400ZR/ZR+ management through automation

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IP/Optical Network Automation
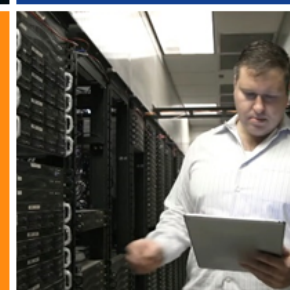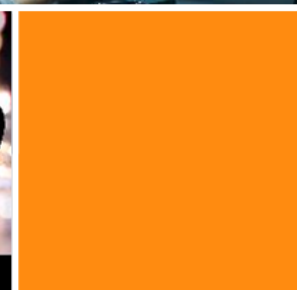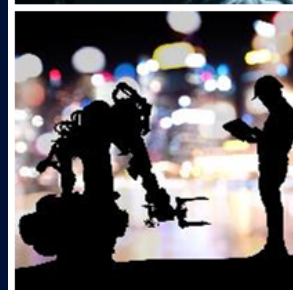
Agenda

- Coherent Landscape
- Managing coherent optical
- Why automate IP/optical control?
- Typical use cases

The 400ZR Landscape

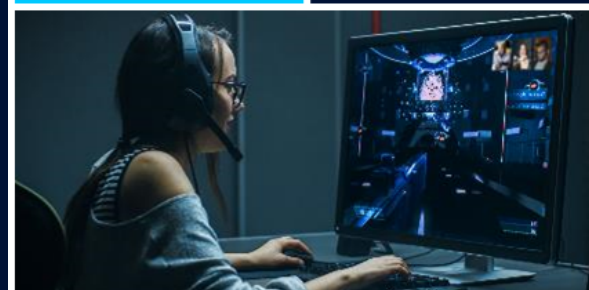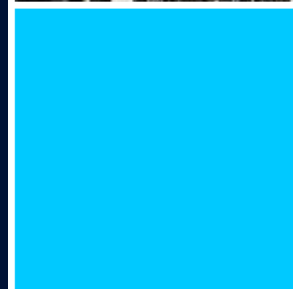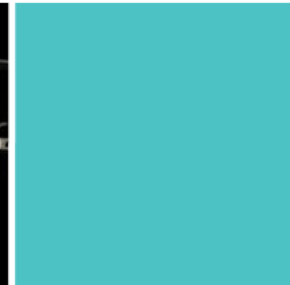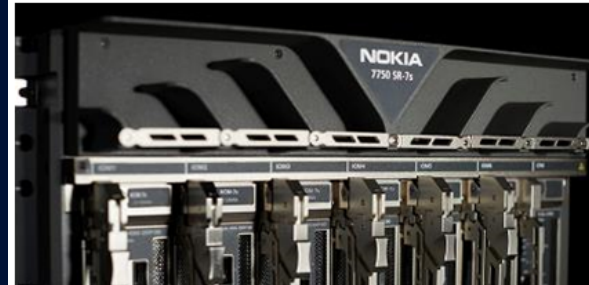# 400G ZR/ZR+: The advent of pluggable coherent optics

QSFP56-DD 400G-ZR   QSFP56-DD 400G-ZR+   QSFP56-DD 400G-ZR++
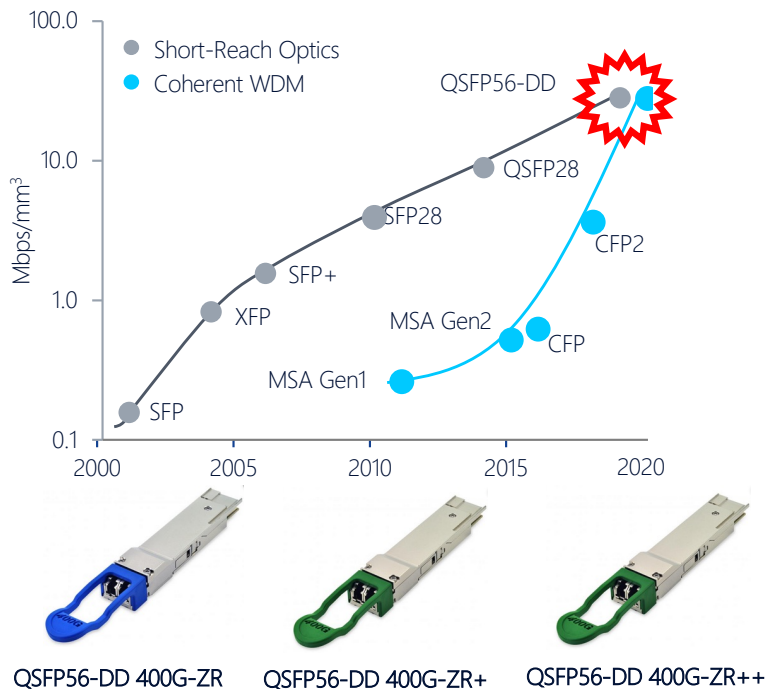
- Industry standard OIF 400ZR with multiple vendors targeting introduce products in mid-2021

- Same form-factor as short-reach 400GE optics

- Integration in routers without compromising I/O density

- 7 nm silicon CMOS enabling low-power DSPs

- Allows for coherent 400G WDM in QSFP-DD/OSFP

- Reduces cost/space/power of WDM system elements

- Trade-off in terms of spectral efficiency and reach versus highest-performance, non-pluggable coherent optics

400G ZR/ZR+ will enable coherent WDM in standard router ports

400GE TCO modeling study

Metro-regional applications

Objectives

- Evaluate IP aggregation in access/metro networks
- Cost/benefit of using ROADMs and wave routing
- Evaluate different ring sizes and traffic volumes
- Quantify 400GE port count, router capacity and power consumption

Assumptions

- Hub-and-spoke IP aggregation with distributed access routers connecting to a centralized hub
- Ring size: From 3 to 8 access nodes per ring
- Traffic: From 50 to 800 Gb/s per access node
- Full traffic protection against a single fiber cut
- Optical line systems with or without ROADM
- ZR++ 0dBm pluggables

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IP backbone

Metro-regional core

Metro aggregation

Access

CVE/CO
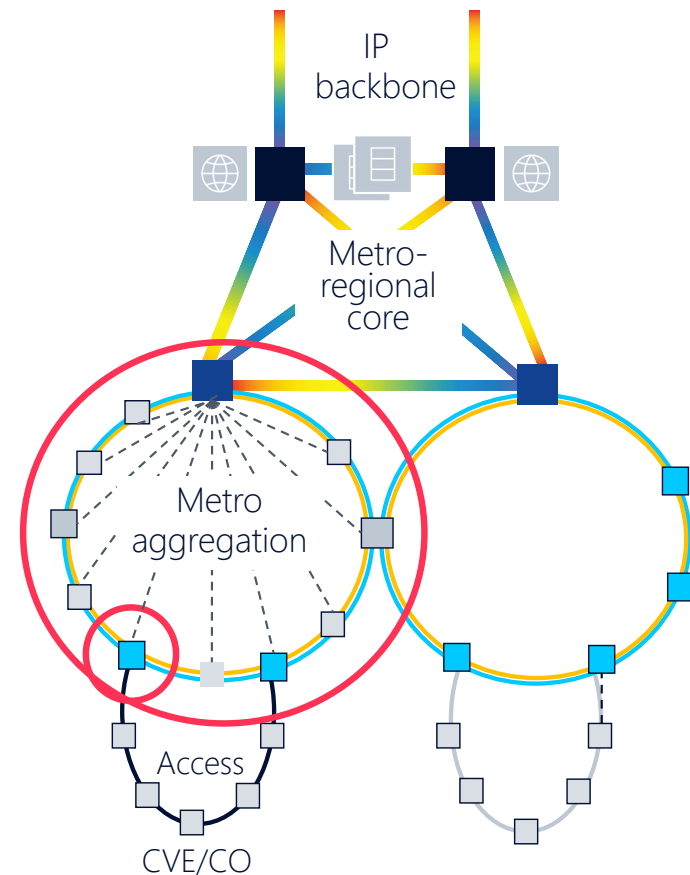
Scenarios and assumptions

400ZR+ with ROADMs

A3 West

A3

Transit traffic
A1- A2, A4-A8

Add/drop

A3 East

Access node detail
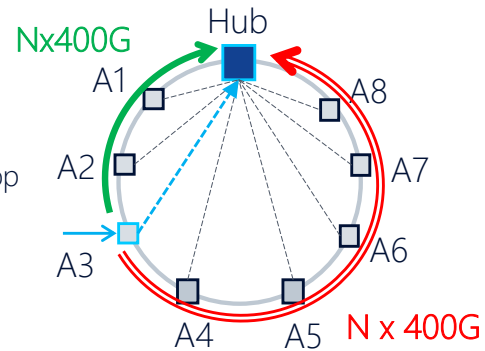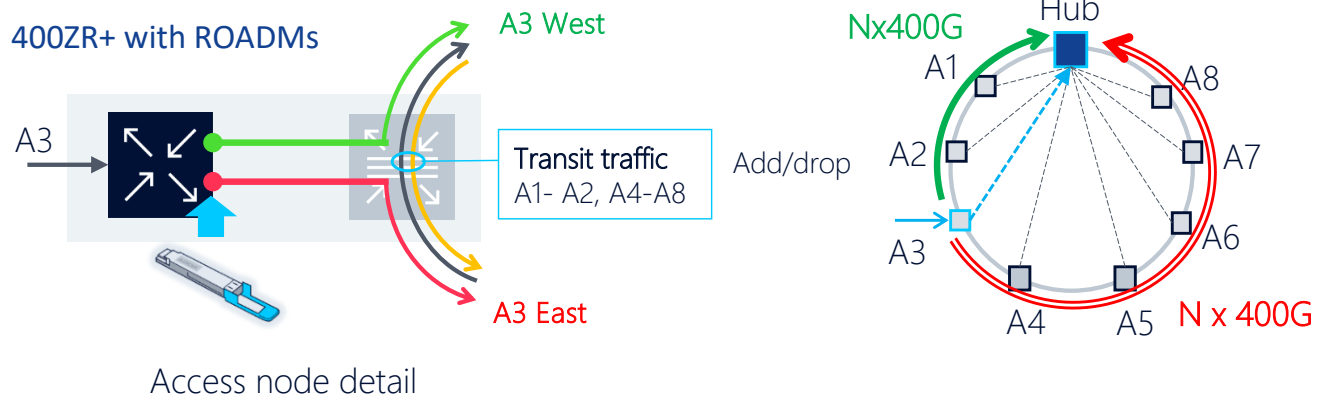
L1/L2 ring topology with ROADM bypass

Nx400G — Hub

A1

A2

A3

A4   A5

A6

A7

A8

N x 400G

400ZR without ROADMs

Σ (A3-A8) west

A3

FOADM+ILA

Σ (A1-A3) east
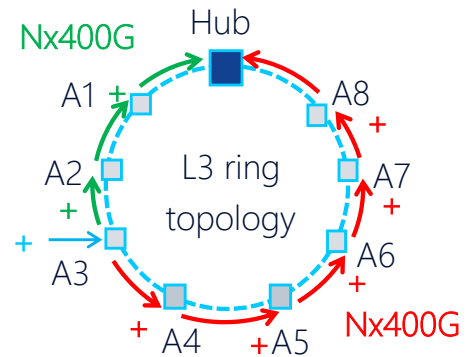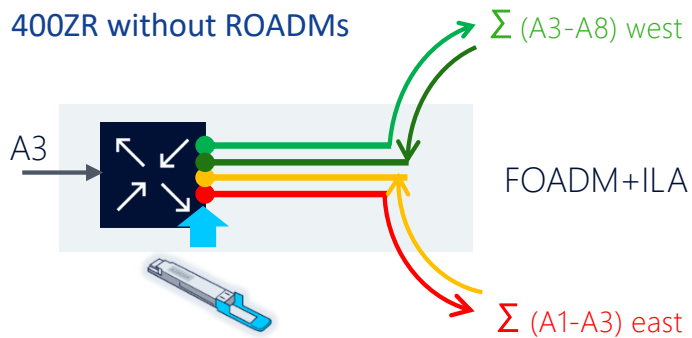
L3 ring topology (no ROADM)
Hop-by-hop IP aggregation
All ports at 400G/16QAM

Nx400G   Hub

A1 +

A2
+

A3
+

+ A4   +A5

A6
+

A7
+

A8
+

L3 ring topology

Nx400G

Scaling metro/regional aggregation rings with 400G DCOs

Scaling 400ZR ports with ring size
(800Gb/s ingress traffic per access node)

DCOs per access router

	3 node	4 node	5 node	6 node	7 node	8 node	9 node
400ZR+/ROADM	4	4	5	5	6	6	6
400ZR+ HBH	8	12	16	20	24	28	32

2x   5x

■ 400ZR+/ROADM   ■ 400ZR+ HBH   ······· Linear (400ZR+ HBH)

- 400G port count on hop-by-hop aggregation rings grows linearly with the amount of access nodes
- Hub-and-spoke traffic aggregation using ROADMs is **2 – 5x** more capacity efficient than hop-by-hop

Scaling 400ZR ports with access traffic
(9 node ring: 8x access + 1 hub)

	50G	100G	200G	400G	800G
400ZR+/OADM	2	2	2	4	6
400ZR HBH	2	4	8	16	32

■ 400ZR+/OADM   ■ 400ZR HBH   ······· Expon. (400ZR HBH)

- 400G port count and router capacity on hop-by-hop rings grows in lockstep with aggregate access traffic
- Hub-and-spoke traffic aggregation using ROADMs offers efficient and independent capacity scaling

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Application-optimized IP-optical networks

Metro core use case

400G ZR+ Hop-by-hop	400G ZR+ w/opt bypass
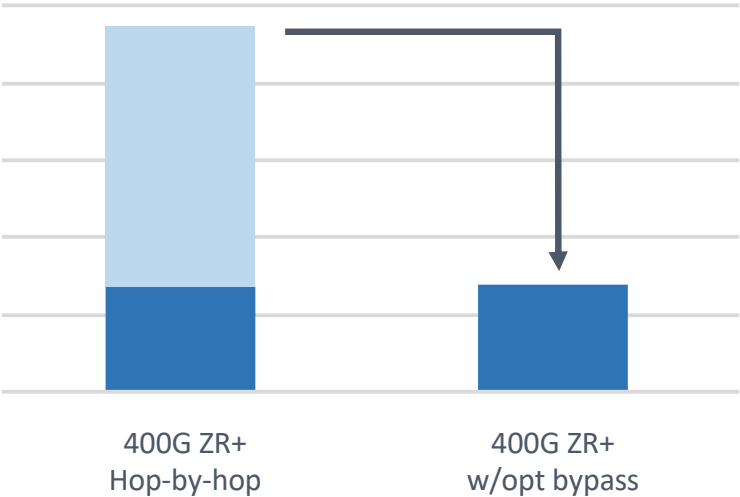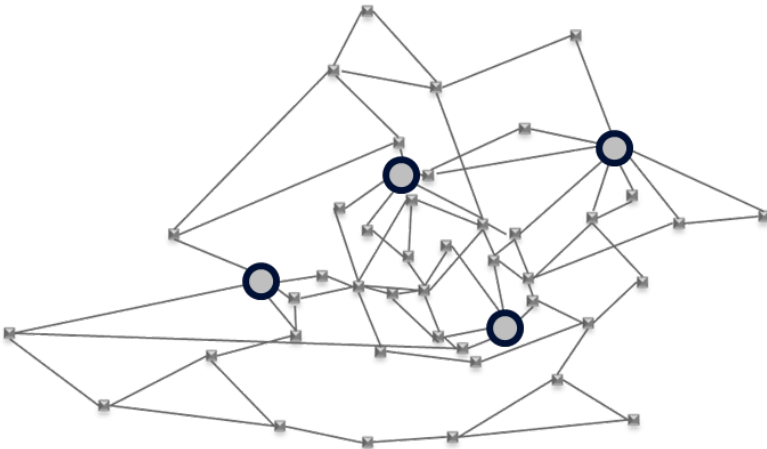
■ Router WDM I/F (Add/drop)   ■ Router WDM I/F (Transit)

Routers with pluggable 400G DCOs + optimized bypass = efficient IP-0ptical

Power consumption of packet transport through routers versus ROADMs
Wavelength routing saves up to 100 Watt per router hop per 400Gb flow

IP routing: >100 watts/400G

IP Fabric — **0.15W/Gb**

Coherent optics (400ZR+) — **20W/DCO**

Optical Line System — **~4W/lambda**

FOADM

Wave routing: 4 watts/400G

ROADM

Power consumption per ring

Watt

-70%

DCOs   IP fabric   (800 Gb/s local access traffic per node)

3 node 4 node 5 node 6 node 7 node 8 node 9 node
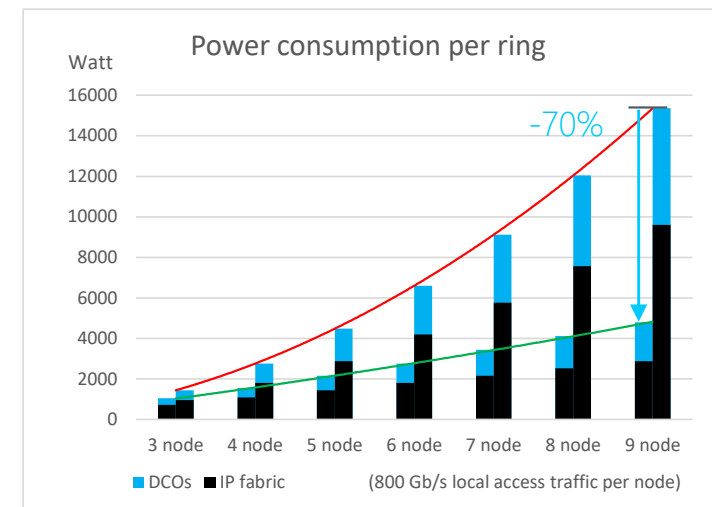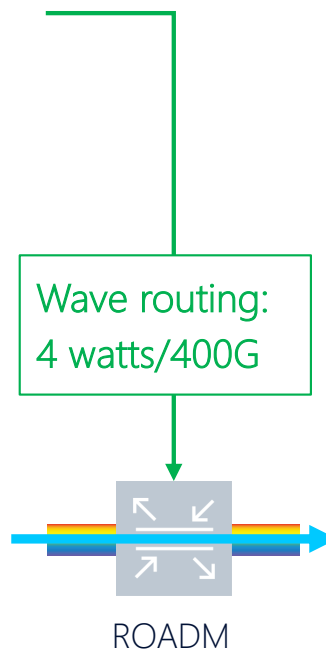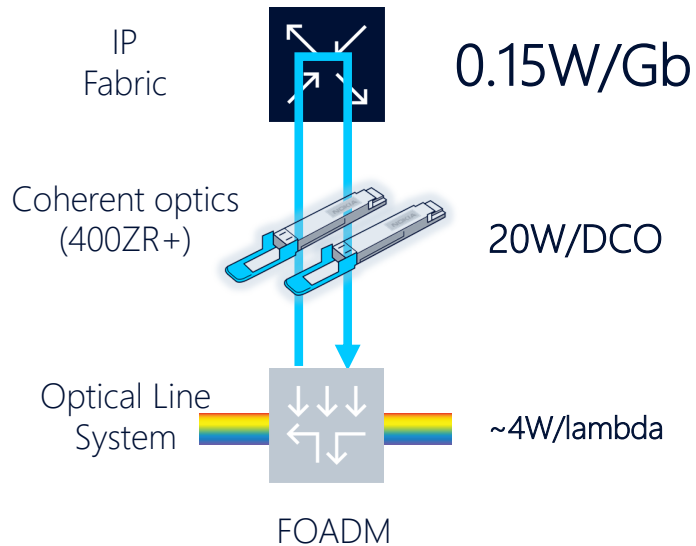
Using ROADMs to optimize IP transport in ring topologies is up to 70% more power efficient

Managing coherent optical

400ZR: network management gradient

Increased complexity = Increased need for automation

IP — IP — IP — IP — Optical — Optical

| SR/LR grey optics: Up to 10 km | ZR unamplified: 40 km | ZR DWDM Amplified: 120 km | ZR+ DWDM Amplified + OCM: 400 km | ZR+ DWDM Amplified + Raman/DGE/OCM: 1300 km | ZR+ DWDM Amplified + transponder and ROADM |

SR/LR grey optics: Up to 10 km
- ✓ Link up

ZR unamplified: 40 km
- ✓ Link up

ZR DWDM Amplified: 120 km
- ✓ Channel plan
- ✓ Go/no go
- ✓ Power ramp

ZR+ DWDM Amplified + OCM: 400 km
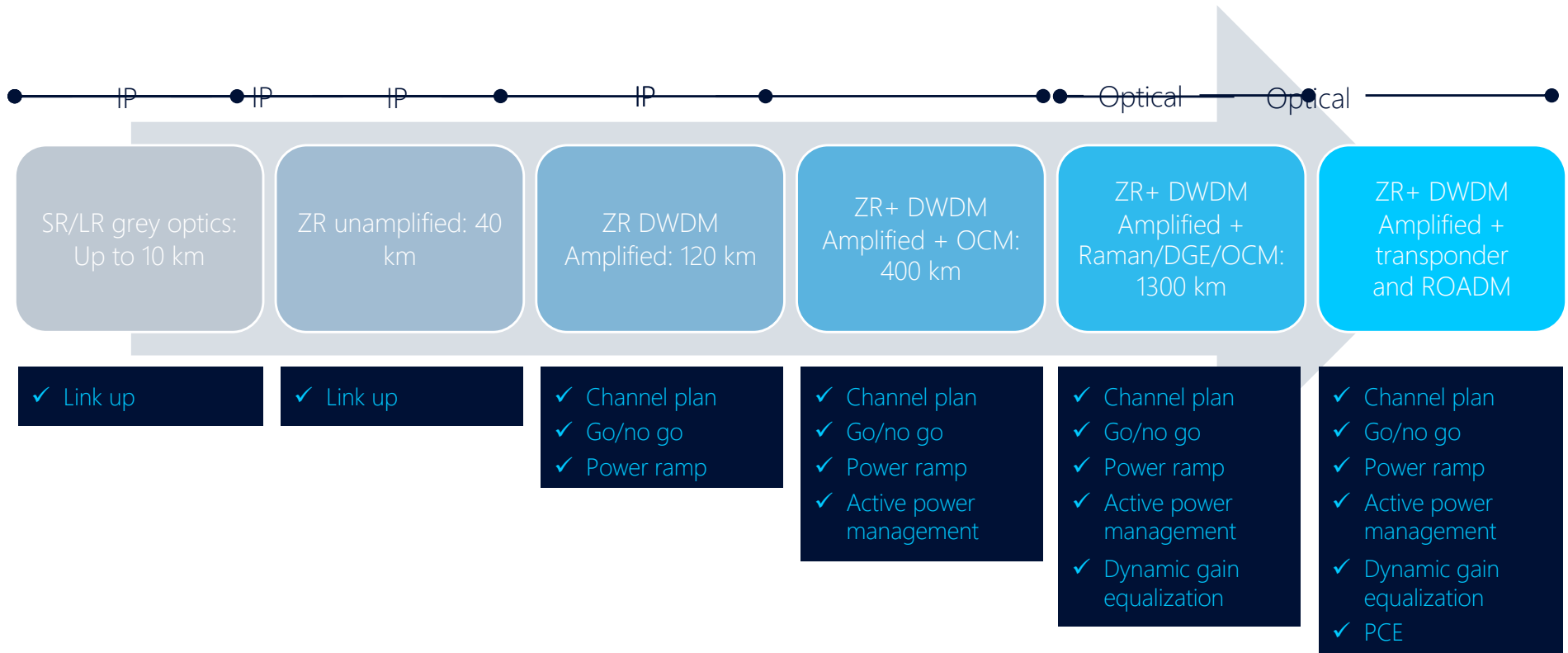- ✓ Channel plan
- ✓ Go/no go
- ✓ Power ramp
- ✓ Active power management

ZR+ DWDM Amplified + Raman/DGE/OCM: 1300 km
- ✓ Channel plan
- ✓ Go/no go
- ✓ Power ramp
- ✓ Active power management
- ✓ Dynamic gain equalization

ZR+ DWDM Amplified + transponder and ROADM
- ✓ Channel plan
- ✓ Go/no go
- ✓ Power ramp
- ✓ Active power management
- ✓ Dynamic gain equalization
- ✓ PCE

Native line control

IP management

Optical management

Open Line System

Router

Router

- **Alien Wavelength** is required on OLS, which is sub-optimal

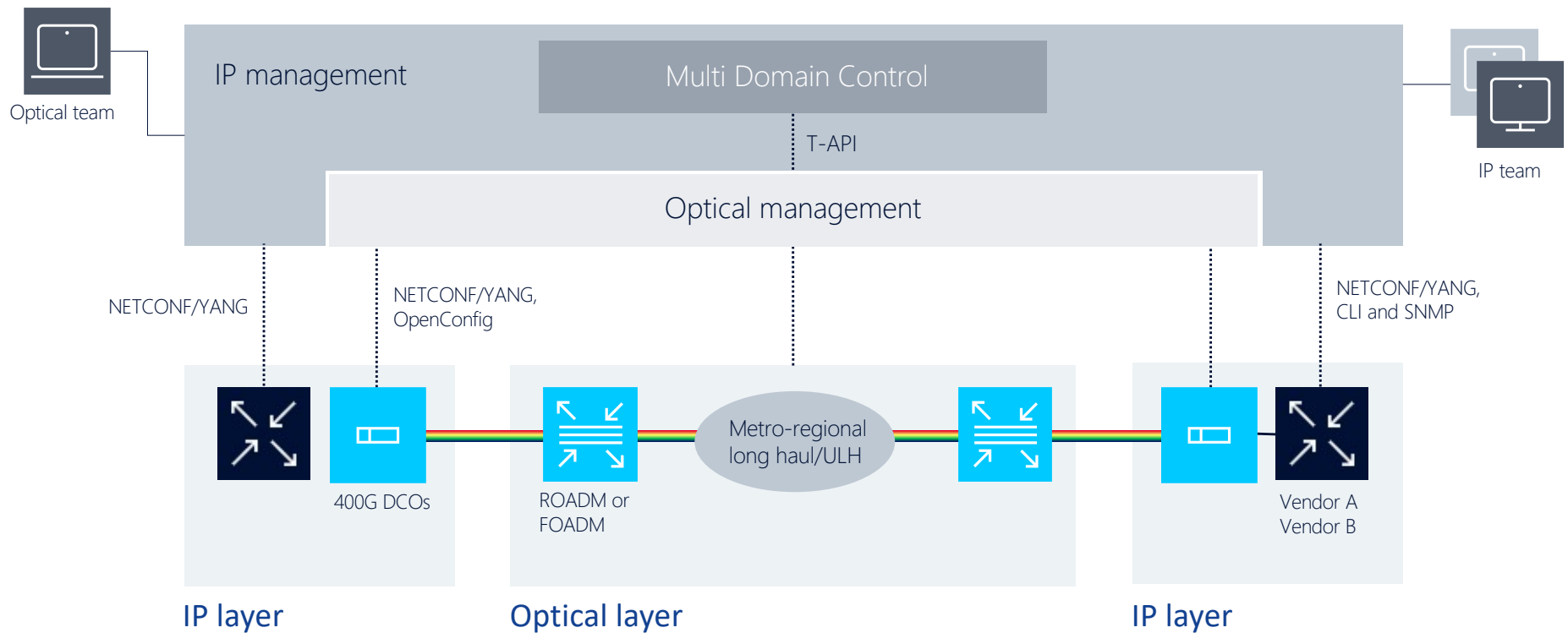- Ok for simple OLS, but as ZR++ is introduced combined management is desirable

+ 400ZR+ pluggable

End-to-end IP/optical management, coordination and automation

Optical team

IP management

Multi Domain Control

T-API

Optical management

IP team

NETCONF/YANG

NETCONF/YANG,
OpenConfig

NETCONF/YANG,
CLI and SNMP

400G DCOs

ROADM or
FOADM

Metro-regional
long haul/ULH

Vendor A
Vendor B

IP layer

Optical layer

IP layer

Why automate IP/Optical?

Limitations with today's IP and optical operations practice

"Lost in translation" syndrome

IP team
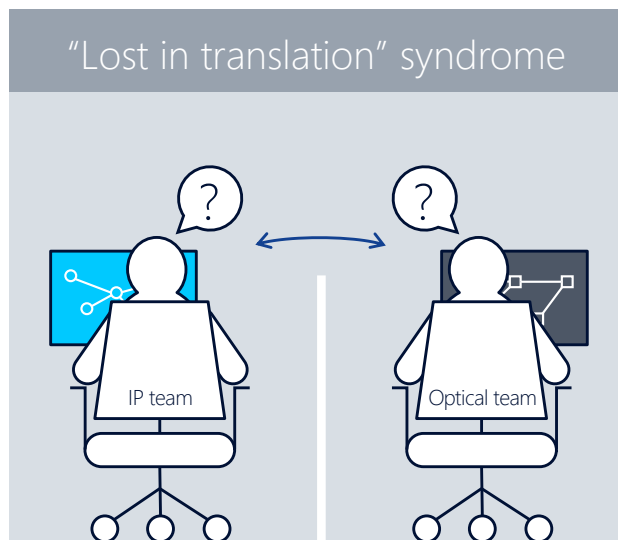
Optical team

Two separate teams using different tools

Operational silos

× Slow processes
× Cost duplication
× Services interruption

Better coordination can improve operational efficiency and network availability

"Swivel chair" effect

IP network

Optical network
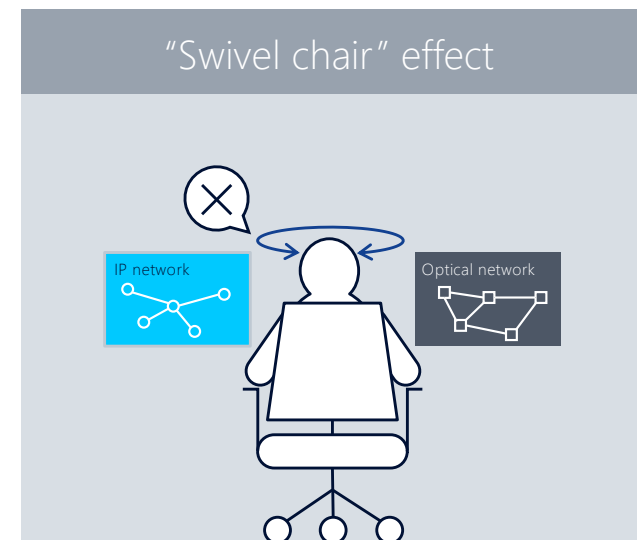
One person using different tools

Cross domain control

Issues

- ✗ Lack of real-time IP-optical cross-layer insights can lead to severe operational issues, including unpredictable failure impacts and suboptimal performance
- ✗ Impact of optical layer operations (maintenance, restoration and protection) on IP layer
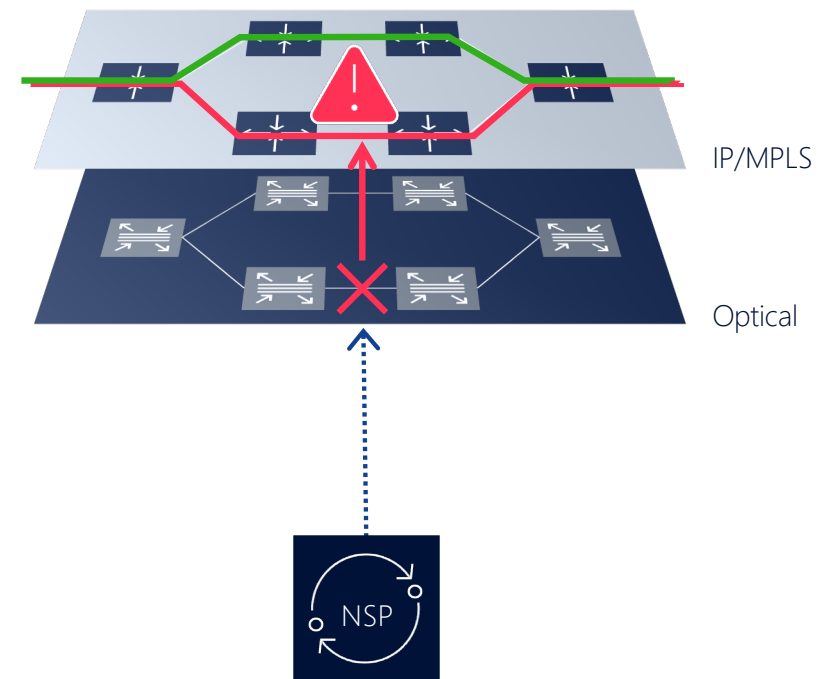
Solution

- Gain full control over the optical topology
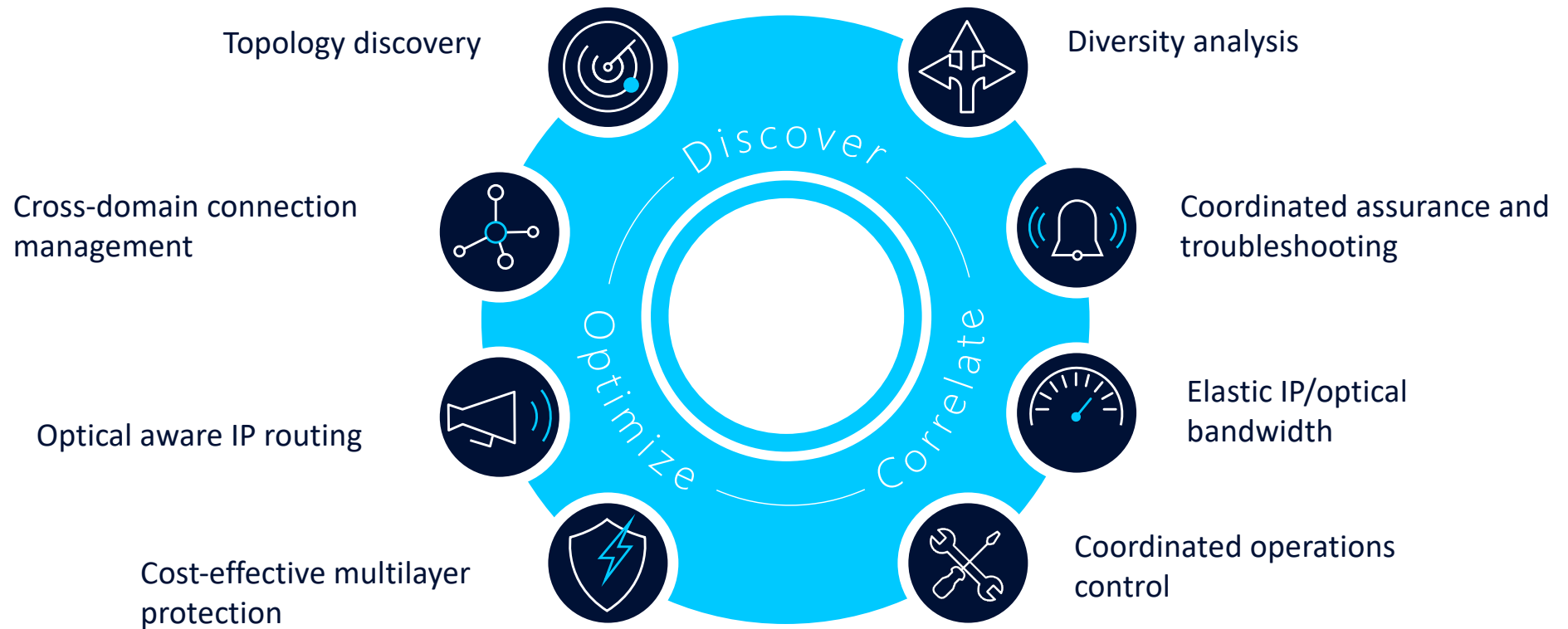- Use shared risk link group (SRLG) constraints and optical latency for network optimization

Benefits

- ✓ Improve network resiliency
- ✓ Enable latency-sensitive IP services
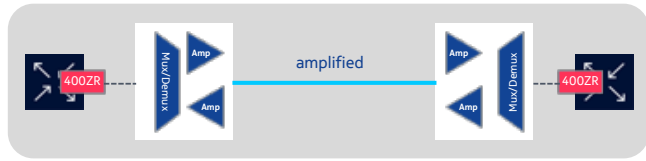- ✓ Enhance troubleshooting through alarm correlation

IP/MPLS

Optical

NSP

IP/Optical use cases

Topology discovery

Cross-domain connection management

Optical aware IP routing

Cost-effective multilayer protection

Discover

Optimize

Correlate

Diversity analysis

Coordinated assurance and troubleshooting

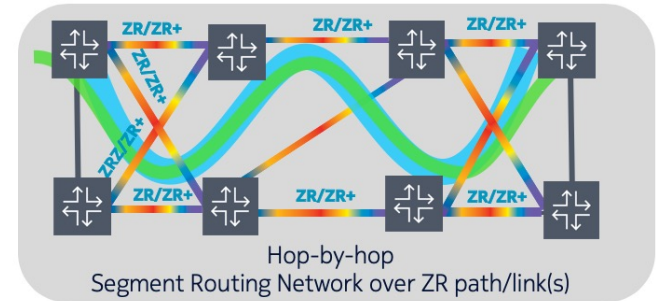Elastic IP/optical bandwidth

Coordinated operations control

400ZR Use cases

Various architectures, different solutions

Point-to-point

Management
Automation
SDN Control
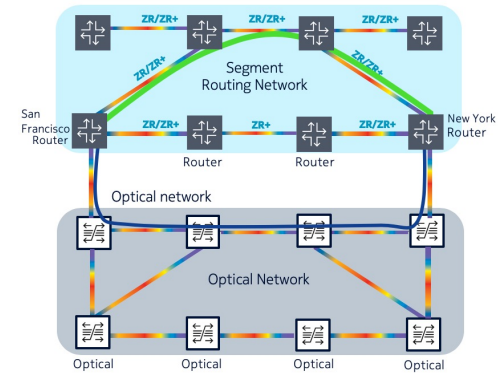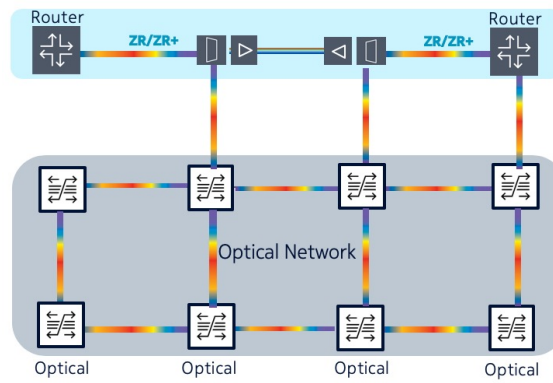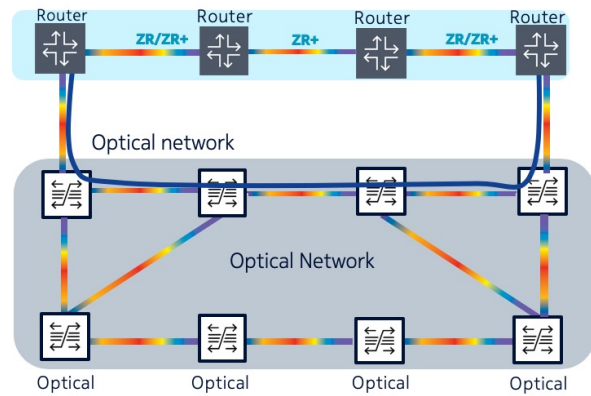
Hop-by-hop
Segment Routing Network over ZR path/link(s)

Hop-by-hop network wide

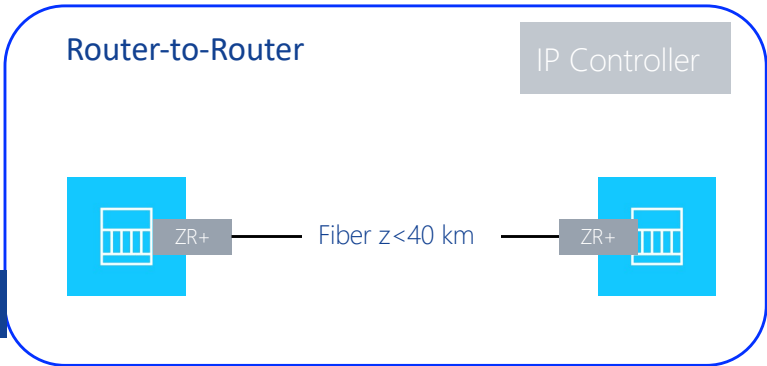Hybrid Models with IP/Optical Bypasses

Use cases and building blocks

Router-to-Router

IP Controller

ZR+ —— Fiber z<40 km —— ZR+

1
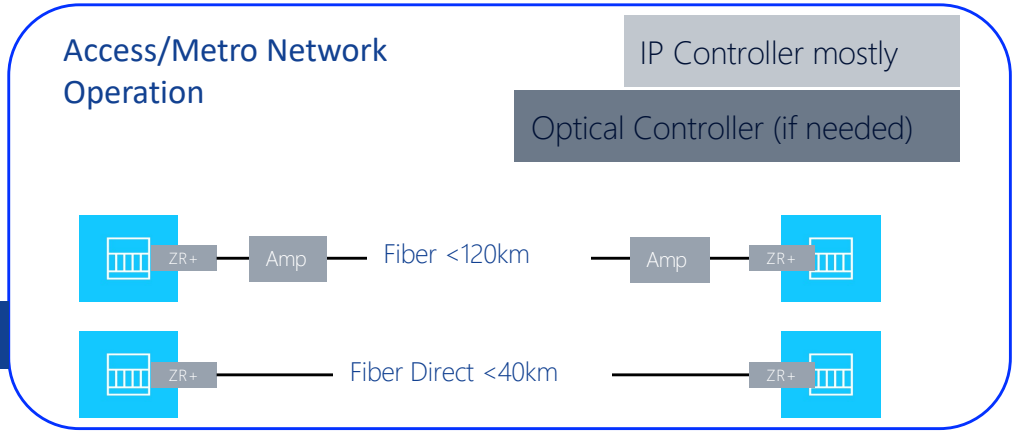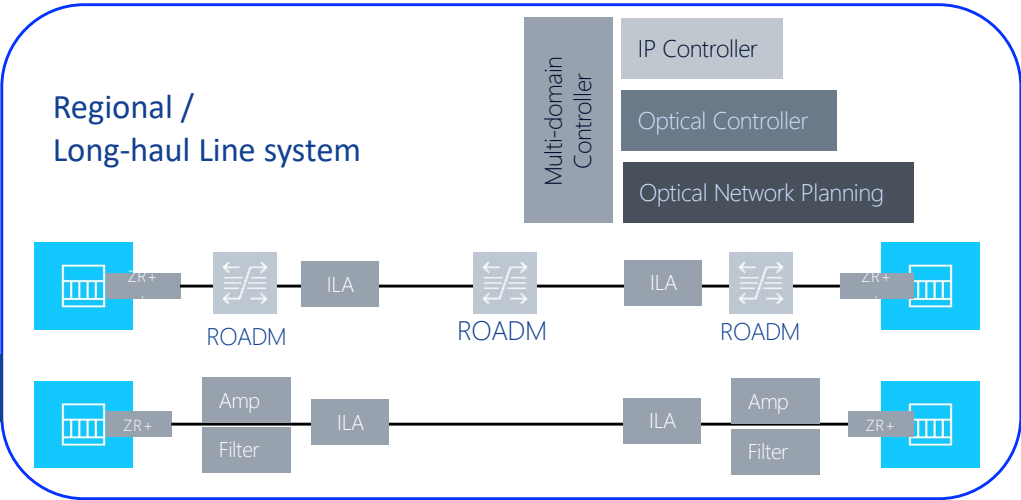
Note: IP/Optical controllers include management and operations functions such as network supervision, assurance, configuration, commissioning, etc.

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Access/Metro Network Operation

IP Controller mostly

Optical Controller (if needed)

ZR+ — Amp — Fiber <120km — Amp — ZR+

ZR+ —— Fiber Direct <40km —— ZR+

2

Regional / Long-haul Line system

Multi-domain Controller

IP Controller

Optical Controller

Optical Network Planning

ZR+ — ROADM — ILA — ROADM — ILA — ROADM — ZR+

ZR+ — Amp / Filter — ILA — ILA — Amp / Filter — ZR+

3

Hybrid scenario with bypass tunnels

Intent= *"Establish 400G connection/service between San Francisco & New York"*

Controller

Segment Routing LSP built from 400GE "ZR/ZR+" lambda Ethernet links

ZR/ZR+   ZR/ZR+   ZR/ZR+

ZR/ZR+   ZR/ZR+

Segment Routing Network

San Francisco Router

ZR/ZR+   ZR+   ZR/ZR+

NYC

Router   Router

ZR+/Grey links

Optical network

Bypass optical path (over CDL links)

Optical Network

Optical   Optical   Optical   Optical

WorkFlow

YANG & RestConf

Intent management

WorkFlow Management

PCEP/BGP-SR-TE Path Placement & Optimization

Cross-Domain Path Analysis & Simulation

Optical Domain Controller

Best Path ZR Segment Routing Path

Best Path Optical Path (Bypass)

Establish 400G Segment Routing ZR LSP

Establish 400G Optical Service

Issues to overcome

Challenges and solutions

- No one size fits all solution: depends on the network architecture selected and the level of integration required with existing deployments)

- The challenge of overcoming separate IP, Optical operational teams and who end up managing the ZR/+ plugs on the router (IP or Optical)

- Need to factor in MV both at IP level (router) and Optical network level but also at the supplier level of the 400ZR+ pluggables and ensure standard-based interoperability

- Cross-domain controllers can help manage the complexity through intent-based provisioning in hybrid and MV environments in addition to the multi-layer IP/Optical capabilities

References

- https://opennetworking.org/wp-content/uploads/2020/08/TR-547-TAPI-v2.1.3-Reference-Implementation-Agreement-1.pdf
- https://www.oiforum.com/technical-work/hot-topics/400zr-2/
- https://openzrplus.org
- https://tools.ietf.org/html/rfc8453 (ACTN)