Cisco Routed Optical Networking Solution Guide, Release 2.0

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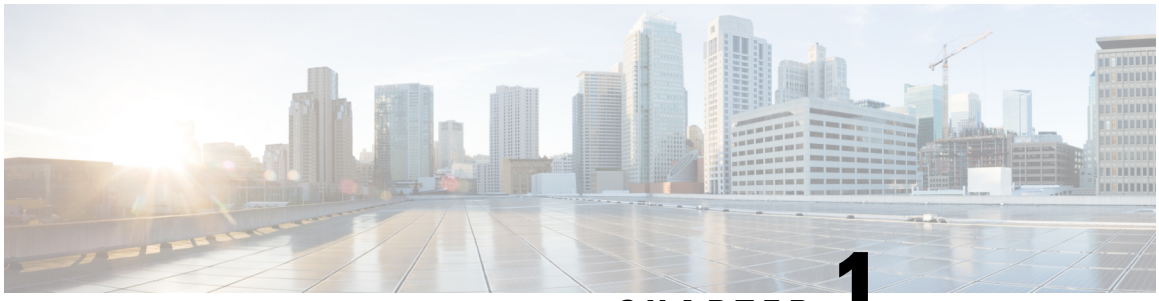


CHAPTER 1

Introduction to Traditional Networks

This chapter provides insight into the business challenge, components of a network, and the current challenges faced by IP and optical networks.

- Business Challenge, on page 1
- Traditional Multilayer Network Architectures, on page 1
- Network Building Blocks, on page 2
- Challenges with Current IP and Optical Networks, on page 4

Business Challenge

Today's networks, such as optical and packet networks, consist of multiple layers which are stitched together from many domains and vendors. Provisioning services in such complex environments requires intricate coordination between different management systems and organizations. It is challenging to operate these networks and the total cost of ownership (TCO) is rising. Service providers must simplify and reimagine the architecture to curtail the rising operational costs and fast-track the delivery of new services.

Solution

The Routed Optical Networking solution aims to simplify networks by removing the complexities inherent to the infrastructure. This simplification allows service providers to leverage their assets more effectively by:

- unifying the IP and optical layers of the network using a single control plane
- using high-speed coherent pluggable modules that offer reach and performance at appropriate cost points and power profiles
- simplifying the network life-cycle management by leveraging automation in all phases of the lifecycle

Changing the paradigm, the Cisco Routed Optical Networking solution improves operational efficiency and reduces network TCO. The transformed network also increases service agility.

Traditional Multilayer Network Architectures

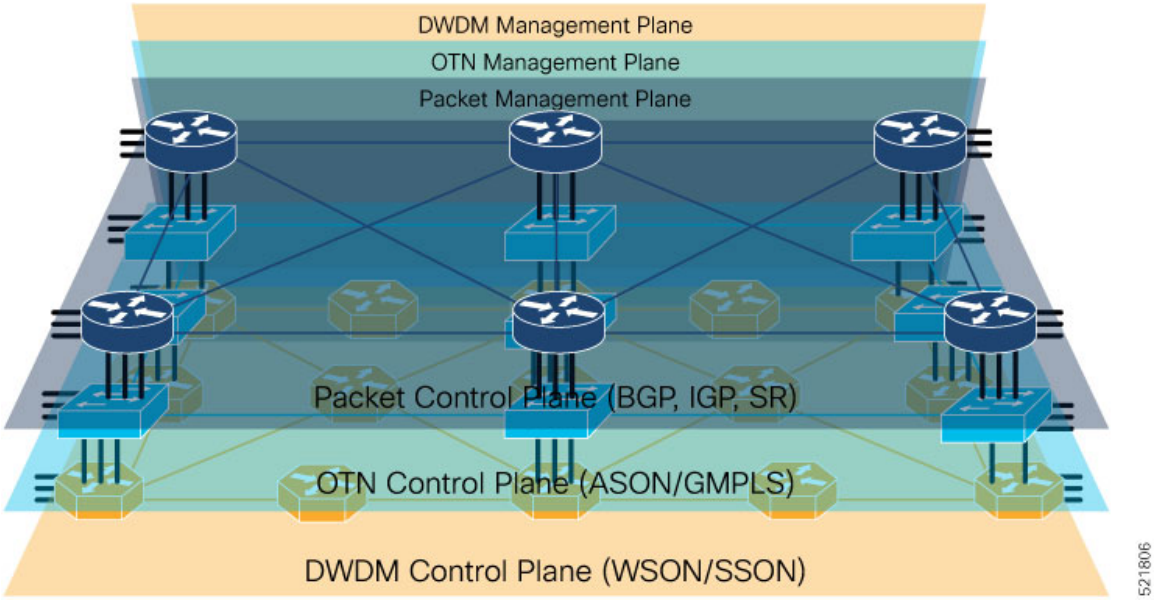
Traditional network infrastructure consists of an IP layer and an optical transport layer. The optical layer consists of a Dense Wavelength Division Multiplexing (DWDM) layer, and optionally an Optical Transport Network (OTN) switching layer. Each layer has its own independent control and management planes.

A distributed control plane communicates network information between network elements to enable end-to-end communication between network clients. Distributing routing information is the responsibility of the IP control plane. Resource and connection management between optical endpoints is the responsibility of the optical control plane.

The following table lists network layers and their corresponding control planes:

Layer	Control Plane
Packet layer/IP layer	BGP, IGP, Segment routing
Optical Transport Network layer	ASON/GMPLS
Dense Wavelength Division Multiplexing layer	WSON/SSON

Figure 1: Traditional Network Architecture



Each layer operates independently with separate redundancy and life cycles. Logically different teams are necessary to establish and maintain each layer.

Network Building Blocks

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

IP Layer

The IP layer is responsible for creating and maintaining the routing table and forwarding packets according to the routing table. The IP layer of traditional networks consists of interconnected routers.

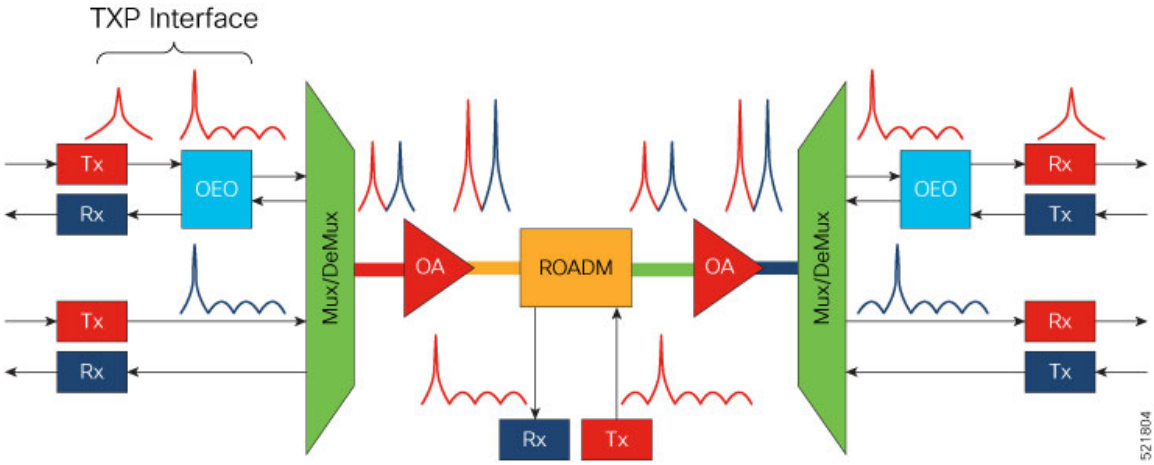
Routers are the building blocks of packet networks and are responsible for efficiently forwarding IP or MPLS packets. Routers are used to create any to any fabrics used to carry virtually all networking traffic today, including the global Internet. Routers are also responsible for providing different functions based on their role in the network. Two examples 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

The following diagram shows a typical DWDM network:

Figure 2: Typical DWDM Network



This table lists the abbreviations in the preceding image and their expansions:

TXP	Transponder
OEO	Optical-electrical-optical
Mux	Multiplexer
DeMux	Demultiplexer
OA	Optical amplifier
ROADM	Reconfigurable optical add/drop multiplexer

The building blocks of a typical DWDM network are:

- **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 optical signals to 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/Demultiplexers**: Multiplexers take multiple wavelengths on separate fibers and combine them into a single 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 to enable the signal transmission across longer distances. Without amplifiers, the signal attenuation over longer distances makes it impossible to coherently receive signals. We use different types of optical amplifiers in optical networks. For example: preamplifiers, booster amplifiers, inline amplifiers, and optical line amplifiers.
- **Optical add/drop multiplexers (OADMs)**: OADMs are devices capable of adding one or more DWDM channels into or dropping them from a fiber.
- **Reconfigurable optical add/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 also often results in separate opaque redundancy mechanisms at each layer, increasing complexity and reducing overall network efficiency. The large number of devices used to interconnect the layers increases power utilization and drives up the overall carbon footprint of the network.

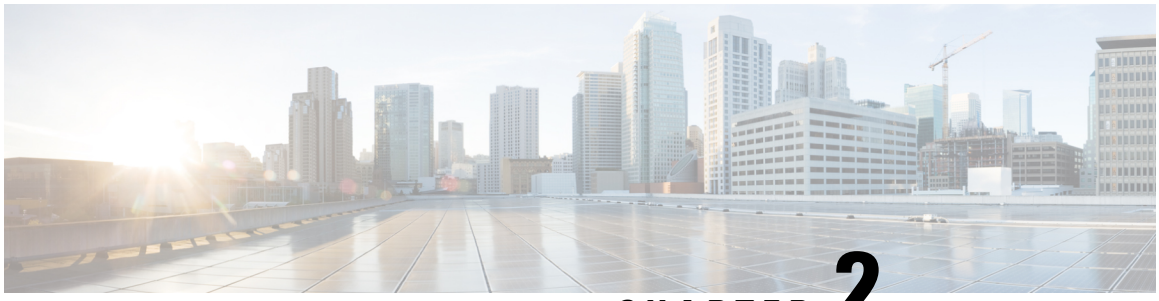
The layered and siloed architecture warrants manual service-stitching across network domains. The necessity for manual intervention hinders end-to-end automation and results in higher time to resolution and loss of efficiency.

Traffic runs over 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.

Current service provider networks have immense complexities and face challenges in:

- Network planning
- Provisioning
- Path and network optimization
- Network monitoring
- Fault correction

These complexities and overlapping redundancies present bottlenecks to scaling the service provider networks efficiently.



CHAPTER 2

Routed Optical Networking

This chapter provides an overview of Routed Optical Networking, its benefits, and supported deployment models.

- Routed Optical Networking Overview, on page 5
- Routed Optical Networking Strategy, on page 6
- Technology Overview, on page 7
- Benefits of Routed Optical Networking, on page 9
- Routed Optical Networking Deployment Models, on page 10
- What's New in Routed Optical Networking 2.0, on page 11

Routed Optical Networking Overview

Routed Optical Networking simplifies complex multilayer networks by collapsing network layers and minimizing the functional overlap. Routed Optical Networking also improves the overall network efficiency by optimizing each layer of the network. The architecture also integrates open data models and standard APIs, enriching powerful automation making Routed Optical Networking easier to operate than legacy networks.

Routed Optical Networking is able to provide improvements and simplification because it:

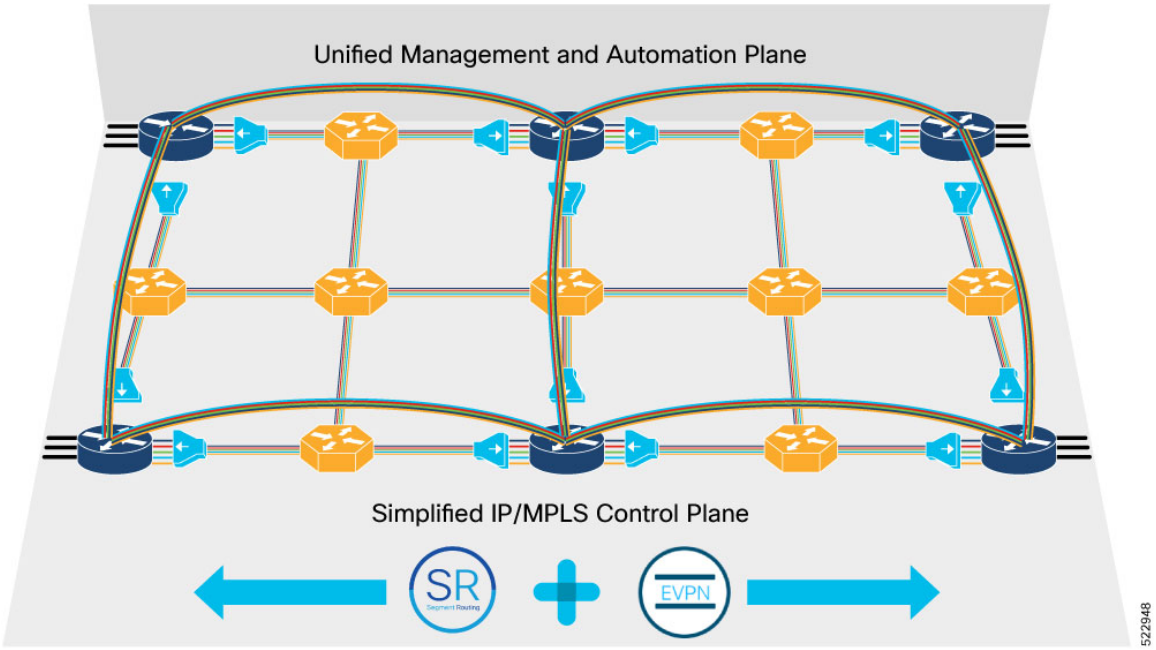
- Leverages state of the art optical and routing technologies to converge services over an IP infrastructure connected by a simplified DWDM layer
- Merges IP and private line services onto a single unified IP layer
- Simplifies end-to-end network architecture
- Utilizes a modern software stack that spans 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
- Total Cost of Ownership savings across CapEx and OpEx

Routed Optical Networking utilizes high-density routers, high-capacity ZR or ZR+ pluggable digital coherent optics, simplified DWDM line systems, and end-to-end multi-layer automation to create next generation networks.

Routed Optical Networking Strategy

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



A Converged SDN Transport architecture simplifies the network by converging services on a unified, automated infrastructure for maximum scalability and agility to support emerging services for the 5G era and beyond. See Converged SDN Trasnport.

Routed Optical Networking as part of Cisco's Converged SDN Transport 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 DCO pluggables.

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
- Convergence of IP and private line services on a single converged packet network infrastructure with guaranteed SLAs

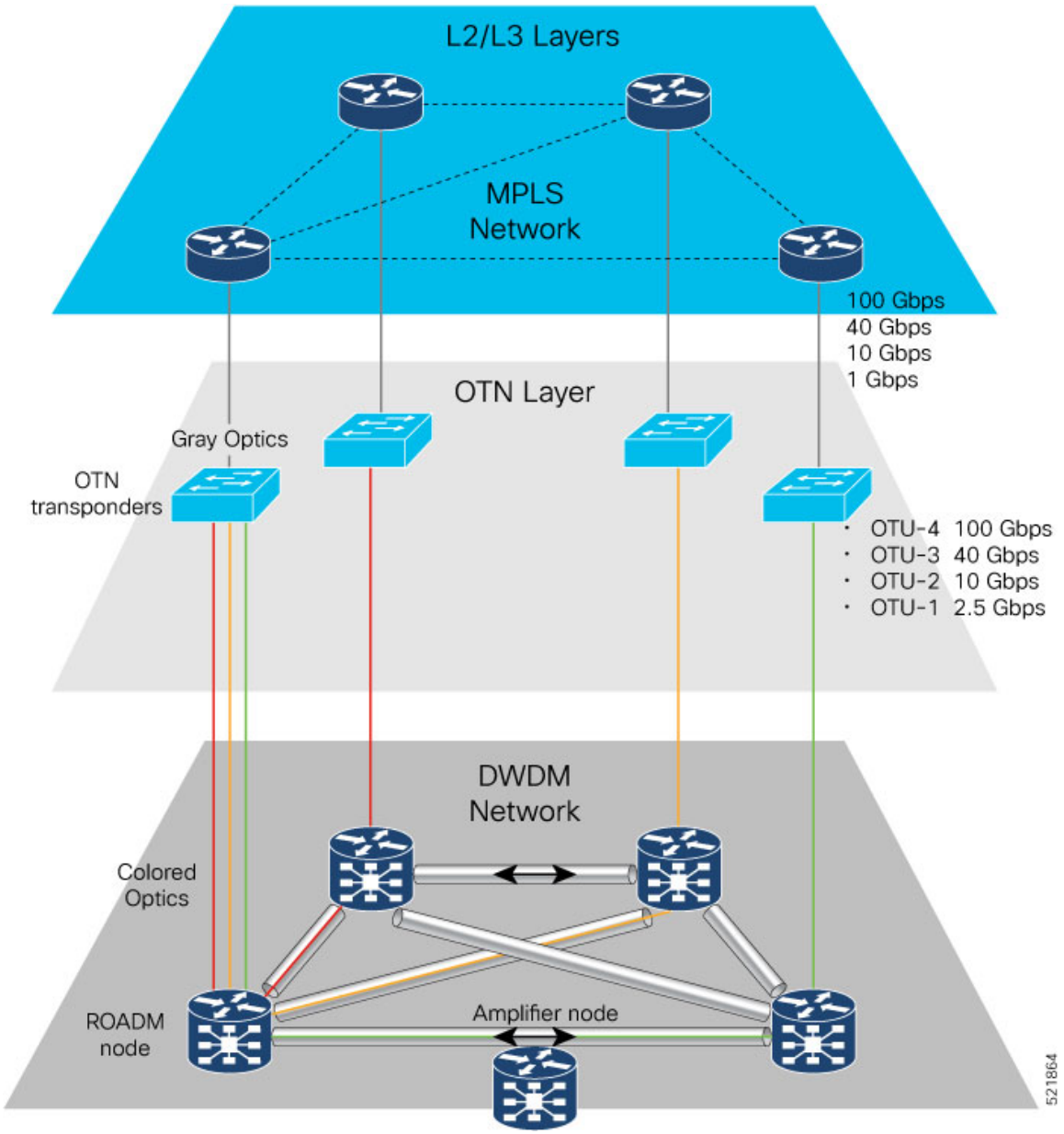
The following table compares the legacy multilayered architecture and the Routed Optical Networking architecture.

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

Technology Overview

The following diagram displays the current multilayer architecture.

Figure 4: Multilayer Architecture



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

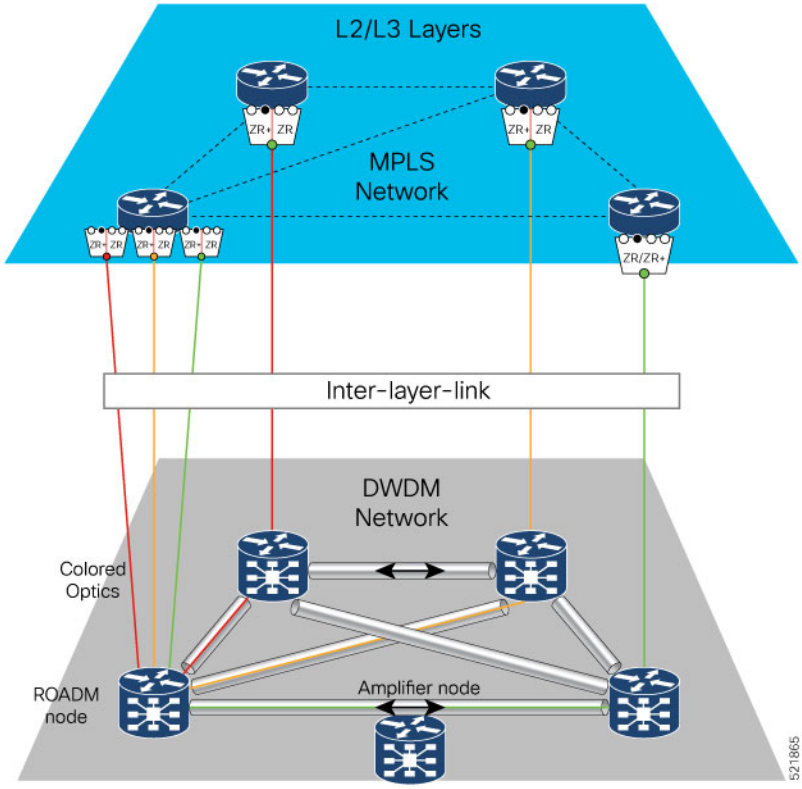
The routers are connected over either dark fiber or a DWDM network with standardized pluggable digital coherent optics, such as ZR and ZR+ transceivers. These transceivers reduce cabling, power consumption, and physical footprint requirements versus using traditional external transponders.

The routers are connected with standardized pluggable coherent optics, such as ZR/ZR+ transceivers. These transceivers reduce cabling, power consumption, and footprint requirements.

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.

The following diagram displays the Routed Optical Networking architecture.

Figure 5: Routed Optical Networking Architecture



Benefits of Routed Optical Networking

The benefits of Routed Optical Networking are:

- **Cost Savings:** Routed Optical Networking provides a decreased network total cost of ownership. Routed Optical networks make the most efficient use of high capacity routers and DWDM optical infrastructure. Utilizing the routers high capacity switching allows denser interconnection and the ability to move all traffic protection to the IP layer of the network. Routed Optical Networking saves costs by converging service layers, moving to a simplified DWDM optical system, and using industry standard ZR/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 Converged SDN Transport technologies such as Segment Routing and EVPN along with the 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 current private line service SLAs. This convergence leads to simplified planning, design, activation, management, and troubleshooting.

- **Automation:** Automation improves resiliency, failure detection, and ease of repair. Enhanced multi-layer visibility and root cause analysis allows network operators to quickly discover and remediate faults. Troubleshooting is enhanced with rich network telemetry at each layer.
- **Optimize Capacity:** Routed Optical Networking takes advantage of the IP layer's ability to statistical multiplex network traffic at the packet level. Statistical multiplexing is the most efficient way to carry network traffic with the ability to adapt to instantaneous traffic demands and avoid 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.

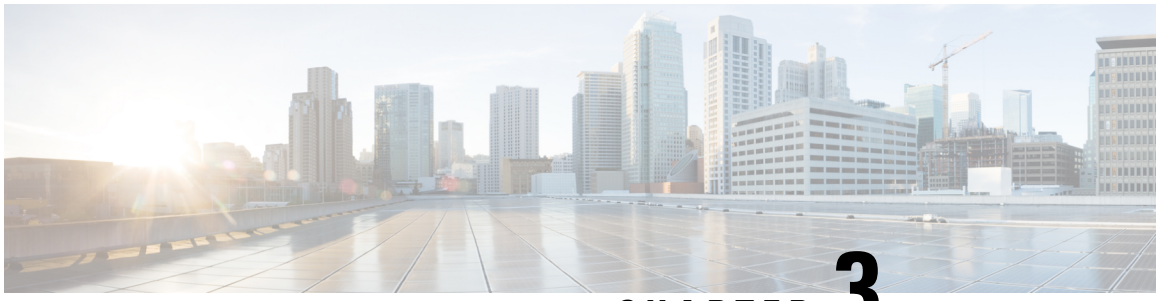
Routed Optical Networking Deployment Models

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. Thus, it is critical to have a flexible control platform that supports a phased deployment and a smooth evolution. The models are:

- **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, is installed from scratch. In fact, it may be useful to install Crosswork Hierarchical Controller ahead of time, in preparation for the Routed Optical Networking deployment, over existing parts of the network, to help plan out the Routed Optical Networking network based on accurate data about the existing services, network, and fiber assets. See Automation Components, on page 34.Cisco Networks managed using Cisco EPNM can utilize EPNM to manage Routed Optical Networking
- **Third-party Optical Network Routed Optical Networking Deployment:** When routers with ZR/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 2.0

Feature	Release	Description
Simple Optical Line Systems	**IOS-XR: 7.7.1**	NCS 1010 OLS platform is an integral component of Routed Optical Networking solution. It provides point-to-point connectivity between routers with ZR/ZR+ optics and multiplexes signals from multiple routers over a single fiber. The OLS platform supports ROADM nodes of up to eight degrees. The NCS 1010 OLS platform provides: • Versatility by supporting multiple coherent sources • Simplicity by using integrated Optical line cards that minimize fiber patching and cabling errors in the field. • Automation through IOS XR operating system that provides a rich suite of automation features including Zero Touch Provisioning (ZTP), open config YANG model support with NETCONF, and streaming telemetry. • Network Monitoring through a combination of probes based on OTDR, OSC, OCM, and telemetry data.
OpenConfig support for ZR/ZR+	**IOS-XR: 7.7.1**	You can manage the pluggable digital coherent optics using open models from the OpenConfig consortium.
Private Line Emulation	**IOS-XR: 7.7.1**	Private line emulation (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. Private Line Emulation (PLE) utilizes Circuit Emulation (CEM) to transparently transfer PLE client frames over MPLS or Segment Routing networks without changing the characteristics of the original signal.



CHAPTER 3

Routed Optical Networking Solution Components

This chapter describes the Routed Optical Networking solution components.

- Hardware Components, on page 13
- Network Planning Components, on page 33
- Automation Components, on page 34
- IOS-XR Software Components, on page 44

Hardware Components

The hardware components that enable Routed Optical Networking are:

- High Density Routers
  - Cisco 8000 Series Routers
    - Cisco 8200 Series Routers, on page 15
    - Cisco 8800 Series Routers, on page 15
    - Cisco 8800 Series Line Cards, on page 15
  - Cisco Network Convergence System 5500 Series
    - Cisco NCS-55A2 Series Fixed Port Routers, on page 16
    - Cisco NCS-57B1 Series Fixed Port Routers, on page 16
    - Cisco NCS-57C1 Series Fixed Port Routers, on page 17
    - Cisco NCS-57C3 Series Fixed Port Routers, on page 17
    - Cisco NCS 5500 Modular Chassis, on page 17
    - NCS 5700 Series Line Cards, on page 18
    - NCS 5700 Series Modular Port Adapters, on page 18
  - Cisco ASR 9000 Series Aggregation Services Routers, on page 19
    - Cisco ASR 9903 Compact High-Performance Router, on page 20
    - Cisco ASR 9000 Series Line Cards, on page 20

- Cisco Network Convergence System 540 Series Routers, on page 21
  - Cisco Network Convergence System 540 Large Density Routers, on page 22

- High Capacity Pluggable Optical Modules
  - 400G ZR/ZR+ Transceivers

- Optical Line Systems
  - Cisco Network Convergence System 2000 Series, on page 26
    - Cisco NCS 2006 Shelf, on page 26
    - Control Cards, on page 27
    - ROADM Cards, on page 27
    - Amplifier Cards, on page 27
      - EDFA Cards, on page 28
      - EDRA Cards, on page 28
      - Raman Amplifier Cards, on page 28
  - Passive Multiplexer and Demultiplexer Module, on page 28
  - Passive Patch Panel Modules, on page 29
    - MPO-16 to 16-LC Fan-Out Module, on page 29
    - Cisco 1 x 6 Colorless FlexSpectrum Add/Drop Module, on page 29
    - 5-Degree Modular Patch Panel Module, on page 29
    - Cisco 4-Degree Upgrade Modular Patch Panel Module, on page 29
  - Cisco Network Convergence System 1010, on page 30
    - Cisco NCS 1000 32-Channel Mux/Demux Patch Panel, on page 32
    - Cisco NCS 1000 Breakout Patch Panel and Modules, on page 32

Cisco 8000 Series Routers

The Cisco 8000 series routers utilize Cisco's Silicon One ASIC to deliver full routing functionality at higher capacities and a lower environmental footprint than any other routing silicon available. The Silicon One architecture supports large forwarding tables, deep buffers, flexible packet operations, and enhanced programmability.

The 8000 series are highly scalable, deep-bufferred, 100G/400G/800G optimized routers. They are also available with additional on-chip High Bandwidth Memory (HBM) to support additional resource scale. The Cisco 8000 series routers support both ZR and ZR+ modules.

Cisco 8200 Series Routers

The Cisco 8200 Series uses a single Cisco Silicon One ASIC to deliver full routing functionality. The Cisco 8200 Series is designed for relatively high-buffer and high-scale use cases. These fixed port, high-density routers provide 10.8 Tbps of network bandwidth with dramatically lower power consumption than contemporary 10 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 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 delivers density and efficiency with the extensive scale, buffering, and all feature capabilities that are common to Cisco 8000 Series routers. The 8800 series routers provide up to approximately 260 Tbps through 648 400 GbE ports. The 8800 series includes four chassis to meet a broad set 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.

This table details the specifications of the line cards.

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/ZR+ port support, see 400G ZR/ZR+ Transceivers, on page 22.

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

Cisco Network Convergence System 5500 Series

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, 2-rack unit form-factor router. It supports 24 SFP/SFP+ ports capable of supporting Gigabit Ethernet or 10-Gigabit Ethernet, and 16 SFP/SFP+/SFP28 ports capable of supporting Gigabit Ethernet, 10-Gigabit Ethernet, or 25-Gigabit Ethernet. The router also supports up to 2 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

The NCS-57B1-6D24-SYS and NCS-57B1-5DSE-SYS combine 4.8 Terabits of 400GE/100GE optimized forwarding capacity, 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, 1-rack-unit 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/25GE with higher port densities of 50GE/100GE/400GE and QSFP-DD optics, deep packet buffering, MACsec, Class C 1588 Precision Time Protocol (PTP), and Synchronous Ethernet (SyncE) in a power-efficient, 1-rack-unit 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-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 3-rack-unit compact form factor. The chassis along with the Modular Port Adapters (MPAs) provide options of using different types of interfaces ranging from 1GE to 400GE along with industry-leading MACSec encryption and Class C Timing support. These devices also provide Control Plane redundancy, which enables high availability and reliability.

The Cisco NCS 57C3 Series Routers are well equipped for a range of applications such as Carrier Ethernet Aggregation, Subscriber Services, Business Ethernet, Mobile Edge, Campus, Peering, and Core roles. Powered by the industry-leading Cisco IOS® XR Software, the NCS 57C3 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, NCS 5516. All NCS systems are highly reliable and resilient platforms. They 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 consists 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.

For information on ZR/ZR+ port support, see 400G ZR/ZR+ Transceivers, on page 22.

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. Equipping the chassis and the line cards with various interfaces is crucial to cater to a plethora of use cases and services. The Modular Port Adapters provide the much-needed flexibility and capability to the chassis and the 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. This modular port adapter supports the following 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/STM-16, OC-192/STM-64

NC55-OIP-02 MPA is used to support Private Line Emulation.

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.

Cisco ASR 9000 Series Aggregation Services Routers

The Cisco ASR 9000 Series Aggregation Services Routers (ASR 9000 Series) represent an exciting new paradigm in edge and core routing, with exceptional scalability, carrier-class reliability, environmentally conscious design, incredible flexibility, and an attractive price-to-performance benchmark. The Cisco ASR 9000 Series has a wide product portfolio, ranging from the Cisco ASR 9001 (2 RU) to the Cisco ASR 9922 (44 RU), with each system that is designed to provide true carrier-class reliability using the Cisco IOS XR operating system, comprehensive system redundancy, and a full complement of network resiliency schemes. Finally, the Cisco ASR 9000 Series is designed to simplify and enhance the operational and deployment aspects of service-delivery networks.

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 Aggregation Services Routers, see Cisco ASR 9000 Series Aggregation Services Routers Data Sheet.

Cisco ASR 9902 Compact High-Performance Router

The Cisco ASR 9902 Router is a compact, high-performance router that delivers up to 800 Gbps of nonblocking, full-duplex capacity in a Two-Rack-Unit (2RU) form factor. Based on the same Cisco IOS® XR software image as the other routers in the Cisco ASR 9000 Series, the Cisco ASR 9902 Router delivers the features

and services found on the ASR 9000 Series platforms, allowing customers to standardize on the same Cisco IOS XR operating system. Multiple port rates are supported by ASR 9902: 100/40 Gigabit Ethernet, 25-Gigabit Ethernet, and 10-Gigabit Ethernet, providing customers the flexibility to mix and match interface types on the same chassis and offering operators the readiness for mass-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 High-Performance 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 consists of the fixed board, with 16 integrated QSFP28-based 100GE ports, 20 integrated SFP+-based ports, and an optional Port Expansion Card (PEC), which you can insert into the dedicated slot on demand.

The ASR 9903 fixed board supports maximum 1.6T data bandwidth. The Cisco A9903-20HG-PEC offers 20 physical ports with maximum 2T data bandwidth capacity. Five of the 20 physical ports are 400GE/200GE/100GE multirate QSFP-DD/QSFP28-based ports, which you can individually migrate to 400GE using licenses. 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

The Cisco ASR 9000 Series routers support 400G line cards.

ASR 9000 Series 5th Generation High-Density Multi-Rate Line Cards

The ASR 9000 Series 5th Generation High-Density Multi-Rate Line Cards are fully compatible with the following 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 the following 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/ZR+ port support, see Table 1: ZR/ZR+ Support Matrix, on page 23.

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.

Cisco Network Convergence System 540 Series Routers

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

Cisco Network Convergence System 540 Large Density Routers

The Cisco Network Convergence System (NCS) 540 large density router is a 1-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 ranging from 1G up 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 and best-in-class security both from a hardware and software standpoint.

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/ZR+ port support, see Table 1: ZR/ZR+ Support Matrix, on page 23.

For more informtion on Cisco Network Convergence System 540 Large Density Routers, see Cisco Network Convergence System 540 Large Density Routers Data Sheet.

400G ZR/ZR+ Transceivers

The QDD-400G-ZR-S and QDD-400G-ZRP-S optical modules offload wavelength-division multiplexing (WDM) functionality to the router. The QDD-400G-ZR-S and QDD-400G-ZRP-S optical modules are 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 400G Ethernet rate.

This table lists some specifications of the ZR/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

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

This table is the support matrix showing the supported ZR/ZR+ ports.

Table 1: ZR/ZR+ Support Matrix

Platform	Line card/ Fixed Platform	Ports Supporting ZR	Ports Supporting ZR+	Breakout Modes Supported
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	0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30	1x100, 2x100, 3x100, 4x100, 1x400
	88-LC0-36FH-M 8800-LC-36FH 88-LC0-36FH	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
	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/ Fixed Platform	Ports Supporting ZR	Ports Supporting ZR+	Breakout Modes Supported
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

The following table shows the maximum number of ZR and ZR+ modules that are supported in each breakout mode.

Platform	Max no. of ZR supported in mode		Max no. 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
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
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

Platform	Max no. of ZR supported in mode		Max no. of ZR+ supported in mode				
	400G	4x100G	400G	4x100G	3x100G	2x100G	1x100G
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

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.

Device Supported Software

This table shows the IOS XR Software necessary on the routers.

This table shows the required IOS XR Software version on the routers to support specific breakout modes.

Platform	ZR support		ZR+ support				
	400G	4x100G	400G	4x100G	3x100G	2x100G	1x100G
NC57-24DD	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
NC57-18DD-SE	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
NC57-36H6D-S (400G ports)	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
NCS-57B1-6D24-SYS (400G ports)	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
NCS-57B1-5DSE-SYS (400G ports)	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
NCS-55A2-MOD-S(E)-S	-	7.5.1	-	7.5.1	7.5.1	7.5.1	7.5.1
With 2x400G MPA-2D4H							
NCS-57C3-MOD(S)-SYS	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1
With 2x800G+1x400G MPA-2D4H							

NC57-MOD-S (Fixed ports)	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1
NC57-MOD-S With 2x800G MPA-2D4H	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1
NCS-57C1-48Q6-SYS	7.5.2	7.5.2	7.5.2	7.5.2	7.5.2	7.5.2	7.5.2
NCS-57D2-18DD-SYS	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1	7.8.1
N540-24Q8L2DD-SYS	7.4.1	7.4.1	7.4.1	7.4.1	7.4.1	7.4.1	7.4.1
8201	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
8202	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
8800-LC-36FH	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
88-LC0-36FH-M	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
8101-32FH	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
8201-32FH	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
88-LC0-36FH	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
A99-10X400GE-X-SE/TR	7.3.2	7.3.2	7.3.2	7.3.2	7.9.1	7.3.2	7.3.2
A9K-20HG-FLEX-SE/TR	7.3.2	7.3.2	7.3.2	7.3.2	7.8.1	7.8.1	7.3.2
A9K-8HG-FLEX-SE/TR	7.3.2	7.3.2	7.3.2	7.3.2	7.8.1	7.8.1	7.3.2
A9903-20HG-PEC	7.3.2	7.3.2	7.3.2	7.8.1	7.8.1	7.8.1	7.3.2
ASR-9902	-	-	-	-	-	-	7.7.1

The following table shows the required IOS XR Software version on the routers to support specific breakout modes on Bright ZR+ pluggable optical modules.

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 Shelf Virtualization Orchestrator (SVO), Release 12.3.1.

Cisco NCS 2006 Shelf

The NCS 2006 shelf has eight horizontal cardslots. The Cisco NCS 2006 chassis is 6 RU and has six slots for service cards and two slots for controller cards. It supports multishelf management up of 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 maximize revenue to customers and ease the 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 along with the application software provides functionality-based licenses for alarm correlation, performance monitoring, connection verification, and optical time domain reflectometry (OTDR).

The Cisco NCS 2000 SVO helps to maintain and improve customers' profitability with the orchestration of network elements and their functionalities. SVO allows the network elements to do only forwarding functions. SVO maintains the configuration and monitoring of the same at the node level with 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 system initialization, provisioning, alarm reporting, maintenance, diagnostics, IP addressing, Data-Communications-Channel (DCC) termination, monitoring of system input voltage, system fault detection, and multishelf management connections. Optical Time Domain Reflectometry (OTDR) is used to provide information about the basic characteristics of the Optical fiber among Optical nodes, such as insertion loss, concentrate-point of reflection, fiber-to-fiber connection losses and reflectance.

For more information on Cisco Transport Node Controller and Transport Shelf Controller 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 the flex spectrum capability, which gives the flexibility to allocate channel bandwidth and increase the network scalability. With flex capability, the channel bandwidth is not fixed, but can be defined arbitrarily, with a specified granularity and within a given range. The card makes the network flexible as it allows you to reconfigure the optical channels on the run.

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 0–17 and 12–24 dB with controlled tilt and extended gain ranges of 20 dB and 35 dB with uncontrolled tilt.

For more information on Cisco NCS 2000 Flex Spectrum Single Module ROADM Line Cards, 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. Supporting 96 channels in the C-band (wavelengths from 1528.77 to 1566.72 nm), they provide 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 Multiservice Transport Platform (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 Multiservice Transport Platform, 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 an optical passive optical multiplexer and demultiplexer module. The new optical module is based on Athermal Wave Guide (AWG) providing 64 channels at 75-GHz space covering the extended C-band of 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 MUX and the DEMUX functions implemented as two different sections. The NCS1K-MD-64-C module supports bidirectional connection toward the Router/DCI that is equipped with QDD-400G-ZR-S and QDD-400G-ZRP-S.

For more information on Cisco NCS 1000 Mux/Demux 64-Channel Patch Panel module, see Cisco NCS 1000 Mux/Demux 64-Channel Patch Panel Data Sheet

Passive Patch Panel Modules

The passive optical modules are used to build 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 FlexSpectrum Add/Drop Module

The Cisco 1 x 6 Colorless FlexSpectrum Add/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 PD reading. Power values and the manufacturing data stored in the flash memory are provided to a Cisco Transport Controller through the USB connection.

5-Degree Modular Patch Panel Module

The 5-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 a Cisco Transport Controller through the USB connection. This module is single-slot height in the mechanical frame chassis.

Cisco 4-Degree Upgrade Modular Patch Panel Module

The Cisco 4-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 Cisco Transport Controller 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.

Cisco Network Convergence System 1010

Cisco NCS 1010 is a next-generation optical line system that is optimized for ZR/ZR+ WDM interfaces in the routers. It provides point-to-point connectivity between routers with WDM interfaces and multiplex WDM signals from multiple routers over single fiber. In addition, it supports ROADM express of up to 8 degrees. It caters to both C-band only and C+L combined WDM transmission to maximize capacity. Cisco NCS 1010 is a 3RU chassis that has an in-built External Interface Timing Unit (EITU) and the following field-replaceable modules.

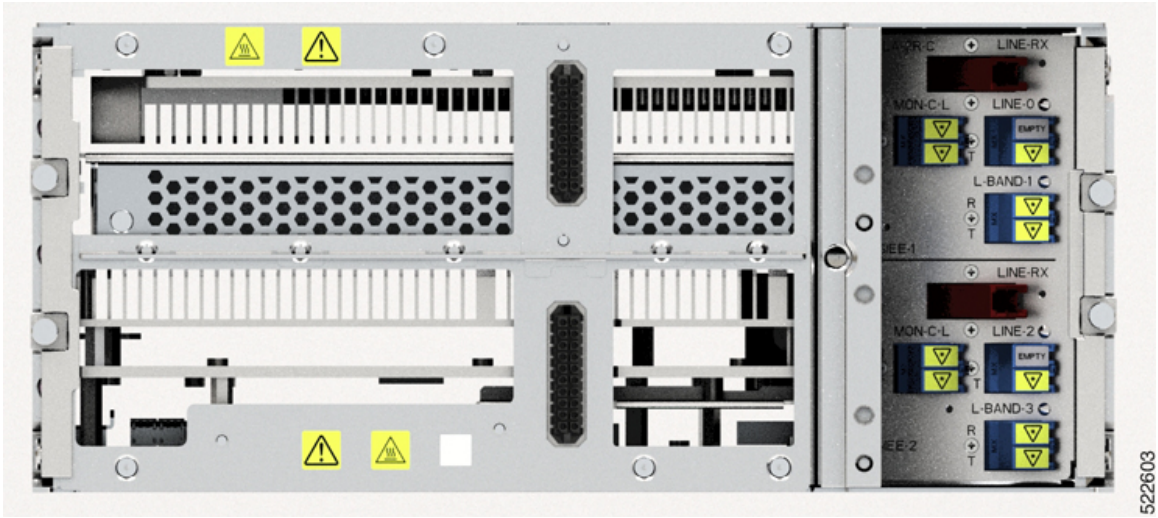
- Controller
- Two power supply units
- Two fan trays
- Fan filter
- Line card

There are five different variants of the line card:

- OLT-C Line Card—C-band Optical Line Terminal without Raman
- OLT-R-C Line Card—C-band Optical Line Terminal with Raman
- ILA-C Line Card—C-band In-Line Amplifier without Raman
- ILA-R-C Line Card—C-band In-Line Amplifier with one side Raman
- ILA-2R-C—C-band In-Line Amplifier 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

The following features of the NCS 1010 Optical Line Systems 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 95/140 G Baud-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/drop
- Simplicity of the OLS
  - Simpler patching – integrated module
  - Independent degree operation
  - Automated turn-up
  - Full spectrum loading from the start
  - DGE on ILAs for equalization and better control of Raman Gain ripple
- Automation of entire life cycle
  - Device automation - ZTP, OC YANG config, Telemetry
  - Automated E2E turn-up with embedded control loops
  - Automated Connection Verification for patch loss checks at each site

- Enhanced visibility - OTDR, OSC, OCM

Cisco NCS 1000 32-Channel Mux/Demux Patch Panel

The Cisco NCS 1000 32-Channel Mux/Demux patch panels are a pair of passive Athermal Arrayed Waveguide Grating (AAWG) base modules (PIDs NCS1K-MD-32O-C and NCS1K-MD32E-C). Each mux/demux panel has 32 channels and works as an add/drop unit for the OLT-C and OLT-R-C line cards. Each mux/demux 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 panels are used on the same OLT (OLT-C and OLT-R-C) line cards, the combined capacity becomes 64 channels with 75-GHz spacing. Each mux/demux panel provides a wide optical pass-band support. When used as a standalone, each panel acts as an add/drop unit for 32 channels at 140 gigabauds.

The NCS1K-MD32O/E-C panel operates in C-band. The Cisco NCS 1000 Mux/Demux patch panels are fully passive. The units are powered with 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 that are installed in the NCS 1010 chassis and the optical passive modules using MPO cables. The breakout panel is 4 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 4RU breakout patch panel. It interfaces four passive optical modules with the NCS 1010 chassis. The breakout panel supports up to 72 colorless mux/demux channels. The breakout panel supports 8-directional interconnections.

The panel is shipped with USB 2.0 connectors that are 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 4-11, A/D 12-19, A/D 20-27 and A/D 28-33 MPO connector ports of the OLT-C and OLT-R-C line cards to provide ROADM node internal connections and for local channels add/drop. The breakout panel supports the following 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/DROPi signals of the MPO ports of 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 on Cisco Network Convergence System 1010, see the Cisco Network Convergence System 1010 Data Sheet .

Network Planning Components

Use the following components to plan the network:

- Routed Optical Networking Planning Service, on page 33
- Cisco WAN Automation Engine, on page 33
- Cisco Optical Network Planner, on page 34

Routed Optical Networking Planning Service

In Cisco Routed Optical Networking Release 2.0, Cisco CX provides a unified planning service to help you simplify and plan the transition to a converged IP-Optical Routed Optical Network. By modeling your current and future architectures, Unified Networking Planning accelerates your progress toward Routed Optical Networking and create opportunities for customers to work on their OpEx reduction goals.

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, and so on.
- Visualizes network layout with forecasted capacity and performs network modeling.
- Estimates traffic behaviors in failure scenarios and assesses failure impact.
- Compares network architectures in terms of number of interfaces, hardware, sites, rack space, and power requirements.

Cisco CX provides ongoing technical consultative advice and guidance for the 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 the continual monitoring and analysis of the network and the traffic demands that are placed on it. At a given time, this network model contains all relevant information about a network, including topology, configuration, and traffic information. You can use this information as a basis for analyzing the impact on the network due to changes in traffic demands, paths, node and link failures, network optimizations, or other changes.

Cisco WAE is used for IP and optical network planning of multi-vendor 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 Dense Wavelength Division Multiplexing 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 performs the following:

- Generates a rack view of all the sites in the network
- Shows the differences between the instances
- 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.

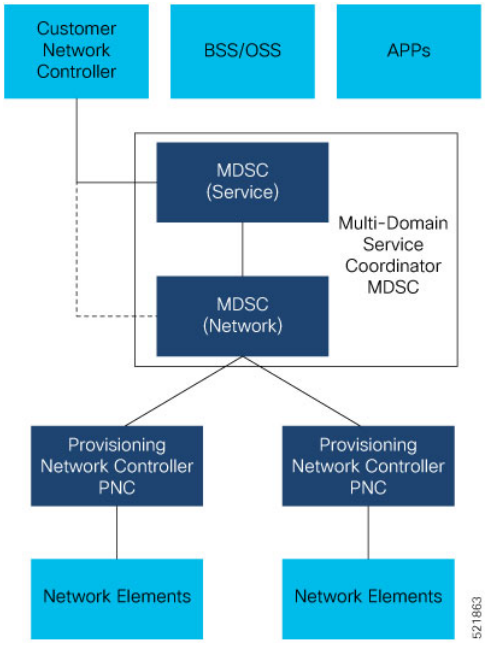
Note Cisco ONP must be used to perform the final optical network feasibility analysis and generate production network designs.

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

Automation Components

Automation of the Routed Optical Networking solution follows the IETF ACTN SDN controller framework. Cisco Optical Network Controller is the Cisco optical domain PNC, Crosswork Network Controller (Crosswork Network Controller) is the multi-vendor IP-domain PNC. Crosswork Hierarchical Controller unifies IP and optical information from Cisco Optical Network Controller and Crosswork Network Controller, providing multi-layer and multi-domain visualization, Routed Optical Networking service assurance, and Routed Optical Networking service management in the MDSC role.

Figure 8: IETF ACTN – Open Automation Reference Framework



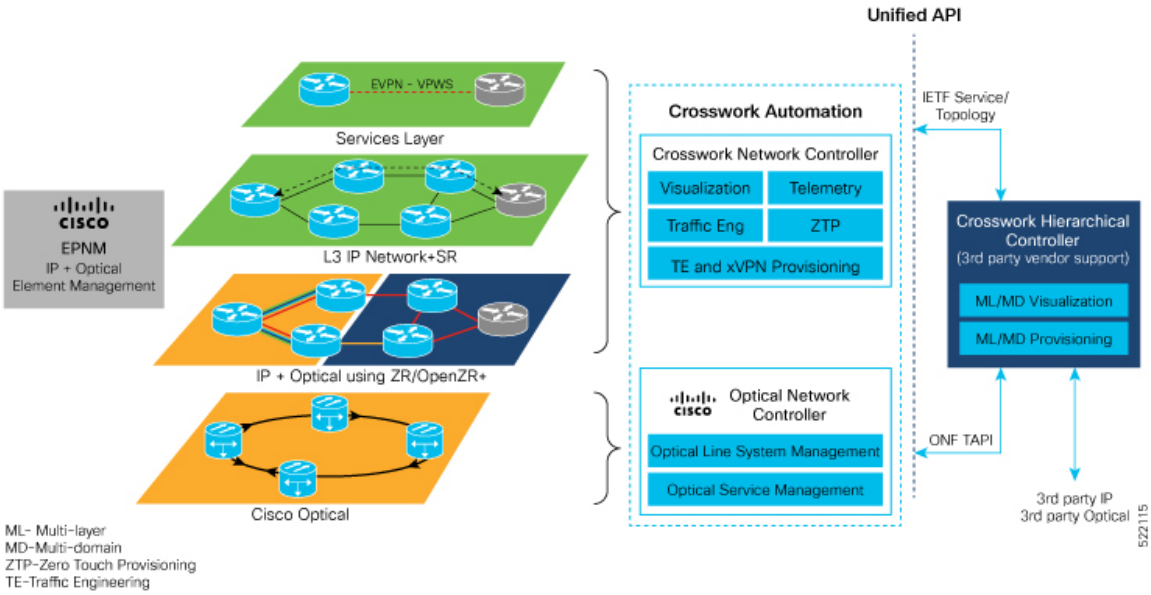
The automation stack consists of the following components:

- Crosswork Hierarchical Controller manages Routed Optical Networking deployments by leveraging advanced multi-layer and multi-vendor capabilities to provision and assure both IP and optical networks.
- Cisco Optical Network Controller helps in configuring Cisco optical network elements, monitors the topology (physical or virtual) of networks, performs optical path computation, and collects information about the topology.
- Crosswork Network Controller simplifies and automates intent-based network service provisioning, monitoring, and path optimization in a IP multi-vendor network environment with a common GUI and API.
- EPNM is the unified EMS that performs deep inventory. It is an element management system for device lifecycle management 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

The following diagram provides a high-level illustration of how the solution's components work together.

Figure 9: Routed Optical Networking Automation Architecture



Cisco Crosswork Hierarchical Controller

Cisco Crosswork Hierarchical Controller provides an API and single pane of glass UI 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 multi-layer networks which before now were commonly managed by independent NMS/EMS products.

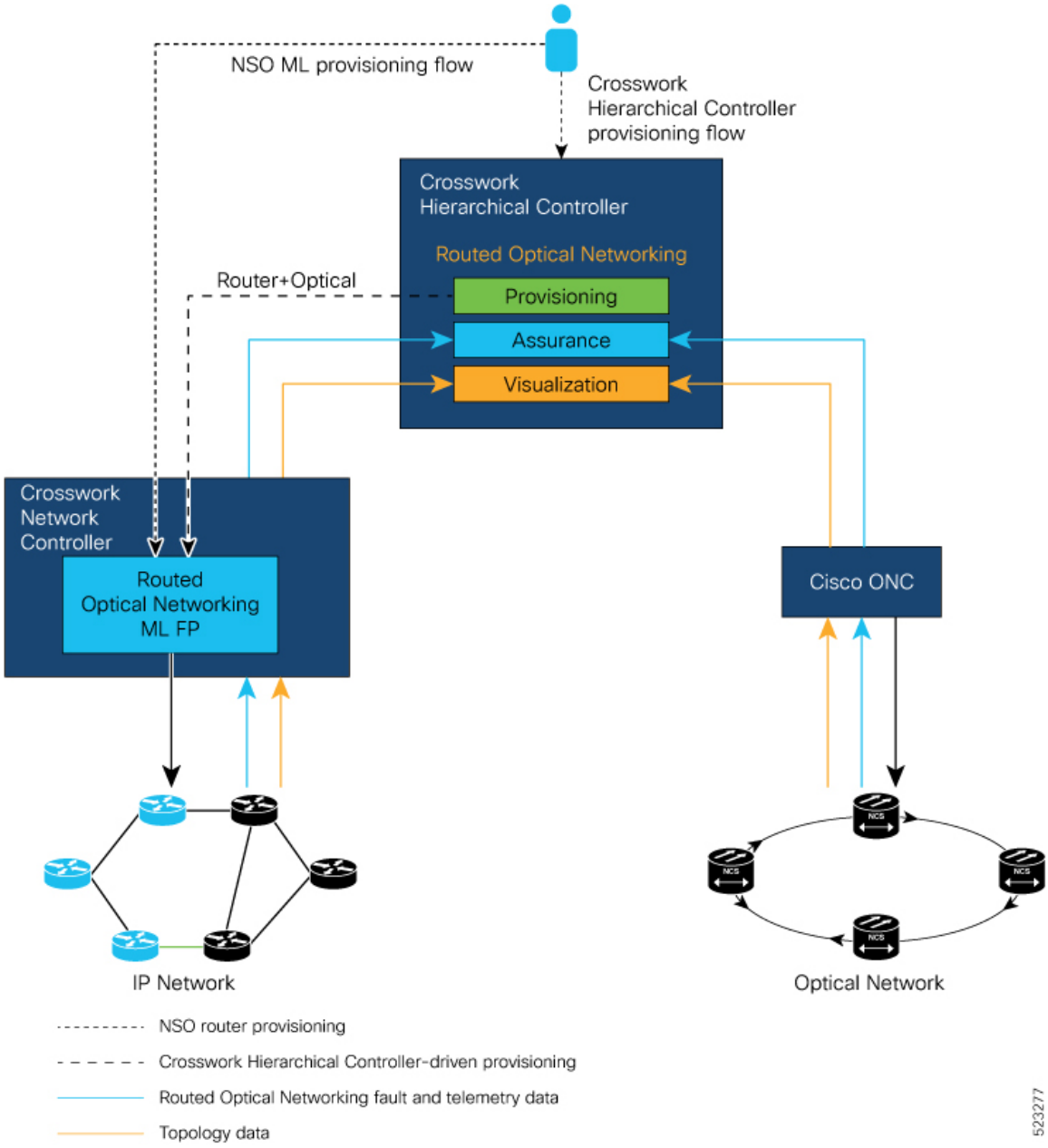
Crosswork Hierarchical Controller addresses the role of a multi-domain, multi-layer, and multi-vendor network controller. Crosswork Hierarchical Controller is capable to learn the mapping between IP/MPLS and optical layer ports (cross-layer mapping). This capability is key to providing a comprehensive view of the network. The system interfaces with SDN Domain Controllers for the packet layers (IP, MPLS) and transport layers (WDM, OTN, Packet-Optical) to create a coherent view of the entire transport network. Crosswork Hierarchical Controller enables automation of its functions and simplified abstracted interaction with Service Orchestrators and OSS tools.

Key Capabilities

Key capabilities of Crosswork Hierarchical Controller that Routed Optical Networking uses are:

- **Multi-layer discovery and visualization** of Routed Optical Networking links based on network data allows you to create a trustworthy digital twin of your network to help operations and to feed OSS tools.
- **Multi-layer provisioning** of 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.

Figure 10: Crosswork Hierarchical Controller Workflow



Adapters

Crosswork Hierarchical Controller uses adapters to connect to a device or management system. Crosswork Hierarchical Controller uses the adapters to collect information for the network model and configure the device. Routed Optical Networking requires the following adapters. These adapters are installed as part of the Crosswork Hierarchical Controller installation.

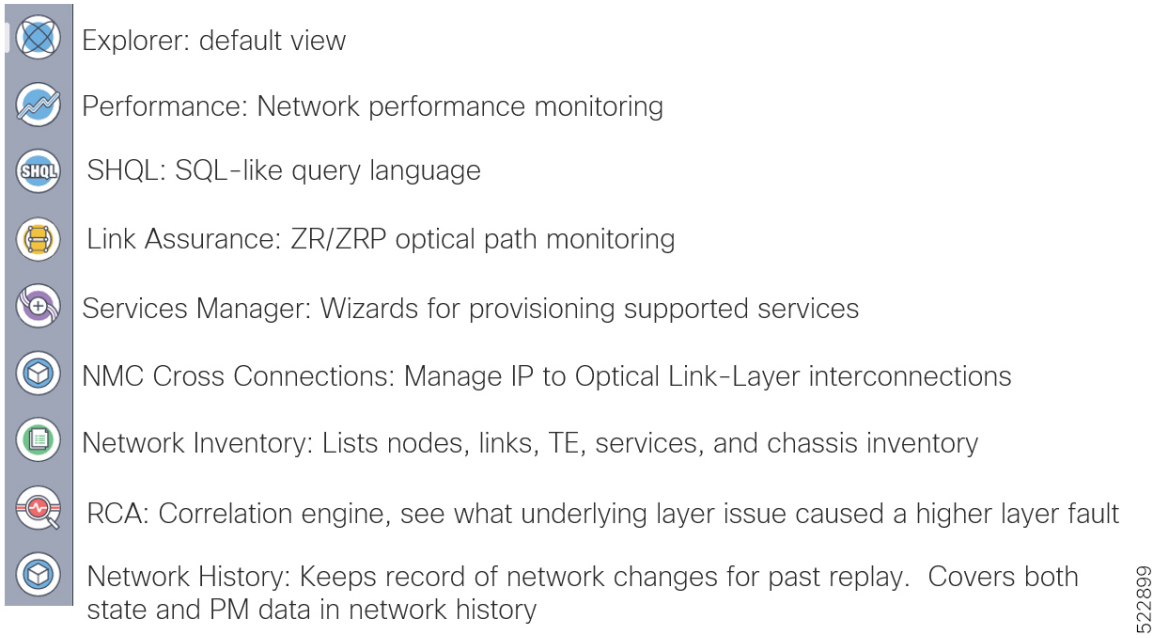
- cisco-cnc-adpt –IP network topology and link state information
- cisco-onc-adpt –Cisco optical network controller

- cisco-ios-xr-adpt –Gathers inventory data and statistics
- cisco-cdg-adpt – Collects performance measurement data using streaming telemetry

You can have multiple adapters of the same type. For instance, if you have multiple optical domains with different Cisco Optical Network Controller instances, each domain has a separate Cisco Optical Network Controller adapter.

Crosswork Hierarchical Controller Applications

The Crosswork Hierarchical Controller is a customized bundle of apps and adapters and can be installed using an executable installer. The Crosswork Hierarchical Controller web interface can be accessed using a custom URL. The Crosswork Hierarchical Controller consists of multiple applications that are described in the following figure.



For more information, see Cisco Crosswork Hierarchical Controller

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 delivers network optimization capabilities that are nearly impossible to replicate even with a highly skilled and dedicated staff operating the network.

The integrated solution combines core capabilities from multiple innovative, industry-leading products including 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 services, as well as service and transport provisioning, through a single pane of glass.

The Crosswork Network Controller features are:

- **Active Topology:** Active Topology's logical and geographical maps provide real-time visibility into the physical and logical network topology, service inventory, and SR-TE policies and RSVP-TE tunnels, all in a single pane of glass. They enable operators to see, at-a-glance, the status and health of the 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.

  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 brings together streaming telemetry and model-driven application programming interfaces (APIs) to redefine service provider network operations. It retrieves real-time information from the network, analyzes the data, and uses APIs to apply network changes. It employs a cluster architecture to be extensible, scalable, and highly available.

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 enables closed loop tracking of the network state, reacting quickly to changes in network conditions to support a self-healing network. 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 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 the following Cisco NSO function packs:
  - SR-TE core function pack (CFP)

- Sample function packs for IETF-compliant L2VPN and L3VPN provisioning
- Sample IETF-compliant RSVP-TE function pack

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 quickly and easily bring up 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 L2/L3 VPN services and enables operators to pinpoint why and where a service is degraded. It can also provide service-specific monitoring, troubleshooting, assurance, and proactive causality through a heuristic model that visualizes the:
  - Health status of subservices (device, tunnel) 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 Cisco Crosswork's Device Lifecycle Management (DLM). 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 collection is persisted in the database and monitored 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 allows operators to view, import, and delete software images, as well as push software images to the devices in the network. SWIM improves compliance, accelerates upgrades, and improves the network engineer experience.

As it uses standards-based protocols, Cisco Crosswork Network Controller is multivendor capable for:

- Network service orchestration
- Telemetry data collection
- Topology and transport discovery
- Transport path computation

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

Cisco Optical Network Controller

Cisco Optical Network Controller (Optical Network Controller) is an SDN Domain Controller for optical networks. Optical Network Controller collects optical data and uses it to provide network information in an abstracted format to higher layer controllers. This abstraction enables centralized control of optical networks.

Cisco Optical Network Controller serves as a domain controller for optical products and provides data to Hierarchical Controllers. Optical Network Controller supports a standardized TAPI model, which enables it to abstract the device level details from a hierarchical controller. As a Provisioning Network Controller, Optical Network Controller helps in configuring the network elements, monitors the topology (physical or virtual) of networks, and collects information about the topology. Cisco Optical Network Controller improves hardware capability by supporting addition of optical applications to the controller. It centralizes some of the control loop functions that are critical for maintaining and programming the optical components in the hardware.

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

Cisco Network Services Orchestrator

Cisco Network Services Orchestrator (NSO) is an orchestration platform that takes advantage of pluggable function packs to translate networkwide service intent into device-specific configuration. Cisco NSO provides flexible service orchestration and lifecycle management across physical network elements and cloud-based virtual network functions (VNFs), fulfilling the role of the Network Orchestrator within the ETSI architecture. It provides complete support for physical and virtual network elements, with a consistent operational model across both. It can orchestrate across multivendor environments and support multiple technology stacks, enabling extension of end-to-end automation to virtually any use case or device.

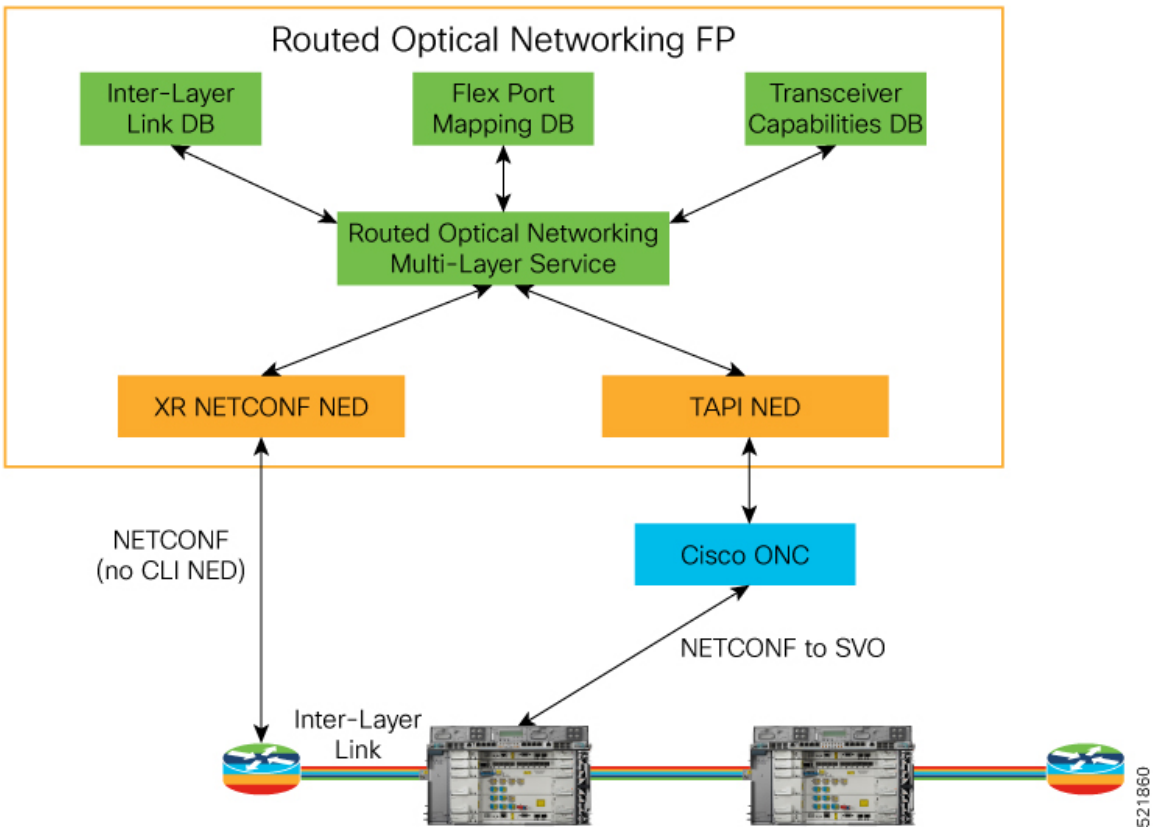
Cisco NSO has a rich set of APIs designed to allow developers to implement service applications. It provides the infrastructure for defining and executing the YANG data models necessary to realize customer services. NSO is also responsible for providing the overall lifecycle management at the network service level.

For more information on Cisco Network Services Orchestrator, see Cisco Network Services Orchestrator Data Sheet

Cisco NSO Routed Optical Networking Core Function Pack

The NSO Routed Optical Networking CFP uses NSO to automate the management of the devices in the Routed Optical Networking network and perform end-to-end service provisioning seamlessly across the IP layer and optical layers. The NSO Routed Optical Networking CFP uses the same NSO instance as Crosswork Network Controller.

Figure 11: Routed Optical Networking ML Function Pack



This table describes the functions of different components of the Routed Optical Networking ML Function Pack.

Component	Function
Inter-layer link DB	Stores the IP to optical physical connections between the router and the optical line system
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 preprovisioned
Transceiver capabilities DB	Map optics PID to capabilities. ZR = 400G, 4x100G, ZR+ = 100G, 2x100G, 3x100G, 4x100G, or 400G
Routed Optical Networking ML service	Performs IP and ZR router provisioning and optical provisioning
XR NETCONF NED	Used to provision router elements. Native YANG models used
TAPI NED	NETCONF-based NED to communicate with Optical Network Controller via TAPI

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.

The Routed Optical Networking ML service connects two DWDM optical ports with a fixed bandwidth of either 100, 200, 300, 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 400G optics
- Create the optical circuit via the Optical Network Controller
- Configure the optical parameters on the ZR or ZR+ optics
- Assign IP address to Ethernet interfaces or bundle interfaces
- Bundle discrete Ethernet interfaces

Routed Optical Networking CFP communicates with Cisco Optical Network Controller by using the standardized Transport Application Program Interface (TAPI) models through the TAPI NED. After the Cisco Optical Network Controller provisions the optical network, it sends notifications to NSO. NSO then provisions the router service to configure the ZR pluggable routers.

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 EPN Manager supports the Cisco Routed Optical Network architecture and delivers Cisco Optical and IP full device management and Cisco optical circuit network assurance. The Cisco EPN Manager discovers and represents the physical and logical configuration of managed devices.

Cisco EPN Manager provides full software image management and configuration management for the Cisco optical and IP devices.

A graphical chassis view with status indications gives network operators a live-live view of the device. EPNM differentiates itself from other network management systems with the ability to discover optical circuit from the network and maintain up-to-date representation of the optical circuit and the infrastructure dependency.

EPNM helps reduce the time to know about network or optical circuit-affecting conditions by correlating raw events and associating alarm conditions with affected managed network elements, network connectivity, and circuit. Contextual dashboards and 360-degree views (device and port levels) display the most relevant information for fast and efficient problem identification and remediation. To help reduce the time to restore and repair, EPNM guides the troubleshooting process using alarm correlation, identification of affected components or optical circuit, and connectivity. EPNM collects fault and alarm information, and performs node-level performance measurement statistics collection.

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

Routed Optical Networking Components Software Versions

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

Component	Software Version
Cisco Crosswork Network Controller	4.1
Crosswork Network Controller cApps	4.1
Crosswork Data Gateway	4.1
Network Services Orchestrator	5.7.6.2
NSO RON Core Function Pack	2.0
Cisco Optical Network Planner	5.0
Cisco Crosswork Infrastructure	4.4
Cisco Optical Network Controller	2.0
Crosswork Hierarchical Controller	5.3
Cisco Evolved Programmable Network Manager	6.1

IOS-XR Software Components

Cisco IOS XR is a modern and flexible network operating system. XR improves operational efficiencies with management API integration to provide near real-time, actionable telemetry data. Two features of IOS XR that enable Routed Optical Networking are:

- **YANG-modeled management layer APIs**: To automate device provisioning and management. These models include native IOS XR YANG models and OpenConfig models.
- **Streaming telemetry capabilities**: For cadence-based or event-driven monitoring of data that is derived from YANG-modeled paths in the manageability layer over gRPC, TCP, or UDP.

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, the same procedures are able to configure or collect data from non-Cisco devices as well. 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.

Network Configuration (NETCONF) Protocol

NETCONF is a standard-based and XML-encoded protocol. NETCONF provides the transport to communicate YANG formatted configuration or operational data requests from an application, which runs on a centralized management platform, to the Cisco device that you wish to configure or request operational data from. It provides transaction-based services, such as aborting the entire configuration request when a portion of that configuration request fails.

NETCONF uses a simple Remote Procedure Call based mechanism to facilitate communication between clients (centralized management platform script or application) and servers (Cisco switch or router). It uses SSH as the transport layer across network devices.

Yet Another Next Generation Data Modeling Language

YANG is a standards-based data modeling language. You can use YANG to create device configuration requests or requests for operational (**show** commands) data. It has a structured format similar to a computer program that is human-readable. Several applications that can run on a centralized management platform to create these configuration and operational data requests are available.

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 both Cisco and non-Cisco devices.)
- Device (native, vendor-specific) data models that facilitate configuring or collecting operational data concerning proprietary vendor features.

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

Native 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-controller-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/IPv6 interface configuration
Controller-otu-oper	No equivalent	Coherent DSP operation data

Note

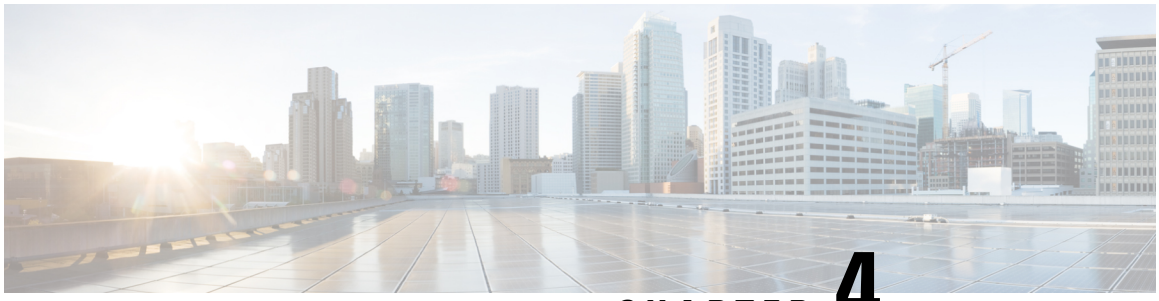
- openconfig-terminal-device configures logical hierarchy of connections from ingress to egress. For Cisco optical devices, you can use OpenConfig to configure nx100G muxponder or transponder modes, and trunk rate.
- Use openconfig-platform to configure the physical layer parameters:
  - Frequency
 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

Model Driven Telemetry

Telemetry is an automated communications process that you use to collect measurements and other data at remote or inaccessible points and transmit to receiving equipment for monitoring. Model-driven telemetry (MDT) provides a mechanism to stream YANG-modeled data to a data collector. Model-driven telemetry allows network devices to continuously stream real-time configuration and operating state information to subscribers.

Applications can subscribe to specific data items they need, by using standards-based YANG data models over NETCONF, RESTCONF, or gRPC Network Management Interface (gNMI) protocols. You can also create subscriptions by using CLIs if they are configured subscriptions. Devices publish structured data at a defined cadence, or on-change, based on the subscription criteria and data type. See Troubleshoot Provisioning Issues, on page 91 for information on telemetry sensor paths and corresponding data fields.

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



CHAPTER 4

PLE Service Configuration

This chapter describes the Private Line Emulation (PLE) service and the configuration procedures.

- Understanding Private Line Emulation, on page 47
- Circuit-Style Segment Routing, on page 48
- Configure PLE over EVPN-VPWS, on page 51
- Configure Optics Controller with Payloads, on page 52
- Configure QoS Policy, on page 53
- Configure CEM Interface for L2VPN Service, on page 53
- Configure Performance Measurement, on page 54
- Configure Segment Routing Adjacency SIDs, on page 54
- Define Paths Between PLE Endpoints, on page 55
- Configure Static Circuit-Style SR-TE Policies, on page 57
- Configure PLE over EVPN-VPWS, on page 59
- Verification, on page 60

Understanding Private Line Emulation

Private Line Emulation (PLE) is a pillar of the Routed Optical Networking solution. It enables service providers and enterprises to further collapse network layers, decreasing network complexity and increasing network efficiency. PLE enables private line services to be carried over the same MPLS or Segment Routing network for non-Ethernet type services such as SONET/SDH, OTN, and Fiber Channel. PLE also supports bit-transparent Ethernet services where required.

High revenue legacy private line services exist in the network infrastructure of most service providers, often carried over a dedicated inefficient TDM OTN layer. 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 transparently transfer PLE client frames over MPLS or SR networks without changing the characteristics of the original signal.

How PLE Works

Ethernet, OTN, Fiber Channel, or SONET/SDH PLE client traffic is carried on an EVPN-VPWS single homed service that is created between PLE endpoints. 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. The 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.

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 L1 frame between sender and receiver. CEM over a Packet Switched Network (PSN) places the client bit streams into packet payload with appropriate pseudowire emulation headers.

The PLE initiator encapsulates the PLE client traffic and carries it over the EVPN-VPWS service running on MPLS or Segment Routing transport. The PLE terminator node extracts the bit streams from the EVPN-VPWS packets and places them onto the PLE client interface as defined by the client attribute and CEM profile.

Supported Payloads

The following payloads are supported through PLE:

Table 2: Supported Payloads

PLE Transport Type	Supported Payloads
Ethernet	1GE and 10GE
OTN	OTU2 and OTU2e
SONET	OC-48 and OC-192
SDH	STM-16 and STM64
Fiber Channel	FC1, FC2, FC4, FC8, FC16, and FC32

The combination of payloads is also supported.

Supported Hardware

PLE is supported on 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 Cisco NCS 5500 Modular Chassis, on page 17

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 TI-LFA. Connection-oriented transport, which was historically delivered over circuit-switched SONET/SDH networks, requires the following:

- 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-msec path protection.
- Persistent end-to-end paths regardless of the state of the control plane.

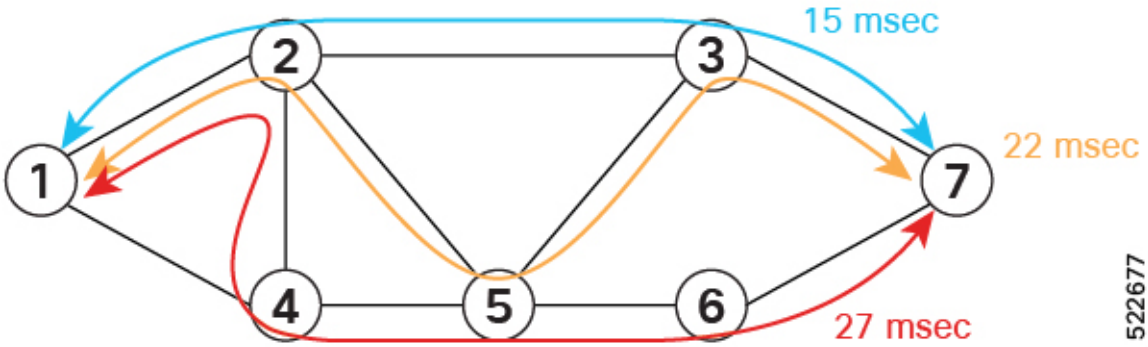
Introduction to Circuit-Style SR Policies

Circuit-Style SR policies have the following properties:

- Guaranteed Latency over Non-ECMP Paths
- Control-Plane Independent Persistency
- Co-Routed Bidirectional Path
- Liveness Monitoring with Path Protection Switching

Guaranteed Latency over Non-ECMP Paths

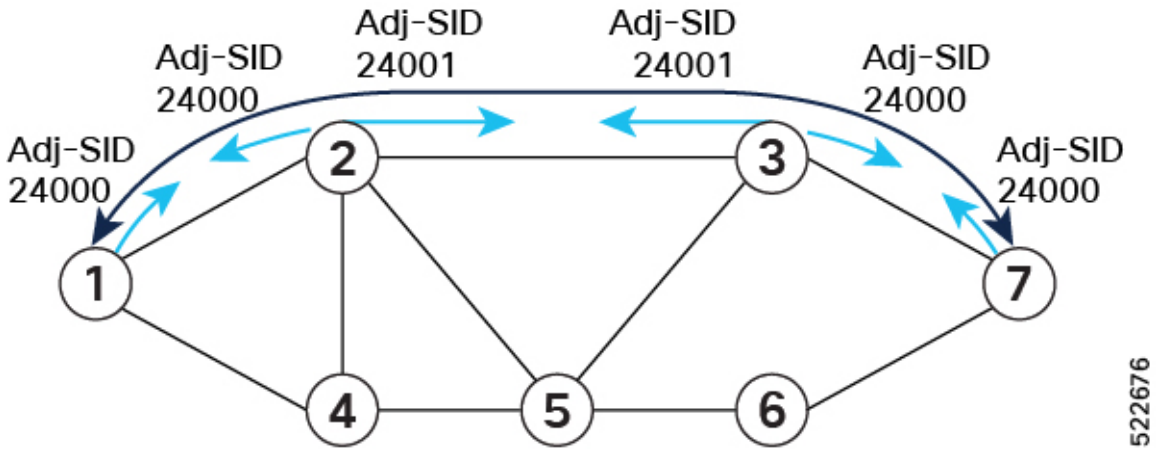
Consider the following network with three possible paths from node 1 to node 7. Of the three paths, the best end-to-end delay is provided by the blue path (1 -> 2 -> 3 -> 7). The chosen path is then encoded with adjacency SIDs corresponding to the traversed interfaces to avoid any ECMP, and therefore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



Control-Plane Independent Persistency

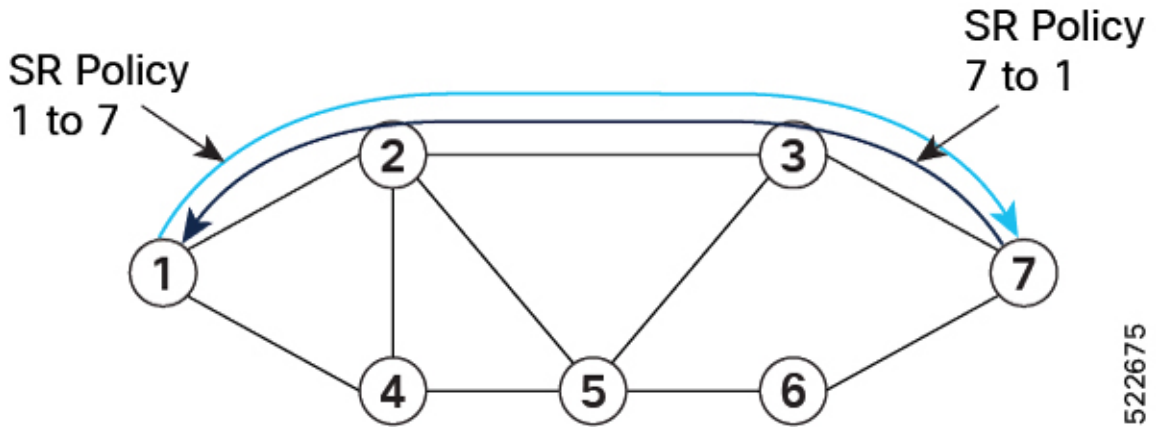
Adjacency SIDs can provide a persistent path independent from control-plane changes (such as IGP neighbor flaps), and network events (such as interface additions or interface flaps) and even the presence of IP on an interface. To achieve this, adjacency SIDs can be manually allocated to ensure persistent values, for example, after a node reload event. In addition, adjacency SIDs can be programmed as non-protected to avoid any local TI-LFA protection.

With the adjacency SIDs depicted in the following figure, the path from node 1 to node 7 is encoded with the segment list of {24000, 24001, 24000}. By manually allocating the same adjacency SID values for other direction, the path from node 7 to node 1 is encoded with the same segment list of {24000, 24001, 24000}.



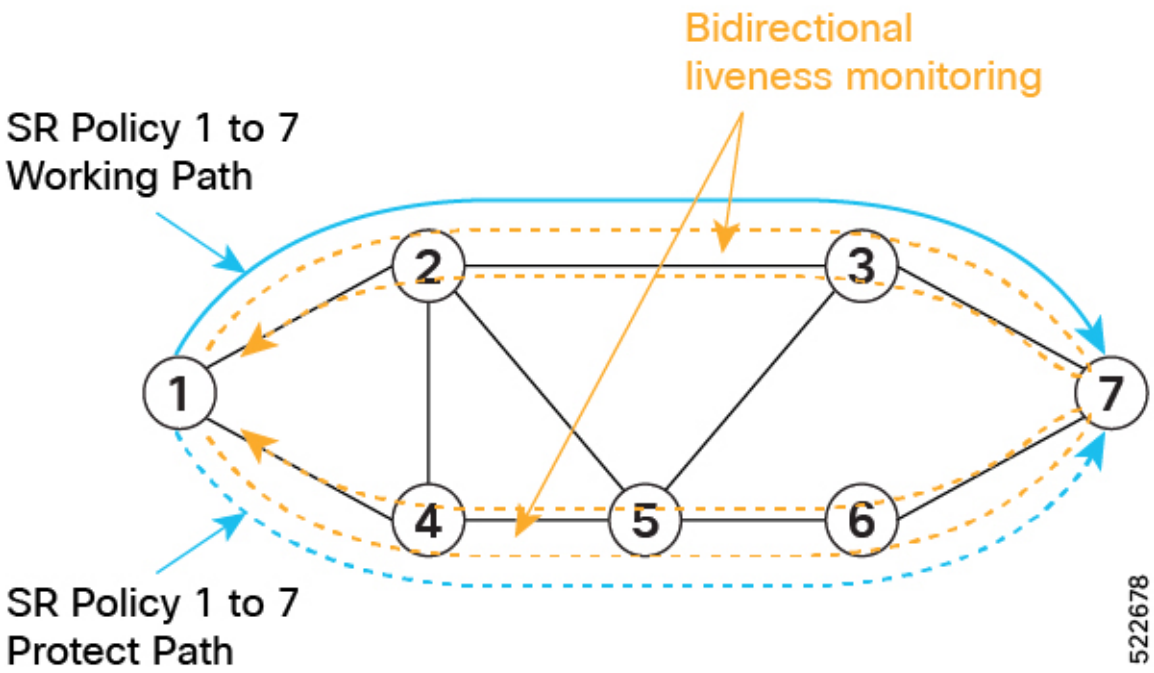
Co-Routed Bidirectional Path

Forward and return SR 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, while a protect path is pre-programmed over disjoint facilities.



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 the following tasks:

1. Configure Optics Controller with Payloads, on page 52
2. Configure QoS Policy, on page 53
3. Configure CEM Interface for L2VPN Service, on page 53

4. Configure Performance Measurement, on page 54
5. Configure Segment Routing Adjacency SIDs, on page 54
6. Define Paths Between PLE Endpoints, on page 55
7. Configure Static Circuit-Style SR-TE Policies, on page 57
8. Configure PLE over EVPN-VPWS, on page 59

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

Configure Optics Controller with Payloads

Use this task to configure the Optics controller with different payloads.

Each port on the NC55-OIP-2 (PID of PLE Modular Port Adapter) can be independently configured for a specific PLE transport type. This configuration is done by configuring the **port-mode** command under the optics controller.

The **port-mode** command has several parameters. The first parameter sets the PLE transport type: Ethernet, OTN, SONET, SDH, or Fibre Channel. The **framing** parameter is required and must be set to **cem-packetize**, specifying this as a PLE CEM configuration. The **rate** parameter is used to configure the specific payload.

See the **Supported Payloads** section for information on all the payloads supported.

The following examples show how to configure the Optics controller for different payloads.

Ethernet:

Router(config)# **controller Optics0/0/3/1**

Router(config-Optics)# **port-mode Ethernet framing cem-packetize rate 10GE**

OTN:

Router(config)# **controller Optics0/0/3/2**

Router(config-Optics)# **port-mode otn framing cem-packetize rate otu2**

SONET/SDH:

Router(config)# **controller Optics0/0/3/3**

Router(config-Optics)# **port-mode sonet framing cem-packetize rate OC48**

Router(config)# **controller Optics0/0/3/4**

Router(config-Optics)# **port-mode sdh framing cem-packetize rate STM16**

Fiber Channel:

Router(config)# **controller Optics0/0/3/5**

Router(config-Optics)# **port-mode FC framing cem-packetize rate FC1**

Configure QoS Policy

Use this task to configure QoS policy to prioritize PLE traffic. This configuration is optional but is recommended so that higher priority PLE traffic is not dropped during network congestion.

Step 1 Router(config)# **policy-map ple-policy**

Defines the parent QoS policy to be applied to the CEM interface to prioritize the PLE traffic.

Step 2 Router(config-pmap)# **class class-default**

There is only one traffic flow type in a PLE service. Hence, the default class is used to match all the ingress packets on the PLE CEM interface.

Step 3 Router(config-pmap-c)# **set traffic-class 6**

Cisco NCS 5500 and NCS 5700 platforms use traffic class within the router to identify specific traffic flows and differentiate how they are treated on egress. In this example, traffic class 6 is set on ingress. The egress QoS policy matches traffic class 6 and sets 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 egress QoS policy, see *Modular QoS Configuration Guide for Cisco NCS 5500 Series Routers*.

Step 4 Router(config-pmap-c)# **set mpls experimental topmost 6**

Sets the topmost MPLS EXP (TC) value to 6. The 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.

Step 5 Router(config-pmap-c)# **end-policy-map**

Configure CEM Interface for L2VPN Service

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

Step 1 Router(config)# **interface CEM0/0/3/1**

Configures the appropriate CEM interface.

Step 2 Router(config-if)# **l2transport**

Enables the CEM interface to be used in a L2VPN EVPN-VPWS service.

Configure Performance Measurement

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

Step 1 Router(config)# **performance-measurement**

Enters the performance measurement configuration.

Step 2 Router(config-perf-meas)# **liveness-profile sr-policy name liveness-check**

Creates a SR Policy liveness profile.

Step 3 Router(config-perf-meas)# **liveness-detection**

Configures liveness detection parameters.

Step 4 Router(config-perf-meas)# **multiplier 3**

Configures the number of missed liveness probes to determine whether the SR Policy is down.

Step 5 Router(config-pm-ld-srpolicy)# **probe**

Enters the probe parameter configuration mode.

Step 6 Router(config-pm-ld-srpolicy-probe)# **measurement-mode loopback**

Sets the mode to loopback, where probe packets from the sender node are looped back to the sender node from the receiver node to test end-to-end liveness.

Step 7 Router(config-pm-ld-srpolicy-probe)# **tx-interval 30000**

Sets the interval of probe packets that are sent by the sender. The interval value is set in microseconds, and set to 30 seconds in this example.

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

Step 8 Router(config-pm-ld-srpolicy-probe)# **tos dscp 48**

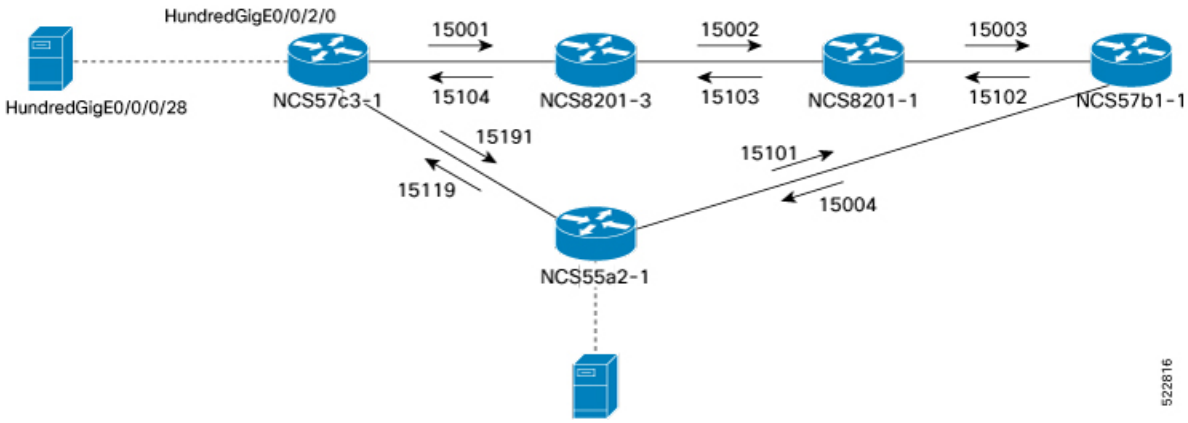
The *tos* parameter sets the Differentiated Services Code Point (DSCP) value on the probe packets to the specified DSCP. In this example it is 48, but must be set to the appropriate QoS value on the provider network to treat the liveness probe packets at high priority.

Configure Segment Routing Adjacency SIDs

Use this task to configure SR Adjacency SIDs between routers. Adjacency SIDs are unidirectional and are used to define the explicit path between endpoints. Adjacency SIDs must set on each interface participating in the SR policy path.

The following figure illustrates the SR adjacency SIDs configured between routers.

Figure 12: Segment Routing Adjacency SIDs



Step 1 Router(config)# **router isis core**

Enters IS-IS configuration mode for the appropriate instance. In this example, the instance is core.

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

Configures specific IS-IS interface.

Step 3 Router(config-isis-if)# **address-family ipv4 unicast**

Enters the IPv4 address family configuration if MPLS segment routing is used.

Step 4 Router(config-isis-if-af)# **adjacency-sid absolute 15001**

Configures a persistent SR adjacency SID on the interface. This value must be assigned from the Segment Routing Local Block (SRLB) of the router. The default SRLB range in IOS-XR is 15000–15999.

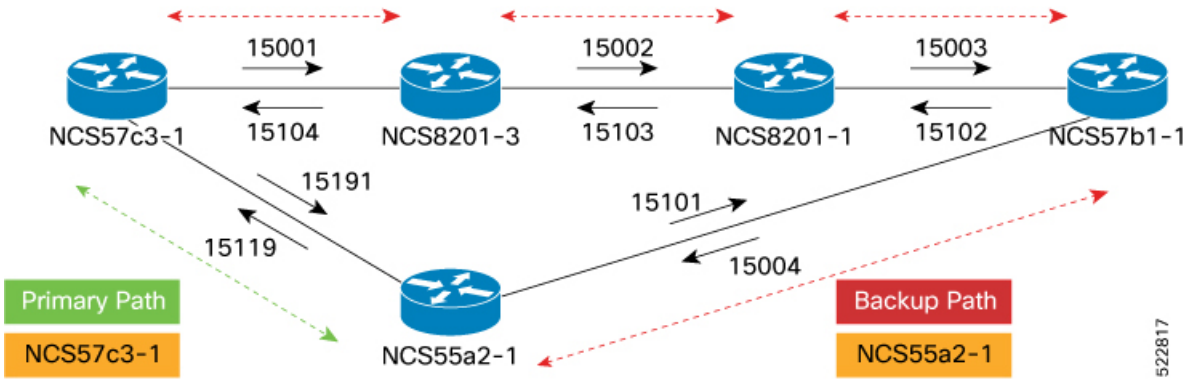
Configure other SR adjacency SIDs as appropriate.

Define Paths Between PLE Endpoints

Use this task to define end-to-end paths between PLE endpoints.

Note This task applies only for static circuit-style SR-TE policies.

Figure 13: Working and Reverse Path Definitions



Perform the following configurations on the NCS57C3-1 router to define the working forward path. In the illustration, the working forward path is a single hop between directly connected routers.

Step 1 Router(config)# **segment-routing**

Enters segment routing configuration.

Step 2 Router(config-sr)# **traffic-engineering**

Enters segment routing TE configuration.

Step 3 Router(config-sr-te)# **segment-list working-forward-path**

Creates segment list with name *working-forward-path*.

Step 4 Router(config-sr-te-sl)# **index 1 mpls label 15191**

Sets index 1 to the first hop interface adjacency SID.

Perform the following configurations on the NCS57C3-1 router to define the working reverse path. In the illustration, the working reverse path is a single hop between directly connected routers.

```
Router(config-sr-te)# segment-list working-reverse-path
Router(config-sr-te-sl)# index 1 mpls label 15119
```

Perform the following configurations on the NCS57C3-1 router to define the protect forward path. In the illustration, the protect forward path has four interface hops between the near-end and far-end router.

```
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
```

Perform the following configurations on the NCS57C3-1 router to define the protect reverse path. In the illustration, the protect reverse path has four interface hops between the near-end and far-end router.

```
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
```

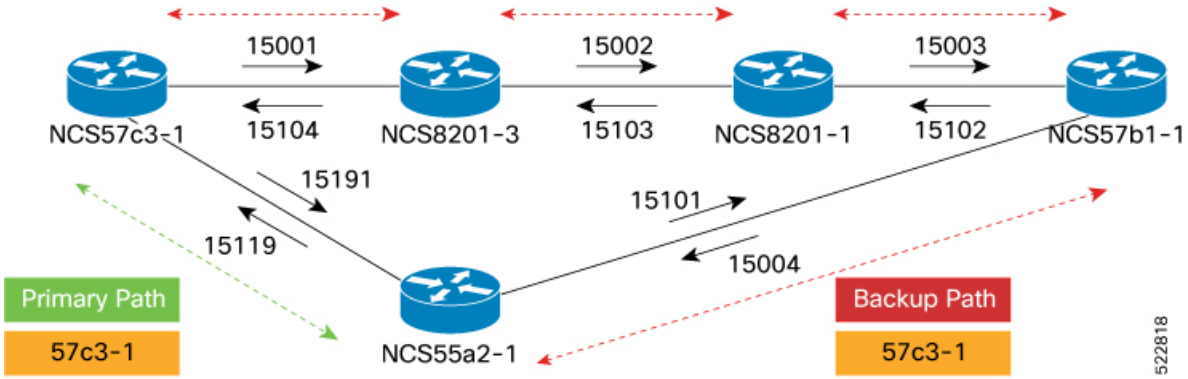
Perform the following configurations on the NCS55A2-1 router to define all the paths according to the illustration.

```
Router(config)# segment-routing
Router(config-sr)# traffic-eng
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 SR-TE policies.

Figure 14: Segment Routing Traffic Engineering Policy



Perform the following configurations on the NCS57C3-1 router.

Before you begin

Static Circuit-Style SR-TE policies requires IOS XR 7.7.1 or later software.

Step 1 Router(config)# **segment-routing**

Enters segment routing configuration.

Step 2 Router(config-sr)# **traffic-engineering**

Enters segment routing TE configuration.

Step 3 Router(config-sr-te)# **policy to-55a2-1**

Creates a SR-TE policy with the name *to-55a2-1*.

Step 4 Router(config-sr-te-policy)# **color 1001 end-point ipv4 10.0.0.44**

Configures the SR-TE policy with the user-defined color and loopback address of the remote PLE far-end router.

Step 5 Router(config-sr-te-policy)# **path-protection**

Enables path protection on the SR-TE policy. When configured, the near-end router keeps the protect path in warm-standby state to quickly transition to it if the working path is down.

Step 6 Router(config-sr-te-policy)# **candidate-paths**

Configures the SR working and protect candidate paths.

Step 7 Router(config-sr-te-policy-path)# **preference 50**

Sets the user-defined preference on the protect path. Higher preference candidate paths are preferred over lower preference paths.

Note The protect path must always be set with lower preference value.

Step 8 Router(config-sr-te-policy-path-pref)# **explicit segment-list protect-forward-path**

Configures the candidate path to use an explicit segment list. The previously defined *protect-forward-path* explicit segment list is used.

Step 9 Router(config-sr-te-policy-path-pref)# **reverse-path segment-list protect-reverse-path**

Configures the reverse path to ensure that the SR-TE Policy uses a corouted bidirectional path. The previously defined *protect-reverse-path* explicit segment list is used.

Configure the higher priority working path similar to the protect path using the following 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 10 Router(config)# **performance-measurement**

Configures performance-measurement for the SR-TE policy.

Step 11 Router(config-perf-meas)# **liveness-detection**

Configures liveness detection parameters.

Step 12 Router(config-perf-meas)# **liveness-profile name liveness-check**

Configures a user-defined liveness policy to be used. In this case, the previously defined liveness profile *liveness-check* is used.

Perform the following configurations on 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 PLE over EVPN-VPWS

Use this task to configure PLE over EVPN-VPWS. The two core components are the Pseudowire class specifying the transport type and xconnect service to configure the EVPN-VPWS service parameters.

Figure 15: PLE EVPN-VPWS Service

Perform the following configurations on the NCS57C3-1 router.

Step 1 Router(config)# **l2vpn**

Enters l2vpn configuration.

Step 2 Router(config-l2vpn)# **pw-class circuit-style-srte**

Defines the Pseudowire class to be used with the PLE service. 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 MPLS using a specific SR-TE policy. The **pw-class** command is followed by a user-defined name, in this example, *circuit-style-srte.*

Step 3 Router(config-l2vpn-pwc)# **encapsulation mpls**

Configures transport encapsulation.

Step 4 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. The preferred-path is used to configure an explicit MPLS path to be used 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 is not the configured name of the policy; it is the computed name.

Step 5 Router(config-l2vpn)# **xconnect group ple**

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

Step 6 Router(config-l2vpn-xc)# **p2p ple-cs-1**

Creates point-to-point L2VPN service with user-defined name *ple-cs-1*.

Step 7 Router(config-l2vpn-xc-p2p)# **interface cem 0/0/2/1**

Specifes the client interface. This interface is the CEM interface type for PLE.

Step 8 Router(config-l2vpn-xc-p2p)# **neighbor evpn evi 100 target 4201 source 4401**

Configures EVPN-VPWS parameters. The user-defined *evi* value must be the same on each far-end router. The target must be the “source” value that is configured on the remote endpoint.

Step 9 Router(config-l2vpn-xc-p2p-pw)# **pw-class circuit-style-srte**

Attaches the previously defined Pseudowire class *circuit-style-te* to the L2VPN service.

Perform the following configurations on 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
```

Verification

The following example shows the general CEM statistics.

```
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
```

The following example shows the PM statistics for 30 seconds.

```
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
```

The following example shows the controller information for Ethernet 10GE.

```
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
```

The following example shows the PM statistics for Ethernet controller.

```
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
```

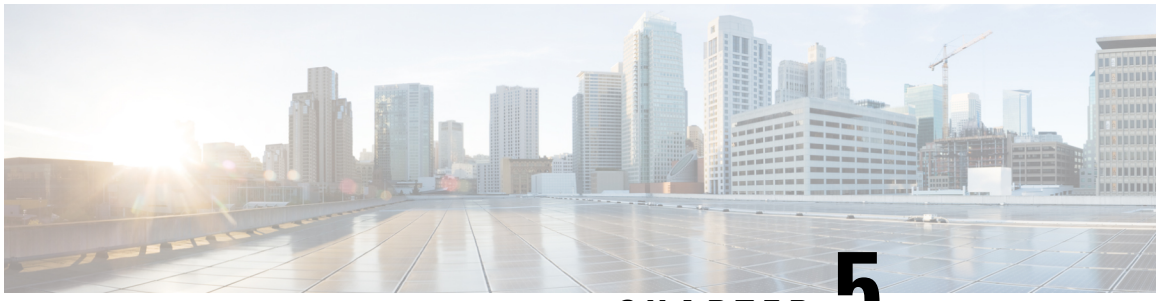
The following example shows the controller information for Fiber Channel 8G.

```
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
```

The following example shows the PM statistics for Fiber Channel.

```
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
```



CHAPTER 5

Deployment Topologies

This chapter describes examples of deployment topologies that utilize the Routed Optical Networking architecture.

Routed Optical Networking supports the following deployment topologies.

- Metro/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 in network (core, aggregation, or DCI). The only differentiating factor is the hardware that is used for any deployment. The following topologies are examples of specific hardware deployments.

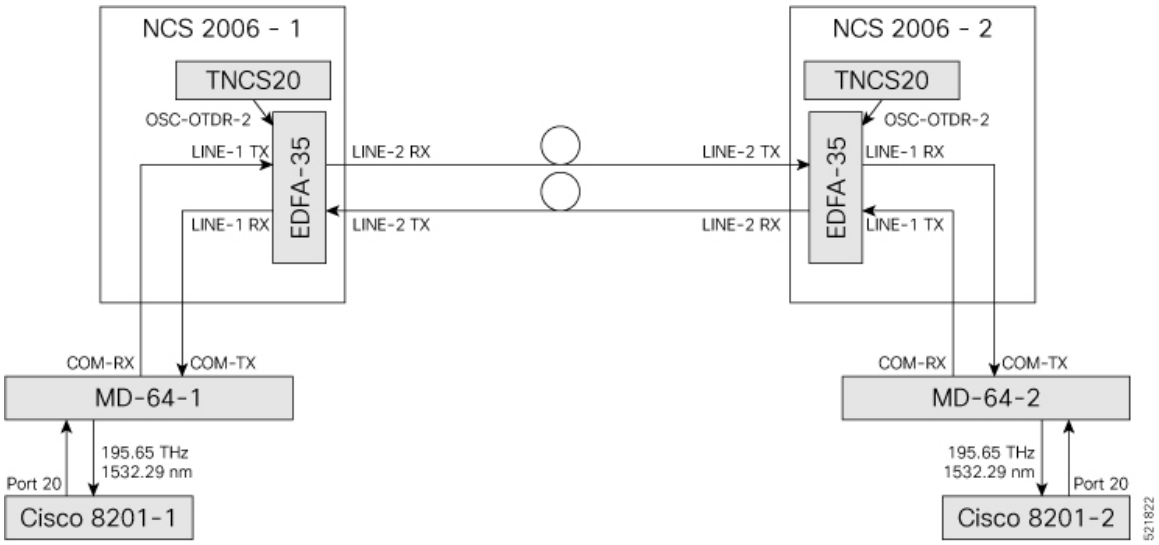
- Metro/Regional Topology, on page 65
- Mesh Topology, on page 68
- Long Haul Topology, on page 72
- Point-to-point Topology (with NCS 1010 Nodes), on page 77
- Multi-Degree Topology (with NCS 1010 Nodes), on page 79

Metro/Regional Topology

Figure 16: 400G-ZR P2P Short Haul Applications with Cisco NCS 2006

This diagram displays the wiring diagram for the metro/regional topology:

Figure 17: Wiring Diagram for a Metro/Regional Topology



In this sample topology, we assume that Cisco 8201-1 is the source router and Cisco 8201-2 is the destination router.

Topology Components

To build this topology, you need the following hardware:

- Cisco 8200 Series Routers
- NCS1K-MD-64-C Modules
- Cisco NCS 2006
- TNCS-2O Cards
- OPT-EDFA-35 Cards
- QDD-400G-ZR-S transceiver
- LC/LC cables

For more information, see Hardware Components, on page 13.

Port Connections

To build this topology, connect the cables in the following sequence:

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, 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 (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 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 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 (NCS 2001-1).
5. Connect an LC/LC fiber from the LINE-2-RX port of the EDFA-35 card (NCS 2006 -1) to the outside plant fiber that is connected to the LINE-2-TX port of EDFA-35 card (NCS 2006 -2).
6. Connect an LC/LC fiber from the LINE-2-TX port of the EDFA-35 card (NCS 2006 -1) to the outside plant fiber that is connected to the LINE-2-RX port of EDFA-35 card (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 (NCS 2006-2).
8. Connect an LC/LC fiber from the LINE-1-RX port of the EDFA-35 (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 (NCS 2006 -2) to the COM-RX port of the MD-64-2 module.

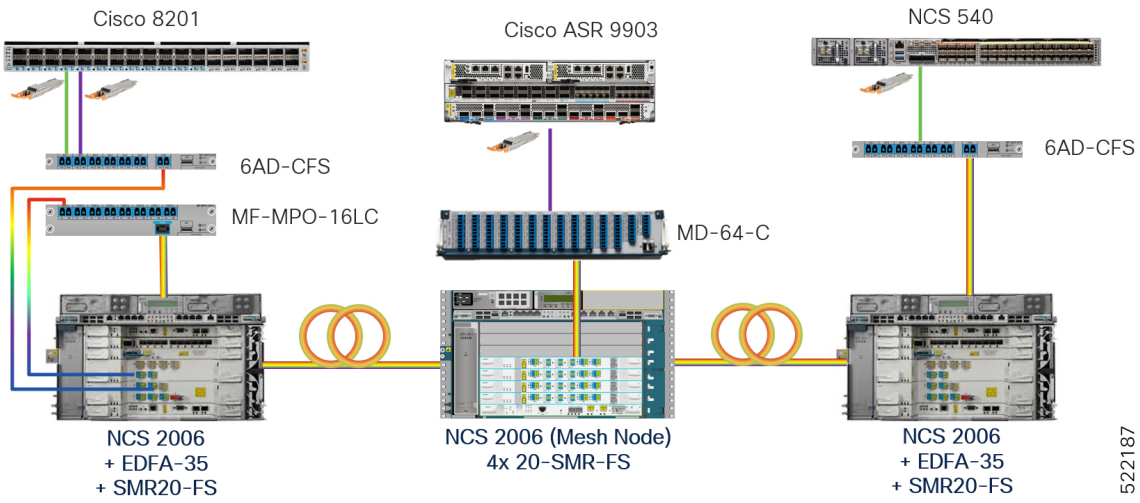
Next Steps

After you complete building the topology, perform the following steps:

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

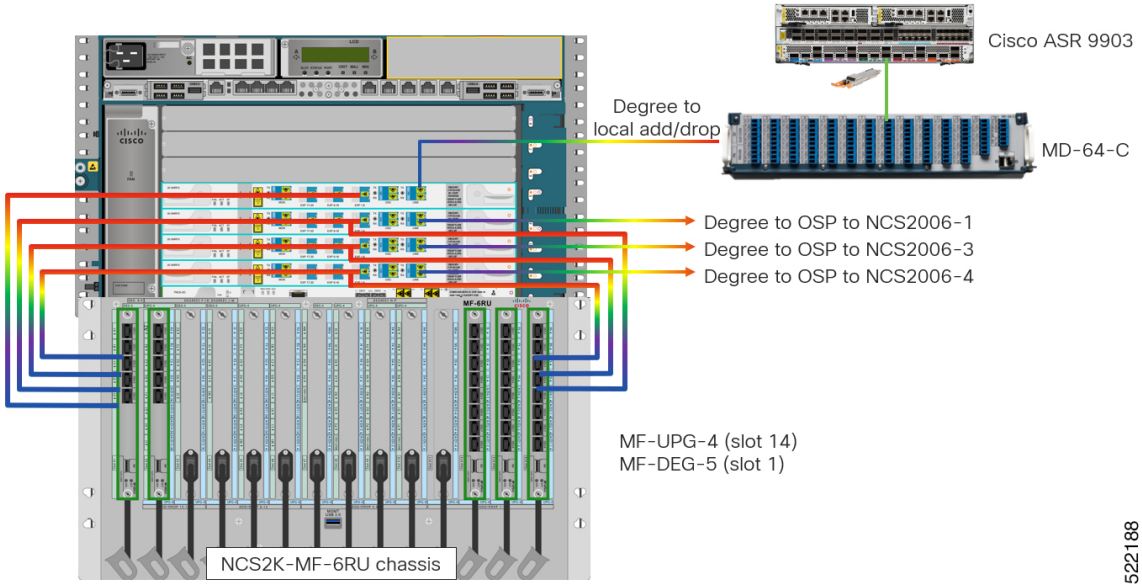
Mesh Topology

Figure 18: Optical Bypass with Colorless Add/Drop and 4-Degree ROADM Node



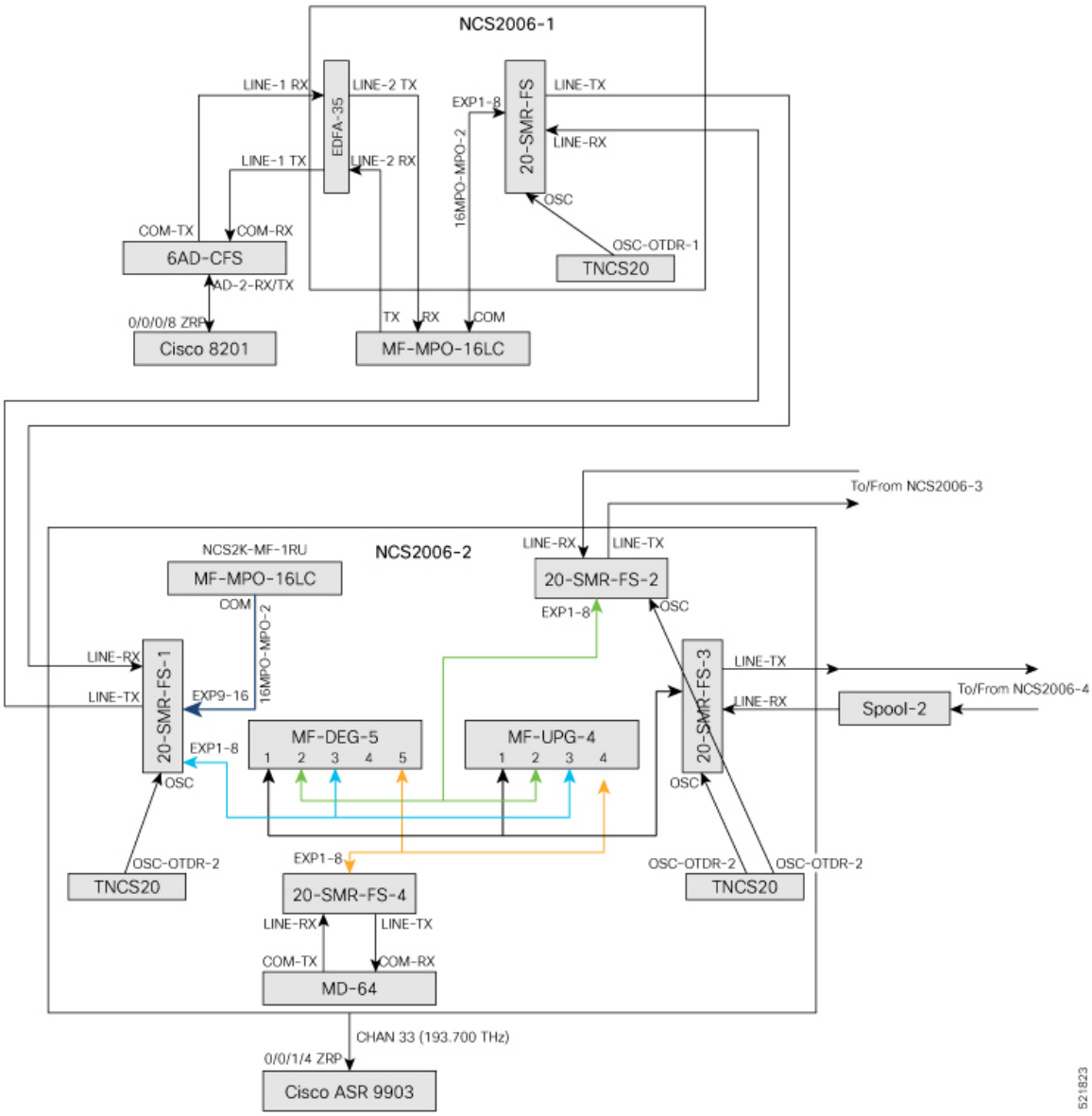
This figure displays the NCS 2006 mesh node in detail with mesh panels:

Figure 19: 4-Degree Mesh Node Configuration



This diagram displays the wiring diagram for the mesh topology:

Figure 20: Wiring Diagram for a Mesh Topology



In this sample topology, we assume that Cisco 8201 is the source router and Cisco ASR 9903 is the destination router. This example uses a four-degree node. Nodes with lesser 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. In this example, 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

To build this topology, you need the following hardware:

- 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 Cards
- OPT-EDFA-35 Cards
- 20-SMR-FS cards
- QDD-400G-ZR-S transceivers
- LC/LC cables
- 16MPO-MPO-2 cables
- ONS-MPO16-2x8-2 cables

For more information, see Hardware Components, on page 13.

Port Connections

To build this topology, connect the cables in the following sequence:

1. On the Cisco 8201 router:
   a. Align the QDD-400G-ZR-S transceiver module in front of the transceiver socket opening 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 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 6AD-CFS module (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 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 in NCS 2006-1.
4. Connect an LC/LC fiber from the LINE-2-RX port of the EDFA-35 card (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 (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 (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 (NCS 2006 -1).
8. Connect an LC/LC fiber from the LINE-TX port of the 20-SMR-FS card (NCS 2006 -1) to the LINE-RX port of the 20-SMR-FS-1 card (NCS 2006 -2).
9. Connect an LC/LC fiber from the LINE-RX port of the 20-SMR-FS card (NCS 2006 -1) to the LINE-TX port of the 20-SMR-FS-1 card (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 (NCS 2006-2).
11. Connect an 16MPO-MPO-2 fiber from the EXP9-16 port of the 20-SMR-FS-1 card (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 (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 (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 (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 (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 (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 (NCS 2006-2).
18. Connect LC/LC fibers from the LINE-TX and LINE-RX ports of 20-SMR-FS-2 card (NCS 2006-2) to the ports of NCS2006-3.
19. Connect LC/LC fibers from the LINE-TX and LINE-RX ports of 20-SMR-FS-3 card (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 (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 (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 complete building the topology, perform the following steps:

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

Long Haul Topology

This diagram displays the architecture that is used for long-haul networks. This topology uses several regular amplifier nodes (ILA) along with 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.

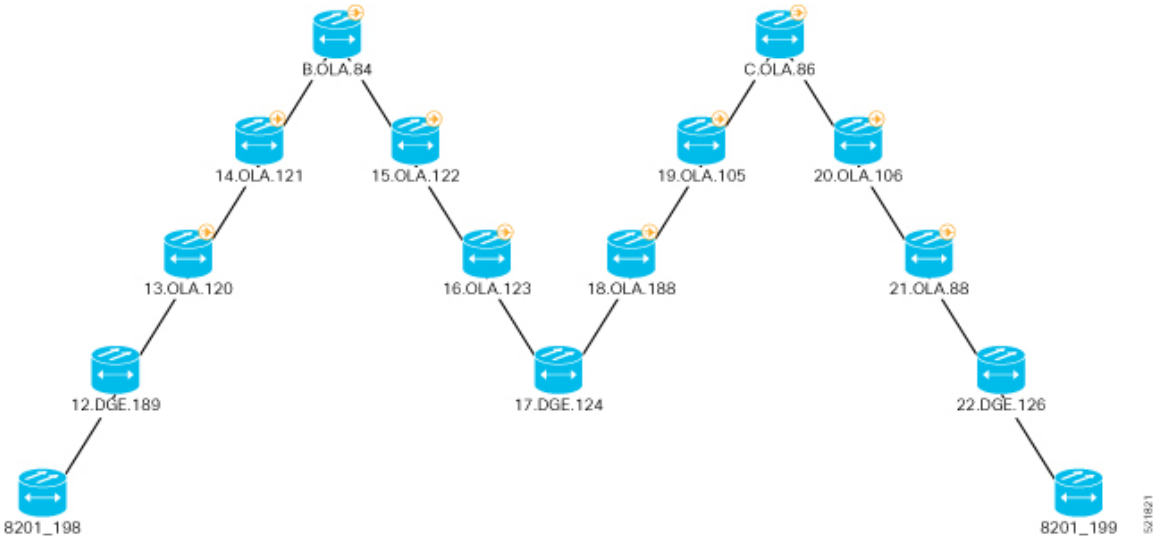
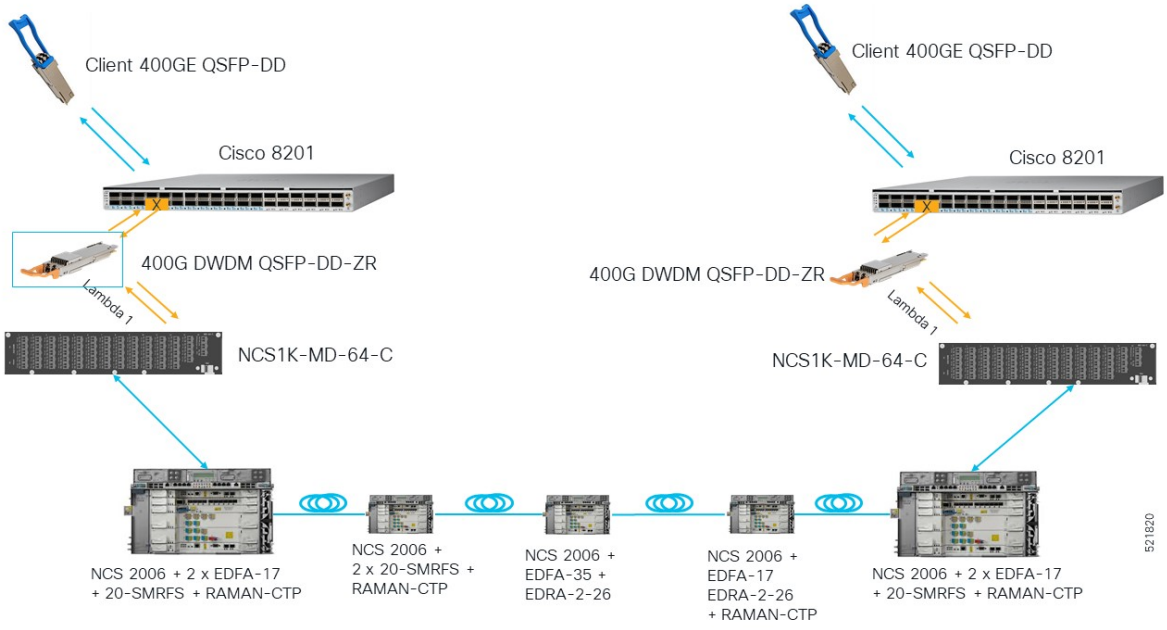
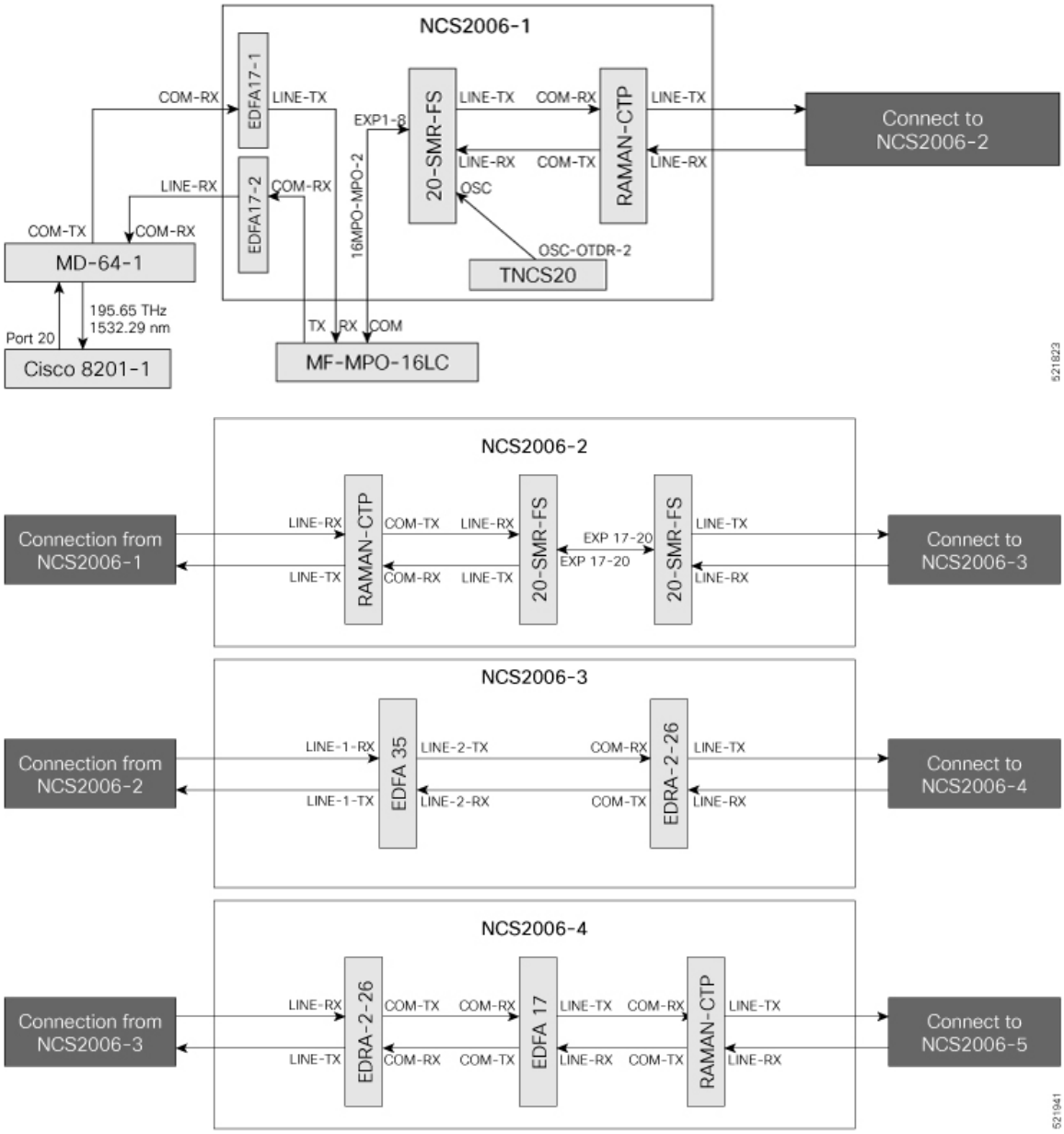


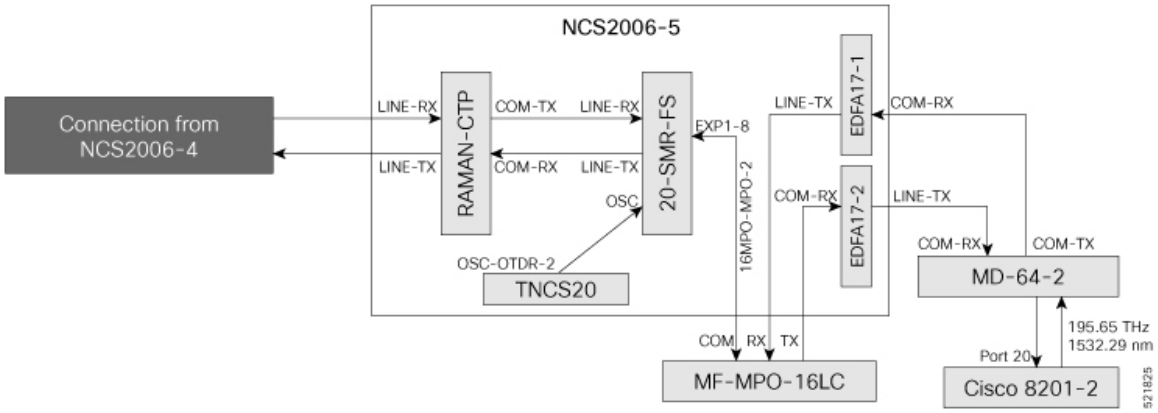
Figure 21: 400G-ZR P2P Long Haul Applications with Cisco NCS 2006



This diagram displays the wiring diagram for the long haul topology:

Figure 22: 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

To build this topology, you need the following hardware:

- Cisco 8200 Series Routers
- NCS1K-MD-64-C Modules
- Cisco NCS 2006
- TNCS-2O Cards
- OPT-EDFA-17 Cards
- EDRA-2-26 cards
- RAMAN-CTP Cards
- SMR20 FS Cards
- 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 13.

Port Connections

To build this topology, connect the cables in the following sequence:

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

20. Connect an LC/LC fiber from the LINE-RX port of the EDRA-2-26 card (NCS 2006-3) to the LINE-TX port of the EDRA-2-26 card (NCS 2006 -4).
21. Connect an LC/LC fiber from the COM-TX port of the EDRA-2-26 card (NCS 2006-4) to the COM-RX port of the EDFA-17 card (NCS 2006 -4).
22. 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 (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 (NCS 2006 -4).
24. Connect an LC/LC fiber from the LINE-TX port of the EDFA-17 card (NCS 2006-4) to the COM-RX port of RAMAN-CTP card (NCS 2006-4).
25. Connect an LC/LC fiber from the LINE-RX port of the EDFA-17 card (NCS 2006-4) to the COM-TX port of RAMAN-CTP card (NCS 2006-4).
26. Connect an LC/LC fiber from the LINE-TX port of the RAMAN-CTP card (NCS 2006-4) to the LINE-RX port of RAMAN-CTP card (NCS 2006-5).
27. Connect an LC/LC fiber from the LINE-RX port of the RAMAN-CTP card (NCS 2006-4) to the LINE-TX port of RAMAN-CTP card (NCS 2006-5).
28. Connect an LC/LC fiber from the COM-TX port of the RAMAN-CTP card (NCS 2006-5) to the LINE-RX port of the 20-SMR-FS card (NCS 2006-5).
29. Connect an LC/LC fiber from the COM-RX port of the RAMAN-CTP card (NCS 2006-5) to the LINE-TX port of the SMR20 card (NCS 2006-5).
30. Connect an LC/LC fiber from the OSC-OTDR-2 port of the TNCS-2O card (NCS 2006 -5) to the OSC-TX port of the 20-SMR-FS card (NCS 2006 -5).
31. Connect a 16MPO-MPO-2 cable from the EXP1-8 port of the 20-SMR-FS card (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 (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 (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 (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 (NCS 2006-5) to the COM-RX port of the MD-64-2 module.

Next Steps

After you complete building the topology, perform the following steps:

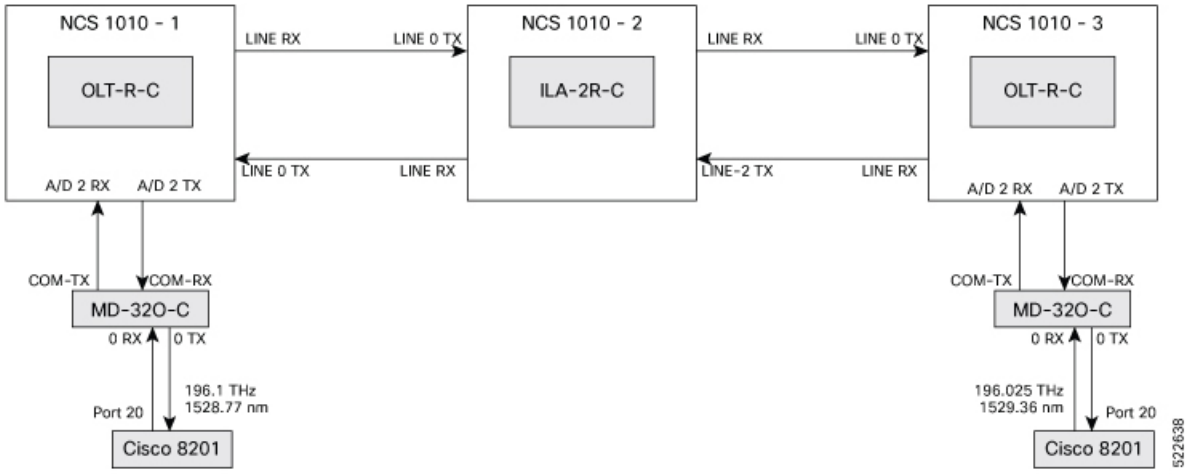
- Import the Cisco ONP Configuration File into SVO.
- Manage Expected Input Power

Point-to-point Topology (with NCS 1010 Nodes)

Figure 23: Point-to-point Topology with NCS 1010 Nodes

This diagram displays the wiring diagram for the point-to-point topology that uses NCS 1010 nodes.

Figure 24: Wiring Diagram for Point-to-point Topology



Topology Components

To build this topology, you need the following hardware:

- 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 13.

Port Connections

To build this topology, connect the cables in the following sequence:

1. On the Cisco 8201 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, 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.

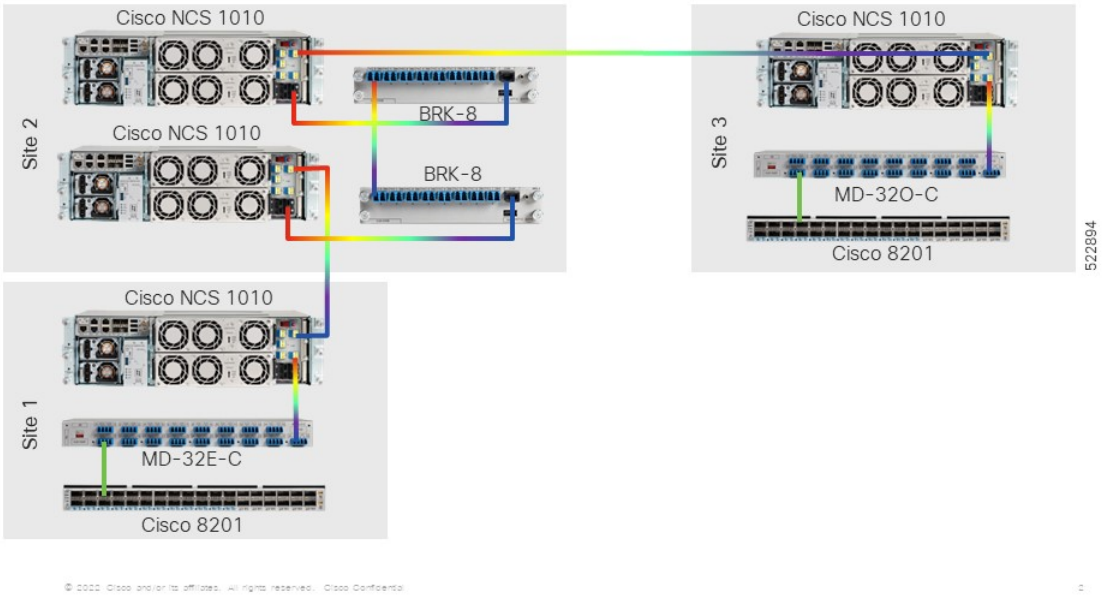
Next Steps

After you complete building the topology, perform the following steps:

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

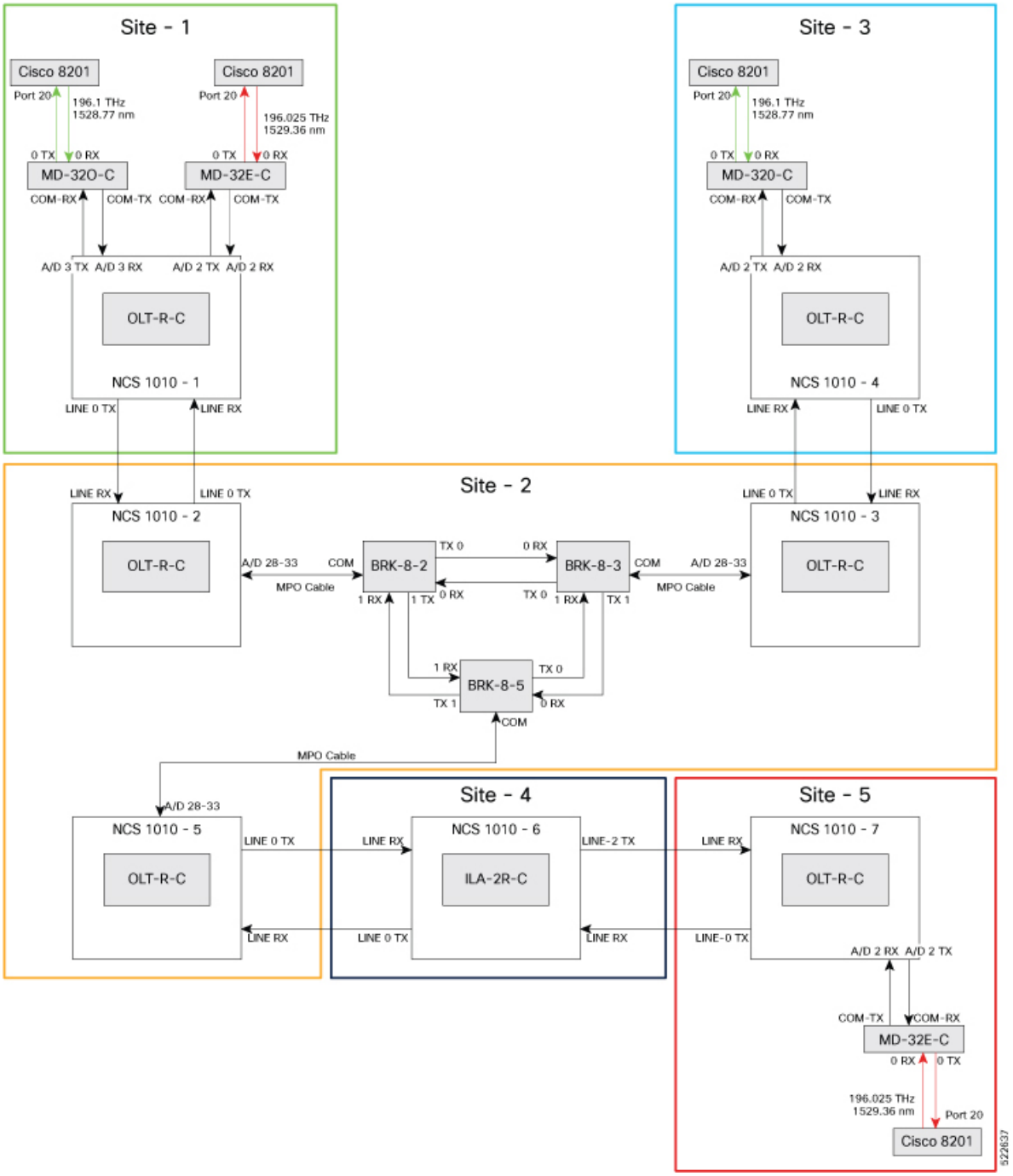
Multi-Degree Topology (with NCS 1010 Nodes)

Figure 25: Multi-degree Topology with NCS 1010 Nodes



This diagram displays the wiring diagram for the multi-degree topology that uses NCS 1010 nodes.

Figure 26: Wiring Diagram for Multi-degree Topology



Topology Components

To build this topology, you need the following hardware:

- 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 13.

Port Connections

To build this topology, connect the cables in the following sequence:

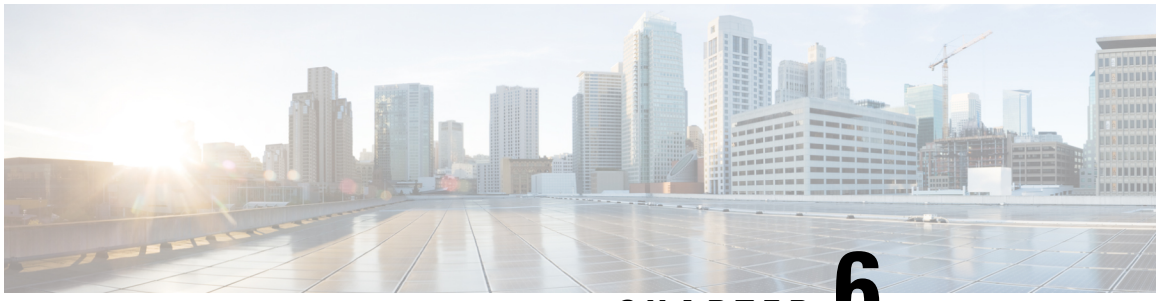
1. On the Cisco 8201 routers:
   a. Align the QDD-400G-ZR-S transceiver module in front of the transceiver socket opening in Port 20. Then, carefully slide the transceiver into the socket until the transceiver comes in contact with the socket electrical connector.
   b. Holding the pull-tab, seat the 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 as seen in the wiring diagram.
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 complete building the topology, perform the following steps:

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



CHAPTER 6

Automation Workflows

This chapter describes the installation and communication sequence of the Routed Optical Networking components. The chapter also includes some Routed Optical Networking ML service provisioning examples.

- Sequence for Installation of Routed Optical Networking Components, on page 83
- Communication Sequence, on page 84
- Service Provisioning Examples, on page 86
- Crosswork Hierarchical Controller Provisioning Workflow, on page 91
- Troubleshoot Provisioning Issues, on page 91

Sequence for Installation of Routed Optical Networking Components

We recommend this installation sequence:

Note Cisco Crosswork Network Controller (Crosswork Optimization Engine, CAT) and Cisco Optical Network Controller are the minimum required components for the Routed Optical Networking solution.

- Install Cisco ONP. Cisco ONP is used to determine the optical layer feasibility and components used to support the network. A BoM is generated for hardware to be utilized in the planned deployment. For more information, see Cisco Optical Network Planner Installation Guide .
- Install the router and optical hardware as specified in the network design. Complete the physical wiring between all the components. For more information see, Deployment Topologies, on page 65.
- Install SVO to manage the NCS 2000 optical components. Create SVO instances to manage NCS 2000 devices. For more information, see Cisco NCS 2000 Series SVO Configuration Guide, Release 12.3.x.
- Install the Crosswork Infrastructure 4.4, Crosswork Data Gateway, and supporting Crosswork Network Controller 4.1 applications (Crosswork Optimization Engine, CAT, Hi). For more information, see *Cisco Crosswork Infrastructure 4.4 and Applications Installation Guide*.
- Install Cisco Optical Network Controller 2.0. For more information, see *Cisco Optical Network Controller 2.0 Configuration Guide*.

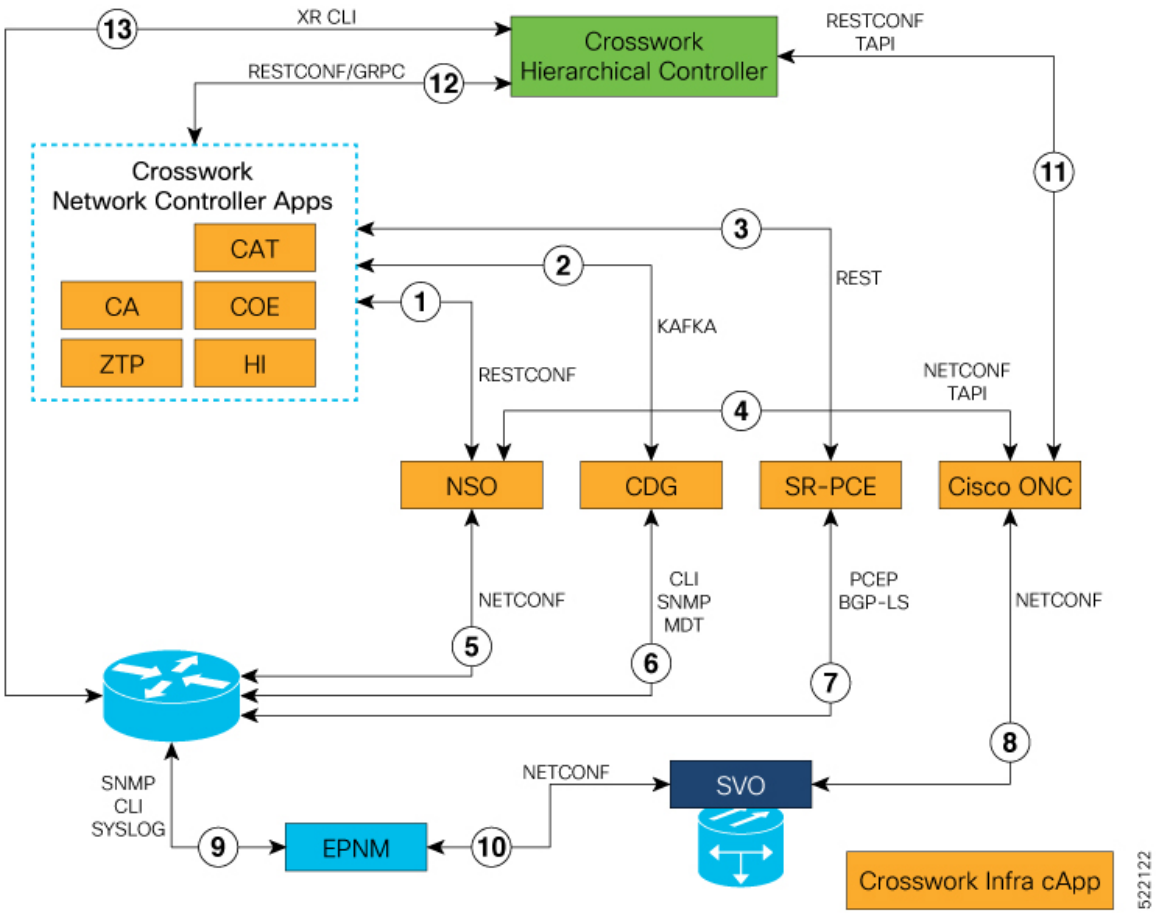
- Install EPNM 6.1.1. EMS to manage the physical router and the optical network nodes. For more information, see *Installation Guide for Cisco Evolved Programmable Network Manager 6.1* .
- Install Cisco NSO 5.7.6.2, Routed Optical Networking Multi-layer Function Pack 2.0, and Crosswork DLM function pack. Optionally, install the Cisco Transport SDN Function pack for SR-TE and xVPN service management. For more information, see the Cisco Network Services Orchestrator Installation Guide, *Cisco NSO Routed Optical Networking Core Function Pack Installation Guide*, *Cisco NSO Transport-SDN Function Pack Bundle User Guide 4.4*, Cisco Network Services Orchestrator DLM Service Pack Installation Guide 4.1.0.
- Add SVO and NCS 1010 devices to Cisco Optical Network Controller for the optical service management. For more information, see *Cisco Optical Network Controller 2.0 Configuration Guide*.
- Install SR-PCE in the network for SR-TE or RSVP-TE discovery and visualization.
- Add NSO, SR-PCE, and Cisco routers to the Crosswork cluster. For more information, see 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. For more information, see the *Cisco NSO Routed Optical Networking Core Function Pack User Guide*.

Communication Sequence

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

Figure 27: Routed Optical Networking Communication Flow



1. Crosswork Network Controller discovers services. Crosswork Network Controller populates NSO with device information via RESTCONF and handles NSO provisioning requests.
2. Crosswork Data Gateway sends device status to Crosswork Network Controller using Kafka. Crosswork Network Controller manages the Crosswork Data Gateway instance.
3. SR-PCE sends SR-TE/RSVP-TE and topology information to Crosswork Network Controller via REST APIs.
4. NSO discovers information from Cisco Optical Network Controller and provisions to Cisco Optical Network Controller via NETCONF TAPI.
5. NSO manages XR router configuration using NETCONF.
6. Crosswork Data Gateway collects network information from XR routers using CLI, SNMP, and MDT.
7. SR-PCE acts as a network PCE and collects IGP topology information from the network using PCEP and BGP-LS.
8. Cisco Optical Network Controller manages the SVO network nodes via NETCONF.
9. EPNM performs router inventory, SWIM, fault, and performance data collection using SNMP, CLI, and SYSLOG.

10. EPNM performs optical inventory, SWIM, fault, and performance data collection via NETCONF.
11. Crosswork Hierarchical Controller discovers optical equipment, topology, and services and provisions optical services via TAPI.
12. Crosswork Hierarchical Controller discovers IGP nodes and topology and provisions services using Crosswork Network Controller NB API.
13. Crosswork Hierarchical Controller collects the inventory data for ZR/ZR+ optics discovery using XR adapter directly from routers. This is also used to verify successful provisioning.

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

Service Provisioning Examples

In this section, two service provisioning examples have been provided. These examples use the Cisco NSO Routed Optical Networking Core Function Pack for service provisioning. The examples are:

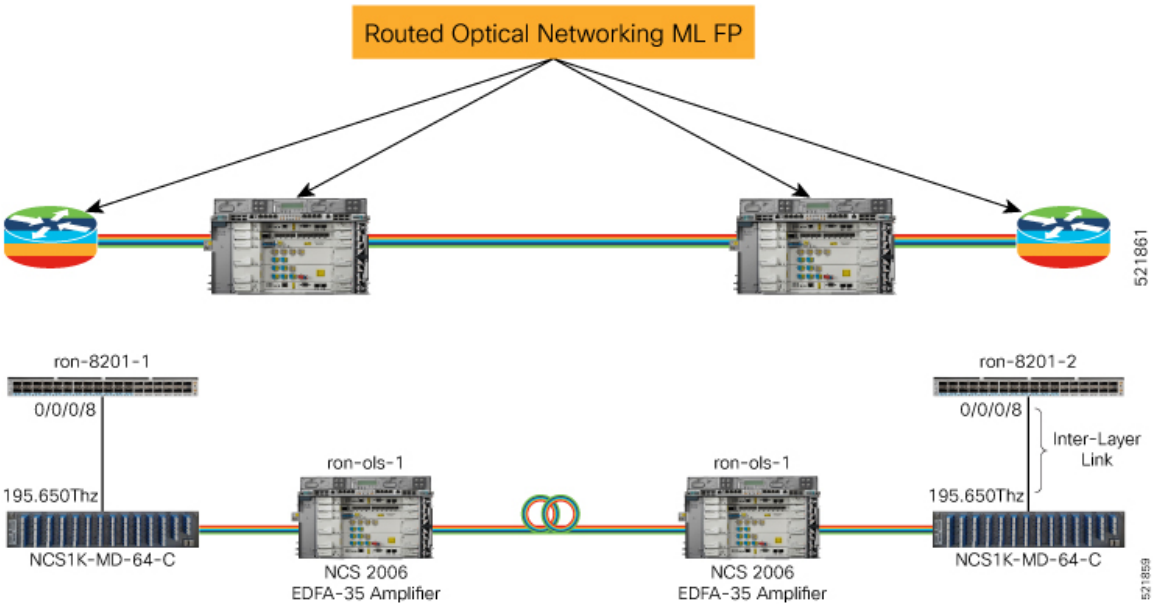
In this section, a service provisioning example has been provided. This example uses the Cisco NSO Routed Optical Networking Core Function Pack for service provisioning.

- Cisco routers with ZR or ZR+ transceivers and NCS 2000 optical devices.
- Cisco routers with ZR or ZR+ transceivers only. This example does not involve optical provisioning.

Provision End-to-end Service (Cisco Routers with ZR/ZR+ Optics and NCS 2000 Devices)

These diagrams display a network that contains Cisco routers with ZR or ZR+ optics and NCS 2000 devices.

Figure 28: Cisco Routers (with ZR/ZR+ Optics) and NCS 2000 Devices



1. Define the inter-layer links.

```
ron inter-layer-link ron-8201-1 0/0/0/8
 site "Los Angeles"
 ols-domain network-element ron-ols-1
 ols-domain optical-add-drop 1/2007/1/18,17
 ols-domain optical-controller onc-cw-100
!
ron inter-layer-link ron-8201-2 0/0/0/8
 site Phoenix
 ols-domain network-element ron-ols-2
 ols-domain optical-add-drop 1/2007/1/18,17
 ols-domain optical-controller onc-cw-100
!
```

Note The add drop port on ron-ols-1 in R/S/I/P format is 1/2007/1/17,18. Two ports are configured for both RX and TX but a single port can also be given.

In the function pack, the network-element and optical-add-drop is converted into the TAPI inventory format.

```
ron-ols-1 and 1/2007/1/18,17 = /ne=ron-ols-1/r=1/sh=2007/sl=1/s_sl=0/p=18,17
```

2. Create Routed Optical Networking ML service with following parameters:

Input	Value
End-points	ron-8201-1, ron-8201-2
Model	Transponder (1x400G mode)
Bandwidth	400G
Frequency	Supplied by Cisco Optical Network Controller. This value may be user defined too.
TX Power	Supplied by Cisco Optical Network Controller. This value may be user defined too.
IP Addressing	10.2.1.10/31 and 10.2.1.11/31 on FourHundredGigE 0/0/0/8

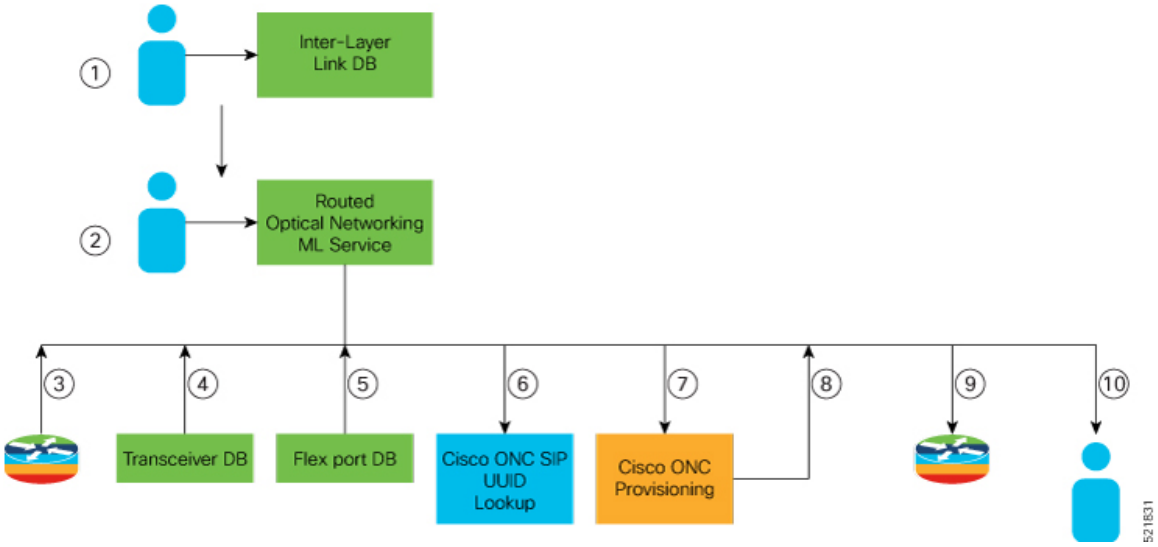
```
ron ron-ml ron-8201-1_ron-8201-2
 mode      transponder
 bandwidth 400
 ols-domain service-state UNLOCKED
 end-point ron-8201-1
  terminal-device-optical line-port 0/0/0/8
  ols-domain end-point-state UNLOCKED
  terminal-device-packet interface 0
   ip-address v4 10.2.1.10/31
  !
 !
 end-point ron-8201-2
  terminal-device-optical line-port 0/0/0/8
  ols-domain end-point-state UNLOCKED
  terminal-device-packet interface 0
   ip-address v4 10.2.1.11/31
  !
```

!
!

NSO Routed Optical Networking ML Service

This diagram displays the NSO Routed Optical Networking ML service workflow for an end-to-end service (Cisco routers with ZR/ZR+ optics and NCS 2000 devices).

Figure 29: NSO Routed Optical Networking ML Service Sequence



The workflow of the Routed Optical Networking ML service is as follows:

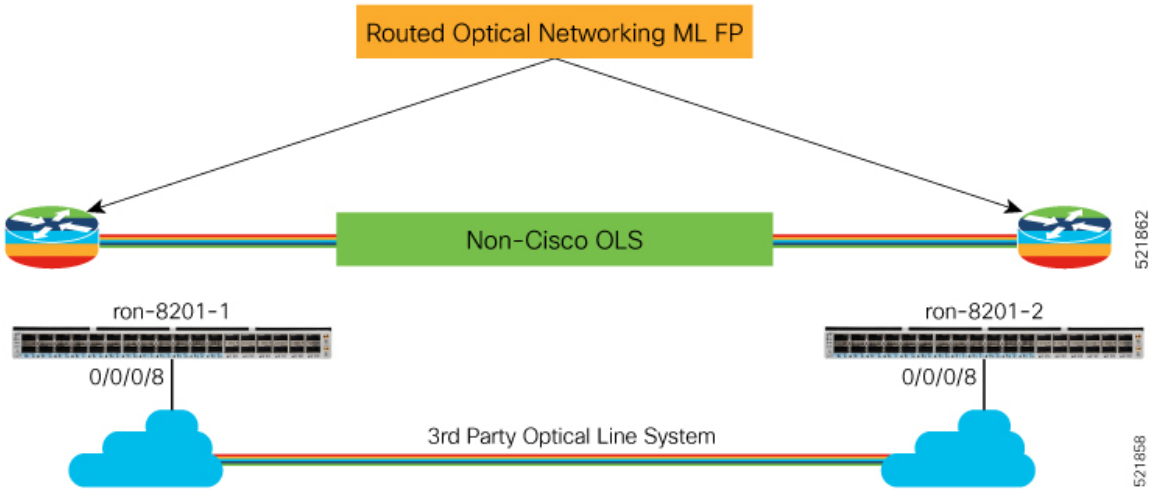
1. User populates the inter-Layer link DB for each router end-point.
2. User initiates the Routed Optical Networking ML provisioning request.
3. The Routed Optical Networking ML service retrieves the transceiver and line card PIDs for each router end-point using Cisco YANG models.
4. The Routed Optical Networking ML service compares the received transceiver PIDs and determines if the transceivers can support the service.
5. The Routed Optical Networking ML service compares the received line card PIDs, and determines if the line cards need to be configured.
6. If there is no explicit SIP UUID, the Routed Optical Networking ML service performs a lookup for the SIP via the Optical Network Controller TAPI using the INVENTORY_ID.
7. The Routed Optical Networking ML service sends a TAPI connectivity-service request to Optical Network Controller for optical provisioning using SIPs and ZR/ZR+ application IDs.
8. Cisco Optical Network Controller returns the state after the provisioning is complete. Cisco Optical Network Controller optionally returns the wavelength and TX power if these parameters are not user-defined.
9. The Routed Optical Networking ML service provisions the router optics ports. It optionally performs Shared Risk Link Group (SRLG), bundle and IP configuration using the Cisco YANG models.

10. The Routed Optical Networking ML service stores the service information as NSO operational data and also returns the service state to user.

Provision End-to-end Service (Cisco Routers with ZR/ZR+ Optics Only)

These diagrams display a network that contains Cisco routers with ZR or ZR+ optics and a non-Cisco optical line system.

Figure 30: Cisco Routers (with ZR/ZR+ Optics)



1. Create Routed Optical Networking ML Service with the following parameters:

Input	Value
End-points	ron-8201-1, ron-8201-2
Model	Transponder (1x400G mode)
Bandwidth	400G
Frequency	1952000
TX Power	-12dB on both endpoints
IP Addressing	10.2.1.10/31 and 10.2.1.11/31 on FourHundredGigE 0/0/0/8

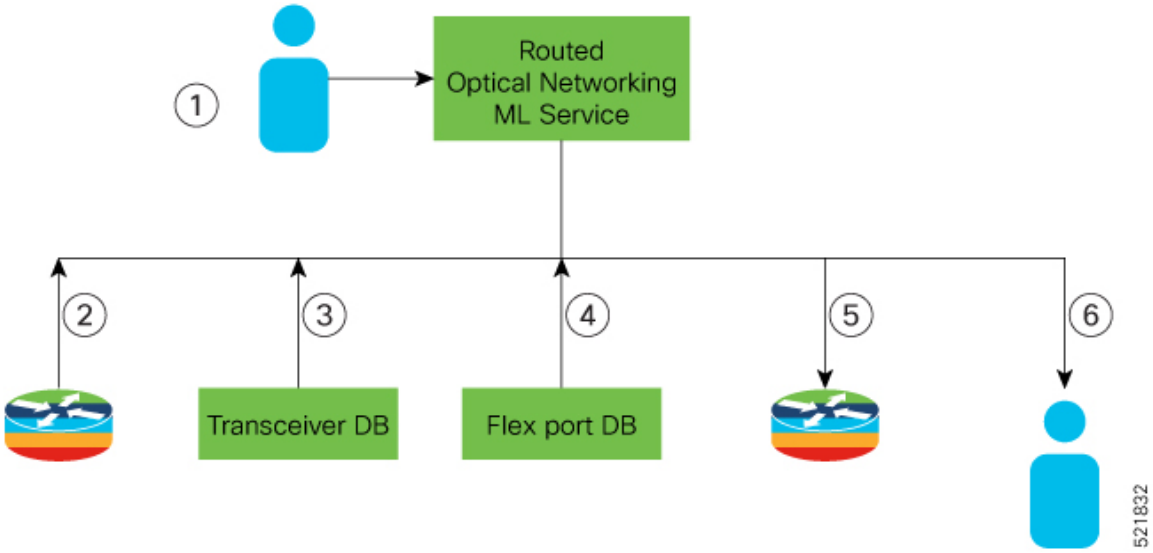
```
ron ron-ml ron-8201-1_ron-8201-2
 mode       transponder
 bandwidth 400
 circuit-id "Router Only"
 frequency  1952000
 end-point ron-8201-1
  terminal-device-optical line-port 0/0/0/8
  terminal-device-optical transmit-power -120
  terminal-device-packet interface 0
   ip-address v4 10.2.1.10/31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

NSO Routed Optical Networking ML Service

This diagram displays the NSO Routed Optical Networking ML service workflow for an end-to-end service (only Cisco routers with ZR/ZR+ optics).

Figure 31: NSO Routed Optical Networking ML Service Sequence



The workflow of the Routed Optical Networking ML service is as follows:

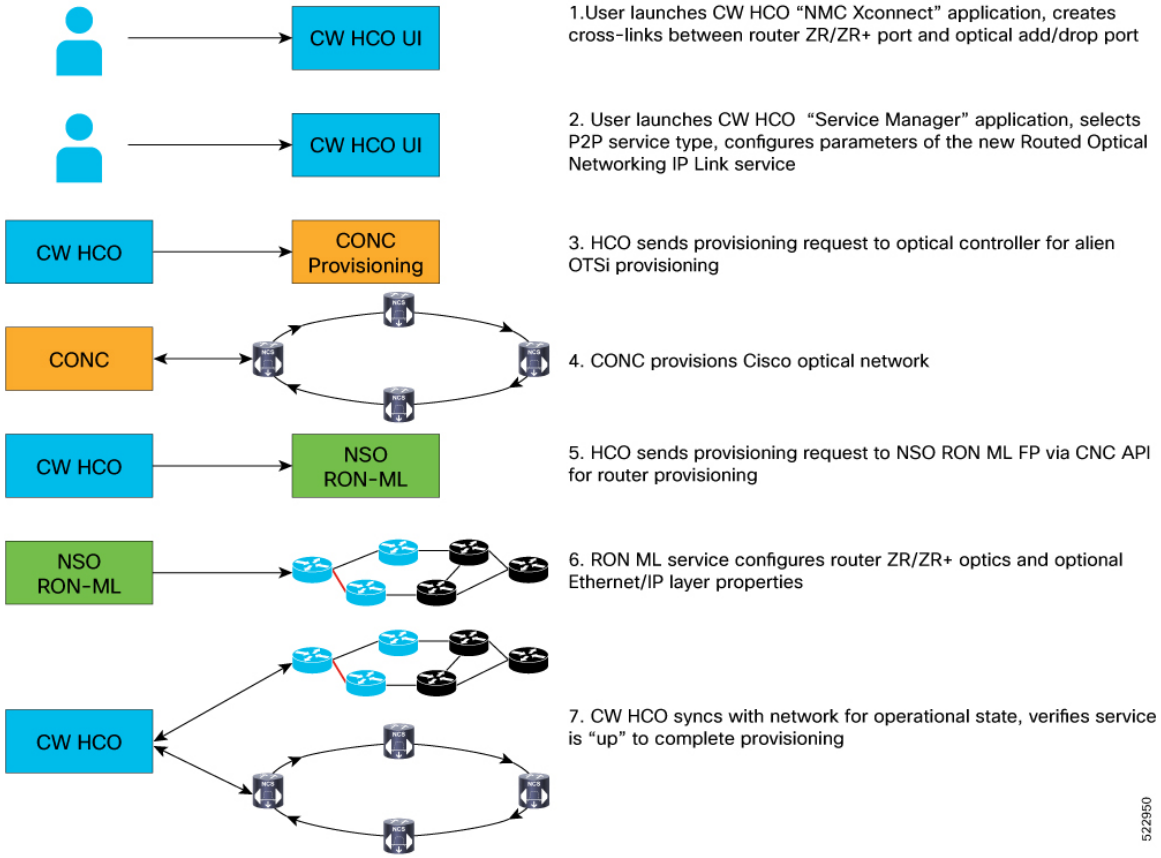
1. User initiates the Routed Optical Networking ML provisioning request.
2. The Routed Optical Networking ML service retrieves the transceiver and line card PIDs for each router end-point using CLI NED.
3. The Routed Optical Networking ML service compares the received transceiver PIDs and determines if the transceivers can support the service.
4. The Routed Optical Networking ML service compares the received line card PIDs, and determines if the line cards must be configured.
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 user.

Crosswork Hierarchical Controller Provisioning Workflow

This section describes the workflow for provisioning the Routed Optical Networking circuit in the Crosswork Hierarchical Controller GUI via the Crosswork Network Controller.

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

Figure 32: Crosswork Hierarchical Controller Provisioning Workflow



Troubleshoot Provisioning Issues

Provisioning on ZR or ZR+ Optics

- To check the controller state on the router, use:

```
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
```

- To gather the performance measurement data, use:

```
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

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.

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.

NSO Provisioning

The following figure displays a successful provisioning scenario.

Figure 33: *

```
admin@ncs# show ron ron-ml-plan 030f63ab_84fb_4ff1_9871_6c1421f99b0f
                                                BACK         STATUS                                                                                                                  POST ACTION
TYPE                                    NAME                TRACK  GOAL  CODE     STATE                                                STATUS   WHEN                ref  STATUS
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
self                                    self                false  -     RON-200  init                                                 reached  2021-06-11T16:47:25  -    create-reached
                                                                                    ready                                                reached  2021-06-11T16:47:53  -    -
optical-controller                      Optical-Controller  false  -     RON-200  init                                                 reached  2021-06-11T16:47:30  -    -
                                                                                    cisco-ron-cfp-nano-plan-services:config-apply        reached  2021-06-11T16:47:30  -    -
                                                                                    ready                                                reached  2021-06-11T16:47:47  -    -
cisco-ron-cfp-nano-plan-services:router  ron-8201-1         false  -     RON-200  init                                                 reached  2021-06-11T16:47:47  -    -
                                                                                    cisco-ron-cfp-nano-plan-services:config-apply        reached  2021-06-11T16:47:47  -    -
                                                                                    ready                                                reached  2021-06-11T16:47:53  -    -
cisco-ron-cfp-nano-plan-services:router  ron-8201-2         false  -     RON-200  init                                                 reached  2021-06-11T16:47:47  -    -
                                                                                    cisco-ron-cfp-nano-plan-services:config-apply        reached  2021-06-11T16:47:47  -    -
                                                                                    ready                                                reached  2021-06-11T16:47:53  -    -
```

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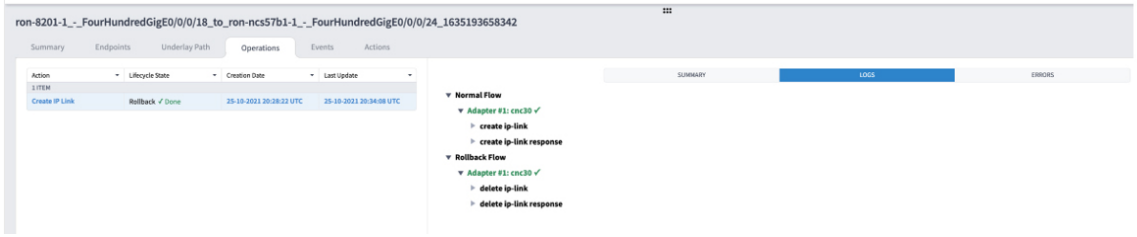
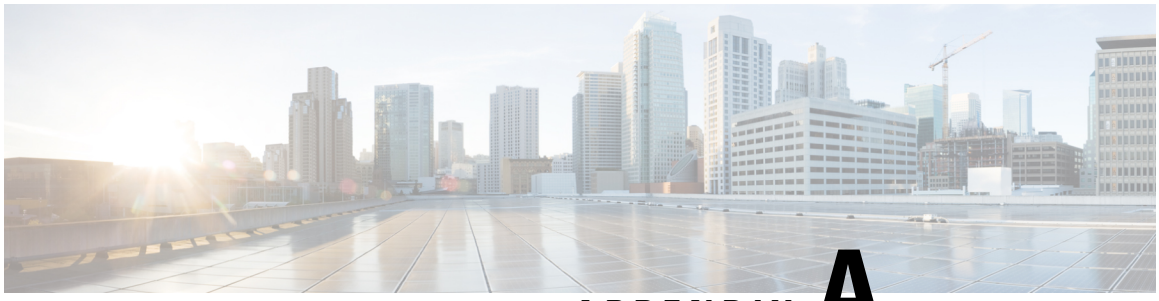
The following figure displays a failed provisioning scenario, due to an error in the Cisco Optical Network Controller provisioning.

```
admin@ncs# show ron ron-ml-plan ron_poc_demo_195200 plan
                                                
```

Figure 36: Crosswork Hierarchical Controller UI - Operations Tab



522180



APPENDIX A

Sample End-to-end Configuration

This appendix describes an end-to-end provisioning example for a Routed Optical Networking topology.

- Sample Configuration, on page 97

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.

- Network Sizing Requirements, on page 97
- Planning and Design Phase, on page 99
- Implement Phase, on page 100
- Operate Phase, on page 150
- Optimization Phase, on page 162

Network Sizing Requirements

This section details the sizing requirements for a network. For a small lab installation, three servers with 256 GB of RAM is enough to run the Crosswork, Crosswork Network Controller, Cisco Optical Network Controller, NSO, Crosswork Hierarchical Controller, and EPNM in a non-HA deployment. For a production setup, calculate the total resources required using information in the following tables.

Network Profiles

Network profiles are defined based on network size, services, and application features.

Network Entity/Feature	Lab (20%)	Production (100%)
Devices	2000	10000
Total number of interfaces	100000	650000
IGP interfaces	20000	100000

Network Entity/Feature	Lab (20%)	Production (100%)
VPN Services (L2, L3)	40000	200000
Endpoints per VPN service	2 to 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 per Network Profile

The following table is the recommended deployment sizing requirement based on the defined network profiles for solution using Cisco Crosswork Network Controller.

Network Profile	Crosswork Cluster	Crosswork Data Gateway	NSO	SR-PCE HA Pairs	Crosswork Hierarchical Controller
Lab	3 VMs	1+1 VM	1+1 VM	1	1+1 VM
Production	5 VMs **Essentials package:** 3 Hybrid VMs + 1 Worker VM **Advantage package:** 3 Hybrid VMs + 2 Worker VMs	5+5 VM	1+1 VM	6	1+1 VM

VM Resources

The following table provide the details on CPU, memory, and disk requirements needed for each Crosswork VM and the 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: 1TB
			• CPU: 8 vCPU
			• RAM: 24 GB
			• DISK: 45 GB
				• CPU: 10 cores
				• RAM: 96 GB
				• DISK: 400G SSD (lab) , 3TB SSD (production)
					• Professional (Small)
					  • CPU: 16 vCPU
					  • RAM: 64 GB
					  • DISK: 2.8 TB
					• Extended (Medium/Large)
					  • CPU: 24 vCPU
					  • RAM: 128 GB
					  • DISK: 4 TB

Note When Cisco Optical Network Controller is deployed on the same cluster as Crosswork Network Controller, the Crosswork VM must be deployed with 12 cores and 96 GB of RAM.

Cisco Optical Network Controller Scale Support

Cisco Optical Network Controller supports a maximum of 500 nodes and 600 services. Cisco Optical Network Controller can run on the same cluster. Cisco Optical Network Controller adds more resources incrementally at the maximum supported scale. It is captured in Crosswork VM resources in the table above.

Planning and Design Phase

The planning and design phase involves:

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 is used to determine the optical layer feasibility and components that are used to support the network.

   Output for a sample configuration:

This topology uses two Cisco 8201 routers, two NCS 2006 terminal nodes with NCS1K-MD-64 add/drop multiplexers, and EDFA-35 bi-directional amplifiers. The span length is 75 kms. Longer spans may require additional ILA nodes for amplification.

2. **Automation Software Resource Planning**

   Server requirements for the Routed Optical Networking software elements

   Determine the servers required for the full solution. See Network Sizing Requirements, on page 97 and Installation Requirements for Routed Optical Networking Components, on page 100.

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

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

Installation Requirements for Routed Optical Networking Components

The following list points to the installation requirements for different Routed Optical Networking components.

- Cisco Optical Network Planner
- Cisco WAN Automation Engine 7.5.0
- Cisco NCS 2000 Shelf Virtualization Orchestrator 12.3.x
- Cisco Crosswork Cluster, Crosswork Data Gateway, and Crosswork Applications
- Cisco Optical Network Controller 2.0
- *Cisco Evolved Programmable Network Manager 6.1*
- Cisco Network Services Orchestrator 5.7.6.2
  - *Cisco NSO Routed Optical Networking Core Function Pack 1.0*
  - Cisco NSO Transport-SDN Function Pack Bundle User Guide 4.1
  - Cisco Network Services Orchestrator DLM Service Pack Installation Guide 4.4.0

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/ZR+ optics. See Deployment Topologies, on page 65.

   d. SVO 12.2 server or line card based installation to support NCS 2000 nodes. See Install the External Server, and Run the SVO Installation Tool.

e. Create SVO instances for all NCS 2000 nodes. See Create an SVO Instance.

2. **Installation of the Automation Software Components**

   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 5.0 (for optical planning)
      - Cisco WAN Automation Engine 7.5.0 (for IP planning)
      - Cisco Crosswork Cluster, Crosswork Data Gateway, and Crosswork Applications (for supporting Crosswork Network Controller)
      - *Cisco Optical Network Controller 2.0* Cisco Optical Network Controller 2.1 (for supporting optical network)
      - Cisco Evolved Programmable Network Manager 6.1.1 (for managing the physical router and the optical network nodes)
      - Cisco Network Services Orchestrator 5.7.6.2 (base installation to support RON FP)
        - *Cisco NSO Routed Optical Networking Core Function Pack 1.0* (for RON ML provisioning)
        - Cisco NSO Transport-SDN Function Pack Bundle 3.0 (for Crosswork Network Controller SR and xVPN provisioning)
        - Cisco Network Services Orchestrator DLM Service Pack 4.1.0 (for device synchronization between Crosswork Network Controller and NSO)
      - Cisco Crosswork Hierarchical Controller 5.1 (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, NSO, and Routers to Crosswork Network Controller, on page 102.

   c. Add routers to NSO using the IOS-XR CLI NED. See Step 3 in Provision ML Service Using NSO Routed Optical Networking CFP , on page 115.

   d. Add Cisco Optical Network Controller to NSO using the ONF TAPI NED.

   e. Add and configure the following Crosswork Hierarchical Controller adapters. See Add Adapters to Crosswork Hierarchical Controller, on page 108.

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 5.1.
- 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 ML Service Using NSO Routed Optical Networking CFP , on page 115.
         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 page 91.
      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 Routed Optical Networking ML Service Using Crosswork Hierarchical Controller, on page 135.
         b. Verify the router optics controller state using the Link Assurance tool in Crosswork Hierarchical Controller. See Step 3 in Provision Routed Optical Networking ML Service Using Crosswork Hierarchical Controller, on page 135.

Add SR-PCE, NSO, and Routers to Crosswork Network Controller

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

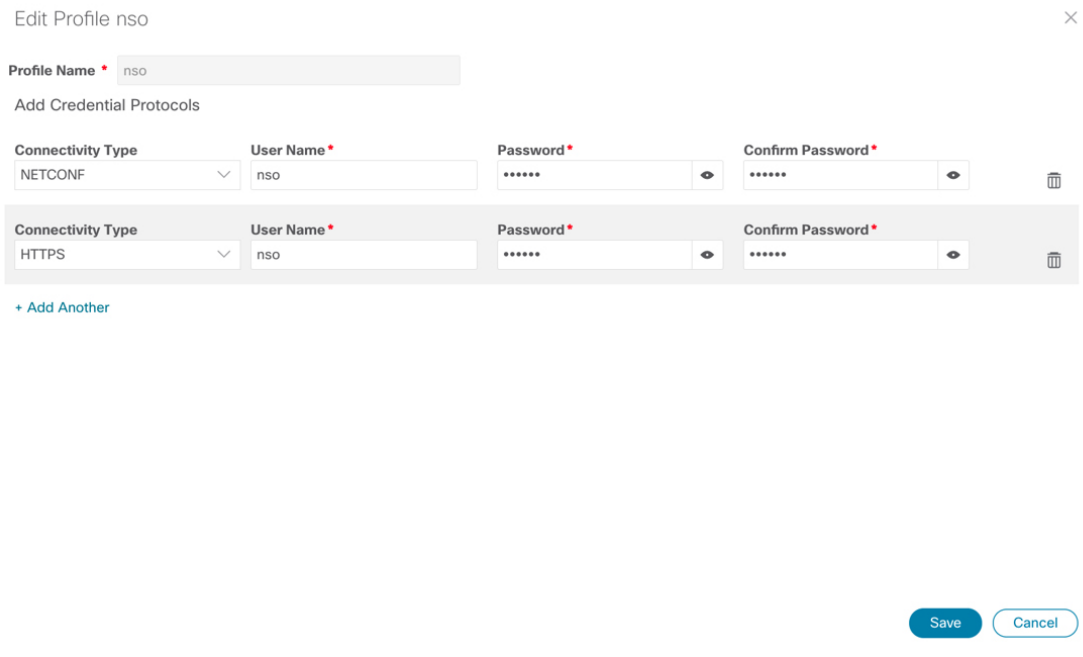
Note When you add or import devices, or create providers, you need to specify the credential profile.

1. Log in to the Crosswork user interface.

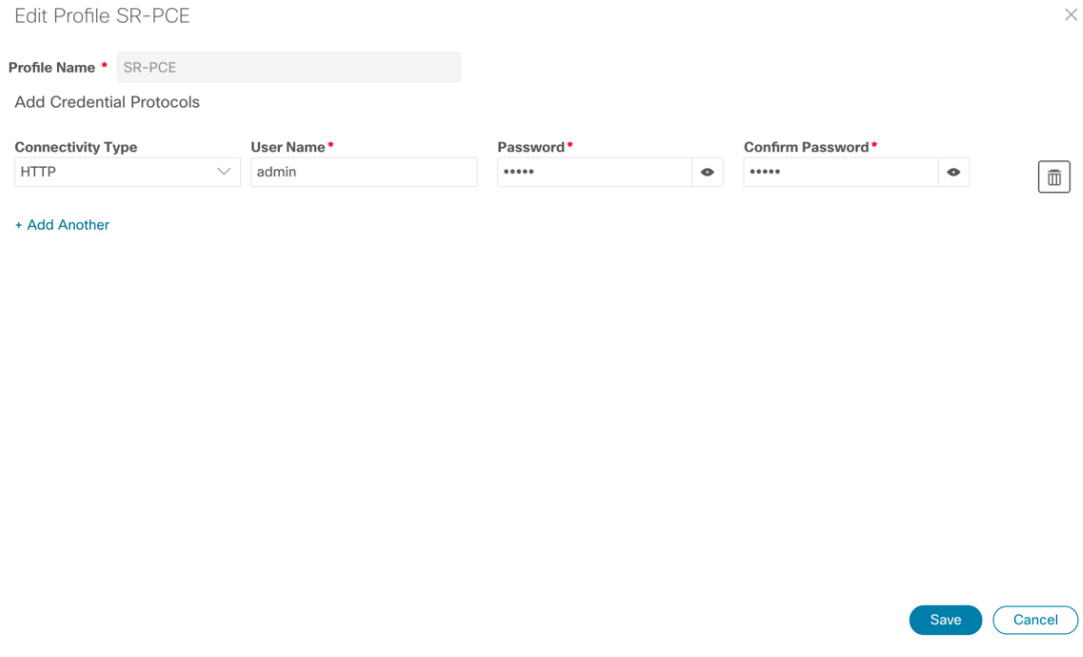
Sample End-to-end Configuration

2. To create a credential profile, choose **Device Management** > **Credential Profiles** from the main menu. 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.

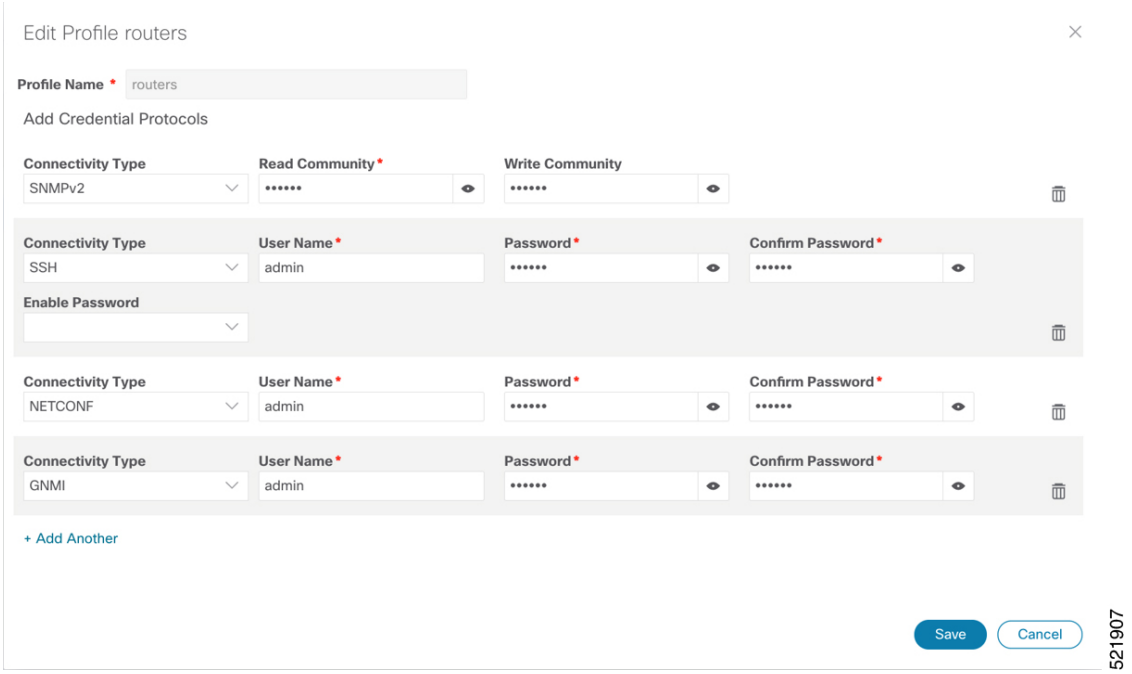


   b. The SR-PCE credential profile requires HTTP credentials to communicate with the SR-PCE Northbound API.



Sample End-to-end Configuration

c. The router credential profile requires at a minimum, the SNMPv2 or SNMPv3 and SSH connectivity types. NETCONF is optional. GNMi is used when utilizing GNMi to configure streaming telemetry sensors on the node.



3. Add the providers. See About Adding Providers.

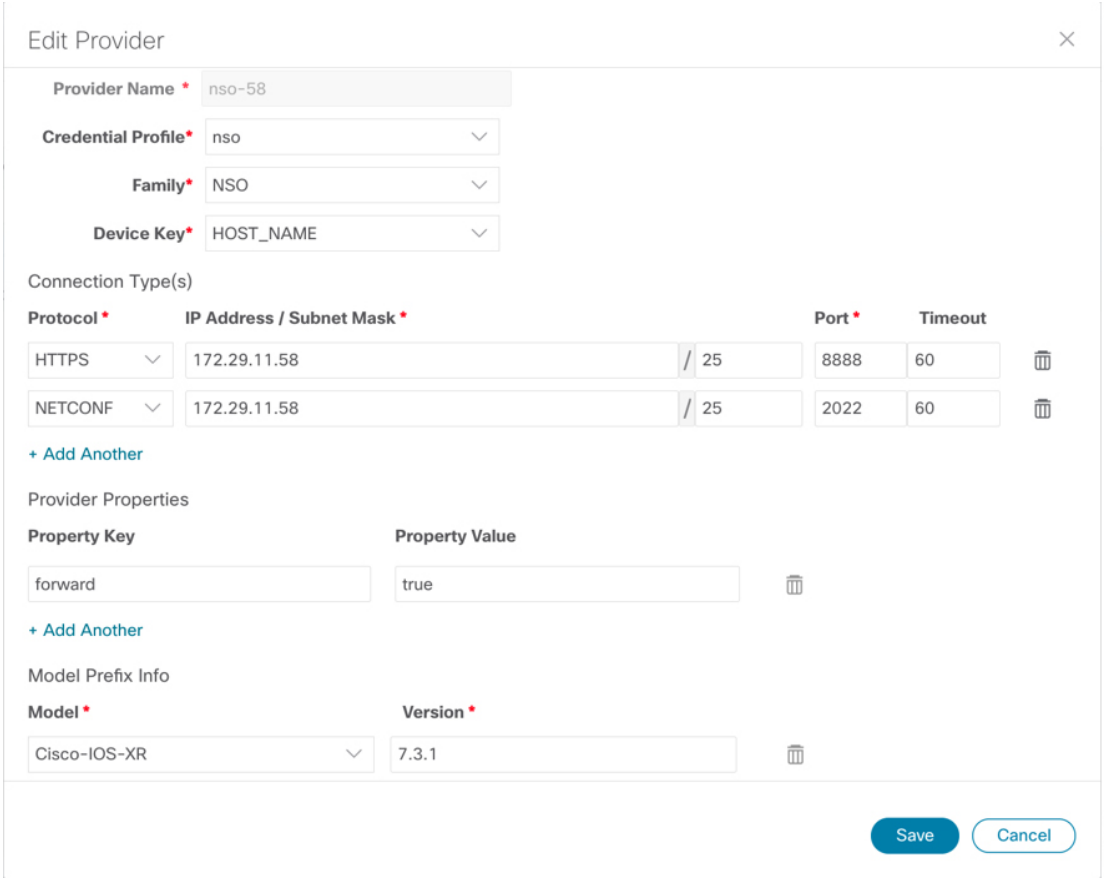
   a. To add the SR-PCE or NSO provider, choose **Administration** > **Manage Provider Access** from the main menu. See Manage Providers.

   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 the HOST_NAME or INVENTORY_ID depending on the specific deployment.

      The following image demonstrates the connectivity to NSO's RESTCONF API over SSL using port 8888 and NETCONF using the default port of 2022. Since the Routed Optical Networking NSO CFP utilizes the XR NETCONF NED, the Cisco-IOS-XR model is not applicable and may be set to any version.

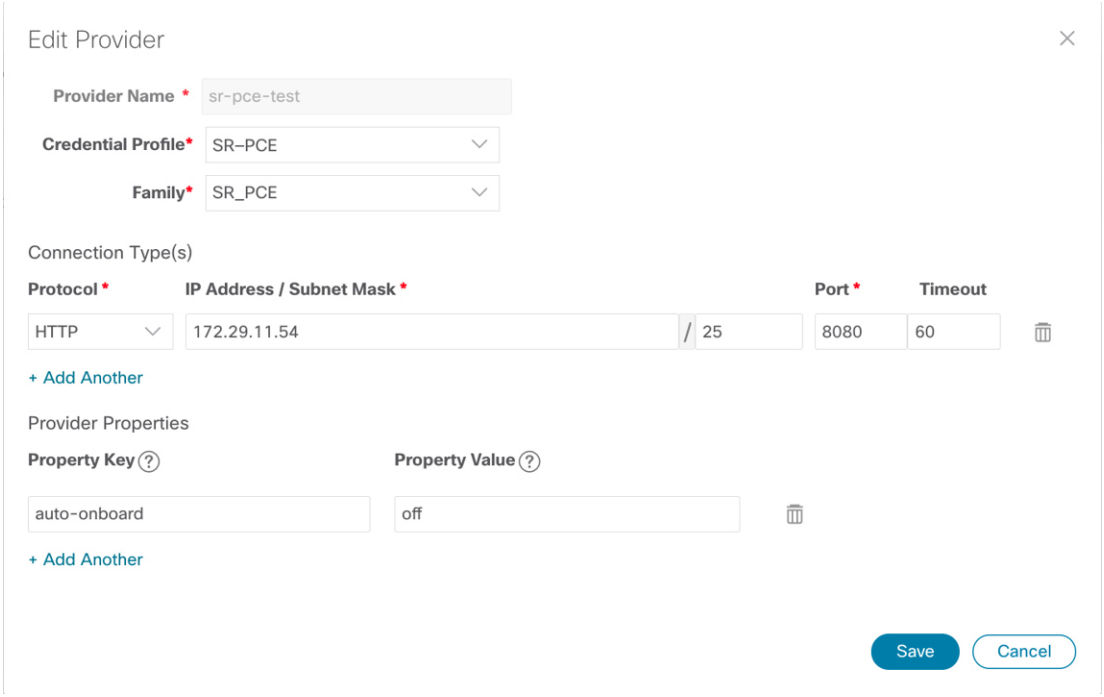
Sample End-to-end Configuration



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 the HTTP. In the following 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.

Sample End-to-end Configuration

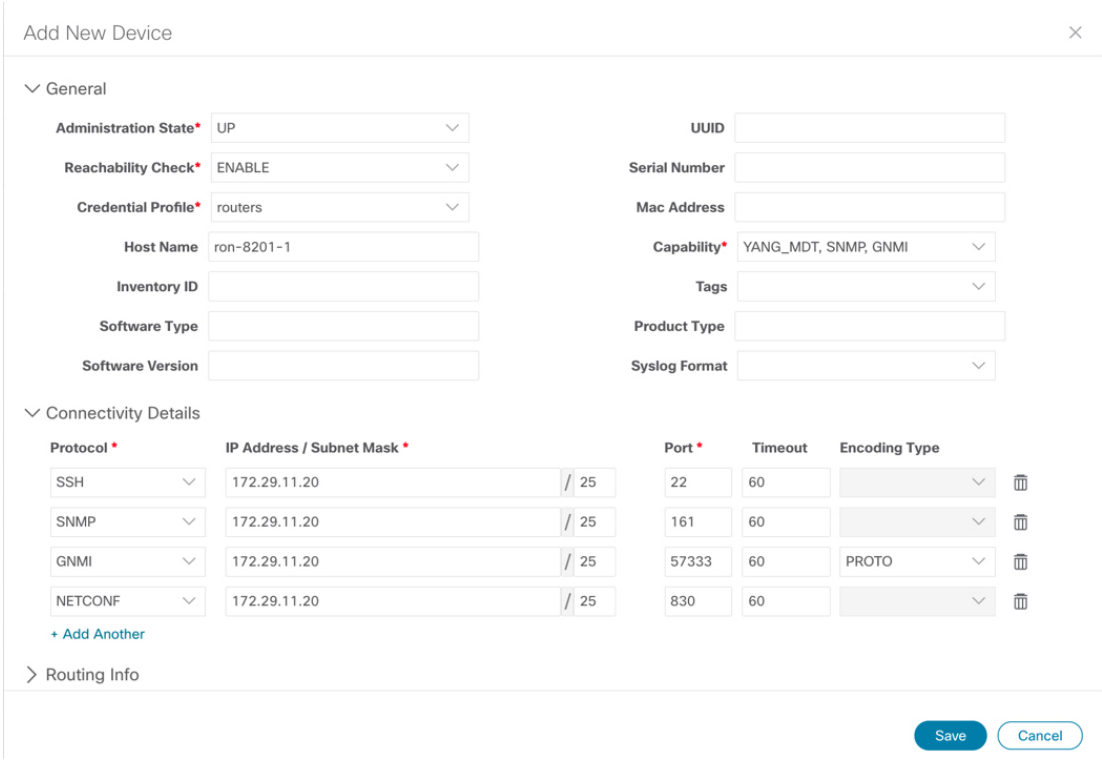


4. Validate communications with one or more providers. Check on the provider's reachability using the steps in Get Provider Details.

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

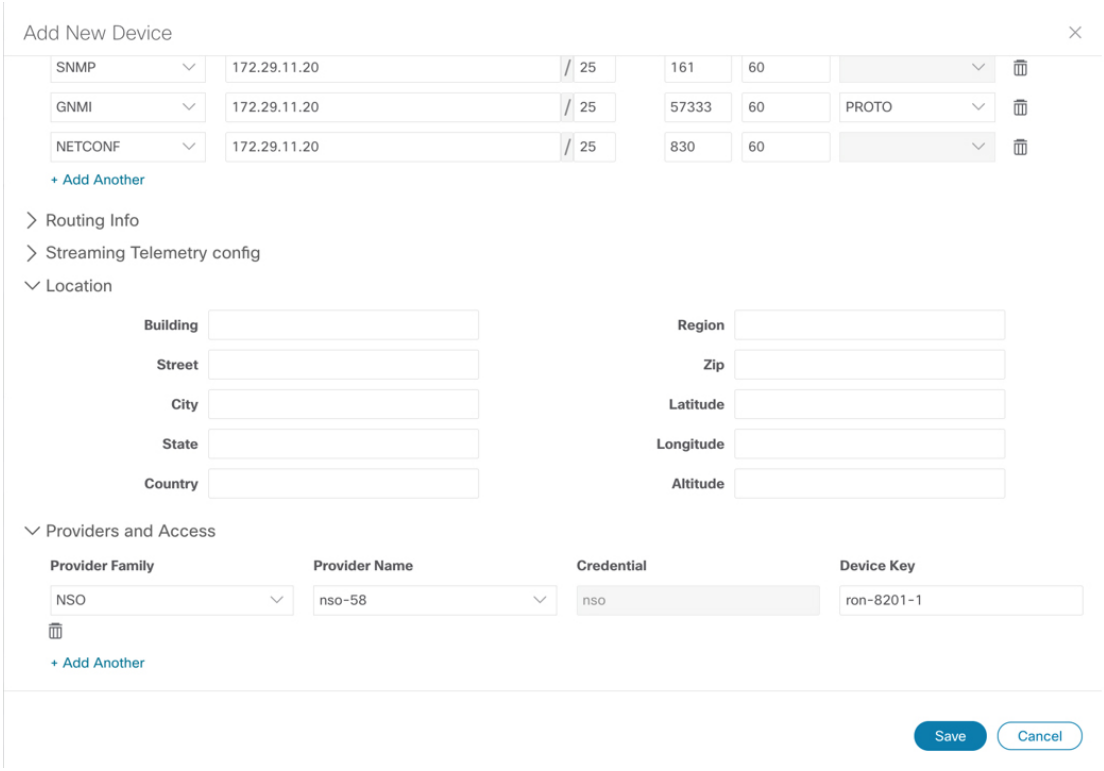
   a. The Administration State, Reachability Check, and Credential Profile are mandatory elements. The Host Name must be used if the NSO provider device key is set to the Host Name value. If the NSO provider device key is set to Inventory ID that field must be populated. The Software Type, Software Version, 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, location information can be entered. Latitude and Longitude information place the node at a specific location on a geographic map.

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

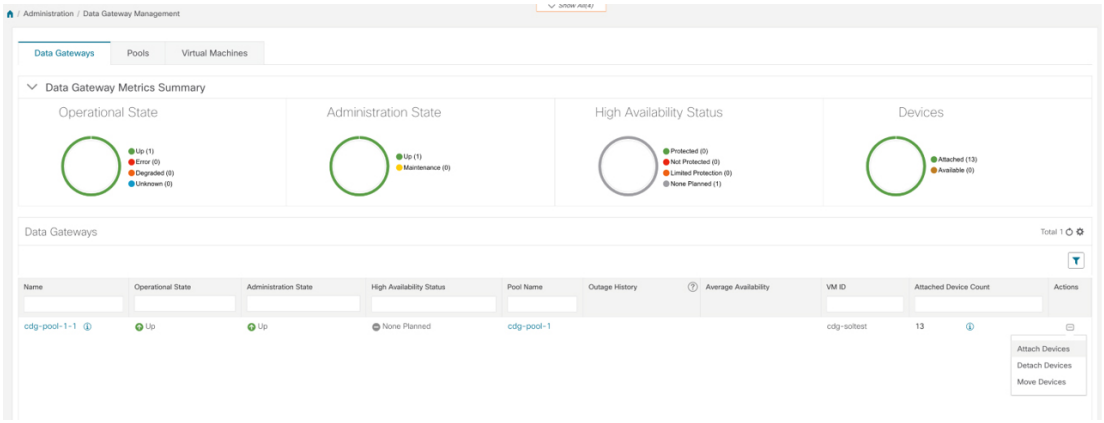


521911

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**.

Follow the steps in Attach Devices to Cisco Crosswork Data Gateway.



521912

Add Adapters to Crosswork Hierarchical Controller

Prerequisite

When you work with Crosswork Hierarchical Controller adapters you are required to use credentials. These credentials are used for authentication when a device is assigned to an adapter. The same credentials may be shared by multiple adapters. The credentials are added under the **Services > Device Manager > Credentials**

tab in the Crosswork Hierarchical Controller GUI. The adapters needed for the Routed Optical Networking solution are:

Table 3: Routed Optical Networking Adapters

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

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

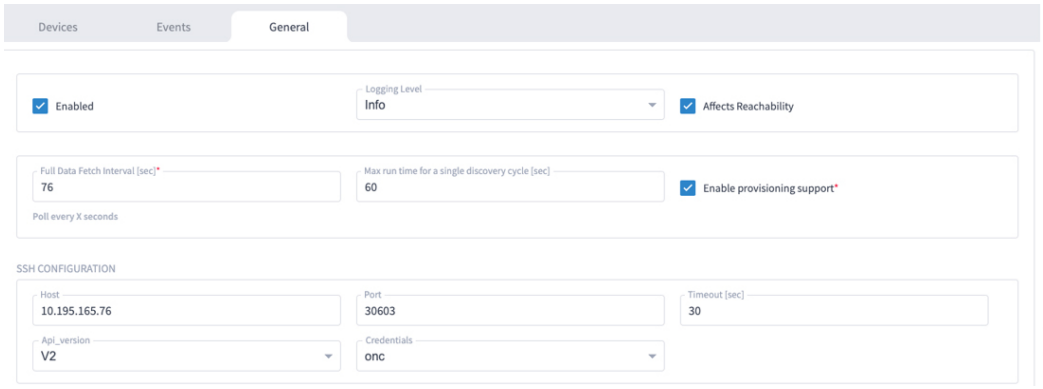
To add the adapters, perform the following steps:

1. In the applications bar in Crosswork Hierarchical Controller, select **Services** > **Device Manager** > **Adapters**.
2. Click **Add new adapter.**
3. Enter the adapter details:
   - **Adapter Type**: Select an adapter type from the list of available adapter types currently installed in Crosswork Hierarchical Controller.
   - **Adapter Name**: Unique user defined name of this adapter type instance (there can be several instances of the same adapter type).
4. To configure the adapter, select the adapter in the Adapters pane. Configure the parameters as displayed in the following images.
   - **Crosswork Network Controller Adapter**:

Note API version for Crosswork Network Controller must be V2.

Sample End-to-end Configuration

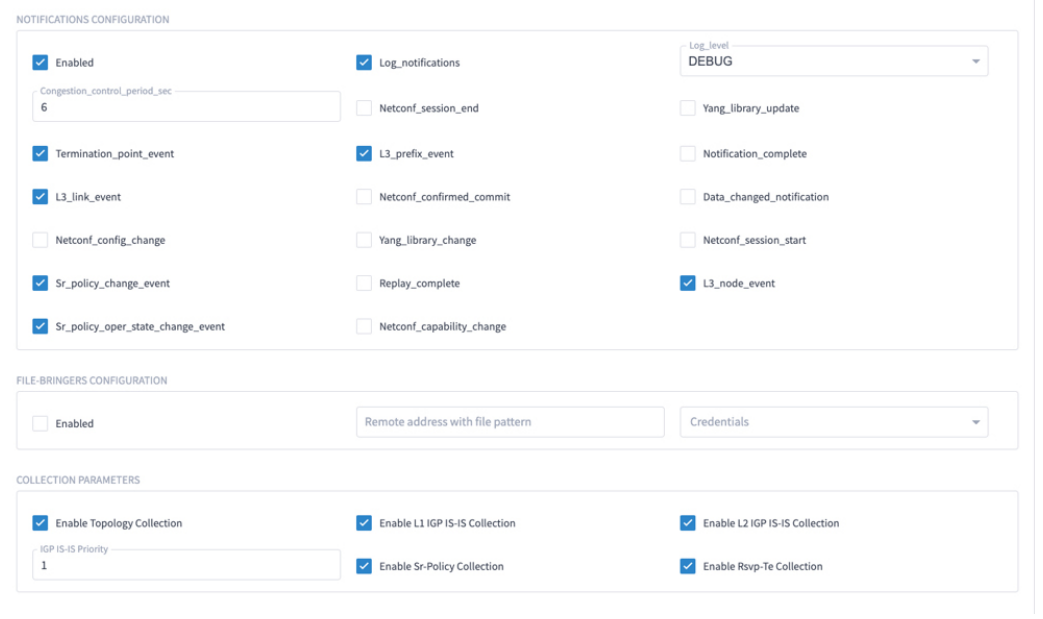
Figure 37: Crosswork Network Controller Adapter Configuration - General Tab



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

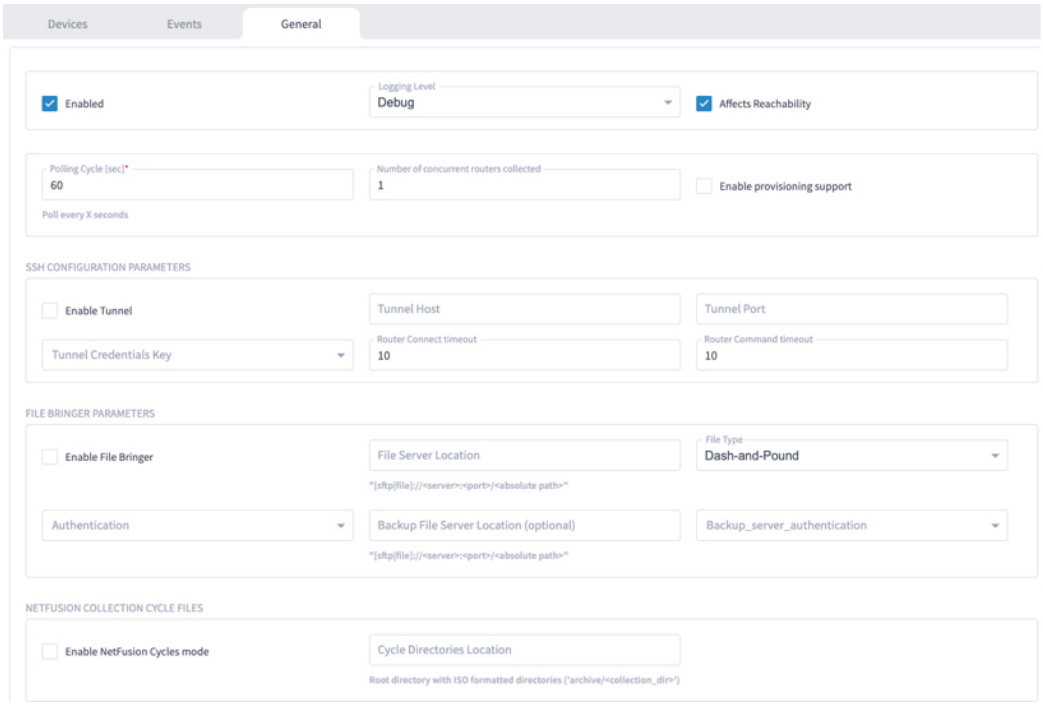
The following parameters must be configured for Crosswork Network Controller notifications and collection.

Figure 38: Crosswork Network Controller Adapter Configuration - General Tab



- **IOS-XR Adapter**

Figure 39: IOS-XR Adapter - General Tab

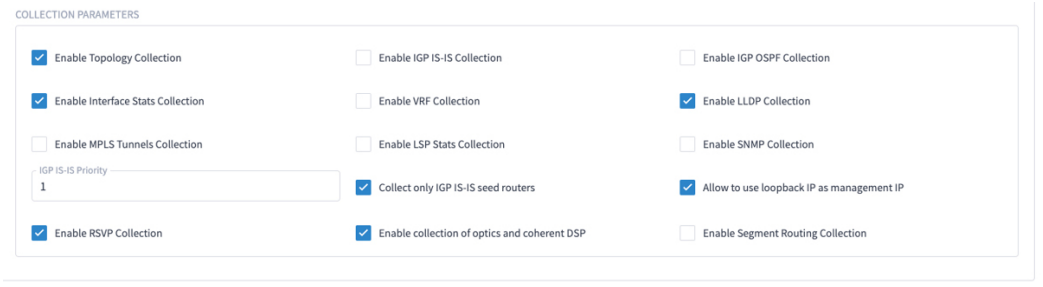


522154

Note The Polling Cycle should not be less than 300s in a production network. Concurrency can be increased. The Logging Level must be set to Info if everything is working correctly.

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

Figure 40: IOS-XR Adapter - General Tab

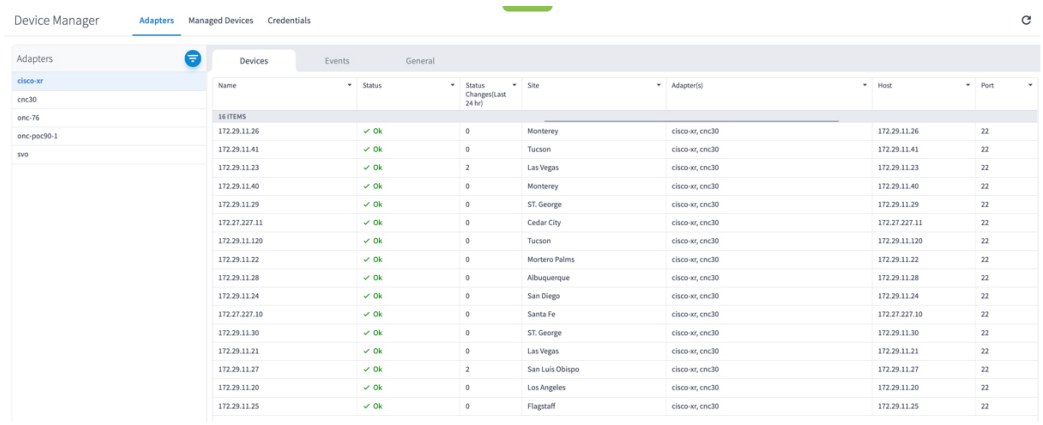


522155

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

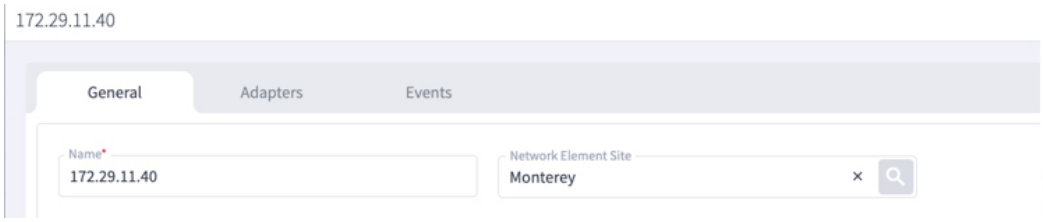
Sample End-to-end Configuration

Figure 41: IOS-XR Adapter - Devices Tab



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

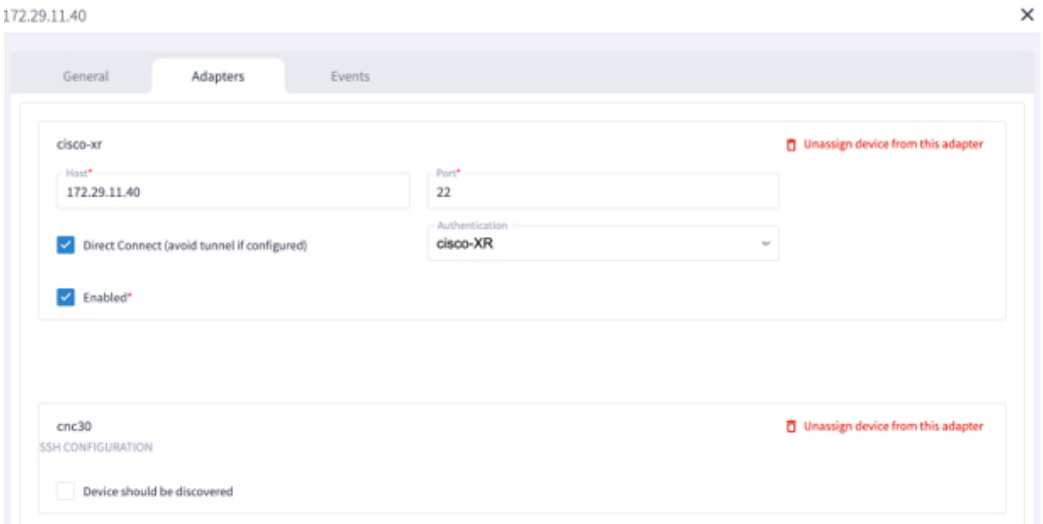
Figure 42: IOS-XR Adapter -Add New Device - General Tab



It is recommended to use the hostname+hco (ron-8201-1-hco) or the device IP address. The device must be assigned a site for it to be displayed in the Explorer UI.

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

Figure 43: IOS-XR Adapter -Add New Device - Adapters Tab

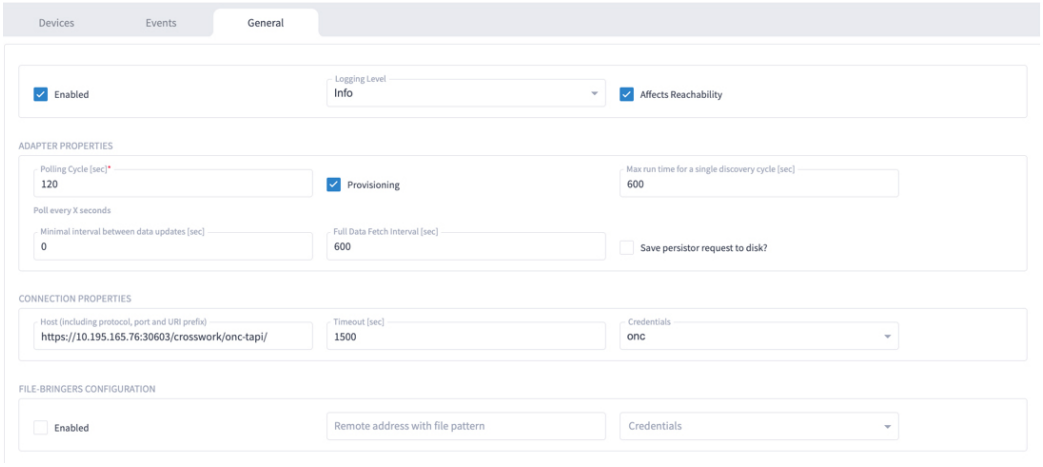


Sample End-to-end Configuration

- **Cisco Optical Network Controller Adapter**

Figure 44: Cisco Optical Network Controller Adapter - General Tab

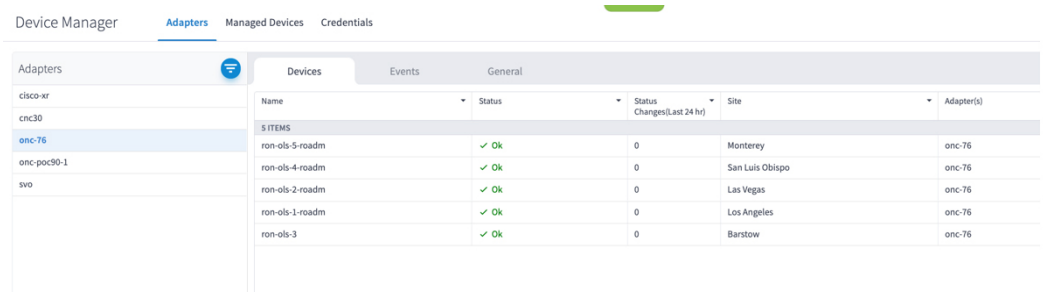
The Polling cycle must be set to 300s or higher in a production network. Polling retrieves TAPI SIPs, topology, and connectivity services. The URL in the following figure is for the Cisco Optical Network Controller cApp installed on the CW cluster.



522159

The optical nodes are discovered automatically from Cisco Optical Network Controller. Nodes must be assigned a site for it to be displayed in the Explorer UI.

Figure 45: Cisco Optical Network Controller Adapter - Devices Tab



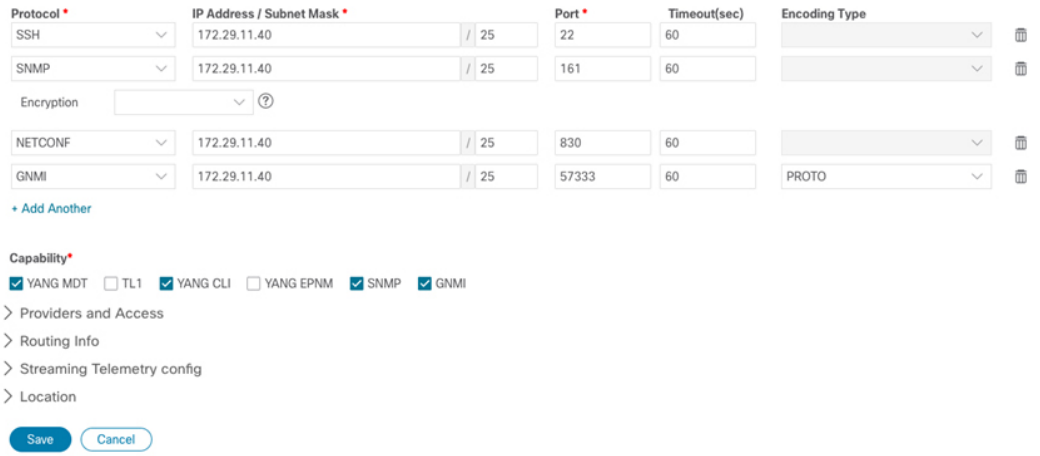
522160

- **Crosswork Network Controller Crosswork Data Gateway Adapter**

Crosswork Network Controller Crosswork Data Gateway adapter is used to collect telemetry data via gNMI 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.

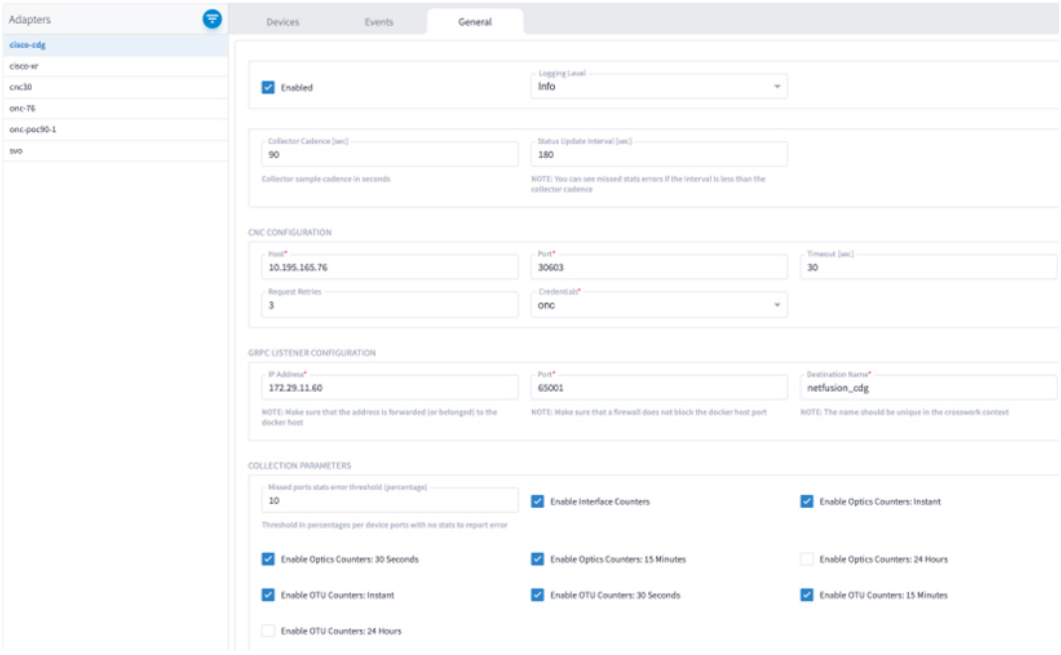
Sample End-to-end Configuration

Figure 46: 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.

Figure 47: 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 setup by Cisco Crosswork Hierarchical Controller and user interaction is not required. 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 48: Crosswork Network Controller Crosswork Data Gateway Adapter - Data Destinations

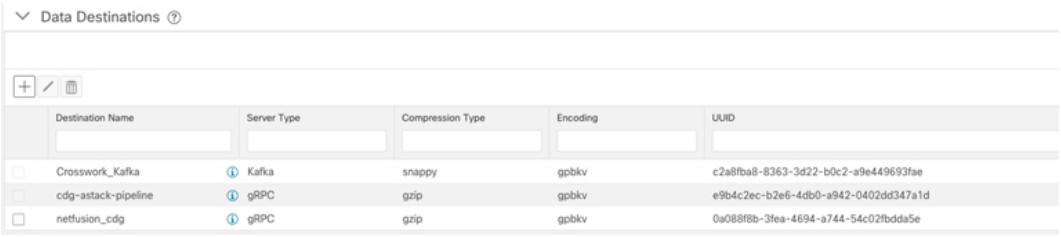
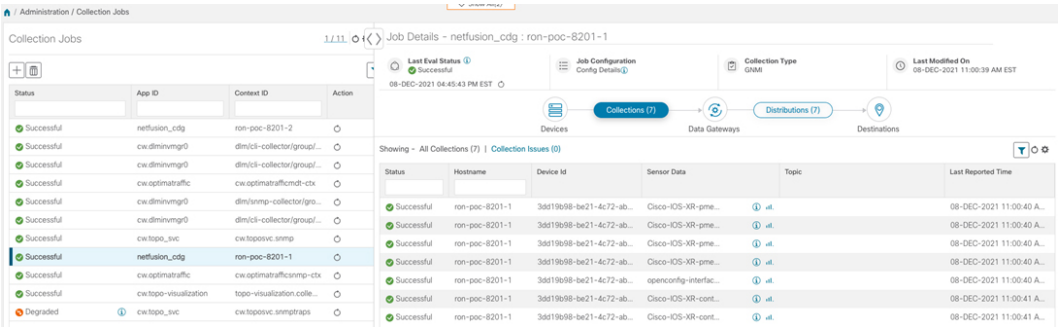


Figure 49: Crosswork Network Controller Crosswork Data Gateway Adapter - Collection Jobs

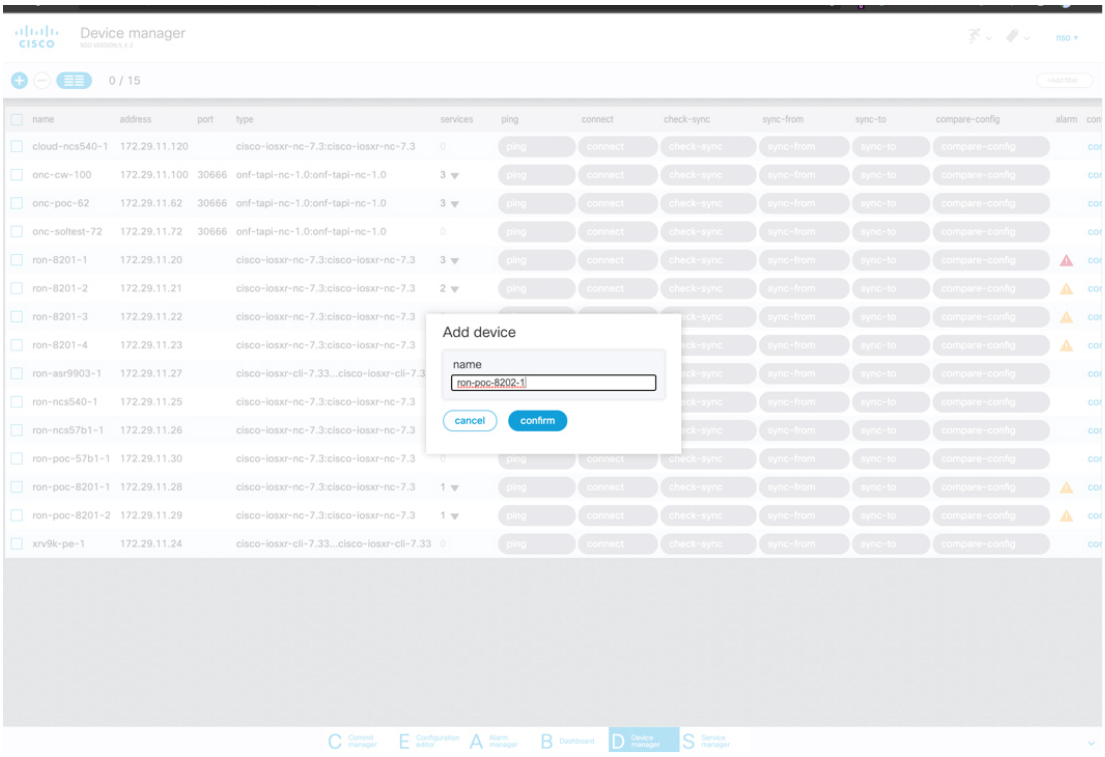


Provision ML Service Using NSO Routed Optical Networking CFP

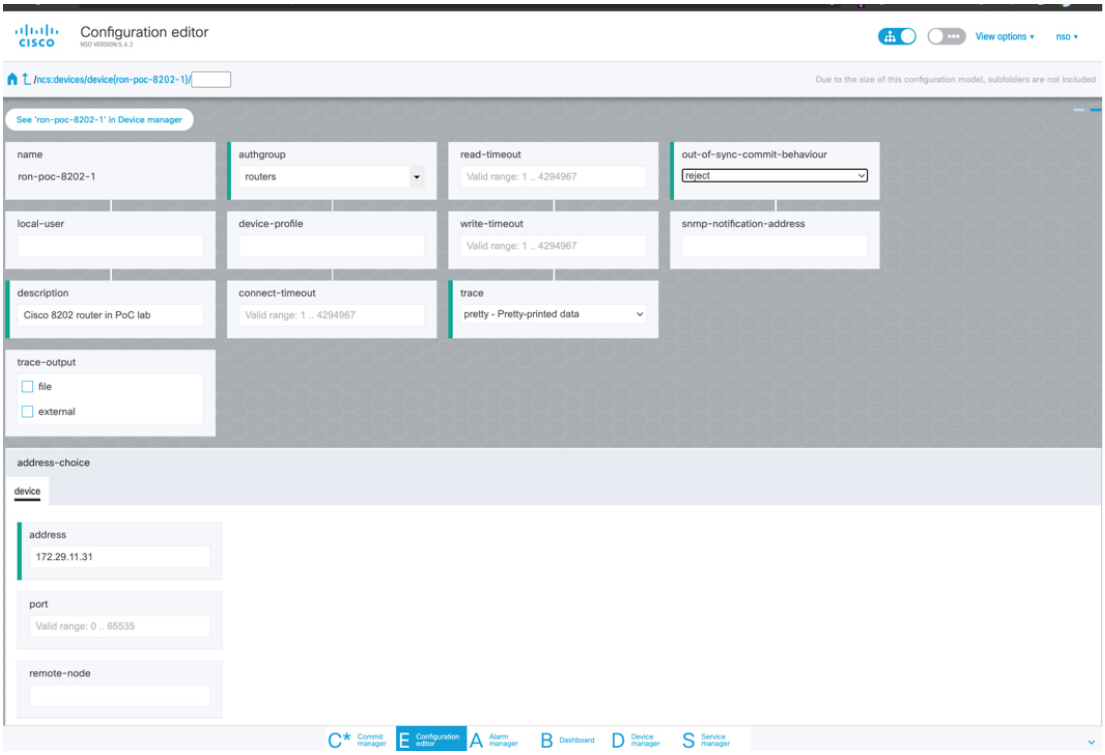
Perform the following steps to provision the Routed Optical Networking ML service using the NSO Web UI.

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. Click **Confirm**.

Sample End-to-end Configuration

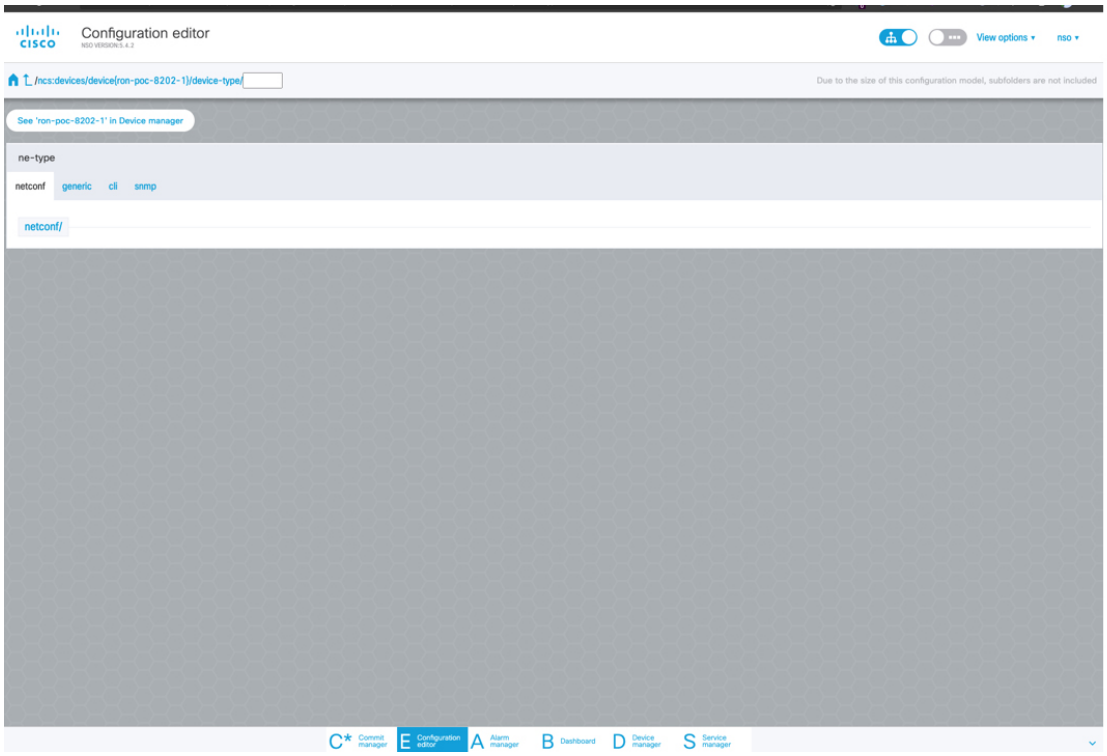


b. After creating the new device, click the device name to fill required and optional parameters. In this screen, the required parameters are the authgroup and IP address of the device.



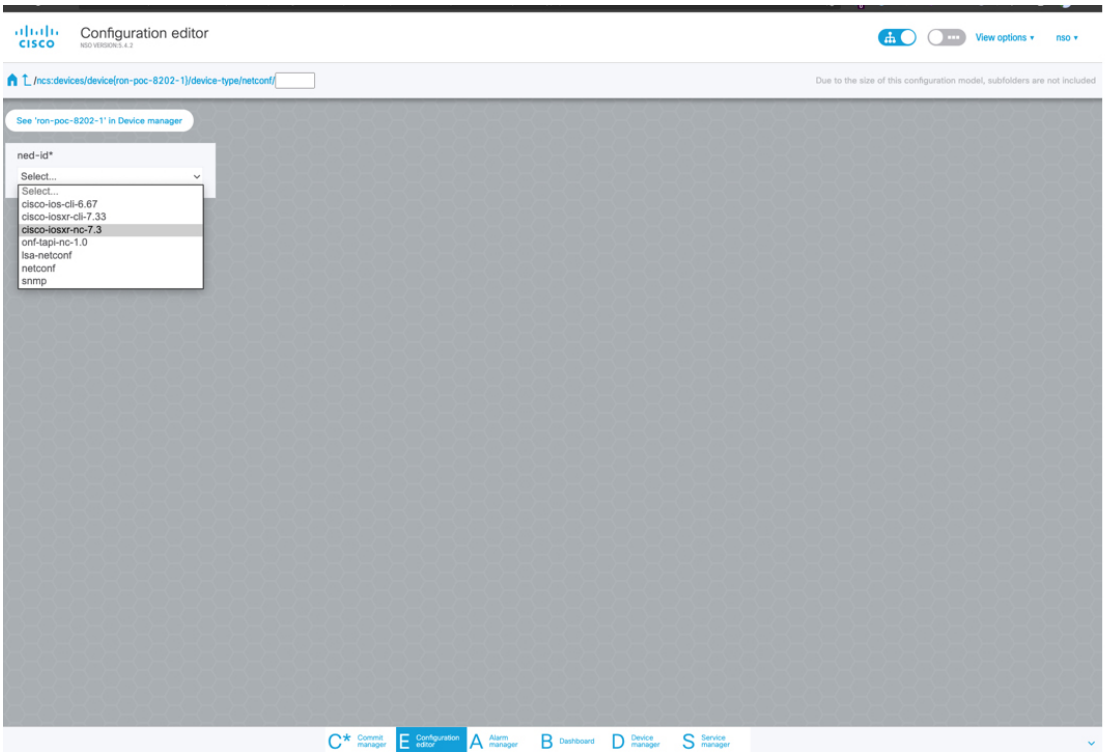
Sample End-to-end Configuration

c. Scroll down in the device configuration screen. Click the “device-type” to bring up the device type selection screen. The device-type that is supported in the Routed Optical Networking ML FP is IOS-XR CLI NED.



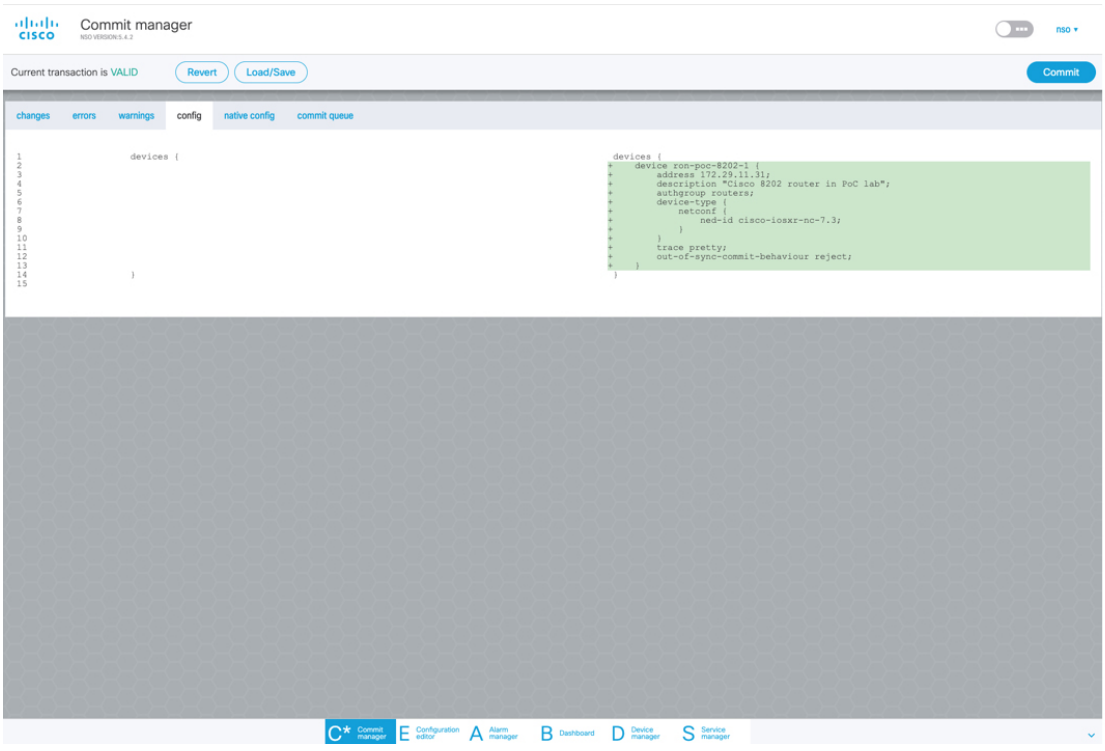
d. Click the blue NETCONF text to select the proper NED. The Routed Optical Networking ML FP requires the use of the **cisco-iosxr-nc-7.3** NED.

Sample End-to-end Configuration



521938

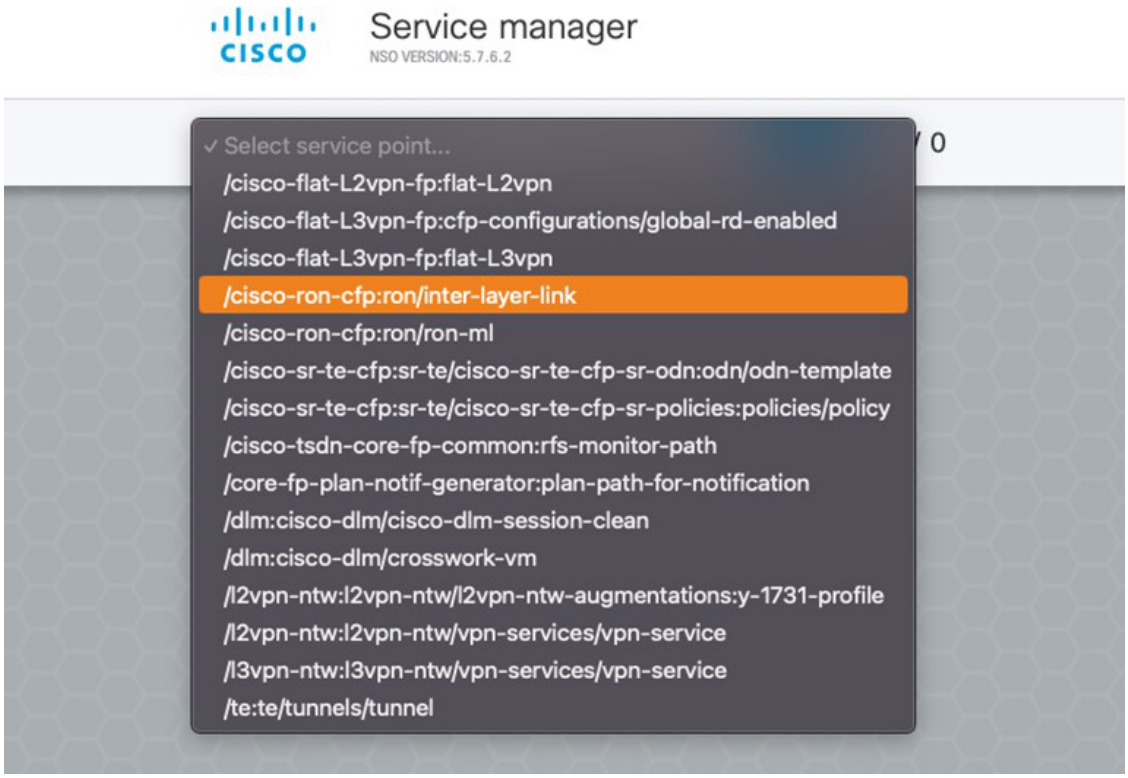
e. Click the Commit manager to view the NSO CLI configuration being applied. Click **Commit** to save the device configuration to NSO.



521939

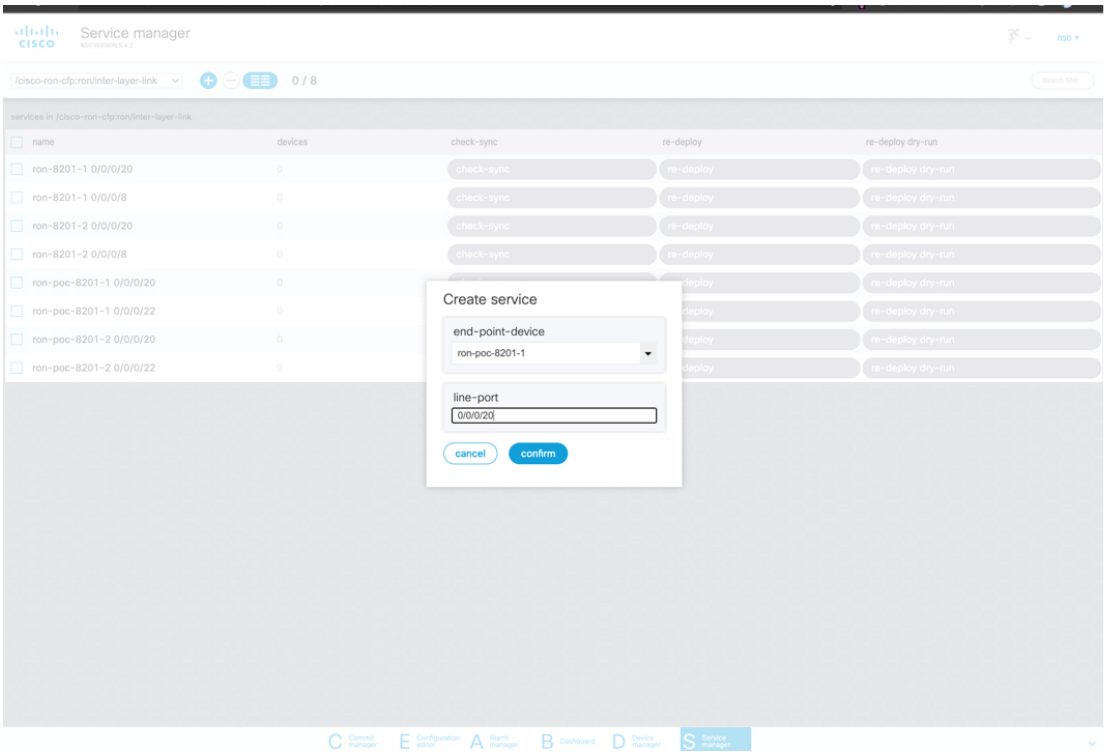
2. To configure the interlayer link service in NSO, perform these steps:

a. In the Service manager, select the inter-layer-link service point from the drop-down list.



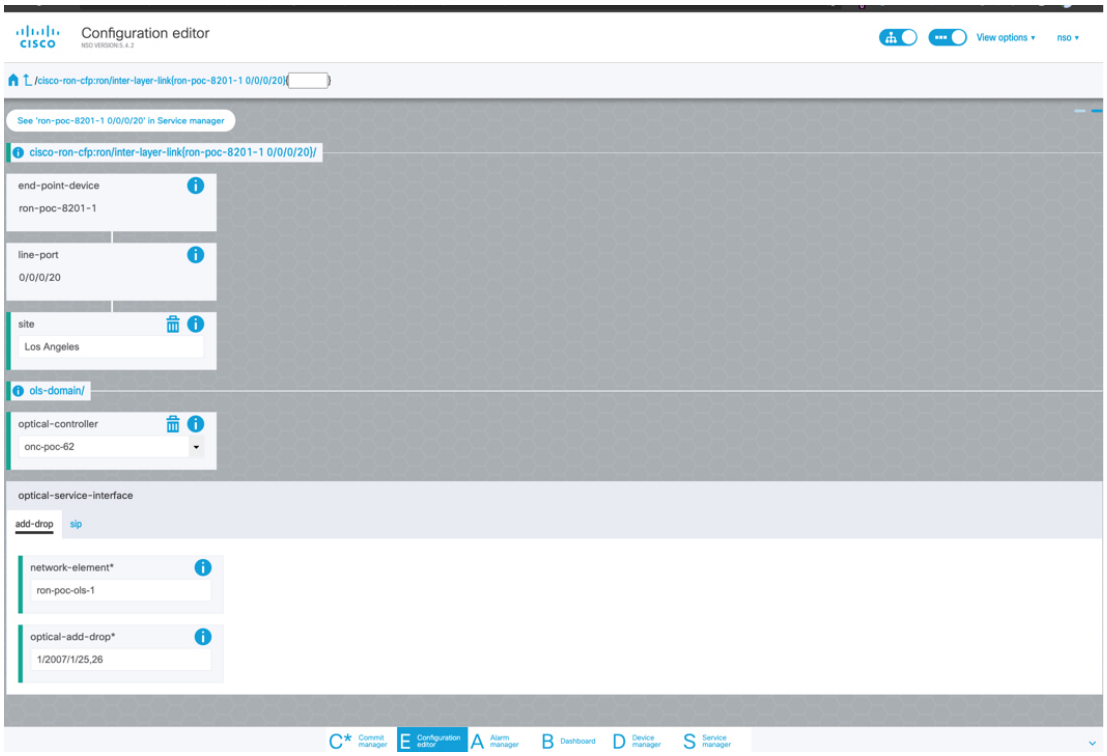
b. Specify the end-point-device and the line-port. These are required values. The end-point-device is the 8201 router. Specify the router optics port that is connected to the optical line system add/drop port in the line-port field. Click **Confirm**.

Sample End-to-end Configuration



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 the Optical Network Controller instance to be 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 corresponds with the inventory ID of the physical port on the NCS1K-MD-64-C multiplexer corresponding to a frequency XXXX.YY. Both the RX and TX directions are included as part of the add/drop reference. 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

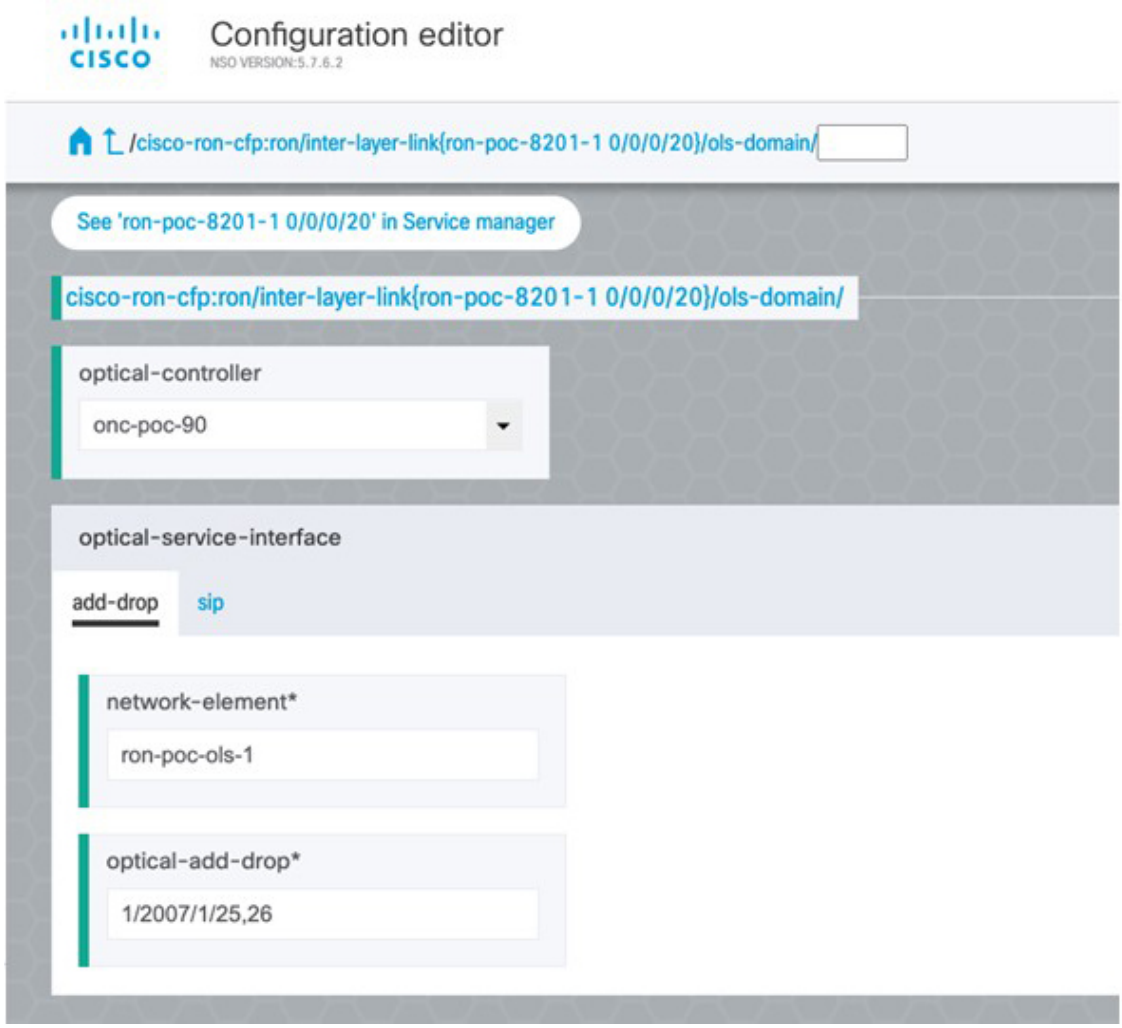


These elements are the only required elements in the inter-layer-link service type.

d. Perform Ols-domain optical-service-interface configuration.

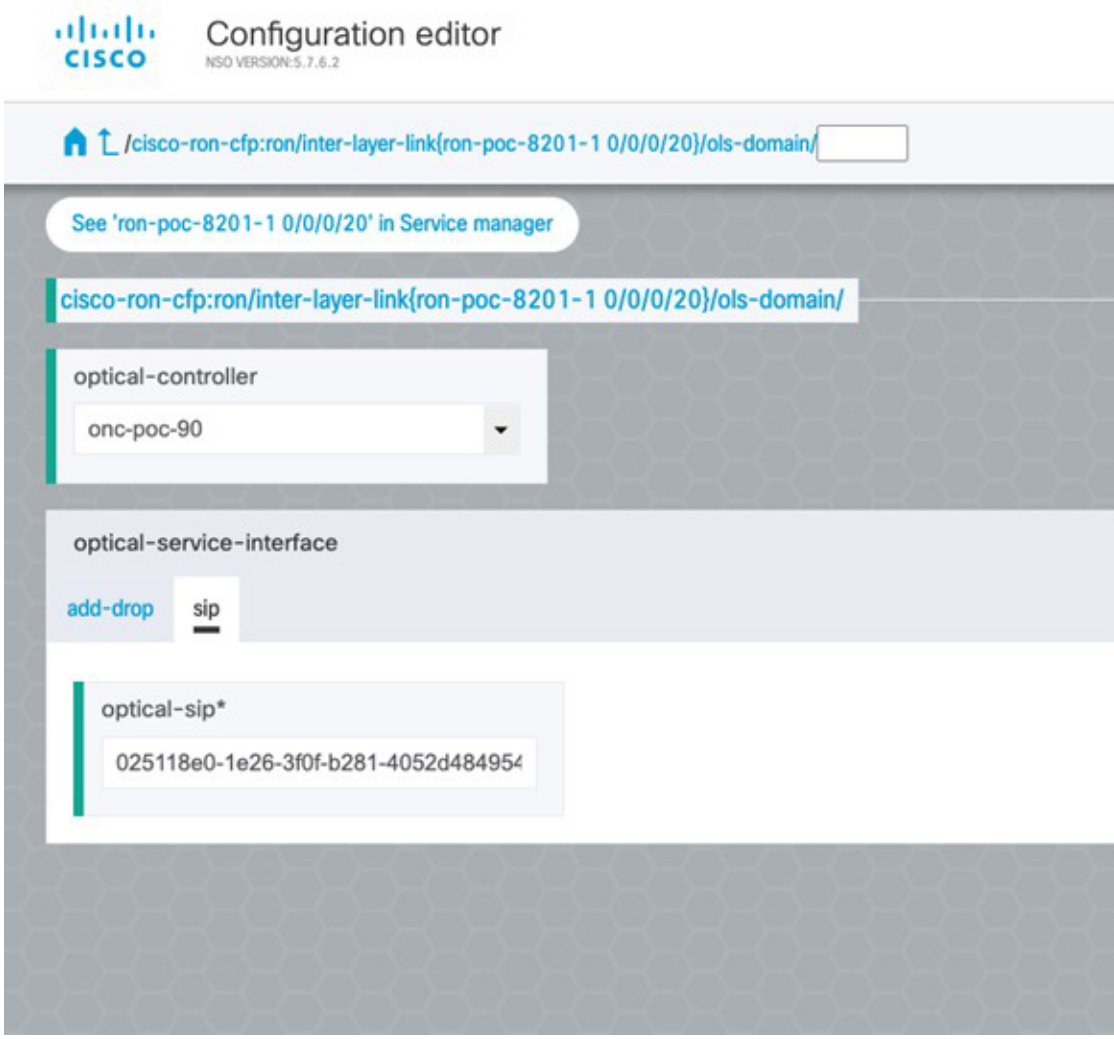
- Optical-controller specifies the Cisco Optical Network Controller instance managing the OLS.
- Network-element specifies the optical element name as show in TAPI topology.
- Optical-add-drop specifies the port to be used on the optical network element.

Sample End-to-end Configuration

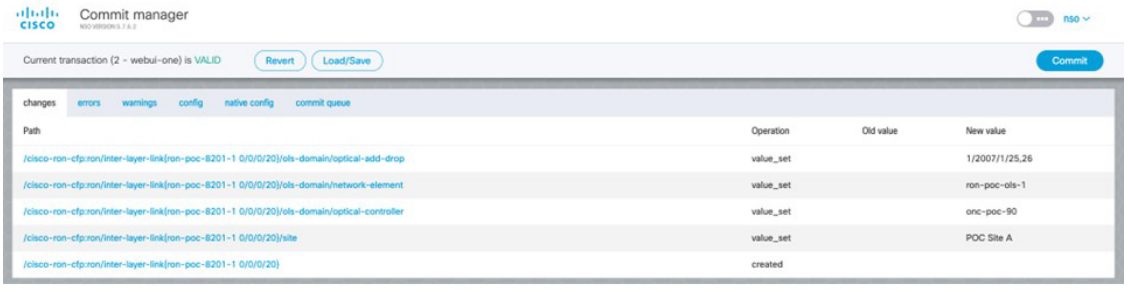


- The optical-service-interface can also be added as a TAPI SIP UUID.

Sample End-to-end Configuration

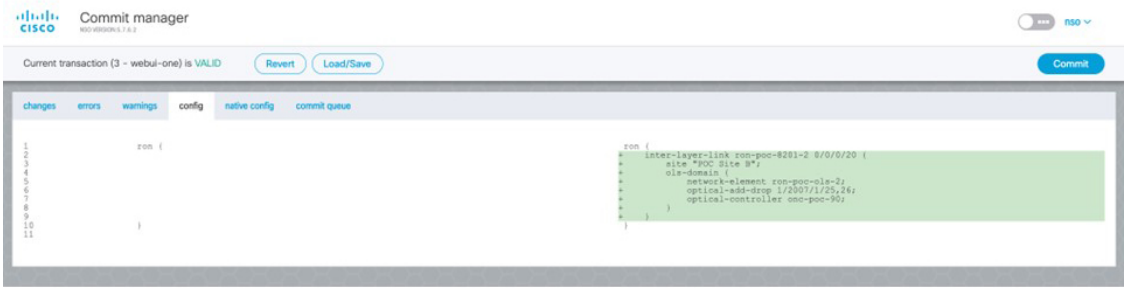


e. Click the config tab in the Commit manager to see the NSO CLI configuration that will be committed to NSO.

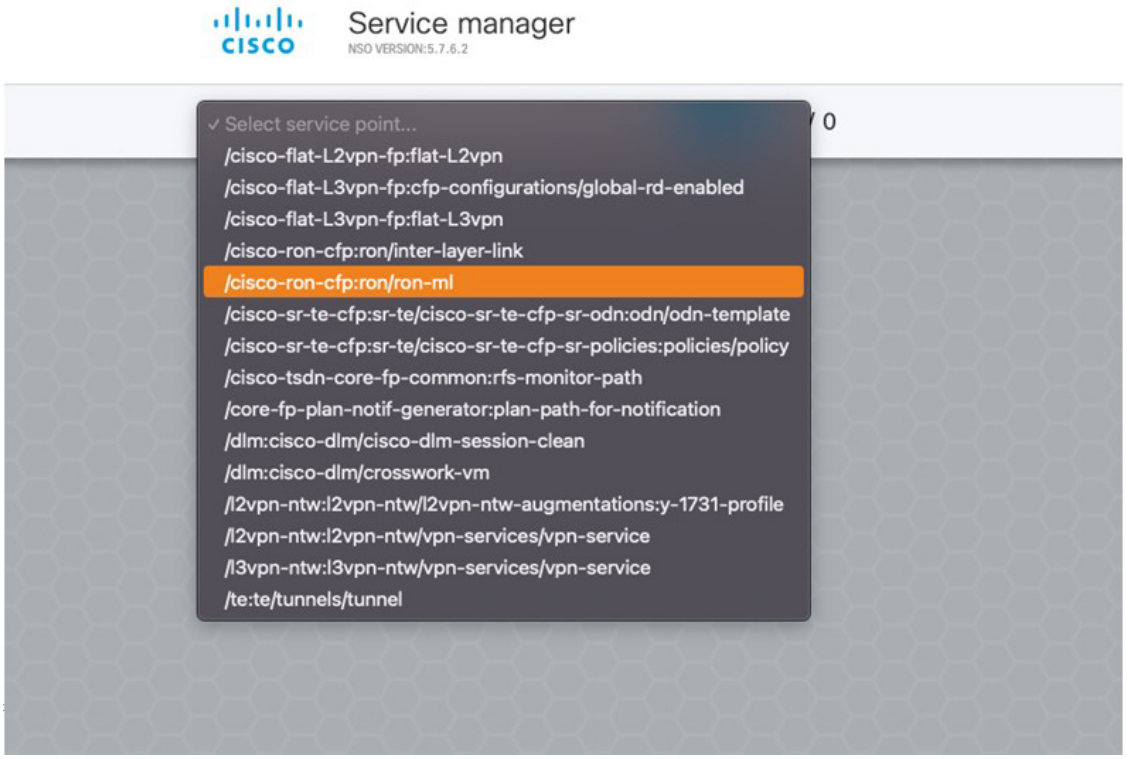


f. Click **Commit** in the upper right corner to commit the service. An end-to-end service requires two inter-layer-links, one for each router connected to its optical line system add/drop port.

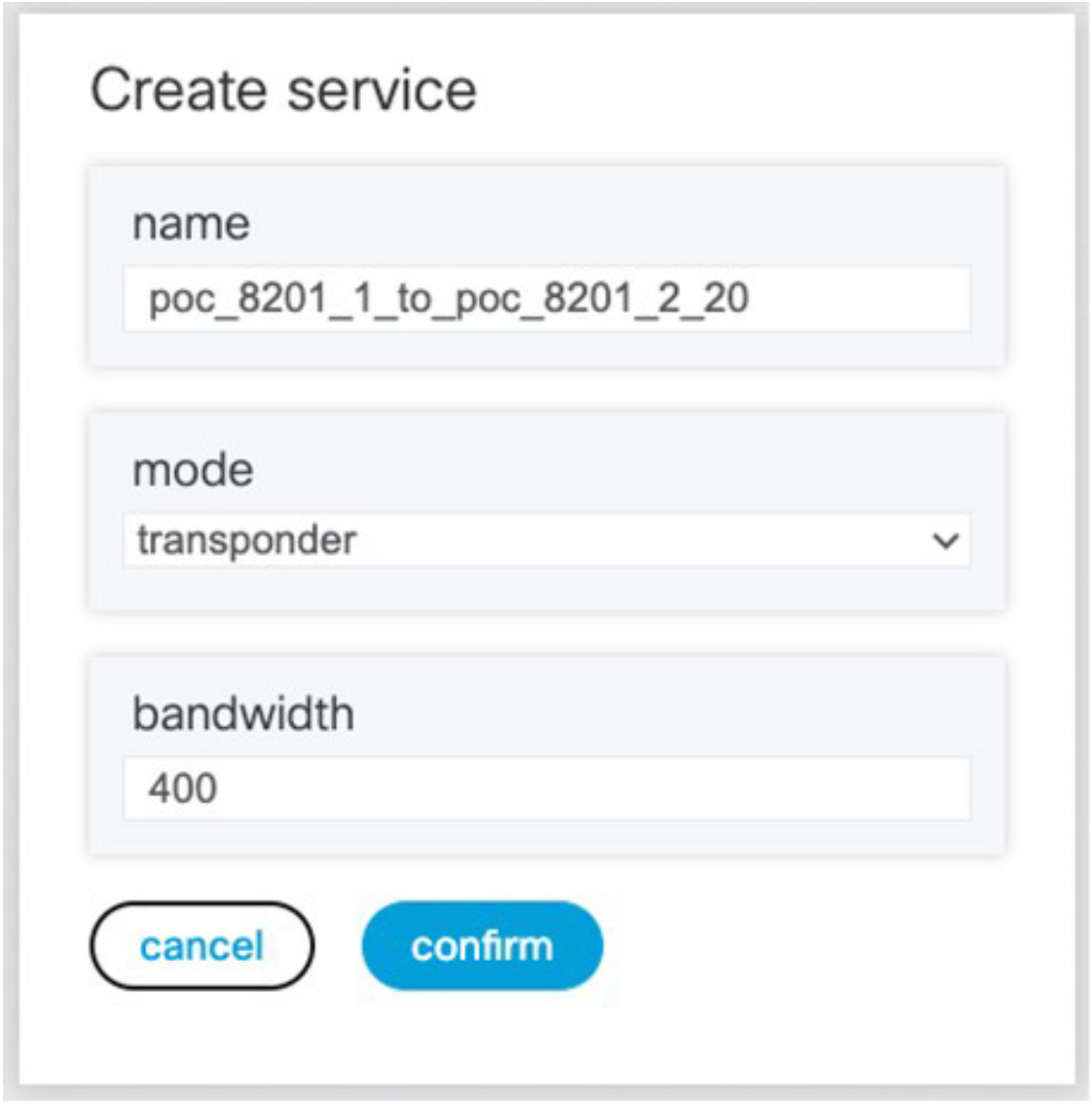
Sample End-to-end Configuration



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.



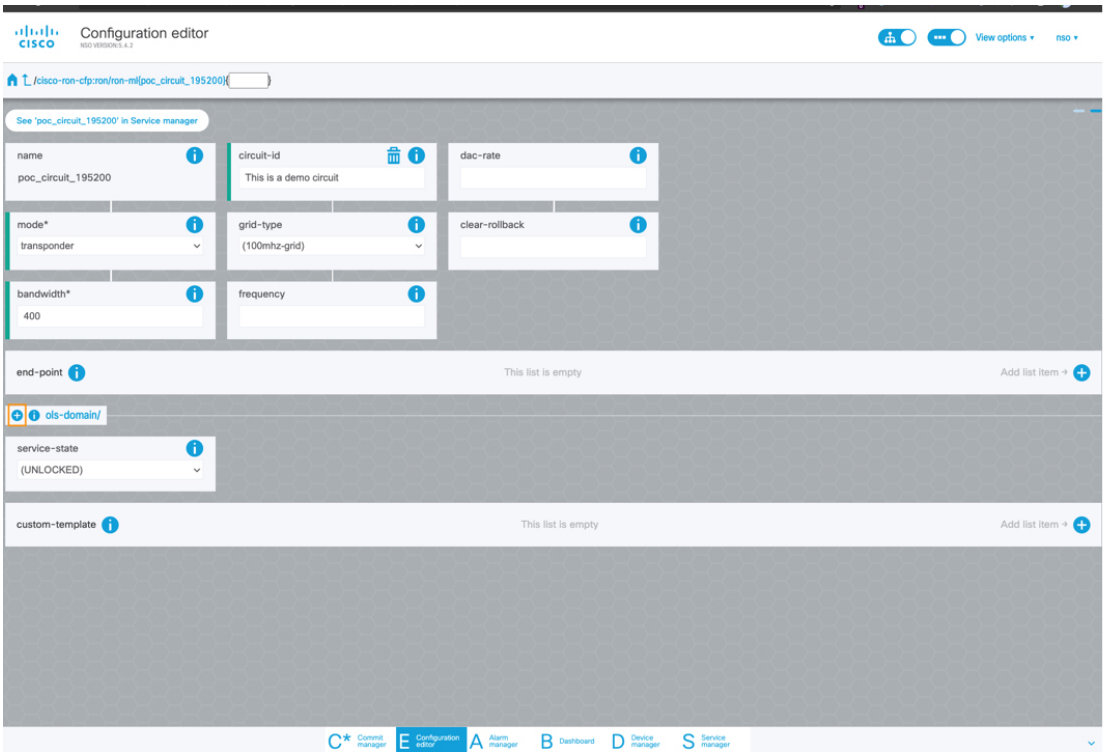
3. To create Routed Optical Networking ML service, perform these steps:
   a. In the Service manager, select the Routed Optical Networking ML service point from the drop-down list. When we create the new Routed Optical Networking ML service, the required components are the service name, mode of the service (transponder or muxponder), and the bandwidth. The bandwidth corresponds to the line rate of the ZR/ZR+ optics. Click **Confirm**.



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, we 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

Sample End-to-end Configuration

is set to the default value.

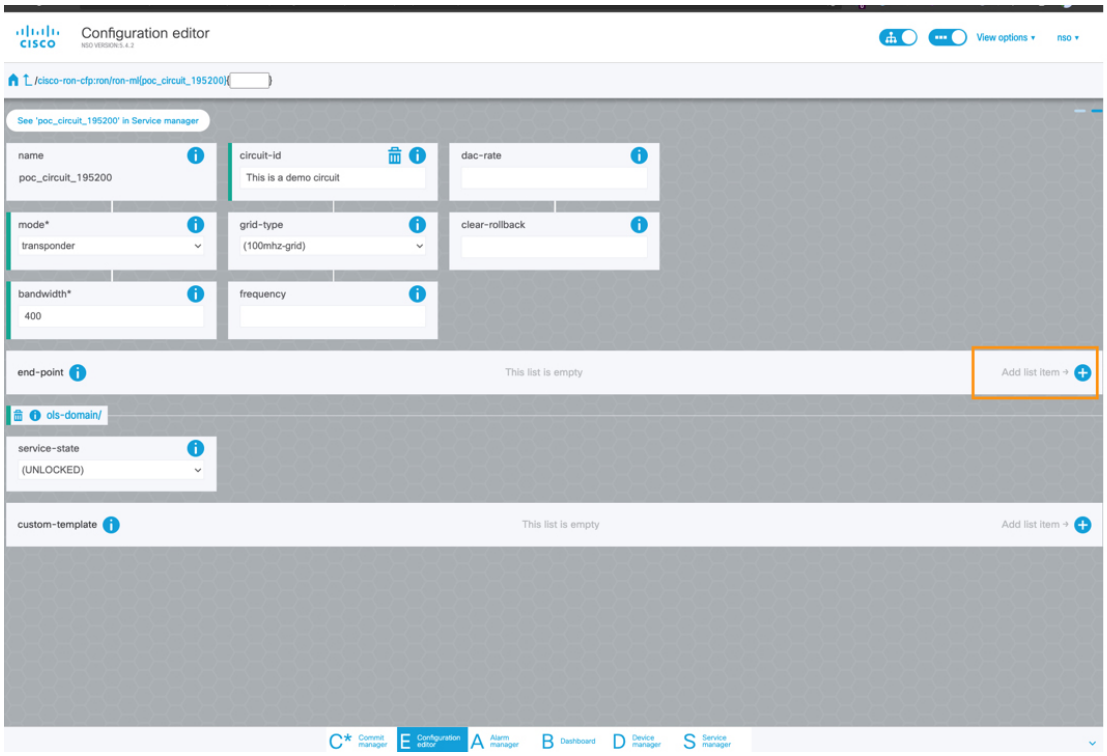


Note

- User configuration global options are frequency and dac-rate
- If OLS provisioning is being performed and OLS can provide the frequency, it is optional, otherwise frequency must be provided.
- Dac-rate controls the TX shaping parameters: 1x1.25 = enabled, 1x1 = disabled. Leaving it blank uses system default of enabled, and can be used in most circumstances

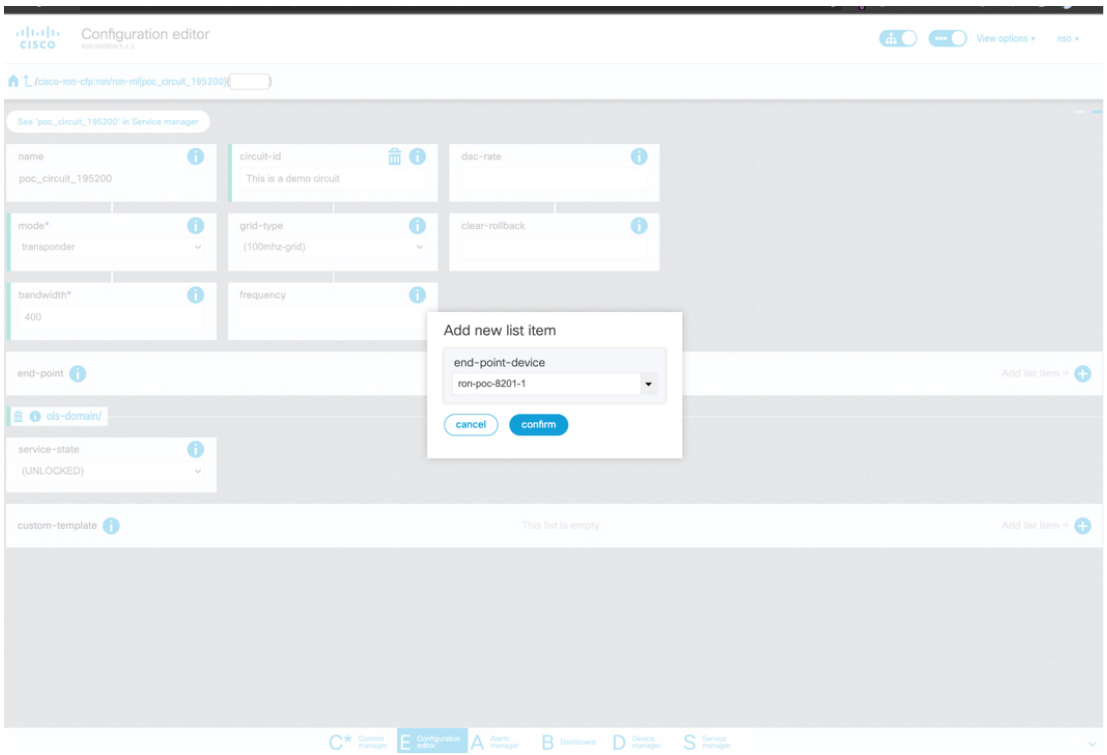
c. After the ols-domain is added, you must add end-points to the circuit. Two end-points are always required. The end-points are the routers with ZR/ZR+ optics.

Sample End-to-end Configuration



521927

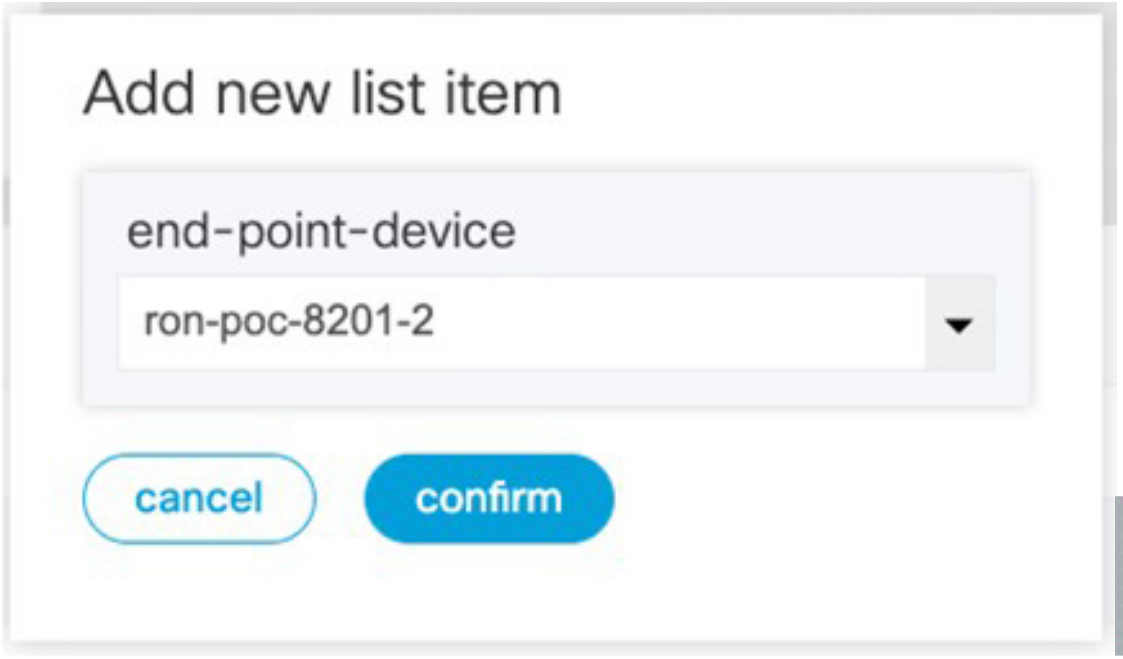
d. Add the end-point-device to the service. Click **Confirm**.



521928

Sample End-to-end Configuration

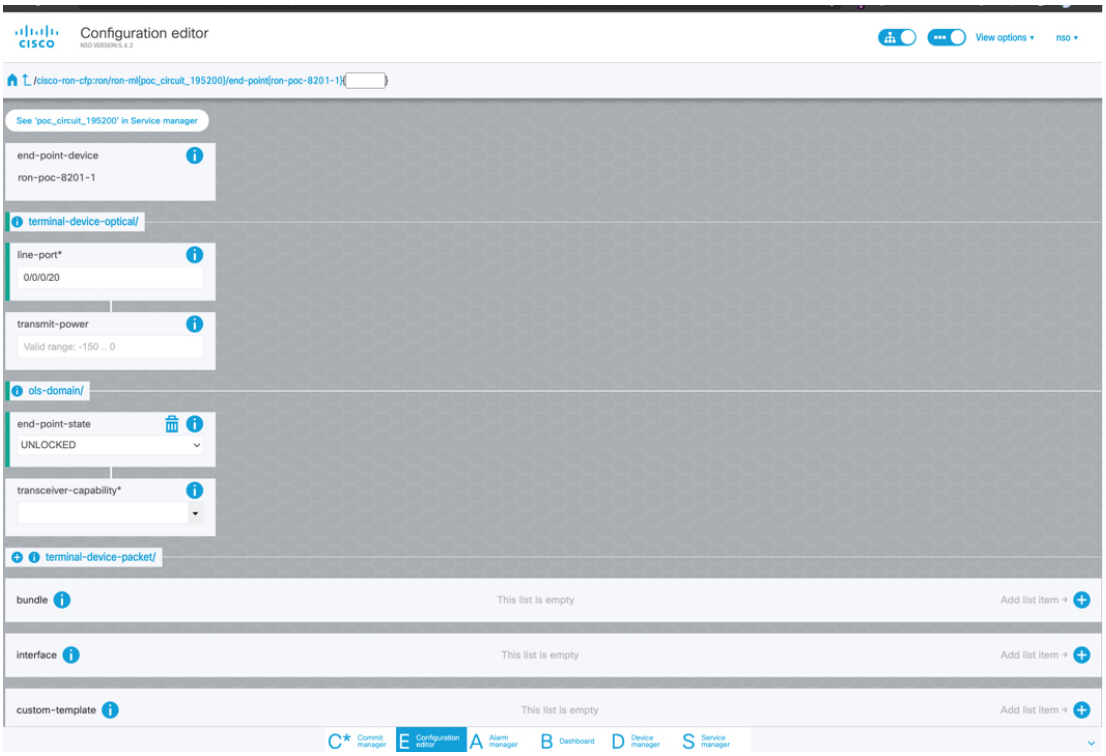
After the end-point is created, click the end-point to edit the end-point parameters. The line-port is a required parameter and refers to the optics port on the router. In this example, this is the same as the line-port specified in the inter-layer-link service for the end-point router.



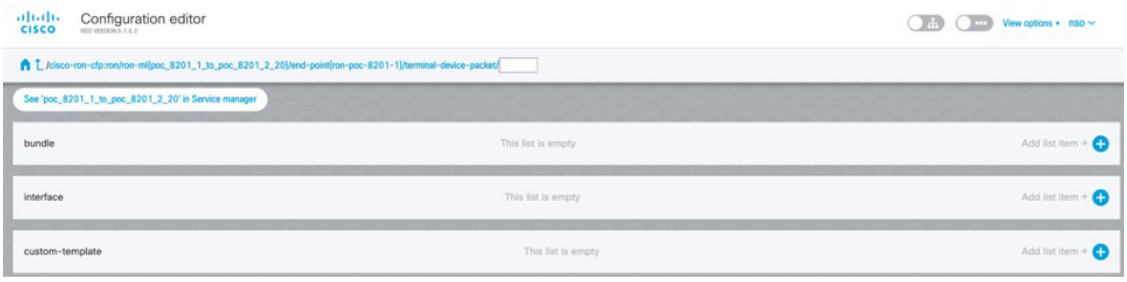
The transmit-power is an optional parameter for end-to-end provisioning. If it is omitted the optical controller (Cisco Optical Network Controller) will provide the transmit power. Transmit power sets the transmit power, the value is in 100*value in 0.1dBm increments. For example, –100 is -10dBm. If no value is specified the default of -10dBM is used for QDD-400G-ZR-S or QDD-400G-ZRP-S, or 0dBm 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 end-point to go back to the top-level endpoint configuration, click **terminal-device-packet** to configure Ethernet/IP parameters



Note

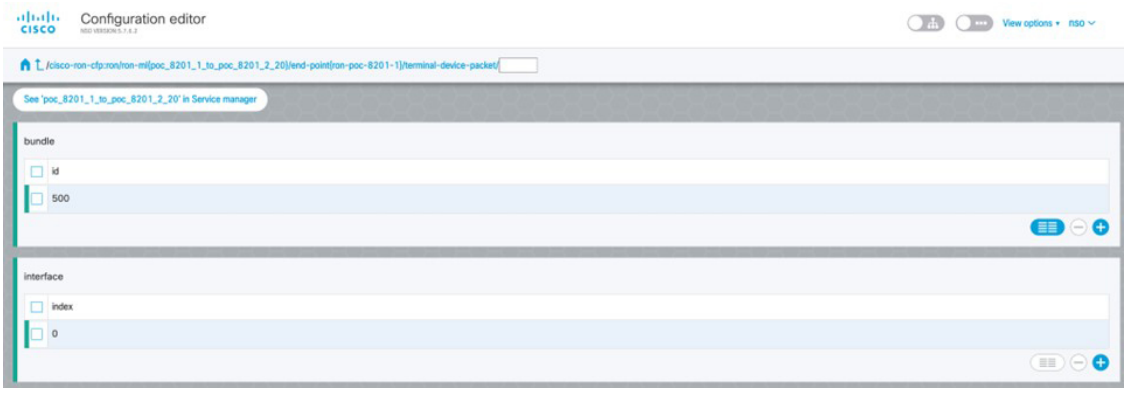
- Ethernet/IP configuration is optional.
- Bundle configuration adds an interface to an existing bundle or creates a new bundle and adds the newly created IP interface to it.

  Interface configuration is used for configuring IP address parameters on newly created Ethernet interfaces.

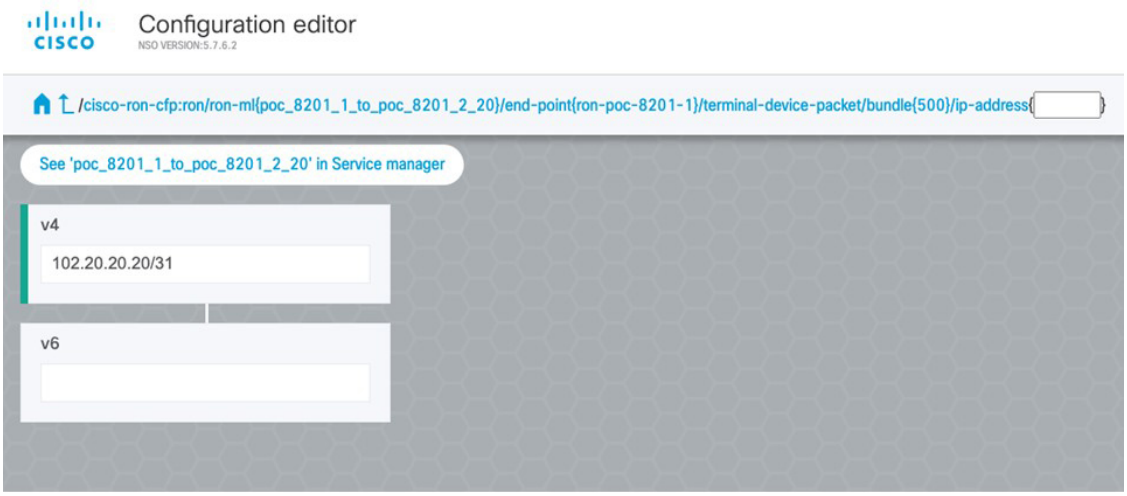
  In this example we add a new Bundle and assign an IP address to the Bundle.

f. Click the plus sign next to bundle to add a bundle, in this case with an identifier of 500. This creates a bundle interface Bundle-Ether 500 on the endpoint router

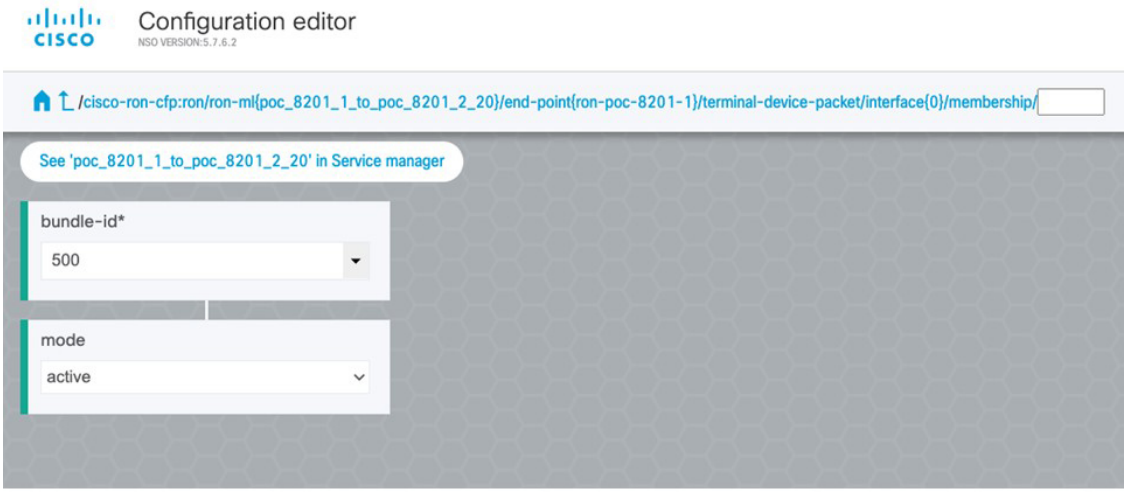
The interface index for a bundle use case is always 0. In case of a non-bundle configuration in muxponder mode, the index can be 0–3 representing the number of interfaces created as part of the muxponder configuration.



g. Click the bundle number and *ip-address* to configure an IP address on the bundle.



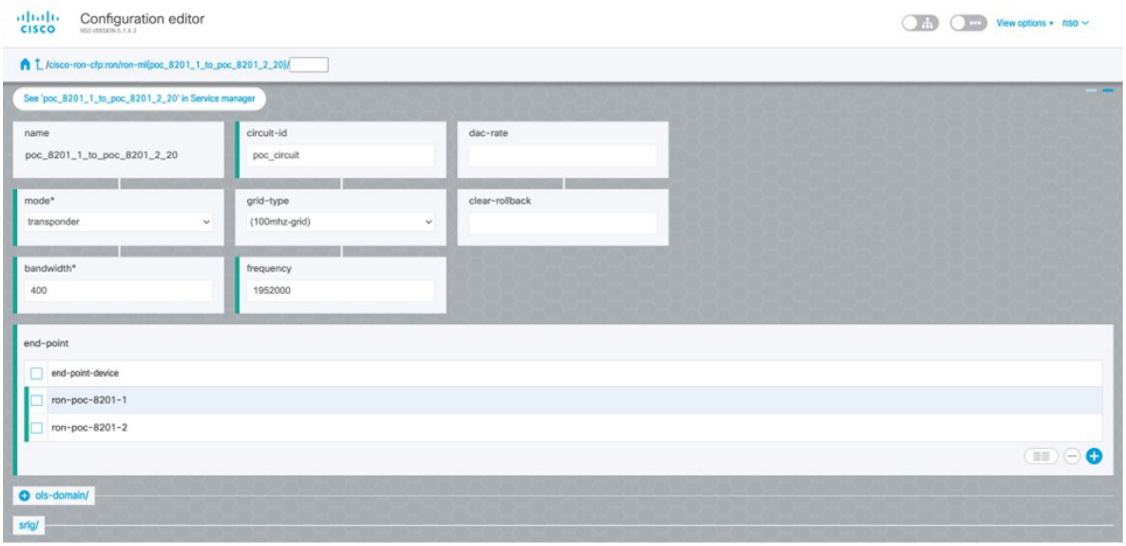
h. Return to the top-level endpoint configuration, select the index 0 previously created and click **membership** to add the interface to the bundle



Note

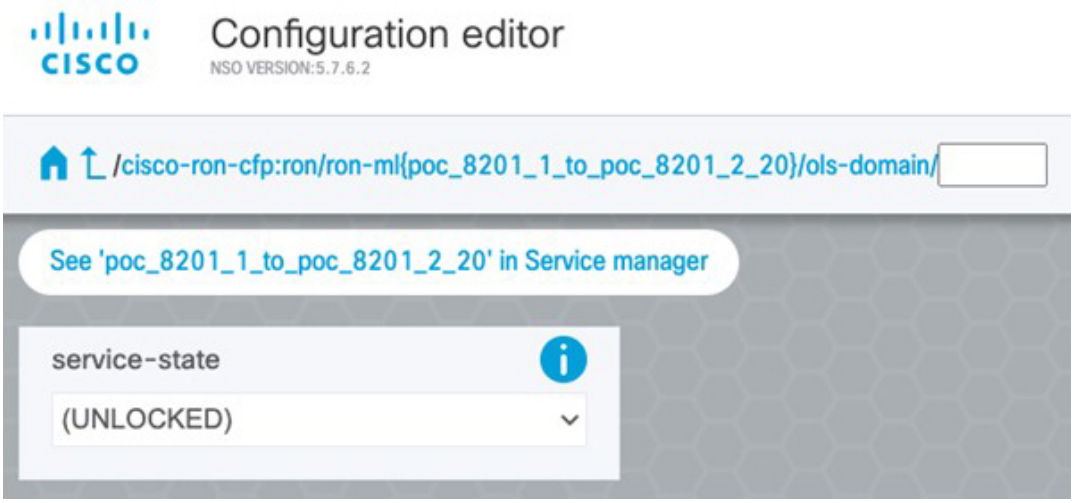
- Bundle-id selects the previously created bundle.
- Mode sets the bundle LAG signaling mode. Active=LACP, passive=LACP listener only, on=No active signaling, inherit=Inherit signaling from Bundle interface configuration. Default is active.

i. Return to the top level of the service configuration and similarly configure the second endpoint.

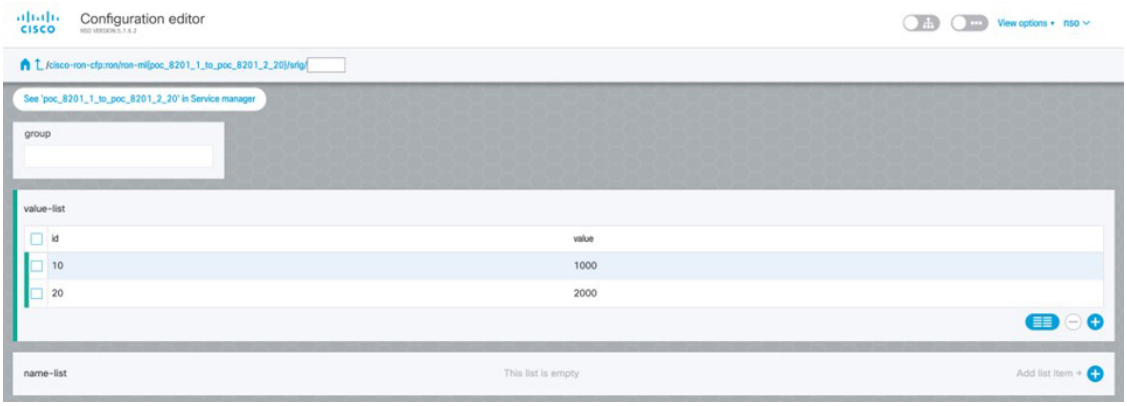


j. Click **ols-domain** to enable OLS provisioning through Cisco Optical Network Controller.

k. Select “Unlocked” under service-state, no additional configuration is necessary as all configuration needed for OLS provisioning is part of the interlayer link and the rest of the ron-ml service.



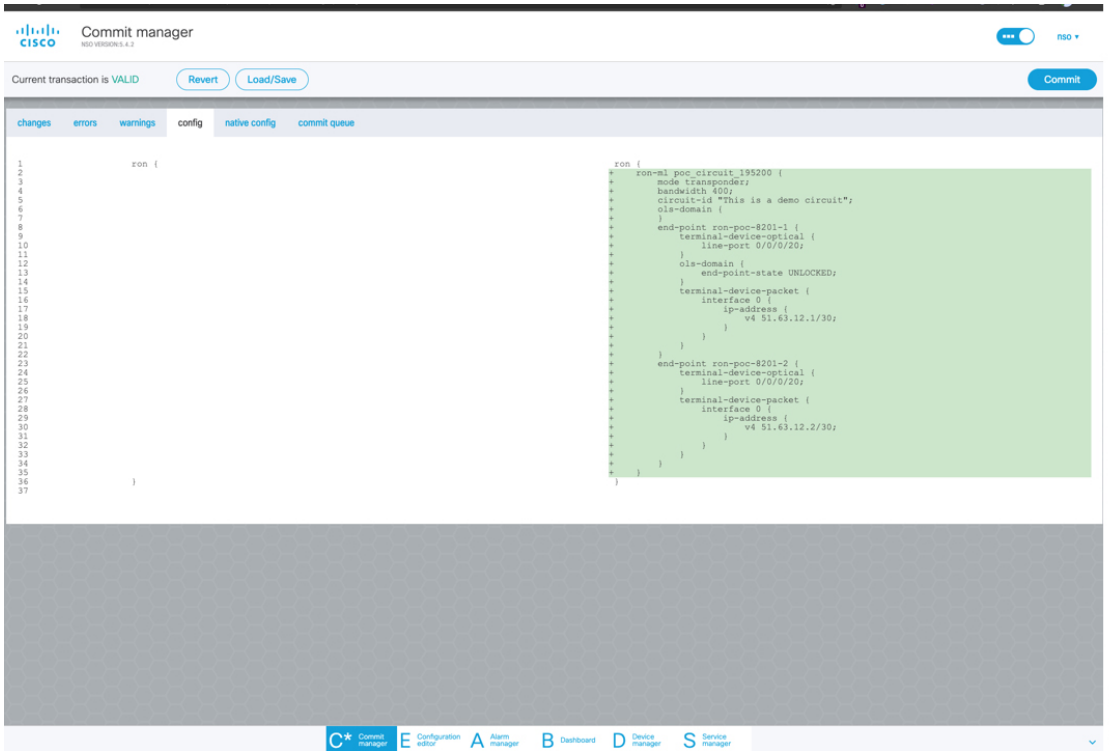
l. Click **SRLG** to perform SRLG configuration



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.

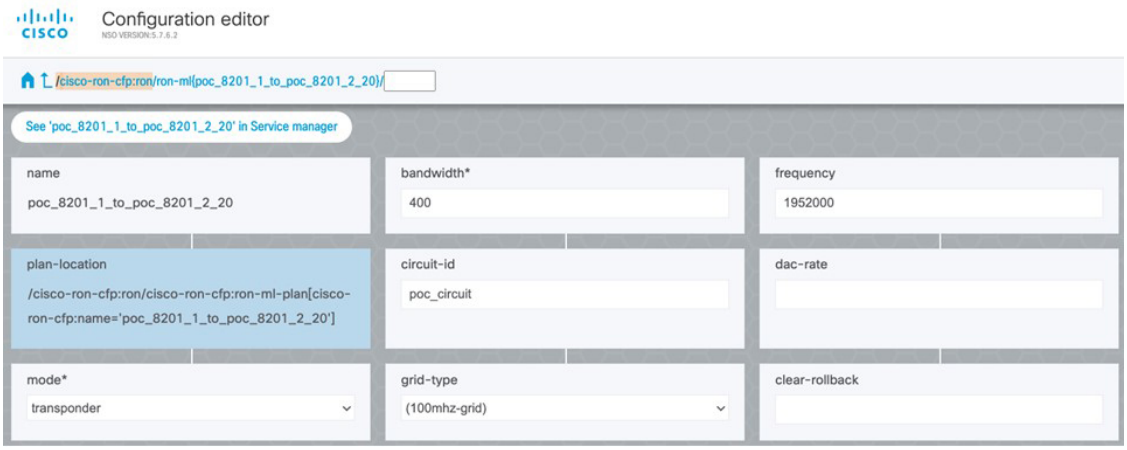
4. In the Commit manager, click the config tab. The NSO CLI configuration for the end-to-end service is displayed. If the ols-domain component is not specified in the global configuration, no optical line system provisioning is performed, only router provisioning. You can preview and then commit the configuration.



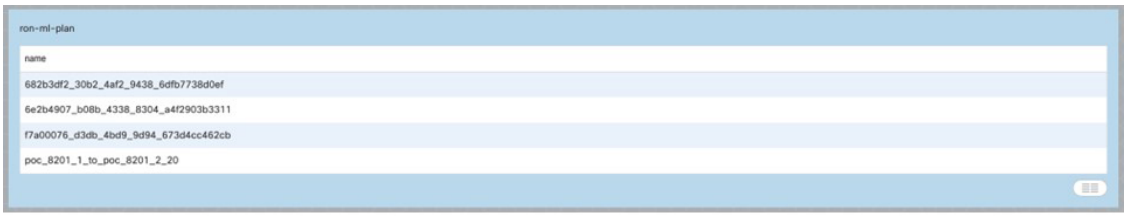
5. Verify status in NSO UI.

   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 the following image.

Sample End-to-end Configuration



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

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
```

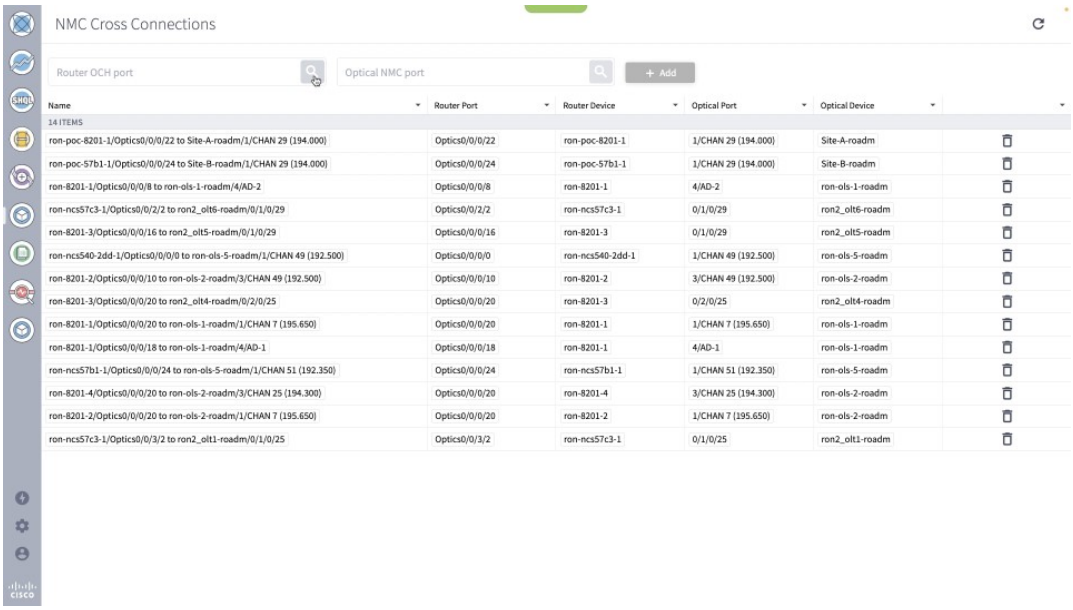
```
RP/0/RP0/CPU0:ron-poc-8201-1#show controllers optics 0/0/0/20
Mon Oct 17 09:57:25.475 PDT

 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 Routed Optical Networking ML Service Using Crosswork Hierarchical Controller

1. To create the router DCO port to the NMC cross-connect:

   a. In the applications bar in the Crosswork Hierarchical Controller, click the **NMC Cross Connections** icon.

   Figure 50: NMC Cross Connections



   The Network Media Channel (NMC) is the service across the optical line system of the network.

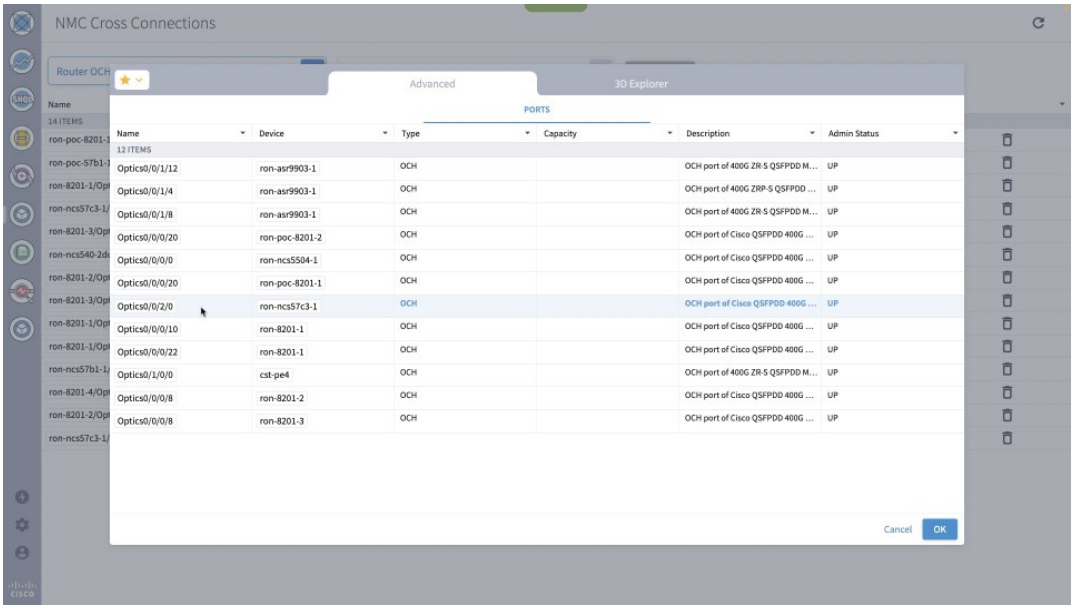
   b. Click the magnifying glass icon in the **Router OCH** port field.

   The application displays routers and ports with ZR/ZR+ transceivers in the **Advanced** tab in a new window. The description indicates whether it is a ZR or ZR+ transceiver.

   c. Select the router ZR/ZR+ optics interface. In this case, select ron-ncs57c3-1 0/0/0/20. Click **OK** after selecting the port. You can filter the selection criteria by clicking on the down arrow in each column.

Sample End-to-end Configuration

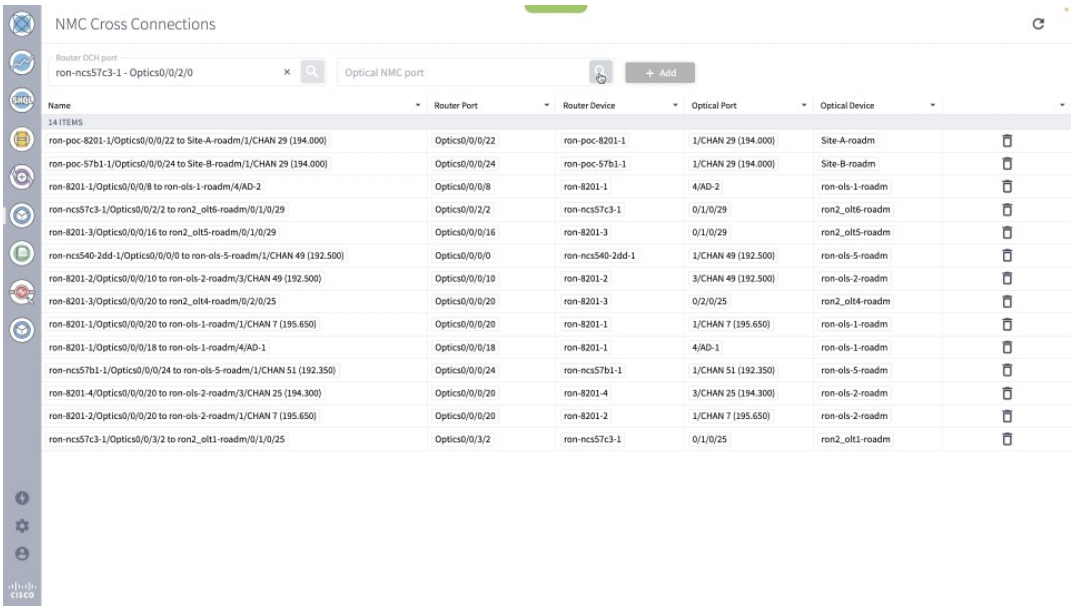
Figure 51: List of Routers with ZR/ZR+ Transceivers



d. Click the magnifying glass icon in the **Optical NMC port** field.

The app displays optical devices and ports. Due to the potentially long list of ports, it is best to filter the selection criteria.

Figure 52: Optical Add/drop Ports



Select the optical add/drop port. In this case, select 0/1/0/6 port on ron2_olt1 and click **OK**.

Sample End-to-end Configuration

Figure 53: Optical Add/drop Ports

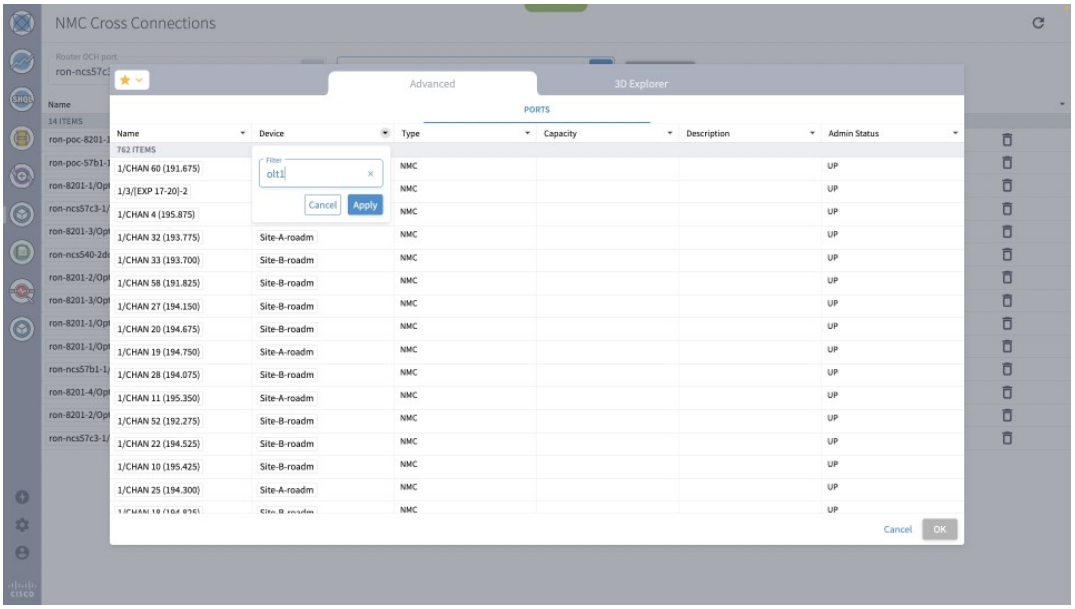
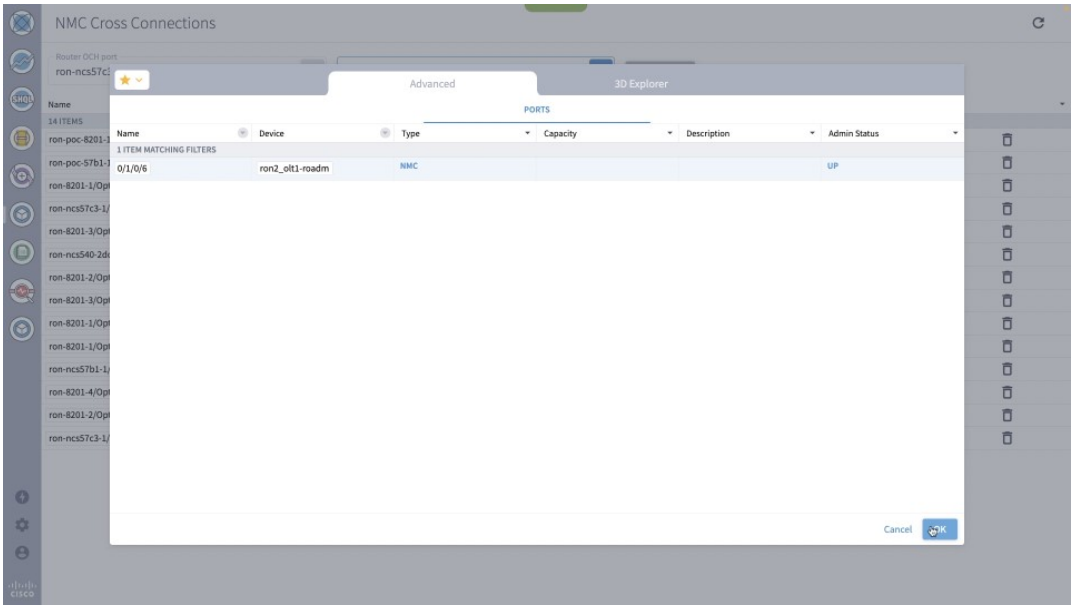


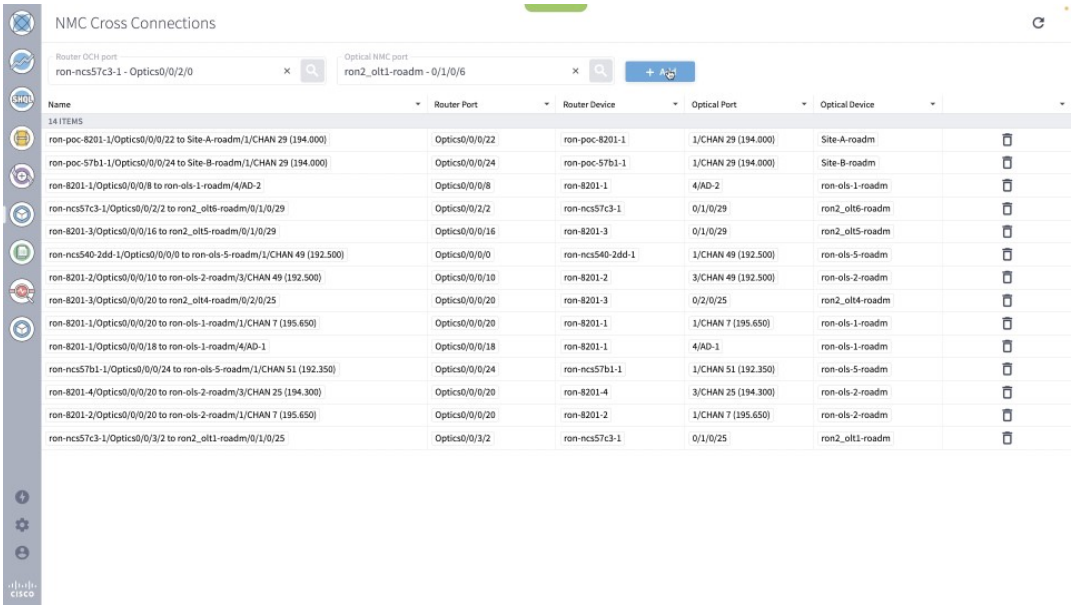
Figure 54: Optical Add/drop Ports



e. After the router and optical interfaces are selected, click **Add** to add the NMC cross-connect.

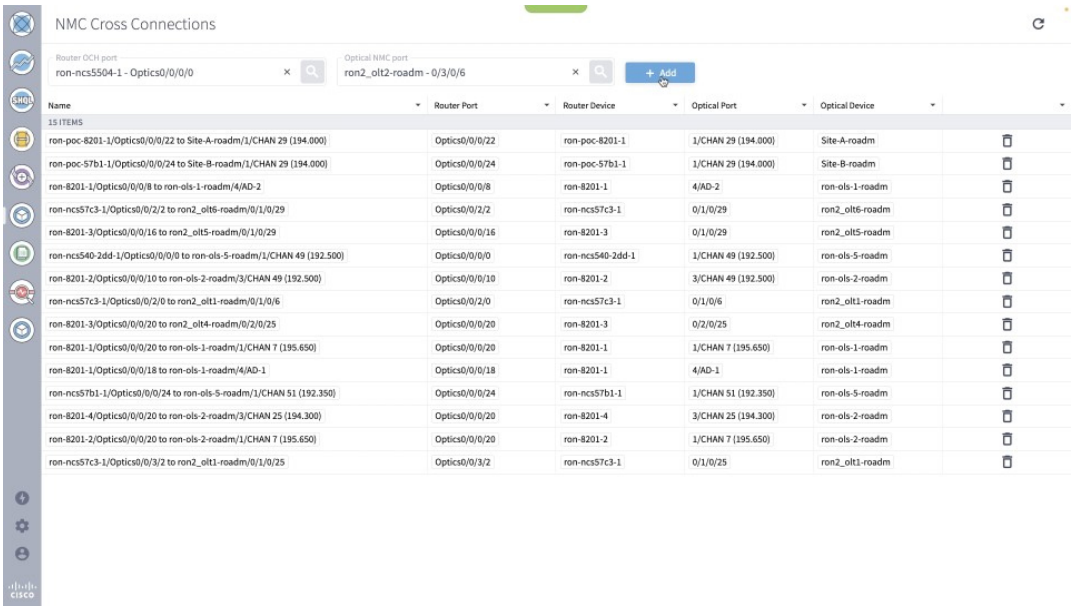
Sample End-to-end Configuration

Figure 55: NMC Cross Connection Creation



f. Select and add second router port, ron-5504-1 0/0/0/0 and OLS add/drop port, ron2_olt2 0/3/0/6.

Figure 56: Second Router Port and OLS Port

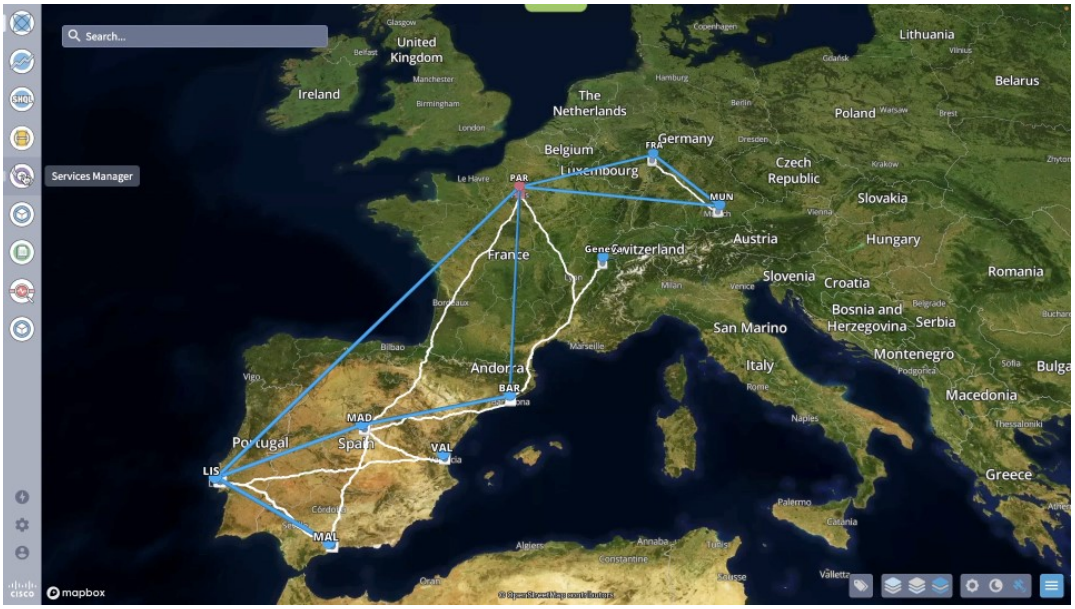


2. To provision the Routed Optical Networking IP link, perform these steps:

a. In the applications bar in the Crosswork Hierarchical Controller, click the **Services Manager** icon.

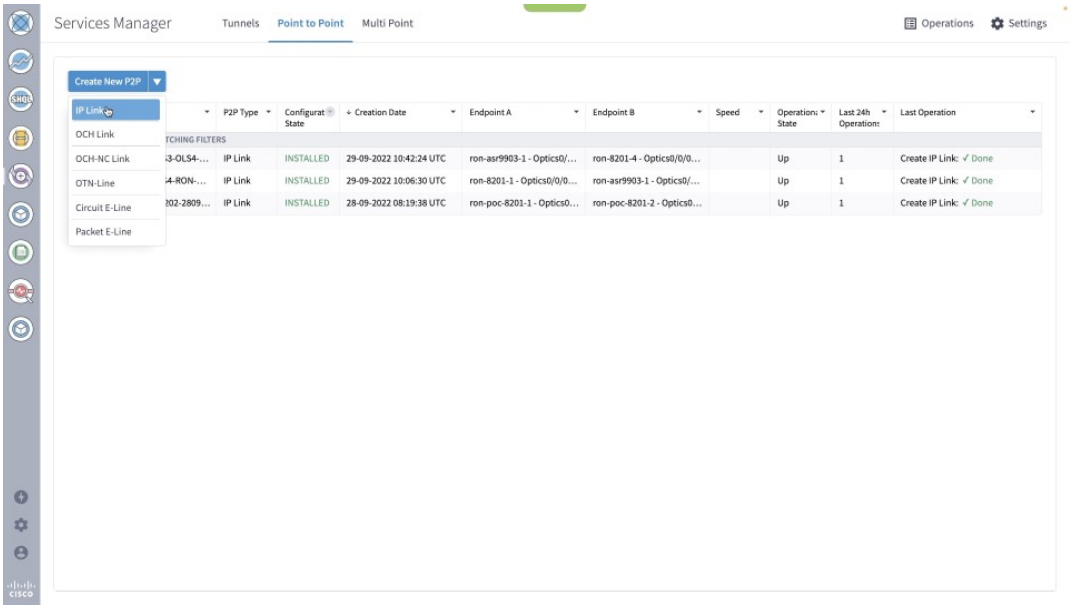
Sample End-to-end Configuration

Figure 57: Services Manager



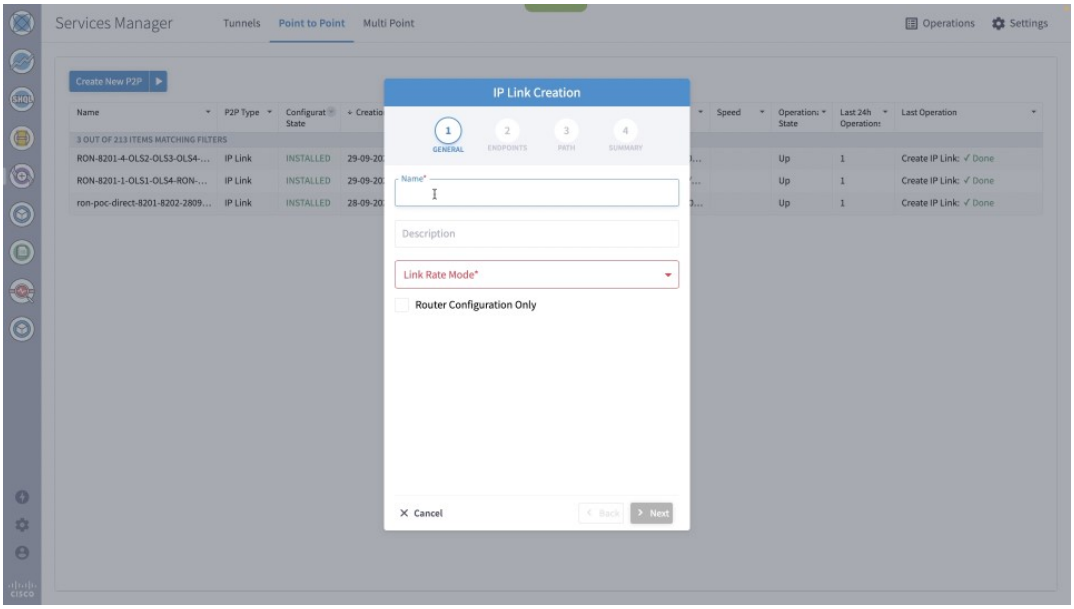
b. Select the **Point to Point** tab and click **IP Link** from the **Create New P2P** drop-down list to start the provisioning process.

Figure 58: Create IP Link



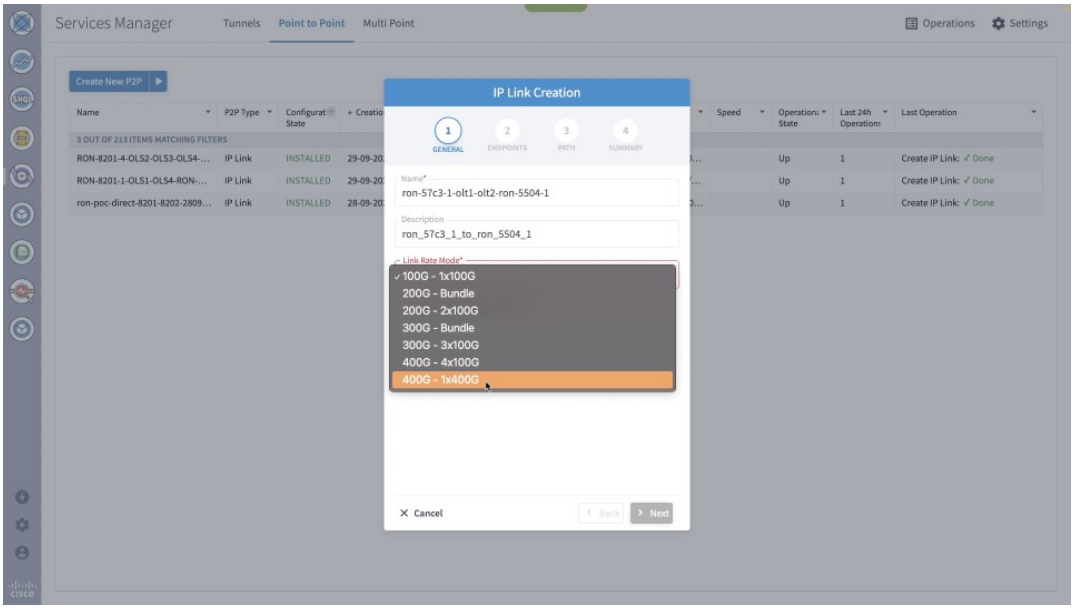
The **IP Link Creation** wizard appears.

Figure 59: IP Link Creation Wizard



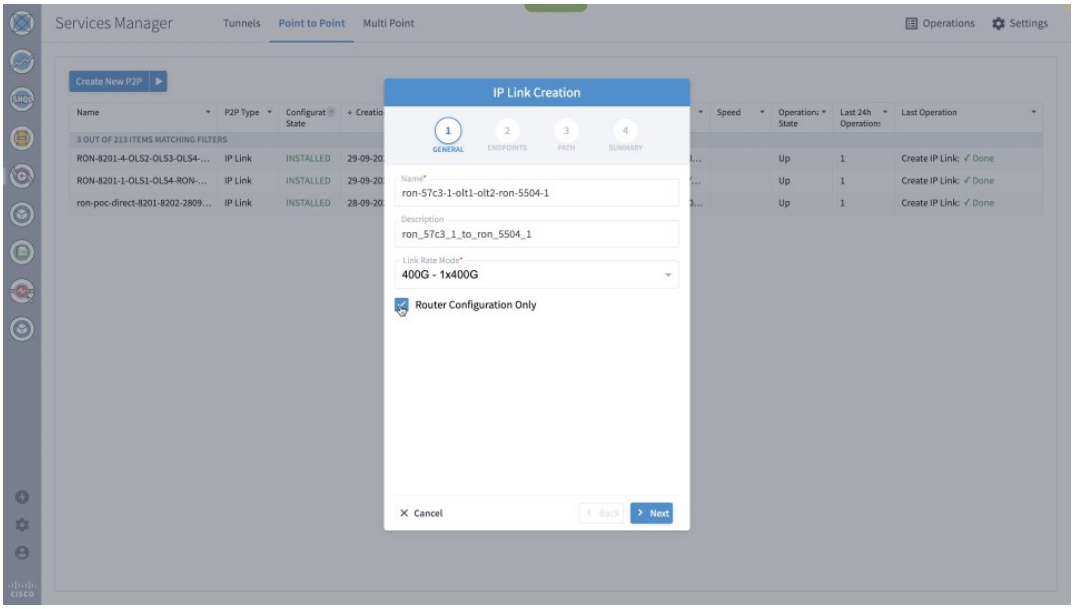
c. Enter the Cisco Crosswork Hierarchical Controller service name, description of the router optical controller, and the link type in the **General** tab.

Figure 60: IP Link Creation Wizard - General



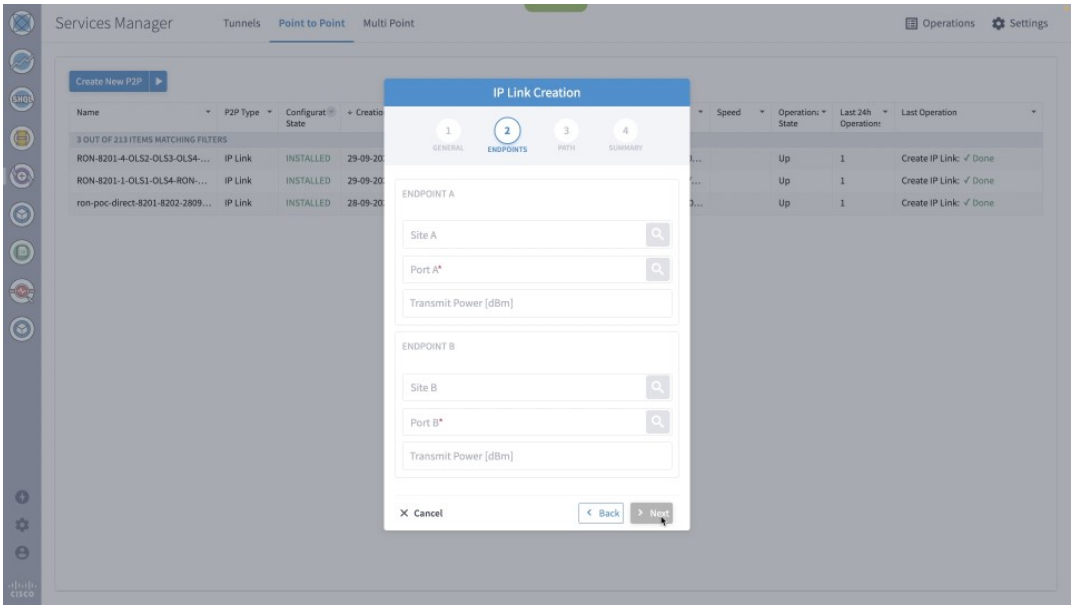
(Optional) Check the **Router Configuration Only** check box to configure only the router optical controller and IP information and not the optical line system. This configuration is used when the OCHNC is created outside Cisco Crosswork Hierarchical Controller.

Figure 61: IP Link Creation Wizard - General



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 TX power is used if no value is provided.

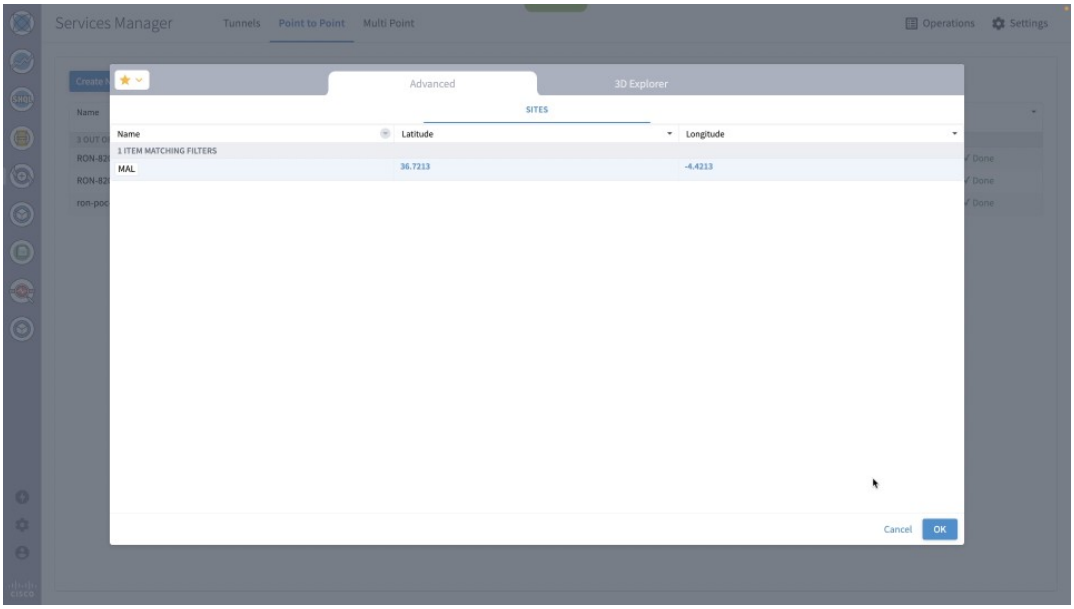
Figure 62: IP Link Creation Wizard - Router Endpoints



e. Click the magnifying glass icon to select the site. The site can be selected either by selecting from the list or by using the 3D Explorer.

Sample End-to-end Configuration

Figure 63: IP Link Creation Wizard - Site Selection

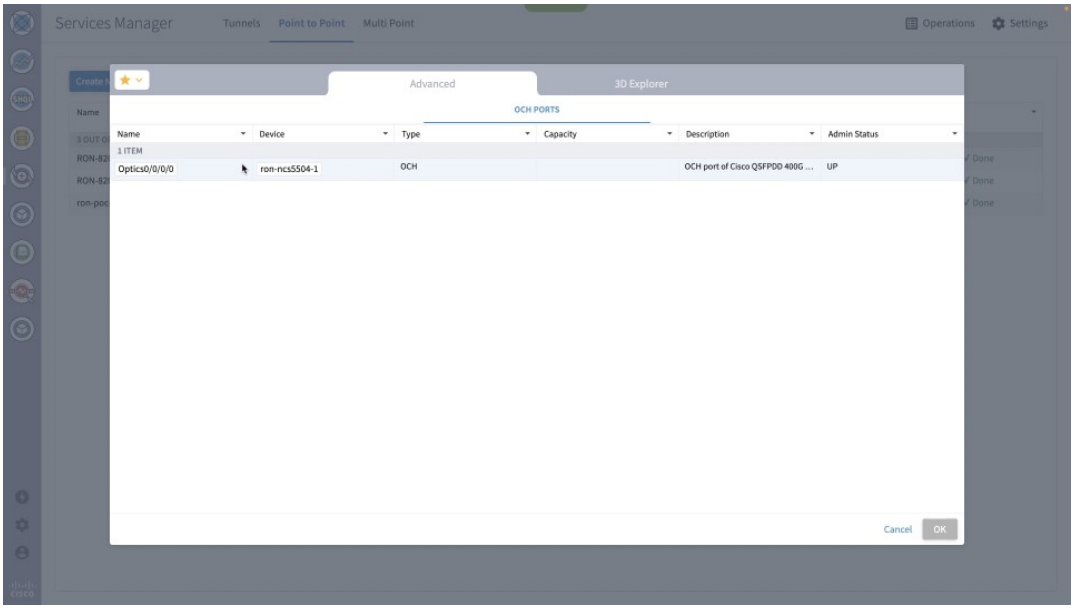


f. Click the magnifying glass icon to select the router port.

The ports are displayed based on the following criteria:

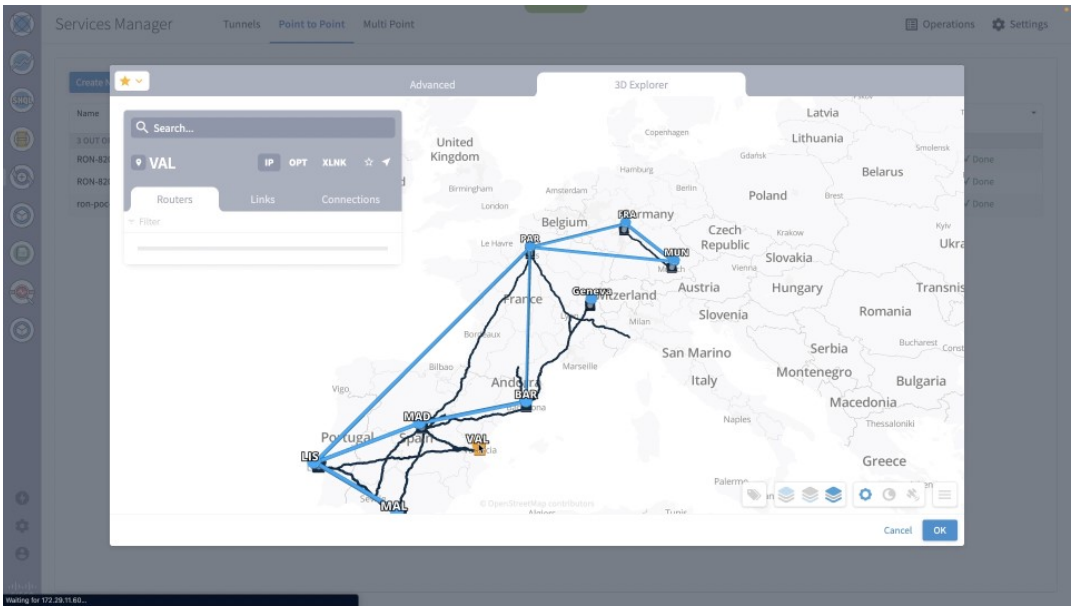
- Is a ZR/ZR+ interface
- Has no existing optics configuration
- Has a proper NMC cross-connect configured

Figure 64: IP Link Creation Wizard - Port Selection



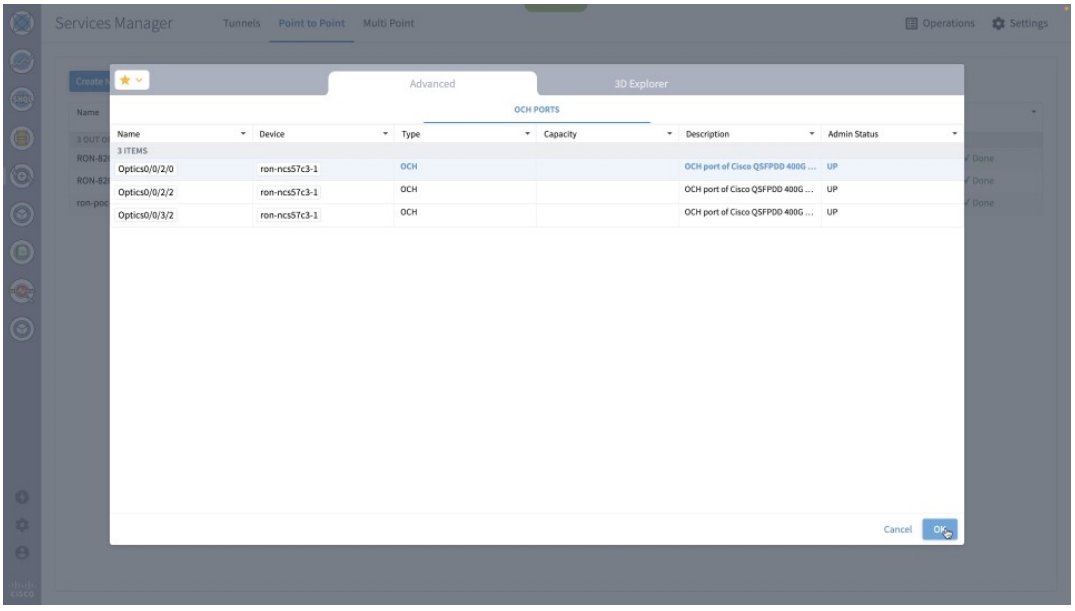
g. Select the second site using the 3D Explorer. VAL is the site of the other endpoint router and port.

Figure 65: IP Link Creation Wizard - Site Selection Using 3D Explorer



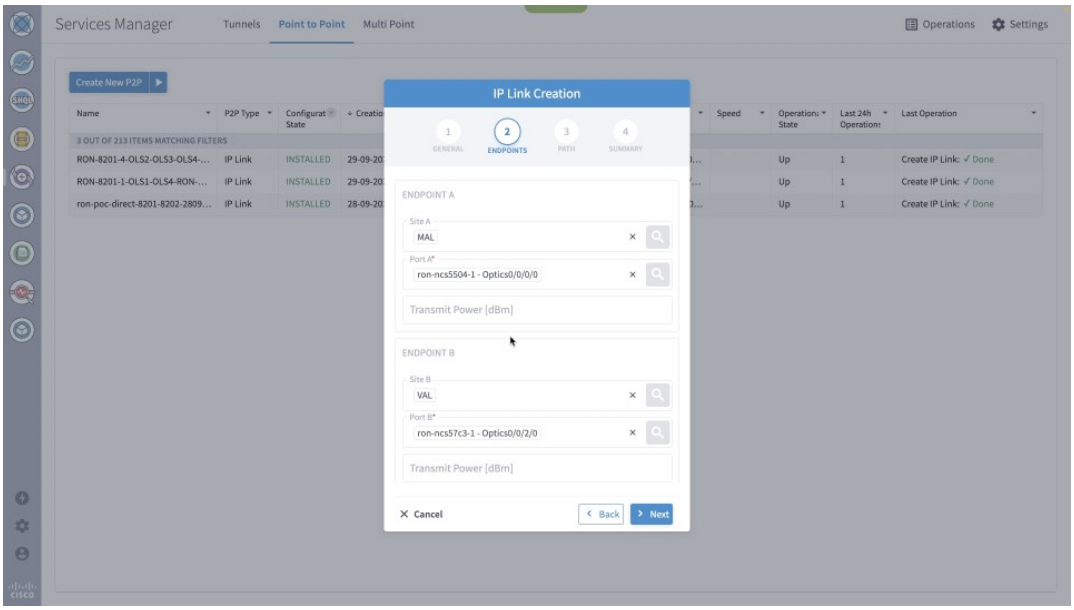
h. Select the second router port.

Figure 66: IP Link Creation Wizard - Router Port Selection



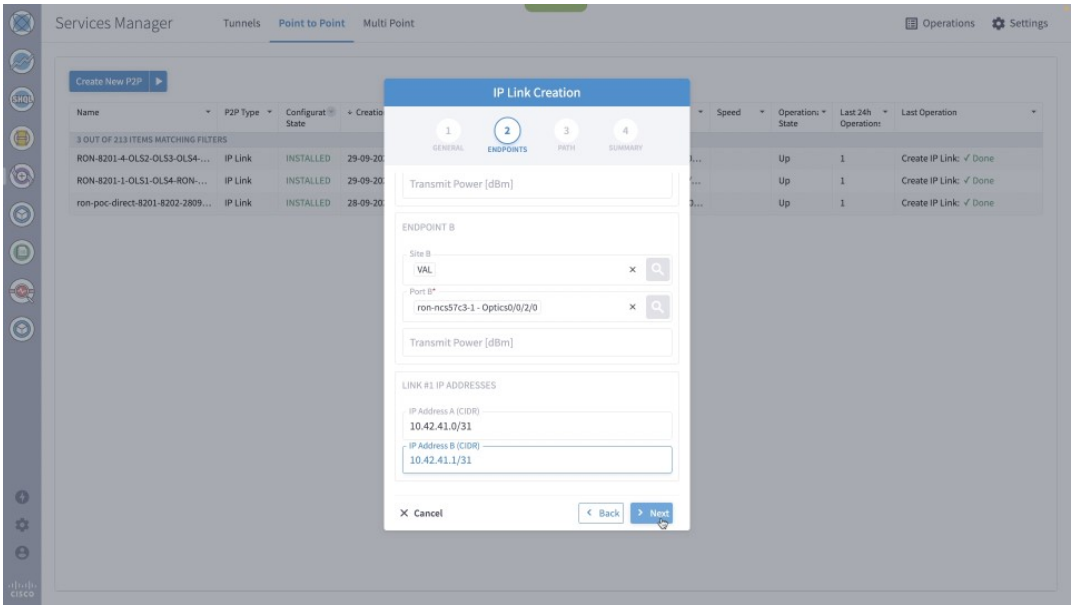
Both the router ports are selected.

Sample End-to-end Configuration



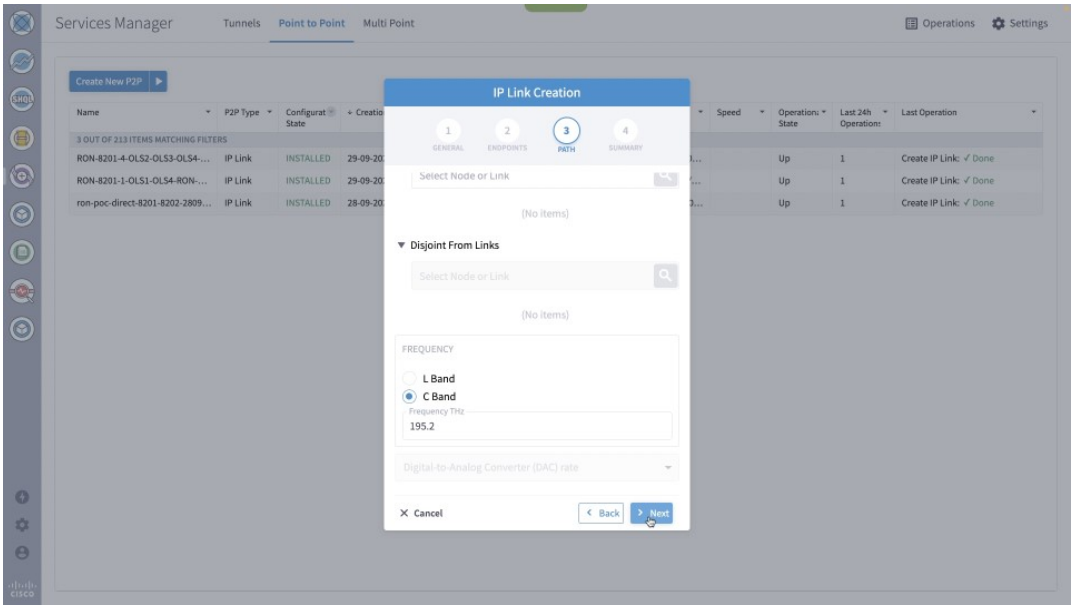
i. (Optional) Enter the IP address information for interfaces. If IP addresses are not entered, ZR/ZR+ router optical configuration happens; however, IP addresses are not configured.

Figure 67: IP Link Creation Wizard - IP Addresses



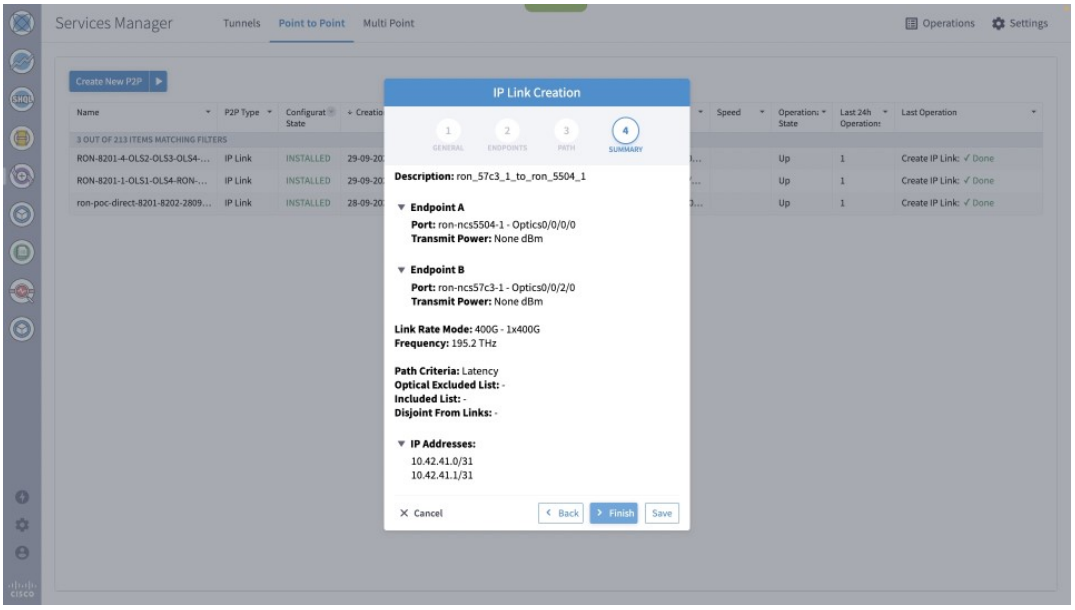
j. In the optical path configuration, optical node exclusion can be configured. The frequency can be manually set in this step. In router only configuration, the frequency is mandatory. If OLS provisioning is performed, Cisco Optical Network Controller returns the proper frequency to be configured on the router endpoints; hence, the frequency may be omitted. In this case, the manual frequency is set to the same value returned by Cisco Optical Network Controller.

Figure 68: IP Link Creation Wizard - Path



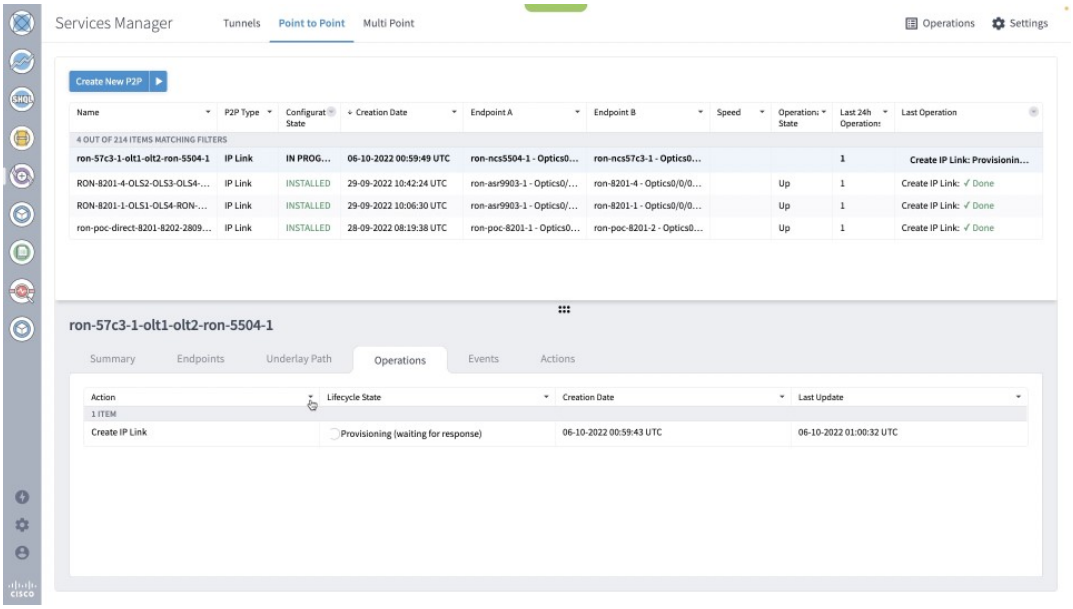
k. Click **Next** to review the final configuration. Click **Finish** to start provisioning, or click **Save** to save for later provisioning.

Figure 69: IP Link Creation Wizard - Summary



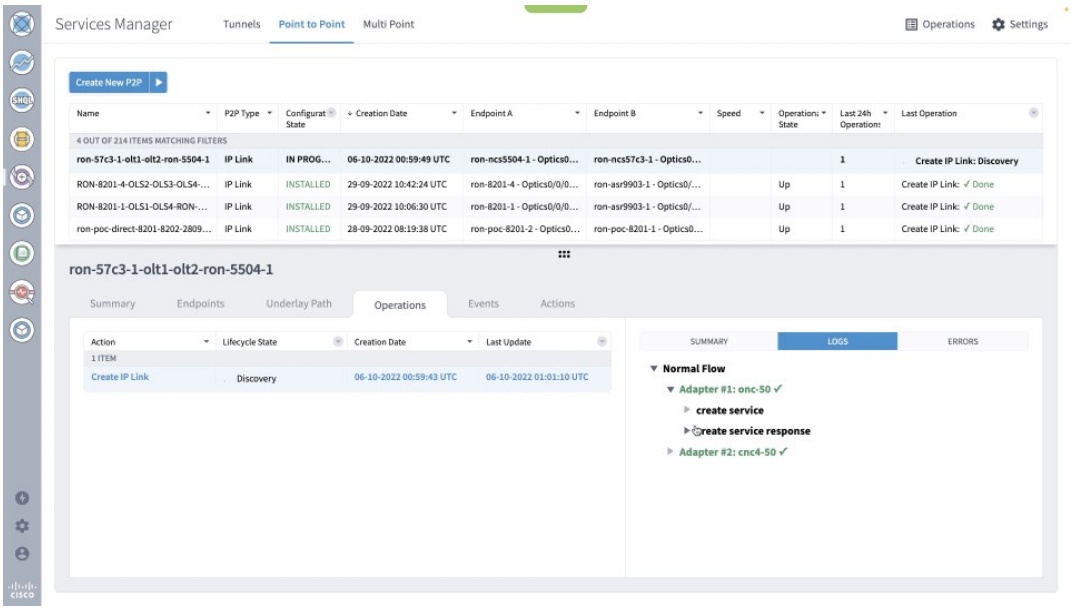
l. The progress of provisioning is shown in the Services Manager.

Figure 70: Provisioning Progress - Services Manager



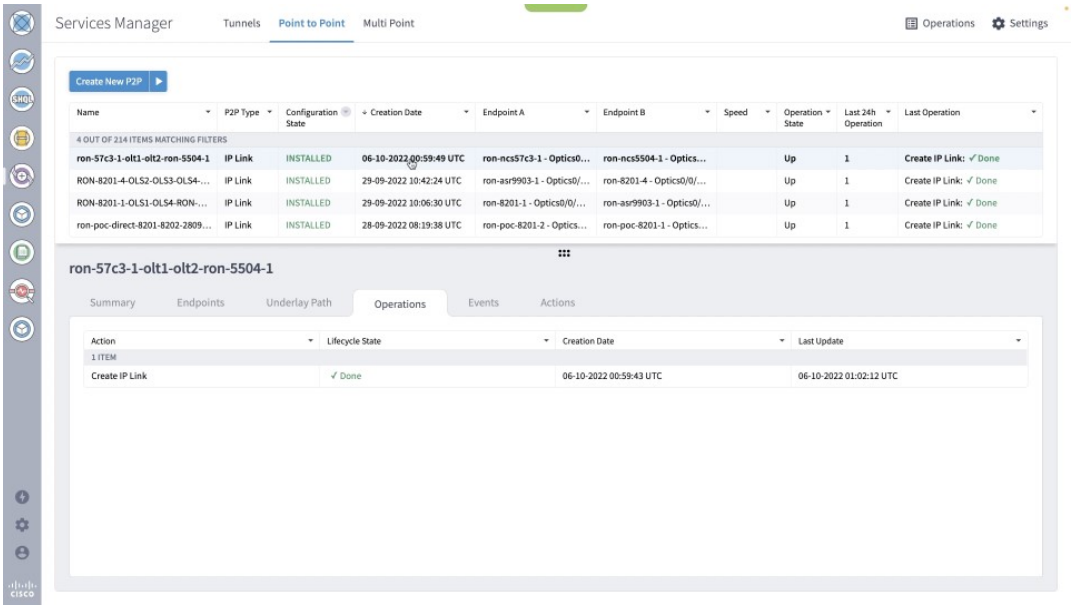
m. Click the **Operations** > **Logs** tab to view the provisioning API calls used and responses.

Figure 71: Provisioning Progress - Logs



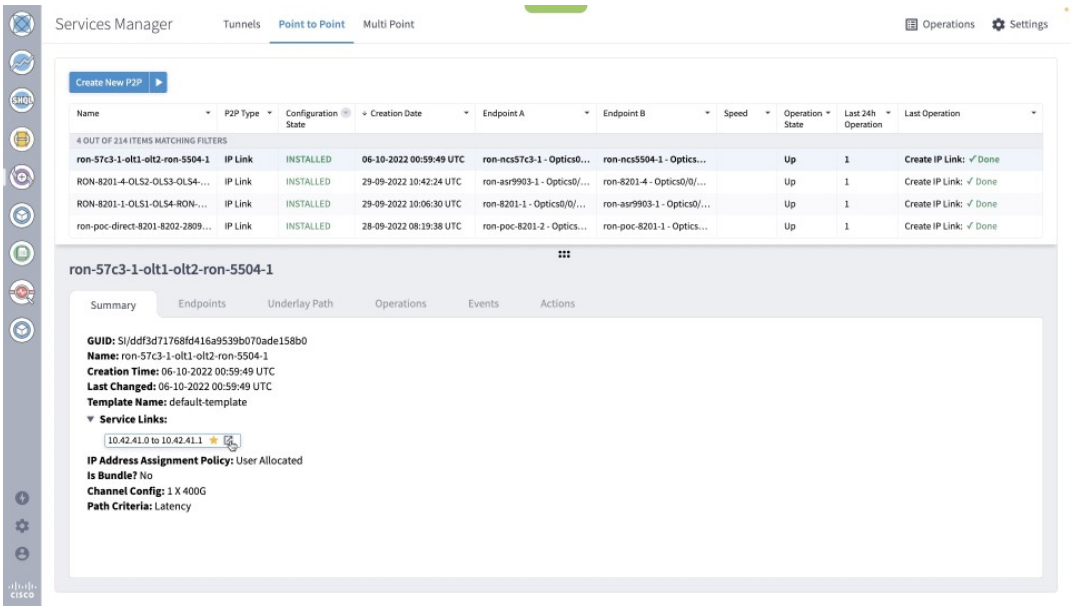
n. If the provisioning is successful, the **Configuration State** field changes to INSTALLED state and the **Operational State** field changes to UP state.

Figure 72: Successful Provisioning



o. Click the **Summary** tab to see the new service link and click the square to show the new link in the 3D Explorer view.

Figure 73: Provisioned Service Link



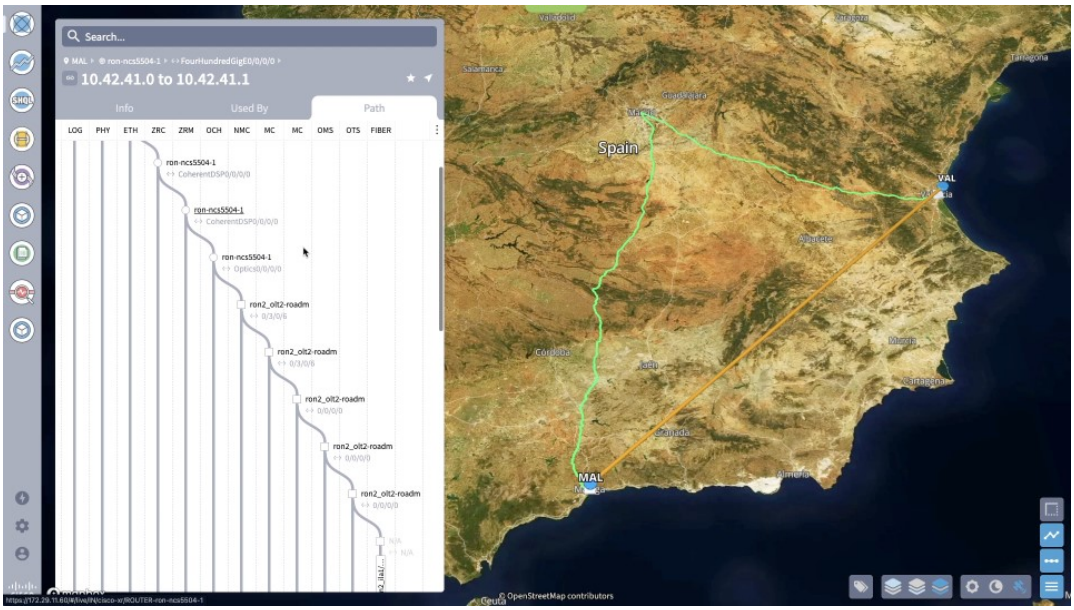
p. 3D Explorer view highlights the new logical router link along with the underlying optical path that is shown in Green.

Sample End-to-end Configuration

Figure 74: Provisioned Link in 3D Explorer

q. Click **Path** to show the full multilayer path including each optical line system segment.

Figure 75: Multilayer Path View in 3D Explorer



3. The Link Assurance app can be used to inspect the end-to-end link path.

Figure 76: Link Assurance Tool

Select a specific layer to show PM data (ZRM, OCH, and OTS layers only).

Figure 77: Link Assurance Tool

Select a specific port to show PM data for the port.

Figure 78: Link Assurance Tool

Operate Phase

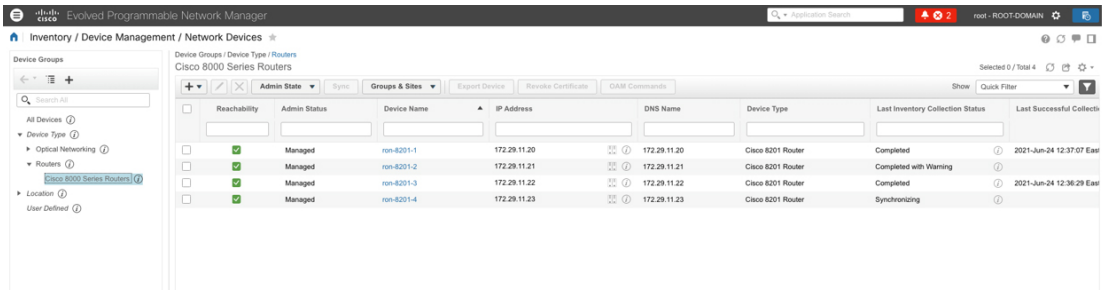
To monitor the ZR/Z+ optics:

1. Use either CLI commands or EPNM to monitor router ZR/ZR+ optics for proper operation. See Monitor ZR or ZR+ Optics Using EPNM, on page 150.
2. (Optional) Setup router ZR/ZR+ optics data collection in CW Health Insights. See Monitor Performance of ZR/ZR+ Optics Using KPIs, on page 159.

Monitor ZR or ZR+ Optics Using EPNM

This section adds the 8201 router to EPNM for monitoring the PM parameters on the ZR or ZR+ optics.

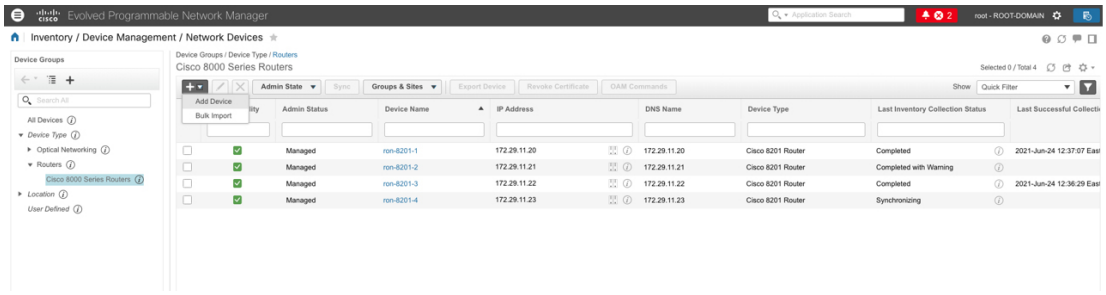
1. To add a new device to EPNM choose **Inventory > Device Management > Network Devices**. Click **Routers** or a subgroup if it is already defined in the left panel.



521942

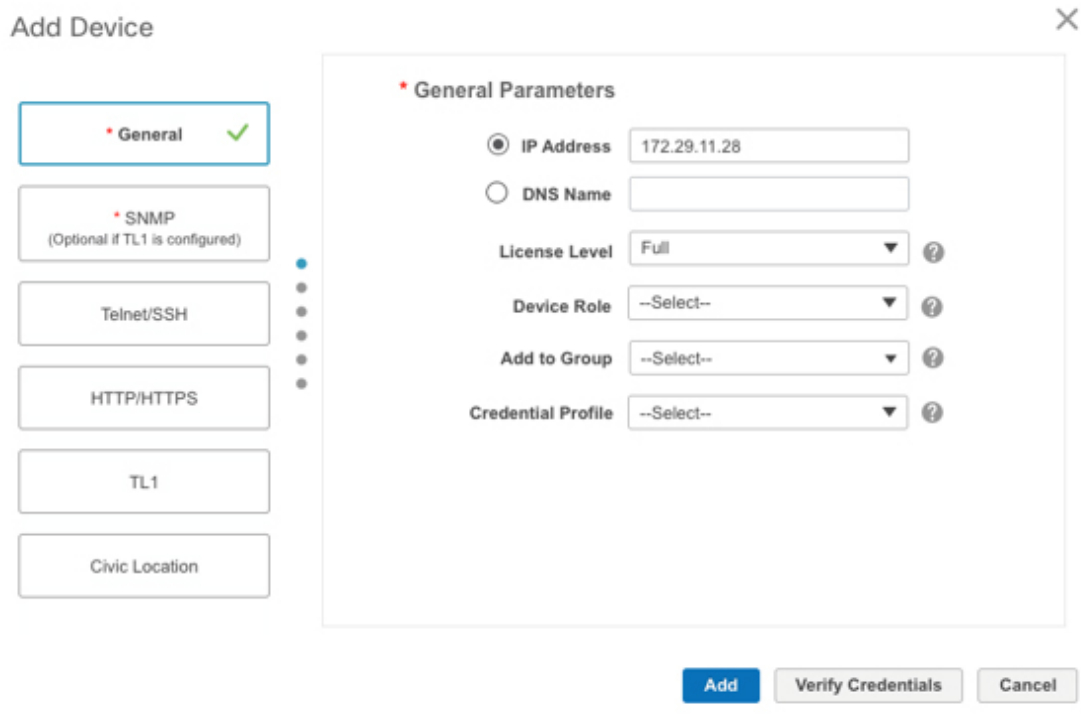
2. Click the + icon above the Network Devices table, then choose **Add Device**.

Sample End-to-end Configuration



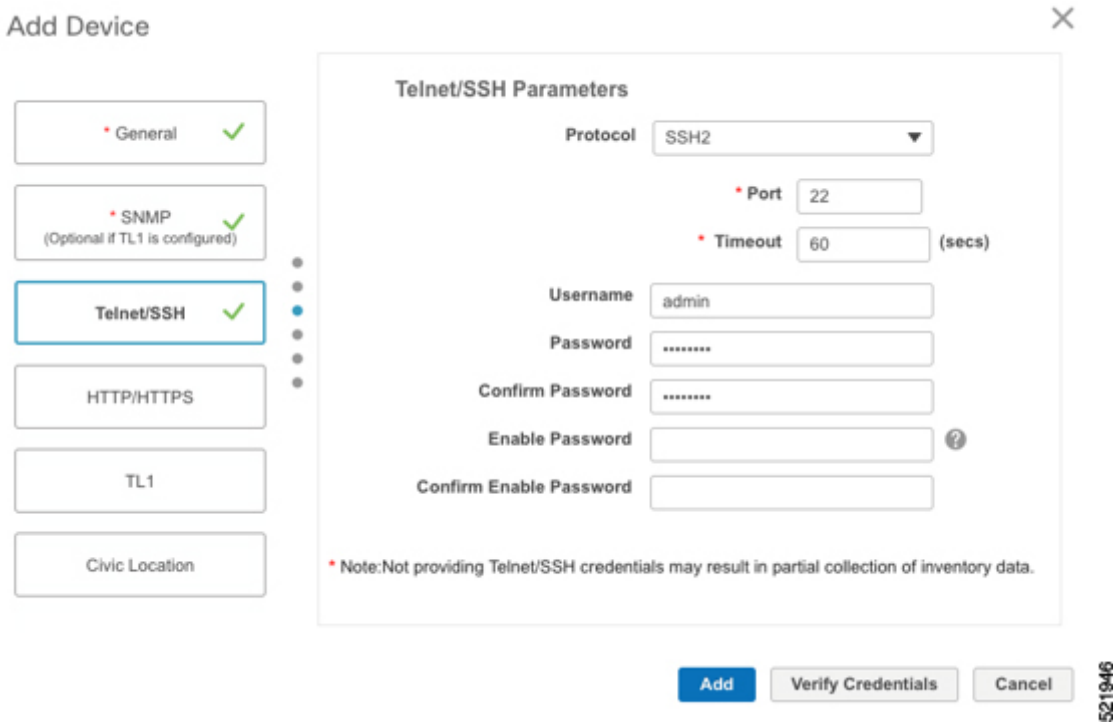
521943

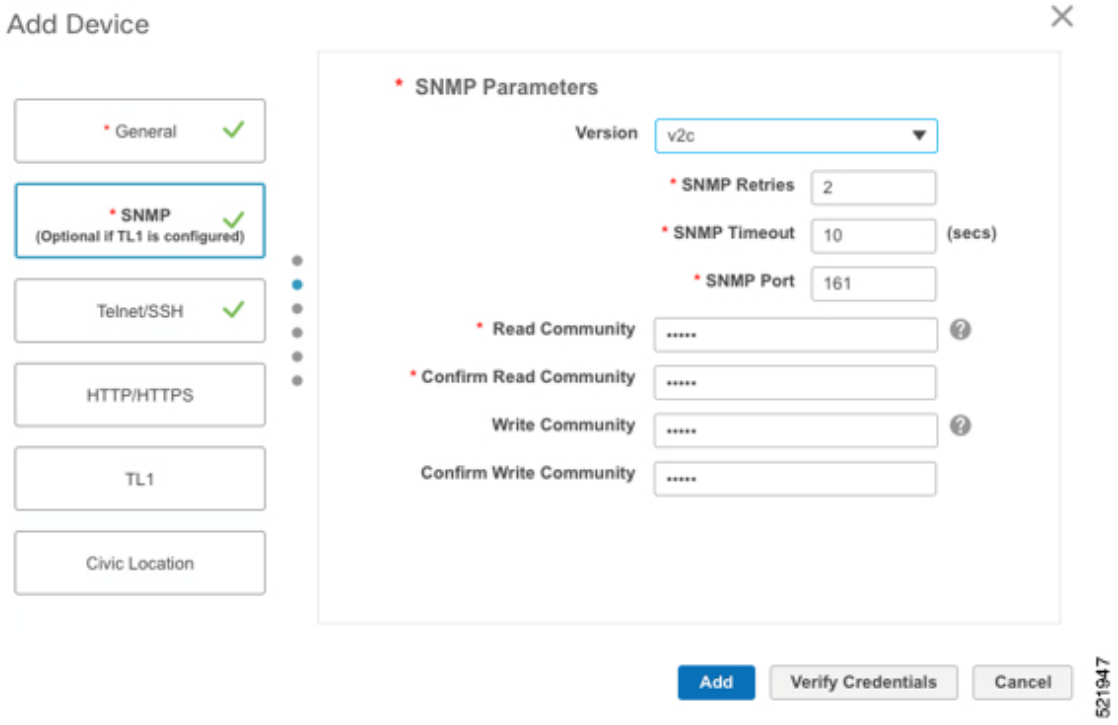
3. Configure the General, SNMP, and SSH parameters as seen in that following figures. Click **Verify Credentials** to validate that Cisco EPN Manager can reach the device. Click **Add** to add the device to EPNM.



521945

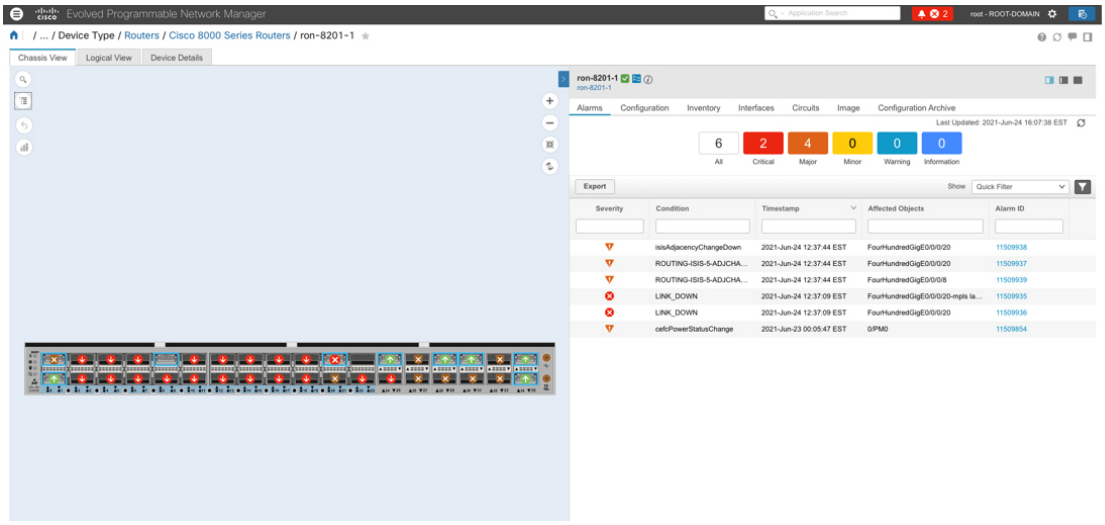
Sample End-to-end Configuration





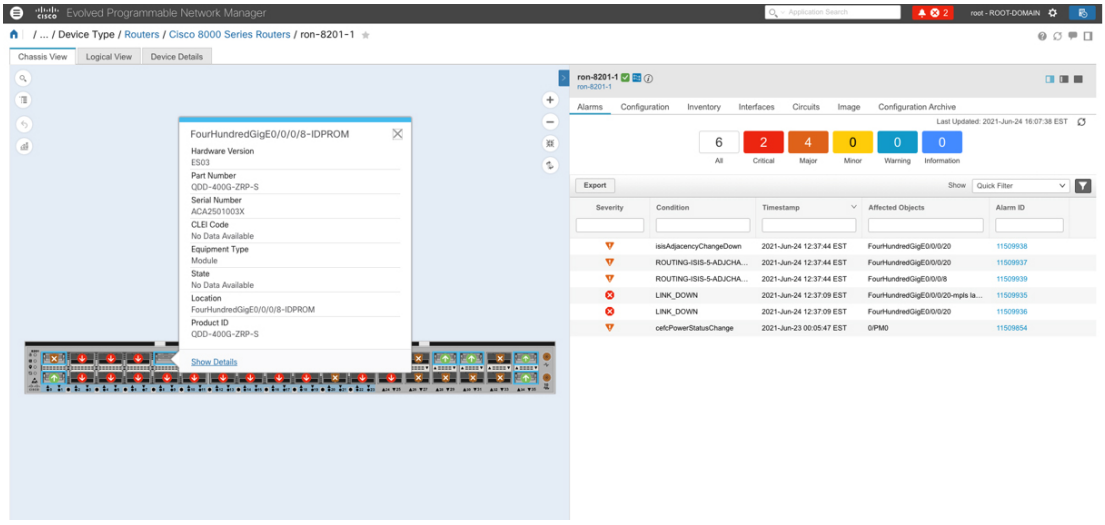
4. To open the chassis view from the Network devices table, click the device name link. The following figure displays the chassis view of the 8201 router.

Sample End-to-end Configuration



521948

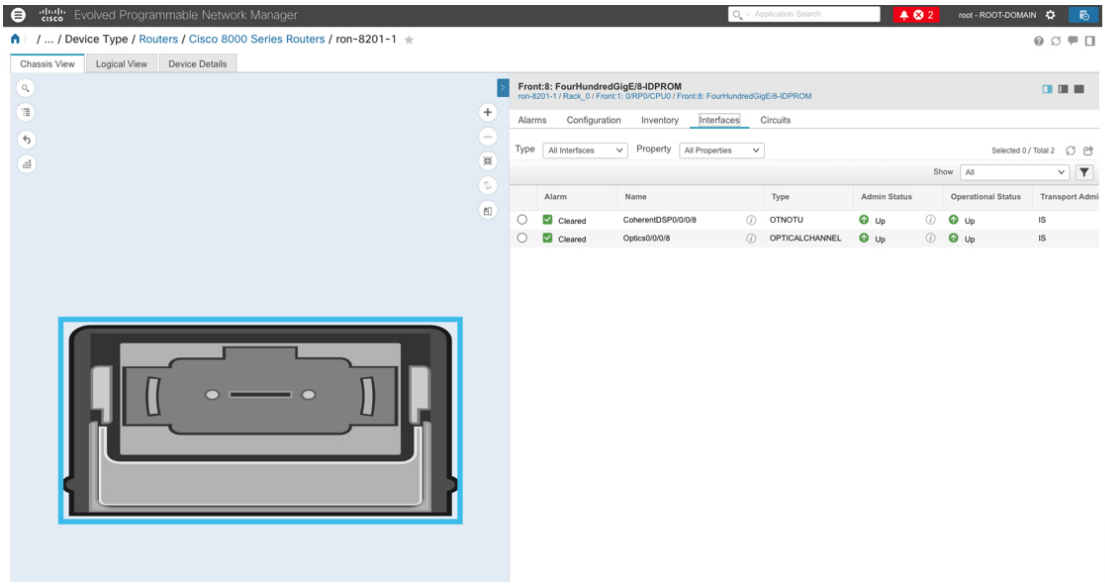
5. Click the QSFP-DD ZR+ port to see specific data about that port.



521949

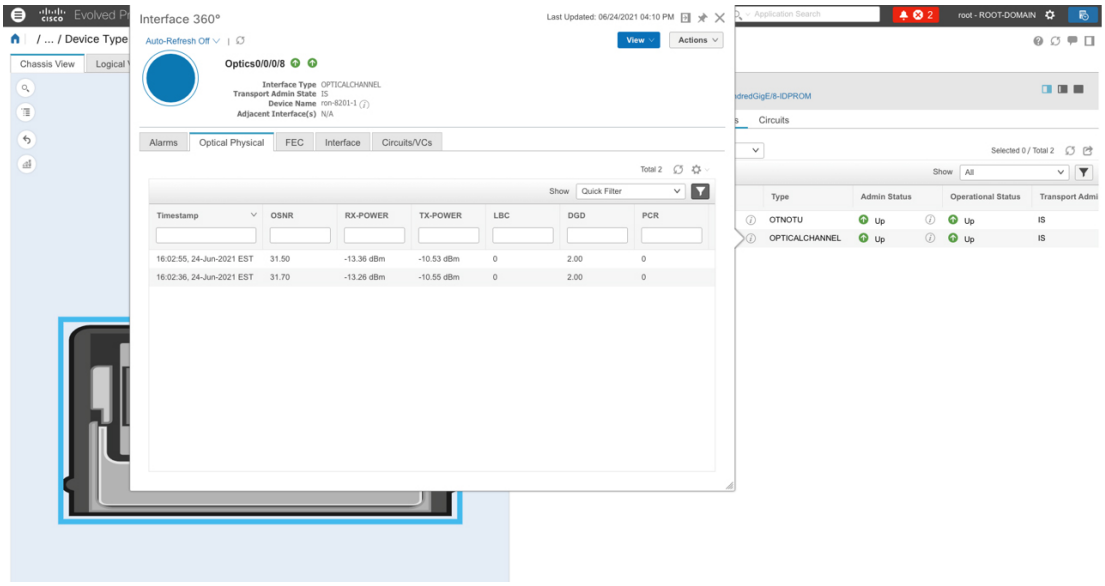
Here you can view the port and specific optical channel and CoherentDSP entities.

Sample End-to-end Configuration



521950

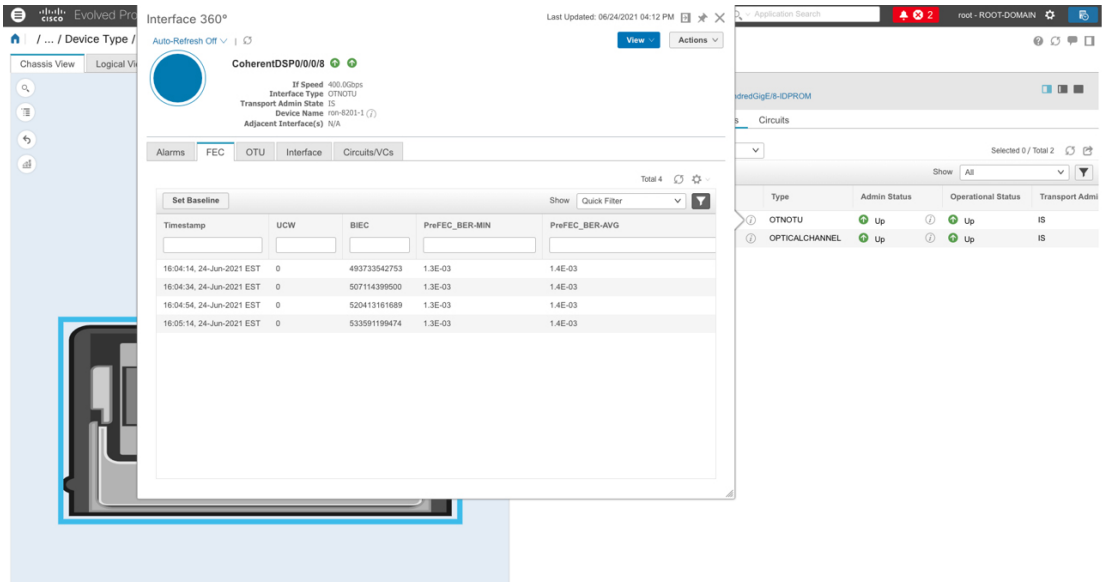
6. Clicking the additional information icon for the optical channel and then the **Optical Physical** measurement tab displays the relevant optical PM values such as **RX/TX signal power** and **OSNR** values.



521951

7. Clicking the additional information icon for the coherent DSP and then the **FEC** measurement tab displays the 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.

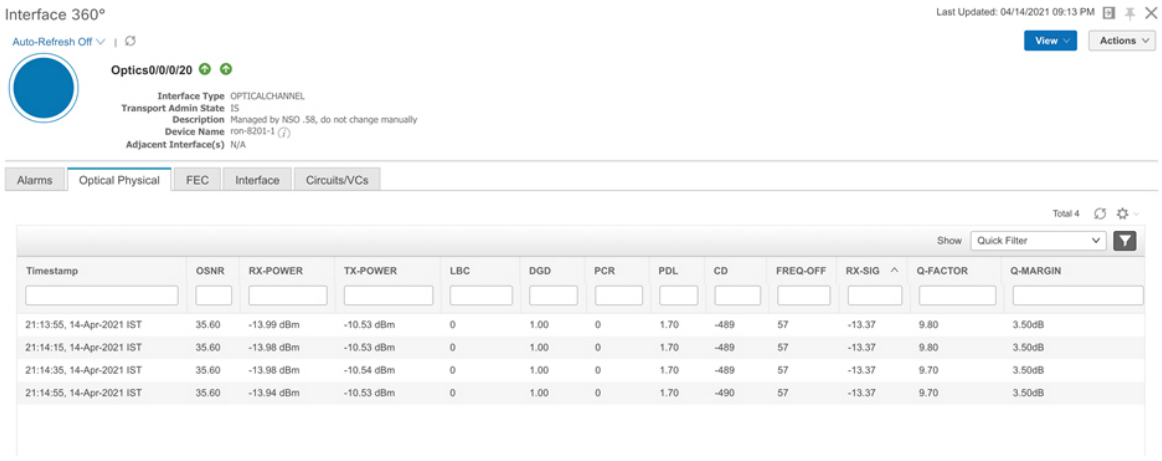
Sample End-to-end Configuration



521952

The following figures display the current and historical performance monitoring data in EPNM that is specific to the ZR or ZR+ optics.

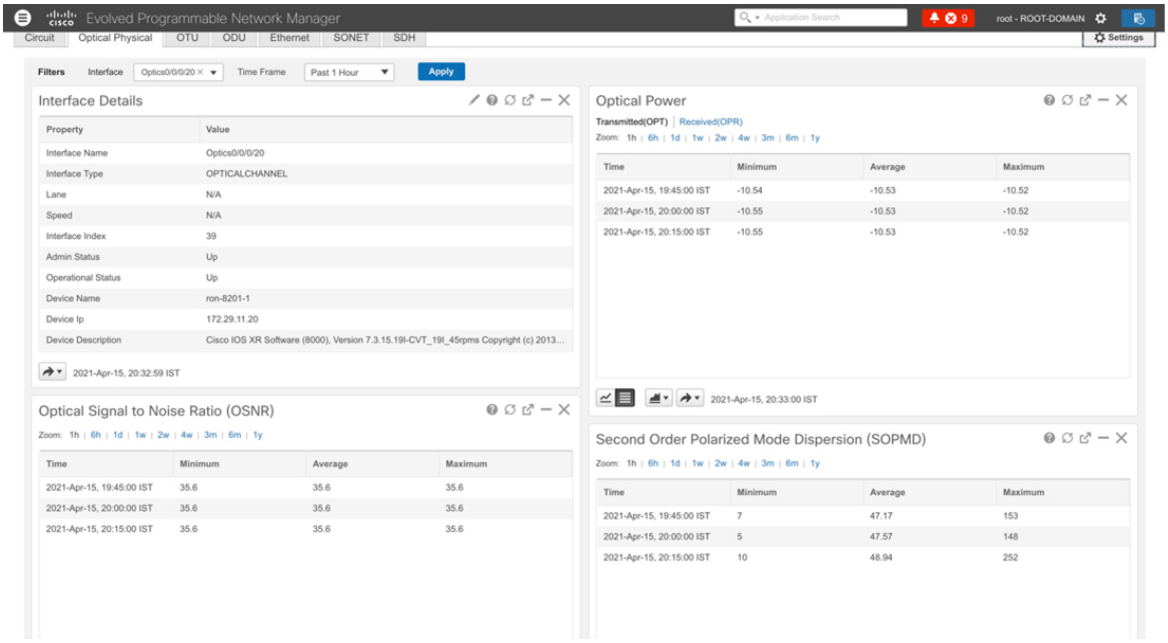
Figure 79: Optical Physical Parameters



521883

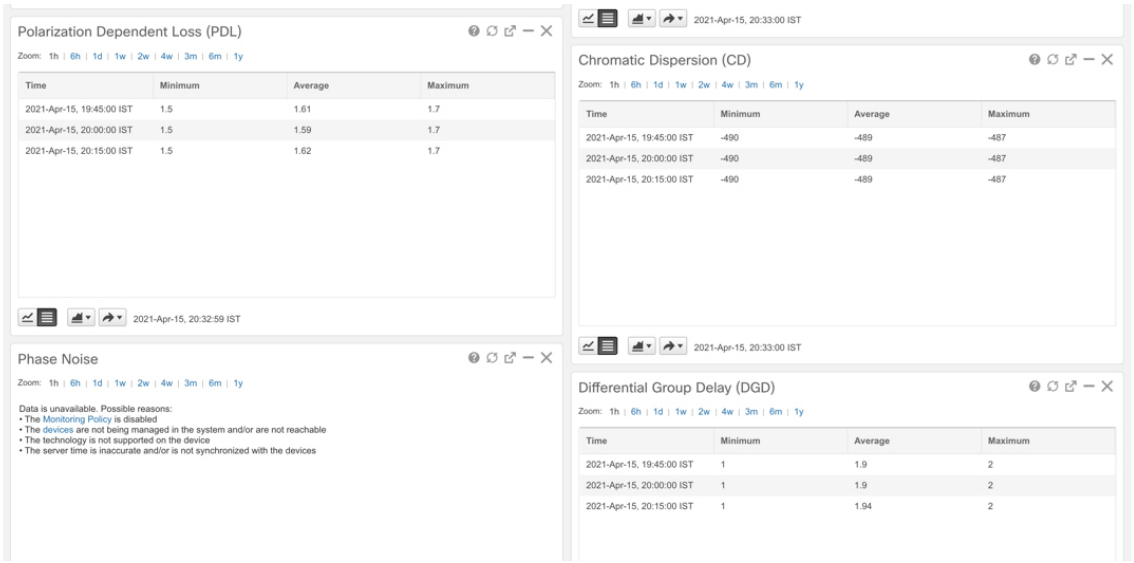
Sample End-to-end Configuration

Figure 80: Historical Optical Physical Parameters



521884

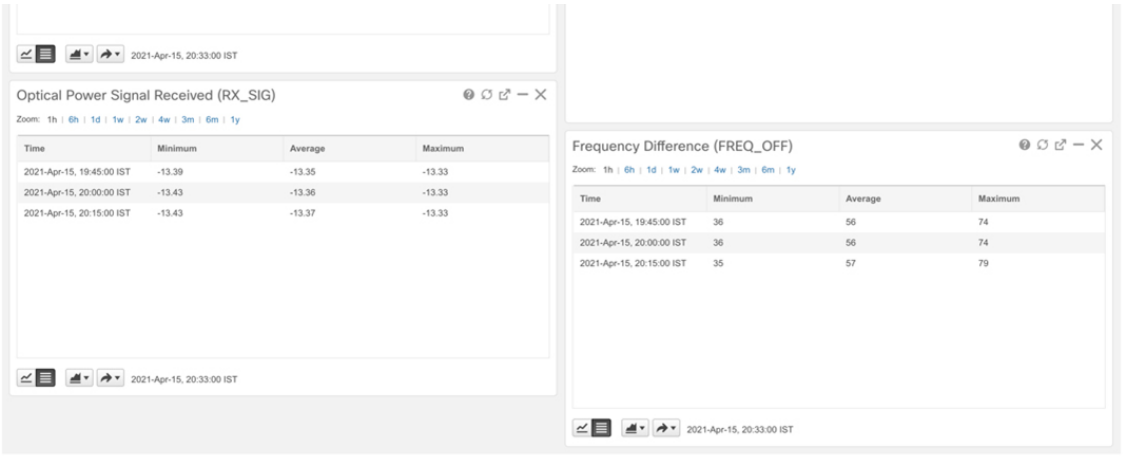
Figure 81: Historical Optical Physical Parameters



521885

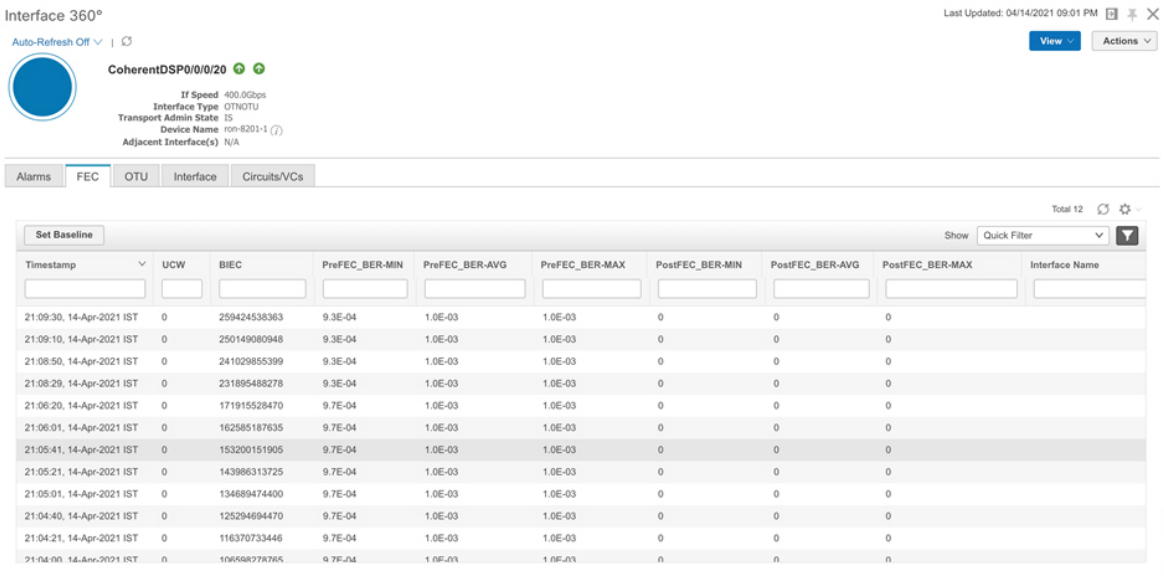
Sample End-to-end Configuration

Figure 82: Historical Optical Physical Parameters



521888

Figure 83: FEC Parameters



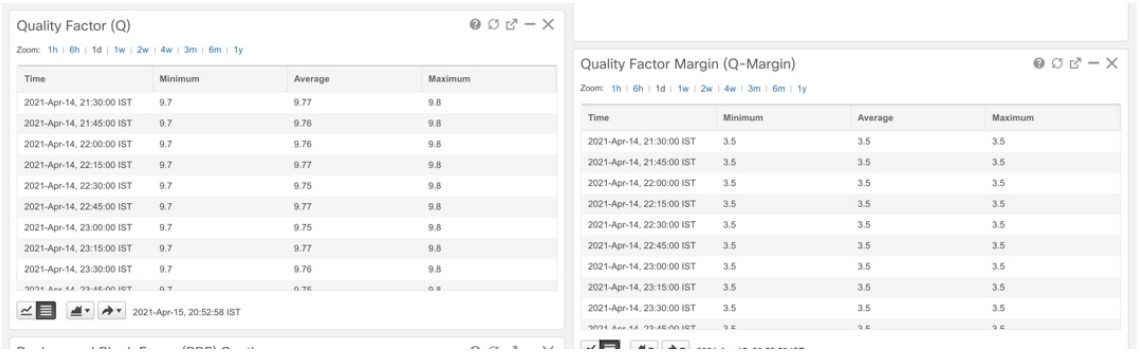
521881

Sample End-to-end Configuration

Figure 84: Historical FEC Parameters

521889

Figure 85: Historical FEC Parameters



521890

Figure 86: Historical OTN Parameters

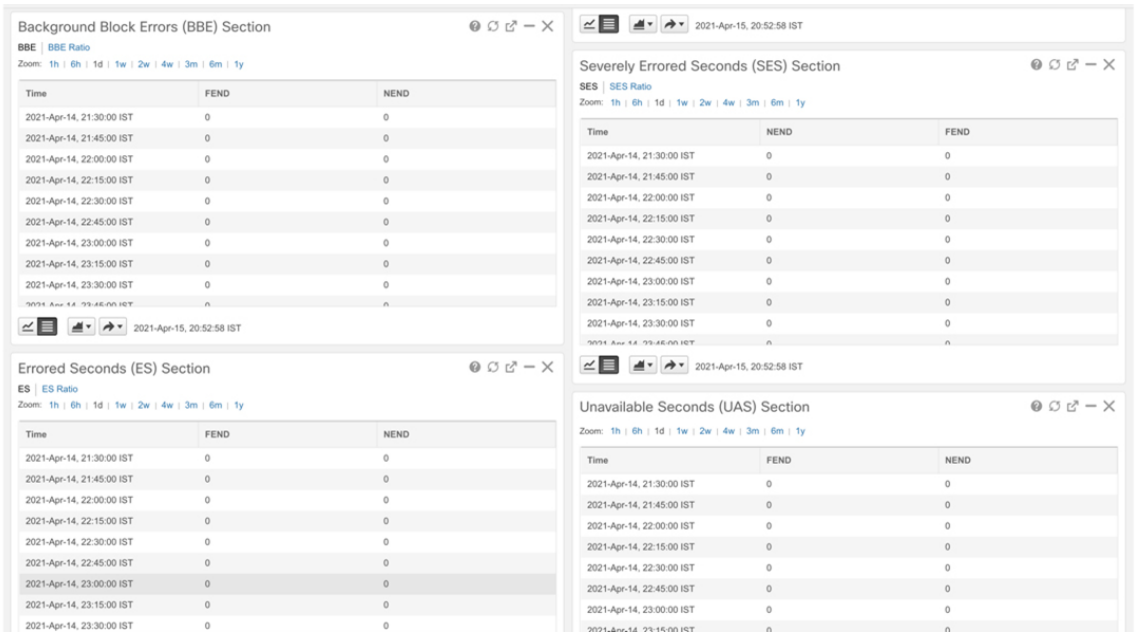
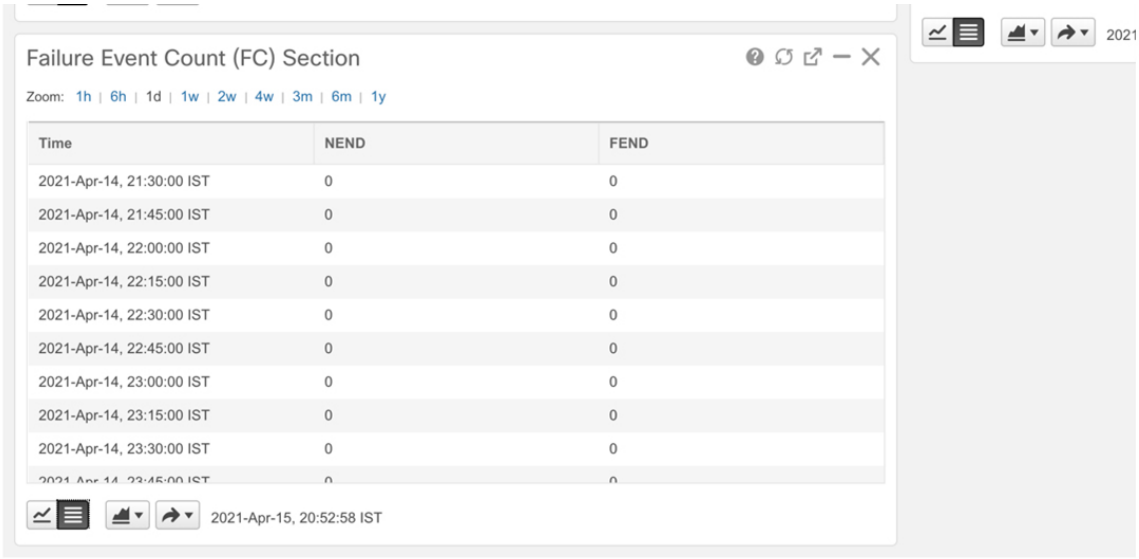


Figure 87: Historical OTN Parameters

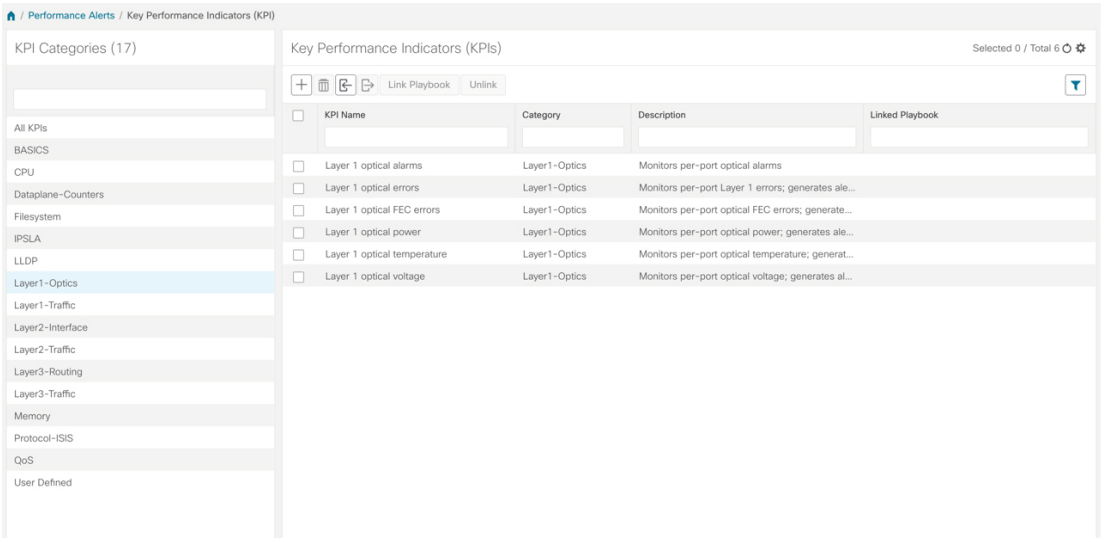


Monitor Performance of ZR/ZR+ Optics Using KPIs

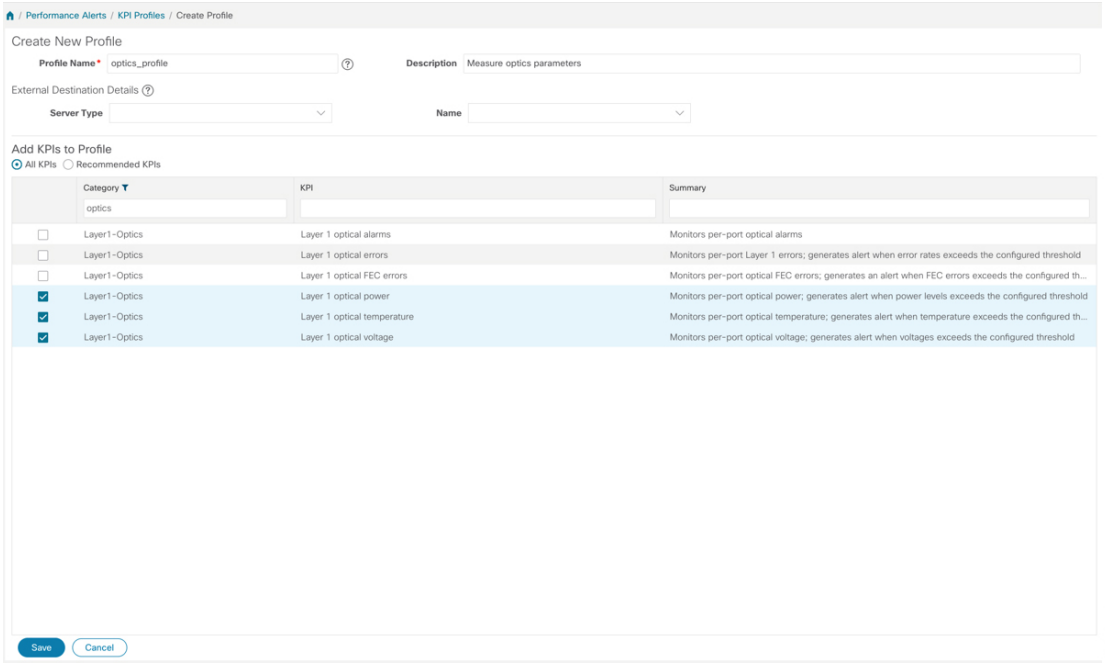
Perform the following steps to create KPI Profiles in Health Insights and enable them on the devices to monitor network health.

Sample End-to-end Configuration

Note Plan which Cisco-supplied KPIs you want to begin using, based on each device's function and the device performance characteristics you want to monitor. Review the Cisco-supplied KPIs documented in List of Health Insights KPIs. In the following image, you see the available default L1 optics KPIs.



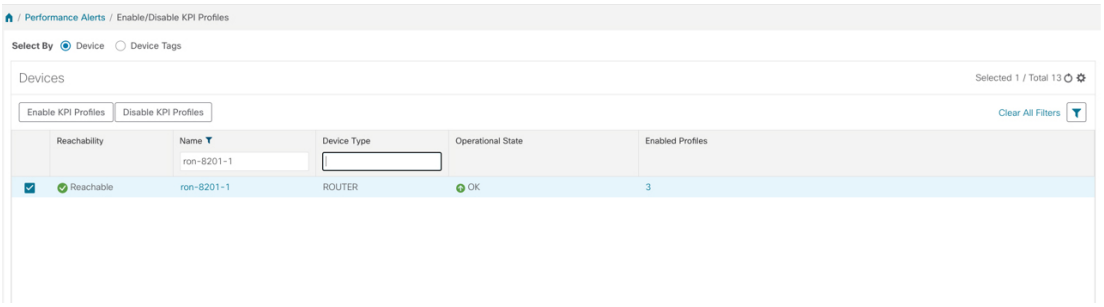
1. Group the relevant KPIs to form a KPI Profile. A KPI profile can have many different KPIs assigned. In this case, the focus is only on some specific optics KPIs to add to the **optics_profile** KPI profile.



See Create a New KPI Profile.

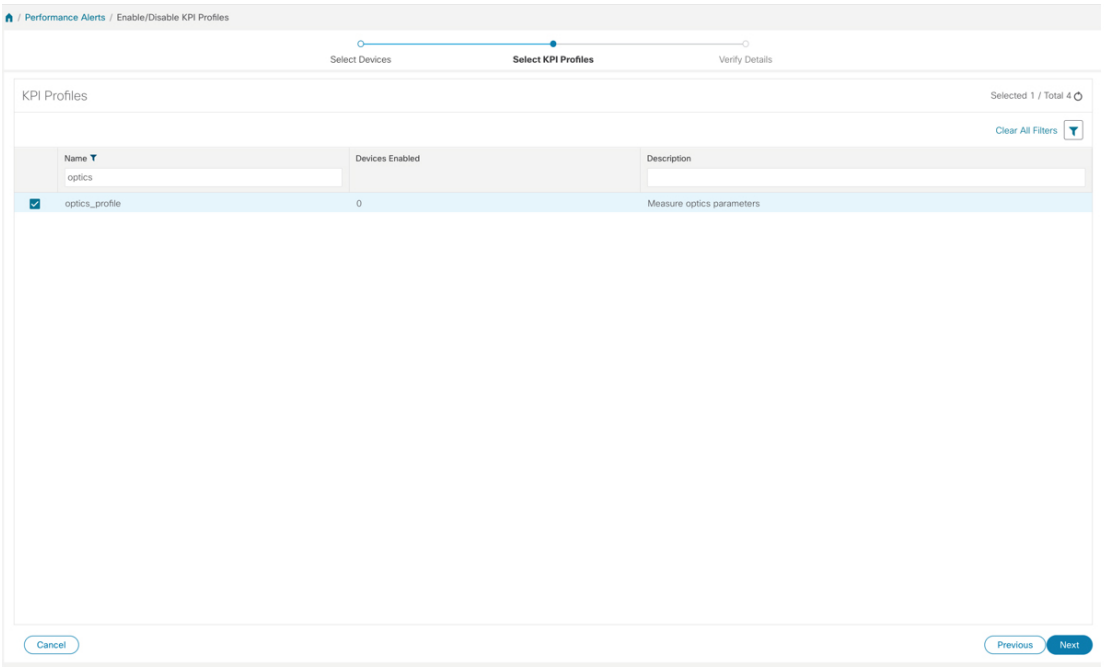
2. Enable the appropriate KPI Profiles on the devices you want to monitor. From the main menu, choose **Performance Alerts** > **Enable/Disable KPI Profiles**. Check the checkboxes of all the nodes to which the profile must be applied to, and click **Enable KPI Profiles.**

   Multiple nodes may be selected. In the following figure, we are applying the KPI profile to a single node.



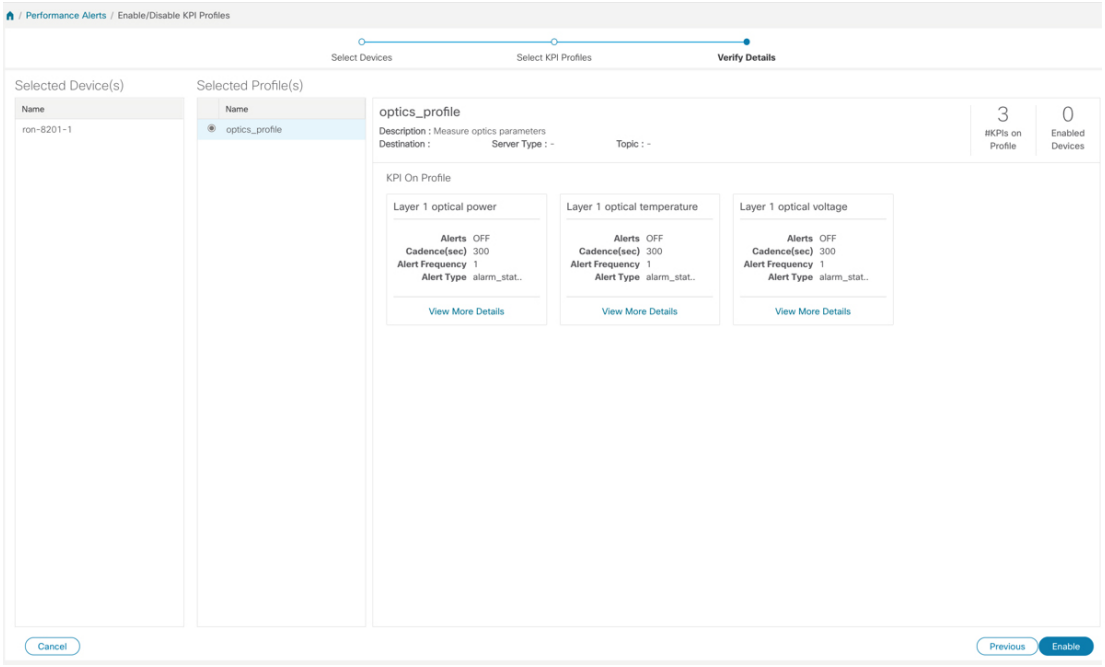
521915

3. Select the optics_profile KPI profile that was created in the previous step and click next to finalize enabling the KPI for the selected device.



521916

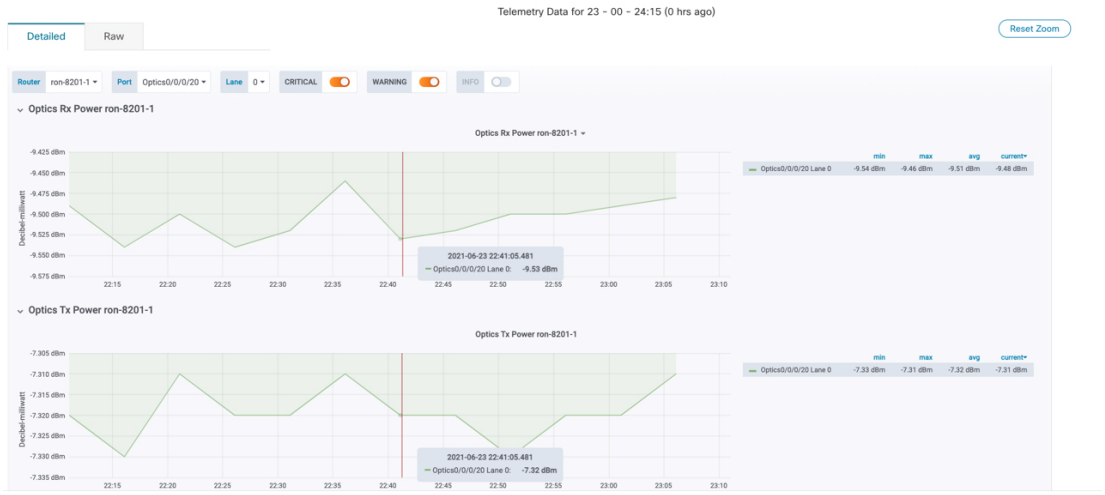
4. The following image displays the final page before enabling the KPI profile for the router. After you click **Enable**, the appropriate configuration is applied to the router to begin streaming the telemetry sensors data for the selected optical KPIs.



See Enable KPI Profiles on Devices.

5. To view alerts from network devices, see View Alerts for Network Devices.

   The following figure displays the RX and TX power of the QDD-400G-ZR-S transceiver.



Optimization Phase

The optimization phase involves:

1. Return to planning stage.
2. Continue to add or change circuits on the network to match packet demands.