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https://github.com/ios-xr/design/blob/master/Routed-Optical-Networking/2022-12-01-cst-routed-optical-2_0.pdf

Revision History

| Version | Date | Comments |
|---------|------------|--|
| 1.0 | 01/10/2022 | Initial Routed Optical Networking Publication |
| 2.0 | 12/01/2022 | Private Line Services, NCS 1010, CW HCO updates |
| 2.1 | 06/24/2023 | High-Power ZR+ Optics, Bandwidth Guaranteed PLE, Connectivity Verification |

Solution Component Software Versions

| Element | Version |
|-----------------------------------|---------|
| Router IOS-XR | 7.9.1 |
| NCS 2000 SVO | 12.3.1 |
| NCS 1010 IOS-XR | 7.9.1 |
| Cisco Optical Network Controller | 2.1 |
| Crosswork Network Controller | 5.0 |
| Crosswork Hierarchical Controller | 7.0 |
| Cisco EPNM | 7.0.1 |

What is Routed Optical Networking?

Routed Optical Networking as part of Cisco's Converged SDN Transport architecture brings network simplification to the physical network infrastructure, just as EVPN and Segment Routing simplify the service and traffic engineering network layers. Routed Optical Networking collapses complex technologies and network layers into a single cost efficient and easy to manage network infrastructure. Here we present the Cisco Routed Optical Networking architecture and validated design.

| Network Element | Legacy Networks | | Converged SDN Transport with Routed Optical Networking | |
|------------------------|--------------------------|------------------------------|--|--|
| xVPN Services | LDP | BGP | ✓ BGP for all L2VPN/L3VPN | |
| IP Network Scaling | BGP-LU | |  | |
| TE, FRR | RSVP-TE | | | |
| MPLS Overlay Protocol | RSVP-TE | LDP | | |
| IPv6 Transport Overlay | None | | | |
| IP to DWDM Transition | Transponder or Muxponder | | ✓ DCO transceivers in Cisco routers | |
| Private Line Services | Dedicated OTN | Dedicated Ethernet over DWDM | ✓ Circuit-style Segment Routing ✓ Private Line Emulation over Converged SDN Transport | |

Key Drivers

Changing Networks

Internet traffic has seen a compounded annual growth rate of 30% or higher over the last ten years, as more devices are connected, end user bandwidth speeds increase, and applications continue to move to the cloud. The introduction of 5G in mobile carriers and backhaul providers is also a disruptor, networks must be built to handle the advanced services and traffic increase associated with 5G. Networks must evolve so the infrastructure layer can keep up with the service layer. 400G Ethernet is the next evolution for SP IP network infrastructure, and we must make that as efficient as possible.

Network Complexity

Computer networks at their base are a set of interconnected nodes to deliver data between two endpoints. In the very beginning, these networks were designed using a layered approach to separate functions. The OSI model is an example of how functional separation has led to innovation by allowing different standards bodies to work in parallel at each layer. In some cases even these OSI layers are further split into different layers. While these layers can bring some cost benefit, it also brings added complexity. Each layer has its own management, control plane, planning, and operational model.

Inefficiencies Between Network Layers

OTN and IP network traffic must be converted into wavelength signals to traverse the DWDM network. This has traditionally required dedicated external hardware, a transponder. All of these layers bring complexity, and today some of those layers, such as OTN, bring little to the table in terms of efficiency or additional value. OTN switching, like ATM previously, has not been able to keep up with traffic demands due to very complex hardware. Unlike Ethernet/IP, OTN also does not have a widely interoperable control plane, locking providers into a single vendor or solution long-term.

Operational Complexity

Networks involving opaque layers are difficult to plan, build, and operate. IP and optical networks often have duplicate teams covering similar tasks. Network protection and restoration is also often complicated by different schemes running independently across layers. The industry has tried over decades to solve some of these issues with complex control planes such as GMPLS, but we are now at an evolution point where simplifying the physical layers and reducing control plane complexity in the optical layer allows a natural progression to a single control-plane and protection/restoration layer.

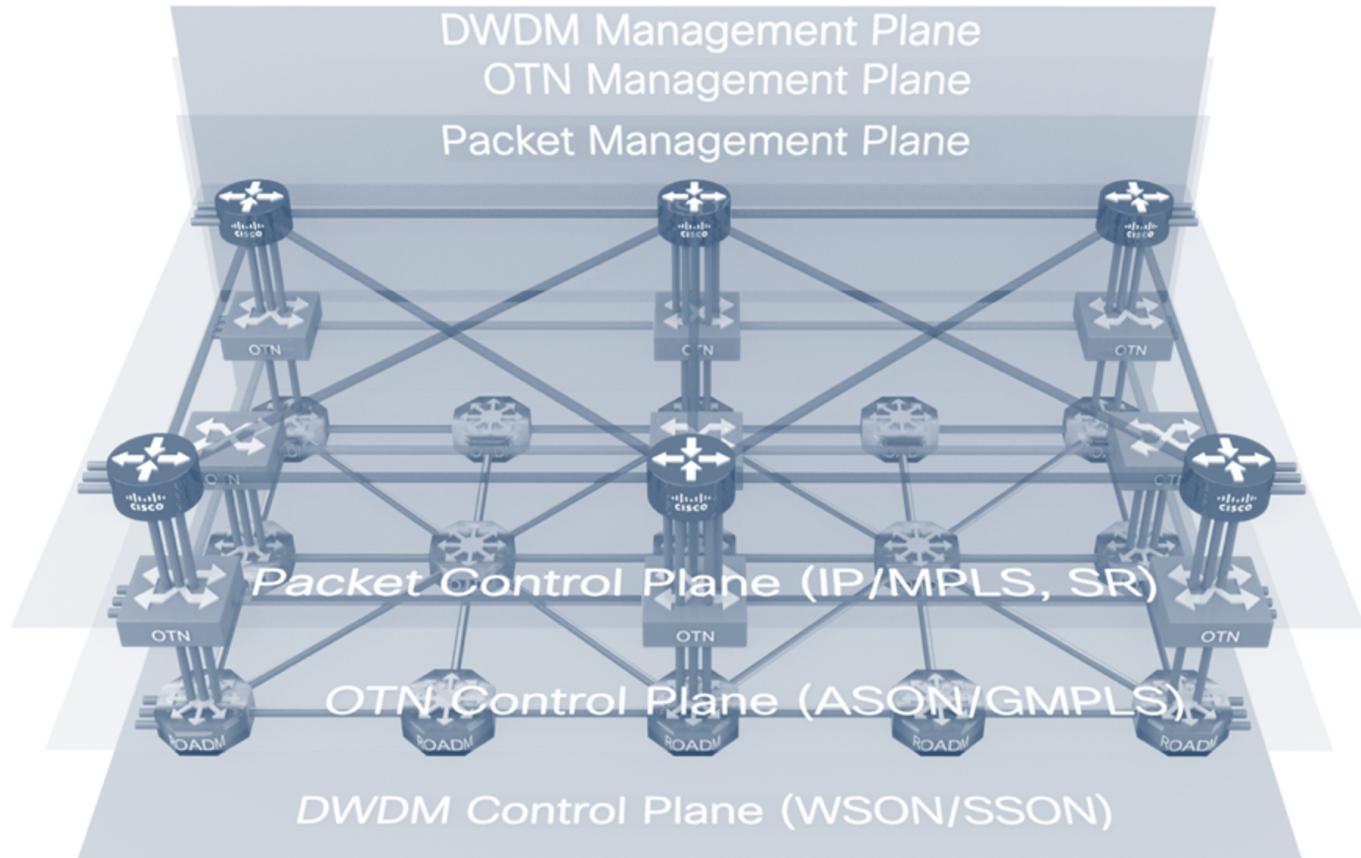
Network Cost

Simplifying networks reduces both capex and opex. As we move to 400G, the network cost is shifted away from routers and router ports to optics. Any way we can reduce the number of 400G interconnects on the network will greatly reduce cost. Modeling networks with 400ZR and OpenZR+ optics in place of traditional transponders and muxponders shows this in almost any network scenario. It also results in a reduced space and power footprint.

Routed Optical Networking Solution Overview

As part of the Converged SDN Transport architecture, Routed Optical Networking extends the key tenet of network simplification. Routed Optical Networking tackles the challenges of building and managing networks by simplifying both the infrastructure and operations.

Today's Complex Multi-Layer Network Infrastructure



DWDM

Most modern SP networks start at the physical fiber optic layer. Above the physical fiber is technology to allow multiple photonic wavelengths to traverse a single fiber and be switched at junction points, we will call that the DWDM layer.

OTN

In some networks, above this DWDM layer is an OTN layer, OTN being the evolution of traditional SONET/SDH networks. OTN grooms low speed TDM services into higher speed containers, and if OTN switching is involved, allows switching these services at intermediate points in the network. OTN is primarily used in network to carry guaranteed bandwidth services.

Ethernet/IP

In all high bandwidth networks today, there is an Ethernet layer on which IP services traverse, since almost all data traffic today is IP. Ethernet and IP is used due to its ability to support statistical multiplexing, topology flexibility, and widespread interoperability between different vendors based on well-defined standards. In larger networks today carrying Internet traffic, the Ethernet/IP layer does not typically traverse an OTN layer, the OTN layer is primarily used only for business services.

Enabling Technologies

Pluggable Digital Coherent Optics

Simple networks are easier to build and easier to operate. As networks scale to handle traffic growth, the level of network complexity must decline or at least remain flat.

IPoDWDM has attempted to move the transponder function into the router to remove the transponder and add efficiency to networks. In lower bandwidth applications, it has been a very successful approach. CWDM, DWDM SFP/SFP+, and CFP2-DCO pluggable transceivers have been used for many years now to build access, aggregation, and lower speed core networks. The evolution to 400G and advances in technology created an opportunity to unlock this potential in higher speed networks.

Transponder or muxponders have typically been used to aggregate multiple 10G or 100G signals into a single wavelength. However, with reach limitations, and the fact transponders are still operating at 400G wavelength speeds, the transponder becomes a 1:1 input to output stage in the network, adding no benefit.

The Routed Optical Networking architecture unlocks this efficiency for networks of all sizes, due to advancements in coherent plugable technology.

QSFP-DD, 400ZR, and OpenZR+ Standards

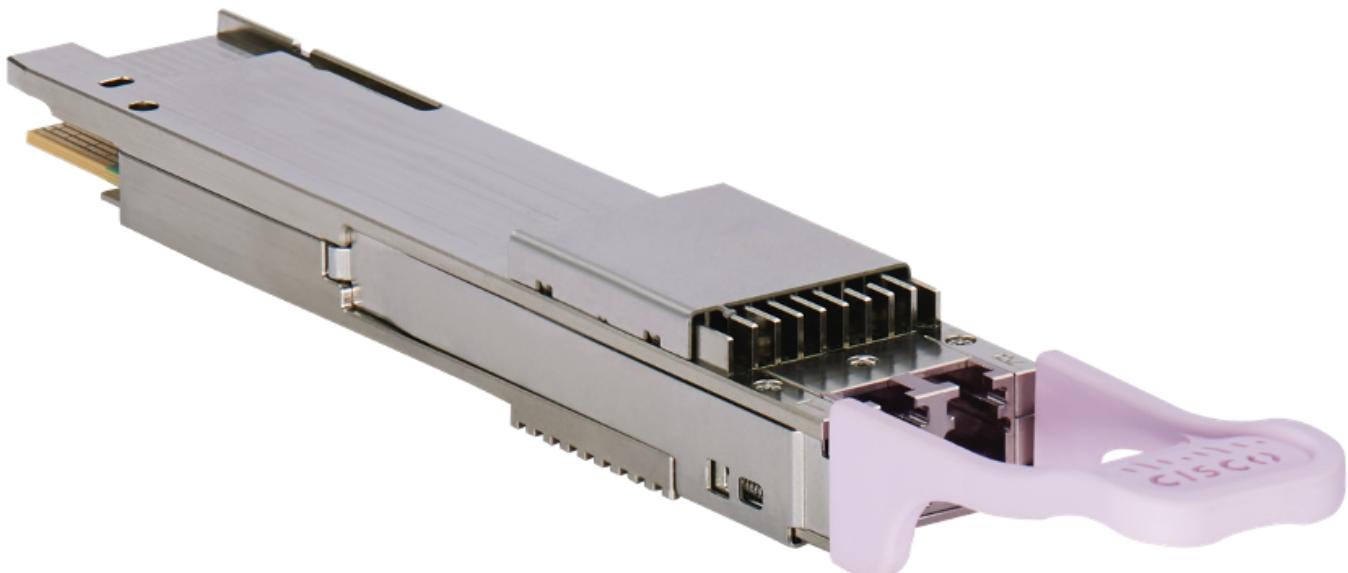
As mentioned, the industry saw a point to improve network efficiency by shifting coherent DWDM functions to router pluggables. Technology advancements have shrunk the DCO components into the standard QSFP-DD form factor, meaning no specialized hardware and the ability to use the highest capacity routers available today. ZR/OpenZR+ QSFP-DD optics can be used in the same ports as the highest speed 400G non-DCO transceivers.

Cisco High Power OpenZR+ Transceiver (DP04QSDD-HE0) **New for 2.1**

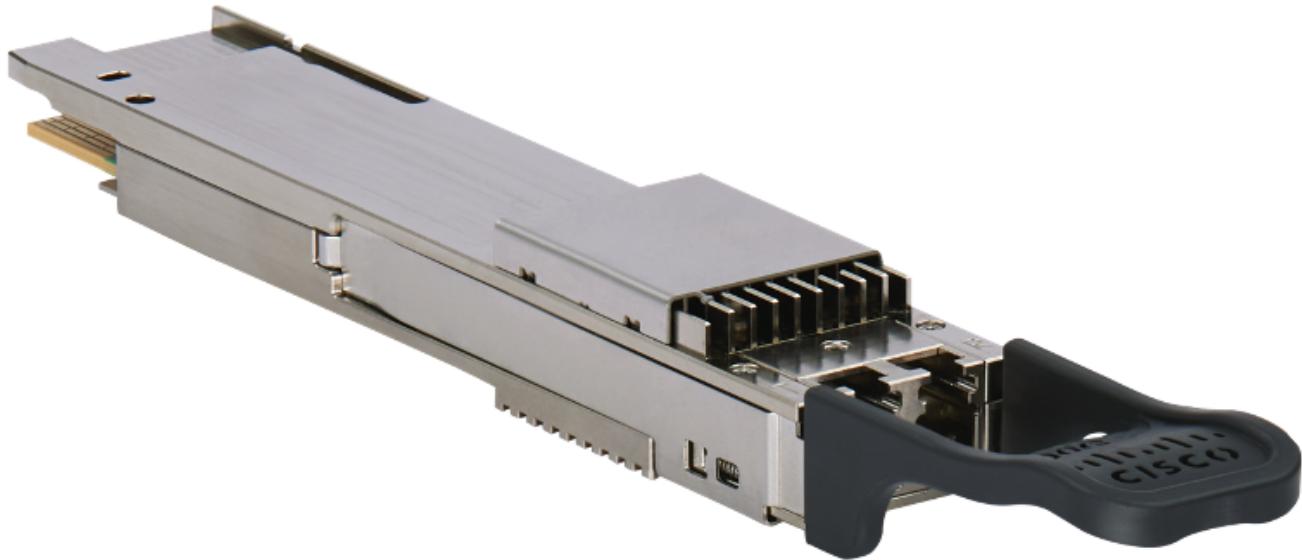
Routed Optical Networking 2.1 introduces the Cisco High Power +1dB ZR+ transceiver. This high launch power DCO enables the use of the optics with optical add drop systems requiring higher input power, and enables longer distances when used in passive or dark fiber applications without amplification.



Cisco OpenZR+ Transceiver (QDD-400G-ZRP-S)



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Cisco OIF 400ZR Transceiver (QDD-400G-ZR-S)

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Two industry optical standards have emerged to cover a variety of use cases. The OIF created the 400ZR specification, <https://www.oiforum.com/technical-work/hot-topics/400zr-2> as a 400G interopable standard for metro reach coherent optics. The industry saw the benefit of the approach, but wanted to cover longer distances and have flexibility in wavelength rates, so the OpenZR+ MSA was created, <https://www.openzrplus.org>. The following table outlines the specs of each standard. ZR400 and OpenZR+ transceivers are tunable across the ITU C-Band, 196.1 To 191.3 THz.



| Reach | < 120km | > 120km |
|------------------------|-------------------------|---------------------------------|
| Client | 400GbE Only | 100-400GbE |
| Application | Campus, Metro, Edge DCI | DCI, Metro, Regional, Long Haul |
| FEC | C-FEC | oFEC |
| Max. Power Consumption | 15W | ~20W |
| Multi-vendor Interop | Yes | Yes |
| Standards | OIF | OpenZR+ MSA |

The following part numbers are used for Cisco's ZR400 and OpenZR+ MSA transceivers

| Standard | Part |
|----------|---------------|
| 400ZR | QDD-400G-ZR-S |

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| Standard | Part |
|--------------------|----------------|
| OpenZR+ | QDD-400G-ZRP-S |
| High Power OpenZR+ | DP04QSDD-HE0 |

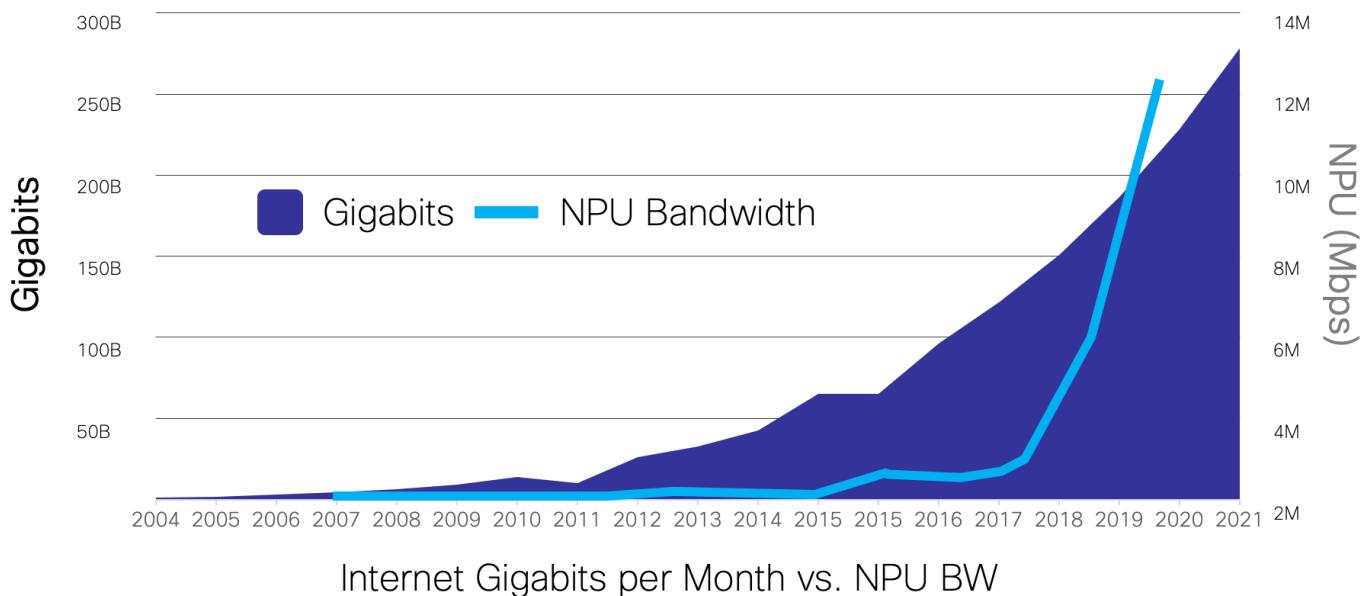
Cisco datasheet for the QDD-400G-ZRP-S and QDD-400G-ZR-S transceivers can be found at
<https://www.cisco.com/c/en/us/products/collateral/interfaces-modules/transceiver-modules/datasheet-c78-744377.html>

Cisco datasheet for the DP04QSDD-HE0 can be found at
<https://www.cisco.com/c/en/us/products/collateral/interfaces-modules/transceiver-modules/400g-qsfdd-high-power-optical-module-ds.html>

Cisco Routers

We are at a point in NPU development where the pace of NPU bandwidth growth has outpaced network traffic growth. Single NPUs such as Cisco's Silicon One have a capacity exceeding 12.8Tbps in a single NPU package without sacrificing flexibility and rich feature support. This growth of NPU capacity also brings reduction in cost, meaning forwarding traffic at the IP layer is more advantageous vs. a network where layer transitions happen often.

Cisco supports 400ZR and OpenZR+ optics across the NCS 540, NCS 5500, NCS 5700, ASR 9000, and Cisco 8000 series routers. This enabled providers to utilize the architecture across their end to end infrastructure in a variety of router roles. See



Cisco Private Line Emulation

Starting in Routed Optical Networking 2.0, Cisco now supports Private Line Emulation (PLE) hardware and IOS-XR support to provide bit-transparent private line services over the converged packet network. Private Line Emulation supports the transport of Ethernet, SONET/SDH, OTN, and Fiber Channel services. See the PLE section of the document for in-depth information on PLE.

Circuit Style Segment Routing

Circuit Style Segment Routing (CS-SR) is another Cisco advancement bringing TDM circuit like behavior to SR-TE Policies. These policies use deterministic hop by hop routing, co-routed bi-directional paths, hot standby protect paths with end to end liveness detection, and bandwidth guaranteed services. Standard Ethernet services not requiring bit transparency can be transported over a Segment Routing network similar to OTN networks without the additional cost, complexity, and inefficiency of an OTN network layer.

Cisco DWDM Network Hardware

Routed Optical Networking shifts an expensive and now often redundant transponder function into a pluggable transceiver. However, to make the most efficient use of a valuable resource, the underlying fiber optic network, we still need a DWDM layer. Routed Optical Networking is flexible enough to work across point to point, ROADM based optical networks, or a mix of both. Cisco multiplexers, amplifiers, and ROADMs can satisfy any network need.

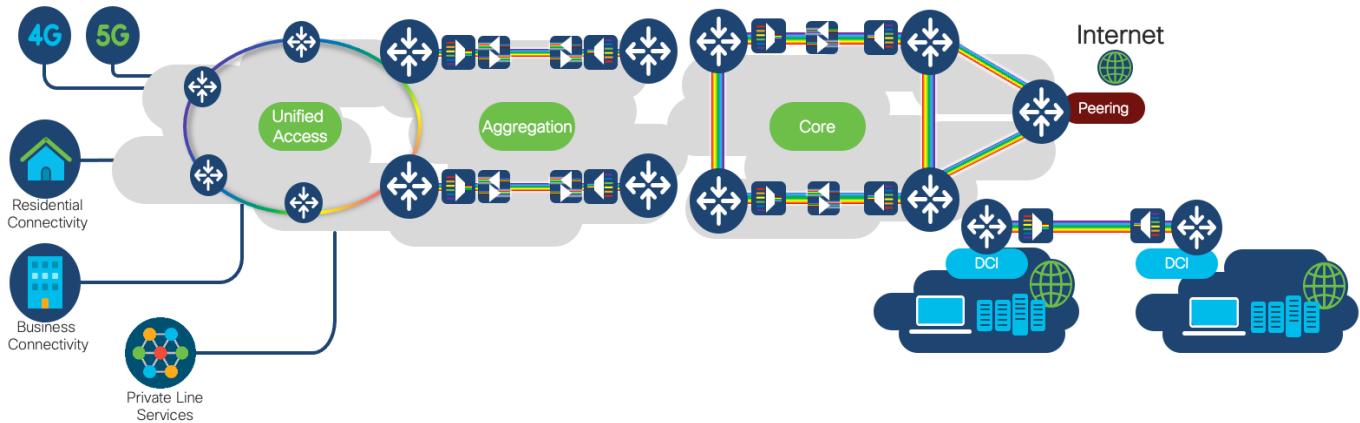
Cisco NCS 1010

Routed Optical Networking 2.0 introduces the new Cisco NCS 1010 open optical line system. The NCS 1010 represents an evolution in open optical line systems, utilizing the same IOS-XR software as Cisco routers and NCS 1004 series transponders. This enables the rich XR automation and telemetry support to extend to the DWDM photonic line system. The NCS 1010 also simplifies how operators build DWDM networks with advanced integrated functions and a flexible twin 1x33 WSS.

See the validated design hardware section for more information.

Routed Optical Networking Network Use Cases

Cisco is embracing Routed Optical Networking in every SP router role. Access, aggregation, core, peering, DCI, and even PE routers can be enabled with high speed DCO optics. Routed Optical Networking is also not limited to SP networks, there are applications across enterprise, government, and education networks.



Where to use 400ZR and where to use OpenZR+

The OIF 400ZR and OpenZR+ MSA standards have important differences.

400ZR supports 400G rates only, and targets metro distance point to point connections up to 120km. 400ZR mandates a strict power consumption of 15W as well. Networks requiring only 400G over distances less than 120km may benefit from using 400ZR optics. DCI and 3rd party peering interconnection are good use cases for 400ZR.

If a provider needs flexibility in rates and distances and wants to standardize on a single optics type, OpenZR+ can fulfill the need. In areas of the network where 400G may not be needed, OpenZR+ optics can be run at 100G or 200G. Additionally, hardware with QSFP-DD 100G ports can utilize OpenZR+ optics in 100G mode. This can be ideal for high density access and aggregation networks.

Supported DWDM Optical Topologies

For those unfamiliar with DWDM hardware, please see the overview of DWDM network hardware in [Appendix A](#) {[: .notice--warning}](#)

The future of networks may be a flat L3 network with simple point to point interconnection, but it will take time to migrate to this type of architecture. Routed Optical Network supports an evolution to the architecture by working over most modern photonic DWDM networks. Below gives just a few of the supported optical topologies including both point to point and ROADM based DWDM networks.

NCS 2000 64 Channel FOADM P2P Deployment

This example provides up to 25.6Tb on a single network span, and highlights the simplicity of the Routed Optical Networking solution. The "optical" portion of the network including the ZR/ZR+ configuration can be completed in a matter of minutes from start to finish.



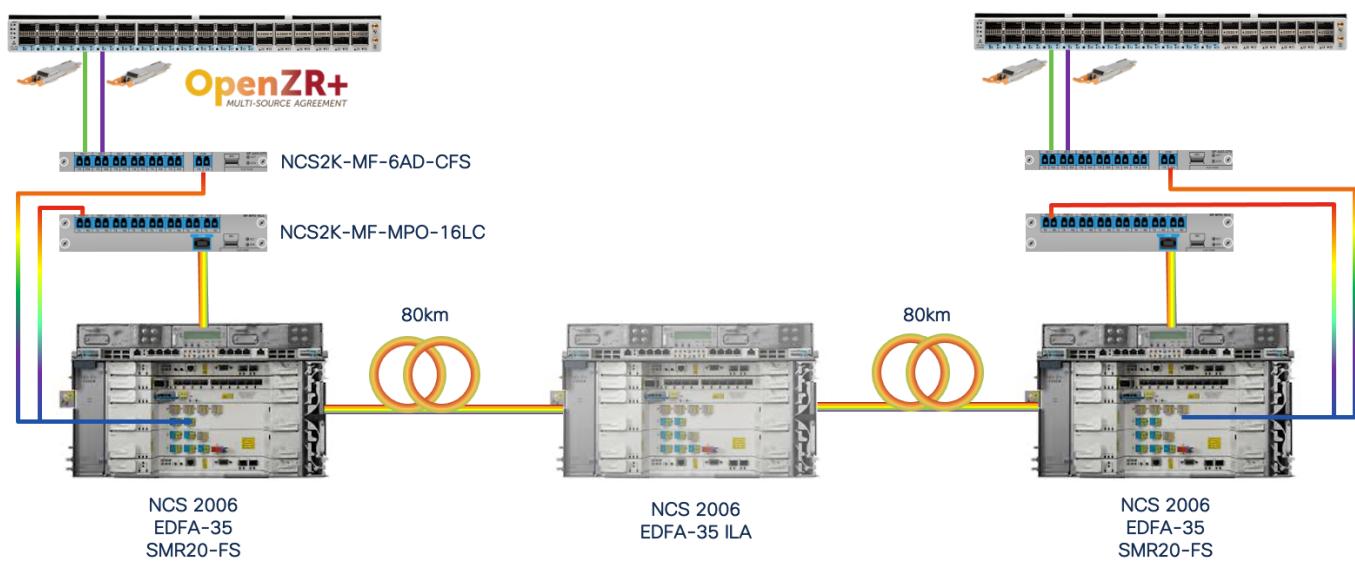
NCS 1010 64 Channel FOADM P2P Deployment

The NCS 1010 includes two add/drop ports with embedded bi-directional EDFA amplifiers, ideal for connecting the new MD-32-E/O 32 channel, 150Ghz spaced passive multiplexer. Connecting both even and odd multiplexers allows the use of 64 total channels.



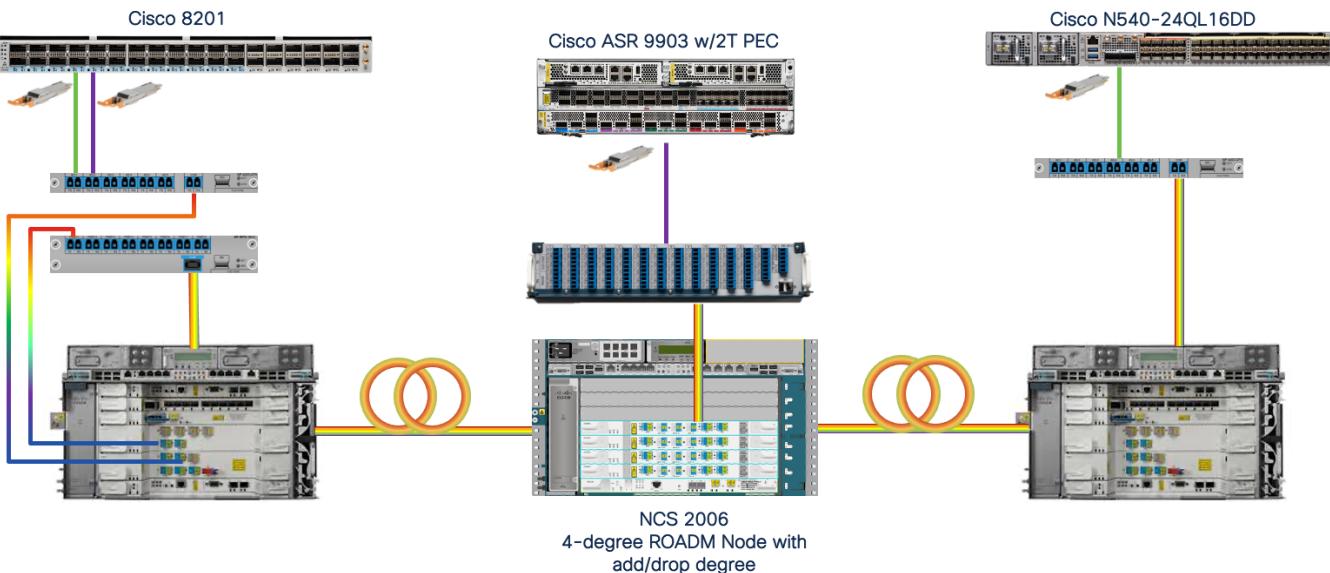
NCS 2000 Colorless Add/Drop Deployment

Using the NCS2K-MF-6AD-CFS colorless NCS2K-MF-LC module along with the LC16 LC aggregation module, and SMR20-FS ROADM module, a scalable colorless add/drop complex can be deployed to support 400ZR and OpenZR+.



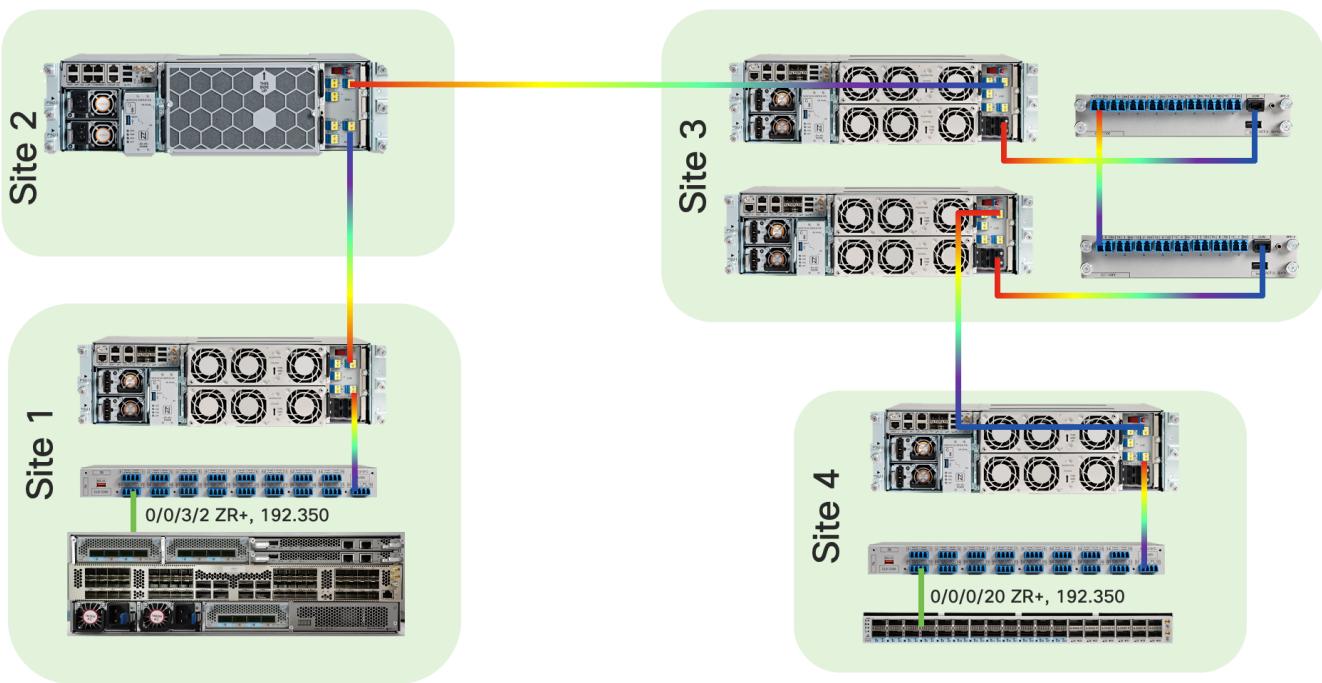
NCS 2000 Multi-Degree ROADM Deployment

In this example a 3 degree ROADM node is shown with a local add/drop degree. The Routed Optical Networking solution fully supports ROADM based networks with optical bypass. The traffic demands of the network will dictate the most efficient network build. In cases where an existing or new build requires DWDM switching capability, ZR and ZR+ wavelengths are easily provisioned over the infrastructure.



NCS 1010 Multi-Degree Deployment

A multi-degree NCS 1010 site utilizes a separate NCS 1010 OLT device for each degree. The degree may be an add/drop or bypass degree. In our example Site 3 can support the add/drop of wavelengths via its A/D ports on the upper node, or express those wavelengths through the interconnect to site 4 via the additional 1010 OLT unit connected to site 4. In our example the wavelength originating at sites 1 and 4 using ZR+ optics is expressed through site 3.



Long-Haul Deployment

Cisco has demonstrated in a physical lab 400G OpenZR+ services provisioned across 1200km using NCS 2000 and NCS 1010 optical line systems. 300G, 200G, and 100G signals can achieve even greater distances. OpenZR+ is not just for shorter reach applications, it fulfills an ideal sweet spot in most provider networks in terms of bandwidth and reach.

Core Networks

Long-haul core networks also benefit from the CapEx and OpEx savings of moving to Routed Optical Networking. Moving to a simpler IP enabled converged infrastructure makes networks easier to manage and operate vs. networks with complex underlying optical infrastructure. The easiest place to start in the journey is replacing external transponders with OpenZR+ QSFP-DD transceivers. At 400G connecting a 400G gray Ethernet port to a transponder with a 400G or 600G line side is not cost or environmentally efficient. Cisco can assist in modeling your core network to determine the TCO of Routed Optical Networking compared to traditional approaches.

Metro Aggregation

Tiered regional or metro networks connecting hub locations to larger aggregation site or datacenters can also benefit from Routed Optical Networking. Whether deployed in a hub and spoke topology or hop by hop IP ring, Routed Optical Networking satisfied provider's growth demands at a lower cost than traditional approaches.

Access

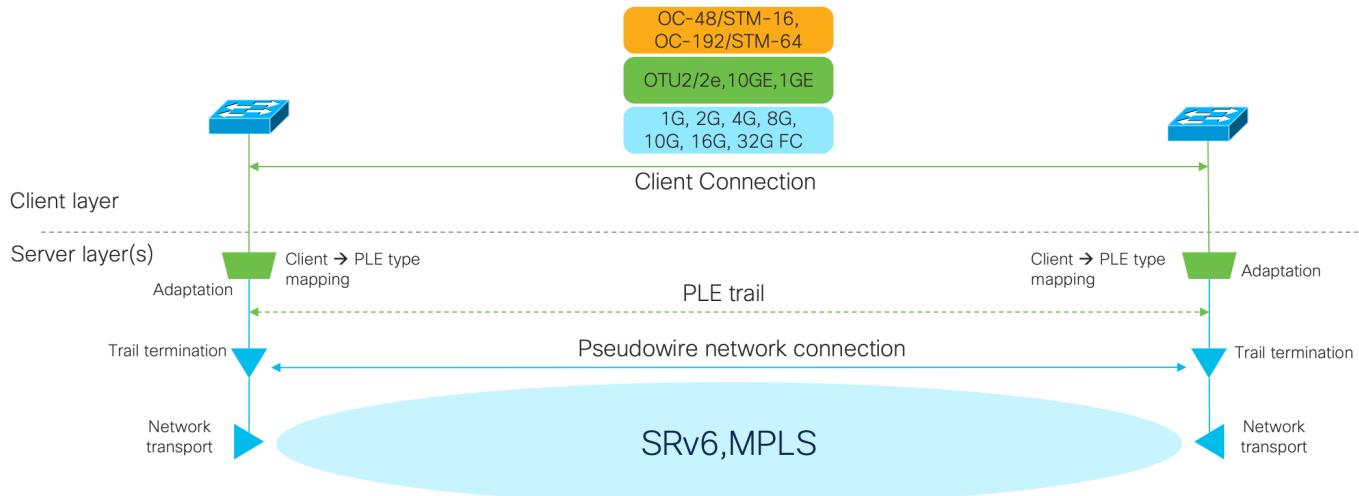
Access deployments in a ring or point-to-point topology are ideal for Routed Optical Networking. Shorter distances over dark fiber may not require active optical equipment, and with up to 400G per span may provide the bandwidth necessary for growth over a number of years without the use of additional multiplexers.

DCI and 3rd Party Location Interconnect

In this use case, Routed Optical Networking simplifies deployments by eliminating active transponders, reducing power, space, and cabling requirements between end locations. 25.6Tbps of bandwidth is available over a single fiber using 64 400G wavelengths and simple optical amplifiers and multiplexers requiring no additional configuration after initial turn-up.

Routed Optical Networking Private Line Services

Release 2.0 introduces Circuit Style Segment Routing TE Policies and Private Line Emulation hardware to enable traditional TDM-like private line services over the converged Segment Routing packet network. The following provides an overview of the hardware and software involved in supporting PL services. The figure below gives an overview of PLE service signaling and transport.



Circuit Style Segment Routing

CS-SR provides the underlying TDM-like transport to support traditional private line Ethernet services without additional hardware and bit-transparent Ethernet, OTN, SONET/SDH, and Fiber Channel services using Private Line Emulation hardware.

CS SR-TE paths characteristics

- Co-routed Bidirectional - Meaning the paths between two client ports are symmetric
- Deterministic without ECMP - Meaning the path does not vary based on any load balancing criteria
- Persistent - Paths are routed on a hop by hop basis, so they are not subject to path changes induced by network changes
- End-to-end path protection - Entire paths are switched from working to protect with the protect path in a hot standby state for fast transition
- Bandwidth guaranteed paths

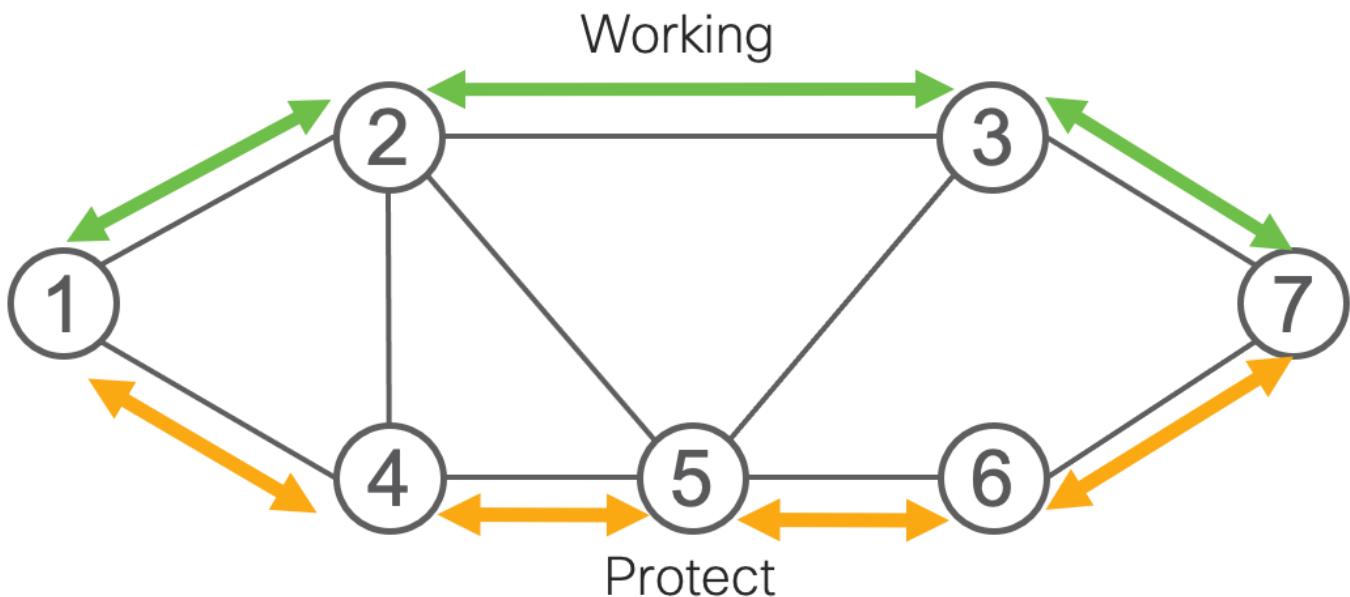
SR CS-TE policies are built using link adjacency SIDs without protection to ensure the paths do not take a TI-LFA path during path failover and instead fail over to the pre-determined protect path.

CS SR-TE path liveness detection

Paths can be configured with end to end liveness detection. Liveness detection uses STAMP (Simple Two-Way Active Measurement Protocol) probes which are looped at the far end to determine if the end to end path is up bi-directionally. If more than the set number of probes is missed (set by the multiplier) the path will be considered down. Once liveness detection is enabled probes will be sent on all candidate paths. Either the default liveness probe profile can be used or if you want to modify the default parameters a customized one can be created.

CS SR-TE path failover behavior

CS SR-TE policies contain multiple candidate paths. The highest preference candidate path is considered the working path, the second highest preference path is the protect path, and if a third lower preference path is configured would be a dynamic restoration path. This provides 1:1+R protection for CS SR-TE policies.



Static CS SR-TE Policies

Static CS SR-TE policies are policies using explicit pre-defined paths for the working and protect paths in both the forward and reverse direction. These explicit paths define the hop by hop path using adjacency-SIDs. The explicit SID lists are defined on the head-end routers and part of the persistent device configuration. They can be built by a user or an external controller which is creating the paths by available network information. Explicit SID lists can be referenced by multiple SR Policies.

The following below shows the configuration of a static CS SR-TE Policy with a working, protect, and restoration path.

```
segment-routing
  traffic-eng
    policy to-55a2-1
      color 1001 end-point ipv4 100.0.0.44
      path-protection
        !
        candidate-paths
          preference 25
            dynamic
              metric-type igp
            !
            !
          preference 50
            explicit segment-list protect-forward-path
            reverse-path segment-list protect-reverse-path
          !
          !
        preference 100
          explicit segment-list working-forward-path
          reverse-path segment-list working-reverse-path
        !
        !
    !
```

```
performance-measurement
liveness-detection
liveness-profile name liveness-check
```

CS SR-TE Policy operational details

```
RP/0/RP0/CPU0:ron-ncs55a2-1#show segment-routing traffic-eng policy color
1001
Sat Dec 3 13:32:38.356 PST
```

SR-TE policy database

Color: 1001, End-point: 100.0.0.42 Name: srte_c_1001_ep_100.0.0.42 Status: adjmin: up Operational: up for 2d09h (since Dec 1 04:08:12.648) Candidate-paths: Preference: 100 (configuration) (active) Name: to-100.0.0.42 Requested BSID: dynamic PCC info: Symbolic name: cfg_to-100.0.0.42_discr_100 PLSP-ID: 1 Constraints: Protection Type: protected-preferred Maximum SID Depth: 12 Explicit: segment-list forward-adj-path-working (valid) Reverse: segment-list reverse-adj-path-working Weight: 1, Metric Type: TE SID[0]: 15101 [adjacency-SID, 100.1.1.21 - 100.1.1.20] SID[1]: 15102 SID[2]: 15103 SID[3]: 15104 Reverse path: SID[0]: 15001 SID[1]: 15002 SID[2]: 15003 SID[3]: 15004 Protection Information: Role: WORKING Path Lock: Timed Lock Duration: 300(s) State: ACTIVE Preference: 50 (configuration) (protect) Name: to-100.0.0.42 Requested BSID: dynamic PCC info: Symbolic name: cfg_to-100.0.0.42_discr_50 PLSP-ID: 2 Constraints: Protection Type: protected-preferred Maximum SID Depth: 12 Explicit: segment-list forward-adj-path-protect(valid) Reverse: segment-list reverse-adj-path-protect Weight: 1, Metric Type: TE SID[0]: 15119 [adjacency-SID, 100.1.42.1 - 100.1.42.0] Reverse path: SID[0]: 15191 Protection Information: Role: PROTECT Path Lock: Timed Lock Duration: 300(s) State: STANDBY Attributes: Binding SID: 24017 Forward Class: Not Configured Steering labeled-services disabled: no Steering BGP disabled: no IPv6 caps enable: yes Invalidation drop enabled: no Max Install Standby Candidate Paths: 0

Dynamic Circuit Style SR-TE

Release 2.1 of Routed Optical Networking introduces the concept of dynamic CS SR-TE. Dynamic CS SR-TE utilizes Cisco's SR-PCE Path Computation Element to compute the working and protection paths of the CS SR-TE policy. Each head-end node acts as a Path Computation Client, utilizing PCEP and Circuit Style PCEP extensions to communicate the required path characteristics to SR-PCE. Utilizing SR-PCE to compute the optimal disjoint paths simplifies the configuration and deployment of Circuit-Style Policies.

Bi-directional Association ID

Circuit style paths are bi-directional and co-routed. The association ID value is used to communicate the constraint to SR-PCE. SR-PCE will then compute the same co-routed path from each head-end router to the tail-end router. The working paths on both head-end routers require using the same ID. The protect paths will also use the same ID, but unique from the working path ID. Likewise, the optional restoration paths will also utilize a unique ID. The identifiers should be globally unique for each pair of CS SR-TE policies. The following gives an example of the identifiers:

| Router | Path Type | Association ID |
|---------------|------------------|-----------------------|
| A | Working | 100 |
| Z | Working | 100 |
| A | Protect | 200 |
| Z | Protect | 200 |
| A | Restoration | 300 |
| Z | Restoration | 300 |

Disjoint path group ID

Another property of CS SR-TE policies is working and protect paths are fully disjoint. A disjoint group ID is used to communicate the constraint to SR-PCE. On each head-end node the working and protect candidate paths are assigned the same disjoint group ID. The disjoint group ID will be globally unique on each head-end node. Available options for path disjointness are node, link, and srlg.

| Router | Path Type | Disjoint Group ID |
|---------------|------------------|--------------------------|
| A | Working | 101 |
| Z | Working | 201 |
| A | Protect | 101 |
| Z | Protect | 201 |

Path constraints

Circuit style paths utilize only unprotected adjacency SID, those constraints are communicated to SR-PCE using specific configuration and flags in PCEP.

The following configuration shows the full dynamic SR-TE configuration on each head-end node.

Router A

```
policy dynamic-cs-srte-to-55a2-p2
  color 119 end-point ipv4 100.0.0.44
  path-protection
  !
  candidate-paths
    preference 100
    dynamic
      pcep
      !
      metric
        type igrp
      !

```

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

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

Router Z

```
policy dynamic-cs-srte-to-57c3-p2
color 119 end-point ipv4 100.0.0.42
path-protection
!
candidate-paths
preference 100
dynamic
pcep
!
metric
type igp
!
!
constraints
segments
protection unprotected-only
adjacency-sid-only
!
disjoint-path group-id 11 type link
!
bidirectional
co-routed
association-id 101
!
!
preference 200
dynamic
pcep
!
metric
type igp
!
!
lock
duration 30
!
```

```
constraints
  segments
    protection unprotected-only
    adjacency-sid-only
  !
  disjoint-path group-id 11 type link
  !
  bidirectional
  co-routed
  association-id 201
  !
  !
  preference 50
  dynamic
  pcep
  !
  metric
  type igrp
  !
  !
  backup-ineligible
  lock
  duration 60
  !
  constraints
  segments
    protection unprotected-only
    adjacency-sid-only
  !
  !
  bidirectional
  co-routed
  association-id 301
```

! performance-measurement liveness-detection liveness-profile backup name CS-PROTECT liveness-profile name CS-WORKING invalidation-action down

Circuit-Style SR-TE with Bandwidth Admission Control using Crosswork Circuit Style Manager

Routed Optical Networking 2.1 with Crosswork Network Controller 5.0 and IOS-XR 7.9.1 now supports utilizing the new Circuit Style Manager to provide Bandwidth Admission Controller and guaranteed bandwidth paths for Circuit-Style Policies. CNC 5.0 also supports full provisioning, monitoring, and visualization of Circuit-Style Policies.

CNC Circuit-Style Manager Configuration

In CNC 5.0, Circuit Style Manager uses a simple network-wide bandwidth percentage setting to reserve a specific amount of bandwidth for BW-guaranteed CS-SRTE policies. CNC's network model will track the allocation of bandwidth on each link and the amount of capacity reserved by active CS-SRTE Policies.

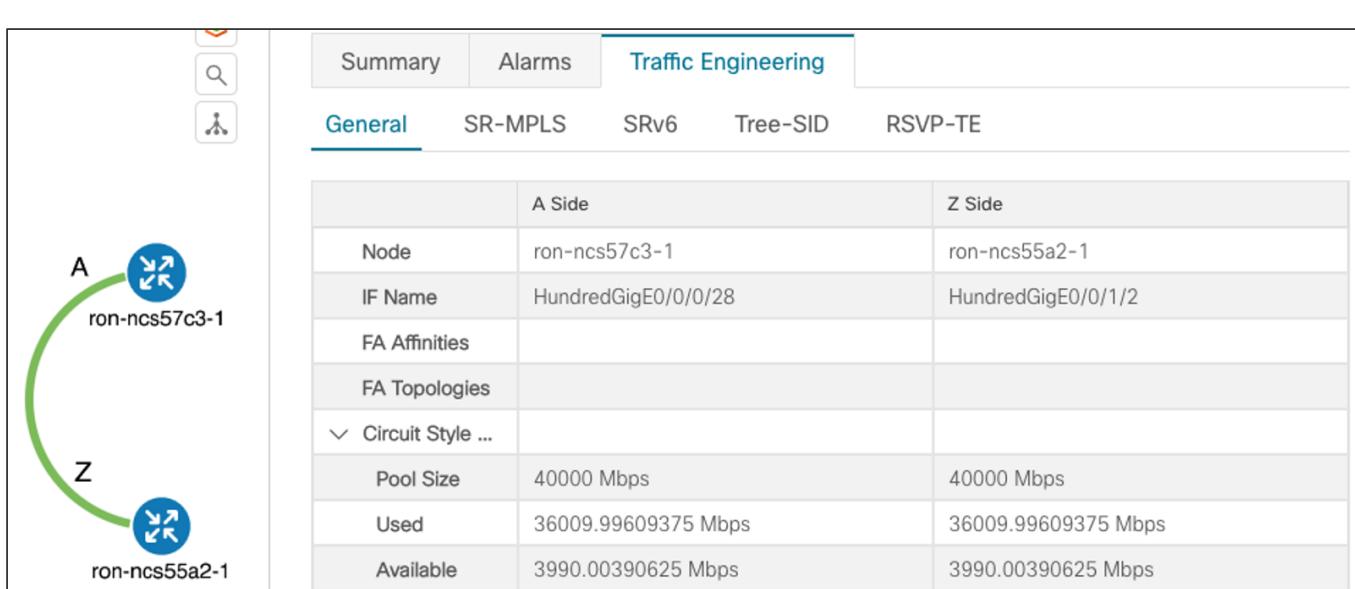
The Link CS BW Min Threshold configuration is used to trigger system alerts when the BW on a link meets or exceeds the threshold percentage configured by the user.

Enables CS-SRTE BW Feature

% of pool BW reserved to trigger high utilization alert

% of link BW to allocate for CS policies with BW reservations

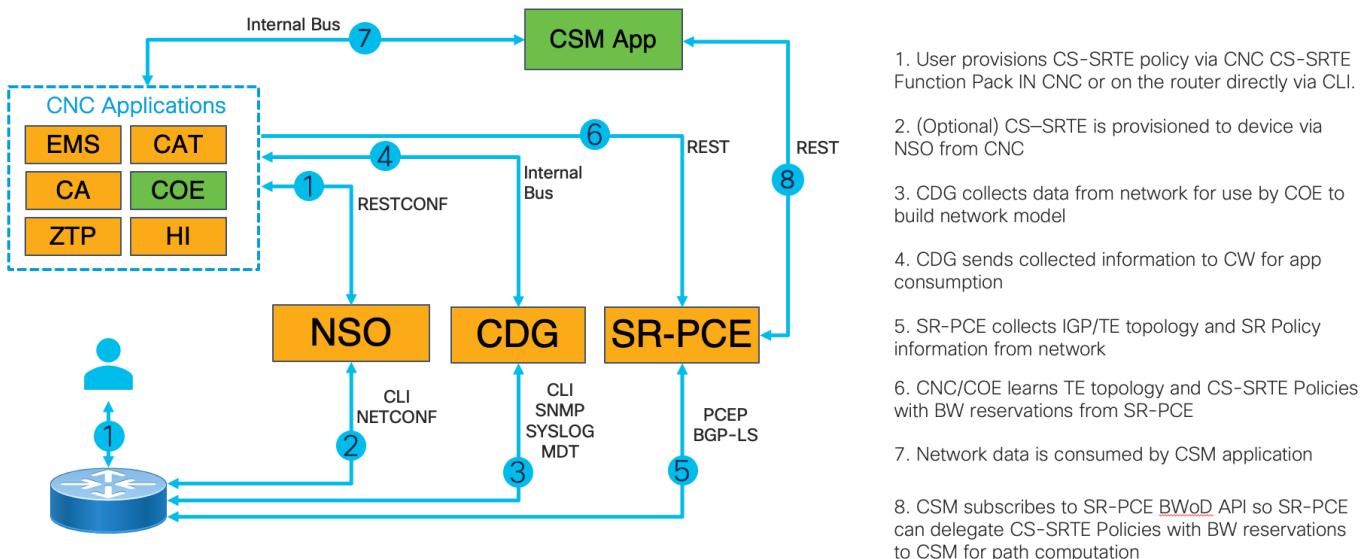
{:height="100%" width="100%"}



SR-PCE to Circuit Style Manager (CSM) Communication

CSM communicates to SR-PCE through the SR-PCE northbound API. When the session is established between CSM and SR-PCE, SR-PCE will delegate all CS-SRTE Policies with bandwidth constraints to CSM for path computation.

COE Circuit Style Manager Communication (Simplified)



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Bandwidth Admission Control Operation

BW CAC is supported for dynamic CS SR-TE Policies. Utilizing the "bandwidth" configuration option for the policy triggers the inclusion of the "bandwidth" object in the PCEP request to SR-PCE. SR-PCE will delegate path computation requests with bandwidth constraints to CNC CSM. Based on the CS-SRTE Policy configuration, CSM will compute a Working, Protect, and Restoration path to be used by the policy. The paths computed by CSM will adhere to the CS-SRTE properties with Working and Protect paths being fully disjoint (link, node, or SRLG) and each path will be co-routed meaning the Working path from A to Z will be identical to the path from Z to A.

CS SR-TE Policy Bandwidth Configuration

```

segment-routing
traffic-eng
policy srte_c_3000_ep_100.0.0.44
bandwidth 10000000
color 3000 end-point ipv4 100.0.0.44
path-protection
  
```

Operational Information

```

RP/0/RP0/CPU0:ron-ncs55a2-2#show segment-routing traffic-eng policy color
3000 | beg Attributes
Mon Jun 12 17:55:44.238 PDT
Attributes:
  Binding SID: 24010
  Forward Class: Not Configured
  Steering labeled-services disabled: no
  Steering BGP disabled: no
  
```

```
IPv6 caps enable: yes
Bandwidth Requested: 10.000 Gbps
Bandwidth Current: 10.000 Gbps
```

CNC CS-SRTE Monitoring

Starting in CNC 5.0, CS-SRTE Policies are fully supported. CS-SRTE Policies are identified as a specific type of policy in the Traffic Engineering dashboard and have enhanced visualization and monitoring capabilities.

CS-SRTE Dashboard

The screenshot shows the CNC CS-SRTE Monitoring interface. At the top, there's a summary bar with the following counts: Total 46, Circuit Style 8, BWoD 0, LCM 0, Admin Down 0, Open Up 41, and Open Down 5. Below this is a navigation bar with links for Home, Show, Traffic Engineering, Device Groups, Location, Saved Views, Select a saved view, Save View, and a refresh indicator (Last Refresh: 15-Aug-2023 11:53:51 AM EDT). The main area is titled "Traffic Engineering" and displays an "SR Policy" table. The table has columns for Headend, Endpoint, Policy Type (Circuit-Style), Color, Disjoint Group, Admin Status, Open Status, Traffic Rate(Mbps), Last Update, and Actions. The table lists 8 rows of data, each with a checkbox, Headend, Endpoint, Policy Type, Color, Disjoint Group, Admin Status (green up arrow), Open Status (red down arrow), Traffic Rate (e.g., 10594.49, 10735.61), Last Update (e.g., 04-Jul-2023 10:24:42 AM EDT), and Actions (three dots). A sidebar on the left shows navigation icons for Home, Show, Traffic Engineering, Device Groups, Location, and a City map icon.

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CS-SRTE Policy Visualization of Working and Protect Paths When visualizing CS-SRTE policies we can see both Working and Protect paths including which path is currently active, denoted by the A icon.

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CS-SRTE Policy Path Details When we inspect the policy path details we can see both the requested and reserved bandwidth for the path and then the additional details such as path constraints and hop by hop path.

The screenshot shows the Crosswork Network Controller interface for Traffic Engineering. The left sidebar includes navigation links for Home, Topology, Performance Alerts, Services & Traffic Engineering, Device Management, and Administration. The main header is "Crosswork Network Controller" with a Cisco logo.

The top navigation bar shows the path: Home / Traffic Engineering / Traffic Engineering. On the right, it says "Last Refresh: 03-Jun-2023 09:43:23 PM EDT".

The main content area has tabs for "Show" (selected), "Traffic Engineering", "Device Groups", and "PLE Nodes". Below these are filters for "Location / All Locations / RON Lab / PLE Nodes", "Show: Participating Only", and "IGP Path" and "Bi-Dir Path" checkboxes.

The central part of the screen displays a network topology with four nodes: ron-ncs57b1-1, ron-8201-1, ron-ncs55a2-2, and ron-ncs55a2-1. A green line connects ron-ncs57b1-1 and ron-8201-1. A purple line connects ron-ncs55a2-2 and ron-ncs55a2-1. Arrows indicate bidirectional traffic flow between the nodes.

To the right, a large panel titled "Circuit Style Policy Details" shows "Current" and "History" tabs. It lists a path entry:

| Path Name | Pref | State | | | | | |
|--|----------|---------------------------------------|------|-----------|--------|-------------|-------|
| cfg_srite_c_3000_ep_100.0.0.22_discr_100 | 100 | Up Active | | | | | |
| S... | Segme... | L... | Algo | IP | N... | Interfa... | Sl... |
| 0 | IGP ... | 15... | 0 | 100.22... | ron... | HundredGigE | U |

Below this, detailed information for the path is shown:

| | |
|---------------------|--|
| Path Name | cfg_srite_c_3000_ep_100.0.0.22_discr_100 |
| Oper State | Up Active |
| Metric Type | LATENCY |
| Requested Bandwidth | 10000 Mbps |
| Reserved Bandwidth | 10000 Mbps |
| Config ID | CS-clus-demo-pie-fc8-head-end-internal |
| Disjoint Group ID | 900 |
| Association Source | 0.0.0.0 |
| Type | Node-disjoint |
| PCE Initiated | false |
| Affinity | Exclude-Any: - Include-Any: - Include-All: - |
| Segment Type | Unprotected |
| SID Algorithm | - |

At the bottom, there are buttons for "Auto-Focus" and "Save View".

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CNC CS-SRTE Provisioning

In CNC 5.0 the Circuit-Style SR-TE Function Pack is supported. This service type simplifies CS-SRTE provisioning by dynamically allocating IDs for the bi-directional association ID and disjoint-group ID. It also simplifies provisioning by provisioning both the A to Z and Z to A policies at one time vs. defining each one independently.

NSO Payload for Dynamic CS SR-TE Policy

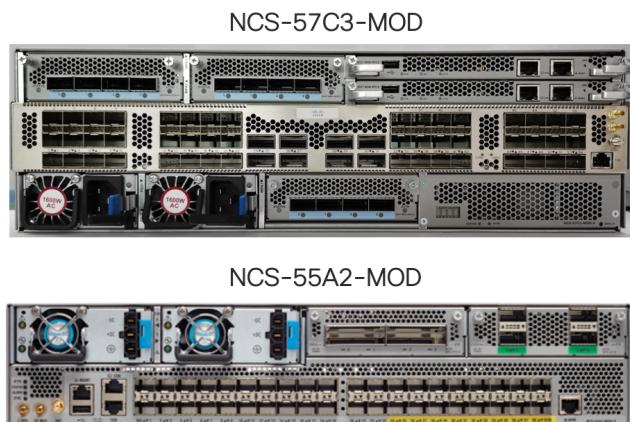
```
{
  "data": {
    "cisco-cs-sr-te-cfp:cs-sr-te-policy": [
      {
        "name": "clus-demo-ple-fc8",
        "head-end": {
          "device": "ron-ncs55a2-1",
          "ip-address": "100.0.0.44"
        },
        "tail-end": {
          "device": "ron-ncs55a2-2",
          "ip-address": "100.0.0.22"
        },
        "color": 3000,
        "bandwidth": 10000000,
        "disjoint-path": {
          "forward-path": {
            "type": "node",
            "group-id": 900
          },
          "reverse-path": {
            "type": "node",
            "group-id": 901
          }
        },
        "path-protection": {
        },
        "performance-measurement": {
          "liveness-detection": {
            "profile": "ple",
            "backup": "ple",
            "logging": {
              "session-state-change": [null]
            }
          }
        },
        "working-path": {
          "dynamic": {
            "constraints": {
              "segments": {
                "protection": "unprotected-only"
              }
            },
            "pce": {

```

```
        },
        "metric-type": "latency",
        "bidirectional-association-id": 1000
    }
},
"protect-path": {
    "dynamic": {
        "constraints": {
            "segments": {
                "protection": "unprotected-only"
            }
        },
        "pce": {
        },
        "metric-type": "latency",
        "bidirectional-association-id": 1001
    },
    "revertive": true,
    "wait-to-revert-timer": 30
}
}
]
}
}
```

Private Line Emulation Hardware

Starting in IOS-XR 7.7.1 the NC55-OIP-02 Modular Port Adapter (MPA) is supported on the NCS-55A2-MOD and NCS-57C3-MOD platforms. The NC55-OIP-02 has 8 SFP+ ports



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Each port on the PLE MPA can be configured independently. The PLE MPA is responsible for receiving data frames from the native PLE client and packaging those into fixed frames for transport over the packet network.

More information on the NC55-OIP-02 can be found in its datasheet located at <https://www.cisco.com/c/en/us/products/collateral/routers/network-convergence-system-5500-series/network-con-5500-series-ds.pdf>. A full detailed end to end configuration for PLE can be found in

the Routed Optical Networking 2.0 Solution Guide found at

<https://www.cisco.com/c/en/us/td/docs/optical/ron/2-0/solution/guide/b-ron-solution-20/m-ron.pdf>

Supported Client Transceivers

| Transport Type | Supported Transceivers |
|----------------|---|
| Ethernet | SFP-10G-SR/LR/ER, GLC-LH/EX/ZX-SMD, 1G/10G CWDM |
| OTN (OTU2e) | SFP-10G-LR-X, SFP-10G-ER-I, SFP-10G-Z |
| SONET/SDH | ONS-SC+-10G-LR/ER/SR (OC-192/STM-64), ONS-SI-2G-L1/L2/S1 (OC-48/STM-16) |
| Fiber Channel | DS-SFP-FCGE, DS-SFP-FC8G, DS-SFP-FC16G, DS-SFP-FC32G, 1/2/4/8G FC CWDM |

Note FC32G transceivers are supported in the even ports only and will disable the adjacent odd SFP+ port.
{: .notice--warning}

Private Line Emulation Pseudowire Signaling

PLE utilizes IETF SAToP pseudowire encoding carried over dynamically signalled EVPN-VPWS circuits.

Enhancements to the EVPN VPWS service type have been introduced to the IETF via

<https://datatracker.ietf.org/doc/draft-schmutzler-bess-ple>.

PLE services use Differential Clock Recovery (DCR) to ensure proper frame timing between the two PLE clients. In order to maintain accuracy of the clock each PLE endpoint router must have its frequency source traceable to a common primary reference clock (PRC).

Private Line Emulation EVPN-VPWS Configuration

PLE services can be configured to utilize a CS SR-TE Policy or use dynamic MPLS protocols. The example below shows the use of CS SR-TE Policy as transport for the PLE EVPN-VPWS service. Note the name of the sr-te policy in the preferred path command is the persistent generated name and not the name used in the CLI configuration. This can be determined using the "show segment-routing traffic-engineering policies" command.

```
l2vpn
pw-class circuit-style-srte
encapsulation mpls
preferred-path sr-te policy srte_c_1001_ep_100.0.0.42
!
!
xconnect group ple
p2p ple-cs-1
interface CEM0/0/2/1
neighbor evpn evi 100 target 4201 source 4401
pw-class circuit-style-srte
!
!
```

PLE Monitoring and Telemetry

The following "show" command can be used to monitor the state of PLE ports and services.

Client Optics Port State

```
RP/0/RP0/CPU0:ron-ncs55a2-1#show controllers optics 0/0/2/1
Sat Dec 3 14:00:10.873 PST
```

Controller State: Up

Transport Admin State: In Service

Laser State: On

LED State: Not Applicable

Optics Status

```
Optics Type: SFP+ 10G SR
Wavelength = 850.00 nm
```

Alarm Status:

```
-----  
Detected Alarms: None
```

LOS/LOL/Fault Status:

```
Laser Bias Current = 8.8 mA
Actual TX Power = -2.60 dBm
RX Power = -2.33 dBm
```

Performance Monitoring: Disable

THRESHOLD VALUES

| Parameter | High Alarm | Low Alarm | High Warning | Low Warning |
|-------------------------|------------|-----------|--------------|-------------|
| Rx Power Threshold(dBm) | 2.0 | -13.9 | -1.0 | |
| Tx Power Threshold(dBm) | 1.6 | -11.3 | -1.3 | |
| LBC Threshold(mA) | 13.00 | 4.00 | 12.50 | |
| | 5.00 | | | |

| | | | |
|--------------------------|-------|-------|-------|
| Temp. Threshold(celsius) | 75.00 | -5.00 | 70.00 |
| 0.00 | | | |
| Voltage Threshold(volt) | 3.63 | 2.97 | 3.46 |

3.13

Polarization parameters not supported by optics

Temperature = 33.00 Celsius

Voltage = 3.30 V

Transceiver Vendor Details

| | | |
|---------------------|---|------------------|
| Form Factor | : | SFP+ |
| Optics type | : | SFP+ 10G SR |
| Name | : | CISCO-FINISAR |
| OUI Number | : | 00.90.65 |
| Part Number | : | FTLX8574D3BCL-CS |
| Rev Number | : | A |
| Serial Number | : | FNS23300J42 |
| PID | : | SFP-10G-SR |
| VID | : | V03 |
| Date Code(yy/mm/dd) | : | 19/07/25 |

PLE CEM Controller Stats

| | | |
|--|---|--------------------|
| RP/0/RP0/CPU0:ron-ncs57c3-1#show controllers CEM 0/0/3/1 | | |
| Sat Sep 24 11:34:22.533 PDT | | |
| Interface | : | CEM0/0/3/1 |
| Admin state | : | Up |
| Oper state | : | Up |
| Port bandwidth | : | 10312500 kbps |
| Dejitter buffer (cfg/oper/in-use) | : | 0/813/3432 usec |
| Payload size (cfg/oper) | : | 1280/1024 bytes |
| PDV (min/max/avg) | : | 980/2710/1845 usec |
| Dummy mode | : | last-frame |
| Dummy pattern | : | 0xaa |
| Idle pattern | : | 0xff |
| Signalling | : | No CAS |
| RTP | : | Enabled |
| Clock type | : | Differential |
| Detected Alarms | : | None |

Statistics Info

Ingress packets : 517617426962, Ingress packets drop : 0 Egress packets : 517277124278, Egress packets drop : 0 Total error : 0 Missing packets : 0, Malformed packets : 0 Jitter buffer underrun : 0, Jitter buffer

overrun : 0 Misorder drops : 0 Reordered packets : 0, Frames fragmented : 0 Error seconds : 0, Severely error seconds : 0 Unavailable seconds : 0, Failure counts : 0

Generated L bits : 0, Received L bits : 0 Generated R bits : 339885178, Received R bits : 17

Endpoint Info

Passthrough : No

PLE CEM PM Statistics

```
RP/0/RP0/CPU0:ron-ncs57c3-1#show controllers CEM 0/0/3/1 pm current 30-sec
cem
Sat Sep 24 11:37:02.374 PDT
```

CEM in the current interval [11:37:00 - 11:37:02 Sat Sep 24 2022]

CEM current bucket type : Valid INGRESS-PKTS : 2521591 Threshold : 0 TCA(enable) : NO EGRESS-PKTS : 2521595 Threshold : 0 TCA(enable) : NO INGRESS-PKTS-DROPPED : 0 Threshold : 0 TCA(enable) : NO EGRESS-PKTS-DROPPED : 0 Threshold : 0 TCA(enable) : NO INPUT-ERRORS : 0 Threshold : 0 TCA(enable) : NO OUTPUT-ERRORS : 0 Threshold : 0 TCA(enable) : NO MISSING-PKTS : 0 Threshold : 0 TCA(enable) : NO PKTS-REORDER : 0 Threshold : 0 TCA(enable) : NO JTR-BFR-UNDERRUNS : 0 Threshold : 0 TCA(enable) : NO JTR-BFR-OVERRUNS : 0 Threshold : 0 TCA(enable) : NO MIS-ORDER-DROPPED : 0 Threshold : 0 TCA(enable) : NO MALFORMED-PKT : 0 Threshold : 0 TCA(enable) : NO ES : 0 Threshold : 0 TCA(enable) : NO SES : 0 Threshold : 0 TCA(enable) : NO UAS : 0 Threshold : 0 TCA(enable) : NO FC : 0 Threshold : 0 TCA(enable) : NO TX-LBITS : 0 Threshold : 0 TCA(enable) : NO TX-RBITS : 0 Threshold : 0 TCA(enable) : NO RX-LBITS : 0 Threshold : 0 TCA(enable) : NO RX-RBITS : 0 Threshold : 0 TCA(enable) : NO

PLE Client PM Statistics

```
RP/0/RP0/CPU0:ron-ncs57c3-1#show controllers EightGigFibreChanCtrlr0/0/3/4
pm current 30-sec fc
Sat Sep 24 11:51:55.168 PDT
```

FC in the current interval [11:51:30 - 11:51:55 Sat Sep 24 2022]

FC current bucket type : Valid IFIN-OCTETS : 16527749196 Threshold : 0 TCA(enable) : NO RX-PKT : 196758919 Threshold : 0 TCA(enable) : NO IFIN-ERRORS : 0 Threshold : 0 TCA(enable) : NO RX-BAD-FCS : 0 Threshold : 0 TCA(enable) : NO IFOUT-OCTETS : 0 Threshold : 0 TCA(enable) : NO TX-PKT : 0 Threshold : 0 TCA(enable) : NO TX-BAD-FCS : 0 Threshold : 0 TCA(enable) : NO RX-FRAMES-TOO-LONG : 0 Threshold : 0 TCA(enable) : NO RX-FRAMES-TRUNC : 0 Threshold : 0 TCA(enable) : NO TX-FRAMES-TOO-LONG : 0 Threshold : 0 TCA(enable) : NO TX-FRAMES-TRUNC : 0 Threshold : 0 TCA(enable) : NO

Routed Optical Networking Architecture Hardware

All Routed Optical Networking solution routers are powered by Cisco IOS-XR.

Routed Optical Networking Validated Routers

Below is a non-exhaustive snapshot of platforms validated for use with ZR and OpenZR+ transceivers. Cisco supports Routed Optical Networking in the NCS 540, NCS 5500/5700, ASR 9000, and Cisco 8000 router families. The breadth of coverage enabled the solution across all areas of the network.

8201



8201-32FH



8202



NC57-18DD-SE



ASR 9903



A9K-20HG-FLEX-SE



NCS57B1-6D24H



N540-24Q8L2DD-SYS



NCS-57C3-MOD (R2.0)



Cisco 8000 Series

The Cisco 8000 and its Silicone One NPU represents the next generation in routers, unprecedented capacity at the lowest power consumption while supporting a rich feature set applicable for a number of network roles.

See more information on Cisco 8000 at <https://www.cisco.com/c/en/us/products/collateral/routers/8000-series-routers/datasheet-c78-742571.html>

Specific information on ZR/ZR+ support can be found at

<https://www.cisco.com/c/en/us/td/docs/iosxr/cisco8000/interfaces/73x/configuration/guide/b-interfaces-config-guide-cisco8k-r73x/m-zr-zrp-cisco-8000.html>

Cisco 5700 Systems and NCS 5500 Line Cards

The Cisco 5700 family of fixed and modular systems and line cards are flexible enough to use at any location in the networks. The platform has seen widespread use in peering, core, and aggregation networks.

See more information on Cisco NCS 5500 and 5700 at

<https://www.cisco.com/c/en/us/products/collateral/routers/network-convergence-system-5500-series/datasheet-c78-736270.html> and <https://www.cisco.com/c/en/us/products/collateral/routers/network-convergence-system-5500-series/datasheet-c78-744698.html>

Specific information on ZR/ZR+ support can be found at

<https://www.cisco.com/c/en/us/td/docs/iosxr/ncs5500/interfaces/73x/configuration/guide/b-interfaces-hardware-component-cg-ncs5500-73x/m-zr-zrp.html>

ASR 9000 Series

The ASR 9000 is the most widely deployed SP router in the industry. It has a rich heritage dating back almost 20 years, but Cisco continues to innovate on the ASR 9000 platform. The ASR 9000 series now supports 400G QSFP-DD on a variety of line cards and the ASR 9903 2.4Tbps 3RU platform.

See more information on Cisco ASR 9000 at https://www.cisco.com/c/en/us/products/collateral/routers/asr-9000-series-aggregation-services-routers/data_sheet_c78-501767.html

Specific information on ZR/ZR+ support can be found at

https://www.cisco.com/c/en/us/td/docs/routers/asr9000/software/asr9k-r7-3/interfaces/configuration/guide/b-interfaces-hardware-component-cg-asr9000-73x/m-zr-zrp.html#Cisco_Concept.dita_59215d6f-1614-4633-a137-161ebe794673

NCS 500 Series

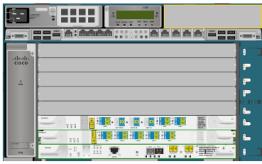
The 1Tbps N540-24QL16DD-SYS high density router brings QSFP-DD and Routed Optical Networking ZR/OpenZR+ optics to a flexible access and aggregation platform. Using OpenZR+ optics it allows a migration path from 100G to 400G access rings or uplinks when used in an aggregation role.

See more information on Cisco NCS 540 at

<https://www.cisco.com/c/en/us/products/collateral/routers/network-convergence-system-500-series-routers/ncs-540-large-density-router-ds.html>

Routed Optical Networking Optical Hardware

NCS 2000 (SVO 12.2)



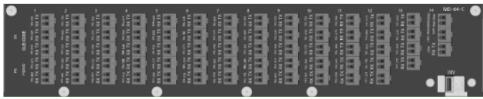
NCS2K-MF-MPO-16LC



NCS2K-MF-6AD-CFS



NCS1K-MD64-C



NCS 1001



This is what is tested in the solution lab, not an exhaustive list of supported hardware

Also fully supported:
MD-48-EVEN/ODD mux/demux,
RAMAN, and EDRA amplifiers

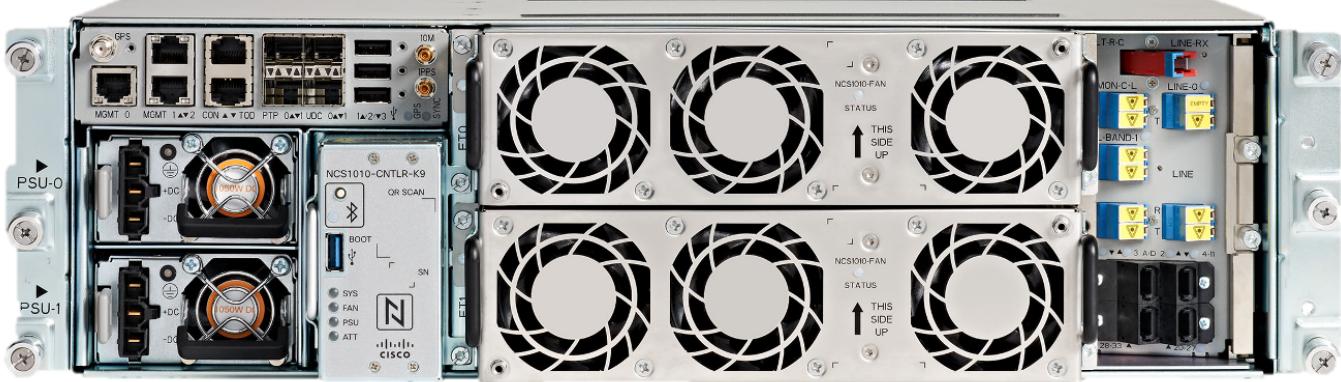
Network Convergence System 1010

The NCS 1010 Open Optical Line System (O-OLS) is a next-generation DWDM platform available in fixed variants to satisfy building a modern flexible DWDM photonic network.

The NCS 1010 Optical Line Terminal (OLT) uses a twin 33-port WSS architecture allowing higher scale for either add/drop or express wavelengths. The OLT also has two LC add/drop ports with integrated fixed gain EDFA to support the add/drop of lower power optical signals. OLTs are available in models with or without RAMAN amplification. NCS 1010 Inline Amplifier nodes are available as bi-directional EDFA, EDFA with RAMAN in one direction, or bi-directional RAMAN. Each model of NCS 1010 is also available to support both C and L bands. In Routed Optical Networking 2.0 ZR and ZR+ optics utilize the C band, but may be used on the same fiber with L band signals using the NCS 1010 C+L combiner.

The NCS 1010 utilizes IOS-XR, inheriting the advanced automation and telemetry features similar to IOS-XR routers.

NCS 1010 OLT with RAMAN

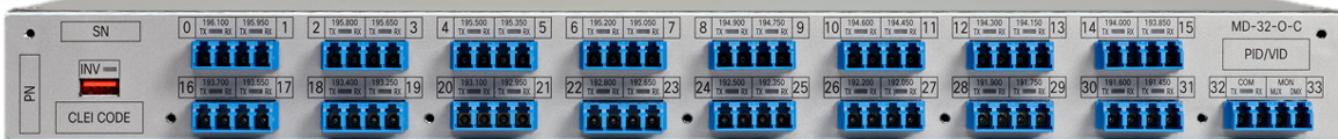


NCS 1010 ILA with RAMAN



The NCS1K-MD32-E/O-C 32-port 150Ghz spaced passive multiplexer is used with the NCS 1010, supporting the 75Ghz ZR/ZR+ signals and future higher baud rate signals. The MD-32 contains photodiodes to monitor RX power levels on each add/drop port.

NCS 1010 MD-32 Passive Filter



The NCS 1010 supports point to point and express DWDM optical topologies in Routed Optical Networking 2.0. All NCS 1010 services in Routed Optical Networking are managed using Cisco Optical Network Controller.

See more information on the NCS 1010 series at <https://www.cisco.com/c/en/us/products/collateral/optical-networking/network-convergence-system-1000-series/network-conver-system-1010-ds.html>

Network Convergence System 2000

The NCS 2000 Optical Line System is a flexible platform supporting all modern optical topologies and deployment use cases. Simple point to point to multi-degree CDC deployments are all supported as part of Routed Optical Networking.

See more information on the NCS 2000 series at <https://www.cisco.com/c/en/us/products/optical-networking/network-convergence-system-2000-series/index.html>

Network Convergence System 1000 Multiplexer

The NCS1K-MD-64-C is a new fixed multiplexer designed specifically for the 400G 75Ghz 400ZR and OpenZR+ wavelengths, allowing up to 25.6Tbps on a single fiber.

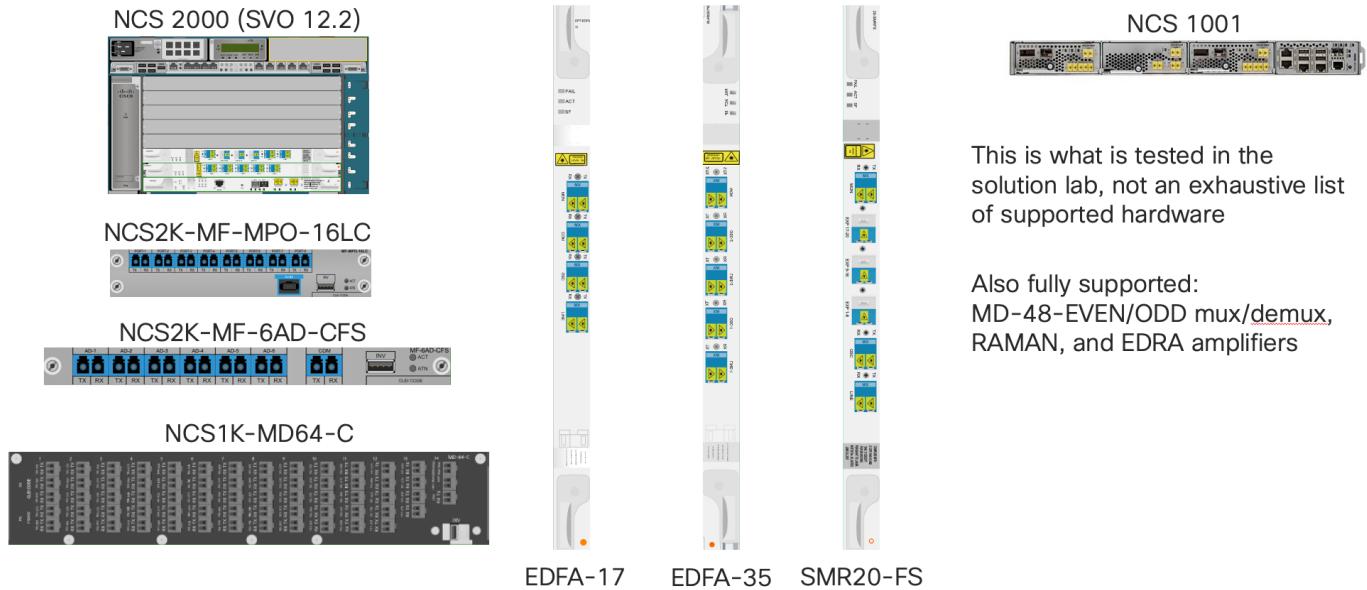
Network Convergence System 1001

The NCS 1001 is utilized in point to point network spans as an amplifier and optionally protection switch. The NCS 1001 now has specific support for 75Ghz spaced 400ZR and OpenZR+ wavelengths, with the ability to monitor incoming wavelengths for power. The 1001 features the ability to determine the proper amplifier gain setpoints based on the desired user power levels.

See more information on the NCS 1001 at <https://www.cisco.com/c/en/us/products/collateral/optical-networking/network-convergence-system-1000-series/datasheet-c78-738782.html>

NCS 2000 and NCS 1001 Hardware

The picture below does not represent all available hardware on the NCS 2000, however does capture the modules typically used in Routed Optical Networking deployments.



Routed Optical Networking Automation

Overview

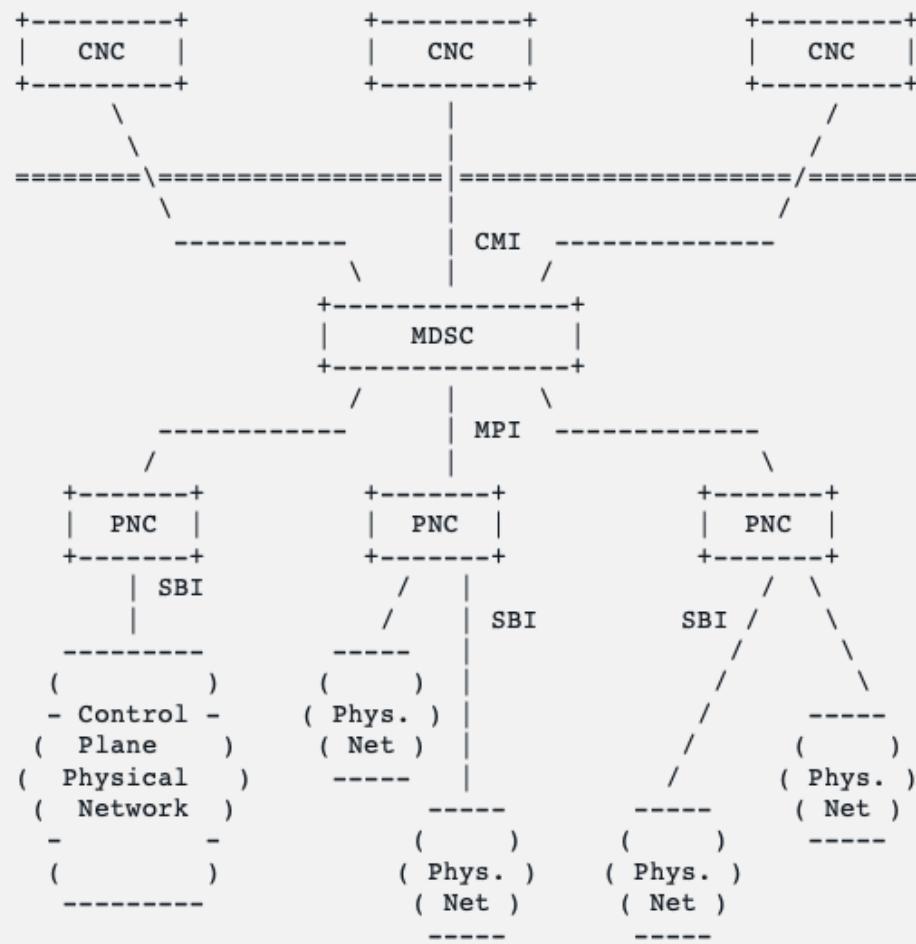
Routed Optical Networking by definition is a disaggregated optical solution, creating efficiency by moving coherent endpoints in the router. The solution requires a new way of managing the network, one which unifies the IP and Optical layers, replacing the traditional siloed tools used in the past. Real transformation in operations comes from unifying teams and workflows, rather than trying to make an existing tool fit a role it was not originally designed for. Cisco's standards based hierarchical SDN solution allows providers to manage a multi-vendor Routed Optical Networking solution using standard interfaces and YANG models.

IETF ACTN SDN Framework

The IETF Action and Control of Traffic Engineered Networks group (ACTN) has defined a hierarchical controller framework to allow vendors to plug components into the framework as needed. The lowest level controller, the Provisioning Network Controller (PNC), is responsible for managing physical devices. These controllers expose their resources through standard models and interfaces to a Hierarchical Controller (HCO), called a Multi-Domain Service Controller (MDSC) in the ACTN framework.

Note that while Cisco is adhering to the IETF framework proposed in [RFC8453](#), Cisco is supporting the most widely supported industry standards for controller to controller communication and service definition. In optical the de facto standard is Transport API from the ONF for the management of optical line system networks and optical services. In packet we are leveraging Openconfig device models where possible and IETF models for packet topology (RFC8345) and xVPN services (L2NM and L3NM).

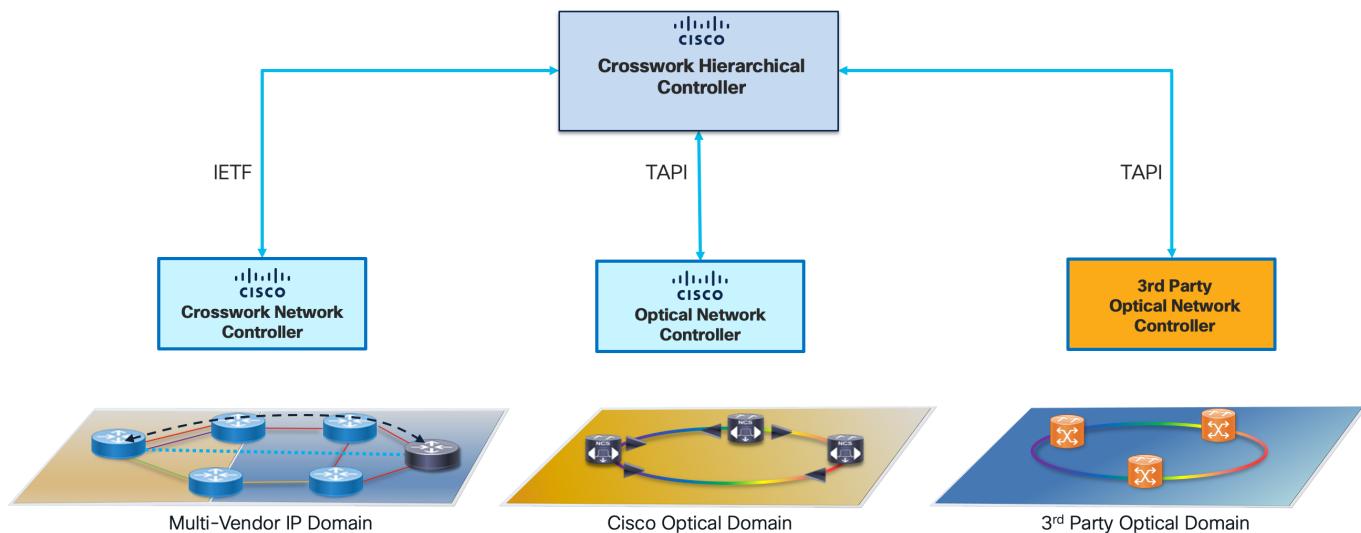
ACTN SDN Control Framework



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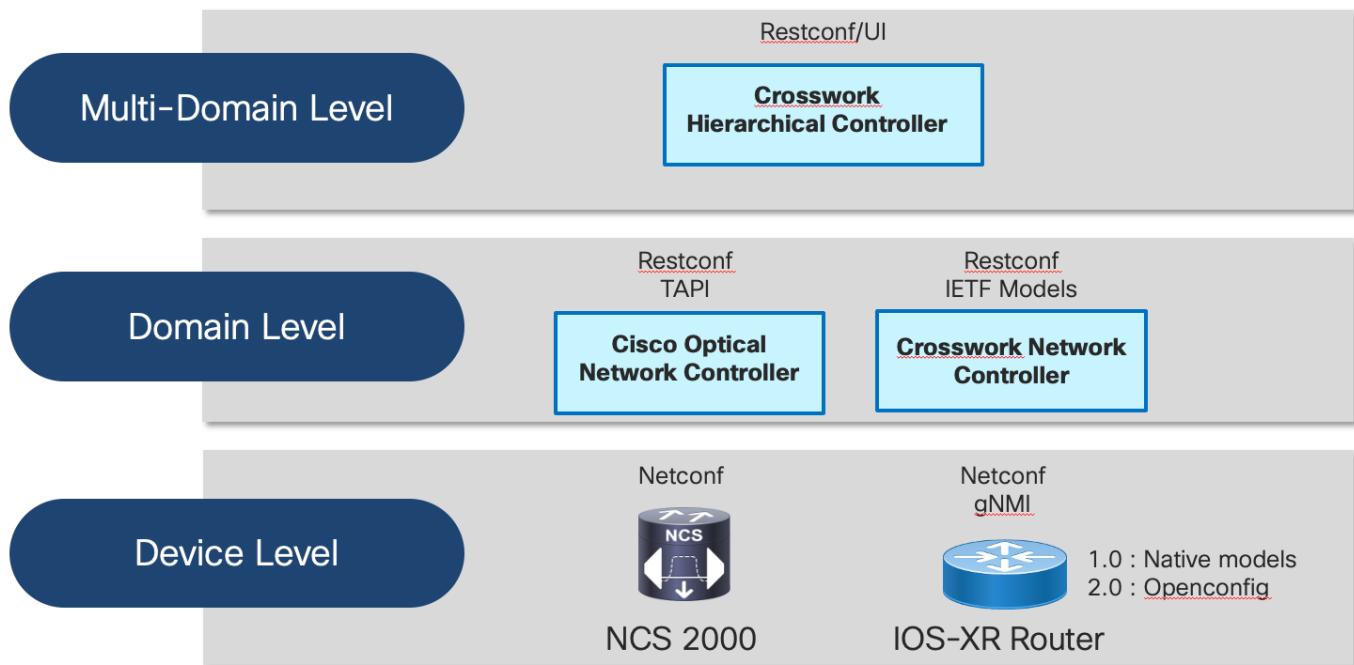
Cisco's SDN Controller Automation Stack

Aligning to the ACTN framework, Cisco's automation stack includes a multi-vendor IP domain controller (PNC), optical domain controller (PNC), and multi-vendor hierarchical controller (HCO/MDSC).



Cisco Open Automation

Cisco believes not all providers consume automation in the same way, so we are dedicated to make sure we have open interfaces at each layer of the network stack. At the device level, we utilize standard NETCONF, gRPC, and gNMI interfaces along with native, standard, and public consortium YANG models. There is no aspect of a Cisco IOS-XR router today not covered by YANG models. At the domain level we have Cisco's network controllers, which use the same standard interfaces to communicate with devices and expose standards based NBIs. Our multi-layer/multi-domain controller likewise uses the same standard interfaces.



Crosswork Hierarchical Controller

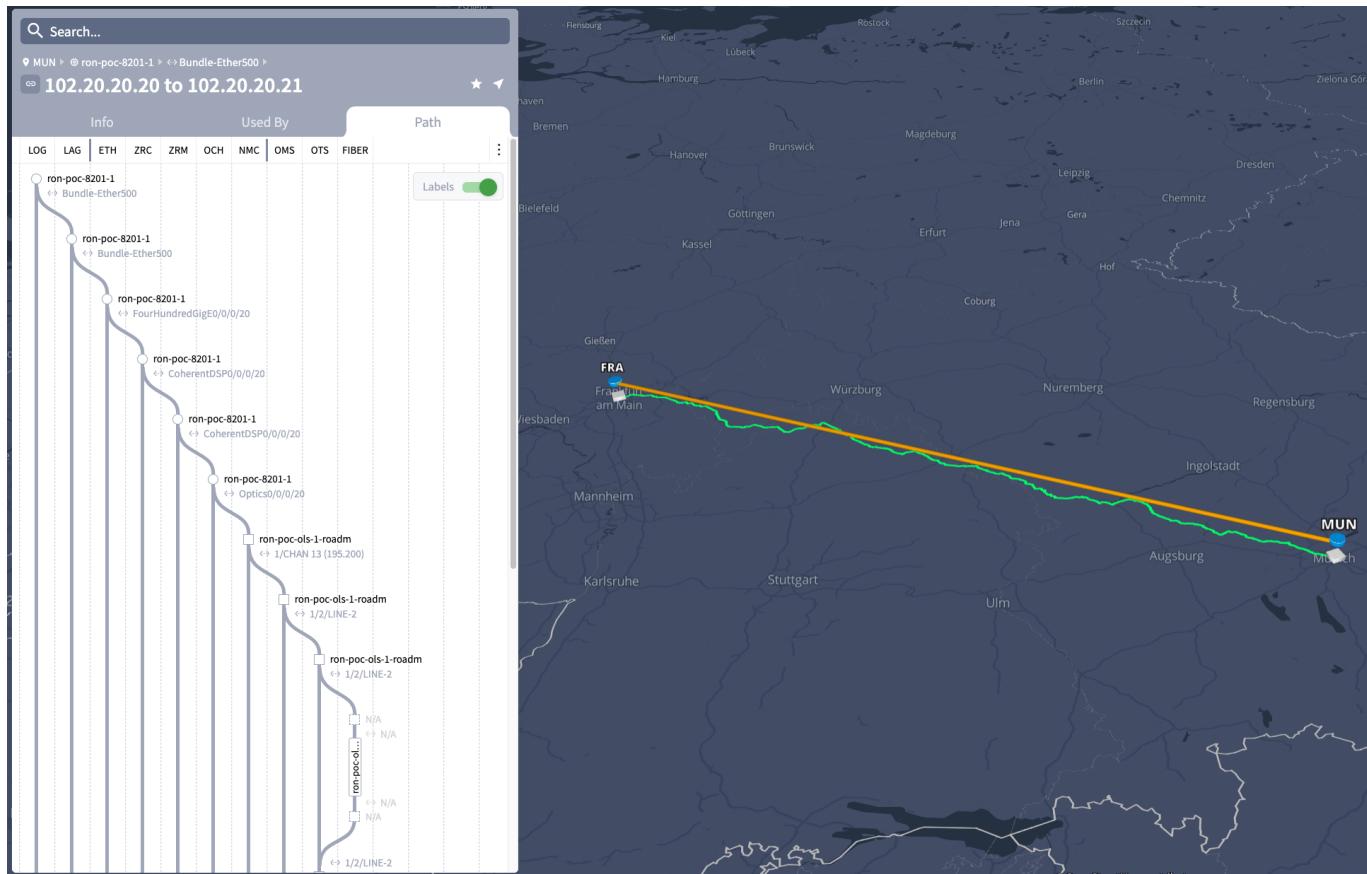
Responsible for Multi-Layer Automation is the Crosswork Hierarchical Controller. Crosswork Hierarchical Controller is responsible for the following network functions:

- CW HCO unifies data from the IP and optical networks into a single network model. HCO utilizes industry standard IETF topology models for IP and TAPI for optical topology and service information. HCO can also leverage legacy EMS/NMS systems or use device interrogation.
 - Responsible for managing multi-layer Routed Optical Networking links using a single UI.
 - Providing assurance at the IP and optical layers in a single tool. The network model allows users to quickly correlate faults and identify at which layer faults have occurred.
 - Additional HCO applications include the following
 - Root Cause Analysis: Quickly correlate upper layer faults to an underlying cause.
 - Layer Relations: Quickly identify the lower layer resources supporting higher layer network resource or all network resources reliant on a selected lower layer network resource.
 - Network Inventory: View IP and optical node hardware inventory along with with network resources such as logical links, optical services, and traffic engineering tunnels
 - Network History: View state changes across all network resources at any point in time
 - Performance: View historical link utilization

Please see the following resources for more information on Crosswork HCO.

<https://www.cisco.com/c/en/us/products/collateral/cloud-systems-management/crosswork-network->

[automation/solution-overview-c22-744695.html](#)



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Crosswork Network Controller

Crosswork Network Controller is a multi-vendor IP domain controller. Crosswork Network Controller is responsible for the following IP network functions.

- Collecting Ethernet, IP, RSVP-TE, and SR network information for internal applications and exposing northbound via IETF RFC 8345 topology models
 - Collecting traffic information from the network for use with CNC's traffic optimization application, Crosswork Optimization Engine
 - Enable Bandwidth Guaranteed Circuit-Style Segment Routing paths using Circuit Style Manager **New in CNC 5.0 / RON 2.1**
 - Perform provisioning of SR-TE, RSVP-TE, L2VPN, and L3VPN using standard industry models (IETF TEAS-TE, L2NM, L3NM) via UI or northbound API
 - Visualization and assurance of SR-TE, RSVP-TE, and xVPN services
 - Optimization of network resources with its industry first Tactical Traffic Engineering applications to perform traffic when needed.
 - Use additional Crosswork applications to perform telemetry collection/alerting, zero-touch provisioning, and automated and assurance network changes

More information on Crosswork and Crosswork Network Controller can be found at [Crosswork](#).

<https://www.cisco.com/c/en/us/products/collateral/cloud-systems-management/crosswork-network-automation/datasheet-c78-743456.html>

Cisco Optical Network Controller

Cisco Optical Network Controller (Cisco ONC) is responsible for managing Cisco optical line systems and circuit services. Cisco ONC exposes a ONF TAPI northbound interface, the de facto industry standard for optical network management. Cisco ONC runs as an application on the same Crosswork Infrastructure as CNC.

More information on Cisco ONC can be found at <https://www.cisco.com/c/en/us/support/optical-networking/optical-network-controller/series.html>

Cisco Network Services Orchestrator and Routed Optical Networking ML Core Function Pack

Cisco NSO is the industry standard for service orchestration and device configuration management. The RON-ML CFP can be used to fully configure an IP link between routers utilizing 400ZR/OpenZR+ optics over a Cisco optical line system using Cisco ONC. This includes IP addressing and adding links to an existing Ethernet LAG. The CFP can also support optical-only provisioning on the router to fit into existing optical provisioning workflows.

Routed Optical Networking Service Management

Supported Provisioning Methods

We support multiple ways to provision Routed Optical Networking services based on existing provider workflows.

- Unified IP and Optical using Crosswork Hierarchical Controller
- IP router DCO provisioning using Cisco NSO Routed Optical Networking Multi-Layer Function Pack
- ZR/ZR+ Optics using IOS-XR CLI
- Cisco Native Model-driven ZR/ZR+ Optics configuration using Netconf or gNMI
- OpenConfig ZR/ZR+ Optics configuration using Netconf or gNMI

OpenZR+ and 400ZR Properties

ZR/ZR+ Supported Frequencies

The frequency on Cisco ZR/ZR+ transceivers may be set between 191.275Thz and 196.125Thz in increments of 6.25Ghz, supporting flex spectrum applications. To maximize the available C-Band spectrum, these are the recommended 64 75Ghz-spaced channels, also aligning to the NCS1K-MD-64-C fixed channel add/drop multiplexer.

| | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|---------|
| 196.100 | 196.025 | 195.950 | 195.875 | 195.800 | 195.725 | 195.650 | 195.575 |
| 195.500 | 195.425 | 195.350 | 195.275 | 195.200 | 195.125 | 195.050 | 194.975 |
| 194.900 | 194.825 | 194.75 | 194.675 | 194.600 | 194.525 | 194.450 | 194.375 |
| 194.300 | 194.225 | 194.150 | 194.075 | 194.000 | 193.925 | 193.850 | 193.775 |

| | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|---------|
| 193.700 | 193.625 | 193.550 | 193.475 | 193.400 | 193.325 | 193.250 | 193.175 |
| 193.100 | 193.025 | 192.950 | 192.875 | 192.800 | 192.725 | 192.650 | 192.575 |
| 192.500 | 192.425 | 192.350 | 192.275 | 192.200 | 192.125 | 192.050 | 191.975 |
| 191.900 | 191.825 | 191.750 | 191.675 | 191.600 | 191.525 | 191.450 | 191.375 |

Supported Line Side Rate, FEC, and Modulation

OIF 400ZR transceivers support 400G only with the cFEC FEC type per the OIF specification. OpenZR+ transceivers can support 100G, 200G, 300G, or 400G line side rate. See router platform documentation for supported rates on each platform or line card. OpenZR+ optics can utilize the cFEC type in 400G mode to retain compatibility with OIF 400ZR.

50Ghz Spectrum Compatibility Modes (New)

Starting in Routed Optical Networking 2.1 and IOS-XR 7.9.1 additional support has been added for the 200G-8QAM and 200G-16QAM modes. 200G-8QAM utilizes a symbol rate of 40.1Gbaud and 200G-16QAM utilizes a symbol rate of 30.1Gbaud. This ensures the signal width is compatibility with legacy 50Ghz filter optical line systems. 100G-QPSK also utilizes a 30.1Gbaud symbol rate.

OpenZR+ Supported Configurations

| Transceiver Type | Rate | FEC | Modulation | Standard |
|------------------|------|------|------------|-----------|
| QDD-400G-ZR-S | 400 | cFEC | 16QAM | OIF 400ZR |
| QDD-400G-ZRP-S | 400 | cFEC | 16QAM | OIF 400ZR |
| QDD-400G-ZRP-S | 400 | oFEC | 16QAM | OpenZR+ |
| QDD-400G-ZRP-S | 300 | oFEC | 8QAM | OpenZR+ |
| QDD-400G-ZRP-S | 200 | oFEC | QPSK | OpenZR+ |
| QDD-400G-ZRP-S | 200 | oFEC | 8QAM | OpenZR+ |
| QDD-400G-ZRP-S | 200 | oFEC | 16QAM | OpenZR+ |
| QDD-400G-ZRP-S | 100 | oFEC | QPSK | OpenZR+ |
| DP04QSDD-HE0 | 400 | cFEC | 16QAM | OIF 400ZR |
| DP04QSDD-HE0 | 400 | oFEC | 16QAM | OpenZR+ |
| DP04QSDD-HE0 | 300 | oFEC | 8QAM | OpenZR+ |
| DP04QSDD-HE0 | 200 | oFEC | QPSK | OpenZR+ |
| DP04QSDD-HE0 | 200 | oFEC | 8QAM | OpenZR+ |
| DP04QSDD-HE0 | 200 | oFEC | 16QAM | OpenZR+ |
| DP04QSDD-HE0 | 100 | oFEC | QPSK | OpenZR+ |

Crosswork Hierarchical Controller UI Provisioning

End-to-End IP+Optical provisioning can be done using Crosswork Hierarchical Controller's GUI IP Link provisioning. Those familiar with traditional GUI EMS/NMS systems for service management will have a very familiar experience. Crosswork Hierarchical Controller provisioning will provision both the router optics as well as the underlying optical network to support the ZR/ZR+ wavelength.

Cross-Layer Link Definition

End to end provisioning requires first defining the Cross-Layer or Inter-Layer links between the router ZR/ZR+ optics and the optical line system add/drop ports. This is done in Crosswork HCO using a UI based "Link Manager" application, used to define the Network Media Channel (NMC) interconnection between ZR/ZR+ port and optical add/drop port.

The below screenshot shows defined NMC cross-links.

The screenshot shows the 'Cross Links' tab of the Link Manager. A single link entry is listed:

| Link Name | Description | Type | Provider | Device A / Port A | Device B / Port B | Status | Method | Last Change |
|------------------------------------|------------------|------|----------|-------------------------------|---|---------|--------|-------------------------|
| Optics0/0/22 / 1/CHAN 29 (194.000) | ron-poc-8201-... | NMC | Manual | ron-poc-8201-1 / Optics0/0/22 | ron-poc-ols-1-roadm / 1/CHAN 29 (194.000) | Unknown | N/A | 2023-04-24 10:23:34 EDT |

Below the table, the 'Summary' section displays the link details:

| | | |
|---|--|--|
| LINK NAME Optics0/0/22 / 1/CHAN 29 (194.000) | DEVICE A / PORT A ron-poc-8201-1/Optics0/0/22 | DEVICE B / PORT B ron-poc-ols-1-roadm/1/CHAN 29 (194.000) |
| TIME ADDED N/A | SOURCE Manual | STATUS Unknown |
| METHOD N/A | LAST CHANGE N/A | DESCRIPTION ron-poc-8201-1 port 0/0/22 to NCS 2000 ron-poc-ols-1 MD-64 channel 29 |

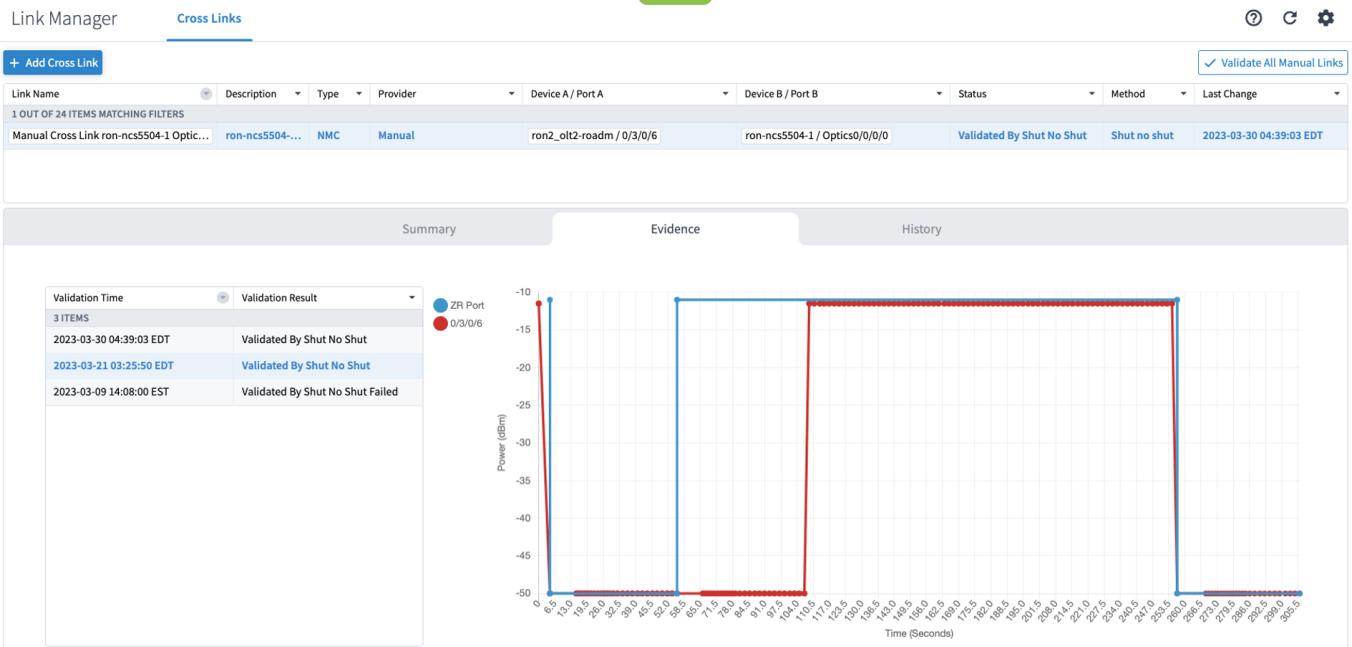
At the bottom left is a 'Validate Link' button, and at the bottom right is a 'Delete Link' button.

Cross-Layer Link Validation (New)

Starting in RON 2.1 and HCO 7.0 users now have the ability to validate the connectivity of an NMC Cross-Layer link. Validation is done by manipulating the transmit power of the optics on the routers and continuously monitoring the power seen on the receive side of the optical line system add/drop port. In RON 2.1 the link validation solution is supported using all XR based Cisco routers and NCS 1010 optical line systems. Validation can be done for all links or per-link using the "Validate Link" option.

Using the Cross-Layer Link Validation is service affecting {
: .notice--warning}

The screenshot below shows a successful validation.



IP Link Provisioning using Crosswork HCO

Crosswork HCO supports end-to-end multi-layer provisioning of Routed Optical Networking circuits, providing a simplified way to provisioning DCO optics in the routers and the supporting optical line system OTSiMC channel in a single operation.

HCO also supports separating the router and optical line system provisioning as two separate tasks, and also supports router-only provisioning for use cases where either dark fiber or passive optical components are being used.

Once the cross layer links are created, the user can then proceed in provisioning an end to end circuit spanning both IP and optical networks. The provisioning UI takes as input the two router endpoints, the associated ZR/ZR+ ports, and the IP addressing or bundle membership of the link. The optical line system provisioning is abstracted from the user, simplifying the end to end workflow. The frequency and power is automatically derived by Cisco Optical Network Controller based on the add/drop port and returned as a parameter to be used in router optics provisioning.

Services Manager Tunnels Point to Point Multi Point

Create New P2P

| Name | P2P Type | Configuration State | Creation Date | Endpoint A | Endpoint B | Speed | Operational State | Last 24h Operations | Last Operation |
|---|----------|---------------------|-------------------------|------------|------------|------------------------------|-------------------|---------------------|------------------------|
| 7 OUT OF 153 ITEMS MATCHING FILTERS | | | | | | | | | |
| ron-8201-1_ron-ncs57b1-1 | IP Link | INSTALLED | 02-12-2022 15:26:45 UTC | | | 100/0/0/18 100.20.26.18/31 | Up | 1 | Create IP Link: ✓ Done |
| PassThrough Link Between OLT1 to OLT4 | IP Link | INSTALLED | 29-11-2022 05:44:49 UTC | | | 201c0/0/3/2 80.80.80.0/31 | Up | 1 | Create IP Link: ✓ Done |
| Test-OLT5-OLT6 | IP Link | INSTALLED | 28-11-2022 14:47:29 UTC | | | 201c0/0/2/2 40.40.40.0/31 | Up | 1 | Create IP Link: ✓ Done |
| test_vlan06_ron-ncs57c3-1_olt1_ll1_1_olt2_ron-ncs5504-6 | IP Link | INSTALLED | 24-11-2022 11:20:25 UTC | | | 201c0/0/2/0 11.1.9.0/31 | Up | 1 | Create IP Link: ✓ Done |
| ron-poc-8201_ols1_ols2_ron-ncs5701-1 | IP Link | INSTALLED | 16-11-2022 14:53:38 UTC | | | 201c0/0/0/24 100.28.30.22/31 | Up | 1 | Create IP Link: ✓ Done |
| ron-8201-1_ols1_ols2_ron-8201-2 | IP Link | INSTALLED | 16-11-2022 14:33:33 UTC | | | 201c0/0/20 100.20.21.21/31 | Up | 1 | Create IP Link: ✓ Done |
| test | IP Link | INSTALLED | 14-11-2022 21:33:58 UTC | | | 201c0/0/0/0 | Up | 1 | Create IP Link: ✓ Done |

IP Link Creation

GENERAL ENDPOINTS PATH SUMMARY

Port A*: ron-8201-4 - Optics0/0/0/20
Transmit Power [dBm]: -10.5

ENDPOINT B

Site B
Port B*: ron-asr9903-1 - Optics0/0/1/8
Transmit Power [dBm]: -10.5

LINK #1 IP ADDRESSES

IP Address A (CIDR): 100.26.27.0/31

Cancel Back Next

Operational Discovery

The Crosswork Hierarchical Controller provisioning process also performs a discovery phase to ensure the service is operational before considering the provisioning complete. If operational discovery fails, the end to end service will be rolled back.

NSO RON-ML CFP Provisioning

Providers familiar with using Cisco Network Service Orchestrator have an option to utilize NSO to provision optical and IP layer configuration for ZR/ZR+ router DCOs.

Cisco has created the Routed Optical Network Multi-Layer Core Function Pack, RON-ML CFP to perform the provisioning of Routed Optical Networking services on the router endpoints. The aforementioned Crosswork HCO provisioning utilizes the RON-ML CFP to perform end device provisioning.

Please see the Cisco Routed Optical Networking RON-ML CFP documentation for more details.

RON-ML End to End Service

The RON-ML service is responsible for router DCO provisioning. All IP layer configuration such as bundle membership and IP addressing is optional, allowing potentially different teams to perform optical parameter provisioning vs. Ethernet/IP layer configuration.

RON-ML API Provisioning

Use the following URL for NSO RESTCONF provisioning using a PATCH operation: http://<nso_host>:<port>/restconf/data

Provisioning ZR+ optics and adding interface to Bundle-Ether 100 interface

```
{
  "cisco-ron-cfp:ron": {
    "ron-ml": [
      {
        "name": "E2E_Bundle_ZRP_ONC57_2",
        "mode": "transponder",
        "bandwidth": "400",
        "circuit-id": "E2E Bundle ONC-57 S9|chan11 - S10|chan11",
        "grid-type": "100mhz-grid",
        "end-point": [
          {
            "end-point-device": "ron-8201-1",
            "terminal-device-optical": {
              "line-port": "0/0/0/11",
              "transmit-power": -100
            },
            "ols-domain": {
              "end-point-state": "UNLOCKED"
            },
            "terminal-device-packet": {
              "bundle": [
                {
                  "id": 100
                }
              ]
            }
          }
        ]
      }
    ]
  }
}
```

```
        }
    ],
    "interface": [
        {
            "index": 0,
            "membership": {
                "bundle-id": 100,
                "mode": "active"
            }
        }
    ]
},
{
    "end-point-device": "ron-8201-2",
    "terminal-device-optical": {
        "line-port": "0/0/0/11",
        "transmit-power": -100
    },
    "ols-domain": {
        "end-point-state": "UNLOCKED"
    },
    "terminal-device-packet": {
        "bundle": [
            {
                "id": 100
            }
        ],
        "interface": [
            {
                "index": 0,
                "membership": {
                    "bundle-id": 100,
                    "mode": "active"
                }
            }
        ]
    }
}
]
```

IOS-XR CLI Configuration

Configuring the router portion of the Routed Optical Networking link is very simple. All optical configuration related to the ZR/ZR+ optics configuration is located under the optics controller relevant to the faceplate port. Default configuration the optics will be in an up/up state using a frequency of 193.10Thz. The default transmit power is dependent on the optics type. The default transmit power for the QDD-400G-ZR-S (OIF

400ZR) and QDD-400G-ZRP-S is -10 dBm. The default transmit power for the High-Power ZR+ DP04QSDD-HE0 is 0 dBm.

The basic configuration with a specific frequency of 195.65 Thz is located below, the only required component is the bolded channel frequency setting.

ZR/ZR+ Optics Configuration

```
controller Optics0/0/0/20
transmit-power -100
dwdm-carrier 100MHz-grid frequency 1956500
logging events link-status
```

Model-Driven Configuration using IOS-XR Native Models using NETCONF or gNMI

All configuration performed in IOS-XR today can also be done using NETCONF/YANG. The following payload exhibits the models and configuration used to perform router optics provisioning. This is a more complete example showing the FEC, power, and frequency configuration. .

Note in Release 2.0 using IOS-XR 7.7.1 the newer IOS-XR Unified Models are utilized for provisioning

```
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
<controllers xmlns="http://cisco.com/ns.yang/Cisco-IOS-XR-um-interface-
cfg">
    <controller>
        <controller-name>Optics0/0/0/0</controller-name>
        <transmit-power xmlns="http://cisco.com/ns.yang/Cisco-IOS-XR-um-
cont-optics-cfg">-115</transmit-power>
        <fec xmlns="http://cisco.com/ns.yang/Cisco-IOS-XR-um-cont-optics-
cfg">0FEC</fec>
        <dwdm-carrier xmlns="http://cisco.com/ns.yang/Cisco-IOS-XR-um-
cont-optics-cfg">
            <grid-100mhz>
                <frequency>1913625</frequency>
            </grid-100mhz>
        </dwdm-carrier>
        <dac-rate xmlns="http://cisco.com/ns.yang/Cisco-IOS-XR-um-dac-
rate-cfg">1x1.25</dac-rate>
    </controller>
</controllers>

</data>
```

Model-Driven Configuration using OpenConfig Models

Starting on Release 2.0 all IOS-XR 7.7.1+ routers supporting ZR/ZR+ optics can be configured using OpenConfig models. Provisioning utilizes the openconfig-terminal-device model and its extensions to the openconfig-platform model to support DWDM configuration parameters.

Below is an example of an OpenConfig payload to configure ZR/ZR+ optics port 0/0/0/20 with a 300G trunk rate with frequency 195.20 THz.

Please visit the blog at <https://xrdocs.io/design/blogs/zr-openconfig-mgmt> for in depth information about configuring and monitoring ZR/ZR+ optics using OpenConfig models.

```
<config>
    <terminal-device xmlns="http://openconfig.net/yang/terminal-
device">
        <logical-channels>
            <channel>
                <index>100</index>
                <config>
                    <index>200</index>
                    <rate-class
xmlns:idx="http://openconfig.net/yang/transport-
types">idx:TRIB_RATE_100G</rate-class>
                    <admin-state>ENABLED</admin-state>
                    <description>ETH Logical Channel</description>
                    <trib-protocol
xmlns:idx="http://openconfig.net/yang/transport-
types">idx:PROT_100G_MLG</trib-protocol>
                    <logical-channel-type
xmlns:idx="http://openconfig.net/yang/transport-
types">idx:PROT_ETHERNET</logical-channel-type>
                    </config>
                    <logical-channel-assignments>
                        <assignment>
                            <index>1</index>
                            <config>
                                <index>1</index>
                                <allocation>100</allocation>
                                <assignment-
type>LOGICAL_CHANNEL</assignment-type>
                                <description>ETH to Coherent
assignment</description>
                                <logical-channel>200</logical-channel>
                            </config>
                        </assignment>
                    </logical-channel-assignments>
                </channel>
                <channel>
                    <index>101</index>
                    <config>
                        <index>101</index>
                        <rate-class
xmlns:idx="http://openconfig.net/yang/transport-
```

```
types">idx:TRIB_RATE_100G</rate-class>
        <admin-state>ENABLED</admin-state>
        <description>ETH Logical Channel</description>
        <trib-protocol
xmlns:idx="http://openconfig.net/yang/transport-
types">idx:PROT_100G_MLG</trib-protocol>
        <logical-channel-type
xmlns:idx="http://openconfig.net/yang/transport-
types">idx:PROT_ETHERNET</logical-channel-type>
        </config>
        <logical-channel-assignments>
            <assignment>
                <index>1</index>
                <config>
                    <index>1</index>
                    <allocation>100</allocation>
                    <assignment-
type>LOGICAL_CHANNEL</assignment-type>
                    <description>ETH to Coherent
assignment</description>
                    <logical-channel>200</logical-channel>
                </config>
            </assignment>
        </logical-channel-assignments>
    </channel>
    <channel>
        <index>102</index>
        <config>
            <index>102</index>
            <rate-class
xmlns:idx="http://openconfig.net/yang/transport-
types">idx:TRIB_RATE_100G</rate-class>
            <admin-state>ENABLED</admin-state>
            <description>ETH Logical Channel</description>
            <trib-protocol
xmlns:idx="http://openconfig.net/yang/transport-
types">idx:PROT_100G_MLG</trib-protocol>
            <logical-channel-type
xmlns:idx="http://openconfig.net/yang/transport-
types">idx:PROT_ETHERNET</logical-channel-type>
            </config>
            <logical-channel-assignments>
                <assignment>
                    <index>1</index>
                    <config>
                        <index>1</index>
                        <allocation>100</allocation>
                        <assignment-
type>LOGICAL_CHANNEL</assignment-type>
                        <description>ETH to Coherent
assignment</description>
                        <logical-channel>200</logical-channel>
                    </config>
                </assignment>
            </logical-channel-assignments>
        </channel>
    </channel>
```

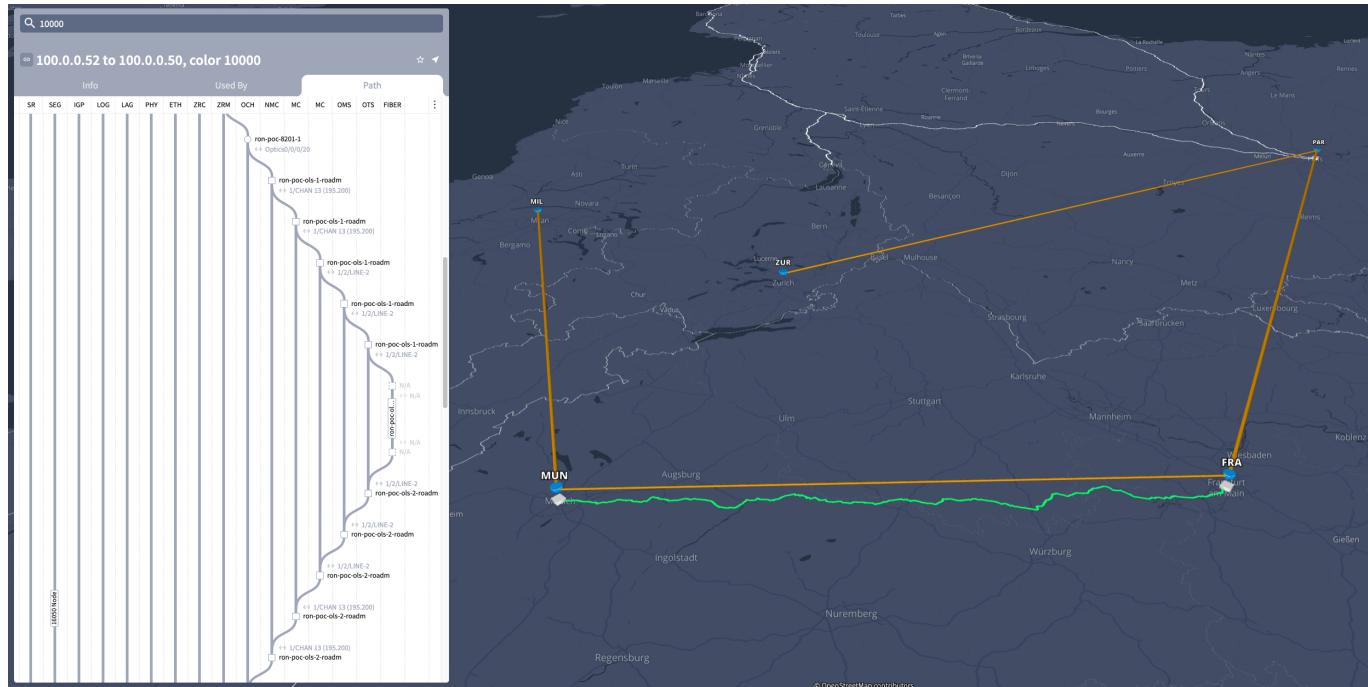
```
        </assignment>
    </logical-channel-assignments>
</channel>
<channel>
    <index>200</index>
    <config>
        <index>200</index>
        <admin-state>ENABLED</admin-state>
        <description>Coherent Logical
Channel</description>
        <logical-channel-type
xmlns:idx="http://openconfig.net/yang/transport-
types">idx:PROT_0TN</logical-channel-type>
    </config>
    <logical-channel-assignments>
        <assignment>
            <index>1</index>
            <config>
                <index>1</index>
                <allocation>300</allocation>
                <assignment-
type>OPTICAL_CHANNEL</assignment-type>
                <description>Coherent to optical
assignment</description>
                <optical-channel>0/0-
OpticalChannel0/0/0/20</optical-channel>
            </config>
            </assignment>
        </logical-channel-assignments>
    </channel>
</logical-channels>
</terminal-device>
<components xmlns="http://openconfig.net/yang/platform">
    <component>
        <name>0/0-OpticalChannel0/0/0/20</name>
        <optical-channel
xmlns="http://openconfig.net/yang/terminal-device">
            <config>
                <operational-mode>5007</operational-mode>
                <frequency>195200000</frequency>
            </config>
            </optical-channel>
        </component>
    </components>
</config>
```

Routed Optical Networking Assurance

Crosswork Hierarchical Controller

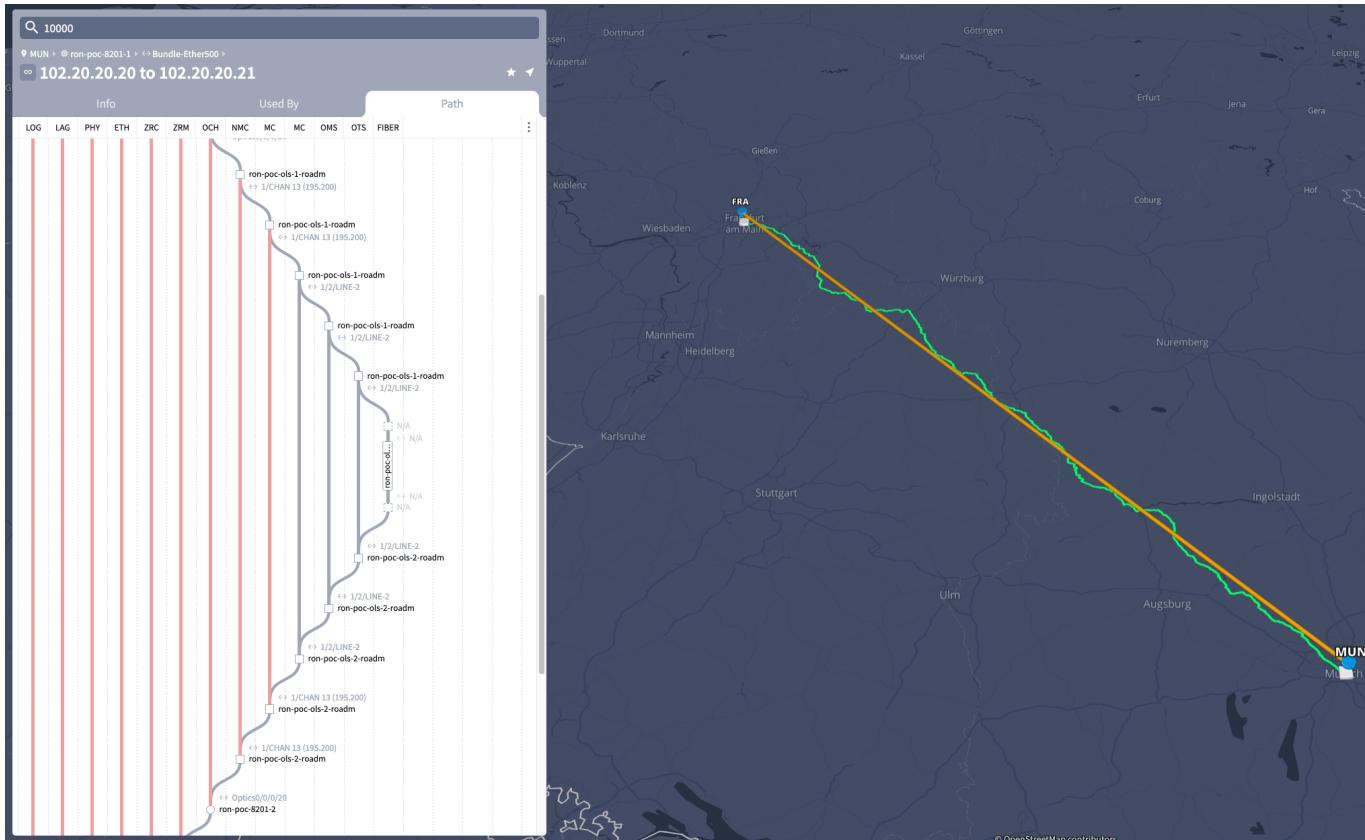
Multi-Layer Path Trace

Using topology and service data from both the IP and Optical network CW HCO can display the full service from IP services layer to the physical fiber. Below is an example of the "waterfall" trace view from the OTS (Fiber) layer to the Segment Routing TE layer across all layers. CW HCO identifies specific Routed Optical Networking links using ZR/ZR+ optics as seen by the ZRC (ZR Channel) and ZRM (ZR Media) layers from the 400ZR specification.



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When faults occur at a specific layer, faults will be highlighted in red, quickly identifying the layer a fault has occurred. In this case we can see the fault has occurred at an optical layer, but is not a fiber fault. Having the ability to pinpoint the fault layer even within a specific domain is a powerful way to quickly determine the root cause of the fault.



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Routed Optical Networking Link Assurance

The Link Assurance application allows users to view a network link and all of its dependent layers. This includes Routed Optical Networking multi-layer services. In addition to viewing layer information, fault and telemetry information is also available by simply selecting a link or port.

ZRM Layer TX/RX Power

Link Assurance

Inspect Links

Settings

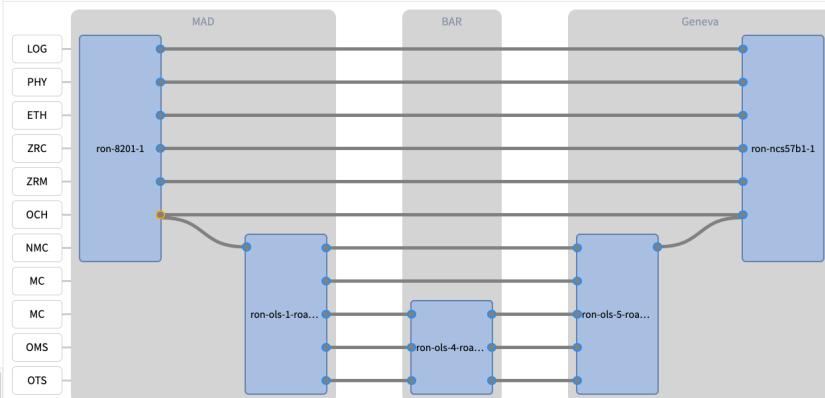
Select Links For In-Depth Analysis

- Define Valid Links For Inspection By:
- Specific link(s) / underlay link(s)
 - Tags
 - Device(s) in 1 of the endpoints
 - Device(s) in both endpoints

[Q Add Tag](#)

Links UnderlayType is "RON"

100.20.26.18 to 100.20.26.19 L3 Logical Link



| Name | Type | Status |
|------------------------------|------------|--------|
| 10 ITEMS | | |
| 100.21.22.0 to 100.21.22.1 | L3 Logical | UP |
| 102.20.20.20 to 102.20.20.21 | L3 Logical | DOWN |
| 21.1.9.0 to 21.1.9.1 | L3 Logical | UP |
| 100.20.21.20 to 100.20.21.21 | L3 Logical | UP |
| 100.20.26.18 to 100.20.26.19 | L3 Logical | UP |
| 100.21.40.0 to 100.21.40.1 | L3 Logical | UP |
| 80.80.80.1 to 80.80.80.0 | L3 Logical | UP |

| Summary | | | |
|--------------------|------|---|---|
| Name | Type | Parent | Admin Status |
| Optics0/0/0/18 | OCH | ron-8201-1 | UP |
| Operational Status | UP | Tx Power [dbm] | Rx Power [dbm] |
| | | Min: -11.56 Average: -11.56 Max: -11.52 | Min: -12.81 Average: -12.81 Max: -12.69 |

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ZRC Layer BER and Q-Factor / Q-Margin

Link Assurance

Inspect Links

Settings

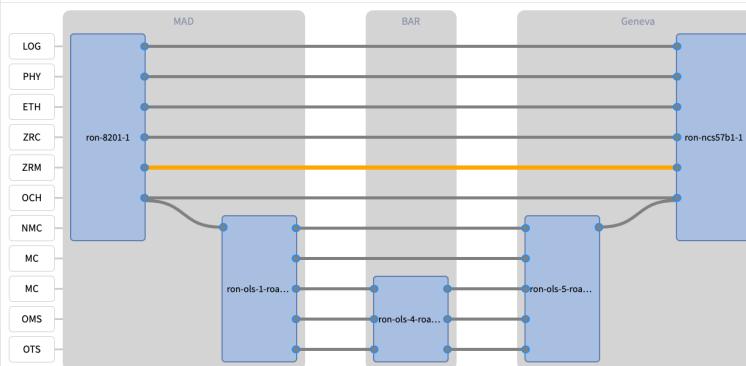
Select Links For In-Depth Analysis

- Define Valid Links For Inspection By:
- Specific link(s) / underlay link(s)
 - Tags
 - Device(s) in 1 of the endpoints
 - Device(s) in both endpoints

[Q Add Tag](#)

Links UnderlayType is "RON"

100.20.26.18 to 100.20.26.19 L3 Logical Link



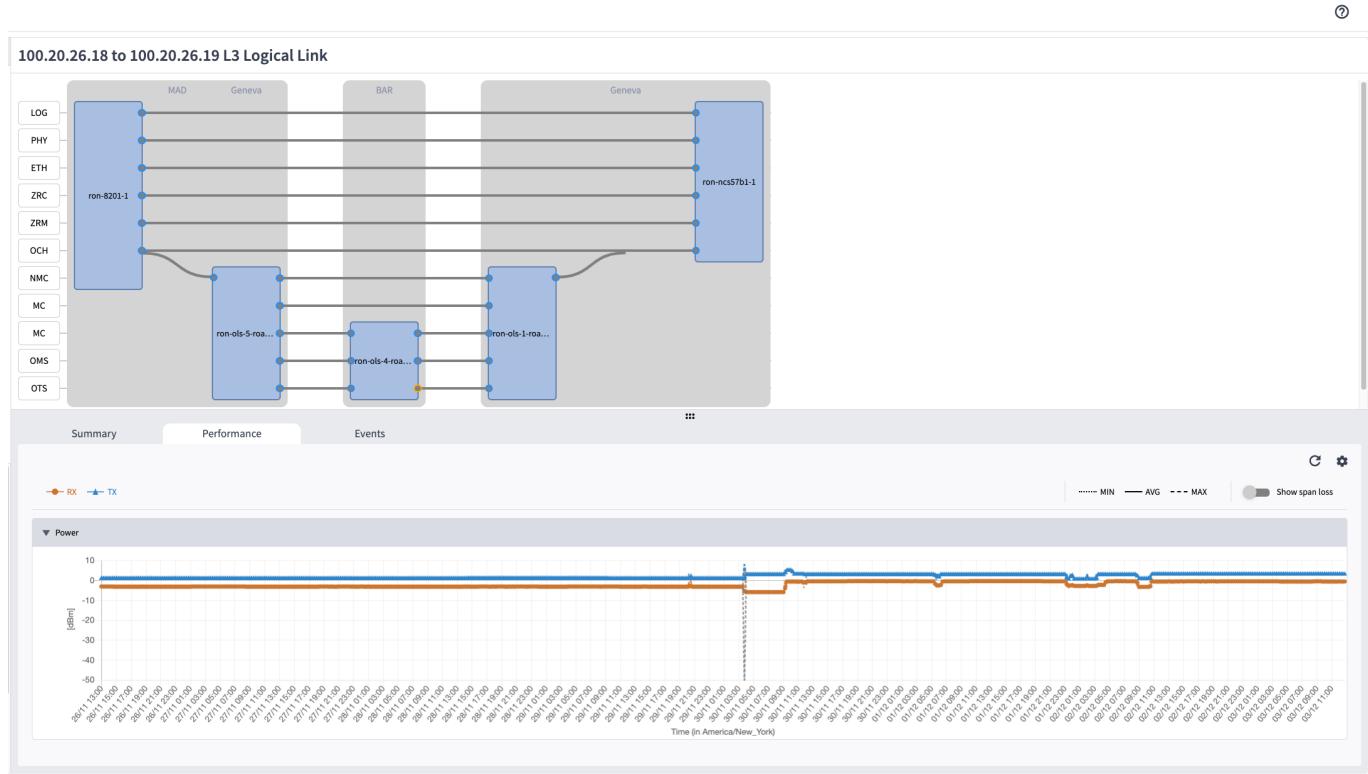
| Name | Type | Status |
|------------------------------|------------|--------|
| 10 ITEMS | | |
| 100.21.22.0 to 100.21.22.1 | L3 Logical | UP |
| 102.20.20.20 to 102.20.20.21 | L3 Logical | DOWN |
| 21.1.9.0 to 21.1.9.1 | L3 Logical | UP |
| 100.20.21.20 to 100.20.21.21 | L3 Logical | UP |
| 100.20.26.18 to 100.20.26.19 | L3 Logical | UP |
| 100.21.40.0 to 100.21.40.1 | L3 Logical | UP |
| 80.80.80.1 to 80.80.80.0 | L3 Logical | UP |

| Summary | | | | | |
|---|---|---|---|---|--------------------------|
| Name | Layer | Admin Status | Operational Status | Endpoint A | Endpoint Z |
| CoherentDSP0/0/0/18... | ZR Media | UP | UP | ron-8201-1 | ron-ncs57b1-1 |
| Port A Pre-FEC BER | Port Z Pre-FEC BER | Port A Post-FEC BER | Port Z Post-FEC BER | Port A Q Factor [db] | Port Z Q Factor [db] |
| Min: 4.8000e-03 Average: 4.9000e-03 Max: 5.0000e-03 | Min: 1.7000e-03 Average: 1.8000e-03 Max: 1.9000e-03 | Min: 0.0000e+00 Average: 0.0000e+00 Max: 0.0000e+00 | Min: 0.0000e+00 Average: 0.0000e+00 Max: 0.0000e+00 | Min: 8.20 Average: 8.20 Max: 8.20 | Min: Average: Max: |

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Optionally the user can see graphs of collected telemetry data to quickly identify trends or changes in specific operational data. Graphs of collected performance data is accessed using the "Performance" tab when a link or port is selected.

OTS Layer RX/TX Power Graph



Select Links For In-Depth Analysis

Define Valid Links For Inspection By:

- Specific link(s) / underlay link(s)
- Tags
- Device(s) in 1 of the endpoints
- Device(s) in both endpoints

[Add Tag](#)

Links UnderlayType is "RON"

| Name | Type | Status |
|------------------------------|------------|--------|
| 100.21.22.0 to 100.21.22.1 | L3 Logical | UP |
| 102.20.20.20 to 102.20.20.21 | L3 Logical | UP |
| 21.1.9.0 to 21.1.9.1 | L3 Logical | UP |
| 100.20.21.20 to 100.20.21.21 | L3 Logical | UP |
| 100.20.26.18 to 100.20.26.19 | L3 Logical | UP |
| 100.21.40.0 to 100.21.40.1 | L3 Logical | UP |
| 80.80.80.1 to 80.80.80.0 | L3 Logical | UP |

102.20.20.20 to 102.20.20.21 L3 Logical Link

Events

Events were fetched from 01/12/2022 19:08:21 UTC to now

| Time | Operational Status Change |
|-------------------------|---------------------------|
| 17:36:59 12-03-2022 UTC | DOWN → UP |
| 17:18:17 12-03-2022 UTC | UP → DOWN |

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IOS-XR CLI Monitoring of ZR400/OpenZR+ Optics

Optics Controller

The optics controller represents the physical layer of the optics. In the case of ZR/ZR+ optics this includes the frequency information, RX/TX power, OSNR, and other associated physical layer information.

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

Controller State: Up
Transport Admin State: In Service
Laser State: On
LED State: Green
FEC State: FEC ENABLED

Optics Status

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

Alarm Status:

Detected Alarms: None

LOS/LOL/Fault Status:

Alarm Statistics:

```
-----  
HIGH-RX-PWR = 0           LOW-RX-PWR = 0  
HIGH-TX-PWR = 0           LOW-TX-PWR = 4  
HIGH-LBC = 0              HIGH-DGD = 1  
00R-CD = 0                OSNR = 10  
WVL-OOL = 0               MEA = 0  
IMPROPER-REM = 0  
TX-POWER-PROV-MISMATCH = 0  
Actual TX Power = -7.17 dBm  
RX Power = -9.83 dBm  
RX Signal Power = -9.18 dBm  
Frequency Offset = 9 MHz  
Baud Rate = 59.8437500000 GBd  
Modulation Type: 16QAM  
Chromatic Dispersion 6 ps/nm  
Configured CD-MIN -2400 ps/nm  CD-MAX 2400 ps/nm  
Second Order Polarization Mode Dispersion = 34.00 ps^2  
Optical Signal to Noise Ratio = 35.50 dB  
Polarization Dependent Loss = 1.20 dB  
Polarization Change Rate = 0.00 rad/s  
Differential Group Delay = 2.00 ps
```

Performance Measurement Data

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

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

| Optics current bucket type : Valid | | | | | |
|------------------------------------|-------------|----------------|----------------|----------------|------------------------|
| TCA | Operational | MIN Configured | Avg | MAX TCA | Operational Configured |
| | | (min) | Threshold(max) | Threshold(max) | (max) |
| LBC[%] | : 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NO | 100.0 | NA | | NO | NA |
| OPT[dBm] | : -7.17 | -7.17 | -7.17 | -15.09 | NA |
| NO | 0.00 | NA | | NO | NA |
| OPR[dBm] | : -9.86 | -9.86 | -9.85 | -30.00 | NA |
| NO | 8.00 | NA | | NO | NA |
| CD[ps/nm] | : -489 | -488 | -488 | -80000 | NA |
| NO | 80000 | NA | | NO | NA |
| DGD[ps] | : 1.00 | 1.50 | 2.00 | 0.00 | NA |
| NO | 80.00 | NA | | NO | NA |

| | | | | | |
|-------------------|---------|-------|-------|--------|----|
| SOPMD [ps^2] | : 28.00 | 38.80 | 49.00 | 0.00 | NA |
| NO 2000.00 | | NA | NO | | |
| OSNR [dB] | : 34.90 | 35.12 | 35.40 | 0.00 | NA |
| NO 40.00 | | NA | NO | | |
| PDL [dB] | : 0.70 | 0.71 | 0.80 | 0.00 | NA |
| NO 7.00 | | NA | NO | | |
| PCR [rad/s] | : 0.00 | 0.00 | 0.00 | 0.00 | NA |
| NO 2500000.00 | | NA | NO | | |
| RX_SIG [dBm] | : -9.23 | -9.22 | -9.21 | -30.00 | NA |
| NO 1.00 | | NA | NO | | |
| FREQ_OFFSET [MHz] | : -2 | -1 | 4 | -3600 | NA |
| NO 3600 | | NA | NO | | |
| SNR [dB] | : 16.80 | 16.99 | 17.20 | 7.00 | NA |
| NO 100.00 | | NA | NO | | |

Coherent DSP Controller

The coherent DSP controller represents the framing layer of the optics. It includes Bit Error Rate, Q-Factor, and Q-Margin information.

```
RP/0/RP0/CPU0:ron-8201-1#show controllers coherentDSP 0/0/0/20
Sat Dec  4 17:24:38.245 PST

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

Alarm Information:
LOS = 10      LOF = 0  LOM = 0
OOF = 0  OOM = 0 AIS = 0
IAE = 0  BIAE = 0      SF_BER = 0
SD_BER = 0    BDI = 0  TIM = 0
FECMISMATCH = 0 FEC-UNC = 0      FLEXO_GIDM = 0
FLEXO-MM = 0   FLEXO-LOM = 3   FLEXO-RDI = 0
FLEXO-LOF = 5
Detected Alarms                  : None

Bit Error Rate Information
PREFEC BER                      : 1.7E-03
POSTFEC BER                      : 0.0E+00
Q-Factor                          : 9.30 dB
Q-Margin                          : 2.10dB
```

| | | |
|----------|---|-------|
| FEC mode | : | C_FEC |
|----------|---|-------|

Performance Measurement Data

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

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

```
FEC current bucket type : Valid
```

```
  EC-BITS   : 20221314973                           Threshold : 83203400000
```

```
  TCA(enable) : YES
```

```
  UC-WORDS   : 0                                   Threshold : 5
```

```
  TCA(enable) : YES
```

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

EPNM Monitoring of Routed Optical Networking

Evolved Programmable Network Manager, or EPNM, can also be used to monitor router ZR/ZR+ performance measurement data and display device level alarms when faults occur. EPNM stores PM and alarm data for historical analysis.

EPNM Chassis View of DCO Transceivers

The following shows a chassis view of a Cisco 8201 router. The default view is to show all active alarms on the device and its components. Clicking on a specific component will give information on the component and narrow the scope of alarms and data.

Chassis View

Chassis View | Logical View | Device Details

FourHundredGigE0/0/0/8-IDPROM

| | |
|------------------|-------------------------------|
| Hardware Version | ES03 |
| Part Number | QDD-400G-ZRP-S |
| Serial Number | ACA2501003X |
| CLEI Code | No Data Available |
| Equipment Type | Module |
| State | No Data Available |
| Location | FourHundredGigE0/0/0/8-IDPROM |
| Product ID | QDD-400G-ZRP-S |

Show Details

ron-8201-1 ron-8201-1

Last Updated: 2021-Jun-24 16:07:38 EST

Alarms Configuration Inventory Interfaces Circuits Image Configuration Archive

6 Critical 2 Major 4 Minor 0 Warning 0 Information

Export Show Quick Filter

| Severity | Condition | Timestamp | Affected Objects | Alarm ID |
|----------|--------------------------|--------------------------|------------------------------------|----------|
| ▼ | isisAdjacencyChangeDown | 2021-Jun-24 12:37:44 EST | FourHundredGigE0/0/0/20 | 11509938 |
| ▼ | ROUTING-ISIS-5-ADJCHA... | 2021-Jun-24 12:37:44 EST | FourHundredGigE0/0/0/20 | 11509937 |
| ▼ | ROUTING-ISIS-5-ADJCHA... | 2021-Jun-24 12:37:44 EST | FourHundredGigE0/0/0/8 | 11509939 |
| ✗ | LINK_DOWN | 2021-Jun-24 12:37:09 EST | FourHundredGigE0/0/0/20-mpls la... | 11509935 |
| ✗ | LINK_DOWN | 2021-Jun-24 12:37:09 EST | FourHundredGigE0/0/0/20 | 11509936 |
| ▼ | celcPowerStatusChange | 2021-Jun-23 00:05:47 EST | 0/PM0 | 11509854 |

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Interface/Port View

Chassis View | Logical View | Device Details

Front:8: FourHundredGigE/8-IDPROM
ron-8201-1 / Rack_0/ Front:1_0/RP0/CPU0 / Front:8: FourHundredGigE/8-IDPROM

Alarms Configuration Inventory **Interfaces** Circuits

Type All Interfaces Property All Properties Selected 0 / Total 2

| Alarm | Name | Type | Admin Status | Operational Status | Transport Admin |
|-------|----------------------------|----------------|--------------|--------------------|-----------------|
| ○ | Cleared CoherentDSP0/0/0/8 | OTNOTU | Up | Up | IS |
| ○ | Cleared Optics0/0/0/8 | OPTICALCHANNEL | Up | Up | IS |

Show All

Front:8: FourHundredGigE/8-IDPROM

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EPNM DCO Performance Measurement

EPNM continuously monitors and stores PM data for DCO optics for important KPIs such as TX/RX power, BER, and Q values. The screenshots below highlight monitoring. While EPNM stores historical data, clicking on a specific KPI will enable realtime monitoring by polling for data every 20 seconds.

DCO Physical Layer PM KPIs

The following shows common physical layer KPIs such as OSNR and RX/TX power. This is exposed by monitoring the Optics layer of the interface.

DCO.

The screenshot displays a network management interface for an optical interface named "Optics0/0/0/8".

Interface Details:

- Interface Type: OPTICALCHANNEL
- Transport Admin State: IS
- Device Name: ron-8201-1 ⓘ
- Adjacent Interface(s): N/A

Performance Data:

| Timestamp | OSNR | RX-POWER | TX-POWER | LBC | DGD | PCR |
|---------------------------|-------|------------|------------|-----|------|-----|
| 16:02:55, 24-Jun-2021 EST | 31.50 | -13.36 dBm | -10.53 dBm | 0 | 2.00 | 0 |
| 16:02:36, 24-Jun-2021 EST | 31.70 | -13.26 dBm | -10.55 dBm | 0 | 2.00 | 0 |

Logical View:

- Alarms
- Optical Physical
- FEC
- Interface
- Circuits/VCS

Logical Circuits:

| Type | Admin Status | Operational Status |
|----------------|--------------|--------------------|
| OTNOTU | Up | Up |
| OPTICALCHANNEL | Up | Up |

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The following shows common framing layer KPIs such as number of corrected words per interval and (BIEC) Bit Error Rate. This is exposed by monitoring the CoherentDSP layer of the interface.

The screenshot displays a network management interface for a device named "CoherentDSP0/0/0/8".

Device Summary:

- Interface Speed: 400.0Gbps
- Interface Type: OTNOUTU
- Transport Admin State: IS
- Device Name: son-8201-1 (i)
- Adjacent Interface(s): N/A

Performance Data:

| Timestamp | UCW | BIEC | PreFEC_BER-MIN | PreFEC_BER-AVG |
|---------------------------|-----|--------------|----------------|----------------|
| 16:04:14, 24-Jun-2021 EST | 0 | 49373542753 | 1.3E-03 | 1.4E-03 |
| 16:04:34, 24-Jun-2021 EST | 0 | 507114399500 | 1.3E-03 | 1.4E-03 |
| 16:04:54, 24-Jun-2021 EST | 0 | 520413161689 | 1.3E-03 | 1.4E-03 |
| 16:05:14, 24-Jun-2021 EST | 0 | 533591199474 | 1.3E-03 | 1.4E-03 |

Circuits:

| Type | Admin Status | Operational Status |
|----------------|--------------|--------------------|
| OTNOUTU | Up | Up |
| OPTICALCHANNEL | Up | Up |

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Cisco IOS-XR Model-Driven Telemetry for Routed Optical Networking Monitoring

All operational data on IOS-XR routers and optical line systems can be monitored using streaming telemetry based on YANG models. Routed Optical Networking is no different, so a wealth of information can be streamed from the routers in intervals as low as 5s.

ZR/ZR+ DCO Telemetry

The following represents a list of validated sensor paths useful for monitoring the DCO optics in IOS-XR and the data fields available within these sensor paths. Note PM fields also support 15m and 24h paths in addition to the 30s paths shown in the table below.

| Sensor Path | Fields |
|---|---|
| Cisco-IOS-XR-controller-optics-oper:optics-oper/optics-ports/optics-port/optics-info | alarm-detected, baud-rate, dwdm-carrier-frequency, controller-state, laser-state, optical-signal-to-noise-ratio, temperature, voltage |
| Cisco-IOS-XR-controller-optics-oper:optics-oper/optics-ports/optics-port/optics-lanes/optics-lane | receive-power, receive-signal-power, transmit-power |
| Cisco-IOS-XR-controller-otu-oper:otu/controllers/controller/info | bandwidth, ec-value, post-fec-ber, pre-fec-ber, qfactor, qmargin, uc |
| Cisco-IOS-XR-pmengine-oper:performance-management/optics/optics-ports/optics-port/optics-current/optics-second30/optics-second30-optics/optics-second30-optic | dd_average, dgd_average, opr_average, opt_average, osnr_average, pcr_average, pmd_average, rx-sig-pow_average, snr_average, sopmd_average |
| Cisco-IOS-XR-pmengine-oper:performance-management/otu/otu-ports/otu-port/otu-current/otu-second30/otu-second30fec/otu-second30fec | ec-bits_data, post-fec-ber_average, pre-fec-ber_average, q_average, qmargin_average, uc-words_data |

NCS 1010 Optical Line System Monitoring

The following represents a list of validated sensor paths useful for monitoring the different optical resources on the NCS 1010 OLS. The OTS controller represents the lowest layer port interconnecting optical elements. The NCS 1010 supports per-channel monitoring, exposed as the OTS-OCH

| Sensor Path | Fields |
|---|---|
| Cisco-IOS-XR-controller-ots-oper:ots-oper/ots-ports/ots-port/ots-info | total-tx-power, total-rx-power, transmit-signal-power, receive-signal-power, agress-ampi-gain, ingress-ampli-gain, controller-state |
| Cisco-IOS-XR-controller-ots-och-oper:ots-och-oper/ots-och-ports/ots-och-port/ots-och-info | total-tx-power, total-rx-power, transport-admin-state, line-channel, add-drop-channel |
| Cisco-IOS-XR-controller-oms-oper | rx-power, tx-power, controller-state, led-state |
| Cisco-IOS-XR-controller-och-oper:och-oper/och-ports/och-port/och-info | channel-frequency, channel-wavelength, controller-state, rx-power, tx-power, channel-width, led-state |
| Cisco-IOS-XR-pmengine-oper:performance-management/optics/optics-ports | opr, opt, opr-s, opt-s |

Sensor Path

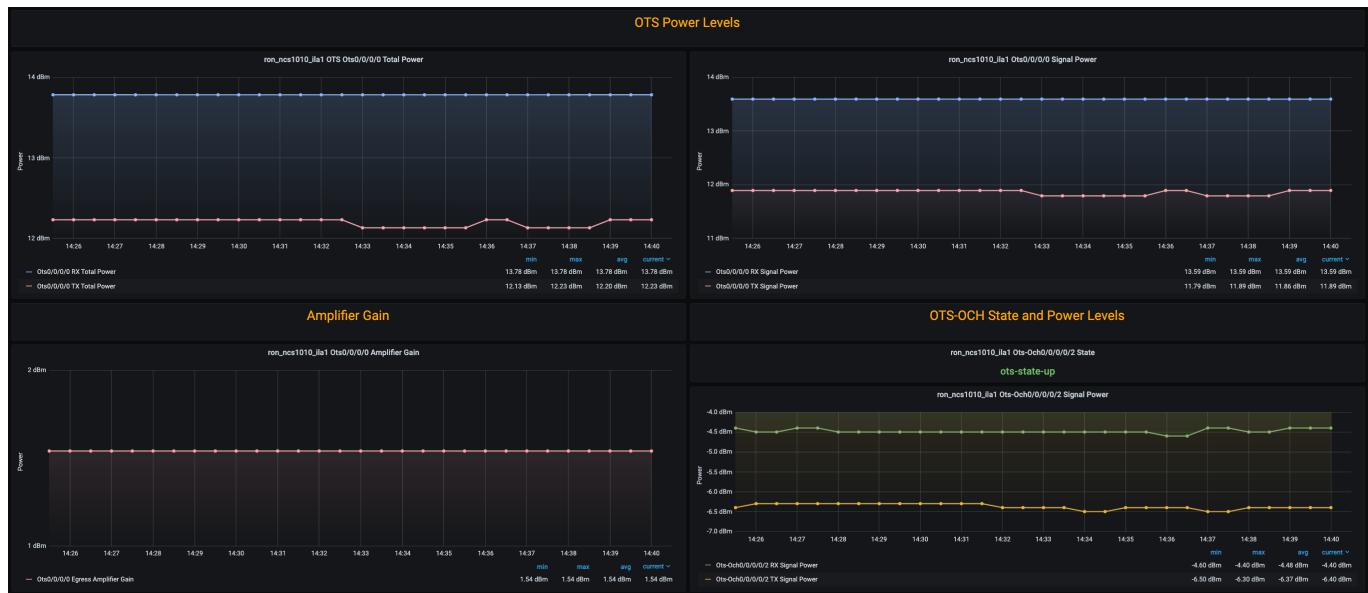
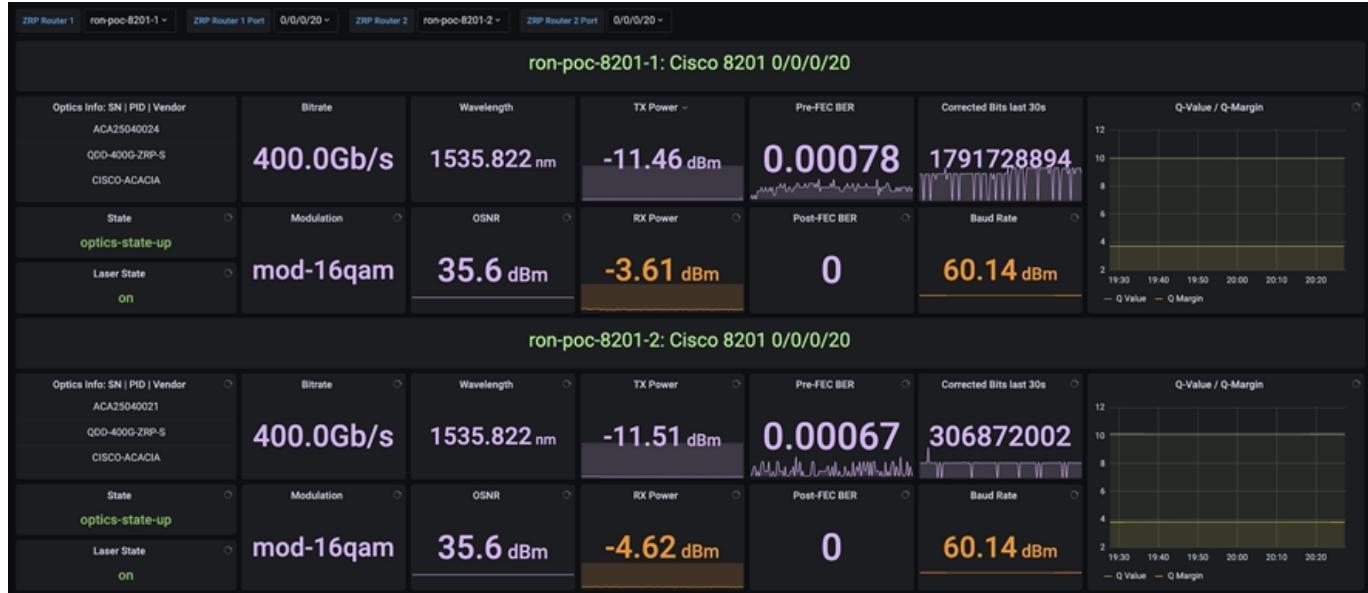
Fields

Cisco-IOS-XR-olc-oper:olc/span-loss-ctrlr-tables/span-loss-ctrlr-table

neighbor-rid, rx-span-loss, tx-span-loss, name

Open-source Monitoring

Cisco model-driven telemetry along with the open source collector Telegraf and the open source dashboard software Grafana can be used to quickly build powerful dashboards to monitor ZR/ZR+ and NCS 1010 OLS performance.



Additional Resources

Cisco Routed Optical Networking 2.1 Solution Guide

<https://www.cisco.com/content/en/us/td/docs/optical/ron/2-1/solution/guide/b-ron-solution-21.html>

Cisco Routed Optical Networking Home

- <https://www.cisco.com/c/en/us/solutions/service-provider/routed-optical-networking.html>

Cisco Routed Optical Networking Tech Field Day

- Solution Overview: <https://techfieldday.com/video/build-your-network-with-cisco-routed-optical-networking-solution/>
- Automation Demo: <https://techfieldday.com/video/cisco-routed-optical-networking-solution-demo/>

Cisco Champion Podcasts

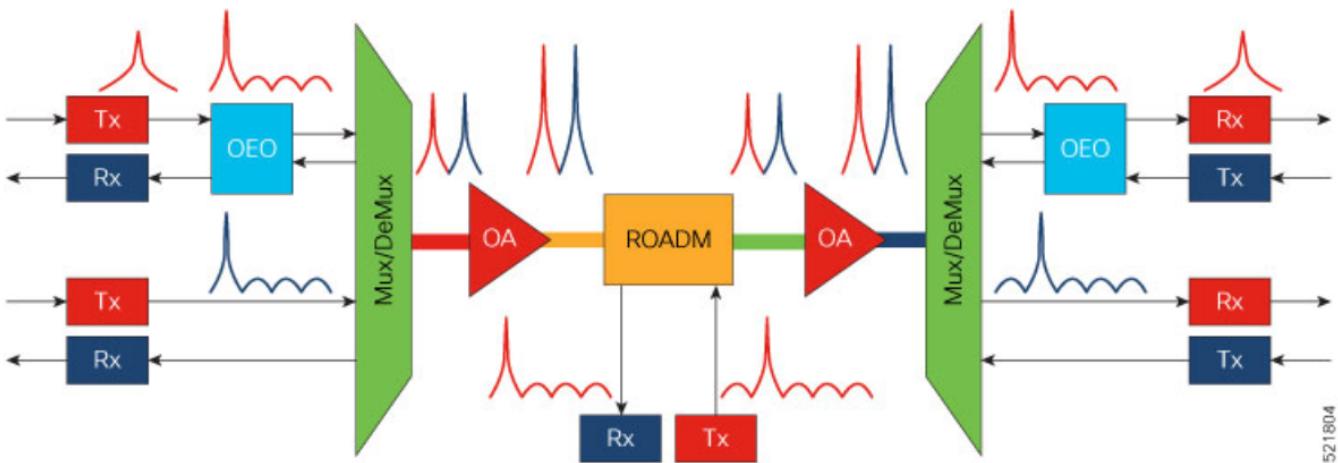
- Cisco Routed Optical Networking Solution for the Next Decade <https://smarturl.it/CCRS8E24>
- Simplify Network Operations with Crosswork Hierarchical Controller: <<https://smarturl.it/CCRS8E48>>

Appendix A

Acronyms

| | |
|-------|---|
| DWDM | Dense Waveform Division Multiplexing |
| OADM | Optical Add Drop Multiplexer |
| FOADM | Fixed Optical Add Drop Multiplexer |
| ROADM | Reconfigurable Optical Add Drop Multiplexer |
| DCO | Digital Coherent Optics |
| FEC | Forward Error Correction |
| OSNR | Optical Signal to Noise Ratio |
| BER | Bit Error Rate |

DWDM Network Hardware Overview



521804

Optical Transmitters and Receivers

Optical transmitters provide the source signals carried across the DWDM network. They convert digital electrical signals into a photonic light stream on a specific wavelength. Optical receivers detect pulses of light and convert signals back to electrical signals. In Routed Optical Networking, digital coherent QSFP-DD OpenZR+ and 400ZR transceivers in routers are used as optical transmitters and receivers.

Multiplexers/Demultiplexers

Multiplexers take multiple wavelengths on separate fibers and combine them into a single fiber. The output of a multiplexer is a composite signal. Demultiplexers take composite signals that compatible multiplexers generate and separate the individual wavelengths into individual fibers.

Optical Amplifiers

Optical amplifiers amplify an optical signal. Optical amplifiers increase the total power of the optical signal to enable the signal transmission across longer distances. Without amplifiers, the signal attenuation over longer distances makes it impossible to coherently receive signals. We use different types of optical amplifiers in optical networks. For example: preamplifiers, booster amplifiers, inline amplifiers, and optical line amplifiers.

Optical add/drop multiplexers (OADMs)

OADMs are devices capable of adding one or more DWDM channels into or dropping them from a fiber carrying multiple channels.

Reconfigurable optical add/drop multiplexers (ROADMs)

ROADMs are programmable versions of OADMs. With ROADM, you can change the wavelengths that are added or dropped. ROADM make optical networks flexible and easily modifiable.