

Cisco Routed Optical Networking Solution Guide, Release 3.0

First Published: 2024-05-02

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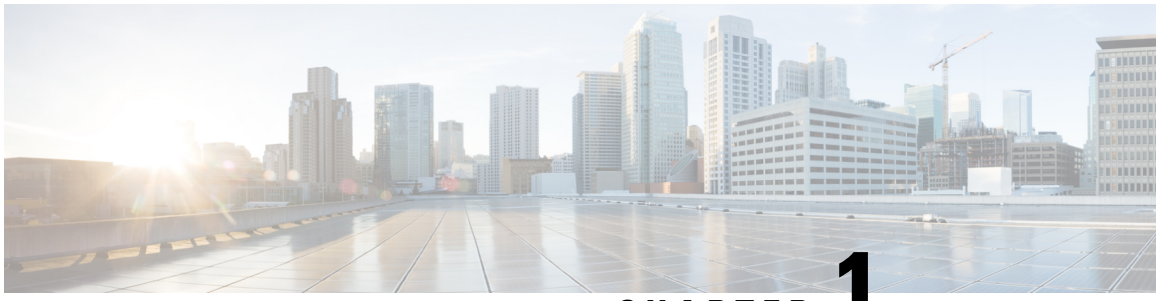
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CHAPTER 1

Introduction to Traditional Networks

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- Network building blocks, on page 3
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Routed Optical Networking solution

Business challenge

Today's optical and packet networks consist of multiple layers that are stitched together from various domains and vendors. Provisioning services in such complex environments requires tight coordination among different management systems and organizations. It is challenging to operate these networks and the service providers face rising total cost of ownership (TCO). Service providers must simplify and reimagine the architecture to reduce rising operational costs and accelerate the delivery of new services.

Routed Optical Networking solution

The Routed Optical Networking solution aims to simplify networks by removing the complexities inherent to the infrastructure. This solution improves operational efficiency, reduces network TCO, and increases service agility.

The Routed Optical Networking solution allows service providers to leverage their assets more effectively by

- creating a simplified converged IP and Optical network,
- using high-speed coherent pluggable modules that provide optimal reach and performance at appropriate cost points and power profiles, and
- simplifying the network and service lifecycle management by using automation in all phases.

Traditional multilayer network architectures

Traditional network infrastructure consists of an Internet Protocol (IP) layer and an optical transport layer. The optical layer includes a Dense Wavelength Division Multiplexing (DWDM) layer, and optionally, an

Optical Transport Network (OTN) switching layer. Each layer possesses its own independent control and management planes.

Types of control planes

- Distributed control plane: communicates network information between network elements to enable end-to-end communication between network clients.
- IP control plane: distributes routing information.
- Optical control plane: performs resource and connection management between optical endpoints.

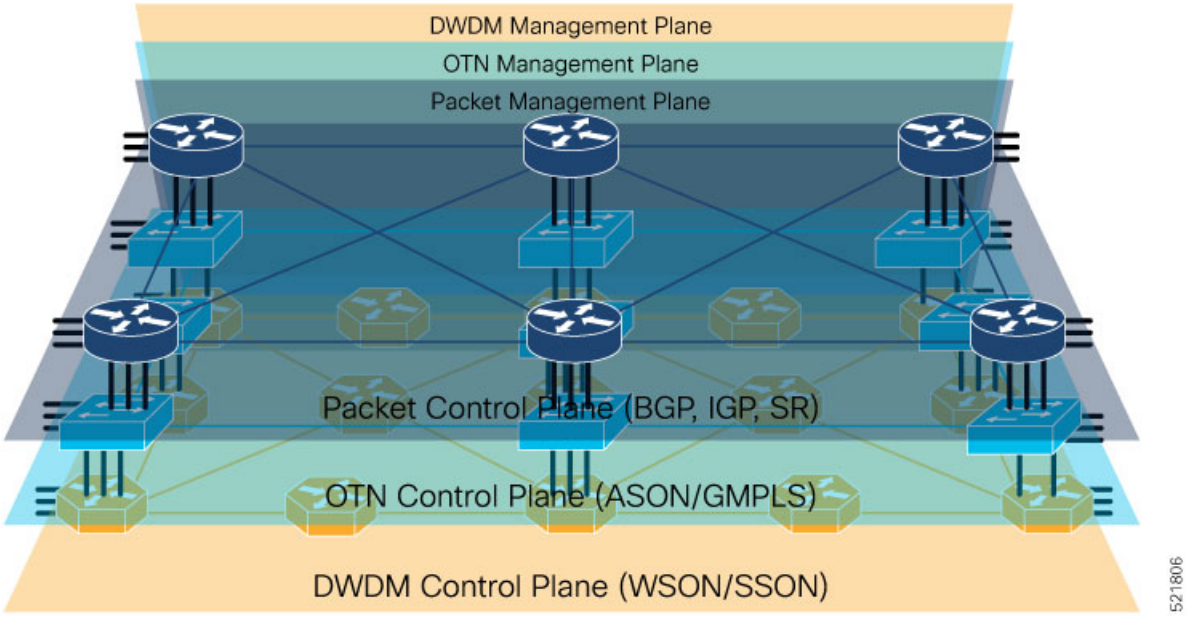
Network layers and control planes

This table lists the network layers and their corresponding control planes.

Table 1: Network layers and control planes

Network layers	Control planes
Packet layer or IP layer	BGP, IGP, and segment routing
OTN layer	Automatically Switched Optical Network (ASON) and Generalized Multiprotocol Label Switching (GMPLS)
DWDM layer	Wavelength Switched Optical Network (WSON) and Shared Services and Outsourcing Network (SSON)

Figure 1: Traditional network architecture



Each layer operates independently with separate redundancy and life cycles. Separate teams are needed to establish and maintain each layer.

Network building blocks

Traditional hierarchical networks consist of an IP layer and an optical transport layer.

IP layer

The IP layer creates and maintains the routing table and forwards packets accordingly. The IP layer of traditional networks consists of interconnected routers.

Routers

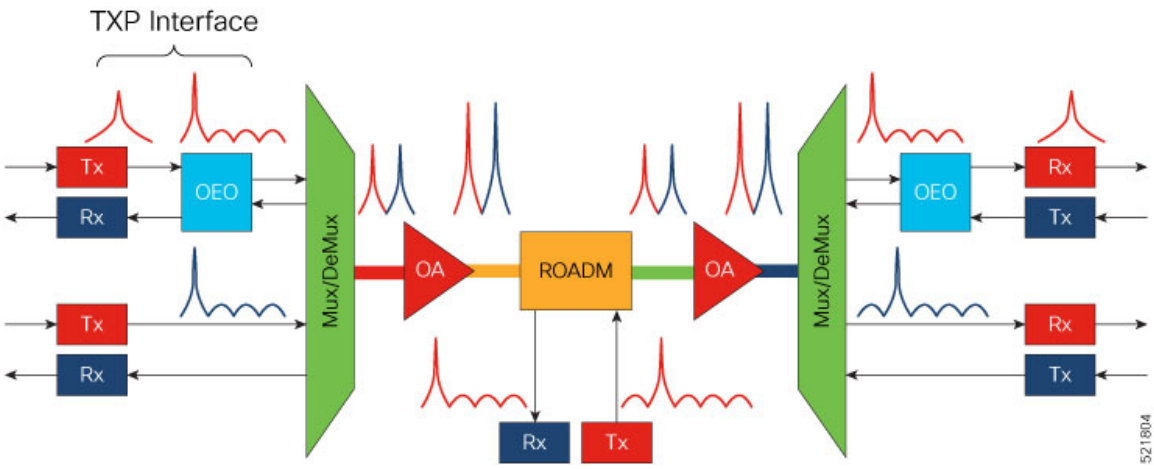
Routers are the building blocks of packet networks. They efficiently forward IP or MPLS packets. Routers create any-to-any fabrics to carry most networking traffic, including global Internet traffic. Routers are also responsible for providing different functions based on their role in the network.

Two examples of routers are Core and Provider Edge routers. Core routers use a simplified set of implemented features and supply high capacity interconnect between different regions in a network. Provider Edge (PE) routers support high scale overlay VPN services.

Optical layer

This diagram shows a typical DWDM network.

Figure 2: Typical DWDM network



This table lists the abbreviations in this image and their expansions.

Table 2: Abbreviations and expansions

TXP	Transponder
OEO	Optical-electrical-optical
Mux	Multiplexer
DeMux	Demultiplexer
OA	Optical amplifier

ROADM	Reconfigurable optical add/drop multiplexer

Building blocks of a typical DWDM network

These are the key building blocks of a typical DWDM network.

- **Optical Transmitters and Receivers**: Transmitters provide source signals. They convert digital electrical signals into a light stream of a specific wavelength. Optical receivers detect pulses of light on optical fibers and convert the optical signals into electrical signals.
- **Transponders**: Transponders take signals on gray wavelengths and send them in colored wavelengths. Colored wavelengths are wavelengths in the WDM standard. Gray wavelengths are wavelengths not in the WDM standard. A bidirectional transponder also receives a WDM standard bit-stream and converts the signals back to the wavelength used by the client device.
- **Muxponders**: Muxponders are similar to transponders. Muxponders take multiple gray wavelength signals and send them in a single colored-wavelength using Time Division Multiplexing (TDM).
- **Multiplexers and Demultiplexers**: Multiplexers combine multiple wavelengths from separate fibers into a single composite signal within one fiber. The output of a multiplexer is a composite signal. Demultiplexers take composite signals that compatible multiplexers generate and separate the individual wavelengths into individual fibers.
- **Optical Amplifiers**: Optical amplifiers amplify an optical signal. Optical amplifiers increase the total power of the optical signal, enabling its transmission across longer distances. Without amplifiers, the signal attenuation over such distances makes it impossible to coherently receive signals. We use different types of optical amplifiers in optical networks, such as preamplifiers, booster amplifiers, inline amplifiers, and optical line amplifiers.
- **Optical Add and Drop Multiplexers (OADMs)**: OADMs are devices capable of adding one or more DWDM channels into or dropping them from a fiber.
- **Reconfigurable Optical Add and Drop Multiplexers (ROADMs)**: ROADMs are programmable versions of OADMs. With ROADMs, you can change the wavelengths that are added or dropped. ROADMs make optical networks flexible and easily modifiable.

Challenges with current IP and optical networks

Current hierarchical service provider networks have up to three different layers, IP, OTN, and DWDM, each with separate control planes. These networks have a layered and siloed architecture relying on dedicated hardware to exchange traffic between layers. The siloed architecture creates separate opaque redundancy mechanisms at each layer, increasing complexity and reducing network efficiency. The large number of devices used to interconnect the layers increase power utilization and the carbon footprint of the network.

The layered and siloed architecture warrants manual service-stitching across network domains. Manual intervention hinders end-to-end automation and increases resolution time, reducing efficiency

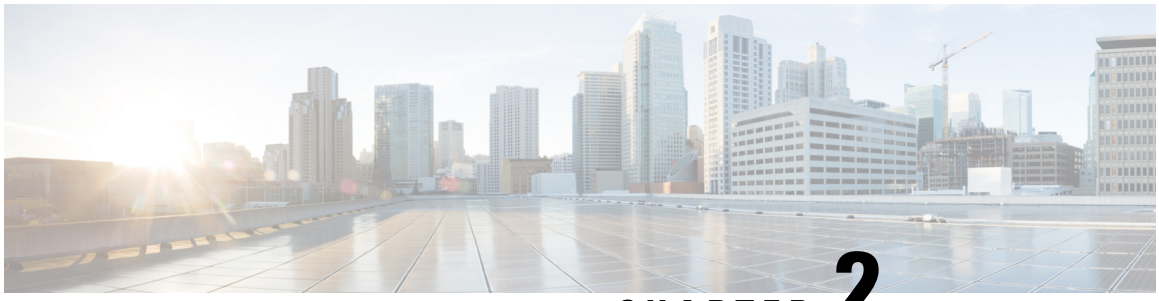
Traffic passes through too many elements. The need for separate management of these elements by different departments and the lack of automated management increases the complexity and cost of the network.

Challenges with current service provider networks

Current service provider networks face immense complexities and challenges in

- network planning
- provisioning
- path and network optimization
- network monitoring, and
- fault correction.

These complexities and overlapping redundancies create bottlenecks that hinder the efficient scaling of service provider networks.



CHAPTER 2

Routed Optical Networking

- Routed Optical Networking, on page 7
- Legacy architecture and Routed Optical Networking architecture, on page 8
- Routed Optical Networking architecture, on page 10
- Benefits of Routed Optical Networking, on page 11
- Routed Optical Networking deployment models, on page 12
- What's new in Routed Optical Networking 3.0, on page 13

Routed Optical Networking

Benefits of Routed Optical Networking

Routed Optical Networking

- simplifies complex multilayer networks by collapsing network layers and minimizing the functional overlap
- improves overall network efficiency by optimizing each layer of the network, and
- integrates open data models and standard APIs, enriching powerful automation.

Routed Optical Networking offers improvements and simplification because it

- uses modern optical and routing technologies to converge services over an IP infrastructure connected by a simplified DWDM layer
- merges IP and private line services onto a single unified IP layer
- simplifies end-to-end network architecture
- utilizes a modern software stack that spans across network management and control planes
- improves the capacity and cost efficiency of networks
- has a smaller carbon footprint
- offers unified capacity planning, unified EMS, unified path optimization, orchestration, and assurance
- provides an automation ecosystem with open, programmable, and modular components, and
- provides savings on Total Cost of Ownership (TCO) across CapEx and OpEx.

Components of Routed Optical Networking

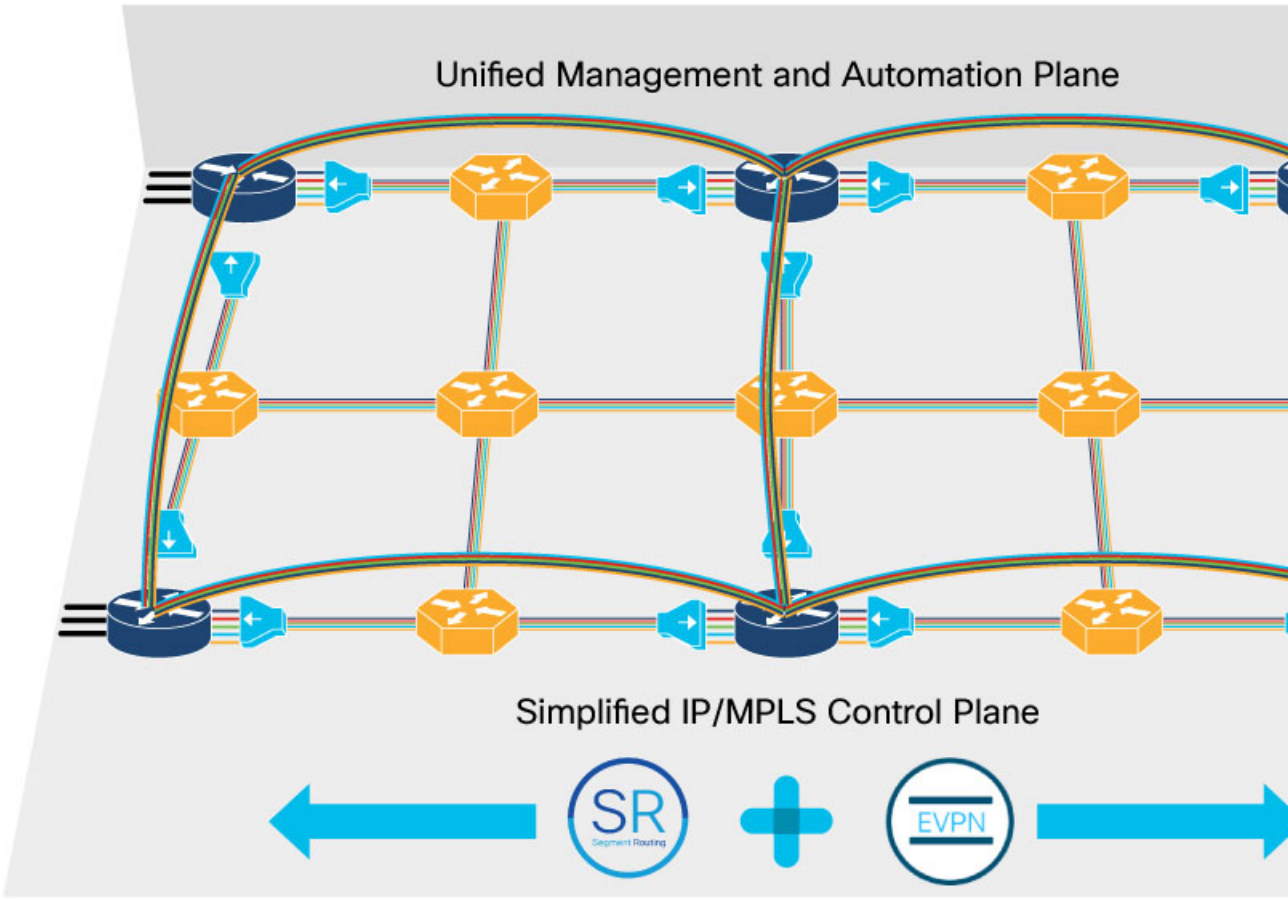
Routed Optical Networking uses these components:

- High-density Cisco routers
- High-capacity ZR or ZR+ pluggable digital coherent optics
- Simplified DWDM line systems
- End-to-end multi-layer automation

Legacy architecture and Routed Optical Networking architecture

Routed Optical Networking architecture unifies the WDM, OTN, and packet transport layers into a single, easy-to-control layer.

Figure 3: Routed Optical Networking strategy



Agile Services Networking transport architecture

The Agile Services Networking architecture simplifies the network by converging services on a unified, automated infrastructure, providing scalability and agility for new services in the AI era and beyond. See Agile Services Networking.

Routed Optical Networking as part of Cisco's Agile Services Networking architecture brings network simplification to the physical network infrastructure, just as EVPN and Segment Routing simplify the service and traffic engineering network layers. Routed Optical Networking collapses complex technologies and network layers into a more cost efficient and easy to manage network infrastructure.

Routed Optical Networking achieves this architecture by leveraging high-density routers, high-capacity digital coherent pluggable optical modules, simplified optical elements, and advanced automation capabilities. Components of Routed Optical Network are also fully compliant ROADM-based networks and can interoperate seamlessly with a mix or traditional transponders and Routed Optical Networking pluggable DCO.

The converged architecture enables

- unified planning and design
- seamless multi-layer provisioning
- unified multi-layer management
- end-to-end multi-layer and multi-domain network visibility
- end-to-end network optimization for IP and private line services, and
- convergence of IP and private line services on a single converged packet network infrastructure with guaranteed SLAs.

Comparison of legacy multilayered and Routed Optical Networking architectures

This table compares legacy multilayered and Routed Optical Networking architectures.

Table 3: Comparison of legacy multilayered and Routed Optical Networking architectures

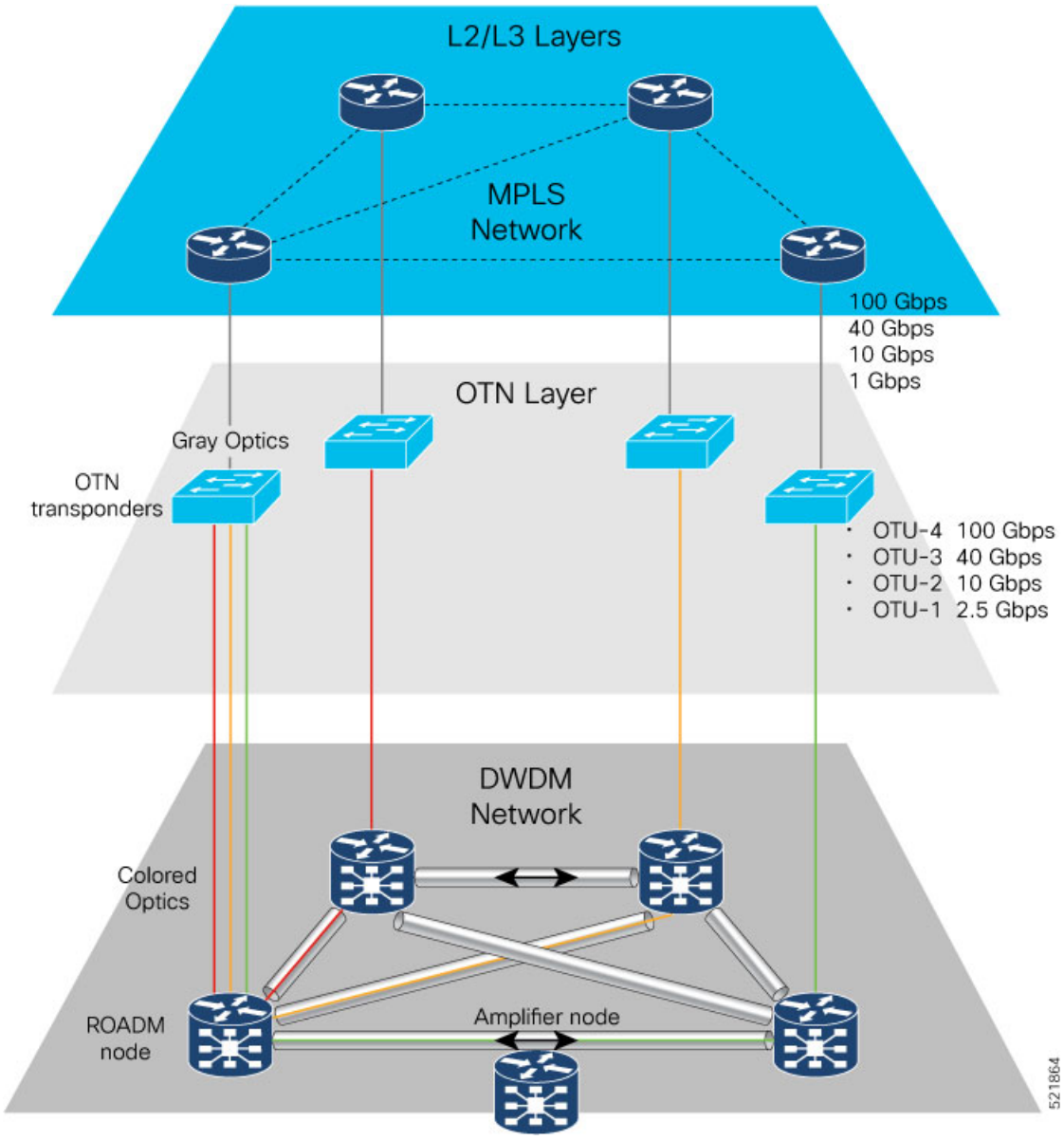
Layered architecture	Routed Optical Networking architecture
Trades off port density and capacity on router line cards for coherent optical transmission	Higher port density and capacity on the router line cards using digital coherent pluggable optical modules
Proprietary components; noninteroperable	Standards-based approach; interoperable across vendors
Siloed approach; separate control and management planes	Common control and management planes for converged optical and IP layer
Manual service stitching necessary across network domains	Enables end-to-end closed-loop automation and manageability
Independent capacity planning on IP and optical layers, where additional capacity is dimensioned on each layer separately leading to CapEx inefficiencies.	Unified capacity planning on a converged network optimizing CapEx investments

Routed Optical Networking architecture

Multilayer architecture

This diagram displays the current multilayer architecture.

Figure 4: Multilayer architecture



Routed Optical Networking architecture

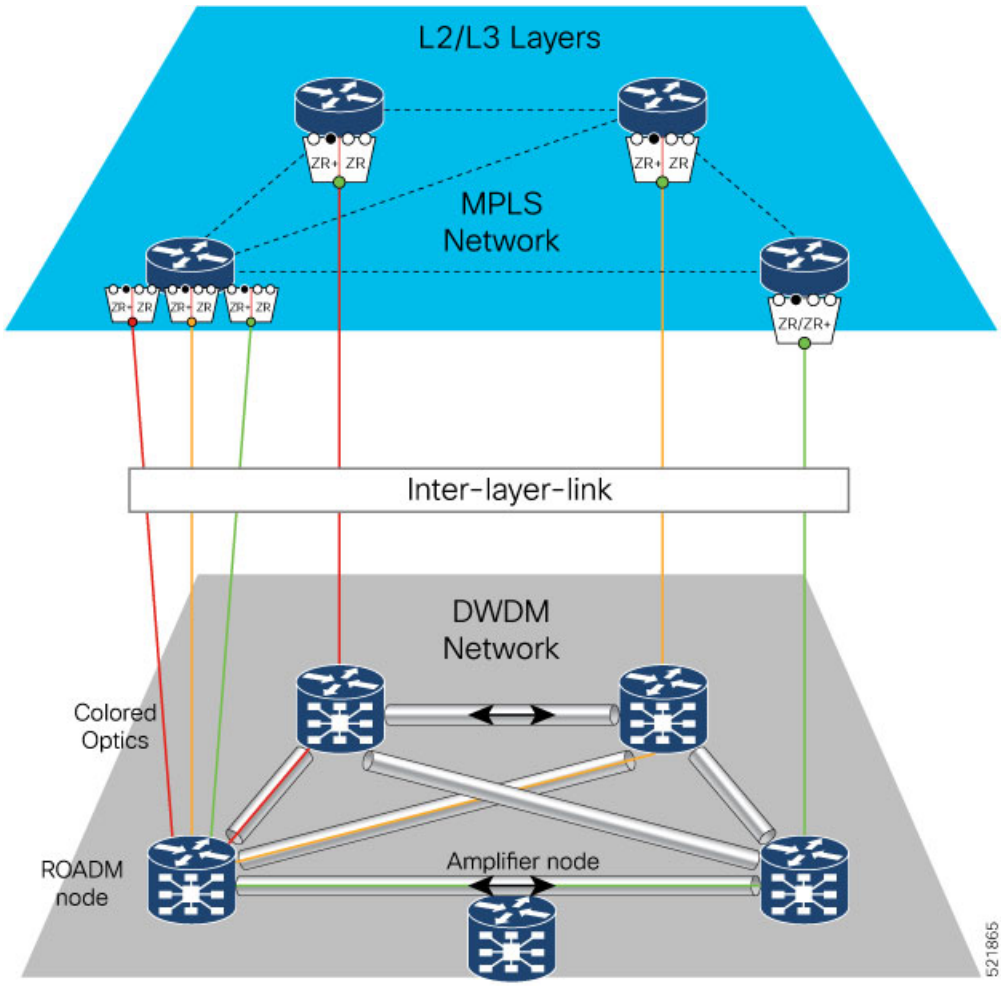
Routed Optical Networking is a transformative architecture that disrupts the existing multilayer network architecture. It converges all network services into a single layer.

The routers are connected through dark fiber or a DWDM network using standardized pluggable digital coherent optics, such as ZR and ZR+ transceivers. These transceivers reduce cabling, power consumption, and physical footprint compared to traditional external transponders.

With a single service layer based on IP, flexible management tools can leverage telemetry and model-driven programmability to streamline lifecycle operations. This simplified architecture integrates open data models and standard APIs, enabling a provider to focus on automation initiatives for a simpler topology.

This diagram displays the Routed Optical Networking architecture.

Figure 5: Routed Optical Networking architecture



Benefits of Routed Optical Networking

Routed Optical Networking has these benefits.

- **Cost Savings:** Routed Optical Networking reduces the network's total cost of ownership. Routed Optical networks make the most efficient use of high capacity routers and DWDM optical infrastructure. The routers' high-capacity switching allows networks to achieve denser interconnection and move traffic protection to the IP layer. Routed Optical Networking saves costs by converging service layers, simplifying

the DWDM optical system, and using industry-standard ZR and ZR+ pluggable digital coherent optics. Elimination of multiple layers reduces power usage and hardware footprint. End-to-end multi-layer automation enables better utilization of network capacity.

- **Simplification:** Using Agile Services Networking technologies like Segment Routing, EVPN. and Routed Optical Networking simplifies networks from the base infrastructure layer to the services layer. Using Circuit-Style Segment Routing and Private Line Emulation, Routed Optical Networking allows providers to converge services while maintaining or exceeding existing private line service SLAs. This convergence leads to simplified planning, design, activation, management, and troubleshooting.
- **Automation:** Automation enhances resiliency, improves failure detection, and simplifies repair processes. Enhanced multi-layer visibility and root cause analysis allow network operators to quickly discover and remedy faults. Troubleshooting is enhanced with rich network telemetry at each layer.
- **Optimize Capacity:** Routed Optical Networking uses the IP layer's capability to statistically multiplex network traffic at the packet level. Statistical multiplexing efficiently carries network traffic, adapting to instantaneous traffic demands and avoiding idle link capacity. Routed Optical Networking networks utilize fiber capacity to its fullest by intelligently utilizing capacity at the IP layer instead of wasting DWDM resources with unnecessary bypass circuits.

Routed Optical Networking deployment models

There is no one-size-fits-all solution for deploying a new architecture. The approach depends on the structure of the network and the goals of its owner. Therefore, it is critical to have a flexible control platform that supports a phased deployment and a smooth evolution.

Routed Optical Networking deployment

When a new IP and optical network is deployed, the hardware, together with its control architecture – including Crosswork Hierarchical Controller, Crosswork Network Controller, and Cisco Optical Network Controller, are installed from scratch. Install Crosswork Hierarchical Controller ahead of time to prepare for Routed Optical Networking deployment. This helps in planning the network using accurate data on existing services, network, and fiber assets. See Components of automation, on page 42.

Third-party optical network Routed Optical Networking deployment

When routers with ZR and ZR+ optics are deployed over networks that use third-party optical devices, Crosswork Hierarchical Controller is integrated with Crosswork Network Controller and the existing DWDM optical controllers. Crosswork Hierarchical Controller creates IP links between the routers by configuring the optical path through the optical controllers and terminates those paths on the DWDM transceivers in the routers.

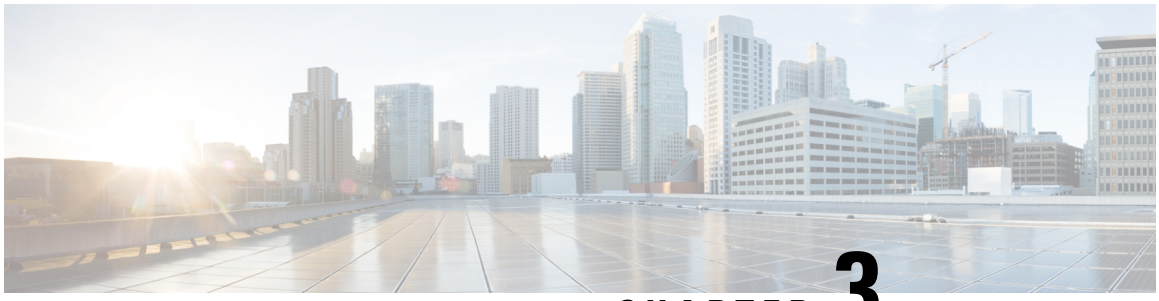
What's new in Routed Optical Networking 3.0

Feature	Release	Description
Automation Starter Solution	Crosswork Hierarchical Controller 8.0	Automation Starter Solution accelerates adoption of Routed Optical Networking by simplifying the installation and deployment of the overall Routed Optical Networking solution. It is a simplified automation stack that is used to manage ZR and ZR+ optics in Cisco routers. The primary difference between the starter and full solution is the absence of Crosswork Network Controller in the Starter solution.
Support for QDD-based Optical Line System	Cisco IOS XR Release 7.11.1	These routers support Cisco QSFP-DD Pluggable Open Line System Modules (QSFP-DD OLS): • NCS-57B1-6D24-SYS and NCS-57B1-5DSE-SYS routers • NCS-57C3-MOD and NCS-55A2-MOD routers (only through NC57-MPA-2D4H-S modular port adapter)

Support for 100G-ZR coherent transceivers	Cisco IOS XR Release 7.11.1	These routers support DP01QSDD-ZF1:
		• N540-24Q8L2DD-SYS
		• NCS-57B1-6D24H-S
		• NCS-57B1-5D24-SE
		• NCS-57D2-18DD-S
		• NC57-48Q2D-S
		• NC57-48Q2D-SE-S
		• NC57-MOD-S and NC57-MPA-2D4H-S on:
		  • NCS-55A2
		  • NC55-MOD
		  • NC57-MOD
		  • NCS-57C3

Support for 400G-ER coherent transceivers	Cisco IOS XR Release 7.11.1	These routers support DP04QSDD-ER1: • NC57-18DD-SE

Feature	Release	Description
Cisco Optical Site Manager	Cisco IOS XR Release 7.11.2	Cisco Optical Site Manager runs as an additional application on IOS-XR on the NCS 1010 and is packaged with NCS 1010 IOS-XR releases. Cisco Optical Site Manager . • provides site-level management for an NCS 1010 network built using multiple disaggregated NCS 1010 devices • offers a single communication point for controllers such as Cisco Optical Network Controller, and • allows users to perform management and assurance tasks related to the site nodes such as viewing alarms, performance statistics, and performing OAM functions like OTDR and connectivity verification.
Cross Launch between Automation software suite applications	Cisco Optical Site Manager 7.11.2 Crosswork Hierarchical Controller 8.0 Cisco Crosswork Network Controller 6.0 Cisco Optical Network Controller 3.1	You can now setup SSO login for Cisco Optical Site Manager, Crosswork Hierarchical Controller, Cisco Crosswork Network Controller, and Cisco Optical Network Controller. After setting up SSO, you can cross-launch among these applications. For example, you can launch the node functional view in Cisco Optical Site Manager from the Link Assurance application in Crosswork Hierarchical Controller.



CHAPTER 3

Routed Optical Networking Solution Components

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Hardware components

The hardware components that enable Routed Optical Networking are:

- High density routers
  - Cisco 8000 series routers
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    - Cisco 8200 series routers, on page 17
    - Cisco 8800 series routers, on page 18
    - Cisco 8800 series line cards, on page 18
  - Cisco NCS 5500 series routers
    - Cisco NCS-55A2 series fixed port routers, on page 18
    - Cisco NCS-57B1 series fixed port routers, on page 19
    - Cisco NCS-57C1 series fixed port routers, on page 19
    - Cisco NCS-57C3 series fixed port routers, on page 20
    - Cisco NCS 5500 modular chassis, on page 20
    - NCS 5700 series line cards, on page 21
    - NCS 5700 series modular port adapters, on page 21
  - Specifications of Cisco ASR 9000 series, on page 22
    - Cisco ASR 9903 compact router, on page 23
    - Cisco ASR 9000 series line cards, on page 23

- Specifications of Cisco NCS 540 series routers, on page 24
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- High capacity pluggable optical modules
  - 400G ZR and ZR+ transceivers

- Optical line systems
  - Modules in Cisco Network Convergence System 2000 series, on page 34
    - Cisco NCS 2006 shelf, on page 34
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    - Control cards, on page 35
    - ROADM cards, on page 35
    - Amplifier cards, on page 35
      - EDFA cards, on page 35
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      - Raman amplifier cards, on page 36
  - Passive multiplexer and demultiplexer module, on page 36
  - Passive patch panel modules in Cisco Network Convergence System 2000 series, on page 37
    - MPO-16 to 16-LC fan-out module, on page 37
    - Cisco 1 x 6 colorless flex spectrum add and drop module, on page 37
    - Cisco five-degree modular patch panel module, on page 37
    - Cisco four-degree upgrade modular patch panel module, on page 37
  - Modules in Cisco Network Convergence System 1010, on page 37
    - Cisco NCS 1000 32-channel multiplexer and demultiplexer patch panel, on page 40
    - Cisco NCS 1000 breakout patch panel and modules, on page 40

Specifications of Cisco 8000 series routers

The Cisco 8000 series routers use Silicon One ASIC to provide full routing functionality. They offer higher capacity and a lower environmental footprint than other available routing silicon.

The Silicon One architecture supports large forwarding tables, deep buffers, flexible packet operations, and enhanced programmability to help you manage complex network requirements.

The 8000 series routers are highly scalable, have deep buffering, and are optimized for 100G, 400G, and 800G. They are also available with additional on-chip High Bandwidth Memory (HBM) to support additional resource scale.

Cisco 8010 series router: PLE service endpoint router

The Cisco 8011-2X2XP4L PLE (Private Line Emulation) Service Endpoint Router (PLE-SER) is a fixed-port router in a one rack unit form factor. It supports 2 x 10G SFP+ PLE, 2 x 10G SFP+ Ethernet, and 4 x 10G, 25G, or 50G SFP56 ports. Private Line Emulation (PLE) enables private line services to be carried over the same IP network for non-Ethernet type services like SONET, SDH, and Fiber Channel.

The PLE client ports support these configuration options:

- 2 x 1G and 10G
- 2 x 10G
- 2 x OTU2
- 2 x OC192 or STM64
- 2 x OTU2e
- 2 x OC48
- 2 x FC-1, 2, 4, 8, or 16G
- 1 x FC-32G (only on port 0)

Cisco 8200 series routers

The Cisco 8200 series uses a single Silicon One ASIC to provide full routing functionality. It is designed for use cases that require high buffering and high scale. These fixed-port and high-density routers provide up to 19.2 Tbps of network bandwidth while consuming significantly less power than comparable 20 Tbps systems.

This table details the specifications of the routers.

Router	Capacity	Form factor	400G QSFP-DD ports	100G QSFP28 ports
Cisco 8201	10.8 Tbps	1 rack unit (RU)	24	12
Cisco 8202	10.8 Tbps	2 RU	12	60
Cisco 8201-32FH	12.8 Tbps	1 RU	32	–
Cisco 8202-32FH-M	12.8 Tbps	2 RU	32	–
Cisco 8201-24H8FH	5.6 Tbps	1 RU	8	24

Cisco 8800 series routers

The Cisco 8800 series provides high density and efficiency. It provides the extensive scale, buffering, and feature capabilities found in all Cisco 8000 series routers. The 8800 series routers provide up to 260 Tbps through 648 400 GbE ports. The 8800 series includes four chassis options to meet a variety of network and facility requirements.

This table details the specifications of the routers.

Router	Capacity	Form factor	400G QSFP-DD ports
Cisco 8804	Up to 57.6 Tbps	4-slot, 10 RU	Up to 144
Cisco 8808	Up to 115.2 Tbps	8-slot, 16 RU	Up to 288
Cisco 8812	Up to 172.8 Tbps	12-slot, 21 RU	Up to 432
Cisco 8818	Up to 259.2 Tbps	18-slot, 33 RU	Up to 648

Cisco 8800 series line cards

The Cisco 8800 series modular platform supports 400 GbE line cards for high-speed networking.

This table details the specifications of the routers.

Line cards	Bandwidth	400G QSFP-DD ports
8800-LC-36FH	14.4 Tbps	36
88-LC0-36FH-M	14.4 Tbps	36
88-LC0-36FH	14.4 Tbps	36

For information on ZR and ZR+ port support, see Specifications of 400G ZR and ZR+ transceivers.

For more information about Cisco 8000 series routers, see the Cisco 8000 series Routers Data Sheet.

Specifications of Cisco NCS 5500 series routers

The Network Convergence System (NCS) 5500 platform offers high port density, high-performance forwarding, low jitter, and low power consumption.

Cisco NCS-55A2 series fixed port routers

NCS-55A2-MOD-S is a fixed port, high-density, two RU form factor router. It provides 24 SFP or SFP+ ports supporting Gigabit Ethernet or 10-Gigabit Ethernet, and 16 SFP, SFP+, or SFP28 ports supporting Gigabit Ethernet, 10-Gigabit Ethernet, or 25-Gigabit Ethernet. The router supports up to two Modular Port Adapters (MPA).

This table details the specifications of the routers.

Router	Capacity	Form factor	Nx100G QSFP-DD ports on MPA-2D4H	100G QSFP28 ports on MPA-4H
NCS-55A2-MOD-S	900Gbps	2 RU	8	8

For more information about Cisco NCS-55A2 series fixed port routers, see the Cisco Network Convergence System 5700 series: NCS-55A2 Fixed Chassis Data Sheet.

Cisco NCS-57B1 series fixed port routers

NCS-57B1-6D24-SYS and NCS-57B1-5DSE-SYS routers provide 4.8 terabits (Tbps) of 400GE or 100GE optimized forwarding capacity. They include QSFP-DD optics, deep packet buffering, full line-rate MACsec, Class C 1588 Precision Time Protocol (PTP), and Synchronous Ethernet (SyncE) in a power-efficient, one RU package.

This table details the specifications of the routers.

Router	Capacity	Form factor	400G QSFP-DD ports	100G QSFP-DD ports
NCS-57B1-6D24-SYS	Up to 4.8 Tbps	1 RU	6	24
NCS-57B1-5DSE-SYS	Up to 4.4 Tbps	1 RU	5	24

For more information about Cisco NCS-57B1 series fixed port routers, see the Cisco Network Convergence System 5700 series: NCS-57B1 Fixed Chassis Data Sheet.

Cisco NCS-57C1 series fixed port routers

NCS-57C1-48Q6D-S is a fixed chassis that combines low port densities of 1GE, 10GE, or 25GE with higher port densities of 50GE, 100GE, or 400GE. It also offers QSFP-DD optics, deep packet buffering, MACsec, Class C 1588 PTP, and SyncE in a power-efficient, one RU package.

This table details the specifications of the routers.

Router	Capacity	Form factor	400G QSFP-DD ports	100G QSFP28 ports
NCS-57C1-48Q6-SYS	Up to 2.4 Tbps	1 RU	6 Four 400G and two Nx100G ports	-

For more information about Cisco NCS-57C1 series fixed port routers, see the Cisco Network Convergence System 5700 series: NCS-57C1 Fixed Chassis Data Sheet.

Cisco NCS-57D2 series fixed port routers

The NCS-57D2-18DD-SYS is a two RU router designed for mass-scale core and aggregation networks. It delivers 7.2 Tbps of 400GE or 100GE optimized forwarding capacity and features high power efficiency, QSFP-DD optics, deep packet buffering, full line-rate MACsec, IPSec, Class C 1588 PTP, and SyncE. The router runs on Cisco IOS XR7. It offers advanced capabilities such as next-generation security, automation, telemetry, segment routing, EVPN, and Equal-Cost Multipathing (ECMP). The router supports 18 ports of 400G and 66 ports of 100G, all with QSFP-DD. Breakout options are available for 10G, 25G, and 100G.

This table details the specifications of the routers.

Router	Capacity	Form factor	400G QSFP-DD ports	100G QSFP28 ports
NCS-57D2-18DD-SYS	Up to 7.2 Tbps	2 RU	18	66

For more information about Cisco NCS-57C1 series fixed port routers, see the Cisco Network Convergence System 5700 series: NCS-57C1 Fixed Chassis Data Sheet.

Cisco NCS-57C3 series fixed port routers

The Cisco Network Convergence System 57C3 series routers are designed for cost-effective delivery of next-generation networking services. These routers are high-capacity and low-power consuming devices available in a three RU compact form factor. The chassis, along with the Modular Port Adapters (MPAs), provides options for using different types of interfaces ranging from 1GE to 400GE. It also supports industry-standard MACSec encryption and Class C Timing. These devices also provide Control Plane redundancy, which enables high availability and reliability.

The Cisco NCS 57C3 series routers are suited for a range of applications, including Carrier Ethernet Aggregation, Subscriber Services, Business Ethernet, Mobile Edge, Campus, Peering, and Core roles. The router runs on Cisco IOS XR. It supports a rich and comprehensive set of features like QoS, IP/MPLS, Segment Routing, SRv6, and Ethernet VPN (EVPN).

This table details the specifications of the routers.

Router	Capacity	Form factor	400G QSFP-DD ports on MPA-2D4H	100G QSFP28 ports on base unit
NCS-57C3-MOD-S	Up to 2.4 Tbps	3 RU	Slot 1 - 4 Nx100G ports, Slot 2 and 3 - two 400G ports or four Nx100G ports	8
NCS-57C3-MOD-SE	Up to 2.4 Tbps	3 RU		4

For more information about Cisco NCS-57C1 series fixed port routers, see the Cisco Network Convergence System 5700 series: NCS-57C3 Fixed Chassis Data Sheet.

Cisco NCS 5500 modular chassis

The Cisco NCS 5500 modular chassis series is available in three system sizes: NCS 5504, NCS 5508, and NCS 5516. All NCS systems are highly reliable and resilient platforms. These platforms support a wide range of line card options. NCS 5500 modular router line cards and fabric modules directly attach to each other with connecting pins. In contrast, most traditional modular platform designs require a midplane.

This table details the specifications of the routers.

Platform	Capacity	Form factor	400G QSFP-DD ports	100G QSFP28 ports
NCS 5504	Up to 14.4 Tbps	4-slot, 7 RU	Up to 96	Up to 144
NCS 5508	Up to 76.8 Tbps	8-slot, 13 RU	Up to 192	Up to 288

NCS 5516	Up to 153.6 Tbps	16-slot, 21 RU	Up to 384	Up to 576

For more information about Cisco Network Convergence System 5500 series modular chassis, see the Cisco Network Convergence System 5500 series Modular Chassis Data Sheet.

NCS 5700 series line cards

NCS 5700 series line cards are 400G line cards for the NCS 5500 series modular chassis. NCS 5700 series line cards consist of two versions of 400GE optimized line cards: the base version and the scale version. The two 400GE optimized line cards in the NCS5700 series are NC57-24DD and NC57-18DD-SE.

The Cisco NCS 5700 series 100G optimized baseline card, NC57-36H6D-S is a combo line card with 4.8-Tbps throughput. NC57-36H6D-S provides a mix of 100GE, 200GE, and 400GE ports. NC57-36H6D-S line card provides flexible port configuration and can be used as 36x100GE or 24x100GE + 12x200GE(2x100GE) or 24x100GE + 6x400GE ports.

The Cisco NCS 5700 series line card, NC57-48Q2D-S, is a high-density line card with a 2.4-Tbps throughput. It provides a mix of 1GE, 10GE, 25GE, 50GE, 100GE, and 400GE ports. The NC57-48Q2D-S line card features 32 SFP28 ports capable of 1/10/25G, 16 SFP56 ports capable of 1/10/25/50G, and 2 QSFP-DD ports supporting 40/100/200/400G with breakout options.

The Cisco NCS 5700 series line card, NC57-48Q2D-SE-S, is a high-density scale edition line card with a 2.4-Tbps throughput. It provides a mix of 1GE, 10GE, 25GE, 50GE, 100GE, and 400GE ports. The NC57-48Q2D-SE-S line card features 32 SFP28 ports capable of 1, 10, or 25G, 16 SFP56 ports capable of 1, 10, 25, or 50G, and 2 QSFP-DD ports supporting 40, 100, 200, or 400G with breakout options. This "Scale Edition" variant includes an external TCAM (OP2) that enables higher prefix and service scale.

For information on ZR and ZR+ port support, see Specifications of 400G ZR and ZR+ transceivers.

For more information about Cisco Network Convergence System 5700 series 400GE, see the Cisco Network Convergence System 5700 series: 400GE and 100GE Line Cards Data Sheet.

NCS 5700 series modular port adapters

The Cisco Network Convergence System 5700 series is designed to efficiently scale between data centers and large enterprises, web, and service provider WAN and aggregation networks. The chassis and line cards support many applications and services through available interfaces. The Modular Port Adapters deliver flexibility to the chassis and line cards. They provide ports with bandwidth up to 400GE and pluggable form factors like QSFP-DD.

NC57-MPA-2D4H-S MPA

NC57-MPA-2D4H-S is a 4-port 800GE modular port adapter (NC57-MPA-2D4H-S) that supports QSFP28 and QSFP-DD optical transceivers. All 4 ports support QSFP28-100GE transceivers. Ports 0 and 2 (even-numbered ports) support two QDD-400G transceivers at the same time. This configuration is supported in both the MPA slots of the NCS-55A2-MOD-HD-S, NC55-55A2-MOD-SE-S, NCS-55A2-MOD-S, or NCS-55A2-MOD-HX-S chassis. Port 0 supports only one QDD-400G transceiver in Nx100G modes in both the MPA slots of the NCS-55A2-MOD-HD-S, NC55-55A2-MOD-SE-S, NCS-55A2-MOD-S, or NCS-55A2-MOD-HX-S chassis.

NC55-OIP-02 MPA

NC55-OIP-02 is an 8-port modular port adapter that supports SFP+ optical transceivers. This MPA is supported in the NC55A2-MOD-S and NC57C3-MOD-SYS routers.

The modular port adapter supports these port modes:

- Ethernet - 1GE and 10GE
- Fiber channel (FC) - 1GFC, 2GFC, 4GFC, 8GFC, 16GFC, 32GFC
- Optical Transport Network (OTN) – OTU2, and OTU2e
- SONET/SDH - OC-48 or STM-16, OC-192 or STM-64

NC55-OIP-02 MPA is used to support PLE.

For more information about Cisco Network Convergence System 5700 series modular port adapters, see the Cisco Network Convergence System 5700 series: Modular Port Adapters Data Sheet.

Specifications of Cisco ASR 9000 series

The Cisco ASR 9000 series Aggregation Services Routers (ASR 9000 series) introduces a new paradigm in edge and core routing. These routers offer exceptional scalability, carrier-class reliability, environmentally conscious design, flexibility, and a compelling price-to-performance benchmark. The Cisco ASR 9000 series includes a wide range of products, from the Cisco ASR 9001 (two RU) to the Cisco ASR 9922 (44 RU). Each system is designed to provide true carrier-class reliability with the Cisco IOS XR operating system, comprehensive system redundancy, and full network resiliency. Finally, the Cisco ASR 9000 series is designed to enhance and simplify the operational aspects of service delivery network deployment.

The Cisco ASR 9000 series offers advanced switching capacity, optimized power consumption and cooling, high availability design, and a modular operating system to significantly lower the Total Cost of Ownership (TCO) for service providers.

This table details the specifications of the routers.

Router	Capacity	Form factor	400G QSFP-DD ports
ASR 9006	Up to 16 Tbps	10 RU	Up to 20
ASR 9010	Up to 32 Tbps	21 RU	Up to 32
ASR 9904	Up to 16 Tbps	6 RU	Up to 8
ASR 9906	Up to 32 Tbps	14 RU	Up to 16
ASR 9910	Up to 64 Tbps	21 RU	Up to 32
ASR 9912	Up to 80 Tbps	30 RU	Up to 40
ASR 9922	Up to 160 Tbps	44 RU	Up to 80

For more information on Cisco ASR 9000 series, see Cisco ASR 9000 series Aggregation Services Routers Data Sheet.

Cisco ASR 9902 compact router

The Cisco ASR 9902 router is a compact, high-performance device that delivers up to 800 Gbps of nonblocking, full-duplex capacity in a two RU form factor. It uses the same Cisco IOS XR software as other routers in the Cisco ASR 9000 series and provides the same features and services. Customers can standardize on the Cisco IOS XR operating system. ASR 9902 supports multiple port rates, including 100 and 40 Gigabit Ethernet, 25 Gigabit Ethernet, and 10 Gigabit Ethernet. Customers can mix and match interface types on the same chassis. Operators are equipped to support large-scale networking.

This table details the specifications of the router.

Router	Capacity	Form factor	100G QSFP-DD ports
ASR 9902	Up to 800 Gbps	2 RU	Up to 2

For more information on Cisco ASR 9902 compact high-performance router, see Cisco ASR 9902 Compact High-Performance router Data Sheet.

Cisco ASR 9903 compact router

The Cisco ASR 9903 router is a compact router that supports two redundant Route Processors (RP), two integrated switch fabrics, four AC or DC power supply modules, and four fans in redundant configuration. The router includes a fixed board, with 16 integrated QSFP28-based 100GE ports and 20 integrated SFP+-based ports. . It also offers an optional Port Expansion Card (PEC), which you can insert into the dedicated slot when needed

The ASR 9903 fixed board supports up to 1.6Tbps data bandwidth. The Cisco A9903-20HG-PEC module offers 20 physical ports and provides up to 2 Tbps data capacity. Five of these ports are 400GE, 200GE, or 100GE multirate QSFP-DD or QSFP28-based ports. You can migrate each port to 400GE with the appropriate license. The other 15 ports are 100GE QSFP28-based ports.

This table details the specifications of the router.

Router	Capacity	Form factor	400G QSFP-DD ports
ASR 9903	Up to 7.2 Tbps	3 RU	Up to 5

For more information on Cisco ASR 9903 compact high-performance router, see Cisco ASR 9903 Compact High-Performance router Data Sheet.

Cisco ASR 9000 series line cards

Cisco ASR 9000 series routers support 400G line cards.

ASR 9000 series 5th generation high-density multi-rate line cards

ASR 9000 series 5th generation high-density multi-rate line cards are fully compatible with these routers:

- Cisco ASR 9006
- Cisco ASR 9010
- Cisco ASR 9904

- Cisco ASR 9906
- Cisco ASR 9910
- Cisco ASR 9912
- Cisco ASR 9922

This table details the specifications of the line cards.

Line card	Bandwidth	400G QSFP-DD ports
A9K-20HG-FLEX-SE	2 Tbps	5
A9K-20HG-FLEX-TR	2 Tbps	5
A9K-8HG-FLEX-SE	800 Gbps	2
A9K-8HG-FLEX-TR	800 Gbps	2

For more information on Cisco ASR 9000 series 5th generation high-density multi-rate line cards, see Cisco ASR 9000 series 5th Generation High-Density Multi-Rate Line Cards: 2 Terabit and 0.8 Terabit Cards Data Sheet.

ASR 9900 series 5th generation 10-port 400-Gigabit Ethernet line cards

The ASR 9900 series 5th generation 10-port 400-Gigabit Ethernet line cards are fully compatible with these routers:

- Cisco ASR 9904
- Cisco ASR 9906
- Cisco ASR 9910
- Cisco ASR 9912
- Cisco ASR 9922

This table details the specifications of the line cards.

Line card	Bandwidth	400G QSFP-DD ports
A99-10X400GE-X-SE	4 Tbps	10
A99-10X400GE-X-TR	4 Tbps	10

For information on ZR and ZR+ port support, see Specifications of 400G ZR and ZR+ transceivers.

For more information on Cisco ASR 9900 series 5th generation 10-Port 400-Gigabit Ethernet line card, see Cisco ASR 9900 series 5th Generation 10-Port 400 Gigabit Ethernet Line Card Data Sheet.

Specifications of Cisco NCS 540 series routers

Cisco Network Convergence System (NCS) 540 series is a converged access platform designed to cost-effectively deliver services and applications. The NCS 540 offers temperature-hardened hardware, low power consumption, and a small form factor suitable for indoor or outdoor use.

Cisco NCS 540 large density routers

The Cisco Network Convergence System (NCS) 540 large density router is a one RU platform that supports QSFP56-DD ports and offers you a 400G coherent optics transport solution. The NCS 540 large density platform enhances the existing NCS 540 portfolio by offering high throughput and flexible port interfaces that range from 1G to 400G.

Cisco NCS 540 large density routers are suitable for both outdoor and indoor deployments. The NCS 540 large density platform offers 1 Tbps throughput as well as best-in-class hardware and software security.

This table details the specifications of the router.

Router	Capacity	Form factor	400G QSFP-DD ports
N540-24Q8L2DD-SYS	1 Tbps	1 RU	2

For information on ZR and ZR+ port support, see Specifications of 400G ZR and ZR+ transceivers.

For more information on Cisco Network Convergence System 540 large density routers, see Cisco Network Convergence System 540 Large Density Routers Data Sheet.

Specifications of 400G ZR and ZR+ transceivers

The QDD-400G-ZR-S and QDD-400G-ZRP-S optical modules offload wavelength-division multiplexing (WDM) functionality to the router. They operate as DWDM C-band (196.1 to 191.3 THz with 100-MHz spacing) tunable optical modules. These optical modules enable high-bandwidth 400G links and support the 400G Ethernet rate.

The ZR/ZR+ pluggable optical modules are based on the QSFP-DD form factor. This standard form factor ensures interoperability with other vendors.

This table provides specifications for the ZR and ZR+ pluggable modules.

Table 4: Specifications of ZR and ZR+ pluggable modules

Parameter	QDD-400G-ZR-S	QDD-400G-ZRP-S
Client speed	400G, 4x100G	400G, 4x100G, 3x100G, 2x100G, 1x100G
Trunk speed	400G	400G, 300G, 200G, 100G
FEC	cFEC	oFEC, cFEC
Modulation	16-QAM	16-QAM, 8QAM, QPSK
Frequency	C-Band, 196.1 to 191.3 THz	C-Band, 196.1 to 191.3 THz

This table provides the ports on line cards that support ZR and ZR+ pluggable modules.

Table 5: Support matrix of ZR and ZR+ pluggable modules

Platform	Line card or fixed platform	Ports supporting ZR	Ports supporting ZR+	Supported breakout modes
Cisco ASR 9000 series routers	A99-10X400GE-X-TR A99-10X400GE-X-SE	3, 4, 5, 7, 9	3, 4, 5, 7, 9	1x100, 2x100, 4x100, 1x400
	A9K-8HG-FLEX-TR **A9K-8HG-FLEX-SE**	0, 7	0, 7	1x100, 2x100, 4x100, 1x400
	A9K-20HG-FLEX-TR **A9K-20HG-FLEX-SE**	0, 7, 8, 12, 19	0, 7, 8, 12, 19	1x100, 2x100, 4x100, 1x400
	A9903-20HG-PEC	0, 4, 8, 12, 16	0, 4, 8, 12, 16	1x100, 1x400
	ASR-9902	-	11,37	1x100
Cisco NCS 540 series routers	N540-24Q8L2DD-SYS	0, 1	0, 1	1x100, 2x100, 4x100, 1x400
Cisco 8000 series routers	8201-SYS	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22	1x100, 2x100, 3x100, 4x100, 1x400
	8202-SYS	48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59	48, 50, 52, 54, 56, 58	1x100, 2x100, 3x100, 4x100, 1x400
	8101-32FH **8201-32FH**	All ports	All ports	1x100, 2x100, 3x100, 4x100, 1x400
	88-LC0-36FH-M **8800-LC-36FH**	All ports	0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34	1x100, 2x100, 3x100, 4x100, 1x400
	88-LC0-36FH	All ports	All ports	1x100, 2x100, 3x100, 4x100, 1x400
	8201-24H8FH	0,2,4,6,8,10,12,14	0,2,4,6,8,10,12,14	1x100, 2x100, 3x100, 4x100, 1x400
	8101-32FH-M	All ports	All ports	1x100, 2x100, 3x100, 4x100, 1x400

Platform	Line card or fixed platform	Ports supporting ZR	Ports supporting ZR+	Supported breakout modes
Cisco NCS 5500 series routers	NCS57B1-6D24H-SYS	24, 25, 26, 27, 28, 29	24, 25, 26, 27, 28, 29	1x100, 2x100, 3x100, 4x100, 1x400
	NCS57B1-5D-SE-SYS	24, 25, 26, 27, 28	24, 25, 26, 27, 28	1x100, 2x100, 3x100, 4x100, 1x400
	NC57-24DD	0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22	0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22	1x100, 2x100, 3x100, 4x100, 1x400
	NC57-18DD-SE	12, 14, 16, 18, 20, 22, 24, 26, 28	14, 16, 18, 20, 22, 24	1x100, 2x100, 3x100, 4x100, 1x400
	NC57-36H6D-S	24, 26, 28, 30, 32, 34	24, 26, 28, 30, 32, 34	1x100, 2x100, 3x100, 4x100, 1x400
	NCS-57C1-48Q6-SYS	0, 2, 4	0, 2, 4	1x100, 2x100, 3x100, 4x100, 1x400
	NC57-MOD-S (fixed ports)	8, 9	8, 9	1x100, 2x100, 3x100, 4x100, 1x400
	MPA-2D4H 400G slot	0, 1, 2, 3	0, 1, 2, 3	1x100, 2x100, 3x100, 4x100
	NC57-48Q2D-S(E)-S	48	48	1x100, 2x100, 3x100, 4x100, 1x400
	NCS-57D2-18DD-SYS	0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48, 52, 56, 60, 64, 65	0, 3, 4, 7, 8, 11, 12, 15, 16, 19, 20, 23, 24, 27, 28, 31, 32, 35, 36, 39, 40, 43, 44, 47, 48, 51, 52, 55, 56, 59, 60, 63, 64, 65	1x100, 2x100, 3x100, 4x100, 1x400
	MPA-2D4H 800G slot	0, 1, 2, 3	0, 1, 2, 3	1x100, 2x100, 3x100, 4x100, 1x400

This table provides the maximum number of ZR and ZR+ modules supported in each breakout mode.

Table 6: Support matrix of ZR and ZR+ pluggable modules

Line card	Max number of ZR supported in mode		Max number of ZR+ supported in mode				
	400G	4x100G	400G	4x100G	3x100G	2x100G	1x100G
NC57-24DD	12	12	12	12	12	12	12
NC57-18DD-SE	9	9	6	6	6	6	6
NC57-36H6D-S (400G ports)	6	6	6	6	6	6	6
NCS-57B1-6D24-SYS (400G ports)	6	6	6	6	6	6	6

Line card	Max number of ZR supported in mode		Max number of ZR+ supported in mode				
	400G	4x100G	400G	4x100G	3x100G	2x100G	1x100G
NCS-57B1-5DSE-SYS (400G ports)	5	5	5	5	5	5	5
MPA-2D4H-S (400G mode MPA)	-	1	-	1	1	2	4
NCS-55A2-MOD-S(E)-S with 2x400G MPA-2D4H	-	2	-	2	2	4	8
MPA-2D4H-S (800G mode MPA)	2	2	2	2	2	4	4
NCS-57C3-MOD(S)-SYS with 2x800G+1x400G MPA-2D4H	4	5	4	5	5	10	12
NC57-MOD-S (Fixed ports)	2	2	2	2	2	2	2
NC57-MOD-S with 2x800G MPA-2D4H	6	6	6	6	6	10	10
NCS-57C1-48Q6-SYS	3	3	3	3	3	3	3
NCS-57D2-18DD-SYS	18	18	18	18	18	34	34
NC57-48Q2D-S(E)-S	1	1	1	1	1	1	1
NC55-MOD-A(-SE)-S with 2x400G MPA-2D4H	-	2	-	2	2	4	8
N540-24Q8L2DD-SYS	2	2	2	2	2	2	2
8201	24	24	12	12	12	12	12
8202	12	12	6	6	6	6	6
8800-LC-36FH	36	36	18	18	18	18	18
88-LC0-36FH-M	36	36	18	18	18	18	18
8101-32FH	32	32	16	16	16	16	16
8201-32FH	32	32	16	16	16	16	16
8201-24H8FH	8	8	8	8	8	8	8
8202-32FH-M	32	32	32	32	32	32	32
88-LC0-36FH	36	36	18	18	18	18	18
A99-10X400GE-X-SE/TR	5	5	5	5	-	5	5
A9K-20HG-FLEX-SE/TR	5	5	5	5	-	-	5
A9K-8HG-FLEX-SE/TR	2	2	2	2	-	-	2
A9903-20HG-PEC	5	-	5	-	-	-	5
ASR-9902	-	-	-	-	-	-	2

This table provides the ports on line cards that support Bright ZR+ pluggable module.

Table 7: Support matrix of Bright ZR+ pluggable module

Line card or fixed platform	Ports supporting Bright ZR+	Supported breakout modes
A9K-20HG-FLEX-TR **A9K-20HG-FLEX-SE**	0, 7, 8, 12, 19	1x100, 2x100, 4x100, 1x400
A9K-8HG-FLEX-TR **A9K-8HG-FLEX-SE**	0, 7	1x100, 2x100, 4x100, 1x400
8201-32FH	0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30	1x100, 2x100, 3x100, 4x100, 1x400
8201-24H8FH	0,2,4,6,8,10,12,14	1x100, 2x100, 3x100, 4x100, 1x400
NCS-57C3-MOD-SYS with NC57-MPA-2D4H-S	Slot 1, 2, 3: Ports 0, 1, 2, 3 Only on MPA ports	1x100, 2x100, 4x100, 1x400

For more information on Cisco 400G Digital Coherent Optics QSFP-DD optical modules, see the Cisco 400G Digital Coherent Optics QSFP-DD Optical Modules Data Sheet.

Specifications of Cisco high-power QSFP-DD ZR+ module

Cisco 400G QSFP-DD high-power (Bright) optical modules are high Tx power variants (+2dBm of Tx Power) of the 400G QSFP-DD modules.

These high-power optical modules allow easier interoperability with all deployed add and drop architectures and enhance unamplified reach by about 12dB as compared to QDD-400G-ZR-S and QDD-400G-ZRP-S. The optical specifications of these Bright ZR+ pluggables are aligned with current OpenZR+.

Cisco Bright QSFP-DD ZR+ modules operate at a default TX power of +1 dBm for all platforms. In contrast to ZR and ZR+ modules, the TX power level for Bright ZR+ remains at +1 dBm at all speeds and modulations. If you configure the FEC type to cFEC, the power reduces to -10 dBm for ZR compatibility. Cisco Bright QSFP-DD ZR+ modules support the same modes as QDD-400G-ZRP-S -10 dBm optics.

Two product variants are available:

- Ethernet variant (DP04QSDD-HE0)
- Multirate OTN and ethernet variant (DP04QSDD-HK9)

Cisco 400G QSFP-DD high-power (Bright) optical module ethernet variant

Cisco 400G QSFP-DD high-power (Bright) optical module Ethernet variant is an enhanced version of the existing QSFP-DD ZR+ optical module. It leverages the same operational modes, but the main enhancement is an increase in Tx optical power to +2 dBm.

The supported client interface for this pluggable is Ethernet-based, making this model suitable for hosting on a router or switch. The module uses GMP to map an ethernet signal from a switch or router to an intermediate 400ZR frame structure, and then adapts this frame to the appropriate FEC engine. The encoded signal is then DSP-framed and modulated for transmission as a coherent dual-polarity mQAM signal. The PID for this pluggable optical module is DP04QSDD-HE0.

In Cisco IOS XR Release 7.9.1, these routers support Cisco Bright QSFP-DD ZR+:

- NCS-57C3-MOD
- 8201-32FH
- 8201-24H8FH
- A9K-20HG-FLEX-SE/TR
- A9K-8HG-FLEX-SE/TR

From Cisco IOS XR Release 7.10.1, all NCS-5500 and NCS-5700 platforms support Cisco Bright QSFP-DD ZR+ modules.



Note NCS-55A2-MOD-S(E)-S with MPA-2D4H support Bright ZR+ from Cisco IOS XR Release 7.11.1.

Cisco 400G QSFP-DD high-power (Bright) optical module multirate ethernet and OTN variant

The Cisco 400G QSFP-DD high-power (Bright) optical module multirate Ethernet and OTN variant shares the same hardware platform and high Tx power as the ethernet variant, but it also supports OTN clients. The module leverages intermediate ODUFlex, OTUCn, and FlexO-x frame structures, and then adapts these frame structures with OFEC.

This variant supports Layer-1 (L1) functions, including authentication, encryption, and decryption of the OPU[Cn,4] payload. The security IP enables wire-speed AES 256-bit encryption with Galois-Counter Mode (GCM). It supports authentication using the GMAC algorithm, encryption or decryption using CTR mode, or both using GCM.

For more information on Bright ZR+ optical modules, see the Cisco 400G QSFP-DD High-Power (Bright) Optical Module Data Sheet.

Legacy 200G modulation modes

Cisco ZR+ modules support a ZR+ legacy mode, including 200G-8QAM at 40 Gbaud and 200G-16QAM at 30 Gbaud. These modes allow a 200G rate to fit within a 50 GHz spaced optical system. In the default mode, the modules operate in 200G QPSK at 60 Gbaud.

OpenZR+ compatibility mode

Cisco QDD-400G-ZRP-S and DP04QSDD-HE0 modules have an OpenZR+ MSA compatibility mode. This mode:

- sets modem mode to **standard**
- is set by configuring optics controller Dac-Rate to
  - **1x1** for 400G, 300G, and 200G trunkrates on ZR+
  - **1x1.5** for all trunkrates on Bright ZR+ and 100G trunk rate on ZR+
- is used to interoperate with ZR+ optics from other vendors

Note Setting a DAC rate of 1x1 disables TX shaping as it affects the TX power levels.

This table lists the possible transponder and muxponder configuration values for the DP04QSDD-HE0 optical module.

Table 8: Bright ZR+ transponder and muxponder configuration values

TXP or MXP	Client	Trunk	Modulation	FEC	DAC rate
400G-TXP	1 Client, 400G speed	1 trunk, 400G speed	16 QAM	oFEC	1x1.25
400G-TXP	1 Client, 400G speed	1 trunk, 400G speed	16 QAM	cFEC	1x1.5
400G-TXP	1 Client, 400G speed	1 trunk, 400G speed	16 QAM	oFEC	1x1.5
4x100G- MXP	4 clients, 100G speed	1 trunk, 400G speed	16 QAM	oFEC	1x1.25
4x100G- MXP	4 clients, 100G speed	1 trunk, 400G speed	16 QAM	oFEC	1x1.5
4x100G- MXP	4 clients, 100G speed	1 trunk, 400G speed	16 QAM	cFEC	1x1.5
3x100G-MXP	3 clients, 100G speed	1 trunk, 300G speed	8 QAM	oFEC	1x1.25
3x100G-MXP	3 clients, 100G speed	1 trunk, 300G speed	8 QAM	oFEC	1x1.5
2x100G-MXP	2 clients, 100G speed	1 trunk, 200G speed	QPSK	oFEC	1x1.5
2x100G-MXP	2 clients, 100G speed	1 trunk, 200G speed	8 QAM	oFEC	1x1.25
2x100G-MXP	2 clients, 100G speed	1 trunk, 200G speed	16 QAM	oFEC	1x1.25
1x100G-MXP	1 client, 100G speed	1 trunk, 100G speed	QPSK	oFEC	1x1.5

Specifications of Cisco QSFP-DD pluggable OLS

The QSFP-DD Open Line System (OLS) is a pluggable solution that integrates with Cisco routers. This optical amplifier module, when used with channel breakout options, provides a simple and powerful open line system in a pluggable form factor.

Cisco QSFP-DD pluggable OLS

The QSFP-DD OLS is a pluggable module that integrates two variable-gain amplifiers: a pre-amplifier and a booster amplifier. These amplifiers boost both the up and down fiber streams.

Various channel breakout options are available to combine or separate each channel from a coherent DWDM optical source. The TX-EDFA acts as a booster amplifier and compensates for the loss from the optical multiplexers, providing a power boost before the link. The RX-EDFA serves as a preamplifier that restores link loss, increasing the optical signal to a level above the receiver sensitivity after the demultiplexer.

The QSFP-DD OLS extends the reach of a 400G QSFP-DD ZR and ZR+ link from 40 to 130 km or farther, based on fiber specifications, channel count, and line rate. For Bright 400G QSFP-DD ZR and ZR+ links, the extension range is 80 to 130 km or farther, subject to the same factors.

Industry-standard CS connectors enable you to integrate ingress and egress ports on the QSFP-DD OLS faceplate. The QSFP-DD-OLS offers two bi-directional optical ports: COM-RX and TX, which connect to the Mux or DMX unit, and LINE-TX or RX, which connect to the fiber link.

The optical connectors are 2x CS-UPC. The CS connector provides the characteristics and simplicity of the duplex LC connector into a smaller footprint to allow two pairs of CS connectors to fit within the physical constraints of the QSFP-DD form factor. Since the other optical units like Coherent Interfaces modules, DWDM Add and Drop multiplexers, and fiber patch panels have normally LC connectors, a hybrid adaptation patch cord with a CS dual connector on one side and two LC connectors on the other side is available to interconnect the QSFP-DD-OLS modules with other optical equipment.

Optical safety is enabled by default to

- switch off each section independently in case Optical LOS is detected at its input, and
- set the TX-EDFA in Automatic Power Reduction (APR) at 8dBm in case a LOS is cleared at the COM-RX port, but LOS is still present at LINE-RX.

This table shows the routers and line cards that support Cisco QSFP-DD pluggable OLS (QSFP-DD OLS) and the release from which they support the module.

Table 9: QSFP-DD OLS pluggable support

IOS-XR release	Platform
7.10.1	• NCS-57B1-6D24-SYS • NCS-57B1-5DSE-SYS • NCS-57C3-MOD (using NC57-MPA-2D4H-S modular port adapter) • NCS-55A2-MOD (using NC57-MPA-2D4H-S modular port adapter)
24.1.1	• 8201-32FH • 8201-24H8FH • 8201 • 8202-32FH-M

IOS-XR release	Platform
24.3.1	• 88-LC0-36FH • 88-LC0-34H14FH • 8608 • 88-LC0-36FH-M
24.4.1	• NC57-36H6D-S • NC57-24DD • NC57-18DD-SE • NCS-57C1-48Q6-SYS • NCS-57D2-18DD-SYS • NC57-MOD-S (using 2x800G MPA-2D4H) • NC55-MOD-A-S(E)-S (using 2x400G MPA-2D4H) • NC57-MOD-S • NC57-36H-SE • A9K-20HG-FLEX-SE/TR • A9K-8HG-FLEX-SE/TR • A9903-20HG-PEC • A99-10X400GE-X-SE/TR • N540-24Q8L2DD-SYS

Multi-channel line system using QSFP-DD OLS

The user can build a multi-channel line system using the QSFP-DD OLS and its associated components:

- **A single-channel system**: It requires no special components to add and drop. A special CS-LC cable (ONS-CAB-CS-LC-5) has been made available to interconnect LC ports of the QSFP-DD coherent source or the network with the CS ports of the QSFP-DD OLS. One pair of these cables is sufficient to make a single-channel system. All the gain of the amplifier is available for the single channel in focus.
- **A four-channel system**: To achieve a 4-channel combine and split, an FLD-4 (fixed 4 channel OADM) can be used. This is a passive optical Add/Drop unit belonging to the ONS-15216 platform that is able to multiplex or demultiplex 4 channels over the 100GHz ITU grid.
- **A eight-channel system**: To achieve an 8-channel combine and split, a 1x8 channel breakout cable can be used. This new breakout cable (ONS-BRK-CS-8LC) is a dual fanout 1x8 cable with an embedded passive splitter and coupler. The cable is grid-less, allowing any port to receive any optical frequency without constraints on frequency value or channel spacing.

- **A 16-channel system**: To achieve a 16-channel combine and split, a 1x16 channel breakout cable can be used. This new breakout cable (ONS-BRK-CS-16LC) is a dual fanout 1x16 cable with an embedded passive splitter and coupler. The cable is grid-less so any port can be fed with any optical frequency without any constraints of frequency value or spacing between the channels.
- **A 32-channel system**: To achieve a 32-channel combine and split, a 64-channel multiplexer or demultiplexer can be used (of which 32 channels are used). The NCS1K-MD-64-C is a passive optical Add/Drop unit for the NCS1K platform, capable of multiplexing or demultiplexing up to 64 channels over the 75GHz grid. Due to the limited operating bandwidth of the QSFP-DD-OLS, only a subset of the MD-64 channels can be used: from port CH-19 (194.75 THz) to port CH-50 (192.425 THz).

For more information on configuring Cisco QSFP-DD pluggable OLS, see Configuring QDD Optical Line System. For more information on the Cisco QSFP-DD pluggable OLS, see the Cisco QSFP-DD Pluggable Open Line System Data Sheet.

Modules in Cisco Network Convergence System 2000 series

The Cisco Network Convergence System 2000 series delivers agility, programmability, and massive scale across ultra-long haul, metro, and enterprise optical networks. Using the Cisco NCS 2000 series, you can deploy a simple, yet intelligent dense wavelength-division multiplexing (DWDM) network that scales with operational ease. The NCS 2000 devices are managed by the Shelf Virtualization Orchestrator (SVO) available in , Release 12.3.1.

Cisco NCS 2006 shelf

The NCS 2006 shelf has eight horizontal card slots. The chassis is six RU, with six slots for service cards and two slots for controller cards. It supports multishelf management of up to 50 shelves.

For more information on Cisco Network Convergence System 2000 series, see the Cisco Network Convergence System 2000 Series Data Sheet.

Shelf Virtualization Orchestrator

Cisco NCS 2000 Shelf Virtualization Orchestrator (SVO) introduces programmability of optical network elements and automation with NETCONF interface and YANG models. SVO enables end-to-end, software-defined automated networks that help maximize customer revenue and simplify network turn-up, operation, and maintenance.

SVO is available with a server on a blade encasing a high-speed processor with virtualized instances of multiple reconfigurable optical add/drop multiplexer (ROADM), optical line amplifier (OLA), and dynamic gain equalizer (DGE) sites of the network.

An SVO line card, together with the application software, provides licenses for alarm correlation, performance monitoring, connection verification, and optical time domain reflectometry (OTDR).

The Cisco NCS 2000 SVO helps to maintain and improve profitability with the orchestration of network elements and their functionalities. SVO allows the network elements to do only forwarding functions. SVO manages the configuration and monitoring of network elements at the node level using a centralized controller.

For more information on Cisco NCS 2000 Shelf Virtualization Orchestrator, see the Cisco NCS 2000 Shelf Virtualization Orchestrator Data Sheet.

Control cards

Cisco NCS 2000 Series Transport Node Controller 2 with Optical Time Domain Reflectometry (TNCS-2O) card performs these key operations:

- system initialization
- provisioning
- alarm reporting
- maintenance and diagnostics
- IP addressing
- Data-Communications-Channel (DCC) termination
- monitoring of system input voltage
- system fault detection
- multishelf management connections

Optical Time Domain Reflectometry (OTDR) provides information about the basic characteristics of the optical fiber among optical nodes, such as insertion loss, concentration points of reflection, fiber-to-fiber connection losses, and reflectance.

For more information on Cisco Transport Node Controller (TNC) and Transport Shelf Controller (TSC) cards, see the Cisco Transport Node Controller and Transport Shelf Controller Cards Data Sheet.

ROADM cards

The 20-SMRFS card is tunable over 96 channels in the C band, at 50-GHz spacing on the ITU-T grid. The card provides flex spectrum capability, allowing flexible allocation of channel bandwidth and improved network scalability. With flex capability, channel bandwidth is adjustable and can be defined arbitrarily, with specified granularity and within a given range. The card increases network flexibility by allowing reconfiguration of optical channels at any time.

The 20-SMRFS card is a single-slot card that integrates two cross-connect blocks (multiplexer and demultiplexer), a variable-gain EDFA preamplifier, and a variable-gain EDFA booster amplifier. The card supports up to 20 directions for each ROADM node. The EDFA preamplifier in this card has gain ranges of 0 to 17 dB and 12 to 24 dB with controlled tilt and extended gain ranges of 20 dB and 35 dB with uncontrolled tilt.

For more information on Cisco NCS 2000 SMRFS line card, see the Cisco NCS 2000 Flex Spectrum Single Module ROADM Line Cards Data Sheet.

Amplifier cards

The Cisco NCS 2000 offers enhanced optical amplifier cards operating in the C band region of the optical spectrum to extend the reach and capacity of a metro, regional, or long-haul network. The optical amplifier cards are part of the Cisco NCS 2000 intelligent DWDM architecture that is engineered to reduce DWDM complexity and speed the deployment of next-generation networking solutions.

EDFA cards

The OPT-EDFA-17 and OPT-EDFA-35 cards are C band DWDM EDFA amplifiers and preamplifiers. The cards are true variable gain amplifiers, offering an optimal equalization of the transmitted optical channels

over a wide gain range. They support 96 channels at 50-GHz channel spacing in the C band (that is, 1528.77 to 1566.72 nm wavelength range). The OPT-EDFA-17 card delivers 20 dBm output power. The OPT-EDFA-35 card delivers +23 dBm output power. These cards do not contain midstage access loss for a Dispersion Compensation Unit (DCU). The cards provide a noise-figure optimized version of the EDFA amplifiers to cope with new modulation formats like PM-DQPSK, which do not need dispersion compensation.

For more information on Enhanced C band 96-channel EDFA amplifiers for the Cisco ONS 15454 Multiservice Transport Platform (MSTP), see the Enhanced C-Band 96-Channel EDFA Amplifiers for the Cisco ONS 15454 MSTP Data Sheet.

EDRA cards

The double-slot EDRA-2-26 card combines standard erbium-doped fiber amplifiers and a Raman amplifier to enable amplification on long unregenerated spans. These plug-in modules support an ultra-low noise figure that is critical for long-distance, high-bit-rate transmission. They support 96 channels in the C band (wavelengths from 1528.77 to 1566.72 nm), providing the reach and optical performance required to meet the most demanding distance requirements of service provider and enterprise DWDM networks. EDRA-2-26 includes an erbium-doped preamplifier, EDFA1, with a nominal gain of 14 dB and an erbium-doped booster amplifier, EDFA2. It supports a maximum span of 26 dB on standard single-mode fiber.

For more information on Cisco Network Convergence System 2000 series Erbium Doped Raman amplifiers, see the Cisco Network Convergence System 2000 Series Erbium-Doped Raman Amplifiers Data Sheet.

Raman amplifier cards

The Cisco ONS 15454 MSTP high-power counter-propagating Raman amplifiers operate in the C band region of the optical spectrum to extend the reach and capacity of regional, long-haul, and ultra-long-haul optical.

Raman amplifiers use the intrinsic properties of silica fiber in such a way that the transmission fibers themselves become a medium for amplification. This approach allows the attenuation of data signals transmitted over the fiber to be mitigated within the fiber itself. An amplifier using this principle is commonly known as a distributed Raman amplifier or simply, a Raman amplifier. The high-power counterpropagating unit injects counterpropagating optical power to generate a Raman effect in the span fiber and thus amplifies the signals propagating in the same fiber.

The single-slot RAMAN-CTP card supports counter Raman amplification on long unregenerated spans. The cards manage up to 96 ITU-T 50 GHz spaced channels over the C band of the optical spectrum (wavelengths from 1528.77 to 1566.72 nm).

For more information on high-power counter-propagating and co-propagating Raman units for the Cisco ONS 15454 MSTP, see High Power Counter-Propagating and Co-Propagating Raman units for the Cisco ONS 15454 Multiservice Transport Platform (MSTP).

Passive multiplexer and demultiplexer module

NCS1K-MD-64-C is a passive optical multiplexer and demultiplexer module. The new optical module is based on athermal waveguide (AWG), providing 64 channels at 75 GHz spacing across the extended C band of the optical spectrum. The passive module allows you to transmit 400G ZR and 400G ZR+ wavelengths.

NCS1K-MD-64-C is a bidirectional unit that has the multiplexing and demultiplexing functions implemented as two different sections. The NCS1K-MD-64-C module supports bidirectional connection toward the Router or DCI that is equipped with QDD-400G-ZR-S and QDD-400G-ZRP-S.

For more information on Cisco NCS 1000 multiplexer and demultiplexer 64-channel patch panel module, see Cisco NCS 1000 Mux/Demux 64-Channel Patch Panel Data Sheet

Passive patch panel modules in Cisco Network Convergence System 2000 series

The passive optical modules are used to design the optical network system.

MPO-16 to 16-LC fan-out module

The MPO-16 to 16-LC fan-out module is a double slot module with one MPO-16 connector (COM) and eight LC duplex connectors (Port-i-TX/RX). It contains 16 photodiodes to monitor the power of the channel input ports. The MPO-16 to 16-LC fan-out module provides fan-out of the MPO-16 connector to or from the LC connections and interconnects the optical modules having LC connectors (TXP) with modules having MPO-16 connectors (SMR20 FS).

Cisco 1 x 6 colorless flex spectrum add and drop module

The Cisco 1 x 6 colorless flex spectrum add and drop module (6AD-CFS) is a passive unit including one 1 x 6 splitter and one 6 x 1 combiner, and 7 photodiodes. This module is single-slot height in the mechanical frame chassis. Its primary function is to provide optical multiplexing and demultiplexing for up to six optical signals. Because it is based on optical splitter and combiner technology, only transceivers employing coherent detection can be directly connected to the six client ports of the unit. Integrated photodiodes provide connectivity check and monitoring functions. Virtual PDs are implemented by the unit on the output ports (AD-i-TX, COM-TX) by subtracting the insertion losses from the real photodiode (PD) reading. Power values and the manufacturing data stored in the flash memory are provided to a Cisco Transport Controller (CTC) through the USB connection.

Cisco five-degree modular patch panel module

The Cisco five-degree patch panel module (MF-DEG-5) provides interconnections between five 8-port MPO connectors; it is used to connect any combination of up to five ROADM line degrees (express connections) and add or drop components (add or drop connections). The 40 optical paths are interconnected. Five photodiodes provide power monitoring of fiber 1 of each MPO connector. Power values and the manufacturing data stored in the flash memory are provided to CTC through the USB connection. This module is single-slot height in the mechanical frame chassis.

Cisco four-degree upgrade modular patch panel module

The Cisco four-degree upgrade modular patch panel module (MF-UPG-4) provides interconnections among eight 8-fiber MPO connectors; it is used to expand the number of degrees and the number of add or drop ports that are supported by the node. The 64 optical paths are interconnected. A total of eight photodiodes provides power monitoring of fiber 1 of each MPO connector. Power values, and the manufacturing data stored in the flash memory are provided to a CTC through the USB connection. This module is single-slot height in the mechanical frame chassis.

For more information on Cisco Network Convergence System 2000 series passive patch panel modules, see the Cisco Network Convergence System 2000 Series Passive Patch Panel Modules Data Sheet.

Modules in Cisco Network Convergence System 1010

Cisco NCS 1010 is a next-generation optical line system optimized for ZR and ZR+ WDM interfaces in routers. The system provides point-to-point connectivity between routers with WDM interfaces and multiplexes WDM signals from multiple routers over a single fiber. In addition, the system supports ROADM express of

up to eight degrees. It supports both C band transmission and C+L combined WDM transmission, maximizing capacity.

Modules in Cisco NCS 1010

Cisco NCS 1010 is a three RU chassis that has an in-built External Interface Timing Unit (EITU) and these field-replaceable modules:

- Controller
- Two power supply units
- Two fan trays
- Fan filter
- Line card

Line cards in Cisco NCS 1010

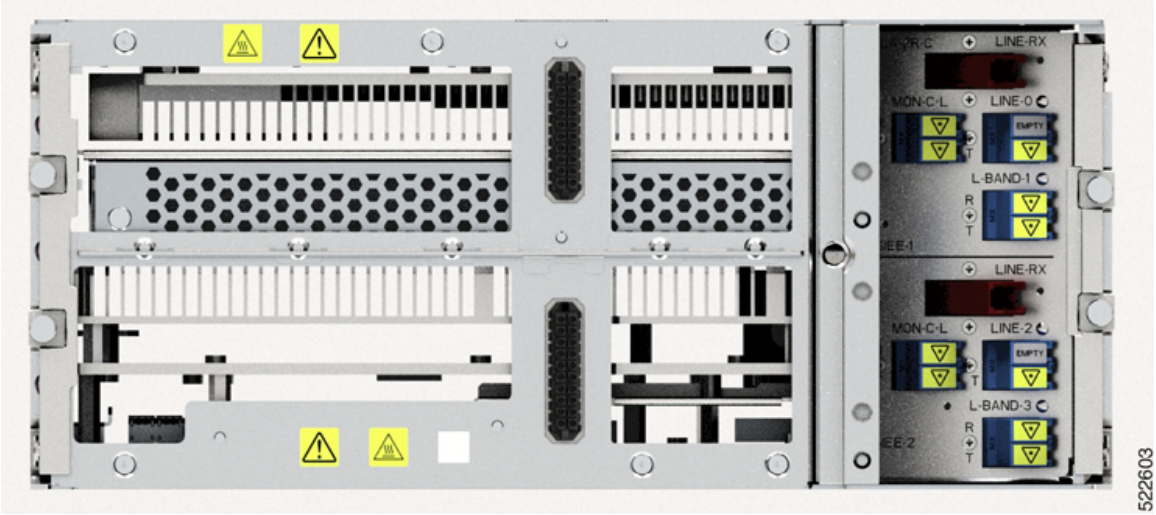
There are five different variants of the line card:

- OLT-C line card: C band Optical Line Terminal (OLT) without Raman
- OLT-R-C line card: C band OLT with Raman
- ILA-C line card: C band In-Line Amplifier (ILA) without Raman
- ILA-R-C line card: C band ILA with one side Raman
- ILA-2R-C line card: C band ILA with both sides Raman

Figure 6: Perspective view of OLT-R-C line card



Figure 7: Front view of ILA-2R-C line card



NCS 1010 for Routed Optical Networking

These features of the NCS 1010 Optical Line Systems (OLS) make it ideal for Routed Optical Networking:

- Support for low-power coherent sources
  - Ingress EDFA amplifier on OLTs to support 400ZR and OpenZR+ DCOs.
  - Low loss couplers to support 95 and 140 GBaud rates that need higher Rx power.
- Capacity scaling built-in by design
  - Hitless upgrade from C band to C+L band
  - Embedded channelized ASE for consistency in performance from day-1 to full capacity growth
  - 33-port Twin-WSS architecture to use as express or add and drop
- Simplicity of the OLS
  - Simpler integrated module
  - Independent degree operation
  - Automated turn-up
  - Full spectrum loading from the beginning
  - DGE on ILAs for equalization and better control of Raman Gain ripple
- Automation of entire life cycle
  - Device automation using ZTP, OpenConfig YANG configuration and telemetry
  - Automated E2E turn-up with embedded control loops
  - Automated connection verification for patch loss checks at each site

- Enhanced visibility using OTDR, OSC, and OCM

Cisco NCS 1000 32-channel multiplexer and demultiplexer patch panel

The Cisco NCS 1000 32-channel multiplexer and demultiplexer patch panels are a pair of passive Athermal Arrayed Waveguide Grating (AAWG) base modules (PIDs NCS1K-MD-32O-C and NCS1K-MD32E-C). Each multiplexer and demultiplexer panel has 32 channels. It serves as an add and drop unit for the OLT-C and OLT-R-C line cards. Each multiplexer and demultiplexer panel allows the multiplexing and demultiplexing of 32 channels with 150-GHz spacing. 75 GHz frequency shift exists between the ODD and EVEN panels. When both the panels are used on the same OLT (OLT-C and OLT-R-C) line cards, their combined capacity is 64 channels with 75 GHz spacing. Each multiplexer and demultiplexer panel provides wide optical pass-band support. When used standalone, each panel acts as an add and drop unit for 32 channels operating at 140 gigabaud.

The NCS1K-MD32O/E-C panel operates in C band. The Cisco NCS 1000 multiplexer and demultiplexer patch panels are fully passive. The units are powered by a USB 3.0 connection in the NCS 1010 chassis. The panels monitor signals, verify connections, and retrieve the inventory data.

Cisco NCS 1000 breakout patch panel and modules

Cisco NCS 1000 breakout patch panel

Cisco NCS 1000 breakout patch panel is a colorless breakout-modular patch panel. It is powered by the NCS 1010 chassis using a single USB 3.0 cable. The breakout panel contains four USB 2.0 connections that power the passive optical modules. It allows connections between the OLT-C and OLT-R-C line cards installed in the NCS 1010 chassis and the optical passive modules using MPO cables. The breakout panel is four RU high and has adjustable fiber guides for fiber routing. The empty slots are covered with dummy covers.

The NCS1K-BRK-SA breakout panel is a four RU breakout patch panel. It interfaces four passive optical modules with the NCS 1010 chassis. The breakout panel supports up to 72 colorless multiplexer and demultiplexer channels. The breakout panel supports 8-directional interconnections.

The panel is shipped with USB 2.0 connectors connected to the corresponding dummy covers. The plastic transparent cover can be installed in front of the panel for fiber protection. The panel is designed to fit a 19-inch rack. The panel can also be installed on ETSI and 23-inch rack using adapter brackets.

Cisco NCS 1000 breakout modules

The Cisco NCS 1000 breakout Modules are a set of three optical breakout units. The modules can be connected to the A/D 4 to 11, A/D 12 to 19, A/D 20 to 27 and A/D 28 to 33 MPO connector ports of the OLT-C and OLT-R-C line cards to provide ROADM node internal connections and for local channels add and drop.

The breakout panel supports these passive optical modules:

NCS1K-BRK-8

The NCS1K-BRK-8 module provides the breakout of 16 fibers from an MPO-24 connector to eight duplex line card connectors. It essentially performs an optical connection adaptation of MPO-to-LC connectors for the ADD and mDROPi signals of the MPO ports on OLT line cards. For each port—MPO and LC—, power monitors with tone detection capability are available. A filtered optical loopback (191.175 THz) from one MPO input port (fiber-1) to all MPO output ports is available for connection verification.

NCS1K-BRK-24

The NCS1K-BRK-24 module provides the breakout of 16 fibers from an MPO-24 connector to 24 duplex LC connectors. The signals on each fiber from the MPO input ports are split over three LC output ports by a 1x3

optical splitter. The signals from the three adjacent input LC ports are combined into a single MPO fiber output port through a 1x3 optical coupler. For each port (MPO and LC), power monitors with tone detection capability are available. A filtered optical loopback (191.175 THz) from one MPO input port (fiber-1) to all MPO output ports is available for connection verification.

For more information about the Cisco Network Convergence System 1010, see the Cisco Network Convergence System 1010 Data Sheet .

Components of network planning

Use these components to plan the network:

- Routed Optical Networking planning service
- Cisco WAN Automation Engine
- Cisco Optical Network Planner

Routed Optical Networking planning service

Cisco CX provides a unified planning service to help customers simplify and plan the transition to a converged IP-Optical Routed Optical Network. By modeling current and future architectures, Unified Networking Planning accelerates progress toward Routed Optical Networking and creates opportunities for customers to reduce operating expenses.

Cisco CX uses questionnaires, workshops, interviews, and documentation reviews to capture unified planning requirements.

To execute network planning and assessment, Cisco CX

- collects information on sites, traffic demand, modeling requirements, interface types
- visualizes network layout with forecasted capacity and performs network modeling
- estimates traffic behaviors in failure scenarios, assesses failure impact, and
- compares network architectures in terms of number of interfaces, hardware, sites, rack space, and power requirements.

Cisco CX provides ongoing technical advice and guidance, enabling customer planning teams to share interim and final planning service results and reports

Cisco WAN Automation Engine

The Cisco WAN Automation Engine (WAE) platform is an open, programmable framework that interconnects software modules, communicates with the network, and provides APIs to interface with external applications.

Cisco WAE provides the tools to create and maintain a model of the current network through continual monitoring and analysis of the network and its traffic demands. At any time, this model contains all relevant network information, including topology, configuration, and traffic details. This information forms the basis for analyzing the impact of changes in traffic demands, paths, node and link failures, network optimizations, or other adjustments.

Cisco WAE is used for IP and optical network planning of multivendor networks.

For more information, see Cisco WAN Automation Engine Data Sheet

Cisco Optical Network Planner

Cisco Optical Network Planner (Cisco ONP) is a tool that models and tests Optical Transport Networks and DWDM optical networks using a graphical environment. The primary purpose of Cisco ONP is to design and validate networks of the NCS 2000 series and NCS 1010. Using the Cisco ONP tool, you create multiple instances of a network, modify different parameters at each instance, and compare the instances.

Cisco ONP

- generates a rack view of all the sites in the network
- shows the differences between the instances, and
- provides a complete Bill of Materials (BOM) for the network.

Cisco ONP models the optical network, generates the BOM, and provides detailed information about the network. This information includes connection reports, optical reports, and traffic matrix.

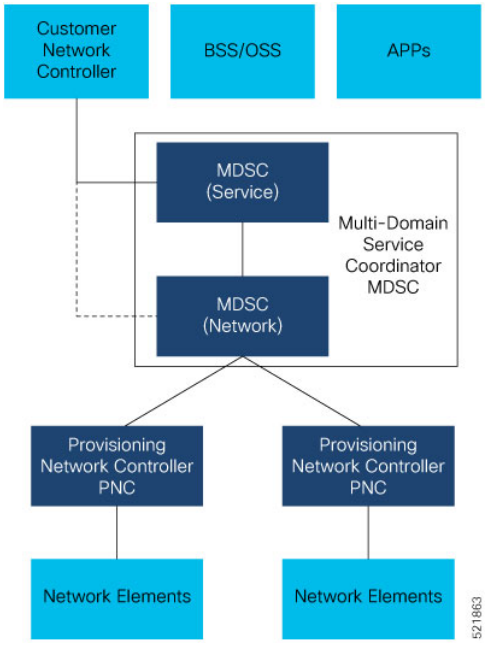
Note Cisco ONP must be used to perform the final optical network feasibility analysis and generate production network designs.

For more information, see Cisco Optical Network Planner (CONP) Data Sheet

Components of automation

Automation of the Routed Optical Networking solution follows the IETF ACTN SDN controller framework. Cisco Optical Network Controller is the Cisco optical domain PNC and Crosswork Network Controller is the multivendor IP-domain PNC. Crosswork Hierarchical Controller unifies IP and optical information from Cisco Optical Network Controller and Crosswork Network Controller. It provides multilayer and multidomain visualization, Routed Optical Networking service assurance, and Routed Optical Networking service management in the MDSC role.

Figure 8: IETF ACTN – open automation reference framework



Components of automation

The automation stack consists of these components:

- Crosswork Hierarchical Controller: manages Routed Optical Networking deployments by leveraging advanced multilayer and multivendor capabilities to provision and assure both IP and optical networks.
- Cisco Optical Network Controller: (CONC) configures Cisco optical network elements, monitors the topology (physical or virtual) of networks, performs optical path computation, and collects topology information.
- Crosswork Network Controller: simplifies and automates intent-based network service provisioning, monitoring, and path optimization in an IP multi-vendor network environment with a common GUI and API.
- Evolved Programmable Network Manager (EPNM): performs deep inventory and is an element management system that manages device lifecycles for converged IP and optical networks. EPNM also collects fault and alarm information, and performs node-level performance measurement statistics collection.

Routed Optical Networking automation solution architecture

This diagram provides a high-level illustration of how the components of the solution work together.

Figure 9: Routed Optical Networking automation architecture

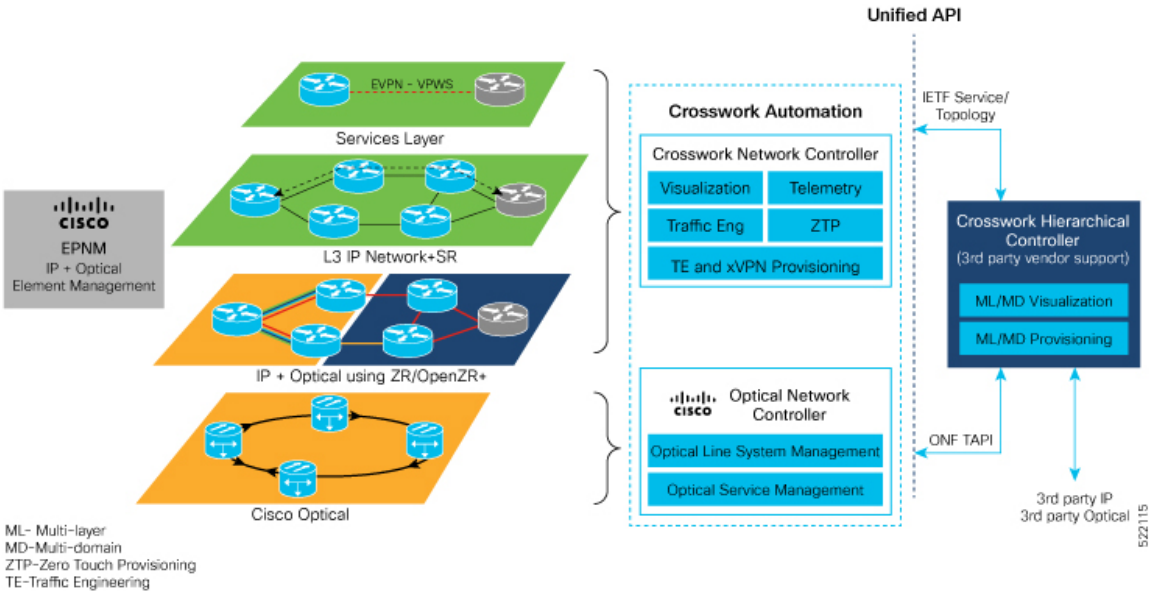


Table 10: Automation software roles

Automation software	Roles
SR-PCE	• Packet layer PCE • Required to advertise IGP topology to Cisco Crosswork Network Controller • Uses BGP-LS to the network for IGP topology • Can run as virtual router or on a hardware router
Cisco Crosswork Infrastructure	• IP domain controller • Crosswork Network Controller Essentials package is required for Routed Optical Networking • RESTConf API covering provisioning, data collection, and topology • EMS app is recommended to collect device-level inventory and alarms
Cisco Crosswork Data Gateway	• Router data collection • Required by Cisco Crosswork Network Controller for all data collection • Required by the Hierarchical Controller for DCO-PM collection

Automation software	Roles
Network Services Orchestrator	• RON service management • RON core function pack is required to be installed for RON service management • Also used for connectivity verification • Communicates to routers using CLI NED
Cisco Optical Network Controller	• Optical domain EMS and controller for NCS 101x • Exposes the TAPI NBI interface for OLS topology, provisioning, and inventory • Communicates with Cisco Optical Site Manager for optical node management and provisioning • Power level data available for NCS 1010 as part of connection verification
Cisco Optical Site Manager	• Optical site manager for NCS 1010 • Embedded in 1010 XR, a cluster is treated as a multishelf node and can run in active or standby mode. • Required component for Cisco Optical Network Controller 3.1 and later releases to communicate to nodes through NETCONF
Cisco Crosswork Hierarchical Controller	• Multivendor or legacy IP plus optical • Communicates to Cisco Crosswork Network Controller through RESTCONF, telemetry through CDG through gRPC • Communicates to Cisco Optical Network Controller through RESTCONF TAPI, 1010 through RESTCONF and gRPC • Router inventory through XR CLI adapter

Automation software	Roles
Cisco Evolved Programmable Network Manager	• Router and OLS element management • Not used for RON service management in this solution • Collects inventory, alarm, and PM data from routers directly using NETCONF over CLI, syslog • Collects inventory, alarm, and PM data from NCS 2000 and NCS 1010

Features of Cisco Crosswork Hierarchical Controller

Cisco Crosswork Hierarchical Controller provides an API and single-pane-of-glass user interface for Routed Optical Networking infrastructure and services. It manages your existing optical and packet domains with the same unified approach. Routed Optical Networking with Crosswork Hierarchical Controller dramatically simplifies the operation of multilayer networks. These networks were previously managed independently using NMS and EMS products.

Crosswork Hierarchical Controller serves as a multidomain, multilayer, multivendor network controller. Crosswork Hierarchical Controller maps between IP and optical layer ports. This capability provides a comprehensive view of the network. The system interfaces with SDN Domain Controllers for the packet layers (IP, MPLS) and transport layers (WDM, OTN, and Packet-Optical) to create a coherent view of the entire transport network. Crosswork Hierarchical Controller enables automation of its functions. It also supports simplified, abstracted interactions with service orchestrators and OSS tools.

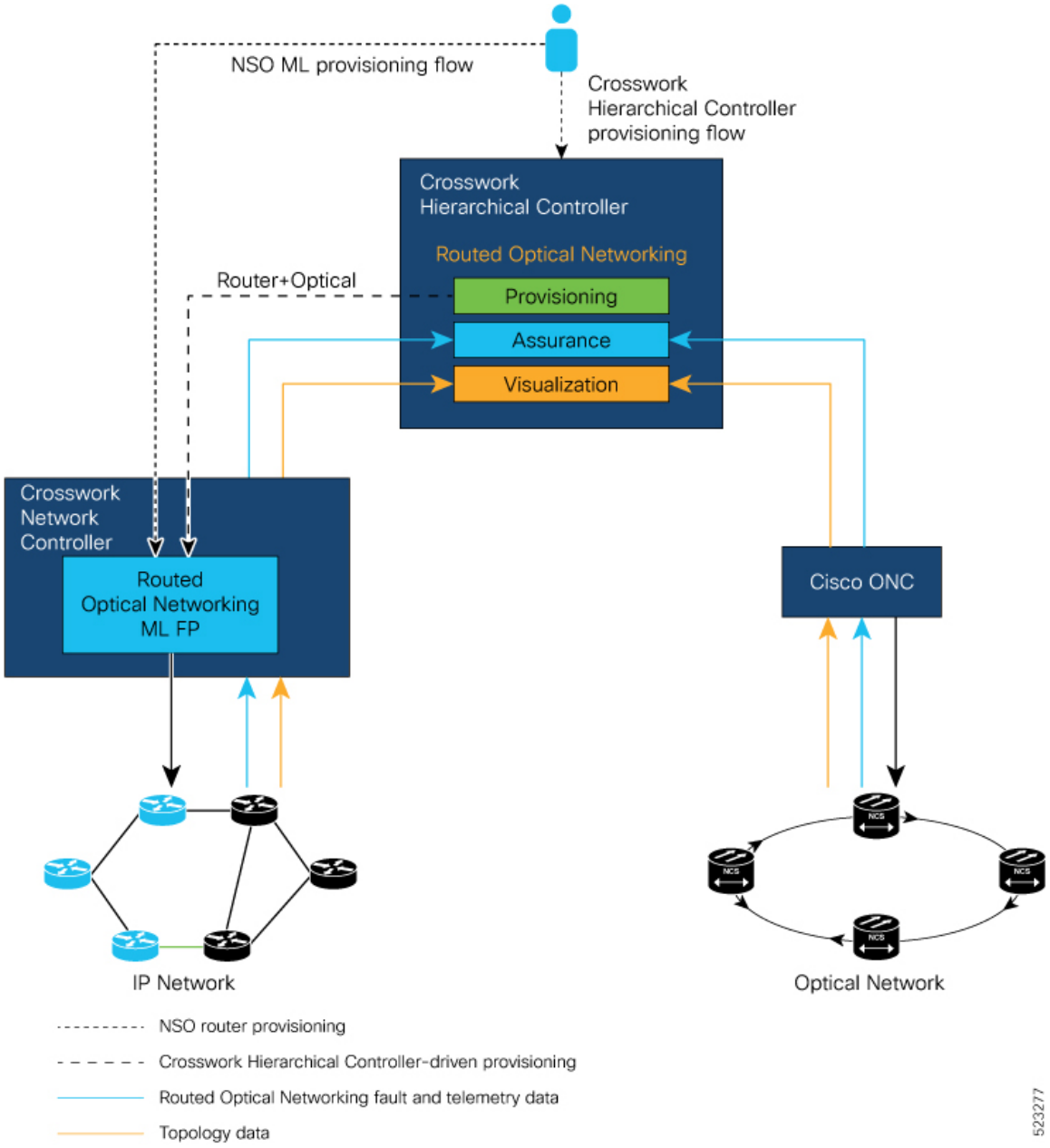
Key capabilities

The key capabilities of Crosswork Hierarchical Controller used by Routed Optical Networking are:

- Multilayer discovery and visualization of Routed Optical Networking links allows you to create a trustworthy digital twin of your network. This digital twin can assist with operations and provide data to OSS tools.
- Multilayer provisioning of 400G Routed Optical Networking links with a multi-layer provisioning interface through domain controllers.
- End-to-end assurance of service across all domains enables you to meet strict service requirements.

This figure shows the workflow of Crosswork Hierarchical Controller.

Figure 10: Crosswork Hierarchical Controller workflow



Crosswork Hierarchical Controller adapters

Crosswork Hierarchical Controller uses adapters to connect to a device or management system and to collect information for the network model and configure the device.

The adapters installed as part of the Crosswork Hierarchical Controller installation are:

- **cisco-cnc-adpt**: collects IP network topology, link state information, and router hardware inventory including discovery for DCO.
- **cisco-onc-adpt**: adapter for Cisco optical network controller.

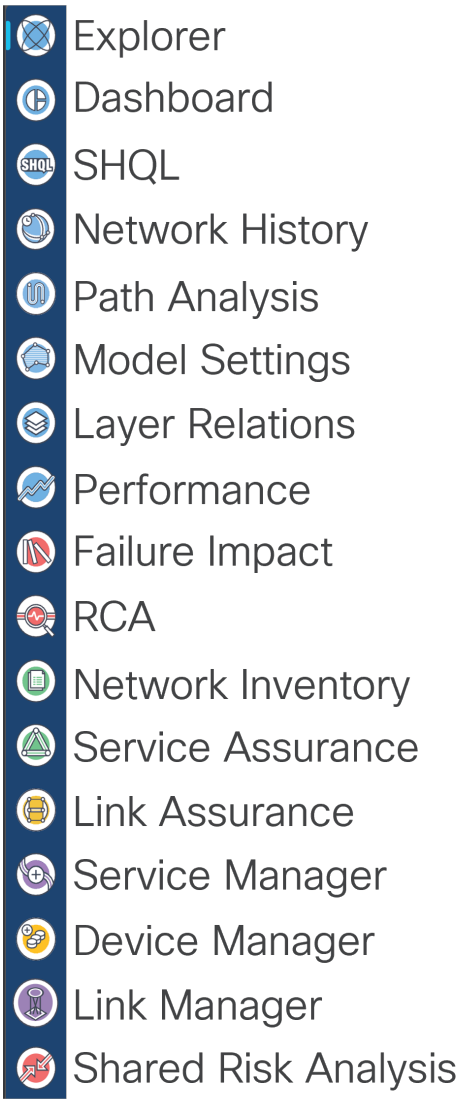
- **cisco-ios-xr-adpt**: collects inventory data and statistics.
- **cisco-cdg-adpt**: collects performance measurement data using streaming telemetry.

You can have multiple adapters of the same type. Each domain uses a separate Cisco Optical Network Controller adapter when several optical domains have different Cisco Optical Network Controller instances.

Crosswork Hierarchical Controller applications

The Crosswork Hierarchical Controller is a customized bundle of applications and adapters. This can be installed using an executable installer. The Crosswork Hierarchical Controller Web interface can be accessed using a custom URL.

This figure shows the applications included in Crosswork Hierarchical Controller.



For more information about Cisco Crosswork Hierarchical Controller, see Cisco Crosswork Hierarchical Controller

Features and components of Cisco Crosswork Network Controller

Cisco Crosswork Network Controller (Crosswork Network Controller) is a network automation solution for deploying and operating IP and Routed Optical Networking converged transport networks. Crosswork Network Controller delivers increased service agility, cost efficiency, and optimization for faster time-to-customer value and lower operating costs.

The solution combines intent-based network automation to deliver critical capabilities for service orchestration and fulfillment, network optimization, service path computation, device deployment and management, and anomaly detection and automatic remediation. Using telemetry gathering and automated responses, Cisco Crosswork Network Controller provides network optimization capabilities that are difficult to replicate manually.

The integrated solution uses core capabilities from several products: Cisco Network Services Orchestrator (NSO), Cisco Segment Routing Path Computation Element (SR-PCE), and the Cisco Crosswork suite of applications. Its unified user interface allows real-time visualization of the network topology and transport provisioning.

Features of Cisco Crosswork Network Controller

The features of Crosswork Network Controller include:

- **Active Topology:** The logical and geographical maps in Active Topology provide real-time visibility into the physical and logical network topology, service inventory, SR-TE policies, and RSVP-TE tunnels. Operators can quickly view the health and status of devices, services, and policies.
- **Common UI and API:** All Crosswork Network Controller functionality is provided within a single, common GUI. This common UI brings together the features of all components of Crosswork Network Controller, including common inventory, network topology and service visualization, service and transport provisioning, and system administration and management functions.
- **Platform Infrastructure and Shared Services:** The Platform Infrastructure provides a resilient and scalable platform on which all Cisco Crosswork applications can be deployed. It is a microservices-based platform that uses streaming telemetry and model-driven APIs to improve network operations of the service provider. The platform retrieves real-time network information, analyzes the data, and applies changes using APIs. The platform uses a cluster architecture for extensibility, scalability, and high availability.

Components of Cisco Crosswork Network Controller

The essential components of Crosswork Network Controller are:

- **Cisco Crosswork Optimization Engine:** Cisco Crosswork Optimization Engine provides real-time network optimization allowing operators to effectively maximize network capacity utilization and increase service velocity. Crosswork Optimization Engine provides closed loop tracking of the network state and responds quickly to changes in network conditions, supporting automated network recovery.. For more information, see Cisco Crosswork Optimization Engine Data Sheet.
- **Cisco Crosswork Data Gateway:** Cisco Crosswork Data Gateway (Crosswork Data Gateway) is a secure, common collection platform for gathering network data from multivendor devices. It is an on-premise application that is deployed close to network devices. Crosswork Data Gateway supports multiple data collection protocols including MDT, SNMP, CLI, standards-based gNMI (dial-in), and syslog. Crosswork Data Gateway can collect any type of data as long as the data can be delivered over one of the supported protocols. See Cisco Crosswork Data Gateway Data Sheet.

- **Cisco Segment Routing Path Computation Element:** Cisco Segment Routing Path Computation Element (SR-PCE) is an IOS-XR multidomain stateful Path Computation Engine (PCE) supporting both segment routing (SR) and Resource Reservation Protocol (RSVP). Cisco SR-PCE builds on the native PCE abilities within IOS-XR devices, and provides the ability to collect topology and segment routing IDs through BGP-LS, calculates paths that adhere to service SLAs, and programs them into the source router as an ordered list of segments. A Path Computation Client (PCC) reports and delegates control of headend tunnels that are sourced from the PCC to a PCE peer. The PCC and PCE establish a Path Computation Element Communication Protocol (PCEP) connection that the SR-PCE uses to push updates to the network and reoptimize paths where necessary.
- **Cisco Network Services Orchestrator (NSO) Function Packs:** Cisco Crosswork Network Controller is packaged with these Cisco NSO function packs:
  - SR-TE core function pack (CFP)
  - Sample function packs for provisioning IETF-compliant L2VPN and L3VPN
  - Sample RSVP-TE function pack that is IETF-compliant

The optional components of Crosswork Network Controller are:

- **Cisco Crosswork Health Insights:** Cisco Crosswork Health Insights is a network health application that performs real-time Key Performance Indicator (KPI) monitoring, alerting, and troubleshooting. Cisco Crosswork Health Insights enables programmable monitoring and analytics. It provides a platform for dynamically addressing changes to the network infrastructure. See Cisco Crosswork Change Automation and Health Insights Data Sheet.
- **Cisco Crosswork Zero-Touch Provisioning:** The Cisco Crosswork Zero-Touch Provisioning (ZTP) application is an integrated solution for onboarding and provisioning new IOS XR devices automatically. ZTP results in faster deployment of new hardware at lower operating costs. Operators can provision devices using a Cisco-certified software image and a day-zero software configuration. Once provisioned in this way, the new device is onboarded to the Crosswork device inventory where it can be monitored and managed like other devices. See Cisco Crosswork Zero–Touch Provisioning Data Sheet.
- **Cisco Service Health:** Service Health substantially reduces the time required to detect and troubleshoot service quality issues. It monitors the health status of provisioned Layer 2 and Layer 3 VPN services and enables operators to pinpoint why and where a service is degraded. It provides service-specific monitoring, troubleshooting, assurance, and proactive root cause identification using a heuristic model that visualizes these elements:
  - Health status of subservices to a map when a single service is selected.
  - Service logical dependency tree and help the operator in troubleshooting in case of degradation by locating where the problem resides, an indication of possible symptoms, and impacting metrics in case of degradation.
  - Historical view of service health status up to 60 days.
- **Crosswork EMS Services:** Element Management System (EMS) services are bundled with the Crosswork Network Controller Advantage pack. The EMS functions include inventory, fault, and Software Image Management (SWIM).
  - Inventory service integrates deep inventory collection with the Device Lifecycle Management (DLM) feature of Cisco Crosswork. It enriches the existing device onboarding workflow to gather more insights about the device. Built-in device packages enable deep inventory collection when the

user manually attaches a device to the Crosswork Data Gateway. The system stores the collected information in the database and monitors it using the Inventory APIs.

- Fault service is associated with alarm management. It provides API support for subscription, request, retrieval, and auto-clearing of alarms for Topology Visualization services. Monitored using the Fault APIs, the fault service improves the existing topology views by showing the alarm status for devices and links.
- SWIM is integrated with Crosswork Change Automation and managed with SWIM APIs. It enables operators to view, import, delete, and push software images to devices in the network. SWIM accelerates upgrades, improves compliance, and enhances the network engineer experience.

Cisco Crosswork Network Controller is multivendor capable for

- network service orchestration,
- telemetry data collection,
- topology and transport discovery,
- transport path computation, and

For more information about Cisco Crosswork Network Controller, see the Cisco Crosswork Network Controller Data Sheet.

Features of Cisco Optical Network Controller

Cisco Optical Network Controller (Optical Network Controller) is a domain controller for optical networks and provides data to Hierarchical Controllers. Optical Network Controller provides centralized network management and control for optical environments.

Features

The features of Optical Network Controller include:

- **SDN domain controller functionality**: collects and abstracts optical network data for higher-layer controllers.
- **Standardized TAPI model support**: abstracts device-level details, enabling hierarchical control and orchestration.
- **Provisioning and monitoring**: configures network elements, monitors physical and virtual topologies, and collects topology information.
- **Application extensibility**: supports addition of optical applications to improve hardware capability.
- **Centralized control loop functions**: maintains and programs optical hardware components efficiently.

For more information about Cisco Optical Network Controller, see the Cisco Optical Network Controller Data Sheet.

Features of Cisco Optical Site Manager

Cisco Optical Site Manager is a software application deployed on NCS 1010 or NCS 1014 controller cards. The software application can be enabled on one or two controllers to provide high availability. Cisco Optical Site Manager software instances use open Netconf or YANG Northbound Interfaces to aggregate current and future NCS 1000 devices at a site. The application provides an abstracted site or node view to the Cisco Optical Network Controller or a third-party controller. Cisco Optical Site Manager also provides a Web user interface for site-level operation and maintenance.

Features

Cisco Optical Site Manager provides these features:

- Seamless integration with Cisco Optical Network Controller for SDN automation
- OLS (Open Line System) site, OT (Open Terminal) site, or OLS+OT site abstraction
- Site aggregation, topology, and nodal functional view
- Site-level database information including inventory, site topology, correlated alarms, and performance monitoring
- Retention of current performance monitoring data up to the last 32 bins
- Connection verification, loopbacks, PRBS, OTDR, and TCA
- Web user interface with site-level management
- Mechanical layout for chassis, cards, and passive devices
- Card and module configurations

Cisco Optical Site Manager works with Cisco Optical Network Controller. It can also function as a standalone tool for Local Craft, which is useful for deployments or local management.

For information about installing and setting up Cisco Optical Site Manager, see System Setup and Software Installation Guide for Cisco Optical Site Manager, IOS XR.

For more information about Cisco Optical Site Manager, see the Cisco Optical Site Manager Data Sheet.

Features of Cisco Network Services Orchestrator

Cisco Network Services Orchestrator (NSO) provides comprehensive orchestration and lifecycle management across physical and virtual network functions.

Features

The features of Cisco NSO include

- pluggable function packs to translate network wide service intent into device-specific configuration
- flexible service orchestration and lifecycle management across physical and cloud based virtual network functions (VNFs)
- multivendor support and compatibility with multiple technology stacks
- rich set of APIs that enable developers to implement service applications and extend automation

- support for YANG data models to define and execute customer service configurations
- consistent operational model for physical and virtual network elements, and
- seamless orchestration in multivendor environments and across different device types.

For more information about Cisco Network Services Orchestrator, see Cisco Network Services Orchestrator Data Sheet.

Functions of Cisco NSO Routed Optical Networking function pack

The NSO Routed Optical Networking CFP uses NSO to automate device management in a Routed Optical Networking network. It also performs end-to-end service provisioning across the IP and optical layers. The NSO Routed Optical Networking CFP uses the same NSO instance as Crosswork Network Controller.

Routed Optical Networking ML service

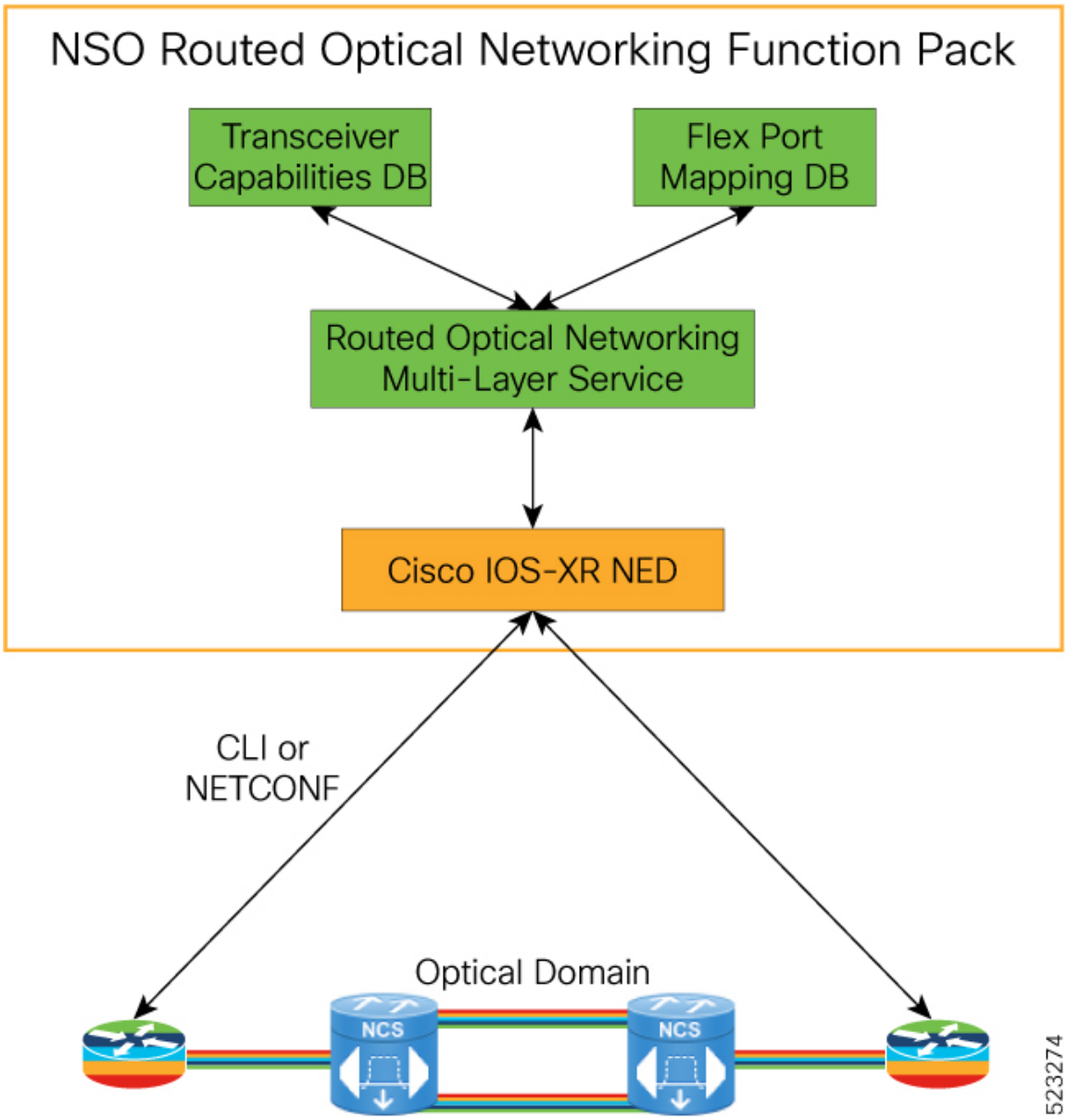
The Routed Optical Networking ML service connects two DWDM optical ports with a fixed bandwidth of either 100G, 200G, 300G, or 400G between the routers. This service is characterized by a single DWDM wavelength.

The Routed Optical Networking ML service helps to

- provision line card modes to support 100G and 400G digital coherent optics
- configure the optical parameters on the digital coherent optics
- assign IP address to Ethernet interfaces or bundle interfaces, and
- bundle discrete Ethernet interfaces.

Functions of Routed Optical Networking ML function pack

Figure 11: Routed Optical Networking ML function pack



This table describes the functions of various components of the Routed Optical Networking ML function pack.

Component	Function
Flex-port mapping DB	Maintains chassis and line card PID database for ports that must be pre-provisioned before the ZR configuration. NCS57-18DD-SE and ASR 9000 multi-rate line cards must be pre-provisioned.

Component	Function
Transceiver capabilities DB	Maps ZR and ZR+ optics PIDs to capabilities. For example, ZR supports 400G, 4x100G; ZR+ supports 100G, 2x100G, 3x100G, 4x100G, or 400G.
Routed Optical Networking ML service	Performs ZR and ZR+ optical layer configuration. The function pack can also optionally configure IP layer LAG membership and IP addressing.
Cisco IOS-XR NED	Provisions router elements. NSO network equipment driver used for southbound communication with routers.



Note The inter-layer link services are user-defined. Flex-port mapping and transceiver capabilities are installed as part of the function pack, but can be modified by the user.

Features of Cisco Evolved Programmable Network Manager

The Cisco Evolved Programmable Network Manager (EPNM) is an all-in-one management solution for today's converging packet and optical networks. Cisco EPNM supports the Cisco Routed Optical Network architecture. It provides Cisco Optical and IP full device management, as well as Cisco optical circuit network assurance. Cisco EPNM discovers the physical and logical configuration of managed devices and represents them. Cisco EPNM provides full software image management and configuration management for Cisco optical and IP devices.

Network operators see a live view of the device through a graphical chassis with status indications. EPNM stands out from other network management systems by discovering optical circuits from the network and maintaining an up-to-date representation of both the optical circuit and infrastructure dependencies.

EPNM reduces the time required to identify conditions that affect the network or optical circuits. It correlates raw events and associates alarm conditions with affected managed network elements, network connectivity, and circuits. Contextual dashboards and 360-degree device and port-level views present relevant information that helps network operators identify and resolve problems quickly and efficiently.

EPNM reduces restoration and repair time by guiding troubleshooting. It uses alarm correlation, identifies affected components or optical circuits, and analyzes connectivity. EPNM collects fault and alarm information. It performs node-level performance statistics measurement.

For more information about Cisco Evolved Programmable Network Manager, see the Cisco Evolved Programmable Network Manager Data Sheet.

Software versions of Routed Optical Networking components

This table lists the software versions of the Routed Optical Networking solution components.

Component	Software version
SR PCE	IOS-XR 7.11.1

Cisco Crosswork Infrastructure	6.0
Crosswork Network Controller cApps	6.0
Crosswork Data Gateway	6.0
Network Services Orchestrator	6.1.9
Cisco Optical Network Controller (CONC)	3.1
Cisco Optical Site Manager (COSM)	7.11.2
Crosswork Hierarchical Controller	8.0
Cisco Evolved Programmable Network Manager	7.1.2
Cisco Optical Network Planner	5.2

IOS-XR software components

Cisco IOS XR is a modern and flexible network operating system. IOS XR improves operational efficiency by integrating management APIs. This integration enables automated configuration and delivers actionable telemetry data in near real time.

The features utilized to help ensure modern standards-based management of Routed Optical Networking are:

- **YANG-modeled management layer APIs**: Automate device provisioning and management using both native IOS XR and OpenConfig models.
- **Streaming telemetry capabilities**: Provide cadence-based or event-driven monitoring of network data derived from YANG-modeled paths in the manageability layer over gRPC, TCP, or UDP.
- **Configuration of Digital Coherent Optics using CMIS Application Selection Code**: Enables configuration of Digital Coherent Optics using CMIS Application Selection Code.

Features of NETCONF protocol

Network Configuration (NETCONF) is a standards-based and XML-encoded protocol. NETCONF provides a transport mechanism to send YANG-formatted configuration or operational data requests from an application running on a centralized management platform to a Cisco device. You can use NETCONF to send requests for configuration or operational data retrieval.

NETCONF provides transaction-based services. For example, if part of a configuration request fails, the entire request is aborted.

NETCONF uses a simple Remote Procedure Call based mechanism to enable communication between clients, such as centralized management platform scripts or applications, and servers, such as Cisco switches or routers. NETCONF uses SSH as the transport layer for communication between network devices.

Types and functions of YANG data models in Routed Optical Networking

Data models provide an alternate centralized way to configure devices instead of using the CLI or SNMP and to collect operational data from Cisco devices. Because the data models are standards-based, you can use the same procedures to configure or collect data from non-Cisco devices. This ability makes them ideal for

customers that support multiple vendors. You can use a centralized management platform to configure or collect data from multiple Cisco devices. The data model architecture allows for automating these procedures.

Yet Another Next Generation (YANG) is a standards-based data modeling language. You can use YANG to create requests for device configuration or operational data. It has a structured, human-readable format similar to a computer program. To create configuration and operational data requests, several applications are available that can run on a centralized management platform.

Types of YANG models

There are two types of YANG models:

- **Standard (common)**: YANG data model that applies to all vendors. For example, a request to disable or shut down an Ethernet interface is identical for Cisco and non-Cisco devices.
- **Device (native, vendor-specific)**: YANG data model that facilitates configuration or that collects of operational data related to proprietary vendor features.

Functions of YANG models in Routed Optical Networking

This table lists Cisco native models, their Open Config equivalents used in the Routed Optical Networking solution, and their functions.

Unified model	Open Config	Function
Cisco-IOS-XR-platform-oper	openconfig-platform	Retrieve line card information for flex-port mapping
Cisco-IOS-XR-optics-port-mode-cfg	No equivalent	Configure flex port modes
Cisco-IOS-XR-controller-optics-oper	openconfig-platform openconfig-platform-transceiver	Retrieve optics PID information
Cisco-IOS-XR-um-cont-optics-cfg	openconfig-terminal-device openconfig-platform-transceiver	Configure ZR optical parameters
Cisco-IOS-XR-um-if-bundle-cfg	openconfig-if-aggregate	Bundle configuration
Cisco-IOS-XR-um-interface-cfg	openconfig-interfaces	IPv4 and IPv6 interface configuration
Controller-otu-oper	No equivalent	Coherent DSP operation data
Cisco-IOS-XR-um-dac-rate-cfg	No equivalent	DAC rate configuration
Cisco-IOS-XR-um-cont-breakout-cfg	No equivalent	Breakout configuration

Note

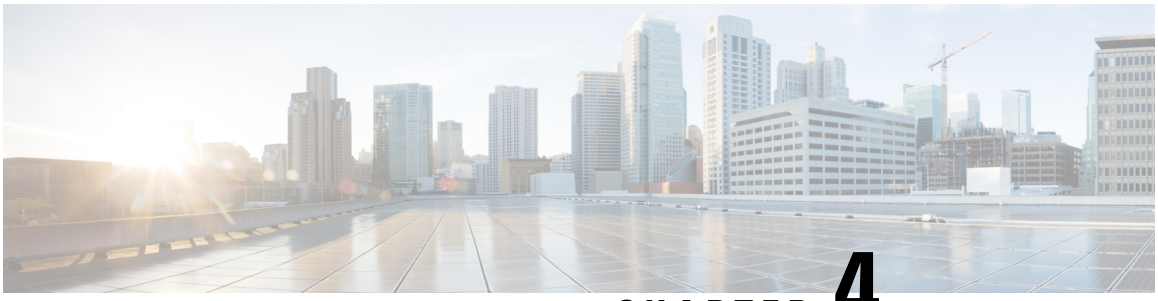
- The openconfig-terminal-device model configures the logical hierarchy of connections from ingress to egress. For Cisco optical devices, you can use OpenConfig to configure nx100G muxponder or transponder modes, and trunk rate.
- Use the openconfig-platform model to configure the physical layer parameters:
  - Frequency
  - TX power
  - Operational-mode (Modulation, FEC, and TX shaping)
- See Managing OpenZR+ and OIF ZR transceivers on Cisco routers using OpenConfig for information about managing pluggable digital coherent optics using OpenConfig.

Features of model-driven telemetry

Telemetry is an automated communications process used to collect measurements and other data at remote or inaccessible points and transmit them to receiving equipment for monitoring. Model-Driven Telemetry (MDT) streams YANG-modeled data to a data collector. Model-Driven telemetry enables network devices to continuously stream real-time configuration and operating state information to subscribers.

Applications can subscribe to specific data items using standards-based YANG data models over Network Configuration Protocol (NETCONF), RESTCONF, or gRPC Network Management Interface (gNMI) protocol. You can also create configured subscriptions using CLIs. Devices publish structured data at a defined cadence or when changes occur, based on the subscription criteria and data type. For information about telemetry sensor paths and corresponding data fields, see Troubleshoot provisioning issues on ZR or ZR+ optics, on page 88.

MDT uses structured data models supported by the networking device. MDT provides critical data that is defined in those data models. Telemetry helps you manage your multivendor network by using a common network management system, standardized processes, and applications. The data collected from the network is standards-based and uniform across vendor implementations.



CHAPTER 4

Deployment Topologies

Routed Optical Networking supports these deployment topologies:

- Metro and Regional: This topology is used for shorter reach metro use cases and longer regional use cases.
- Long Haul: This topology is used for distances greater than 400 km.

  The QDD-400G-ZR-S optic has a maximum reach of 120 km. Longer distances require the use of QDD-400G-ZRP-S optics.

The Routed Optical Networking solution architecture or network design is the same for any network such as core, aggregation, or DCI. The only differentiating factor is the hardware that is used for any deployment.

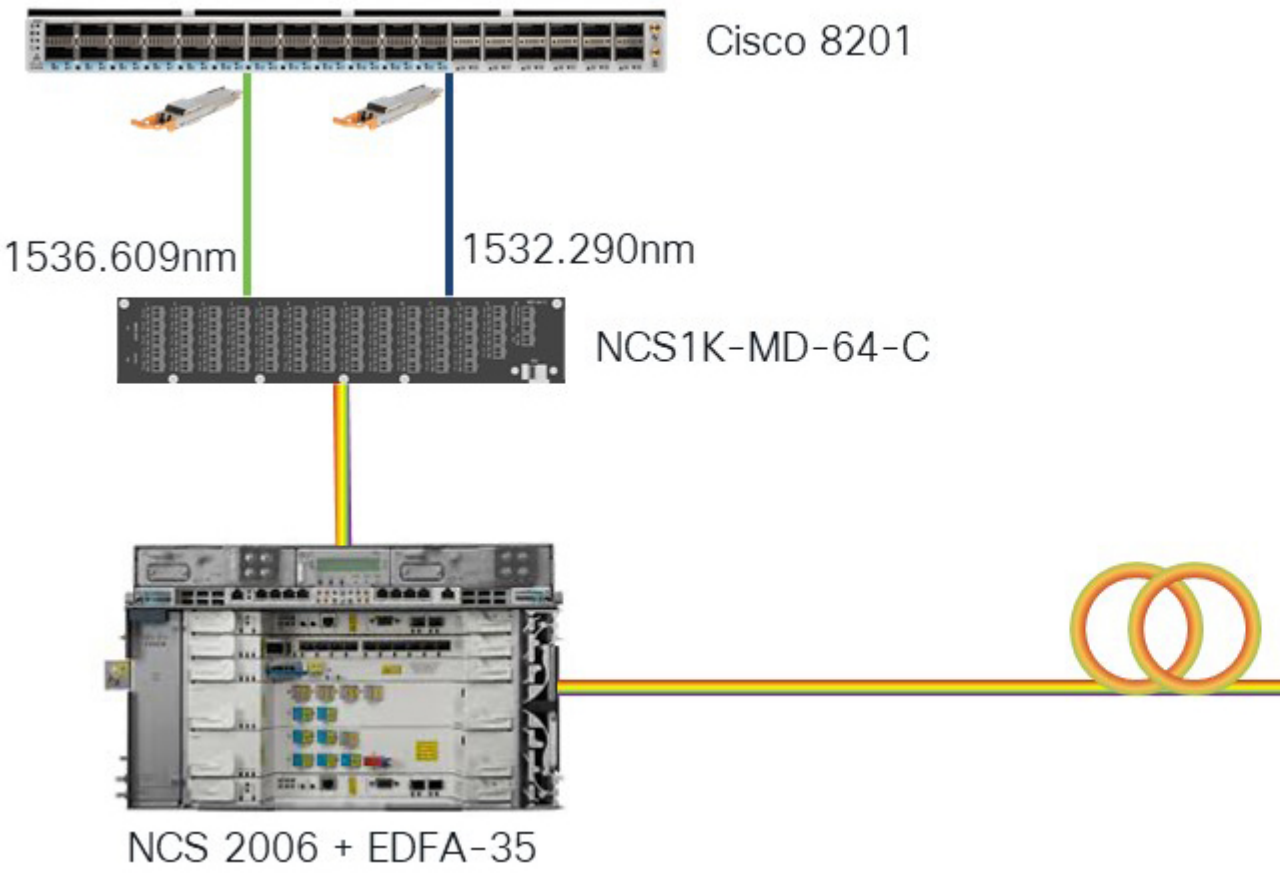
- Components and connections in metro and regional topology, on page 59
- Components and connections in mesh topology, on page 62
- Components and connections in long haul topology, on page 68
- Components and connections in point-to-point topology with NCS 1010 nodes, on page 74
- Components and connections in multi-degree topology with NCS 1010 nodes , on page 76

Components and connections in metro and regional topology

Topology diagram

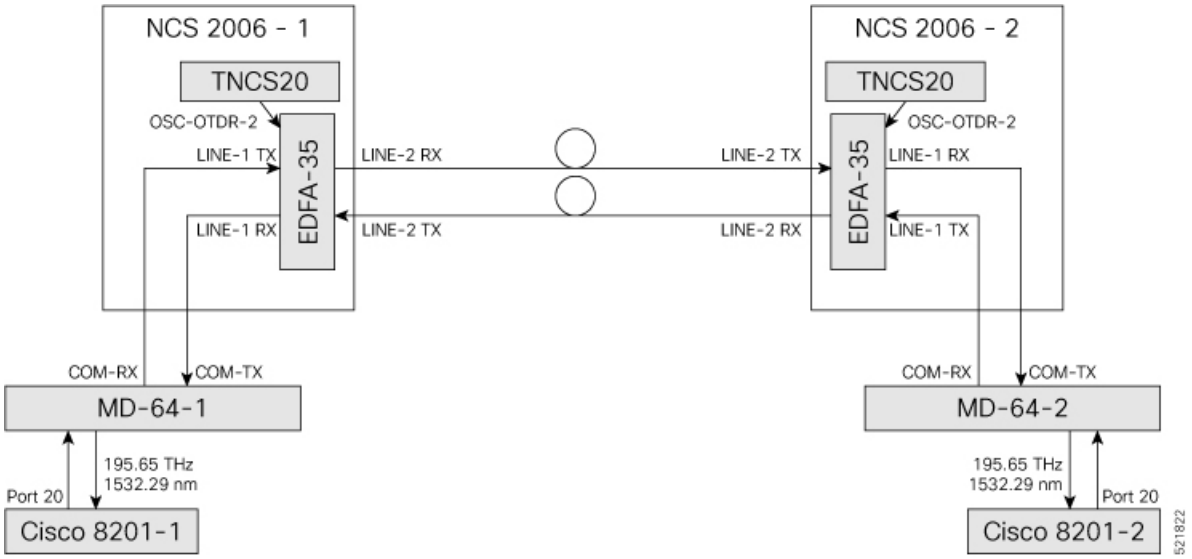
This topology diagram illustrates the setup for metro and regional networks.

Figure 12: 400G-ZR P2P short haul applications with Cisco NCS 2006



This diagram displays the wiring diagram for the metro and regional topology.

Figure 13: Wiring diagram for a metro and regional topology



In this sample topology, Cisco 8201-1 serves as the source router and Cisco 8201-2 serves as the destination router.

Topology components

You need this hardware to build this topology:

- Cisco 8200 series routers
- NCS1K-MD-64-C modules
- Cisco NCS 2006 shelves
- TNCS-2O cards
- OPT-EDFA-35 cards
- QDD-400G-ZR-S transceiver module
- LC/LC cables

For more information, see Hardware components, on page 15.

Port connections

Use this sequence to connect the cables and build this topology:

1. On the Cisco 8201-1 and Cisco 8201-2 routers:
   a. Align the QDD-400G-ZR-S transceiver module in front of the transceiver socket opening in Port 20. Then, carefully slide the transceiver into the socket until the transceiver comes in contact with the socket electrical connector.
   b. Holding the pull-tab, fully seat the transceiver in the module's transceiver socket until it clicks.
   c. Attach an LC/LC fiber immediately to the QDD-400G-ZR-S transceiver module.

d. Connect the other end of the LC/LC fiber to the corresponding bulkhead adapter on the front panel of the NCS1K-MD-64-C (MD-64-1) module. In this sample topology, we use channel ID 7, which corresponds to a frequency of 195.65 THz (a wavelength of 1532.29 nm).

2. Connect an LC/LC fiber from the COM-RX port of the MD-64-1 module to the LINE-1-TX port of the EDFA 35 amplifier card in NCS 2006-1.
3. Connect an LC/LC fiber from the COM-TX port of the MD-64-1 module to the LINE-1-RX port of the EDFA 35 amplifier card in NCS 2006-1.
4. Connect an LC/LC fiber from the OSC-OTDR-2 port on the TNCS-2O card to the OSC port on the EDFA 35 card in NCS 2001-1.
5. Connect an LC/LC fiber from the LINE-2-RX port of the EDFA-35 card in NCS 2006 -1 to the outside plant fiber that is connected to the LINE-2-TX port of the EDFA-35 card in NCS 2006 -2.
6. Connect an LC/LC fiber from the LINE-2-TX port of the EDFA-35 card in NCS 2006 -1 to the outside plant fiber that is connected to the LINE-2-RX port of the EDFA-35 card in NCS 2006 -2.
7. Connect an LC/LC fiber from the OSC-OTDR-2 port on the TNCS-2O card to the OSC port on the EDFA 35 card in NCS 2006-2.
8. Connect an LC/LC fiber from the LINE-1-RX port of the EDFA-35 card in NCS 2006 -2 to the COM-TX port of the MD-64-2 module.
9. Connect an LC/LC fiber from the LINE-1-TX port of the EDFA-35 card in NCS 2006 -2 to the COM-RX port of the MD-64-2 module.

Next steps

After you build the topology, perform these steps:

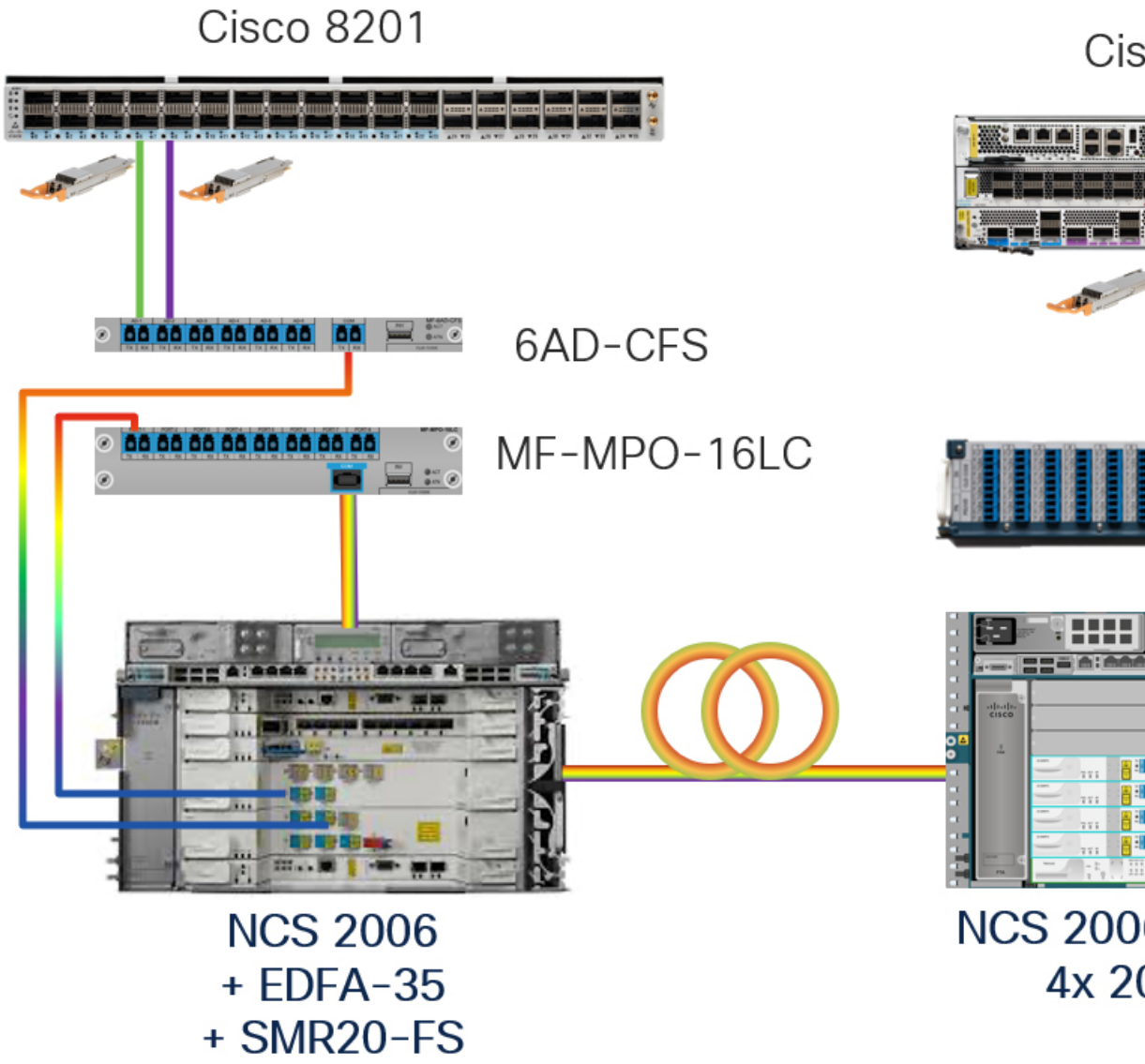
- Import the Cisco ONP Configuration File into SVO.
- Manage Expected Input Power

Components and connections in mesh topology

Topology diagram

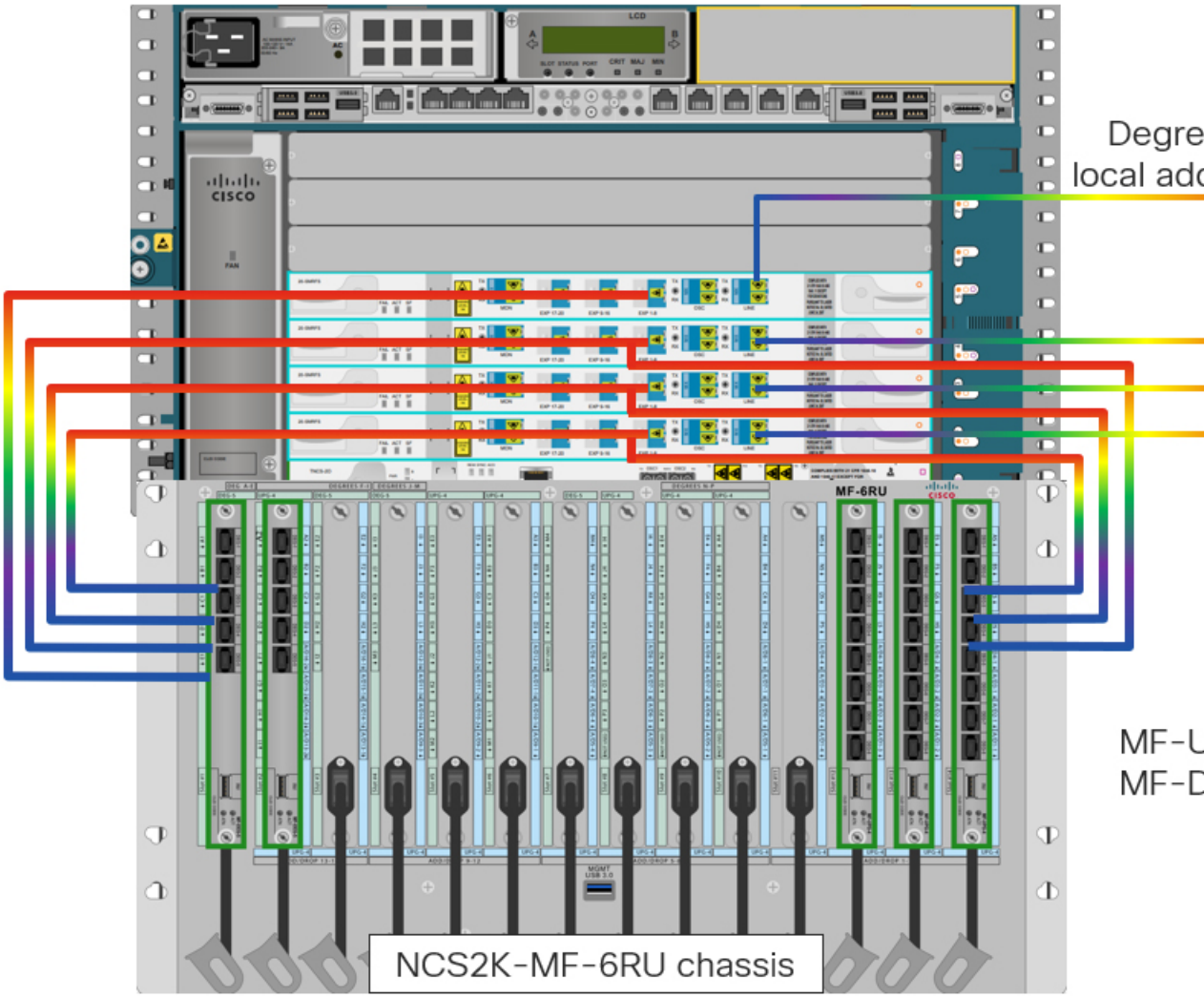
This topology diagram illustrates the setup for mesh networks.

Figure 14: Optical bypass with colorless add/drop and 4-degree ROADM node



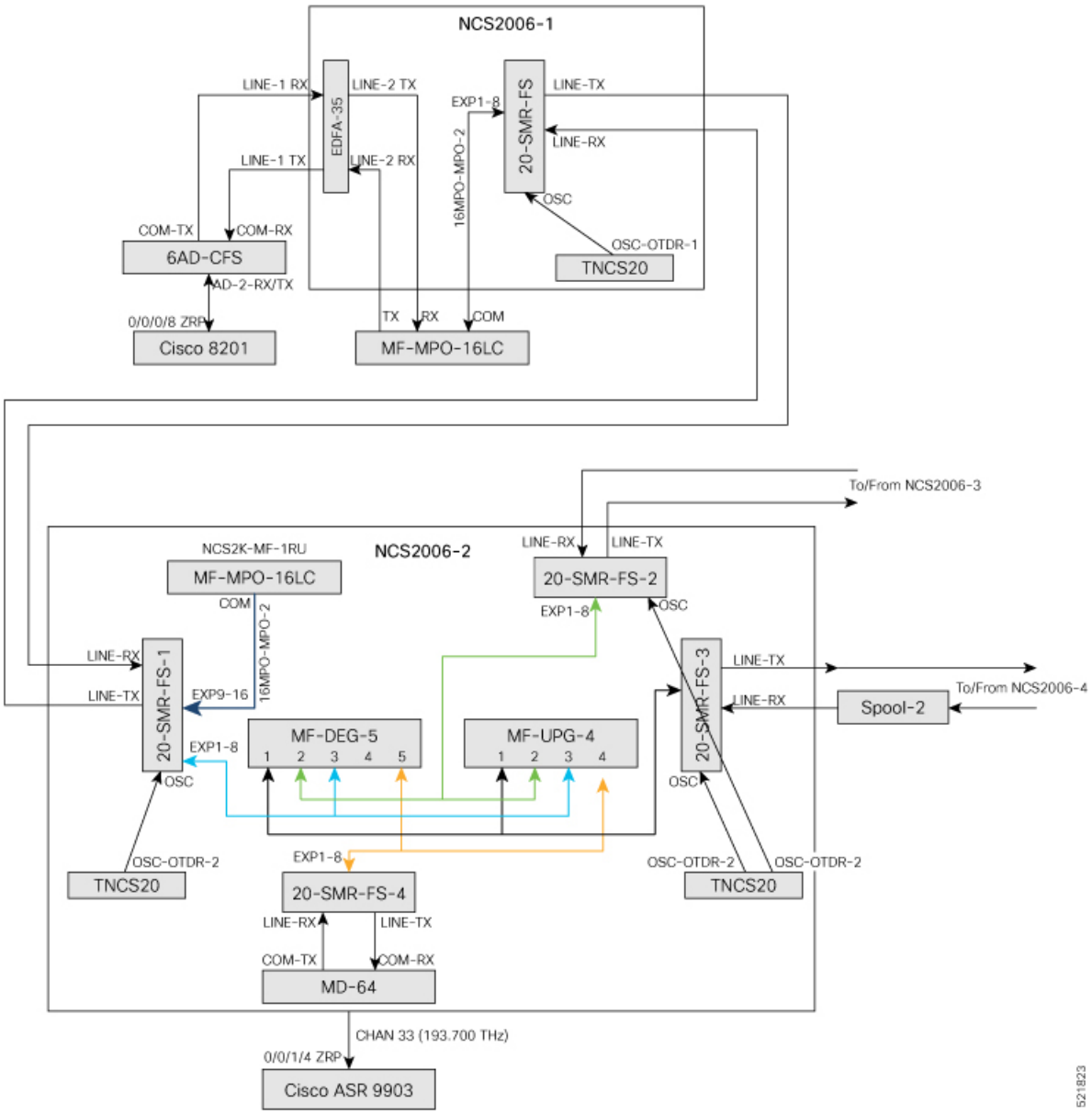
This figure shows the NCS 2006 mesh node in detail with mesh panels.

Figure 15: 4-Degree mesh node configuration



This diagram shows the wiring diagram for the mesh topology.

Figure 16: Wiring diagram for a mesh topology



In this sample topology, Cisco 8201 is the source router and Cisco ASR 9903 is the destination router, using a four-degree node. Nodes with fewer or more degrees are also supported. NCS2006-2 is a four-degree mesh node that drops a colored wavelength on the Cisco ASR 9903 router. The MD-64 unit is used as a fixed channel muxponder but other options can also be connected to the 20-SMR-FS card. The other degrees are connected to NCS 2000 nodes in the network.

Topology components

You need this hardware to build this topology:

- Cisco 8200 series routers

- Cisco ASR 9903 routers
- NCS1K-MD-64-C modules
- 6-AD-CFS units
- MF-DEG-5 units
- MF-UPG-4 units
- MF-MPO-16LC units
- Cisco NCS 2006 shelves
- TNCS-2O, OPT-EDFA-35, and 20-SMR-FS cards
- QDD-400G-ZR-S transceiver modules
- LC/LC cables
- 16MPO-MPO-2 cables
- ONS-MPO16-2x8-2 cables

For more information, see Hardware components, on page 15.

Port connections

Use this sequence to connect the cables and build this topology:

1. On the Cisco 8201 router:
   a. Align the QDD-400G-ZR-S transceiver module in front of the transceiver socket in port 4. Then, carefully slide the transceiver into the socket until the transceiver comes in contact with the socket electrical connector.
   b. Holding the pull-tab, seat the transceiver in the transceiver socket of the module fully until it clicks.
   c. Attach an LC/LC fiber to the QDD-400G-ZR-S transceiver module immediately.
   d. Connect the LC/LC fiber's other end to the matching bulkhead adapter on the 6AD-CFS module's front panel. (AD-2 RX/TX port). In this sample topology, we use channel ID 33, which corresponds to a frequency of 193.700 THz.
2. Connect an LC/LC fiber from the COM-RX port of the 6AD-CFS module to the LINE-1-TX port of the EDFA 35 amplifier card in NCS 2006-1.
3. Connect an LC/LC fiber from the COM-TX port of the 6AD-CFS module to the LINE-1-RX port of the EDFA 35 amplifier card in NCS 2006-1.
4. Connect an LC/LC fiber from the LINE-2-RX port of the EDFA-35 card in NCS 2006 -1 to the TX port of the MF-MPO-16LC unit.
5. Connect an LC/LC fiber from the LINE-2-TX port of the EDFA-35 card in NCS 2006 -1 to the RX port of the MF-MPO-16LC unit.
6. Connect an 16MPO-MPO-2 fiber from the EXP1-8 port of the 20-SMR-FS card in NCS 2006 -1 to the COM port of the MF-MPO-16LC unit.

7. Connect an LC/LC fiber from the OSC-OTDR-2 port on the TNCS-2O card to the OSC port on the 20-SMR-FS card in NCS 2006 -1.
8. Connect an LC/LC fiber from the LINE-TX port of the 20-SMR-FS card in NCS 2006 -1 to the LINE-RX port of the 20-SMR-FS-1 card in NCS 2006 -2.
9. Connect an LC/LC fiber from the LINE-RX port of the 20-SMR-FS card in NCS 2006 -1 to the LINE-TX port of the 20-SMR-FS-1 card in NCS 2006 -2.
10. Connect an LC/LC fiber from the OSC-OTDR-2 port on the TNCS-2O card to the OSC port on the 20-SMR-FS-1 card in NCS 2006-2.
11. Connect an 16MPO-MPO-2 fiber from the EXP9-16 port of the 20-SMR-FS-1 card in NCS 2006 -2 to the COM port of the MF-MPO-16LC unit.
12. Connect one end of the ONS-MPO16-2x8-2 cable to the EXP1-8 port of the 20-SMR-FS-1 card in NCS 2006 -2. Connect the other two ends to port 3 of the MF-DEG-5 unit and MF-UPG-4 unit respectively.
13. Connect one end of the ONS-MPO16-2x8-2 cable to the EXP1-8 port of the 20-SMR-FS-2 card in NCS 2006 -2. Connect the other two ends to port 2 of the MF-DEG-5 unit and MF-UPG-4 unit respectively.
14. Connect one end of the ONS-MPO16-2x8-2 cable to the EXP1-8 port of the 20-SMR-FS-3 card in NCS 2006 -2. Connect the other two ends to port 1 of the MF-DEG-5 unit and MF-UPG-4 unit respectively.
15. Connect one end of the ONS-MPO16-2x8-2 cable to the EXP1-8 port of the 20-SMR-FS-4 card in NCS 2006 -2. Connect the other end to port 5 of the MF-DEG-5 unit only.
16. Connect an LC/LC fiber from the OSC-OTDR-2 port on the TNCS-2O card to the OSC port on the 20-SMR-FS-2 card in NCS 2006-2.
17. Connect an LC/LC fiber from the OSC-OTDR-2 port on the TNCS-2O card to the OSC port on the 20-SMR-FS-3 card in NCS 2006-2.
18. Connect LC/LC fibers from the LINE-TX and LINE-RX ports of the 20-SMR-FS-2 card in NCS 2006-2 to the ports of NCS2006-3.
19. Connect LC/LC fibers from the LINE-TX and LINE-RX ports of the 20-SMR-FS-3 card in NCS 2006-2 to the ports of NCS2006-4.
20. Connect an LC/LC fiber from the LINE-RX port on the 20-SMR-FS-4 card in NCS 2006-2 to the COM-TX port of the MD-64 unit.
21. Connect an LC/LC fiber from the LINE-TX port on the 20-SMR-FS-4 card in NCS 2006-2 to the COM-RX port of the MD-64 unit.
22. Connect one end of the LC/LC fiber to the corresponding bulkhead adapter on the front panel of the NCS1K-MD-64-C (MD-64-1) module. Connect the other end of the fiber to the QDD-400G-ZR-S transceiver module installed in port 4 of the ASR 9903 router.

Next steps

After you build the topology, perform these steps:

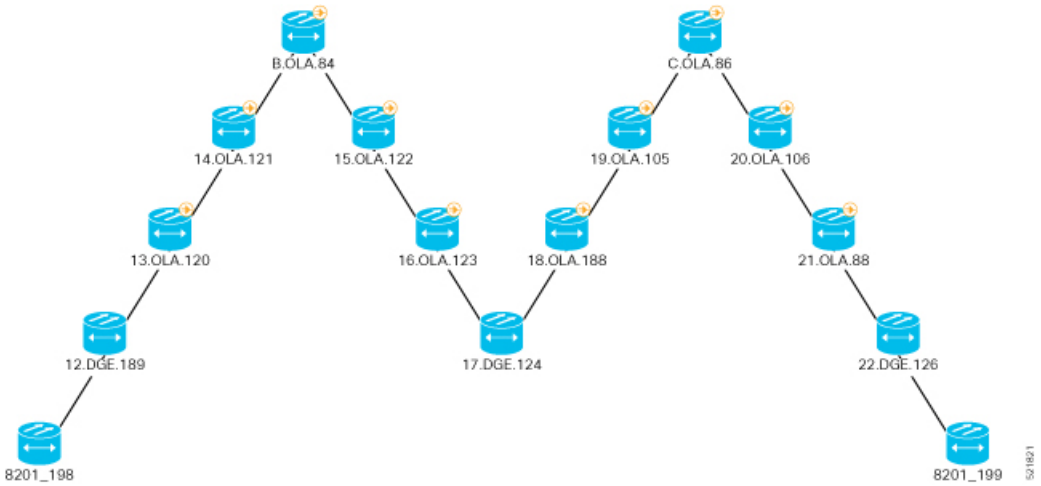
- Import the Cisco ONP Configuration File into SVO.
- Manage Expected Input Power

Components and connections in long haul topology

Topology diagram

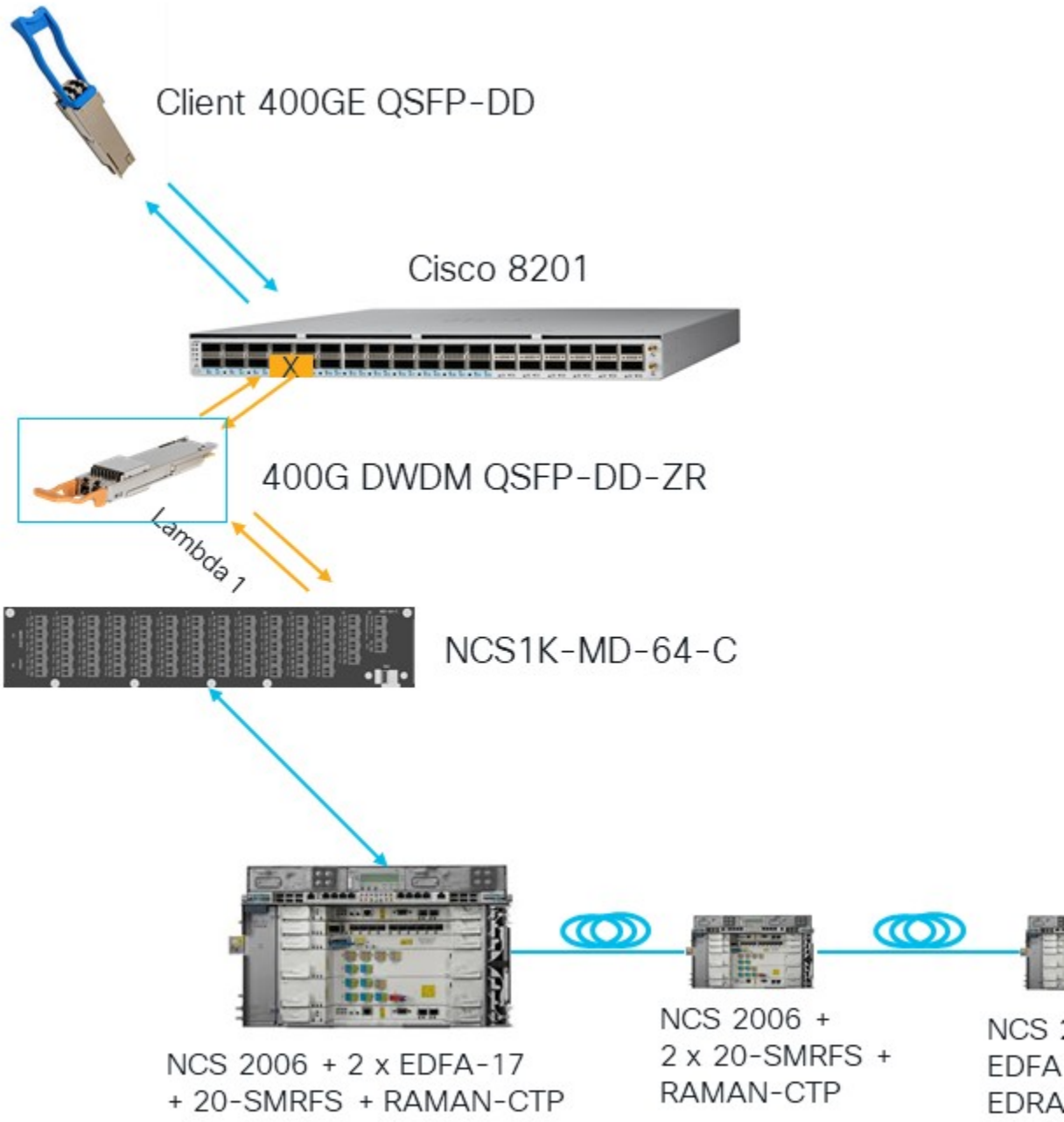
This topology diagram illustrates the setup for long haul networks.

Figure 17: Long haul setup



This topology uses several types of nodes, including ILA, terminal, OLA, and DGE nodes. The ILA nodes span from 80 to 120 km. The DGE nodes allow gain equalization in long haul networks over 1200 km. This topology uses terminal, OLA, and DGE nodes.

Figure 18: 400G-ZR P2P long haul applications with Cisco NCS 2006



These diagrams show the wiring configuration for the long haul topology.

Figure 19: Wiring diagram for a long haul topology

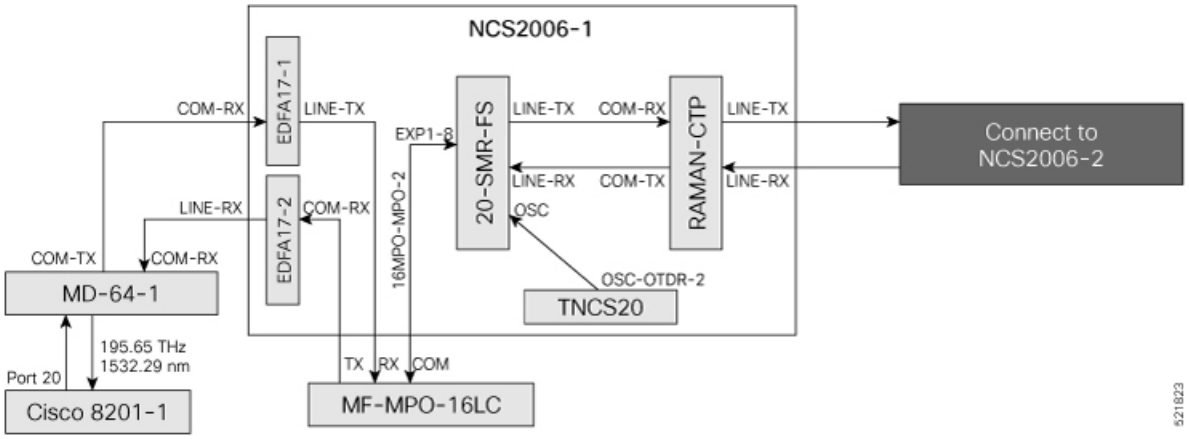


Figure 20: Wiring diagram for a long haul topology

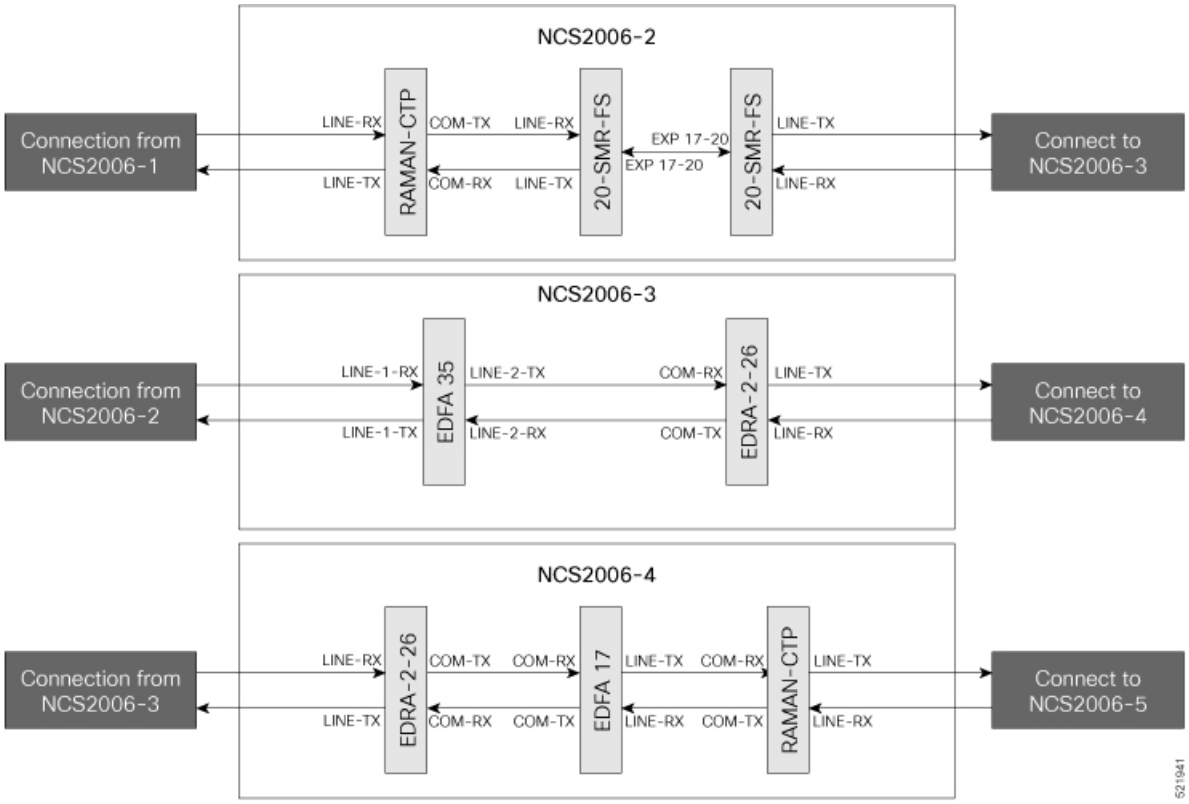
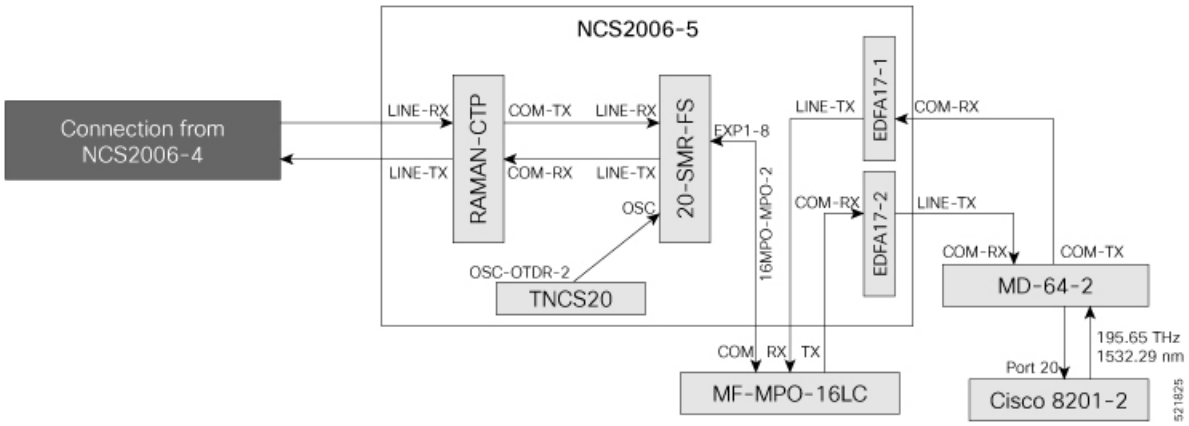


Figure 21: Wiring diagram for a long haul topology



In this sample topology, Cisco 8201–1 is the source router, and Cisco 8201–2 is the destination router.

Topology components

You need this hardware to build this topology:

- Cisco 8200 Series routers
- NCS1K-MD-64-C modules
- Cisco NCS 2006 shelves
- TNCS-2O, OPT-EDFA-17, EDRA-2-26, RAMAN-CTP, and SMR20 FScards
- MF-MPO-16LC passive modules (seated in an NCS2K-MF-1RU mechanical frame)
- QDD-400G-ZR-S transceiver
- LC/LC cables
- 16MPO-MPO-2 cables

For more information, see Hardware components, on page 15.

Port connections

Use this sequence to connect the cables and build this topology:

1. On the Cisco 8201–1 and Cisco 8201–2 routers:
   a. Align the QDD-400G-ZR-S transceiver module with the transceiver socket opening in Port 20. Then, slide the transceiver carefully into the socket until the transceiver comes in contact with the socket electrical connector.
   b. Holding the pull-tab, seat the transceiver in the module's transceiver socket fully until it clicks.
   c. Attach an LC/LC fiber immediately to the QDD-400G-ZR-S transceiver module.
   d. Connect the other end of the LC/LC fiber to the corresponding bulkhead adapter on the front panel of the NCS1K-MD-64-C (MD-64-1) module. In this sample topology, we use channel ID 7, which corresponds to a frequency of 195.65 THz (wavelength of 1532.29 nm).

2. Connect an LC/LC fiber from the COM-TX port of the MD-64-1 module to the COM-RX port of the EDFA-17-1 amplifier in NCS 2006-1.
3. Connect an LC/LC fiber from the COM-RX port of the MD-64-1 module to the LINE-TX port of the EDFA-17-2 amplifier card in NCS 2006-1.
4. Connect an LC/LC fiber from the LINE-TX port of the EDFA-17-1 amplifier card in NCS 2006-1 to the RX port of the MF-MPO-16LC module.
5. Connect an LC/LC fiber from the COM-RX port of the EDFA-17-2 amplifier card in NCS 2006-1 to the TX port of the MF-MPO-16LC module.
6. Connect a 16MPO-MPO-2 cable from the COM port of the MF-MPO-16LC module to the EXP1-8 port of the 20 SMR-FS card in NCS 2006-1.
7. Connect an LC/LC fiber from the LINE-TX port of the SMR20 card in NCS 2006-1 to the COM-RX port of the RAMAN-CTP card in NCS 2006-1.
8. Connect an LC/LC fiber from the LINE-RX port of the SMR20 card in NCS 2006-1 to the COM-TX port of the RAMAN-CTP card in NCS 2006-1.
9. Connect an LC/LC fiber from the OSC-OTDR-2 port of the TNCS-2O card in NCS 2006 -1 to the OSC-TX port of the SMR20 card in NCS 2006 -1.
10. Connect an LC/LC fiber from the LINE-TX port of the RAMAN-CTP card in NCS 2006-1 to the LINE-RX port of the RAMAN-CTP card in NCS 2006-2.
11. Connect an LC/LC fiber from the LINE-RX port of the RAMAN-CTP card in NCS 2006-1 to the LINE-TX port of RAMAN-CTP card in NCS 2006-2.
12. Connect an LC/LC fiber from the COM-TX port of the RAMAN-CTP card in NCS 2006-2 to the LINE-RX port of the 20-SMR-FS card in NCS 2006 -2.
13. Connect an LC/LC fiber from the COM-RX port of the RAMAN-CTP card in NCS 2006-2 to the LINE-TX port of the 20-SMR-FS card in NCS 2006 -2.
14. Connect an LC/LC fiber from the EXP 17–20 port of the 20-SMR-FS card in NCS 2006-2 to the EXP 17–20 port of the 20-SMR-FS card in NCS 2006-2.
15. Connect an LC/LC fiber from the LINE-TX port of the 20-SMR-FS card in NCS 2006-2 to the LINE-1-RX port of the EDFA–35 card in NCS 2006 -3.
16. Connect an LC/LC fiber from the LINE-RX port of the 20-SMR-FS card (NCS 2006-2) to the LINE-1-TX port of the EDFA–35 card (NCS 2006 -3).
17. Connect an LC/LC fiber from the LINE-2-TX port of the EDFA-35 card in NCS 2006 -3 to the COM-RX port of the EDRA-2-26 card in NCS 2006 -3.
18. Connect an LC/LC fiber from the LINE-2-RX port of the EDFA-35 card (NCS 2006 -3) to the COM-TX port of the EDRA-2-26 card in NCS 2006-3.
19. Connect an LC/LC fiber from the LINE-TX port of the EDRA-2-26 card in NCS 2006-3 to the LINE-RX port of the EDRA-2-26 card in NCS 2006 -4.
20. Connect an LC/LC fiber from the LINE-RX port of the EDRA-2-26 card in NCS 2006-3 to the LINE-TX port of the EDRA-2-26 card in NCS 2006 -4.

21. Connect an LC/LC fiber from the COM-TX port of the EDRA-2-26 card in NCS 2006-4 to the COM-RX port of the EDFA-17 card in NCS 2006 -4.
22. Connect an LC/LC fiber from the COM-RX port of the EDRA-2-26 card in NCS 2006-4 to the COM-TX port of the EDFA-17 card in NCS 2006 -4.
23. Connect an LC/LC fiber from the COM-RX port of the EDRA-2-26 card (NCS 2006-4) to the COM-TX port of the EDFA-17 card in NCS 2006 -4.
24. Connect an LC/LC fiber from the LINE-TX port of the EDFA-17 card in NCS 2006-4 to the COM-RX port of the RAMAN-CTP card in NCS 2006-4.
25. Connect an LC/LC fiber from the LINE-RX port of the EDFA-17 card in NCS 2006-4 to the COM-TX port of the RAMAN-CTP card in NCS 2006-4.
26. Connect an LC/LC fiber from the LINE-TX port of the RAMAN-CTP card in NCS 2006-4 to the LINE-RX port of the RAMAN-CTP card in NCS 2006-5.
27. Connect an LC/LC fiber from the LINE-RX port of the RAMAN-CTP card in NCS 2006-4 to the LINE-TX port of the RAMAN-CTP card in NCS 2006-5.
28. Connect an LC/LC fiber from the COM-TX port of the RAMAN-CTP card in NCS 2006-5 to the LINE-RX port of the 20-SMR-FS card in NCS 2006-5.
29. Connect an LC/LC fiber from the COM-RX port of the RAMAN-CTP card in NCS 2006-5 to the LINE-TX port of the SMR20 card in NCS 2006-5.
30. Connect an LC/LC fiber from the OSC-OTDR-2 port of the TNCS-2O card in NCS 2006 -5 to the OSC-TX port of the 20-SMR-FS card in NCS 2006 -5.
31. Connect a 16MPO-MPO-2 cable from the EXP1-8 port of the 20-SMR-FS card in NCS 2006-5 to the COM port of the MF-MPO-16LC module.
32. Connect an LC/LC fiber from the LINE-TX port of the EDFA-17-1 card in NCS 2006-5 to the RX port of the MF-MPO-16LC module.
33. Connect an LC/LC fiber from the COM-RX port of the EDFA-17-2 card in NCS 2006-5 to the TX port of the MF-MPO-16LC module.
34. Connect an LC/LC fiber from the COM-RX port of the EDFA17-1 card in NCS 2006-5 to the COM-TX port of the MD-64-2 module.
35. Connect an LC/LC fiber from the LINE-TX port of the EDFA-17-2 card in NCS 2006-5 to the COM-RX port of the MD-64-2 module.

Next steps

After you build the topology, perform these steps:

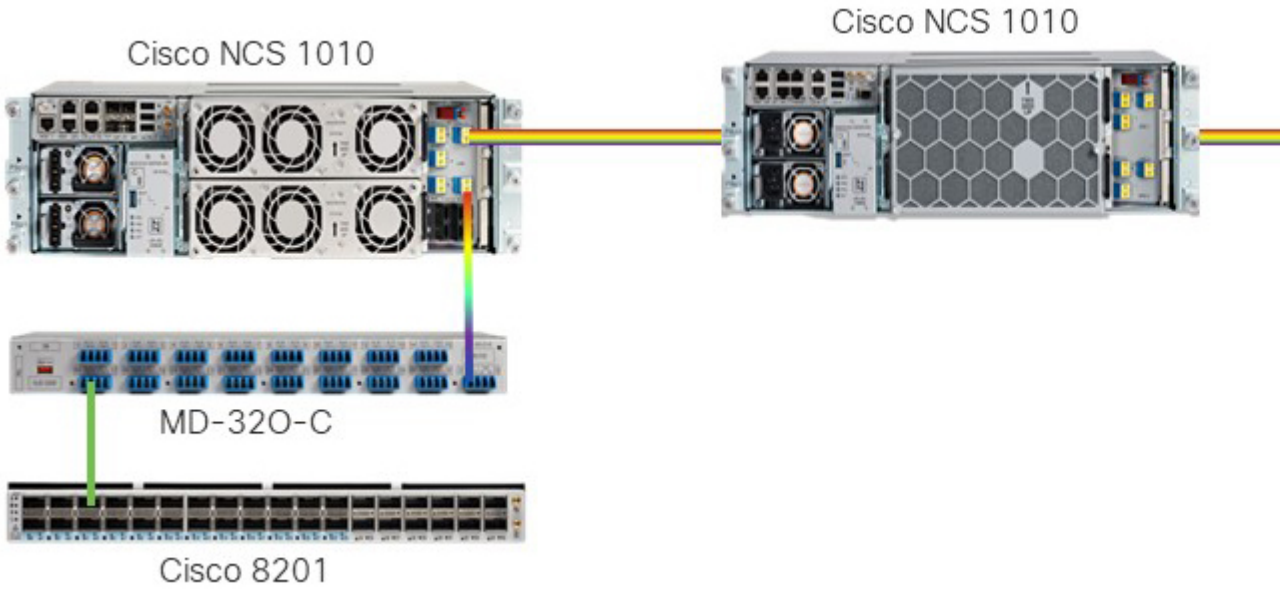
- Import the Cisco ONP Configuration File into SVO.
- Manage Expected Input Power

Components and connections in point-to-point topology with NCS 1010 nodes

Topology diagram

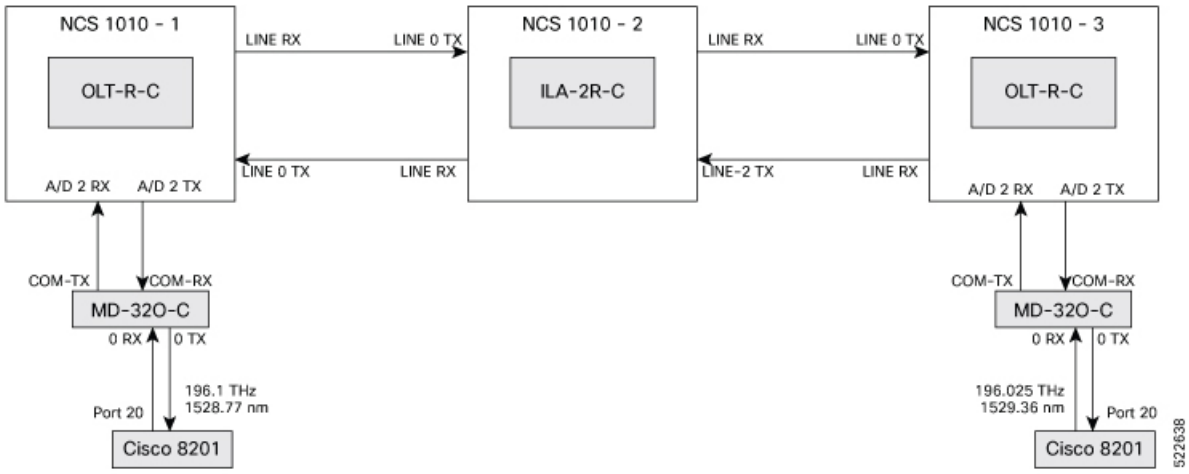
This topology diagram illustrates the setup for point-to-point networks using NCS 1010 nodes.

Figure 22: Point-to-point topology using NCS 1010 nodes



These diagrams show the wiring configuration for point-to-point topology using NCS 1010 nodes.

Figure 23: Wiring diagram for point-to-point topology



Topology components

You need this hardware to build this topology:

- Cisco NCS 1010 devices
- NCS1K-MD-32O-C modules
- QDD-400G-ZR-S transceivers
- LC/LC cables
- Cisco 8201 routers

For more information, see Hardware components, on page 15.

Port connections

Use this sequence to connect the cables and build this topology:

1. On the Cisco 8201 routers:
   a. Align the QDD-400G-ZR-S transceiver module with the transceiver socket opening in Port 20. Then, carefully slide the transceiver into the socket until the transceiver comes in contact with the socket electrical connector.
   b. Holding the pull-tab, seat the transceiver in the module's transceiver socket fully until it clicks.
   c. Attach an LC/LC fiber immediately to the QDD-400G-ZR-S transceiver module.
   d. Connect the other end of the LC/LC fiber to the corresponding bulkhead adapter on the front panel of the NCS1K-MD-32O-C (MD-32-O-C) module. In this sample topology, we use a frequency of 196.1 THz (1528.77 nm).
2. Connect an LC/LC fiber from the COM-TX port of the MD-32-O-C module to the A/D 2 RX port of the OLT-R-C module in NCS 1010–1.
3. Connect an LC/LC fiber from the COM-RX port of the MD-32-O-C module to the A/D 2 TX port of the OLT-R-C module in NCS 1010–1.
4. Connect an LC/LC fiber from the LINE RX port of the OLT-R-C module in NCS 1010–1 to the LINE 0 TX port of the ILA-2R-C module in NCS 1010–2.
5. Connect an LC/LC fiber from the LINE-0 TX port of the OLT-R-C module in NCS 1010–1 to the LINE 0 LINE RX port of the ILA-2R-C module in NCS 1010–2.
6. Connect an LC/LC fiber from the LINE 2 LINE RX port of the ILA-2R-C module in NCS 1010–2 to the LINE 0 TX port of the OLT-R-C module in NCS 1010–3.
7. Connect an LC/LC fiber from the LINE-2 TX port of the ILA-2R-C module in NCS 1010–2 to the LINE RX port of the OLT-R-C module in NCS 1010–3.
8. Connect an LC/LC fiber from the A/D 2 RX port of the OLT-R-C module in NCS 1010–3 to the COM-TX port of the MD-32-O-C module.
9. Connect an LC/LC fiber from the A/D 2 TX port of the OLT-R-C module in NCS 1010–3 to the COM-RX port of the MD-32-O-C module.

Next steps

After you build the topology, perform these steps:

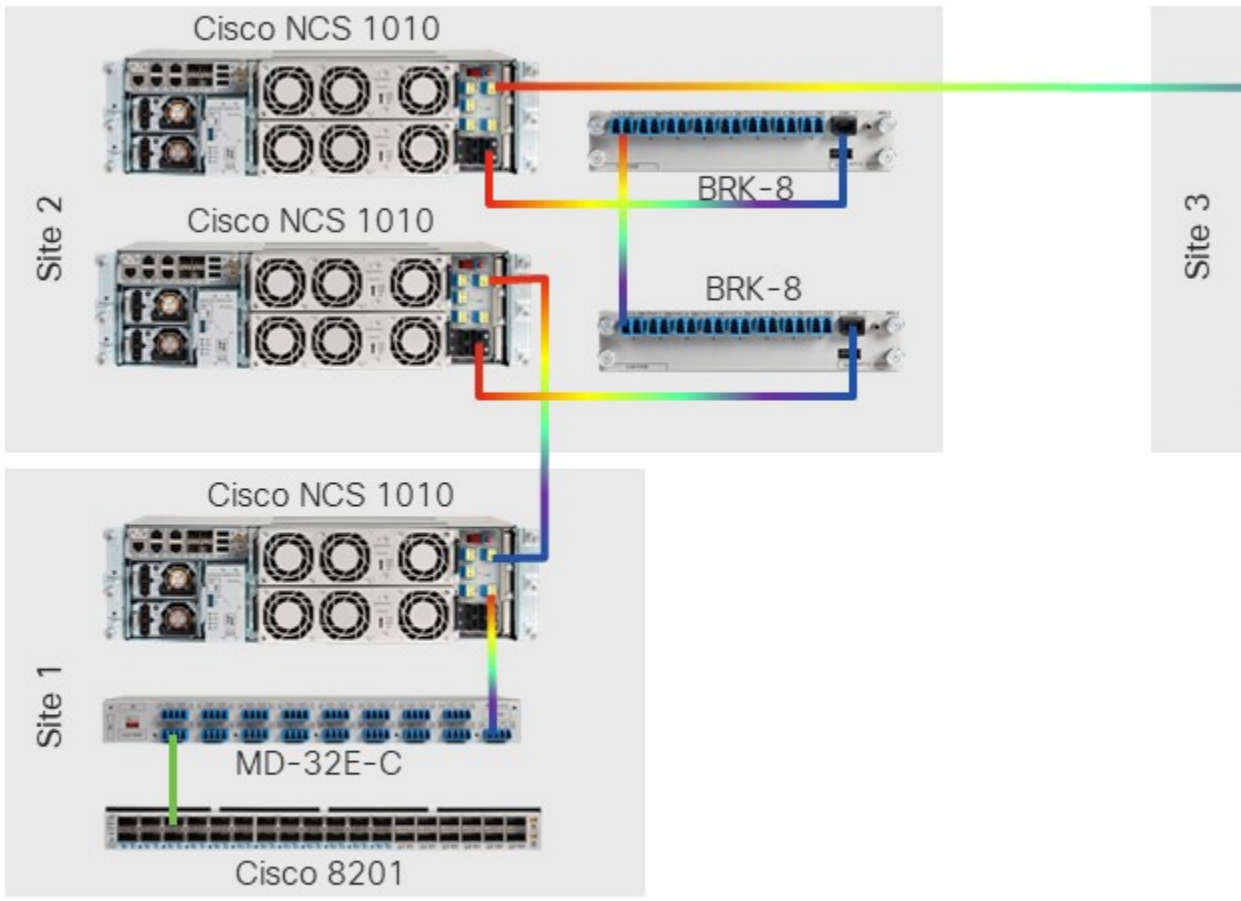
- Import the Cisco ONP Configuration File into SVO.
- Manage Expected Input Power

Components and connections in multi-degree topology with NCS 1010 nodes

Topology diagram

This topology diagram illustrates the setup for multi-degree networks using NCS 1010 nodes.

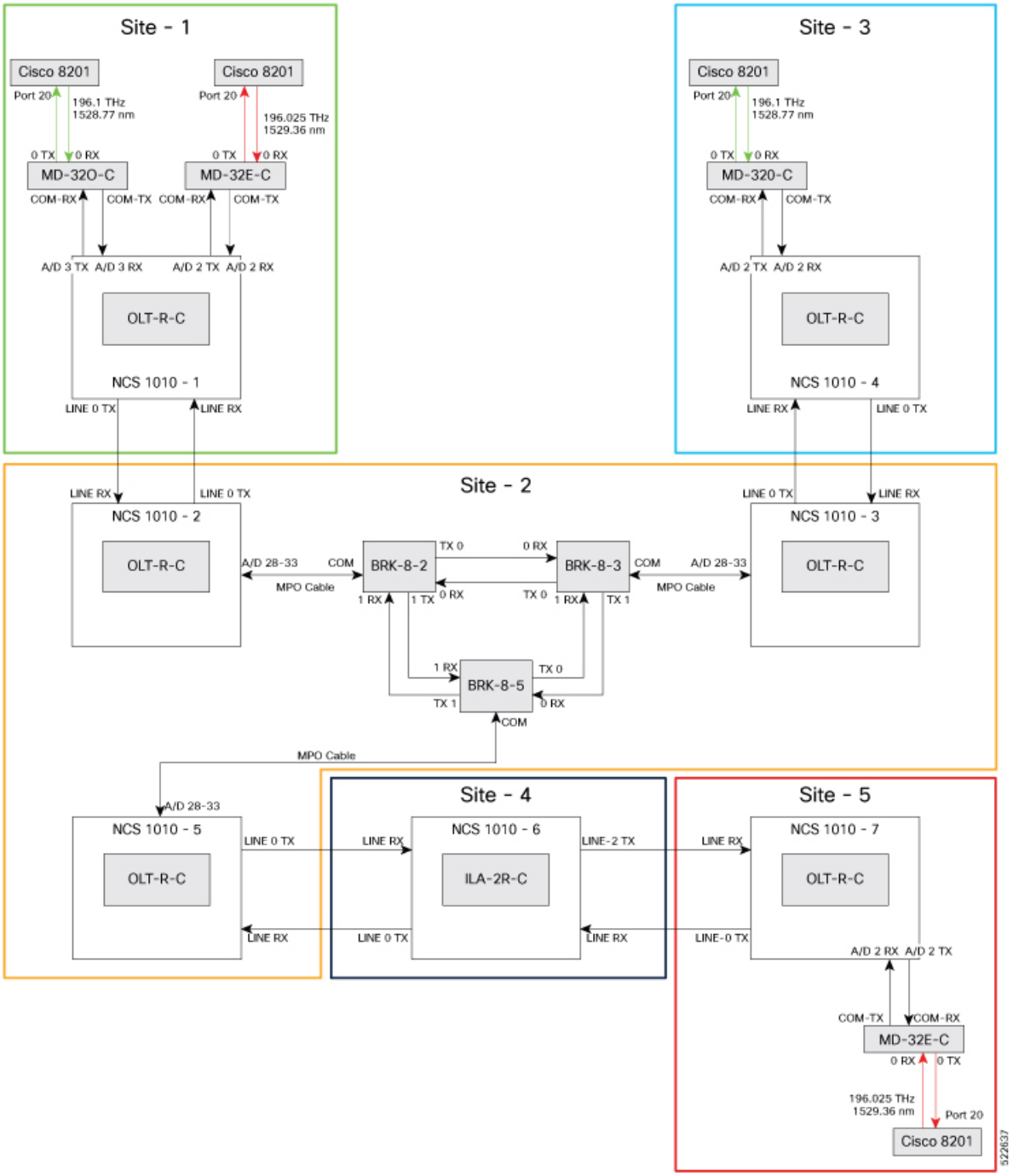
Figure 24: Multi-degree topology using NCS 1010 nodes



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These diagrams show the wiring configuration for the multi-degree topology using NCS 1010 nodes.

Figure 25: Wiring diagram for multi-degree topology



Topology components

You need this hardware to build this topology:

- Cisco NCS 1010 devices
- NCS1K-MD32E-C modules

- NCS1K-MD32O-C modules
- NCS1K-BRK-8 modules
- Cisco 8201 routers
- QDD-400G-ZR-S transceivers
- LC/LC cables
- MPO cables

For more information, see Hardware components, on page 15.

Port connections

Use this sequence to connect the cables and build this topology:

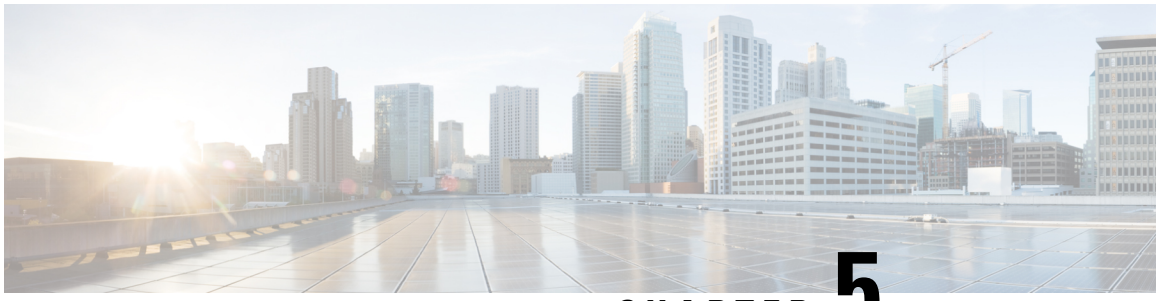
1. On the Cisco 8201 routers:
   a. Align the QDD-400G-ZR-S transceiver module with the transceiver socket opening in Port 20. Carefully slide it into the socket until contact with the socket electrical connector.
   b. Holding the pull-tab, seat the transceiver in the module's transceiver socket fully until it clicks.
   c. Attach an LC/LC fiber immediately to the QDD-400G-ZR-S transceiver module.
   d. Connect the other end of the LC/LC fiber to the corresponding bulkhead adapter on the front panel of the NCS1K-MD-32O-C (MD-32-O-C using frequency 196.1 THz) module or the NCS1K-MD-32E-C (MD-32-E-C using frequency 195.025 THz) module.
2. Connect an LC/LC fiber from the COM-TX port of the MD-32-O-C module to the A/D 3 RX port of the OLT-R-C module in NCS 1010–1.
3. Connect an LC/LC fiber from the COM-RX port of the MD-32-O-C module to the A/D 3 TX port of the OLT-R-C module in NCS 1010–1.
4. Connect an LC/LC fiber from the COM-TX port of the MD-32-E-C module to the A/D 2 RX port of the OLT-R-C module in NCS 1010–1.
5. Connect an LC/LC fiber from the COM-RX port of the MD-32-E-C module to the A/D 2 TX port of the OLT-R-C module in NCS 1010–1.
6. Connect an LC/LC fiber from the LINE RX port of the OLT-R-C module in NCS 1010–1 to the LINE 0 TX port of the OLT-R-C module in NCS 1010–2.
7. Connect an LC/LC fiber from the LINE 0 TX port of the OLT-R-C module in NCS 1010–1 to the LINE RX port of the OLT-R-C module in NCS 1010–2.
8. Connect an MPO fiber from the A/D 4–11 port of the OLT-R-C module in NCS 1010–2 to the COM port of the BRK-8-2 module.
9. Using LC/LC fibers, interconnect the BRK-8-2, BRK-8-3, and BRK-8-5 modules.
10. Connect an MPO fiber from the COM port of the BRK-8-3 module to the A/D 4–11 port of the OLT-R-C module in NCS 1010–3 .
11. Connect an LC/LC fiber from the LINE RX port of the OLT-R-C module in NCS 1010–3 to the LINE 0 TX port of the OLT-R-C module in NCS 1010–4.

12. Connect an LC/LC fiber from the LINE 0 TX port of the OLT-R-C module in NCS 1010–3 to the LINE RX port of the OLT-R-C module in NCS 1010–4.
13. Connect an LC/LC fiber from the COM-TX port of the MD-32-O-C module to the A/D 2 RX port of the OLT-R-C module in NCS 1010–4.
14. Connect an LC/LC fiber from the COM-RX port of the MD-32-O-C module to the A/D 2 TX port of the OLT-R-C module in NCS 1010–4.
15. Connect an MPO fiber from the COM port of the BRK-8-5 module to the A/D 4–11 port of the OLT-R-C module in NCS 1010–5 .
16. Connect an LC/LC fiber from the LINE 0 TX port of the OLT-R-C module in NCS 1010–5 to the LINE 0 LINE RX port of the ILA-2R-C module in NCS 1010–6.
17. Connect an LC/LC fiber from the LINE RX port of the OLT-R-C module in NCS 1010–5 to the LINE 0 TX port of the ILA-2R-C module in NCS 1010–6.
18. Connect an LC/LC fiber from the LINE-2 TX port of the ILA-2R-C module in NCS 1010–6 to the LINE RX port of the OLT-R-C module in NCS 1010–7.
19. Connect an LC/LC fiber from the LINE 2 LINE RX port of the ILA-2R-C module in NCS 1010–6 to the LINE 0 TX port of the OLT-R-C module in NCS 1010–7.
20. Connect an LC/LC fiber from the COM-TX port of the MD-32-E-C module to the A/D 2 RX port of the OLT-R-C module in NCS 1010–7.
21. Connect an LC/LC fiber from the COM-RX port of the MD-32-E-C module to the A/D 2 TX port of the OLT-R-C module in NCS 1010–7.

Next steps

After you build the topology, perform these steps:

- Import the Cisco ONP Configuration File into SVO.
- Manage Expected Input Power



CHAPTER 5

Automation Workflows

- Install Routed Optical Networking components, on page 81
- How Routed Optical Networking components communicate, on page 82
- Provision end-to-end service for Cisco routers with only ZR or ZR+ optics, on page 83
- How NSO Routed Optical Networking ML service works, on page 84
- How Crosswork Hierarchical Controller provisions Routed Optical Networking circuit, on page 85
- Automation starter solution and full solution, on page 86
- Troubleshoot provisioning issues on ZR or ZR+ optics, on page 88

Install Routed Optical Networking components

Cisco Crosswork Hierarchical Controller, Crosswork Network Controller Essentials, and NSO 6.1.9 with Routed Optical Networking 3.0.0 Function Pack are the necessary components for the Routed Optical Networking solution. Cisco Optical Network Controller is required when using Cisco optical networking components.

Follow these steps to install the components of the Routed Optical Networking solution.

Procedure

Install the Routed Optical Networking components in this sequence.

Table 11: Installation sequence of Routed Optical Networking components

Task	See
Install Cisco Optical Network Planner. Cisco Optical Network Planner determines the optical layer feasibility and identifies the components needed to support the network. It also generates a BoM for the planned hardware deployment.	Cisco Optical Network Planner Installation Guide
Install SVO to manage the NCS 2000 optical components and create SVO instances to manage NCS 2000 devices.	Cisco NCS 2000 Series SVO Configuration Guide, Release 12.3.x

Task	See
Install the Crosswork Infrastructure 6.0, Crosswork Data Gateway, and supporting Crosswork Network Controller 6.0 7.1applications such as Crosswork Optimization Engine, CAT, and Hi.	Cisco Crosswork Network Controller 6.0 Installation Guide
Install Cisco Optical Network Controller 3.1	Cisco Optical Network Controller 3.1 Installation Guide
Install EPNM 7.1.2 EMS to manage the physical router and the optical network nodes.	Installation Guide for Cisco Evolved Programmable Network Manager 7.1
Install Cisco NSO 6.1.96.4.1.1, Routed Optical Networking Multi-layer Function Pack 3.0, and Crosswork DLM function pack. Optionally, install the Cisco Transport SDN Function pack for SR-TE and xVPN service management.	Cisco Network Services Orchestrator Getting Started Guide, Cisco NSO Routed Optical Networking Core Function Pack Installation Guide, Cisco NSO Transport SDN Function Pack Installation Guide 6.0.0, Cisco NSO DLM Service Pack Installation Guide 6.0.0
Add NCS 1010 devices to Cisco Optical Network Controller for the optical service management.	Cisco Optical Network Controller 25.1.x Configuration Guide
Install Crosswork Hierarchical Controller 11.0	Crosswork Hierarchical Controller 11.0
Install Segment Routing - Path Computation Element (SR-PCE) in the network for Segment Routing - Traffic Engineering (SR-TE) or Resource Reservation Protocol - Traffic Engineering (RSVP-TE) discovery and visualization and add NSO, SR-PCE, and Cisco routers to the Crosswork cluster.	Add Cisco NSO Providers, Add Cisco SR-PCE Providers, Adding Devices to Inventory
Add the Cisco Optical Network Controller instance as a device in NSO to support end-to-end multi-layer provisioning.	*Cisco NSO Routed Optical Networking Core Function Pack User Guide*

You have installed all the components of the Routed Optical Networking solution.

How Routed Optical Networking components communicate

Summary

The components of Routed Optical Networking perform several operations such as service discovery, node management, and collection of inventory data to communicate together.

Workflow

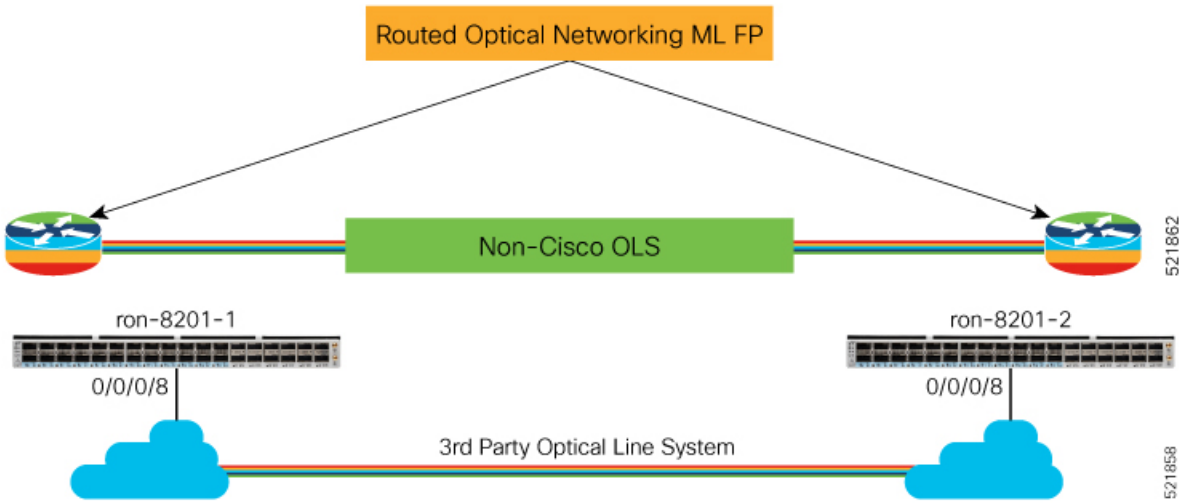
This diagram displays the communication sequence between the Routed Optical Networking components.

Note Routed Optical Networking components are not required in all the deployments.

Provision end-to-end service for Cisco routers with only ZR or ZR+ optics

These diagrams illustrate a network containing Cisco routers equipped with ZR or ZR+ optics and a non-Cisco optical line system.

Figure 26: Cisco routers with ZR or ZR+ optics



Follow this step to provision end-to-end service using Cisco routers with only ZR or ZR+ optics.

Procedure

Create Routed Optical Networking ML service with these parameters.

Table 12: Parameters for Routed Optical Networking ML Service

Input	Value
End-points	ron-8201-1, ron-8201-2
Model	Transponder (1x400G mode)
Bandwidth	400G
Frequency	1952000
TX Power	-12 dB on both endpoints

Input	Value
IP Addressing	10.2.1.10/31 and 10.2.1.11/31 on FourHundredGigE 0/0/0/8

```
ron ron-ml ron-8201-1_ron-8201-2
 mode      transponder
 bandwidth 400
 circuit-id "Router Only"
 frequency  1952000
 end-point ron-8201-1
  terminal-device-optical line-port 0/0/0/8
  terminal-device-optical transmit-power -120
  terminal-device-packet interface 0
   ip-address v4 10.2.1.10/31
  !
 !
 end-point ron-8201-2
  terminal-device-optical line-port 0/0/0/8
  terminal-device-optical transmit-power -120
  terminal-device-packet interface 0
   ip-address v4 10.2.1.11/31
  !
 !
!
```

How NSO Routed Optical Networking ML service works

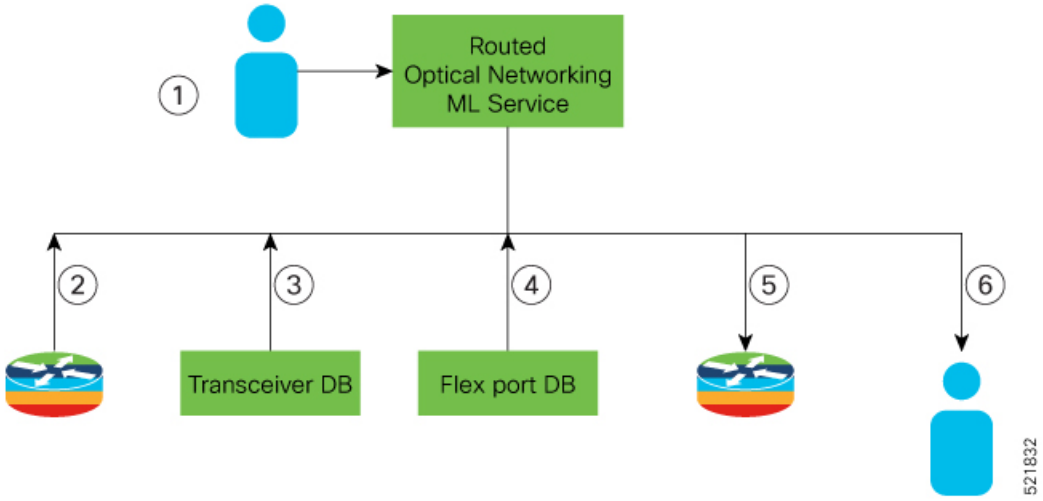
Summary

The Routed Optical Networking ML service performs several operations to provision an end-to-end service using Cisco routers with ZR or ZR+ optics.

Workflow

This diagram displays the NSO Routed Optical Networking ML service workflow for an end-to-end service using Cisco routers with ZR or ZR+ optics.

Figure 27: NSO Routed Optical Networking ML service sequence



These stages describe the workflow of the Routed Optical Networking ML service.

1. The user initiates the Routed Optical Networking ML provisioning request.
2. The Routed Optical Networking ML service retrieves the transceiver and line card PIDs for each router endpoint using Routed Optical Networking CLI NED.
3. The Routed Optical Networking ML service compares the received transceiver PIDs and determines whether the transceivers can support the service.
4. The Routed Optical Networking ML service compares the received line card PIDs and determines whether the line cards require configuration.
5. The Routed Optical Networking ML service provisions the router optics ports. It optionally performs bundle and IP configuration using the Cisco YANG models.
6. The Routed Optical Networking ML service stores the service information as NSO operational data and also returns the service state to the user.

How Crosswork Hierarchical Controller provisions Routed Optical Networking circuit

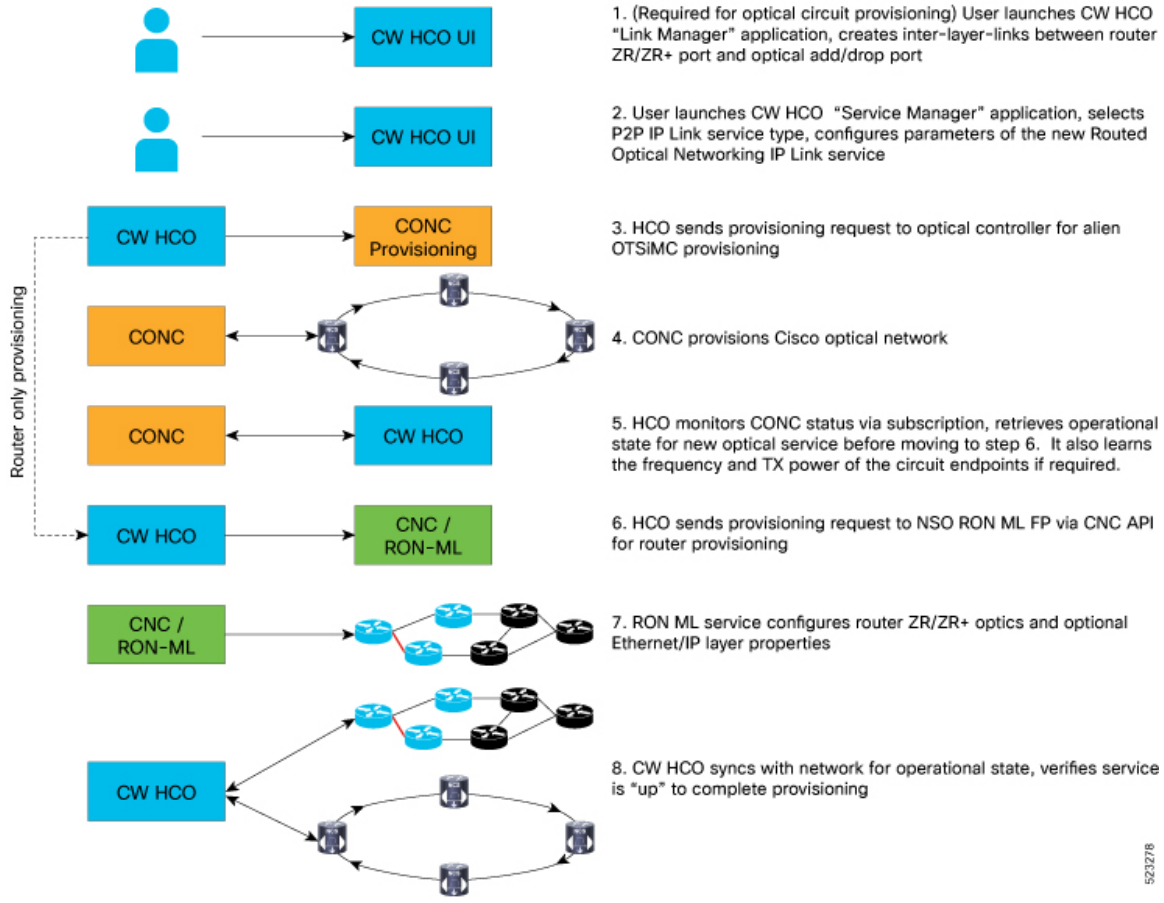
Summary

Crosswork Hierarchical Controller provisions the Routed Optical Networking circuit through several operations.

Workflow

The stages in the diagram describe the workflow for provisioning the Routed Optical Networking circuit in the Crosswork Hierarchical Controller GUI through the Crosswork Network Controller.

Figure 28: Crosswork Hierarchical Controller provisioning workflow



Note The workflow does not support provisioning a complete end-to-end service in a network that contains Cisco routers with ZR or ZR+ optics and a non-Cisco optical line system.

Automation starter solution and full solution

Automation starter solution

The automation starter solution is a simplified automation stack to manage ZR and ZR+ optics in Cisco routers. This solution accelerates the adoption of Routed Optical Networking by simplifying the installation and deployment processes.

The primary difference between the starter and full solutions is that the starter solution lacks CNC. In the starter solution, the Crosswork Hierarchical Controller communicates with Cisco routers using the IOS XR (only in R3.0) and NSO adapters, and communicates with optical networks using the appropriate optical controller adapter.

Both the starter and full solutions use the same NSO RON-ML function pack. The function pack version is 3.0

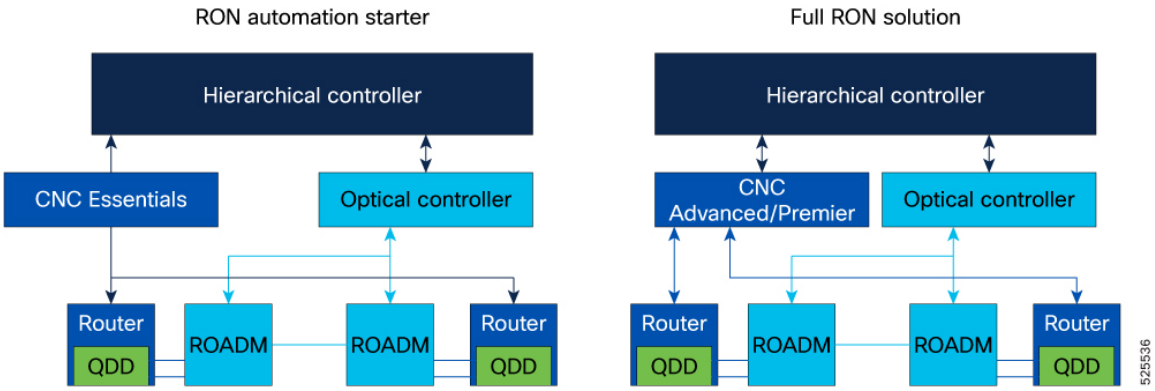
From Release 4.0, IOS XR adapter is not supported in the starter solution. Crosswork Network Controller EMS provides minimal installation to support full IP network inventory, basic topology, and PM data delivered through its integrated Crosswork Data Gateway.

From Release 4.0, IOS XR adapter is not supported in the full solution. Crosswork Network Controller provides the necessary inventory and state information to Crosswork Hierarchical Controller through NB API.

Automation starter solution versus full solution

This diagram displays the components that are involved in the automation starter solution and full solution.

Figure 29: Automation starter solution versus full solution in release 4.0



Features and adapters in automation starter solution and full solution

This table lists the features supported in both the automation starter solution and the full solution.

Table 13: Features in automation starter solution and full solution

Feature	Automation starter solution	Full solution
Wavelength provisioning	Yes	Yes
Optical circuit assurance and troubleshooting	Yes	Yes
Multilayer visualization and History view	Yes	Yes
Management and verification of optical to IP connections	Yes	Yes
SR and SRv6 control plane SDN automation	No	Yes
IP element management and IP SDN path optimization	No	Yes
IP service assurance and service orchestration	No	Yes

Feature	Automation starter solution	Full solution
PLE automation including SR-CS bandwidth reservation, provisioning, and assurance	No	Yes

This table lists the adapters required for both the automation starter solution and the full solution.

Table 14: Required adapters in automation starter solution and full solution

Type of solution	Required adapters	Use
Full solution	• CNC adapter • CDG adapter • (Only in R3.0) IOS-XR adapter • NSO adapter and RON-ML function pack • Optical adapters • CONC adapter	• Inventory, physical and IGP topology, segment routing, and service discovery • PM collection • RON inventory and topology • RON link provisioning • Optical Line System • Cisco Optical Network Controller
Starter solution	• (Only in R3.0) IOS-XR adapter • NSO adapter and RON-ML function pack • Optical adapters • CONC adapter	• RON inventory and topology • RON link provisioning • Optical Line System • Cisco Optical Network Controller

How communication works in automation starter solution

Summary

The components of Routed Optical Networking perform operations to communicate in the automation starter solution.

Workflow

This diagram displays the communication workflow between the Routed Optical Networking components in the automation starter solution.

Troubleshoot provisioning issues on ZR or ZR+ optics

Follow these steps to troubleshoot provisioning issues on ZR or ZR+ optics.

Procedure

Step 1 Use the **show controllers optics** *R/S/I/P* or **show controllers coherentDSP** *R/S/I/P* command to check the controller state on the router.

Example:

```
RP/0/RP0/CPU0:ron-8201-1#show controllers optics 0/0/0/20
Thu Jun  3 15:34:44.098 PDT

 Controller State: Up

 Transport Admin State: In Service

 Laser State: On

 LED State: Green

 FEC State: FEC ENABLED

 Optics Status

         Optics Type:  QSFPDD 400G ZR
         DWDM carrier Info: C BAND, MSA ITU Channel=10, Frequency=195.65THz,
         Wavelength=1532.290nm

         Alarm Status:
         -------------
         Detected Alarms: None


         LOS/LOL/Fault Status:

         Alarm Statistics:

         -------------
         HIGH-RX-PWR = 0            LOW-RX-PWR = 0
         HIGH-TX-PWR = 0            LOW-TX-PWR = 4
         HIGH-LBC = 0               HIGH-DGD = 1
         OOR-CD = 0                 OSNR = 10
         WVL-OOL = 0                MEA  = 0
         IMPROPER-REM = 0
         TX-POWER-PROV-MISMATCH = 0
         Laser Bias Current = 0.0 %
         Actual TX Power = -7.17 dBm
         RX Power = -9.83 dBm
         RX Signal Power = -9.18 dBm
         Frequency Offset = 9 MHz
RP/0/RP0/CPU0:ron-8201-1#show controllers coherentDSP 0/0/0/20
Thu Jun  3 15:38:04.565 PDT

Port                                          : CoherentDSP 0/0/0/20
Controller State                              : Up
Inherited Secondary State                     : Normal
Configured Secondary State                    : Normal
Derived State                                 : In Service
Loopback mode                                 : None
BER Thresholds                                : SF = 1.0E-5  SD = 1.0E-7
Performance Monitoring                        : Enable
Bandwidth                                     : 400.0Gb/s
```

```
Alarm Information:
LOS = 8 LOF = 0 LOM = 0
OOF = 0 OOM = 0 AIS = 0
IAE = 0 BIAE = 0        SF_BER = 0
SD_BER = 0      BDI = 0 TIM = 0
FECMISMATCH = 0 FEC-UNC = 0     FLEXO_GIDM = 0
FLEXO-MM = 0    FLEXO-LOM = 0   FLEXO-RDI = 0
FLEXO-LOF = 2
Detected Alarms                                 : None

Bit Error Rate Information
PREFEC  BER                                     : 1.5E-03
POSTFEC BER                                     : 0.0E+00
Q-Factor                                        : 9.40 dB

Q-Margin                                        : 2.20dB

OTU TTI Received

FEC mode                                        : C_FEC
```

Step 2 Use the **show controllers optics** *R/S/I/P* **pm** command or **show controllers coherentDSP** *R/S/I/P* **pm** command to gather the performance measurement data.

Example:

```
RP/0/RP0/CPU0:ron-8201-1#show controllers optics 0/0/0/20 pm current 30-sec optics 1
Thu Jun  3 15:39:40.428 PDT

Optics in the current interval [15:39:30 - 15:39:40 Thu Jun 3 2021]

Optics current bucket type : Valid
               MIN       AVG       MAX    Operational Configured TCA   Operational Configured TCA
                                           Th(min)     Th(min)    (min) Th(max)     Th(max)    (max)
LBC[% ]      : 0.0       0.0       0.0      0.0          NA        NO   100.0       NA          NO
OPT[dBm]     : -7.17     -7.17     -7.17    -15.09       NA        NO   0.00        NA          NO
OPR[dBm]     : -9.86     -9.86     -9.85    -30.00       NA        NO   8.00        NA          NO
CD[ps/nm]    : -489      -488      -488     -80000       NA        NO   80000       NA          NO
DGD[ps ]     : 1.00      1.50      2.00     0.00         NA        NO   80.00       NA          NO
SOPMD[ps^2]  : 28.00     38.80     49.00    0.00         NA        NO   2000.00     NA          NO
OSNR[dB]     : 34.90     35.12     35.40    0.00         NA        NO   40.00       NA          NO
PDL[dB]      : 0.70      0.71      0.80     0.00         NA        NO   7.00        NA          NO
PCR[rad/s]   : 0.00      0.00      0.00     0.00         NA        NO   2500000.00  NA          NO
RX_SIG[dBm]  : -9.23     -9.22     -9.21    -30.00       NA        NO   1.00        NA          NO
FREQ_OFF[Mhz]: -2        -1        4        -3600        NA        NO   3600        NA          NO
SNR[dB]      : 16.80     16.99     17.20    7.00         NA        NO   100.00      NA          NO
```

Example:

```
RP/0/RP0/CPU0:ron-8201-1#show controllers coherentDSP 0/0/0/20 pm current 30-sec fec
Thu Jun  3 15:42:28.510 PDT

g709 FEC in the current interval [15:42:00 - 15:42:28 Thu Jun 3 2021]

FEC current bucket type : Valid
    EC-BITS   : 20221314973            Threshold : 83203400000           TCA(enable)  : YES
    UC-WORDS  : 0                      Threshold : 5                     TCA(enable)  : YES

              MIN       AVG        MAX      Threshold      TCA     Threshold     TCA
                                              (min)     (enable)    (max)     (enable)
PreFEC BER  : 1.5E-03   1.5E-03   1.6E-03      0E-15        NO       0E-15        NO
PostFEC BER :  E-15     0E-15     0E-15      0E-15        NO       0E-15        NO
Q[dB]       : 9.40      9.40      9.40         0.00         NO        0.00        NO
Q_Margin[dB]: 2.20      2.20      2.20         0.00         NO        0.00        NO
```

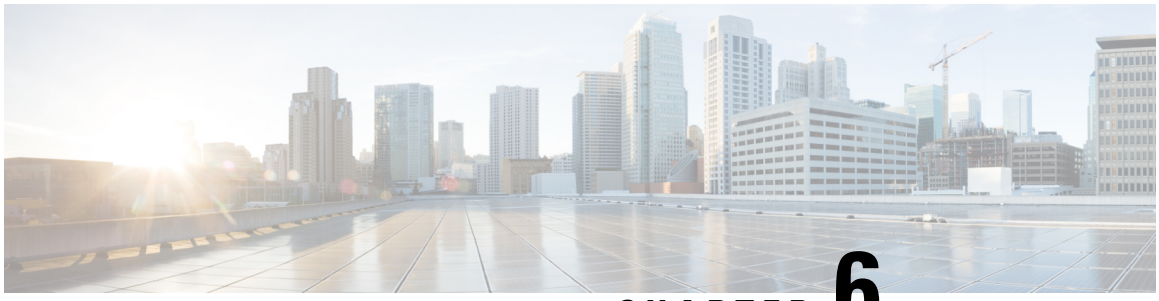
```
Last clearing of "show controllers OTU" counters never
```

This table contains the streaming telemetry sensor paths and the information fields that you receive from them.

Table 15: Telemetry sensor paths

Sensor path	Information fields
Cisco-IOS-XR-controller-optics-oper:optics-oper/optics-ports/optics-port/optics-info	alarm-detected, baud-rate, dwdm-carrier-frequency, controller-state, laser-state, optical-signal-to-noise-ratio, temperature, voltage
Cisco-IOS-XR-controller-optics-oper:optics-oper/optics-ports/optics-port/optics-lanes/optics-lane	receive-power, receive-signal-power, transmit-power
Cisco-IOS-XR-controller-otu-oper:otu/controllers/controller/info	bandwidth, ec-value, post-fec-ber, pre-fec-ber, qfactor, qmargin, uc
Cisco-IOS-XR-pmengine-oper:performance-management/optics/optics-ports/optics-port/optics-current/optics-second30/optics-second30-optics/optics-second30-optic	dd__average, dgd__average, opr__average, opt__average, osnr__average, pcr__average, pmd__average, rx-sig-pow__average, snr__average, sopmd__average
Cisco-IOS-XR-pmengine-oper:performance-management/otu/otu-ports/otu-port/otu-current/otu-second30/otu-second30fecs/otu-second30fec	ec-bits__data, post-fec-ber__average, pre-fec-ber__average, q__average, qmargin__average, uc-words__data

Note
The performance management sensor paths show the sensor path for a 30-second performance measurement (PM) interval. They also support 15 minutes and 24 hours. To access these options, replace `second30` in the sensor path with `minute15` and `hour24` respectively.



CHAPTER 6

PLE Service Configuration

- Private Line Emulation, on page 93
- How PLE works, on page 94
- Properties of circuit-style segment routing, on page 95
- Configure PLE over EVPN-VPWS, on page 98
- Verify PLE configurations, on page 118

Private Line Emulation

Private Line Emulation (PLE) is a pillar of the Routed Optical Networking solution. PLE allows non-Ethernet type services such as SONET/SDH, OTN, and Fiber Channel to be carried over the same MPLS or Segment Routing network. PLE also supports bit-transparent Ethernet services where required.

High-revenue and legacy private line services, carried over a dedicated inefficient TDM OTN layer, exist in the network infrastructure of most service providers. PLE enables service providers to carry SONET/SDH, OTN, Ethernet, and Fiber Channel over a circuit-style segment routed packet network while maintaining existing service SLAs. PLE utilizes Circuit Emulation (CEM) to transfer PLE client frames over MPLS or SR networks transparently, without changing the characteristics of the original signal.

Benefits of PLE

PLE enables service providers and enterprises to

- collapse network layers
- decrease network complexity, and
- increase network efficiency

Supported payloads

PLE supports these payloads.

Table 16: Supported payloads

PLE transport type	Supported payloads
Ethernet	1GE and 10GE

PLE transport type	Supported payloads
OTN	OTU2 and OTU2e
SONET	OC-48 and OC-192
SDH	STM-16 and STM-64
Fiber Channel	FC1, FC2, FC4, FC8, FC16, and FC32

The combination of payloads is also supported.

Supported hardware

PLE supports these hardware:

- NC55-OIP-02 MPA (Modular Port Adapter)

  This MPA is supported in the NC55A2-MOD-S and NC57C3-MOD-SYS routers. For more information, see Specifications of Cisco NCS 5500 series routers, on page 18.

- Cisco 8010 series router: PLE service endpoint router, on page 17

How PLE works

Summary

This process ensures the transparent transmission of client Layer 1 frames over a Packet Switched Network, maintaining the integrity and format of the original traffic.

Workflow

These stages describe how the PLE works.

1. Ethernet, OTN, Fiber Channel, SONET, or SDH PLE client traffic is carried on an EVPN-VPWS single-homed service that is created between PLE endpoints.
2. EVPN-VPWS signalling information is carried using BGP between the PLE circuit endpoints either through direct BGP sessions or through a BGP services route-reflector.
3. EVPN-VPWS pseudowire channel is set up between the endpoints when the CEM (Circuit Emulation) client interfaces are configured on each endpoint router and end-to-end transport connectivity using MPLS or Segment Routing transport is enabled.
4. CEM over a packet-switched network (PSN) places the client bit streams into packet payloads with appropriate pseudowire emulation headers.

   CEM is a method through which client data can be transmitted over MPLS or Segment Routing networks in a bit-transparent manner, retaining the client Layer 1 frame between sender and receiver.
5. The PLE initiator encapsulates the PLE client traffic and carries it using the EVPN-VPWS service, which runs on MPLS or Segment Routing transport.

6. The PLE terminator node extracts the bit streams from the EVPN-VPWS packets and places them onto the PLE client interfaces as defined by the client attribute and CEM profile.

Properties of circuit-style segment routing

Segment routing provides an architecture that caters to both IP-centric transport and connection-oriented transport. IP-centric transport uses the benefits of ECMP and automated protection from Topology-Independent Loop-Free Alternate (TI-LFA).

Connection-oriented transport, which was historically delivered over circuit-switched SONET/SDH networks, must require

- end-to-end bidirectional transport that provides congruent forward and reverse paths, predictable latency, and disjointness
- bandwidth commitment to ensure that there is no impact on the SLA due to network load from other services
- monitoring and maintenance of path integrity with end-to-end 50-millisecond path protection, and
- persistent end-to-end paths regardless of the state of the control plane.

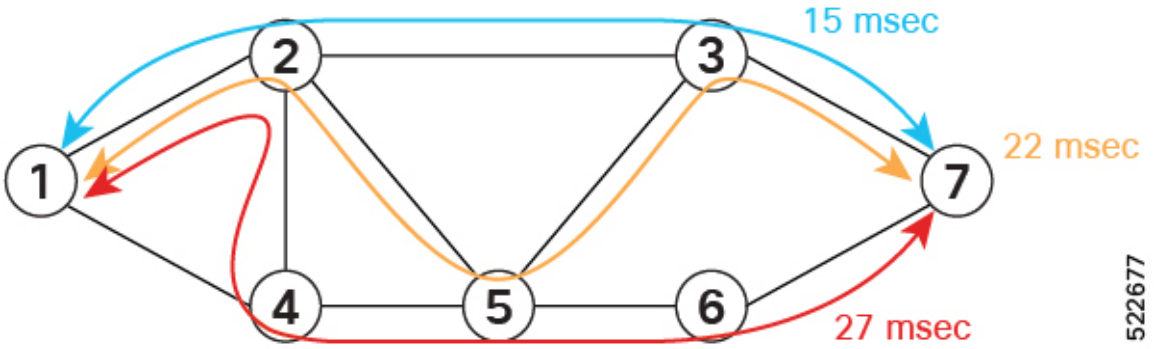
Properties of circuit-style segment routing policies

Circuit-style segment routing (CS-SR) policies provide these properties:

- Guaranteed latency over non-Equal-Cost Multi-Path (ECMP) paths
- Control-plane independent persistency
- Corouted bidirectional path
- Liveness monitoring with path protection switching
- Guaranteed bandwidth

Guaranteed latency over non-ECMP paths

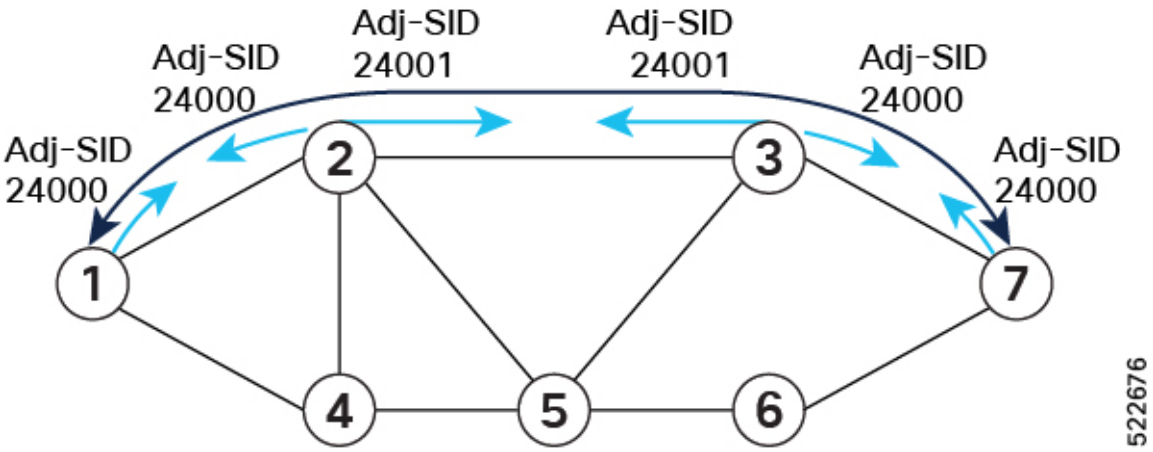
Consider this network with three possible paths from node 1 to node 7. Of the three paths, the best end-to-end delay is provided by the blue path (1 -> 2 -> 3 -> 7). The chosen path is then encoded with adjacency SIDs corresponding to the traversed interfaces to avoid any ECMP. This approach guarantees latency over the path.



Control-plane independent persistency

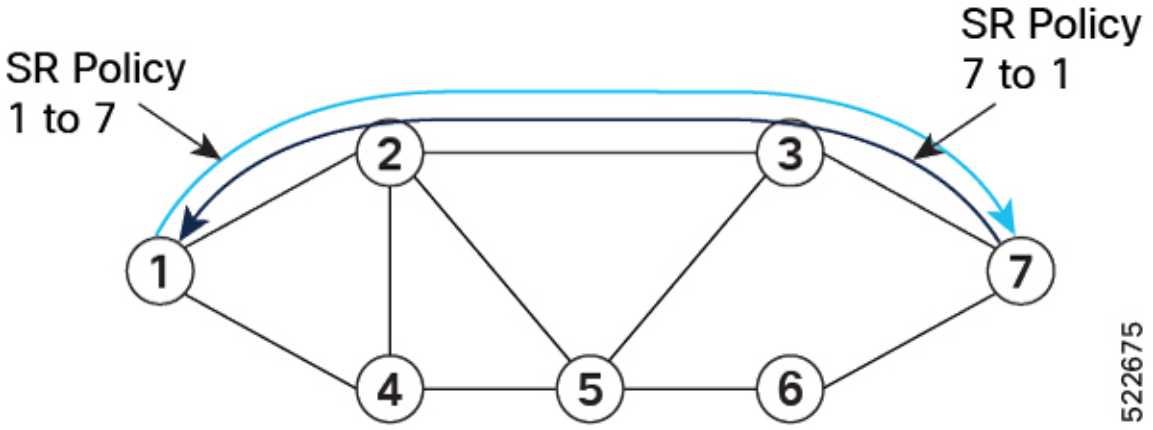
Adjacency SIDs can provide a persistent path independent from control-plane changes such as IGP neighbor flaps and network events such as interface additions, interface flaps, or even the presence of IP on an interface. To achieve this, manually allocate adjacency SIDs to ensure persistent values. For example, this applies after a node reload event. You can also program adjacency SIDs as non-protected to avoid local TI-LFA protection.

The path from node 1 to node 7 is encoded with the segment list of {24000, 24001, 24000} with the adjacency SIDs depicted in this figure. You can encode the path from node 7 to node 1 with the same segment list: {24000, 24001, 24000} by manually allocating the same adjacency SID values for the other direction.



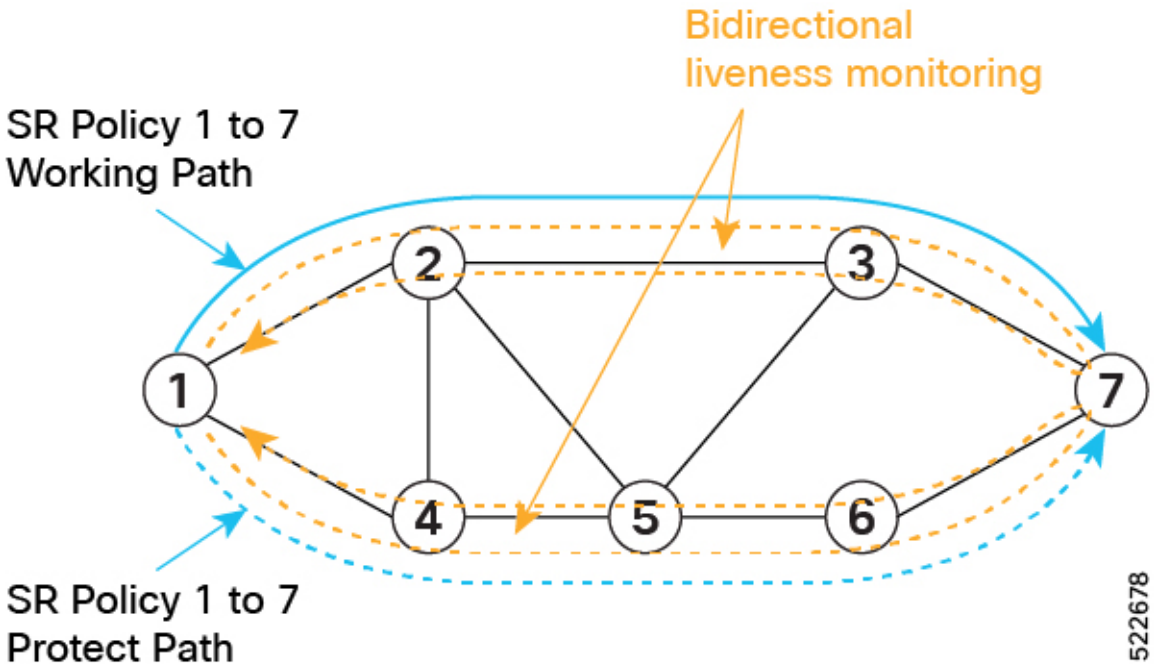
Corouted bidirectional path

Forward and return segment routing policies with congruent paths are routed along the same nodes.



Liveness monitoring with path protection switching

Bidirectional liveness monitoring on the working and protect paths ensures fast and consistent switchover. The protect path is pre-programmed over disjoint facilities.



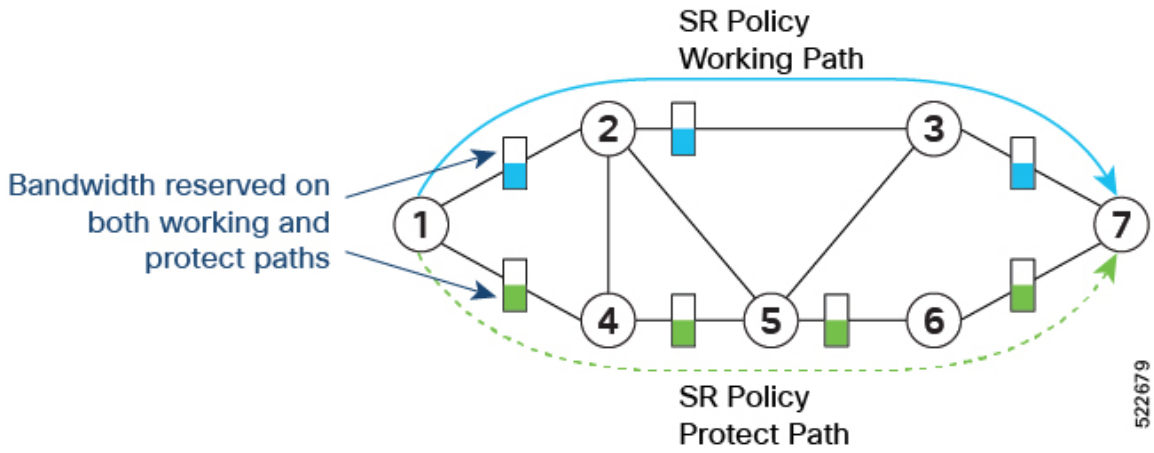
Guaranteed bandwidth

Most services carried over CS-SR policies are constant-rate traffic streams. Any packet loss due to temporary congestion leads to bit errors at the service layer. To prevent this, bandwidth must be tightly managed and guaranteed to the services mapped to CS-SR policies.

A centralized controller manages the bandwidth reservation. The controller maintains the reserved bandwidth on each link based on the requested bandwidth by performing these actions:

- Monitors the amount of traffic
- Uses knowledge of the active path used by the policy
- Computes the per-link reservable bandwidth

Bandwidth is reserved on both the working and protect paths.



Usage guidelines and limitations

- Candidate path (CP) behavior:
  - The working path has the highest CP preference value.
  - The protect path has the second highest CP preference value.
  - The restore path has the lowest CP preference value and is configured as "backup ineligible."
  - Paths with the same role in both directions—working, protect, and restore—must have the same CP preference value.
- Bidirectional path behavior:
  - All paths must be configured as corouted.
  - All paths with the same role in both directions (working, protect, and restore) must have the same bidirectional association ID value.
  - The bidirectional association ID value must be globally unique.

Configure PLE over EVPN-VPWS

Configuring PLE over the EVPN-VPWS service procedure involves these tasks:

1. Enable frequency synchronization, on page 98
2. Configure optics controller with payloads, on page 99
3. Configure a QoS policy, on page 100
4. Configure CEM interface for L2VPN service, on page 101
5. Configure performance measurement, on page 101
6. Configure segment routing adjacency SIDs, on page 102
7. Define paths between PLE endpoints, on page 103
8. Configure static circuit-style SR-TE policies, on page 106
9. Configure PLE over EVPN-VPWS, on page 117

See the Private Line Emulation over EVPN-VPWS Single Homed section for pre-requisites and other details.

Enable frequency synchronization

Use this task to synchronize clocks between Provider Edge 1 (PE1) and Provider Edge 2 (PE2) routers.

Procedure

Step 1 Enter these commands to enable frequency synchronization on PLE-PE1.

Example:

```
Router(config)# frequency synchronization
Router(config-freqsync)# quality itu-t option 1
Router(config-freqsync)# exit
Router(config)# interface TwentyFiveGigE0/0/0/24
Router(config-if)# frequency synchronization
Router(config-if-freqsync)# quality transmit exact itu-t option 1 PRC
```

Step 2 Enter the **show frequency synchronization interfaces** command to verify that the clock signal is being transmitted.

Step 3 Enter these commands to enable frequency synchronization on PLE-PE2.

Example:

```
Router(config)# frequency synchronization
Router(config-freqsync)# quality itu-t option 1
Router(config-freqsync)# exit
Router(config)# interface TwentyFiveGigE0/0/0/32
Router(config-if)# frequency synchronization
Router(config-if-freqsync)# selection input
Router(config-if-freqsync)# priority 1
Router(config-if-freqsync)# wait-to-restore 0
```

Step 4 Enter the **show frequency synchronization selection** command to verify that PLE-PE2 is locked to the clock of PLE-PE1.

You have synchronized the clocks between PE1 and PE2 routers.

Configure optics controller with payloads

Use this task to configure the optics controller to support various payload types.

Each port on the NC55-OIP-2 (PID of PLE Modular Port Adapter) can be configured independently for a specific PLE transport type. Use the **port-mode** command under the optics controller to perform this configuration.

For more information about all the supported payloads, see the Private Line Emulation, on page 93 section.

Procedure

Step 1 Enter these commands to configure the optics controller with Ethernet payload.

Example:

```
Router(config)# controller Optics0/0/3/1
Router(config-Optics)# port-mode Ethernet framing cem-packetize rate 10GE
```

The **port-mode** command has several parameters:

- PLE transport type: Choose Ethernet, OTN, SONET, SDH, or Fibre Channel.
- Framing: Set to **cem-packetize** to specify a PLE CEM configuration. This parameter is required.
- Rate: Configure the specific payload.

Step 2 Enter these commands to configure the optics controller with OTN payload.

Example:

```
Router(config)# controller Optics0/0/3/2
Router(config-Optics)# port-mode otn framing cem-packetize rate otu2
```

Step 3 Enter these commands to configure the optics controller with SONET payload.

Example:

```
Router(config)# controller Optics0/0/3/3
Router(config-Optics)# port-mode sonet framing cem-packetize rate OC48
```

Step 4 Enter these commands to configure the optics controller with SDH payload.

Example:

```
Router(config)# controller Optics0/0/3/4
Router(config-Optics)# port-mode sdh framing cem-packetize rate STM16
```

Step 5 Enter these commands to configure the optics controller with Fiber Channel payload.

Example:

```
Router(config)# controller Optics0/0/3/5
Router(config-Optics)# port-mode FC framing cem-packetize rate FC1
```

The optics controller is configured with different payloads.

Configure a QoS policy

Use this task to configure a QoS policy that prioritizes PLE traffic. QoS policy configuration is recommended to prevent high-priority PLE traffic from being dropped during network congestion.

Procedure

Step 1 Enter the **policy-map ple-policy** command to define the parent QoS policy to be applied to the CEM interface to prioritize the PLE traffic.

Example:

```
Router(config)# policy-map ple-policy
```

Step 2 Enter the **class class-default** command to specify the default class.

Example:

```
Router(config)# class class-default
```

A PLE service has only one traffic flow type. Therefore, the default class is used to match all the ingress packets on the PLE CEM interface.

Step 3 Enter the **set traffic-class** *traffic-class-number* command to specify the traffic class.

Example:

```
Router(config)# set traffic-class 6
```

Cisco NCS 5500 and NCS 5700 platforms use the traffic class to identify specific traffic flows within the router and to determine egress treatment. In this example, ingress traffic is set to traffic class 6. The egress QoS policy matches traffic class 6 to set the appropriate queuing behavior. This value is used as an example; it must be set to the high priority EXP value used across the network. The egress QoS policy is outside the scope of this guide. For details, see *Modular QoS Configuration Guide for Cisco NCS 5500 Series Routers*.

Step 4 Enter the **set mpls experimental topmost** *mpls-exp-value* command to set the topmost MPLS EXP (TC) value.

Example:

```
Router(config)# set mpls experimental topmost 6
```

The MPLS EXP (TC) value can be used at subsequent nodes in the path to classify PLE traffic and set appropriate queuing behavior. This value is used as an example; it must be set to the high priority EXP value used across the network.

You have configured the QoS policy.

Configure CEM interface for L2VPN service

Use this task to configure the CEM interface for the L2VPN EVPN-VPWS service.

Procedure

Step 1 Enter the **interface CEM** command to configure the appropriate CEM interface.

Example:

```
Router(config)# interface CEM0/0/3/1
```

Step 2 Enter the **l2transport** command to enable the CEM interface to be used in a L2VPN EVPN-VPWS service.

Example:

```
Router(config-if)# l2transport
```

Configure performance measurement

Use this task to configure performance measurement for enabling liveness monitoring of the Segment Routing policy.

Procedure

Step 1 Enter the **performance-measurement** command to enter the performance measurement configuration mode.

Example:

```
Router(config)# performance-measurement
```

Step 2 Enter the **liveness-profile name liveness-check** command to create a SR Policy liveness profile.

Example:

```
Router(config-perf-meas)# liveness-profile name liveness-check
```

Step 3 Enter the **liveness-detection multiplier** *multiplier-value* command to configure liveness detection parameters. This command sets the number of missed liveness probes to determine whether the SR Policy is down.

Example:

```
Router(config-perf-meas)# liveness-detection multiplier 3
```

Step 4 Enter the **probe** command to enter the probe parameter configuration mode.

Example:

```
Router(config-pm-ld-srpolicy)# probe
```

Note
The probe measurement mode is set to loopback by default. In this mode, the probe packets from the sender node are looped back to the sender node to test end-to-end liveness.

Step 5 Enter the **tx-interval** *interval-value* command to set the interval of probe packets that are sent by the sender.

Example:

```
Router(config-pm-ld-srpolicy-probe)# tx-interval 30000
```

The interval value is set in microseconds. In this example, it is set to 30 seconds.

Note
Using a **tx-interval** value lower than 30 seconds requires hw-offload support. NCS-55A2-MOD supports this in R7.9.1.

Step 6 Enter the **tos dscp** *dscp-value* command to set the Differentiated Services Code Point (DSCP) value on the probe packets to the specified DSCP.

Example:

```
Router(config-pm-ld-srpolicy-probe)# tos dscp 48
```

In this example, the DSCP value is 48. You must set the DSCP value to the appropriate QoS setting on the provider network so that the liveness probe packets are treated as high priority.

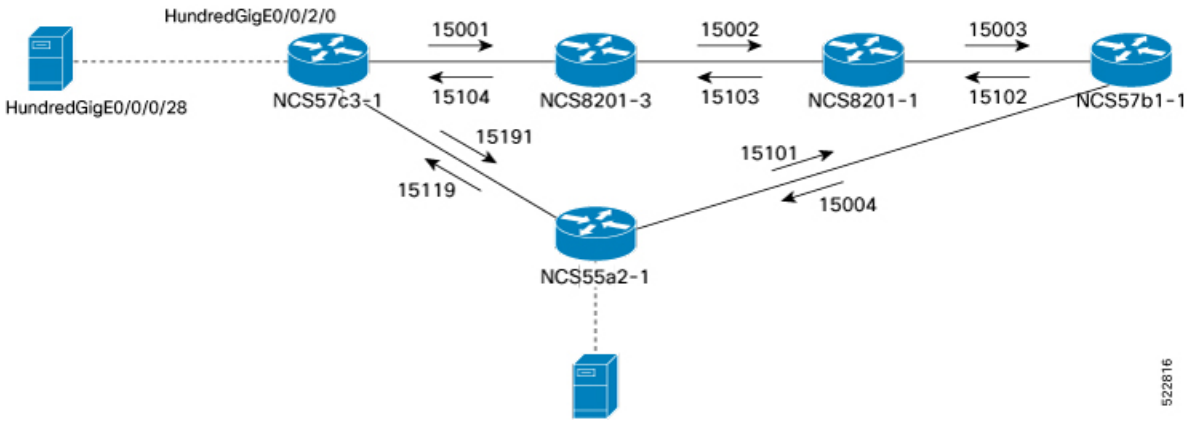
Performance measurement and liveness monitoring are enabled for the Segment Routing policy.

Configure segment routing adjacency SIDs

Adjacency SIDs are unidirectional. They define the explicit path between endpoints. Configure adjacency SIDs on each interface that participates in the SR policy path.

This figure shows the SR adjacency SIDs configured between routers.

Figure 30: Segment routing adjacency SIDs



Use this task to configure segment routing adjacency Segment Identifiers (SIDs), enabling precise control over packet forwarding paths at the link level within a segment routing-enabled network.

Procedure

Step 1 Enter the **router isis** command to enter the IS-IS configuration mode for the appropriate instance.

Example:

```
Router(config)# router isis core
```

Step 2 Enter the **interface** *controller-type rack/slot/instance/port* command to configure the specific IS-IS interface.

Example:

```
Router(config-isis)# interface HundredGigE0/0/2/0
```

Step 3 Enter the **address-family ipv4 unicast** command to enter the IPv4 address family configuration if MPLS segment routing is used.

Example:

```
Router(config-isis)# address-family ipv4 unicast
```

Step 4 Enter the **adjacency-sid absolute** *adjacency-sid-value* command to configure a persistent SR adjacency SID on the interface.

Example:

```
Router(config-isis-if-af)# adjacency-sid absolute 15001
```

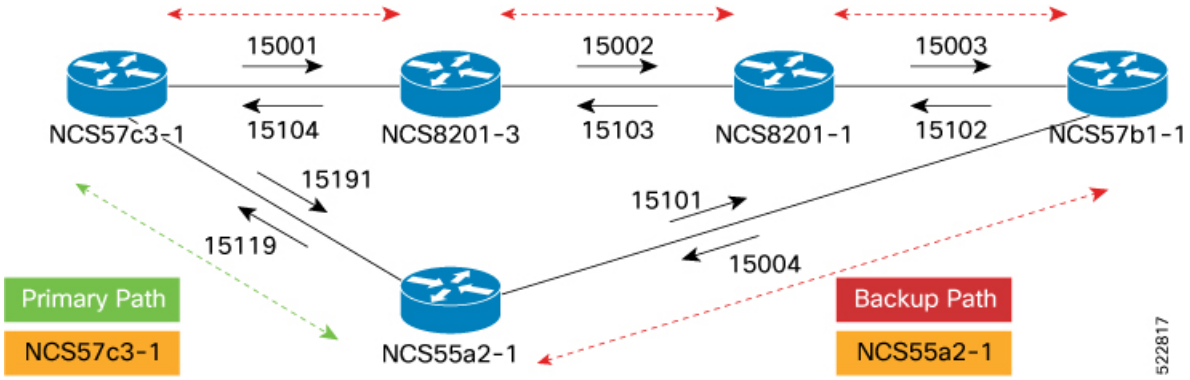
The adjacency SID value must be assigned from the Segment Routing Local Block (SRLB) of the router. The default SRLB range in IOS XR is 15,000 to 15,999. Configure other SR adjacency SIDs as appropriate.

Define paths between PLE endpoints

Use this task to define network paths between PLE endpoints, enabling reliable and optimized connectivity for PLE services.

Note Use this task only with static circuit-style SR-TE policies.

Figure 31: Working and reverse path definitions



Configure the NCS57C3-1 router to set the working forward path according to the illustration. The working forward path is a single hop between directly connected routers.

Procedure

Step 1 Enter the **segment-routing** command to enter segment routing configuration mode.

Example:

```
Router(config)# segment-routing
```

Step 2 Enter the **traffic-engineering** command to enter segment routing TE configuration.

Example:

```
Router(config-sr)# traffic-engineering
```

Step 3 Enter the **segment-list** *working-forward-path* command to create segment list named *working-forward-path*.

Example:

```
Router(config-sr-te)# segment-list working-forward-path
```

Step 4 Enter the **index** command to set the index to the first hop interface adjacency SID.

Example:

```
Router(config-sr-te-sl)# index 1 mpls label 15191
```

The working and protection paths are defined for the selected PLE endpoints.

Example

Configure the NCS57C3-1 router to define all the paths between PLE endpoints according to the illustration. The working forward path is a single hop between directly connected routers. The working reverse path is a single hop between directly connected routers. The protect forward path has four interface hops between the near-end and far-end router. The protect reverse path has four interface hops between the near-end and far-end router.

```
Router(config)# segment-routing

Router(config-sr)# traffic-engineering
Router(config-sr-te)# segment-list working-forward-path
Router(config-sr-te-sl)# index 1 mpls label 15191
!
Router(config-sr-te)# segment-list working-reverse-path

Router(config-sr-te-sl)# index 1 mpls label 15119
!
Router(config-sr-te)# segment-list protect-forward-path
Router(config-sr-te-sl)# index 1 mpls label 15001
Router(config-sr-te-sl)# index 2 mpls label 15002
Router(config-sr-te-sl)# index 3 mpls label 15003
Router(config-sr-te-sl)# index 4 mpls label 15004
!
Router(config-sr-te)# segment-list protect-reversepath
Router(config-sr-te-sl)# index 1 mpls label 15101
Router(config-sr-te-sl)# index 2 mpls label 15102
Router(config-sr-te-sl)# index 3 mpls label 15103
Router(config-sr-te-sl)# index 4 mpls label 15104
```

Configure the NCS55A2-1 router to define all the paths between PLE endpoints according to the illustration.

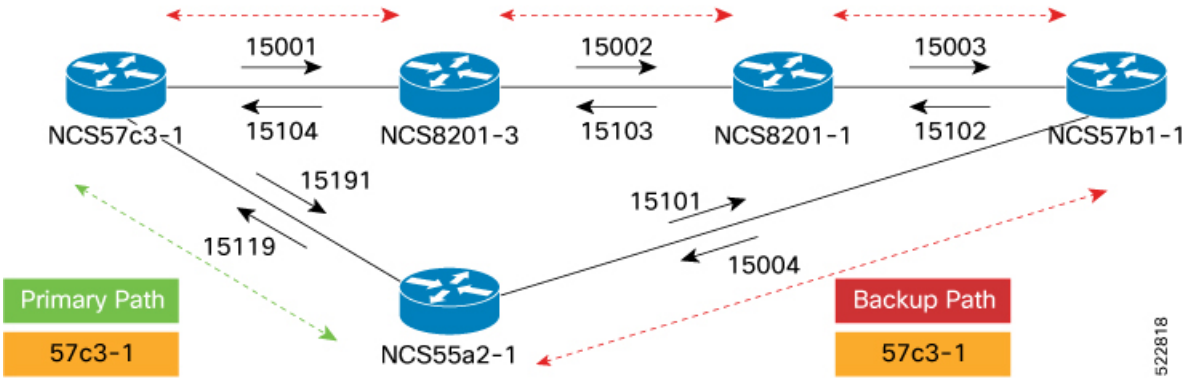
```
Router(config)# segment-routing

Router(config-sr)# traffic-engineering
Router(config-sr-te)# segment-list working-forward-path
Router(config-sr-te-sl)# index 1 mpls label 15119
!
Router(config-sr-te)# segment-list working-reverse-path
Router(config-sr-te-sl)# index 1 mpls label 15191
!
Router(config-sr-te)# segment-list protect-forward-path
Router(config-sr-te-sl)# index 1 mpls label 15101
Router(config-sr-te-sl)# index 2 mpls label 15102
Router(config-sr-te-sl)# index 3 mpls label 15103
Router(config-sr-te-sl)# index 4 mpls label 15104
!
Router(config-sr-te)# segment-list protect-reversepath
Router(config-sr-te-sl)# index 1 mpls label 15001
Router(config-sr-te-sl)# index 2 mpls label 15002
Router(config-sr-te-sl)# index 3 mpls label 15003
Router(config-sr-te-sl)# index 4 mpls label 15004
```

Configure static circuit-style SR-TE policies

Use this task to configure static circuit-style Segment Routing Traffic Engineering (SR-TE) policies, enabling predefined and predictable traffic paths within the network.

Figure 32: Segment routing traffic engineering policy



Configure the NCS57C3-1 router.

Before you begin

Static circuit-style SR-TE policies require IOS XR R7.7.1 or later software.

Procedure

Step 1 Enter the segment routing traffic engineering configuration mode.

Example:

```
Router(config)# segment-routing
Router(config-sr)# traffic-engineering
```

Step 2 Enter the **policy** *policy-name* command to create a SR-TE policy.

Example:

```
Router(config-sr-te)# policy to-55a2-1
```

Step 3 Enter the **color** *color* **end-point ipv4** *loopback-address* command to configure the SR-TE policy with the user-defined color and loopback address of the remote PLE far-end router.

Example:

```
Router(config-sr-te-policy)# color 1001 end-point ipv4 10.0.0.44
```

Step 4 Enter the **path-protection** command to enable path protection on the SR-TE policy.

Example:

```
Router(config-sr-te-policy)# path-protection
```

When path protection is configured, the near-end router keeps the protect path in a warm standby state. This allows it to quickly transition to the protect path if the working path is down.

Step 5 Enter the **candidate-paths** command to configure the SR working and protect candidate paths.

Example:

```
Router(config-sr-te-policy)# candidate-paths
```

Step 6 Enter the **preference** *preference-value* command to set the user-defined preference on the protect path.

Example:

```
Router(config-sr-te-policy-path)# preference 50
```

Paths with higher preference values are chosen over those with lower preference values.

Note
You must always set the protect path with a lower preference value.

Step 7 Enter the **explicit segment-list** command to configure the candidate path to use an explicit segment list.

Example:

```
Router(config-sr-te-policy-path-pref)# explicit segment-list protect-forward-path
```

The policy uses the previously defined *protect-forward-path* explicit segment list.

Step 8 Enter the **reverse-path segment-list** command to configure the reverse path to ensure that the SR-TE policy uses a corouted bidirectional path.

Example:

```
Router(config-sr-te-policy-path-pref)# reverse-path segment-list protect-reverse-path
```

The policy uses the previously defined *protect-reverse-path* explicit segment list.

Configure the higher-priority working path similar to the protect path using these commands:

```
Router(config-sr-te-policy-path)# preference 100
Router(config-sr-te-policy-path-pref)# explicit segment-list working-forward-path
Router(config-sr-te-policy-path-pref)# reverse-path segment-list working-reverse-path
```

Step 9 Configure a user-defined liveness policy.

Example:

```
Router(config)# performance-measurement
Router(config-perf-meas)# liveness-detection
Router(config-perf-meas)# liveness-profile name liveness-check
```

The policy uses the previously defined liveness profile named *liveness-check*.

Example

Configure the NCS55A2-1 router.

```
Router(config)# segment-routing
Router(config-sr)# traffic-eng
Router(config-sr-te)# policy to-57c3-1
Router(config-sr-te-policy)# color 1001 end-point ipv4 10.0.0.42
Router(config-sr-te-policy)# path-protection
Router(config-sr-te-policy)# candidate-paths
```

```
Router(config-sr-te-policy-path)# preference 50
Router(config-sr-te-policy-path-pref)# explicit segment-list protect-forward-path
Router(config-sr-te-policy-path-pref)# reverse-path segment-list protect-reverse-path
Router(config-sr-te-policy-path)# preference 100
Router(config-sr-te-policy-path-pref)# explicit segment-list working-forward-path
Router(config-sr-te-policy-path-pref)# reverse-path segment-list working-reverse-path
Router(config)# performance-measurement
Router(config-perf-meas)# liveness-detection
Router(config-perf-meas)# liveness-profile name liveness-check
```

Configure dynamic circuit-style SR-TE policies without bandwidth CAC

Use this task to configure dynamic circuit-style Segment Routing Traffic Engineering (SR-TE) policies without enabling bandwidth Call Admission Control (CAC), allowing for flexible path selection without bandwidth reservation constraints.

Before you begin

Dynamic circuit-style SR-TE policies without bandwidth CAC require this software:

- IOS XR R7.8.1 or later
- SR-PCE 7.8.1 or later

Procedure

Step 1 Enter the segment routing traffic engineering configuration mode.

Example:

```
Router(config)# segment-routing
Router(config-sr)# traffic-engineering
```

Step 2 Enter the **policy** *policy-name* command to create a SR-TE policy.

Example:

```
Router(config-sr-te)# policy to-55a2-1
```

Step 3 Enter the **color** *color* **end-point ipv4** *loopback-address* command to configure the SR-TE policy with the user-defined color and loopback address of the remote PLE far-end router.

Example:

```
Router(config-sr-te-policy)# color 119 end-point ipv4 10.0.0.44
```

Step 4 Enter the **path-protection** command to enable path protection on the SR-TE policy.

Example:

```
Router(config-sr-te-policy)# path-protection
```

When path protection is configured, the near-end router keeps the protect path in a warm standby state. This allows it to quickly transition to the protect path if the working path is down.

Step 5 Enter the **candidate-paths dynamic pcep** command to configure the SR working, protect, and restoration candidate paths.

Example:

```
Router(config-sr-te-policy)# candidate-paths dynamic pcep
```

The **candidate-paths** parameter is set to **dynamic->pcep** to enable SR-PCE delegation. The dynamic computation uses standard metrics, including traffic engineering, IGP, and latency.

Step 6 Enter the **preference** *preference-value* command to set the user-defined preference on the protect path.

Example:

```
Router(config-sr-te-policy-path)# preference 50
```

Paths with higher preference values are chosen over those with lower preference values.

Note
You must always set the protect path with a lower preference value.

A third candidate path with a preference lower than 100 can be defined as a restoration path. This path is not pre-signaled and must be configured with **backup-ineligible**. While the restoration path does not have a disjoint-path ID, it uses a bidirectional association ID that matches the reverse policy.

The **lock-duration** parameter determines the reversion behavior. When a higher-preference path becomes available, the policy switches to it after the lock-duration expires. By default, the lock-duration is set to 300 seconds. Setting the value to 0 disables dynamic reversion.

Step 7 Enter the **constraints segments protection** command to configure the protection behavior constraints of adjacency SID.

Example:

```
Router(config-sr-te-policy-path)# constraints segments protection {unprotected-only |
adjacency-sid-only}
```

Circuit-style uses the segments constraints of **unprotected-only** and **adjacency-sid-only**. If manual adjacency-SIDs are configured, they are used; otherwise, dynamic adjacency-SIDs are used. It is recommended to configure manual adjacency-SIDs.

Step 8 Enter the **disjoint-path group-id 10 type {link | node | srlg | srlg-node}** command to configure the disjoint-path constraints.

The **group-id** for the disjoint-path must be identical on both the active and backup paths. Additionally, the **group-id** must be unique among nodes that use the same SR-PCE

The co-routed association ID must be the same for both bidirectional active and backup paths.

Step 9 Configure a user-defined liveness policy.

Example:

```
Router(config)# performance-measurement
Router(config-perf-meas)# liveness-detection
Router(config-perf-meas)# liveness-profile name liveness-check
```

The policy uses the previously defined liveness profile named *liveness-check*.

This example configures the dynamic circuit-style SR-TE policy without bandwidth CAC.

```
policy dynamic-cs-srte-to-55a2-p2
   color 119 end-point ipv4 10.0.0.44
```

```
path-protection
!
candidate-paths
 preference 100
  dynamic
   pcep
   !
   metric
    type igp
   !
  !
  constraints
   segments
    protection unprotected-only
    adjacency-sid-only
   !
   disjoint-path group-id 10 type link
  !
  bidirectional
   co-routed
   association-id 101
  !
 !
 preference 200
  dynamic
   pcep
   !
   metric
    type igp
   !
  !
  lock
    duration 30
  !
  constraints
   segments
    protection unprotected-only
    adjacency-sid-only
   !
   disjoint-path group-id 10 type link
  !
  bidirectional
   co-routed
   association-id 201
  !
 !
 preference 50
  dynamic
   pcep
   !
   metric
    type igp
   !
  !
  backup-ineligible
  lock
    duration 60
  !
  constraints
   segments
    protection unprotected-only
    adjacency-sid-only
   !
  !
```

```
  bidirectional
   co-routed
   association-id 301
  !
 !
!
performance-measurement
 liveness-detection
  liveness-profile backup name CS-PROTECT
  liveness-profile name CS-WORKING
  invalidation-action down
```

Configure dynamic circuit-style SR-TE policies with bandwidth CAC

Use this task to configure dynamic circuit-style SR-TE policies with bandwidth Call Admission Control (CAC).

Dynamic PLE with bandwidth CAC is supported through Crosswork Network Controller. The bandwidth constraint is specified for the circuit-style policy. The Cisco Crosswork Optimization Engine application is included in Circuit Style Manager.

The circuit-style Segment Routing Traffic Engineering (CS SR-TE) feature pack provides a bandwidth-aware Path Computation Element (PCE) to compute CS SR-TE policy paths that you can visualize in your network. CS SR-TE policies guarantee allocated bandwidth services with predictable latency and persistent bidirectional path protection of critical traffic. CS SR-TE reserves a percentage of bandwidth in the network and computes bidirectional failover paths for CS SR-TE policies using the requested bandwidth.

Circuit Style Manager requires you to configure policies on each head-end node using matching association IDs, bandwidth values, constraints, computation type, and source and endpoint IP addresses.

Figure 33: Crosswork Optimization Engine—SR-PCE communication flow diagram

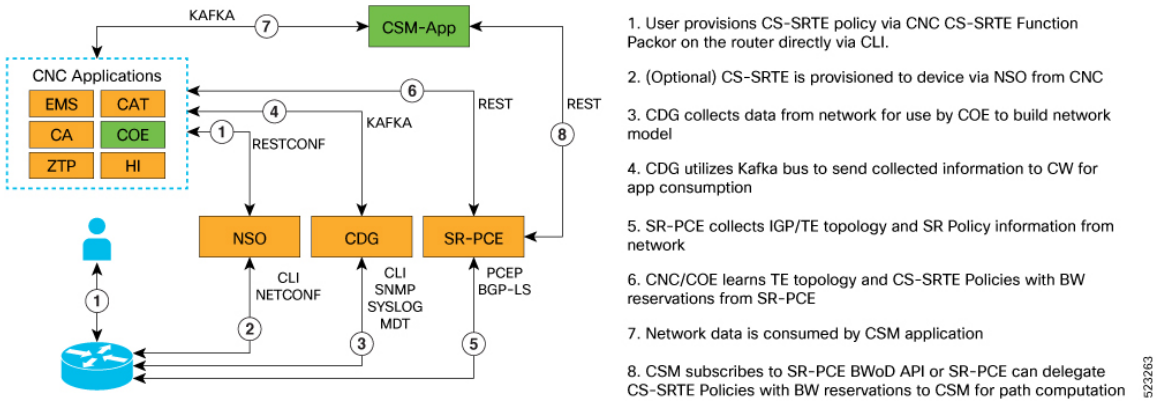
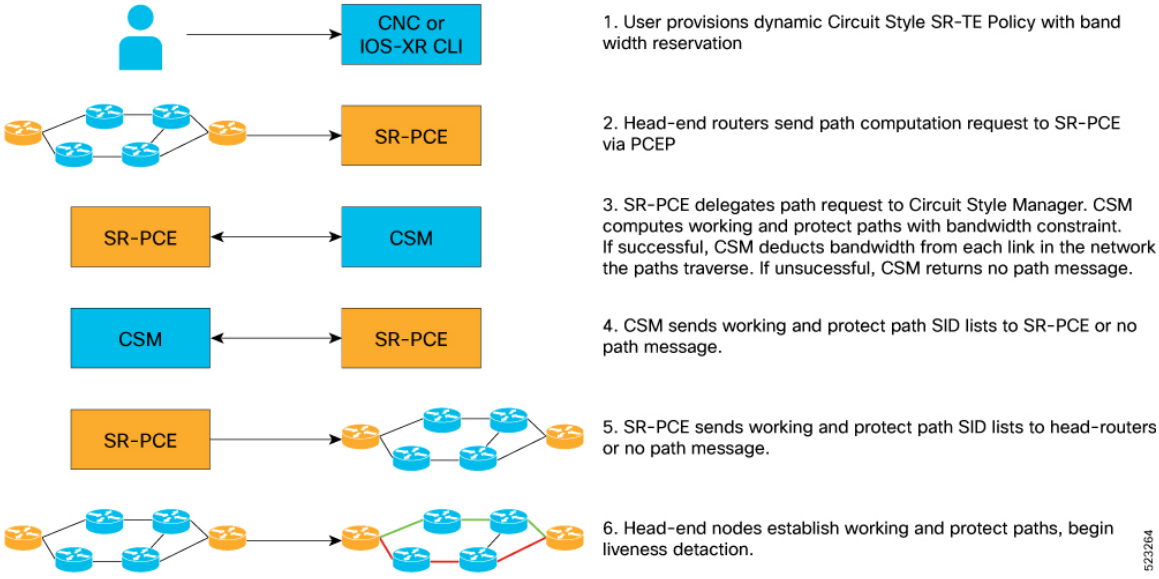


Figure 34: Crosswork Optimization Engine —SR-PCE call flow diagram



Before you begin

Dynamic circuit-style SR-TE policies with bandwidth CAC require this software:

- IOS XR R7.9.1 or later
- SR-PCE 7.9.1 or later
- Crosswork Optimization Engine 5.0 or later

Procedure

Step 1 Enable the circuit-style Segment Routing Traffic Engineering (CS SR-TE) feature pack.

Step 2 Configure CS SR-TE policies on the devices.

Step 3 Verify that the CS SR-TE policies appear in the SR Policy table.

Enable circuit-style SR-TE using Crosswork Network Controller

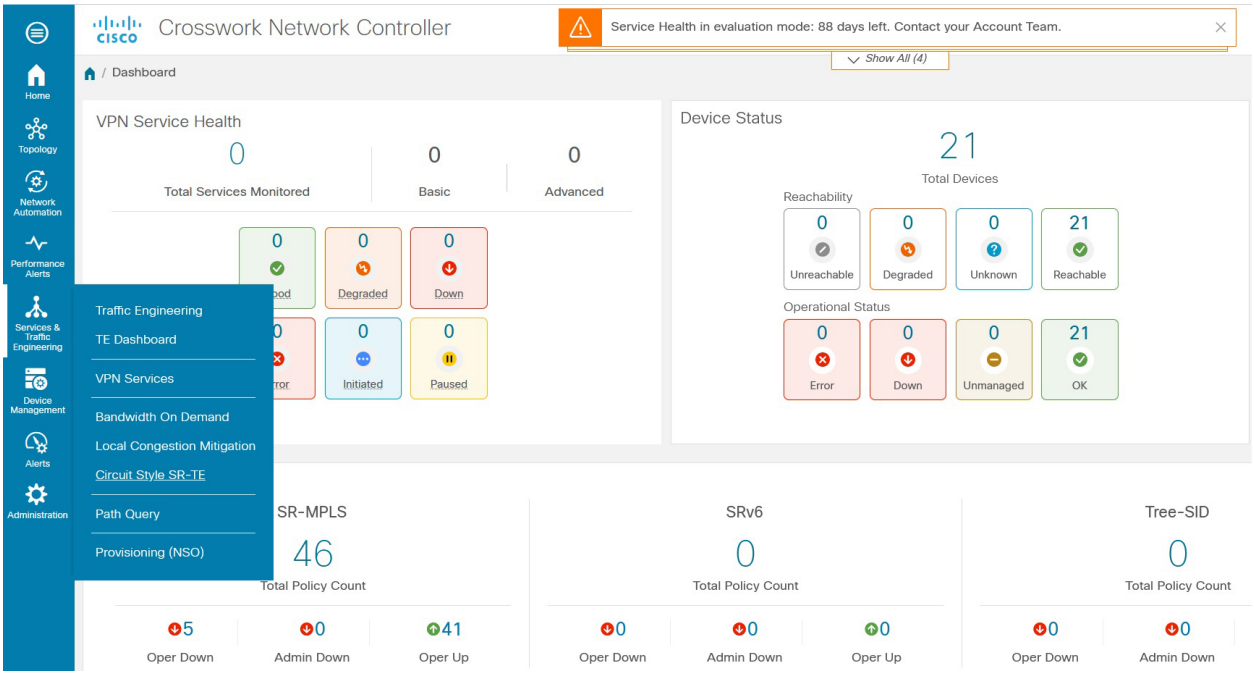
Use this task to enable circuit-style Segment Routing Traffic Engineering (CS SR-TE) policies using Cisco Crosswork Network Controller.

To manage and visualize CS-SR policies on the topology map, you must first enable CS SR-TE and set the bandwidth reservation settings.

When CS SR-TE is enabled, it computes the best failover bidirectional paths between the two nodes, using the requested bandwidth and other constraints defined in the CS SR-TE policy configuration.

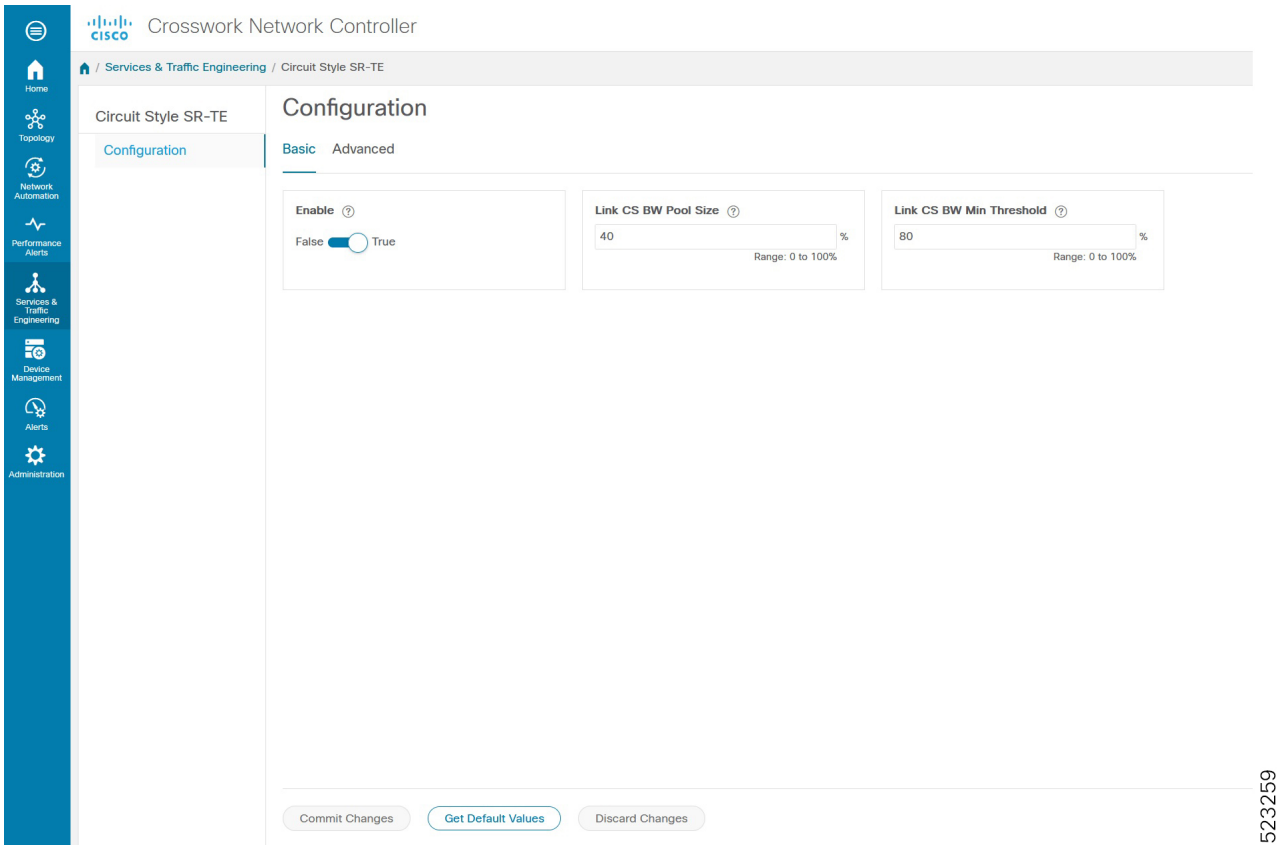
Procedure

Step 1 From the main menu, choose **Services & Traffic Engineering** > **Circuit Style SR-TE** > **Configuration** .



Step 2 Toggle the **Enable** switch to **True**.

Step 3 Enter the required bandwidth pool size and the threshold information.



Option	Description
Basic Pane	
Link CS BW Pool Size	The percentage of bandwidth that each link reserves for CS-SR policies.
Link CS BW Min Threshold	An alert is generated when the bandwidth utilization percentage on a link used for a CS-SR policy exceeds this value.
Advanced Pane	
Validation Interval	The interval that CS-SR policy will wait before the bandwidth that is reserved for an undelegated policy is returned to the CS-SR policy bandwidth pool.
Timeout	The duration until which CS-SR policy will wait for the delegation request, to generate a notification.
Restore Delegation Delay	The duration until which CS-SR policy will pause before processing a restore path delegation.

Step 4 Click **Commit Changes** to save the configuration.

View circuit-style SR-TE policy details using Crosswork Network Controller

Use this task to view details about circuit-style Segment Routing Traffic Engineering (CS SR-TE) policies using Cisco Crosswork Network Controller.

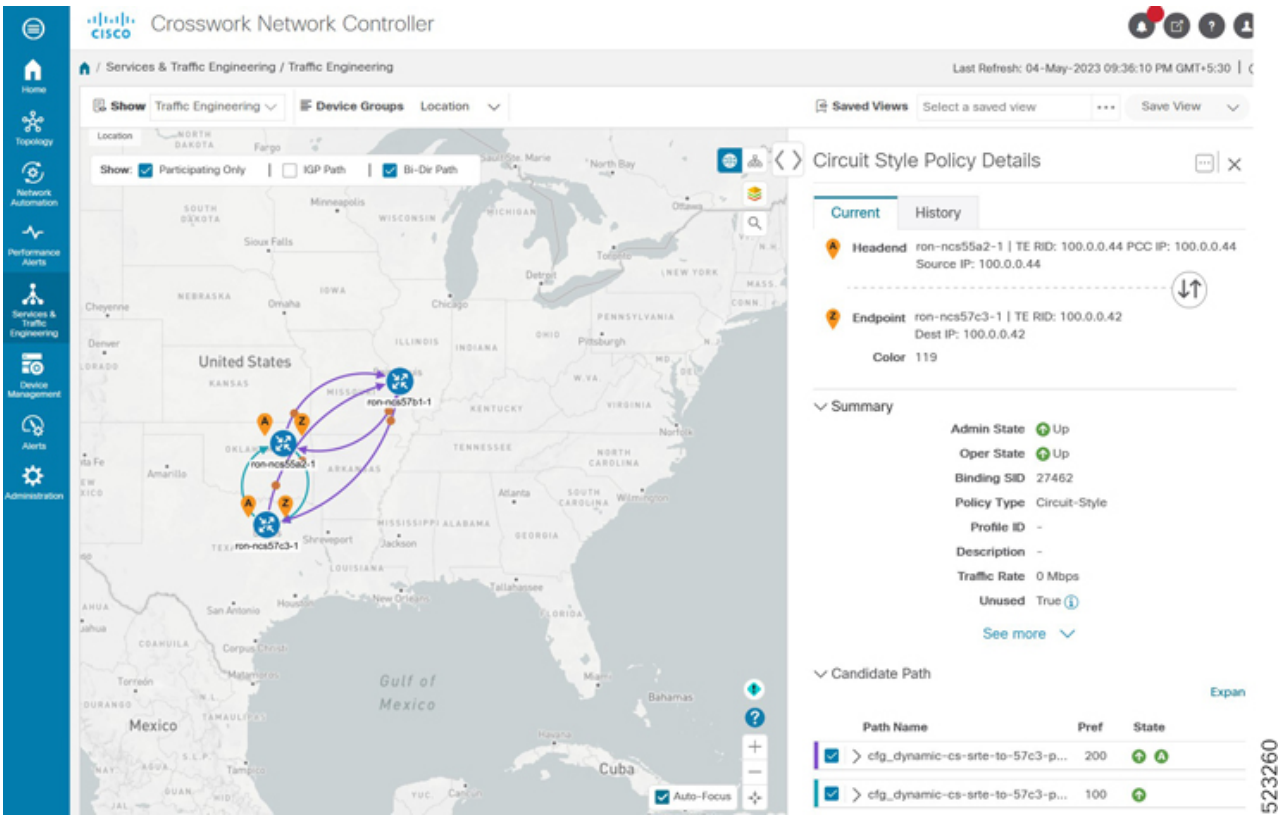
Procedure

Step 1 From the main menu, choose **Services & Traffic Engineering** > **SR-MPLS** and click **Circuit Style**.

The **SR Policy** table lists all the CS SR-TE policies.

Step 2 From the **Actions** column, click **View Details** for one of the CS SR-TE policies.

The **Circuit Style Policy Details** window is displayed in the side panel. By default, the active path is displayed and shows the bidirectional paths (**Bi-Dir Path** checkbox is selected) on the topology map.



If the bandwidth of a new policy exceeds bandwidth pool size, the policy goes down. The requested bandwidth is set to the configured bandwidth, but the reserved bandwidth becomes zero.

If an existing policy is configured with a bandwidth that exceeds the bandwidth pool size, the policy remains up, but the reserved bandwidth stays at its previous value.

The sample output displays a policy's requested bandwidth and current bandwidth.

```
RP/0/RP0/CPU0:ron-ncs57c3-1#show segment-routing traffic-eng policy color 119
Thu May 4 09:01:57.797 PDT
```

```
SR-TE policy database
---------------------

Color: 119, End-point: 10.0.0.44
Name: srte_c_119_ep_10.0.0.44
Status:
Admin: up Operational: up for 11:46:42 (since May 3 21:15:14.898)
Candidate-paths:
Preference: 200 (configuration) (active)
Name: dynamic-cs-srte-to-55a2-p2
Requested BSID: dynamic
PCC info:
Symbolic name: cfg_dynamic-cs-srte-to-55a2-p2_discr_200
PLSP-ID: 7
Constraints:
Protection Type: unprotected-only
Maximum SID Depth: 12
Adjacency SIDs Only: True
Dynamic (pce 201.0.0.106) (valid)
Metric Type: IGP, Path Accumulated Metric: 20
SID[0]: 15739 [Adjacency-SID, 10.139.1.1 - 10.139.1.2]
SID[1]: 15720 [Adjacency-SID, 10.1.26.0 - 10.1.26.1]
Reverse path:
SID[0]: 15227 [Adjacency-SID, 10.1.26.1 - 10.1.26.0]
SID[1]: 15727 [Adjacency-SID, 10.139.1.2 - 10.139.1.1]
Protection Information:
Role: WORKING
Path Lock: Timed
Lock Duration: 300(s)
State: ACTIVE
Preference: 100 (configuration) (protect)
Name: dynamic-cs-srte-to-55a2-p2
Requested BSID: dynamic
PCC info:
Symbolic name: cfg_dynamic-cs-srte-to-55a2-p2_discr_100
PLSP-ID: 6
Constraints:
Protection Type: unprotected-only
Maximum SID Depth: 12
Adjacency SIDs Only: True
Dynamic (pce 201.0.0.106) (valid)
Metric Type: IGP, Path Accumulated Metric: 30
SID[0]: 15734 [Adjacency-SID, 10.1.42.0 - 10.1.42.1]
Reverse path:
SID[0]: 15523 [Adjacency-SID, 10.1.42.1 - 10.1.42.0]
Protection Information:
Role: PROTECT
Path Lock: Timed
Lock Duration: 300(s)
State: STANDBY
Attributes:
Binding SID: 24047
Forward Class: Not Configured
Steering labeled-services disabled: no
Steering BGP disabled: no
IPv6 caps enable: yes
Bandwidth Requested: 35.000 Gbps
Bandwidth Current: 35.000 Gbps
Invalidation drop enabled: no
Max Install Standby Candidate Paths: 0
```

Configure PLE over EVPN-VPWS

Use this task to configure PLE over Ethernet VPN Virtual Private Wire Service (EVPN-VPWS), enabling the delivery of emulated private line services.

The two core components are the Pseudowire class, which specifies the transport type, and the xconnect service, which configures the EVPN-VPWS service parameters.

Figure 35: PLE EVPN-VPWS service



Configure the NCS57C3-1 router.

Procedure

Step 1 Enter the **l2vpn** command to enter l2vpn configuration mode.

Example:

```
Router(config)# l2vpn
```

Step 2 Enter the **pw-class** *user-defined-name* command to define the Pseudowire class used with the PLE service.

Example:

```
Router(config-l2vpn)# pw-class circuit-style-srte
```

The same Pseudowire class can be used for multiple PLE services between the same far-end routers, or a unique class can be used for each service. The Pseudowire class defines the underlying transport for the service. In this case, the transport is MPLS, using a specific SR-TE policy. The **pw-class** command is followed by a user-defined name. In this example, the name is *circuit-style-srte.*

Step 3 Enter the **encapsulation mpls** command to configure transport encapsulation.

Example:

```
Router(config-l2vpn-pwc)# encapsulation mpls
```

Step 4 Enter the **preferred-path sr-te policy** command to configure an explicit MPLS path to be used for the L2VPN service.

Example:

```
Router(config-l2vpn-pwc-mpls)# preferred-path sr-te policy srte_c_1001_ep_10.0.0.42
```

The preferred-path is the circuit-style policy used to configure an explicit MPLS path for the L2VPN service. In this case, the preferred-path is set to the SR-TE policy created from the source node to the 10.0.0.42 endpoint node. The path refers to the computed name of the policy, not the configured name.

Step 5 Enter the **xconnect group ple** command to enter xconnect configuration mode.

Example:

```
Router(config-l2vpn)# xconnect group ple
```

The **xconnect group** command is used to administratively group similar L2VPN services and can be set to any user-defined value.

Step 6 Enter the **p2p** *user-defined-name* command to create point-to-point L2VPN service with user-defined name *ple-cs-1*.

Example:

```
Router(config-l2vpn-xc)# p2p ple-cs-1
```

Step 7 Enter the **interface cem** command to specify the client interface.

Example:

```
Router(config-l2vpn-xc-p2p)# interface cem 0/0/2/1
```

This interface is the CEM interface type for PLE.

Step 8 Enter the **neighbor evpn** command to configure EVPN-VPWS parameters.

Example:

```
Router(config-l2vpn-xc-p2p)# neighbor evpn evi 100 target 4201 source 4401
```

The user-defined *evi* value must be the same on each far-end router. The target must match the source value configured on the remote endpoint.

Step 9 Enter the **pw-class** command to attach the previously defined Pseudowire class *circuit-style-te* to the L2VPN service.

Example:

```
Router(config-l2vpn-xc-p2p-pw)# pw-class circuit-style-srte
```

Configure the NCS55a2-1 router.

```
Router(config)# l2vpn
Router(config-l2vpn)# pw-class circuit-style-srte
Router(config-l2vpn-pwc)# encapsulation mpls
Router(config-l2vpn-pwc-mpls)# preferred-path sr-te policy srte_c_1001_ep_10.0.0.44
Router(config-l2vpn)# xconnect group ple
Router(config-l2vpn-xc)# p2p ple-cs-1
Router(config-l2vpn-xc-p2p)# interface cem0/0/2/1
Router(config-l2vpn-xc-p2p)# neighbor evpn evi 100 target 4201 source 4401
Router(config-l2vpn-xc-p2p-pw)# pw-class circuit-style-srte
```

Verify PLE configurations

Verify PLE configurations using these commands.

Procedure

Step 1 Use this command to show the general CEM statistics.

Example:

```
RP/0/RP0/CPU0:ron-ncs57c3-1#show controllers CEM 0/0/3/1

Sat Sep 24 11:34:22.533 PDT
Interface : CEM0/0/3/1
Admin state : Up
Oper state : Up
Port bandwidth : 10312500 kbps
Dejitter buffer (cfg/oper/in-use) : 0/813/3432 usec
Payload size (cfg/oper) : 1280/1024 bytes
PDV (min/max/avg) : 980/2710/1845 usec
Dummy mode : last-frame
Dummy pattern : 0xaa
Idle pattern : 0xff
Signalling : No CAS
RTP : Enabled
Clock type : Differential
Detected Alarms : None
Statistics Info
---------------
Ingress packets : 517617426962, Ingress packets drop : 0
Egress packets : 517277124278, Egress packets drop : 0
Total error : 0
Missing packets : 0, Malformed packets : 0
Jitter buffer underrun : 0, Jitter buffer overrun : 0
Misorder drops : 0
Reordered packets : 0, Frames fragmented : 0
Error seconds : 0, Severely error seconds : 0
Unavailable seconds : 0, Failure counts : 0
Generated L bits : 0, Received L bits : 0
Generated R bits : 339885178, Received R bits : 17
Endpoint Info
-------------
Passthrough : No
```

Step 2 Use this command to show the PM statistics for 30 seconds.

Example:

```
RP/0/RP0/CPU0:ron-ncs57c3-1#show controllers CEM 0/0/3/1 pm current 30-sec cem

Sat Sep 24 11:37:02.374 PDT
CEM in the current interval [11:37:00 - 11:37:02 Sat Sep 24 2022]
CEM current bucket type : Valid
INGRESS-PKTS : 2521591 Threshold : 0 TCA(enable) : NO
EGRESS-PKTS : 2521595 Threshold : 0 TCA(enable) : NO
INGRESS-PKTS-DROPPED : 0 Threshold : 0 TCA(enable) : NO
EGRESS-PKTS-DROPPED : 0 Threshold : 0 TCA(enable) : NO
INPUT-ERRORS : 0 Threshold : 0 TCA(enable) : NO
OUTPUT-ERRORS : 0 Threshold : 0 TCA(enable) : NO
MISSING-PKTS : 0 Threshold : 0 TCA(enable) : NO
PKTS-REORDER : 0 Threshold : 0 TCA(enable) : NO
JTR-BFR-UNDERRUNS : 0 Threshold : 0 TCA(enable) : NO
JTR-BFR-OVERRUNS : 0 Threshold : 0 TCA(enable) : NO
MIS-ORDER-DROPPED : 0 Threshold : 0 TCA(enable) : NO
MALFORMED-PKT : 0 Threshold : 0 TCA(enable) : NO
ES : 0 Threshold : 0 TCA(enable) : NO
SES : 0 Threshold : 0 TCA(enable) : NO
UAS : 0 Threshold : 0 TCA(enable) : NO
FC : 0 Threshold : 0 TCA(enable) : NO
TX-LBITS : 0 Threshold : 0 TCA(enable) : NO
TX-RBITS : 0 Threshold : 0 TCA(enable) : NO
RX-LBITS : 0 Threshold : 0 TCA(enable) : NO
RX-RBITS : 0 Threshold : 0 TCA(enable) : NO
```

Step 3 Use this command to show the controller information for Ethernet 10GE.

Example:

```
RP/0/RP0/CPU0:ron-ncs57c3-1#show controllers TenGigECtrlr0/0/3/2

Sat Sep 24 11:43:23.164 PDT
Operational data for interface TenGigECtrlr0/0/3/2:
State:
Administrative state: enabled
Operational state: Up
LED state: Green On
PRBS:
Status: Locked
Mode: Source-sink
Pattern: User-defined
Direction: System
Error-inject: None
Framing: Unframed
User-pattern: 0xabcdef0123456789
Phy:
Media type: Not known
Autonegotiation disabled.
Operational values:
Speed: 10Gbps
Duplex: Full Duplex
Flowcontrol: None
Loopback: None (or external)
Inter-packet gap: standard (12)
BER monitoring:
Not supported
```

Step 4 Use this command to show the PM statistics for the Ethernet controller.

Example:

```
RP/0/RP0/CPU0:ron-ncs57c3-1#show controllers TenGigECtrlr0/0/3/2 pm current 30-sec ether

Sat Sep 24 11:45:39.919 PDT
ETHER in the current interval [11:45:30 - 11:45:39 Sat Sep 24 2022]
ETHER current bucket type : Valid
RX-PKT : 4528985 Threshold : 0 TCA(enable) : NO
STAT-PKT : 9057971 Threshold : 0 TCA(enable) : NO
OCTET-STAT : 2318840576 Threshold : 0 TCA(enable) : NO
OVERSIZE-PKT : 0 Threshold : 0 TCA(enable) : NO
FCS-ERR : 0 Threshold : 0 TCA(enable) : NO
LONG-FRAME : 0 Threshold : 0 TCA(enable) : NO
JABBER-STATS : 0 Threshold : 0 TCA(enable) : NO
64-OCTET : 0 Threshold : 0 TCA(enable) : NO
65-127-OCTET : 0 Threshold : 0 TCA(enable) : N
128-255-OCTET : 0 Threshold : 0 TCA(enable) : NO
256-511-OCTET : 9057971 Threshold : 0 TCA(enable) : NO
512-1023-OCTET : 0 Threshold : 0 TCA(enable) : NO
1024-1518-OCTET : 0 Threshold : 0 TCA(enable) : NO
IN-UCAST : 0 Threshold : 0 TCA(enable) : NO
IN-MCAST : 0 Threshold : 0 TCA(enable) : NO
IN-BCAST : 0 Threshold : 0 TCA(enable) : NO
OUT-UCAST : 0 Threshold : 0 TCA(enable) : NO
OUT-BCAST : 0 Threshold : 0 TCA(enable) : NO
OUT-MCAST : 0 Threshold : 0 TCA(enable) : NO
TX-PKT : 4528986 Threshold : 0 TCA(enable) : NO
OUT-OCTET : 1159420416 Threshold : 0 TCA(enable) : NO
IFIN-ERRORS : 0 Threshold : 0 TCA(enable) : NO
IFIN-OCTETS : 0 Threshold : 0 TCA(enable) : NO
STAT-MULTICAST-PKT : 0 Threshold : 0 TCA(enable) : NO
```

```
STAT-BROADCAST-PKT : 0 Threshold : 0 TCA(enable) : NO
STAT-UNDERSIZED-PKT : 0 Threshold : 0 TCA(enable) : NO
IN_GOOD_BYTES : 1159420160 Threshold : 0 TCA(enable) : NO
IN_802_1Q_FRAMES : 0 Threshold : 0 TCA(enable) : NO
IN_GOOD_PKTS : 4528985 Threshold : 0 TCA(enable) : NO
IN_DROP_OTHER : 0 Threshold : 0 TCA(enable) : NO
OUT_GOOD_BYTES : 1159420416 Threshold : 0 TCA(enable) : No
OUT_802_1Q_FRAMES : 0 Threshold : 0 TCA(enable) : NO
OUT_GOOD_PKTS : 4528986 Threshold : 0 TCA(enable) : NO
IN_ERROR_FRAGMENTS : 0 Threshold : 0 TCA(enable) : NO
IN_PKT_64_OCTET : 0 Threshold : 0 TCA(enable) : NO
IN_PKTS_65_127_OCTETS : 0 Threshold : 0 TCA(enable) : NO
IN_PKTS_128_255_OCTETS : 0 Threshold : 0 TCA(enable) : NO
IN_PKTS_256_511_OCTETS : 4528985 Threshold : 0 TCA(enable) : NO
IN_PKTS_512_1023_OCTETS : 0 Threshold : 0 TCA(enable) : NO
IN_PKTS_1024_1518_OCTETS : 0 Threshold : 0 TCA(enable) : NO
OUT_PKT_64_OCTET : 0 Threshold : 0 TCA(enable) : NO
OUT_PKTS_65_127_OCTETS : 0 Threshold : 0 TCA(enable) : NO
OUT_PKTS_128_255_OCTETS : 0 Threshold : 0 TCA(enable) : NO
OUT_PKTS_256_511_OCTETS : 4528986 Threshold : 0 TCA(enable) : NO
OUT_PKTS_512_1023_OCTETS : 0 Threshold : 0 TCA(enable) : NO
OUT_PKTS_1024_1518_OCTETS : 0 Threshold : 0 TCA(enable) : NO
TX_UNDERSIZED_PKT : 0 Threshold : 0 TCA(enable) : NO
TX_OVERSIZED_PKT : 0 Threshold : 0 TCA(enable) : NO
TX_FRAGMENTS : 0 Threshold : 0 TCA(enable) : NO
TX_JABBER : 0 Threshold : 0 TCA(enable) : NO
TX_BAD_FCS : 0 Threshold : 0 TCA(enable) : NO

Last clearing of "show controllers ETHERNET" counters never
```

Step 5 Use this command to show the controller information for Fiber Channel 8G.

Example:

```
RP/0/RP0/CPU0:ron-ncs57c3-1#show controllers EightGigFibreChanCtrlr0/0/3/4

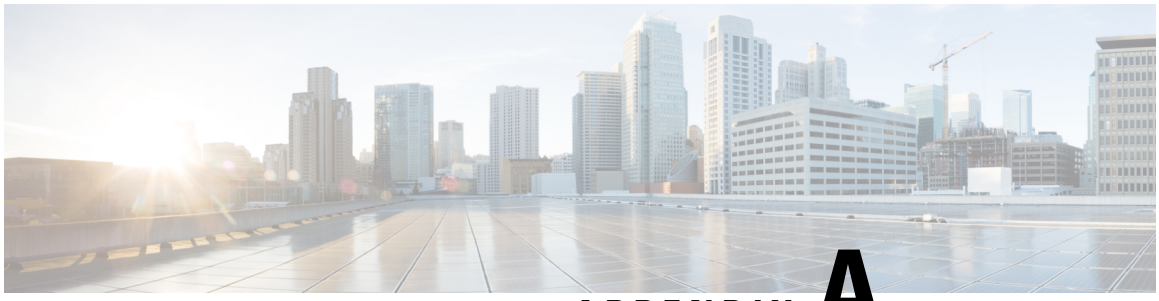
Sat Sep 24 11:53:09.820 PDT
Operational data for Fibre Channel controller EightGigFibreChanCtrlr0/0/3/4
State:
Admin State : Up
Operational state : Up
LED state : Green On
Secondary admin state : Normal
Laser Squelch : Disabled
Performance Monitoring is enabled
Operational values:
Speed : 8 Gbps
Loopback : None
BER monitoring:
Signal Degrade : 1e-0
Signal Fail : 1e-0
Hold-off Time : 0 ms
Forward Error Correction : Not Configured
```

Step 6 Use this command to show the PM statistics for Fiber Channel.

Example:

```
RP/0/RP0/CPU0:ron-ncs57c3-1#show controllers EightGigFibreChanCtrlr0/0/3/4 pm current 30-sec fc
Sat Sep 24 11:51:55.168 PDT
FC in the current interval [11:51:30 - 11:51:55 Sat Sep 24 2022]
FC current bucket type : Valid
IFIN-OCTETS : 16527749196 Threshold : 0 TCA(enable) : NO
RX-PKT : 196758919 Threshold : 0 TCA(enable) : NO
IFIN-ERRORS : 0 Threshold : 0 TCA(enable) : NO
```

```
RX-BAD-FCS : 0 Threshold : 0 TCA(enable) : NO
IFOUT-OCTETS : 0 Threshold : 0 TCA(enable) : NO
TX-PKT : 0 Threshold : 0 TCA(enable) : NO
TX-BAD-FCS : 0 Threshold : 0 TCA(enable) : NO
RX-FRAMES-TOO-LONG : 0 Threshold : 0 TCA(enable) : NO
RX-FRAMES-TRUNC : 0 Threshold : 0 TCA(enable) : NO
TX-FRAMES-TOO-LONG : 0 Threshold : 0 TCA(enable) : NO
TX-FRAMES-TRUNC : 0 Threshold : 0 TCA(enable) : NO
```



APPENDIX A

Sample end-to-end configuration

Network sizing requirements

This section details the sizing requirements for a network. For a small lab installation, you need three servers with 256 GB of RAM to run Crosswork, Crosswork Network Controller, Cisco Optical Network Controller, NSO, Crosswork Hierarchical Controller, and EPNM without high availability (HA). For a production setup, calculate the total resources required using information provided in the tables.

For Cisco Crosswork, see Plan Your Deployment.

For Cisco Optical Network Controller, see Cisco Optical Network Controller 25.1.x Installation Guide.

Network profiles

Network profiles are defined according to network size, available services, and application features.

Network entity or feature	Lab (20%)	Production (100%)
Devices	2000	10000
Total number of interfaces	100000	650000
IGP interfaces	20000	100000
VPN Services (Layer2 and Layer3)	40000	200000
Endpoints for each VPN service	2–10	50
Total LSPs (SR policies and RSVP tunnels)	12000	60000
Number of PCEP sessions	2000	10000

Note Each SR-PCE pair can only support 2000 PCEP sessions which means only 2000 headends for lab networks and 10000 headends for production networks. While counting headends, LCM nodes must be included.

Deployment size for each network profile

This table provides recommended deployment sizing requirements based on the defined network profiles for solutions that use Cisco Crosswork Network Controller.

Package	Contents	Crosswork Data Gateway deployment	Recommended number of cluster VMs
Cisco Crosswork Network Controller Essentials	Cisco Crosswork Optimization Engine	**On-Premise Standard** (default): Collectors only.	When Essentials package is installed without element management functions: • **three hybrid nodes** When Essentials package is installed with element management functions: • **three hybrid nodes and one worker node**
	Cisco Crosswork Active Topology	**On-Premise Standard** (default): Collectors only.	
	Element Management Functions	**On-Premise Standard** (default): Collectors only.	
Cisco Crosswork Network Controller Advantage	Cisco Crosswork Service Health	**On-Premise Extended**: Collectors and offload services.	**three hybrid nodes and two worker nodes**
Add-on Package	Cisco Crosswork Change Automation	**On-Premise Extended**: Collectors and offload services.	**three hybrid nodes and two worker nodes**
	Cisco Crosswork Health Insights	**On-Premise Extended**: Collectors and offload services.	
	Cisco Crosswork Zero Touch Provisioning	**On-Premise Standard** (default): Collectors only.	



Note For non-production lab installations without HA, you can use one hybrid node.

VM resources

This table provides details about CPU, memory, and disk requirements for each Crosswork VM and other VMs in the deployment.

Crosswork VM	Crosswork Data Gateway	NSO	SR-PCE	Crosswork Hierarchical Controller	EPNM

• CPU: 12 vCPU
• RAM: 96 GB
• DISK: 1 TB (SSD)
	• CPU: 20 vCPU
	• RAM: 112 GB
	• DISK: 0.5 TB
		• Small Network Profile
		  • CPU: 8 vCPU
		  • RAM: 64 GB
		  • DISK: 250 GB
		• Large Network Profile
		  • CPU: 24 vCPU
		  • RAM: 132 GB
		  • DISK: 1 TB
			• CPU: 8 vCPU
			• RAM: 24 GB
			• DISK: 45 GB
				• CPU: 10 cores
				• RAM: 96 GB
				• DISK: 400 GB SSD for lab use, 3 TB SSD for production use
					• Professional (Small)
					  • CPU: 16 vCPU
					  • RAM: 64 GB
					  • DISK: 2.8 TB
					• Extended (medium or large)
					  • CPU: 24 vCPU
					  • RAM: 128 GB
					  • DISK: 4 TB

Note In Routed Optical Networking 2.1, Cisco Optical Network Controller and Crosswork Network Controller require different Crosswork Infrastructure versions.

The Crosswork Infrastructure Cluster for Cisco Optical Network Controller must have:

- three VMs
- 12 vCPU
- 96 GB RAM
- DISK: 1TB SSD

Cisco Optical Network Controller scale support

Cisco Optical Network Controller supports up to 500 nodes and 600 services. It can run on the same cluster and adds resources incrementally at the maximum supported scale. These requirements are included in the Crosswork VM resources table.

- Sample configuration, on page 126
- Planning and design phase, on page 126
- Implement phase, on page 127
- Operate phase, on page 196
- Optimization phase, on page 210

Sample configuration

This section details the step-by-step approach to build a new Routed Optical Networking based, 75 km fiber span to replace an existing legacy span in a two node DCI topology.

- Planning and design phase, on page 126
- Implement phase, on page 127
- Operate phase, on page 196
- Optimization phase, on page 210

Planning and design phase

The planning and design phase consists of these activities:

1. Network planning and design

   Inputs needed: packet layer traffic demands, optical fiber topology, resiliency criteria, and other network constraints.

   a. WAE can be used to determine a new network build or augmentations to an existing network.

   b. After the IP network circuits have been determined, Cisco ONP evaluates the optical layer feasibility and identifies the components required to support the network.

   The output for a sample configuration includes these components:

   This topology uses two Cisco 8201 routers, two NCS 2006 terminal nodes equipped with NCS1K-MD-64 add/drop multiplexers, and EDFA-35 bidirectional amplifiers. The span length is 75 km. Additional ILA nodes may be required for amplification if the spans are longer.

2. Automation software resource planning

   Identify the servers required for the full solution. See Sample end-to-end configuration, on page 123 and Installation requirements for Routed Optical Networking components, on page 126.

   a. For a lab or EFT setup, it is recommended to use three servers each with 384 GB of RAM, 32 cores, and two TB SSDs.

   b. The solution requires the use of VMware ESX 6.7 or higher.

Installation requirements for Routed Optical Networking components

The installation requirements for different Routed Optical Networking components are:

- Cisco Optical Network Planner 5.2
- Cisco WAN Automation Engine 7.6.x
- Cisco Crosswork Cluster, Crosswork Data Gateway, and Crosswork Applications

- Cisco Optical Network Controller 3.1
- Cisco Evolved Programmable Network Manager 7.1.2
- Cisco Network Services Orchestrator 6.1.9
  - Cisco NSO Routed Optical Networking Core Function Pack 3.0.0
  - Cisco NSO Transport-SDN Function Pack Bundle 6.0
  - Cisco Network Services Orchestrator DLM Service Pack 6.0
- Cisco Crosswork Hierarchical Controller 8.0
- Cisco Crosswork Network Controller 6.0

Implement phase

The implement phase involves:

1. **Installation of hardware components**
   a. Hardware staging or installation and initial base configuration required for management connectivity.
   b. All onboard software updates must be completed to the required revision.
   c. All associated base wiring must be completed to support the network. This includes connections between the optical elements and connections between routers and optical add/drop end-points to support Routed Optical Networking circuits using ZR and ZR+ optics. See Deployment Topologies, on page 59.
   d. Install Cisco Optical Site Manager to support NCS 1010 nodes. See Install Cisco Optical Site Manager
2. **Installation of automation software somponents**
   a. Complete all server hardware installation and base configuration to support the solution, including VMWare ESX if not already installed.
   b. Install the following software components to support the Routed Optical Networking solution.
      - Cisco Optical Network Planner 5.2 (for optical planning)
      - Cisco WAN Automation Engine 7.6.x (for IP planning)
      - Cisco Crosswork Cluster, Crosswork Data Gateway, and Crosswork Applications (for supporting Crosswork Network Controller)
      - Cisco Optical Network Controller 3.1 (for supporting optical network)
      - Cisco Evolved Programmable Network Manager 7.1.4 (for managing the physical router and the optical network nodes)
      - Cisco Network Services Orchestrator 6.1.9 (base installation to support RON FP)
        - Cisco NSO Routed Optical Networking Core Function Pack 3.0 (for RON ML provisioning)
        - Cisco NSO Transport-SDN Function Pack Bundle 6.0 (for Crosswork Network Controller SR and xVPN provisioning)

- Cisco Network Services Orchestrator DLM Service Pack 6.0 (for device synchronization between Crosswork Network Controller and NSO)

- Cisco Crosswork Hierarchical Controller 8.0 (for provisioning the Routed Optical Networking ML service using the Crosswork Hierarchical Controller)

Note This is required only if the Routed Optical Networking ML service is provisioned via the Crosswork Hierarchical Controller GUI.

3. **Onboarding of devices**
   a. Add devices to Cisco Optical Network Controller. See Onboard Devices to Cisco Optical Network Controller.
   b. Add NSO, SR-PCE, and devices to Crosswork Network Controller. See Add SR-PCE providers, NSO providers, and routers to Crosswork Network Controller, on page 129.
   c. Add routers to NSO using the IOS-XR CLI NED. See Step 3 in Provision an ML service using NSO Routed Optical Networking CFP, on page 153.
   d. Add and configure the following Crosswork Hierarchical Controller adapters. See Configure adapters for Routed Optical Networking in Crosswork Hierarchical Controller, on page 136.

Note This step is required only if the Routed Optical Networking ML service is provisioned via the Crosswork Hierarchical Controller GUI.

- Add and configure the Crosswork Network Controller adapter.
- Create or import sites in Crosswork Hierarchical Controller. See the sections, "Add Sites" and "Export and Import Sites" in the Cisco Crosswork Hierarchical Controller Administration Guide 8.0.
- Add and configure the IOS-XR adapter. Create router devices in Crosswork Hierarchical Controller using the IOS-XR adapter type. After the routers are created, add the Crosswork Network Controller adapter to the router device.
- Add and configure the Cisco Optical Network Controller adapter.

4. **Provisioning of services**
   a. Ensure all device interconnections are complete.
   b. To provision the Routed Optical Networking ML service, use either one of the procedures:
      1. **Using the NSO GUI:**
         a. Utilize the Routed Optical Networking FP ML services to provision and end-to-end service. See Provision an ML service using NSO Routed Optical Networking CFP, on page 153.
         b. Verify that the end-to-end service has been deployed by checking the NSO service deployment status using the check-sync status.

c. Verify the router optics controller state using the CLI or in EPNM. See Troubleshoot provisioning issues on ZR or ZR+ optics, on page 88.

2. **Using the Crosswork Hierarchical Controller GUI:**

   a. Utilize the Crosswork Hierarchical Controller GUI to provision and end-to-end Routed Optical Networking ML service. See *Provision a Routed Optical Networking ML service using Crosswork Hierarchical Controller*.

   b. Verify the router optics controller state using the Link Assurance tool in Crosswork Hierarchical Controller. See Step 4 in *Provision a Routed Optical Networking ML service using Crosswork Hierarchical Controller*.

Add SR-PCE providers, NSO providers, and routers to Crosswork Network Controller

Follow these steps to add SR-PCE providers, NSO providers, and routers to Crosswork Network Controller.

Note When you add or import devices, or create providers, you need to specify the credential profile.

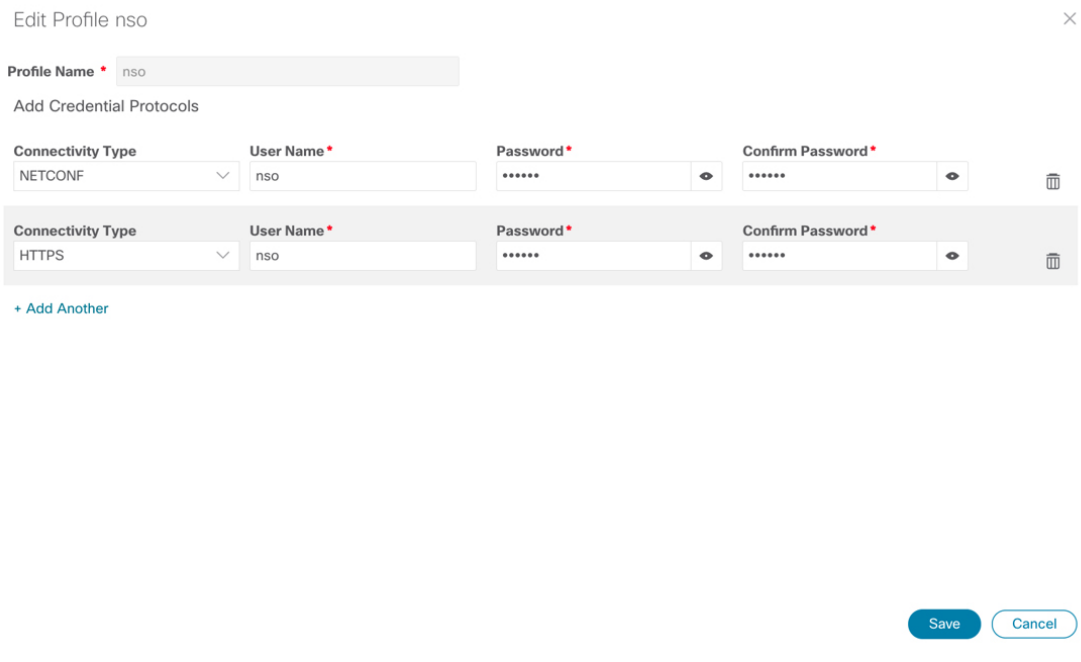
Procedure

Step 1 Log in to the Crosswork user interface.

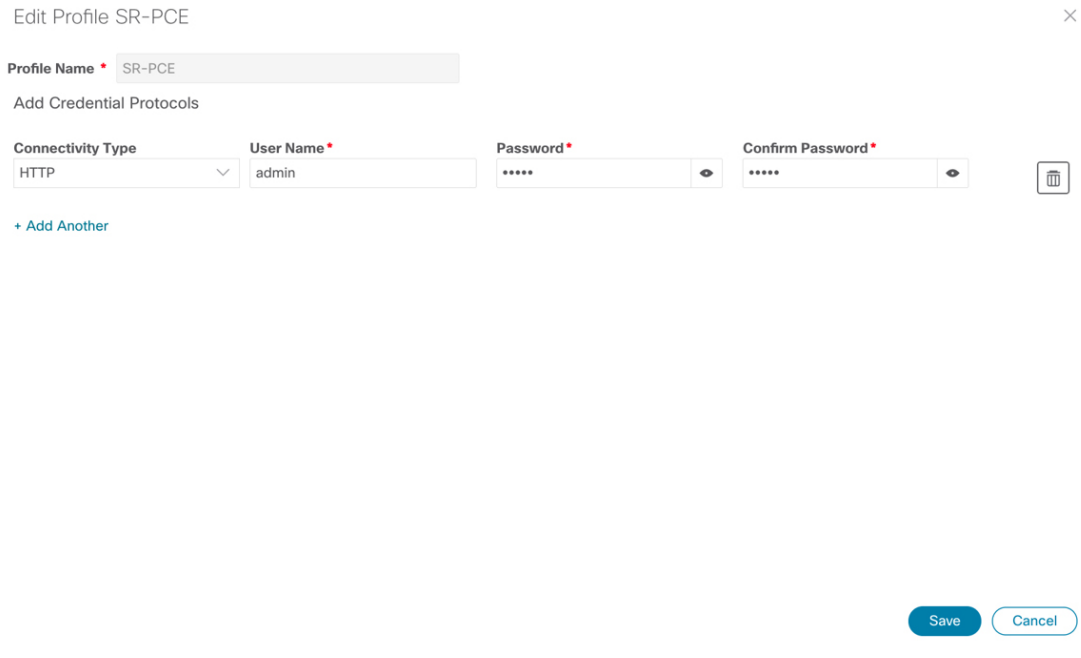
Step 2 Choose **Device Management** > **Credential Profiles** from the main menu to create a credential profile. See Manage Credential Profiles.

a) For the NSO credential profile, the connectivity type must be set to NETCONF and HTTPS. Optionally, HTTP can also be defined if HTTPS is not used in NSO.

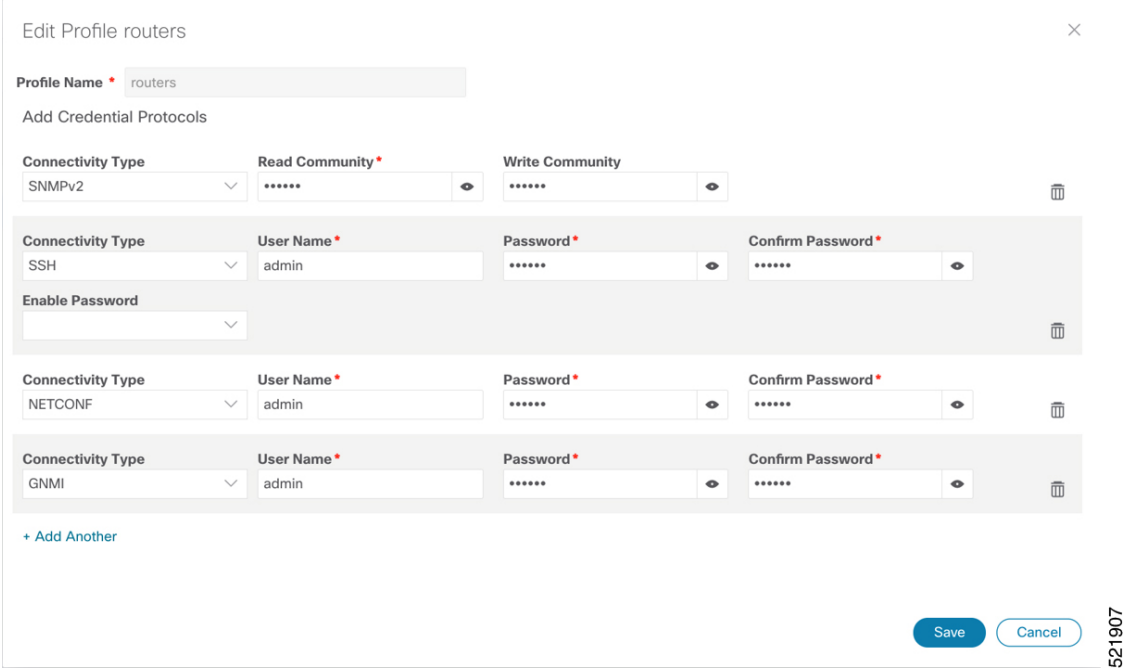
Sample end-to-end configuration



b) The SR-PCE credential profile requires HTTP credentials to communicate with the SR-PCE Northbound API.



c) The router credential profile requires SNMPv2 or SNMPv3 and SSH connectivity types. NETCONF is optional. Use gNMI when you configure streaming telemetry sensors on the node.



Step 3 Add the providers. See About Adding Providers.

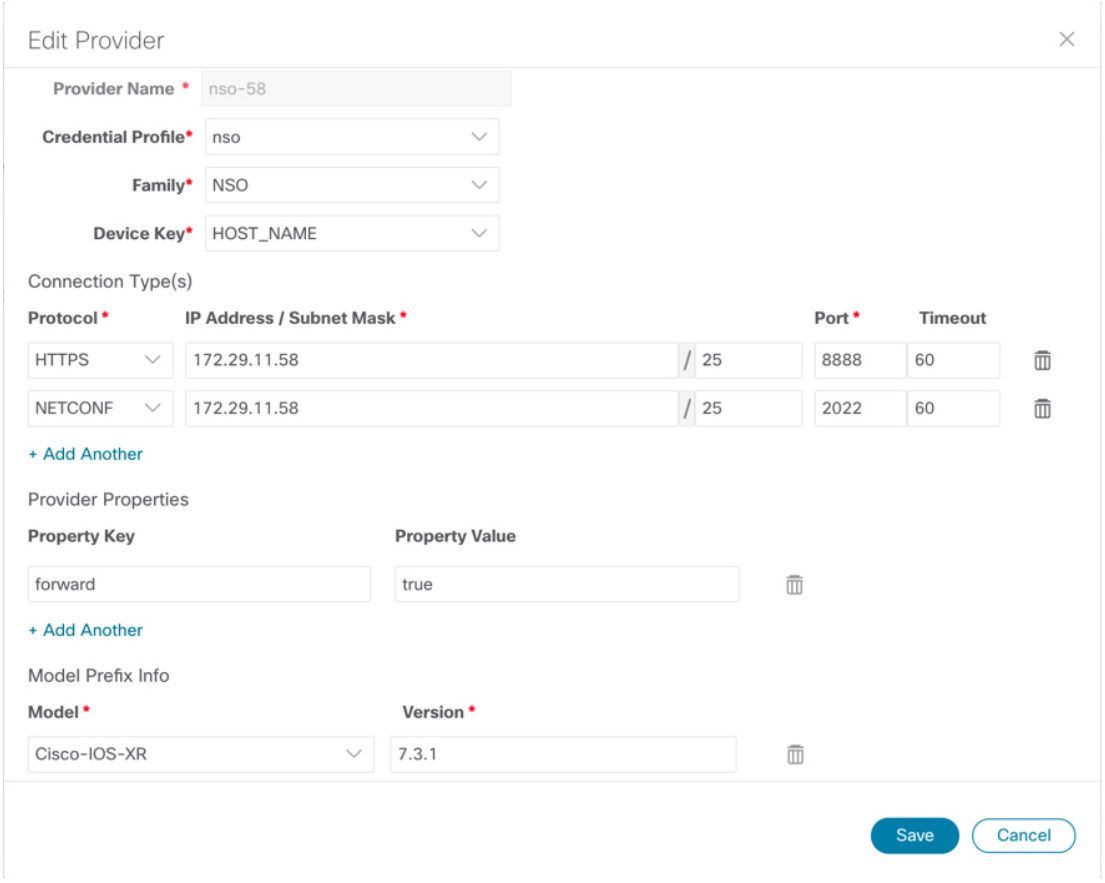
a) Choose **Administration** > **Manage Provider Access** from the main menu to add the SR-PCE or NSO provider. See Manage Providers.

b) Add the NSO provider. See Add Cisco NSO Providers.

Select the credential profile created for NSO. Select the family as NSO. The Device Key may be set to either HOST_NAME or INVENTORY_ID, depending on the specific deployment.

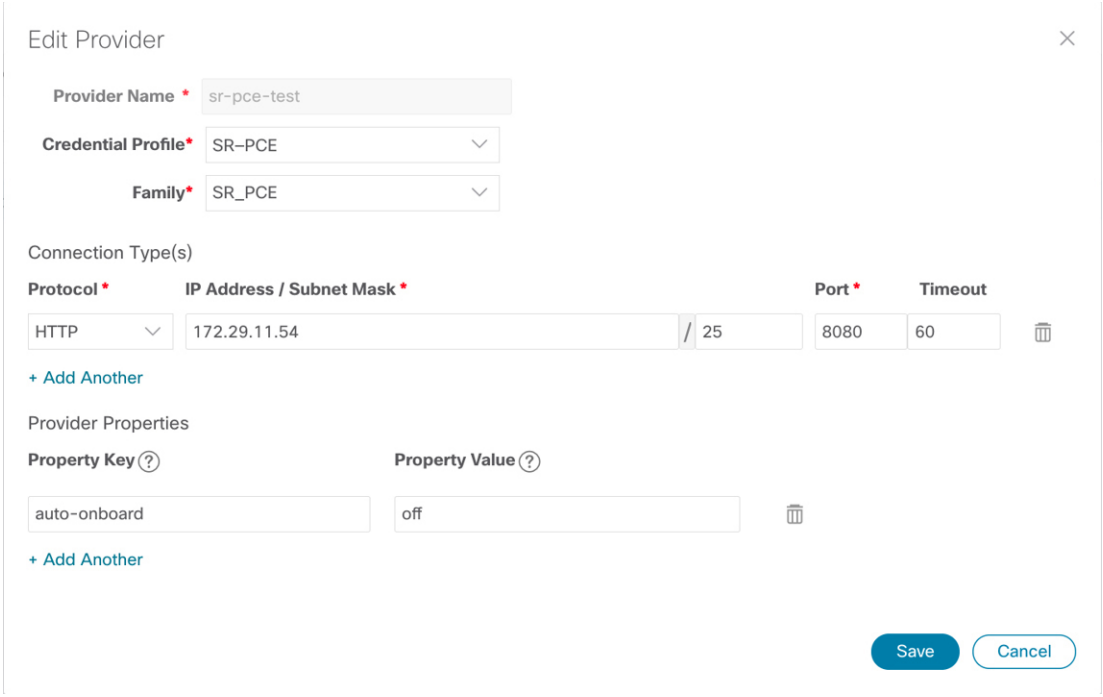
This image shows the connectivity to the RESTCONF API for NSO over SSL using port 8888 and NETCONF using the default port number 2022. Since the Routed Optical Networking NSO CFP utilizes the XR CLI NED, the Cisco-IOS-XR model is not applicable and may be set to any version.

Sample end-to-end configuration



c) Add the SR-PCE provider. See Add Cisco SR-PCE Providers..

Select the credential profile created for SR-PCE. Select the family type as SR_PCE. The connectivity type for SR-PCE must be HTTP. In this image, the default API port of 8080 is specified. When the Property Key, "auto-onboard" is set to a Property value, "off", Crosswork Network Controller does not automatically add nodes that are discovered via the SR-PCE IGP topology to the device inventory. Devices must be added through the Crosswork Network Controller UI or inventory API.

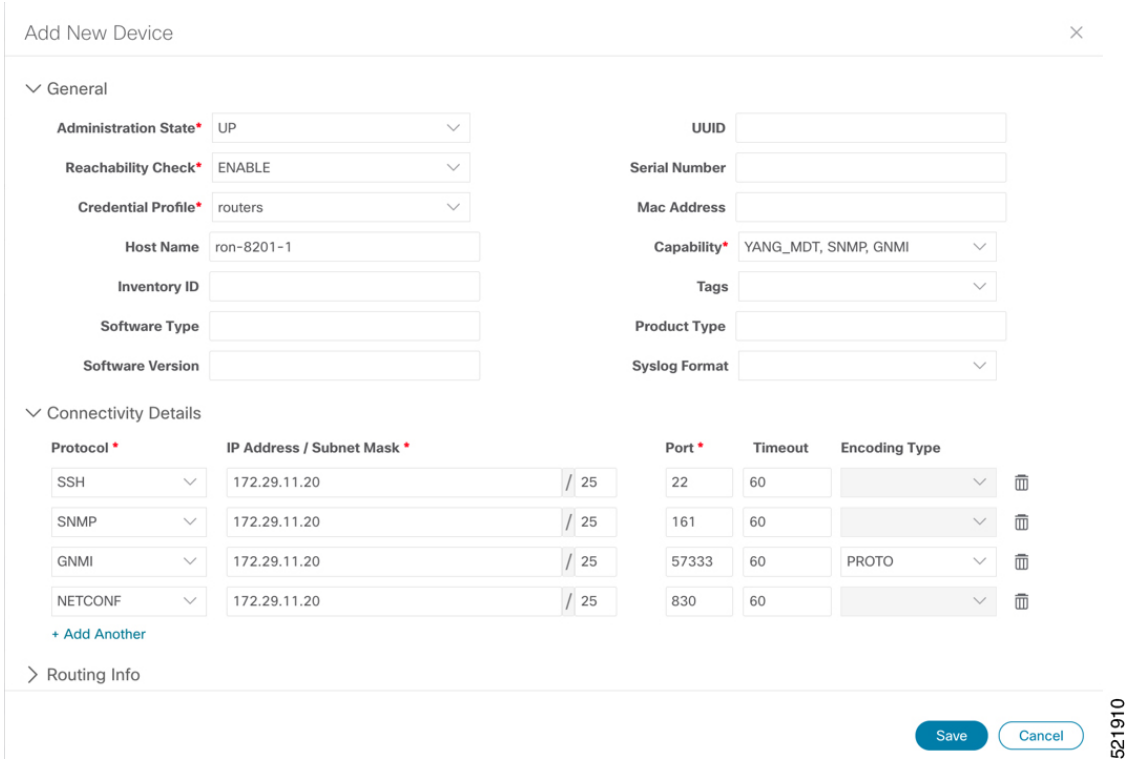


Step 4 Validate communications with one or more providers. Check the reachability of the provider using Get Provider Details.

Step 5 Onboard devices. See Add Devices Through the UI.

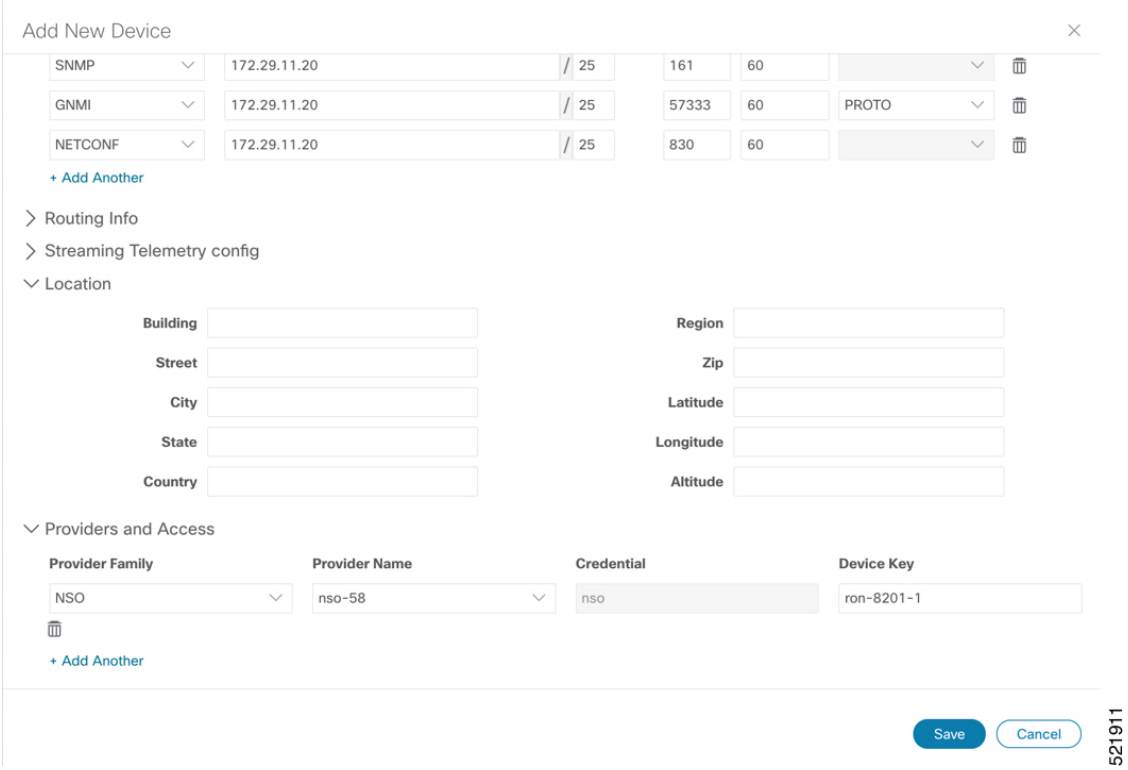
a) The Administration State, Reachability Check, and Credential Profile are mandatory elements. The Host Name must be used if the NSO provider device key is set to the Host Name value. If the NSO provider device key is set to Inventory ID that field must be populated. The Software Type, Software Version, UUID, Serial Number, MAC address, and Product Type are filled by device discovery. Optionally, tags can be applied to the device. The GNMI encoding type can be set to JSON or PROTO.

Sample end-to-end configuration



Optionally, you can enter location information. Latitude and longitude information is used to specify the node's geographic location.

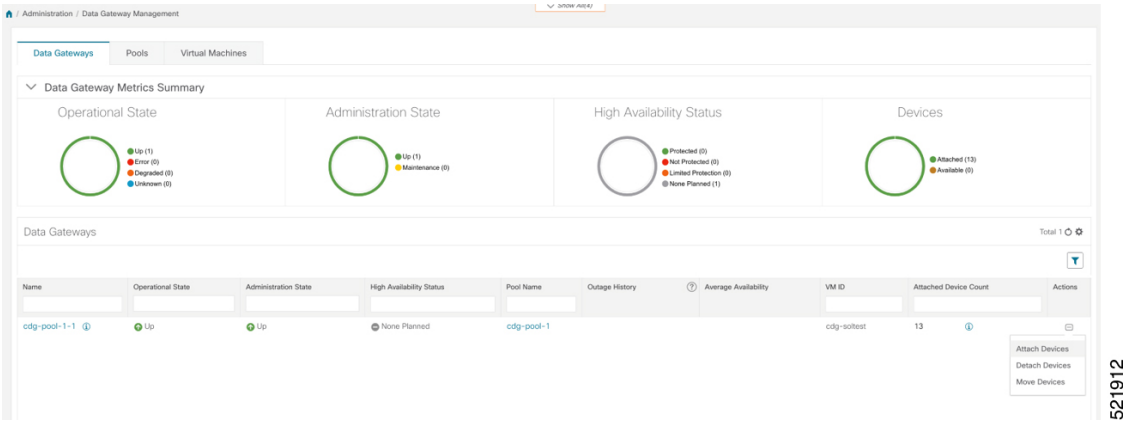
Add the previously configured NSO provider as a provider for the device.



b) Attach the devices to an active Cisco Crosswork Data Gateway pool to manage them (device discovery).

Review the Data Gateways pane (see Overview of Cisco Crosswork Data Gateway). The operational state of the Cisco Crosswork Data Gateway pool to which you want to attach devices must be **Up**.

See Attach Devices to Cisco Crosswork Data Gateway.



SR-PCE providers, NSO providers, and routers appear in Crosswork Network Controller and are ready for management and monitoring.

Configure adapters for Routed Optical Networking in Crosswork Hierarchical Controller

These adapters are needed for the Routed Optical Networking solution.

Table 17: Routed Optical Networking adapters

Adapter	Credential type
Crosswork Network Controller	HTTP (username and password)
Crosswork Network Controller Crosswork Data Gateway	HTTP (username and password)
Cisco Optical Network Controller	HTTP (username and password)
IOS-XR	SSH (username and password)

Note If Cisco Optical Network Controller and Crosswork Network Controller are on the same Crosswork cluster, use the same credential profile for both.

Before you begin

To use Crosswork Hierarchical Controller adapters, you are required to use credentials. These credentials are used for authentication when a device is assigned to an adapter. You can use the same credentials for multiple adapters.

The credentials are added under the **Services** > **Device Manager** > **Credentials** tab in the Crosswork Hierarchical Controller GUI.

Follow these steps to add the adapters:

Procedure

Step 1 Choose **Services** > **Device Manager** > **Adapters** in the applications bar in Crosswork Hierarchical Controller.

Step 2 Click **Add new adapter** to add a new adapter.

Step 3 Enter the adapter details:

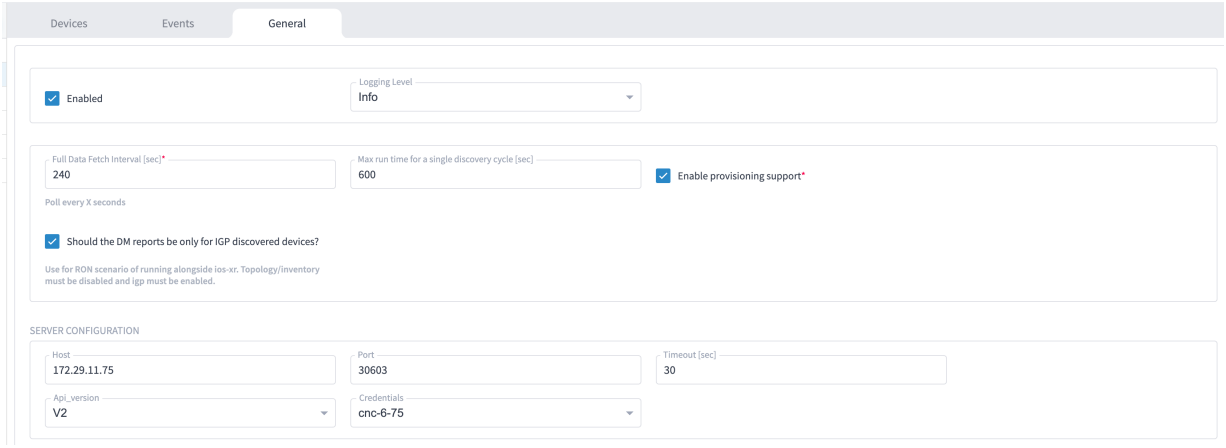
- **Adapter Type**: Select an adapter type from those available and currently installed in Crosswork Hierarchical Controller.
- **Adapter Name**: Enter a unique name for this adapter type instance. Multiple instances of the same adapter type are allowed.

Step 4 Select the adapter in the **Adapters** pane to configure the adapter. Configure the parameters as shown in these images.

- **Crosswork Network Controller adapter**:

  Note
  API version for Crosswork Network Controller must be version 2.

Figure 36: Crosswork Network Controller adapter configuration—General tab



Note
The Full Data Fetch Interval must be set to 300 seconds or higher in a production network.

These parameters must be configured for Crosswork Network Controller notifications and collection.

Figure 37: Crosswork Network Controller notifications

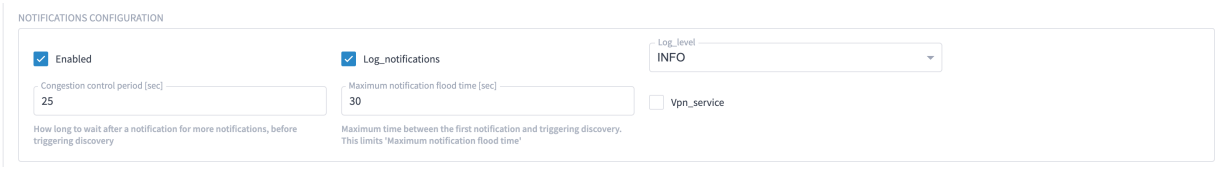
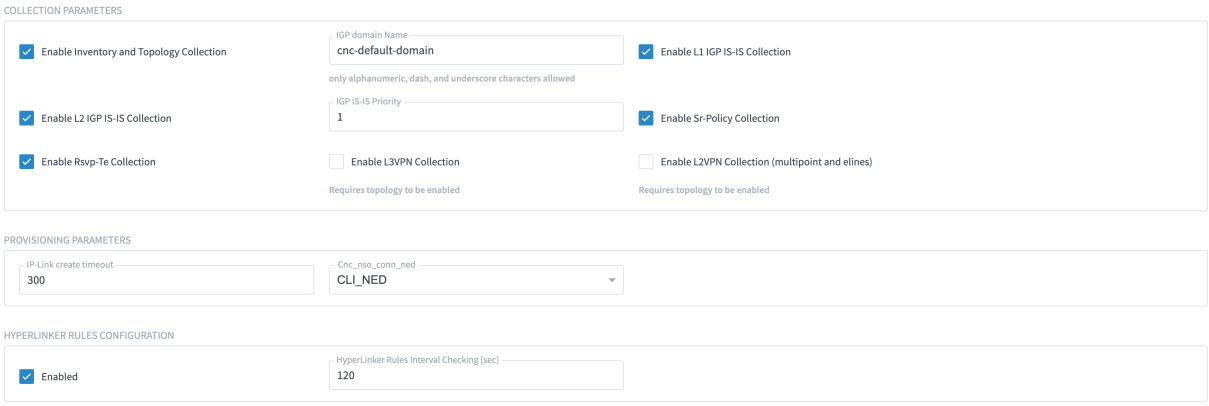


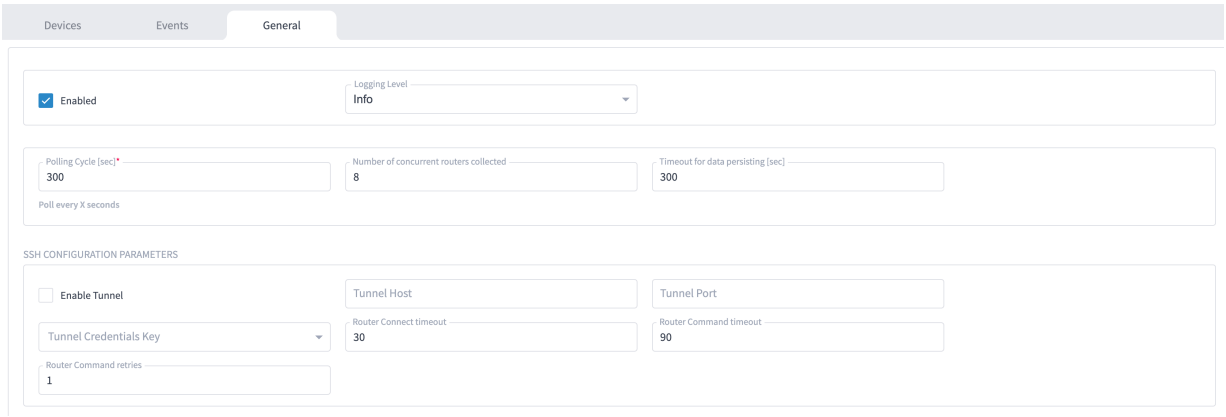
Figure 38: Crosswork Network Controller collection and provisioning



- **IOS-XR adapter**

Sample end-to-end configuration

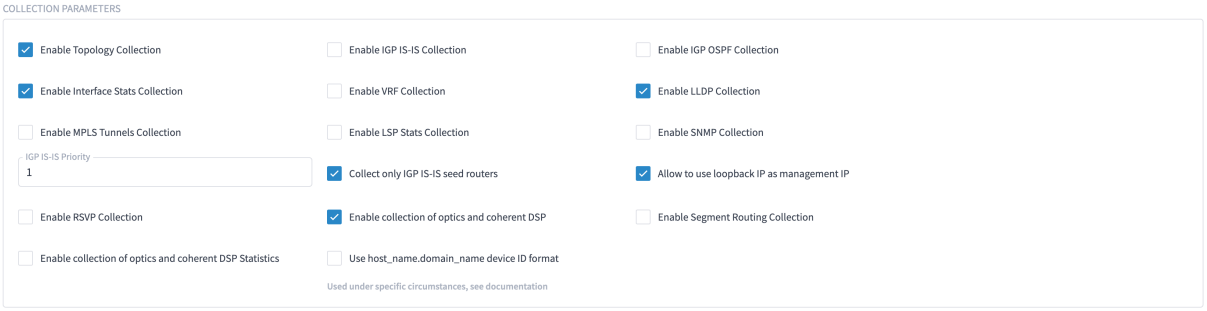
Figure 39: IOS-XR adapter —General tab



Note
The Polling Cycle must be 300 seconds or higher in a production network. Concurrency can be increased. Set the Logging Level to Info when everything is working correctly.

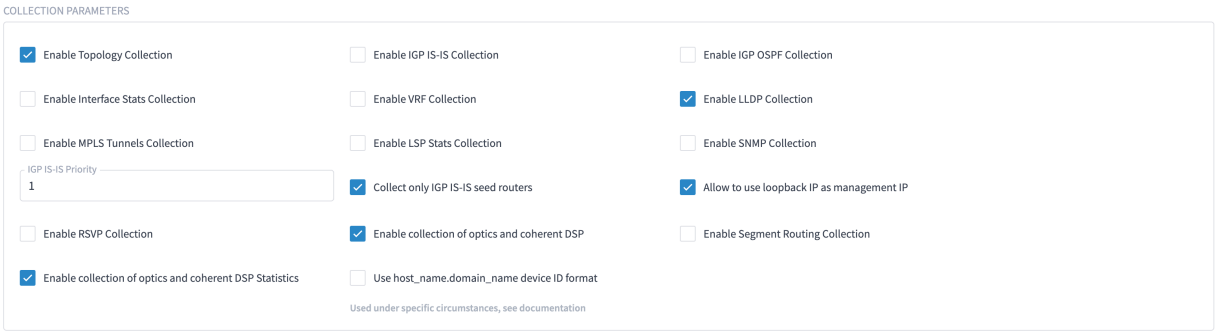
These collection parameters must be configured. These parameters collect optical power values for the link assurance application.

Figure 40: IOS-XR adapter —General tab



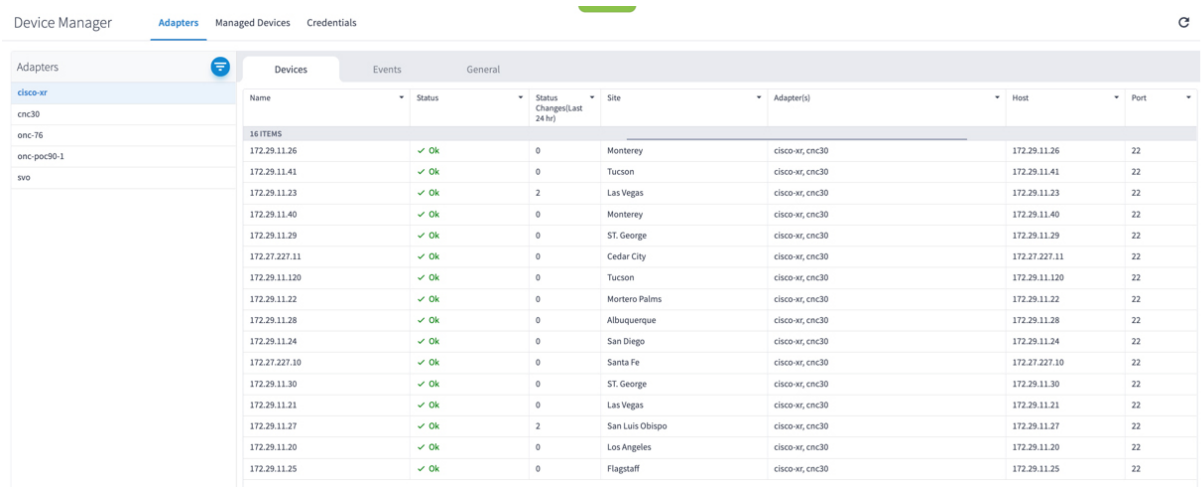
Note
Check the **Enable collection of optics and coherent DSP Statistics** parameter only when using Automation Starter Solution.

Figure 41: IOS-XR adapter —General tab



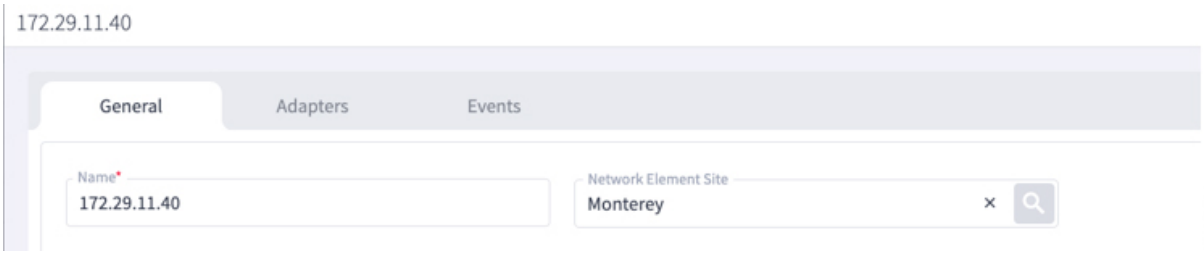
The status of the devices must be **ok** in the **Devices** tab after the addition and completion of a successful collection cycle.

Figure 42: IOS-XR adapter - Devices tab



To add routers to Crosswork Hierarchical Controller, click the **Managed Devices** tab and then **+ Add Device**.

Figure 43: IOS-XR adapter —add new device— General tab

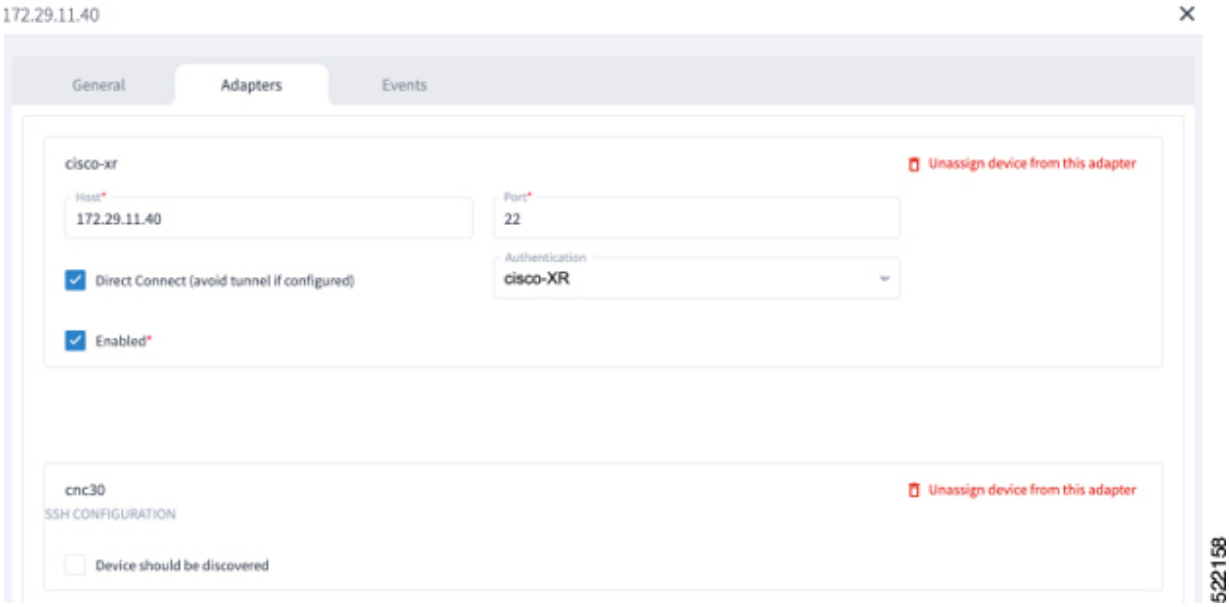


Use the hostname+hco (ron-8201-1-hco) or the device IP address. Assign the device to a site for display in Explorer UI.

Assign both the IOS-XR adapter type and the Crosswork Network Controller adapter type to the device. Do not enable discovery for the Crosswork Network Controller adapter.

Sample end-to-end configuration

Figure 44: IOS-XR Adapter—add new device— Adapters tab

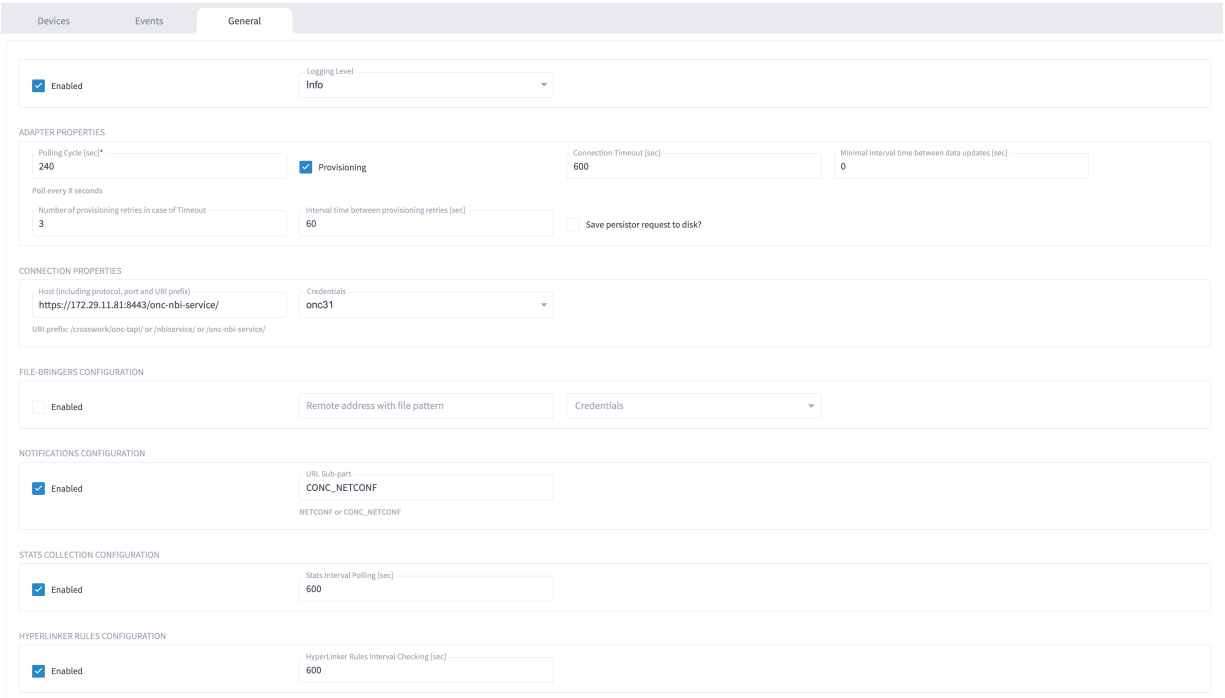


- **Cisco Optical Network Controller adapter**

Figure 45: Cisco Optical Network Controller adapter — General tab

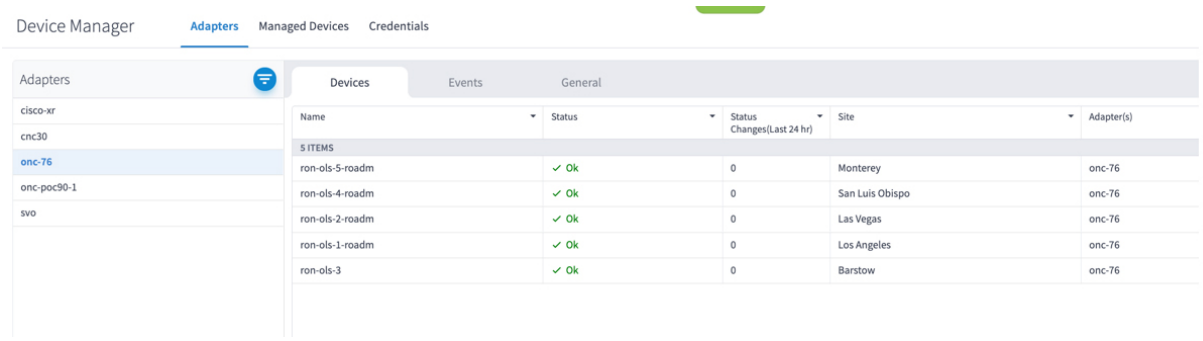
The Polling cycle must be set to 300s or higher in a production network. Polling retrieves TAPI SIPs, topology, and connectivity services.

The URL in this figure is for the Cisco Optical Network Controller 3.1.



Cisco Optical Network Controller automatically discovers optical nodes. Assign a site to the nodes to display them in the Explorer UI.

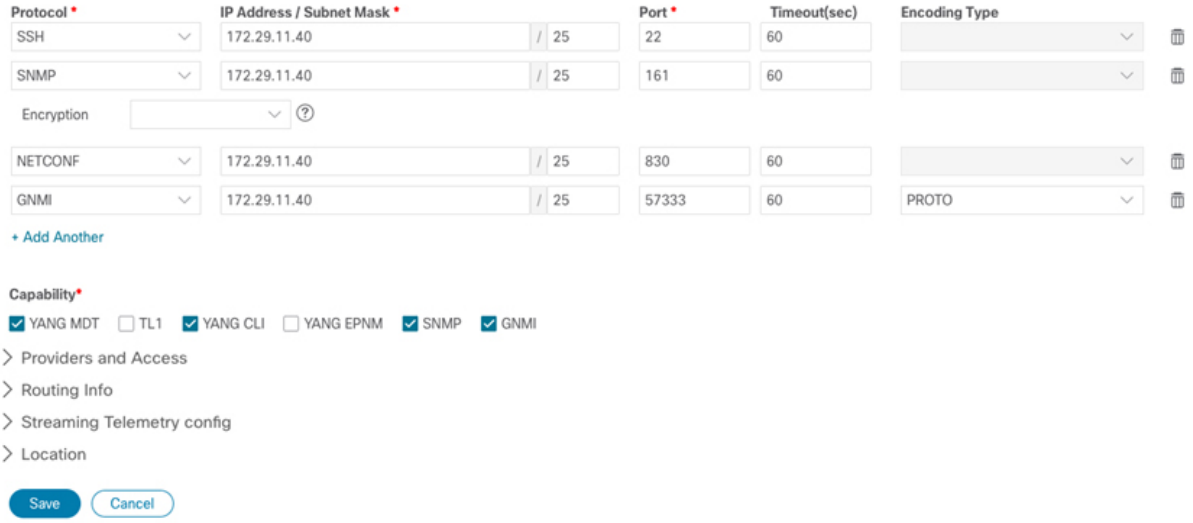
Figure 46: Cisco Optical Network Controller adapter - Devices tab



- **Crosswork Network Controller Crosswork Data Gateway adapter**

Crosswork Network Controller Crosswork Data Gateway adapter is used to collect telemetry data through gNMI (gRPC Network Management Interface) to the router. In Crosswork Network Controller, the routers must be configured with the gNMI protocol with the encoding type set to “PROTO” and the gNMI capability enabled. In IOS XR, the routers must be configured for gRPC so that Crosswork Data Gateway can create gNMI telemetry subscriptions.

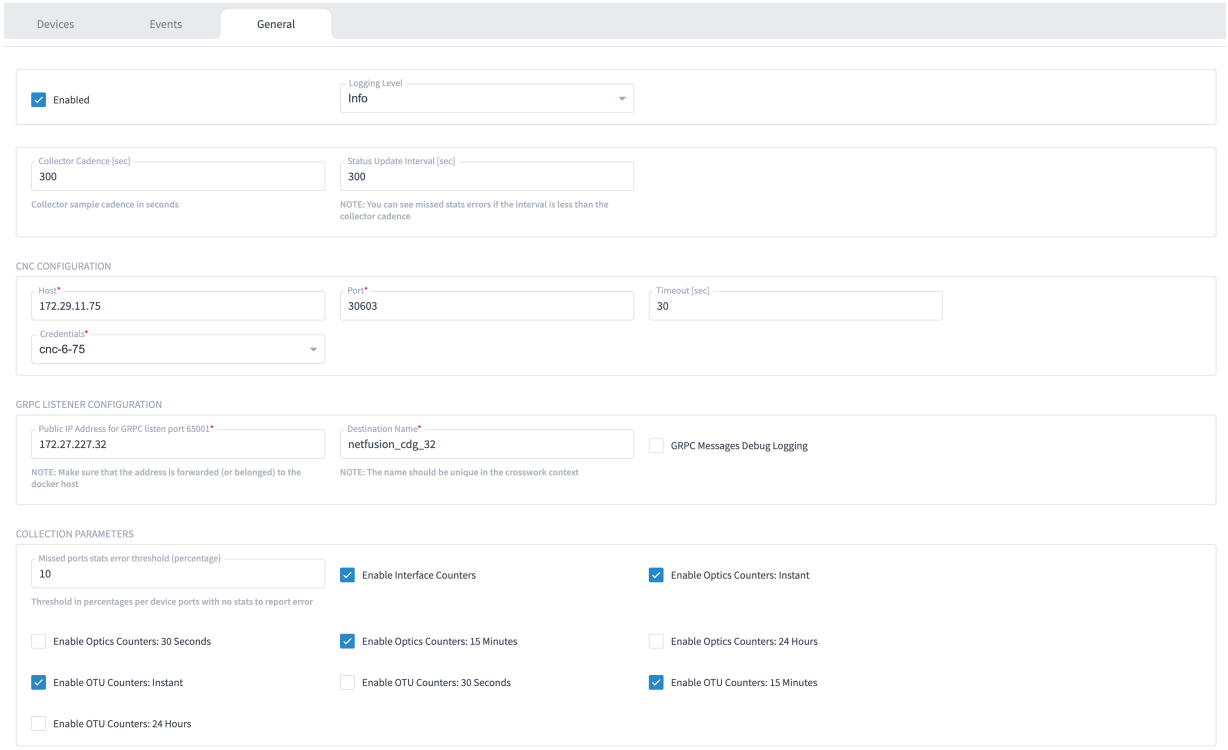
Figure 47: Crosswork Network Controller Crosswork Data Gateway adapter



The Crosswork Data Gateway adapter is configured to connect to Crosswork Network Controller controlling Crosswork Data Gateway instance. It can be the same as the Crosswork Network Controller used for the topology or a different Crosswork Network Controller. The collection parameters describe the supported telemetry collection jobs. The statistics show up in the physical interface statistics and in the Link Assurance application.

Sample end-to-end configuration

Figure 48: Crosswork Network Controller Crosswork Data Gateway adapter—General tab



- The device name in Cisco Crosswork Hierarchical Controller must match the device name in Crosswork Network Controller for successful deployment. If successful, you will see Cisco Crosswork Hierarchical Controller as a new destination in Crosswork Network Controller. This is automatically set up by Cisco Crosswork Hierarchical Controller. As Crosswork Data Gateway is enabled on devices, new collection jobs are populated. A single collection job is available for each router collecting multiple KPIs.

Figure 49: Crosswork Network Controller Crosswork Data Gateway adapter - data destinations

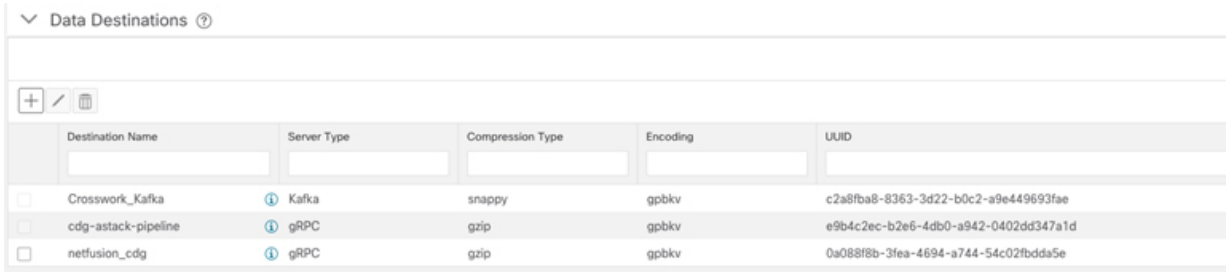
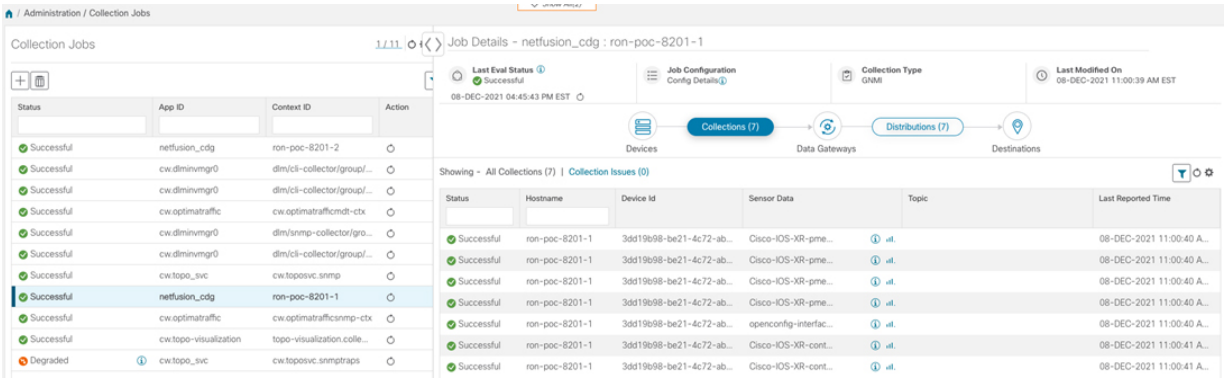


Figure 50: Crosswork Network Controller Crosswork Data Gateway adapter - collection jobs



- **NSO adapter In Hierarchical Controller**

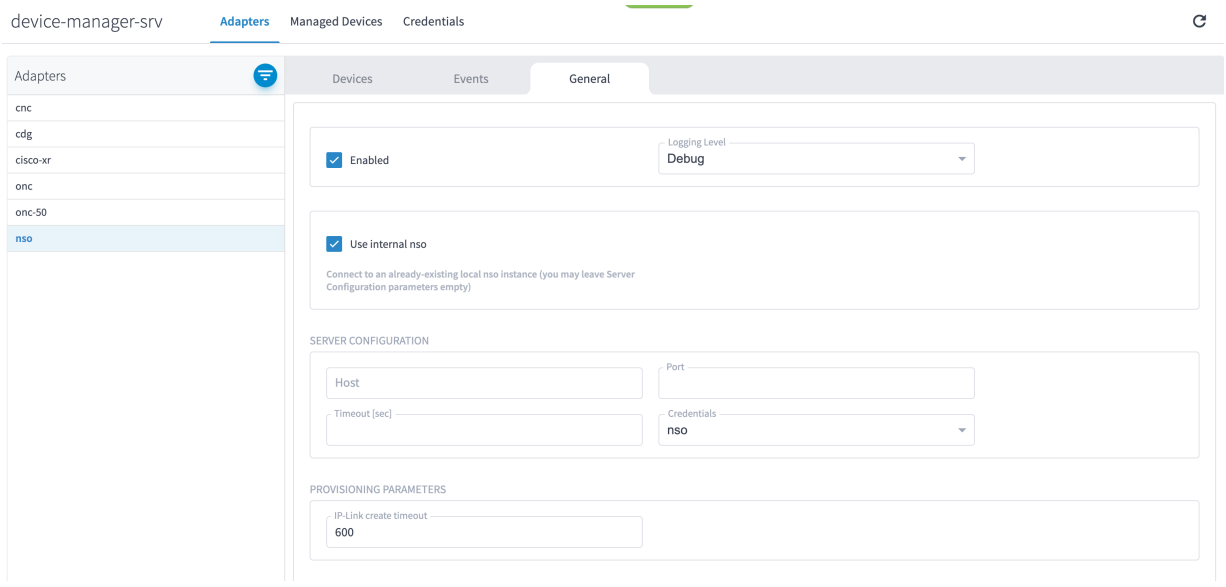
  In Hierarchical Controller 8.0 there is an embedded NSO installed when Hierarchical Controller 8.0 is installed. The NSO adapter can use the internal NSO or an external NSO instance. To provision devices using the NSO adapter, add the NSO adapter to the devices.

  Use the NSO adapter when you use the Automation starter solution and full solution, on page 86.

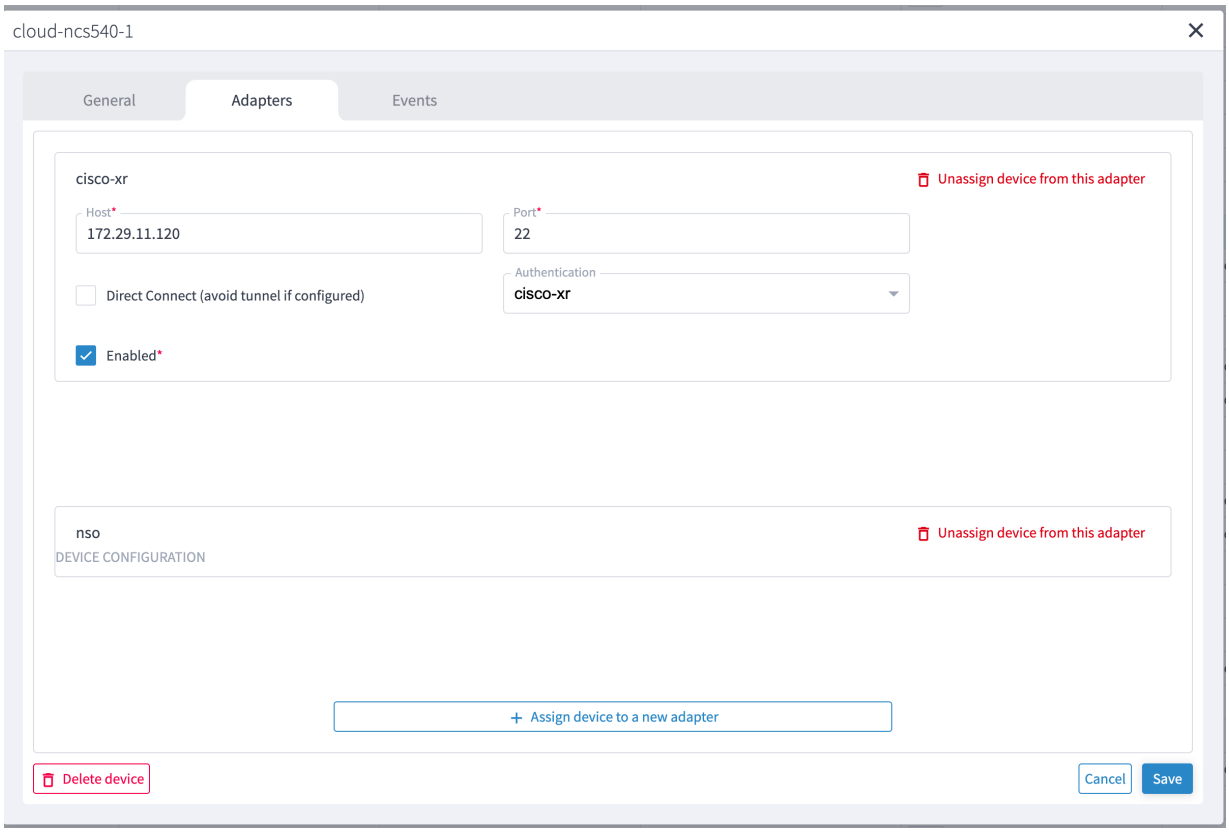
  Note

  - If using the internal NSO, the Routed Optical Networking 3.0 Core Function Pack must be installed on the NSO instance.
  - If using the internal NSO, devices must be added to that NSO, since adding them to Hierarchical Controller does not automatically onboard them into the internal NSO.

Figure 51: NSO adapter—General tab



Begin configuring your NSO and IOS-XR adapters.



The selected adapters are configured and ready for device assignment.

Configure SSO in Crosswork Hierarchical Controller

Enable Single Sign-On (SSO) in Crosswork Hierarchical Controller using Crosswork Network Controller as the identity provider.

Use this task when you need to configure SSO in Crosswork Hierarchical Controller with Crosswork Network Controller as Identity Provider. You can use the same SSO configuration to set up SSO for Cisco Optical Network Controller Release 3.1.

Procedure

Step 1 Configure Crosswork Hierarchical Controller.

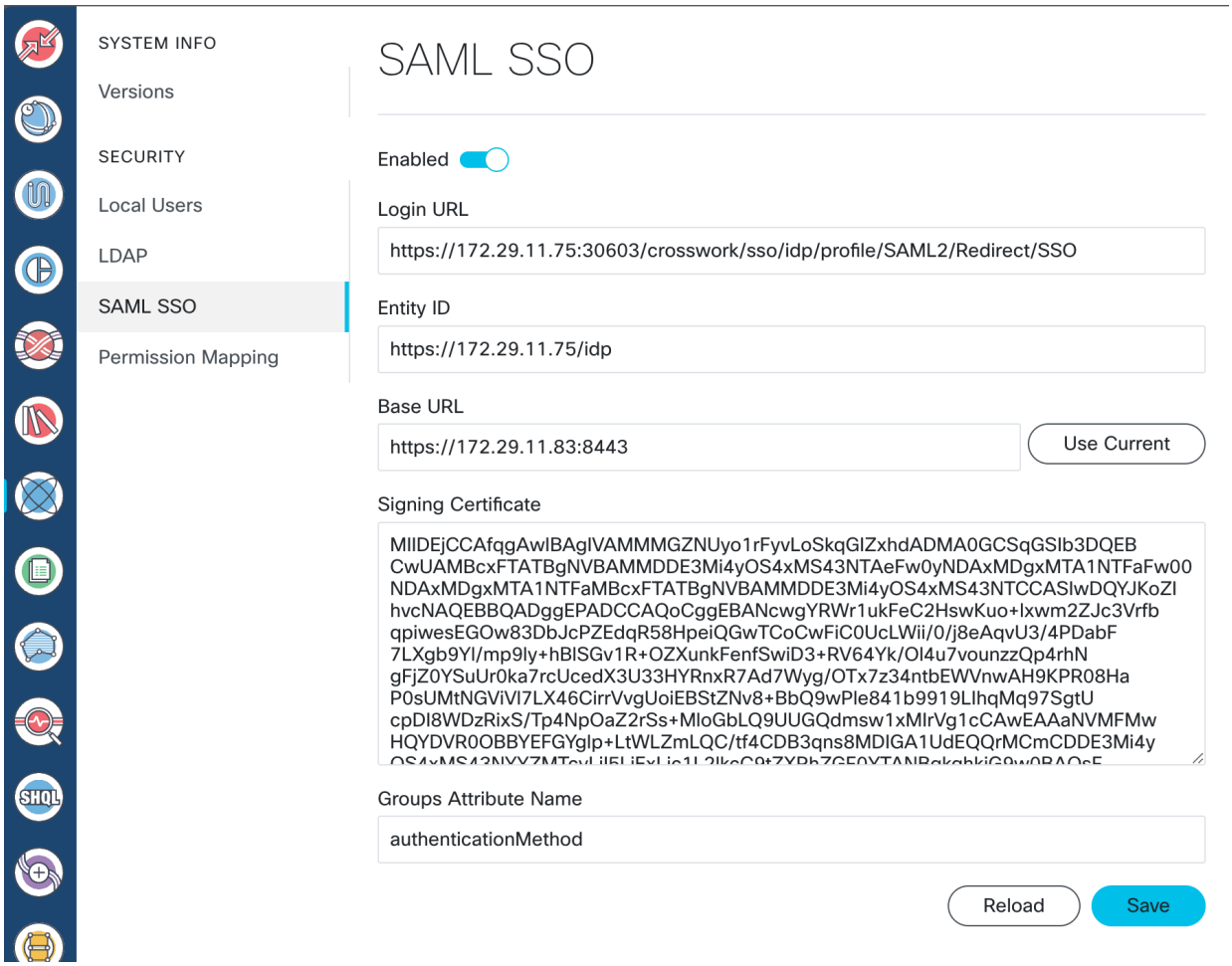
a. Click **Settings** > **Security** > **SAML Configuration**.

Enter the required information:

- **Login URL**: Visit https://<*CNC_IP_address*>:<*port*>/crosswork/sso/idp/profile/SAML2/Redirect/SSO
- **Entity ID**: Visit https://<*CNC_IP_address*>/idp

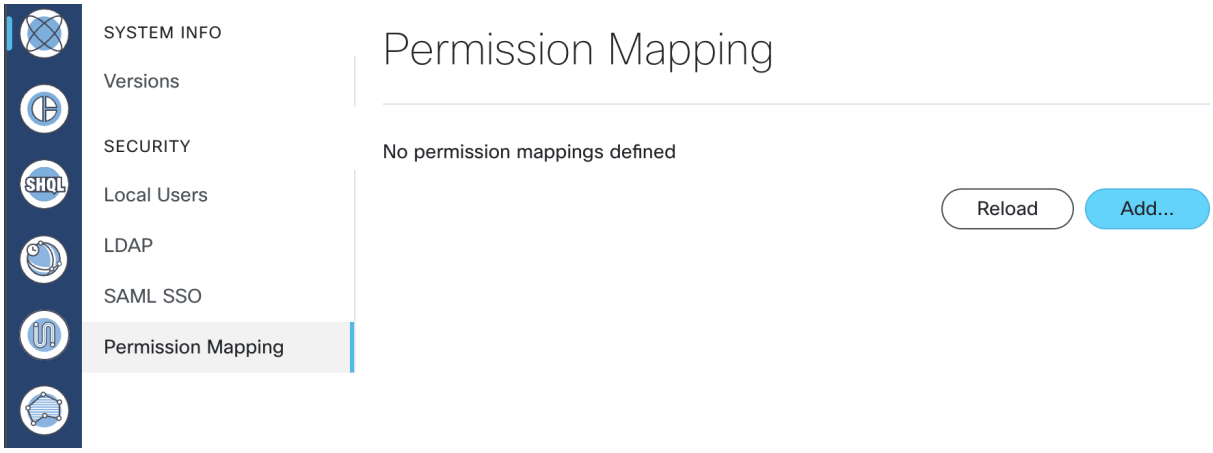
- **Signing Certificate**: Copy the metadata from Crosswork Network Controller at https://**<CNC_IP_address>**:<*port*>crosswork/sso/idp/metadata
- **Groups Attribute Name**: Type `authenticationMethod`.

Figure 52: Crosswork Hierarchical Controller provider configuration sample



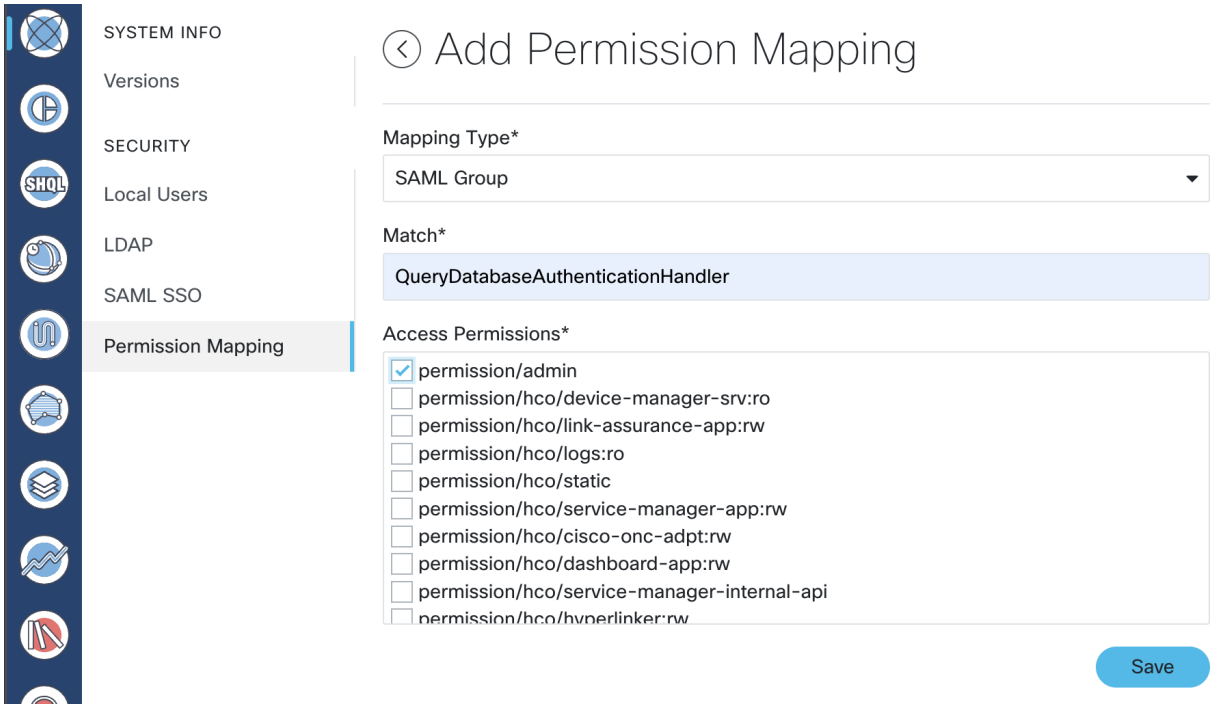
b. Click **Settings** > **Security** > **Permission Mapping**.

Figure 53: Crosswork Hierarchical Controller permission-mapping sample



c. Add a **Match** condition for **SAML Group** of **QueryDatabaseAuthenticationHandler** with a permission of `permission/admin`.

Figure 54: Crosswork Hierarchical Controller permission-mapping sample



Step 2 Copy the SAML metadata from Crosswork Hierarchical Controller to a file.

The metadata is at https://<*HCO_IP_address*>:<*port*>/sso/metadata. This file is a sample.

```
<EntityDescriptor entityID="https://172.29.11.83:8443" xmlns="urn:oasis:names:tc:SAML:2.0:metadata"
 xmlns:assertion="urn:oasis:names:tc:SAML:2.0:assertion" xmlns:ds="http://www.w3.org/2000/09/xmldsig#">

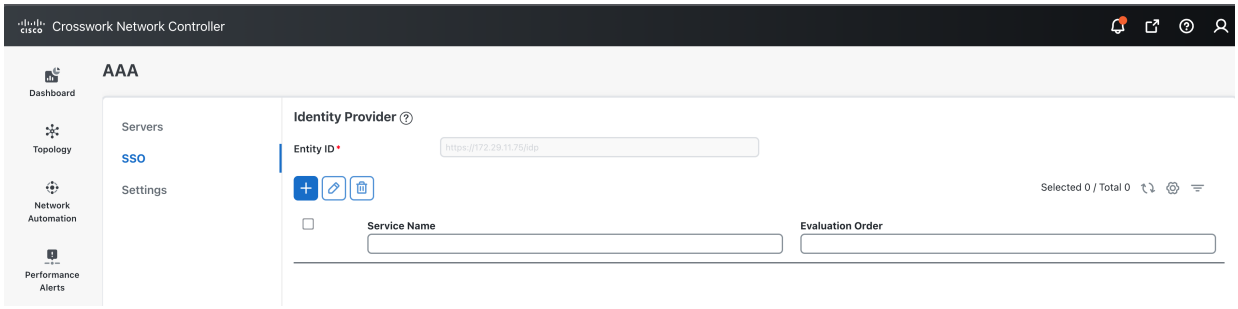
    <SPSSODescriptor AuthnRequestsSigned="false" WantAssertionsSigned="false"
protocolSupportEnumeration="urn:oasis:names:tc:SAML:2.0:protocol">
```

```
    <NameIDFormat>urn:oasis:names:tc:SAML:1.1:nameid-format:emailAddress</NameIDFormat>
    <SingleLogoutService Binding="urn:oasis:names:tc:SAML:2.0:bindings:HTTP-Redirect"
Location="https://172.29.11.83:8443/sso/logout">
    </SingleLogoutService>
    <AssertionConsumerService index="0" Binding="urn:oasis:names:tc:SAML:2.0:bindings:HTTP-POST"
Location="https://172.29.11.83:8443/sso/acs">
    </AssertionConsumerService>
    </SPSSODescriptor>
</EntityDescriptor>
```

Step 3 Configure Crosswork Network Controller.

a. Log in to Crosswork Network Controller and click **Administration** > **AAA** > **SSO**.

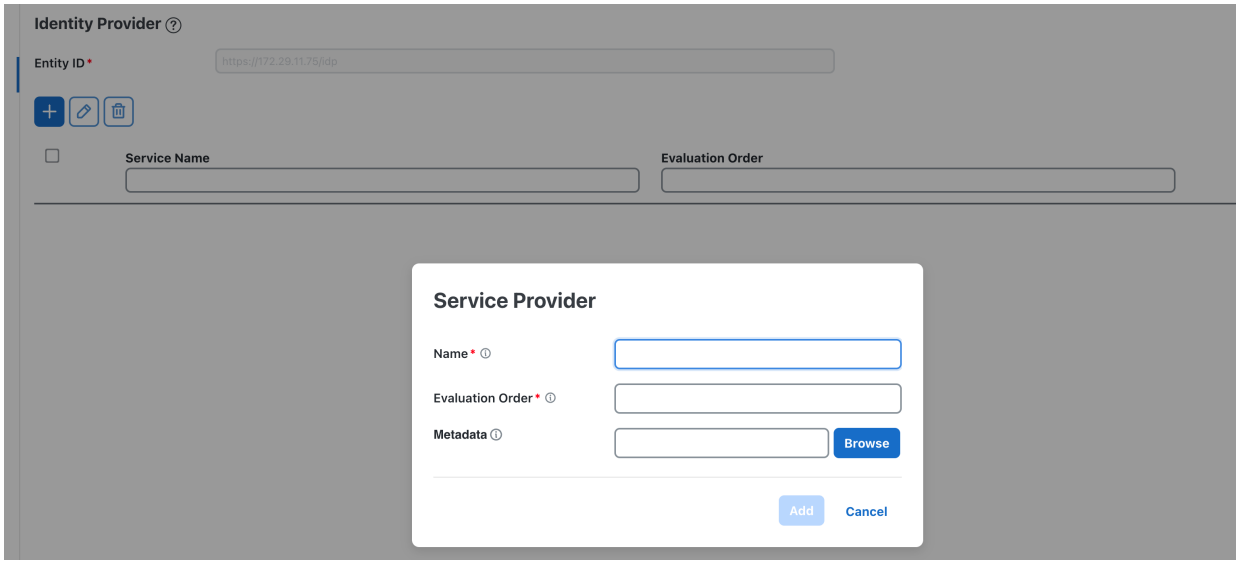
Figure 55: Crosswork Network Controller AAA



b. Click + and enter the required information:

- Enter a name.
- Enter a unique evaluation order number.
- Upload the metadata file of HCO in XML format.

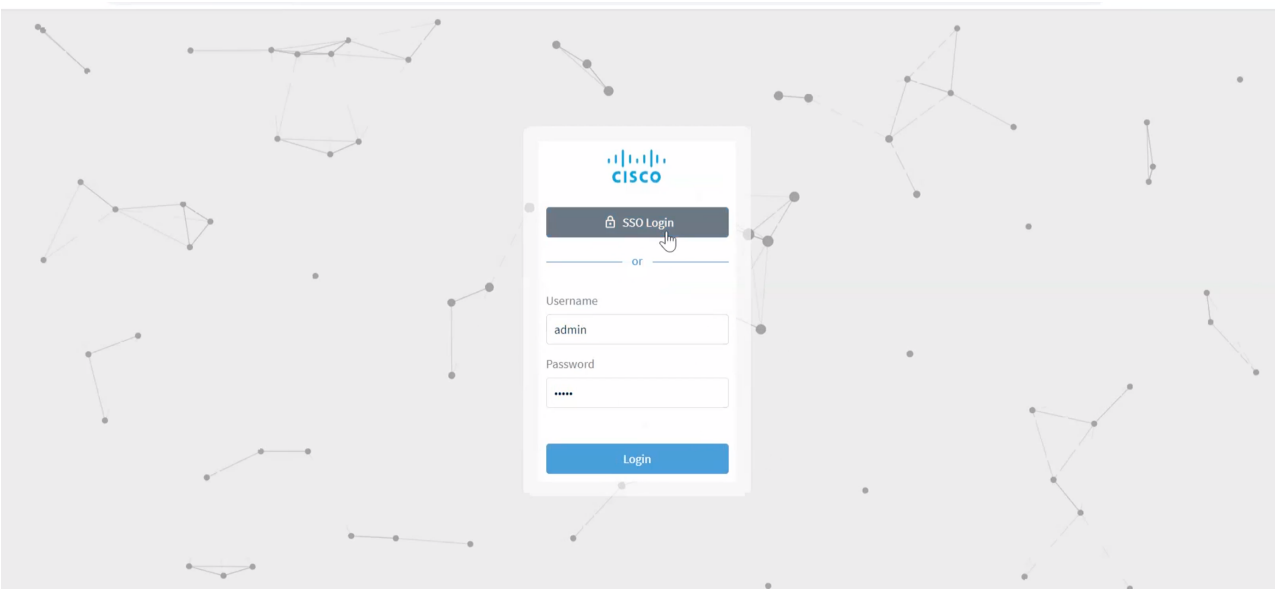
Figure 56: Crosswork Network Controller-add new service provider



c. Click **Save**.

Step 4 Log in to Crosswork Network Controller.

Figure 57: Crosswork Network Controller AAA



Troubleshooting Cisco Crosswork Hierarchical Controller SSO

- Use the **sedo logs security audit** in the Crosswork Hierarchical Controller to get the logs.
- Ensure that the time between Cisco Crosswork Hierarchical Controller and Cisco Crosswork Network Controller is synchronized
- If there is an error related to `QueryDatabaseAuthenticationHandler`, add the SAML group mapping in Crosswork Hierarchical Controller configuration and map to group Admin.

Crosswork Hierarchical Controller enables SSO for authorized users.

Cross-launch from Crosswork Hierarchical Controller

SSO is supported across Crosswork Hierarchical Controller 8.0, Crosswork Network Controller 6.0, Cisco Optical Network Controller, and Cisco Optical Site Manager.

Procedure

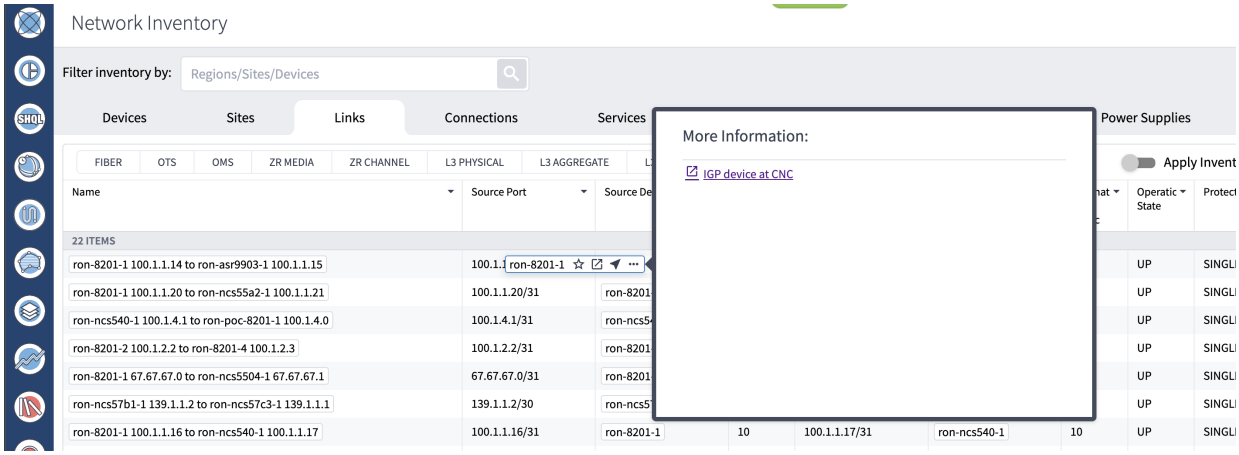
Step 1 Cross launch from the IGP link source or destination router in Crosswork Hierarchical Controller to Crosswork Network Controller.

a. Click **Links** > **IGP** .

b. Hover over the source device or the destination device. Click the ellipsis and then click **IGP device at Crosswork Network Controller**.

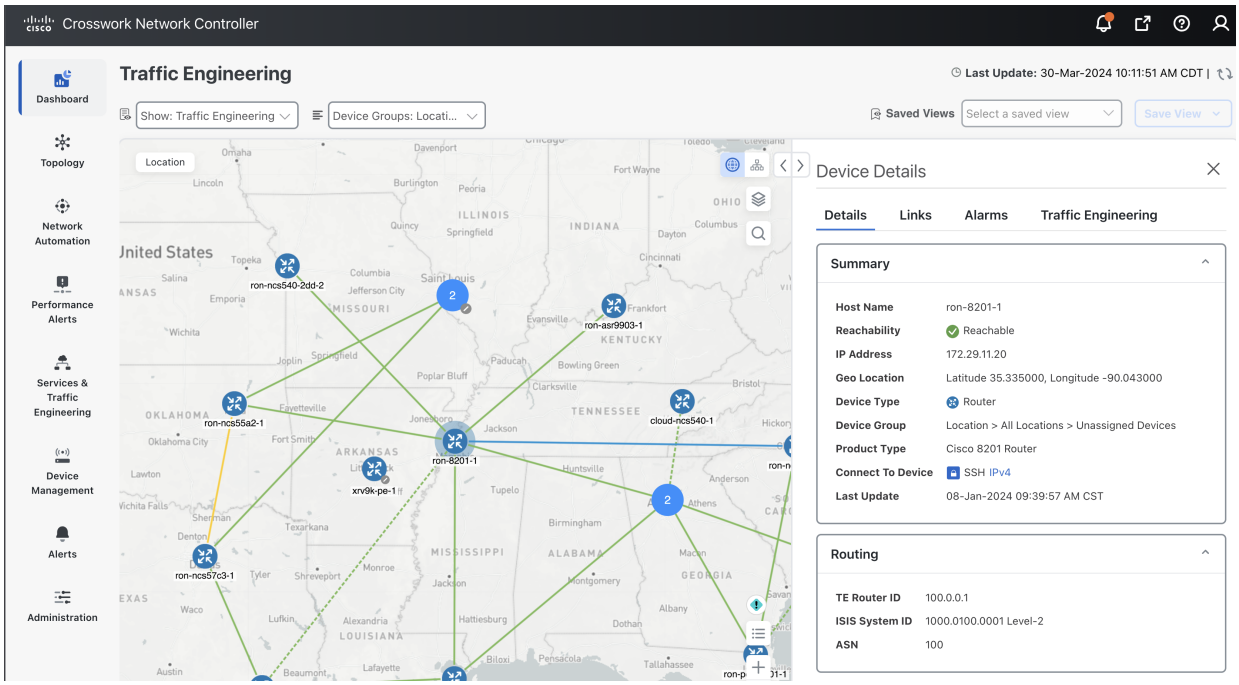
Sample end-to-end configuration

Figure 58: Network inventory



This operation displays router traffic engineering information in Crosswork Network Controller.

Figure 59: Traffic engineering



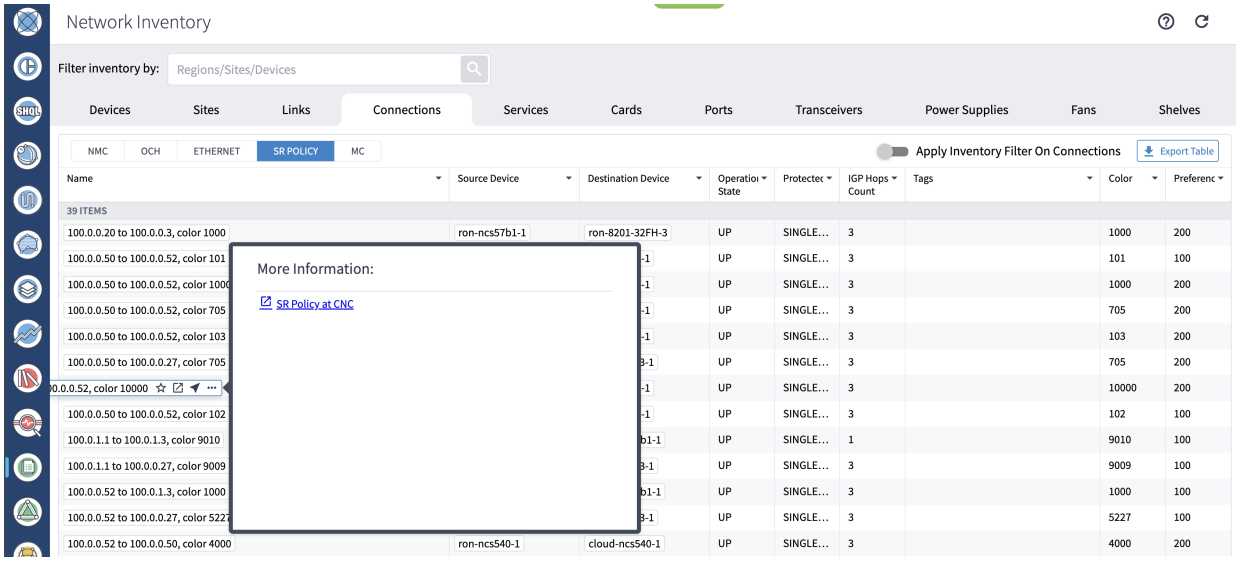
Step 2 Cross launch from Crosswork Hierarchical Controller SR Policy to Crosswork Network Controller.

a. Click **Connections** > **SR Policy**.

b. Hover over a policy, and click the ellipsis to open cross launch.

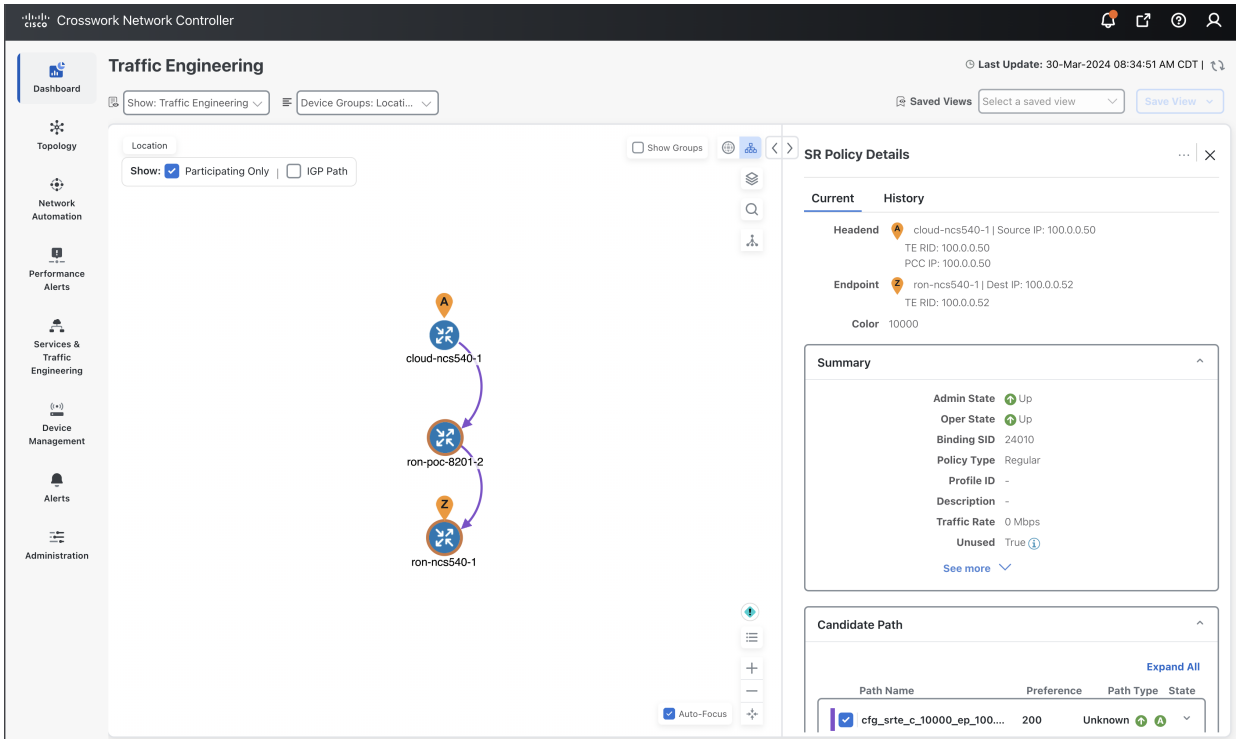
Sample end-to-end configuration

Figure 60: Network inventory



This operation displays detailed policy information in Crosswork Network Controller.

Figure 61: Traffic engineering



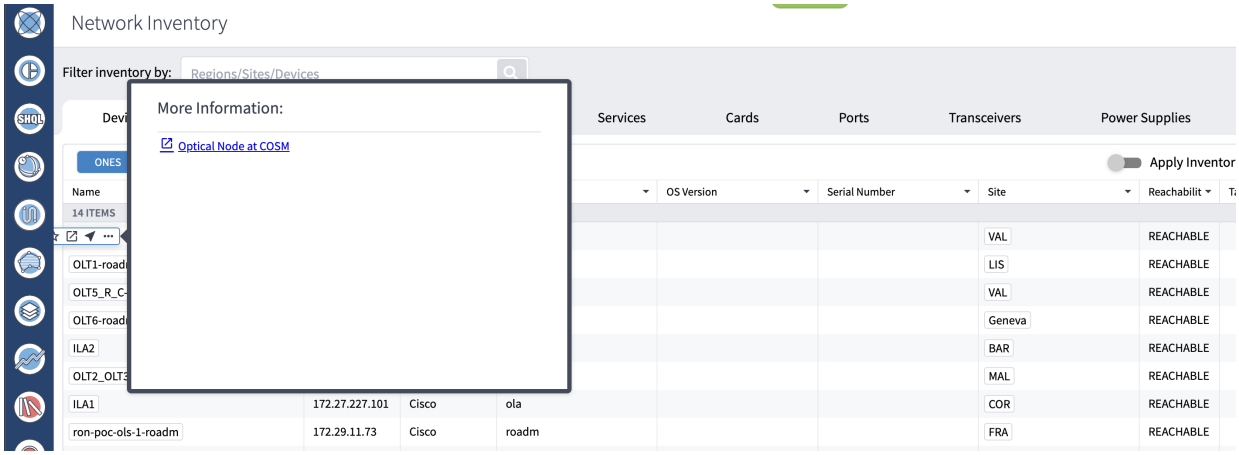
Step 3 Cross launch from Crosswork Hierarchical Controller optical node to Cisco Optical Site Manager.

a. Click **Devices** > **ONS**.

b. Hover over a device, click the ellipsis, and then click **Optical Node at COSM**.

Sample end-to-end configuration

Figure 62: Network inventory

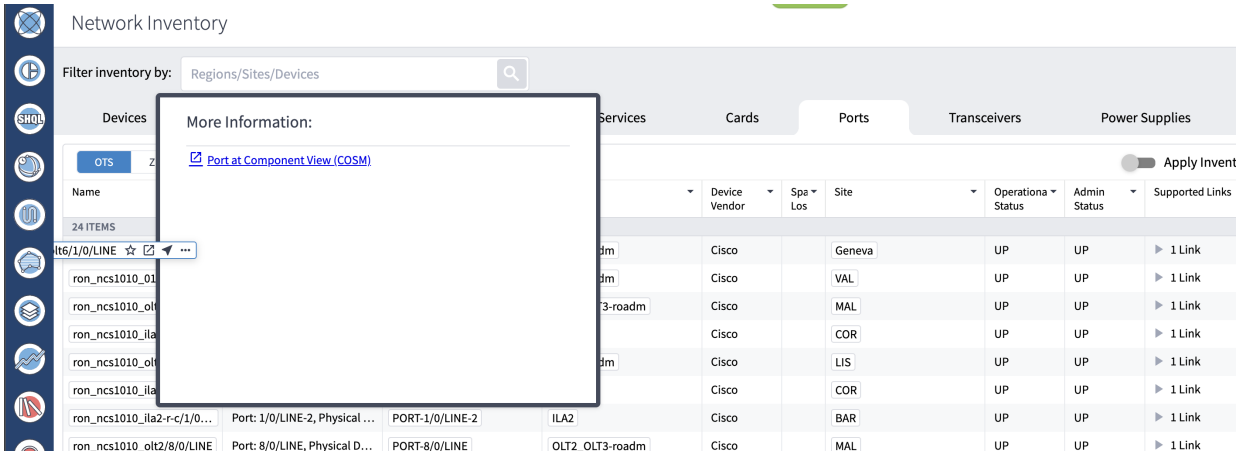


Step 4 Cross launch from Crosswork Hierarchical Controller optical port to Cisco Optical Site Manager.

a. Click **Ports** > **OTS**.

b. Hover over a port, click the ellipsis, and then click **Optical Port at COSM**.

Figure 63: Network inventory



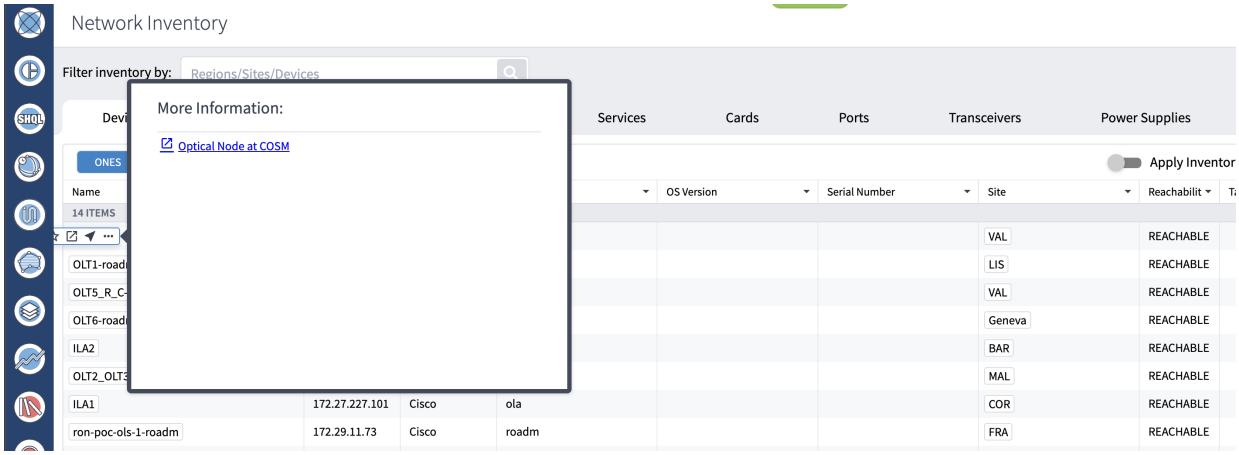
Step 5 Cross launch from Crosswork Hierarchical Controller Link Assurance node to Cisco Optical Site Manager or SVO.

a. Click **Link Assurance** > **Inspect links**.

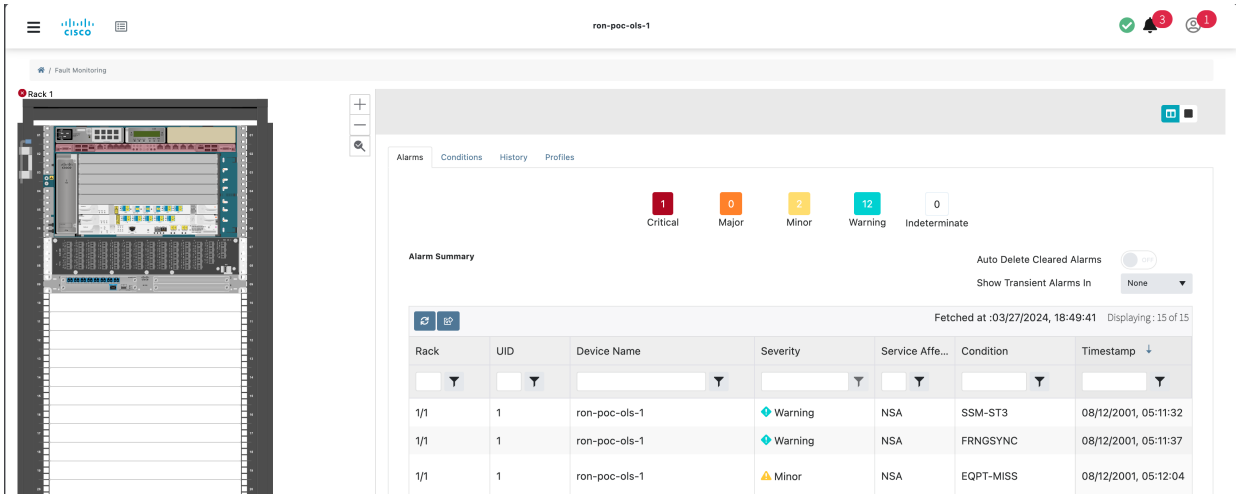
b. Hover over a node, click the ellipsis, and then click **Optical Node at COSM**.

Sample end-to-end configuration

Figure 64: Link assurance



This operation displays the node functional view in Cisco Optical Site Manager for NCS 1000 series devices or in SVO for NCS 2000 series devices.



Step 6 Cross launch from Crosswork Hierarchical Controller Link Assurance port to Cisco Optical Site Manager.

a. Click **Link Assurance** > **Inspect links**.

b. Hover over a port, click the ellipsis, and click **Optical Port at COSM**.

Figure 65: Link assurance



Provision an ML service using NSO Routed Optical Networking CFP

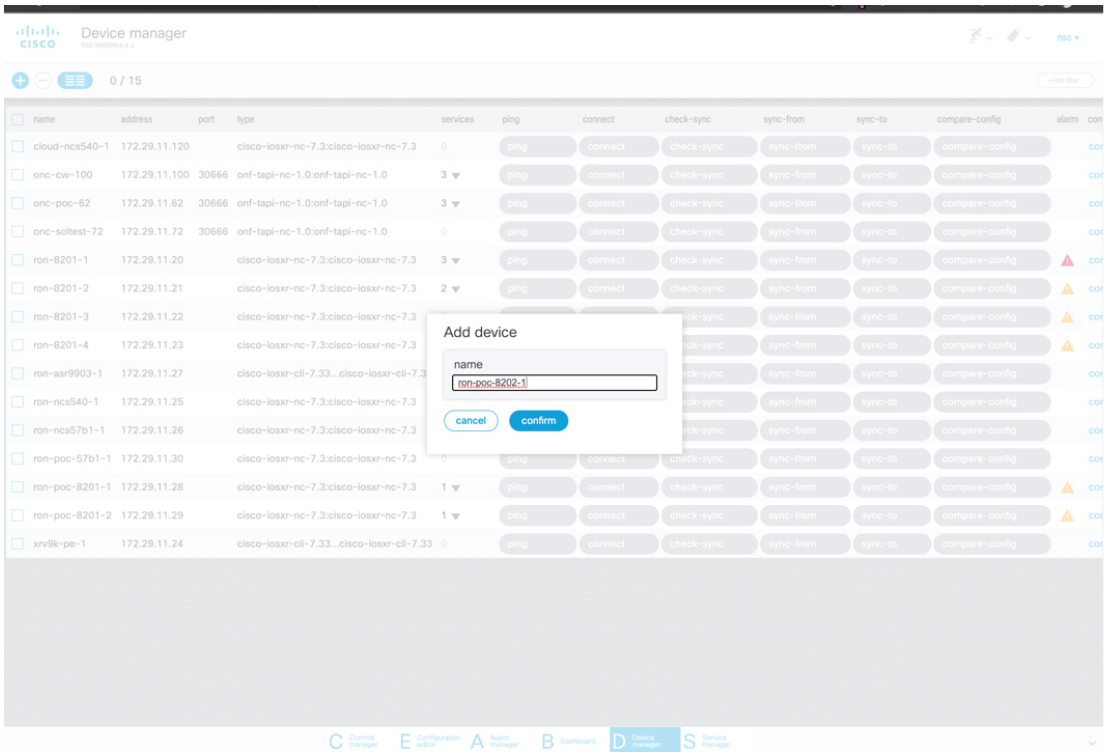
Follow these steps to provision the Routed Optical Networking ML service using the NSO Web UI.

Procedure

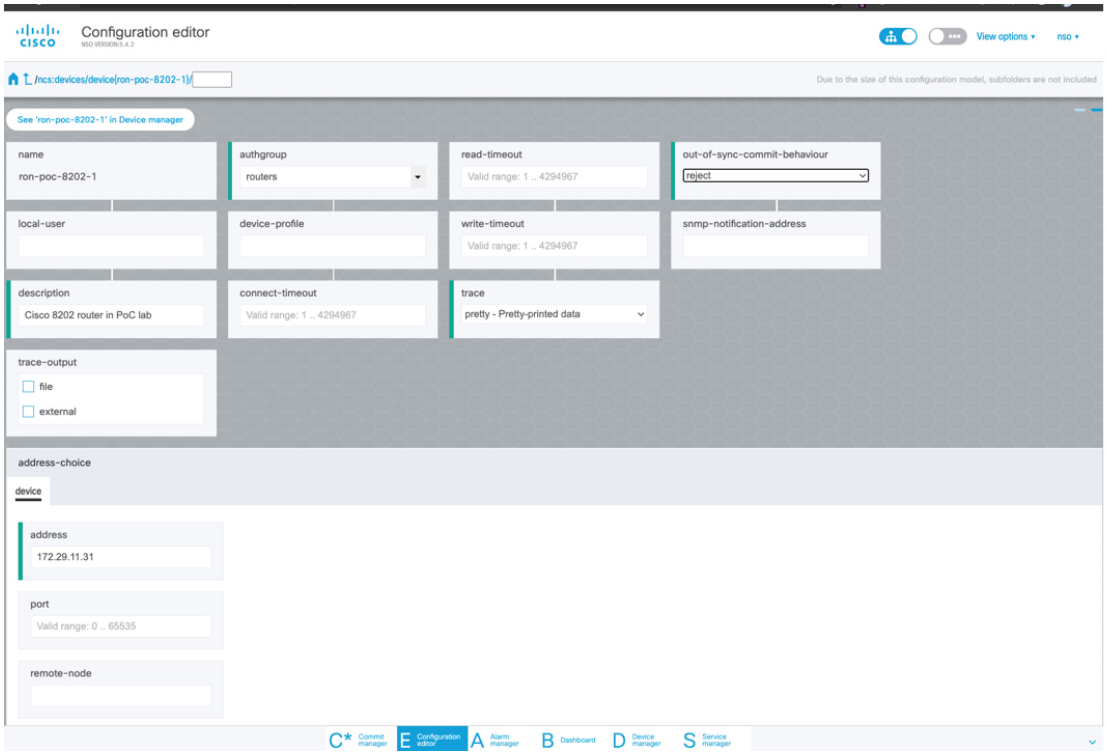
Step 1 To add a new device, perform these steps:

a. In the Device manager, click the + to add a new device. Specify a name for the new device and click **Confirm**.

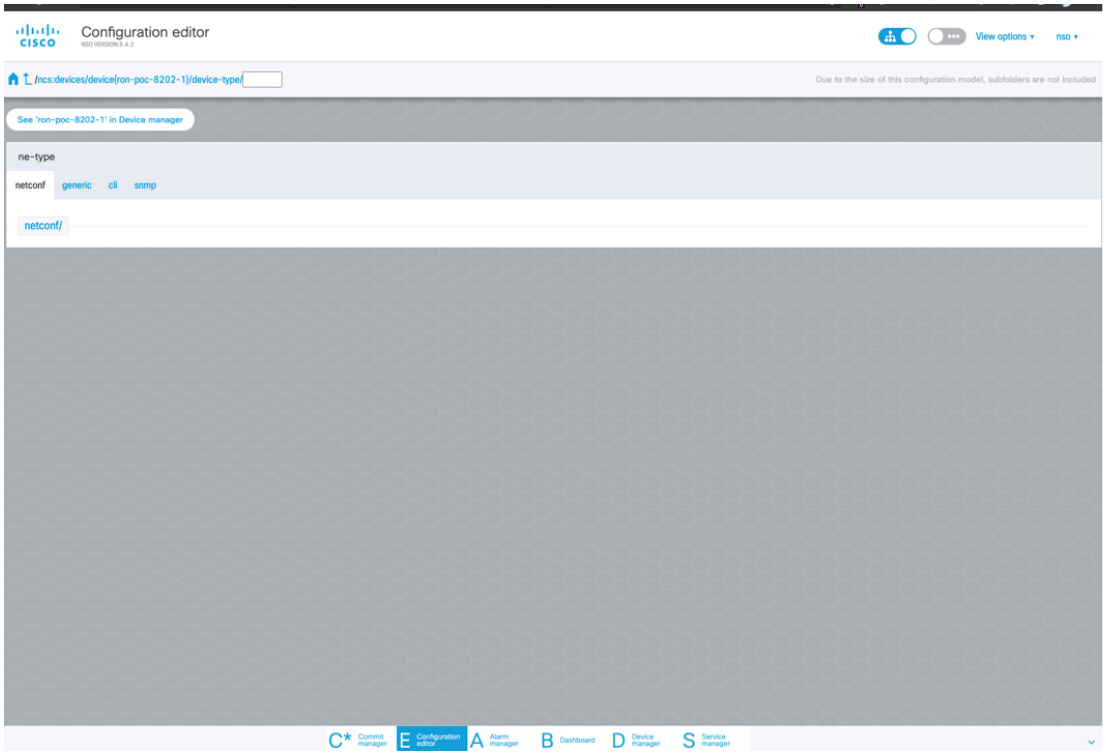
Sample end-to-end configuration



b. After creating the new device, click its name. Then, enter both required and optional parameters. In this screen, you must provide the authgroup and the IP address of the device.

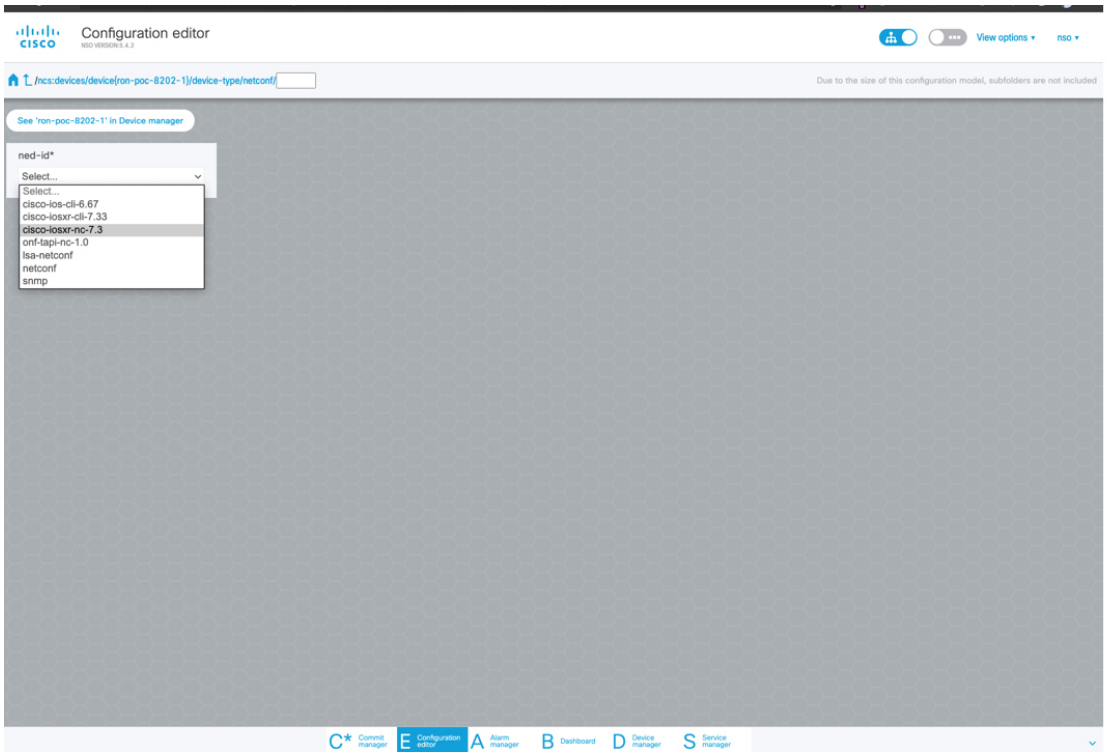


c. Scroll down in the device configuration screen. Click 'device-type' to open the device type selection screen. The supported device type for Routed Optical Networking ML FP is IOS-XR CLI NED.



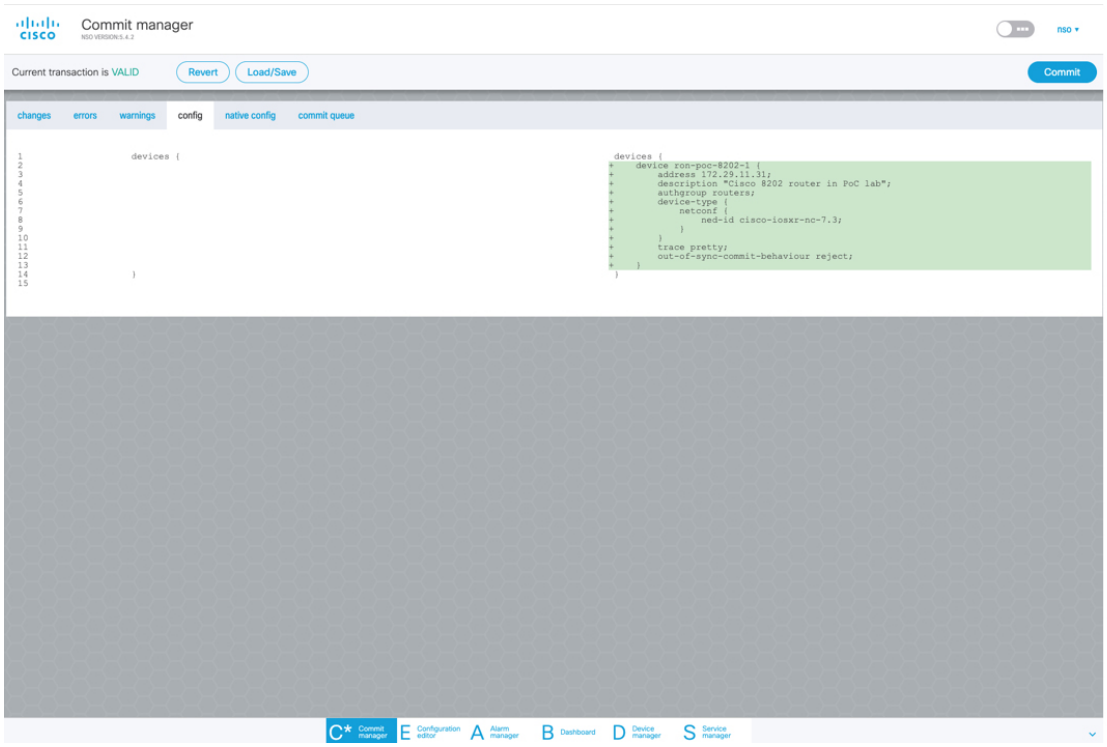
d. Click NETCONF to select the appropriate NED. The Routed Optical Networking ML FP requires the use of the **cisco-iosxr-nc-7.3** NED.

Sample end-to-end configuration



521938

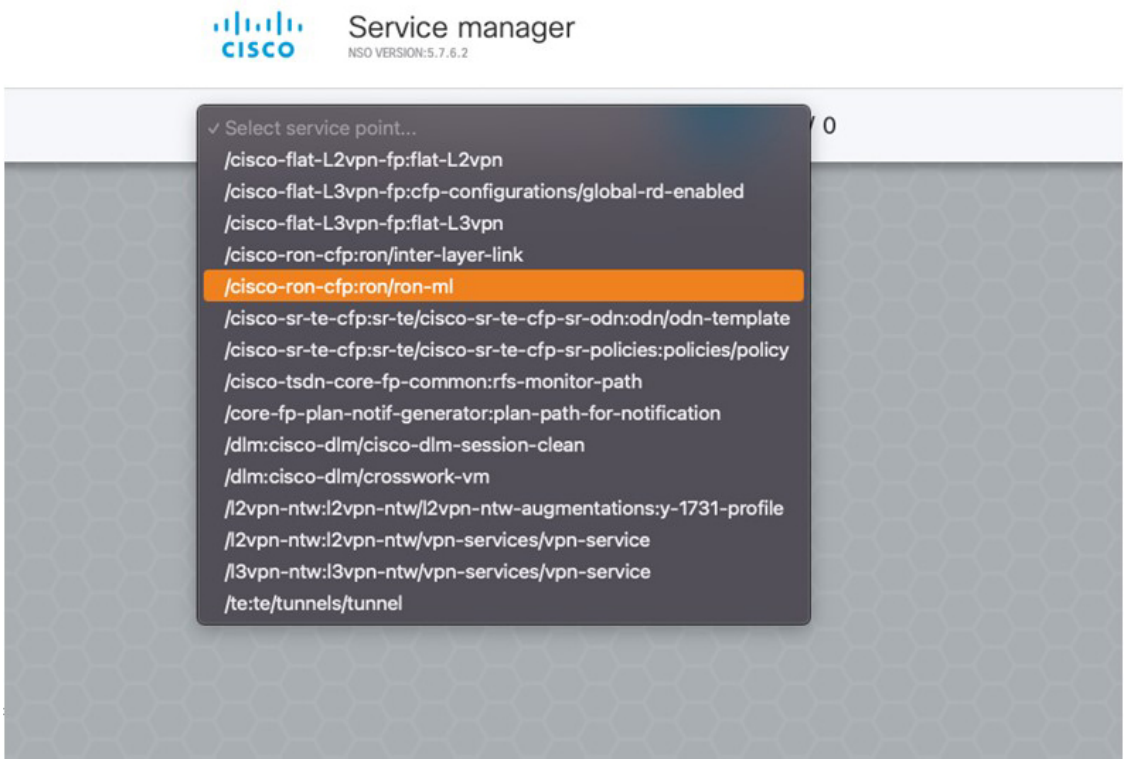
e. Click the Commit manager to view the NSO CLI configuration being applied. Click **Commit** to save the device configuration to NSO.



521939

Note

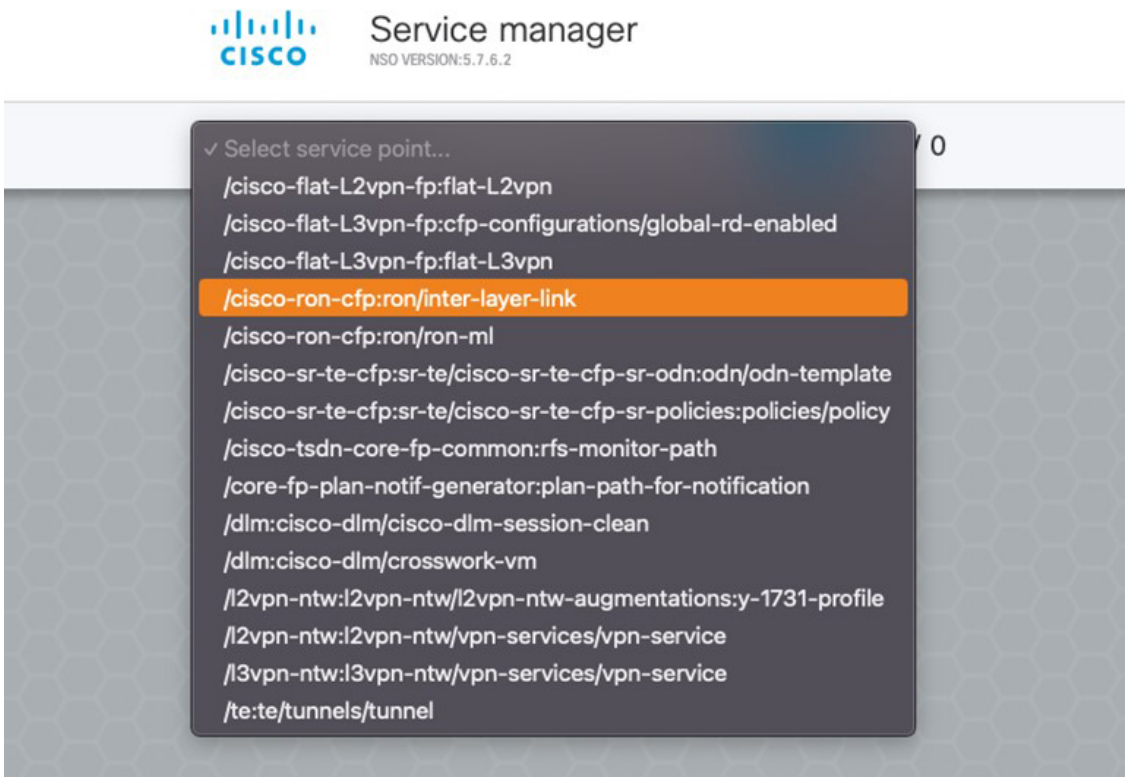
Next we add the multilayer end-to-end service to configure and provision both the optical line system and routers. We recommend you to click **check-sync** in the Device manager to ensure that the device configuration is properly in sync with NSO before provisioning. Initial provisioning fails if the device is out of sync.



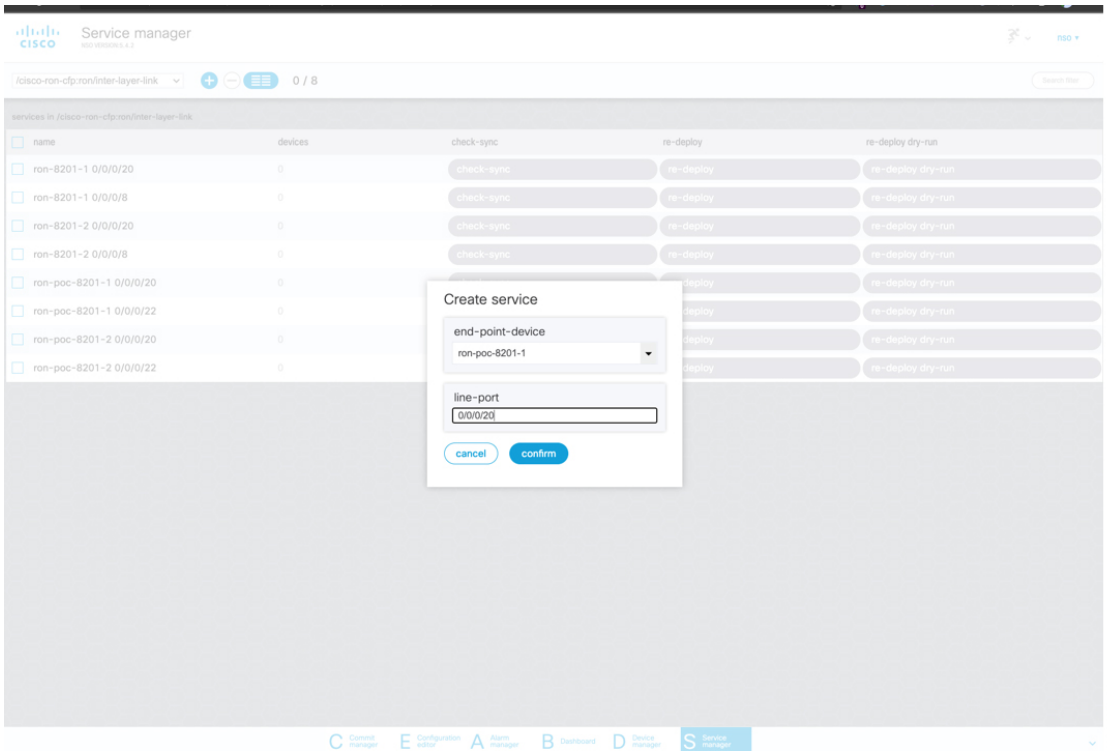
Step 2 To configure the interlayer link service in NSO, perform these steps:

a. In the Service manager, select the inter-layer-link service point from the drop-down list.

Sample end-to-end configuration

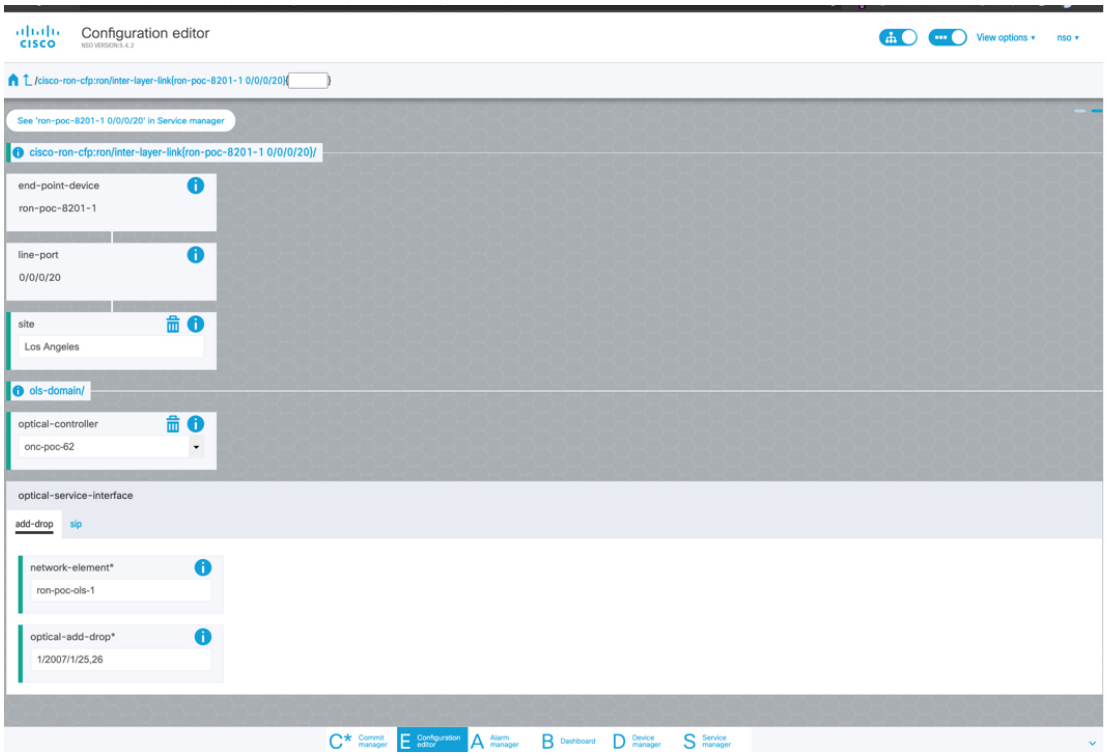


b. Specify the end-point-device and the line port. These are required values. The endpoint device is the 8201 router. Specify the router optics port that is connected to the optical line system add-drop port in the line port field. Click **Confirm**.



c. In the Configuration editor, edit the inter-layer-link service by clicking the newly created draft service to complete the information required. In this example, we add the site name, optical add-drop network element, and the optical add-drop port. The optical controller field specifies which Optical Network Controller instance is used for provisioning. This parameter is optional if a global instance is defined. A global Cisco Optical Network Controller instance can be set in NSO and will be used if the field is not populated. The add-drop port uses the inventory ID of the physical port on the NCS1K-MD-64-C multiplexer for frequency XXXX.YY. The add-drop reference includes both RX and TX directions. In addition to specifying the network-element and add-drop in R/S/I/P form, a TAPI SIP can also be used to identify the add-drop port.

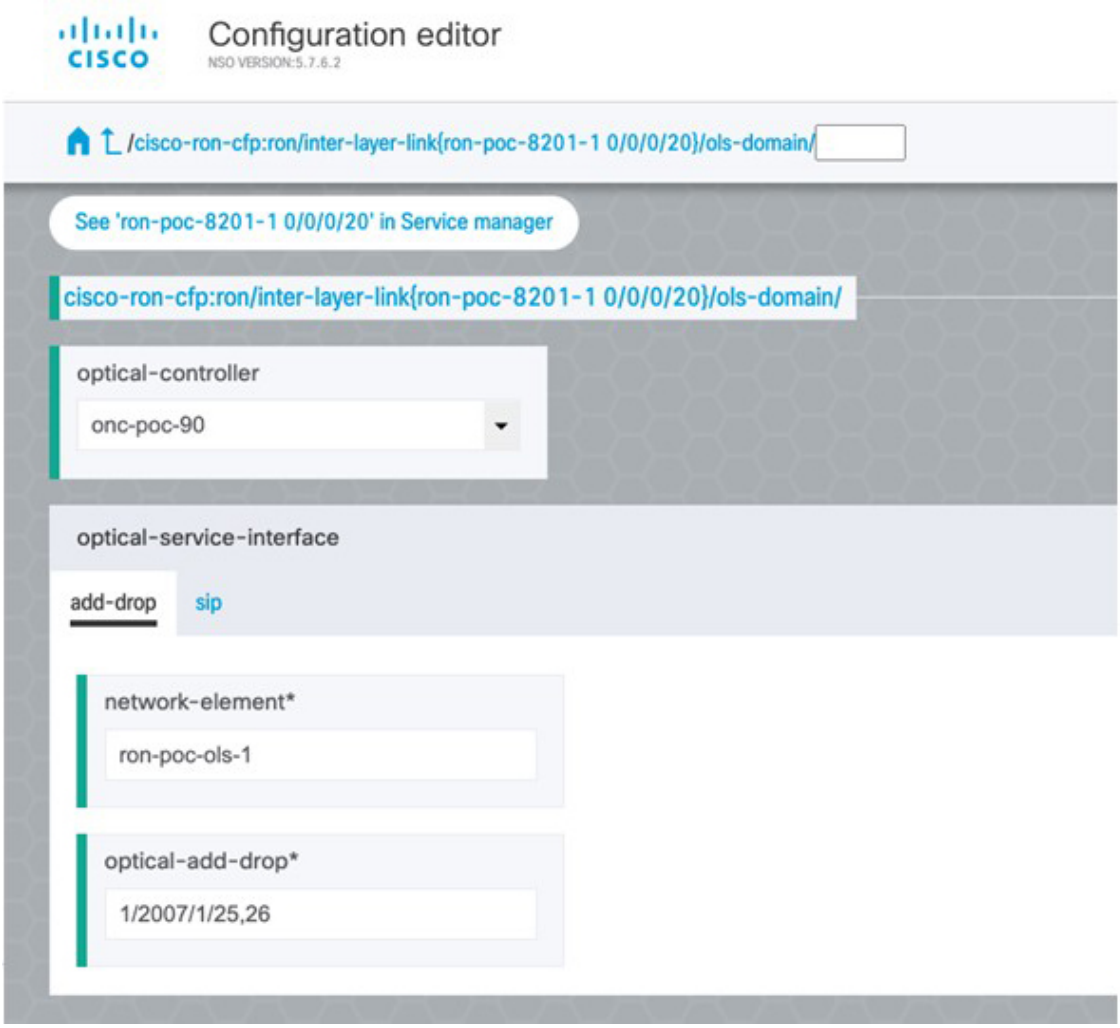
Sample end-to-end configuration



These elements are the only required elements in the inter-layer-link service type.

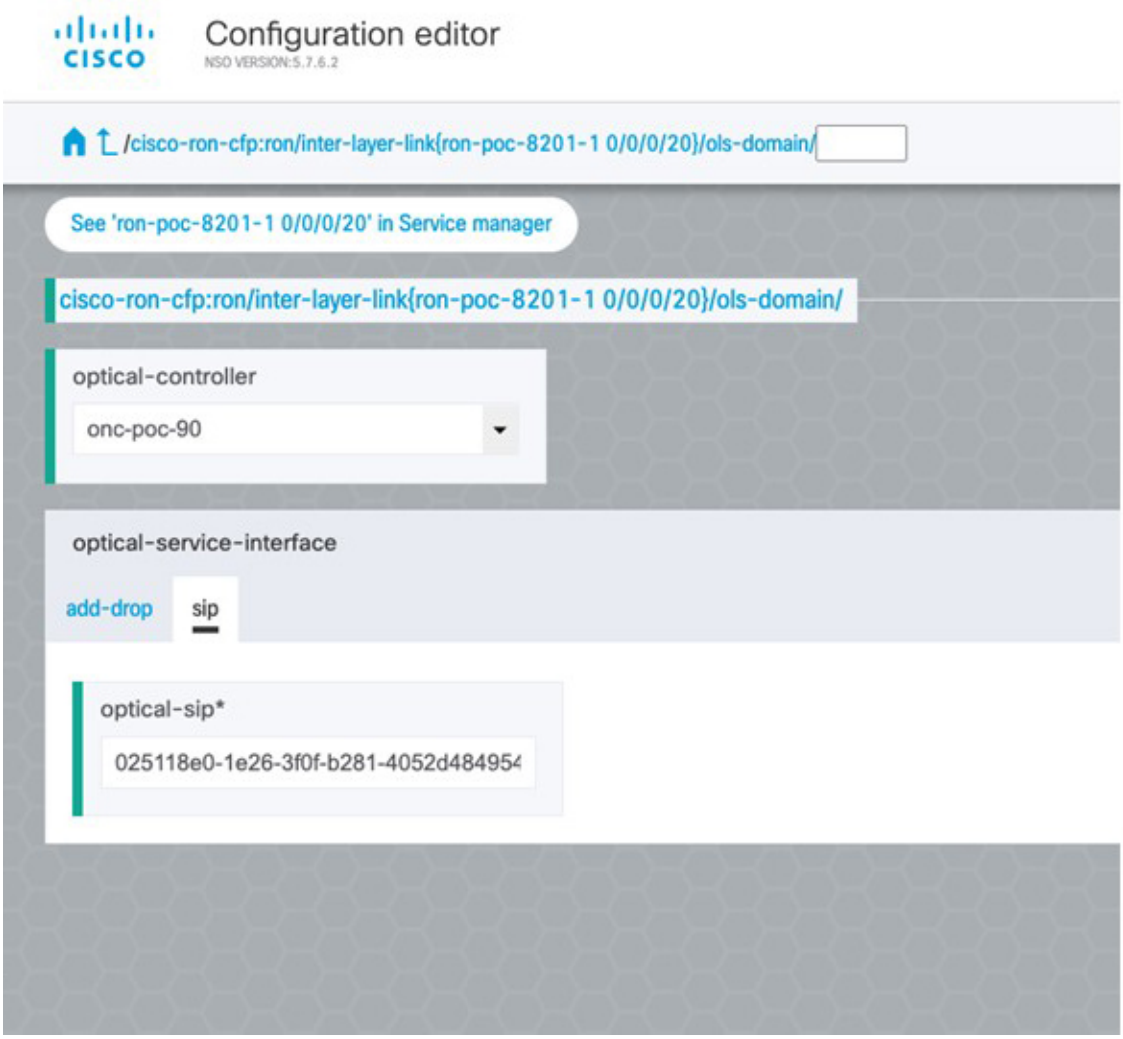
d. Perform Ols-domain optical-service-interface configuration.

- Optical-controller specifies the Cisco Optical Network Controller instance managing the OLS.
- Network-element specifies the optical element name as shown in TAPI topology.
- Optical-add-drop specifies the port to be used on the optical network element.

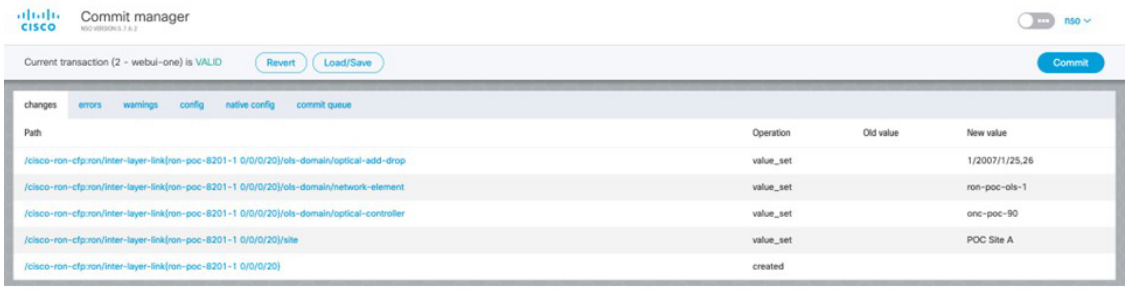


- The optical-service-interface can also be added as a TAPI SIP UUID.

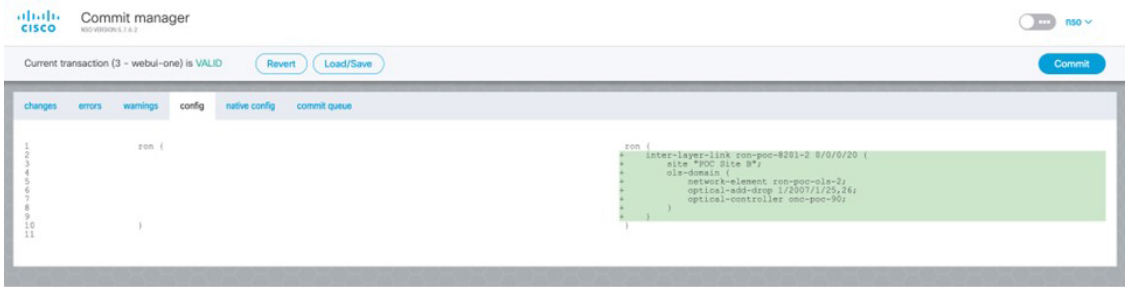
Sample end-to-end configuration



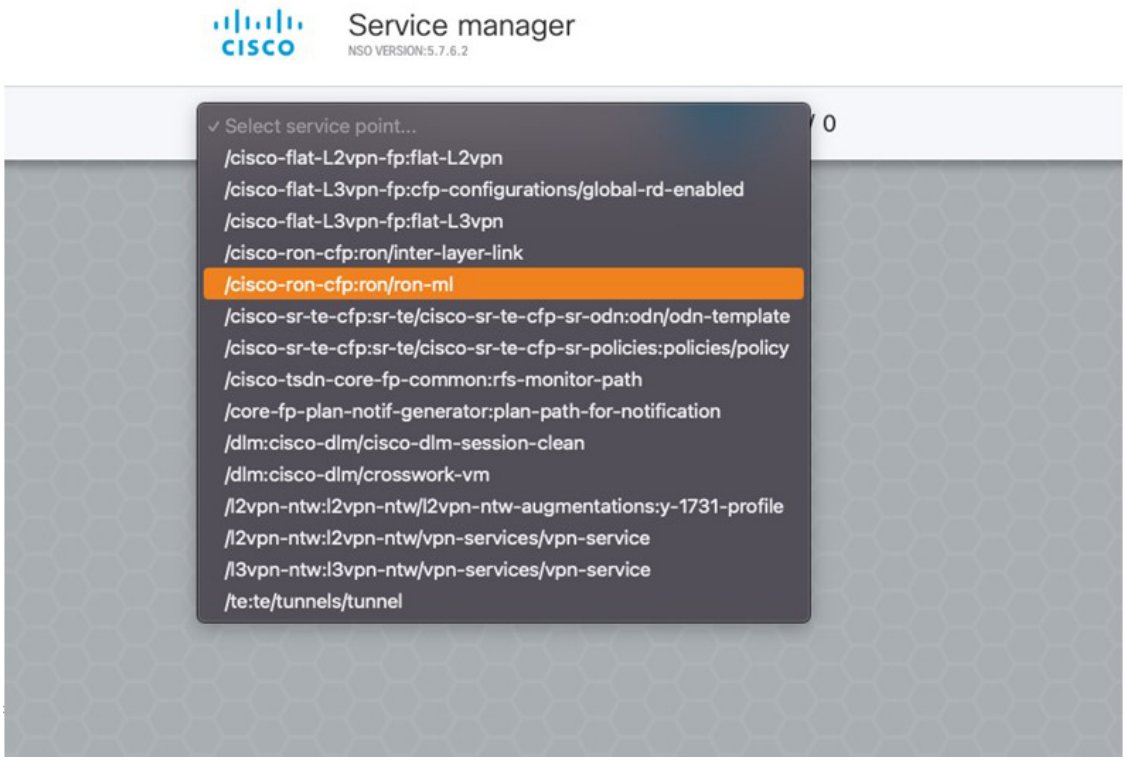
e. Click the config tab in the Commit manager to see the NSO CLI configuration that will be committed to NSO.



f. Click **Commit** in the upper right corner to commit the service. An end-to-end service requires two inter-layer-links, one for each router connected to its optical line system add-drop port.



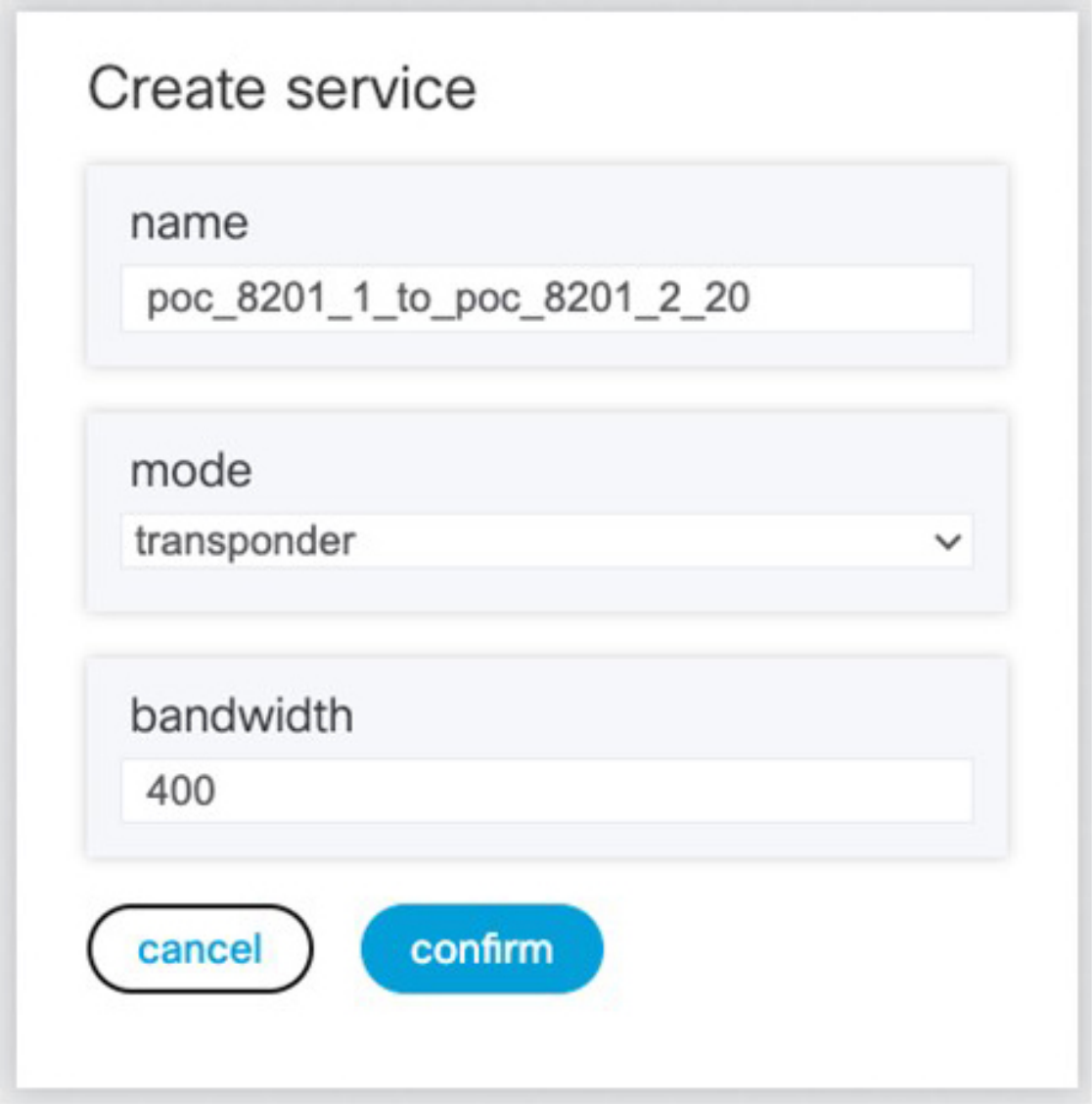
Note
Next we add the multilayer end-to-end service to configure and provision both the optical line system and routers. We recommend you to click **check-sync** in the Device manager to ensure that the device configuration is properly in sync with NSO before provisioning. If the device is out of sync, initial provisioning fails.



Step 3 To create Routed Optical Networking ML service, perform these steps:

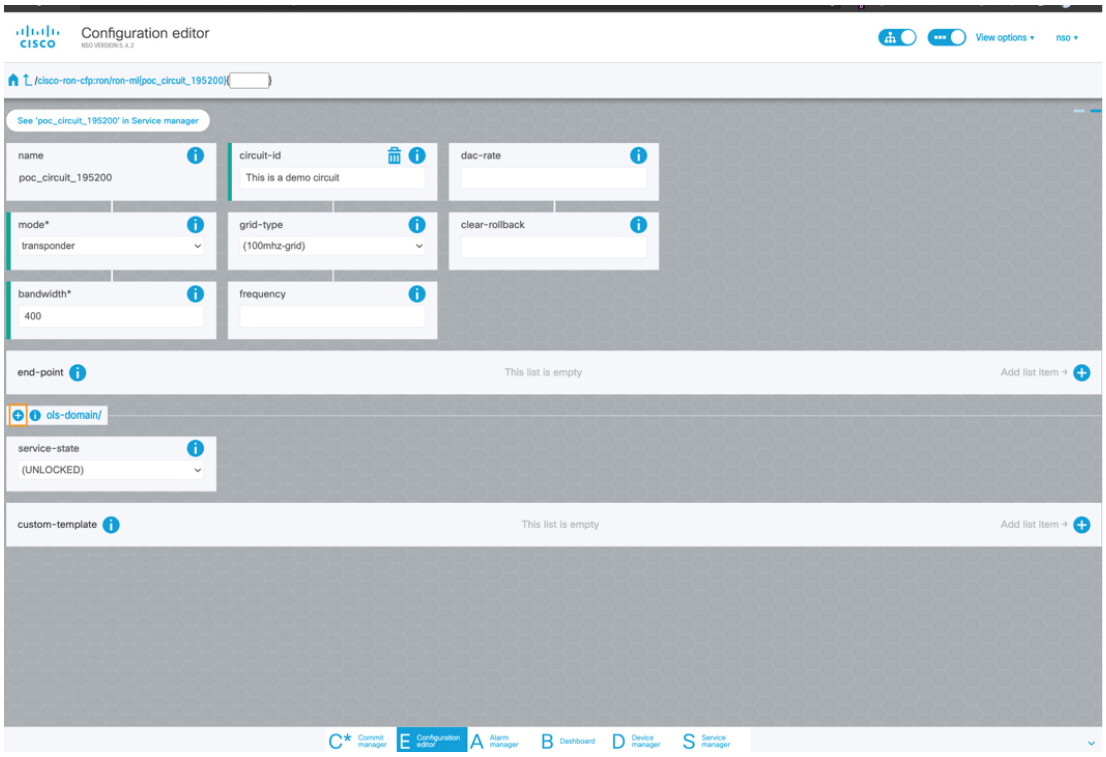
a. In the Service manager, select the Routed Optical Networking ML service point from the drop-down list. When we create the new Routed Optical Networking ML service, the required components are the service name, mode of the service (transponder or muxponder), and the bandwidth. The bandwidth corresponds to the line rate of the ZR or ZR+ optics. Click **Confirm**.

Sample end-to-end configuration



b. In the Configuration editor, click the newly created service name for editing the additional parameters that are required for the service. In this example, set the circuit-id name in the global parameters. The frequency is set by the optical

controller based on the specified optical add-drop port. The dac-rate is set to the default value.

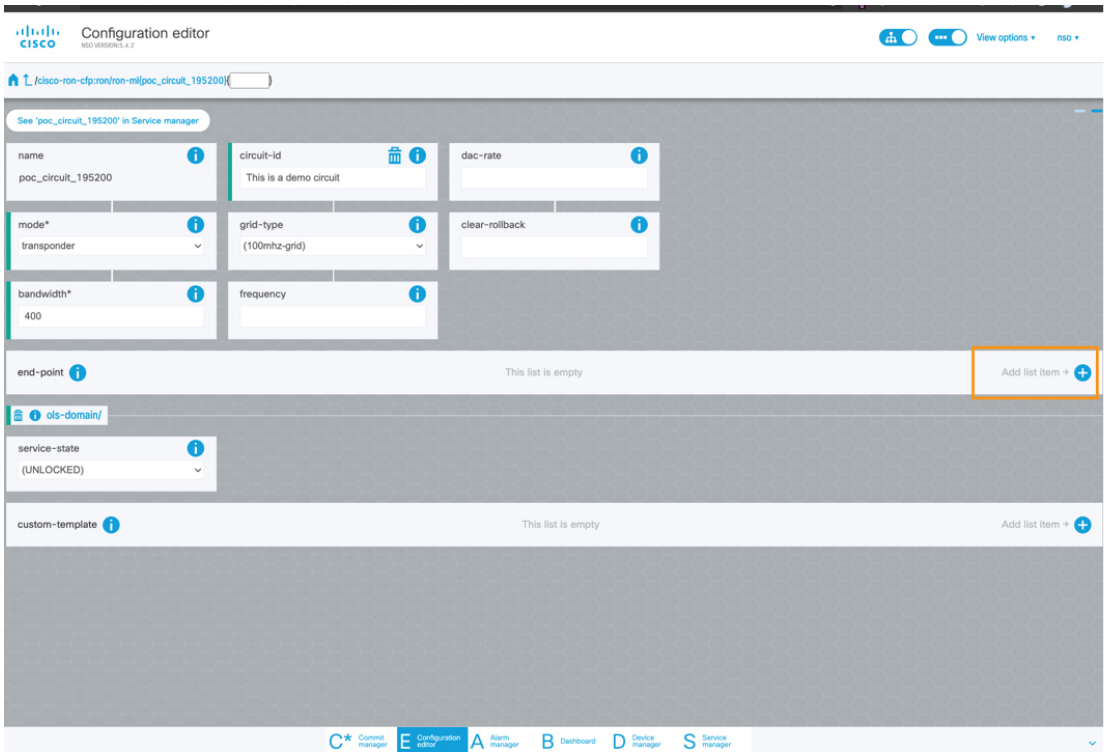


Note

- User configuration global options are frequency and dac-rate.
- Dac-rate controls the TX shaping parameters: 1x1.25 = enabled, 1x1 = disabled. If you leave this field blank, the system uses the default setting of enabled.
- Modulation of 16 QAM is available for 2x100G muxponder mode.

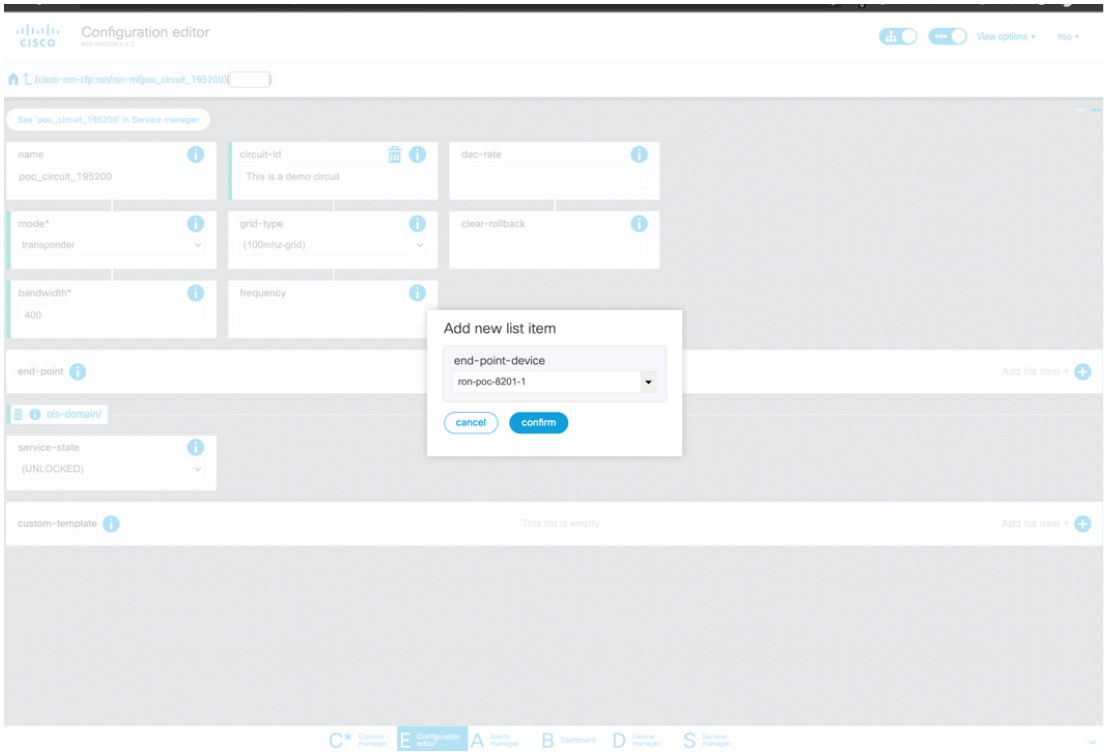
c. After the ols-domain is added, you must add end-points to the circuit. Two end-points are always required. The end-points are the routers with ZR/ZR+ optics.

Sample end-to-end configuration



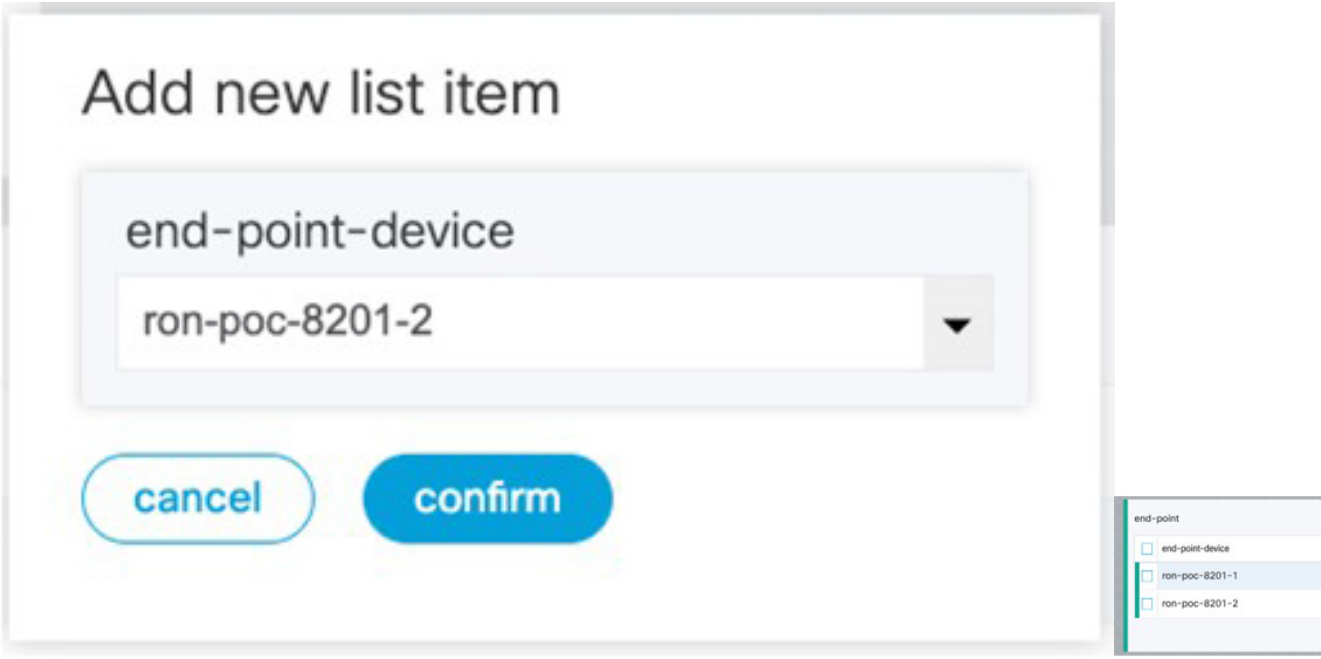
521927

d. Add the end-point-device to the service. Click **Confirm**.



521928

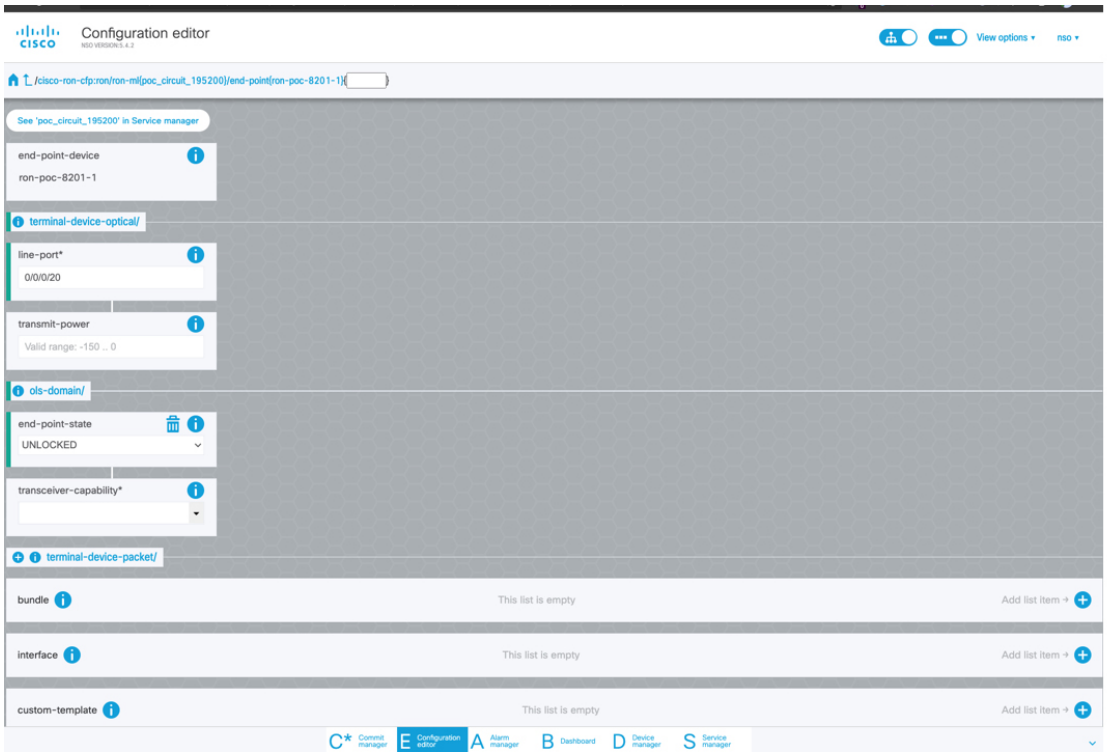
After the end-point is created, click the end-point to edit the end-point parameters. The line port is a required parameter and refers to the optics port on the router. In this example, the line port for the end-point matches the value specified in the inter-layer-link service.



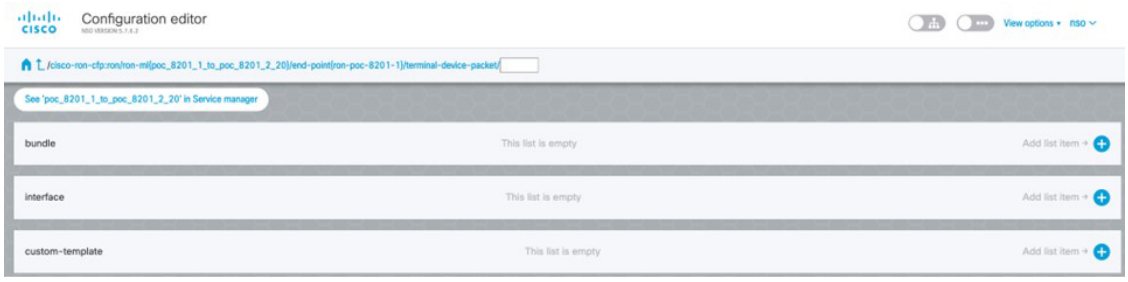
The transmit-power is an optional parameter for end-to-end provisioning. If you omit this parameter, the Cisco Optical Network Controller provides the transmit power.Transmit power sets the transmit power, the value is calculated as 100 times the value in 0.1 dBm increments. For example, a value of –100 equals –10 dBm. If you do not specify a value, the system uses a default of –10 dBm for QDD-400G-ZR-S or QDD-400G-ZRP-S, and 0 dBm for DP04QSDD-HE0 (Bright ZR+). The transceiver-capability field specifies the optic type and is only required if no packet layer configuration is being performed. In this example, you are performing packet layer provisioning so specifying the transceiver capability is not required.

Add the line port of 0/0/0/20 to the Routed Optical Networking ML service.

Sample end-to-end configuration



e. Click endpoint to return to the top-level endpoint configuration, click **terminal-device-packet** to configure Ethernet/IP parameters



Note

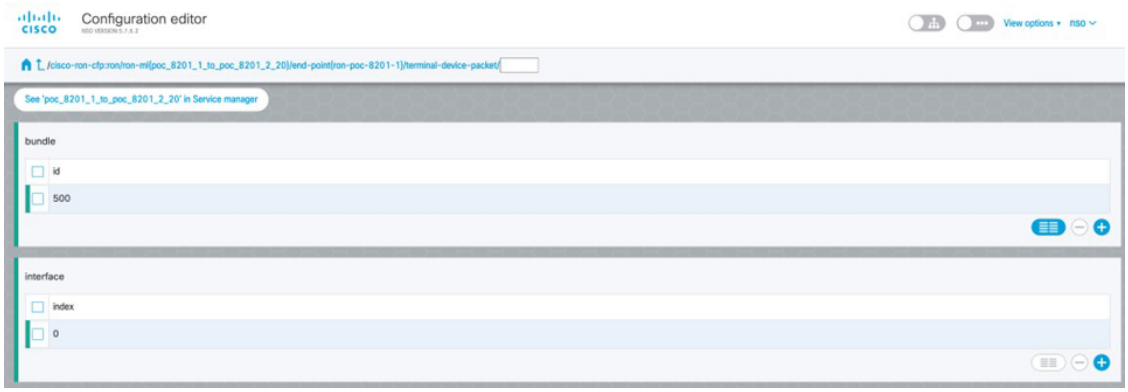
- Ethernet and IP configuration is optional.
- Bundle configuration adds an interface to an existing bundle or creates a new bundle and adds the newly created IP interface to it.

  Interface configuration is used for configuring IP address parameters on newly created Ethernet interfaces.

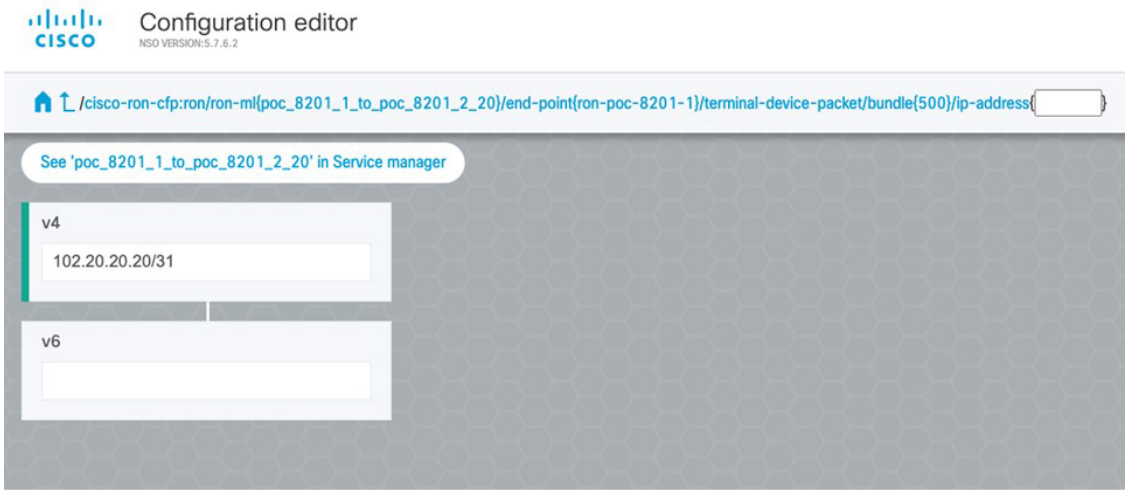
  In this example, we add a new Bundle and assign an IP address to the Bundle.

f. Click the plus sign next to the bundle to create a bundle with the identifier 500. This action creates a bundle interface, Bundle-Ether 500, on the endpoint router.

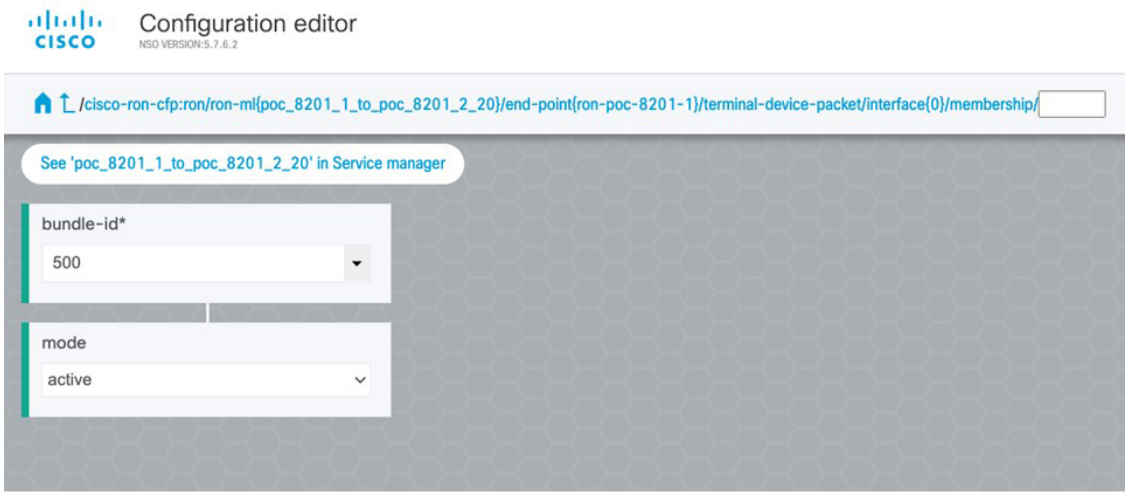
The interface index for a bundle use case is always 0. In a non-bundle configuration in muxponder mode, the index can be 0 to 3, representing the number of interfaces created as part of the muxponder configuration.



g. Click the bundle number and *ip-address* to configure an IP address on the bundle.



h. Return to the top-level endpoint configuration. Select index 0 that you created previously, and click **membership** to add the interface to the bundle.

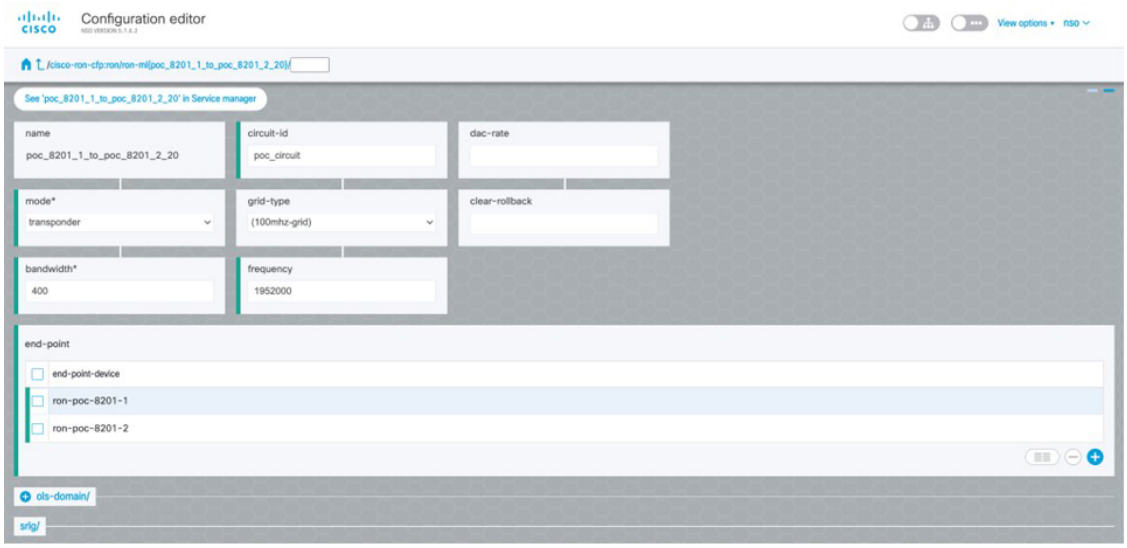


Note

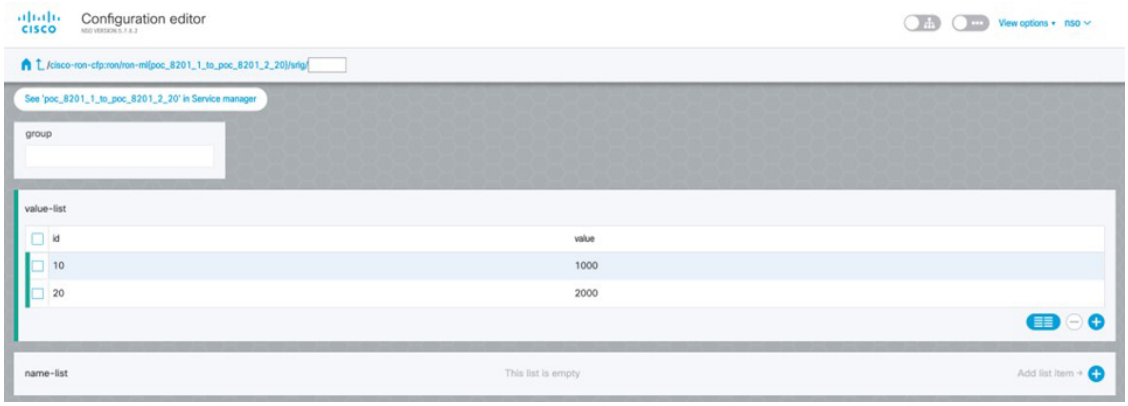
- Bundle-id selects the previously created bundle.

- Mode sets the bundle LAG signaling mode. Active=LACP, passive=LACP listener only, on=No active signaling, inherit=Inherit signaling from Bundle interface configuration. Default is active.

i. Return to the top level of the service configuration. Then configure the second endpoint in the same manner.



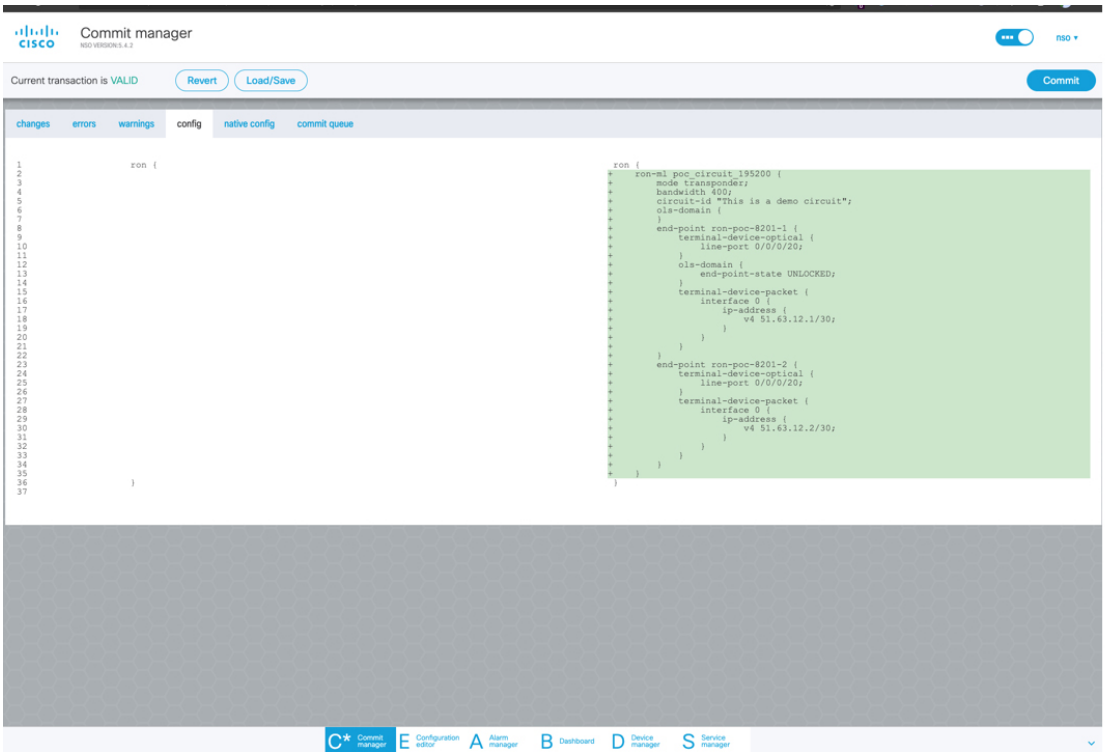
j. Click **SRLG** to perform SRLG configuration



Note

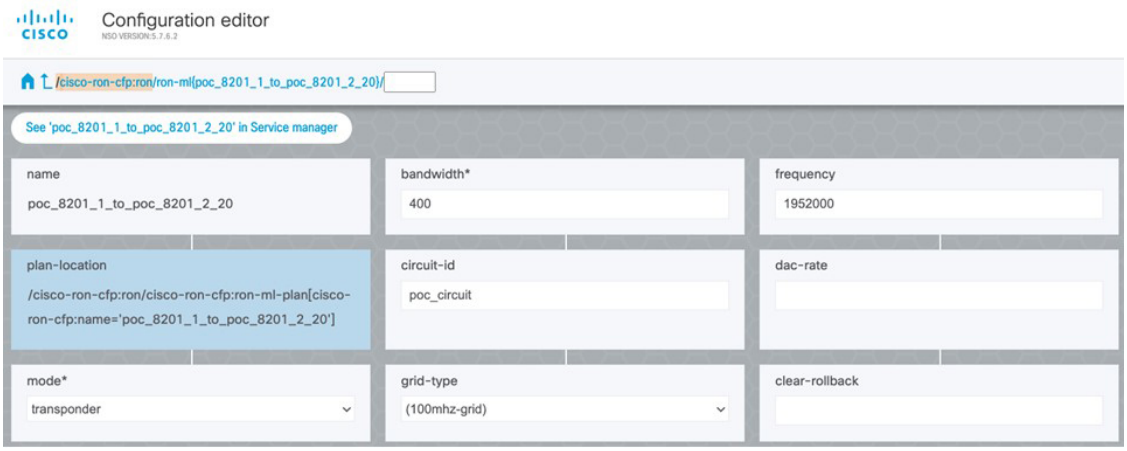
- Configuration options are to specify a preconfigured group, a list of numeric SRLG values, or a list of SRLG names associated with preconfigured name:value pairs.
- Each type can be populated in the same configuration.
- In this example we specify a list of explicit numeric values. An index is used along with the numeric value.

Step 4 In the Commit manager, click the config tab. The NSO CLI configuration for the end-to-end service is displayed. If the ols-domain component is not specified in the global configuration, no optical line system provisioning is performed, only router provisioning. You can preview and then commit the configuration.

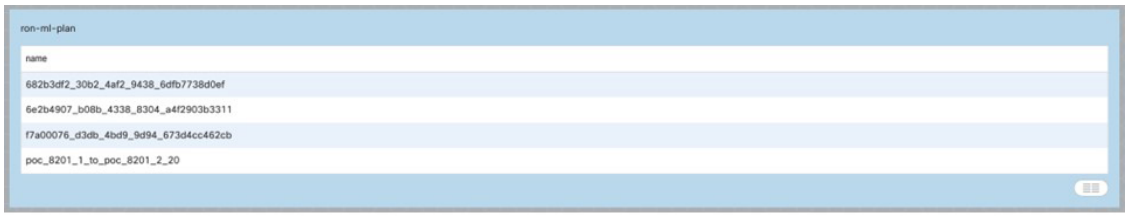


Step 5 Verify status in NSO UI.

You can verify the status by inspecting the plan associated with the service. You can find the plan under the main ron-ml configuration which you can access by clicking the top portion of the service configuration. An example is highlighted in this image.



a. Inspect the plan by clicking on the newly created service



If all steps are green and complete, the service has been properly deployed to the network

```
RP/0/RP0/CPU0:ron-poc-8201-1#show configuration commit changes last 1
Mon Oct 17 09:51:11.625 PDT
Building configuration...
!! IOS XR Configuration 7.7.1
srlg
 interface Bundle-Ether500
  10 value 1000
  20 value 2000
 !
!
interface Bundle-Ether500
 ipv4 address 102.20.20.20 255.255.255.254
!
controller Optics0/0/0/20
 description poc_circuit
 transmit-power -100
 fec OFEC
 dwdm-carrier 100MHz-grid frequency 1952000
 DAC-Rate 1x1.25
!
interface FourHundredGigE0/0/0/20
 bundle id 500 mode active
!
End
```

```
RP/0/RP0/CPU0:ron-poc-8201-1#show controllers optics 0/0/0/20
Mon Oct 17 09:57:25.475 PDT

 Controller State: Up

 Transport Admin State: In Service

 Laser State: On

 LED State: Green

 FEC State: FEC ENABLED

 Optics Status

         Optics Type:  QSFPDD 400G ZRP
         DWDM carrier Info: C BAND, MSA ITU Channel=19, Frequency=195.20THz,
         Wavelength=1535.822nm

         Alarm Status:
         -------------
         Detected Alarms: None
```

b. Inspect router configuration.

The **show configuration commit changes last 1** command shows the CLI config applied to the device during the NSO provisioning.

The **show optics controller 0/0/0/20** command verifies the operational status.

```
RP/0/RP0/CPU0:ron-poc-8201-1#show configuration commit changes last 1
Mon Oct 17 09:51:11.625 PDT
Building configuration...
!! IOS XR Configuration 7.7.1
srlg
 interface Bundle-Ether500
  10 value 1000
  20 value 2000
 !
!
interface Bundle-Ether500
 ipv4 address 102.20.20.20 255.255.255.254
!
controller Optics0/0/0/20
 description poc_circuit
 transmit-power -100
 fec OFEC
 dwdm-carrier 100MHz-grid frequency 1952000
 DAC-Rate 1x1.25
!
interface FourHundredGigE0/0/0/20
 bundle id 500 mode active
!
End
```

```
RP/0/RP0/CPU0:ron-poc-8201-1#show controllers optics 0/0/0/20
Mon Oct 17 09:57:25.475 PDT

 Controller State: Up

 Transport Admin State: In Service

 Laser State: On

 LED State: Green

 FEC State: FEC ENABLED

 Optics Status

         Optics Type:  QSFPDD 400G ZRP
         DWDM carrier Info: C BAND, MSA ITU Channel=19, Frequency=195.20THz,
         Wavelength=1535.822nm

         Alarm Status:
         -------------
         Detected Alarms: None
```

Provision a Routed Optical Networking ML service using Crosswork Hierarchical Controller

Follow these steps to provision Routed Optical Networking ML service using Crosswork Hierarchical Controller.

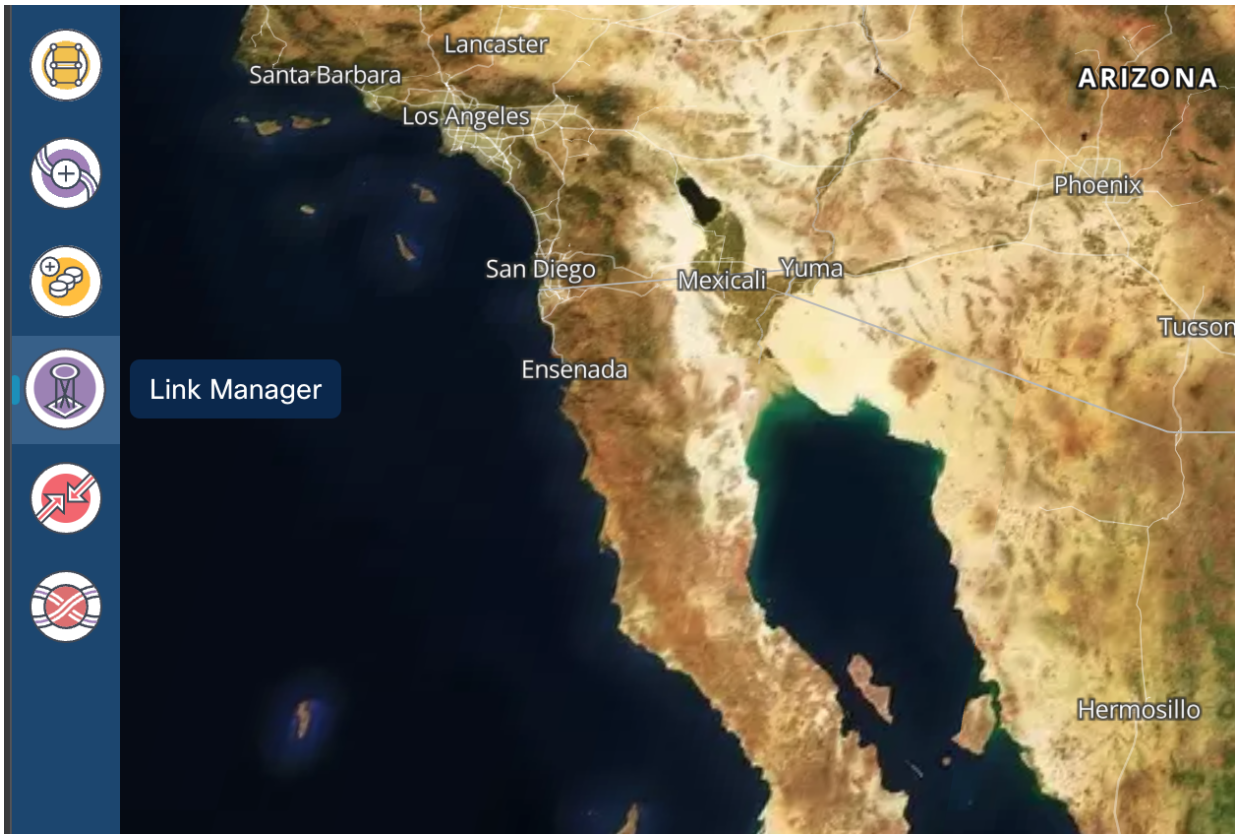
Procedure

Step 1 If you are performing both router and optical line system provisioning, you must create NMC Cross Links between router optics port and optical line system add-drop port.

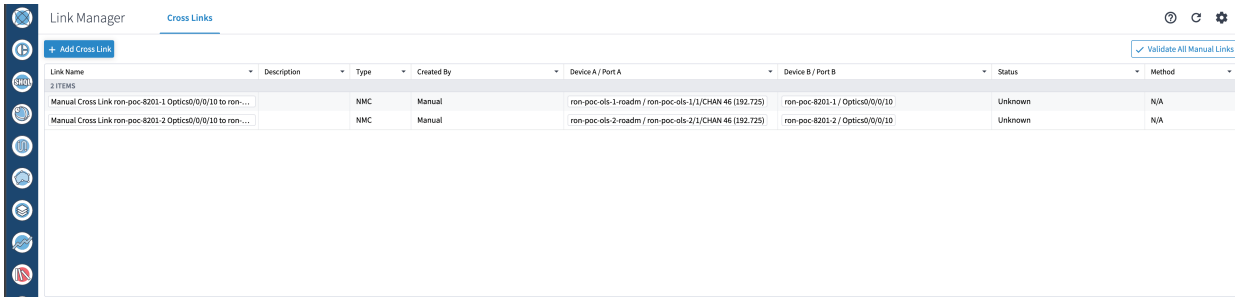
Crosswork Hierarchical Controller 8.0 in Routed Optical Networking 3.0 also supports “router only” provisioning. This type of provisioning applies optical parameters to the router optics port and IP layer parameters, but does not provision the optical line system.

a. Select **Link Manager** application.

Figure 66: Crosswork Hierarchical Controller



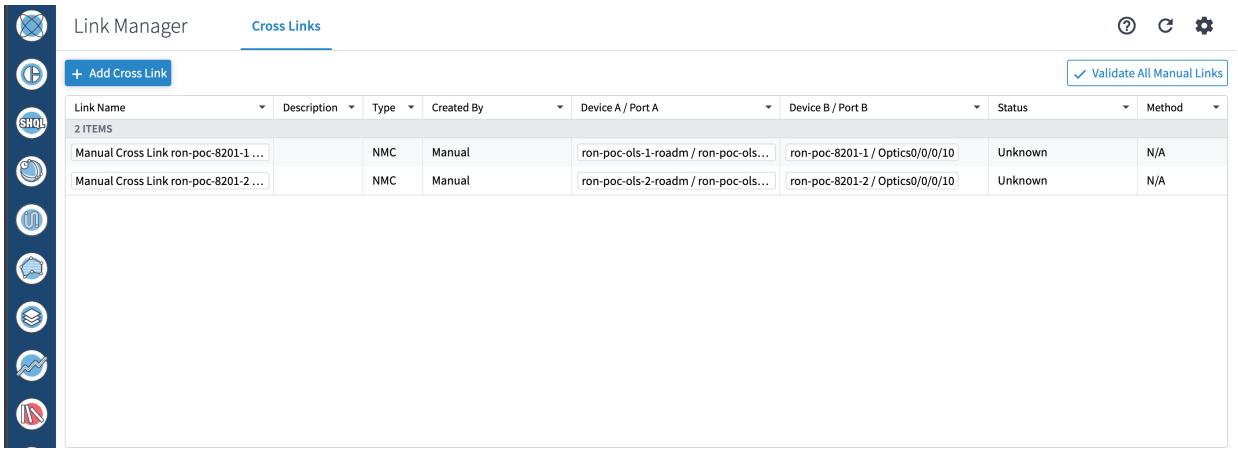
The initial view displays a list of cross links.



Sample end-to-end configuration

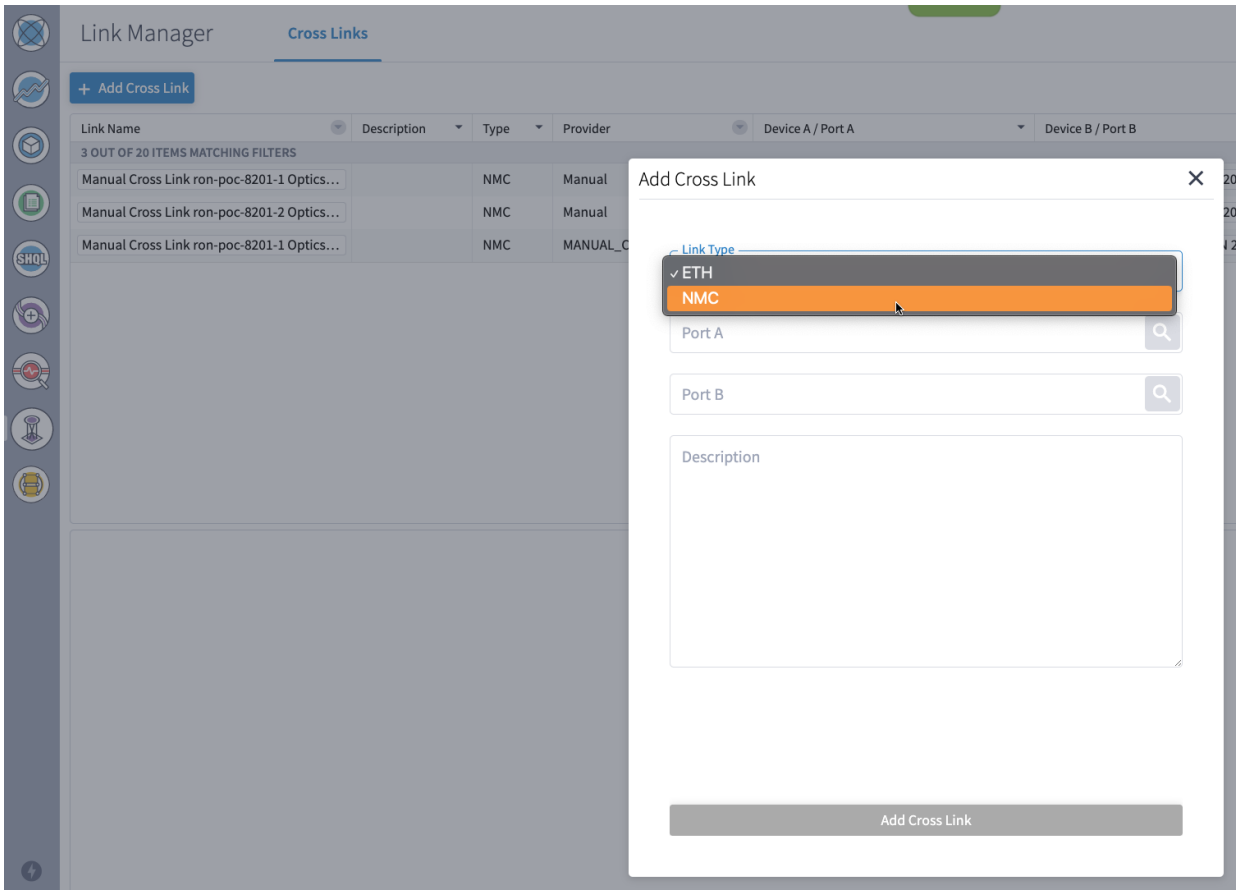
b. Click **Add Cross Link**.

Figure 67: View with list of cross links



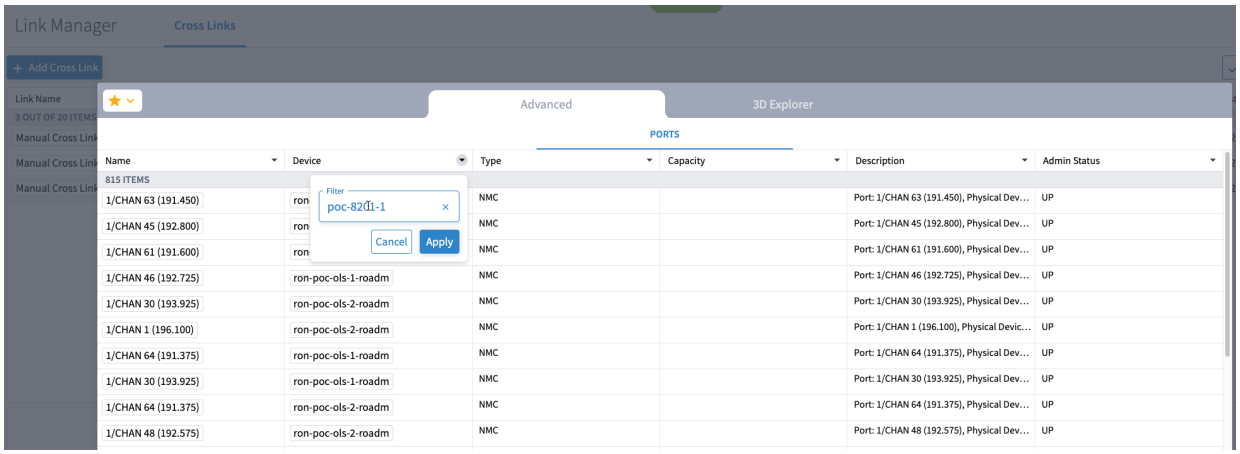
c. Select the NMC cross-link type. Cross Link Manager supports ETH and NMC cross links.

Figure 68: Add cross links screen

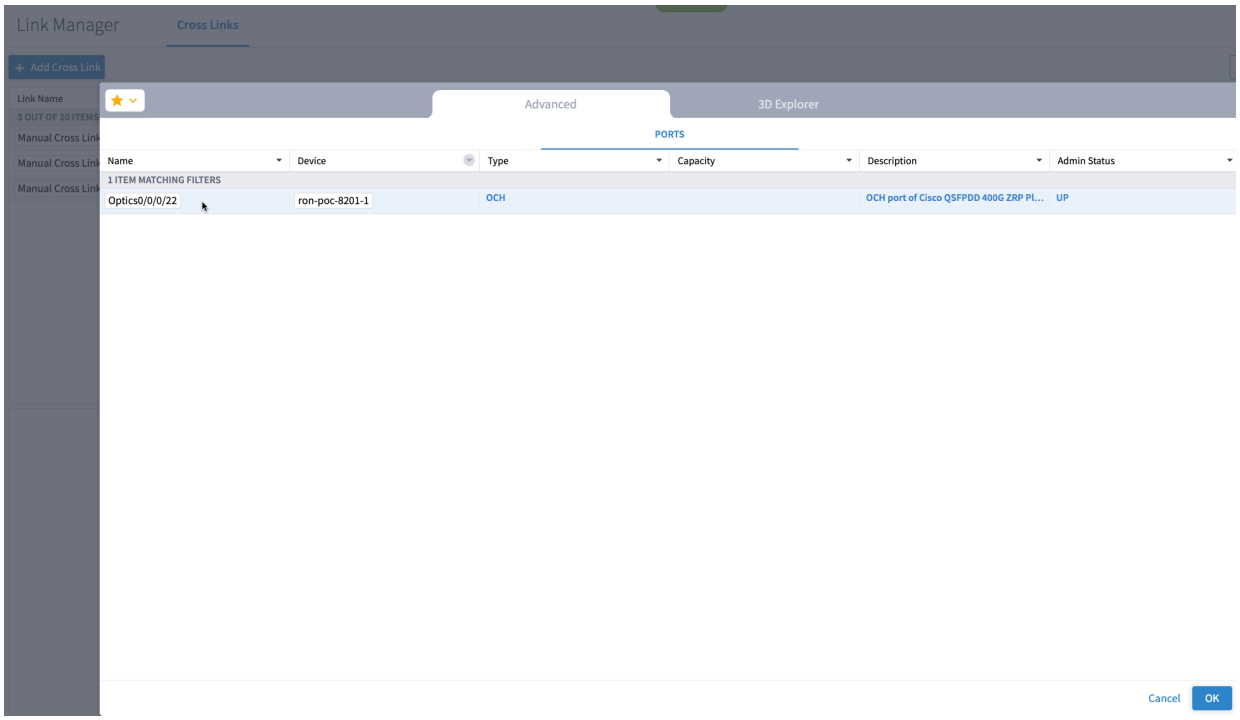


d. ou can select either the router DCO port or the optical add-drop port first using the Link Manager application. In this example, port filtering is performed by the router device used for the NMC cross-link.

Sample end-to-end configuration

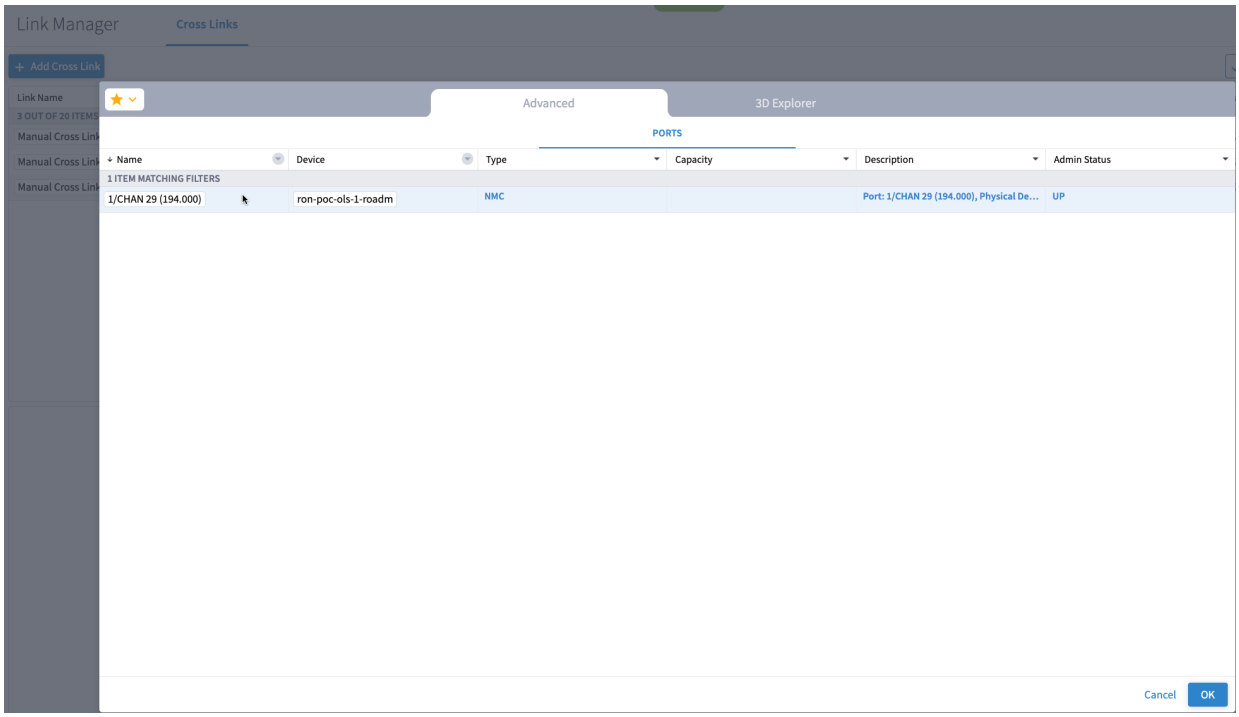


e. The filtered list shows that the router, *ron-poc-8201-1*, has a single ZR+ optics port. Select this port and click OK.



f. Select the second port, which is the optical add-drop port. To filter for the add-drop port, set the device to *ron-poc-ols-1* and the name to *194.000*.

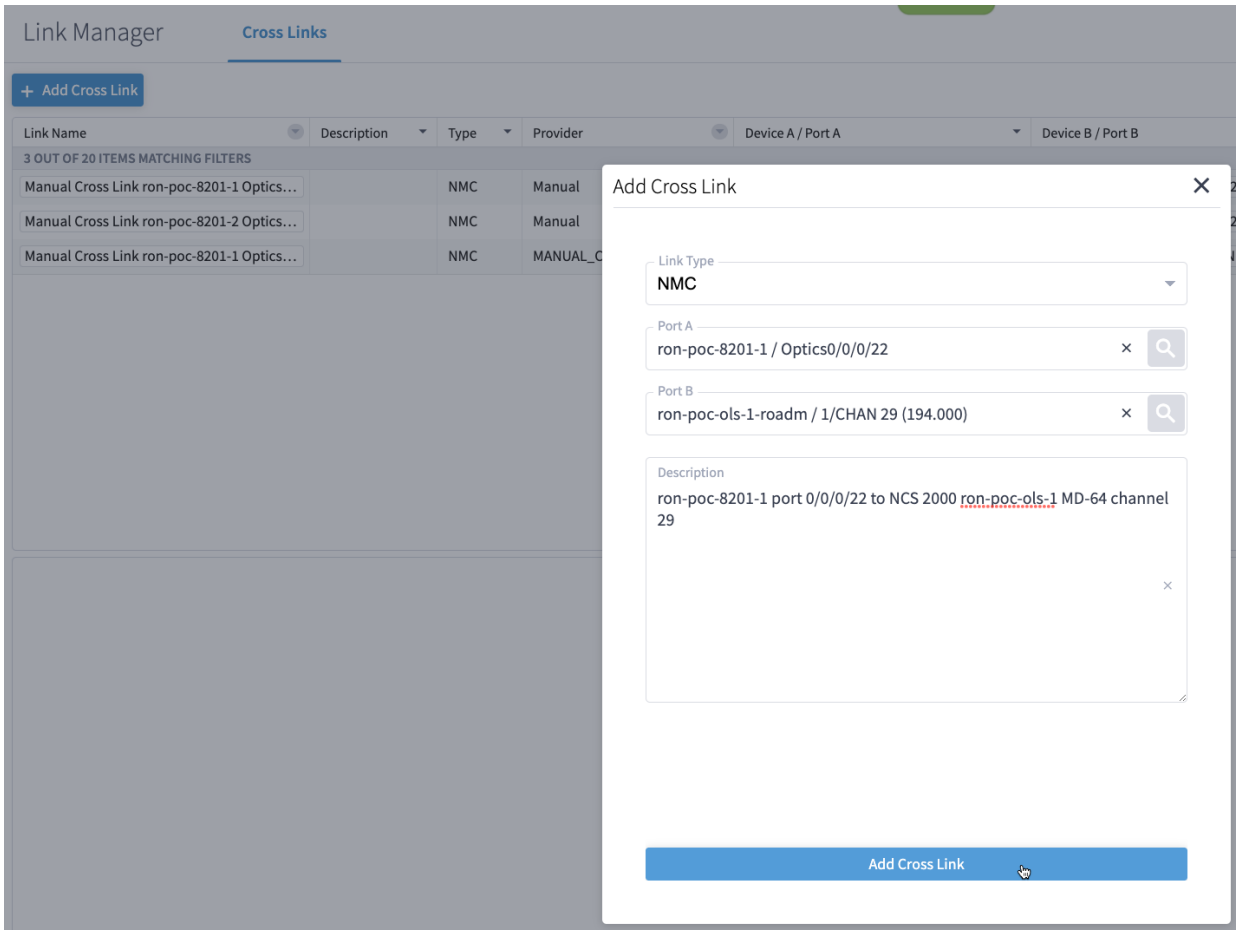
Sample end-to-end configuration



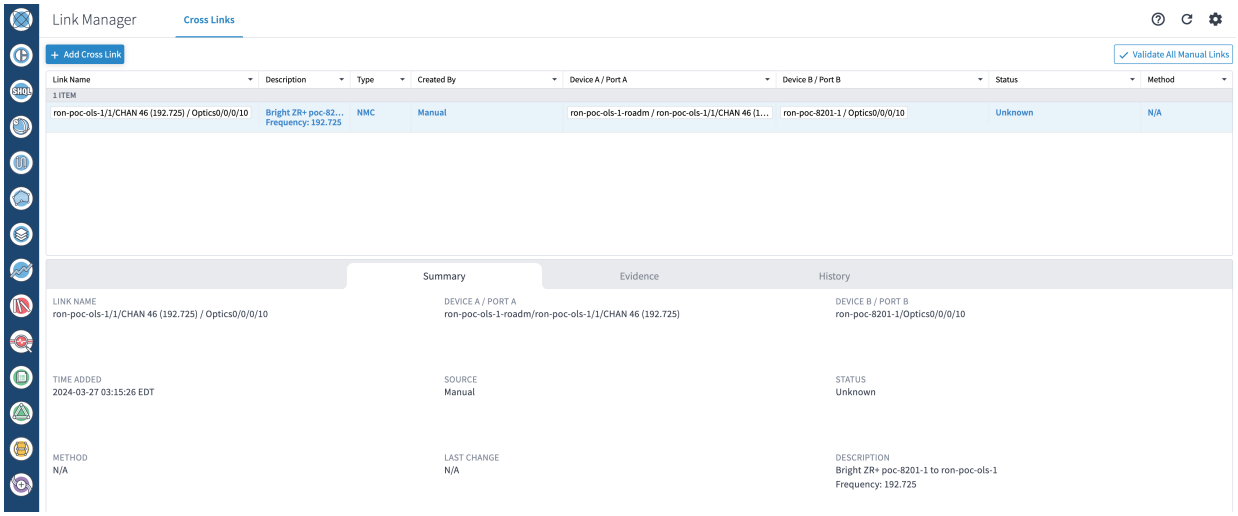
g. Select the two ports, Ethernet and OCH, in your NMC cross-link. Click **Add Cross Link**.

(Optional) Add a description.

Sample end-to-end configuration

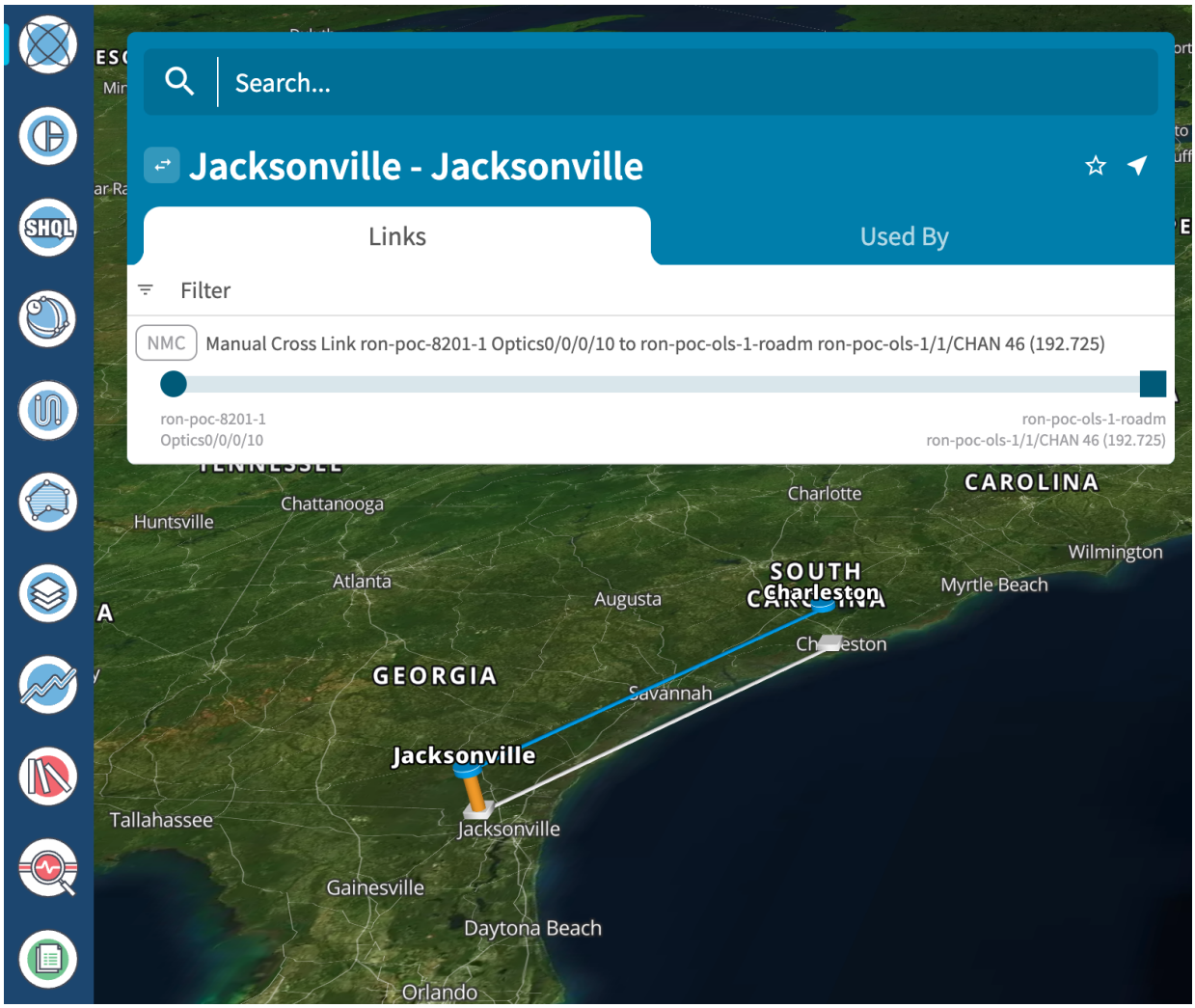


h. Click the added cross-link to see its attributes.

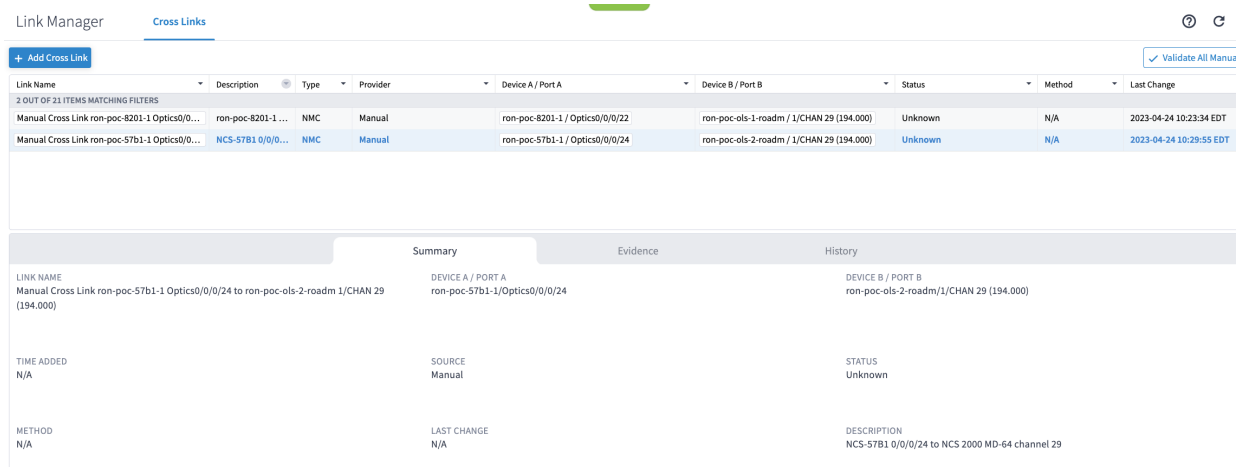


i. To view the added cross-link in the explorer app, click the link.

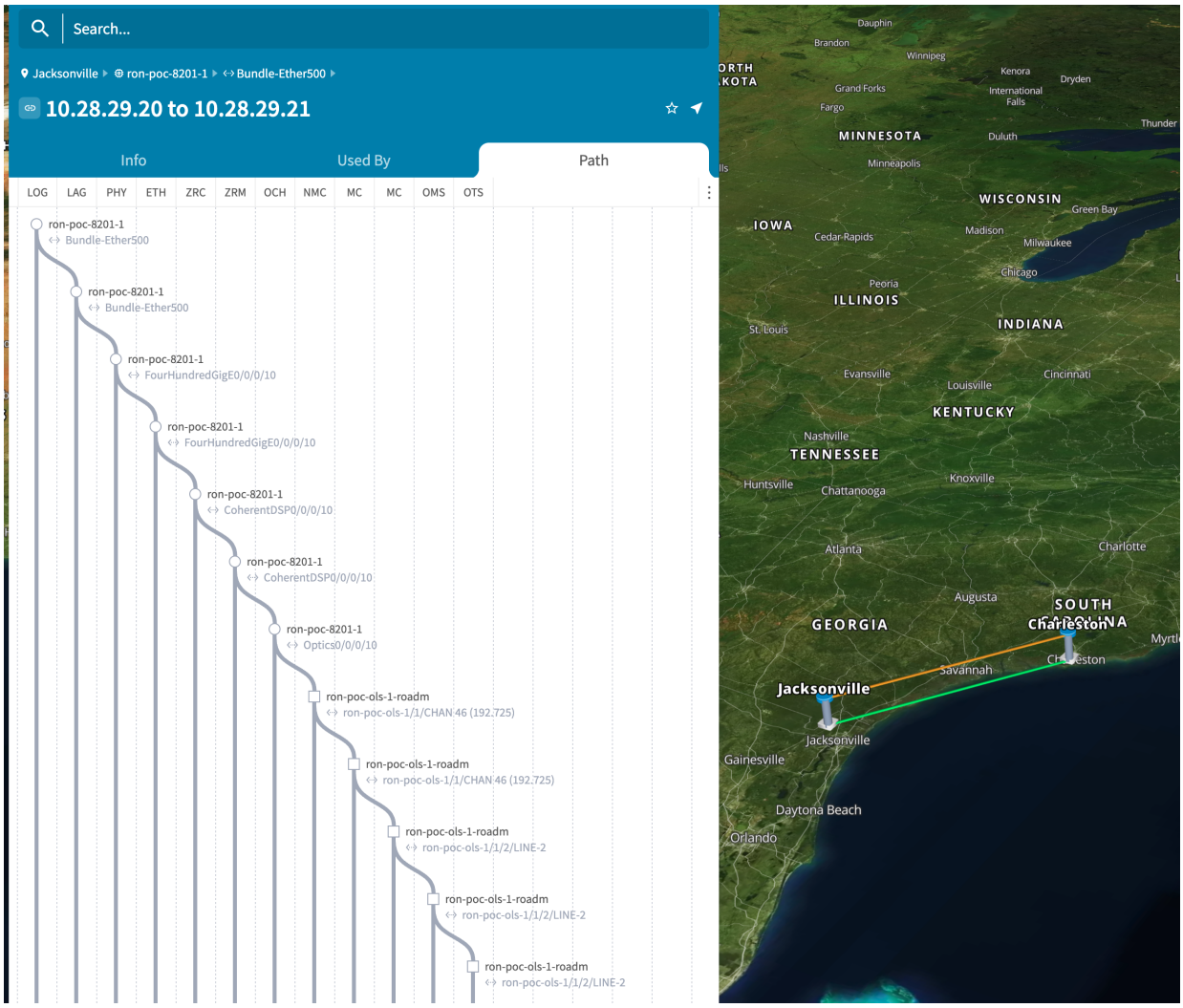
Sample end-to-end configuration



j. Create the second NMC cross-link using the same process as in the previous steps.



k. View the end-to-end network with both cross-links in the Explorer app.

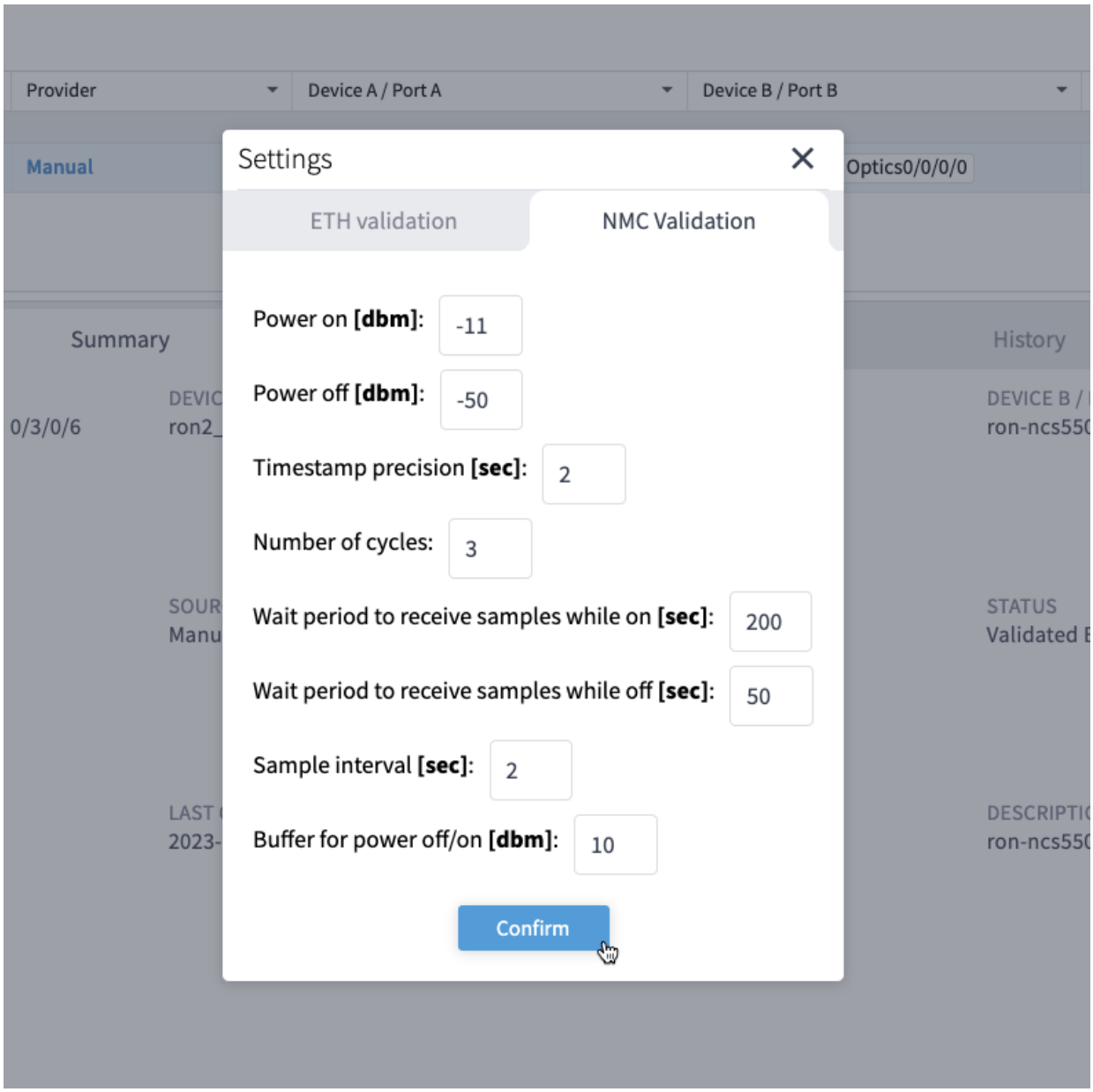


Step 2 (Optional) Cross-link connectivity verification

- Cross-link connectivity verification is supported on all router platforms and on NCS 1010 with MD-32 and BRK-24 modules.
- Connectivity verification uses NSO CLI NED to modify router port state and transmit power, and is service-affecting.
- When validation starts, Crosswork Hierarchical Controller continuously checks the RX power on the optical add-drop port while performing connectivity verification in the background.

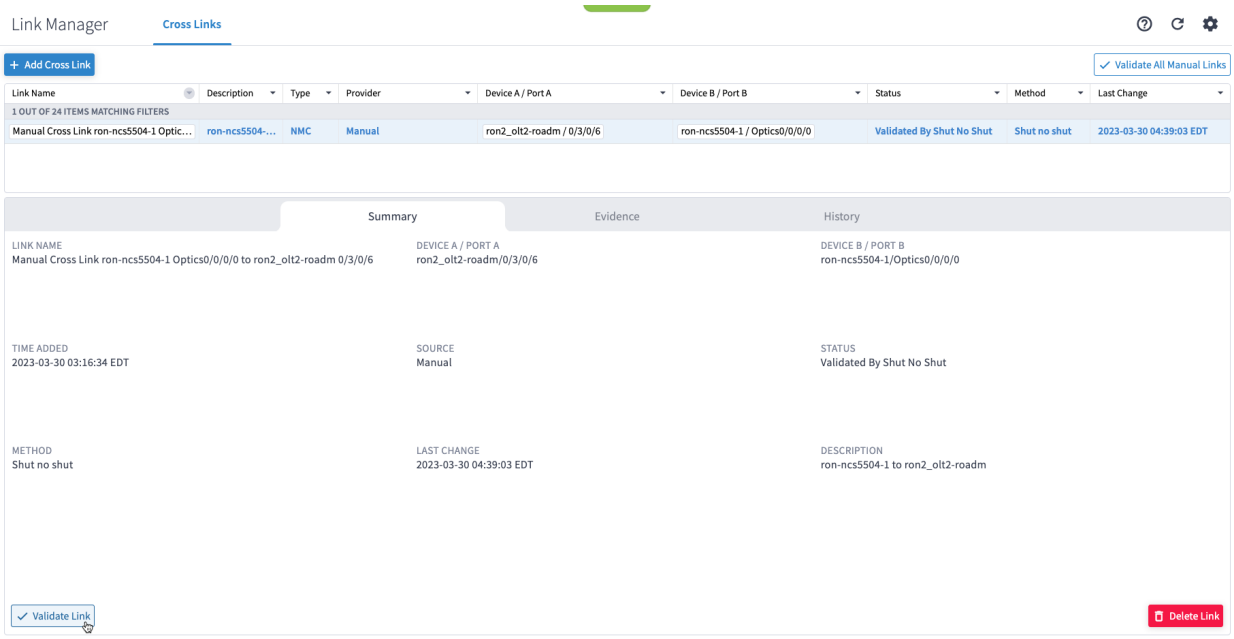
a. Configure NMC validation settings to control validation. Set the **Wait period to receive samples while on** to 180 seconds. Set the **Wait period to receive samples while off** to 50 seconds.

Sample end-to-end configuration

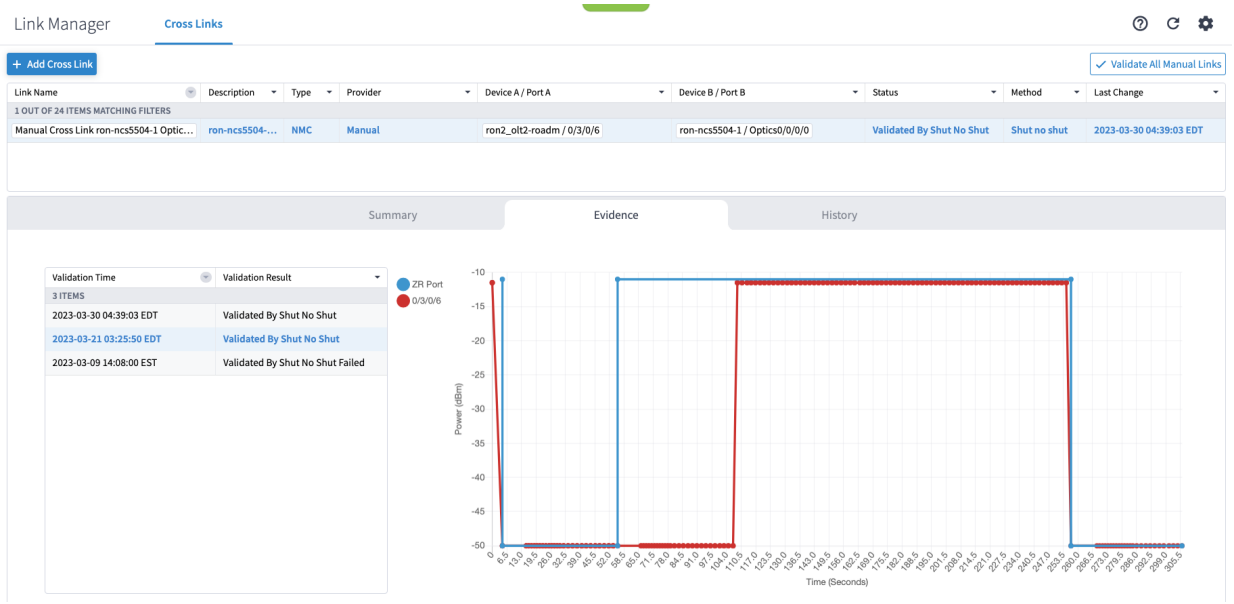


b. Select a link and click **Validate Link**. Alternatively, you can click **Validate All Manual Links** to perform connectivity verification for all the links.

Sample end-to-end configuration

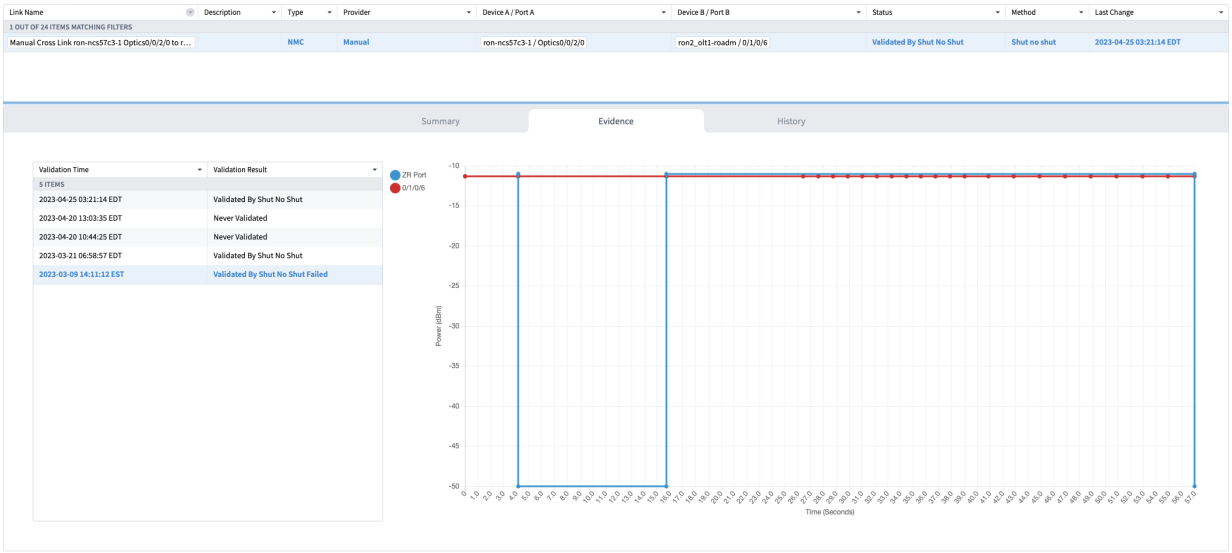


c. After validation completes, inspect the evidence of successful or unsuccessful verification. This image shows a successful verification. The status changes from **Unknown** to **Validated By Shut No Shut**. It typically takes 60 to 80 seconds for the ZR or ZR+ interface to start transmitting after the no shut command is issued.



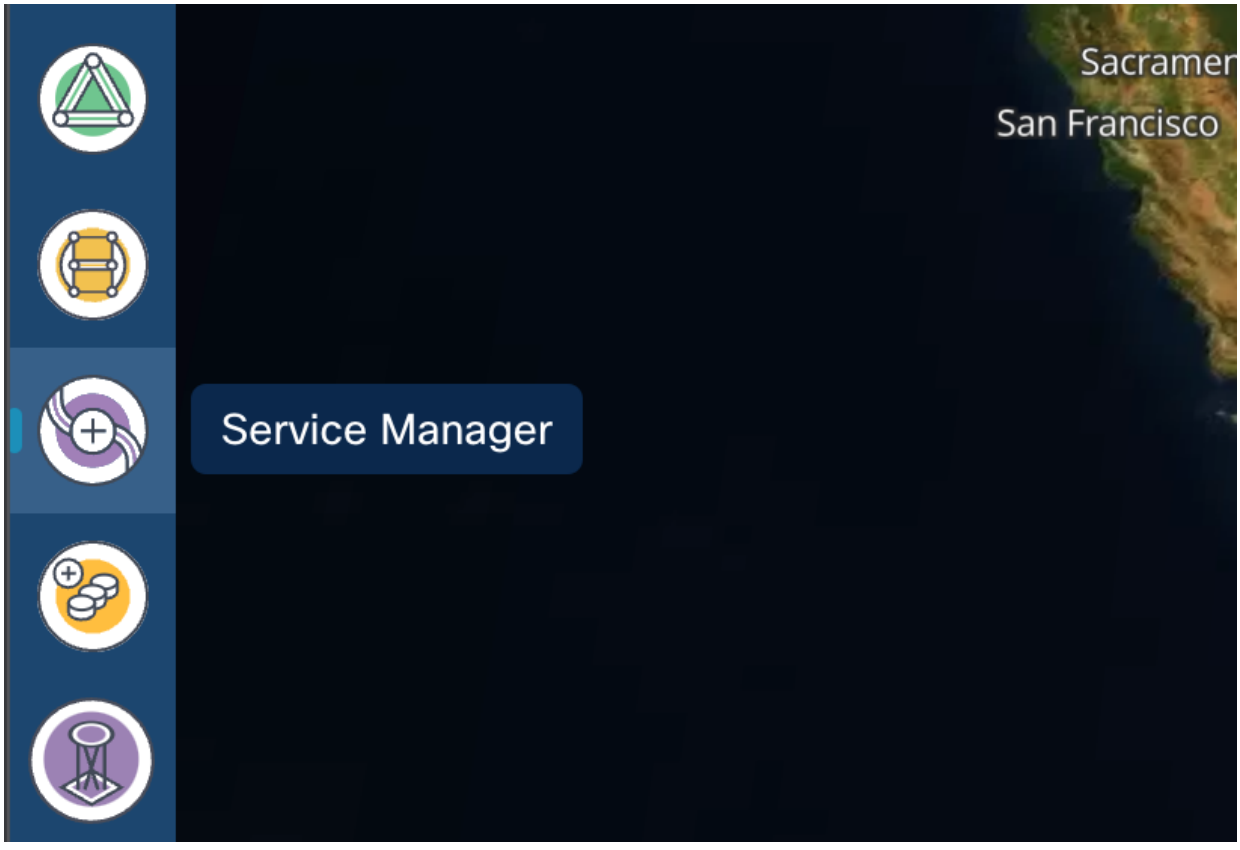
This image shows a failed verification. There is no change in the optical device port power levels after the **no shut** operation.

Sample end-to-end configuration

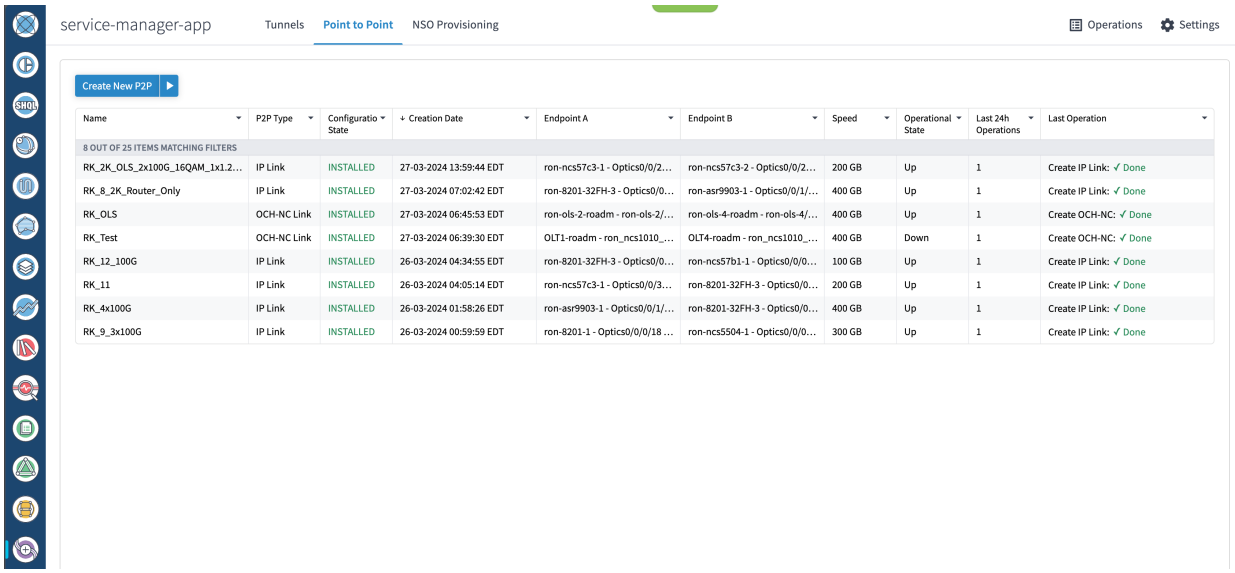


Step 3 Provision the Routed Optical Networking IP link using these steps:

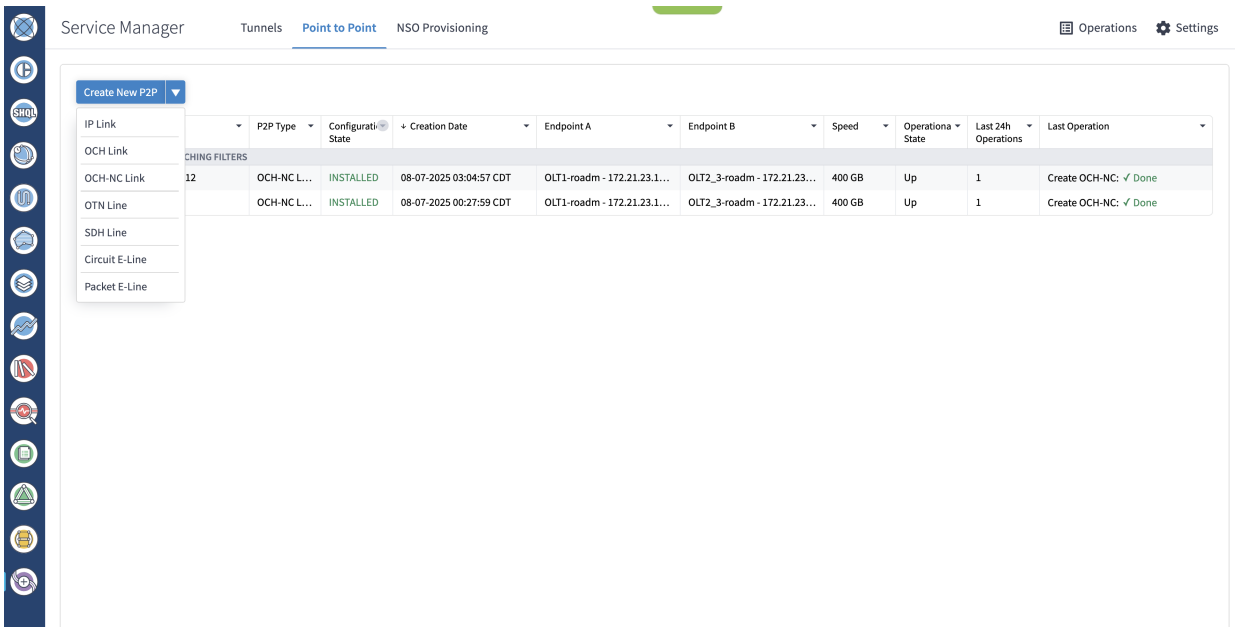
a. In the applications bar in the Crosswork Hierarchical Controller, click the **Services Manager** icon.



The Service Manager application shows you a list of services.



b. Select the **Point to Point** tab and click **IP Link** from the **Create New P2P** drop-down list to create end-to-end service between router DCO ports.

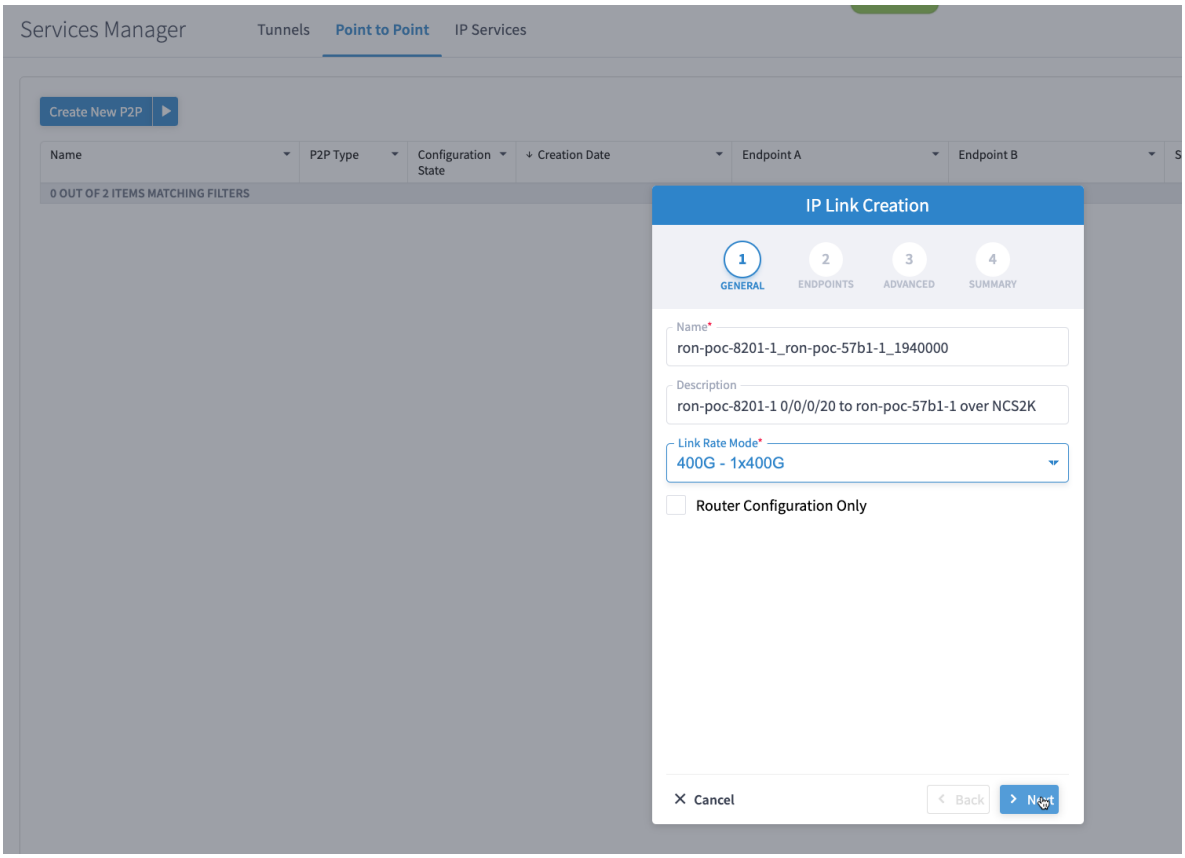


The **IP Link Creation** wizard appears.

c. Enter the Cisco Crosswork Hierarchical Controller service name, description of the router optical controller, and the Link Rate Mode in the **General** tab.

- Here, we are creating a 1x400G link. In 2x100G, 3x100G, and 4x100G modes, you can choose to create separate IP links or create a Bundle with each channel link added as a member.

Sample end-to-end configuration



Alternatively

- To create a 200G 16-QAM link, select the 200G–2x100G link rate mode.

  200G 16-QAM allows the use of 200G signals on 50Ghz optical line systems. The default value for 200G is QPSK at 60.1Ghz.

Alternatively

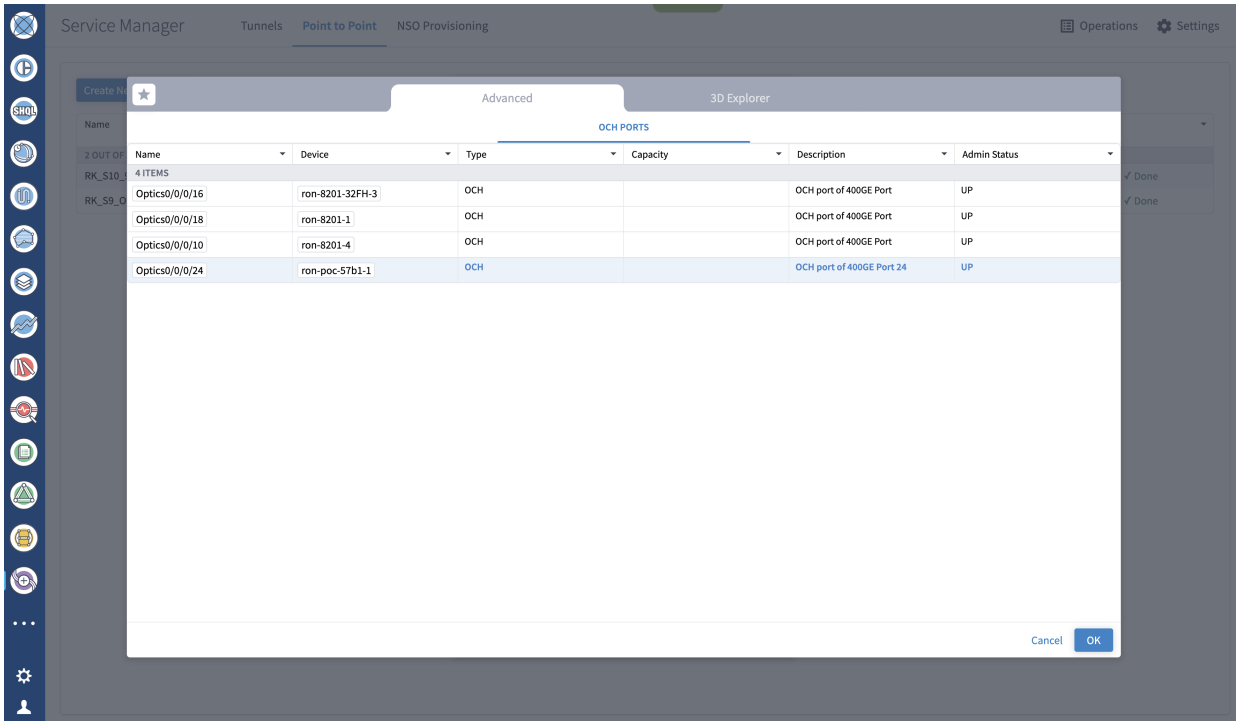
- To create a Bundle interface, Select a bundle option from the link rate mode drop down list.

  ou can create a 400G bundle interface (400G Member). You can also create a 300G bundle (3x100G Members) or a 200G bundle (2x100G Members).

Sample end-to-end configuration

(Optional) Check the **Router Configuration Only** check box to configure only the router optical controller and IP information and not the optical line system. This configuration is used when the OCHNC is created outside Cisco Crosswork Hierarchical Controller.

d. Select the two router ports in the service. This is done by selecting the site and port. The transmit power for each endpoint is an optional parameter. The default transmit power is used if no value is provided.



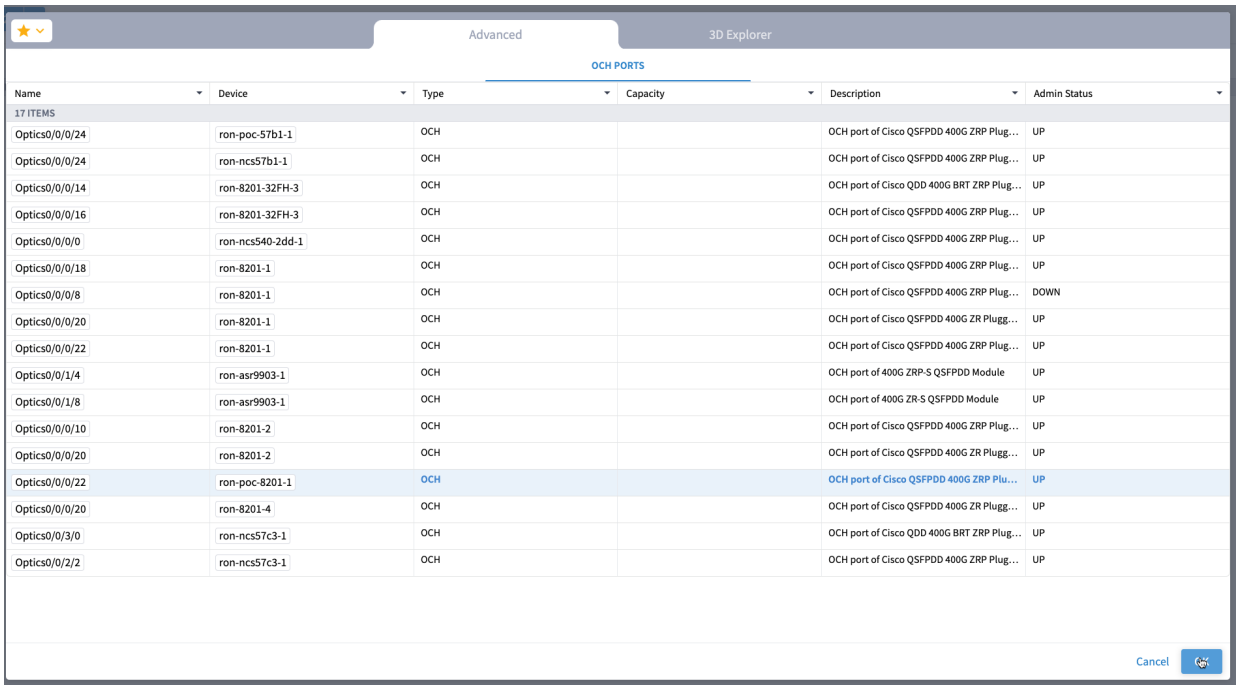
e. Click the magnifying glass icon to select the first router port.

The router interface selection displays interfaces on the router that satisfy these criteria:

- is a ZR or ZR+ interface,
- has no existing optics configuration, and
- has a proper NMC cross-connect configured.

This page lists all the available ZR and ZR+ ports currently unused on all the devices. Select the *ron-poc-8201-1 Optics0/0/0/22* port.

Sample end-to-end configuration



f. Similar to the previous step, choose *ron-poc-57b1-1 Optics 0/0/0/24* as the second router port.

g. (Optional) Set the transmit power in dBm on each port. If OLS provisioning is being performed, the OLS controller returns the optical power. If the OLS controller does not return the optical power or **router only** provisioning is being used, the router default power is used.

h. (Optional) Enter the IP address information for interfaces. If IP addresses are not entered, ZR and ZR+ router optical configuration happens; however, IP addresses are not configured.

i. Click **Next** to move to **Advanced** configuration.

j. (Optional) Set the frequency. If optical provisioning is being performed, the OLS controller can return the frequency to be used, and it may be omitted. If **router only** provisioning is being performed, the frequency must be specified.

k. (Optional) Set the DAC rate. A DAC rate setting can be used to enable OpenZR+ compatibility mode, disabling TX shaping and enhanced modem mode.

l. (Optional) Set links or nodes to include or exclude in the optical path. This setting is not available in **router only** provisioning.

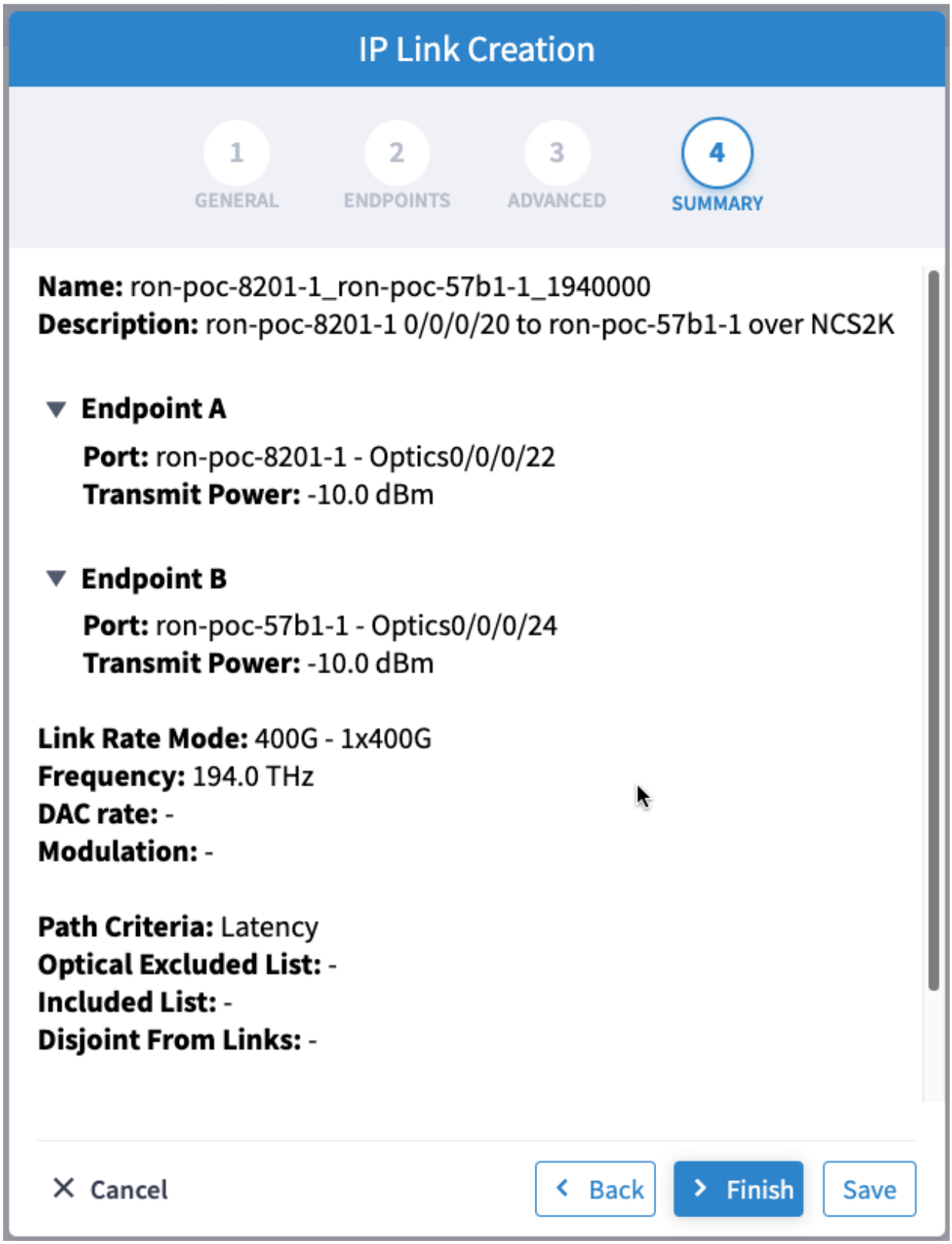
m. (Optional) To add the new link or set of links to an existing Bundle LAG interface configured on the routers, choose the bundle from the **Add to existing LAG** drop-down.

n. (Optional) If you are configuring a 200G 16-QAM link, set the DAC rate to 1 x 1.25.

200G link rate mode enables the **Modulation** selection drop-down. Modulation selection is not available in any other mode. Select the 16 QAM (30GHz) modulation.

o. Click **Next** to review the final configuration. Verify the router endpoint and optical line system parameters. Click **Finish** to start provisioning, or click **Save** to save for later provisioning.

Sample end-to-end configuration

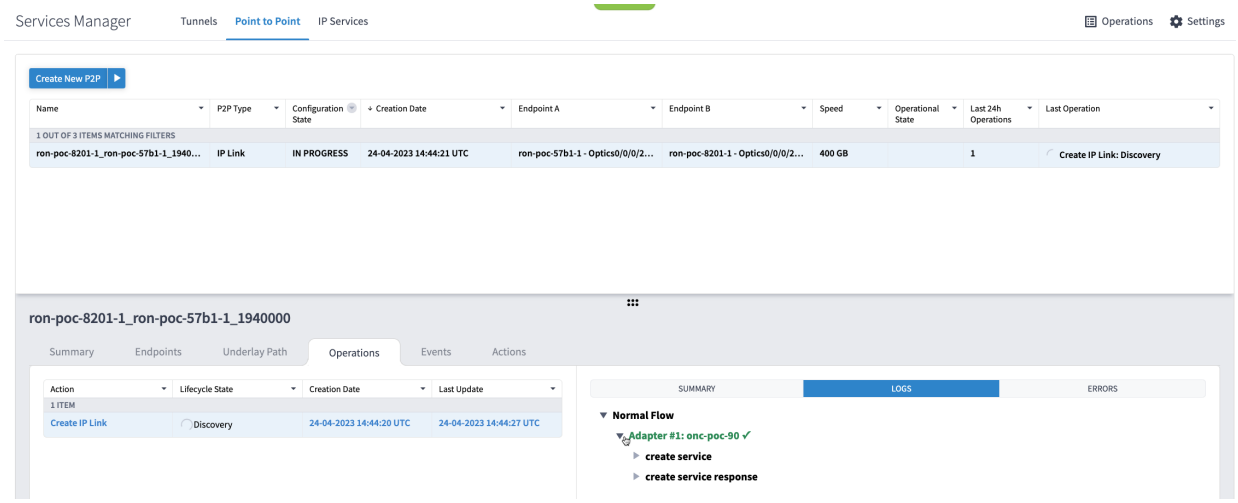


This image shows a sample summary for a 200G 16-QAM link.

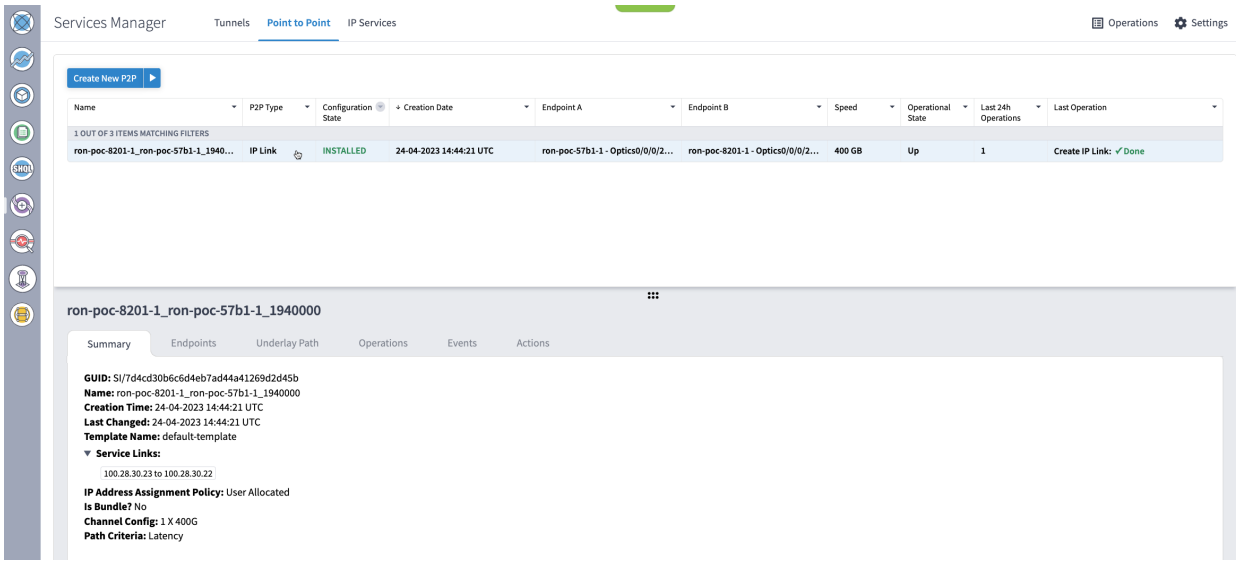
Sample end-to-end configuration

p. Go to Services Manager to view provisioning progress.

Click the **Operations** > **Logs** tab to view the provisioning API calls used and responses. The logs show API calls and responses for both optical line system provisioning through Cisco Optical Network Controller and router provisioning through Crosswork Network Controller.



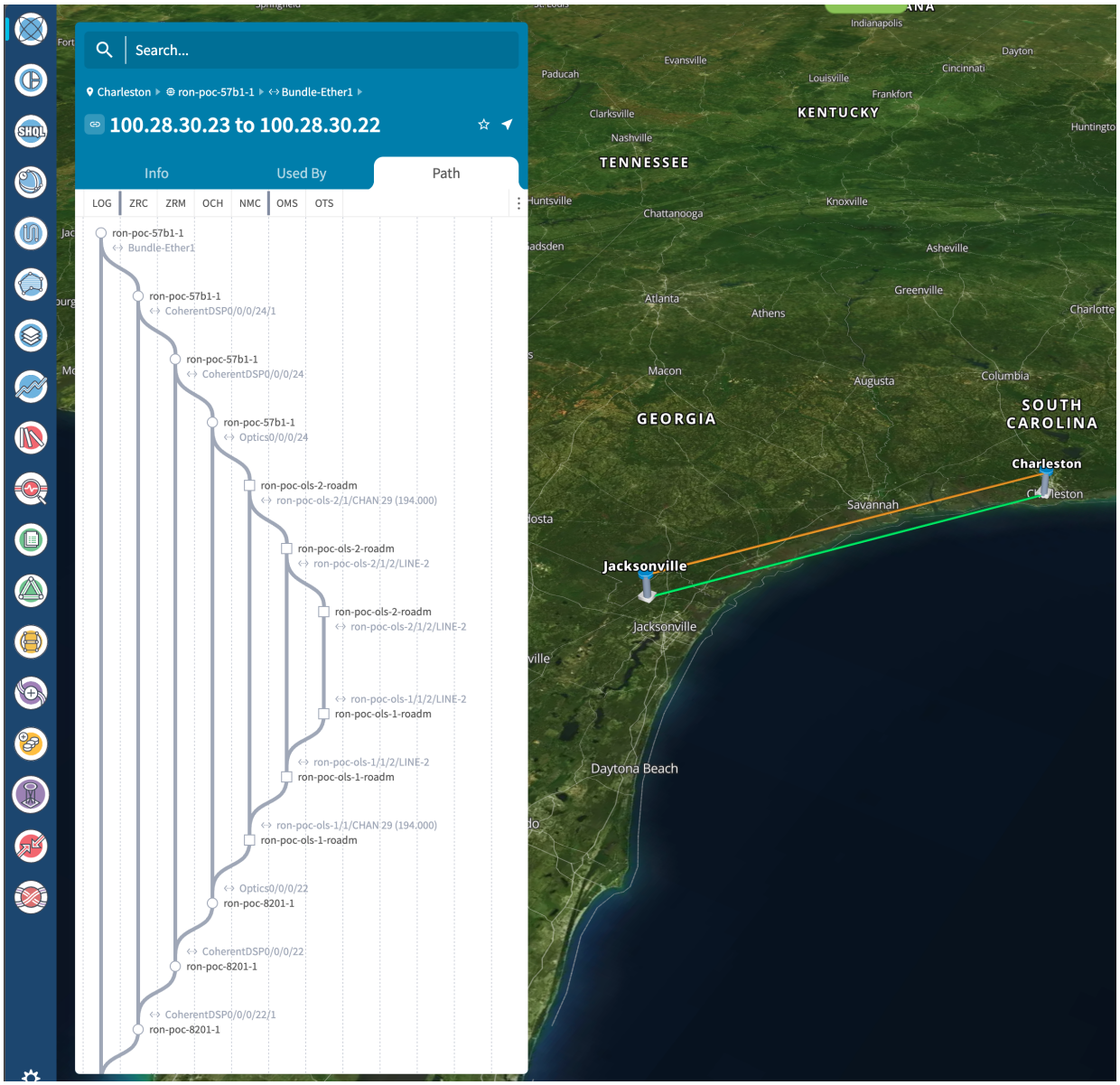
If the provisioning is successful, the **Configuration State** field changes to INSTALLED state and the **Operational State** field changes to UP state.



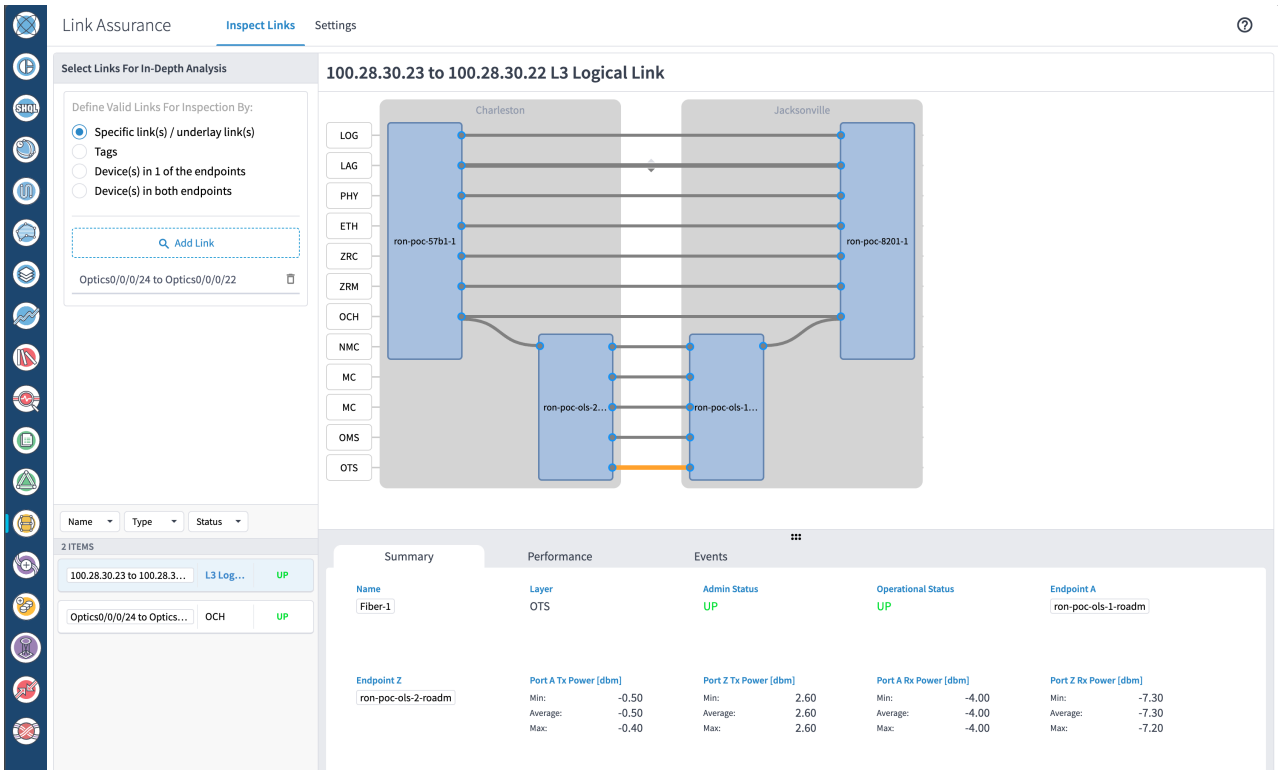
The **Summary** tab displays the new service link.

q. Verify the end-to-end link across both IP and optical layers in the Explorer view.

Sample end-to-end configuration



Step 4 Use the Link Assurance application to verify the end-to-end path and view relevant PM data. Select a link or port to see data on the ZRM, OCH, and OTS layers.



Operate phase

To monitor ZR or ZR+ optics, use EPNM and Crosswork Health Insights.

1. Use either CLI commands or EPNM to monitor router ZR or ZR+ optics for proper operation. See Monitor ZR or ZR+ optics using EPNM, on page 196.
2. (Optional) Setup router ZR or ZR+ optics data collection in Crosswork Health Insights. See Monitor ZR or ZR+ optics performance Using KPIs, on page 206.

To monitor NCS 1010, use Cisco Optical Network Controller and Cisco Optical Site Manager.

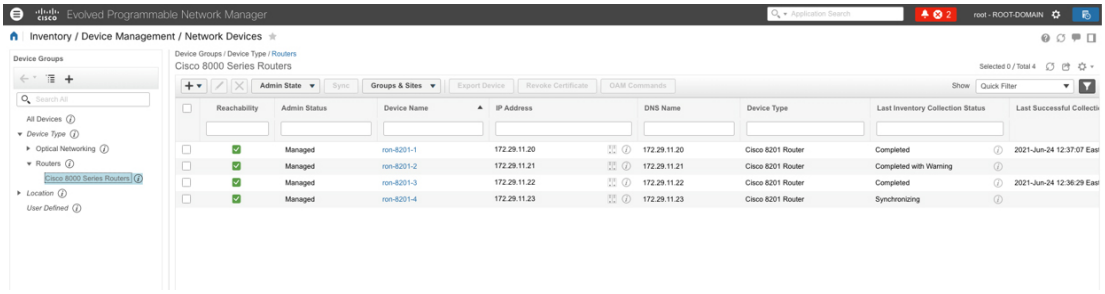
- Monitoring using Cisco Optical Network Controller
- Network and Circuit Monitoring using Workspaces in Cisco Optical Network Controller
- Monitoring Alarms in Cisco Optical Network Controller
- Fault Monitoring using Cisco Optical Site Manager

Monitor ZR or ZR+ optics using EPNM

Follow these steps to add the 8201 router to EPNM for monitoring the PM parameters on the ZR or ZR+ optics.

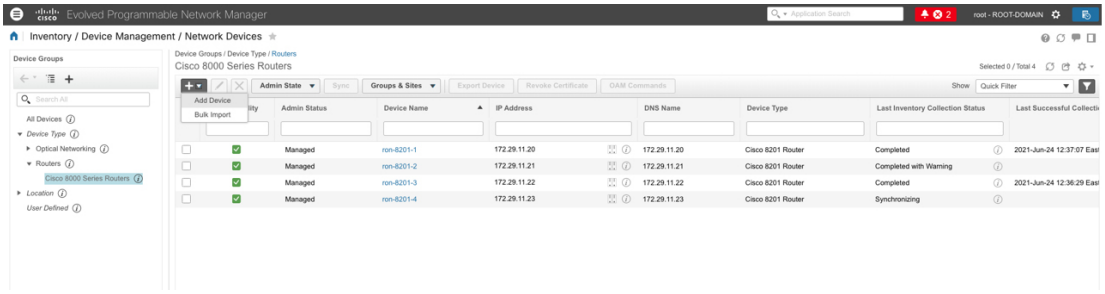
Procedure

Step 1 Choose **Inventory > Device Management > Network Devices** to add a new device to EPNM. Click **Routers** or a subgroup if it is already defined in the left panel.



521942

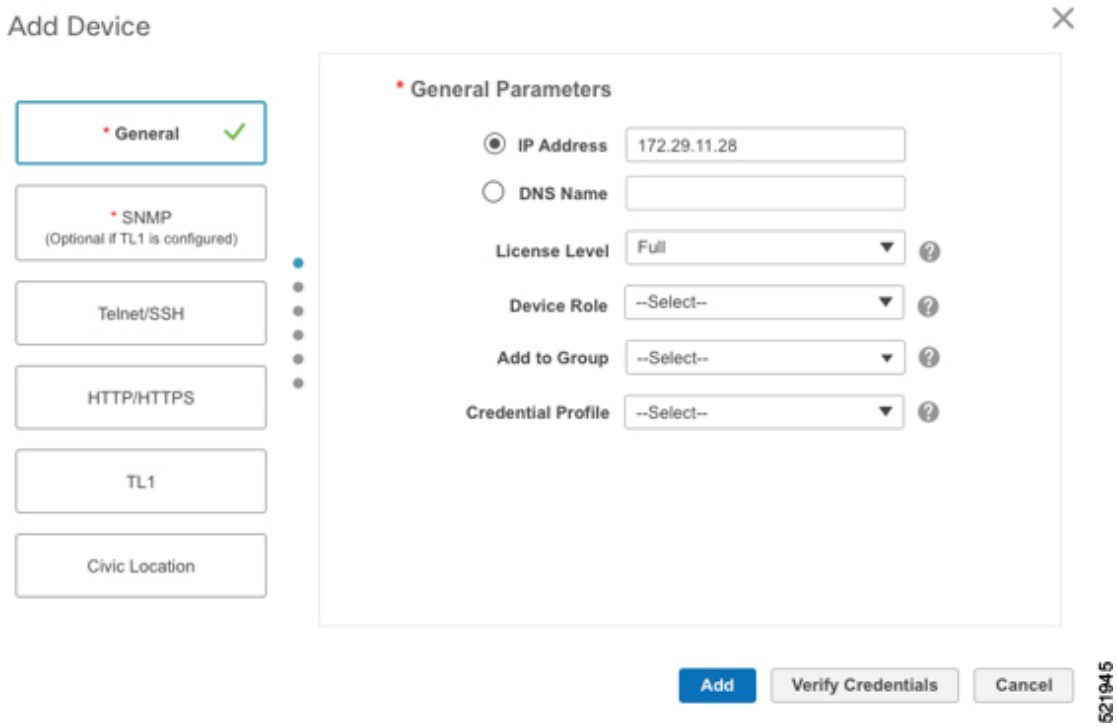
Step 2 Click the + icon above the Network Devices table, then choose **Add Device**.

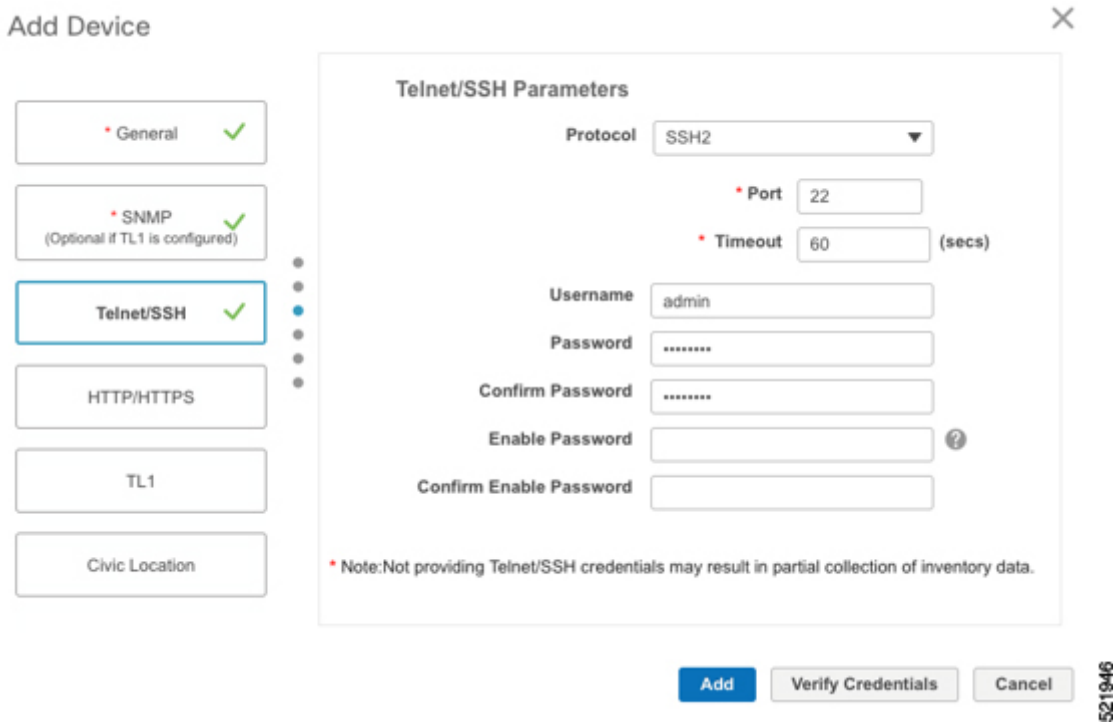


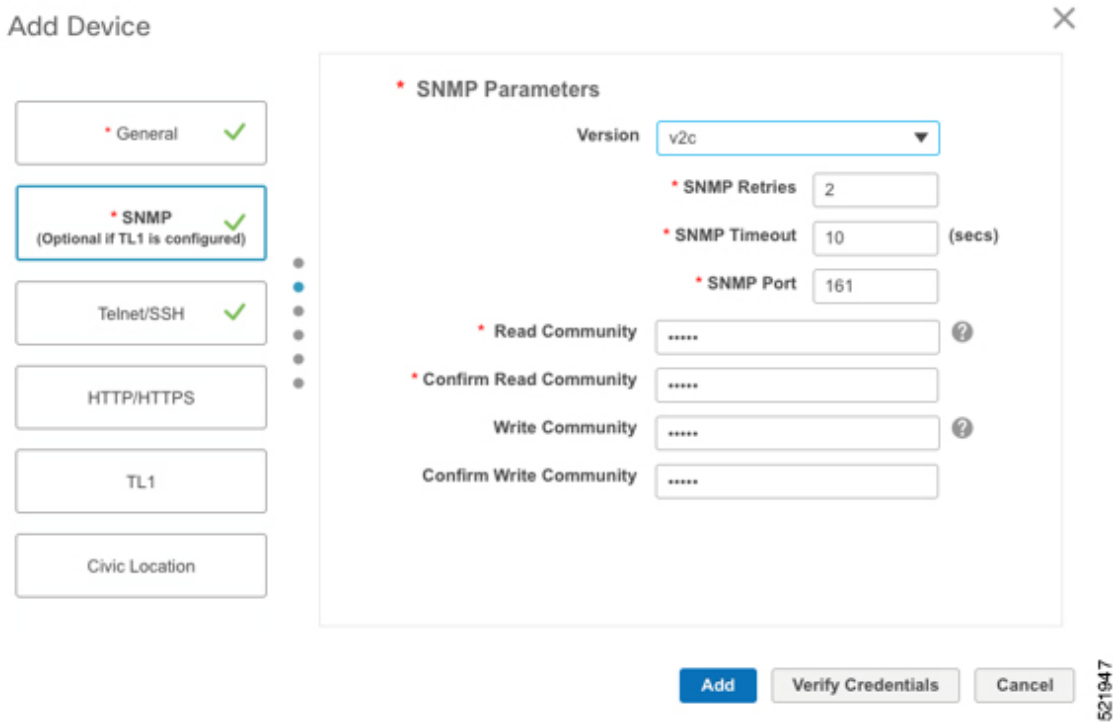
521943

Step 3 Configure the General, SNMP, and SSH parameters as shown in the figures. Then click **Verify Credentials** to confirm that Cisco EPN Manager can reach the device. Click **Add** to add the device to EPNM.

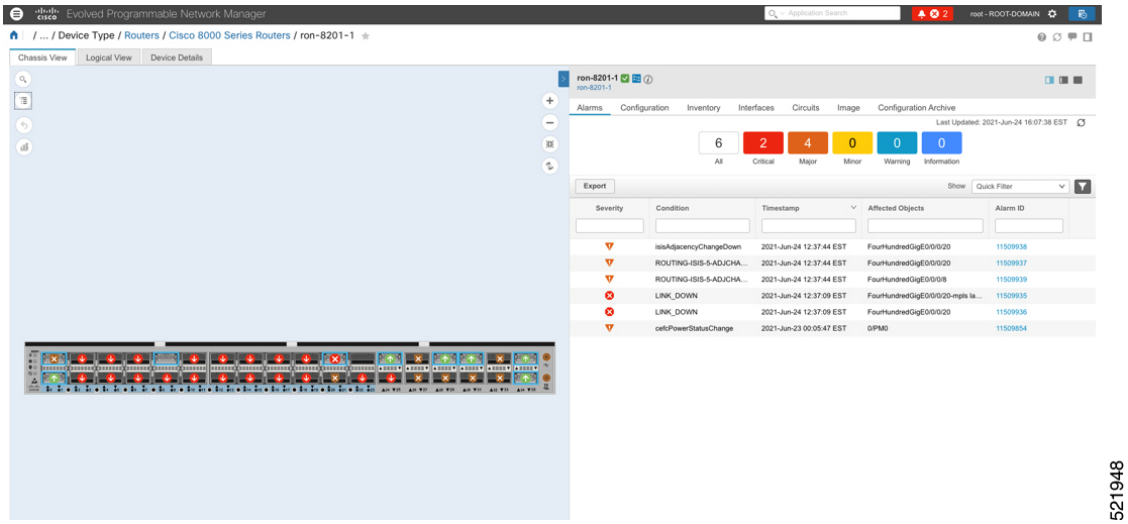
Sample end-to-end configuration





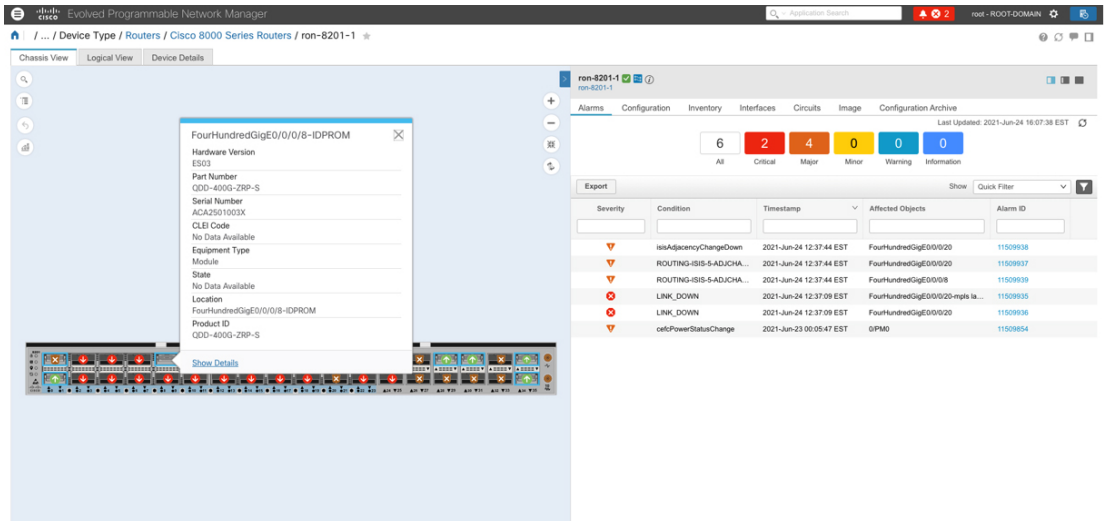


Step 4 Click the device name link in the Network Devices table to open the chassis view. This figure shows the chassis view of the 8201 router.



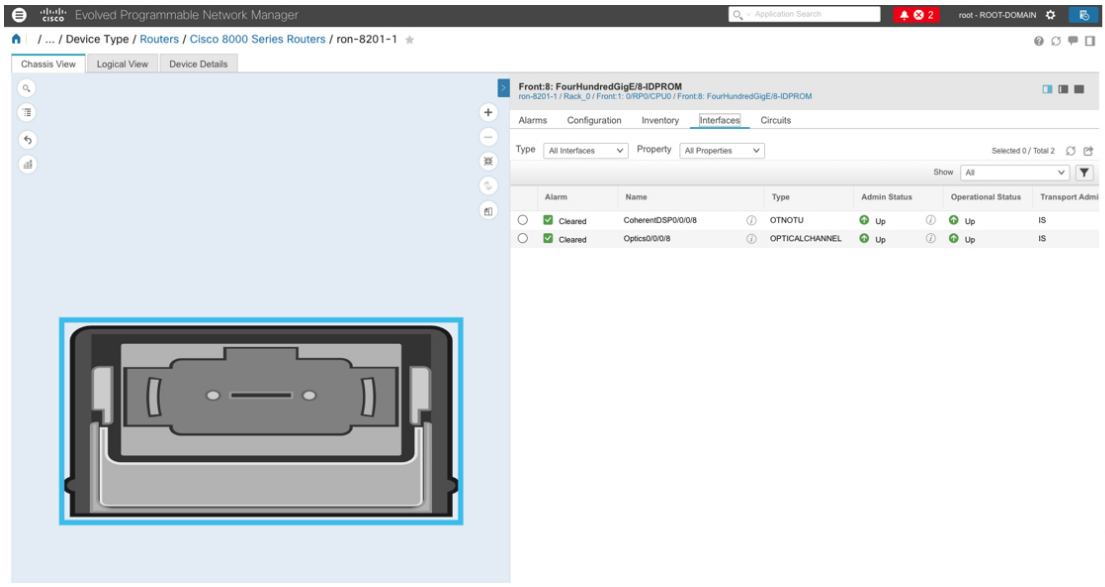
Step 5 Click the QSFP-DD ZR+ port to view details about that port.

Sample end-to-end configuration



521949

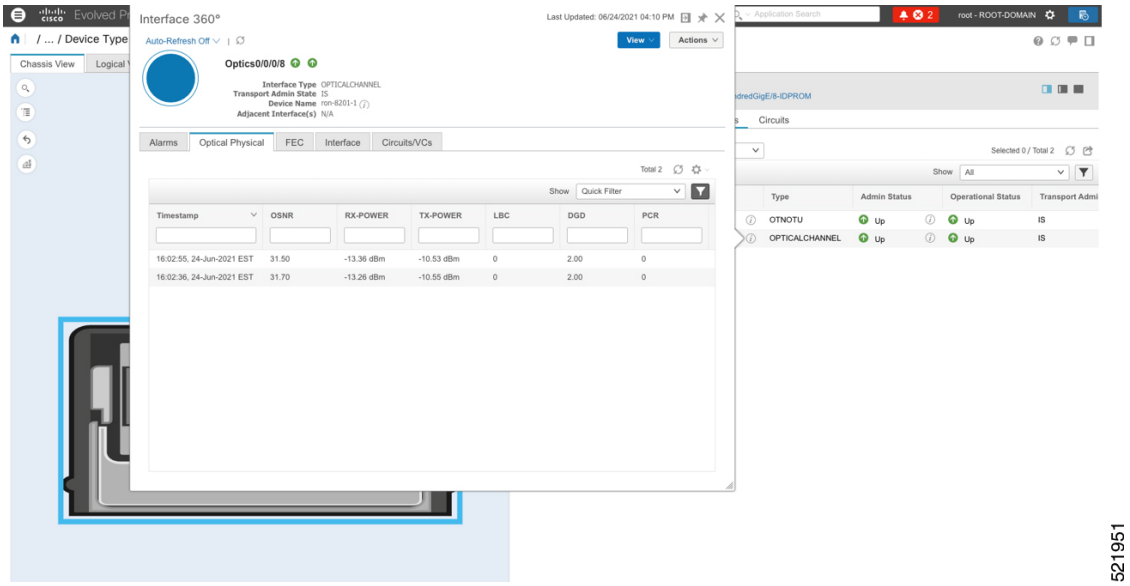
Here, you can view the port, the specific optical channel, and the CoherentDSP entities.



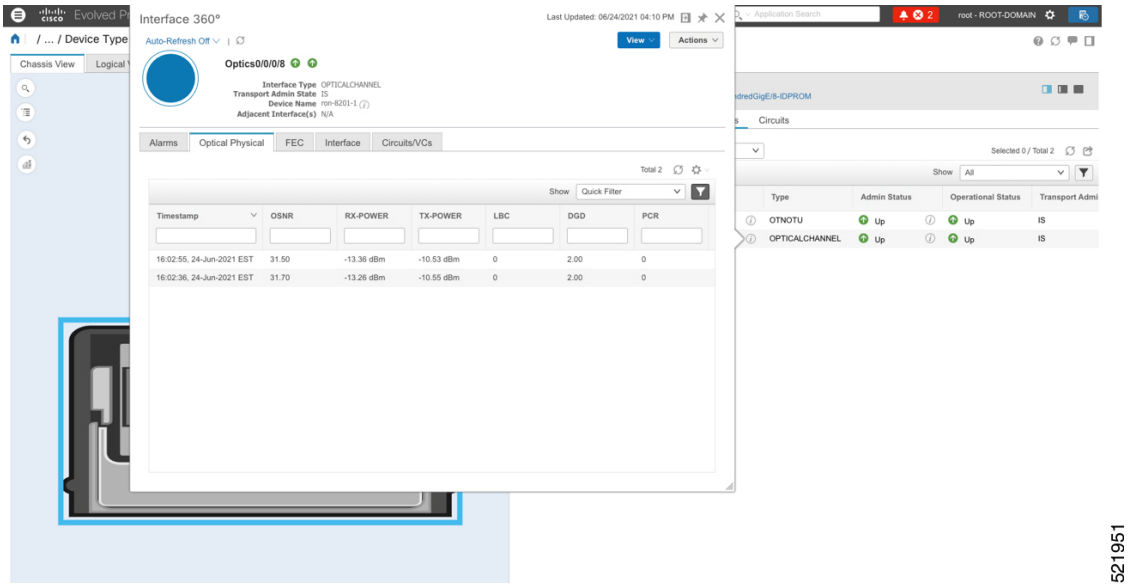
521950

Step 6 Click the additional information icon for the optical channel. Then select the **Optical Physical** measurement tab to display relevant optical PM values such as **RX/TX signal power** and **OSNR** values.

Sample end-to-end configuration



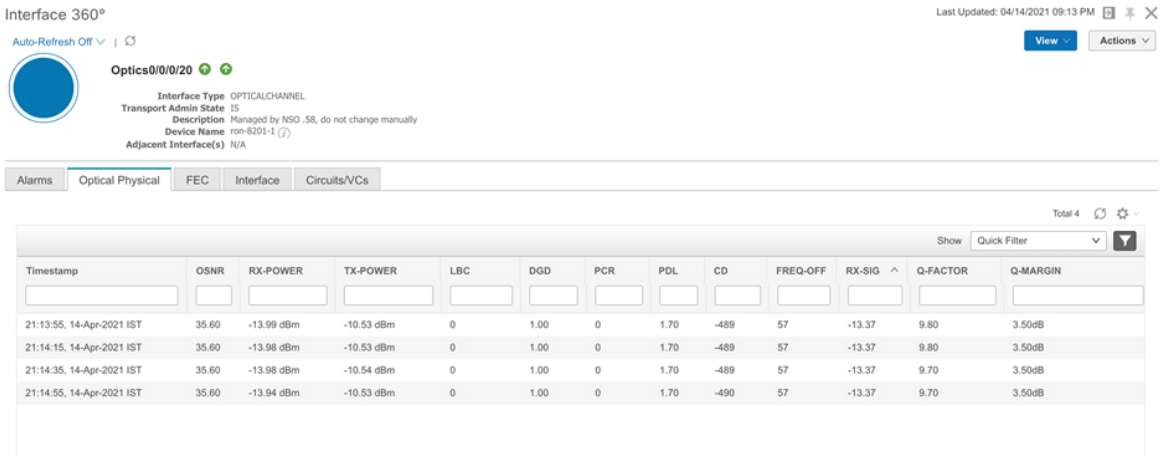
Step 7 Click the additional information icon for the coherent DSP. Then select the **FEC** measurement tab to display relevant coherent DSP FEC statistics such as **PreFEC Bit Error Rate, Bit Error Rate Count (BIEC),** and **Uncorrected Words (UCW)**. The UCW value must remain 0.



These figures display EPNM monitoring data relevant to ZR or ZR+ optics, including current and historical performance.

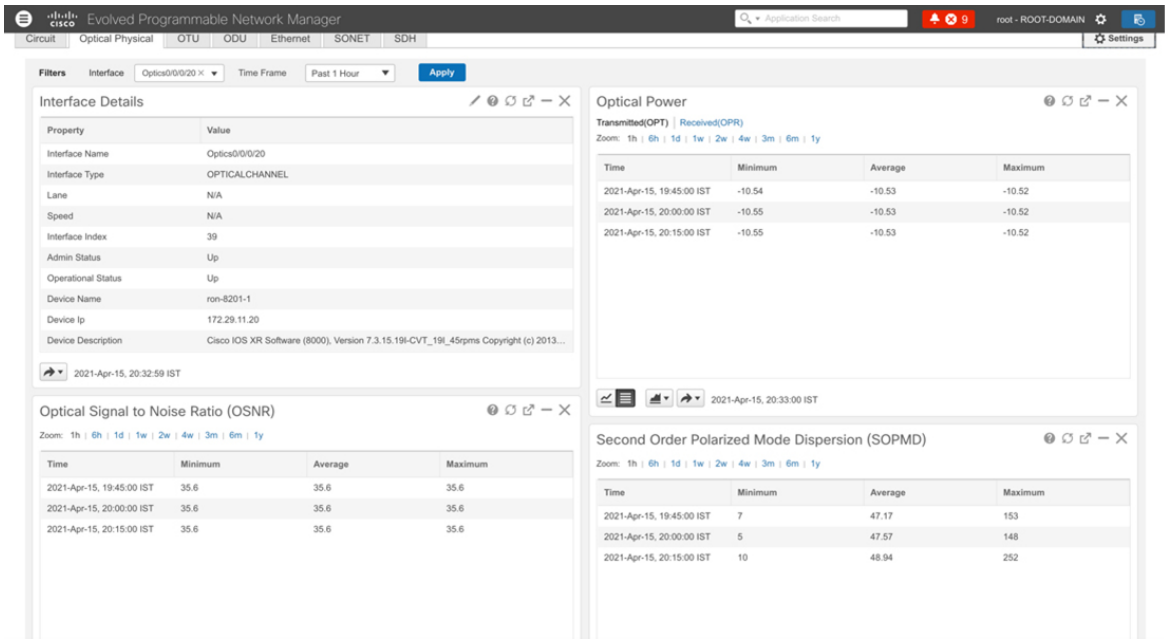
Sample end-to-end configuration

Figure 69: Optical physical parameters



521883

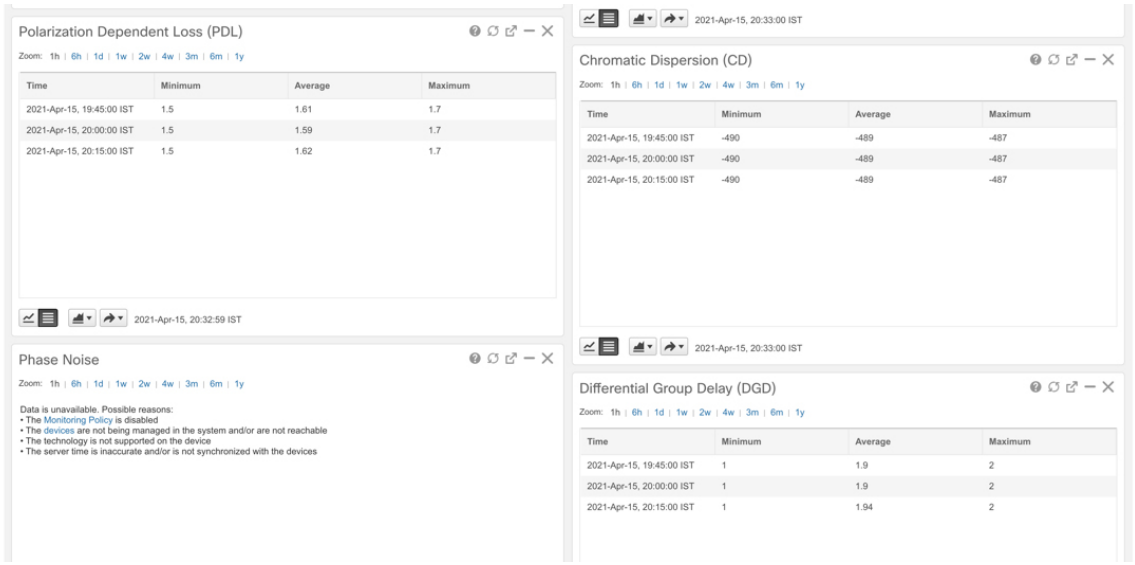
Figure 70: Historical optical physical parameters



521884

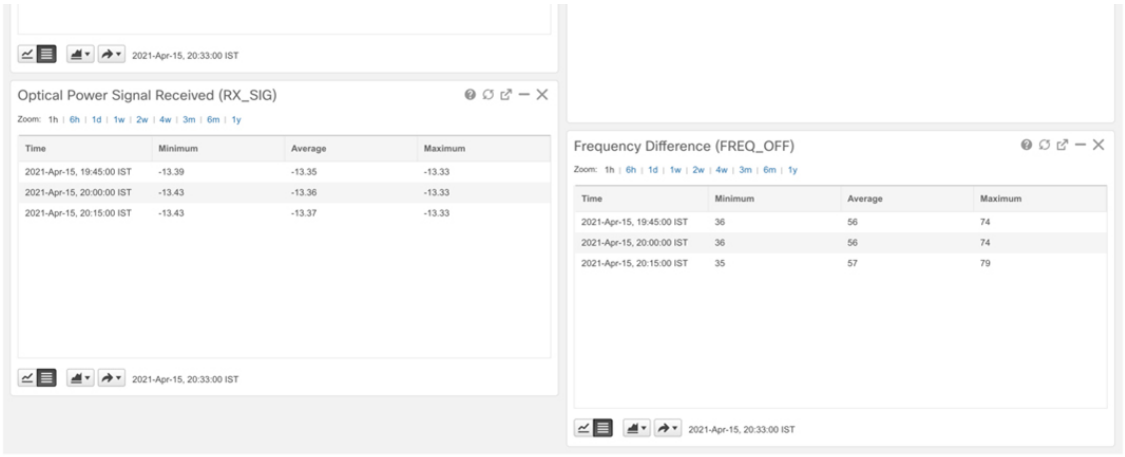
Sample end-to-end configuration

Figure 71: Historical optical physical parameters



521885

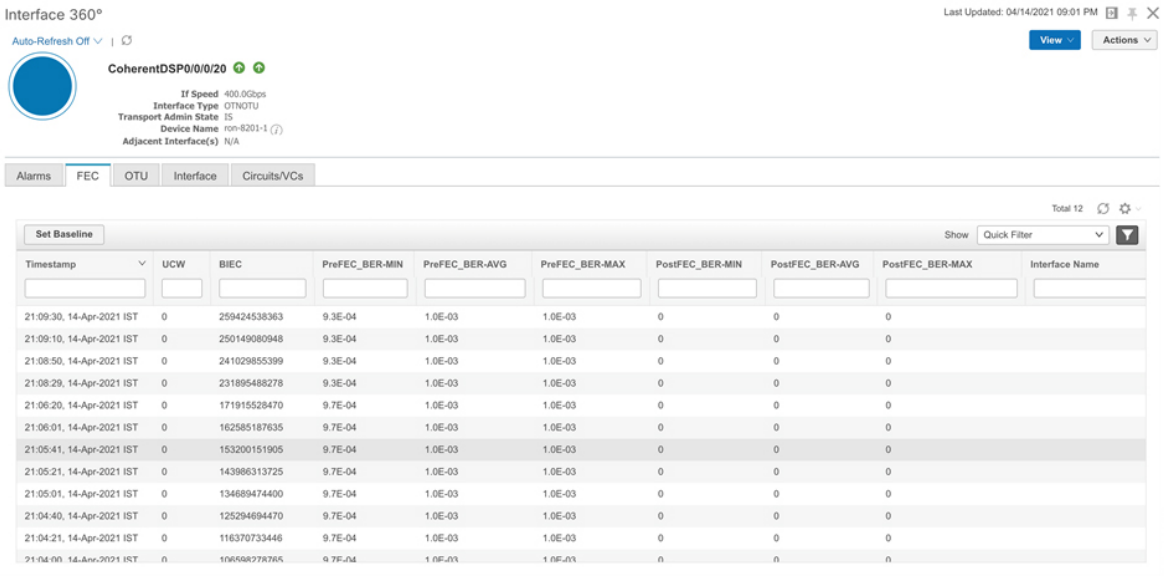
Figure 72: Historical optical physical parameters



521888

Sample end-to-end configuration

Figure 73: FEC parameters



521881

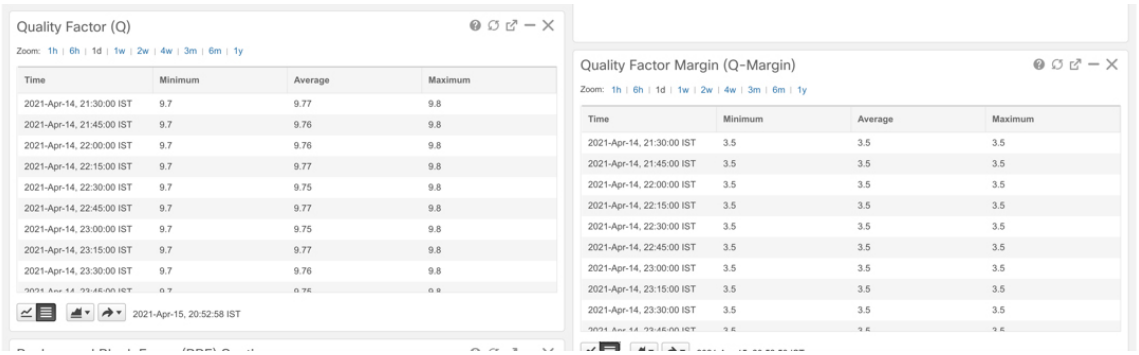
Figure 74: Historical FEC parameters



521889

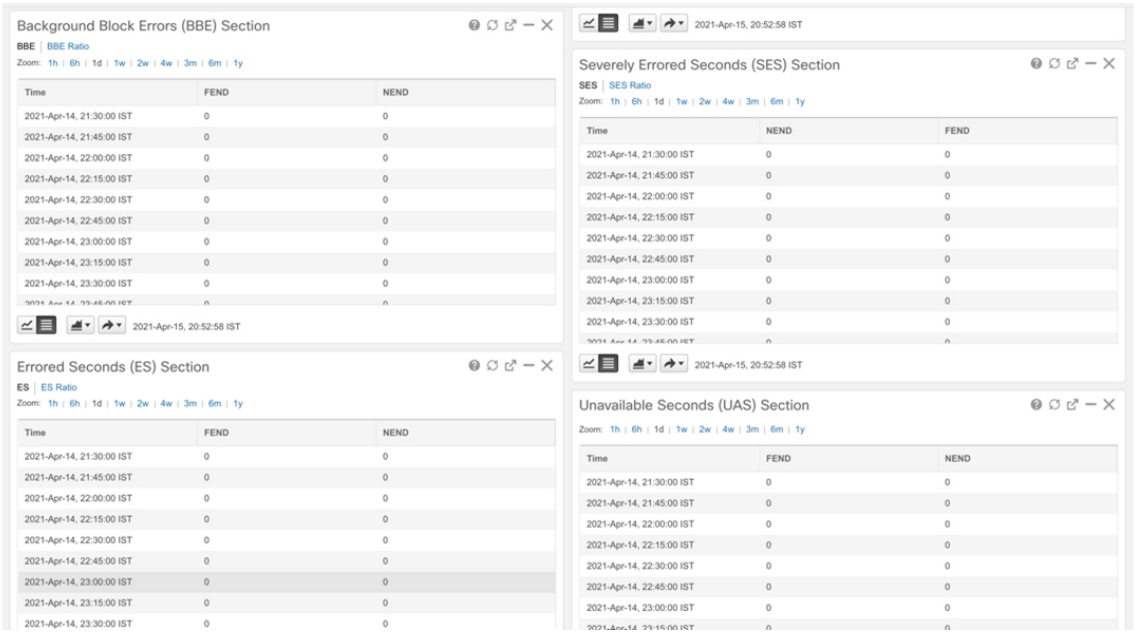
Sample end-to-end configuration

Figure 75: Historical FEC parameters



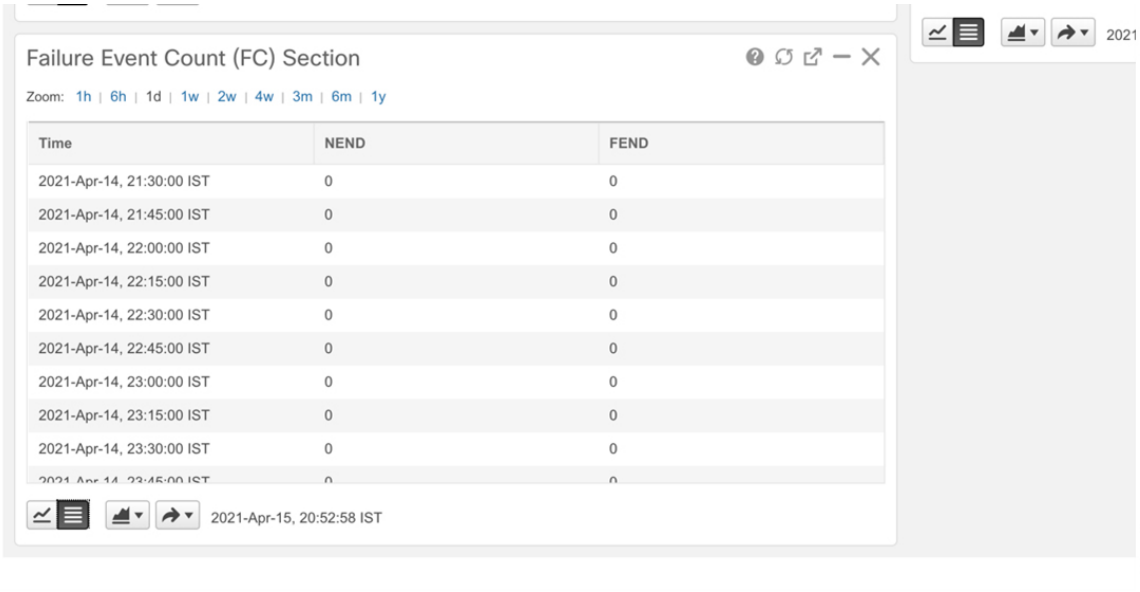
521890

Figure 76: Historical OTN parameters



521891

Figure 77: Historical OTN parameters

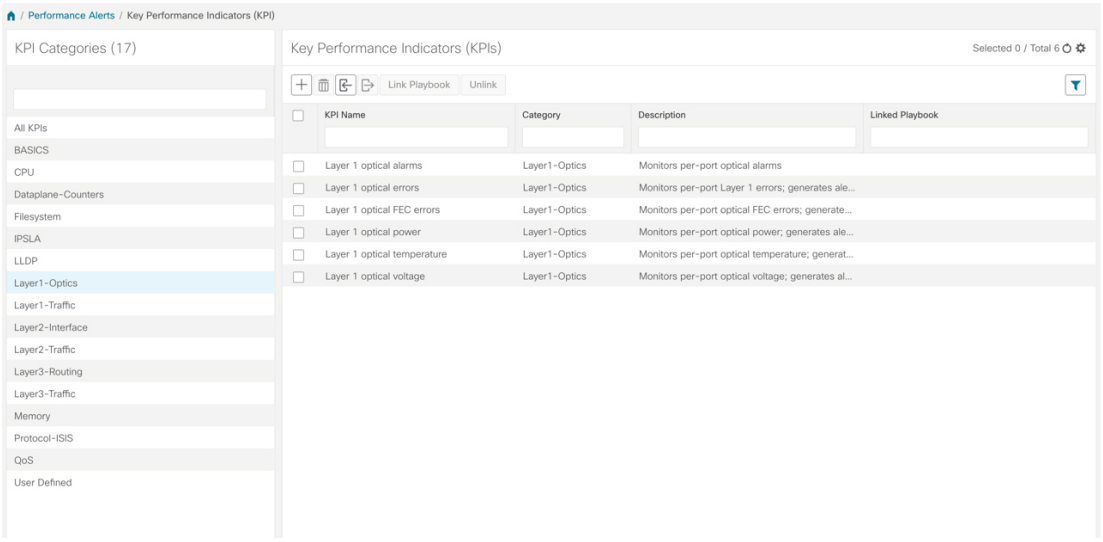


Monitor ZR or ZR+ optics performance Using KPIs

The purpose of the task is to enable KPI monitoring for ZR or ZR+ optics to track device health using Health Insights.

Use the KPIs supplied by Cisco to monitor specific network optics. Configure and enable KPI profiles on devices to start health monitoring.

Note Decide which KPIs supplied by Cisco to use for each device based on its function and the performance characteristics you want to monitor. Review the KPIs supplied by Cisco documented in List of Health Insights KPIs. The image shows the available default L1 optics KPIs.

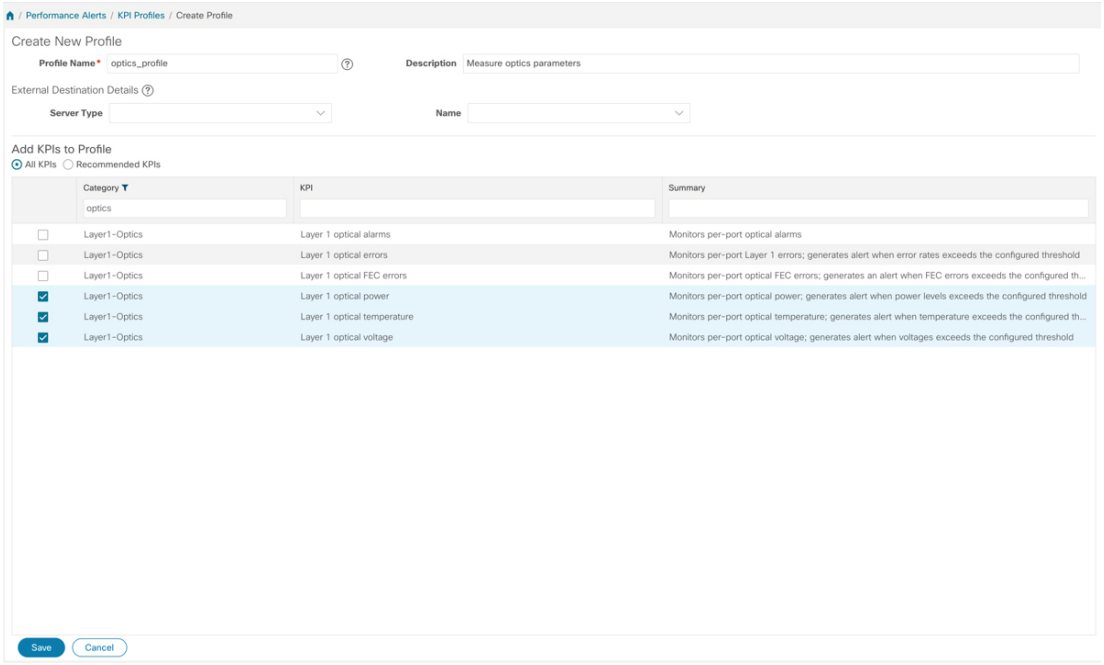


Procedure

Step 1 Group the relevant KPIs to create a KPI Profile focused on optics.

A KPI profile can have many different KPIs assigned. In this procedure, add only specific optics KPIs to the **optics_profile** KPI profile.

Sample end-to-end configuration



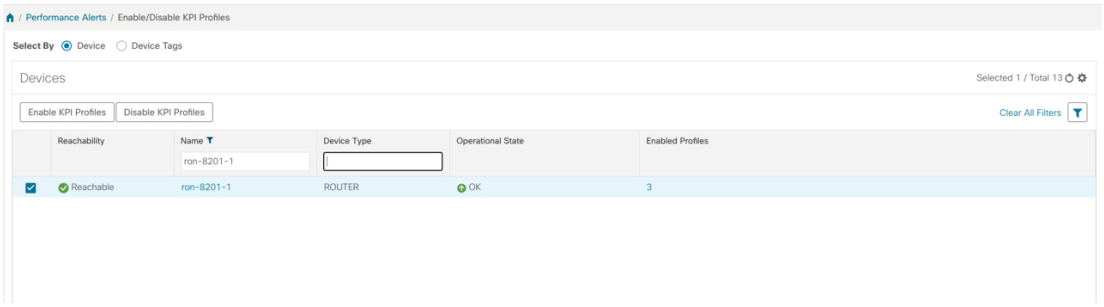
521914

See Create a New KPI Profile.

Step 2 Enable the appropriate KPI Profile on target devices you want to monitor.

a) From the main menu, choose **Performance Alerts** > **Enable/Disable KPI Profiles**.
b) Check the checkboxes for all nodes where you want to apply the profile.
c) Choose the KPI profile and click **Enable KPI Profiles**.

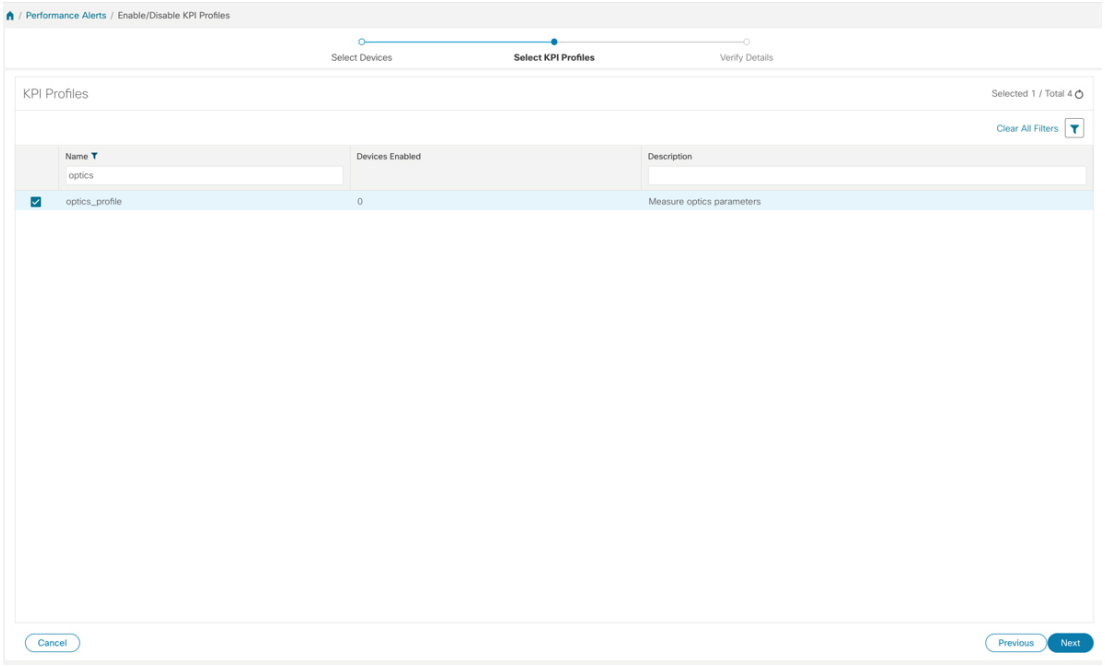
You can select multiple nodes. The image shows the KPI profile being applied to a single node.



521915

Step 3 Select the optics_profile KPI profile and click **Next** to finalize enabling the KPI for the selected devices.

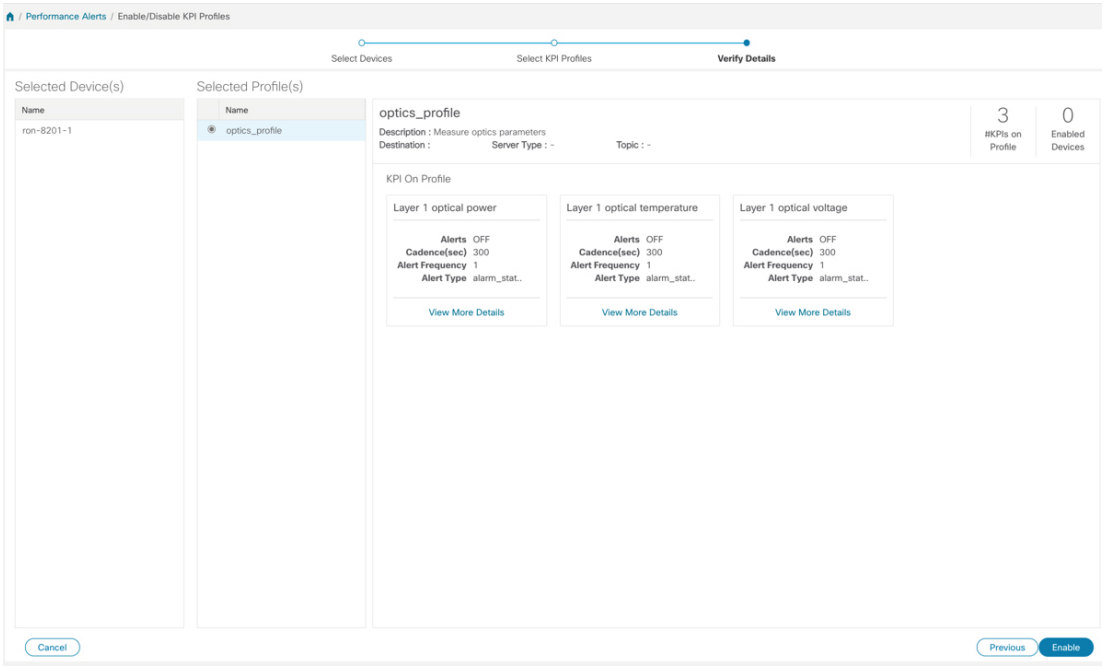
Sample end-to-end configuration



521916

Step 4 Apply the configuration and click **Enable** to start streaming telemetry sensor data for optics KPIs.

See Enable KPI Profiles on Devices.

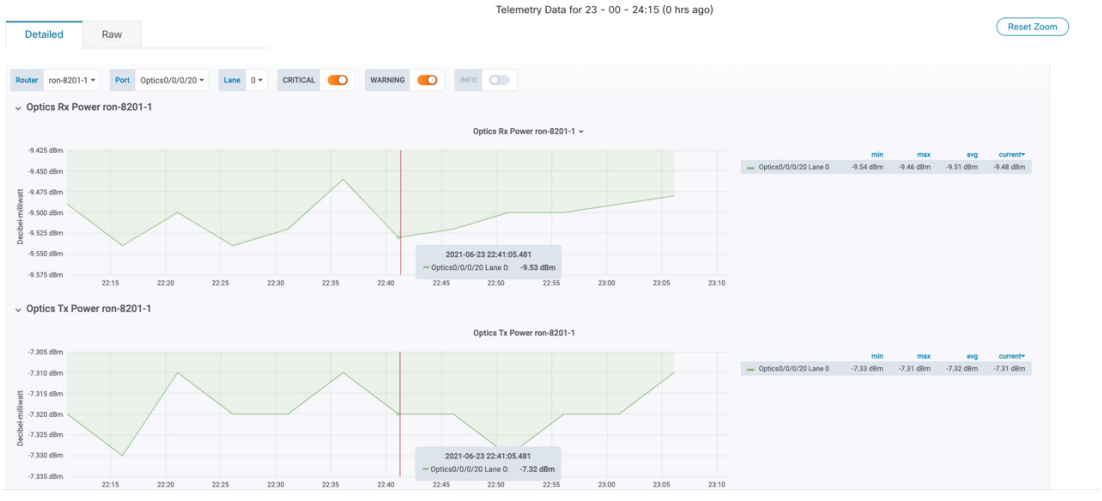


521917

Step 5 View alerts from network devices as the system begins monitoring.

See View Alerts for Network Devices

This image shows the RX and TX power of the QDD-400G-ZR-S transceiver.



Devices begin streaming telemetry data for selected optics KPIs, and alerts become available in Health Insights.

Optimization phase

The optimization phase consists of these activities:

1. Return to planning stage.
2. Continue to add or change circuits on the network to match packet demands.