



Routed Optical Networking Solution Components

This chapter describes the Routed Optical Networking solution components.

- [Hardware Components, on page 1](#)
- [Network Planning Components, on page 28](#)
- [Automation Components, on page 29](#)
- [IOS-XR Software Components, on page 42](#)

Hardware Components

The hardware components that enable Routed Optical Networking are:

- High Density Routers
 - [Cisco 8000 Series Routers](#)
 - [Cisco 8200 Series Routers, on page 3](#)
 - [Cisco 8800 Series Routers, on page 3](#)
 - [Cisco 8800 Series Line Cards, on page 3](#)
 - [Cisco NCS 5500 Series Routers](#)
 - [Cisco NCS-55A2 Series Fixed Port Routers, on page 4](#)
 - [Cisco NCS-57B1 Series Fixed Port Routers, on page 4](#)
 - [Cisco NCS-57C1 Series Fixed Port Routers, on page 5](#)
 - [Cisco NCS-57C3 Series Fixed Port Routers, on page 5](#)
 - [Cisco NCS 5500 Modular Chassis, on page 6](#)
 - [NCS 5700 Series Line Cards, on page 6](#)
 - [NCS 5700 Series Modular Port Adapters, on page 7](#)
 - [Cisco ASR 9000 Series Aggregation Services Routers, on page 7](#)
 - [Cisco ASR 9903 Compact High-Performance Router, on page 9](#)
 - [Cisco ASR 9000 Series Line Cards, on page 9](#)

- [Cisco Network Convergence System 540 Series Routers, on page 10](#)
 - [Cisco Network Convergence System 540 Large Density Routers, on page 10](#)
- High Capacity Pluggable Optical Modules
 - [400G ZR/ZR+ Transceivers](#)
- Optical Line Systems
 - [Cisco Network Convergence System 2000 Series, on page 21](#)
 - [Cisco NCS 2006 Shelf, on page 22](#)
 - [Control Cards, on page 22](#)
 - [ROADM Cards, on page 22](#)
 - [Amplifier Cards, on page 23](#)
 - [EDFA Cards, on page 23](#)
 - [EDRA Cards, on page 23](#)
 - [Raman Amplifier Cards, on page 23](#)
 - [Passive Multiplexer and Demultiplexer Module, on page 24](#)
 - [Passive Patch Panel Modules, on page 24](#)
 - [MPO-16 to 16-LC Fan-Out Module, on page 24](#)
 - [Cisco 1 x 6 Colorless FlexSpectrum Add/Drop Module, on page 24](#)
 - [5-Degree Modular Patch Panel Module, on page 24](#)
 - [Cisco 4-Degree Upgrade Modular Patch Panel Module, on page 24](#)
 - [Cisco Network Convergence System 1010, on page 25](#)
 - [Cisco NCS 1000 32-Channel Mux/Demux Patch Panel, on page 27](#)
 - [Cisco NCS 1000 Breakout Patch Panel and Modules, on page 27](#)

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-buffered, 100G/400G/800G optimized routers. They are also available with additional on-chip High Bandwidth Memory (HBM) to support additional resource scale.

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 up to 19.2 Tbps of network bandwidth with dramatically lower power consumption than contemporary 20 Tbps systems.

This table details the specifications of the routers.

Router	Capacity	Form factor	400G QSFP-DD Ports	100G QSFP28 Ports
Cisco 8201	10.8 Tbps	1 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 11.

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-57D2 Series Fixed Port Routers

The NCS-57D2-18DD-SYS is a 2-rack-unit router designed for mass-scale core and aggregation networks. It delivers 7.2 Terabits of 400GE/100GE optimized forwarding capacity and features high power efficiency, QSFP-DD optics, deep packet buffering, full line-rate MACsec, IPSec, Class C 1588 Precision Time Protocol (PTP), and Synchronous Ethernet (SyncE). Powered by Cisco IOS® XR7, it offers advanced capabilities like next-generation security, automation, telemetry, segment routing, EVPN, and Equal-Cost Multipathing (ECMP). The router supports 18 ports of 400G and 66 ports of 100G, all with QSFP-DD, and breakout options for 10G, 25G, and 100G. Copy to Clipboard Good response

This table details the specifications of the routers.

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

For more information about Cisco NCS-57C1 Series Fixed Port Routers, see the [Cisco Network Convergence System 5700 Series: NCS-57C1 Fixed Chassis Data Sheet](#).

Cisco NCS-57C3 Series Fixed Port Routers

The Cisco Network Convergence System 57C3 Series Routers are designed for cost-effective delivery of next-generation networking services. These routers are high-capacity and low-power-consuming devices available in a 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.

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

The Cisco NCS 5700 Series line card, NC57-48Q2D-SE-S, is a high-density scale edition line card with a 2.4-Tbps throughput. It provides a mix of 1GE, 10GE, 25GE, 50GE, 100GE, and 400GE ports. The NC57-48Q2D-SE-S line card features 32 SFP28 ports capable of 1/10/25G, 16 SFP56 ports capable of

1/10/25/50G, and 2 QSFP-DD ports supporting 40/100/200/400G with breakout options. This "Scale Edition" variant includes an external TCAM (OP2) to enable higher prefix and service scale.

For information on ZR/ZR+ port support, see [400G ZR/ZR+ Transceivers, on page 11](#).

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 11](#).

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 11](#).

For more information 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

Platform	Line card/ Fixed Platform	Ports Supporting ZR	Ports Supporting ZR+	Breakout Modes Supported
Cisco 8000 Series Routers	8201-SYS	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22	1x100, 2x100, 3x100, 4x100, 1x400
	8202-SYS	48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59	48, 50, 52, 54, 56, 58	1x100, 2x100, 3x100, 4x100, 1x400
	8101-32FH 8201-32FH	All ports	All ports	1x100, 2x100, 3x100, 4x100, 1x400
	88-LC0-36FH-M 8800-LC-36FH	All ports	0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34	1x100, 2x100, 3x100, 4x100, 1x400
	88-LC0-36FH	All ports	All ports	1x100, 2x100, 3x100, 4x100, 1x400
	8201-24H8FH	0,2,4,6,8,10,12,14	0,2,4,6,8,10,12,14	1x100, 2x100, 3x100, 4x100, 1x400
	8101-32FH-M	All ports	All ports	1x100, 2x100, 3x100, 4x100, 1x400

Platform	Line card/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
	NCS-57C1-48Q6-SYS	0, 2, 4	0, 2, 4	1x100, 2x100, 3x100, 4x100, 1x400
	NC57-MOD-S (fixed ports)	8, 9	8, 9	1x100, 2x100, 3x100, 4x100, 1x400
	MPA-2D4H 400G slot	0, 1, 2, 3	0, 1, 2, 3	1x100, 2x100, 3x100, 4x100
	NC57-48Q2D-S(E)-S	48	48	1x100, 2x100, 3x100, 4x100, 1x400
	NCS-57D2-18DD-SYS	0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48, 52, 56, 60, 64, 65	0, 3, 4, 7, 8, 11, 12, 15, 16, 19, 20, 23, 24, 27, 28, 31, 32, 35, 36, 39, 40, 43, 44, 47, 48, 51, 52, 55, 56, 59, 60, 63, 64, 65	1x100, 2x100, 3x100, 4x100, 1x400
	MPA-2D4H 800G slot	0, 1, 2, 3	0, 1, 2, 3	1x100, 2x100, 3x100, 4x100, 1x400

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

Platform	Max no. of ZR supported in mode		Max no. of ZR+ supported in mode				
	400G	4x100G	400G	4x100G	3x100G	2x100G	1x100G
NCS-57B1-5DSE-SYS (400G ports)	5	5	5	5	5	5	5
MPA-2D4H-S (400G mode MPA)	-	1	-	1	1	2	4
NCS-55A2-MOD-S(E)-S with 2x400G MPA-2D4H	-	2	-	2	2	4	8
MPA-2D4H-S (800G mode MPA)	2	2	2	2	2	4	4
NCS-57C3-MOD(S)-SYS with 2x800G+1x400G MPA-2D4H	4	5	4	5	5	10	12
NC57-MOD-S (Fixed ports)	2	2	2	2	2	2	2
NC57-MOD-S with 2x800G MPA-2D4H	6	6	6	6	6	10	10
NCS-57C1-48Q6-SYS	3	3	3	3	3	3	3
NCS-57D2-18DD-SYS	18	18	18	18	18	34	34
NC57-48Q2D-S(E)-S	1	1	1	1	1	1	1
NC55-MOD-A(-SE)-S with 2x400G MPA-2D4H	-	2	-	2	2	4	8
N540-24Q8L2DD-SYS	2	2	2	2	2	2	2
8201	24	24	12	12	12	12	12
8202	12	12	6	6	6	6	6
8800-LC-36FH	36	36	18	18	18	18	18
88-LC0-36FH-M	36	36	18	18	18	18	18
8101-32FH	32	32	16	16	16	16	16
8201-32FH	32	32	16	16	16	16	16
8201-24H8FH	8	8	8	8	8	8	8
8202-32FH-M	32	32	32	32	32	32	32
88-LC0-36FH	36	36	18	18	18	18	18
A99-10X400GE-X-SE/TR	5	5	5	5	-	5	5
A9K-20HG-FLEX-SE/TR	5	5	5	5	-	-	5
A9K-8HG-FLEX-SE/TR	2	2	2	2	-	-	2
A9903-20HG-PEC	5	-	5	-	-	-	5
ASR-9902	-	-	-	-	-	-	2

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

Table 2: Bright ZR+ Support Matrix

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

For more information on Cisco 400G Digital Coherent Optics QSFP-DD Optical Modules, see the [Cisco 400G Digital Coherent Optics QSFP-DD Optical Modules Data Sheet](#).

Cisco High-Power QSFP-DD ZR+

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

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

Cisco Bright QSFP-DD ZR+ modules operate at a default TX power of +1 dBm for all platforms. Unlike ZR/ZR+ TX power level at all speeds and modulations remain at +1 dBm. Configuring the FEC type to cFEC reduces power to -10dBm for ZR compatibility. Cisco Bright QSFP-DD ZR+ modules support the same modes as QDD-400G-ZRP-S -10dBm optics.

Two product variants are available:

- Ethernet Variant (DP04QSDD-HE0)
- Multirate OTN/Ethernet Variant (DP04QSDD-HK9)

Cisco 400G QSFP-DD High-Power (Bright) Optical Module Ethernet Variant

Cisco 400G QSFP-DD High-Power (Bright) Optical module Ethernet variant is an enhanced version of the currently available QSFP-DD ZR+ Optical Module leveraging the same operational modes but providing as a major enhancement the increase of the Tx Optical Power up to +2dBm.

Supported client interface for this pluggable is Ethernet based, making this model perfectly suitable to be hosted on a router/switch host. The module asynchronously (GMP) maps an Ethernet signal from a switch/router to an intermediate 400ZR frame structure and then adapts the frame structure to the appropriate FEC engine.

The encoded signal is then DSP framed and modulated for transmission as a coherent Dual-Polarity mQAM signal. The PID for this pluggable optical module is DP04QSDD-HE0.

In Cisco IOS XR Release 7.9.1, the following routers support Cisco Bright QSFP-DD ZR+.

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

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



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

Cisco 400G QSFP-DD High-Power (Bright) Optical Module Multirate Ethernet/OTN Variant

The Cisco 400G QSFP-DD High-Power (Bright) Optical module multirate Ethernet/OTN variant shares the same HW platform (and so also the high Tx power) of the Ethernet variant but also supports OTN clients. The module leverages an intermediate ODUFlex, OTUCn/FlexO-x frame structure and then adapts the frame structure with OFEC.

This variant, thanks to the OTN OH, supports Layer-1 (L1) functionality to support authentication and encryption/decryption of the OPU[Cn,4] payload. The security IP provides wire-speed Galois-Counter- Mode (GCM) AES 256-bit security in either authentication-only (GMAC) or encryption/decryption-only (CTR) modes or both (GCM). Interhost key exchange is supported via communication over the GCC channel.

For more information on Bright ZR+ Optical Modules, see the [Cisco 400G QSFP-DD High-Power \(Bright\) Optical Module Data Sheet](#).

Legacy 200G Modulation Modes

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

OpenZR+ Compatibility Mode

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

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



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

The following table contains the possible Transponder and Muxponder configuration values for the DP04QSDD-HE0 optical module:

Table 3: Bright ZR+ Transponder and Muxponder Configuration Values

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

Cisco 400G QSFP-DD Ultra Long Haul Coherent Optics Module

The Cisco 400G QSFP-DD Ultra Long Haul (ULH) Coherent Optics Module is a high-performance, low-power transceiver designed to extend Routed Optical Networking use cases to regional and ultra-long-haul DWDM applications. It enables 400G traffic over amplified dense wavelength division multiplexing (DWDM) networks.

This module is mechanically compliant with the QSFP-DD Type 2A Module Specification and operates within a 24W power envelope. It offers an extended reach of over 3000 km across amplified DWDM links, supports OpenROADM 7.0 and OpenZR+ interoperability, and provides multiple 400G application select codes for optimized spectral efficiency or longer reach. Its high Tx power and Optical Signal-to-Noise Ratio (OSNR) make it compatible with any DWDM photonic network.

In Cisco IOS XR Release 25.2.1, the following routers and line cards support DP04QSDD-ULH-A1.

- 88-LC0-36FH-M
- 88-LC0-36FH
- NC57-18DD-SE
- NC57-24DD

Cisco QSFP28 100G ZR Digital Coherent Optics Module

This module is a QSFP28 form factor digital coherent optics (DCO) transceiver. It extends 100GbE coherent links directly from QSFP28 ports. It supports reaches up to 80km over dark fiber and up to 300km over amplified DWDM links. The module is C-band tunable.

It is compatible with widely deployed QSFP28 100G and 100GBASE ER CAUI-4 client interfaces. It features low power consumption (5.5W for commercial temperature, 6W for industrial temperature). The module supports Precision Timing Protocol (PTP) Class C Timing, making it suitable for low latency and precise frequency requirements. It is compliant with Common Management Interface Specification (CMIS) 5.2 and supports ITU-T G.709.2 standard-compliant staircase FEC.

In Cisco IOS XR Release 25.2.1, the following routers and line cards support DP01QS28-E20 and DP01QS28-E25

- ASR-9902
- ASR-9903
- A9903-20HG-PEC
- A9K-4HG
- A99-4HG
- A9K-8HG
- A9K-20HG
- A99-32HG
- A99-4T

Cisco QSFP-DD Pluggable Open Line System

The QSFP-DD OLS is a pluggable open line system solution that can be directly hosted on a Cisco router. The Cisco QSFP-DD Open Line System (QSFP-DD OLS) is a pluggable optical amplifier module that, together with the channel breakout options, provides a simple yet powerful open line system solution in a pluggable form factor that can be directly hosted on a Cisco router.

This table lists the routers and linecards that support Cisco QSFP-DD Pluggable Open Line System Modules (QSFP-DD OLS) and the release from which they support the module:

Table 4: OLS pluggable support

IOS-XR Release	Platform
7.10.1	• NCS-57B1-6D24-SYS • NCS-57B1-5DSE-SYS • NCS-57C3-MOD (using NC57-MPA-2D4H-S modular port adapter) • NCS-55A2-MOD (using NC57-MPA-2D4H-S modular port adapter)
24.1.1	• 8201-32FH • 8201-24H8FH • 8201 • 8202-32FH-M
24.3.1	• 88-LC0-36FH • 88-LC0-34H14FH • 8608 • 88-LC0-36FH-M

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

The QSFP-DD OLS itself is a pluggable module that integrates in itself two variable-gain amplifiers: a pre-amplifier and a booster amplifier to amplify both the up and down fiber streams. Various channel breakout options are available to combine or separate each channel from a coherent DWDM optical source. The TX-EDFA acting as a Booster amplifier recovers the loss of the optical Multiplexer units, and it provides an optical power boost before the link. The RX-EDFA acting as Preamp recovers the link loss, bringing the optical signal to a power level above the sensitivity of the receivers after the Demultiplexer unit.

The QSFP-DD OLS can extend the reach of a 400G QSFP-DD ZR/ZR+ link from 40 to 130 km or longer depending on fiber specification, the channel count, and the line rate of the signal.

The QSFP-DD OLS can extend the reach of a 400G Bright QSFP-DD ZR/ZR+ link from 80 to 130 km or longer depending on fiber specification, the channel count, and the line rate of the signal.

To be able to integrate a pair of ingress and egress ports on the QSFP-DD OLS pluggable faceplate, industry-standard CS connectors are used. The QSFP-DD-OLS has two bidirectional optical ports: the COM-RX/TX that shall be connected to the Mux/DMX unit, and the LINE-TX/RX that shall be connected to the fiber link. The optical connectors are 2x CS-UPC. The CS connector provides the characteristics and simplicity of the duplex LC connector into a smaller footprint to allow two pairs of CS connectors to fit within the physical constraints of the QSFP-DD form factor. Since the other optical units like Coherent Interfaces modules, DWDM Add/Drop multiplexers, and fiber patch panels have normally LC connectors, a hybrid adaptation patch cord with a CS dual connector on one side and 2x LC connector on the other side is available to interconnect the QSFP-DD-OLS modules with other optical equipment.

Optical safety is enabled by default to:

- Switch off each section independently in case Optical LOS is detected at its input.

- Set the TX-EDFA in Automatic Power Reduction (APR) at 8dBm in case a LOS is cleared at the COM-RX port, but LOS is still present at LINE-RX (this prevents the launch of high optical power on an open line)

One can build an N-channel line system using the QSFP-DD OLS and its associated components:

A single channel system

It requires no special components to add and drop. A special CS-LC cable (ONS-CAB-CS-LC-5) has been made available to interconnect LC ports of the QSFP-DD coherent source or the network with the CS ports of the QSFP-DD OLS. Just one pair of these cables is sufficient to make a single channel system. All the gain of the amplifier is available for the single channel in focus.

A 4-channel system

To achieve a 4-channel combine and split, an FLD-4 (fixed 4 channel OADM) can be used. This is a passive optical Add/Drop unit belonging to the ONS-15216 platform that is able to multiplex/demultiplex 4 channels over the 100GHz ITU grid.

An 8-channel system

To achieve an 8-channel combine and split, a 1x8 channel breakout cable can be used. This new breakout cable (ONS-BRK-CS-8LC) is a dual fanout 1x8 cable with an embedded passive splitter and coupler. The cable is grid-less so any port can be fed with any optical frequency without any constraints of frequency value or spacing between the channels.

A 16-channel system

To achieve a 16-channel combine and split, a 1x16 channel breakout cable can be used. This new breakout cable (ONS-BRK-CS-16LC) is a dual fanout 1x16 cable with an embedded passive splitter and coupler. The cable is grid-less so any port can be fed with any optical frequency without any constraints of frequency value or spacing between the channels.

A 32-channel system

To achieve a 32-channel combine and split, a 64-channel mux/dmx can be used (of which 32 channels are used). This (NCS1K-MD-64-C) is passive optical Add/Drop unit belonging to the NCS1K platform able to multiplex/demultiplex up to 64 channels over the 75GHz grid. Due to the limited operating bandwidth of the QSFP-DD-OLS, only a subset of the MD-64 channels can be used: from port CH-19 (194.75 THz) to port CH-50 (192.425 THz).

For more information on configuring Cisco QSFP-DD Pluggable Open Line System, see [Configuring QDD Optical Line System](#).

For more information on the Cisco QSFP-DD Pluggable Open Line System, see the [Cisco QSFP-DD Pluggable Open Line System Data Sheet](#).

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

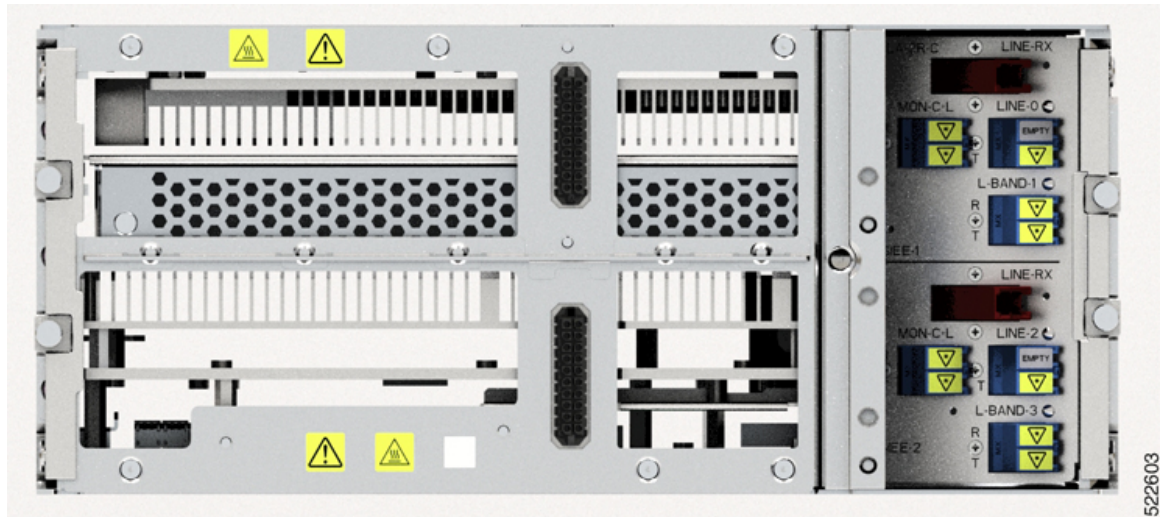
There are five different variants of the line card:

- 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 1: Perspective View of OLT-R-C Line Card



Figure 2: 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 28](#)
- [Cisco WAN Automation Engine, on page 29](#)
- [Cisco Optical Network Planner, on page 29](#)

Routed Optical Networking Planning Service

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.

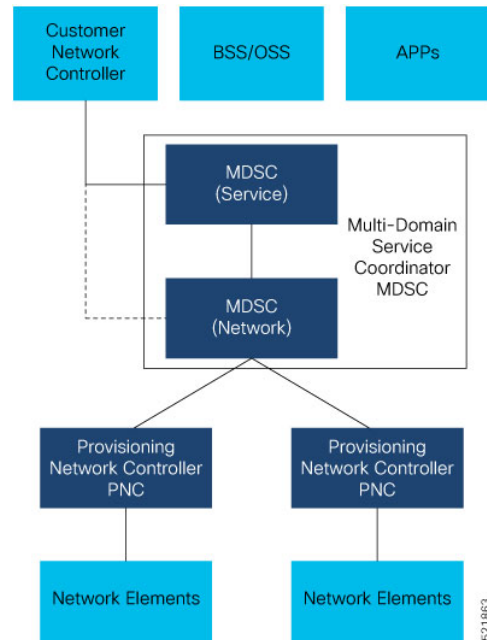
For more information, see [Cisco Optical Network Planner \(CONP\) Data Sheet](#)

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 multivendor 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 3: 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 4: Routed Optical Networking Automation Architecture

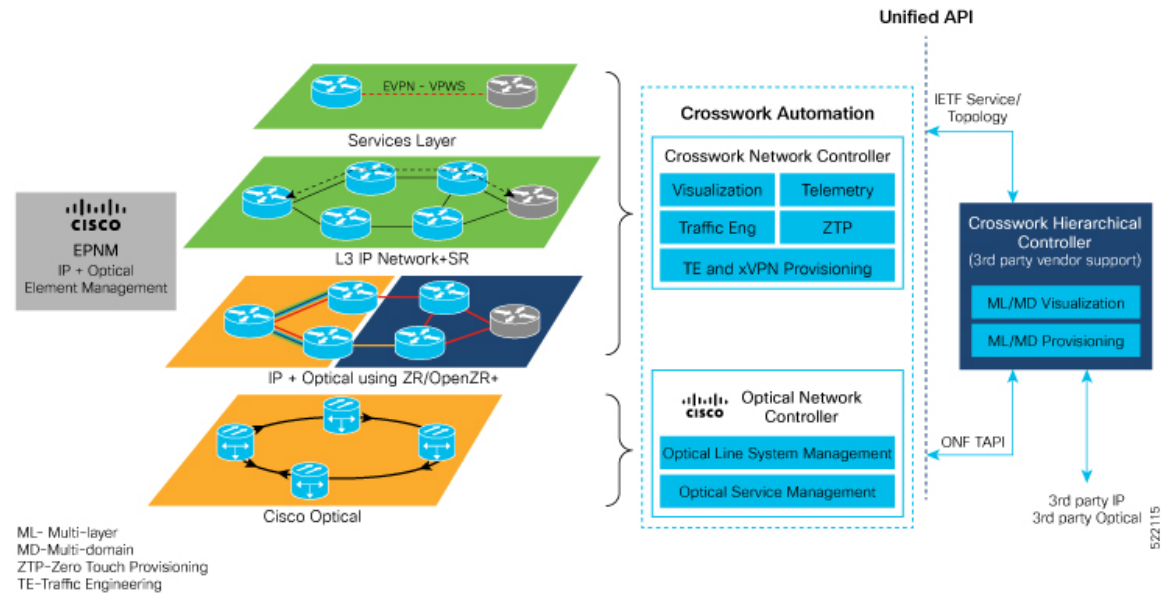


Table 5: Automation Software Roles

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

Automation Software	Roles
Network Services Orchestrator	• RON service management • RON Core Function Pack is required to be installed for RON service management • Also used for connectivity verification • Communicates to routers using CLI NED
Cisco Optical Network Controller 3.1	• Optical domain EMS and controller for NCS 101x • Exposes TAPI NBI interface for OLS topology, provisioning, inventory • Communicates to Cisco Optical Site Manager for optical node management and provisioning • Power level data available for NCS 1010 as part of CV
Cisco Optical Site Manager	• Optical site manager for NCS 1010 • Embedded in 1010 XR, cluster of 1010s are treated as a multi-shelf node and can run in active/standby • Required component for Cisco Optical Network Controller 3.1 and later releases to communicate to nodes via NETCONF
Cisco Crosswork Hierarchical Controller	• Multi-vendor / legacy IP+Optical • Communicates to Cisco Crosswork Network Controller via RESTCONF, telemetry via CDG via gRPC • Communicates to Cisco Optical Network Controller via RESTCONF TAPI, 1010 via RESTCONF/gRPC • Router inventory via XR CLI adapter
Cisco Evolved Programmable Network Manager	• Router and OLS Element Management • NOT used for RON service management in this solution • Collects inventory, alarm and PM data from routers directly using Netconf over CLI, syslog • Collects inventory, alarm, and PM data from NCS 2K and 1010

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.

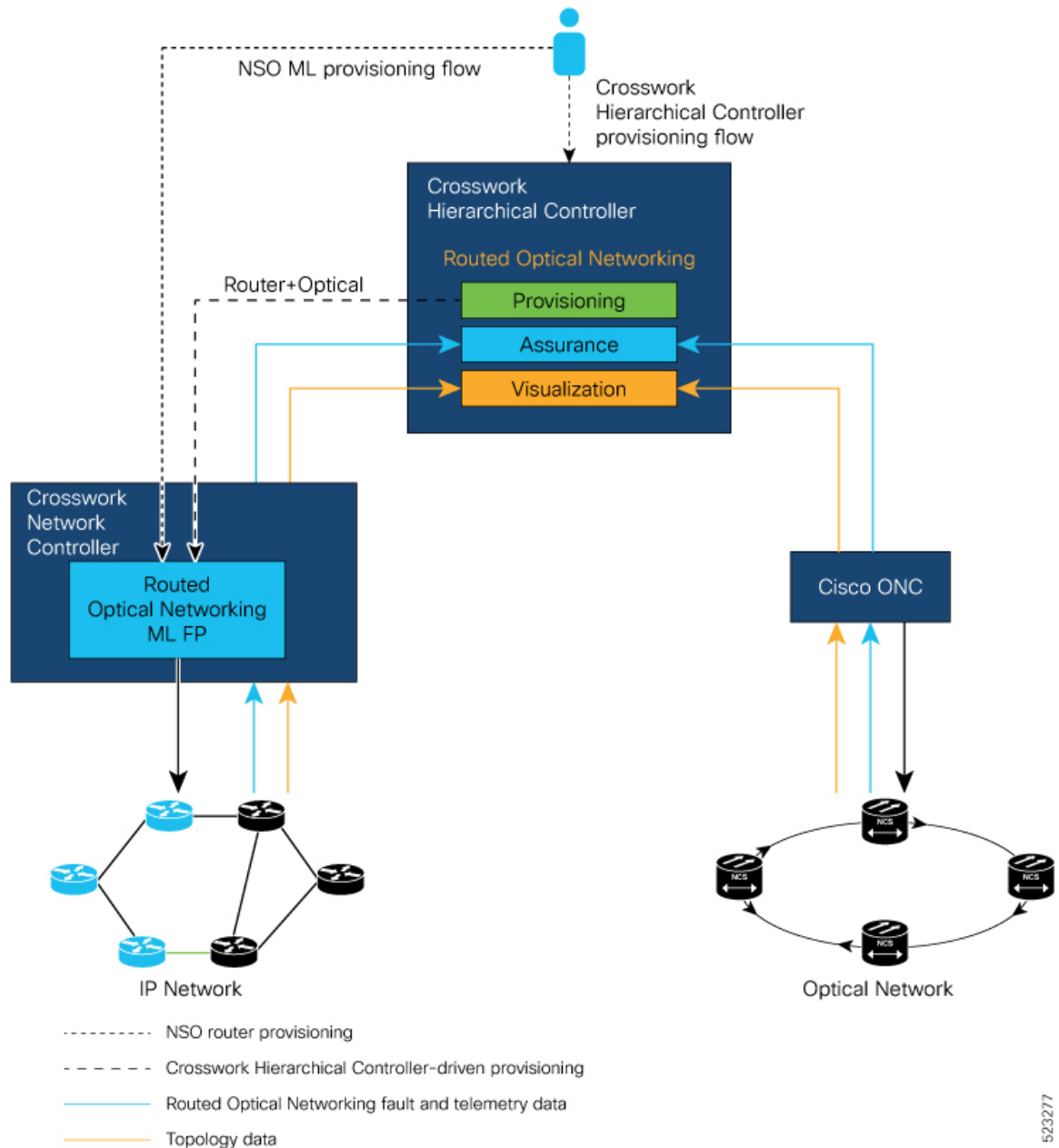
Crosswork Hierarchical Controller addresses the role of a multi-domain, multi-layer, and multi-vendor network controller. Crosswork Hierarchical Controller is capable to learn the mapping between IP/MPLS and optical layer ports (cross-layer mapping). This capability is key to providing a comprehensive 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 5: Crosswork Hierarchical Controller Workflow



523277

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.

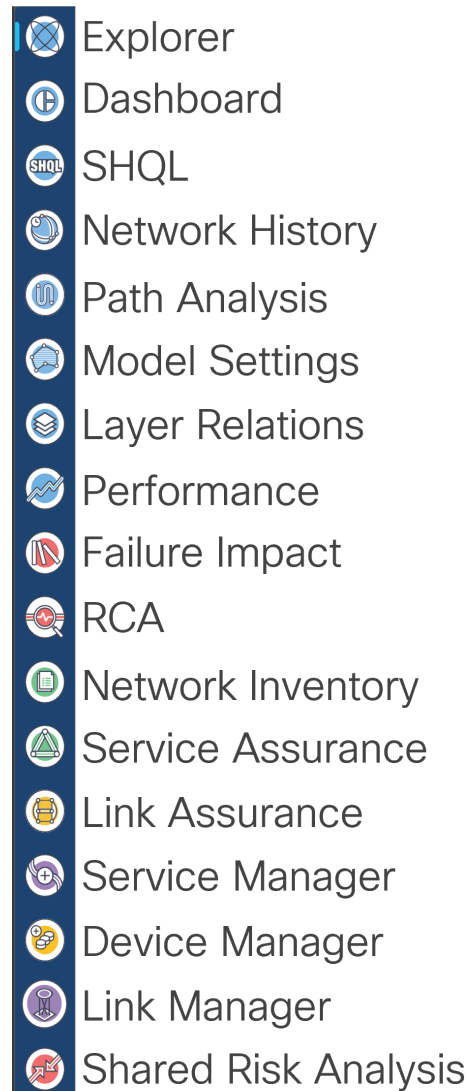
- **cisco-cnc-adpt** –IP network topology and link state information, router hardware inventory including discovery for DCO

- cisco-onc-adpt –Cisco optical network controller

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 fulfilment, 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
- Device performance measurement

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 Optical Site Manager

Cisco Optical Site Manager is a software application deployed in the NCS 1010 or NCS 1014 controller cards. The software application can be enabled in one or two controllers for high availability. Cisco Optical Site Manager (one or two) software instances work with open Netconf/YANG North bound Interface, which aggregates current and future NCS 1000 devices at the site and provides an abstracted site/node to Cisco Optical Network Controller or to a third-party controller. In addition, Cisco Optical Site Manager provides a Web UI for site-level operation and maintenance.

Cisco Optical Site Manager provides a site aggregation function for Optical Sites consisting of any NCS 1000 devices. Cisco Optical Site Manager provides an abstraction of the optical site topology with the underlying connected network elements, interacting with an SDN controller and/or to a web UI user.

Cisco Optical Site Manager provides the following functions:

- Seamless integration with Cisco Optical Network Controller for SDN automation
- OLS site, OT site, or OLS+OT site abstraction (Open Line System, Open Terminal)
- Site aggregation, topology, and nodal functional view
- Site-level alarm correlation
- Current PM up to last 32 bins
- OAM—Connection verification, loopbacks, PRBS, OTDR, and TCA
- Web UI with site-level management
- Mechanical layout for chassis, cards, and passive devices
- Card and module configurations

Cisco Optical Site Manager streams site-level data base information such as inventory, site topology, correlated alarms, and performance monitoring. Cisco Optical Network Controller consumes, stores, and represents the information at the network level, providing end-to-end circuit provisioning, monitoring, and troubleshooting with topology and analytics tools.

While Cisco Optical Site Manager is designed to work seamlessly with Cisco Optical Network Controller, it can also work as a standalone for a GUI Local Craft (useful for deployments, or local management) and/or interaction with a third-party controller.

For information on installing and setting up Cisco Optical Site Manager, see [System Setup and Software Installation Guide for Cisco Optical Site Manager](#)

For more information on Cisco Optical Site Manager, see the [Cisco Optical Site Manager 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.

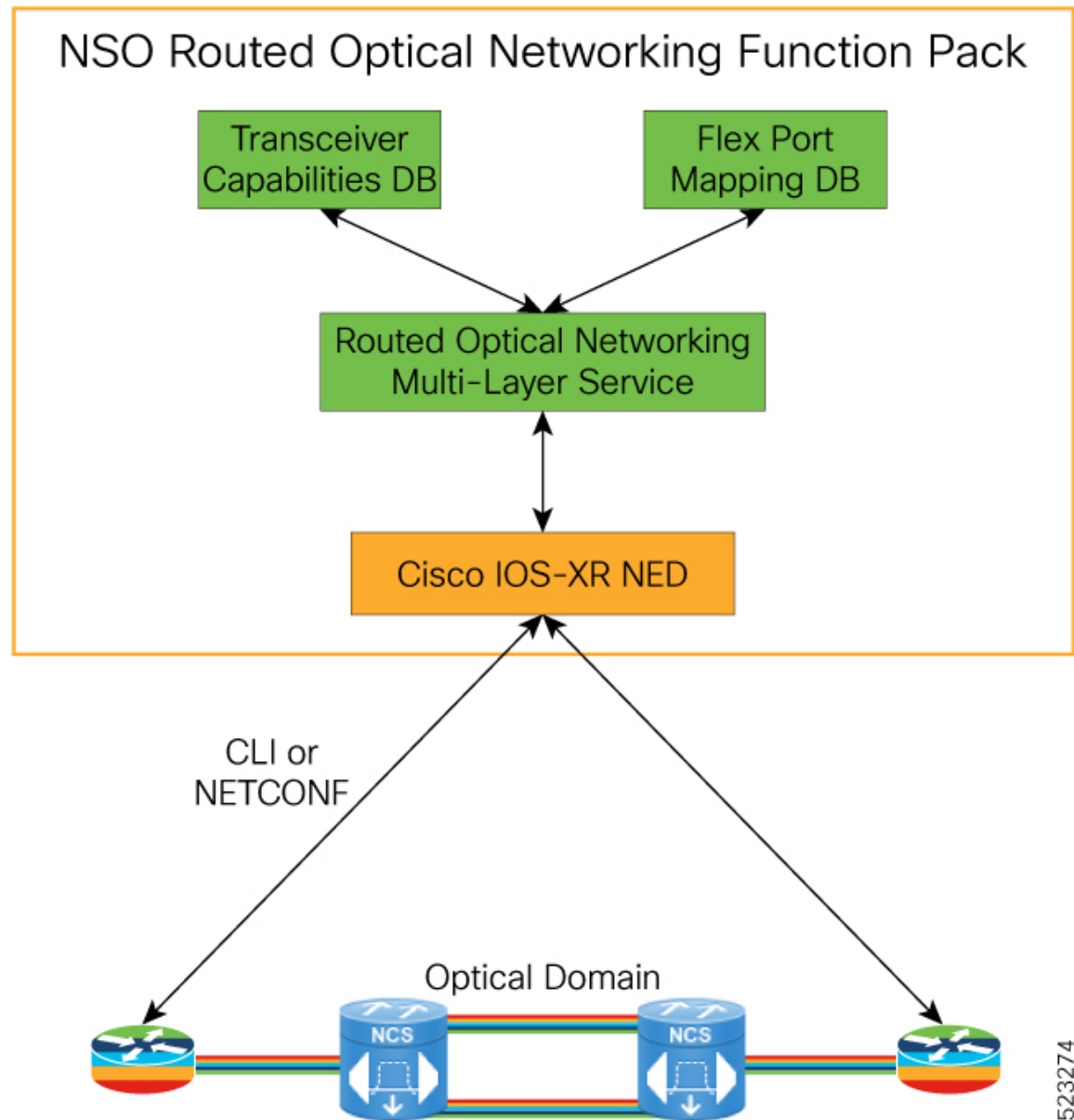
Cisco NSO has a rich set of APIs designed to allow developers to implement service applications. It provides the infrastructure for defining and executing the YANG data models necessary to realize customer services. NSO is also responsible for providing the overall lifecycle management at the network 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 6: Routed Optical Networking ML Function Pack



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

Component	Function
Flex-port mapping DB	Maintains chassis and line card PID database for ports that must be pre-provisioned before the ZR configuration. NCS57-18DD-SE and ASR 9000 multi-rate line cards must be preprovisioned
Transceiver capabilities DB	Map ZR/ZR+ optics PIDs to capabilities for provisioning verification. ZR = 400G, 4x100G, ZR+ = 100G, 2x100G, 3x100G, 4x100G, or 400G
Routed Optical Networking ML service	Performs ZR/ZR+ optical layer configuration. Optionally IP layer configuration of LAG membership and IP addressing
Cisco IOS-XR NED	Used to provision router elements. NSO network equipment driver used for southbound communication to routers.



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

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 100G and 400G digital coherent optics
- Configure the optical parameters on the digital coherent optics
- Assign IP address to Ethernet interfaces or bundle interfaces
- Bundle discrete Ethernet interfaces

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

Component	Software Version
SR PCE	IOS-XR 25.2.1
Cisco Crosswork Infrastructure	7.1
Crosswork Network Controller cApps	7.1
Crosswork Data Gateway	7.1
Network Services Orchestrator	6.4.1.1
Cisco Optical Network Controller (CONC)	25.1.2
Cisco Optical Site Manager (COSM)	25.1.1
Crosswork Hierarchical Controller	11.0
Cisco Evolved Programmable Network Manager	7.1.x / 8.x
Cisco Optical Network Planner	7.1

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 automated configuration and near real-time, actionable telemetry data. The following features are utilized to help ensure modern standards based management of Routed Optical Networking.

- **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.
- **Configuration of Digital Coherent Optics using CMIS Application Selection Code**

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

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.

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.

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

Unified Model	Open Config	Function
Cisco-IOS-XR-um-dac-rate-cfg	No equivalent	DAC Rate configuration
Cisco-IOS-XR-um-cont-breakout-cfg	No equivalent	Breakout configuration

**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.

DCO configuration using OIF CMIS AppSel code

Common Management Interface Specification (CMIS) from the Optical Internetworking Forum (OIF) is the management specification for modern transceivers. CMIS covers both traditional gray optics as well as newer Digital Coherent Optics. A transceiver consists of two sides: an electrical host side, which connects by its electrical pins to the port on the router, and an optical media side, which connects to the external fiber

Different optics modes are called Applications in CMIS. The Application is selected using a specific Application Selection code. The Application Selection code table includes two additional codes: the Media ID code and the Host ID code. The Media ID and Host ID codes can use either vendor proprietary or standards-based codes. In most cases the Host ID will always use a standard code defined by SFF (Small Form Factor Pluggable Consortium). The Host ID configures the transceiver properties to the host. The Media ID configures several line side properties. In the current XR CLI these are covered as separate properties, or configured automatically for a specific breakout mode.

AppSel Applicability

The DP04QSDD-ULH-A1 optics introduced in XR 25.2.1 and RON 4.0 only support configuration using AppSel. Other DCO such as the QDD-400G-ZRP-S and DP04QSDD-HE0 will support AppSel based configuration in a future release, and should be configured using the existing methods in this release.

Displaying AppSel information in IOS-XR using CLI

The “show controller optics <R/S/I/P> appsel advertised” command displays the AppSel values supported by the optics. This table is for a DP04QSDD-ULH-A1 optic.

```
RP/0/RP0/CPU0:ron-poc-8201-1#show controllers optics 0/0/0/16 appsel advertised
Tue May 20 13:10:27.650 UTC
```

App-ID		Host-ID			Media-ID		Standard
		Host	Power				
		Supported	Consumption (W)				
1	17	ETH 400GAUI-8 C2M (Annex	100	OpenROADM FLEXO-4e-DO-QP	OpenROADM		
		Yes n/a					
2	15	ETH 200GAUI-4 C2M (Annex	100	OpenROADM FLEXO-4e-DO-QP	OpenROADM		
		Yes n/a					
3	13	ETH 100GAUI-2 C2M (Annex	100	OpenROADM FLEXO-4e-DO-QP	OpenROADM		
		Yes n/a					
4	17	ETH 400GAUI-8 C2M (Annex	216	ACA FlexO-4e-MPCS098-OS	ACA		
		Yes n/a					
5	15	ETH 200GAUI-4 C2M (Annex	216	ACA FlexO-4e-MPCS098-OS	ACA		
		Yes n/a					
6	13	ETH 100GAUI-2 C2M (Annex	216	ACA FlexO-4e-MPCS098-OS	ACA		
		Yes n/a					
7	17	ETH 400GAUI-8 C2M (Annex	201	ACA FlexO-4e-MPCS087-OS	ACA		
		Yes n/a					
8	15	ETH 200GAUI-4 C2M (Annex	201	ACA FlexO-4e-MPCS087-OS	ACA		
		Yes n/a					
9	13	ETH 100GAUI-2 C2M (Annex	201	ACA FlexO-4e-MPCS087-OS	ACA		
		Yes n/a					
10	17	ETH 400GAUI-8 C2M (Annex	194	ACA FlexO-4e-MPCS075-OS	ACA		
		Yes n/a					
11	15	ETH 200GAUI-4 C2M (Annex	194	ACA FlexO-4e-MPCS075-OS	ACA		
		Yes n/a					
12	13	ETH 100GAUI-2 C2M (Annex	194	ACA FlexO-4e-MPCS075-OS	ACA		
		Yes n/a					
13	17	ETH 400GAUI-8 C2M (Annex	192	ACA FlexO-4e-MPCS066-OS	ACA		
		Yes n/a					
14	15	ETH 200GAUI-4 C2M (Annex	192	ACA FlexO-4e-MPCS066-OS	ACA		
		Yes n/a					
15	13	ETH 100GAUI-2 C2M (Annex	192	ACA FlexO-4e-MPCS066-OS	ACA		
		Yes n/a					
16	17	ETH 400GAUI-8 C2M (Annex	198	ACA OpenZR400-16QAM-OS-E	ACA		
		Yes n/a					
17	15	ETH 200GAUI-4 C2M (Annex	198	ACA OpenZR400-16QAM-OS-E	ACA		
		Yes n/a					
18	13	ETH 100GAUI-2 C2M (Annex	198	ACA OpenZR400-16QAM-OS-E	ACA		
		Yes n/a					
19	17	ETH 400GAUI-8 C2M (Annex	70	OpenZR+ ZR400-OFEC-16QAM	OpenZR+		
		Yes n/a					
20	15	ETH 200GAUI-4 C2M (Annex	70	OpenZR+ ZR400-OFEC-16QAM	OpenZR+		
		Yes n/a					
21	13	ETH 100GAUI-2 C2M (Annex	70	OpenZR+ ZR400-OFEC-16QAM	OpenZR+		
		Yes n/a					
22	17	ETH 400GAUI-8 C2M (Annex	54	OpenZR+ ZR400-OFEC-16QAM	OpenZR+		
		Yes n/a					
23	15	ETH 200GAUI-4 C2M (Annex	54	OpenZR+ ZR400-OFEC-16QAM	OpenZR+		
		Yes n/a					
24	13	ETH 100GAUI-2 C2M (Annex	54	OpenZR+ ZR400-OFEC-16QAM	OpenZR+		
		Yes n/a					
25	60	OTN-ITU-T FOIC1.2 (ITU-T	220	ACA FlexO-4-MPCS101-OS	ACA		
		No n/a					
26	60	OTN-ITU-T FOIC1.2 (ITU-T	202	ACA FlexO-4-MPCS087-OS	ACA		
		No n/a					
27	60	OTN-ITU-T FOIC1.2 (ITU-T	196	ACA FlexO-4-MPCS079-OS	ACA		
		No n/a					
28	60	OTN-ITU-T FOIC1.2 (ITU-T	193	ACA FlexO-4-MPCS069-OS	ACA		
		No n/a					

The “show controller optics <R/S/I/P> appsel active” command will display the current AppSel programmed into the transceiver.

```
RP/0/RP0/CPU0:ron-poc-8201-1#show controllers optics 0/0/0/16 appsel active
Tue May 20 13:12:09.599 UTC
```

```
Instance           :1
App-ID             :19
Host-ID            :17  ETH 400GAUI-8 C2M (Annex 120E)
Media-ID           :70  OpenZR+ ZR400-OFEC-16QAM
Host Lane Count    :8
Media Lane Count   :1
Host Lane Assign   :0x1
Media Lane Assign  :0x0
```

CLI AppSel configuration In IOS-XR

```
controller optics R/S/I/P appsel simple code <1-5000>
controller optics R/S/I/P appsel simple descriptor
media-id <1-5000>,
host-id <1-5000>
```

The “simple” mode uses the defined AppSel code to configure the media and line side of the optics for all lanes. The AppSel code used is determined by the user based on the AppSel code values stored within the transceiver firmware.

The “descriptor” mode allows the user to select the appropriate AppSel based on the media and host ID values represented by the AppSel. The appropriate AppSel code will be configured on the transceiver based on the combination of <media-id, host-id>. One reason to use this method of configuration is the media-id and host-id values are standardized, whereas the AppSel code values are not.

The AppSel configuration does not configure the NPU side of the configuration. Changing the NPU configuration is required when using different line rates. Using AppSel to configure the transceiver still requires configuring the NPU using the “breakout” or “hw-module” platform specific commands. In RON 4.0 the only speed supported is 400G, however some platforms with flexible ports may default to 100G, so commands are necessary to configure the NPU in 400G mode.

When configuring optics using automation tools such as Crosswork HCO and the NSO RON Function Pack, they will configure the optics using the “simple” method of configuration.

OpenConfig AppSel configuration

OpenConfig terminal-device models utilize the “operational-mode” value to configure line side optical parameters, similar to the AppSel media ID. In XR 25.2.1 OpenConfig models can be used with AppSel by using an operational-mode of 6xxx where xxx is the AppSel value.

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](#) 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.

gNMI Configuration

IOS-XR also supports configuration management using gRPC Network Management Interface. gNMI is a high performance set of remote procedure calls and functions used to manage network devices. Cisco native and OpenConfig models are supported using gNMI based configuration.

