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The bridge to possible

Optical and Optics 101 for IP Engineers

Brad Riapolov and Kent Dailey, Technical Solution Architects

BRKOPT-1260

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with the speaker after the session

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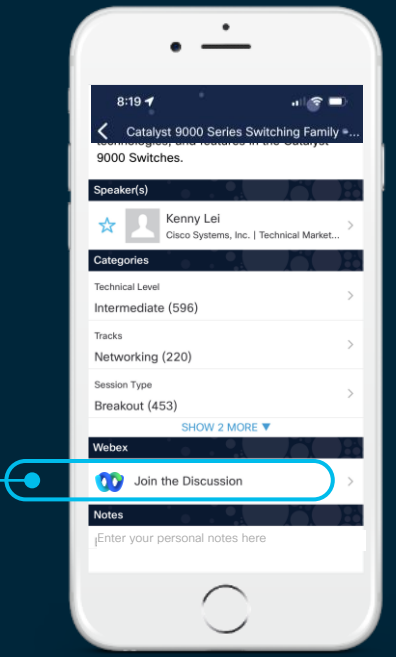
4. Enter messages/questions in the Webex space



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Webex spaces will be moderated by the speaker until June 17, 2022.

Agenda

- Introduction
- DWDM Fundamentals and Necessaries
- Forward with Optical Line Systems and Transponders
- Forward with Routed Optical Networking
- Which is better – decision time
- Conclusion

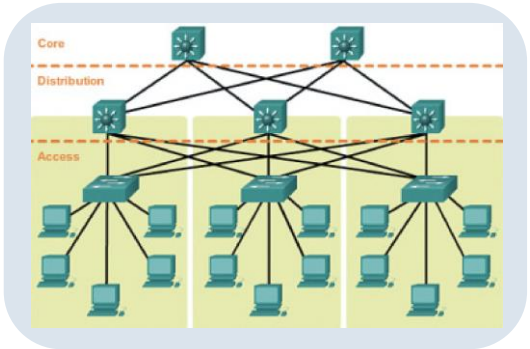
DWDM Fundamentals and Necessaries

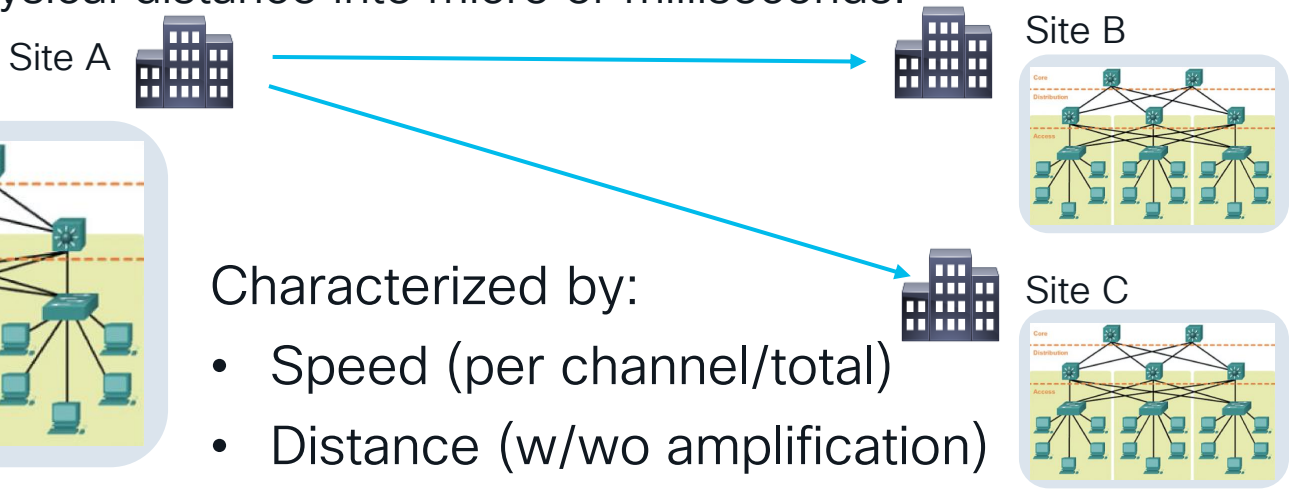
Traditional IP Engineer's view of Optical Networking

- Grey optics connect buildings/floors together, a mystery beyond
- Layer 1 requires a different skillset from Ethernet
- Fiber optic technology has a "perceived" steep learning curve
- Traditional Engineers understand IP, not Transport, hard to find both skillsets
- Fiber optic networks are costly

What is optical transport and why do you need it?

- Copper or fiber cables are abundant at a site. But…
- What do you need to connect other sites – across the city or to another state?
  - Answer: Optical transport over fiber (longest transmission medium) to transform physical distance into micro or milliseconds.



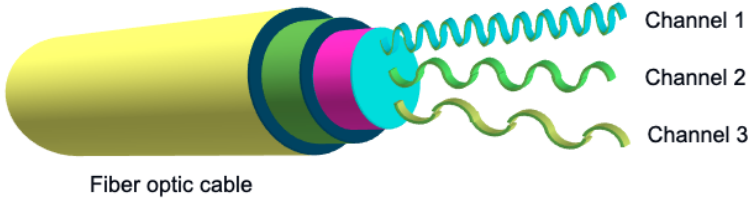


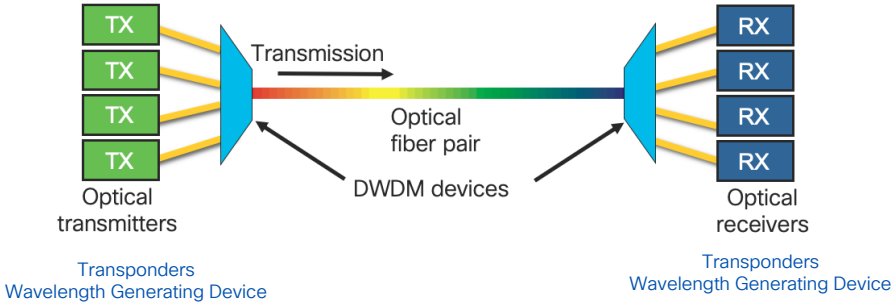
Characterized by:

- Speed (per channel/total)
- Distance (w/wo amplification)

Why WDM (Wave Division Multiplexing)

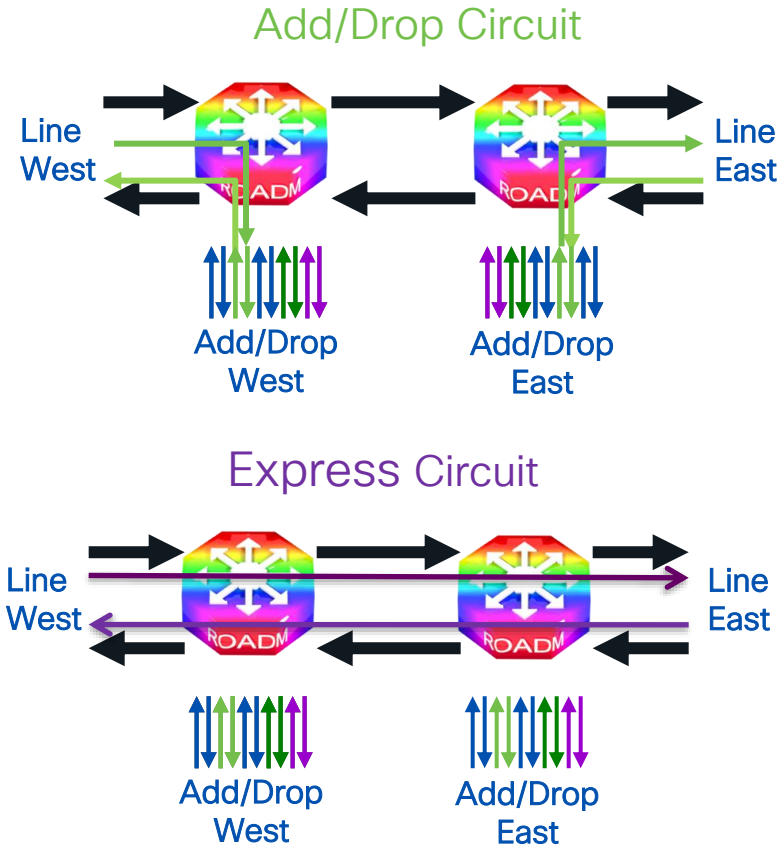
- Maximize Fiber Utilization – it is costly
- Supports multi-site connectivity w/o physical direct connectivity
- WDM = a “wire” between two Client Devices (even between large distances)
- WDM is Agnostic – Protocol and Bit-Rate
- Allows underlying infrastructure to evolve and grow while meeting immediate network needs
- Different formats – WDM, CWDM, DWDM – same concept/more channels



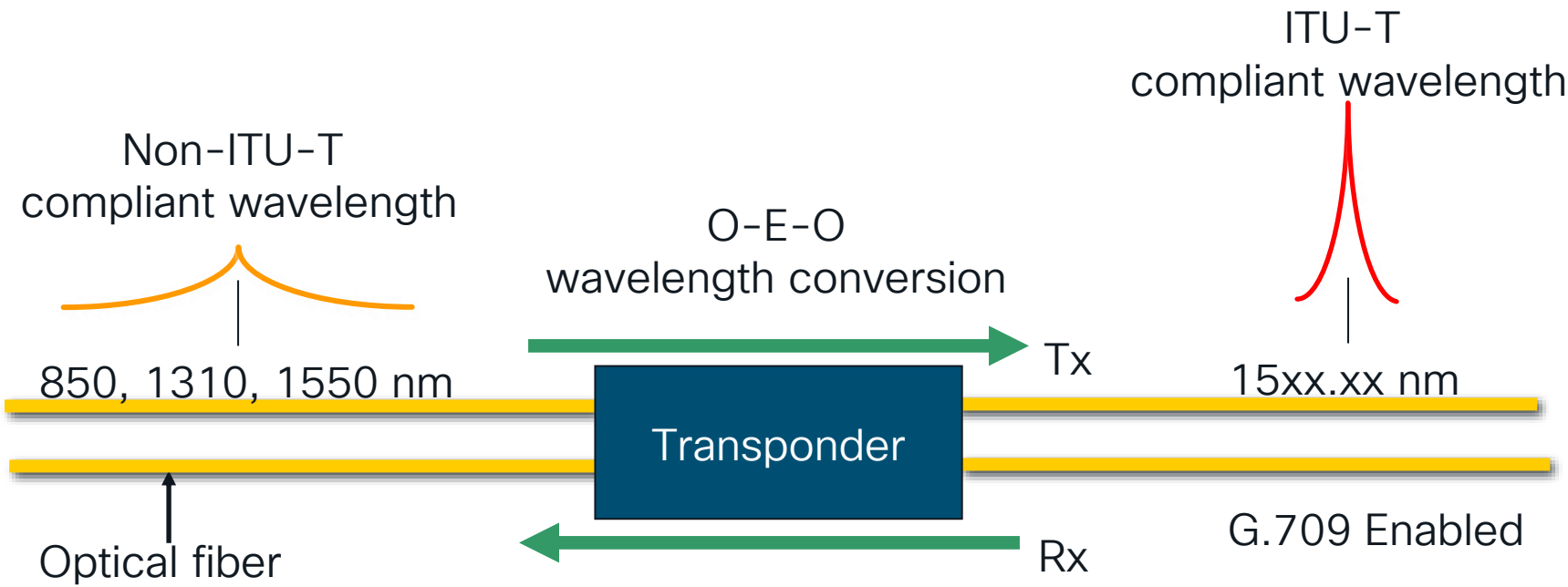


What is ROADM?

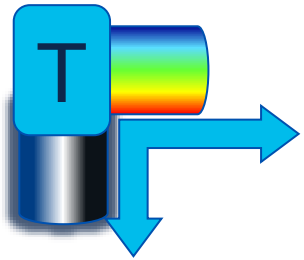
- ROADM is an optical Network Element able to Add/Drop or Express through any wavelength
  - R in ROADM: SW “reconfigurable”
- Legacy ROADM implementations have Add/Drop interfaces dedicated to a direction
- Next-gen ROADM’s can leverage “omni-directional, colorless and contentionless” A/D architectures (CDC or CCOFS terms)



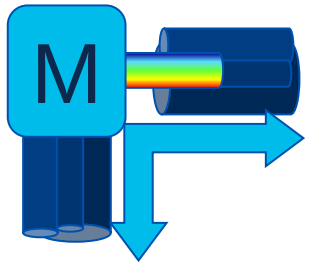
Visualizing Optical Transmissions



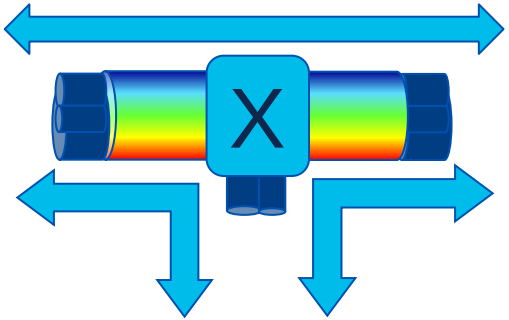
Types of DWDM Services and Cards...



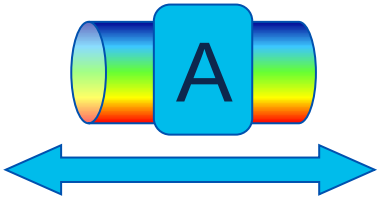
Transponder: One→Wavelength



Muxponder: Many→Wavelength



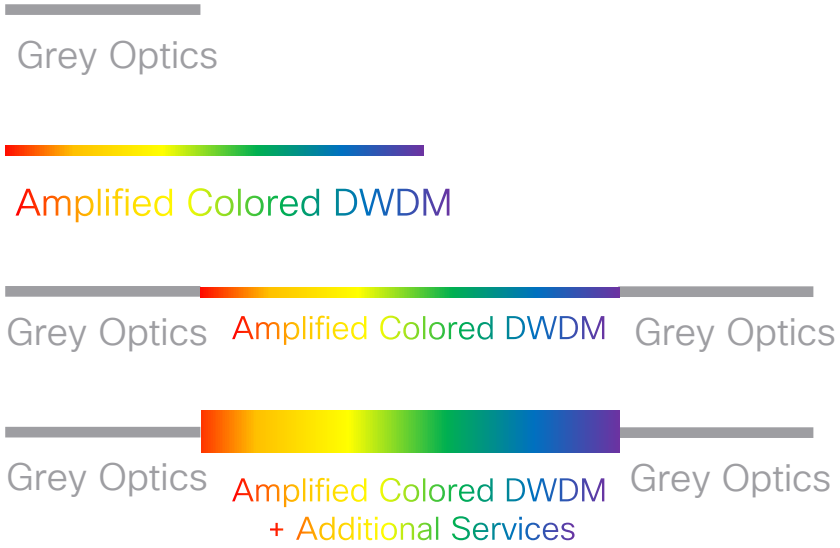
Crossponder: Muxponder+



Alien: Foreign DWDM→Wavelength

Optical Distances

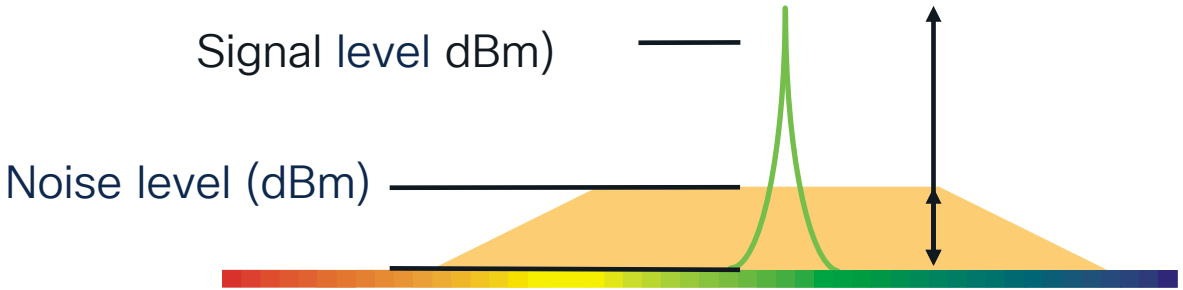
- Maximize Fiber Efficiency
- Longer reach
- Increased Capacity
- Improved Visibility
- Multiple Connections
- Management



One of the performance metrics that matters… Optical Signal-to-Noise Ratio (OSNR)

- OSNR is a measure of the ratio of signal level to the level of system noise
- As OSNR decreases, possible errors increase
- EDFAs are the source of noise
- Different Devices have different OSNR floors – Pluggables, Transponders, etc.

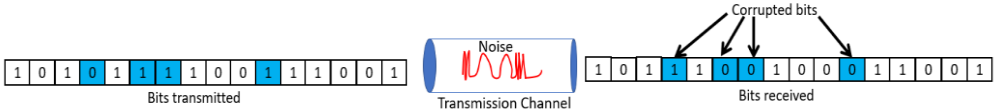
```
RP/0/RP0/CPU0:8201-C-237#sh controller optics 0/0/0/2
!
Baud Rate =  60.1385459900 GBd
Modulation Type: 16QAM
Chromatic Dispersion 328 ps/nm
!
Optical Signal to Noise Ratio = 28.90 dB
!
 Transceiver Vendor Details
         Form Factor             : QSFP-DD
         Optics type             : QSFPDD 400G ZRP
         Name                    : CISCO-ACACIA
!
```

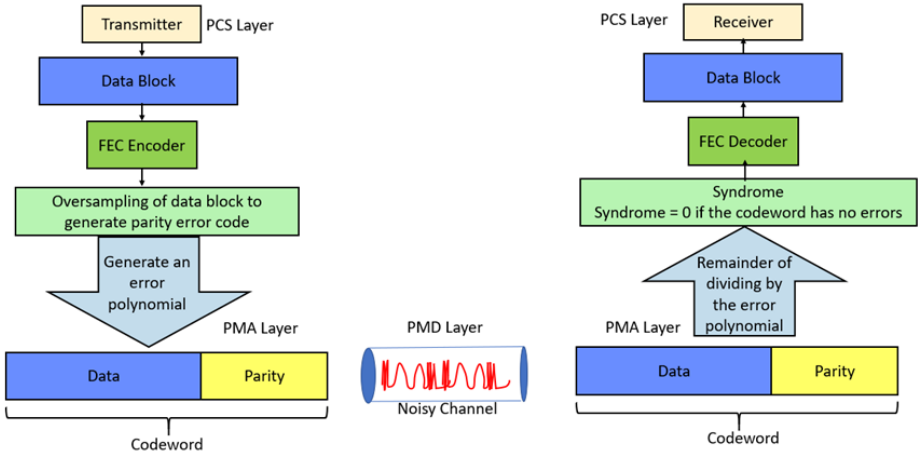


$$OSNR = \frac{\text{Signal level}}{\text{Noise level}} (dB)$$

1st Step to improve OSNR: Forward Error Correction

- FEC extends reach and design flexibility, at “silicon cost”
- FEC detects and corrects errored bits
- Offers intrinsic performance monitoring (error statistics)
- Reduces the SNR necessary for a link to operate at a specified BER
- Not just DWDM Interfaces anymore – many Client Optics use FEC too





Benefit: FEC/EFEC Extends Reach

Forward with Optical Line Systems and Transponders

Cisco NCS 1000 Products

NCS 1004

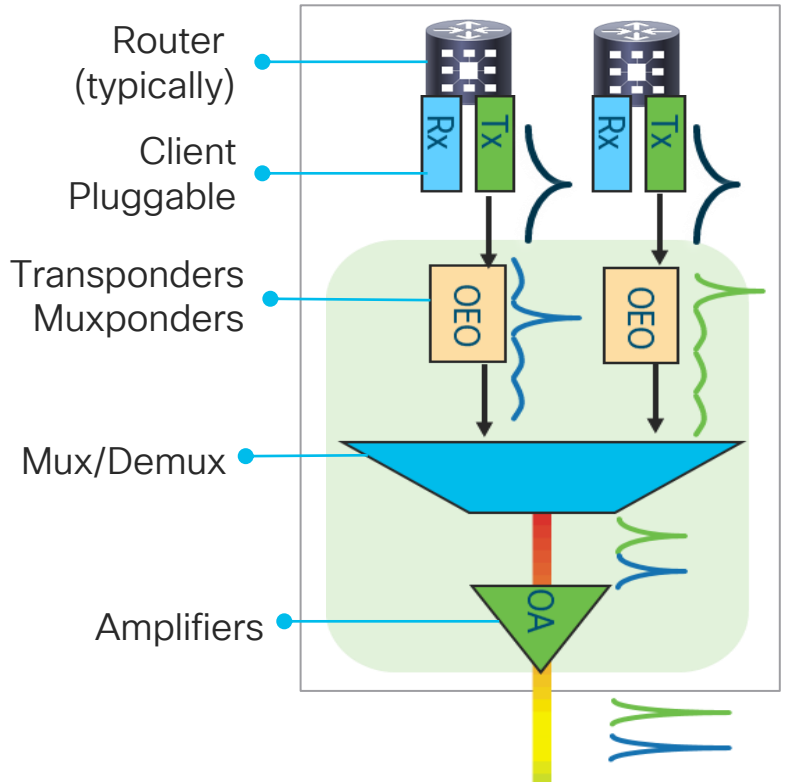
ONS 15216 Filters – 4, 48, 64ch variants

P2P

NCS 1001

ROADM, RAMAN, L-Band Support

NCS 1010 – available Mid-CY22



NCS 1004 – IOS-XR Multi-Haul Solution

2RU with 4x Line Cards – fully modular

Dual DC and AC Power Supplies

Supports Transport Encryption Option

1.2Tbps C & L-Band

- 12x Client QSFP28's
- C-Band Variant :
  - 2x 100G-600G Trunks in 50G Increments
- L-Band Variant:
  - 2x 200-400G Trunks

1.2T Xponder

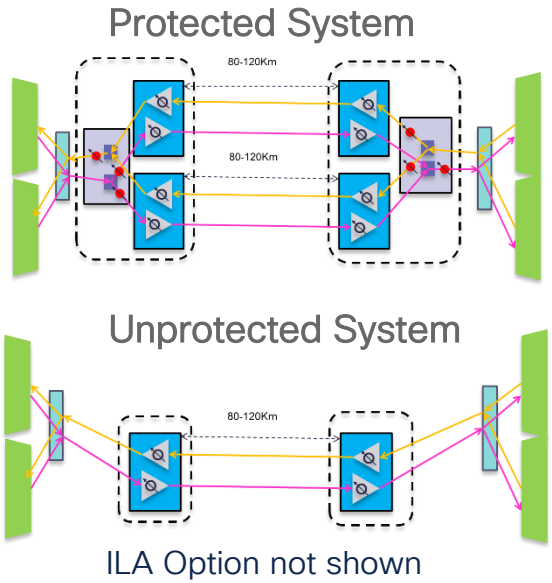
- All Pluggable Card
  - 4x DD-QSFP56/QSFP-28/QSFP+
  - 8x QSFP-28/QSFP+
- 2x 400G-CFP-DCO & 400G-QDD-ZR+ Trunks
- Multi-Protocol & OTN Switching

800G-QDD

- 8x Client QSFP28 or 2x QSFPDD56
- 2x 400GE Clients/8x 100GE Clients
- 2x 100G-400G Trunks
- Same Optical Performance as 1.2Tbps C-Band Card

NCS 1001 – IOS-XR Optical Line System (OLS)

- Point to Point Metro/Regional DWDM networks
- Protection and unprotected topologies
- Optical Performance optimized for high baud-rate, higher-order modulation formats
- Visibility with Channel monitoring, OTDR Option
- Automated turn-up



Forward with Routed Optical Networking

Choices for driving distances

Optical Line Systems

Coherent Pluggables

Pluggables in Host Devices

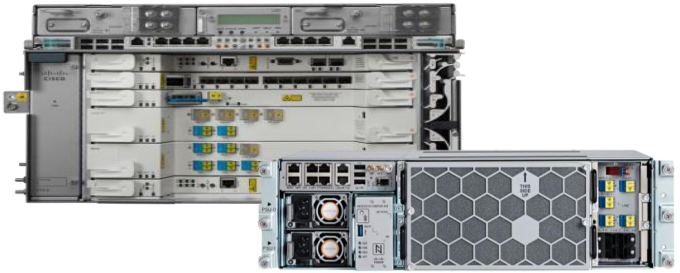
- Native over Dark Fiber
- 40km(QDD)-80km(CFP2) distances
- Single Wavelength

NCS 1001

High bandwidth, point to point optical platform for metro/regional

- Point to point
- ~500 km distances
- Multiple Wavelengths

NCS 2000 / NCS 1010



High bandwidth, full featured optical platform for multipoint and long-distance designs

- Point to multipoint
- +1000's km distances
- Multiple Wavelengths/C+L Bands

Utilize Coherent Pluggables along with Line Systems to extend the distances

OpenZR+
Combination of two standardization efforts

OIF 400ZR
Edge DCI

Client — *400GE*

Line — *400ZR*

Simplified functionality
Edge optimized FEC (C-FEC)

OpenROADM
SP Metro, Regional, LH

100G
200G
300G
400G
Ethernet
OTN
FlexO

Client / Line

100G
200G
300G
400G
OpenROADM

Flexible Client Mapping +
High Performance FEC (oFEC)

Combination of two standardization efforts that enables high performance pluggable modules that provide multi-vendor interoperability

OpenZR+ MSA
Edge DCI and Regional

100GE
200GE
400GE

Client / Line

100G
200G
300G
400G

Simplified functionality +
High performance FEC (oFEC)

Mass-scale Infrastructure Routers @400G

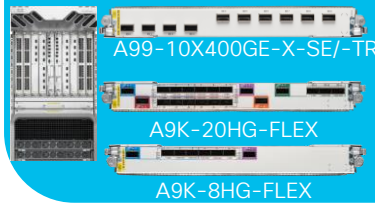
NCS 500

N540-24Q8L2DD-SYS

2x400G + 8x50 + 24x25

ASR 9000

A9903-20HG-PEC — 5x400G



A99-10X400GE-X-SE/-TR — 10x400G

A9K-20HG-FLEX — 5x400G

A9K-8HG-FLEX — 2x400G

8000 Series

8201 — 24x400G

88-LC0-36FH — 36x400G

8202 — 12x400G

88-LC0-34H14FH — 14x400G

8201-32FH — 32x400G

NCS 5500

NCS 55A2 — MPA 1x400G

NCS-57B1 — 1RU: 6x400GE + 24x100GE

NCS-57C3-MOD — 3RU, Dual RP, 2 MPA 2x400G QDD

NC57-36H6D-S — 6x400GE + 24x100GE

NC57-24D — 24x400GE

NC57-18DD-SE — 18x400GE + 12x200/100GE

400G Routers – Customer Favorites

NCS-57C3-MOD-SYS

Dual-RP
5x400G
8x100G
48x1/10/25G
3RU
Flexible MPAs
MACsec
2.3M FIB

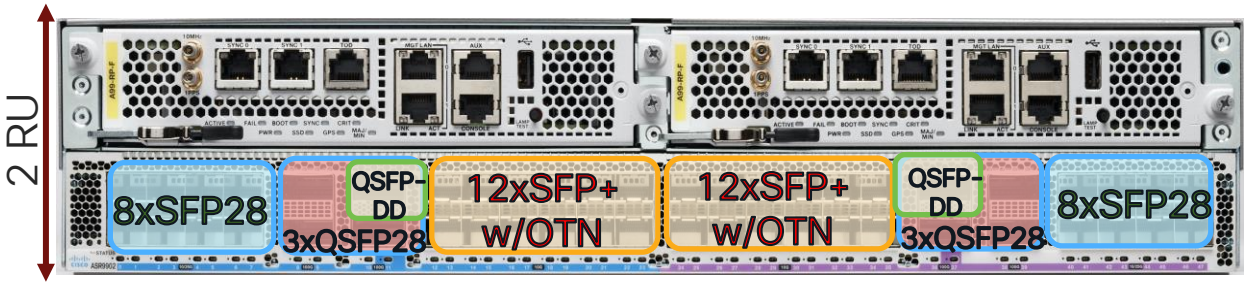
ASR-9903

Dual-RP
16x 100GE + 20x 10GE fixed ports
5x400GE or 20x100GE or
10x200GE or (2T PEC)
32x 25GE/10GE or 48x 10GE
(800G PEC)
3RU
Flexible MPAs
MACsec
6M FIB

8201-32FH

Network Resiliency
32x400G
1RU
12.8Tb
2.25 Watts per
100GbE(!!!)
2.M FIB

A Hidden Gem – ASR 9902

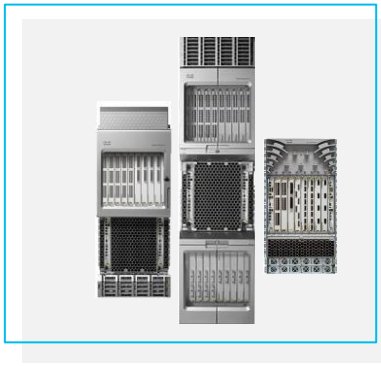


- 2RU chassis with 2x LS+ NPUs
- Redundant Control Plane
- Redundant AC or DC power supplies
- Class C timing & MACSec on all ports

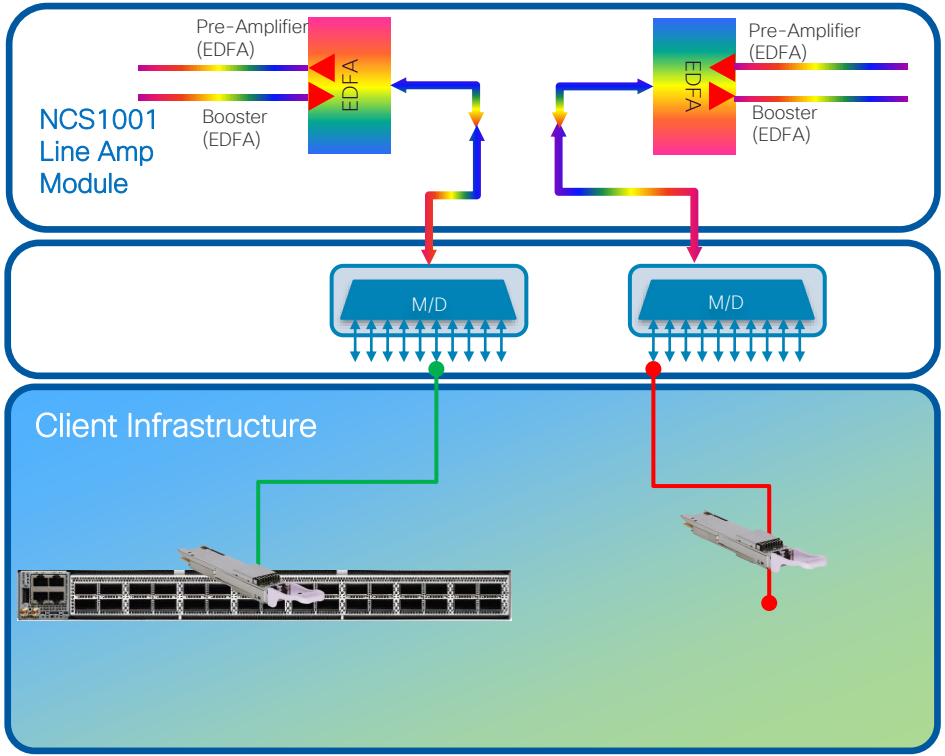
- Mix of 1GE, 10GE, 25GE, and 100GE ports
- 2x 100GE QSFP-DD ports in 100GE mode
- 6x 100GE QSFP28 ports
- 16x 25GE/10GE ports
- 24x 10GE SFP+ ports | OTN | linear tunable optics

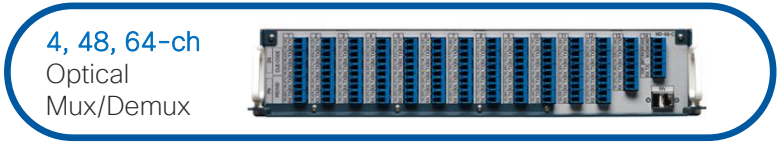
400G-ZR Transport with NCS 1001 Metro-Regional Networks

NCS 540 | NCS 5500 | CISCO 8000 | ASR 9000



Hop-to-Hop Only Design Example



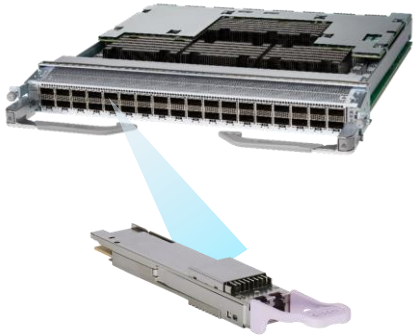


- H2H (Hop-to-Hop) only (no Optimal Bypass)
- ZR @ 400G & ZR+ @ 100G,200G, 300G & 400G
- Compact 1RU NCS1001 having EDFA and OTDR options

Which is better – decision time

Coherent Optics Models for the Router 400G Transition

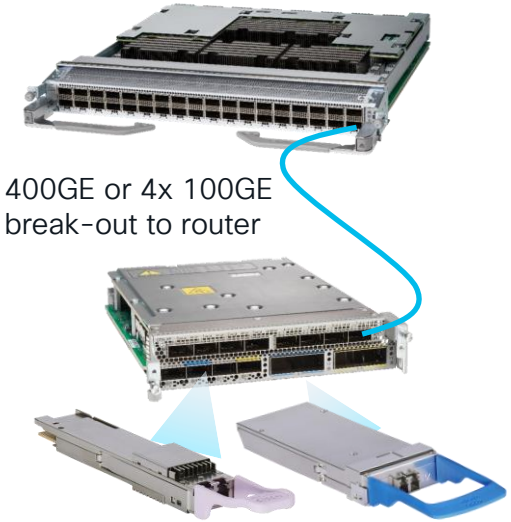
Direct on Router



QSFP-56DD 100G-400G

QDD-ZR - 120km
QDD-ZR+ - 1,000- 4,000km+

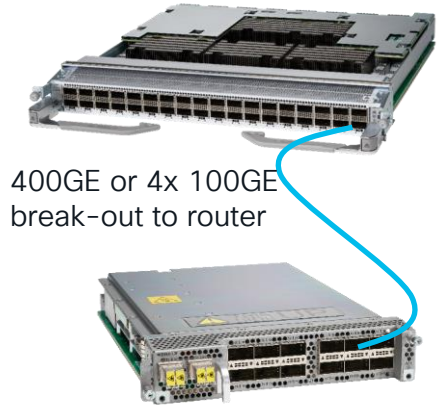
Router and TXP with DCOs



QSFP-56DD 100G-400G
CFP2 – 100G – 400G

QDD-ZR - 120km
QDD-ZR+/CFP2 - 1,000-4,000km+

Router and TXP

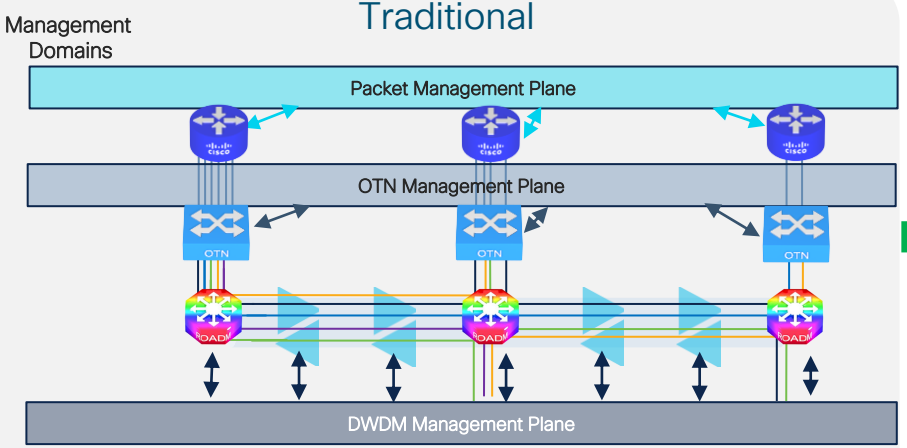


Embedded Trunk 100G – 600G

100KM – 20,000KM

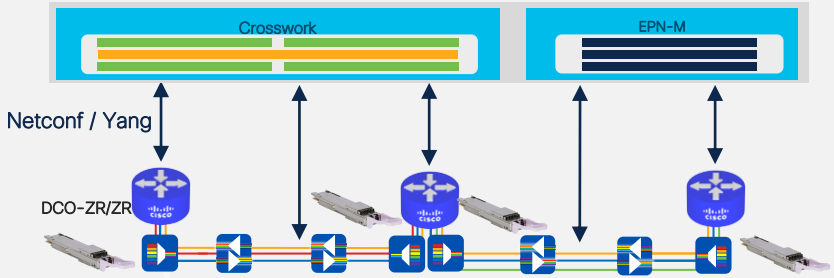
Converging IP and Optical Networks

Traditional



Three Management Domains to address three separate planes

Routing Optical Networking with Operational Simplification



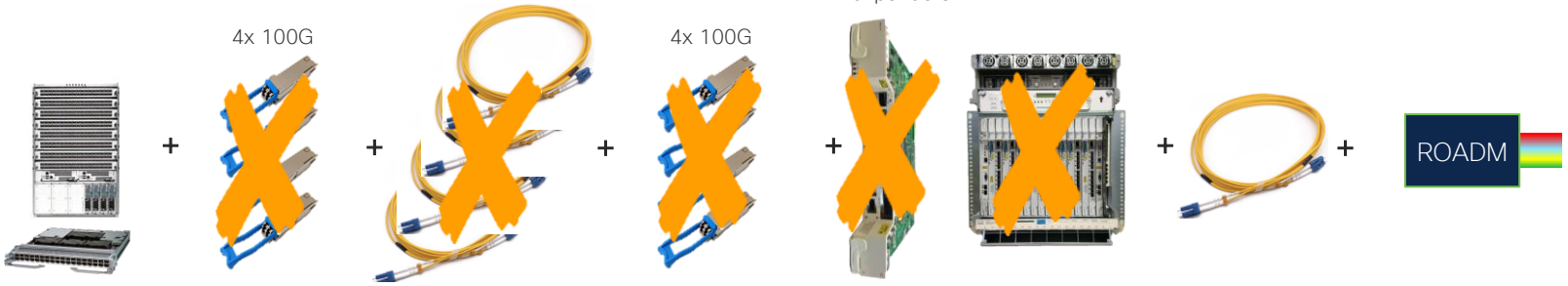
EPN-M providing E2E Management and FCAPS
E2E Automation with Crosswork Platform

Benefits

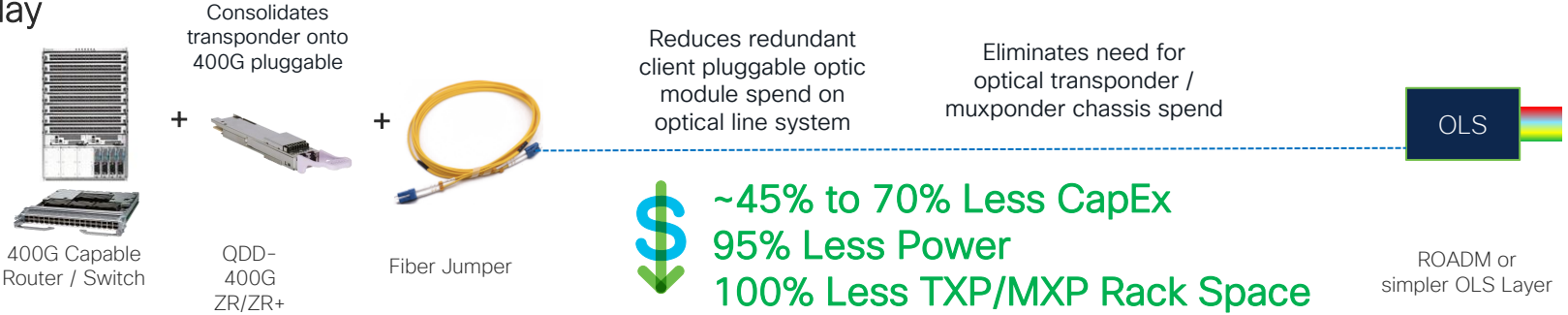
- Provides a single Interface
- Simplifies planning and feasibility
- Moves management and control closer to the
- Reduces power and footprint
- Enables the sharing of network information for
- Leverages industry standards

Routed Optical Networking: Removing Complexity

Previous



Today



Back of the Napkin Cost Comparison
Simple CAPEX Math

Transponder Costs...
Cisco NCS 2000 400G-XP Card= $314k
2x CFP2's= $300k
8x Client LR4 QSFP28's = $312k
TOTAL = ~$232k/100G

2x 200G waves

What is your cost per 100G?

Cisco
ZR+ QSFP-DD Costs...
$150k
TOTAL = ~$38k/100G...

~20% of the TXP Cost

Cisco Global Price List (USD) – April 28, 2022

Back of the Napkin Power Comparison
Simple OPEX Math

Transponder Power…
Cisco NCS 2000 400G-XP Card= 330W
TOTAL = 330W/400G

2x 200G waves

How much power does your Transponder use?

Cisco
ZR+ QSFP-DD Power = ~20W
TOTAL = ~20W/400G

~6% of the TXP Power

what about Space?

A case against G.8032 Ethernet Rings

Smaller size – reconvergence suffers as the ring grows

Short L2 rings, star mesh not supported

Cascaded rings – physical disruption to stop unexplained behavior

Some locations on the ring do not have the best path to destination

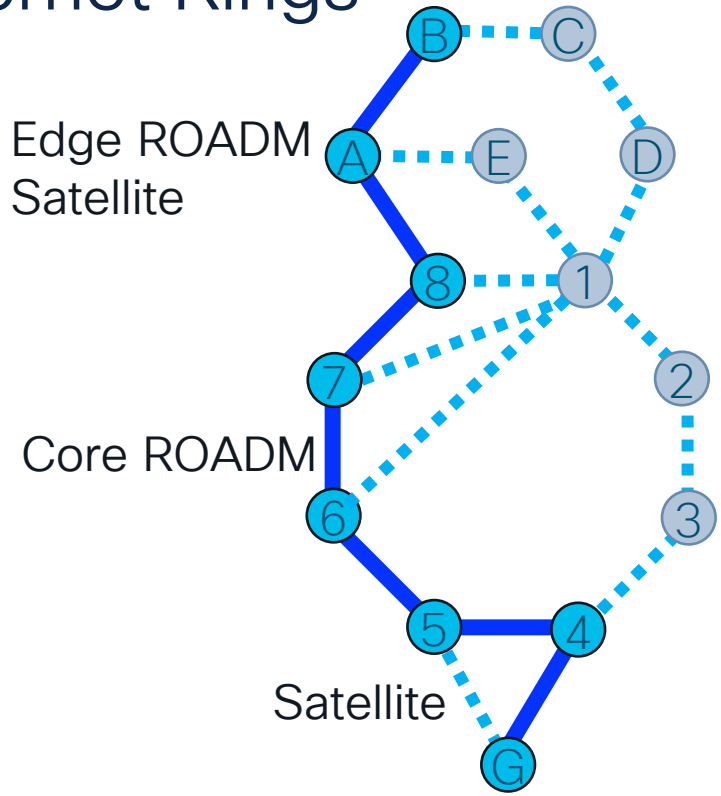
No double-cut advantage

Optical restoration is not faster than IP

No traffic prioritization and engineering

No security for the control plane

No measurable latency advantage (5usec/km)



A case for IP

Using ALL available paths (resilience = # of Fiber paths)

Any-to-Any connectivity = Aggregating traffic from any site onto the optical link and/or offloading traffic directly into any other site

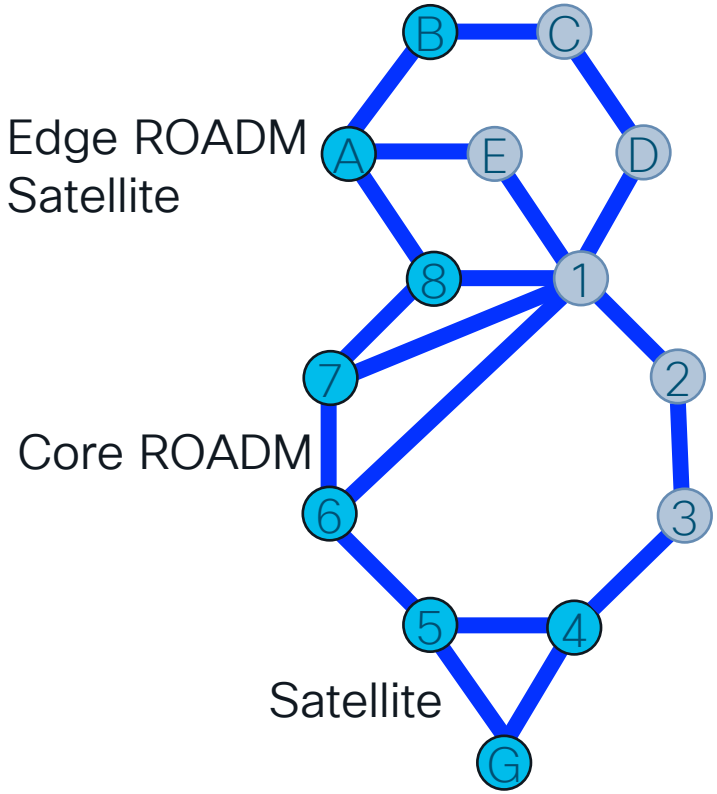
Optical Fiber Path = Routing Topology

Easy & flexible integration and placement of new Platforms, like Far Edge compute, cloud native BNG, etc.

Built-in Fast-Convergence/Protection mechanisms (IP-FRR/TI-LFA)

L3 Control Plane as Single Control Plane vs. IP/MPLS + Optical GMPLS + WSON/SSON

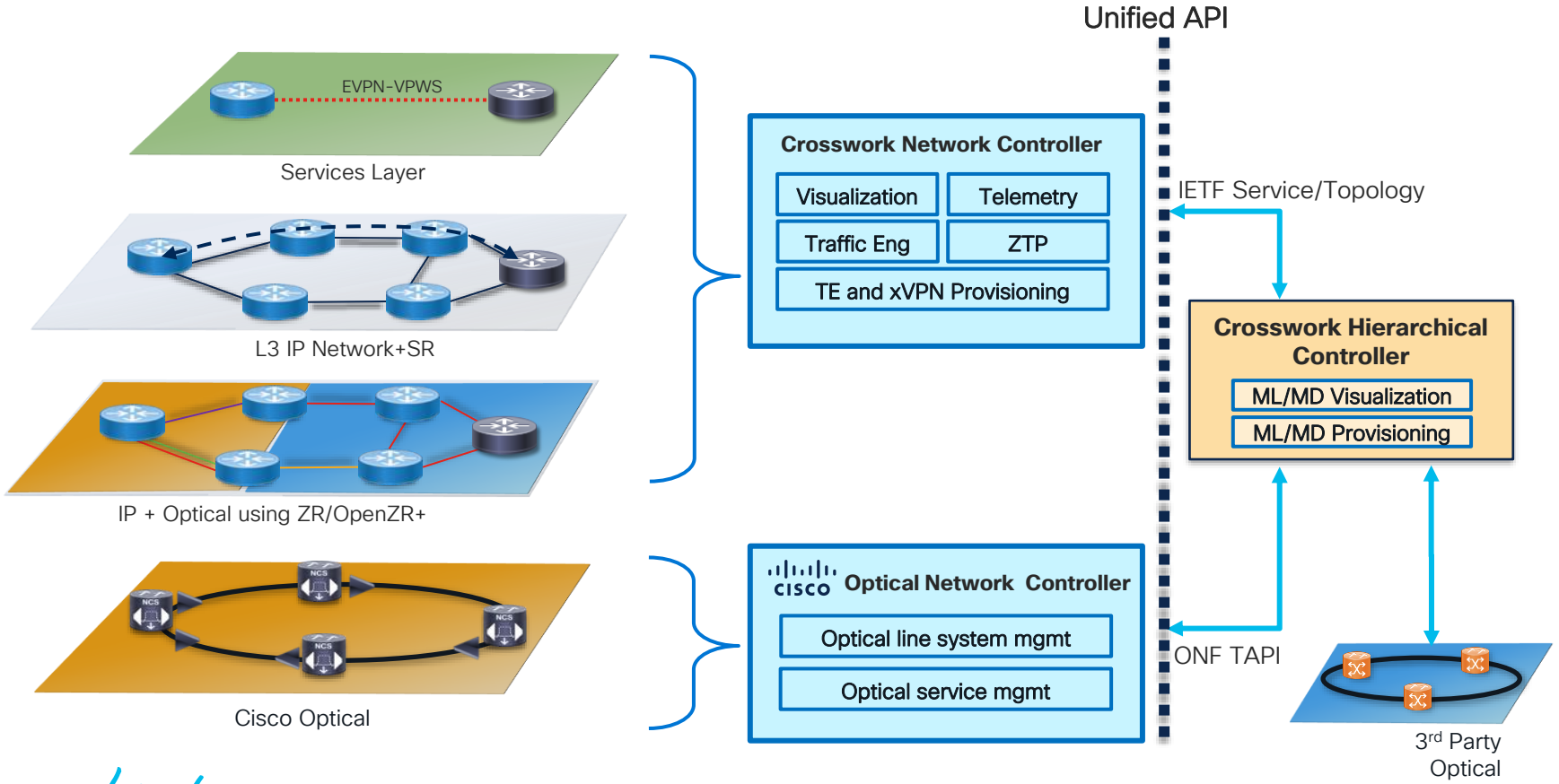
Network Slicing through Segment Routing - Low Latency path, Disjoint Path, Highest BW path, etc.



G.8032 vs IP Compared

	VLAN-Based Solutions	EVPN-SR
Scale	• Large, flat L2 architectures don't scale • VLAN tag stacking is not a manageable solution	• Will scale to thousands of nodes per domain • 20-bit labels yield virtually limitless tunnels and services • 10's of thousands of LSPs
Operations	• Understanding switching path will be very difficult since there is no control-plane state for services or tunnels	• Traffic routing will be deterministic based on dynamic or explicit path selection via control plane • Switching paths are easily traced using MPLS OAM toolkit
Automation	• Requires EMS or manual configuration and assignment (which will be error-prone and complex to manage)	• EVPN dynamically learns remote endpoints • Programmatically define the path for the packet at the source node
Optimization	• Traffic engineering with VLAN-based switching is very difficult if not impossible	• Native ECMP allows efficient use of network resources – no configuration required
Flexibility	• VLAN-based solutions constrained to logical hub-and-spoke or ring architectures	• Any arbitrary topology can be supported with same resiliency and scale

Routed Optical Networking Automation Stack



Conclusion

Takeaways

- You can implement and support DWDM, it is not harder than anything else
- The best person to make the network decisions is you
- You will save $$$ and improve technology by going with Routed Optical Networking
- Always be flexible in your designs and think ahead of others

Packet Optical Networking Conference

Registration is Open!

June 28th

June 29th

June 30th

10am-1pm Eastern Time / 7am-10am Pacific Time

Technical Session Surveys

- Attendees who fill out a minimum of four session surveys and the overall event survey will get Cisco Live branded socks!
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