7705 Service Aggregation Router Gen 2

Release 25.7.R1

Interface Configuration Guide

3HE 21568 AAAB TQZZA 01
Edition: 01
July 2025

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1 Getting started

1.1 About this guide

This guide describes system concepts and provides configuration examples to provision Input/Output modules (IOMs), Media Dependent Adapters (MDAs), and ports.

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

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

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

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

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

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

Note: This guide generically covers Release 25.*x*.R*x* content and may contain some content that will be released in later maintenance loads. See the *SR OS R25.x.Rx Software Release Notes*, part number 3HE 21562 000*x* TQZZA, for information about features supported in each load of the Release 25.*x*.R*x* software. For a list of features and CLI commands that are present in SR OS but not supported on the 7705 SAR Gen 2 platforms, see "SR OS Features not Supported on SAR Gen 2" in the *SR OS R25.x.Rx Software Release Notes*.

1.1.1 Platforms and terminology

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

Table 1: Platforms and terminology

Platform	Collective platform designation
7705 SAR-1	7705 SAR Gen 2

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.
- Unless specified otherwise, the term "card" is used generically to refer to Input Output Modules (IOMs) .

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

The 7705 SAR-1 is a fixed chassis, that is, the system hardware is permanently built into the chassis and has preassigned parameters. The IOM of the 7705 SAR-1 is a virtual entity, defined in software. The I/O ports are grouped and virtualized into slots (MDAs) for convenience of assignment. As a result of this design, the CLI identifiers for the IOM and MDAs are preset. The fixed configuration of the 7705 SAR-1 restricts the router to port-level provisioning; however, the IOM and MDA numbering must still be specified in CLI commands.

The 7705 SAR-1 replaces the CPM with an integrated control and switching functional block that does not need to be provisioned. It is displayed in the CLI as CPM A.

The 7705 SAR-1 is provisioned at the factory with the following permanent configuration:

- CPM card type in slot A is cpm-sar
- IOM card type in slot 1 is iom-sarshow
- MDA types:
  - Slot 1/1 is m10-sfp++6-sfp
  - Slot 1/2 is isa-tunnel-v
  - Slot 1/3 is isa-bb-v

```
===============================================================================
Card State
===============================================================================
Slot/  Provisioned Type                  Admin Operational   Num   Num Comments
Id         Equipped Type (if different)  State State         Ports MDA
-------------------------------------------------------------------------------
1      iom-sar                           up    up                  3
1/1    m10-sfp++6-sfp                    up    up            16
```

```
1/2    isa-tunnel-v                      up    up          2
           isa-ms-v
1/3    isa-bb-v                          up    up          7
           isa-ms-v
A      cpm-sar                           up    up                    Active
===============================================================================
```

2.2 IMMs and MDAs

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.

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

The 7705 SAR-1 does not support removable MDAs. The software uses a the concept of MDA internally (as a logical entity) to represent the ports on the chassis. The MDA type is auto-provisioned on startup, and the MDA slot is always 1.

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.

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 (100BASE-T)
  - Gb Ethernet (1GbE, 1000BASE-T)
  - 10 Gb Ethernet (10GbE, 10GBASE-X)

  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.

- **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
```

  When configuring the port to be in WAN mode, you can change specific SONET/SDH command options to reflect the SONET/SDH requirements for this port.

- **SONET-SDH and TDM**

  Supported SONET-SDH and TDM port types include:

  – DS-1/E-1 channel
  – OC3/STM-1
  – OC12/STM-4

- **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.

- **Automatic Protection Switching (APS)**

Automatic Protection Switching (APS) is a means to provide redundancy on SONET equipment to guard against linear unidirectional or bidirectional failures. The network elements (NEs) in a SONET/SDH network constantly monitor the health of the network. When a failure is detected, the network proceeds through a coordinated pre-defined sequence of steps to transfer (or switchover) live traffic to the backup facility (called protection facility.) This is done very quickly to minimize lost traffic. Traffic remains on the protection facility until the primary facility (called working facility) fault is cleared, at which time the traffic may optionally be reverted to the working facility.

- **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.

4.1.1 Ethernet ports

This section provides information about the support Ethernet port and pluggable transceiver types for 7705 SAR Gen 2 platforms.

The following table lists the supported speeds for pluggable transceiver types.

Table 4: Supported speeds for pluggable transceivers

Pluggable transceiver type	Supported speeds
SFP	SFP transceivers support speeds of 1 Gb/s, unless 100 Mb/s support is noted in other table footnotes.
SFP+	SFP+ transceivers support speeds of 10 Gb/s.

Table 5: Supported Ethernet port and pluggable transceiver types

7705 SAR Gen 2 hardware	Physical port type	Accepted pluggable transceivers	
		SFP	SFP+
7705 SAR-1	SFP	✓	
	SFP+	✓	✓

Note: SFP ports support speeds of 100 Mb/s or 1b Gb/s. however, these ports only advertise their configured speed when **autonegotiate** or **autonegotiate limited** is configured.

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 (for example, LACP for Ethernet 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 6: Relationship of Port state and Oper state.

Table 6: 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 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

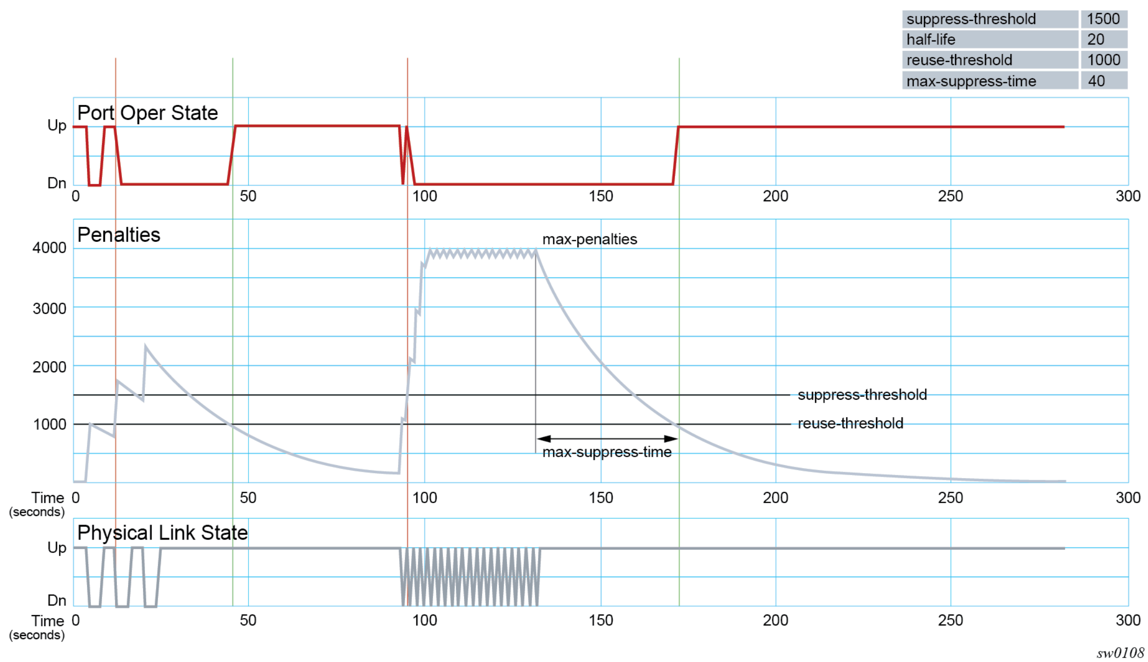
$t_{½}$ is the half-life

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)*.

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

Figure 1: 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 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.

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

5 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
----------------------------------------------
```

5.1 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
----------------------------------------------
```

5.1.1 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.

5.1.2 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.

5.2 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:

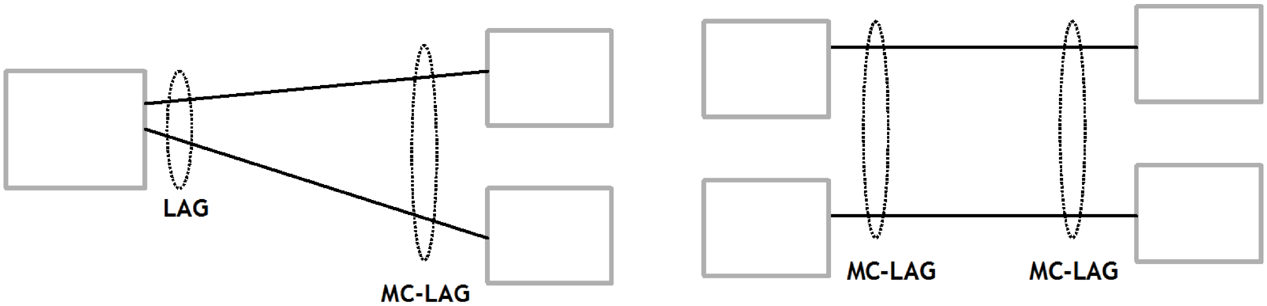
- **lacp**

  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 2: 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 2: Active/standby LAG operation deployment examples



In case of a link failure, as shown in Figure 3: LAG on access interconnection and Figure 4: 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 3: LAG on access interconnection

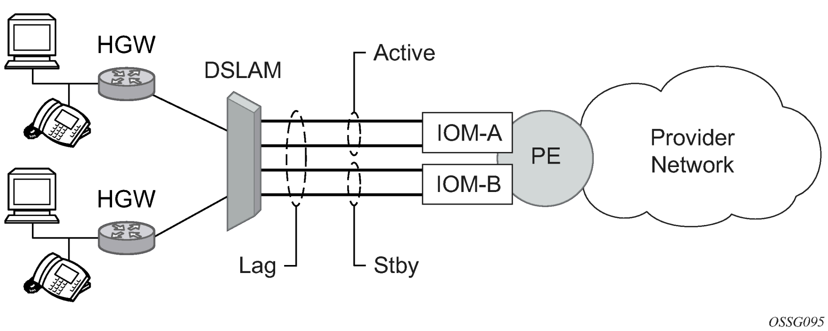
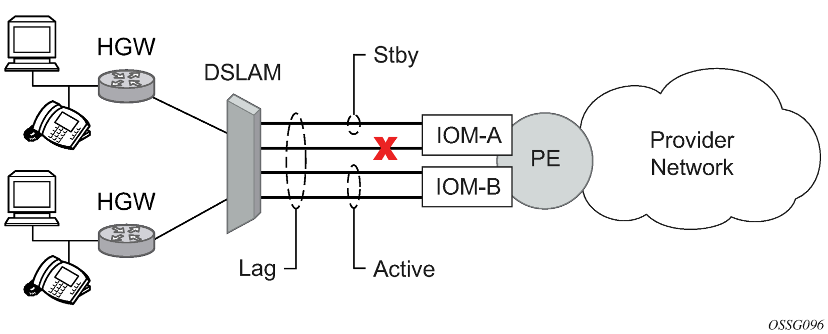


Figure 4: LAG on access failure switchover



5.3 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

5.3.1 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.

5.3.1.1 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 sub-divided into multiple finer-granularity flows if the ports used between a specific SA/DA vary.

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.

5.3.1.2 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
```

5.3.1.3 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
```

5.3.1.4 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 hash label if the hash label is present in the MPLS label stack

5.3.2 LAG port hash weight

The LAG port **hash-weight** command customizes the flow hashing distribution between LAG ports by adjusting the weight of each port independently for both same-speed and mixed-speed LAGs.

The following are common rules for using the LAG port **hash-weight** command.

- The configured **hash-weight** value per port is ignored until the **hash-weight** command is configured for all the ports in the LAG.
- The **hash-weight** value can be set to **port-speed** or an integer value from 1 to 100000:
  - **port-speed**

    This assigns an implicit **hash-weight** value based on the physical port speed.
  - **1 to 100000**

    This value range allows for control of flow hashing distribution between LAG ports.
- The LAG port **hash-weight** value is normalized internally to distribute flows between LAG ports. The minimum value returned by this normalization is 1.
- When the LAG port **hash-weight** command is not configured, the value defaults to the **port-speed** value.

The following table lists the **hash-weight** values using **port-speed** per physical port types.

Table 7: 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

Port type	Port speed
Other ports	port-speed value 1

The LAG port **hash-weight** capability is supported for both same-speed and mixed-speed LAGs.

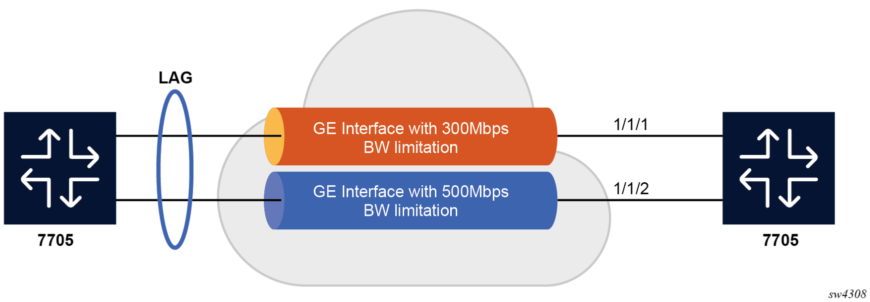
5.3.2.1 Configurable hash weight to control flow distribution

The user can use the LAG port **hash-weight** 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 5: 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 **hash-weight** values.

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 **port-speed**, the configured value is used and normalized to modify the hashing between LAG ports.
- If the LAG ports are all configured to **port-speed**, or if only some of the ports have a customized **hash-weight** value, the system uses a hash weight of 1 for every port. For mixed-speed LAGs, the system uses the **port-speed** value.

5.3.3 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

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 1GE/10GE LAG, set the priority for 10GE ports to a value that is at least 10 times that of the 1GE 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

5.3.4 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.
-
- 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
----------------------------------------------
```

5.3.5 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
```

5.3.6 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.

5.3.6.1 Load balancing per subscriber

Load balancing per subscriber has 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.

Note: The second mode of operation, weighted per-subscriber load balancing, is not supported on 7705 SAR Gen 2 platforms.

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
```

5.3.6.2 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 has 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
```

Note: The second load-balancing mode is not supported on 7705 SAR Gen 2 platforms.

5.3.6.3 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
```

Note: Per-link hashing is not supported on 7705 SAR Gen 2 platforms.

5.3.6.4 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
```

5.4 QoS consideration for access LAG

The following section describes various QoS related features applicable to LAG on access.

5.4.1 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 8: Adapt QoS bandwidth/rate distribution shows examples of rate/BW distributions based on the **adapt-qos** mode used.

Table 8: Adapt QoS bandwidth/rate distribution

	distribute	link	port-fair	distribute include-egr-hash-cfg
SAP Queues	% # local links[1]	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)

1 * % # 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[2] (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

5.4.2 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.

5.4.3 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.

2 %# all links = X* (link speed)/(total LAG speed)

To disable per-fp-egr-queuing, all ports must first be removed from a specific LAG.

5.4.4 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.

5.5 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.

5.6 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).

5.6.1 Overview

Multichassis LAG is a method of providing redundant Layer 2/3 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 2/3 aggregation nodes such that both link and node level redundancy, are provided. By using a multichassis LAG protocol, the paired Layer 2/3 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 6: MC-LAG Layer 2 dual-homing to remote PE pairs and Figure 7: 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 6: MC-LAG Layer 2 dual-homing to remote PE pairs

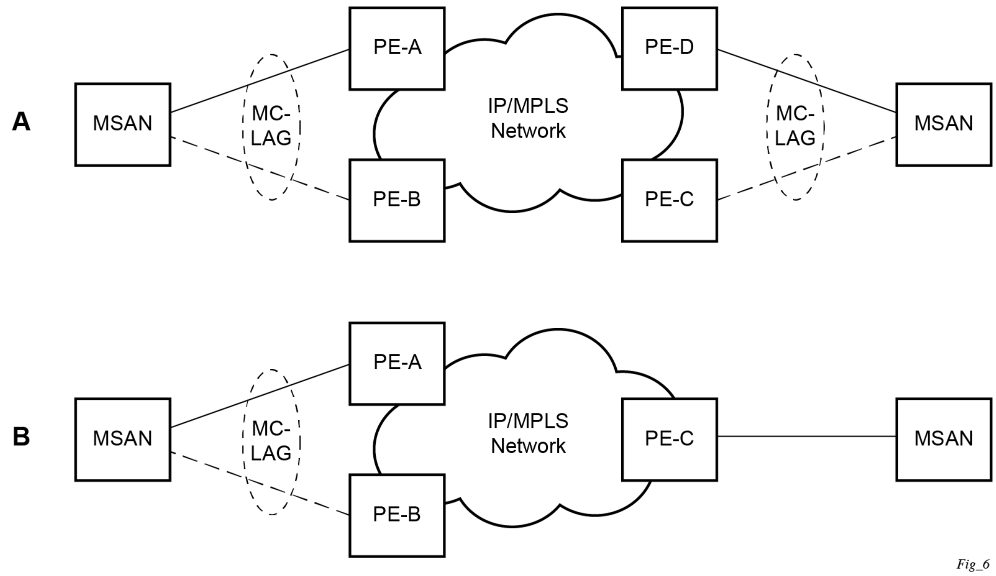
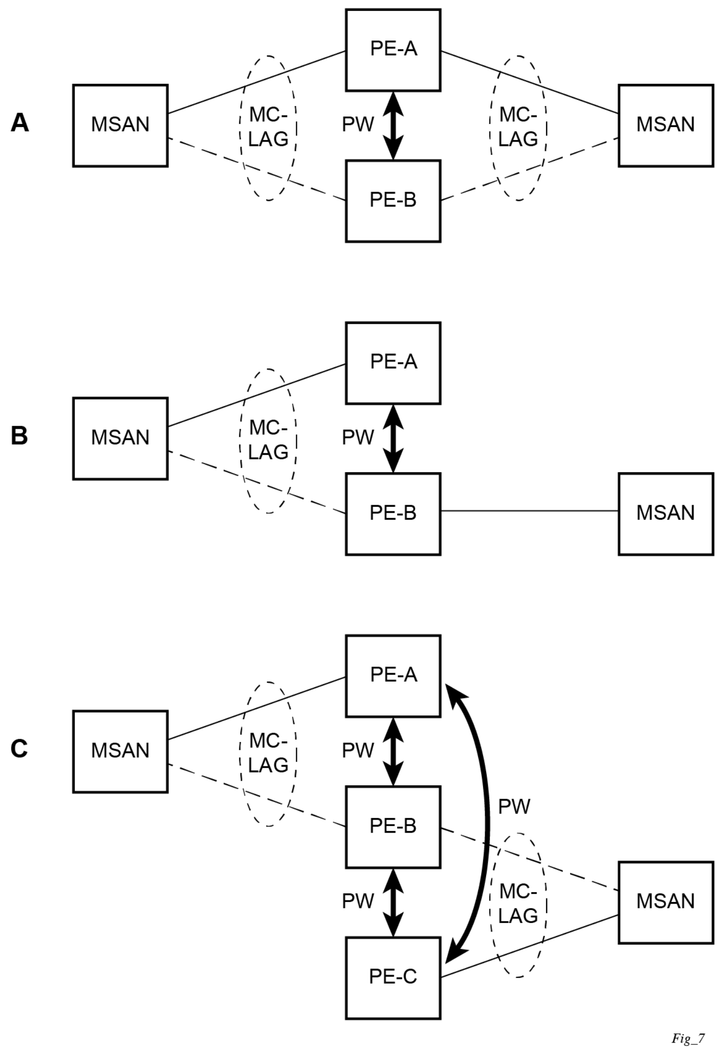


Figure 7: MC-LAG Layer 2 dual homing to local PE pairs



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.

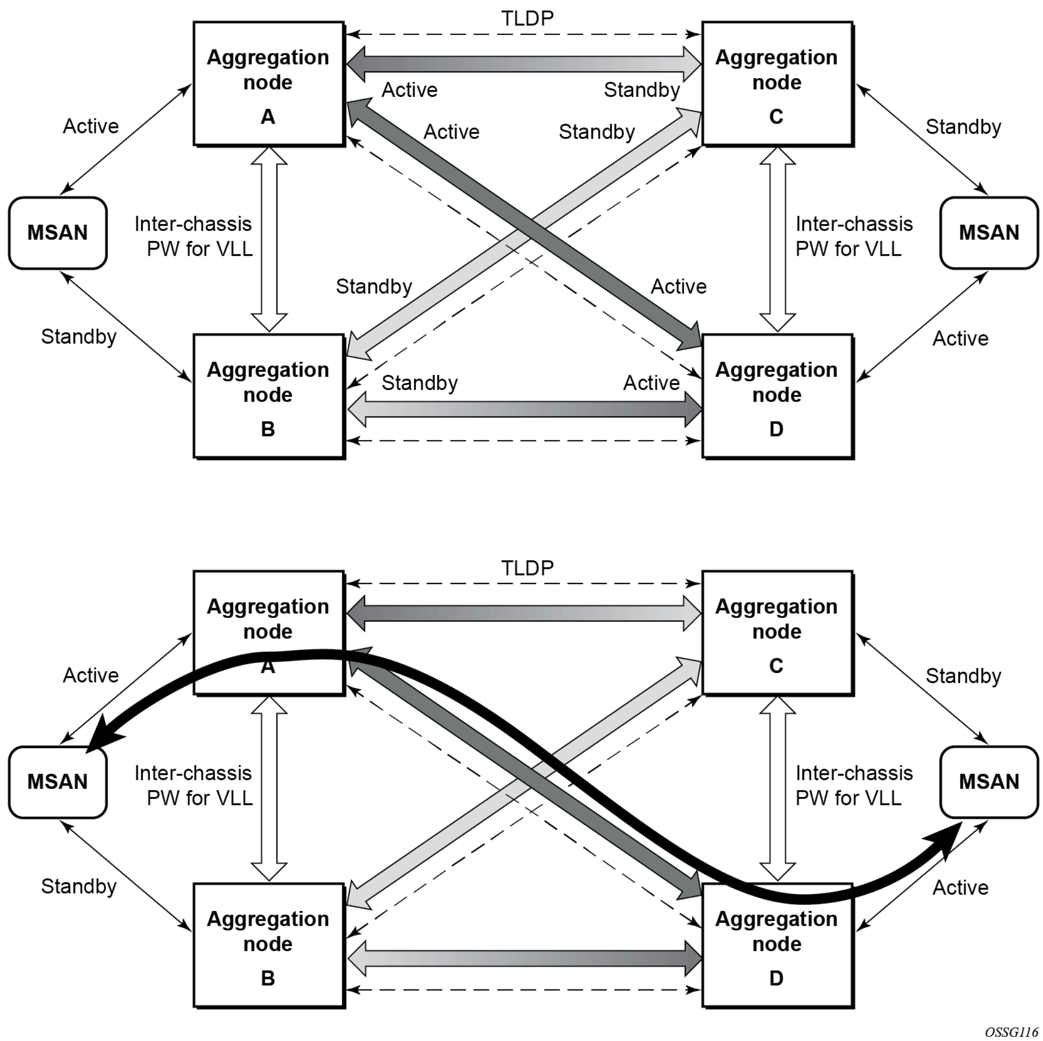
5.6.2 MC-LAG and SRRP

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.

5.6.3 P2P redundant connection across Layer 2/3 VPN network

Figure 8: 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 8: Point-to-Point (P2P) redundant connection through a Layer 2 VPN network



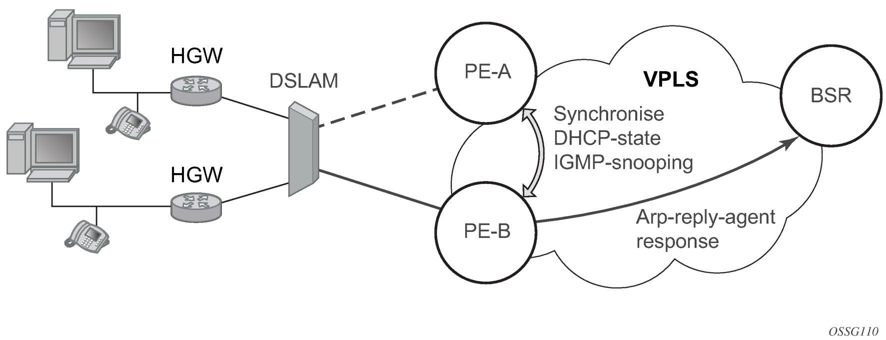
Note that the configuration in Figure 8: Point-to-Point (P2P) redundant connection through a Layer 2 VPN network shows one particular configuration of VLL connections based on MC-LAG, particularly the VLL connection where two ends (SAPs) are on two different redundant-pairs. In addition to this, other 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.

5.6.4 DSLAM dual-homing in a Layer 2/3 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 9: 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.

5.7 LAG port and hash-weight thresholds

The following sections provide information on LAG port and hash-weight thresholds.

5.7.1 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.

5.7.2 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.

6 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 presents 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-Monitor and Symbol-Monitor allows the user to monitor ingress error conditions on the Ethernet medium and compare these error counts to the thresholds. CRC-Monitor monitors CRC errors. Symbol-Monitor 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*10E-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*10E-3 (one error per 1000). Changing the configuration to would sd-threshold 3 multiplier 5 result in a signal degrade rate of 5*10E-3 (5 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-Monitor provides a CRC error rate. Symbol-Monitor 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 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 above configuration results in an SD threshold of 5*10E-5 (0.00005) and an SF threshold of 5*10E-3 (0.005) over the default 10-second window. If this port is a 1GbE port supporting symbol monitoring then the error rate is compared against 1,250,000,000 symbols (10 seconds worth of symbols on a 1GbE port 125,000,000). If the error count in the current 10 second sliding window is less than 62,500 then 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 then 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-Monitor and Symbol-Monitor. Because the port is operationally down without a physical link error monitoring stops. In MD-CLI, the user may enable the port using the **admin-state enable** and **admin-state disable** commands. In classic CLI, the user may enable the port using the **shutdown** and **no shutdown** commands. Other port transition functions like clearing the MDA or slot, removing the cable, and other physical link transition functions.

7 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 *7705 SAR Gen 2 Services Overview Guide* for more information.

7.1 Default MTU values

The following table lists the default MTU values that are dependent upon the (sub-) port type, mode, and encapsulation.

Table 9: MTU default values

Port type	Mode	Encap type	Default (bytes)
Ethernet	access	null	1514
Ethernet	access	dot1q	1518
Fast Ethernet[3]	network	—	1514
Other Ethernet	network	—	9212[4]

7.2 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.

3 Physical/native Fast Ethernet only.

4 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.

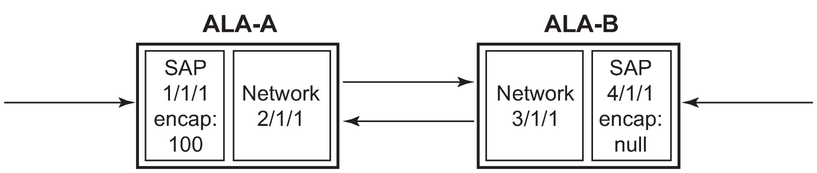
- The port-level MTU command options configure the maximum payload MTU size for an Ethernet port, LAG, or SONET/SDH SONET path (sub-port) or TDM port/channel.

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.

7.3 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 10: MTU configuration example.

Figure 10: 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 10: MTU configuration example values shows example MTU configuration values.

Table 10: 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

8 Deploying preprovisioned components

When a card, or MDA is installed in a preprovisioned slot, the device detects discrepancies between the preprovisioned card type configurations and the types actually installed. Error messages display if there are inconsistencies and the card does not initialize.

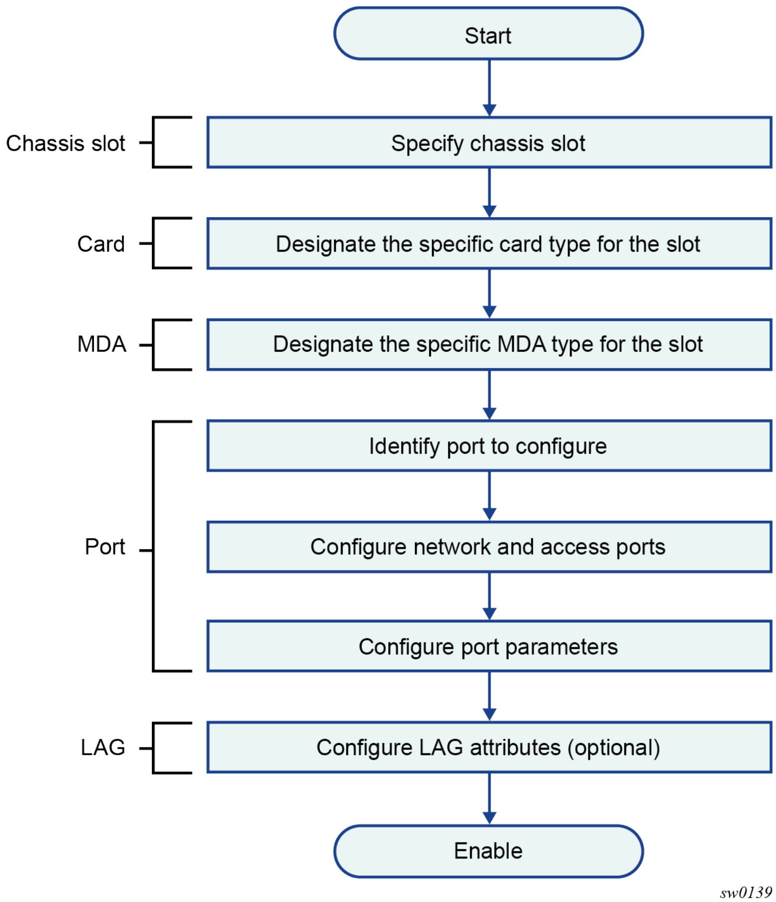
When the correct preprovisioned cards are installed into the appropriate chassis slot, alarm, status, and performance details are displayed.

On bootup, 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.

9 Configuration process overview

The following figure shows the process to provision chassis slots, cards, MDAs, and ports.

Figure 11: Slot, card, MDA, port configuration, and implementation flow



9.1 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.

10 Configuring physical ports with CLI

This section provides information to configure cards, MDAs, and ports.

10.1 Preprovisioning guidelines

7705 SAR Gen 2 platforms have a console port, either located on the CPM or integrated into the chassis, 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.

10.1.1 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.

10.1.2 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.

10.1.3 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. For command syntax for LAG, see Configuring LAG.

10.2 Basic configuration

The most basic configuration must specify the following:

- 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 7705 SAR Gen 2.

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
#--------------------------------------------------
```

10.3 Common configuration tasks

The following sections are basic system tasks that must be performed.

10.3.1 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 7705 SAR Gen 2.

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
```

```
#--------------------------------------------------
```

10.3.2 Configuring ports

This section provides the CLI and examples to configure port command options.

10.3.2.1 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
```

10.3.2.2 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
```

10.3.2.3 Configuring Ethernet ports

10.3.2.3.1 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
----------------------------------------------
```

10.3.2.3.2 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//1/c1/1]
A:admin@node-2# info
    admin-state enable
    description "Ethernet access port"
    ethernet {
        mode access
        encap-type dot1q
    }
```

Example: classic CLI

```
A:node-2>config>port# info
----------------------------------------------
----------------------------------------------
        description "Ethernet access port"
        ethernet
            mode access
            encap-type dot1q
        exit
        no shutdown
----------------------------------------------
```

10.3.2.3.3 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
----------------------------------------------
```

10.3.2.4 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
----------------------------------------------
```

11 Service management tasks

This section discusses basic procedures to complete service management tasks.

11.1 Modifying or deleting an MDA

To change an MDA type already provisioned for a specific slot or card, first you must shut down the slot/MDA/port configuration and then delete the MDA from the configuration.

The following example shows how to modify the configuration of an MDA on the 7705 SAR Gen 2.

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
```

11.2 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 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
```

11.3 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 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 cx20-10g-sfp
```

11.4 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
```

11.5 Soft IOM reset

This section provides basic procedures for soft IOM reset service management tasks.

11.5.1 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 7705 SAR Gen 2 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.

11.5.2 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
```

12 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.

12.1 Bidirectional Forwarding Detection (BFD)

RFC 5880, *Bidirectional Forwarding Detection (BFD)*

RFC 5881, *Bidirectional Forwarding Detection (BFD) IPv4 and IPv6 (Single Hop)*

RFC 5882, *Generic Application of Bidirectional Forwarding Detection (BFD)*

12.2 Border Gateway Protocol (BGP)

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draft-ietf-idr-add-paths-guidelines-08, *Best Practices for Advertisement of Multiple Paths in IBGP*

draft-ietf-idr-best-external-03, *Advertisement of the best external route in BGP*

draft-ietf-idr-bgp-gr-notification-01, *Notification Message support for BGP Graceful Restart*

draft-ietf-idr-bgp-ls-app-specific-attr-16, *Application-Specific Attributes Advertisement with BGP Link-State*

draft-ietf-idr-bgp-optimal-route-reflection-10, *BGP Optimal Route Reflection (BGP-ORR)*

draft-ietf-idr-error-handling-03, *Revised Error Handling for BGP UPDATE Messages*

draft-ietf-idr-link-bandwidth-03, *BGP Link Bandwidth Extended Community*

RFC 1772, *Application of the Border Gateway Protocol in the Internet*

RFC 1997, *BGP Communities Attribute*

RFC 2385, *Protection of BGP Sessions via the TCP MD5 Signature Option*

RFC 2439, *BGP Route Flap Damping*

RFC 2545, *Use of BGP-4 Multiprotocol Extensions for IPv6 Inter-Domain Routing*

RFC 2858, *Multiprotocol Extensions for BGP-4*

RFC 2918, *Route Refresh Capability for BGP-4*

RFC 4271, *A Border Gateway Protocol 4 (BGP-4)*

RFC 4360, *BGP Extended Communities Attribute*

RFC 4364, *BGP/MPLS IP Virtual Private Networks (VPNs)*

RFC 4456, *BGP Route Reflection: An Alternative to Full Mesh Internal BGP (IBGP)*

RFC 4486, *Subcodes for BGP Cease Notification Message*

RFC 4659, *BGP-MPLS IP Virtual Private Network (VPN) Extension for IPv6 VPN*

RFC 4684, *Constrained Route Distribution for Border Gateway Protocol/MultiProtocol Label Switching (BGP/MPLS) Internet Protocol (IP) Virtual Private Networks (VPNs)*

RFC 4724, *Graceful Restart Mechanism for BGP* – helper mode

RFC 4760, *Multiprotocol Extensions for BGP-4*

RFC 4798, *Connecting IPv6 Islands over IPv4 MPLS Using IPv6 Provider Edge Routers (6PE)*

RFC 5004, *Avoid BGP Best Path Transitions from One External to Another*

RFC 5065, *Autonomous System Confederations for BGP*

RFC 5291, *Outbound Route Filtering Capability for BGP-4*

RFC 5396, *Textual Representation of Autonomous System (AS) Numbers* – asplain

RFC 5492, *Capabilities Advertisement with BGP-4*

RFC 5668, *4-Octet AS Specific BGP Extended Community*

RFC 6286, *Autonomous-System-Wide Unique BGP Identifier for BGP-4*

RFC 6368, *Internal BGP as the Provider/Customer Edge Protocol for BGP/MPLS IP Virtual Private Networks (VPNs)*

RFC 6793, *BGP Support for Four-Octet Autonomous System (AS) Number Space*

RFC 6810, *The Resource Public Key Infrastructure (RPKI) to Router Protocol*

RFC 6811, *Prefix Origin Validation*

RFC 6996, *Autonomous System (AS) Reservation for Private Use*

RFC 7311, *The Accumulated IGP Metric Attribute for BGP*

RFC 7606, *Revised Error Handling for BGP UPDATE Messages*

RFC 7607, *Codification of AS 0 Processing*

RFC 7752, *North-Bound Distribution of Link-State and Traffic Engineering (TE) Information Using BGP*

RFC 7911, *Advertisement of Multiple Paths in BGP*

RFC 7999, *BLACKHOLE Community*

RFC 8092, *BGP Large Communities Attribute*

RFC 8097, *BGP Prefix Origin Validation State Extended Community*

RFC 8212, *Default External BGP (EBGP) Route Propagation Behavior without Policies*

RFC 8277, *Using BGP to Bind MPLS Labels to Address Prefixes*

RFC 9494, *Long-Lived Graceful Restart for BGP*

12.3 Bridging and management

IEEE 802.1AB, *Station and Media Access Control Connectivity Discovery*

IEEE 802.1ad, *Provider Bridges*

IEEE 802.1AX, *Link Aggregation*

IEEE 802.1Q, *Virtual LANs*

12.4 Certificate management

RFC 4210, *Internet X.509 Public Key Infrastructure Certificate Management Protocol (CMP)*

RFC 4211, *Internet X.509 Public Key Infrastructure Certificate Request Message Format (CRMF)*

RFC 5280, *Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile*

RFC 6712, *Internet X.509 Public Key Infrastructure -- HTTP Transfer for the Certificate Management Protocol (CMP)*

RFC 7030, *Enrollment over Secure Transport*

RFC 7468, *Textual Encodings of PKIX, PKCS, and CMS Structures*

12.5 Ethernet VPN (EVPN)

draft-ietf-bess-bgp-srv6-args-00, *SRv6 Argument Signaling for BGP Services*

draft-ietf-bess-evpn-ipvpn-interworking-06, *EVPN Interworking with IPVPN*

draft-sr-bess-evpn-vpws-gateway-03, *Ethernet VPN Virtual Private Wire Services Gateway Solution*

RFC 7432, *BGP MPLS-Based Ethernet VPN*

RFC 8214, *Virtual Private Wire Service Support in Ethernet VPN*

RFC 8317, *Ethernet-Tree (E-Tree) Support in Ethernet VPN (EVPN) an Provider Backbone Bridging EVPN (PBB-EVPN)*

RFC 8365, *A Network Virtualization Overlay Solution Using Ethernet VPN (EVPN)*

RFC 8560, *Seamless Integration of Ethernet VPN (EVPN) with Virtual Private LAN Service (VPLS) and Their Provider Backbone Bridge (PBB) Equivalents*

RFC 9047, *Propagation of ARP/ND Flags in an Ethernet Virtual Private Network (EVPN)*

RFC 9135, *Integrated Routing and Bridging in Ethernet VPN (EVPN)*

RFC 9136, *IP Prefix Advertisement in Ethernet VPN (EVPN)*

RFC 9161, *Operational Aspects of Proxy ARP/ND in Ethernet Virtual Private Networks*

RFC 9251, *Internet Group Management Protocol (IGMP) and Multicast Listener Discovery (MLD) Proxies for Ethernet VPN (EVPN)*

12.6 gRPC Remote Procedure Calls (gRPC)

cert.proto version 0.1.0, *gRPC Network Operations Interface (gNOI) Certificate Management Service*

file.proto version 0.1.0, *gRPC Network Operations Interface (gNOI) File Service*

gnmi.proto version 0.8.0, *gRPC Network Management Interface (gNMI) Service Specification*

gnmi_ext.proto version 0.1.0, *gNMI Commit Confirmed Extension*

system.proto version 1.0.0, *gRPC Network Operations Interface (gNOI) System Service*

PROTOCOL-HTTP2, *gRPC over HTTP2*

12.7 Intermediate System to Intermediate System (IS-IS)

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draft-ietf-lsr-igp-ureach-prefix-announce-01, *IGP Unreachable Prefix Announcement* – without U-Flag and UP-Flag

draft-kaplan-isis-ext-eth-02, *Extended Ethernet Frame Size Support*

ISO/IEC 10589:2002 Second Edition, *Intermediate system to Intermediate system intra-domain routeing information exchange protocol for use in conjunction with the protocol for providing the connectionless-mode Network Service (ISO 8473)*

RFC 1195, *Use of OSI IS-IS for Routing in TCP/IP and Dual Environments*

RFC 2973, *IS-IS Mesh Groups*

RFC 3359, *Reserved Type, Length and Value (TLV) Codepoints in Intermediate System to Intermediate System*

RFC 3719, *Recommendations for Interoperable Networks using Intermediate System to Intermediate System (IS-IS)*

RFC 3787, *Recommendations for Interoperable IP Networks using Intermediate System to Intermediate System (IS-IS)*

RFC 5120, *M-ISIS: Multi Topology (MT) Routing in IS-IS*

RFC 5130, *A Policy Control Mechanism in IS-IS Using Administrative Tags*

RFC 5301, *Dynamic Hostname Exchange Mechanism for IS-IS*

RFC 5302, *Domain-wide Prefix Distribution with Two-Level IS-IS*

RFC 5303, *Three-Way Handshake for IS-IS Point-to-Point Adjacencies*

RFC 5304, *IS-IS Cryptographic Authentication*

RFC 5305, *IS-IS Extensions for Traffic Engineering TE*

RFC 5306, *Restart Signaling for IS-IS* – helper mode

RFC 5308, *Routing IPv6 with IS-IS*

RFC 5309, *Point-to-Point Operation over LAN in Link State Routing Protocols*

RFC 5310, *IS-IS Generic Cryptographic Authentication*

RFC 6213, *IS-IS BFD-Enabled TLV*

RFC 6232, *Purge Originator Identification TLV for IS-IS*

RFC 6233, *IS-IS Registry Extension for Purges*

RFC 7775, *IS-IS Route Preference for Extended IP and IPv6 Reachability*

RFC 7794, *IS-IS Prefix Attributes for Extended IPv4 and IPv6 Reachability* – sections 2.1 and 2.3

RFC 7981, *IS-IS Extensions for Advertising Router Information*

RFC 7987, *IS-IS Minimum Remaining Lifetime*

RFC 8202, *IS-IS Multi-Instance* – single topology

RFC 8570, *IS-IS Traffic Engineering (TE) Metric Extensions* – Min/Max Unidirectional Link Delay metric for flex-algo, RSVP, SR-TE

RFC 8919, *IS-IS Application-Specific Link Attributes*

12.8 Internet Protocol (IP) general

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RFC 793, *Transmission Control Protocol*

RFC 854, *Telnet Protocol Specifications*

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RFC 2784, *Generic Routing Encapsulation (GRE)*

RFC 3164, *The BSD syslog Protocol*

RFC 4632, *Classless Inter-domain Routing (CIDR): The Internet Address Assignment and Aggregation Plan*

RFC 5082, *The Generalized TTL Security Mechanism (GTSM)*

12.9 Internet Protocol (IP) multicast

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RFC 2236, *Internet Group Management Protocol, Version 2*

RFC 2365, *Administratively Scoped IP Multicast*

RFC 2375, *IPv6 Multicast Address Assignments*

RFC 2710, *Multicast Listener Discovery (MLD) for IPv6*

RFC 3376, *Internet Group Management Protocol, Version 3*

RFC 3446, *Anycast Rendevous Point (RP) mechanism using Protocol Independent Multicast (PIM) and Multicast Source Discovery Protocol (MSDP)*

RFC 3590, *Source Address Selection for the Multicast Listener Discovery (MLD) Protocol*

RFC 3618, *Multicast Source Discovery Protocol (MSDP)*

RFC 3810, *Multicast Listener Discovery Version 2 (MLDv2) for IPv6*

RFC 4541, *Considerations for Internet Group Management Protocol (IGMP) and Multicast Listener Discovery (MLD) Snooping Switches*

RFC 4604, *Using Internet Group Management Protocol Version 3 (IGMPv3) and Multicast Listener Discovery Protocol Version 2 (MLDv2) for Source-Specific Multicast*

RFC 4610, *Anycast-RP Using Protocol Independent Multicast (PIM)*

RFC 4611, *Multicast Source Discovery Protocol (MSDP) Deployment Scenarios*

RFC 5059, *Bootstrap Router (BSR) Mechanism for Protocol Independent Multicast (PIM)*

RFC 5186, *Internet Group Management Protocol Version 3 (IGMPv3) / Multicast Listener Discovery Version 2 (MLDv2) and Multicast Routing Protocol Interaction*

RFC 5384, *The Protocol Independent Multicast (PIM) Join Attribute Format*

RFC 7761, *Protocol Independent Multicast - Sparse Mode (PIM-SM): Protocol Specification (Revised)*

RFC 8487, *Mtrace Version 2: Traceroute Facility for IP Multicast*

12.10 Internet Protocol (IP) version 4

RFC 791, *Internet Protocol*

RFC 792, *Internet Control Message Protocol*

RFC 826, *An Ethernet Address Resolution Protocol*

RFC 1034, *Domain Names - Concepts and Facilities*

RFC 1035, *Domain Names - Implementation and Specification*

RFC 1191, *Path MTU Discovery* – router specification

RFC 1519, *Classless Inter-Domain Routing (CIDR): an Address Assignment and Aggregation Strategy*

RFC 1812, *Requirements for IPv4 Routers*

RFC 1918, *Address Allocation for Private Internets*

RFC 2131, *Dynamic Host Configuration Protocol*; Relay only

RFC 2132, *DHCP Options and BOOTP Vendor Extensions* – DHCP

RFC 2401, *Security Architecture for Internet Protocol*

RFC 3021, *Using 31-Bit Prefixes on IPv4 Point-to-Point Links*

RFC 3046, *DHCP Relay Agent Information Option (Option 82)*

RFC 3768, *Virtual Router Redundancy Protocol (VRRP)*

RFC 4884, *Extended ICMP to Support Multi-Part Messages* – ICMPv4 and ICMPv6 Time Exceeded

12.11 Internet Protocol (IP) version 6

RFC 2464, *Transmission of IPv6 Packets over Ethernet Networks*

RFC 2529, *Transmission of IPv6 over IPv4 Domains without Explicit Tunnels*

RFC 3122, *Extensions to IPv6 Neighbor Discovery for Inverse Discovery Specification*

RFC 3315, *Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*

RFC 3587, *IPv6 Global Unicast Address Format*

RFC 3596, *DNS Extensions to Support IP version 6*

RFC 3633, *IPv6 Prefix Options for Dynamic Host Configuration Protocol (DHCP) version 6*

RFC 3736, *Stateless Dynamic Host Configuration Protocol (DHCP) Service for IPv6*

RFC 3971, *SEcure Neighbor Discovery (SEND)*

RFC 4007, *IPv6 Scoped Address Architecture*

RFC 4191, *Default Router Preferences and More-Specific Routes* – Default Router Preference

RFC 4193, *Unique Local IPv6 Unicast Addresses*

RFC 4291, *Internet Protocol Version 6 (IPv6) Addressing Architecture*

RFC 4443, *Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification*

RFC 4861, *Neighbor Discovery for IP version 6 (IPv6)*

RFC 5095, *Deprecation of Type 0 Routing Headers in IPv6*

RFC 5722, *Handling of Overlapping IPv6 Fragments*

RFC 5798, *Virtual Router Redundancy Protocol (VRRP) Version 3 for IPv4 and IPv6* – IPv6

RFC 5952, *A Recommendation for IPv6 Address Text Representation*

RFC 6164, *Using 127-Bit IPv6 Prefixes on Inter-Router Links*

RFC 8021, *Generation of IPv6 Atomic Fragments Considered Harmful*

RFC 8200, *Internet Protocol, Version 6 (IPv6) Specification*

12.12 Internet Protocol Security (IPsec)

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draft-ietf-ipsec-isakmp-xauth-06, *Extended Authentication within ISAKMP/Oakley (XAUTH)*

RFC 2401, *Security Architecture for the Internet Protocol*

RFC 2403, *The Use of HMAC-MD5-96 within ESP and AH*

RFC 2404, *The Use of HMAC-SHA-1-96 within ESP and AH*

RFC 2405, *The ESP DES-CBC Cipher Algorithm With Explicit IV*

RFC 2406, *IP Encapsulating Security Payload (ESP)*

RFC 2407, *IPsec Domain of Interpretation for ISAKMP (IPsec DoI)*

RFC 2408, *Internet Security Association and Key Management Protocol (ISAKMP)*

RFC 2409, *The Internet Key Exchange (IKE)*

RFC 2410, *The NULL Encryption Algorithm and Its Use With IPsec*

RFC 2560, *X.509 Internet Public Key Infrastructure Online Certificate Status Protocol - OCSP*

RFC 3526, *More Modular Exponential (MODP) Diffie-Hellman group for Internet Key Exchange (IKE)*

RFC 3566, *The AES-XCBC-MAC-96 Algorithm and Its Use With IPsec*

RFC 3602, *The AES-CBC Cipher Algorithm and Its Use with IPsec*

RFC 3706, *A Traffic-Based Method of Detecting Dead Internet Key Exchange (IKE) Peers*

RFC 3947, *Negotiation of NAT-Traversal in the IKE*

RFC 3948, *UDP Encapsulation of IPsec ESP Packets*

RFC 4106, *The Use of Galois/Counter Mode (GCM) in IPsec ESP*

RFC 4109, *Algorithms for Internet Key Exchange version 1 (IKEv1)*

RFC 4301, *Security Architecture for the Internet Protocol*

RFC 4303, *IP Encapsulating Security Payload*

RFC 4307, *Cryptographic Algorithms for Use in the Internet Key Exchange Version 2 (IKEv2)*

RFC 4308, *Cryptographic Suites for IPsec*

RFC 4434, *The AES-XCBC-PRF-128 Algorithm for the Internet Key Exchange Protocol (IKE)*

RFC 4543, *The Use of Galois Message Authentication Code (GMAC) in IPsec ESP and AH*

RFC 4754, *IKE and IKEv2 Authentication Using the Elliptic Curve Digital Signature Algorithm (ECDSA)*

RFC 4835, *Cryptographic Algorithm Implementation Requirements for Encapsulating Security Payload (ESP) and Authentication Header (AH)*

RFC 4868, *Using HMAC-SHA-256, HMAC-SHA-384, and HMAC-SHA-512 with IPsec*

RFC 4945, *The Internet IP Security PKI Profile of IKEv1/ISAKMP, IKEv2 and PKIX*

RFC 5019, *The Lightweight Online Certificate Status Protocol (OCSP) Profile for High-Volume Environments*

RFC 5282, *Using Authenticated Encryption Algorithms with the Encrypted Payload of the IKEv2 Protocol*

RFC 5903, *ECP Groups for IKE and IKEv2*

RFC 5996, *Internet Key Exchange Protocol Version 2 (IKEv2)*

RFC 5998, *An Extension for EAP-Only Authentication in IKEv2*

RFC 6379, *Suite B Cryptographic Suites for IPsec*

RFC 6380, *Suite B Profile for Internet Protocol Security (IPsec)*

RFC 6960, *X.509 Internet Public Key Infrastructure Online Certificate Status Protocol - OCSP*

RFC 7296, *Internet Key Exchange Protocol Version 2 (IKEv2)*

RFC 7321, *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*

RFC 7383, *Internet Key Exchange Protocol Version 2 (IKEv2) Message Fragmentation*

RFC 7427, *Signature Authentication in the Internet Key Exchange Version 2 (IKEv2)*

RFC 8784, *Mixing Preshared Keys in the Internet Key Exchange Protocol Version 2 (IKEv2) for Post-quantum Security*

12.13 Label Distribution Protocol (LDP)

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draft-pdutta-mpls-ldp-v2-00, *LDP Version 2*

RFC 3037, *LDP Applicability*

RFC 3478, *Graceful Restart Mechanism for Label Distribution Protocol* – helper mode

RFC 5036, *LDP Specification*

RFC 5283, *LDP Extension for Inter-Area Label Switched Paths (LSPs)*

RFC 5443, *LDP IGP Synchronization*

RFC 5561, *LDP Capabilities*

RFC 5919, *Signaling LDP Label Advertisement Completion*

12.14 Multiprotocol Label Switching (MPLS)

RFC 3031, *Multiprotocol Label Switching Architecture*

RFC 3032, *MPLS Label Stack Encoding*

RFC 3270, *Multi-Protocol Label Switching (MPLS) Support of Differentiated Services* – E-LSP

RFC 3443, *Time To Live (TTL) Processing in Multi-Protocol Label Switching (MPLS) Networks*

RFC 5332, *MPLS Multicast Encapsulations*

RFC 5884, *Bidirectional Forwarding Detection (BFD) for MPLS Label Switched Paths (LSPs)*

RFC 6424, *Mechanism for Performing Label Switched Path Ping (LSP Ping) over MPLS Tunnels*

RFC 7308, *Extended Administrative Groups in MPLS Traffic Engineering (MPLS-TE)*

RFC 7746, *Label Switched Path (LSP) Self-Ping*

12.15 Network Address Translation (NAT)

RFC 4787, *Network Address Translation (NAT) Behavioral Requirements for Unicast UDP*

RFC 5382, *NAT Behavioral Requirements for TCP*

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12.16 Open Shortest Path First (OSPF)

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12.28 Yet Another Next Generation (YANG)

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RFC 7951, *JSON Encoding of Data Modeled with YANG*

Customer document and product support

Customer documentation

Customer documentation welcome page

Technical support

Product support portal

Documentation feedback

Customer documentation feedback