer 4 source/dest ports in case NAT traversal is required (Layer 4 load balancing is enabled). If the ESP/AH header is not present in a packet received on a specific interface, the SPI is not part of the hash inputs, and the packet is hashed as per other hashing configurations. SPI hashing is not used for fragmented traffic to ensure first and subsequent fragments use the same hash inputs.

SPI hashing is supported for IPv4 and IPv6 tunnel unicast traffic and for multicast traffic (**mc-enh-load-balancing** must be enabled) on all platforms and requires Layer 3 interfaces or VPLS service interfaces with SPI hashing enabled to reside on supported line cards.

Note: The **spi-load-balancing** command does not affect LSR load balancing.

Use the following commands to enable SPI load balancing at the Layer 3 interface (**service** or **router**) level.

```
configure router interface load-balancing spi-load-balancing
configure service ies interface load-balancing spi-load-balancing
configure service vprn interface load-balancing spi-load-balancing
configure service vprn network-interface load-balancing spi-load-balancing
configure service vpls load-balancing spi-load-balancing
```

8.3.1.8 Inner IP hashing inputs for IPv4 GRE tunnel traffic on Layer 3 interfaces

The inner IP hash for GRE tunnel traffic on Layer 3 interfaces allows the use of inner IP header fields instead of outer IPv4 header fields during per-flow hashing for IPv4-tunneled traffic (IPv4 and GRE) ingressing on Layer 3 interfaces. The inner IP hash is not supported for IPv6 outer-tunneled traffic.

When inner IP hash is enabled under Layer 3 interfaces (in a **service** or **router**) context, source and destination addresses used in a per-flow hash are taken from the inner IP header. If the inner IP header cannot be found or the outer packet is not IPv4, the system uses the outer IPv4 or IPv6 header in hash. Use the following commands to enable inner IP hash:

- **MD-CLI**

```
configure router interface load-balancing ip-load-balancing inner-ip
configure service vprn interface load-balancing ip-load-balancing inner-ip
configure service vprn network-interface load-balancing ip-load-balancing inner-ip
configure service ies interface load-balancing ip-load-balancing inner-ip
```

- **classic CLI**

```
configure router interface load-balancing egr-ip-load-balancing inner-ip
configure service vprn interface load-balancing egr-ip-load-balancing inner-ip
configure service vprn network-interface load-balancing egr-ip-load-balancing inner-ip
configure service ies interface load-balancing egr-ip-load-balancing inner-ip
```

If system IP load balancing, Layer 4 load balancing, or both are also enabled, the system IP, the Layer 4 port information (if available), or both are also included in the hash.

Take the following into consideration when configuring load balancing:

- **MD-CLI**
  The **source** and **destination** command options in the **ip-load-balancing** context and the **inner-ip** command option in the **ip-load-balancing** context are mutually exclusive and cannot be enabled at the same time on an interface.
- **classic CLI**
  The **source** and **destination** command options in the **egr-ip-load-balancing** context and the **inner-ip** command option in the **egr-ip-load-balancing** context are mutually exclusive and cannot be enabled at the same time on an interface.

TEID load balancing and SPI load balancing can be enabled with inner-IP load balancing on an interface.

8.3.1.9 Inner IP hashing inputs for MPLS encapsulated traffic on service SAPs

The inner IP hash for MPLS encapsulated traffic on service SAPs enables hashing of MPLS Ethernet or MPLS IP packets received on the service SAPs of Epipe or VPLS services using the inner IPv4 or IPv6 addresses, port numbers, and GTP TEID if present.

When inner IP hash is configured using the following command for service SAPs under the Epipe or VPLS context, the system parses the frame received on ingress of the service SAP as if it were an MPLS frame received in an LSR router to detect the inner IPv4 or IPv6 header.

```
configure service epipe load-balancing lbl-eth-or-ip-l4-teid
configure service vpls load-balancing lbl-eth-or-ip-l4-teid
```

The system also parses the MPLS L2VPN- or L3VPN-tunneled traffic to use the GTP TEID fields for IPv4 and IPv6 for hashing

8.3.1.10 L2TP load balancing

The Layer 2 tunnelling protocol (L2TP) load balancing option enables load balancing to include the L2TP session ID in the hash algorithm. Use the following command to enable L2TP load balancing.

```
configure system load-balancing l2tp-load-balancing
```

When L2TP load balancing is enabled, the following applies:

- for L2TPv2, both the tunnel ID and session ID are used in the hash
- for L2TPv3, only the session ID is used

8.3.1.11 Enhanced eLER load balancing

When the user enables the enhanced eLER load balancing option on the egress PEs, load balancing of non-IP traffic over the LAG SAP uses the outer MPLS label stack.

Use the following command to enable enhanced load balancing at the eLER:

```
configure system load-balancing eler-enh-load-balancing
```

Note: Enhanced load balancing is operational only in cards using FP4 or higher. For cards with FP3 or lower, this command is available in the CLI but has no effect when configured.

The egress PE load-balances non-IP traffic incoming on the network interface using the following options:

- the entropy label if EL/ELI is present
- the hash label if the hash label is present in the MPLS label stack

If both the hash label and EL/ELI are present, the egress PE load-balances the incoming traffic using the hash label in the MPLS label stack.

Note: The 7450 ESS, 7750 SR, 7950 XRS, and VSR do not support use of the entropy label and hash label at the same time. Consequently, both these labels may only be present in the same packet at the same time if the packet is received from a third-party device in the network.

8.3.2 LAG port hash weight

Use the following command option to customize the flow hashing distribution between LAG ports by adjusting the weight of each port independently for both same-speed and mixed-speed LAGs.

```
configure lag port hash-weight
```

The following are common rules for using a LAG port configured with a hash weight:

- The system ignores the per-port hash weight until the **hash-weight** command option is configured for all ports in the LAG.
- The hash weight for the port can be set to the **port-speed** command option or an integer value from 1 to 100000:
  - **port-speed**

This assigns an implicit value for the hash weight based on the physical port speed.

– **1 to 100000**

This value range allows for control of flow hashing distribution between LAG ports.

- The hash weight of the LAG port is normalized internally to distribute flows between LAG ports. The minimum value returned by this normalization is 1.
- When the hash weight of the LAG port is not configured, the system defaults to the **port-speed** command option.

The following table lists the hash-weight values using the port speed per physical port type.

Table 18: Port types and speeds

Port type	Port speed
FE port	port-speed value 1
1GE port	port-speed value 1
10GE port	port-speed value 10
25GE port	port-speed value 25
40GE port	port-speed value 40
50GE port	port-speed value 50
100GE port	port-speed value 100
400GE port	port-speed value 400
800GE port	port-speed value 800
Other ports	port-speed value 1

The hash-weight capability of the LAG port is supported for both same-speed and mixed-speed LAGs.

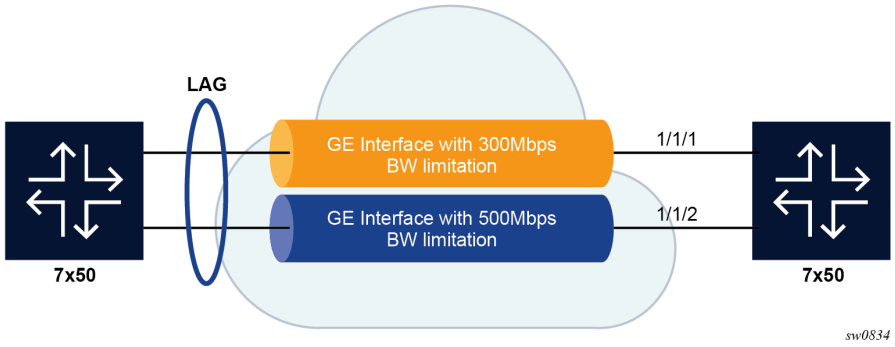
8.3.2.1 Configurable hash weight to control flow distribution

The user can use the hash weight of the LAG port to control traffic distribution between LAG ports by adjusting the weight of each port independently.

This capability is especially useful when LAG links on Nokia routers are rate limited by a third-party transport operator providing the connectivity between two sites, as shown in the following figure, where:

- LAG links 1/1/1 and 1/1/2 are GE
- LAG link 1/1/1 is rate limited to 300 Mb/s by a third-party transport user
- LAG Link 1/1/2 is rate limited to 500 Mb/s by a third-party transport user

Figure 38: Same-speed LAG with ports of different hash weight



In this context, configure the LAG to adapt the flow distribution between LAG ports according to the bandwidth restrictions on each port that uses customized values for the hash weight.

Example: MD-CLI

```
[ex:/configure lag "lag-5"]
A:admin@node-2# info
    admin-state enable
    port 1/1/1 {
        hash-weight 300
    }
    port 1/1/2 {
        hash-weight 500
    }
```

Example: classic CLI

```
A:node-2>config>lag# info
----------------------------------------------
        port 1/1/1 hash-weight 300
        port 1/1/2 hash-weight 500
        no shutdown
----------------------------------------------
```

Use the following command to display the resulting flow distribution between active LAG ports.

```
show lag 3 flow-distribution
```

Output example

```
===============================================================================
Distribution of allocated flows
===============================================================================
Port                        Bandwidth (Gbps) Hash-weight  Flow-share (%)
-------------------------------------------------------------------------------
1/1/1                       10.000           300          37.50
1/1/2                       10.000           500          62.50
-------------------------------------------------------------------------------
Total operational bandwidth: 20.000
===============================================================================
```

Note: The following applies for same-speed LAGs that use the hash-weight capability:

- If all ports have a hash weight configured, other than the **port-speed** command option, the configured value is used and normalized to modify the hashing between LAG ports.
- If the LAG ports are all configured to the **port-speed** command option, or if only some of the ports have a customized hash weight, the system uses a hash weight of 1 for every port. For mixed-speed LAGs, the system uses the **port-speed** command option.

8.3.3 Mixed-speed LAGs

Combining ports of different speeds in the same LAG is supported, in service, by adding or removing ports of different speeds.

The different combinations of physical port speeds supported in the same LAG are as follows:

- 1GE and 10GE
- 10GE, 25GE, 40GE, 50GE and 100GE
- 100GE and 400GE

The following applies to mixed-speed LAGs:

- Traffic is load balanced proportionally to the **hash-weight** value.
- Both LACP and non-LACP configurations are supported. With LACP enabled, LACP is unaware of physical port speed differences.
- QoS is distributed according to the following command.

```
configure qos adv-config-policy child-control bandwidth-distribution internal-scheduler-weight-mode
```

  By default, the **hash-weight** value is taken into account.
- When sub-groups are used, consider the following behavior for selection criteria:
  - **highest-count**

    The **highest-count** criteria continues to operate on physical link counts. Therefore, a sub-group with lower speed links is selected even if its total bandwidth is lower. For example, a 4 * 10GE sub-group is selected over a 100GE + 10 GE sub-group.
  - **highest-weight**

    The **highest-weight** criteria continues to operate on user-configured priorities. Therefore, it is expected that configured weights take into account the proportional bandwidth difference between member ports to achieve the wanted behavior. For example, to favor sub-groups with higher bandwidth capacity but lower link count in a 10GE/100GE LAG, set the priority for 100GE ports to a value that is at least 10 times that of the 10GE ports priority value.
  - **best-port**

    The **best-port** criteria continues to operate on user-configured priorities. Therefore, it is expected that the configured weights take into account proportional bandwidth difference between member ports to achieve the intended behavior.

The following are feature limitations for mixed-speed LAGs:

- The PIM **lag-usage-optimization** command is not supported and must not be configured.

- LAG member links require the default configuration for egress or ingress rates. Use the following commands to configure the rates:
  - **MD-CLI**

    ```
    configure port ethernet egress rate
    configure port ethernet ingress rate
    ```

  - **classic CLI**

    ```
    configure port ethernet egress-rate
    configure port ethernet ingress-rate
    ```

- ESM is not supported.
- The following applies to LAN and WAN port combinations in the same LAG:
  - 100GE LAN with 10GE WAN is supported.
  - 100GE LAN with both 10GE LAN and 10GE WAN is supported.
  - Mixed 10GE LAN and 10GE WAN is supported.

The following ports do not support a customized LAG port **hash-weight** value other than **port-speed** and are not supported in a mixed-speed LAG:

- VSM ports
- 10/100 FE ports
- ESAT ports
- PXC ports

8.3.4 Adaptive load balancing

Adaptive load balancing (ALB) can be enabled per LAG to resolve traffic imbalance dynamically between LAG member ports. The following can cause traffic distribution imbalance between LAG ports:

- hashing limitations in the presence of large flows
- flow bias or service imbalance leading to more traffic over specific ports

ALB actively monitors the traffic rate of each LAG member port and identifies if an optimization is possible to distribute traffic more evenly between LAG ports. The traffic distribution remains flow-based with packets of the same flow egressing a single port of the LAG. The traffic rate of each LAG port is polled at regular intervals, and an optimization is executed only if the ALB tolerance threshold is reached and the minimum bandwidth of the most loaded link in the LAG exceeds the defined bandwidth threshold.

The interval (measured in seconds) for polling LAG statistics from the line cards is configurable. The system optimizes traffic distribution after two polling intervals.

The tolerance is a configurable percentage value corresponding to the difference between the most and least loaded ports in the LAG. The following formula is used to calculate the tolerance:

Tolerance = (rate of the most loaded link - rate of the least loaded link) / rate of the most loaded link * 100

Using a LAG of two ports as an example, where port A = 10 Gb/s and port B = 8 Gb/s, the difference between the most and least loaded ports in the LAG is equal to the following: (10 - 8) / 10 * 100 = 20%.

The bandwidth threshold defines the minimum bandwidth threshold, expressed in percentage, of the most loaded LAG port egress before ALB optimization is performed.

Note:

- The bandwidth threshold default value is 10% for PXC LAG and 30% for other LAG.
- ALB is not supported in combination with the configuration of per-link hashing, mixed-speed LAG, customized hashing weights, per FP egress queuing, per FP SAP instances, or ESM.
- When using cross-connect (PXC) or satellite ports, ALB rates and the tolerance threshold do not consider egress BUM traffic of the LAG, and the ALB algorithm does not take into account the configured link map profile traffic.
- Contact your Nokia technical support representative for more information about scaling when:
  - **MD-CLI**
    - more than 16 ports per LAG are used in combination with the **max-ports** command configured to 64
    - more than 8 ports per LAG are used in combination with the **max-ports** command configured to 32
  - **classic CLI**
    - more than 16 ports per LAG are used in combination with LAGs with ID one to 64
    - more than 8 ports per LAG are used in combination with LAGs with ID 65 to 800

The following example shows an ALB configuration.

Example: MD-CLI

```
[ex:/configure lag "lag-1"]
A:admin@node-2# info
    encap-type dot1q
    mode access
    adaptive-load-balancing {
        tolerance 20
    }
    port 1/1/1 {
    }
    port 1/1/2 {
    }
```

Example: classic CLI

```
A:node-2>config>lag# info
----------------------------------------------
        mode access
        encap-type dot1q
        port 1/1/1
        port 1/1/2
        adaptive-load-balancing tolerance 20
        no shutdown
----------------------------------------------
```

8.3.5 Per-link hashing

The hashing feature described in this section applies to traffic going over LAG and MC-LAG. Per-link hashing ensures all data traffic on a SAP or network interface uses a single LAG port on egress. Because all traffic for a specific SAP/network interface egresses over a single port, QoS SLA enforcement for that SAP, network interface is no longer impacted by the property of LAG (distributing traffic over multiple links). Internally-generated, unique IDs are used to distribute SAPs/network interface over all active LAG ports. As ports go UP and DOWN, each SAP and network interface is automatically rehashed so all active LAG ports are always used.

The feature is best suited for deployments when SAPs/network interfaces on a LAG have statistically similar BW requirements (because per SAP/network interface hash is used). If more control is required over which LAG ports SAPs/network interfaces egress on, a LAG link map profile feature described later in this guide may be used.

Per-link hashing, can be enabled on a LAG as long as the following conditions are met:

- LAG **port-type** must be **standard**.

  ```
  configure lag port-type
  ```

- LAG **access adapt-qos** must be **link** or **port-fair** (for LAGs in **mode access** or **hybrid**).

  ```
  configure lag access adapt-qos
  ```

- LAG mode is **access** or **hybrid** and the **access adapt-qos** mode is **distribute include-egr-hash-cfg**

  ```
  configure lag mode
  ```

8.3.5.1 Weighted per-link-hash

Weighted per-link-hash allows higher control in distribution of SAPs, interfaces, and subscribers across LAG links when significant differences in SAPs, interfaces, and subscribers bandwidth requirements could lead to an unbalanced distribution bandwidth utilization over LAG egress. The feature allows users to configure for each SAP, interface, or subscriber on a LAG, one of three unique classes and a weight value to be used to when hashing this service or subscriber across the LAG links.

Consider the following when configuring class and weight for each SAP, interface, or subscriber:

- **MD-CLI**
  Use the **class** and **weight** commands in the **lag-per-link-hash** context to configure class and weight for each SAP, interface, and subscriber.
- **classic CLI**
  Use the **class** and **weight** parameters in the **lag-per-link-hash** command to configure class and weight for each SAP, interface, and subscriber.

Use the following command to enable the weighted per-link hash for a LAG.

```
configure lag per-link-hash weighted
```

SAPs/interfaces/subscribers are hashed to LAG links, such that within each class the total weight of all SAPs/interfaces/subscribers on each LAG link is as close as possible to each other.

Multiple classes allow grouping of SAPs/interfaces/subscribers by similar bandwidth class/type. For example a class can represent: voice – negligible bandwidth, Broadband – 10 to 100 Mb/s, Extreme Broadband – 300 Mb/s and above types of service. If a class and weight are not specified for a specific service or subscriber, values of 1 and 1 are used respectively.

The following algorithm hashes SAPs, interfaces, and subscribers to LAG egress links:

- TPSDA subscribers are hashed to a LAG link when subscribers are active, MSE SAPs/interfaces are hashed to a LAG link when configured.
- For a new SAP/interface/subscriber to be hashed to an egress LAG link, select the active link with the smallest current weight for the SAP/network/subscriber class.
- On a LAG link failure:
  - Only SAPs/interfaces/subscribers on a failed link are rehashed over the remaining active links.
  - Processing order: per class from lowest numerical, within each class per weight from highest numerical value.
- LAG link recovery/new link added to a LAG:
  - Auto-rebalance disabled: existing SAPs/interfaces/subscribers remain on the currently active links, new SAPs/interfaces/subscribers naturally prefer the new link until balance reached.
  - Auto-rebalance is enabled: when a new port is added to a LAG a non-configurable 5 second rebalance timer is started. Upon timer expiry, all existing SAPs/interfaces/subscribers are rebalanced across all active LAG links minimizing the number of SAPs/interfaces/subscribers moved to achieve rebalance. The rebalance timer is restarted if a new link is added while the timer is running. If a port bounces 5 times within a 5 second interval, the port is quarantined for10 seconds. This behavior is not configurable.
  - On a LAG startup, the rebalance timer is always started irrespective of auto-rebalance configuration to avoid hashing SAPs/interfaces/subscribers to a LAG before ports have a chance to come UP.
- Weights for network interfaces are separated from weights for access SAPs/interfaces/subscribers.
- On a mixed-speed LAG, link selection is made with link speeds factoring into the overall weight for the same class of traffic. This means that higher-speed links are preferred over lower-speed links.

Optionally, a user can use the following command to manually rebalance all weighted per-link-hashed SAPs/interfaces/subscribers on a LAG.

```
tools perform lag load-balance
```

The rebalance follows the algorithm as used on a link failure moving SAPs/interfaces/subscribers to different LAG links to minimize SAPs/interfaces/subscribers impacted.

Along with the restrictions for standard per-link hashing, the following restrictions exist:

- When weighted per-link-hash is deployed on a LAG, no other methods of hash for subscribers/SAPs/interfaces on that LAG (like service hash or LAG link map profile) should be deployed, because the weighted hash is not able to account for loads placed on LAG links by subscriber/SAPs/interfaces using the other hash methods.
- For the TPSDA model only the 1:1 (subscriber to SAP) model is supported.

This feature does not operate properly if the above conditions are not met.

8.3.6 Explicit per-link hash using LAG link mapping profiles

The hashing feature described in this section applies to traffic going over LAG and MC-LAG. LAG link mapping profile feature gives users full control of which links SAPs/network interface use on a LAG egress and how the traffic is rehashed on a LAG link failure. Some benefits that such functionality provides include:

- Ability to perform management level admission control onto LAG ports therefore increasing overall LAG BW utilization and controlling LAG behavior on a port failure.
- Ability to strictly enforce QoS contract on egress for a SAP or network interface or a group of SAPs or network interfaces by forcing egress over a single port and using one of the following commands:
  - **MD-CLI**

    ```
    configure lag access adapt-qos mode link
    configure lag access adapt-qos mode port-fair
    ```

  - **classic CLI**

    ```
    configure lag access adapt-qos link
    configure lag access adapt-qos port-fair
    ```

To enable LAG Link Mapping Profile Feature on a LAG, users configure one or more of the available LAG link mapping profiles on the LAG and then assign that profiles to all or a subset of SAPs and network interfaces as needed. Enabling per LAG link Mapping Profile is allowed on a LAG with services configured, a small outage may take place as result of re-hashing SAP/network interface when a lag profile is assigned to it.

Use the following command to configure a LAG Link Mapping Profile Feature on a LAG.

- **MD-CLI**

  ```
  configure lag link-map-profile link port-type
  ```

- **classic CLI**

  ```
  configure lag link-map-profile link
  ```

Each LAG link mapping profile allows users to configure:

primary link	a port of the LAG to be used by a SAP or network interface when the port is UP. Note that a port cannot be removed from a LAG if it is part of any LAG link profile.
secondary link	a port of the LAG to be used by a SAP or network interface as a backup when the primary link is not available (not configured or down) and the secondary link is UP

When neither primary, nor secondary links are available (not configured or down), use the following command to configure a failure mode of operation.

```
configure lag link-map-profile failure-mode
```

The failure mode of operation command options include:

- **discard**

  Traffic for a specific SAP or network interface is dropped to protect other SAPs/network interfaces from being impacted by re-hashing these SAPs or network interfaces over remaining active LAG ports.

  Note: SAP or network interface status is not affected when primary and secondary links are unavailable, unless an OAM mechanism that follows the datapath hashing on egress is used and causes a SAP or network interface to go down.

- **per-link-hash**

  Traffic for a specific SAP or network interface is re-hashed over remaining active ports of a LAG links using per-link-hashing algorithm. This behavior ensures that SAPs or network interfaces using this profile are provided available resources of other active LAG ports even if it impacts other SAPs or network interfaces on the LAG. The system uses the QoS configuration to provide fairness and priority if congestion is caused by the default-hash recovery.

LAG link mapping profiles, can be enabled on a LAG as long as the following conditions are met:

- LAG **port-type** must be **standard**.
- LAG **access adapt-qos** must be **link** or **port-fair** (for LAGs in **mode access** or **hybrid**)
- All ports of a LAG on a router must belong to a single sub-group.
- Access adapt-qos mode is **distribute include-egr-hash-cfg**.

To assign a link mapping profile to SAP, interface, or subscriber, configure the LAG link map profile under the SAP or interface context using the following commands:

- **MD-CLI**

```
configure service epipe sap lag link-map-profile
configure service ipipe sap lag link-map-profile
configure service vpls sap lag link-map-profile
configure service vprn interface sap lag link-map-profile
configure service ies interface sap lag link-map-profile
```

- **classic CLI**

```
configure service epipe sap lag-link-map-profile
configure service ipipe sap lag-link-map-profile
configure service vpls sap lag-link-map-profile
configure service vprn interface sap lag-link-map-profile
configure service ies interface sap lag-link-map-profile
```

LAG link mapping profile can coexist with any-other hashing used over a specific LAG (for example, per-flow hashing or per-link-hashing [except per-link-hash weighted]). SAPs/network interfaces that have no link mapping profile configured are subject to LAG hashing, while SAPs/network interfaces that have configured LAG profile assigned are subject to LAG link mapping behavior, which is described above.

8.3.7 Consistent per-service hashing

The hashing feature described in this section applies to traffic going over LAG, Ethernet tunnels (**eth-tunnel**) in load-sharing mode, or CCAG load balancing for VSM redundancy. The feature does not apply to ECMP.

Per-service-hashing was introduced to ensure consistent forwarding of packets belonging to one service. The feature can be enabled using the **per-service-hashing** command under the following contexts and is valid for Epipe, VPLS, PBB Epipe, IVPLS, BVPLS, EVPN-VPWS and EVPN-VPLS.

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

The following behavior applies to the usage of the **per-service-hashing** option.

- The setting of the PBB Epipe or I-VPLS children dictates the hashing behavior of the traffic destined for or sourced from an Epipe or I-VPLS endpoint (PW/SAP).
- The setting of the B-VPLS parent dictates the hashing behavior only for transit traffic through the B-VPLS instance (not destined for or sourced from a local I-VPLS or Epipe children).

The following algorithm describes the hash-key used for hashing when the **per-service-hashing** option is enabled:

- If the packet is PBB encapsulated (contains an I-TAG Ethertype) at the ingress side and enters a B-VPLS service, use the ISID value from the I-TAG. For PBB encapsulated traffic entering other service types, use the related service ID.
- If the packet is not PBB encapsulated at the ingress side:
  - For regular (non-PBB) VPLS and Epipe services, use the related service ID.
  - If the packet is originated from an ingress IVPLS or PBB Epipe SAP:
    - If there is an ISID configured, use the related ISID value.
    - If there is no ISID configured, use the related service ID.
  - For BVPLS transit traffic use the related flood list ID.
    - Transit traffic is the traffic going between BVPLS endpoints.
    - An example of non-PBB transit traffic in BVPLS is the OAM traffic.
- The above rules apply to Unicast, BUM flooded without MMRP or with MMRP, IGMP snooped regardless of traffic type.

Users may sometimes require the capability to query the system for the link in a LAG or Ethernet tunnel that is currently assigned to a specific service-id or ISID.

Use the following command to query the system for the link in a LAG or Ethernet tunnel that is currently assigned to a specific service-id or ISID.

```
tools dump map-to-phy-port lag 11 service 1
```

Output example

```
ServiceId  ServiceName   ServiceType     Hashing                  Physical Link
---------- ------------- --------------  -----------------------  -------------
1                        i-vpls          per-service(if enabled)  3/2/8

A:Dut-B# tools dump map-to-phy-port lag 11 isid 1

ISID     Hashing                  Physical Link
-------- -----------------------  -------------
1        per-service(if enabled)  3/2/8

A:Dut-B# tools dump map-to-phy-port lag 11 isid 1 end-isid 4
ISID     Hashing                  Physical Link
```

```
-------- ----------------------  -------------
1        per-service(if enabled)  3/2/8
2        per-service(if enabled)  3/2/7
3        per-service(if enabled)  1/2/2
4        per-service(if enabled)  1/2/3
```

8.3.8 ESM

In ESM, egress traffic can be load balanced over LAG member ports based on the following entities:

- per subscriber, in weighted and non-weighted mode
- per Vport, on non HSQ cards in weighted and non-weighted
- per secondary shaper on HSQ cards
- per destination MAC address when ESM is configured in a VPLS (Bridged CO)

ESM over LAGs with configured PW ports require additional considerations:

- PW SAPs are not supported in VPLS services or on HSQ cards. This means that load balancing per secondary shaper or destination MAC are not supported on PW ports with a LAG configured under them.
- Load balancing on a PW port associated with a LAG with faceplate member ports (fixed PW ports) can be performed per subscriber or Vport.
- Load balancing on a FPE (or PXC)-based PW port is performed on two separate LAGs which can be thought of as two stages:
  - Load balancing on a PXC LAG where the subscribers are instantiated. In this first stage, the load balancing can be performed per subscriber or per Vport.
  - The second stage is the LAG over the network faceplate ports over which traffic exits the node. Load balancing is independent of ESM and must be examined in the context of Epipe or EVPN VPWS that is stitched to the PW port.

8.3.8.1 Load balancing per subscriber

Load balancing per subscriber supports two modes of operation.

The first mode is native non-weighted per-subscriber load balancing in which traffic is directly hashed per subscriber. Use this mode in SAP and subscriber (1:1) deployments and in SAP and service (N:1) deployments. Examples of services in SAP and services deployments are VoIP, video, or data.

In this mode of operation, the following configuration requirements must be met.

- Any form of the **per-link-hash** command in a LAG under the **configure lag** context must be disabled. This is the default setting.
- If QoS schedulers or Vports are used on the LAG, their bandwidth must be distributed over LAG member ports in a port-fair operation.

```
configure lag access adapt-qos port-fair
```

In this scenario, setting this command option to in **adapt-qos** to mode **link** disables per-subscriber load balancing and enables per-Vport load balancing.

The second mode, the weighted per subscriber load balancing is supported only in SAP and subscriber (1:1) deployments, and it requires the following configurations.

```
configure lag per-link-hash weighted subscriber-hash-mode sap
```

In this scenario where hashing is performed per SAP, as reflected in the CLI above, in terms of load balancing, per-SAP hashing produces the same results as per-subscriber hashing because SAPs and subscribers are in in a 1:1 relationship. The end result is that the traffic is load balanced per-subscribers, regardless of this indirection between hashing and load-balancing.

With the **per-link-hash** option enabled, the SAPs (and with this, the subscribers) are dynamically distributed over the LAG member links. This dynamic behavior can be overridden by configuring the **lag-link-map-profiles** command under the static SAPs or under the **msap-policy**. This way, each static SAP, or a group of MSAPs sharing the same **msap-policy** are statically and deterministically assigned to a preordained member port in a LAG.

This mode allows classes and weights to be configured for a group of subscribers with a shared subscriber profile under the following hierarchy.

- **MD-CLI**

```
configure subscriber-mgmt sub-profile egress lag-per-link-hash class
configure subscriber-mgmt sub-profile egress lag-per-link-hash weight
```

- **classic CLI**

```
configure subscriber-mgmt sub-profile egress lag-per-link-hash class weight
```

Default values for **class** and **weight** are 1. If all subscribers on a LAG are configured with the same values for class and weight, load balancing effectively becomes non-weighted.

If QoS schedulers and Vports are used on the LAG, their bandwidth should be distributed over LAG member ports in a port-fair operation.

- **MD-CLI**

```
configure lag "lag-100" access adapt-qos mode port-fair
```

- **classic CLI**

```
configure lag access adapt-qos port-fair
```

8.3.8.2 Load balancing per Vport

Load balancing per Vport applies to user bearing traffic, and not to the control traffic originated or terminated on the BNG, required to setup and maintain sessions, such as PPPoE and DHCP setup and control messages.

Per Vport load balancing supports two modes of operation.

In the first mode, non-weighted load balancing based on Vport hashing, the following LAG-related configuration is required.

The **per-link-hash** command must be disabled.

- **MD-CLI**

```
configure lag access adapt-qos mode link
```

- **classic CLI**

```
configure lag access adapt-qos link
```

If LAG member ports are distributed over multiple forwarding complexes, the following configuration is required.

```
configure subscriber-mgmt sub-profile vport-hashing
```

The second mode, weighted load balancing based on Vport hashing, supports **class** and **weight** command options per Vport. To enable weighted traffic load balancing per Vport, the following configuration must be enabled.

```
configure lag per-link-hash weighted subscriber-hash-mode vport
```

The class and weight can be optionally configured under the Vport definition.

- **MD-CLI**

```
configure port ethernet access egress virtual-port lag-per-link-hash class
configure port ethernet access egress virtual-port lag-per-link-hash weight
```

- **classic CLI**

```
configure port ethernet access egress vport lag-per-link-hash class weight
```

8.3.8.3 Load balancing per secondary shaper

Load balancing based on a secondary shaper is supported only on HSQ cards and only in non-weighted mode. The following LAG-related configuration is required. The **per-link-hash** command first must be disabled.

- **MD-CLI**

```
configure lag "lag-100" access adapt-qos mode link
```

- **classic CLI**

```
configure lag access adapt-qos link
```

Use the following command to disable **per-link-hash**.

- **MD-CLI**

```
configure lag delete per-link-hash
```

- **classic CLI**

```
configure lag no per-link-hash
```

8.3.8.4 Load balancing per destination MAC

This load balancing mode is supported only when ESM is enabled in VPLS in Bridged Central Office (CO) deployments. In this mode of operation, the following configuration is required. The **per-link-hash** command first must be disabled.

```
configure subscriber-mgmt msap-policy vpls-only-sap-parameters mac-da-hashing
configure service vpls sap sub-sla-mgmt mac-da-hashing
```

8.3.9 IPv6 flow label load balancing

IPv6 flow label load balancing enables load balancing in ECMP and LAG based on the output of a hash performed on the triplet {SA, DA, Flow-Label} in the header of an IPv6 packet received on a IES, VPRN, R-VPLS, CsC, or network interface.

IPv6 flow label load balancing complies with the behavior described in RFC 6437. When the **flow-label-load-balancing** command is enabled on an interface, the router applies a hash on the triplet {SA, DA, Flow-Label} to IPv6 packets received with a non-zero value in the flow label.

If the flow label field value is zero, the router performs the hash on the packet header; using the existing behavior based on the global or interface-level commands.

When enabled, IPv6 flow label load balancing also applies hashing on the triplet {SA, DA, Flow-Label} of the outer IPv6 header of an SRv6 encapsulated packet that is received on a network interface of a SRv6 transit router.

At the ingress PE router, SRv6 supports inserting the output of the hash that is performed on the inner IPv4, IPv6, or Ethernet service packet header into the flow label field of the outer IPv6 header it pushes on the SRv6 encapsulated packet.

For more details of the hashing and spraying of packets in SRv6, see the *7750 SR and 7950 XRS Segment Routing and PCE User Guide*.

The flow label field in the outer header of a received IPv6 or SRv6 encapsulated packet is never modified in the datapath.

8.3.9.1 Interaction with other load balancing features

IPv6 flow label load balancing interacts with other load balancing features as follows:

- When the **flow-label-load-balancing** command is enabled on an interface and the global level **l4-load-balancing** command is also enabled, it applies to all IPv4 packets and to IPv6 packets with a flow label field of zero.
- The following global load-balancing commands apply independently to the corresponding non-IPv6 packet encapsulations:
  - **lsr-load-balancing**
  - **mc-enh-load-balancing**
  - **service-id-lag-hashing**
- When the **flow-label-load-balancing** command is enabled on an interface and the global load balancing **l2tp-load-balancing** command is enabled, it applies to the following situations:

  - packets received with L2TPv2 over UDP/IPv4 encapsulation
  - packets received with L2TPv3 over UDP/IPv4 encapsulation
  - packets received with L2TPv3 over UDP/IPv6 encapsulation if the flow label field is zero. Otherwise, flow label hashing applies.

  Packets received with L2TPv3 directly over IPv6 are not hashed on the L2TPv3 session ID. Therefore, hashing of these packets is based on the other interface level hash commands if the flow label field is zero. If the flow label is not zero, flow label hashing applies.

  Note: SR OS implementation of L2TPv3 supports UDP/IPv6 encapsulation only. However, third-party implementations may support L2TPv3 directly over IPv6 encapsulation.

- The global load-balancing command selects a different hashing algorithm and therefore applies all the time when enabled, including when the **flow-label-load-balancing** command is enabled on the interface: **system-ip-load-balancing**.
- When the **flow-label-load-balancing** command is enabled on an interface and the per-interface **spi-load-balancing** or **teid-load-balancing** commands are enabled, they apply to all IPv4 packets and to IPv6 packets with a flow label field of zero.
- The following per-interface load-balancing command applies independently to MPLS encapsulated packets: **lsr-load-balancing**
- The **flow-label-load-balancing** command and the following command are mutually exclusive, which the CLI enforces:
  - **MD-CLI**

    ```
    configure router interface load-balancing ip-load-balancing
    ```

  - **classic CLI**

    ```
    configure router interface load-balancing egr-ip-load-balancing
    ```

- The following per-LAG port packet spraying commands override the **flow-label-load-balancing** command. IPv6 packets, with a non-zero flow label value, are sprayed over LAG links according to the enabled LAG-spraying mode.
  - **per-link-hash**
  - **link-map-profile**

8.4 QoS consideration for access LAG

The following section describes various QoS related features applicable to LAG on access.

8.4.1 Adapt QoS modes

Link Aggregation is supported on the access side with access or hybrid ports. Similarly to LAG on the network side, LAG on access aggregates Ethernet ports into all active or active/standby LAG. The difference with LAG on networks lies in how the QoS or H-QoS is handled. Based on hashing configured, a SAP's traffic can be sprayed on egress over multiple LAG ports or can always use a single port of a LAG.

There are three user-selectable modes that allow the user to best adapt QoS configured to a LAG the SAPs are using:

- **distribute (default)**

  Use the following command to configure the distributed mode:

  – **MD-CLI**

  ```
  configure lag access adapt-qos mode distribute
  ```

  – **classic CLI**

  ```
  configure lag access adapt-qos distribute
  ```

  In the distribute mode, the SLA is divided among all line cards proportionate to the number of ports that exist on that line card for a specific LAG. For example, a 100 Mb/s PIR with 2 LAG links on IOM A and 3 LAG links on IOM B would result in IOM A getting 40 Mb/s PIR and IOM B getting 60 Mb/s PIR. Because of this distribution, SLA can be enforced. The disadvantage is that a single flow is limited to IOM's share of the SLA. This mode of operation may also result in underrun because of hashing imbalance (traffic not sprayed equally over each link). This mode is best suited for services that spray traffic over all links of a LAG.

- **link**

  Use the following command to configure the link mode:

  – **MD-CLI**

  ```
  configure lag access adapt-qos mode link
  ```

  – **classic CLI**

  ```
  configure lag access adapt-qos link
  ```

  In a link mode the SLA is provided to each port of a LAG. With the example above, each port would get 100 Mb/s PIR. The advantage of this method is that a single flow can now achieve the full SLA. The disadvantage is that the overall SLA can be exceeded, if the flows span multiple ports. This mode is best suited for services that are guaranteed to hash to a single egress port.

- **port-fair**

  Use the following command to configure the port-fair mode:

  – **MD-CLI**

  ```
  configure lag access adapt-qos mode port-fair
  ```

  – **classic CLI**

  ```
  configure lag access adapt-qos port-fair
  ```

  Port-fair distributes the SLA across multiple line cards relative to the number of active LAG ports per card (in a similar way to distribute mode) with all LAG QoS objects parented to scheduler instances at the physical port level (in a similar way to link mode). This provides a fair distribution of bandwidth between cards and ports whilst ensuring that the port bandwidth is not exceeded. Optimal LAG utilization relies on an even hash spraying of traffic to maximize the use of the schedulers' and ports' bandwidth. With the example above, enabling port-fair would result in all five ports getting 20 Mb/s.

When port-fair mode is enabled, per-Vport hashing is automatically disabled for subscriber traffic such that traffic sent to the Vport no longer uses the Vport as part of the hashing algorithm. Any QoS object for subscribers, and any QoS object for SAPs with explicitly configured hashing to a single egress LAG port, are given the full bandwidth configured for each object (in a similar way to link mode). A Vport used together with an egress port scheduler is supported with a LAG in port-fair mode, whereas it is not supported with a distribute mode LAG.

- **distribute include-egr-hash-cfg**

  Use the following commands to configure the distributed include-egr-hash-cfg mode:

  – **MD-CLI**

  ```
  configure lag access adapt-qos mode distribute
  configure lag access adapt-qos include-egr-hash-cfg
  ```

  – **classic CLI**

  ```
  configure lag access adapt-qos distribute include-egr-hash-cfg
  ```

  This mode can be considered a mix of link and distributed mode. The mode uses the configured hashing for LAG/SAP/service to choose either link or distributed adapt-qos modes. The mode allows:

  – SLA enforcement for SAPs that through configuration are guaranteed to hash to a single egress link using full QoS per port (as per link mode)

  – SLA enforcement for SAPs that hash to all LAG links proportional distribution of QoS SLA amongst the line cards (as per distributed mode)

  – SLA enforcement for multi service sites (MSS) that contain any SAPs regardless of their hash configuration using proportional distribution of QoS SLA amongst the line cards (as per distributed mode)

The following restrictions apply to adapt-qos distributed include-egr-hash-cfg:

- LAG mode must be access or hybrid.
- When link-map-profiles or per-link-hash is configured, the user cannot change from **include-egr-hash-cfg** mode to **distribute** mode.
- The user cannot change from **link** to **include-egr-hash-cfg** on a LAG with any configuration.

Table 19: Adapt QoS bandwidth/rate distribution shows examples of rate/BW distributions based on the **adapt-qos** mode used.

Table 19: Adapt QoS bandwidth/rate distribution

	distribute	link	port-fair	distribute include-egr-hash-cfg
SAP Queues	% # local links[3]	100% rate	100% rate (SAP hash to one link) or	100% rate (SAP hash to one link) or % # local linksa (SAP hash to all links)

[3] * % # local links = X * (number of local LAG members on a line card/ total number of LAG members)

	distribute	link	port-fair	distribute include-egr-hash-cfg
			%# all links[4] (SAP hash to all links)	
SAP Scheduler	% # local linksa	100% bandwidth	100% rate (SAP hash to one link) or %# all linksb (SAP hash to all links)	100% bandwidth (SAP hash to a one link) or % # local linksa (SAP hash to all links)
SAP MSS Scheduler	% # local linksa	100% bandwidth	% # local linksa	% # local linksa

8.4.2 Per-fp-ing-queuing

Per-fp-ing-queuing optimization for LAG ports provides the ability to reduce the number of hardware queues assigned on each LAG SAP on ingress when the flag at LAG level is set for per-fp-ing-queuing.

When the feature is enabled in the **configure lag access** context, the queue allocation for SAPs on a LAG are optimized and only one queuing set per ingress forwarding path (FP) is allocated instead of one per port.

The following rules apply for configuring the per-fp-ing-queuing at LAG level:

- To enable per-fp-ing-queuing, the LAG must be in access mode.
- The LAG mode cannot be set to network mode when the feature is enabled.
- Per-fp-ing-queuing can only be set if no port members exists in the LAG.

8.4.3 Per-fp-egr-queuing

Per-fp-egr-queuing optimization for LAG ports provides the ability to reduce the number of egress resources consumed by each SAP on a LAG, and by any encap groups that exist on those SAPs.

When the feature is enabled in the **configure lag access** context, the queue and virtual scheduler allocation are optimized. Only one queuing set and one H-QoS virtual scheduler tree per SAP/encap group is allocated per egress forwarding path (FP) instead of one set per each port of the LAG. In case of a link failure/recovery, egress traffic uses failover queues while the queues are moved over to a newly active link.

Per-fp-egr-queuing can be enabled on existing LAG with services as long as the following conditions are met.

- The mode of the LAG must be **access** or **hybrid**.
- The port-type of the LAGs must be **standard**.
- The LAG must have either **per-link-hash** enabled or all SAPs on the LAG must use **per-service-hashing** only and be of a type: VPLS SAP, i-VPLS SAP, or e-Pipe VLL or PBB SAP.

[4] %# all links = X* (link speed)/(total LAG speed)

To disable per-fp-egr-queuing, all ports must first be removed from a specific LAG.

8.4.4 Per-fp-sap-instance

Per-fp-sap-instance optimization for LAG ports provides the ability to reduce the number of SAP instance resources consumed by each SAP on a lag.

When the feature is enabled, in the config>lag>access context, a single SAP instance is allocated on ingress and on egress per each forwarding path instead of one per port. Thanks to an optimized resource allocation, the SAP scale on a line card increases, if a LAG has more than one port on that line card. Because SAP instances are only allocated per forwarding path complex, hardware reprogramming must take place when as result of LAG links going down or up, a SAP is moved from one LAG port on a specific line card to another port on a specific line card within the same forwarding complex. This results in an increased data outage when compared to per-fp-sap-instance feature being disabled. During the reprogramming, failover queues are used when SAP queues are reprogrammed to a new port. Any traffic using failover queues is not accounted for in SAPs statistics and is processed at best-effort priority.

The following rules apply when configuring a per-fp-sap-instance on a LAG:

- Per-fp-ing-queuing and per-fp-egr-queuing must be enabled.
- The functionality can be enabled/disabled on LAG with no member ports only. Services can be configured.

Other restrictions:

- SAP instance optimization applies to LAG-level. Whether a LAG is sub-divided into sub-groups or not, the resources are allocated per forwarding path for all complexes LAG's links are configured on (that is irrespective of whether a sub-group a SAP is configured on uses that complex or not).
- Egress statistics continue to be returned per port when SAP instance optimization is enabled. If a LAG links are on a single forwarding complex, all ports but one have no change in statistics for the last interval – unless a SAP moved between ports during the interval.
- Rollback that changes per-fp-sap-instance configuration is service impacting.

8.5 LAG hold-down timers

Users can configure multiple hold-down timers that allow control how quickly LAG responds to operational port state changes. The following timers are supported:

- **port-level hold-time up/down timer**

  This optional timer allows user to control delay for adding/removing a port from LAG when the port comes UP/goes DOWN. Each LAG port runs the same value of the timer, configured on the primary LAG link. See the Port Link Dampening description in Port features for more details on this timer.

- **sub-group-level hold-time timer**

  This optional timer allows user to control delay for a switch to a new candidate sub-group selected by LAG sub-group selection algorithm from the current, operationally UP sub-group. The timer can also be configured to never expire, which prevents a switch from operationally up sub-group to a new candidate sub-group (manual switchover is possible using tools perform force lag command). Note that, if the port link dampening is deployed, the port level timer must expire before the sub-group-selection takes place and this timer is started. Sub-group-level hold-down timer is supported with LAGs running LACP only.

- **LAG-level hold-time down timer**

  This optional timer allows user to control delay for declaring a LAG operationally down when the available links fall below the required port/BW minimum. The timer is recommended for LAG connecting to MC-LAG systems. The timer prevents a LAG going down when MC-LAG switchover executes break-before-make switch. Note that, if the port link dampening is deployed, the port level timer must expire before the LAG operational status is processed and this timer is started.

8.6 BFD over LAG links

The router supports the application of Micro Bidirectional Forwarding Detection (uBFD) to monitor individual LAG link members to speed up the detection of link failures. When BFD is associated with an Ethernet LAG, BFD sessions are setup over each link member, and are referred to as uBFD sessions. A link is not operational in the associated LAG until the associated uBFD session is fully established. In addition, if the BFD session fails, the router removes the link member from the operational state in the LAG.

When configuring the local and remote IP address for the BFD over LAG link sessions, Nokia recommends making the local IP address value match an IP address associated with an IP interface where this LAG is bound to aid in traceability of the BFD sessions. In addition, make the remote IP address value match an IP address on the remote system and ensure it is also in the same subnet as the local IP address.

Use the following commands to configure the address of the BFD source:

- **MD-CLI**

```
configure lag bfd-liveness ipv4 local-ip-address
configure lag bfd-liveness ipv6 local-ip-address
```

- **classic CLI**

```
configure lag bfd family local-ip-address
```

Use the following commands to configure the address of the BFD destination:

- **MD-CLI**

```
configure lag bfd-liveness ipv4 remote-ip-address
configure lag bfd-liveness ipv6 remote-ip-address
```

- **classic CLI**

```
configure lag bfd family remote-ip-address
```

While Nokia recommends using a subnet that is associated with the LAG for the associated uBFD IP addresses, users are permitted to use any IPv4 or IPv6 address from the router as the local IP addresses, including:

- system IP address
- local IP address
- static link local IPv6
- unique local address (ULA)

8.7 Multi-Chassis LAG

Multi-Chassis LAG (MC-LAG) is an extension of the LAG concept. MC-LAG provides node-level redundancy, in addition to the link-level redundancy provided by LAG.

Typically, MC-LAG is deployed in a network-wide scenario providing redundant connection between different end points. The whole scenario is then built by combination of different mechanisms (for example, MC-LAG and redundant pseudowire to provide e2e redundant p2p connection or dual homing of DSLAMs in Layer 2/3 TPSDA).

8.7.1 Overview

Multichassis LAG is a method of providing redundant Layer 2 or Layer 3 access connectivity that extends beyond link level protection by allowing two systems to share a common LAG end point.

The multiservice access node (MSAN) node is connected with multiple links toward a redundant pair of Layer 2 or Layer 3 aggregation nodes such that both link and node level redundancy, are provided. By using a multichassis LAG protocol, the paired Layer 2 or Layer 3 aggregation nodes (referred to as redundant-pair) appears to be a single node utilizing LACP toward the access node. The multichassis LAG protocol between a redundant-pair ensures a synchronized forwarding plane to and from the access node and synchronizes the link state information between the redundant-pair nodes such that correct LACP messaging is provided to the access node from both redundant-pair nodes.

To ensure SLAs and deterministic forwarding characteristics between the access and the redundant-pair node, MC-LAG provides an active/standby operation to and from the access node. LACP is used to manage the available LAG links into active and standby states, which ensures that links from only one aggregation node are active at a time to and from the access node.

Alternatively, when access nodes do not support LACP, the following command can be used to enforce the active/standby operation.

```
configure lag standby-signaling power-off
```

In this case, the standby ports are **trx_disabled** (power off transmitter) to prevent usage of the LAG member by the access-node. Characteristics related to MC-LAG are:

- The selection of the common system ID, system-priority, and administrative-key are used in LACP messages so that partner systems consider all links as part of the same LAG.
- The selection algorithm is extended to allow the selection of the active sub-group.
  - A sub-group definition in the LAG context is local to the single box, which means that if sub-groups configured on two different systems have the same sub-group ID, they are still considered two separate sub-groups within the specified LAG.
  - Multiple sub-groups per PE in an MC-LAG are supported.
  - In the case where there is a tie in the selection algorithm, (for example, two sub-groups with identical aggregate weight (or number of active links), the group that is local to the system with the lower system LACP priority and LAG system ID is used.
- An inter-chassis communication channel allows LACP support on both systems. The inter-chassis communication channel supports the following:

  - Connections at the IP level that do not require a direct link between two nodes. The IP address configured at the neighbor system is one of the addresses of the system (interface or loop-back IP address).
  - A communication protocol that provides a heartbeat mechanism to enhance the robustness of the MC-LAG operation and to detect node failures.
  - User actions on any node that force an operational change.
  - LAG group-ids that do not have to match between neighbor systems. At the same time, there can be multiple LAG groups between the same pair of neighbors.
  - Verifying the configuration of physical characteristics, such as speed and auto-negotiation, and initiating user notifications (traps) if errors exist. Consistency of MC-LAG configuration (system ID, administrative key, and system priority) is provided. Similarly, the load-balancing mode of operation must be consistently configured on both nodes.
  - Traffic over the signaling link encryption using a user-configurable message digest key.
- MC-LAG provides active/standby status to other software applications to build a reliable solution.

Figure 39: MC-LAG Layer 2 dual-homing to remote PE pairs and Figure 40: MC-LAG Layer 2 dual homing to local PE pairs show the different combinations of MC-LAG attachments that are supported. The supported configurations can be sub-divided into following sub-groups:

- Dual-homing to remote PE pairs
  - both end-points attached with MC-LAG
  - one end-point attached
- Dual-homing to local PE pair
  - both end-points attached with MC-LAG
  - one end-point attached with MC-LAG
  - both end-points attached with MC-LAG to two overlapping pairs

Figure 39: MC-LAG Layer 2 dual-homing to remote PE pairs

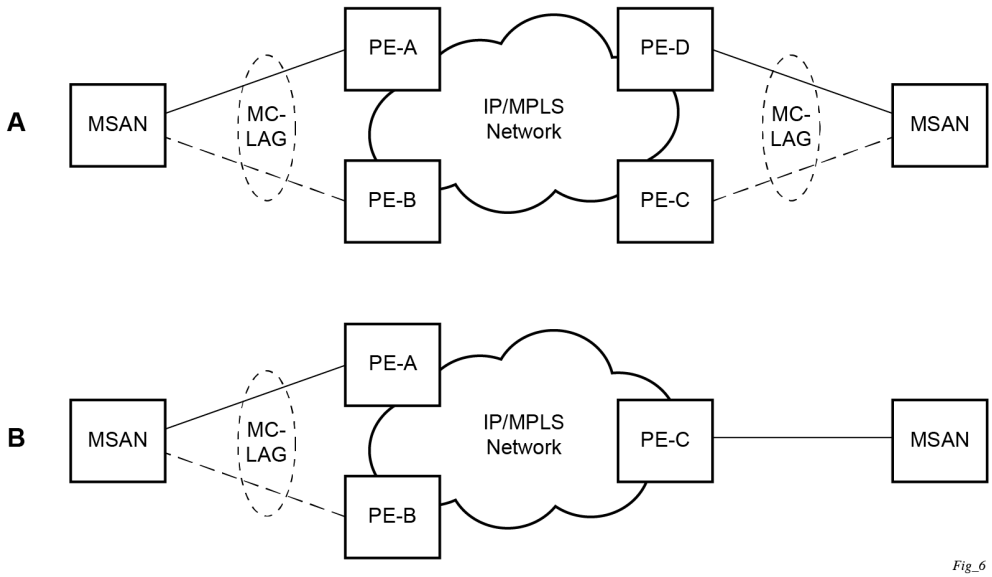
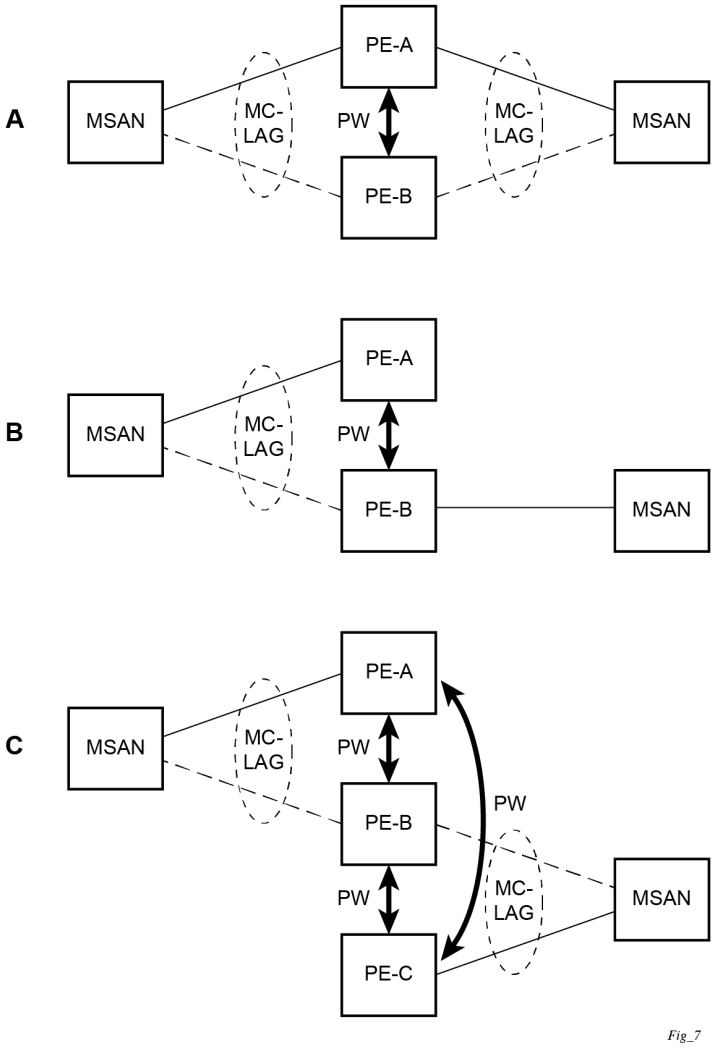


Figure 40: MC-LAG Layer 2 dual homing to local PE pairs



The forwarding behavior of the nodes abide by the following principles. Note that logical destination (actual forwarding decision) is primarily determined by the service (VPLS or VLL) and the principle below applies only if destination or source is based on MC-LAG:

- Packets received from the network are forwarded to all local active links of the specific destination-sap based on conversation hashing. In case there are no local active links, the packets are cross-connected to inter-chassis pseudowire.
- Packets received from the MC-LAG sap are forwarded to active destination pseudowire or active local links of destination-sap. In case there are no such objects available at the local node, the packets are cross-connected to inter-chassis pseudowire.

8.7.2 MC-LAG and SRRP

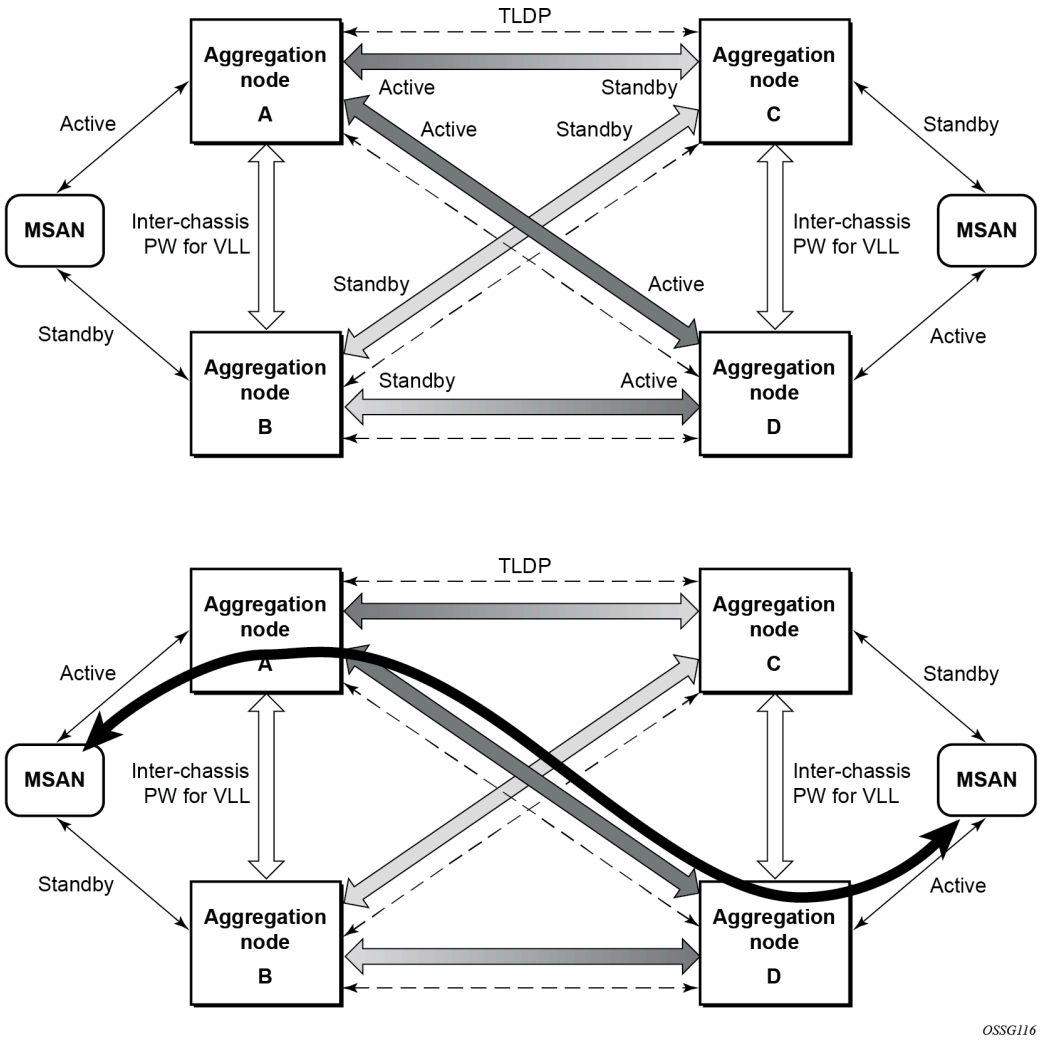
MC-LAG and Subscriber Routed Redundancy Protocol (SRRP) enable dual-homed links from any IEEE 802.1ax (formerly 802.3ad) standards-based access device (for example, a IP DSLAM, Ethernet switch or a Video on Demand server) to multiple Layer 2/3 or Layer 3 aggregation nodes. In contrast with slow recovery mechanisms such as Spanning Tree, multichassis LAG provides synchronized and stateful redundancy for VPN services or triple play subscribers in the event of the access link or aggregation node failing, with zero impact to end users and their services.

See the *7450 ESS, 7750 SR, and VSR Triple Play Service Delivery Architecture Guide* for information about SRRP.

8.7.3 P2P redundant connection across Layer 2/3 VPN network

Figure 41: Point-to-Point (P2P) redundant connection through a Layer 2 VPN network shows the connection between two multiservice access nodes (MSANs) across a network based on Layer 2/3 VPN pseudowires. The connection between MSAN and a pair of PE routers is realized by MC-LAG. From an MSAN perspective, a redundant pair of PE routers acts as a single partner in LACP negotiation. At any time, only one of the routers has an active link in a specified LAG. The status of LAG links is reflected in status signaling of pseudowires set between all participating PEs. The combination of active and stand-by states across LAG links as well as pseudowires gives only one unique path between a pair of MSANs.

Figure 41: Point-to-Point (P2P) redundant connection through a Layer 2 VPN network



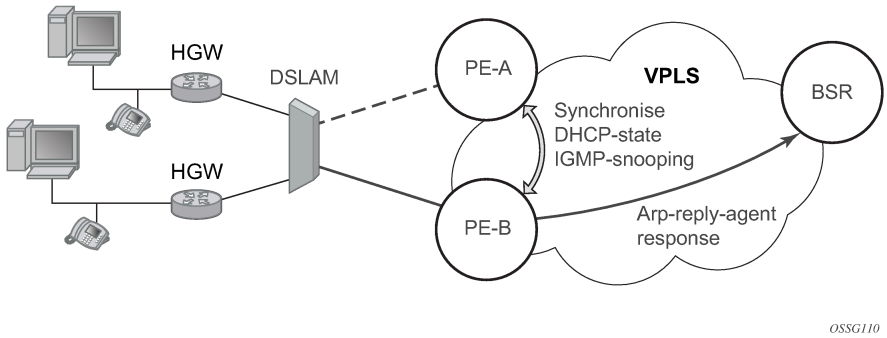
Note that the configuration in Figure 41: Point-to-Point (P2P) redundant connection through a Layer 2 VPN network shows one particular configuration of VLL connections based on MC-LAG, particularly the VLL connection where two ends (SAPs) are on two different redundant-pairs. In addition to this, other configurations are possible, such as:

- Both ends of the same VLL connections are local to the same redundant-pair.
- One end VLL endpoint is on a redundant-pair the other on single (local or remote) node.

8.7.4 DSLAM dual-homing in a Layer 2 or Layer 3 TPSDA model

The following figure shows a network configuration where DSLAM is dual-homed to a pair of redundant PEs by using MC-LAG. In the aggregation network, a redundant pair of PEs is connecting to a VPLS service, which provides a reliable connection to a single or pair of Broadband Service Routers (BSRs).

Figure 42: DSLAM dual-homing using MC-LAG



MC-LAG and pseudowire connectivity, PE-A and PE-B implement enhanced subscriber management features based on DHCP-snooping and creating dynamic states for every subscriber-host. As in any point of time there is only one PE active, it is necessary to provide the mechanism for synchronizing subscriber-host state-information between active PE (where the state is learned) and stand-by PE. In addition, VPLS core must be aware of active PE to forward all subscriber traffic to a PE with an active LAG link. The mechanism for this synchronization is outside of the scope of this document.

8.8 LAG port and hash-weight thresholds

The following sections provide information on LAG port and hash-weight thresholds.

8.8.1 LAG IGP cost

When using a LAG, it is possible to take an operational link degradation into consideration by setting a configurable degradation threshold. The following alternative settings are available through configuration:

```
configure lag port-threshold
configure lag hash-weight-threshold
```

When the LAG operates under normal circumstances and is included in an IS-IS or OSPF routing instance, the LAG must be associated with an IGP link cost. This LAG cost can either be statically configured in the IGP context or set dynamically by the LAG based upon the combination of the interface speed and reference bandwidth.

Under operational LAG degradation however, it is possible for the LAG to set a new updated dynamic or static threshold cost taking the gravity of the degradation into consideration.

As a consequence, there are some IGP link cost alternatives available, for which the most appropriate must be selected. The IGP uses the following priority rules to select the most appropriate IGP link cost:

1. Static LAG cost (from the LAG threshold action during degradation)
2. Explicit configured IGP cost (from the configuration under the IGP routing protocol context)
3. Dynamic link cost (from the LAG threshold action during degradation)
4. Default metric (no cost is set anywhere)

For example:

- Static LAG cost overrules the configured metric.
- Dynamic cost does not overrule configured metric or static LAG cost.

8.8.2 Adjusting the operational state of the LAG

Instead of changing the IGP cost, when using a LAG, a user can also configure to take the operational state of the links or link degradation into consideration to adjust the operational state of the LAG. Use the **action** command option of the following command to control the operational state of the LAG:

- **MD-CLI**

```
configure lag string port-threshold
```

- **classic CLI**

```
configure lag lag-id port-threshold
```

When the total number of operational links for the LAG is at or below the configured threshold value, the LAG operational state is brought down. If the number of operational links for the LAG exceeds the threshold value, the operational state of LAG is brought up.

For LAGs with PXC sub-ports also the operational state can be controlled through the **port-threshold action down** configuration described in the preceding information.

Similar to port threshold, use the hash-weight threshold to control the operational state of the LAG. Use the **action** option in the following the command to control the operational state of the LAG:

- **MD-CLI**

```
configure lag string hash-weight-threshold
```

- **classic CLI**

```
configure lag lag-id hash-weight-threshold
```

When the sum of hash weights of all the operational links of LAG is at or below the configured threshold value (weight), the LAG operational state is brought down. If the sum of hash weights of all operational LAG links exceeds the hash-weight threshold value, the operational state of LAG is brought up.

9 G.8031 protected Ethernet tunnels

The Nokia PBB implementation offers the capability to use core Ethernet tunnels compliant with ITU-T G.8031 specification to achieve 50 ms resiliency for failures in a native Ethernet backbone. For more information about Ethernet tunnels, see "G.8031 Protected Ethernet Tunnels" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Services Overview Guide*.

10 G.8032 protected Ethernet rings

Ethernet ring protection switching offers ITU-T G.8032 specification compliance to achieve resiliency for Ethernet Layer 2 networks. Similar to G.8031 linear protection (also called Automatic Protection Switching (APS)), G.8032 (Eth-ring) is also built on Ethernet OAM and often referred to as Ring Automatic Protection Switching (R-APS).

For more information about Ethernet rings, see "G.8032 Protected Ethernet Rings" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Services Overview Guide*.

11 Ethernet port monitoring

Ethernet ports can record and recognize various medium statistics and errors. There are two main types of errors:

- **frame based**

  Frame based errors are counted when the arriving frame has an error that means the frame is invalid. These types of errors are only detectable when frames are present on the wire.

- **symbol based**

  Symbol errors are invalidly encoded symbols on the physical medium. Symbols are always present on an active Ethernet port regardless of the presence of frames.

CRC error monitoring and symbol monitoring allow the user to monitor ingress error conditions on the Ethernet medium and compare these error counts to the thresholds. CRC monitoring monitors CRC errors. Symbol monitoring monitors symbol errors. Symbol error is not supported on all Ethernet ports. Crossing a signal degrade (SD) threshold causes a log event to be raised. Crossing the configured signal failure (SF) threshold causes the port to enter an operation state of down. The user may consider the configuration of other protocols to convey the failure, through timeout conditions.

The error rates are in the form of $M*10^{(-N)}$. The user has the ability to configure both the threshold (N) and a multiplier (M). By default if the multiplier is not configured the multiplier is 1. As an example, **sd-threshold** 3 would result in a signal degrade error rate of $1*10^{-3}$ (one error per 1000). Changing the configuration **sd-threshold** 3 to a multiplier of 5 would result in a signal degrade rate of $5*10^{-3}$ (five errors per 1000). The signal degrade value must be a lower error rate than the signal failure threshold. This threshold can be used to provide notification that the port is operating in a degraded but not failed condition. These do not equate to a bit error rate (BER). CRC monitoring provides a CRC error rate. Symbol monitoring provides a symbol error rate.

The configured error thresholds are compared to the user specified sliding window to determine if one or both of the thresholds have been crossed. Statistics are gathered every second. This means that every second the oldest statistics are dropped from the calculation. The default 10-second sliding window means that at the 11th second, the oldest 1-second statistical data is dropped and the 11th second is included.

Symbol error crossing differs slightly from CRC-based error crossing. The error threshold crossing is calculated based on the window size and the fixed number of symbols that arrive (ingress) on that port during that window.

The following configuration demonstrates this concept.

Example: MD-CLI

```
[ex:/configure port 2/1/2 ethernet]
A:admin@node-2# info
    symbol-monitor {
        admin-state enable
        signal-degrade {
            threshold 5
            multiplier 5
        }
        signal-failure {
            threshold 3
            multiplier 5
```

```
        }
    }
```

Example: classic CLI

```
A:node-2>config>port>ethernet# info detail
----------------------------------------------
            symbol-monitor
                sd-threshold 5 multiplier 5
                sf-threshold 3 multiplier 5
                no shutdown
            exit
```

Use the following command to display Ethernet port statistics.

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

Output example: Ethernet port statistics output

```
===============================================================================
Ethernet Interface
===============================================================================
Description        : 1-Gig/10-Gig Ethernet
Interface          : 2/1/2                       Oper Speed       : 10 Gbps
Link-level         : Ethernet                    Config Speed     : 10 Gbps
Admin State        : down                        Oper Duplex      : full
Oper State         : down
Config Duplex      : N/A
Physical Link      : No                          MTU              : 8704
Single Fiber Mode  : No                          Min Frame Length : 64 Bytes
IfIndex            : 35684352                    Hold time up     : 0 seconds
Last State Change  : 11/29/2022 18:37:14         Hold time down   : 0 seconds
Hold Time Down Rmng: 0 cs                        Hold Time Up Rmng: 0 cs
Last Cleared Time  : N/A                         DDM Events       : Enabled
Phys State Chng Cnt: 0
RS-FEC Config Mode : None
RS-FEC Oper Mode   : None

Configured Mode    : network                     Encap Type       : null
Dot1Q Ethertype    : 0x8100                      QinQ Ethertype   : 0x8100
PBB Ethertype      : 0x88e7
Ing. Pool % Rate   : 100                         Egr. Pool % Rate : 100
Net. Egr. Queue Pol: default
Egr. Sched. Pol    : n/a
DCPU Prot Policy   : _default-port-policy
Oper DCPU Prot Plcy: _default-port-policy
Monitor Port Sched : Disabled
Monitor Agg Q Stats: Disabled
Monitor Oper Group : none
Auto-negotiate     : N/A                         MDI/MDX          : N/A
Oper Phy-tx-clock  : not-applicable
Accounting Policy  : None                        Collect-stats    : Disabled
Acct Plcy Eth Phys : None                        Collect Eth Phys : Disabled
Egress Rate        : Default                     Ingress Rate     : Default
Oper Egress Rate   : Unrestricted
Load-balance-algo  : Default                     LACP Tunnel      : Disabled
Access Bandwidth   : Not-Applicable              Booking Factor   : 100
Access Available BW: 0
Access Booked BW   : 0
Sflow              : Disabled
Discard Rx Pause   : Disabled
```

```
Suppress Threshold : 2000                       Reuse Threshold  : 1000
Max Penalties      : 16000                      Max Suppress Time: 20 seconds
Half Life          : 5 seconds

Down-when-looped   : Disabled                   Keep-alive       : 10
Loop Detected      : False                      Retry            : 120
Use Broadcast Addr : False

Sync. Status Msg.  : Disabled                   Rx Quality Level : N/A
Tx DUS/DNU         : Disabled                   Tx Quality Level : N/A
SSM Code Type      : sdh                        ESMC Tunnel      : Disabled

Down On Int. Error : Disabled                   DOIE Tx Disable  : Disabled

CRC Mon SD Thresh  : Disabled                   CRC Mon Window   : 10 seconds
CRC Mon SF Thresh  : Disabled

Sym Mon SD Thresh  : 5*10E-5                    Sym Mon Window   : 10 seconds
Sym Mon SF Thresh  : 5*10E-3                    Tot Sym Mon Errs : 0

EFM OAM            : Disabled                   EFM OAM Link Mon : Disabled
Ignr EFM OAM State : False

Configured Address : b6:1b:01:01:00:01
Hardware Address   : b6:1b:01:01:00:01
Cfg Alarm          : remote local

Transceiver Data

Transceiver Status : operational
Transceiver Type   : SFP                        DCO              : Disabled
Model Number       : 3HE04823AAAA01  ALA  IPU3ANKEAA
TX Laser Wavelength: 1310 nm                    Diag Capable     : yes
Connector Code     : LC                         Vendor OUI       : 00:90:65
Manufacture date   : 2009/12/17                 Media            : Ethernet
Serial Number      : UGR04DK
Part Number        : FTLX1471D3BCL-A5
Optical Compliance : 10GBASE-LR
Link Length support: 10km for SMF

===============================================================================
Transceiver Digital Diagnostic Monitoring (DDM), Internally Calibrated
===============================================================================
                             Value High Alarm  High Warn   Low Warn  Low Alarm
-------------------------------------------------------------------------------
Temperature (C)              +25.4     +78.0      +73.0       -8.0      -13.0
Supply Voltage (V)            3.31      3.70       3.60       3.00       2.90
Tx Bias Current (mA)          35.6      85.0       80.0       20.0       15.0
Tx Output Power (dBm)        -1.46      2.00       1.00      -7.00      -8.00
Rx Optical Power (avg dBm)   -2.18      2.50       2.00     -18.01     -20.00
===============================================================================
===============================================================================

===============================================================================
Traffic Statistics
===============================================================================
                                                  Input                 Output
-------------------------------------------------------------------------------
Octets                                               0                      0
Packets                                              0                      0
Errors                                               0                      0
Utilization (300 seconds)                        0.00%                  0.00%

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

```
Port Statistics
===============================================================================
                                                    Input                Output
-------------------------------------------------------------------------------
Unicast Packets                                         0                     0
Multicast Packets                                       0                     0
Broadcast Packets                                       0                     0
Discards                                                0                     0
Unknown Proto Discards                                  0
===============================================================================

===============================================================================
Ethernet-like Medium Statistics
===============================================================================

Alignment Errors :                  0  Sngl Collisions  :                    0
FCS Errors       :                  0  Mult Collisions  :                    0
SQE Test Errors  :                  0  Late Collisions  :                    0
CSE              :                  0  Excess Collisns  :                    0
Too long Frames  :                  0  Int MAC Tx Errs  :                    0
Symbol Errors    :                  0  Int MAC Rx Errs  :                    0
In Pause Frames  :                  0  Out Pause Frames :                    0
===============================================================================
```

The preceding configuration results in an SD threshold of $5*10^{-5}$ (five errors per 100 000) and an SF threshold of $5*10^{-3}$ (five errors per 1000) over the default 10-second window. If this port is a 1 GE port supporting symbol monitoring, the error rate is compared against 1,250,000,000 symbols (10 seconds worth of symbols on a 1 GE port [125,000,000]). If the error count in the current 10-second sliding window is less than 62,500, the error rate is below the signal degrade threshold and no action is taken. If the error count is between 62,501 and 6,250,000, the error rate is above signal degrade but has not breached the signal failure signal threshold and a log event is raised. If the error count is above 6,250,000, the signal failure threshold is crossed and the port enters an operation state of down. Consider that this is a very simple example meant to demonstrate the function and not meant to be used as a guide for configuring the various thresholds and window times.

A port is not returned to service automatically when a port enters the failed condition as a result of crossing a signal failure threshold for both CRC monitoring and symbol monitoring. Because the port is operationally down without a physical link error, monitoring stops.

In MD-CLI, the user can enable the port using the **admin-state enable** and **admin-state disable** commands.

In the classic CLI, the user can enable the port using the **no shutdown** and **shutdown** commands.

12 IEEE 802.3ah OAM

Note: See the "OAM continuity" section of "Port Cross-Connect (PXC)" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Interface Configuration Advanced Configuration Guide for Classic CLI* for information about advanced configurations.
See the "OAM continuity" section of "Port Cross-Connect (PXC)" in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Interface Configuration Advanced Configuration Guide for MD CLI* for information about advanced configurations.

IEEE 802.3ah Clause 57 (EFM OAM) defines the Operations, Administration, and Maintenance (OAM) sublayer, which provides mechanisms that are useful for monitoring link operation, such as remote fault indication and remote loopback control. In general, OAM provides network operators the ability to monitor the health of the network and determine the location of failing links or fault conditions. EFM OAM described in this clause provides data link layer mechanisms that complement applications that may reside in higher layers.

OAM information is conveyed in slow protocol frames called OAM PDUs. OAM PDUs contain the control and status information used to monitor, test, and troubleshoot OAM-enabled links. OAM PDUs traverse a single link, being passed between peer OAM entities, and therefore, are not forwarded by MAC clients (like bridges or switches).

The following EFM OAM functions are supported:

- **EFM OAM capability discovery**
- **active and passive modes**
- **remote failure indication**

  Handling of critical link events (for example, link fault, dying gasp)
- **loopback**

  Support for a data link layer frame-level loopback mode. Both remote and local loopback modes are supported.
- **EFM OAM PDU tunneling**
- **high-resolution timer for EFM OAM in 100 ms interval (minimum)**
- **EFM OAM link monitoring**
- **non-zero Vendor Specific Information Field**

  The 32-bit field is encoded using the format 00:PP:CC:CC and references TIMETRA-CHASSIS-MIB.

  – **00**

    This must be zeros.

  – **PP**

    This represents the platform type based on the installed IOM from tmnxHwEquippedPlatform. 7450 ESS deployments may yield different platform values in the same chassis. Because this is IOM-specific, the IOM’s unique hardware ID (tmnxCardHwIndex) must be included to retrieve the correct value.

  – **CC:CC**

This represents the chassis type index value from tmnxChassisType which is indexed in tmnxChassisTypeTable. The table identifies the specific chassis backplane.

The value 00:00:00:00 is sent for all releases that do not support the non-zero value or are unable to identify the required elements. There is no decoding of the peer or local vendor information fields on the network element. The hexadecimal value is included in the output of the following command.

```
show port ethernet efm-oam
```

When the **efm-oam** protocol fails to negotiate a peer session or encounters a protocol failure following an established session the *Port State* enters the *Link Up* condition. This port state is used by many protocols to indicate the port is administratively UP and there is physical connectivity but a protocol, such as **efm-oam**, has caused the ports operational state to enter a DOWN state. A reason code has been added to help discern if the **efm-oam** protocol is the underlying reason for the Link Up condition.

Use the following command to display port information.

```
show port
```

Output example

```
===============================================================================
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
-------------------------------------------------------------------------------
1/1/1       Down  No   Down    1578 1578    - netw null xcme
1/1/2       Down  No   Down    1578 1578    - netw null xcme
1/1/3       Up    Yes  Link Up 1522 1522    - accs qinq xcme
1/1/4       Down  No   Down    1578 1578    - netw null xcme
1/1/5       Down  No   Down    1578 1578    - netw null xcme
1/1/6       Down  No   Down    1578 1578    - netw null xcme
```

Use the following command to display information about a specific.

```
show port 1/1/3
```

Output example

```
===============================================================================
Ethernet Interface
===============================================================================
Description        : 10/100/Gig Ethernet SFP
Interface          : 1/1/3                       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        : efmOamDown
Physical Link      : Yes                         MTU              : 1522
Single Fiber Mode  : No                          Min Frame Length : 64 Bytes
IfIndex            : 35749888                    Hold time up     : 0 seconds
Last State Change  : 12/18/2012 15:58:29         Hold time down   : 0 seconds
Last Cleared Time  : N/A                         DDM Events       : Enabled
Phys State Chng Cnt: 1

Configured Mode    : access                      Encap Type       : QinQ
Dot1Q Ethertype    : 0x8100                      QinQ Ethertype   : 0x8100
```

```
PBB Ethertype      : 0x88e7
Ing. Pool % Rate   : 100                        Egr. Pool % Rate : 100
Ing. Pool Policy   : n/a
Egr. Pool Policy   : n/a
Net. Egr. Queue Pol: default
Egr. Sched. Pol    : n/a
Auto-negotiate     : true                       MDI/MDX          : unknown
Oper Phy-tx-clock  : not-applicable
Accounting Policy  : None                       Collect-stats    : Disabled
Acct Plcy Eth Phys : None                       Collect Eth Phys : Disabled
Egress Rate        : Default                    Ingress Rate     : Default
Load-balance-algo  : Default                    LACP Tunnel      : Disabled

Down-when-looped   : Disabled                   Keep-alive       : 10
Loop Detected      : False                      Retry            : 120
Use Broadcast Addr : False

Sync. Status Msg.  : Disabled                   Rx Quality Level : N/A
Tx DUS/DNU         : Disabled                   Tx Quality Level : N/A
SSM Code Type      : sdh                        ESMC Tunnel      : Disabled

Down On Int. Error : Disabled

CRC Mon SD Thresh  : Disabled                   CRC Mon Window   : 10 seconds
CRC Mon SF Thresh  : Disabled

Configured Address : d8:ef:01:01:00:03
Hardware Address   : d8:ef:01:01:00:03
```

The user also has the opportunity to decouple the **efm-oam** protocol from the port state and operational state. In cases where a user wants to remove the protocol, monitor the protocol only, migrate, or make changes the **ignore-efm-state** command can be configured under the following context.

```
configure port ethernet efm-oam
```

When the **ignore-efm-state** command is configured on a port the protocol continues as normal. However, any failure in the protocol state machine (discovery, configuration, time-out, loops, and so on) does not impact the port on which the protocol is active and the optional ignore command is configured. There is only a protocol warning message if there are issues with the protocol. The default behavior when this optional command is not configured means the port state is affected by any **efm-oam** protocol fault or clear conditions. Adding and removing this optional ignore command immediately represents the *Port State* and *Oper State* based on the active configuration. For example, if the **ignore-efm-state** command is configured on a port that is exhibiting a protocol error that protocol error does not affect the port state or operational state and there is no *Reason Down* code. If the **ignore-efm-state** is removed from a port with an existing **efm-oam** protocol error, the port transitions to *Link UP*, *Oper Down* with the reason code *efmOamDown*.

12.1 OAM events

The Information OAMPDU is transmitted by each peer at the configured intervals. This OAMPDU performs keepalive and critical notification functions. Various local conditions are conveyed through the setting of the Flags field. The following Critical Link Event defined in IEEE 802.3 Section 57.2.10.1 are supported:

- **link fault**

  The PHY has determined a fault has occurred in the receive direction of the local DTE.

- **dying gasp**

  An unrecoverable local failure condition has occurred.

- **critical event**

  An unspecified critical event has occurred.

The local node can set an unset the various Flag fields based on the operational state of the port, shutdown or activation of the efm-oam protocol or locally raised events. These Flag fields maintain the setting for the continuance of a particular event. Changing port conditions, protocol state or user intervention may impact the setting of these fields in the Information OAMPDU.

A peer processing the Information OAMPDU can take a configured action when one or more of these Flag fields are set. By default, receiving a set value for any of the Flag fields causes the local port to enter the previously mentioned Link Up port state and an event is logged. If this default behavior is not wanted, the user may choose to log the event without affecting the local port. This is configurable per Flag field using the options under the following context.

```
configure port ethernet efm-oam peer-rdi-rx
```

12.1.1 Link monitoring

The EFM-OAM protocol provides the ability to monitor the link for error conditions that may indicate the link is starting to degrade or has reached an error rate that exceeds an acceptable threshold.

Link monitoring can be enabled for three types of frame errors; **errored-frame**, **errored-frame-period**, and **errored-frame-seconds**. The **errored-frame** monitor is the number of frame errors compared to the threshold over a window of time. The **errored-frame-period** monitor is the number of frame errors compared to the threshold over a window of number of received packets. This window is checked once per second to see if the window command option has been reached. The **errored-frame-seconds** monitor is the number of errored seconds compared to the threshold over a window of time. An errored second is any second with a single frame error.

An errored frame is counted when any frame is in error as determined by the Ethernet physical layer, including jabbers, fragments, FCS or CRC and runts. This excludes jumbo frames with a byte count higher than 9212, or any frame that is dropped by the physical layer before reaching the monitoring function.

Each frame error monitor functions independently of other monitors. Each of monitor configuration includes an optional signal degrade threshold , a signal failure threshold, a **window** and the ability to communicate failure events to the peer by setting a Flag field in the Information OAMPDU or the generation of the Event Notification OAMPDU, **event-notification**. The command options are uniquely configurable for each monitor.

Use the following commands to configure a signal degrade or signal failure threshold:

- **MD-CLI**

  ```
  configure port ethernet symbol-monitor signal-degrade threshold
  configure port ethernet symbol-monitor signal-failure threshold
  ```

- **classic CLI**

  ```
  configure port ethernet symbol-monitor sd-threshold
  configure port ethernet symbol-monitor sf-threshold
  ```

A degraded condition is raised when the configured signal degrade threshold is reached. This provides a first level log only action indicating a link could become unstable. This event does not affect the port state. The critical failure condition is raised when the configured signal failure threshold is reached. By default, reaching the signal failure threshold causes the port to enter the *Link Up* condition unless the local signal failure has been modified to a **log-only** action. Signal degrade conditions for a monitor in signal failed state is suppressed until the signal failure has been cleared.

Use the following command to configure a local signal failure action.

```
configure port ethernet efm-oam link-monitoring local-sf-action local-port-action
```

The initial configuration or the modification of either of the threshold values take effect in the current window. When a threshold value for a monitor is modified, all active local events for that specific monitor are cleared. The modification of the threshold acts the same as the **clear** command described later in this section.

Notification to the peer is required to ensure the action taken by the local port detecting the error and its peer are synchronized. If peers do not take the same action then one port may remain fully operational while the other enters a non-operational state. These threshold crossing events do not shutdown the physical link or cause the protocol to enter a non-operational state. The protocol and network element configuration is required to ensure these asymmetrical states do not occur. There are two options for exchanging link and event information between peers; Information OAMPDU and the Event Notification OAMPDU.

As discussed earlier, the Information OAMPDU conveys link information using the Flags field; dying gasp, critical link and link fault. This method of communication has a number of significant advantages over the Event Notification OAMPDU. The Information OAMPDU is sent at every configured **transmit-interval**. This allows the most recent information to be sent between peers, a critical requirement to avoid asymmetrical forwarding conditions. A second major advantage is interoperability with devices that do not support Link Monitoring and vendor interoperability. This is the lowest common denominator that offers a robust communication to convey link event information. Because the Information OAMPDU is already being sent to maintain the peering relationship this method of communication adds no additional overhead. The **local-sf-action** options allow the dying gasp and critical event flags to be set in the Information OAMPDU when a signal failure threshold is reached. It is suggested that this be used in place of or in conjunction with Event Notification OAMPDU.

Event Notification OAMPDU provides a method to convey very specific information to a peer about various Link Events using Link Event TLVs. A unique Event Notification OAMPDU is generated for each unique frame error event. The intention is to provide the peer with the Sequence Number, Event Type, Timestamp, and the local information that caused the generation of the OAMPDU; window, threshold, errors and error running total and event running total specific to the port.

- **sequence number**

  The unique identification indicating a new event.

- **window**

  The size of the unique measurement period for the error type. The window is only checked at the end. There is no mid-window checking.

- **threshold**

  The value of the configured sf-threshold.

- **errors**

  The errors counted in that specific window.

- **error running total**

  The number of errors accumulated for that event type since monitoring started and the protocol and port have been operational or a reset function has occurred.

- **event running total**

  The number of events accumulated for that event type since the monitoring started and the protocol and port have been operational.

By default, the Event Notification OAMPDU is generated by the network element detecting the signal failure event. The Event Notification OAMPDU is sent only when the initial frame event occurs. No Event Notification OAMPDU is sent when the condition clears. A port that has been operationally affected as a result of a Link Monitoring frame error event must be recovered manually. The typical recovery method is to administratively disable the port and administratively enable the port. This clears all events on the port. Any function that affects the port state, physical fiber pull, soft or hard reset functions, protocol restarts, and so on, also clears all local and remote events on the affected node experiencing the operation. None of these frame errors recovery actions cause the generation of the Event Notification OAMPDU. If the chosen recovery action is not otherwise recognized by the peer and the Information OAMPDU Flag fields have not been configured to maintain the current event state, there is a high probability that the ports have different forwarding states, notwithstanding any higher level protocol verification that may be in place.

A burst of between one and five Event Notification OAMPDU packets may be sent. By default, only a single Event Notification OAMPDU is generated, but this value can be changed under the **local-sf-action** context. An Event Notification OAMPDU is only processed if the peer had previously advertised the EV capability. The EV capability is an indication the remote peer supports link monitoring and may send the Event Notification OAMPDU.

The network element receiving the Event Notification OAMPDU uses the values contained in the Link event TLVs to determine if the remote node has exceeded the failure threshold. The locally configured action determines how and if the local port is affected. By default, processing of the Event Notification OAMPDU is log only and does not affect the port state. By default, processing of the Information OAMPDU Flag fields is port affecting. When Event Notification OAMPDU has been configured as port affecting on the receiving node, action is only taken when errors are equal to or above the threshold and the threshold value is not zero. No action is taken when the errors value is less than the threshold or the threshold is zero.

Symbol error monitoring is also supported but requires specific hardware revisions and the appropriate code release.

Use the following command to configure symbol error handling.

```
configure port ethernet efm-oam link-monitoring errored-symbols
```

The symbol monitor differs from the frame error monitors. Symbols represent a constant load on the Ethernet wire whether service frames are present or not. This means the optional signal degrade threshold has an additional purpose when configured as part of the symbol error monitor. When the signal degrade threshold is not configured, the symbol monitor acts similar to the frame error monitors, requiring manual intervention to clear a port that has been operationally affected by the monitor. When the optional signal degrade threshold is configured, it again represents the first level warning. However, it has an additional function as part of the symbol monitor. If a signal failure event has been raised, the configured signal degrade threshold becomes the equivalent to a lowering threshold. If a subsequent window does not reach the configured signal degrade threshold then the previous event is cleared and the previously affected port is returned to service without user intervention. This return to service automatically clears any previously set Information OAMPDU Flags fields set as a result of the signal failure threshold. The Event Notification

OAMPDU is generated with the symbol error Link TLV that contains an error count less than the threshold. This indicates to the peer that initial problem has been resolved and the port should be returned to service.

The **errored-symbol** window is a measure of time that is automatically converted into the number of symbols for that specific medium for that period of time. The standard MIB entries "dot3OamErrSymPeriodWindowHi" and "dot3OamErrSymPeriodWindowLo" are marked as read-only instead of read-write. These values cannot be configured directly. The configuration of the window converts the time and programs the two MIB values in an appropriate manner.

Use the following command to configure the symbol error window.

```
configure port ethernet efm-oam link-monitoring errored-symbols window
```

Use the following command to display both the configured window and the number of symbols.

```
show port 1/1/1 ethernet efm-oam
```

Output example

```
===============================================================================
Ethernet Oam (802.3ah)
===============================================================================
Admin State        : up
Oper State         : operational
Mode               : active
Pdu Size           : 1518
Config Revision    : 0
Function Support   : LB
Transmit Interval  : 1000 ms
Multiplier         : 5
Hold Time          : 0
Tunneling          : false
Loop Detected      : false
Grace Tx Enable    : true (inactive)
Grace Vendor OUI   : 00:16:4d
Dying Gasp on Reset: true (inactive)
Soft Reset Tx Act  : none
Trigger Fault      : none
Vendor OUI         : 00:16:4d (alu)
Vendor Info        : 00:01:00:02
Peer Mac Address   : d8:1c:01:02:00:01
Peer Vendor OUI    : 00:16:4d (alu)
Peer Vendor Info   : 00:01:00:02
Peer Mode          : active
Peer Pdu Size      : 1518
Peer Cfg Revision  : 0
Peer Support       : LB
Peer Grace Rx      : false
Loopback State     : None
Loopback Ignore Rx : Ignore
Ignore Efm State   : false
Link Monitoring    : disabled
Peer RDI Rx
  Critical Event   : out-of-service
  Dying Gasp       : out-of-service
  Link Fault       : out-of-service
  Event Notify     : log-only
Local SF Action                      Discovery
  Event Burst      : 1                 Ad Link Mon Cap  : yes
  Port Action      : out-of-service
  Dying Gasp       : disabled
```

```
  Critical Event   : disabled
Errored Frame                          Errored Frame Period
  Enabled          : no                  Enabled          : no
  Event Notify     : enabled             Event Notify     : enabled
  SF Threshold     : 1                   SF Threshold     : 1
  SD Threshold     : disabled (0)        SD Threshold     : disabled (0)
  Window           : 10 ds               Window           : 1488095 frames
Errored Symbol Period                  Errored Frame Seconds Summary
  Enabled          : no                  Enabled          : no
  Event Notify     : enabled             Event Notify     : enabled
  SF Threshold     : 1                   SF Threshold     : 1
  SD Threshold     : disabled (0)        SD Threshold     : disabled (0)
  Window (time)    : 10 ds               Window           : 600 ds
  Window (symbols) : 125000000
===============================================================================
Active Failure Ethernet OAM Event Logs
===============================================================================
Number of Logs : 0
===============================================================================
===============================================================================
Ethernet Oam Statistics
===============================================================================
                                                    Input                Output
-------------------------------------------------------------------------------
Information                                        238522                238522
Loopback Control                                        0                     0
Unique Event Notify                                     0                     0
Duplicate Event Notify                                  0                     0
Unsupported Codes                                       0                     0
Frames Lost                                                                   0
===============================================================================
```

Use the following commands to clear local and remote port affecting events on the local node on which the command is issued.

```
clear port ethernet efm-oam events local
clear port ethernet efm-oam events remote
```

When the optional [**local | remote**] command options are omitted, both local and remote events are cleared for the specified port. This command is not specific to the link monitors as it clears all active events. When local events are cleared, all previously set Information OAMPDU Flag fields are cleared regardless of the cause of the event that set the Flag field.

In the case of symbol errors only, if Event Notification OAMPDU is enabled for symbol errors and a local symbol error signal failure event exists at the time of the clear, the Event Notification OAMPDU generates with an error count of zero and a threshold value reflecting the local signal failure threshold. An error value lower than the threshold value indicates the local node is not in a signal failed state. The Event Notification OAMPDU is not generated in the case where the **clear** command clears local frame error events. This is because frame error event monitors only acts on an Event Notification OAMPDU when the error value is higher than the threshold value, a lower value is ignored. As stated previously, there is no automatic return to service for frame errors.

If the **clear** command clears remote events, events conveyed to the local node by the peer, no notification is generated to the peer to indicate a clear function has been performed. Since the Event Notification OAMPDU is only sent when the initial event was raised, there is no further Event Notification and blackholes can result. If the Information OAMPDU Flag fields are used to ensure a constant refresh of information, the remote error is reinstated as soon as the next Information OAMPDU arrives with the appropriate Flag field set.

Local and remote EFM-OAM port events are stored in the EFM-OAM event logs. These logs maintain and display active and cleared signal failure degrade events. These events are interacting with the EFM-OAM protocol. This logging is different than the time stamped events for information logging purposes included with the system log.

Use the following commands to view these events.

```
show port ethernet efm-oam event-log
```

This includes the location, the event type, the counter information or the decoded Network Event TLV information, and if the port has been affected by this active event. A maximum of 12 port events are retained. The first three indexes are reserved for the three Information Flag fields, dying gasp, critical link, and link fault. The other nine indexes maintain the current state for the various error monitors in a most recent behavior and events can wrap the indexes, dropping the oldest event.

In mixed environments where Link Monitoring is supported on one peer but not the other the following behavior is normal, assuming the Information OAMPDU has been enabled to convey the monitor fault event. The arriving Flag field fault triggers the EFM-OAM protocol on the receiving unsupportive node to move from operational to "send local and remote". The protocol on the supportive node that set the Flag field to convey the fault enters the "send local and remote ok" state. The supportive node maintains the Flag field setting until the condition has cleared. The protocol recovers to the operational state after the original event has cleared; assuming no other fault on the port is preventing the negotiation from progressing. If both nodes were supportive of the Link Monitoring process, the protocol would remain operational.

In summary, Link monitors can be configured for frame and symbol monitors (specific hardware only). By default, Link Monitoring and all monitors are shutdown. When the Link Monitoring function is enabled, the capability (EV) is advertised. When a monitor is enabled, a default window size and a default signal failure threshold are activated. The local action for a signal failure threshold event is to administratively disable the local port. Notification is sent to the peer using the Event Notification OAMPDU. By default, the remote peer does not take any port action for the Event Notification OAMPDU. The reception is only logged. It is suggested the user evaluate the various defaults and configure the **local-sf-action** to set one of the Flag fields in the Information OAMPDU.

Use commands under the following context to configure options when fault notification to a peer is required.

```
configure port ethernet efm-oam link-monitoring local-sf-action info-notification
```

Non-Nokia vendor specific information is not processed.

12.1.1.1 Capability advertising

A supported capability, sometimes requiring activation, is advertised to the peer. The EV capability is advertisement when Link Monitoring is active on the port.

Use the following command option to disable this capability:

- **MD-CLI**

```
configure port ethernet efm-oam discovery advertise-capabilities link-monitoring false
```

- **classic CLI**

```
configure port ethernet efm-oam discovery advertise-capabilities no link-monitoring
```

12.2 Remote loopback

EFM OAM provides a link-layer frame loopback mode that can be remotely controlled.

To initiate remote loopback, the local EFM OAM client sends a loopback control OAM PDU by enabling the OAM **remote-loopback** command. After receiving the loopback control OAM PDU, the remote OAM client puts the remote port into local loopback mode.

To exit remote loopback, the local EFM OAM client sends a loopback control OAM PDU by disabling the OAM **remote-loopback** command. After receiving the loopback control OAM PDU, the remote OAM client puts the port back into normal forwarding mode.

During remote loopback test operation, all frames except EFM OAM PDUs are dropped at the local port for the receive direction, where remote loopback is enabled. If local loopback is enabled. If the received looped back non-EFM frames must be forwarded, use the following command to enable the forwarding of those frames:

- **MD-CLI**

```
configure port ethernet efm-oam remote-loopback-forward-non-efm-frames true
```

- **classic CLI**

```
configure port ethernet efm-oam remote-lb-fwd-non-efm-frames true
```

If local loopback is enabled, all frames received on the port are looped back, and any frames generated or forwarded by the node are dropped in the transmit direction. This behavior may result in some protocols (for example, STP or LAG) resetting the state machines.

When a port is in loopback mode, service mirroring does not work if the port is a mirror-source or a mirror-destination.

12.3 802.3ah OAM PDU tunneling for Epipe service

Nokia routers support 802.3ah. Customers who subscribe to Epipe service treat the Epipe as a wire, so they demand the ability to run 802.3ah between their devices which are located at each end of the Epipe.

This feature applies only to port-based Epipe SAPs because 802.3ah runs at the port level, not at the VLAN level. These ports must be configured as null encapsulated SAPs.

When OAM PDU tunneling is enabled, 802.3ah OAM PDUs received at one end of an Epipe are forwarded through the Epipe. 802.3ah can run between devices that are located at each end of the Epipe. When OAM PDU tunneling is disabled (by default), OAM PDUs are dropped or processed locally according to the **efm-oam** configuration state.

Enabling 802.3ah for a specific port and enabling OAM PDU tunneling for the same port are mutually exclusive.

12.3.1 802.3ah Grace announcement

The SR OS implementation of the EFM-OAM protocol supports vendor-specific soft reset graceful recovery. This feature is not enabled by default.

Use the following commands to enable soft reset graceful recovery:

- **MD-CLI**

```
configure system ethernet efm-oam grace-tx
configure port ethernet efm-oam grace-tx
```

- **classic CLI**

```
configure system ethernet efm-oam grace-tx-enable
configure port ethernet efm-oam grace-tx-enable
```

When this feature is enabled, the EFM-OAM protocol does not enter a non-operational state when both nodes acknowledge the grace function. The ports associated with the hardware that has successfully executed the soft reset clears all local and remote events. The peer that acknowledges the graceful restart procedure for EFM-OAM clears all remote events that it has received from the peer that performed the soft reset. The local events are not cleared on the peer that has not undergone soft reset. The Information OAM PDU Flag fields are critical in propagating the local event to the peer. The Event Notification OAM PDU, which is only sent when the event is initially raised, is not sent.

A vendor-specific Grace TLV is included in the Information PDU generated as part of the 802.3ah OAM protocol when a network element undergoes an ISSU function. Nodes that support the Soft Reset messaging functions allow the local node to generate the Grace TLV.

The Grace TLV informs a remote peer that the negotiated interval and multiplier should be ignored and the new 900 s timeout interval should be used to timeout the session. The peer receiving the Grace TLV must be able to parse and process the vendor-specific messaging.

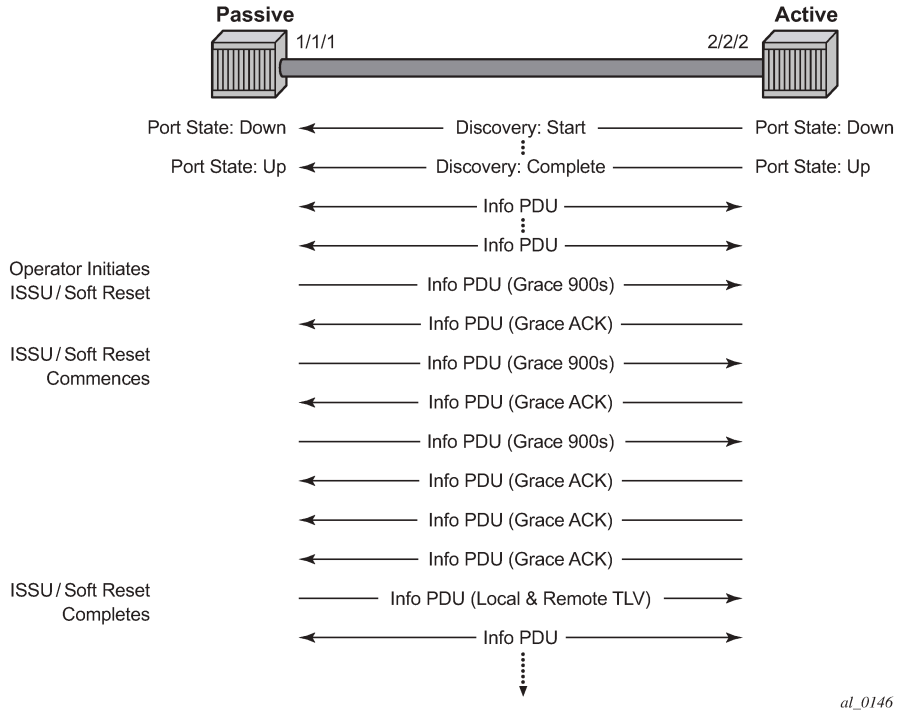
This command exists at two levels of the hierarchy: system level and port level. By default, this feature is enabled on the port. At the system level, this command defaults to disabled. To enable this feature, both the port and the system commands must be enabled. If either is not enabled, the combination does not allow those ports to generate the vendor specific Grace TLV. This feature must be enabled at both the system and port level before the ISSU or soft reset function. If this feature is enabled during a soft reset or after the ISSU function is already in progress, it has no affect during that window. Both Passive and Active 802.3ah OAM peers can generate the Grace TLV as part of the informational PDU.

There is no CLI command to enable this feature on the receiving node. As long as the receiver understands and can parse the Grace TLV, it enters the grace mode of operation.

Note: The Nokia 7750 SR minimum release required to support the reception and processing of the Grace TLV is Release 11.0.R.4.

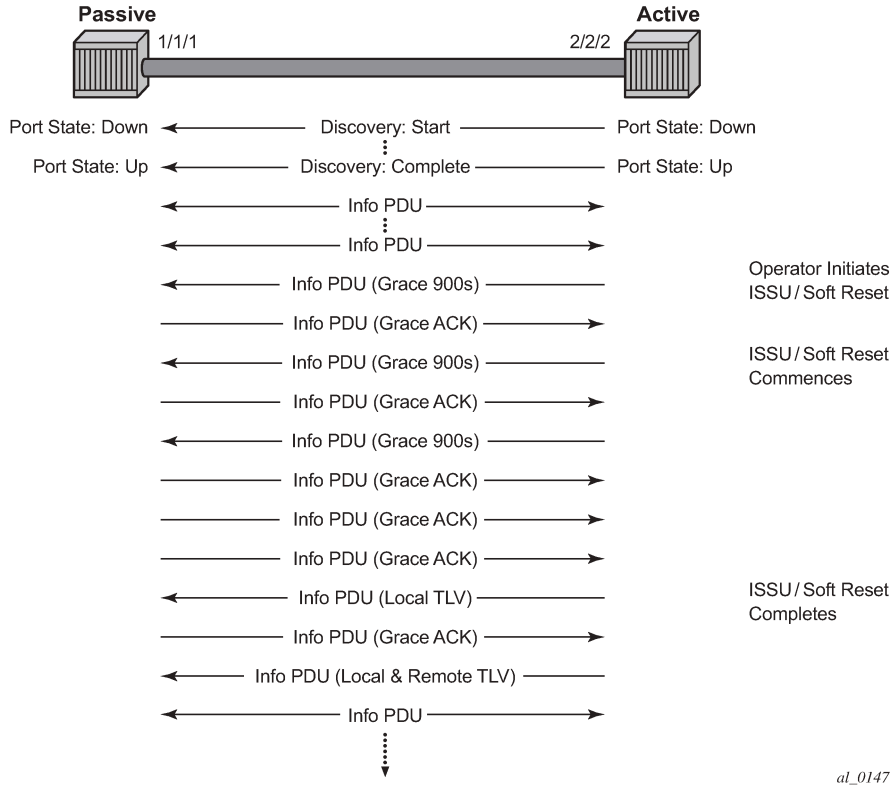
The following basic protocol flows demonstrate the interaction between passive/active and active/active peer combinations supporting the Grace TLV. In the following figure, the passive node is entering an ISSU on a node that supports soft reset capabilities.

Figure 43: Grace TLV passive node with soft reset



In the following figure, the active node is experiencing the ISSU function on a node that supports soft reset capabilities.

Figure 44: Grace TLV active node with soft reset



The difference between Figure 43: Grace TLV passive node with soft reset and Figure 44: Grace TLV active node with soft reset is subtle but important. When an active node performs this function, it generates an Informational TLV with the Local TLV following the successful soft reset. When the active node receives the Information PDU with the Grace Ack, it sends its own Information PDU with both Local and Remote TLV completed, which completes the protocol restart. When a passive node is reset, the passive port waits to receive the 802.3ah OAM protocol before sending its own Information PDU with both the Local and Remote TLV, completing the protocol restart.

The renegotiation process allows the node, which experienced the soft reset, to rebuild the session without restarting the session from the discovery phase. This significantly reduces the native protocol impact on data forwarding.

Any situation that could cause the renegotiation to fail forces the protocol to revert to the discovery phase and fail the graceful restart. During an ISSU when the EFM-OAM session is held operational by the Grace function, if the peer MAC address of the session changes, there is no log event raised for the MAC address change.

The vendor-specific grace function benefits are realized when both peers support the transmitting, receiving, and processing of the vendor-specific Grace TLV. In the case of mixed code versions, products, or vendor environments, a standard EFM-OAM message to the peer can be used to instruct the peer to treat the session as failed.

Use the following command to enable the soft reset function to trigger ETH-OAM to set the dying gasp flag or critical event flag in the Information OAMPDU.

```
configure port ethernet efm-oam dying-gasp-tx-on-reset
```

An initial burst of three Informational OAM PDUs is sent using a 1-second spacing, regardless of the protocol interval. The peer may process these flags to affect its port state and take the appropriate action. The control of the local port state where the soft reset is occurring is left to the soft reset function. This EFM-OAM function does not affect local port state. If the peer has acted on the exception flags and affected its port state, the local node must take an action to inform the upstream nodes that a condition has occurred and forwarding is no longer possible. Routing protocols like ISIS and OSPF overload bits are typically used in routed environments to accomplish this notification.

This feature is similar to the following:

- **MD-CLI**

```
configure system efm-oam grace-tx
```

- **classic CLI**

```
configure system efm-oam grace-tx-enable
```

Intercepting system messaging, when the feature is active on a port (enabled both at the port and at the system level) and when the messaging occurs, is a similar concept. However, because the **dying-gasp-tx-on-reset** command is not a graceful function it is interruptive and service affecting. Using **dying-gasp-tx-on-reset** requires peers to reestablish the peering session from an initial state, not rebuild the state from previous protocol information. The transmission of the dying gasp or the critical event commences when the soft reset occurs and continues for the duration of the soft reset.

If both functions are active on the same port the following function is preferred if the peer is setting and sending the Vendor OUI to 00:16:4d (ALU) in the Information OAM PDU:

- **MD-CLI**

```
configure system efm-oam grace-tx
```

- **classic CLI**

```
configure system efm-oam grace-tx-enable
```

In this situation, the dying gasp function is not invoked. Should an additional Vendor OUI prefer to support the reception, parsing, and processing of the vendor-specific grace message instead of the dying gasp, a secondary Vendor OUI can be configured using the following command.

```
configure port ethernet efm-oam grace-vendor-oui
```

If only one of those functions is active on the port then that specific function is called. The grace function should not be enabled if the peer Vendor OUI is equal to 00:16:4d (ALU) and the peer does not support the grace function.

ETH-OAM allows the use of the following command to generate a fault condition.

```
configure port ethernet efm-oam trigger-fault
```

This sets the appropriate flag fields in the Information OAM PDU and transitions a previously operational local port to Link Up. Removing this command from the configuration stops the flags from being set and allows the port to return to service, assuming no other faults would prevent this resumption of service. In cases where a port must be administratively shut down, this command can be used to signal a peer using the EFM-OAM protocol, and the session should be considered failed.

These features do not support clearing an IOM that does not trigger a soft reset. IOM clearing is a forceful event that does not trigger graceful protocol renegotiation.

The **show** commands are enhanced to help users determine the state of the 802.3ah OAM Grace function and whether the peer is generating or receiving the Grace TLV.

Use the following command to view system level information.

```
show system information
```

Output example

```
===============================================================================
System Information
===============================================================================
System Name            : system-name
System Type            : 7750 SR-12
System Version         : 11.0r4
System Contact         :
System Location        :
System Coordinates     :
System Active Slot     : A
System Up Time         : 62 days, 20:29:48.96 (hr:min:sec)

…snip…

EFM OAM Grace Tx Enable: False
===============================================================================
```

The system-level EFM OAM Grace Tx Enable field displays one of the following two states.

- **False**

  The system-level functionality is not enabled. Grace is not generated on any ports regardless of the state of the option on the individual ports.

- **True**

  The system-level functionality is enabled and the determination of whether to send grace is based on the state of the option configured at the port level.

Individual ports also contain information about the current port configuration and whether the Grace TLV is being sent or received.

The port-level Grace Tx Enable field has two enable states with the current state in brackets to the right.

- **False**

  The port-level functionality is not enabled. Grace is not generated on the port regardless of the state of the option at the system level.

- **True**

  The port-level functionality is enabled and the determination of whether to send grace is based on the state of the option configured at the system level. The following applies:

  – (inactive) Not currently sending Grace TLV

  – (active) Currently sending the Grace TLV as part of the Information PDU

The port-level Peer Grace Rx field displays one of the following two states.

- **False**

The port is not receiving Grace TLV from the peer.

- **True**

  The port is receiving Grace TLV from the peer.

13 MTU configuration guidelines

The following MTU configuration guidelines apply:

- The router provides the option to configure MTU limitations at many service points. The physical (access and network) port, service, and SDP MTU values must be individually defined.
- Identify the ports that are designated as network ports intended to carry service traffic.
- MTU values should not be modified frequently.
- The service MTU values must conform to the following conditions:
  - must be less than or equal to the SDP path MTU
  - must be less than or equal to the access port (SAP) MTU
- When the network group encryption (NGE) feature is enabled, additional bytes because of NGE packet overhead must be considered. See the "NGE Packet Overhead and MTU Considerations" section in the *7450 ESS, 7750 SR, 7950 XRS, and VSR Services Overview Guide* for more information.

13.1 Default MTU values

The following table lists the default MTU values that are dependent upon the (sub-) port type, mode, and encapsulation.

Table 20: MTU default values

Port type	Mode	Encap type	Default (bytes)
Ethernet	access	null	1514
Ethernet	access	dot1q	1518
Fast Ethernet[5]	network	—	1514
Other Ethernet	network	—	9212[6]

13.2 Modifying MTU defaults

MTU command options must be modified on the service level as well as the port level.

- The service-level MTU command options configure the service payload (Maximum Transmission Unit – MTU) in bytes for the service ID overriding the service-type default MTU.

5 Physical/native Fast Ethernet only.

6 The default MTU for Ethernet ports other than Fast Ethernet is actually the lesser of 9212 and any MTU limitations imposed by hardware which is typically 16K.

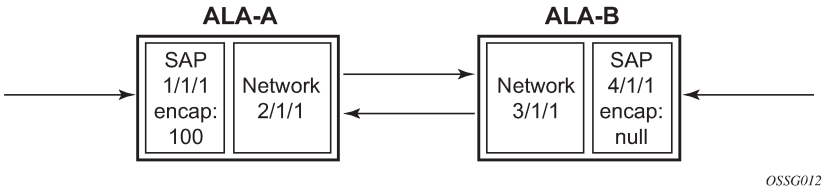
- The port-level MTU command options configure the maximum payload MTU size for an Ethernet port or LAG.

The default MTU values must be modified to ensure that packets are not dropped because of frame size limitations. The service MTU must be less than or equal to both the SAP port MTU and the SDP path MTU values. When an SDP is configured on a network port using default port MTU values, the operational path MTU can be less than the service MTU. In this case, enter the `show service sdp` command to check the operational state. If the operational state is down, then modify the MTU value accordingly.

13.3 Configuration example

In order for the maximum length service frame to successfully travel from a local ingress SAP to a remote egress SAP, the MTU values configured on the local ingress SAP, the SDP (GRE or MPLS), and the egress SAP must be coordinated to accept the maximum frame size the service can forward. For example, the targeted MTU values to configure for a distributed Epipe service (ALA-A and ALA-B) are shown in Figure 45: MTU configuration example.

Figure 45: MTU configuration example



Because ALA-A uses Dot1q encapsulation, the SAP MTU must be set to 1518 to be able to accept a 1514 byte service frame (see Default MTU values for MTU default values). Each SDP MTU must be set to at least 1514 as well. If ALA-A's network port (2/1/1) is configured as an Ethernet port with a GRE SDP encapsulation type, then the MTU value of network ports 2/1/1 and 3/1/1 must each be at least 1556 bytes (1514 MTU + 28 GRE/Martini + 14 Ethernet). Finally, the MTU of ALA-B's SAP (access port 4/1/1) must be at least 1514, as it uses null encapsulation.

Table 21: MTU configuration example values shows example MTU configuration values.

Table 21: MTU configuration example values

	ALA-A		ALA-B	
	Access (SAP)	**Network**	**Network**	**Access (SAP)**
Port (slot/MDA/port)	1/1/1	2/1/12	3/1/1	4/1/1
Mode or ECAP-type	dot1q	network	network	null
MTU	1518	1556	1556	1514

14 Deploying preprovisioned components

When a card, MDA, XCM, or XMA is installed in a preprovisioned slot, the device detects discrepancies between the preprovisioned card type configurations and the types actually installed. Similarly, for cards or XMAs that have license levels, the device also detects discrepancies between the provisioned level and the level of the installed card or XMA. Error messages display if there are inconsistencies and the card does not initialize.

When the correct preprovisioned cards are installed into the appropriate chassis slot, alarm, status, and performance details are displayed.

On bootup, or High Availability (HA) switchover, preprovisioned (and administratively enabled) slots are checked after an initial 15-minute period to ensure that they are present in the slot. If the card is not detected the system raises an alarm.

15 Setting fabric speed

To set the fabric speed for the 7750 SR-7/12/12e, 7450 ESS-7/12, 7750 SR-7s/14s, and 7950 XRS-20/20e and is associated with the FP3 or newer generation of switch fabric, use the following command.

```
tools perform system set-fabric-speed
```

15.1 7750 SR-7/12/12e and 7450 ESS-7/12

The **fabric-speed-a** command option enables the chassis to operate at the following speeds using N+1 switch fabric redundancy:

- up to 100 Gb/s per slot for the 7450 ESS-7/12 and the 7750 SR-7/12
- up to 200 Gb/s per slot for the 7750 SR-12e

This command option is compatible with SFM5, which allows a mixture of FP2- and FP3-based cards to coexist. This fabric speed is displayed as "6 Gig" in the **show chassis** output.

The **fabric-speed-b** command option enables the chassis to operate at the following speeds using N+1 switch fabric redundancy:

- up to 200 Gb/s per slot for the 7450 ESS-7/12 and the 7750 SR-7/12
- up to 400 Gb/s per slot for the 7750 SR-12e

This command option is compatible with SFM5. All cards in the system must be FP3-based. The system does not support any FP2-based cards when the chassis is set to **fabric-speed-b**. This fabric speed is displayed as "10 Gig" in the **show chassis** output.

Note: To set **fabric-speed-b** for the 7750 SR-7/12 and 7450 ESS-7/12, the chassis must support 200 Gb/s per slot capability. To check if the chassis supports **fabric-speed-b**, execute the **show system switch-fabric** command and verify that the "chassis is 200G/slot capable" message is displayed.

The **fabric-speed-c** command option enables the use of both FP3- and FP4-based cards and is compatible with SFM6. This speed is mandatory if FP4 cards are used. The performance of FP3 cards is the same as **fabric-speed-b**. This fabric speed is displayed as "S4" in the **show chassis** output.

Note: To set **fabric-speed-c** for the 7750 SR-7/12/12e and 7450 ESS-7/12, the chassis must support S4 fabric capability. To check if the chassis supports **fabric-speed-c**, execute the **show system switch-fabric** command and verify that the "chassis is s4 fabric capable" message is displayed.

If no fabric speed has previously been set on the chassis, either **fabric-speed-a** or **fabric-speed-b** is automatically selected and set based on the physically equipped cards. If no FP2-based cards are physically equipped and the chassis meets the required capabilities, **fabric-speed-b** is selected; if not, **fabric-speed-a** is selected.

15.2 7950 XRS-20/20e

The **none** command option enables the 7950 XRS-20/20e to use only FP3 cards. This fabric speed is compatible with the following SFMs: **sfm-x20**, **sfm-x20-b**, and **sfm-x20s-b**. When the **none** command option is used, there is no fabric speed configured or displayed in the **show chassis** output.

The **fabric-speed-c** command option enables the use of both FP3- and FP4-based cards and is compatible with **sfm2-x20s**. For the 7950 XRS-20/20e, the performance of FP3 cards is the same as the **none** command option. This fabric speed is displayed as "S4" in the **show chassis** output.

If no fabric speed has previously been set on the chassis, the **none** command option is set as the default.

The following command is not used in 7950 XRS-40 systems.

```
tools perform system set-fabric-speed
```

15.3 7750 SR-7s/14s

The **none** command option enables the 7750 SR-7s/14s to use only FP4 cards. This fabric speed is compatible with sfm-s. When the **none** command option is used, there is no fabric speed displayed in the **show chassis** output.

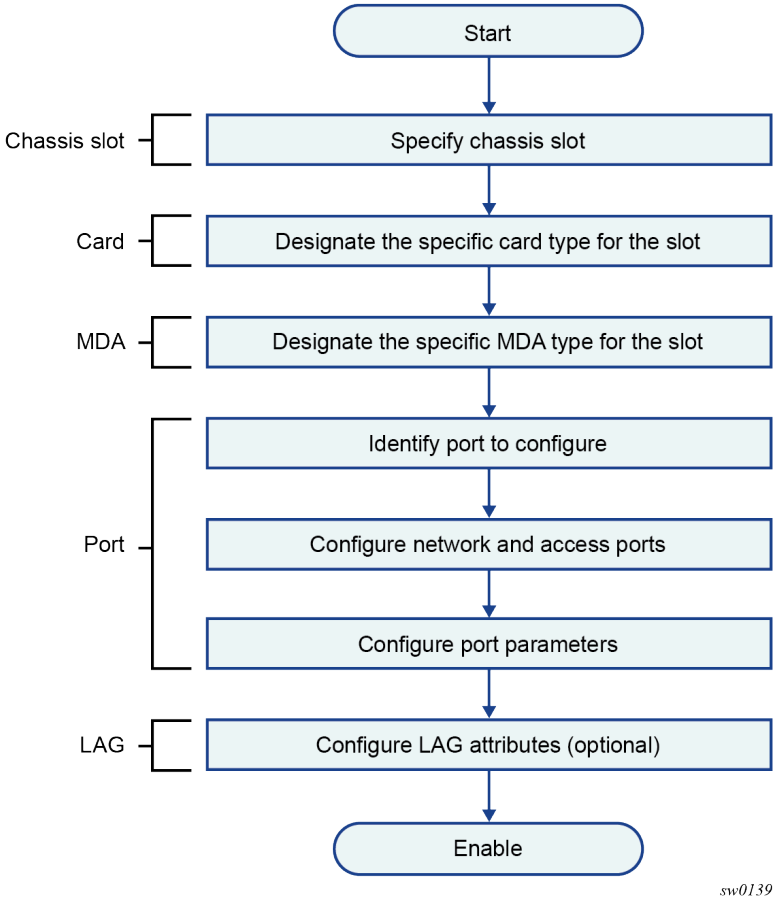
The **fabric-speed-d** command option enables the use of both FP4- and FP5-based cards and is compatible with sfm2-s for the 7750 SR-7s and 7750 SR-14s. This speed is mandatory if FP5 cards are used. This fabric speed is displayed as "S5" in the **show chassis** output.

If no fabric speed has previously been set on the chassis, then the default is based on the specific chassis variant. For the FP4 chassis, the default is **none**; for the FP5 chassis the default is **fabric-speed-d**.

16 Configuration process overview

The following figure shows the process to provision chassis slots, cards, MDAs, and ports.

Figure 46: Slot, card, MDA, port configuration, and implementation flow



16.1 Configuration notes

The following information describes provisioning restrictions.

- If a card or MDA type is installed in a slot provisioned for a different type, the card does not initialize.
- A card or MDA installed in an unprovisioned slot remains administratively and operationally down until the card type and MDA are specified.
- Ports cannot be provisioned until the slot, card and MDA type are specified.
- cHDLC does not support HDLC windowing features, nor other HDLC frame types such as S-frames.

- cHDLC operates in the HDLC Asynchronous Balanced Mode (ABM) of operation.
- APS configuration rules:
  - A physical port (either working or protection) must be shut down before it can be removed from an APS group port.
  - For a single-chassis APS group, a working port must be added first. Then a protection port can be added or removed at any time.
  - A protection port must be shut down before being removed from an APS group.
  - A path cannot be configured on a port before the port is added to an APS group.
  - A working port cannot be removed from an APS group until the APS port path is removed.
  - When ports are added to an APS group, all path-level configurations are available only on the APS port level and configuration on the physical member ports are blocked.
  - For APS-protected bundles, all members of a working bundle must reside on the working port of an APS group. Similarly all members of a protecting bundle must reside on the protecting circuit of that APS group.

17 Configuring physical ports with CLI

This section provides information to configure cards, MDAs, and ports.

17.1 Preprovisioning guidelines

SR OSs have a console port, either located on the CPM or CCM, or integrated into the chassis (on the 7750 SR-c4 models), to connect terminals to the router.

Configure command options from a system console connected to a router console port, using Telnet to access a router remotely or SSH to open a secure shell connection.

17.1.1 Predefining entities

To initialize a card, the chassis slot, line card type, and MDA type must match the preprovisioned command options. In this context, preprovisioning means to configure the entity type (such as the card type, MDA type, port, and interface) that is planned for a chassis slot, card, or MDA. Preprovisioned entities can be installed but not enabled or the slots can be configured but remain empty until populated. Provisioning means that the preprovisioned entity is installed and enabled.

You can:

- Preprovision ports and interfaces after the line card and MDA types are specified.
- Install line cards in slots with no pre-configuration command options specified. After the card is installed, the card and MDA types must be specified.
- Install a line card in a slot provisioned for a different card type (the card does not initialize). The existing card and MDA configuration must be deleted and replaced with the current information.

17.1.2 Preprovisioning a port

Before a port can be configured, the slot must be preprovisioned with an allowed card type and the MDA must be preprovisioned with an allowed MDA type. Some recommendations to configure a port include:

- **Ethernet**
  - Configure an access port for customer facing traffic on which services are configured.
  - An encapsulation type may be specified to distinguish services on the port or channel. Encapsulation types are not required for network ports.
  - To configure an Ethernet access port, see Configuring Ethernet access ports.

17.1.3 Maximizing bandwidth use

After ports are preprovisioned, Link Aggregation Groups (LAGs) can be configured to increase the bandwidth available between two nodes.

All physical links or channels in a LAG/bundle combine to form one logical connection. A LAG/bundle also provides redundancy in case one or more links that participate in the LAG/bundle fail.

17.2 Basic configuration

The most basic configuration must specify the following:

- chassis slot
- line card type (must be an allowed card type)
- MDA slot
- MDA (must be an allowed MDA type)
- specific port to configure

The following is an example of card configuration for the 7750 SR.

Example: MD-CLI

```
[ex:]
A:admin@node-2# admin show configuration
    configure {
        card 6 {
            card-type iom4-e
            mda 1 {
                mda-type me1-100gb-cfp2
            }
            fp 1 {
            }
        }
        card 7 {
            card-type iom4-e
            mda 1 {
                mda-type me10-10gb-sfp+
            }
            mda 2 {
                mda-type me1-100gb-cfp2
            }
            fp 1 {
            }
        }
        card 8 {
            card-type iom4-e
            mda 1 {
                mda-type me10-10gb-sfp+
            }
        }
```

Example: classic CLI

```
A:node-2> admin display-config
echo "Card Configuration"
#--------------------------------------------------
    card 6
        card-type iom4-e
        no shutdown
    exit
    card 7
        card-type iom4-e
```

```
        mda 1
            mda-type me10-10gb-sfp+
            no shutdown
        exit
        mda 2
            mda-type me1-100gb-cfp2
            no shutdown
        exit
        no shutdown
    exit
    card 8
        card-type iom4-e
        no shutdown
    exit
#--------------------------------------------------
```

The following is an example of card configurations for the 7950 XRS.

Example: MD-CLI

```
[ex:/configure card 1]
A:admin@node-2# info
    card-type xcm-x20
    mda 1 {
        mda-type x2-100g-tun
           }
    mda 2 {
        mda-type x40-10g-sfp
            }
    fp 1 {
    }
```

Example: classic CLI

```
A:node-2>configure card 1# info
----------------------------------------------
        card-type xcm-x20
        mda 1
            mda-type x2-100g-tun
            no shutdown
        exit
        mda 2
            mda-type x40-10g-sfp
            no shutdown
        exit
        no shutdown
----------------------------------------------
```

17.3 Common configuration tasks

The following sections are basic system tasks that must be performed.

17.3.1 Configuring cards and MDAs

Card configurations include a chassis slot designation. A slot must be preconfigured with the type of cards and MDAs which are allowed to be provisioned.

The following example shows card and MDA configurations for the 7750 SR or 7450 ESS.

Example: MD-CLI

```
[ex: /configure card 8]
A:admin@node-2# info
    card-type iom4-e
    mda 1 {
        mda-type me10-10gb-sfp+
    }
    mda 2 {
        mda-type me1-100gb-cfp2
    }
    fp 1 {
    }
```

Example: classic CLI

```
A:node-2>config>card# info
#------------------------------------------------
    card 8
        card-type iom4-e
        mda 1
            mda-type me10-10gb-sfp+
            no shutdown
        exit
        mda 2
            mda-type me1-100gb-cfp2
            no shutdown
        exit
        no shutdown
              exit
#------------------------------------------
```

The following example shows card configurations for the 7950 XRS.

Example: MD-CLI

```
[ex:/configure card 1]
A:admin@node-2# info
    card-type xcm-x20
    mda 1 {
        mda-type x40-10g-sfp
           }
    mda 2 {
        mda-type x2-100g-tun
           }
    fp 1 {
    }
```

Example: classic CLI

```
A:node-2>config>card# info
----------------------------------------------
        card-type xcm-x20
        mda 1
            mda-type x40-10g-sfp
            no shutdown
        exit
        mda 2
            mda-type x2-100g-tun
```

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

17.3.1.1 Configuring FP network pools

FP-level pools are used by ingress network queues. Network policies can be applied (optional) to create and edit QoS pool resources for ingress network queues. Network-queue and slope policies are configured in the following context.

```
configure qos
```

The following example shows an FP pool configuration for 7750 SR or 7450 ESS.

Example: MD-CLI

```
[ex:/configure card 1 fp 1]
A:admin@node-2# info
    ingress {
        network {
            queue-policy "10"
            pool "default" {
                slope-policy "slope1"
                resv-cbs {
                    cbs 50
                }
            }
        }
    }
```

Example: classic CLI

```
A:node-2>config>card>fp# info
-----------------------------------------------
            ingress
                network
                    pool "default"
                        resv-cbs 50
                        slope-policy "slope1"
                    exit
                    queue-policy "10"
                exit
            exit
-----------------------------------------------
```

17.3.2 Configuring ports

This section provides the CLI and examples to configure port command options.

17.3.2.1 Configuring port pools

The buffer space is portioned out on a per port basis. Each port gets an amount of buffering which is its fair-share based on the port’s bandwidth compared to the overall active bandwidth.

This mechanism takes the buffer space available and divides it into a portion for each port based on the port's active bandwidth relative to the amount of active bandwidth for all ports associated with the buffer space. The number of ports sharing the same buffer space depends on the type of MDAs populated on the IOM. An active port is considered to be any port that has an active queue associated. After a queue is created for the port, the system allocates the appropriate amount of buffer space to the port. This process is independently performed for both ingress and egress.

Normally, the amount of active bandwidth is considered as opposed to total potential bandwidth for the port when determining the port's fair share. If a port is channelized and not all bandwidth is allocated, only the bandwidth represented by the configured channels with queues configured is counted toward the bandwidth represented by the port. Also, if a port may operate at variable speeds (as in some Ethernet ports), only the current speed is considered. Based on the above, the number of buffers managed by a port may change because of queue creation and deletion, channel creation and deletion and port speed variance on the local port or other ports sharing the same buffer space.

After the active bandwidth is calculated for the port, the result may be modified through the use of the following commands.

- **MD-CLI**

```
configure port modify-buffer-allocation percentage-of-rate egress
configure port modify-buffer-allocation percentage-of-rate ingress
```

- **classic CLI**

```
configure port modify-buffer-allocation egr-percentage-of-rate
configure port modify-buffer-allocation ing-percentage-of-rate
```

The default value of each is 100% which allows the system to use all of the ports active bandwidth when deciding the relative amount of buffer space to allocate to the port. When the value is explicitly modified, the active bandwidth on the port is changed according to the specified percentage. If a value of 50% is given, the ports active bandwidth is multiplied by 5, if a value of 150% is given, the active bandwidth is multiplied by 1.5. The ports rate percentage command options may be modified at any time.

To modify (in this example, to double) the size of buffer allocated on ingress for a port.

Example: MD-CLI

```
configure port 1/2/1 modify-buffer-allocation-rate percentage-of-rate ingress 200
```

Example: classic CLI

```
configure port 1/2/1 modify-buffer-allocation-rate ing-percentage-of-rate 200
```

To modify (in this example, to double) the size of buffer allocated on egress for a port.

Example: MD-CLI

```
configure port 1/2/1 modify-buffer-allocation-rate percentage-of-rate egress 200
```

Example: classic CLI

```
configure port 1/2/1 modify-buffer-allocation-rate egr-percentage-of-rate 200
```

The default buffer allocation has the following characteristics:

- Each port manages a buffer according to its active bandwidth (ports with equal active bandwidth get the same buffer size).
- An access port has 2 default pools created: access-ingress and access-egress.
- A network port has 2 default pools created: ingress-FP (common pool for all ingress network ports) and network-egress.
- All queues defined for a port receive buffers from the same buffer pool.

The following example shows port pool configurations.

Example: MD-CLI

```
[ex:/configure port 1/1/1]
A:admin@node-2# info
    admin-state enable
    access {
        egress {
            pool "default" {
                slope-policy "slopePolicy1"
            }
        }
    }
    network {
        egress {
            pool "default" {
                slope-policy "slopePolicy2"
            }
        }
    }
```

Example: classic CLI

```
A:node-2>config>port# info
----------------------------------------------
        access
            egress
                pool
                    slope-policy "slopePolicy1"
                exit
            exit
        exit
        network
            egress
                pool
                    slope-policy "slopePolicy2"
                exit
            exit
        exit
        no shutdown
----------------------------------------------
```

The following shows a CBS configuration over subscription example.

Example: MD-CLI

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

```
            pool "default" {
                amber-alarm-threshold 10
                resv-cbs {
                    cbs 10
                    amber-alarm-action {
                        step 1
                        max 30
                    }
                }
            }
        }
    }
    ethernet {
        mode access
        encap-type dot1q
    }
```

Example: classic CLI

```
A:node-2>config>port# info
----------------------------------------------
        access
            ingress
                pool
                    amber-alarm-threshold 10
                    resv-cbs 10 amber-alarm-action step 1 max 30
                exit
            exit
        exit
        ethernet
            mode access
            encap-type dot1q
        exit
        no shutdown
```

17.3.2.2 Changing hybrid-buffer-allocation

The following example shows a hybrid-buffer-allocation value change (from default) for ingress. In this example, the network-egress buffer pool is two times the size of the access-egress.

Example: MD-CLI

```
[ex:/configure port 1/1/2 hybrid-buffer-allocation]
A:admin@node-2# info
    egress-weight {
        access 20
        network 40
    }
```

Example: classic CLI

```
A:node-2config>port>hybrid-buffer-allocation# info
----------------------------------------------
egr-weight access 20 network 40
```

17.3.2.3 Configuring Ethernet ports

17.3.2.3.1 Configuring Ethernet network ports

A network port is network-facing and participates in the service provider transport or infrastructure network processes.

The following example shows a network port configuration.

Example: MD-CLI

```
[ex:/configure port A/3]
A:admin@node-2# info
    admin-state enable
    description "Ethernet network port"
```

Example: classic CLI

```
A:node-2config>port# info
----------------------------------------------
        description "Ethernet network port"
        ethernet
        exit
        no shutdown
----------------------------------------------
```

17.3.2.3.2 Configuring Ethernet access ports

Services are configured on access ports that are used for customer-facing traffic. If a SAP is to be configured on a port, it must be configured as access mode. When a port is configured for access mode, the appropriate encapsulation type can be specified to distinguish the services on the port. After a port has been configured for access mode, multiple services can be configured on the port.

The following example shows an Ethernet access port configuration.

Example: MD-CLI

```
[ex:/configure port 1/2/3]
A:admin@node-2# info
    admin-state enable
    description "Ethernet access port"
    access {
        egress {
            pool "default" {
                slope-policy "slopePolicy1"
            }
        }
    }
    ethernet {
        mode access
        encap-type dot1q
    }
    network {
        egress {
```

```
            pool "default" {
                slope-policy "slopePolicy2"
            }
        }
    }
```

Example: classic CLI

```
A:node-2>config>port# info
----------------------------------------------
        description "Ethernet access port"
        access
            egress
                pool
                    slope-policy "slopePolicy1"
                exit
            exit
        exit
        network
            egress
                pool
                    slope-policy "slopePolicy2"
                exit
            exit
        exit
        ethernet
            mode access
            encap-type dot1q
        exit
        no shutdown
----------------------------------------------
```

17.3.2.3.3 Configuring an 802.1x authentication port

The following example shows an 802.1x port configuration.

Example: MD-CLI

```
[ex:/configure port 1/2/4 ethernet dot1x]
A:admin@node-2# info detail
...
    admin-state enable
    max-authentication-requests 2
    port-control auto
    quiet-period 60
    radius-policy dot1xpolicy
    server-timeout 30
    supplicant-timeout 30
    transmit-period 30
    tunneling false
    tunnel-dot1q true
    tunnel-qinq true
    re-authentication {
        period 3600
    }
   ...
```

Example: classic CLI

```
A:node-2>config>port>ethernet>dot1x# info detail
----------------------------------------------
                port-control auto
                radius-plcy dot1xpolicy
                re-authentication
                re-auth-period 3600
                max-auth-req 2
                transmit-period 30
                quiet-period 60
                supplicant-timeout 30
                server-timeout 30
                no tunneling
                no shutdown
----------------------------------------------
```

17.3.2.4 Configuring OTU port command options

The following example shows an OTU port configuration:

Example: MD-CLI

```
[ex:/configure port 3/2/1 otu]
A:admin@node-2# info detail
 ...
    fec enhanced
    otu2-lan-data-rate 11.049
    sd-threshold 7
    sf-threshold 5
    sf-sd-method fec
    report-alarm {
        loc true
        los true
        lof true
        lom true
        otu-ais false
        otu-ber-sf true
        otu-ber-sd false
        otu-bdi true
        otu-tim false
        otu-iae false
        otu-biae false
        fec-sf true
        fec-sd false
        fec-fail false
        fec-uncorr false
        odu-ais false
        odu-oci false
        odu-lck false
        odu-bdi false
        odu-tim false
        opu-plm false
    }
    ...
    path-monitoring {
        trail-trace-identifier {
         ## mismatch-reaction
            expected {
                auto-generated
             ## string
```

```
            ## bytes
           }
           transmit {
               auto-generated
            ## string
            ## bytes
           }
       }
   }
   payload-structure-identifier {
       payload {
           expected auto
        ## mismatch-reaction
           transmit auto
       }
   }
   section-monitoring {
       trail-trace-identifier {
        ## mismatch-reaction
           expected {
               auto-generated
            ## string
            ## bytes
           }
           transmit {
               auto-generated
            ## string
            ## bytes
           }
       }
   }
```

Example: classic CLI

```
A:node-2>config>port>otu# info detail
----------------------------------------------
          otu2-lan-data-rate 11.049
          sf-sd-method fec
          sf-threshold 5
          sd-threshold 7
          fec enhanced
          no report-alarm otu-ais otu-ber-sd otu-tim otu-iae otu-biae fec-sd
          no report-alarm fec-fail fec-uncorr odu-ais odu-oci odu-lck odu-bdi
          no report-alarm odu-tim opu-plm
          report-alarm loc los lof lom otu-ber-sf otu-bdi fec-sf
          sm-tti
              tx auto-generated
              expected auto-generated
              no mismatch-reaction
          exit
          pm-tti
              tx auto-generated
              expected auto-generated
              no mismatch-reaction
          exit
          psi-payload
              tx auto
              expected auto
              no mismatch-reaction
          exit
----------------------------------------------
```

The following example shows the **show port** *port-id* **otu detail** for the preceding default OTU configuration.

```
show port 3/2/1 otu detail
```

Output example

```
===============================================================================
OTU Interface
===============================================================================
OTU Status         : Enabled                    FEC Mode         : enhanced
Async Mapping      : Disabled                   Data Rate        : 11.049 Gb/s

Cfg Alarms         : loc los lof lom otu-ber-sf otu-bdi fec-sf
Alarm Status       :
SF/SD Method       : FEC                        SF Threshold     : 1E-5
                                                SD Threshold     : 1E-7

SM-TTI Tx (auto)   : ALA-A:3/2/1/C44
SM-TTI Ex (bytes)  : (Not Specified)
SM-TTI Rx          : ALA-A:5/2/1/C34
OTU-TIM reaction   : none

PM-TTI Tx (auto)   : ALA-A:3/2/1/C44
PM-TTI Ex (bytes)  : (Not Specified)
PM-TTI Rx          : ALA-A:5/2/1/C34
ODU-TIM reaction   : none

PSI-PT Tx (auto)   : 0x03 (syncCbr)
PSI-PT Ex (auto)   : 0x03 (syncCbr)
PSI-PT Rx          : 0x03 (syncCbr)
OPU-PLM reaction   : none
===============================================================================
OTU Statistics
===============================================================================
Elapsed Seconds                                              10
-------------------------------------------------------------------------------
Near End Statistics                                  Count
-------------------------------------------------------------------------------
FEC Corrected 0s                                         0
FEC Corrected 1s                                         0
FEC Unrrectable Sub-rows                                 0
FEC ES                                                   0
FEC SES                                                  0
FEC UAS                                                  0
Pre-FEC BER                                      0.000E+00
Post-FEC BER                                     0.000E+00
-------------------------------------------------------------------------------
SM BIP8                                                  0
SM ES                                                    0
SM SES                                                   0
SM UAS                                                   0
SM-BIP8-BER                                      0.000E+00
-------------------------------------------------------------------------------
PM BIP8                                                  0
PM ES                                                    0
PM SES                                                   0
PM UAS                                                   0
PM-BIP8-BER                                      0.000E+00
-------------------------------------------------------------------------------
NPJ                                                      0
PPJ                                                      0

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

```
Far End Statistics                                      Count
-------------------------------------------------------------------------------
SM BEI                                                  0
PM BEI                                                  0
===============================================================================
```

The window over which the Bit Error Rate (BER) determined is based on the configured threshold level. The higher the error rate the shorter the window and as the error rate decreases the window increases. Table 22: Configured BER thresholds and window lengths lists the configured BER thresholds and corresponding window lengths.

Table 22: Configured BER thresholds and window lengths

Configured BER threshold	Window length
10^-3	8ms
10^-4	8ms
10^-5	8ms
10^-6	13ms
10^-7	100ms
10^-8	333ms
10^-9	1.66s

17.3.2.5 Configuring LAG

LAG configurations should include at least two ports. Other considerations include the following.

- A maximum of 64 ports (depending on the lag-id) can be included in a LAG. All ports in the LAG must share the port characteristics inherited from the primary port.
- Auto-negotiation must be disabled or set to limited mode for ports that are part of a LAG, to guarantee a specific port speed.
- Ports in a LAG must be configured as full duplex.

The following example shows the LAG configuration output.

Example: MD-CLI

```
[ex:/configure lag "lag-2"]
A:admin@node-2# info
    description "LAG2"
    mac-address 04:68:ff:00:00:01
    dynamic-cost true
    port-threshold {
        value 4
        action down
    }
    port 1/1/1 {
    }
    port 1/3/1 {
    }
```

```
    port 1/5/1 {
    }
    port 1/7/1 {
    }
    port 1/9/1 {
    }
```

Example: classic CLI

```
A:node-2>config>lag# info detail
----------------------------------------------
        description "LAG2"
        mac 04:68:ff:00:00:01
        port  1/1/1
        port  1/3/1
        port  1/5/1
        port  1/7/1
        port  1/9/1
        dynamic-cost
        port-threshold 4 action down
----------------------------------------------
```

17.3.2.5.1 Configuring BFD on LAG links

About this task

BFD can be configured under the LAG context to create and establish the micro-BFD session per link after the LAG and associated links have been configured. An IP interface must be associated with the LAG or a VLAN within the LAG, if dot1q encapsulation is used, before the micro-BFD sessions can be established.

The following contexts are used to configure BFD over LAG links:

- **MD-CLI**

  ```
  configure lag bfd-liveness family
  ```

- **classic CLI**

  ```
  configure lag bfd family
  ```

When configuring the local and remote IP address for the BFD over LAG link sessions, the *local-ip-address* value should always match an IP address associated with the IP interface to which this LAG is bound. In addition, the *remote-ip-address* value should match an IP address on the remote system and should also be in the same subnet as the *local-ip-address*. If the LAG bundle is re-associated with a different IP interface, the *local-ip-address* and *remote-ip-address* values should be modified to match the new IP subnet. The *local-ip-address* and *remote-ip-address* values do not have to match a configured interface in the case of tagged LAG/ports.

Configuring the following optional command options for the BFD over LAG links is supported.

- **transmit-interval**

  This command option specifies the transmit timer interval used for micro-BFD session over the associated LAG links.

- **receive-interval**

This command option specifies the receive interval timer used for micro-BFD session over the associated LAG links.

- **multiplier**

  This command option specifies the detect multiplier used for a micro-BFD session over the associated LAG links.

- **max-setup-time**

  This command option specifies how long a link remains active if BFD is enabled after the LAG and associated links are active and in a forwarding state.

- **max-admin-down-time**

  This command option specifies how long the system waits before bringing the associated link out of service if an ADMIN-DOWN state message is received from the far end.

Perform the following steps to enable and configure BFD over the individual LAG links:

Procedure

Step 1. Enable BFD within the LAG context, which also enters the CLI into the BFD context.

Step 2. Configure the address family for the micro-BFD sessions. Only one address family can be configured per LAG.

Step 3. Configure the local IP address for the BFD sessions.

Step 4. Configure the remote IP address for the BFD sessions.

Example

MD-CLI

```
[ex:/configure]
A:admin@node-2# info
  ...
    lag "lag-2" {
        admin-state enable
        bfd-liveness {
            ipv4 {
                admin-state enable
                receive-interval 1000
                transmit-interval 1000
                local-ip-address 10.120.1.2
                remote-ip-address 10.120.1.1
            }
        }
    }
```

Example

classic CLI

```
A:node-2config>lag# info
----------------------------------------------
        bfd
            family ipv4
                local-ip-address 10.120.1.2
                receive-interval 1000
                remote-ip-address 10.120.1.1
                transmit-interval 1000
                no shutdown
            exit
```

```
        exit
        no shutdown
```

17.3.2.6 Configuring G.8031 protected Ethernet tunnels

Ethernet tunnel configuration can include at most two paths. Other considerations include:

- A path contains one member port and one control-tag (backbone VLAN ID/BVID).
- If the user wants to replace an existing member port or a control-tag, the whole path needs to be shutdown first. The alternate path is activated as a result keeping the traffic interruption to a minimum. Then the whole path must be deleted and re-created. To replace an existing member port or control tag, the whole path needs to be shutdown first. The alternate path is activated as a result keeping traffic interruption to a minimum. Then the whole path must be deleted, the alternate path precedence modified to primary before re-creating the new path.
- The Ethernet tunnel inherits the configuration from the first member port. The following port-level configuration needs to be the same between member ports of an Ethernet tunnel:

```
configure port ethernet access egress queue-group
configure port access egress pool
configure port ethernet dot1q-etype
configure port ethernet qinq-etype
configure port ethernet pbb-etype
configure port ethernet mtu
```

  – **MD-CLI**

```
configure port ethernet egress port-scheduler-policy
```

  – **classic CLI**

```
configure port ethernet egress-scheduler-policy
```

- The user can update these port command options only if the port is the sole member of an Ethernet tunnel. This means that in the example that follows, the user needs to remove port 1/1/4 and port 1/1/5 before being allowed to modify 1/1/1 for the preceding command options.

Note: The following information applies to the classic CLI.

Example: classic CLI

```
A:node-2>config# eth-tunnel 1
    path 1
        member 1/1/1
    path 2
        member 1/1/4
A:node-2>config# eth-tunnel 2
    path 1
        member 1/1/1
    path 2
        member 1/1/5
```

The following example shows eth-tunnel configuration output.

Example: classic CLI

```
A:node-2>config# port 1/1/1
ethernet
    encap-type dot1q
A:node-2>config> port 2/2/2
ethernet
    encap-type dot1q
A:node-2>config# eth-tunnel 1
    path 1
        member 1/1/1
        control-tag 100
        precedence primary
        eth-cfm
            mep 51 domain 1 association 1
            ccm-enable
            low-priority-defect allDef
            mac-address 00:AE:AE:AE:AE:AE
            control-mep
            no shutdown
    no shutdown
    path 2
        member 2/2/2
        control-tag 200
        eth-cfm
            mep 52 domain 1 association 2
            ccm-enable
            low-priority-defect allDef
            mac-address 00:BE:BE:BE:BE:BE
            control-mep
            no shutdown
    no shutdown
```

17.3.2.7 Configuring connectors and connector ports

Some assemblies have support for QSFP28 or QSFP-DD transceiver modules. These modules have different variants, some of which provide multiple physical ports out of a single module (breakout modules). There is a QSFP28 breakout module that supports ten physical 10 Gb Ethernet ports. On assemblies that support these breakout variants, the front panel cages are modeled as connectors instead of as direct ports. The connector must be configured for the type of breakout module that is to be inserted and then the appropriate ports are created and can be configured. The options for breakout on specific connectors depend on both the card type and level (or XMA type and level). See the applicable installation guides for details.

The connector reference is in the format *slot*/*mda*/*connector* (for example, 1/1/c3) and the ports owned by the connector use the format *slot*/*mda*/*connector*/*port*. For example, in a 7750 SR-1 with the 6-port QSFP28 mda-e-xp installed in the first MDA slot, initially there are no ports available, only six connectors:

Use the following command to display the MDA information.

```
show mda
```

Output example

```
===============================================================================
MDA Summary
===============================================================================
Slot  Mda   Provisioned Type                          Admin     Operational
```

```
                Equipped Type (if different)           State     State
-------------------------------------------------------------------------------
1     1     me6-100gb-qsfp28                           up        up
```

Use the following command to display the port information.

```
show port
```

Output example

```
===============================================================================
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/c1        Up    No   Down                - unkn unkn conn
1/1/c2        Up    No   Down                - unkn unkn conn
1/1/c3        Up    No   Down                - unkn unkn conn
1/1/c4        Up    No   Down                - unkn unkn conn
1/1/c5        Up    No   Down                - unkn unkn conn
1/1/c6        Up    No   Down                - unkn unkn conn
===============================================================================
```

After configuring a module with four 10 Gb breakout ports in connector position 1/1/c1 and a module with one 100 Gb breakout port in connector position 1/1/c2, the physical ports are created.

Use the following commands to configure the port.

```
configure port 1/1/c1 connector breakout c4-10g
configure port 1/1/c2 connector breakout c1-100g
```

Use the following command to display the updated port information.

```
show port
```

Output example

```
===============================================================================
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/c1        Up    No   Link Up             - unkn unkn conn   40GBASE-SR4
1/1/c1/1      Down  No   Down    9212 9212   - netw null xgige
1/1/c1/2      Down  No   Down    9212 9212   - netw null xgige
1/1/c1/3      Down  No   Down    9212 9212   - netw null xgige
1/1/c1/4      Down  No   Down    9212 9212   - netw null xgige
1/1/c2        Down  No   Link Up             - unkn unkn conn   100GBASE-LR4
1/1/c2/1      Down  No   Down    1578 1578   - netw null cgige
1/1/c3        Up    No   Down                - unkn unkn conn
1/1/c4        Up    No   Down                - unkn unkn conn
1/1/c5        Up    No   Down                - unkn unkn conn
1/1/c6        Up    No   Down                - unkn unkn conn
```

These physical ports can now be used as Ethernet port references in other commands.

Use the following command to display the transceiver information that is shown under the connector.

```
show port 1/1/c1
```

Output example

```
===============================================================================
QSFP28 Connector
===============================================================================
Description        : QSFP28 Connector
Interface          : 1/1/c1
Admin State        : up
Oper State         : up
IfIndex            : 104939520
Last State Change  : 10/31/2017 13:23:22
Last Cleared Time  : N/A                         DDM Events       : Enabled
Breakout           : c4-10g

Transceiver Data

Transceiver Status : operational
Transceiver Type   : QSFP28
Model Number       : 3HE10551AARA01  NOK  IPU3BFVEAA
TX Laser Wavelength: 850 nm                      Diag Capable     : yes
Number of Lanes    : 4
Connector Code     : MPO 1x12                    Vendor OUI       : 44:7c:7f
Manufacture date   : 2017/03/12                  Media            : Ethernet
Serial Number      : INHAG8480890
Part Number        : TR-FC85S-NNO
Optical Compliance : 100GBASE-SR4 or 25GBASE-SR
Link Length support: 70m for OM3; 100m for OM4

===============================================================================
Transceiver Digital Diagnostic Monitoring (DDM)
===============================================================================
                             Value High Alarm  High Warn   Low Warn  Low Alarm
-------------------------------------------------------------------------------
Temperature (C)              +29.8     +80.0      +75.0       -5.0      -10.0
Supply Voltage (V)            3.29      3.63       3.46       3.14       2.97
===============================================================================

===============================================================================
Transceiver Lane Digital Diagnostic Monitoring (DDM)
===============================================================================
                                  High Alarm   High Warn    Low Warn   Low Alarm
-------------------------------------------------------------------------------
Lane Tx Bias Current (mA)              12.0        10.0         4.5         3.0
Lane Tx Output Power (dBm)             5.40        2.40       -8.40      -11.40
Lane Rx Optical Pwr (avg dBm)          5.40        2.40      -10.30      -13.30

-------------------------------------------------------------------------------
Lane ID Temp(C)/Alm       Tx Bias(mA)/Alm   Tx Pwr(dBm)/Alm   Rx Pwr(dBm)/Alm
-------------------------------------------------------------------------------
    1              -              7.1             -0.08             -4.56
    2              -              0.0/L-WA       -40.00/L-WA       -40.00/L-WA
    3              -              0.0/L-WA       -40.00/L-WA       -40.00/L-WA
    4              -              0.0/L-WA       -40.00/L-WA       -40.00/L-WA
===============================================================================
```

Use the following command to display the Ethernet-related items under the connector ports.

```
show port 1/1/c1/1
```

Output example

```
===============================================================================
Ethernet Interface
===============================================================================
Description        : 10-Gig Ethernet
Interface          : 1/1/c1/1                  Oper Speed       : 10 Gbps
Link-level         : Ethernet                  Config Speed     : N/A
Admin State        : up                        Oper Duplex      : full
Oper State         : up                        Config Duplex    : N/A
Physical Link      : Yes                       MTU              : 9212
Single Fiber Mode  : No                        Min Frame Length : 64 Bytes
IfIndex            : 104939521                 Hold time up     : 0 seconds
Last State Change  : 10/31/2017 13:23:23       Hold time down   : 0 seconds
Last Cleared Time  : N/A
Phys State Chng Cnt: 1                         RS-FEC Mode      : None

Configured Mode    : network                   Encap Type       : null
Dot1Q Ethertype    : 0x8100                    QinQ Ethertype   : 0x8100
PBB Ethertype      : 0x88e7
Ing. Pool % Rate   : 100                       Egr. Pool % Rate : 100
Ing. Pool Policy   : n/a
Egr. Pool Policy   : n/a
Net. Egr. Queue Pol: default
Egr. Sched. Pol    : n/a
HS Scheduler Plcy  : default
HS Port Pool Plcy  : default
Monitor Port Sched : Disabled
Monitor Agg Q Stats: Disabled
Auto-negotiate     : N/A                       MDI/MDX          : N/A
Oper Phy-tx-clock  : not-applicable
Accounting Policy  : None                      Collect-stats    : Disabled
Acct Plcy Eth Phys : None                      Collect Eth Phys : Disabled
Egress Rate        : Default                   Ingress Rate     : Default
Load-balance-algo  : Default                   LACP Tunnel      : Disabled
Access Bandwidth   : Not-Applicable            Booking Factor   : 100
Access Available BW: 0
Access Booked BW   : 0
Sflow              : Disabled

Suppress Threshold : 2000                      Reuse Threshold  : 1000
Max Penalties      : 16000                     Max Suppress Time: 20 seconds
Half Life          : 5 seconds

Down-when-looped   : Disabled                  Keep-alive       : 10
Loop Detected      : False                     Retry            : 120
Use Broadcast Addr : False

Sync. Status Msg.  : Disabled                  Rx Quality Level : N/A
Tx DUS/DNU         : Disabled                  Tx Quality Level : N/A
SSM Code Type      : sdh

Down On Int. Error : Disabled                  DOIE Tx Disable  : N/A

CRC Mon SD Thresh  : Disabled                  CRC Mon Window   : 10 seconds
CRC Mon SF Thresh  : Disabled

EFM OAM            : Disabled                  EFM OAM Link Mon : Disabled
Ignr EFM OAM State : False
```

```
Configured Address : 00:03:fa:2b:ef:1a
Hardware Address   : 00:03:fa:2b:ef:1a
Cfg Alarm          : remote local
===============================================================================

===============================================================================
Traffic Statistics
===============================================================================
                                                  Input                 Output
-------------------------------------------------------------------------------
Octets                                                0                      0
Packets                                               0                      0
Errors                                                0                      0
Utilization (300 seconds)                         0.00%                  0.00%

===============================================================================
Port Statistics
===============================================================================
                                                  Input                 Output
-------------------------------------------------------------------------------
Unicast Packets                                       0                      0
Multicast Packets                                     0                      0
Broadcast Packets                                     0                      0
Discards                                              0                      0
Unknown Proto Discards                                0
===============================================================================

===============================================================================
Ethernet-like Medium Statistics
===============================================================================
Alignment Errors :                   0  Sngl Collisions  :                   0
FCS Errors       :                   0  Mult Collisions  :                   0
SQE Test Errors  :                   0  Late Collisions  :                   0
CSE              :                   0  Excess Collisns  :                   0
Too long Frames  :                   0  Int MAC Tx Errs  :                   0
Symbol Errors    :                   0  Int MAC Rx Errs  :                   0
In Pause Frames  :                   0  Out Pause Frames :                   0
===============================================================================
```

17.3.2.8 Configuring GNSS ports

Some 7750 SR FP5 CPMs are equipped with an integrated GNSS receiver and GNSS RF port for retrieval and recovery of GPS and Galileo signals.

Note: GPS signal recovery must always be enabled in the system when using the GNSS receiver.

Use the commands in the following context to configure integrated GNSS RF ports including antenna-cable delay, signal recovery, and elevation-mask angle.

```
configure port gnss
```

18 Service management tasks

This section discusses basic procedures to complete service management tasks.

18.1 Modifying or deleting an MDA or XMA

To change an MDA or XMA type already provisioned for a specific slot or card, first you must shut down the slot/MDA/port configuration and then delete the MDA or the XMA from the configuration.

To modify or delete XMAs, use the MDA command structure.

The following example shows how to modify the configuration of an MDA on the 7450 ESS and 7750 SR platforms (or an XMA on the 7950 XRS platforms):

Example: MD-CLI

```
*[ex:/ configure]
A:admin@node-2# port 1/2/12

*[ex:/ configure port]
A:admin@node-2# admin-state disable

*[ex:/ configure card]
A:admin@node-2# mda 2

*[ex:/ configure card mda]
A:admin@node-2# admin-state disable
```

Example: classic CLI

```
*A:node-2>config# port 1/2/12
*A:node-2>config>port# shutdown
*A:node-2>config>card> mda 2
*A:node-2>config>card>mda# shutdown
*A:node-2>config>card>mda# no mda-type
```

18.2 Modifying a card type

To modify the card type already provisioned for a specific slot, you must shutdown existing port configurations and shutdown and remove all MDA or XMA configurations.

You must reset the IOM after changing the MDA type from MS-ISA to any other MDA type.

The following example shows how to administratively disable a port and card before you modify a card type already provisioned for a specific slot.

Example: MD-CLI

```
*[ex:/ configure]
A:admin@node-2# port 1/2/12
```

```
*[ex:/ configure port]
A:admin@node-2# admin-state disable

*[ex:/ configure card]
A:admin@node-2# mda 2

*[ex:/ configure card mda]
A:admin@node-2# admin-state disable
```

Example: classic CLI

```
*A:node-2>config# port 1/2/12
*A:node-2>config>port# shutdown
*A:node-2>config>card> mda 2
*A:node-2>config>card>mda# shutdown
*A:node-2>config>card>mda# no mda-type
```

18.3 Deleting a card

To delete a card type provisioned for a specific slot, you must shutdown existing port configurations and shutdown and remove all MDA or XMA configurations.

The following example shows the deletion of a card provisioned for a specific slot.

Example: MD-CLI

```
*[ex:/ configure]
A:admin@node-2# port 1/2/12

*[ex:/ configure port]
A:admin@node-2# admin-state disable

*[ex:/ configure card]
A:admin@node-2# mda 2

*[ex:/ configure card mda]
A:admin@node-2# admin-state disable
```

Example: classic CLI

```
*A:node-2>config# port 1/2/12
*A:node-2>config>port# shutdown
*A:node-2>config>card> mda 2
*A:node-2>config>card>mda# shutdown
*A:node-2>config>card>mda# no mda-type x40-10g-sfp
```

18.4 Deleting port command options

The following example shows the deletion of a port provisioned for a specific card:

Example: MD-CLI

```
*[ex:/ configure]
```

```
A:admin@node-2# port 1/2/12

*[ex:/ configure port]
A:admin@node-2# admin-state disable
```

Example: classic CLI

```
*A:node-2>config# port 1/2/12
*A:node-2>config>port# shutdown
*A:node-2>config>port# exit
*A:node-2>config# no port 1/2/12
```

18.5 Soft IOM reset

This section provides basic procedures for soft IOM reset service management tasks.

18.5.1 Soft reset

Soft reset is an advanced high availability feature that greatly reduces the impact of IOM/IMM resets either during a software upgrade or during other maintenance or debug operations. The combination of In Service Software Upgrade (ISSU) and Soft reset maximizes service availability in an operational network.

A soft reset re-initializes the control plane while the data plane continues operation with only very minimal impact to data forwarding. During the soft reset some processes that rely on the IOM control plane do not run for a duration that is similar to the duration of an IOM Hard reset. These processes include the updating of the IP forwarding table on the IOM (IP FIB downloads from the CPM), Layer 2 learning of new MAC addresses on the IOM, updating of the MAC forwarding table (for MAC addresses learned from other IOMs), ARP, Ethernet OAM 802.3ah, LLDP and handling for specific ICMP functions such as Can't Fragment, Redirect, Host Unreachable, Network Unreachable and TTL Expired. Note that protocols and processes on the CPM continue to operate during a Soft Reset (BGP continues to learn new routes from peers, and the new routes are downloaded to the IOM after the Soft Reset has completed).

The combination of the very small data plane impact and special soft reset enhancements for protocols ensures that most protocols do not go down and no visible impacts to most protocols are detected externally to the SR/ESS platforms. BFD timers are temporarily increased for the duration of a soft reset to keep BFD sessions up. Protocols such as BGP, OSPF, IS-IS, PIM, and so on with default timers remain up. A protocol using aggressive timers may go down momentarily during a soft reset.

Although the majority of protocols stay up during a Soft Reset, there are some limitations for a few protocols. See *Known Limitations* in the *Release Notes* for the relevant release for details.

Configuration changes are not allowed while any card is in the process of a soft reset.

The soft IOM reset procedure is applicable during the ISSU process and for a manual soft reset procedure.

To manually perform a soft IOM reset, enter the following command.

```
clear card soft
```

Soft Reset is supported on Ethernet IMMs and on IOMs that have Ethernet MDAs provisioned. The user can optionally force a Soft Reset on an IOM that contains at least one MDA that supports Soft Reset but also has an MDA that does not support Soft Reset or is operationally down. To force Soft Reset in this case

the following command is used and the supported MDAs and the card itself are soft reset while the MDAs that do not support soft reset (or are operationally down) are hard reset.

```
clear card soft hard-reset-unsupported-mdas
```

The **show card** and **show mda** commands indicate that a soft IOM reset is occurring during the soft reset process.

18.5.2 Deferred MDA reset

As part of an ISSU, soft reset is supported even if the (old) firmware version on the MDAs is not the same as the (new) firmware version in the software load to which the user is upgrading. The soft reset is allowed to proceed by leaving the previous version of the firmware running while upgrading the rest of the MDA/IOM/IMM. The user can then issue a hard reset of the MDA/IMM at some time in the future to upgrade the firmware.

The soft reset is only allowed to proceed if the older firmware is compatible with the new IOM/IMM software load. Otherwise the soft reset is blocked and a hard reset must be used instead.

After a soft reset has been completed, a log event is raised to warn the user that the MDA (or IMM) is running older firmware and that they can perform a hard reset of the MDA (or IMM) at some point if required.

If the MDA/IMM is not hard reset by the user, and then a software upgrade is performed, and the older firmware is no longer compatible with the newest load being upgraded to, then the soft reset is blocked (or an automatic hard reset occurs for ISSU).

The user can see whether they are running with older MDA/IMM firmware at any time by using the following command.

```
show mda detail
```

19 DWDM provisioning

This section provides information to provision the DWDM coherent optic, frequency, and coherent command options.

Note: Different procedures are required if the DWDM port is managed using the OpenConfig component YANG model.

19.1 Provisioning the DWDM coherent optic

About this task

This procedure describes how to provision the DWDM coherent optic. To provision the DWDM coherent optic, provision the connector breakout type and enable the transceiver Digital Coherent Optics (DCO) on the cage where the device is present. Use the following command to show connector information.

```
show port 1/1/c1
```

Output example

The following example shows that the starting point is a new default connector 1/1/c1 that is not provisioned, is administratively shutdown, and has a DWDM coherent optic transceiver installed.

```
===============================================================================
QSFP-DD Connector
===============================================================================
Description        : QSFP-DD Connector
Interface          : 1/1/c1
FP Number          : 1                          MAC Chip Number  : 1
Licensed           : Yes
Admin State        : down
Oper State         : down
IfIndex            : 1610899520
Last State Change  : 03/01/2022 18:10:14
Last Cleared Time  : 03/01/2022 18:20:32        DDM Events       : Enabled
Breakout           : no breakout
RS-FEC Config Mode : None

Transceiver Data

Transceiver Status : operational
Transceiver Type   : QSFP-DD                    DCO              : Disabled
Model Number       : 3HE16565AARA01  NOK  INUIAPJHAA
TX Laser Wavelength: 1547 nm                    Diag Capable     : yes
Number of Lanes    : 1
Connector Code     : LC                         Vendor OUI       : 20:20:20
Manufacture date   : 2021/06/03                 Media            : Ethernet
Serial Number      : 11111111111
Part Number        : DP04QSDD-E30-090
Optical Compliance : 400G-ZR-Amp 400G-ZR-Unamp 400G-ZR-Amp Custom (197) Custo*
Link Length support: Unknown
```

Procedure

Step 1. Use the following command to configure the connector breakout.

```
configure port connector breakout
```

Example

MD-CLI

```
*[ex:/configure port 1/1/c1 connector]
A:admin@node-2# breakout c1-400g
```

Example

classic CLI

```
*A:node-2# configure port 1/1/c1 connector breakout c1-400g
```

Step 2. Use the following command to configure the DCO.

```
configure port transceiver digital-coherent-optics
```

Example

MD-CLI

```
*[ex:/configure port 1/1/c1 transceiver]
A:admin@node-2# digital-coherent-optics true
```

Example

classic CLI

```
*A:node-2# configure port 1/1/c1 transceiver digital-coherent-optics
```

19.2 Provisioning DWDM frequency

Prerequisites

Before provisioning DWDM frequency, configure the connector breakout and apply the DCO setting to the transceiver (as described in Provisioning the DWDM coherent optic). After the DCO is enabled, and the physical optical transceiver is present in the front panel cage, the optic transceiver data shows the optic DWDM details. To initially provision the frequency or change what was previously configured, the user must shut down or disable the 1/1/c1 connector before provisioning.
Use the following command to display the provisionable frequency range.

```
show port 1/1/c1
```

The following example shows the "Model Number", "Fine Tune Range", "Fine Tune Resolu*", and "Supported Grids" fields.

Output example

```
Transceiver Type   : QSFP-DD                    DCO              : Enabled
```

```
Model Number       : 3HE16565AARA01  NOK  INUIAPJHAA
TX Laser Wavelength: 1547 nm
Laser Tunability   : flex-tunable
Config Freq (MHz)  : 0                          Min Freq (MHz)   : 191300000
Oper Freq (MHz)    : not-operational            Max Freq (MHz)   : 196100000
Fine Tune Range    : 6000 MHz                   Fine Tune Resolu*: 1 MHz
Supported Grids    : 100GHz 75GHz 50GHz 25GHz 12.5GHz 6.25GHz
Diag Capable       : yes
Number of Lanes    : 1
Connector Code     : LC                         Vendor OUI       : 20:20:20
Manufacture date   : 2021/06/03                 Media            : Ethernet
Serial Number      : 11111111111
Part Number        : DP04QSDD-E30-090
Optical Compliance : 400G-ZR-Amp 400G-ZR-Unamp
Link Length support: Unknown

===============================================================================
Transceiver Digital Diagnostic Monitoring (DDM)
===============================================================================
                            Value High Alarm  High Warn   Low Warn  Low Alarm
-------------------------------------------------------------------------------
Temperature (C)              +36.0     +80.0      +75.0      +15.0       -5.0
Supply Voltage (V)            3.30      3.46       3.43       3.17       3.13
===============================================================================

===============================================================================
Transceiver Lane Digital Diagnostic Monitoring (DDM)
===============================================================================
                                High Alarm   High Warn    Low Warn   Low Alarm
-------------------------------------------------------------------------------
Lane Tx Output Power (dBm)            0.00       -2.00      -16.00      -18.01
Lane Rx Optical Pwr (avg dBm)         2.00        0.00      -23.01      -28.24

-------------------------------------------------------------------------------
Lane ID Temp(C)/Alm       Tx Bias(mA)/Alm   Tx Pwr(dBm)/Alm   Rx Pwr(dBm)/Alm
-------------------------------------------------------------------------------
    1              -                  -            -40.00            -40.00
===============================================================================

===============================================================================
Coherent Optical Module
===============================================================================
Cfg Tx Target Power:   1.00 dBm              Present Rx Channel : N/A
Cfg Rx LOS Thresh  : -23.00 dBm              Cfg Rx Channel     : 0 (auto)

Disp Control Mode  : automatic               Sweep Start Disp   : -25500 ps/nm
Cfg Dispersion     :      0 ps/nm            Sweep End Disp     :   2000 ps/nm
CPR Window Size    : 32 symbols              Rx LOS Reaction    : squelch
Compatibility      : longHaul
Cfg Tx Power Min   : -22.90 dBm              Cfg Tx Power Max   :   4.00 dBm

Cfg Alarms         : modflt mod netrx nettx hosttx
Alarm Status       :
Defect Points      :

Rx Q Margin        :    0.0 dB               Chromatic Disp     :      0 ps/nm
SNR X Polar        :    0.0 dB               Diff Group Delay   :      0 ps
SNR Y Polar        :    0.0 dB               Pre-FEC BER        : 0.000E+00

Module State       : lowPower
Tx Turn-Up States  :
Rx Turn-Up States  :
```

About this task

This procedure describes how to provision the DWDM frequency.

Procedure

Step 1. Configure the frequency using the following context.

By default, no frequency is configured. A frequency must be provisioned. The following example displays a frequency configuration of 194400000:

Example

```
configure port 1/1/c1 dwdm frequency 194400000
```

Step 2. To enable the laser and have the optic reach the "ready" state, the connector port must be enabled per the configured breakout. Administratively enable frequency for each connector port using the following commands:

- **MD-CLI**

  ```
  configure port port-id admin-state enable
  ```

- **classic**

  ```
  configure port port-id no shutdown
  ```

Expected outcome

In the following example, the “Config Freq” and “Oper Freq” fields in the output reflect the frequency setting, the “Coherent Optical Module” values are present, and the “Module State” displays the “txOff” value until the connector ports are administratively enabled. Use the following command to display port information.

```
show port port-id
```

Output example

```
Transceiver Type   : QSFP-DD                    DCO             : Enabled
Model Number       : 3HE16565AARA01  NOK  INUIAPJHAA
TX Laser Wavelength: 1542.142 nm
Laser Tunability   : flex-tunable
Config Freq (MHz)  : 194400000                  Min Freq (MHz)   : 191300000
Oper Freq (MHz)    : 194400000                  Max Freq (MHz)   : 196100000
Fine Tune Range    : 6000 MHz                   Fine Tune Resolu*: 1 MHz
Supported Grids    : 100GHz 75GHz 50GHz 25GHz 12.5GHz 6.25GHz
Diag Capable       : yes
Number of Lanes    : 1
Connector Code     : LC                         Vendor OUI       : 7c:b2:5c
Manufacture date   : 2020/01/11                 Media            : Ethernet
Serial Number      : 111111111
Part Number        : DP04QSDD-E30-090
Optical Compliance : 400G-ZR-Amp 400G-ZR-Unamp 400G-ZR-Amp Custom (197) Custo*
Link Length support: Unknown

===============================================================================
Transceiver Digital Diagnostic Monitoring (DDM)
===============================================================================
                             Value High Alarm  High Warn   Low Warn  Low Alarm
-------------------------------------------------------------------------------
Temperature (C)              +63.0     +80.0      +75.0      +15.0       -5.0
```

```
Supply Voltage (V)             3.25      3.46       3.43       3.17       3.13
===============================================================================

===============================================================================
Transceiver Lane Digital Diagnostic Monitoring (DDM)
===============================================================================
                                 High Alarm   High Warn    Low Warn   Low Alarm
-------------------------------------------------------------------------------
Lane Tx Output Power (dBm)             0.00       -2.00      -13.00      -14.00
Lane Rx Optical Pwr (avg dBm)          2.00        0.00      -21.02      -23.01
-------------------------------------------------------------------------------
Lane ID Temp(C)/Alm       Tx Bias(mA)/Alm   Tx Pwr(dBm)/Alm   Rx Pwr(dBm)/Alm
-------------------------------------------------------------------------------
    1              -                 -            -40.00             -9.78
===============================================================================

===============================================================================
Coherent Optical Module
===============================================================================
Cfg Tx Target Power:   1.00 dBm
Cfg Rx LOS Thresh  : -23.00 dBm

Disp Control Mode  : automatic               Sweep Start Disp   : -25500 ps/nm
Cfg Dispersion     :      0 ps/nm            Sweep End Disp     :   2000 ps/nm
CPR Window Size    : 32 symbols              Rx LOS Reaction    : squelch
Compatibility      : longHaul
Cfg Tx Power Min   : -22.90 dBm              Cfg Tx Power Max   :   4.00 dBm

Cfg Alarms         : modflt mod netrx nettx hosttx
Alarm Status       :
Defect Points      :

Rx Q Margin        :    4.1 dB               Chromatic Disp     :      1 ps/nm
SNR/OSNR X Polar   :   19.2 dB / 35.7 dB     Diff Group Delay   :      3 ps
SNR/OSNR Y Polar   :   19.2 dB / 35.7 dB     Pre-FEC BER        : 3.340E-04

Module State       : txOff
Tx Turn-Up States  : init laserTurnUp laserReadyOff laserReady
                     modulatorConverge
Rx Turn-Up States  : init laserReady waitForInput adcSignal opticalLoc
                     demodLock
```

For any DWDM frequency changes, after the port is administratively enabled again, the coherent module initializes and transitions through various states as visible in the “Module State” field.

19.3 Provisioning DWDM coherent commands

About this task

This procedure describes how to configure the following DWDM coherent commands.
Use the following commands to configure DWDM coherent command options:

Note: For ZR and ZR+ optics, only the following **dwdm coherent** commands apply.

- **MD-CLI**

```
configure port dwdm coherent compatibility
configure port dwdm coherent report-alarm
```

```
configure port dwdm coherent rx-los-thresh
configure port dwdm coherent target-power
configure port dwdm coherent rx-los-reaction
```

- **classic CLI**

```
configure port dwdm coherent compatibility
configure port dwdm coherent report-alarms
configure port dwdm coherent rx-los-thresh
configure port dwdm coherent target-power
configure port dwdm coherent rx-los-reaction
```

Procedure

Step 1. Configure the coherent **compatibility** command using the following context. The example below displays a **compatibility metro** configuration.

Example

```
configure port 1/1/c1 dwdm coherent compatibility metro
```

The coherent compatibility applies different optic application codes. The command default is **long-haul** and to change what has been previously configured, the user must shut down or disable the 1/1/c1 connector before provisioning for coherent compatibility.
For any DWDM compatibility changes, after the 1/1/c1 connector is enabled, the coherent module initializes and transitions through various states as visible in the “Module State” field until it is ready again.

Step 2. Enable the port using the following command:

- **MD-CLI**

```
configure port admin-state enable
```

- **classic CLI**

```
configure port no shutdown
```

Step 3. Configure alarm reporting. The following example displays a configuration where the alarms are not reported.

Example

MD-CLI

```
[ex:/configure port 1/1/c1 dwdm coherent report-alarm]
A:admin@node-2# info
    modflt false
    mod false
    netrx false
    nettx false
    hosttx false
```

Example

classic CLI

```
A:node-2>config>port>dwdm>coherent# info detail
----------------------------------------------
no report-alarm modflt mod netrx nettx hosttx
```

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

When an alarm is reported, it is logged in the event logs and a trap is sent to the Network Management System (NMS). For details about the alarms and defect points, see the TIMETRA-PORT-MIB.mib. By default, all alarms are reported.

Step 4. Configure the **rx-los-thresh** command. The following example shows the command to configure -18 dBm.

Example

```
configure port 1/1/c1 dwdm coherent rx-los-thresh -18
```

This command configures the received optical power threshold at which the Loss of Signal (LOS) alarm is declared. To clear the LOS alarm, the received optical power must be higher than the configured **rx-los-thresh** command.

Step 5. Configure the power target. The following example shows the command to configure a power target of -12 dBm.

Example

```
configure port 1/1/c1 dwdm coherent target-power -12
```

This command configures the average output power target for the port.

Expected outcome

Use the following command to display the actual measured Tx power along with the configured power.

```
show port 1/1/c1 detail
```

Output example

```
===============================================================================
Transceiver Lane Digital Diagnostic Monitoring (DDM)
===============================================================================
                                High Alarm   High Warn    Low Warn   Low Alarm
-------------------------------------------------------------------------------
Lane Tx Output Power (dBm)             0.00       -2.00      -13.00      -14.00
Lane Rx Optical Pwr (avg dBm)          2.00        0.00      -21.02      -23.01

-------------------------------------------------------------------------------
Lane ID Temp(C)/Alm       Tx Bias(mA)/Alm   Tx Pwr(dBm)/Alm   Rx Pwr(dBm)/Alm
-------------------------------------------------------------------------------
    1              -                 -            -11.91             -9.86
===============================================================================
* indicates that the corresponding row element may have been truncated.

===============================================================================
Coherent Optical Module
===============================================================================
Cfg Tx Target Power: -12.00 dBm
Cfg Rx LOS Thresh  : -23.00 dBm

Disp Control Mode  : automatic               Sweep Start Disp   : -25500 ps/nm
Cfg Dispersion     :      0 ps/nm            Sweep End Disp     :   2000 ps/nm
CPR Window Size    : 32 symbols               Rx LOS Reaction    : squelch
Compatibility      : longHaul
Cfg Tx Power Min   : -22.90 dBm               Cfg Tx Power Max   :   4.00 dBm
```

```
Cfg Alarms         : modflt mod netrx nettx hosttx
Alarm Status       :
Defect Points      :

Rx Q Margin        :    4.1 dB                Chromatic Disp     :      1 ps/nm
SNR/OSNR X Polar   :   19.1 dB / 35.7 dB      Diff Group Delay   :      2 ps
SNR/OSNR Y Polar   :   19.1 dB / 35.7 dB      Pre-FEC BER        : 3.430E-04

Module State       : ready
Tx Turn-Up States  : init laserTurnUp laserReadyOff laserReady
                     modulatorConverge outputPowerAdjust
Rx Turn-Up States  : init laserReady waitForInput adcSignal opticalLock
                     demodLock

-------------------------------------------------------------------------------
Coherent Optical Port Statistics (Elapsed Seconds: 588)
-------------------------------------------------------------------------------
Statistic                          Current      Average      Minimum      Maximum
-------------------------------------------------------------------------------
Rx BER                          3.430E-04    3.415E-04    3.050E-04    3.780E-04
Rx SNR (dB)                          19.2         19.1         19.1         19.2
Rx OSNR (dB)                         35.7         35.7         35.7         35.7
Rx Chromatic Disp (ps/nm)               1            2            1            3
Rx Diff Group Delay (ps)                2            2            2            3
Rx Freq Offset (MHz)                  287          284          182          387
Rx Q (dB)                            10.6         10.5         10.5         10.6
Rx Per-Channel Power (dBm)          -9.69        -9.63        -9.78        -9.49
Tx Power (dBm)                     -11.93       -10.69       -11.93        -9.72
-------------------------------------------------------------------------------
```

20 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.

20.1 Access Node Control Protocol (ANCP)

draft-ietf-ancp-protocol-02, *Protocol for Access Node Control Mechanism in Broadband Networks*

RFC 5851, *Framework and Requirements for an Access Node Control Mechanism in Broadband Multi-Service Networks*

20.2 Bidirectional Forwarding Detection (BFD)

draft-ietf-lsr-ospf-bfd-strict-mode-10, *OSPF BFD Strict-Mode*

RFC 5880, *Bidirectional Forwarding Detection (BFD)*

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ITU-T G.8275.1, *Precision time protocol telecom profile for phase/time synchronization with full timing support from the network*

ITU-T G.8275.2, *Precision time protocol telecom profile for phase/time synchronization with partial timing support from the network*

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RFC 8573, *Message Authentication Code for the Network Time Protocol*

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20.42 Yet Another Next Generation (YANG) OpenConfig Models

openconfig-aaa.yang version 0.4.0, *OpenConfig AAA Model*

openconfig-aaa-radius.yang version 0.3.0, *OpenConfig AAA RADIUS Model*

openconfig-aaa-tacacs.yang version 0.3.0, *OpenConfig AAA TACACS+ Model*

openconfig-acl.yang version 1.0.0, *OpenConfig ACL Model*

openconfig-alarms.yang version 0.3.2, *OpenConfig System Alarms Model*

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openconfig-bgp.yang version 6.1.0, *OpenConfig BGP Model*

openconfig-bgp-common.yang version 6.0.0, *OpenConfig BGP Common Model*

openconfig-bgp-common-multiprotocol.yang version 6.0.0, *OpenConfig BGP Common Multiprotocol Model*

openconfig-bgp-common-structure.yang version 6.0.0, *OpenConfig BGP Common Structure Model*

openconfig-bgp-global.yang version 6.0.0, *OpenConfig BGP Global Model*

openconfig-bgp-neighbor.yang version 6.1.0, *OpenConfig BGP Neighbor Model*

openconfig-bgp-peer-group.yang version 6.1.0, *OpenConfig BGP Peer Group Model*

openconfig-bgp-policy.yang version 4.0.1, *OpenConfig BGP Policy Model*

openconfig-if-aggregate.yang version 2.4.3, *OpenConfig Interfaces Aggregated Model*

openconfig-if-ethernet.yang version 2.12.2, *OpenConfig Interfaces Ethernet Model*

openconfig-if-ip.yang version 3.1.0, *OpenConfig Interfaces IP Model*

openconfig-if-ip-ext.yang version 2.3.1, *OpenConfig Interfaces IP Extensions Model*

openconfig-igmp.yang version 0.3.1, *OpenConfig IGMP Model*

openconfig-interfaces.yang version 3.0.0, *OpenConfig Interfaces Model*

openconfig-isis.yang version 1.1.0, *OpenConfig IS-IS Model*

openconfig-isis-policy.yang version 0.5.0, *OpenConfig IS-IS Policy Model*

openconfig-isis-routing.yang version 1.1.0, *OpenConfig IS-IS Routing Model*

openconfig-lacp.yang version 2.1.0, *OpenConfig LACP Model*

openconfig-lldp.yang version 0.1.0, *OpenConfig LLDP Model*

openconfig-local-routing.yang version 1.2.0, *OpenConfig Local Routing Model*

openconfig-mpls.yang version 2.3.0, *OpenConfig MPLS Model*

openconfig-mpls-ldp.yang version 3.0.2, *OpenConfig MPLS LDP Model*

openconfig-mpls-rsvp.yang version 2.3.0, *OpenConfig MPLS RSVP Model*

openconfig-mpls-te.yang version 2.3.0, *OpenConfig MPLS TE Model*

openconfig-network-instance.yang version 1.1.0, *OpenConfig Network Instance Model*

openconfig-network-instance-l3.yang version 0.11.1, *OpenConfig L3 Network Instance Model* – static routes

openconfig-ospfv2.yang version 0.4.0, *OpenConfig OSPFv2 Model*

openconfig-ospfv2-area.yang version 0.4.0, *OpenConfig OSPFv2 Area Model*

openconfig-ospfv2-area-interface.yang version 0.4.0, *OpenConfig OSPFv2 Area Interface Model*

openconfig-ospfv2-common.yang version 0.4.0, *OpenConfig OSPFv2 Common Model*

openconfig-ospfv2-global.yang version 0.4.0, *OpenConfig OSPFv2 Global Model*

openconfig-packet-match.yang version 1.1.0, *OpenConfig Packet Match Model*

openconfig-pim.yang version 0.4.3, *OpenConfig PIM Model*

openconfig-platform.yang version 0.15.0, *OpenConfig Platform Model*

openconfig-platform-fan.yang version 0.1.1, *OpenConfig Platform Fan Model*

openconfig-platform-linecard.yang version 0.1.2, *OpenConfig Platform Linecard Model*

openconfig-platform-port.yang version 0.4.2, *OpenConfig Port Model*

openconfig-platform-transceiver.yang version 0.9.0, *OpenConfig Transceiver Model*

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openconfig-qos.yang version 0.11.2, *OpenConfig QoS Model*

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openconfig-qos-mem-mgmt.yang version 0.11.2, *OpenConfig QoS Memory Management Model*

openconfig-relay-agent.yang version 0.1.0, *OpenConfig Relay Agent Model*
openconfig-routing-policy.yang version 3.0.0, *OpenConfig Routing Policy Model*
openconfig-rsvp-sr-ext.yang version 0.1.0, *OpenConfig RSVP-TE and SR Extensions Model*
openconfig-system.yang version 0.10.1, *OpenConfig System Model*
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openconfig-system-logging.yang version 0.3.1, *OpenConfig System Logging Model*
openconfig-system-terminal.yang version 0.3.0, *OpenConfig System Terminal Model*
openconfig-telemetry.yang version 0.5.0, *OpenConfig Telemetry Model*
openconfig-terminal-device.yang version 1.9.0, *OpenConfig Terminal Device Model*
openconfig-vlan.yang version 3.2.2, *OpenConfig VLAN Model*

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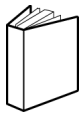

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