

The background features a vibrant, abstract design. On the left, there are horizontal, wavy bands of color in shades of red, orange, yellow, and green. On the right, a bright white light source emits a series of colorful rays in shades of blue, cyan, and yellow, creating a sunburst effect.

cisco *Live!*

Let's go

#CiscoLiveAPJC



The bridge to possible

Designing Successful Routed Optical Networks

... or how to embrace tradeoffs for fun and profit

Dirk Schroetter, Technical Solutions Architect

Velimir Vujnovic, Principal Architect

BRKSPG-3359

CISCO *Live!*

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Cisco Webex App

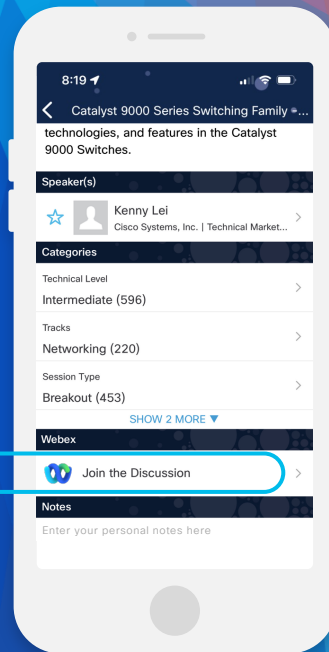
Questions?

Use Cisco Webex App to chat with the speaker after the session

How

- 1 Find this session in the Cisco Live Mobile App
- 2 Click “Join the Discussion”
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- 4 Enter messages/questions in the Webex space

Webex spaces will be moderated by the speaker until December 22, 2023.

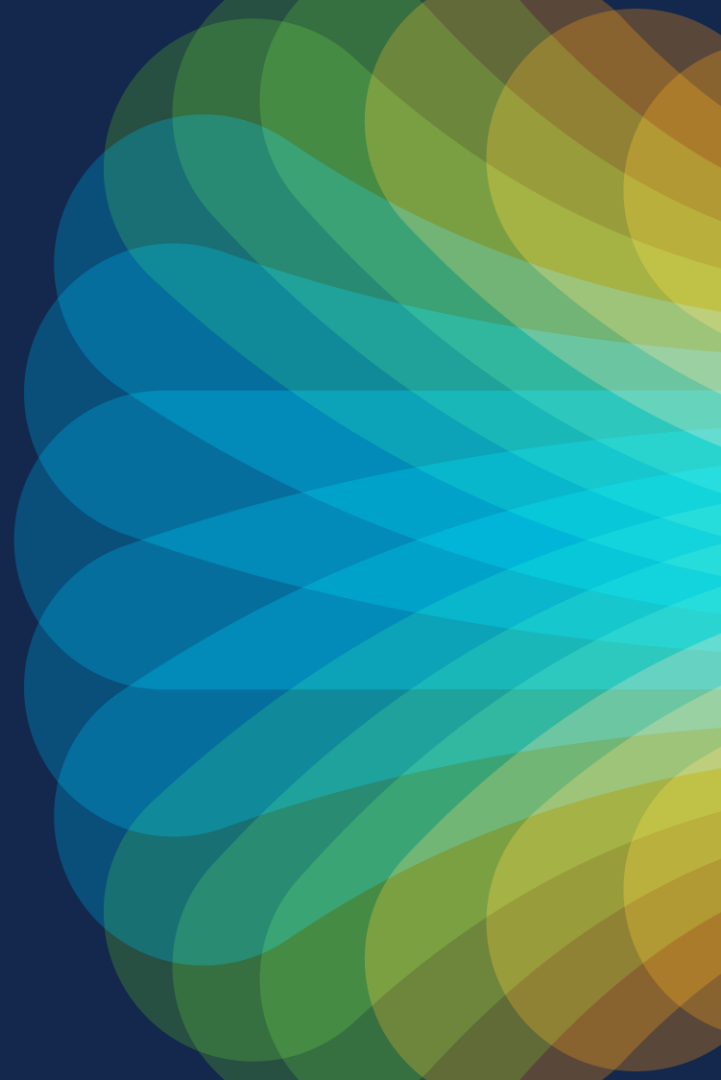


<https://ciscolive.ciscoevents.com/ciscolivebot/#BRKSPG-3359>

Agenda

- Introduction
- Bare minimum of the analog domain
- Lesson 1: Optical Performance
- Lesson 2: Build on traffic demands not capabilities
- Lesson 3: Topologies & Arch. matter, Constraints even more so
- Lesson 4: IP Services are protected & restored using IP
- Shifting Arch. & Technologies
- Conclusion

Introduction



Innovation in Network Architectures

Innovations in ASIC Design

Optimized forwarding performance and cost

- Bifurcation of routing and switching silicon
- Massive reduction in power consumption
- Shared memory architecture for higher scale

Network Programmability

Intent-based underlay network to build services

- Segment Routing and network slicing
- Centralized view of network topology (controller)
- Simplified configuration and resiliency

Automation and Software

Untangling the complexity of integration

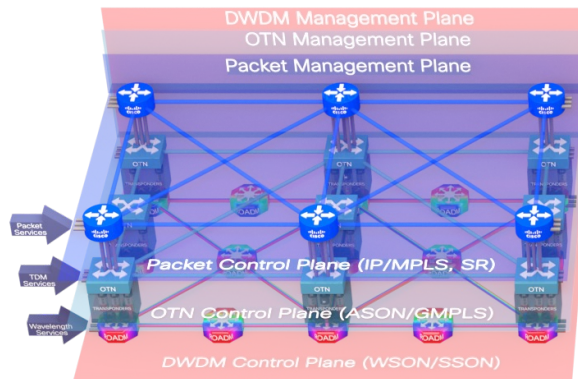
- Disaggregation of hardware and software
- Well defined APIs between systems
- Native platform data models, open/industry models

Optical and Optic Innovation

Converging optical and IP networks

- Shift in economics – cost moving to the transceiver
- Coherent optics extending reach and bandwidth
- Traffic demands almost entirely packet

What is Routed Optical Networking? What does it do?



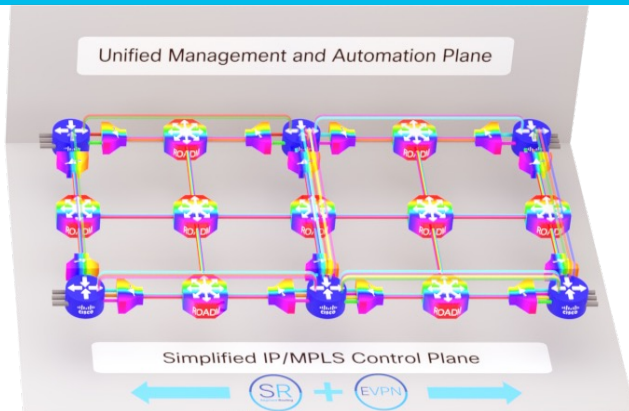
Today's network
Layered architecture

**Collapses 3 layers
into 1**

- A switching element
- Control plane
- Services layer

**Single pane of
glass**

Internet for the Future Routed Optical Networking



*Route when you can and
ROADM when you need to!*

3 S' of RON :

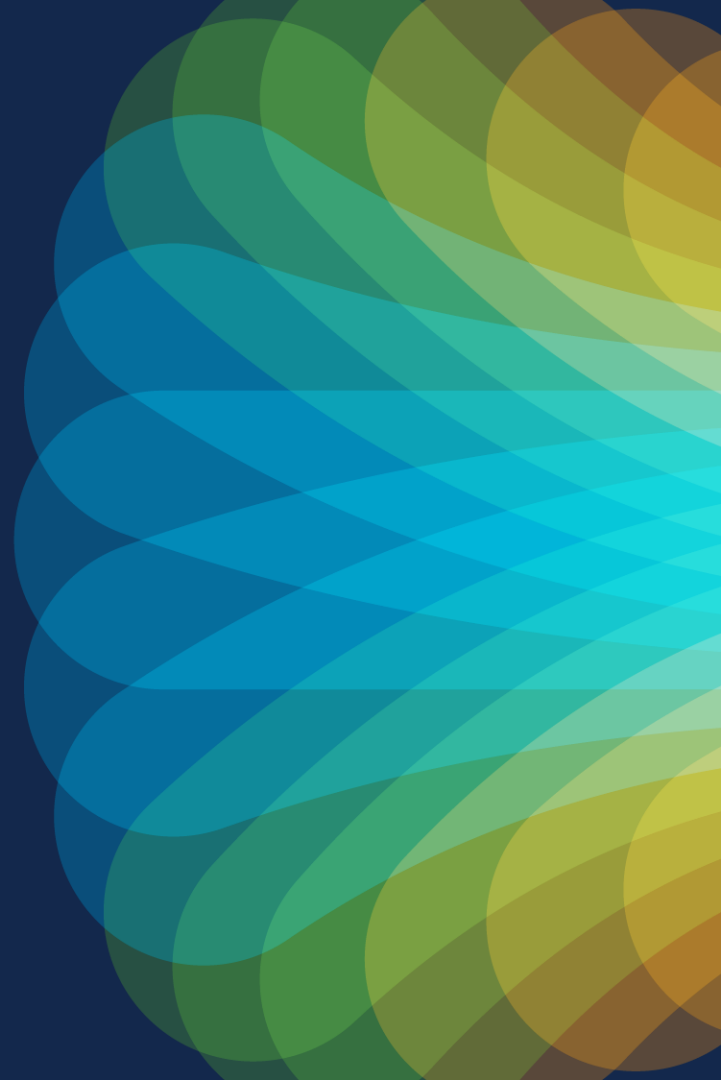
Simplification, Savings and Sustainability

*“If you haven’t found the tradeoffs,
you haven’t looked hard enough.”*

Russ White’s Rule #1

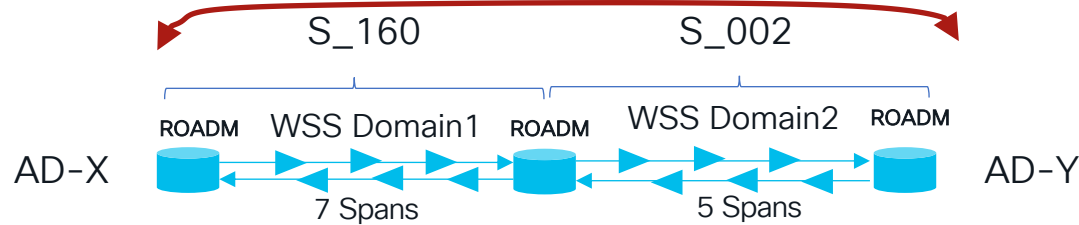
Mr. EIGRP

The bare
minimum on the
analog domain



DWDM transport is analog technology

WSS Domain 1 = S_160
WSS Domain 2 = S_002



End to End Service is split into smaller WSS Domains:
ROADM to ROADM -> WSS Domain 1 and WSS Domain 2

Input Baud Rate
Channel Spacing
Amplifier Choice
Span Distance(km)
Span Loss (dB)& EOL

Optimal
Launch
Power
Defined

per WSS Domain
Compute Linear
OSNR with worse
case EDFA
Specification

per WSS Domain
Compute non-
linear noise using
Gaussian Noise
Model

Add Linear and
non linear Noise
+ Additional
penalty , i.e. CD,
PDL, Ripple

Add the WSS
Domains +
Mux / Demux
subtract
OSNR Margin

Associate
interface
based on
performance

Required input:

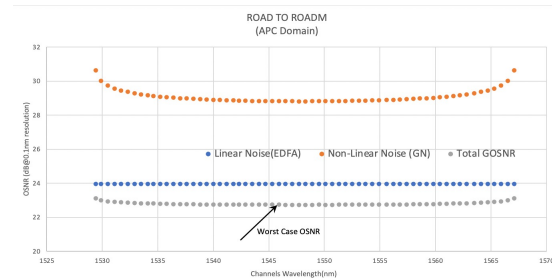
- Topology (span length & attenuation), EOL margins

Method:

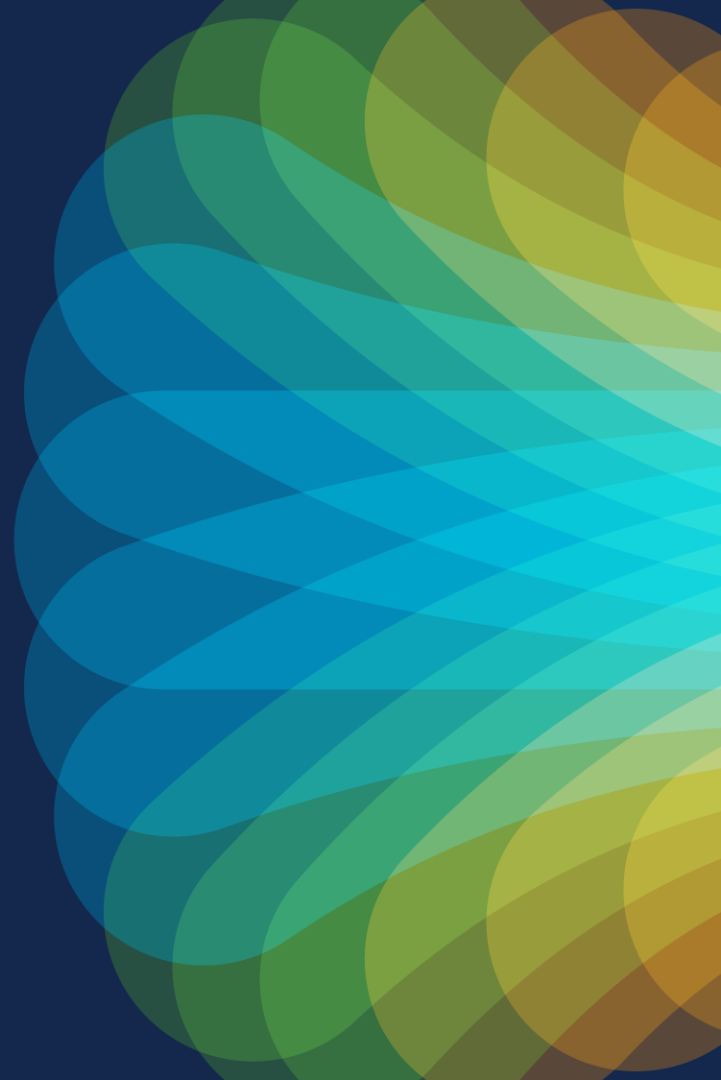
- Gaussian Noise simulation

Interesting:

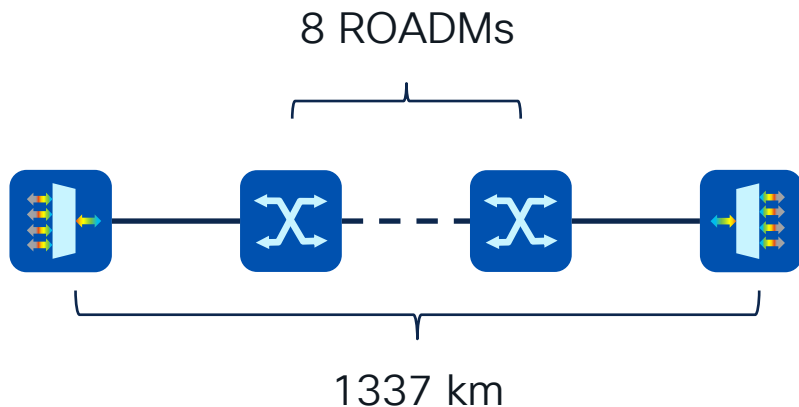
- How we build the Add/Drop structure for the ROADM



Lesson 1: Optical Performance



ZR+ and Transponder performance – comparable



Latest customer ZR+ test over 3rd
party DWDM

400 Gbps



OSNR(dB) @
0.1 nm RBw

23.1

22.6

Baudrate
(GBd)

60.14

69

Channels
per "Band"

64

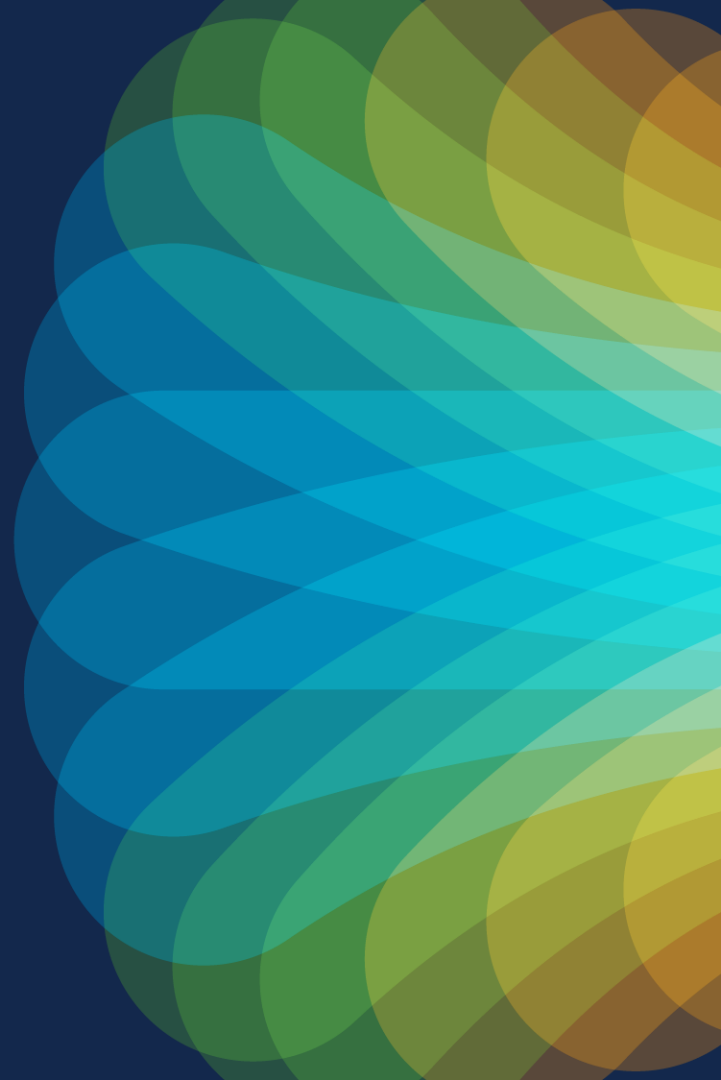
54

Modulation

16-QAM

16-QAM

Lesson 2: Build on traffic demands, not capacities



US operator “metro” simulation results

01

Simulation using P95 of busy hour traffic

02

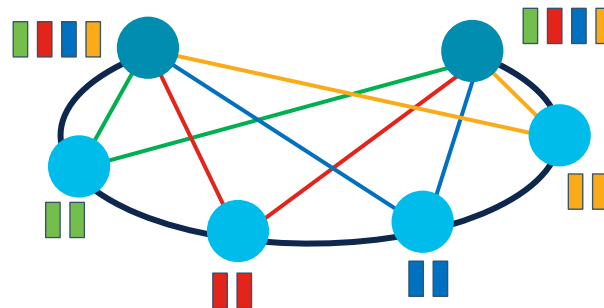
X Tb/s busy hour traffic.

03

8 X Tb/s installed capacity

04

Single wavelength on aggregation rings



34.1
Gb/s

Average site traffic

29.3
Gb/s

Median site traffic

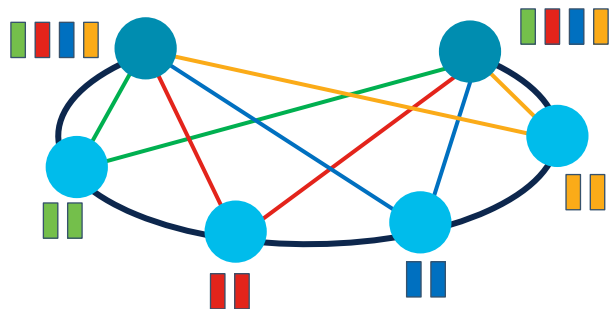
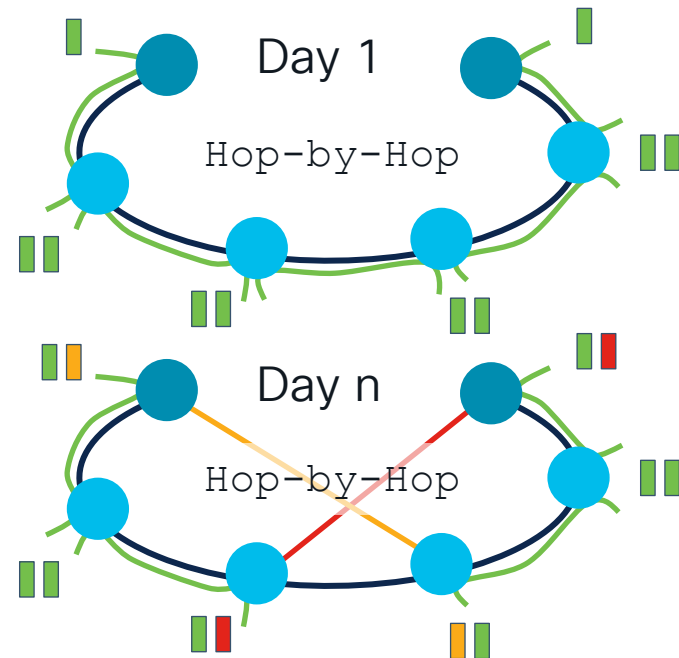
Wavelength usage

-97%

-95%

Energy usage

Transforming Hub & Spoke to Hop-by-Hop



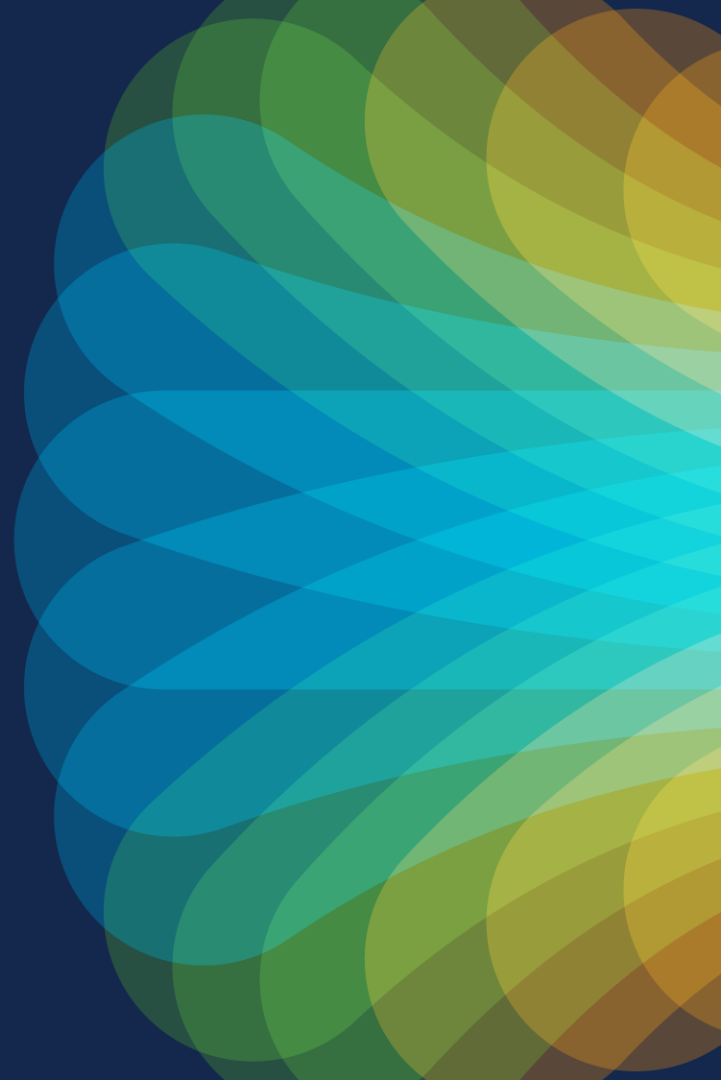
Customer reported being short on wavelengths

Simulation Results

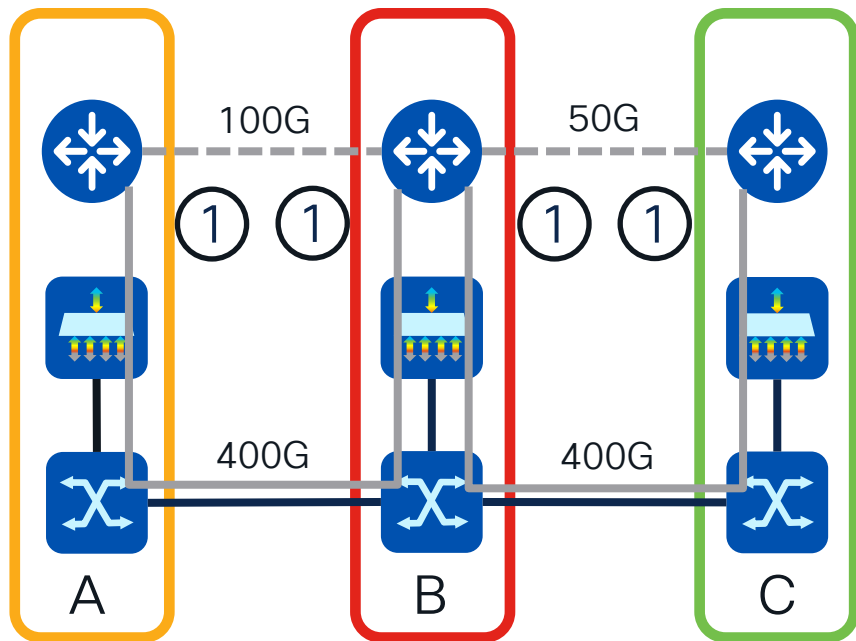
	40% installed PMO capacity	P95 busy hour traffic
Sum inter-site demands	6.408 Tb	1.976 Tb
Inter-site installed capacity	38.7 Tb	30.3 Tb
Intra-site installed capacity	67.26 Tb	62.8 Tb
ZR/ZR+ pluggables	194	152
Grey pluggables	334	314
Maximum λ used between hubs	4	2
Maximum λ used on rings	2	1
WC link utilization	100 %	70.69 %

Power savings from TXP elimination alone: 55.000 kWh p.a.

Lesson 3: Topologies & Architectures matter, but Constraints even more so.

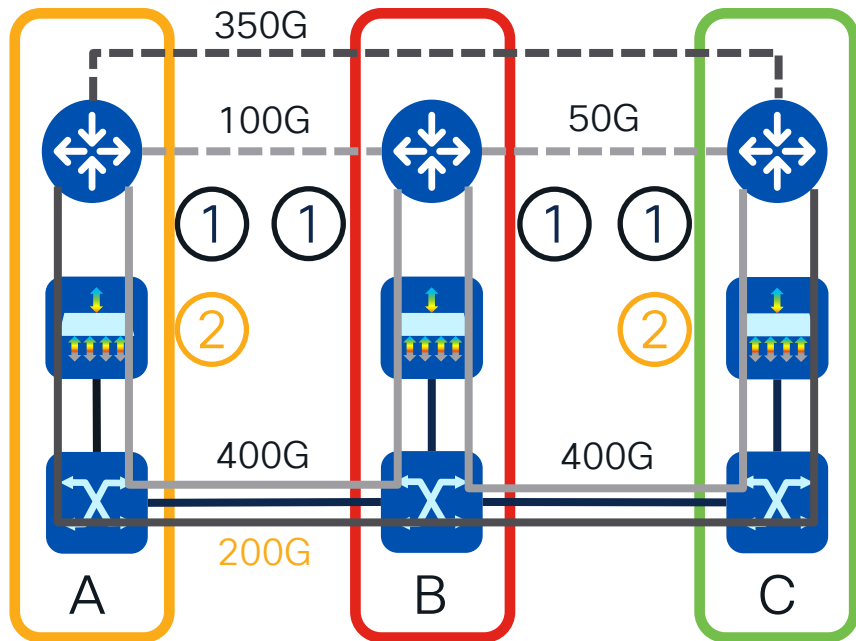


A toy network showing the concept ...



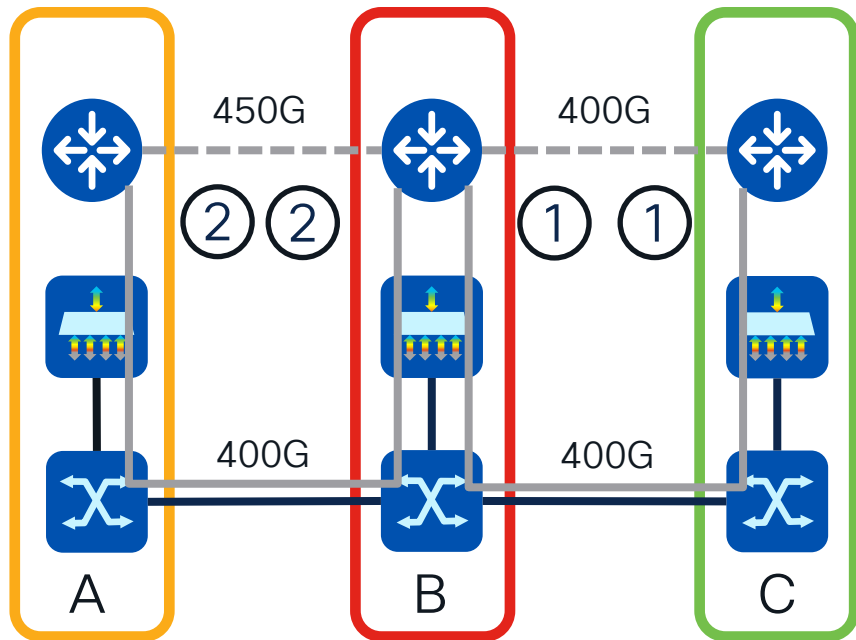
- Not “one size fits all”
- Consider:
 - Fiber cost / availability
 - Relative importance of sites
 - Achievable bitrates
 - Impact on resiliency
 - Physics
- Both approaches have their place in designs.

A toy network showing the concept ...



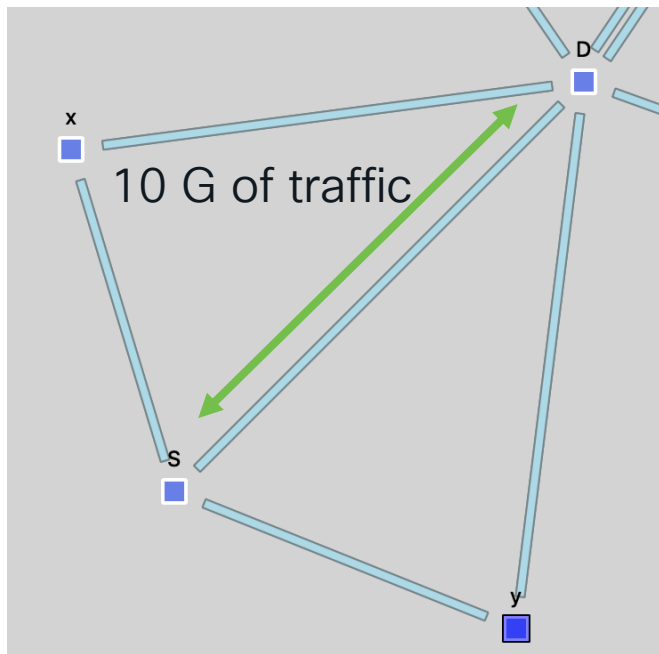
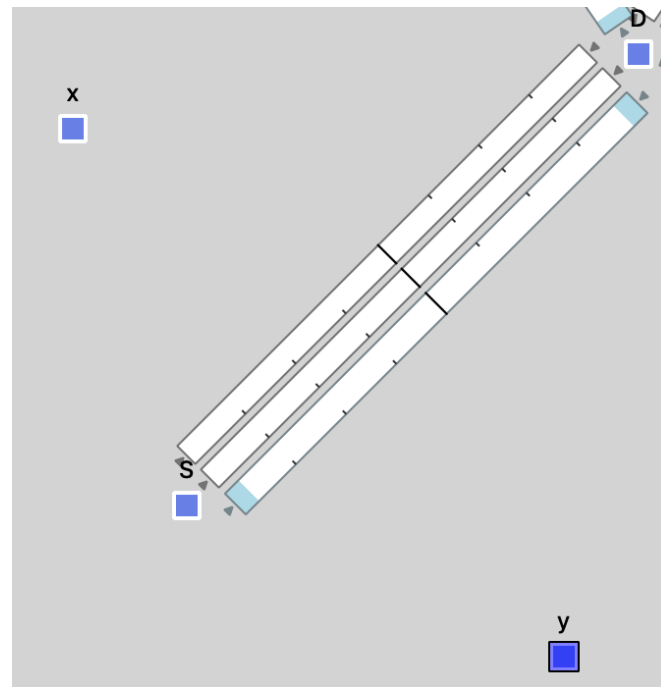
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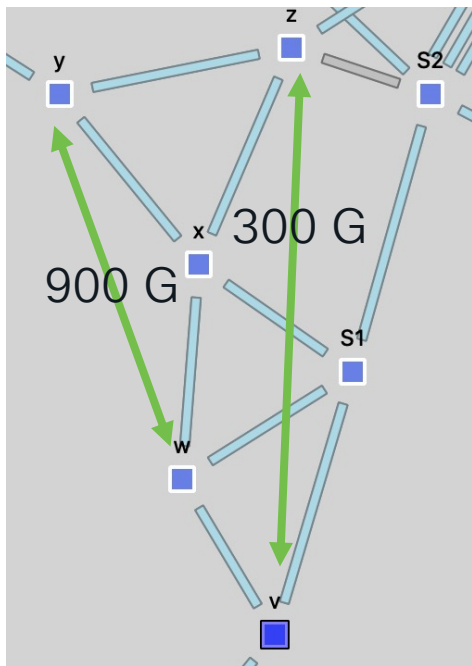
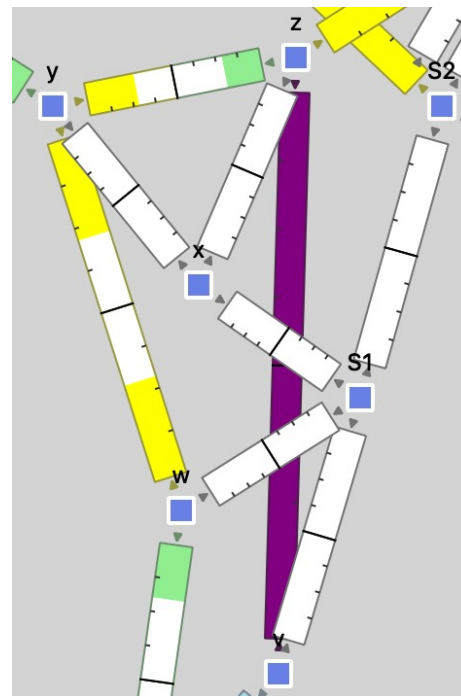


- Not “one size fits all”
- Consider:
 - Fiber cost / availability
 - Relative importance of sites
 - Achievable bitrates
 - Impact on resiliency
 - Physics
- Both approaches have their place in designs.

Real example 1



Real example 2

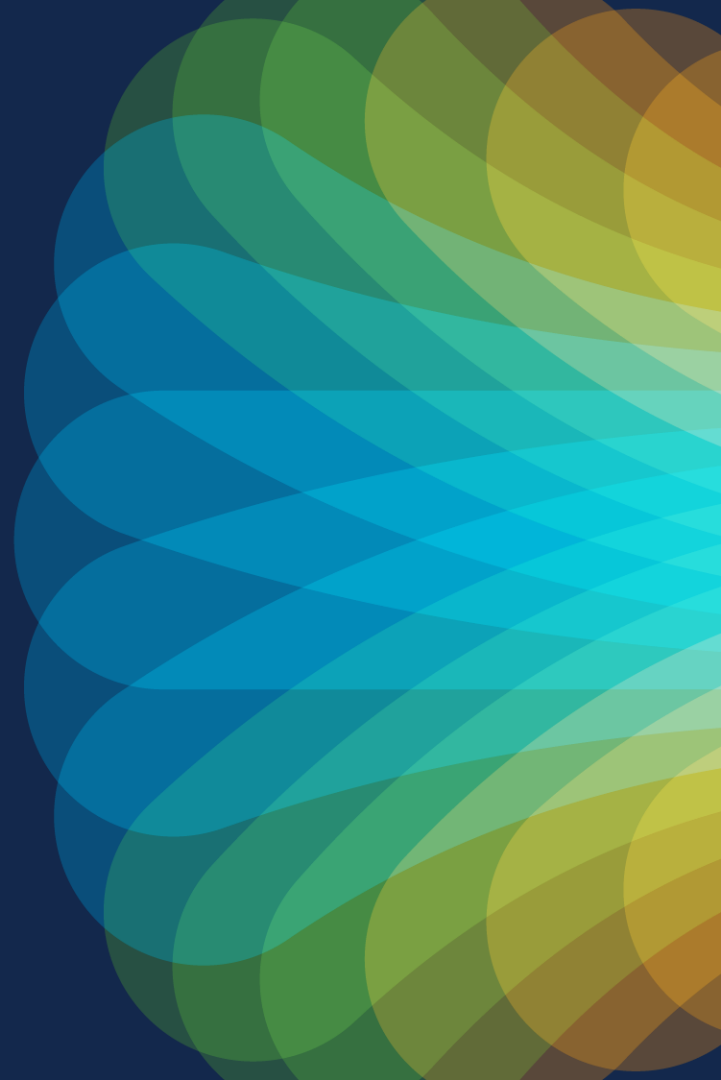


Physics forcing architectures

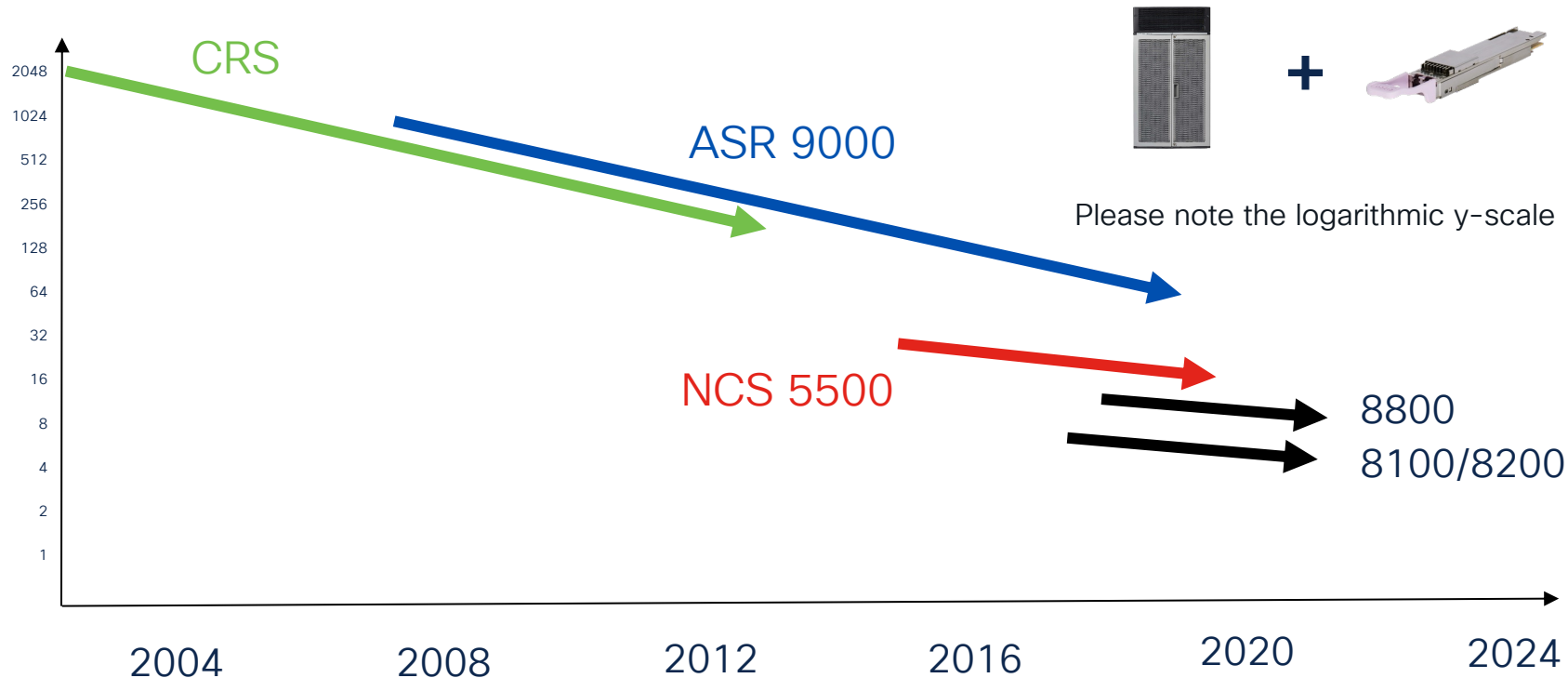
Wider channel	Better FEC	Higher modulation	Better spectral efficiency	Use L-Band
"Easily" done	Increased reach	More bits per symbol -> Higher capacity	More b/s/Hz	"Easily" done
Increased capacity per channel	Higher overhead eats into usable capacity	Reach ~ 1/constellation size	Dispersion coefficient β	Doubles # channels
Fewer channels	Power, real estate, cost	X km @ 16QAM -> X/4 km @ 64QAM	Nonlinear coefficient γ	Increases attenuation
Increased blocking probability	No "dramatically better" FEC on horizon		Reduce attenuation	Negatively impacts spectral efficiency
			Reduce reach	Requires drastically different fiber to to have big effect

Not a question of "if" but "when" physics mandates shorter paths

Lesson 4: IP services are protected and restored using IP

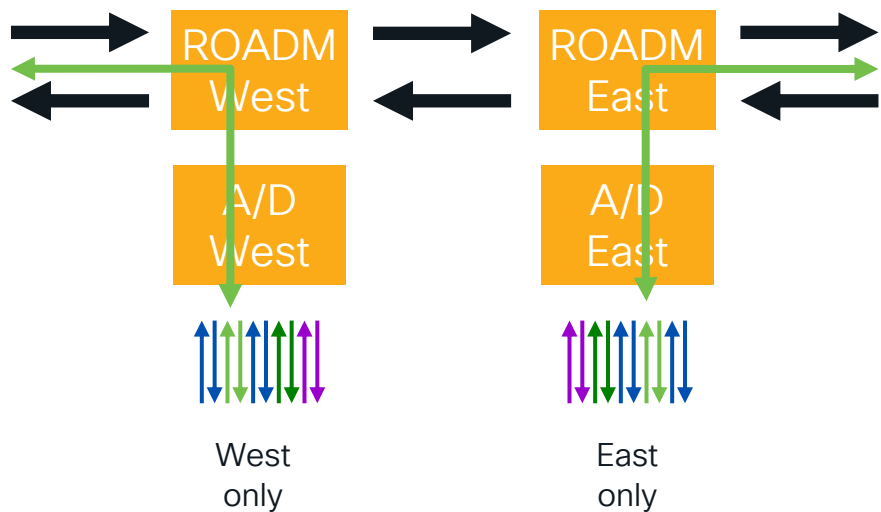


System Efficiency w/ Optics (w/100G)

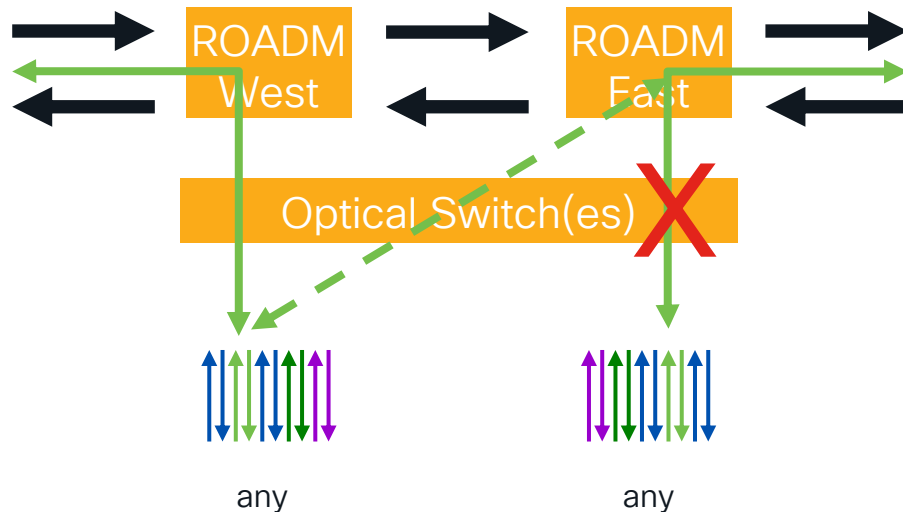


Omnidirectional Add/Drop

Wiring determines direction



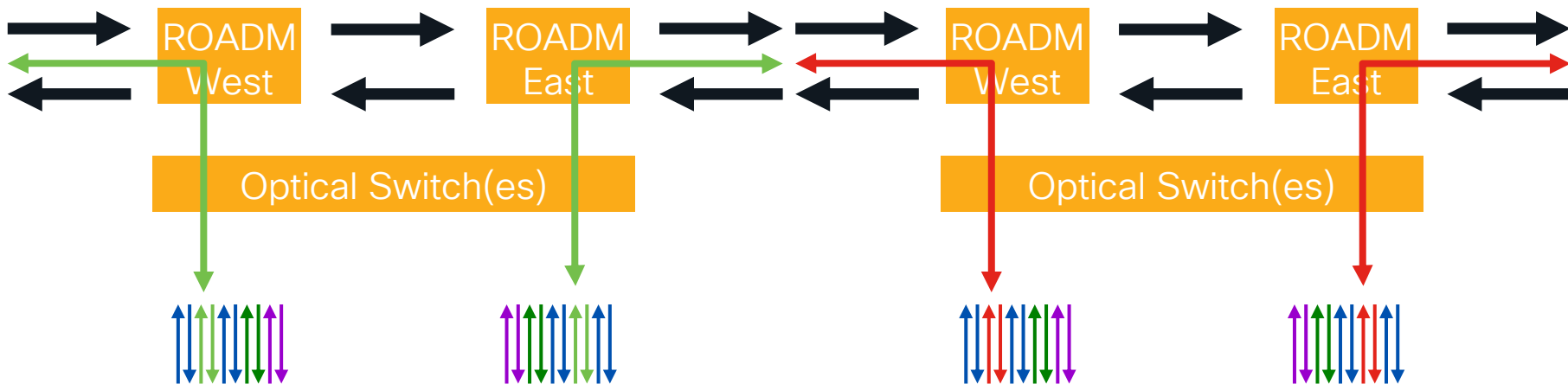
Channel switched to direction



Colorless Add/Drop

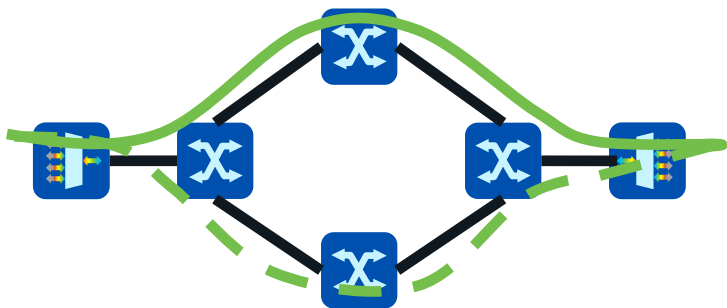
Green λ on port

Red λ on port



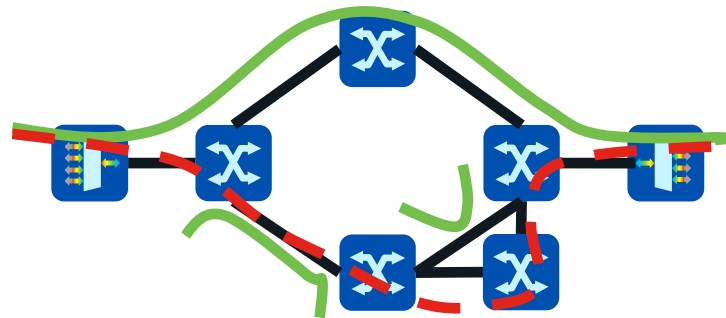
OK, so what is the use case ?

Optical Protection



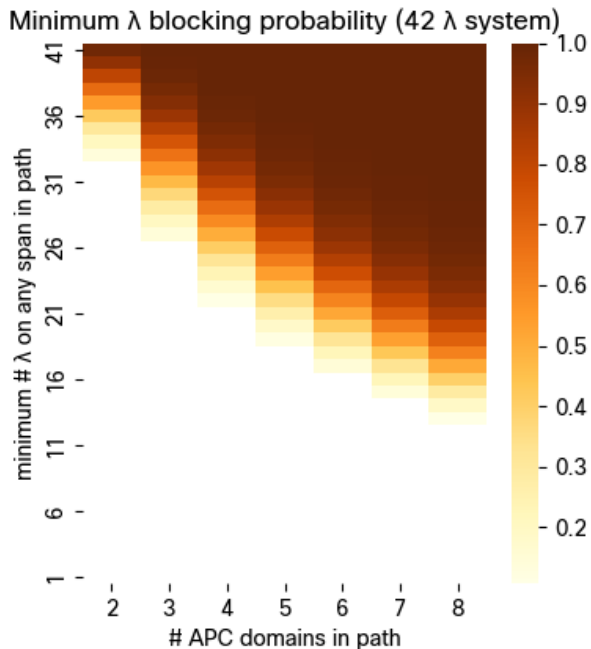
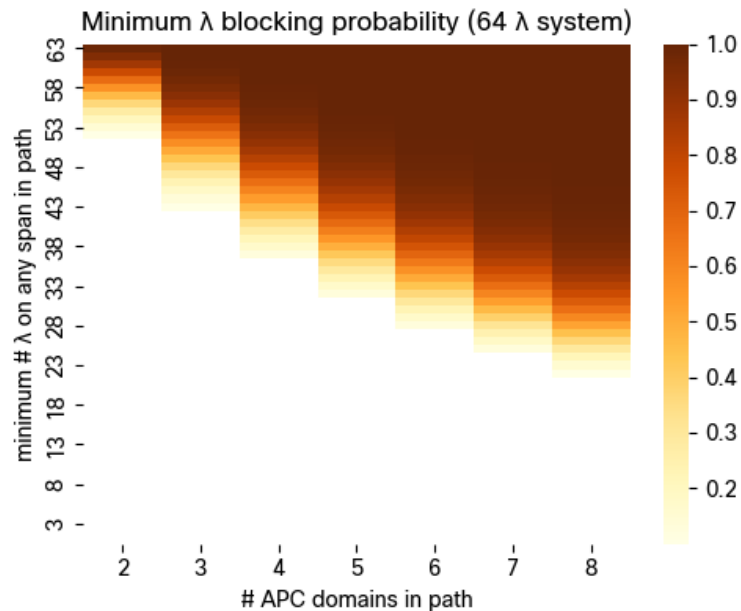
Bridge green λ to lower part of network – same patch panel port

Optical Restoration



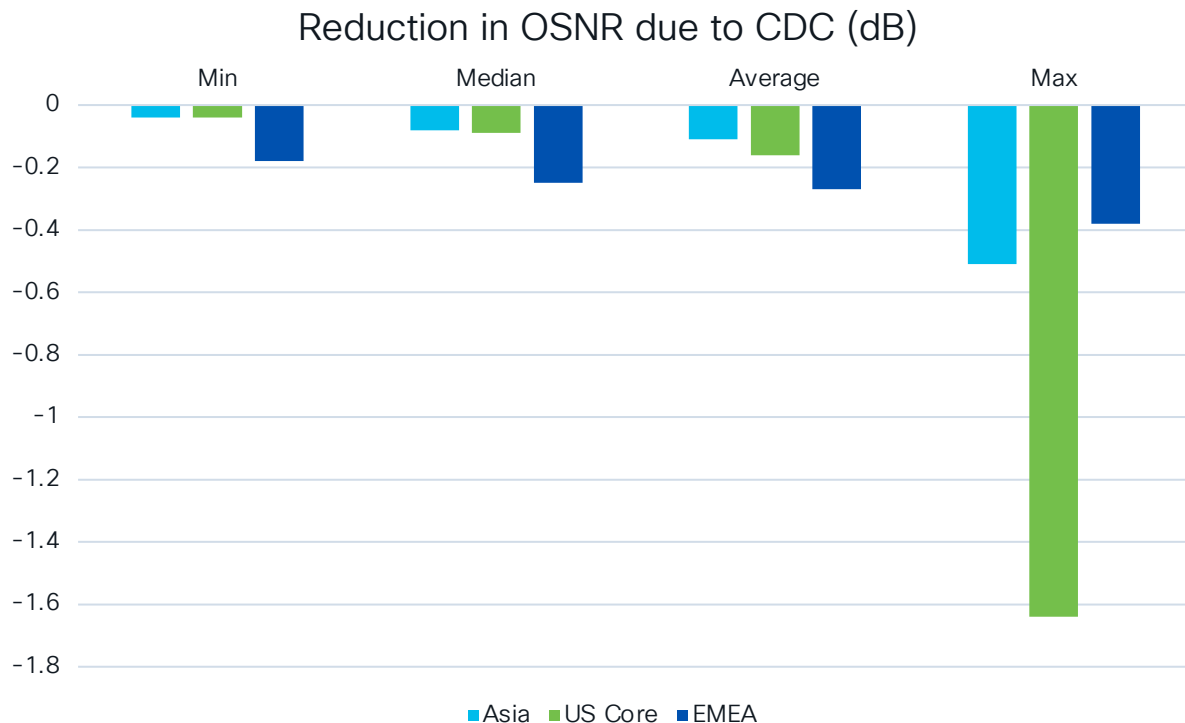
Compute new path (optical control plane) and change to red λ – same port

Is λ blocking really an issue ?



It can be – especially in meshed networks ! (Only probabilities $\geq 10\%$ shown)

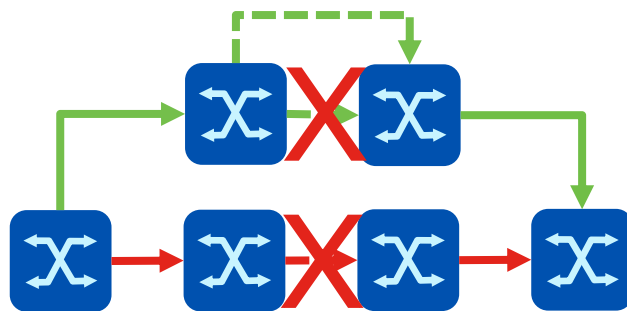
Negative effect on OSNR & bitrate due to CDC



	Decreased Bitrate (% of non-regen circuits)
Asia	3 %
US Core	4 %
EMEA	0 %

Does optical restoration work for the Asia net ?

Relations	157
Relations w/o regenerators	121
Relations ≥ 2 spans	117
Restorable on same bitrate	82
Requires regenerator	35

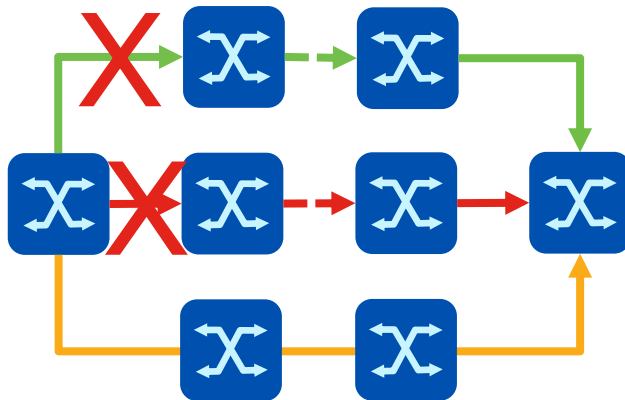


Optical restoration is (by design) not fast – think minute(s)

Of the three networks, Asia network was specifically set up for DWDM restoration

Does optical restoration work for the Asia net ?

Relations	157
Relations w/o regenerators	121
Relations > 2 spans	117
Restorable on same bitrate	82
Requires regenerator	35



Relations	157
Relations w/o regenerators	121
Relations > 2 spans	N/A
Restorable on same bitrate	72
Requires regenerator	49

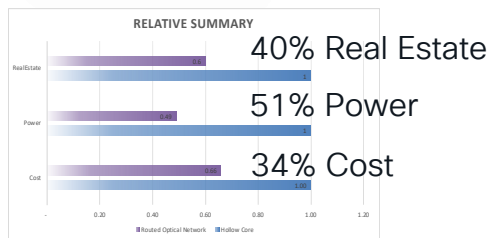
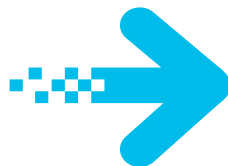
Optical restoration is (by design) not fast – think minute(s)

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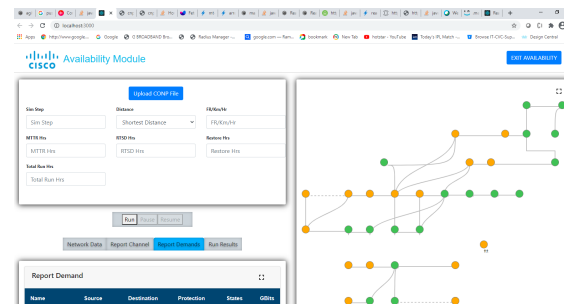
Actual Network Results

Reduced TCO with enhanced availability vs. Present mode of Operation

>80,000km Long Haul



What about Reliability?



PMO = 50% additional cost for equivalent availability to the Routed Optical Network

Present Mode of Operation

~ 45 Tbps traffic demands

Optical Restoration used

Routed Optical Networking

All IP Protection/Restoration

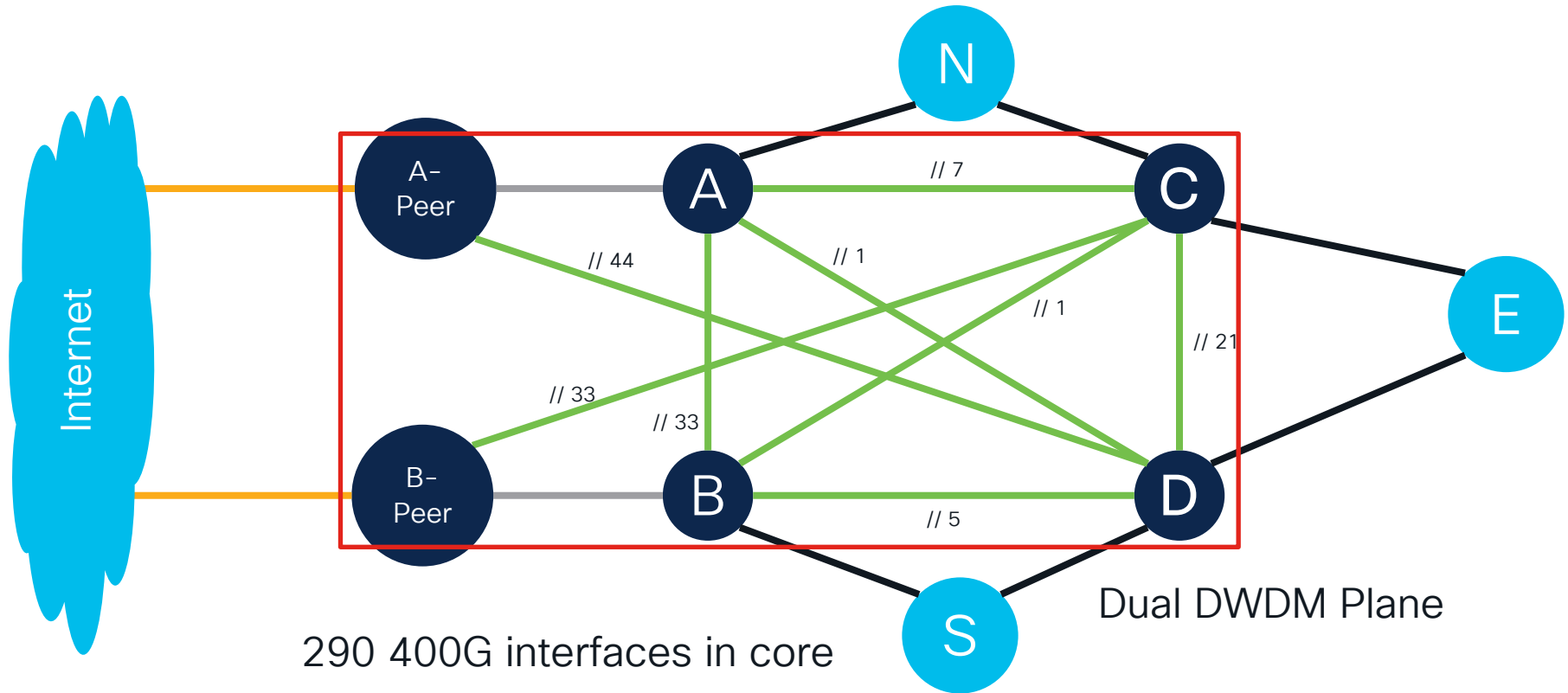
Saved 12000 km of fiber (3 x LA -> NYC)

“Design is an iterative process. You probably need one more iteration than you’ve done to get it right.”

Russ White’s Rule #2

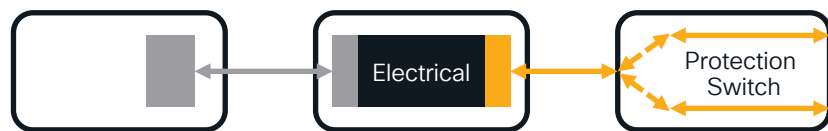
Mr. EIGRP

That EMEA network – customer view



Switching to single plane

Customer Ask



Router

Transponder

OPS

400G IFs

290

Wavelengths

580

DWDM
systems

2

Final Solution



Router

400G IFs

292

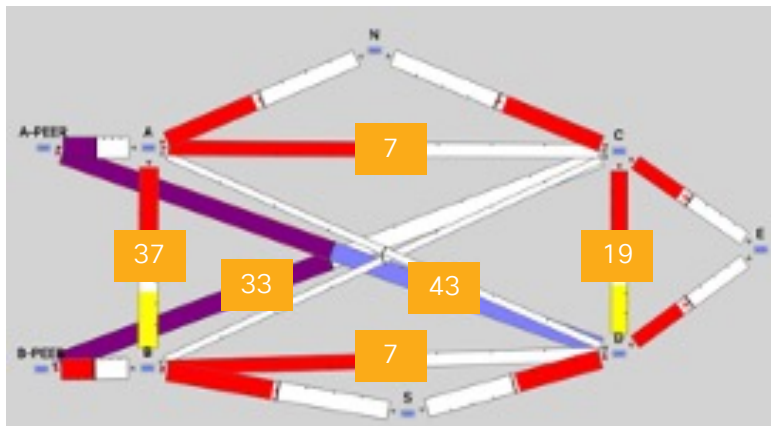
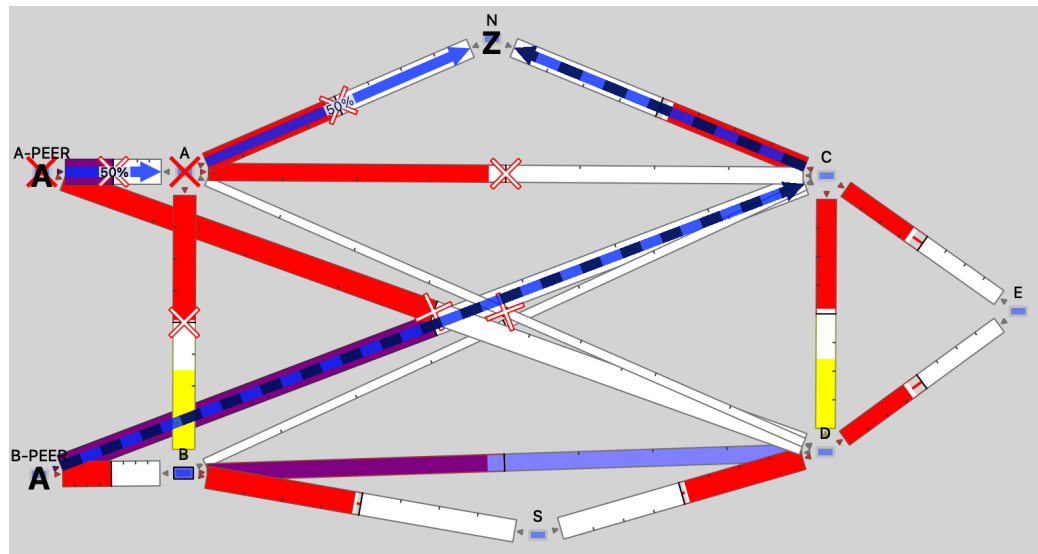
Wavelengths

292

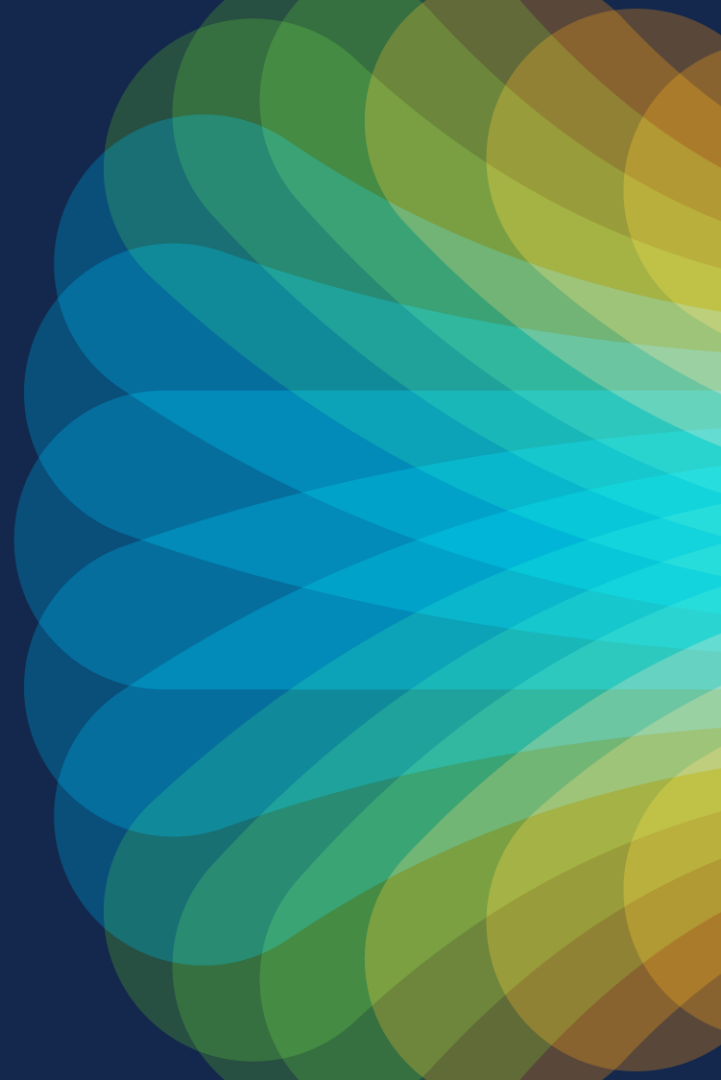
DWDM
systems

1

... still survives complete failure at A, B



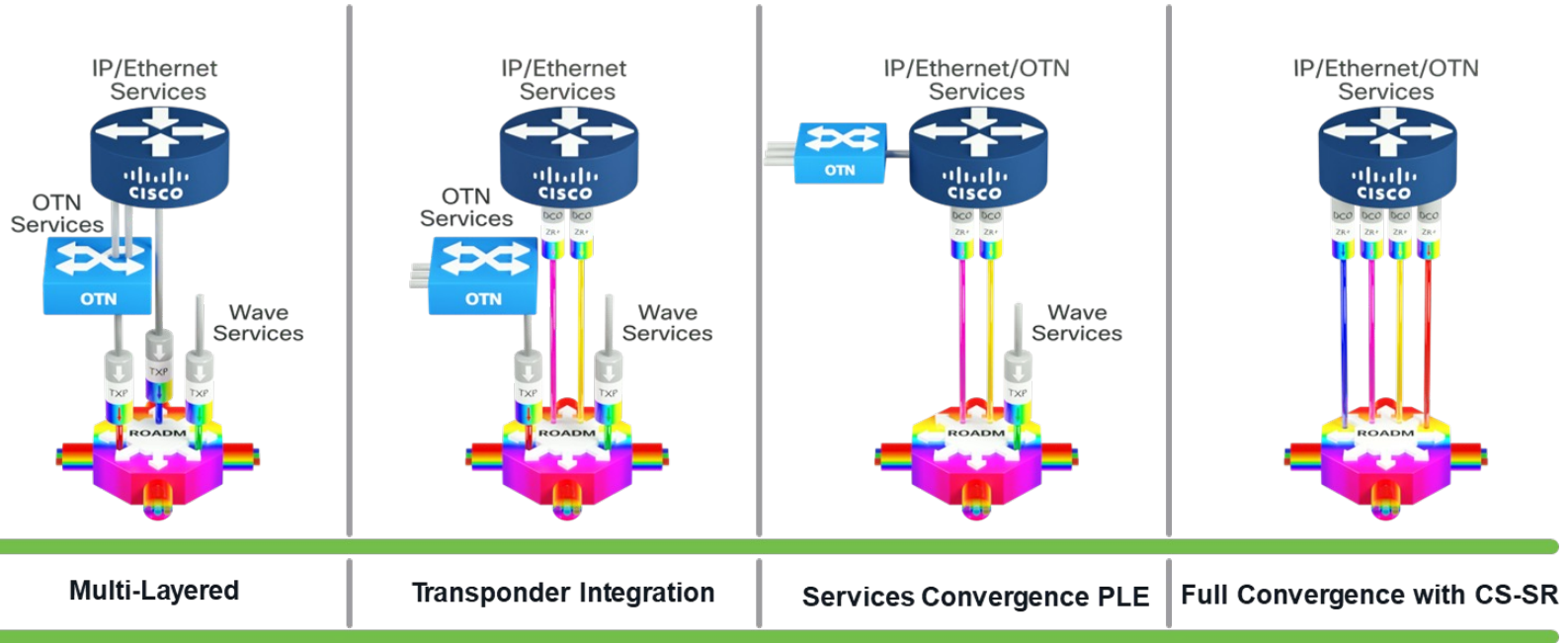
Shifting architectures and technologies



Routed Optical Networking Journey & Phases

Present

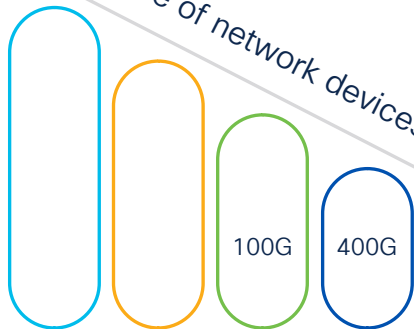
Future



Total cost of network connectivity



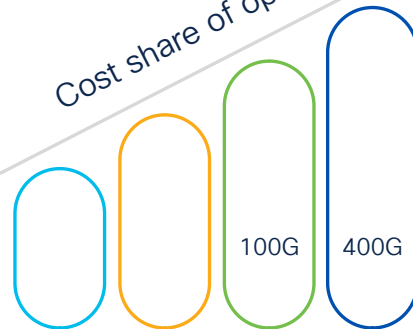
Cost share of network devices



Over time, network device cost per gigabit of bandwidth is going down as speed and density increases



Cost share of optics



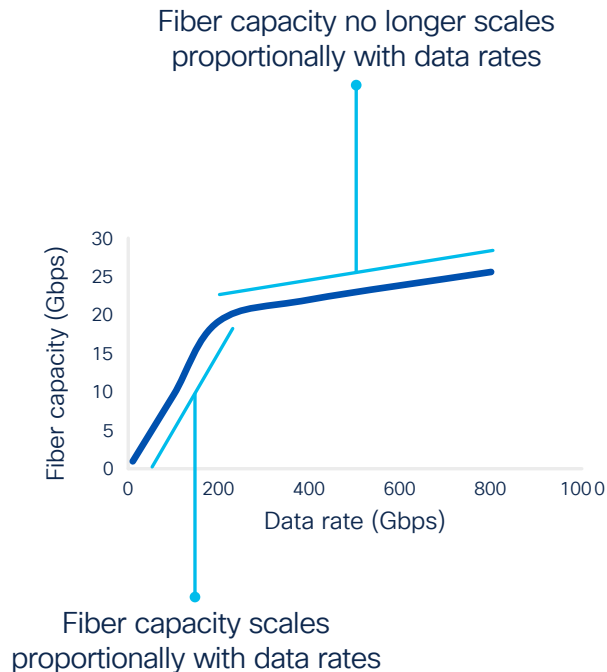
Over time, pluggable optics costs reduce slower as speed increases because complexity increases

Increasing fiber capacity

Data rate	Modulation	Grid spacing	Fiber capacity
10G	NRZ	50G	960G
100G	QPSK	50G	9.6T
200G	16QAM	50G	19.2T
400G	16QAM	87.5G	22.0T
800G	16QAM	150G	25.6T

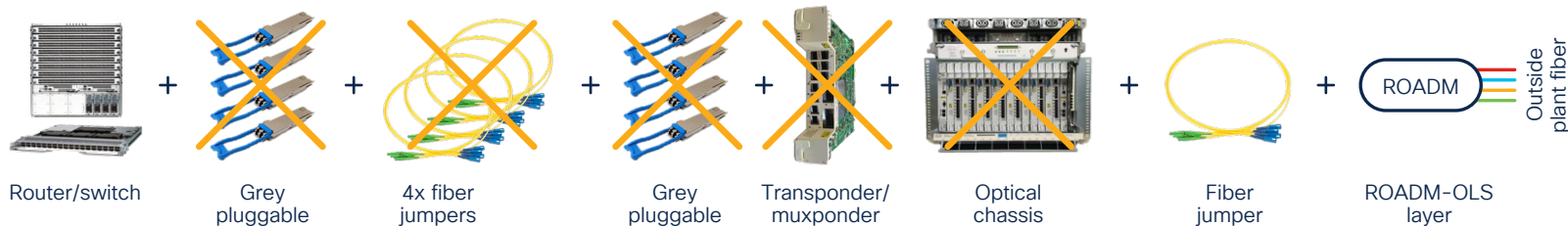
Scaling fiber capacity going forward...

- Baud rate
- C and L band
- Regeneration

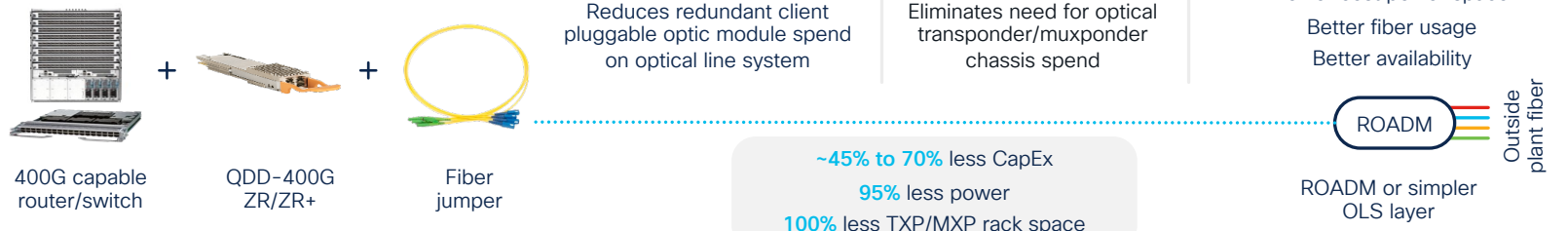


Routed optical networking: Removing complexity

Previous



Today



Cisco Bright QSFP-DD ZR+

OpenZR+
MULTI-SOURCE AGREEMENT

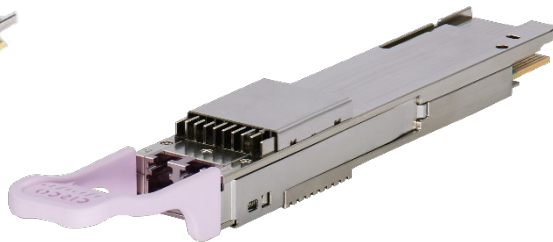
or

OIF
400ZR

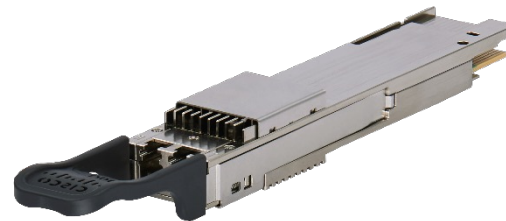
OIF
400ZR



DP04QSDD-HE0



QDD-400G-ZRP-S



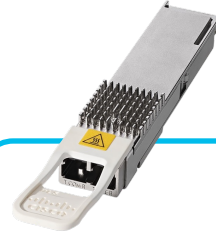
QDD-400G-ZR-S

Pluggable Optics Innovations



Bright QDD ZR+

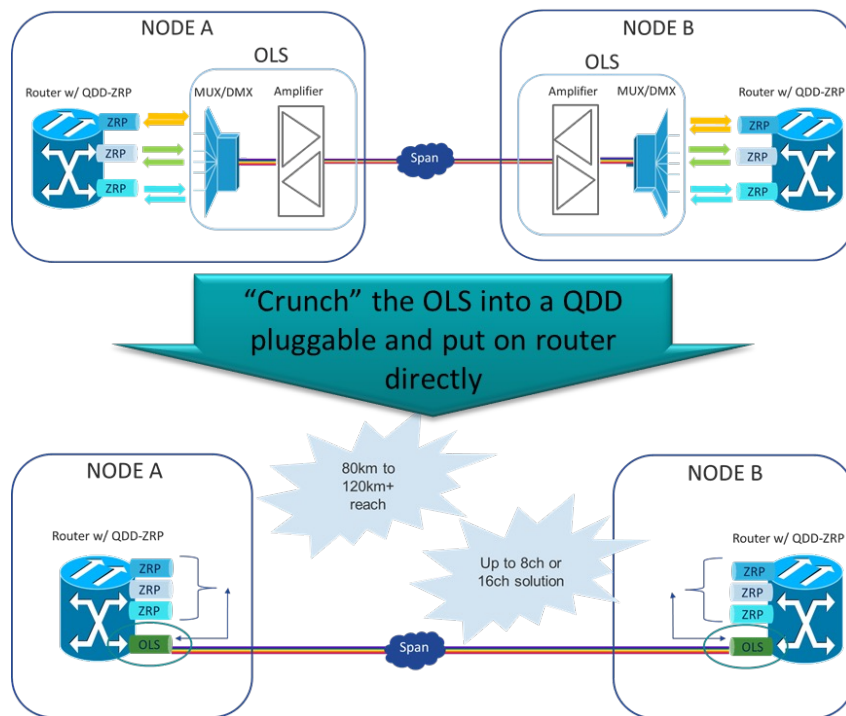
- 400G ZR+ QDD pluggable with up to +2dBm TX Power
 - Allows interoperability with all deployed Add/Drop architectures
 - Enhances by about 12dB the un-amplified reach
- Optical specs aligned with current QDD ZR+ ones
- Two different versions
 - Ethernet only (for Routers and Switches)
 - OTN (with optional support of L1 Encryption, available in Full Feature and Licensed versions)



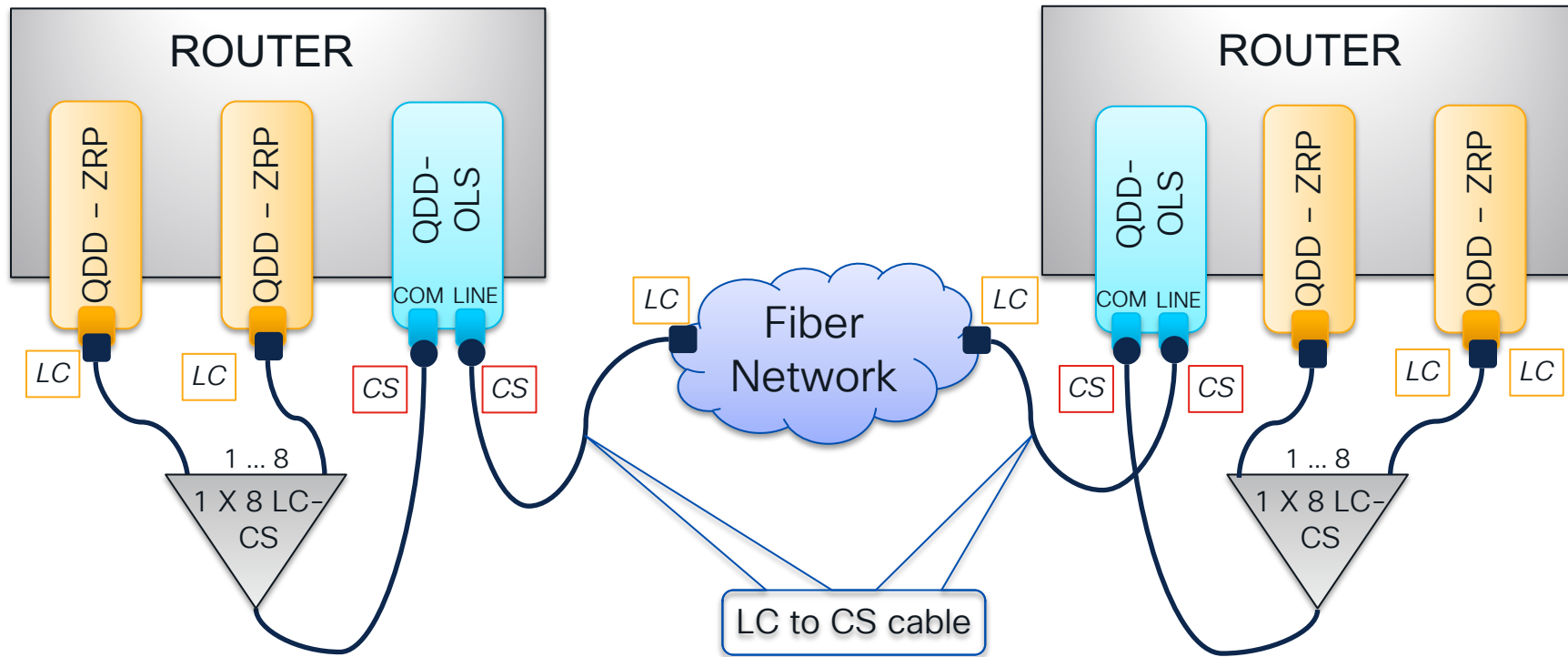
QDD OLS

- Bi-directional EDFA amplification integrated into pluggable QDD
 - Up to 17dBm Output Power
 - 7dB to 25dB Gain Range for Booster EDFA
 - 2dB to 25dB Gain Range for Pre-amplifier
 - 2.4THz C-band range
- Can be used in conjunction with 64chs Mux/Demux to support up to 32 wavelengths (75GHz grid)
- Passive 8chs Coupler/Splitter integrated in a cable available as well for low-end applications

What is QDD-OLS. The High-Level Solution



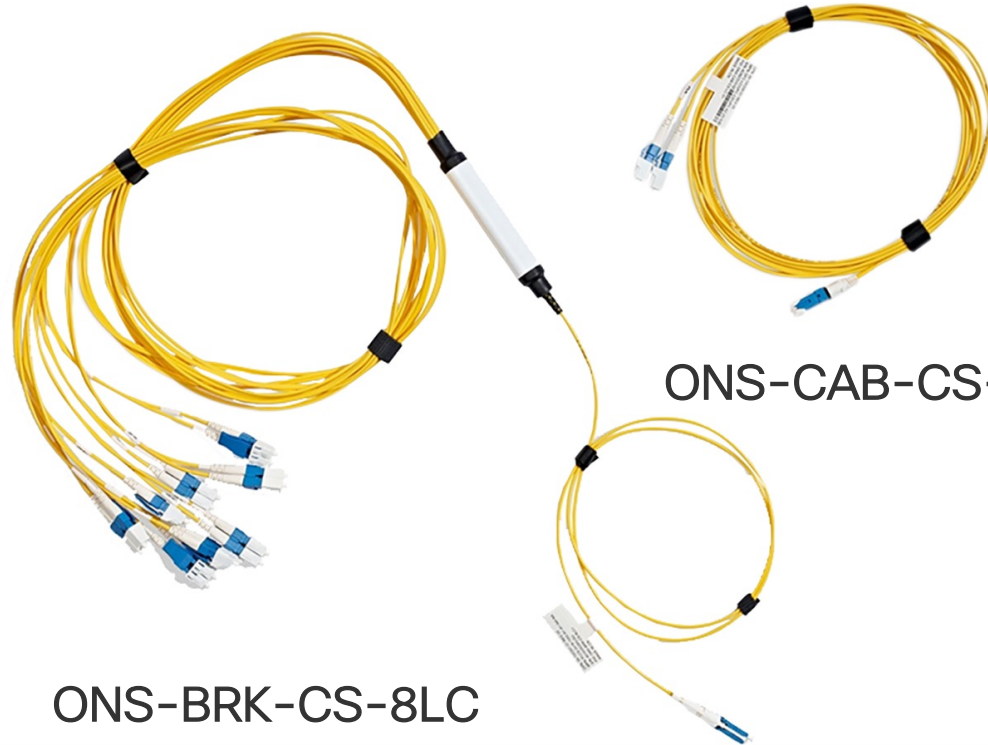
The solution in more details



QSFP-DD Open Line System (OLS)



ONS-QDD-OLS

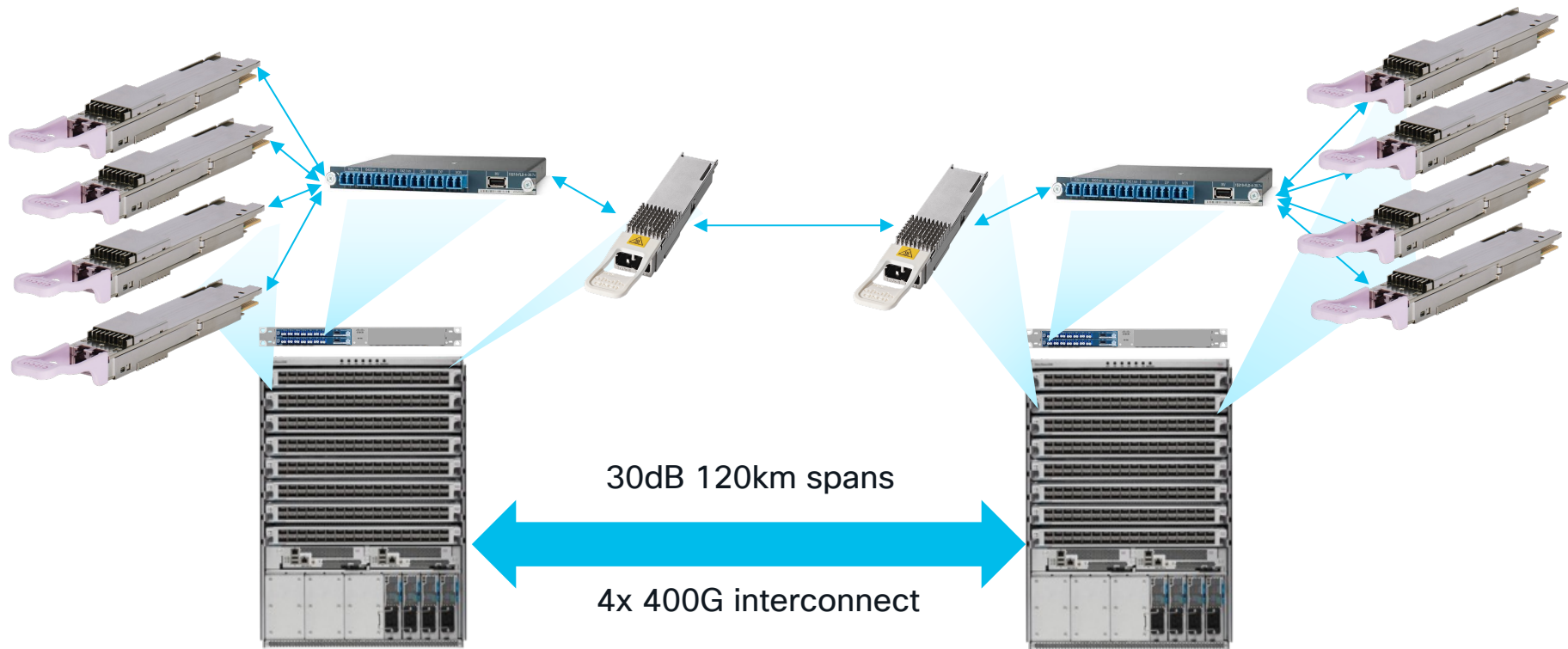


ONS-BRK-CS-8LC

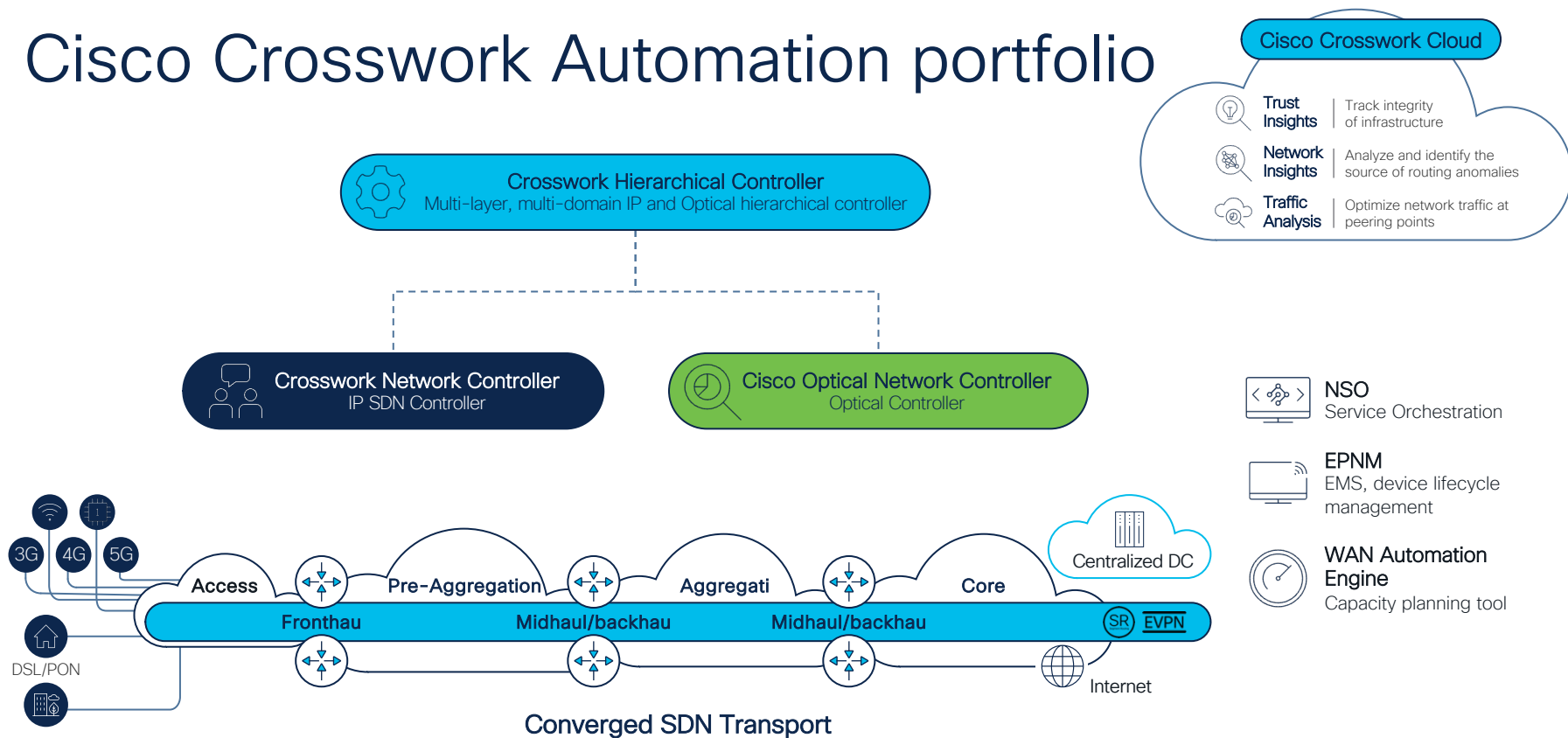
ONS-CAB-CS-LC-5

<https://www.cisco.com/c/en/us/products/collateral/interfaces-modules/transceiver-modules/qsfdd-plug-open-line-system-ds.html>

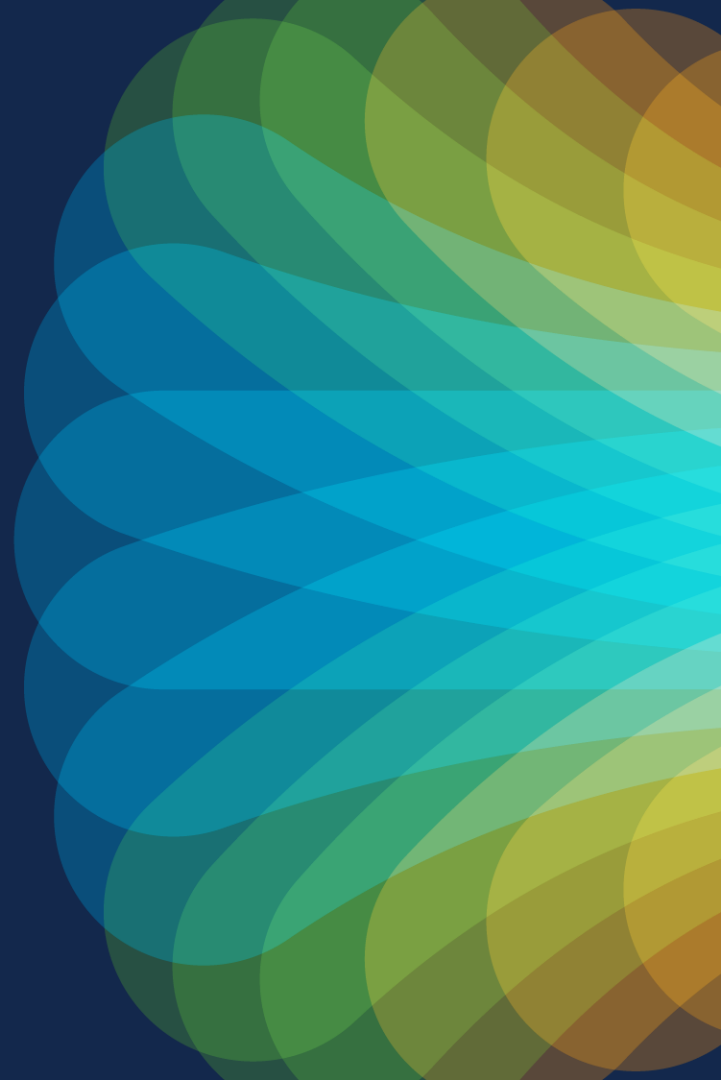
Leverage QDD-OLS with Passive Filters



Cisco Crosswork Automation portfolio



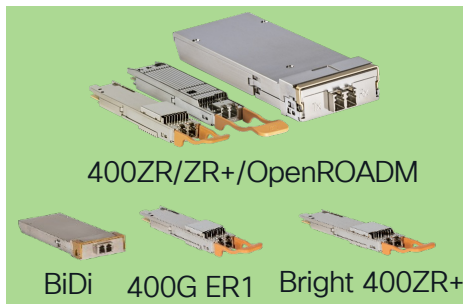
Road Ahead



Road ahead for Coherent MSA pluggable

Today

Expanding applications
for 400G pluggables

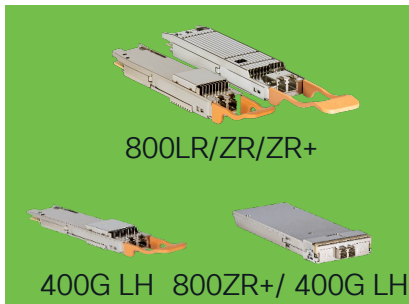


50G SerDes

16-22W

Future

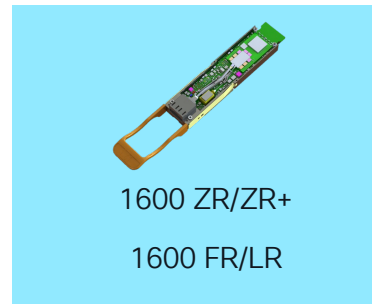
Next-Gen 800G and
400G LH pluggables



50G/100G SerDes

22-30W

1.6T Coherent for
DC, carrier networks

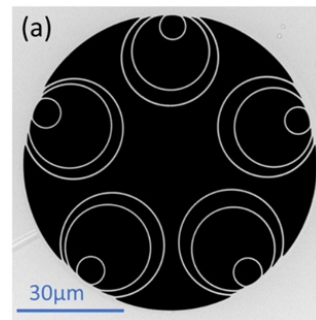
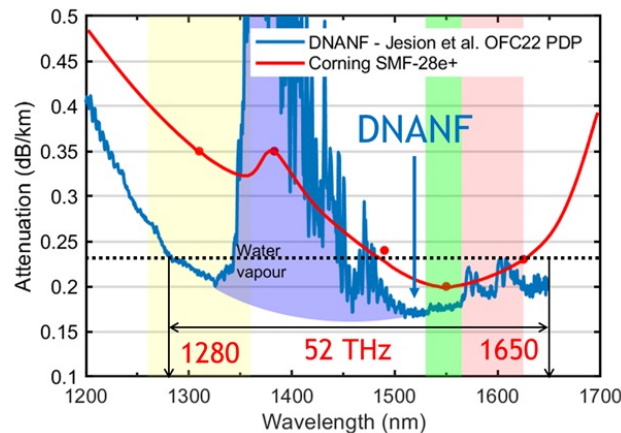


100G/200G SerDes

25-40W

Nested Anti-resonant Nodeless Fiber (NANF)

- Hollow-core fibers have been around for about 20 years
- Light propagation occurs mostly in air
 - (theoretically) low loss
 - low dispersion & ultra-low non-linearity
 - 50% greater propagation speed & much greater optical bandwidth (10s of THz)
- NANF has been proposed in 2014 to provide Lower Loss and Inter-Modal Interference (IMI)



Key Takeaways



Conclusion

- It is all about tradeoffs
- Design from IP layer down
- Physics ...
- Know your IP demands
- Simplify DWDM network
 - Add/Drop structures
 - IP “restoration”
- Design tools



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Thursday	9:30am – 4:00pm
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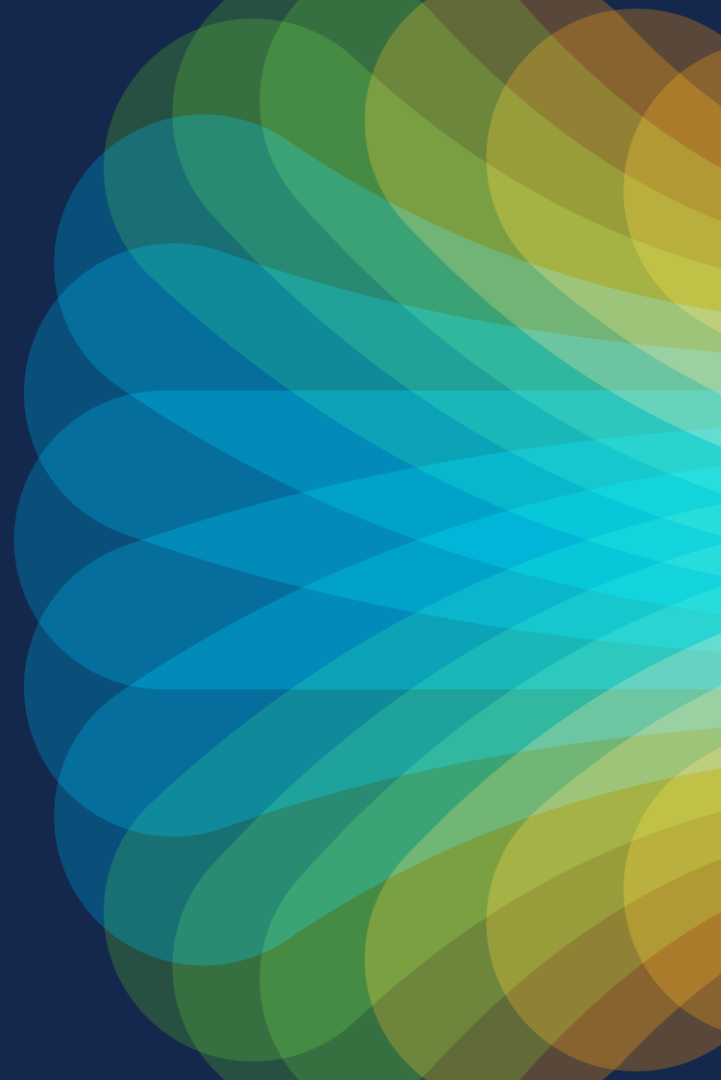


The bridge to possible

Thank you

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The background features a vibrant, multi-colored abstract design. On the left, there are horizontal, wavy bands of color in shades of red, orange, yellow, and green. On the right, a bright white light source emits a series of colorful rays in shades of blue, green, and yellow, creating a sunburst effect.

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Let's go

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