



The bridge to possible

Scaling Wide Area Networks with Routed Optical Networking

Subtitle goes here

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BRKOPT-2017

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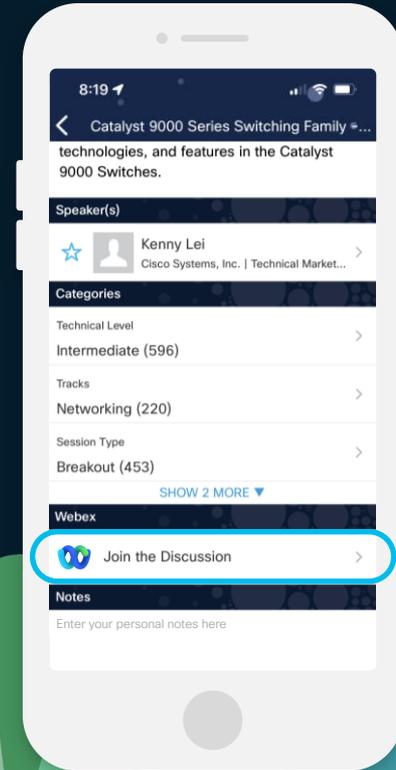
How

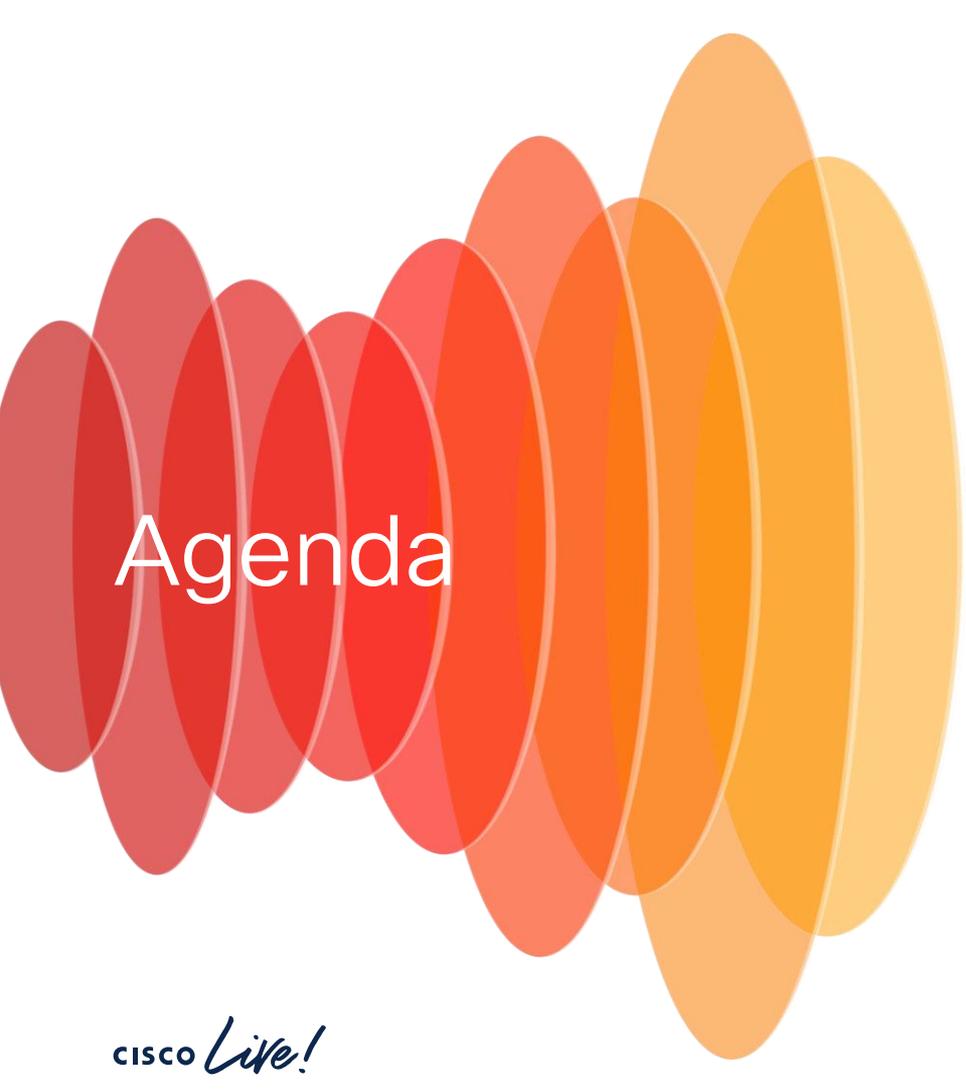
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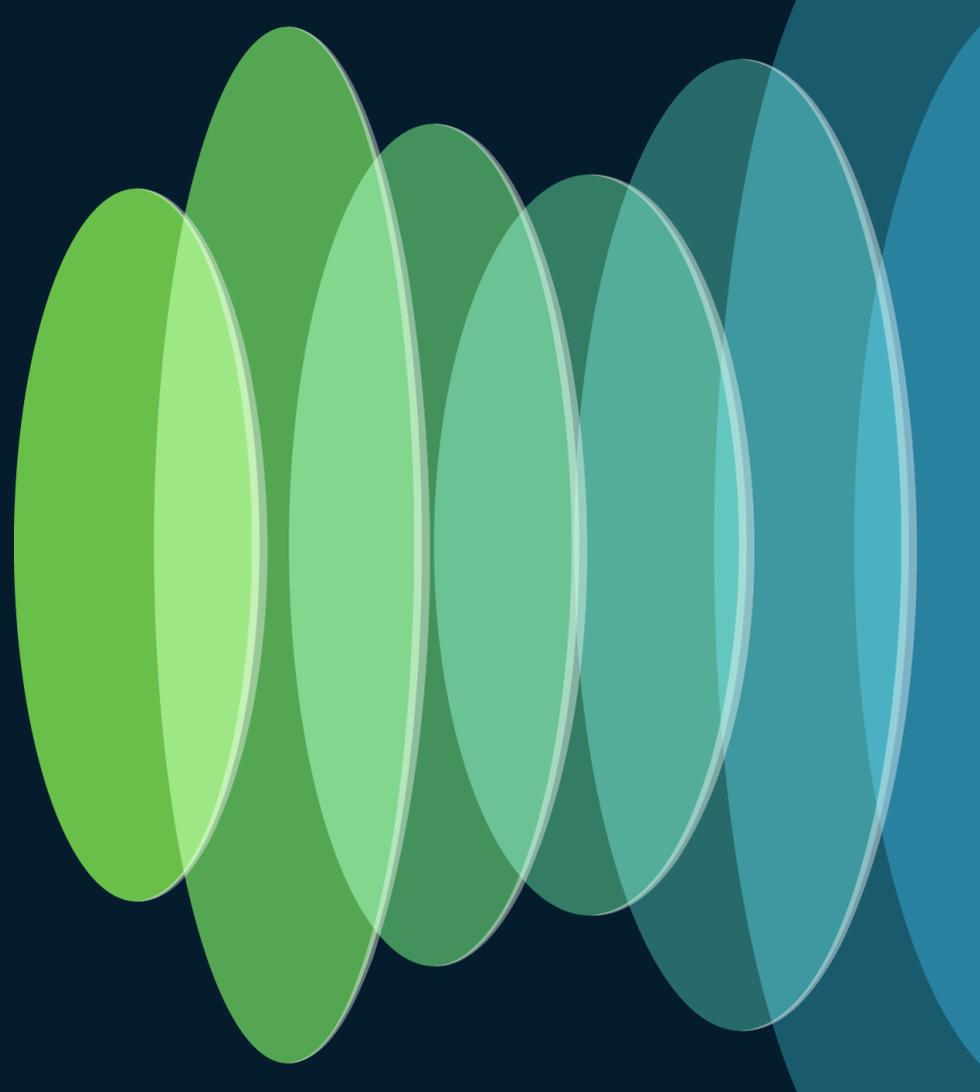


Agenda

- Introduction
- Scaling & Simplifying Wide Area Networks
- Technology Building Blocks
- Adoption Journey
- Conclusion

Introduction

“How to simplify WAN networks to address traffic growth and connectivity demands?”

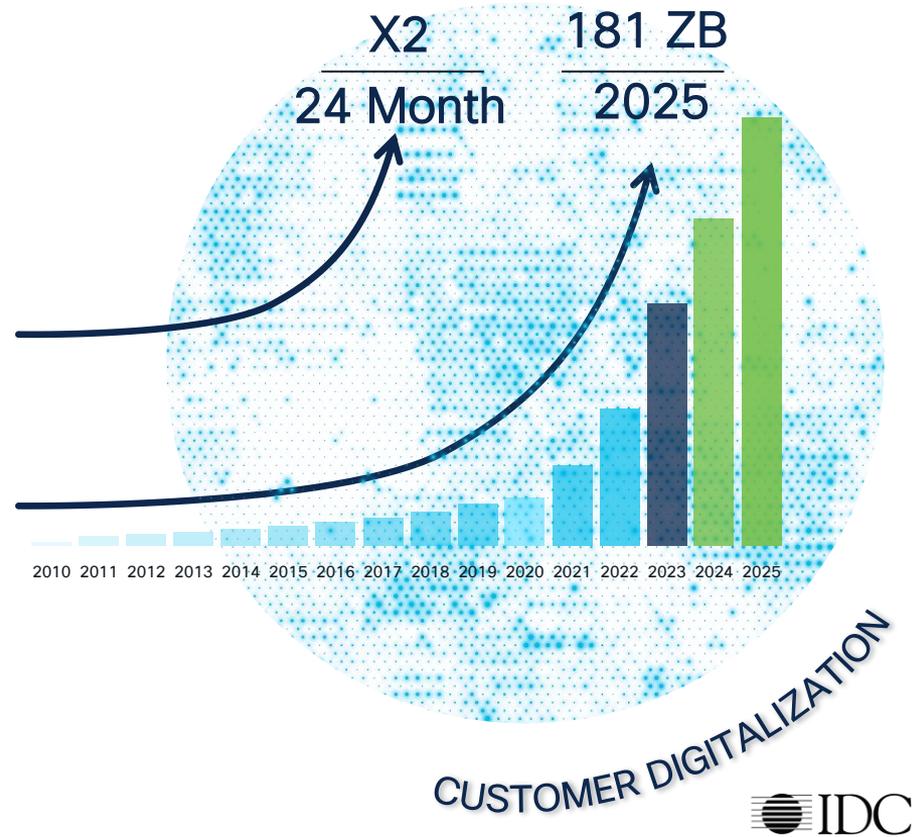


Data explosion

Consumption of Data is growing
50% per each year!

Creation of Data will grow
150% to 181 zettabytes in 2025!

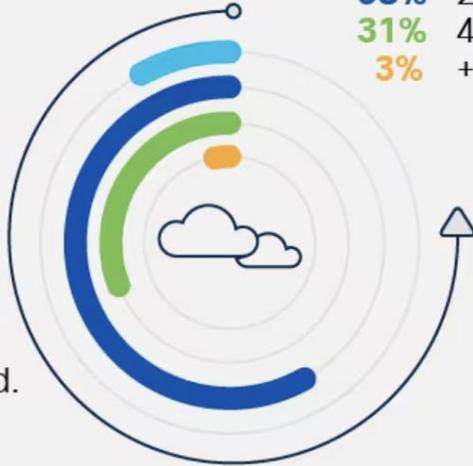
Over the last 2 years,
90% of the world's data was generated.



The Move to Multicloud Continues Unabated

Number of IaaS cloud providers

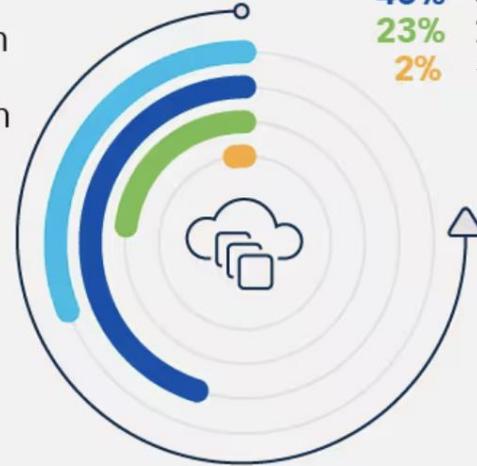
Multicloud is the norm, with **92%** reporting using more than one public cloud.



Number of IaaS cloud providers	Percentage
0-1	8%
2-3	58%
4-10	31%
+10	3%

Number of SaaS applications

SaaS application use is proliferating, with **69%** saying they use more than five services.



Number of SaaS applications	Percentage
1-5	31%
5-10	45%
20-100	23%
+100	2%

Cisco 2023 Global Networking Trends Report

But applications are built in complex environment

Challenges



Data Placement –connectivity, performance, privacy, solvency



Security – regulatory requirements data privacy



Efficient Hybrid Cloud Connectivity

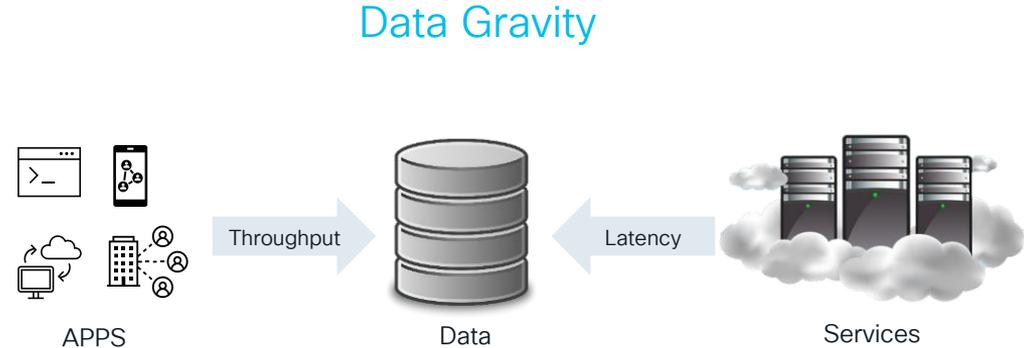


Sustainability



Improving Customer Experience through Efficient Data Access

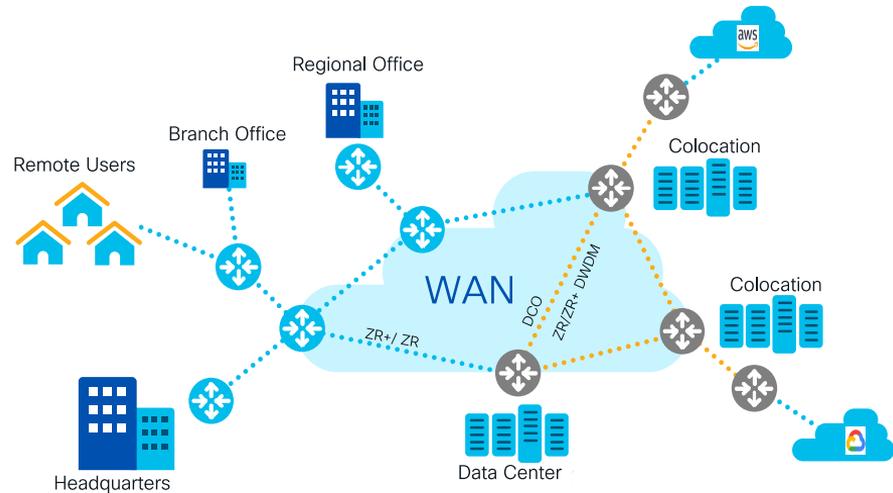
- **Data Gravity** is one of the key issues causing poor apps performances and user experiences with hybrid-cloud
- When **applications** and **data** are scattered in different locations, a private service backbone network with the following characteristics is required:
 - High bandwidth
 - Low and consistent latency
 - Time to market (Immediate Services Availability)
 - Reduced OpEx



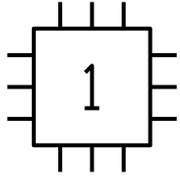
[Data Gravity: Driving Design for Intelligent Mission Fabric](#)

Network needs to Adapt to new Requirements

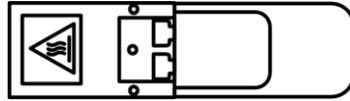
- More exit points to data and applications
- High bandwidth at lower cost per bit
- High resiliency, predictability, performance
- Network simplification
 - Device operation, visibility, fiber efficiency, troubleshooting
 - Service convergence
 - Operational Efficiency -Simpler and scalable operations
- Sustainability



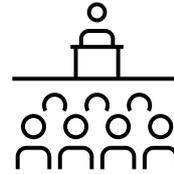
Industry Innovations Enabling Network Scaling and Simplification



Silicon



Optics



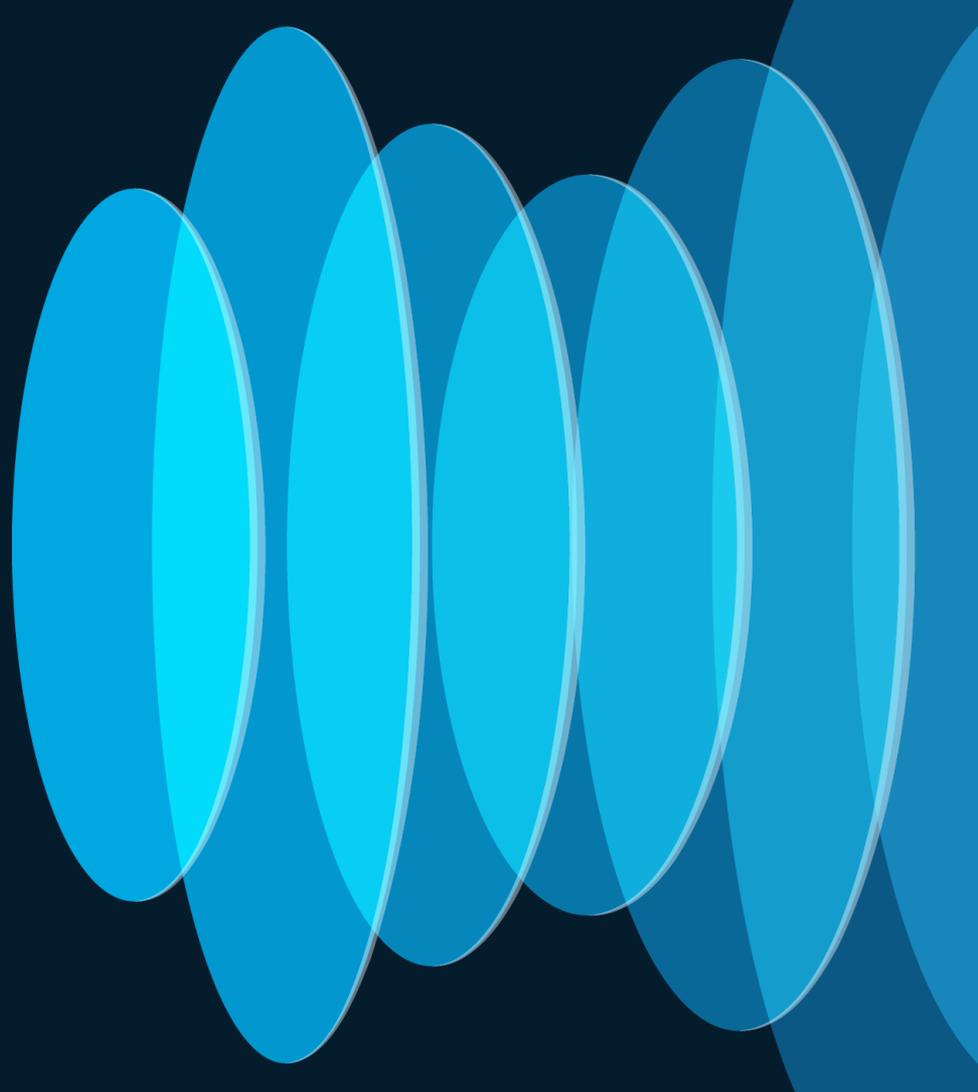
Standards & Systems



Software

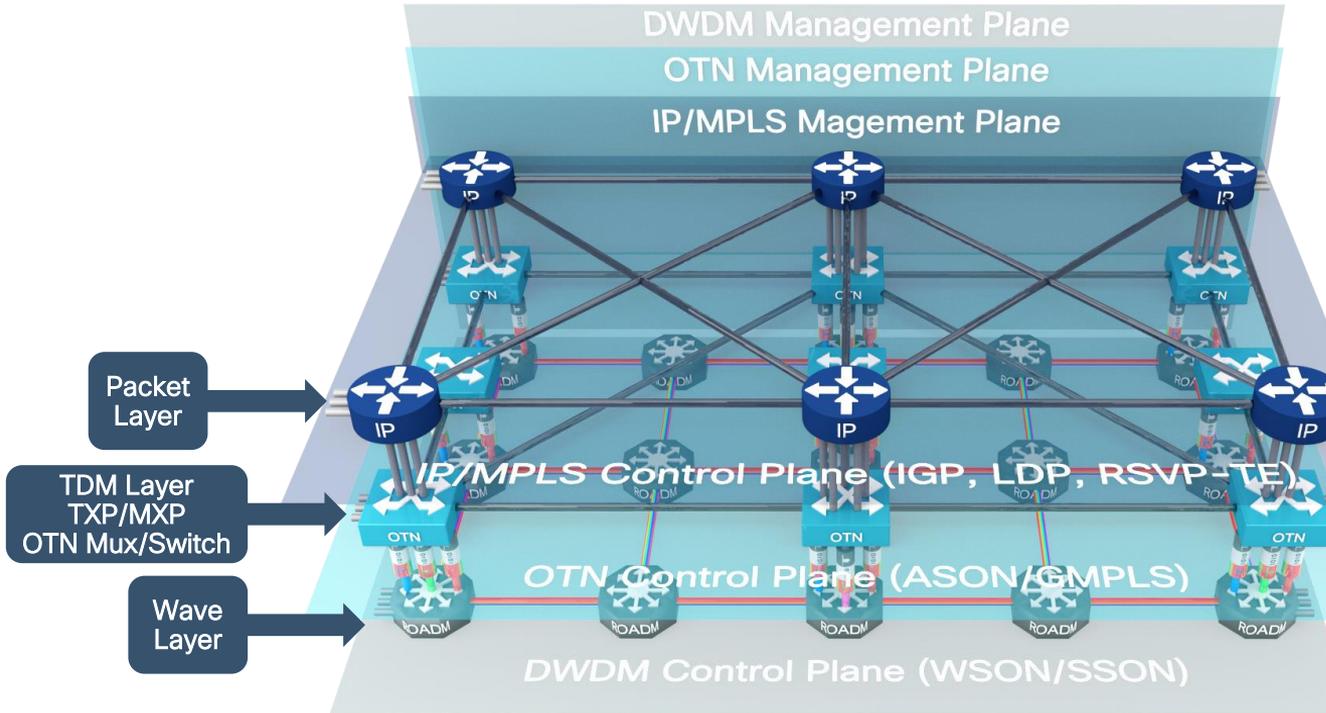
Why Change Now !

Scaling and Simplifying Wide Area Networks



Today's Layered Network

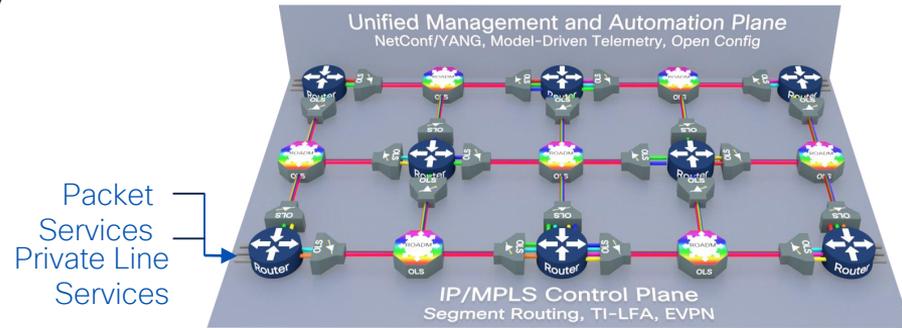
What's wrong with it?.



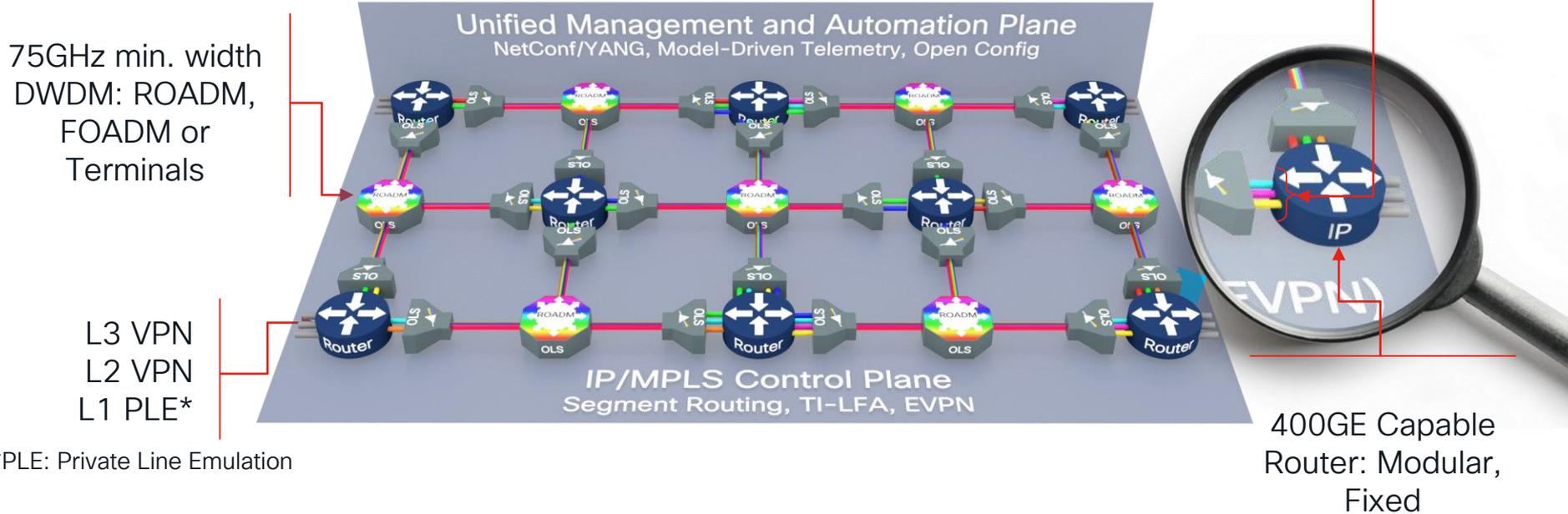
- Three Different control Planes (each treated individually)
- At a minimum – three Management Platforms
- 90%+ of services at Packet Layer
- Separate staff and skills to operate the networks.
- Huge amount of idle and/or duplicate capacity
- Not trivial to make changes / engineer network expansions.

Addressing Scaling WAN w/ Routed Optical Networking (RON)

- Routed Optical Networking is a new architecture that greatly improves the economics, scale and efficiency of networking including:
 - Lower interconnect cost w/DCO
 - IP/MPLS awareness of the optical network and its performance, more predictability
 - Higher utilization of network assets – better efficiency and sustainability
 - Simplified network architecture & capacity expansion
 - Automation friendly – Open programmable
 - Massive capacity w/ latest silicon technology



Defining Routed Optical Networking



Extensible IP Centric Architecture with Simplified Optical Transport

Routed Optical Networking benefits

Previous Generation Networking *Closed, proprietary, silo'd*

Routed Optical Networking *Open, disaggregated, integrated*

DWDM Transponders
Complex and expensive

Digital Coherent Optics pluggables – Lower cost, lower power and integrated into router / switch / host

Packet switching
Scarce and expensive

Cost effective packet switching – highest capacity at lower cost/bit available everywhere. Mix match DCO/non DCO on LC

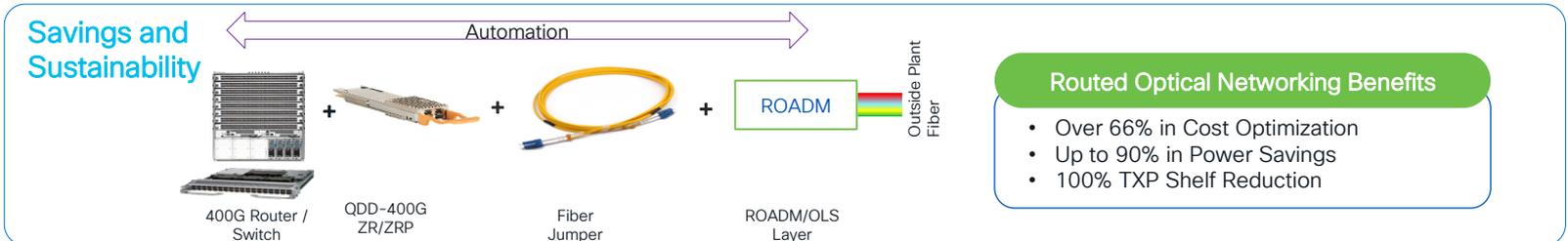
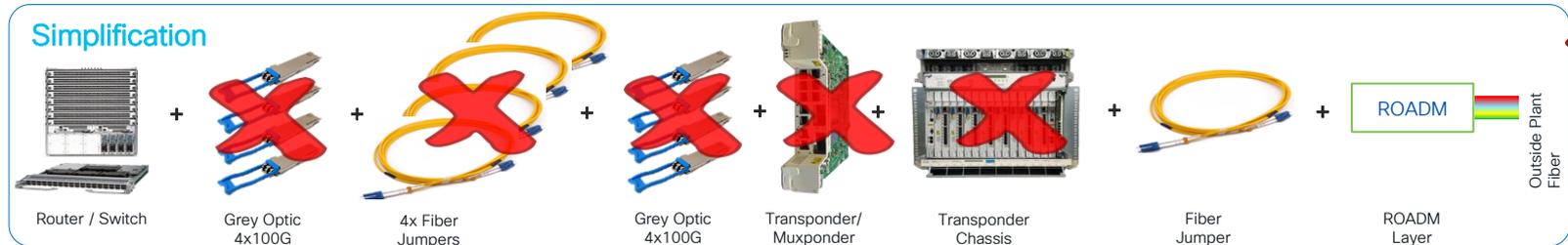
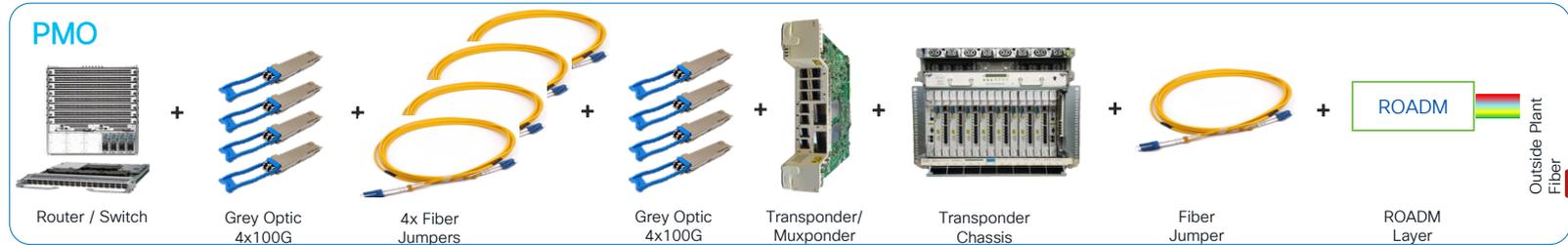
Multiple services = Multiple networks
IP, Ethernet, OTN, DWDM

Full services convergence – all services and SLAs supported over one end-to-end network

Management systems
Closed, proprietary, siloed

OLS, Open APIs and data models – lower cost for Systems Integration and automation

Coherent Optics enables - Simplification, Cost Saving & Sustainability



Routed Optical Networking addresses WAN scaling requirements

Cost
Effective
Capacity

Today's DCO optics support longer distances
Campus – Metro – Regional – Long-Haul Applications
Up to ~46% TCO Savings
Shorter time-to-market for services

Full IP
Convergence

IP Flexibility to deploy applications where needed
Better ROI and TCO
Converged IP/MPLS/SR EVPN End-to-End

50% Fewer
Devices

Reduced deployment costs
Reduced failure domain, easier troubleshooting
Improved reliability
Integrate TXPs fewer devices

Operational
Efficiency

Simplified network
Converged all Services on a single Network Layer
Eliminate siloed IP and Optical layers
Standardization and interop

Sustainability 

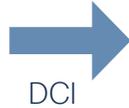
Compact DCO form-factor
Massively Scalable Silicon – efficient power/bit
Silicon Photonics
Space, power

Routed Optical Network – Market Segment Agnostic

SP & Enterprise Application

Customer Outcome

Simplification



DCO & non SPP



RON

Si1 powered platforms



Coherent Optics/ SP Routing



Customer Outcome

Power Optimized



Open / no vendor lock



3rd Party Platforms / OLSs



Automation L0-L3 Visibility

LH/Hybrid

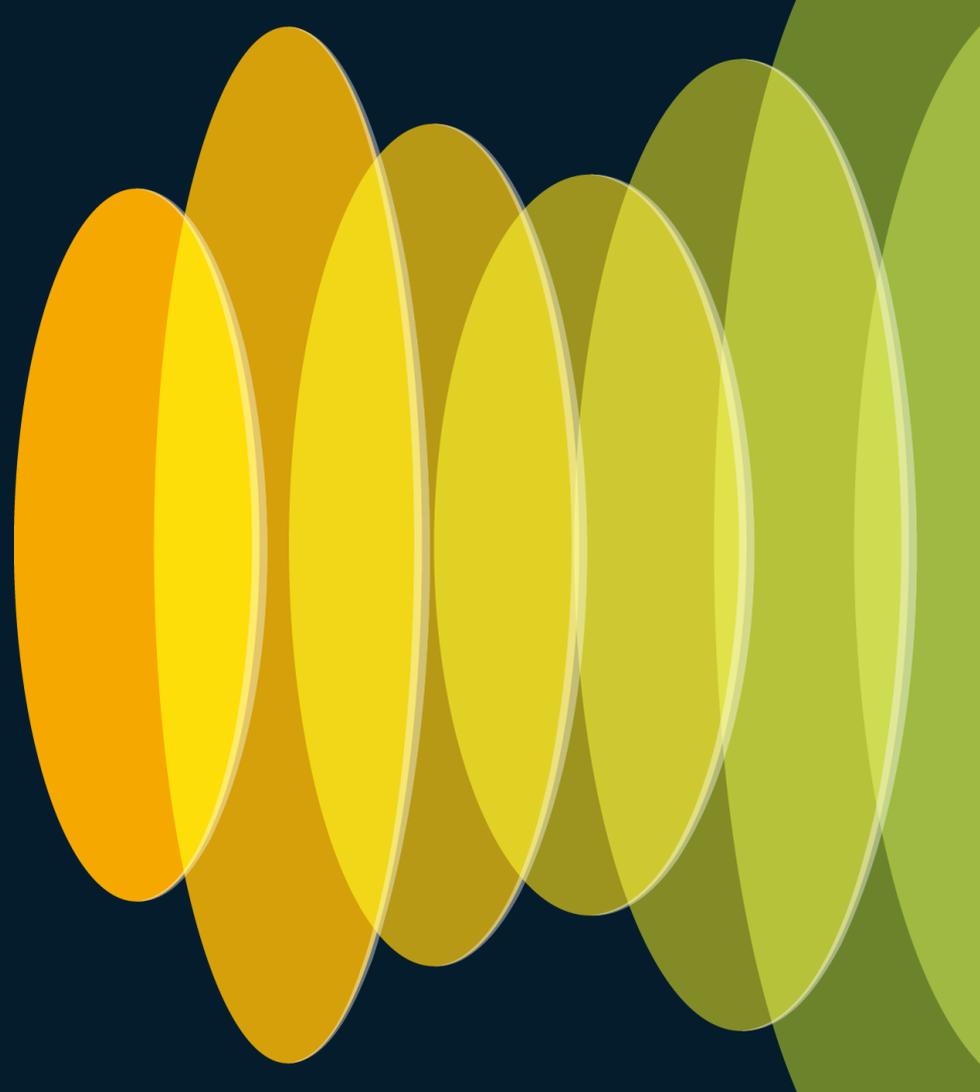
Optical Systems



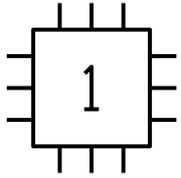
Performance Optimized

Sustainability/TCO Optimized Architecture

Technology Building Blocks

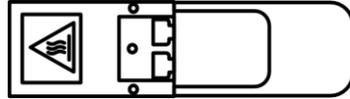


Game-Changing Industry Innovations



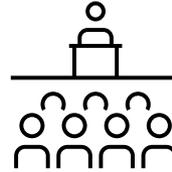
Silicon

- Routing scale evolution
- Enabling >25 Tbps / RU
- SoC and multi-purpose
- Lowest power and footprint per bit
- Increasing router/switch bandwidth



Optics

- Shift in economics in optics economics
- QSFP-DD – form factor best port density, excellent power/thermal profile
- 90% more power efficient than traditional transponder
- Digital Coherent Optics (DCO)
 - SiPh, 5nm-7nm DSPs,
- Optics: 400ZR, 400G ZR+, 800ZR, 800G ZR+



Standards & Systems

- Optical Systems Evolution
- OIF, OpenROADM, MSA's, IEEE, ..
- DWDM: Open Line Systems, Pluggables
- Data Models: OpenConfig
- CMIS



Software

- Automation
- IP/MPLS
- SR-MPLS, SRv6
- Hierarchical Controller
- Converged Transport Services over IP

It's all about ASICs, SerDes, and Optics



← 204.8T is 16x the bandwidth of 12.8T



Cisco 8201-32F 32 ports of 400GE in 1U

Switching Capacity



640G



1.28T



3.2T



6.4T



12.8T



25.6T



51.2T



102.4T



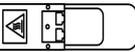
204.8T

320x increase in switching bandwidth over 16 years

Cisco One ASICs

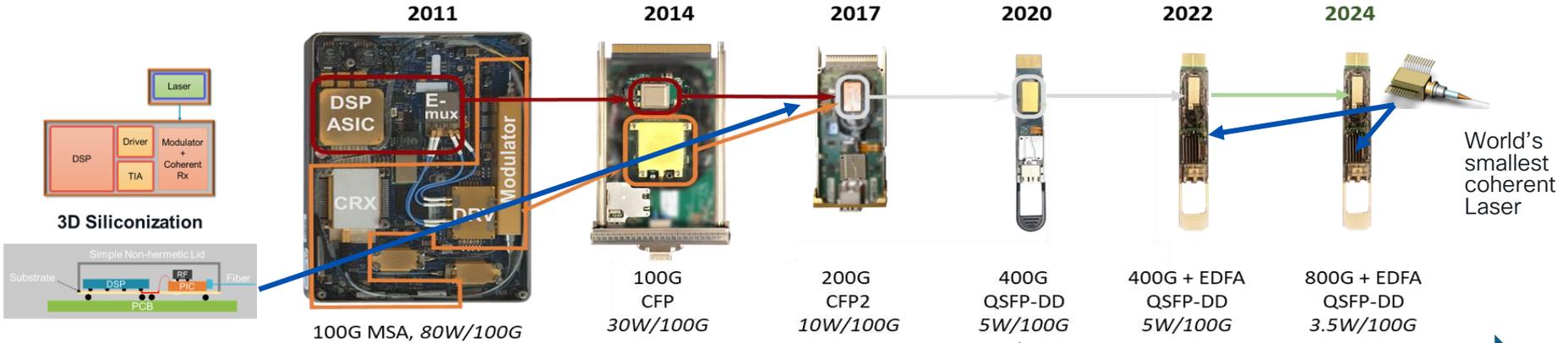
Year	2010	2012	2014	2016	2018	2020	2022	~2024 ?	~2026 ?	in 16 years ...
ASIC # SerDes	64	128		256		512			1024	16x
Serdes Gbps	10G NRZ		25G NRZ		50G NRZ		100G PAM4	200G PAM4		20x
Optics/Port	QSFP+		QSFP28		QSFP-DD56		QSFP-DD800	QSFP-DD1600		5 pkgs
Port Gbps	40G		100G		400G		800G	1.6T		40x
Ports/Router	16	32	64	32	64	64	64	64	128	

ASIC density continues to redefine how products are built. Gates & GHz. SerDes & Interconnect. Optics & wavelengths.



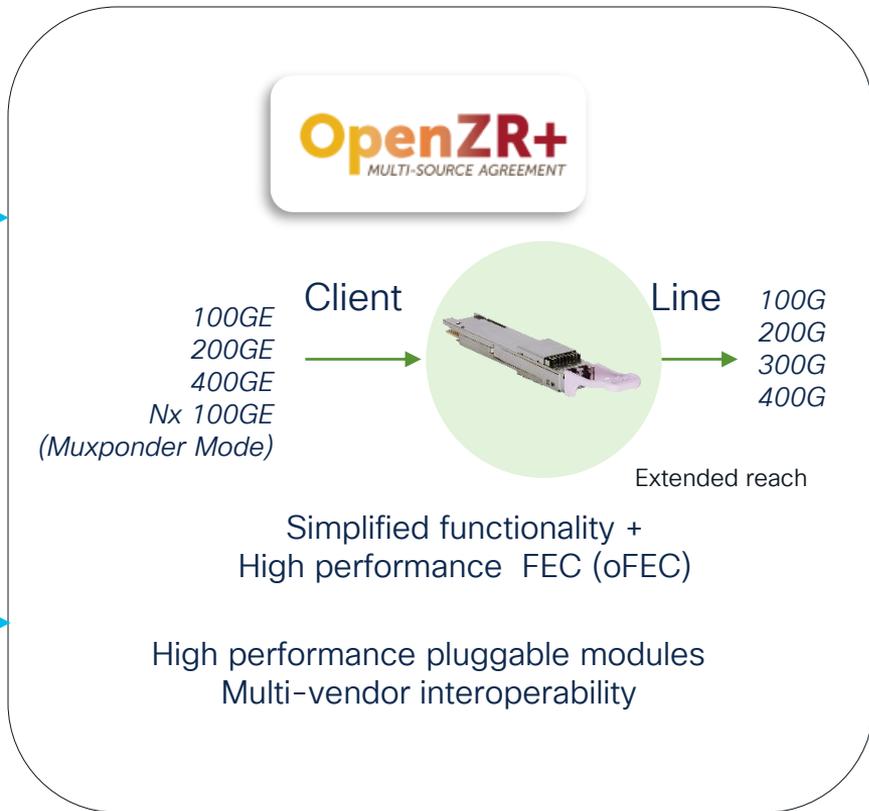
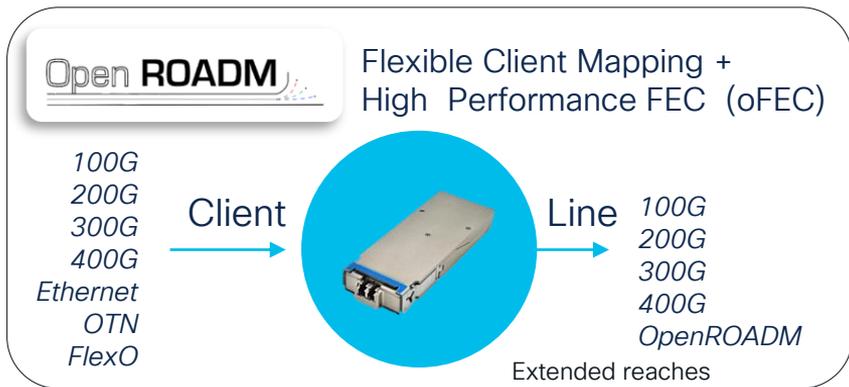
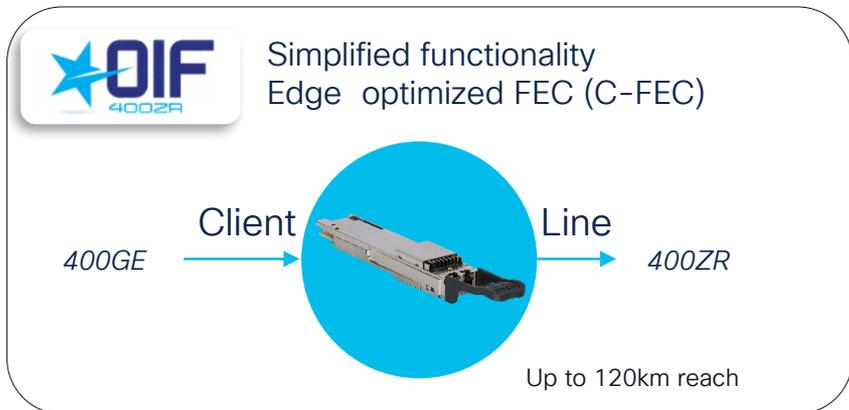
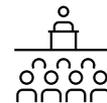
Coherent Optics Evolution

Vertical Integration is Key to Density & Performances



QAM:	QPSK	QPSK	16QAM	16QAM	PCS
CMOS:	40nm	28nm	16nm	7nm	4/3nm
Optics:	Discrete, InP, LiNbO3	SiPh	SiPh	SiPh	SiPh

400G DCO Standards and Industry Specifications



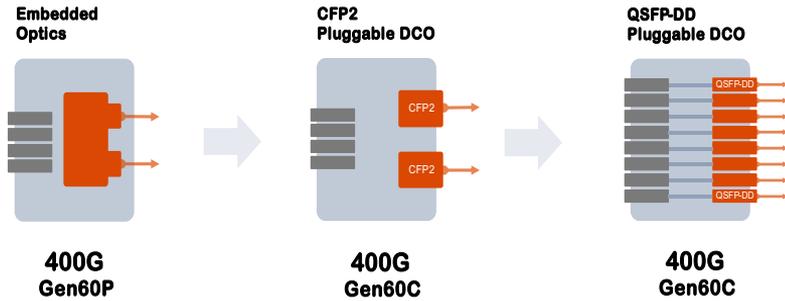
Digital Coherent Optics Target Use Cases



	400ZR	OpenROADM	OpenZR+
Reach*	< 120km	> 120km	> 120km
Client	400GE, 4x100GE	100-400GE, OTN	Nx100GE, 400GE
Application	Campus, Metro, Edge DCI	SP Metro, Regional, LH, Carrier ROADM mesh	DCI, Metro, Regional, Long Haul
Form Factor	QSFP-DD, OSFP or other (no constraints in the spec)	CFP2 or other (no constraints in the spec)	QSFP-DD, OSFP or other
FEC	C-FEC	oFEC	oFEC
Max. Power Consumption*	~15W	Not Defined (no constraints in the spec)	~23W
Multivendor Interop	Yes	Yes	Yes
Standards	OIF	OpenROADM	OpenZR+ MSA

*Dependent on modulation format and data rate. Target reaches consider use of optical amplifiers.

Coherent pluggable – Enabling efficient network architectures



Density is improving many folds;
power per bit coming down
dramatically*

Routed Optical Networking (RON)



Deployment Models:

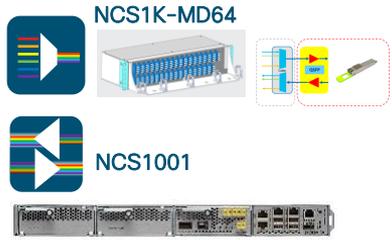
- 3rd party OLS / Cisco OLS
- Dark fiber or Passive DWDM

400G Enabled Router & Switch Platforms

Cisco 8000
ASR 9000
NCS
5500/5700
NCS 540

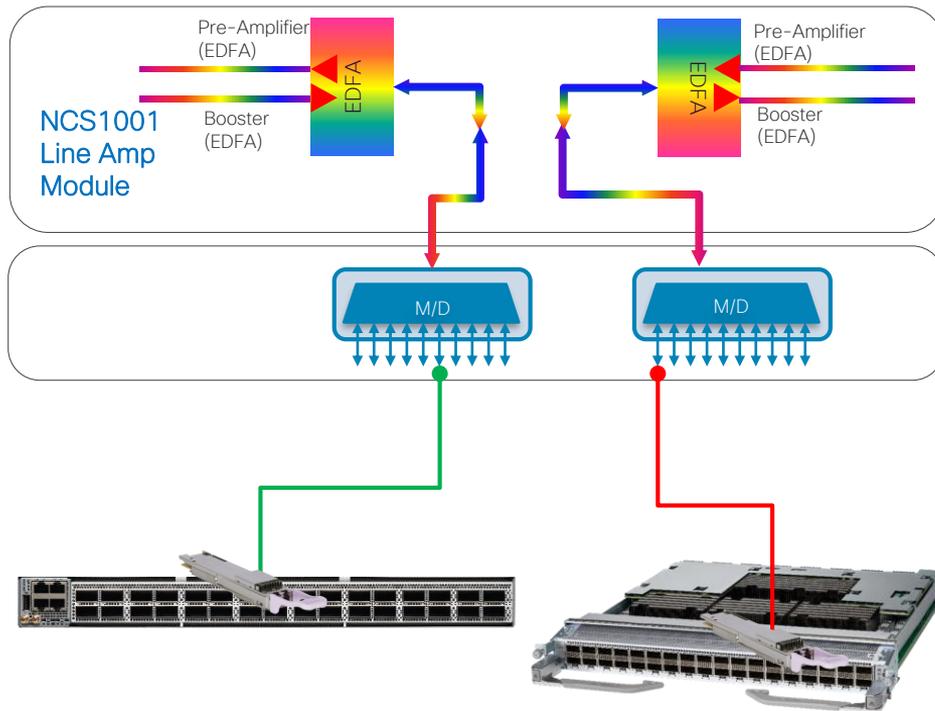
Nexus 9800
Nexus 9500
Nexus 9400
Nexus 9300
Nexus 9232E

Catalyst 9600X
Catalyst 9500X





Routed Optical Network over simple line systems



NCS 1001
Line Terminal/ILA



4, 48, 64-ch
Optical
Mux/Demux

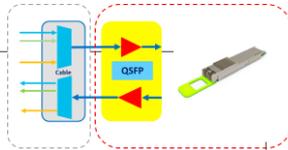


- H2H (Hop-to-Hop) only (no Optical Bypass)
- ZR @ 400G & ZR+ @ 100G, 200G, 300G & 400G
- Compact 1RU NCS1001 having EDFA and OTDR options



OLS Simplification w/ QSFP-DD Pluggable

Overview



- Bi-directional EDFA integrated into 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
- Supports 4/8/16/32 channel systems
- Passive 8chs Coupler/Splitter integrated in a cable available as well for low-end applications

Benefits

- No need of external WDM system for point-to-point applications
 - Everything embedded in the router
 - No need to manage/operate/upgrade/plan an external WDM system
 - Extremely simple to install and use without any need of optical expertise
- Various solutions with few channels (FLD4 FOADM) or many channels (64ch Mux/Demux for 32x 400G point-to-point system)

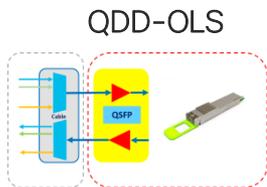


Open Optical Line System Options

Open – Supports all compatible transponders



Cost Optimized



NCS-1001

- 120km Point to Point
- FOADM



Reach/Reliability

NCS-1010

- Metro-Regional-ULH
- PtP, Ring and Mesh
- FOADM/ROADM/FLEX



Flexibility

NCS-2000

- Metro-Regional-ULH
- PtP, Ring and Mesh
- FOADM/ROADM/Flex



Key Technologies in RON IP/MPLS Layer

- IGP of choice (IS-IS, OSPF)
- MP-BGP and BGP-LS
- DiffServ QoS

“Business as usual”

- YANG model-driven programmability & telemetry
- Segment Routing (SR) and SR-TE (Traffic Engineering)
- Centralized (SDN) Controller with PCE (Path Computation Engine)
- PLE (Private Line Emulation)

Optional

Routed Optical Networking *can* leverage SDN architecture for network optimization. New service capabilities are also available with PLE.

Segment Routing (SR) at a glance

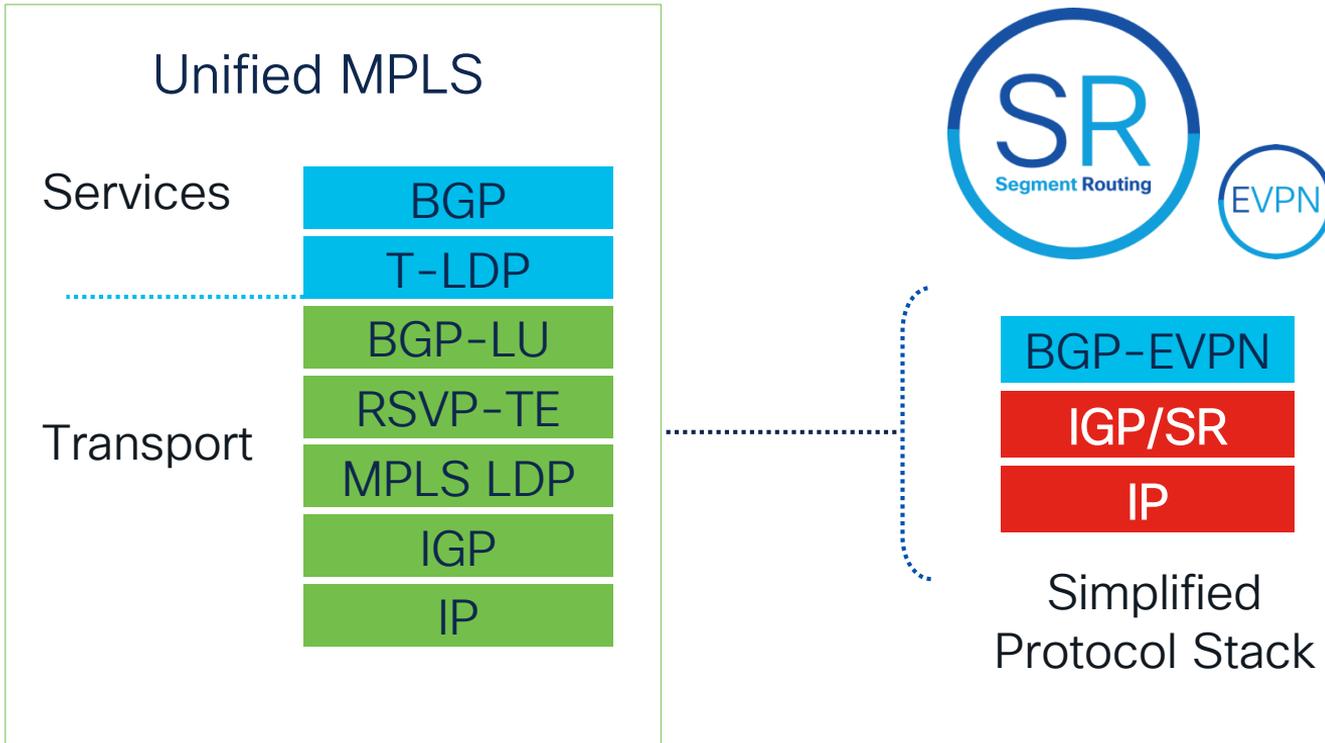


- A programmatic IP source-routing architecture that provides the optimal balance **between distributed** intelligence and **centralized control**
- **Network simplification**
 - Reduces control plane protocols (no LDP, no RSVP-TE)
 - Delivery of all network services (IP, MPLS, Ethernet, Private Line, Wave) over IP
 - Automatic <50 ms protection (topology independent), automated traffic steering
- **Realtime dynamic network optimization**
 - Sophisticated traffic rerouting around failures [TI-LFA, Remote weighted SRLG]
 - Performance measurement and path adjustment [TWAMP]
- **Advanced capabilities**
 - Advanced TE (flow-based, ECMP-aware, multi-domain, disjointness, circuit-style)
 - Network slicing, service chaining, data plane monitoring, delay performance monitoring



Segment Routing = Network Simplification

do more with less



Routed Optical Networking and Segment Routing

- Segment Routing (SR) *is not* mandatory for Routed Optical Networking. Classic IP/MPLS is supported as well.
- However, Routed Optical Networking will provide the best benefits when deployed over Segment Routing
 - Both SR MPLS and SRv6 are supported
 - Each option has its own set of benefits

Private Line Emulation (PLE)

- **CS-SR** provides the strict circuit-style TE required for supporting Private Line services over IP
- **PLE** provides the bit-stream IP packetization, clock synchronization and OAM
 - From the outside PLE looks like an OTN circuit
 - On the inside it's packet switching!
- **EVPN-VPWS** is the proposed MP-BGP based signaling protocol and VPWS demultiplexing mechanism for PLE bit-stream services

PLE

- Bit transparent (100% control protocol transparent)
- Multi-protocol (OTN, SONET/SDH, Ethernet, FibreChannel)
- SyncE, no MTU limits

EVPN-VPWS

- MP-BGP EVPN mechanism for Point-to-Point VPWS services
- Extensions added (PLE attribute) to support delivery of bit-stream services

Circuit-Style SR (CS-SR)

- Guaranteed bandwidth
- Persistent, co-routed, bi-directional paths
- 1:1 End-to-end path protection and restoration

Private Line Emulation (PLE)



structure agnostic emulation packet



Bit-stream packetization

EVPN-VPWS

Bit-stream de-packetization

Mapping the VPWS to a suitable path

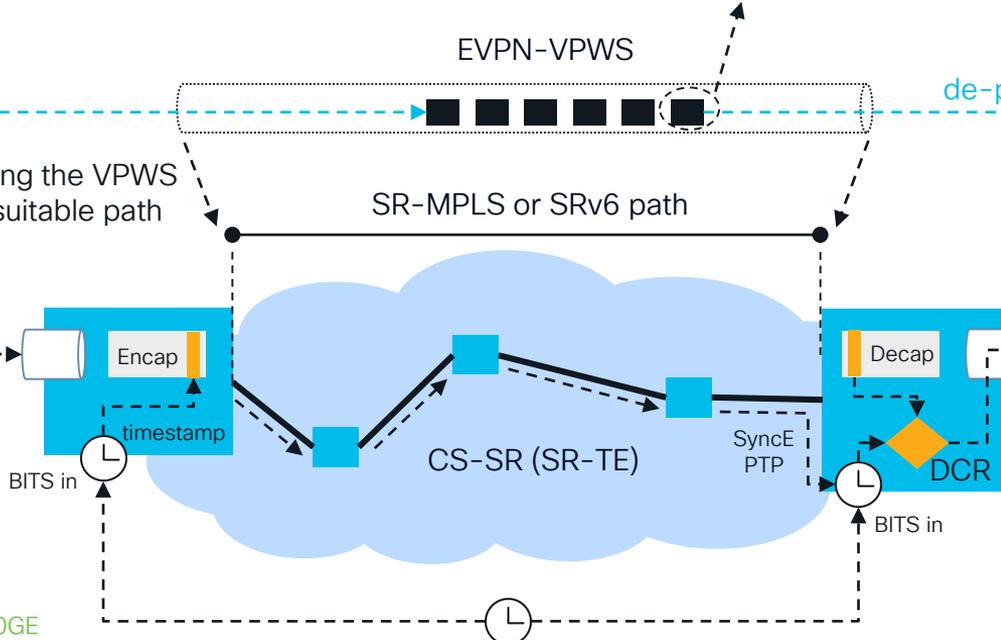
SR-MPLS or SRv6 path

Attachment circuit
(OTN, SONET/SDH, Ethernet)

Tx clock Attachment circuit
(OTN, SONET/SDH, Ethernet)

Transfer delay <10us per hop
Data Rates

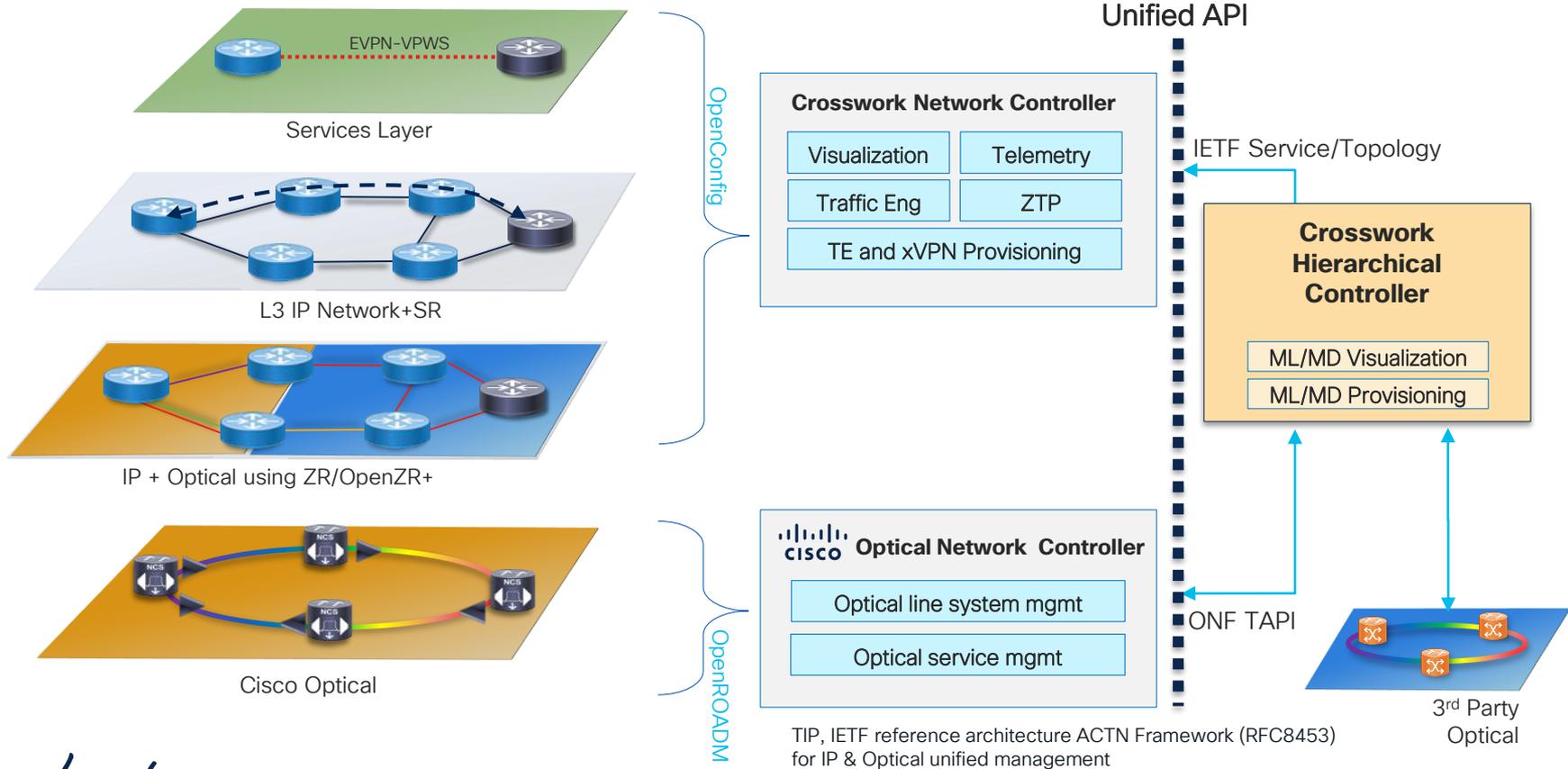
- ODU0, 1GE, FC100
- ODU1, OC48/STM16, FC200, FC400, FC800
- ODU2/ODU2e, OC192/STM64, 10GE
- FC1600, FC3200
- ODU4, 100GE, 200/400GE, 64/128GFC future



Common clock (frequency)
via SyncE, PTP or BITS

DCR ... differential clock recovery
CS-SR ... circuit-style SR policy

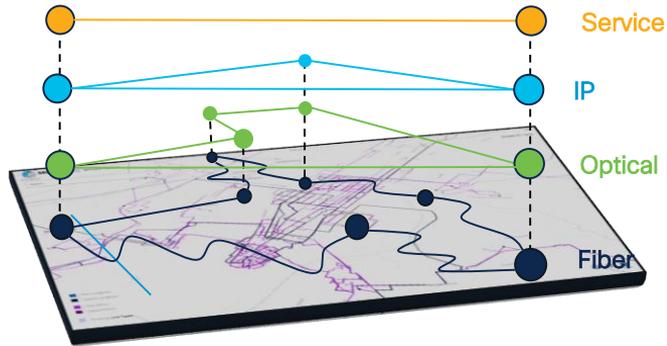
Routed Optical Network Solution Automation Stack



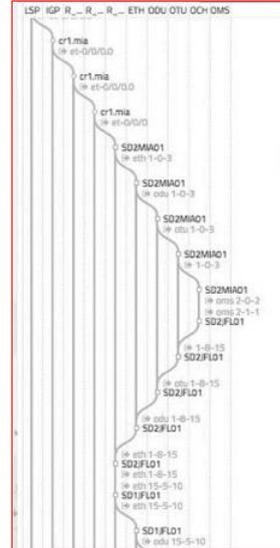
RON Automation

Service-to-fiber Visibility

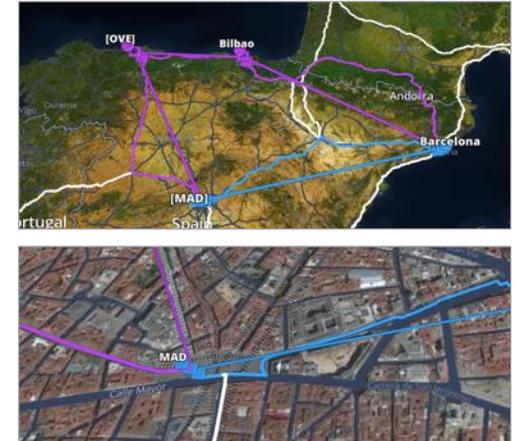
The Crosswork Hierarchical Controller Network Model – from service to fiber



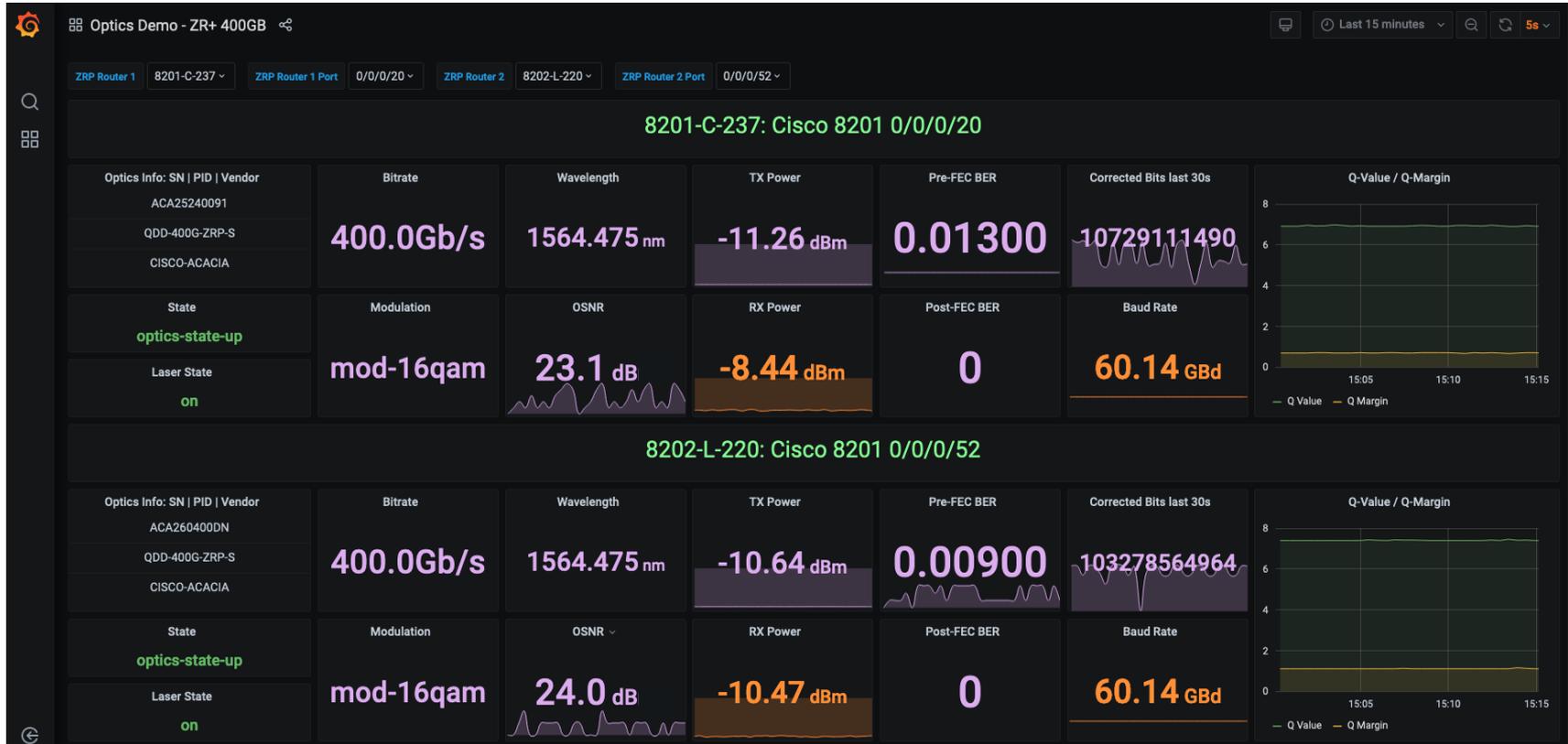
Layered service view in Crosswork Hierarchical Controller UI



Visualization of a protected private line service – zoom-out and zoom-in views



DCO monitoring using open-source Grafana



Routed Optical Networking Today and Future

Technology Innovations

Routing	Private-Line Emulation (Sub-100Gbps)	Private-Line Emulation (100Gbps)	
Optical Line System	Zero-touch Line System (NCS 1010)	Pluggable based Optical Line System	
DCO	400G DCO Bright ZR+	100G DCO (QSFP-28) 800ZR/ZR+ 400ZR LH	1.6 Tbps
Automation	Multi-vendor Hierarchical Controller with built-in DCO Mngt	Circuit-Style Segment Routing	Adaptive Routed Optical Networking



Legal Disclaimer: Many of the products and features described herein remain in varying stages of development and will be offered on a when-and-if-available basis. This roadmap is subject to change at the sole discretion of Cisco, and Cisco will have no liability for delay in the delivery or failure to deliver any of the products or features set forth in this document.

What is Adaptive Routed Optical Networking?

Network Controller based

Adaptive
Networking



Adapting optical connection
(RON link) to changing
transmission conditions



Adapting IP traffic to
change in RON link
capacity

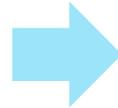
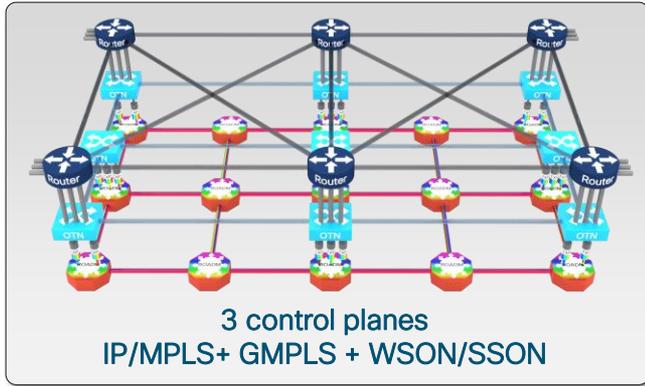


Adaptive Capacity: Modifying IP link capacity after optical path degradation

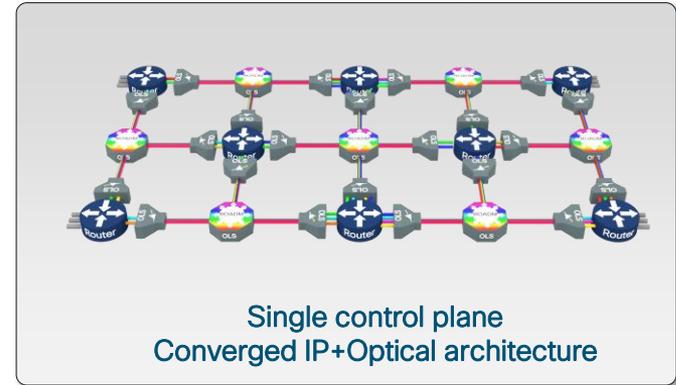
Multilayer Restoration: Modifying optical path and IP link capacity after optical path failure

Cisco Routed Optical Networking Investments

Today's Architecture



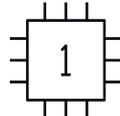
Routed Optical Networking Architecture



Cisco Investment to realize Routed Optical Networking



Transponder → pluggable
With ZR/ZR+ optics
(No capacity penalty)



leaba
semiconductor

Massively scalable
silicon



sedona
systems

Hierarchical Controller
Manageability of IP+Optical:
Industry standardization &
interop

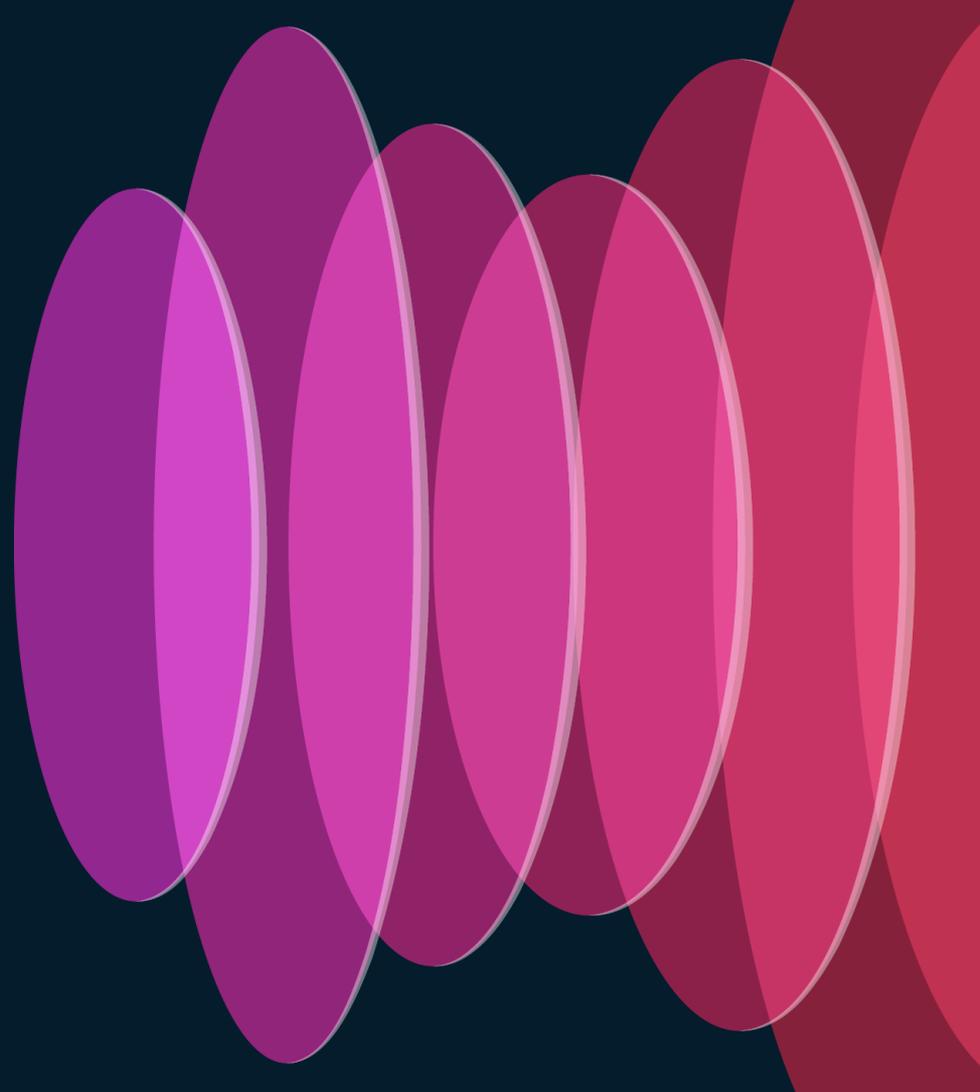


Open DWDM: Industry
standardization & interop
MSAs, IETF, Open
Standards



45% TCO savings
CAPEX: Higher
wavelength utilization
OPEX: Less power/space

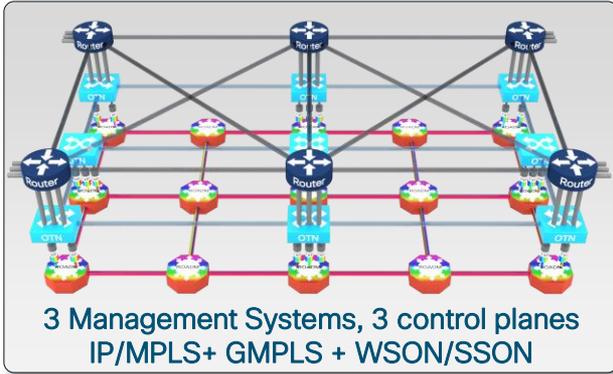
Adoption Journey



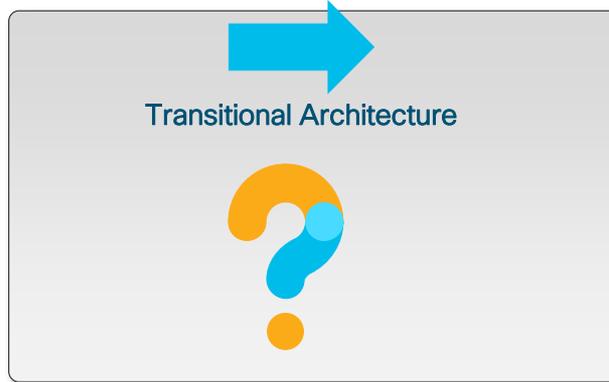
Routed Optical Networking Adoption Journey

How to get there?

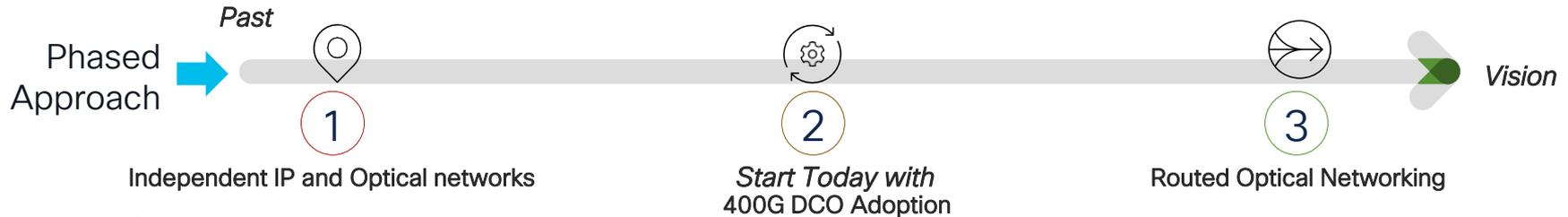
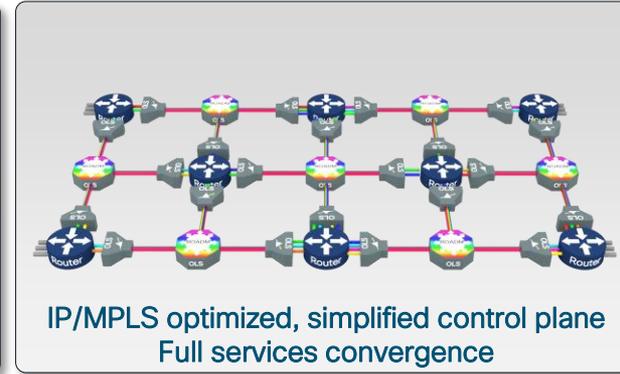
Traditional Multi-Layer Architecture



Transitional Architecture



Routed Optical Networking Architecture

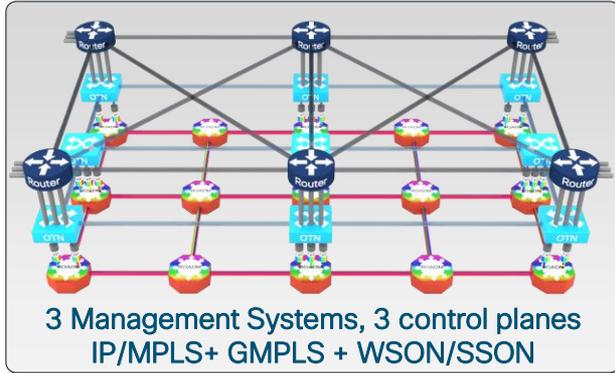


cisco Live!

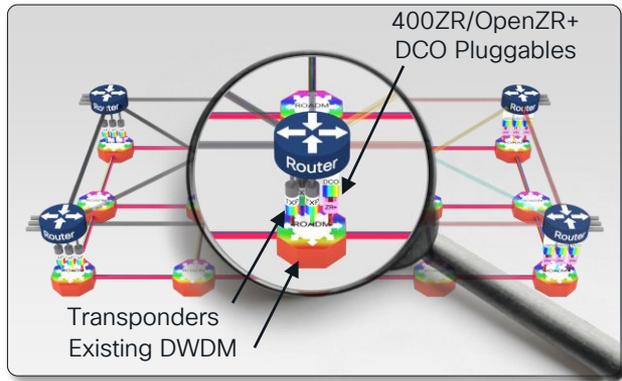
Routed Optical Networking Journey

How to get there?

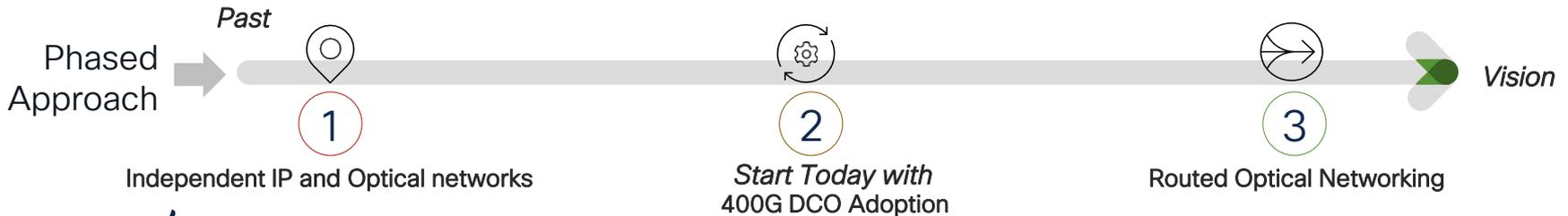
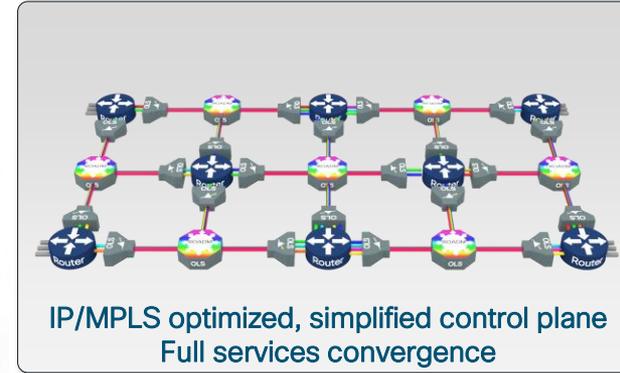
Traditional Multi-Layer Architecture



Transitional Architecture



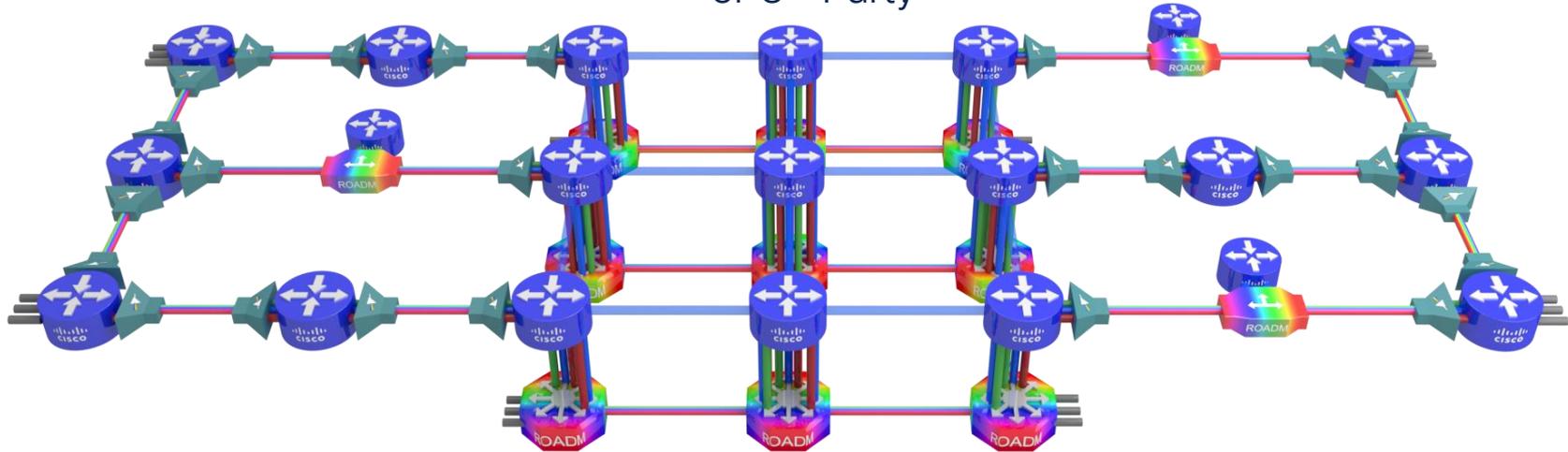
Routed Optical Networking Architecture



CISCO Live!

Routed Optical Networking Deployment Scenarios

Routed Optical Networking can leverage existing DWDM networks, Cisco or 3rd Party



Greenfield

Brownfield
(e.g. NCS 2000)

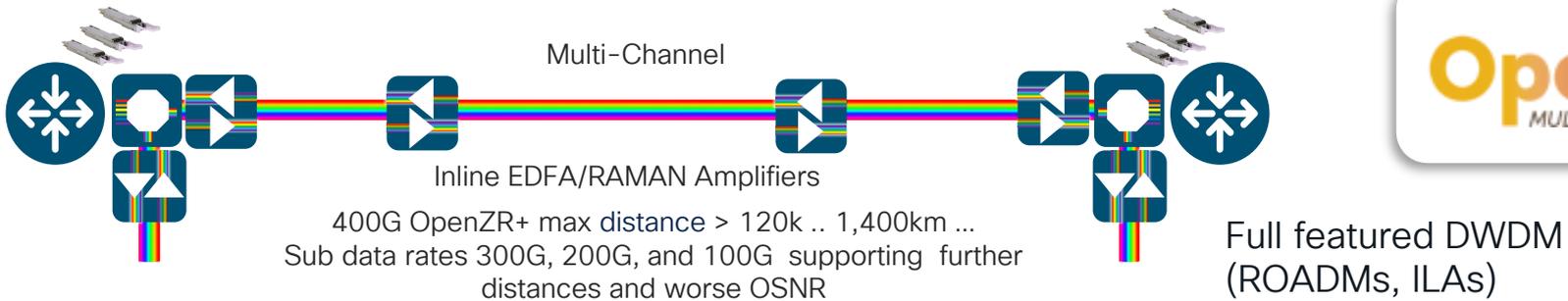
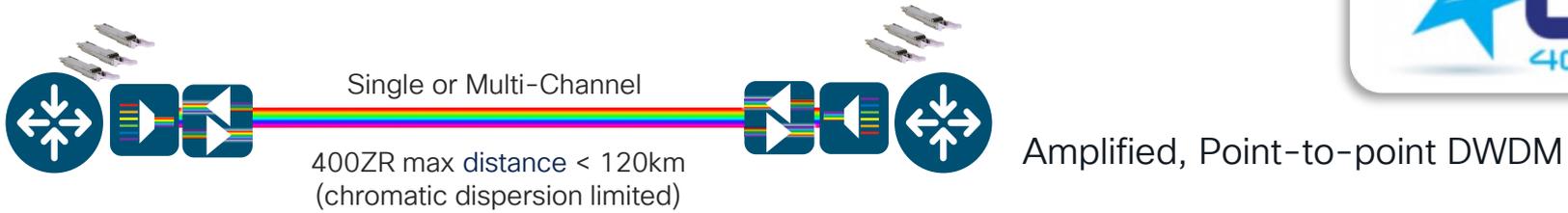
3rd party DWDM

Scaling WAN with Routed Optical Networking Use Case Examples

DCO integration foundational to all use cases

Data Center Interconnect
Metro, Edge, Regional, Long Haul
Enterprise WAN Underlay
Hybrid Cloud Private WAN Backbone
Public Sector – Government, Education, Municipality..
Service Providers, Utilities, Oil & Gas

PtP Link Engineering Options: Examples

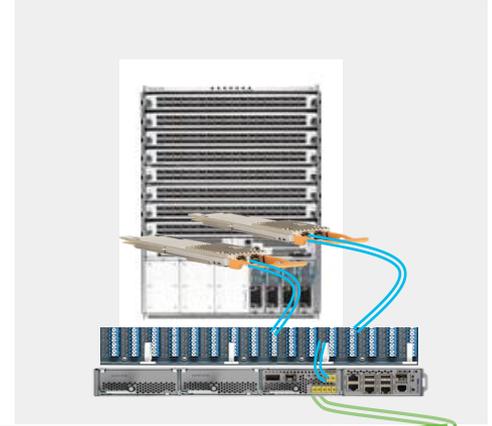


Simple P2P DCI Optical Transport with QDD-OLS

Router / QDD-ZR/ZR+

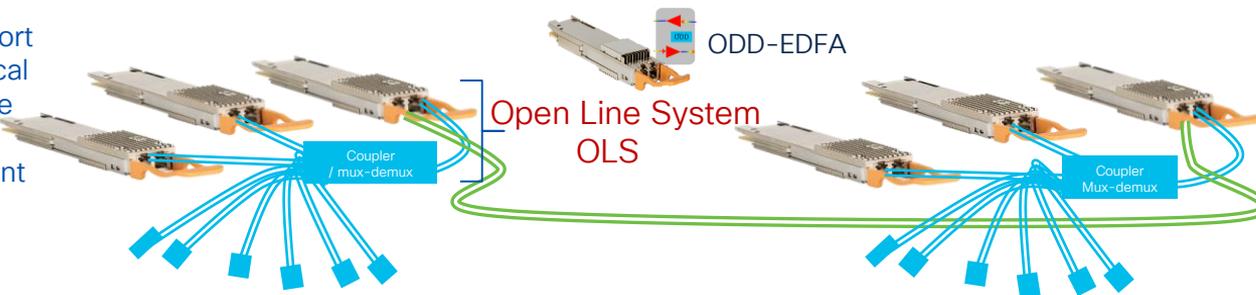


ZR or ZR+ for DCI
QSFP-DD form for
Transport
Optimization

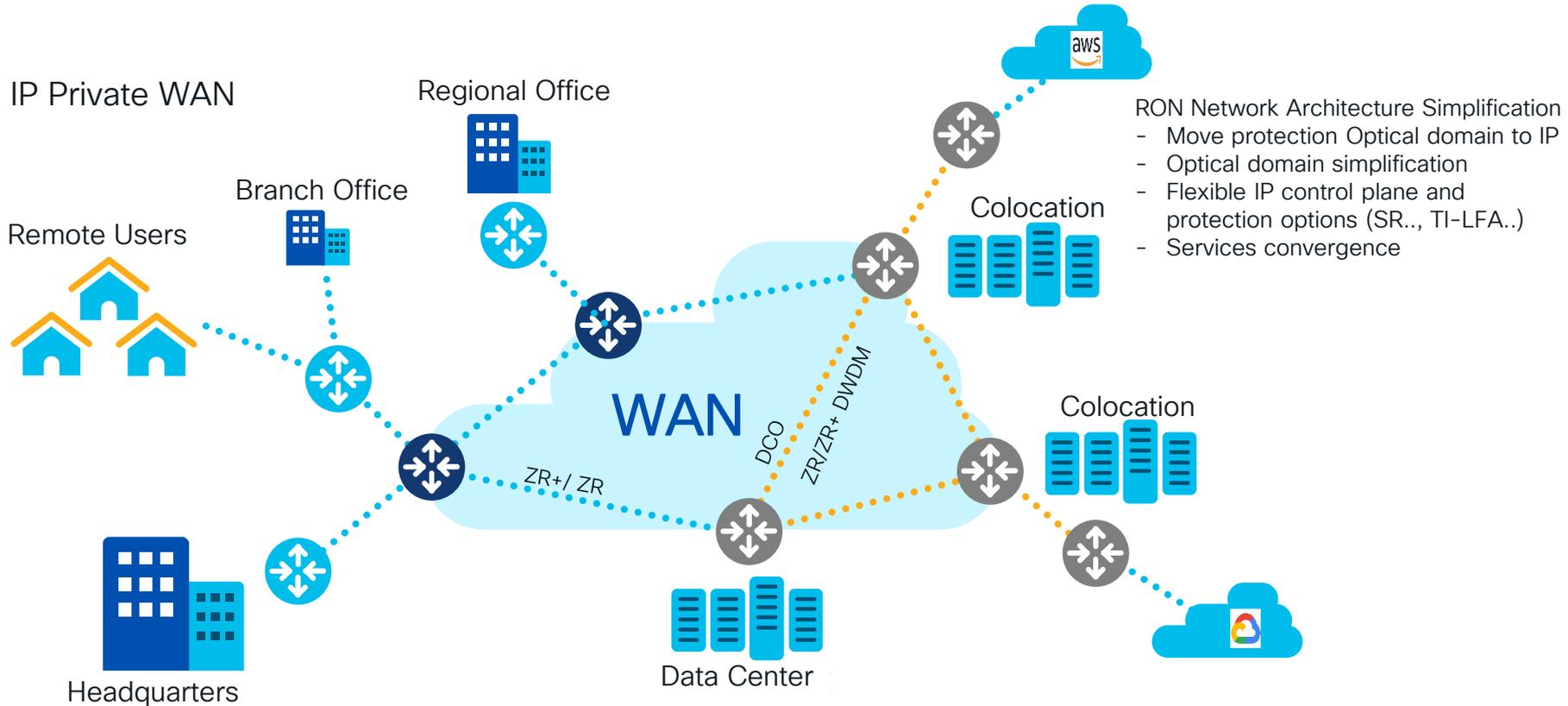


30dB 120km spans

OLS in a QSFP-DD transport optimization provides optical amplification in a pluggable QSFP-DD form-factor for Low and high channel count application



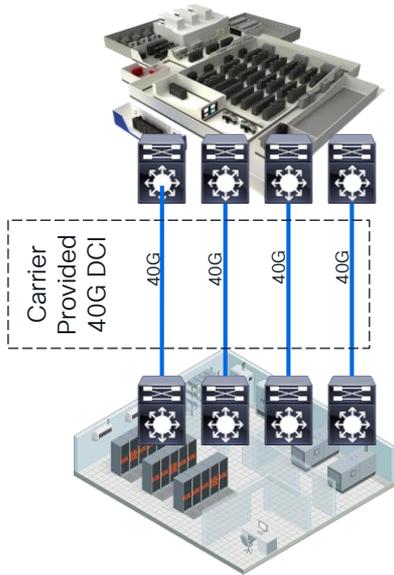
WAN Edge & Data Center Underlay Connectivity



- RON Network Architecture Simplification
- Move protection Optical domain to IP
 - Optical domain simplification
 - Flexible IP control plane and protection options (SR., TI-LFA..)
 - Services convergence

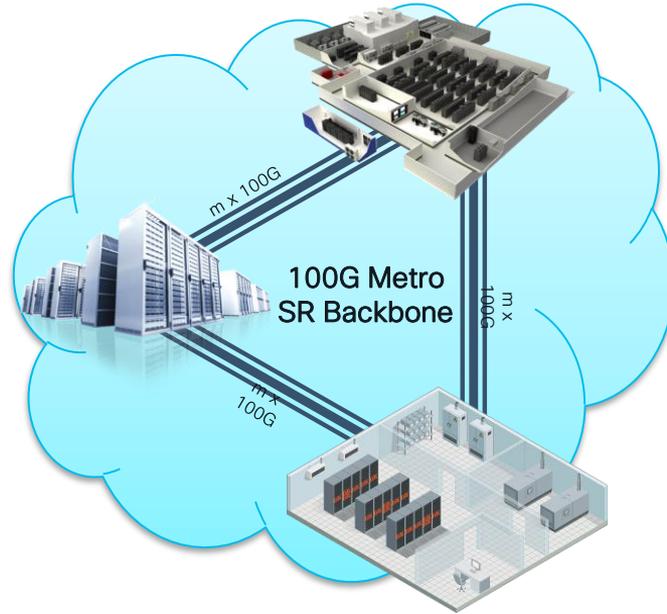
Resilient Hybrid Cloud Backbone

Large Financial Services Customer Journey

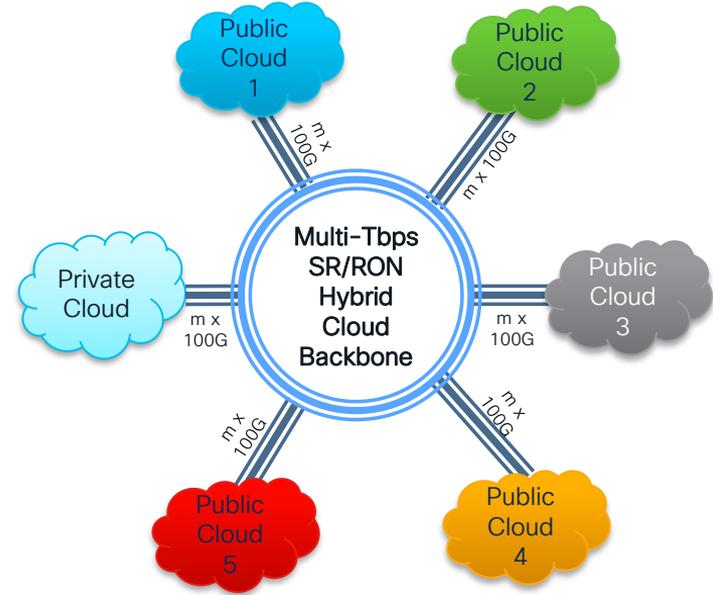


Prior 2018, 40G DCIs. Started research for a private backbone solution in 2015

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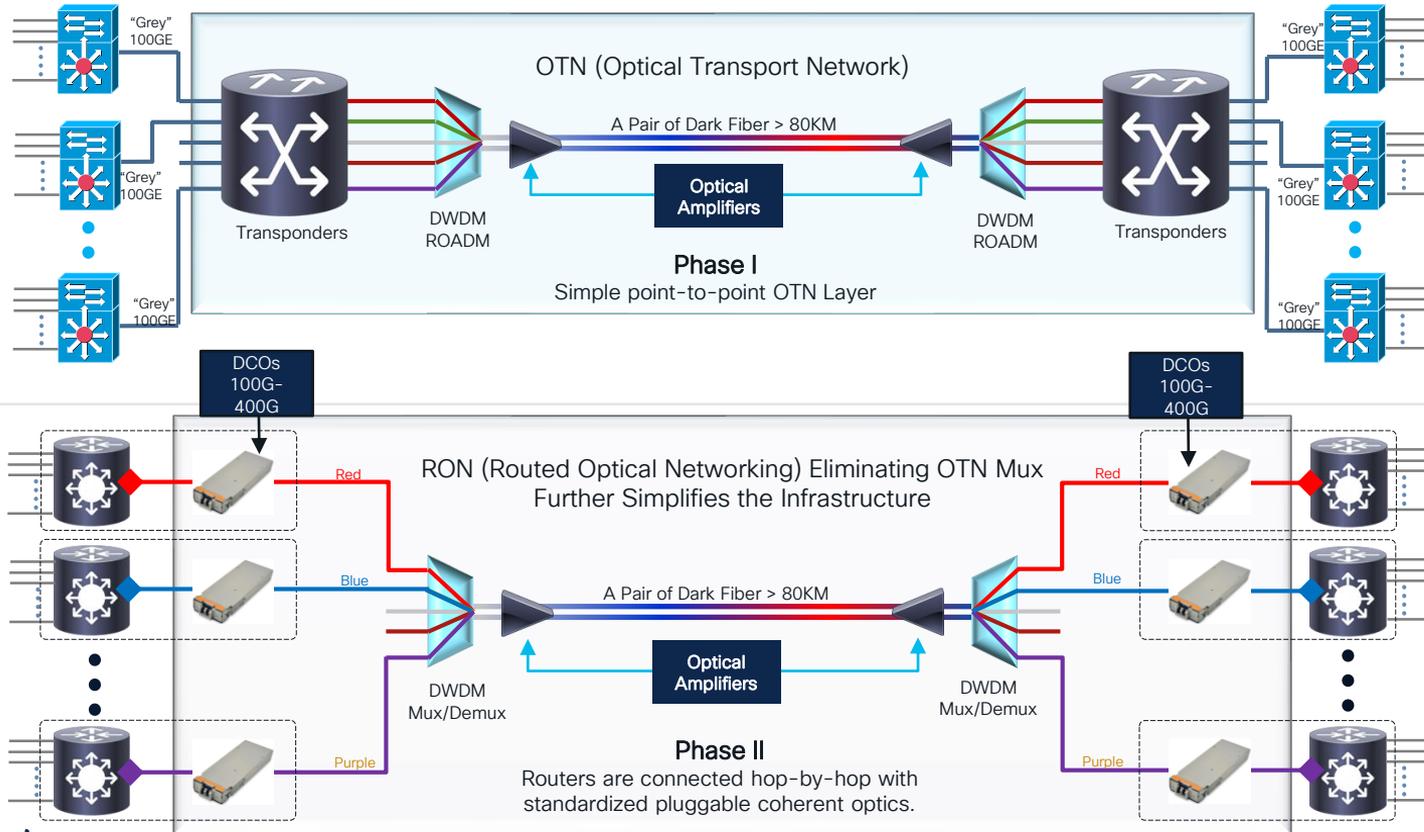


A multi-Tbps SR private backbone was in production 2018, consolidating all circuits and enabling a successful private cloud.

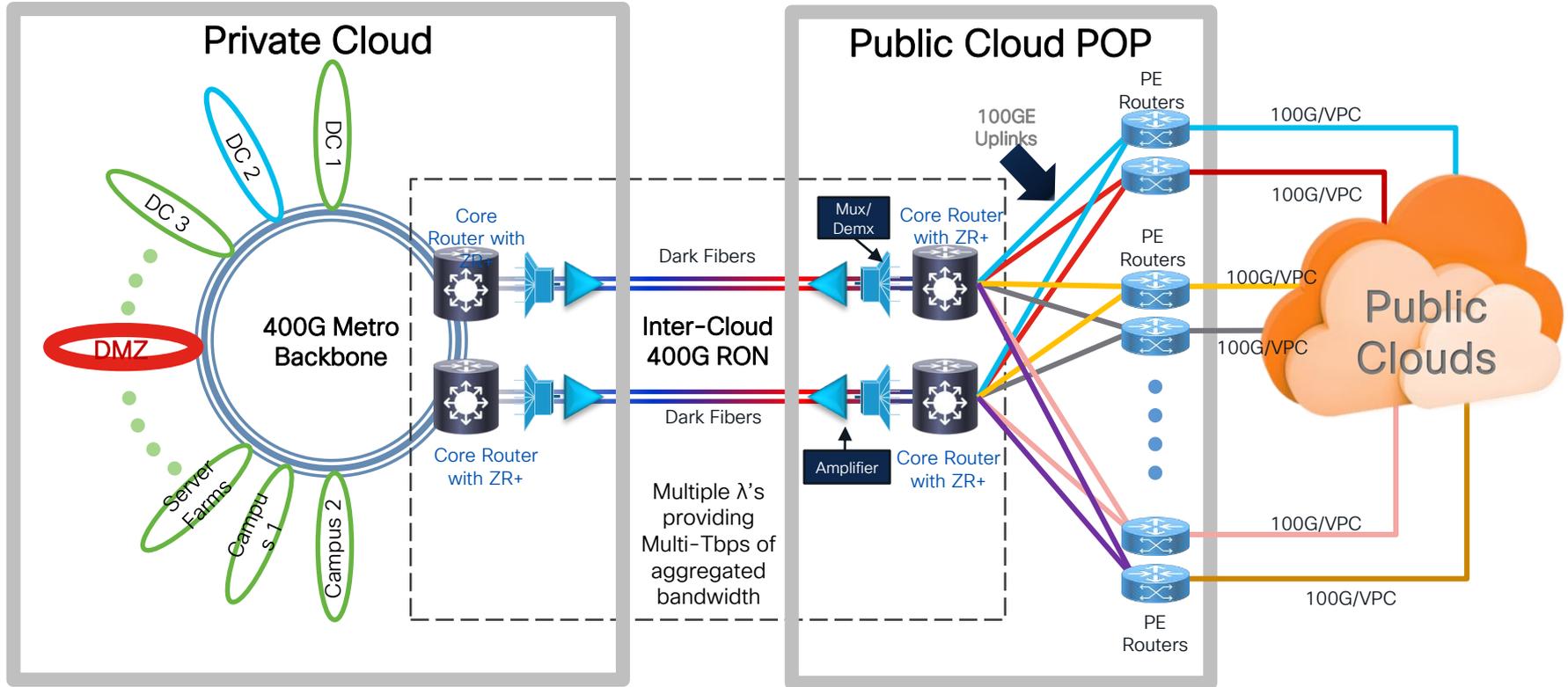


Adopting SR/RON in 2021 to build the hybrid cloud backbone with multi-Tbps bandwidth.

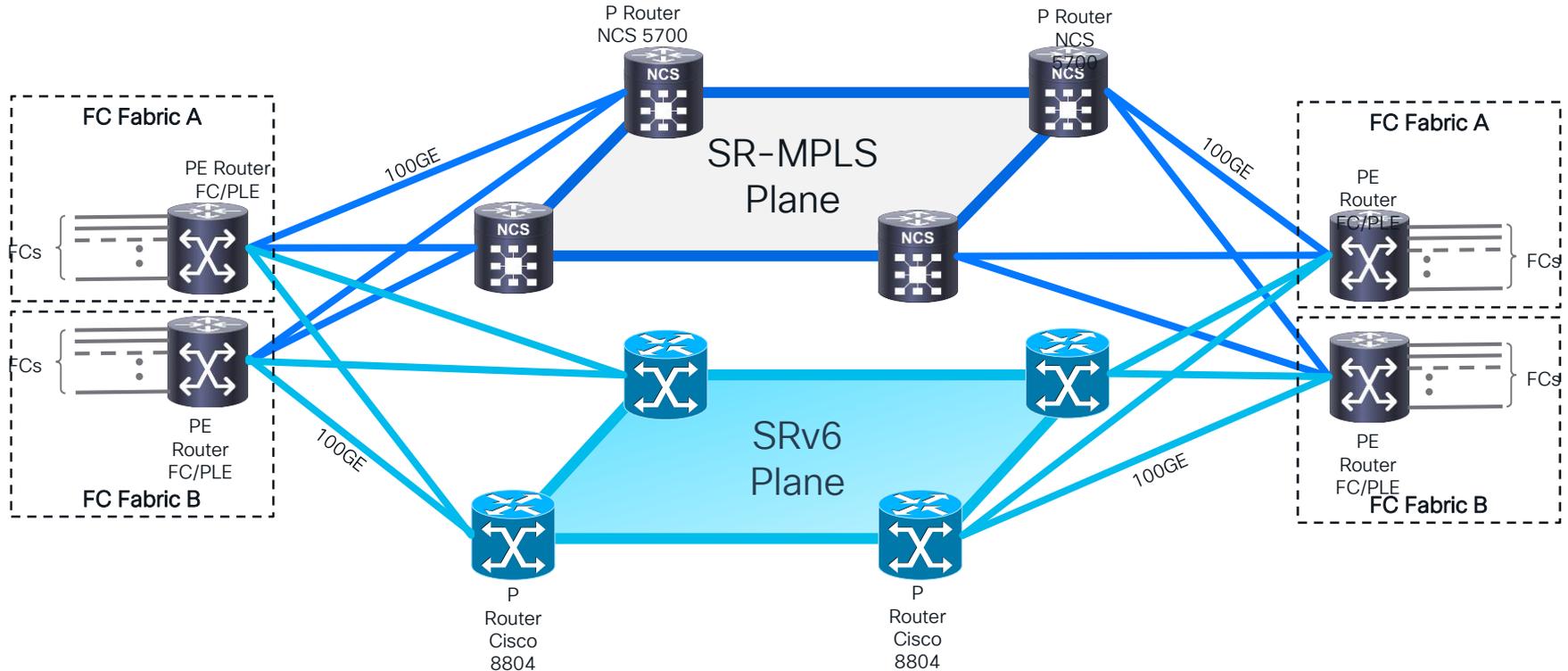
Routed Optical Networking Simplifies the Infrastructure – Game Changer Digital Coherent Optic



SR w/RON Backbone Extension for Hybrid Cloud



FC/PLE Over Dual-Plane Backbone



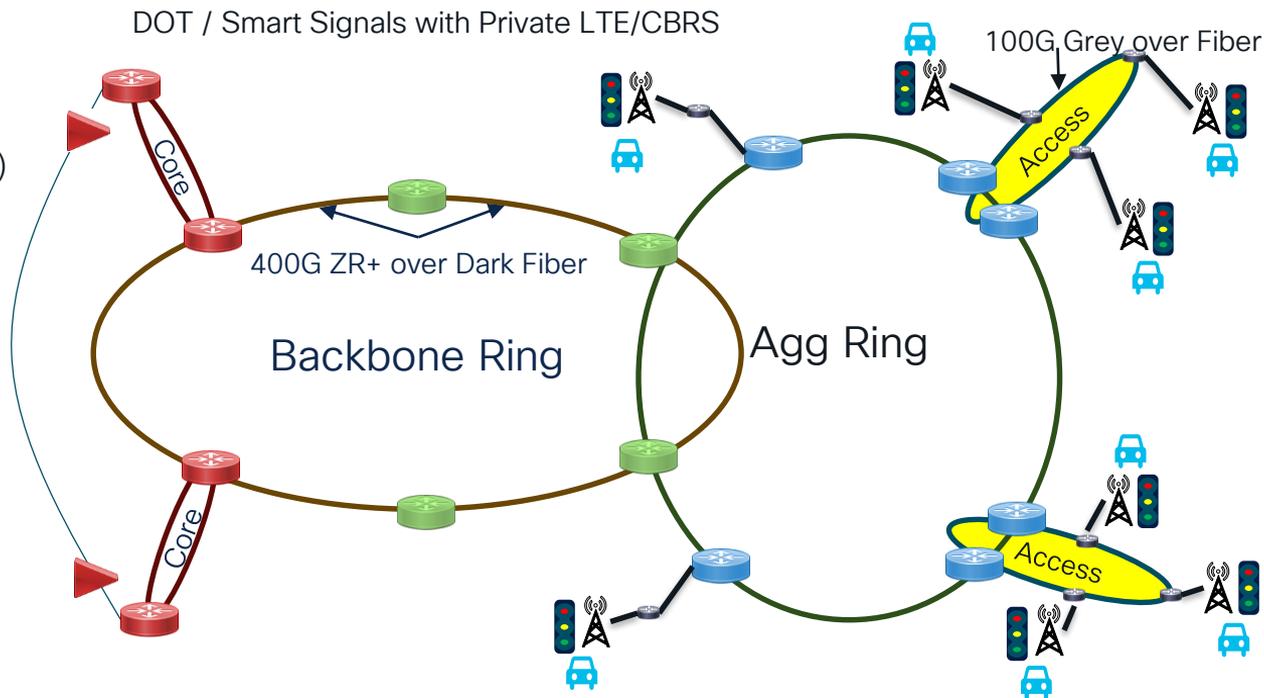
City Government Metro RON Deployment

Challenges:

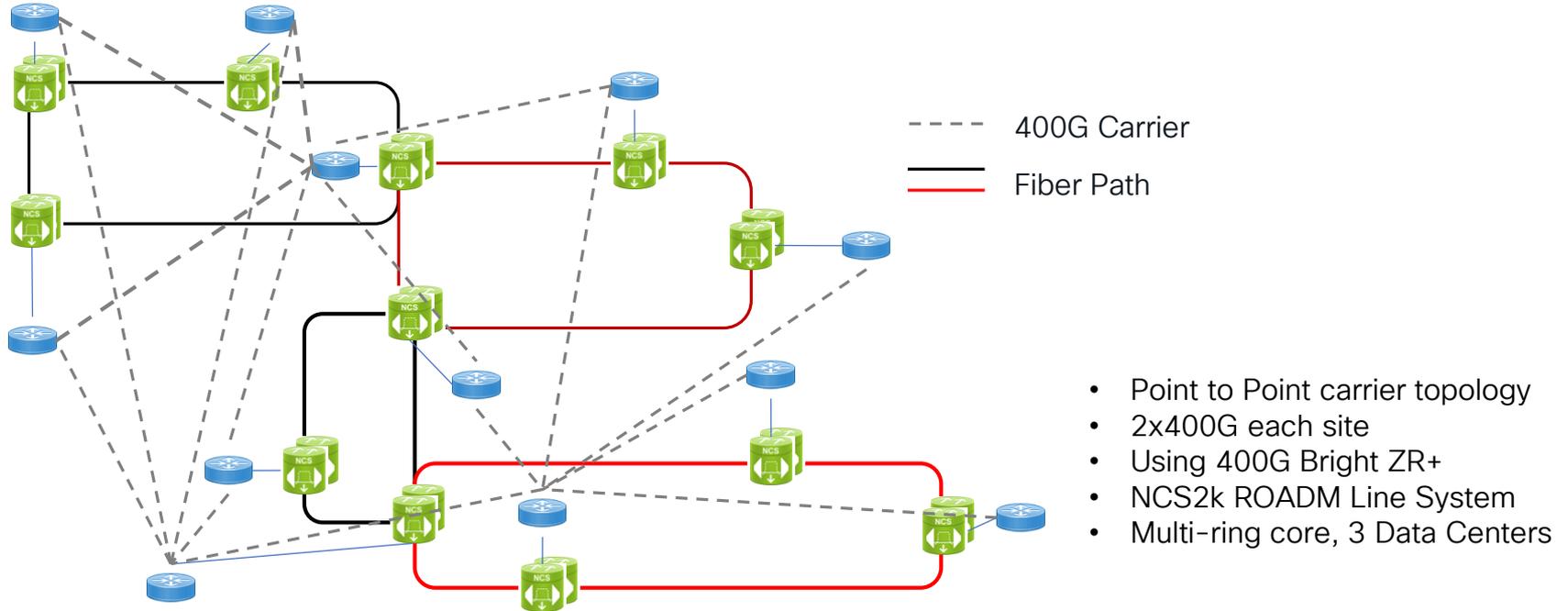
- Greater bandwidth requirements at access
- Class C clocking requirements (5G)
- High availability / Survivability

Solution

- DCO optics native over fiber

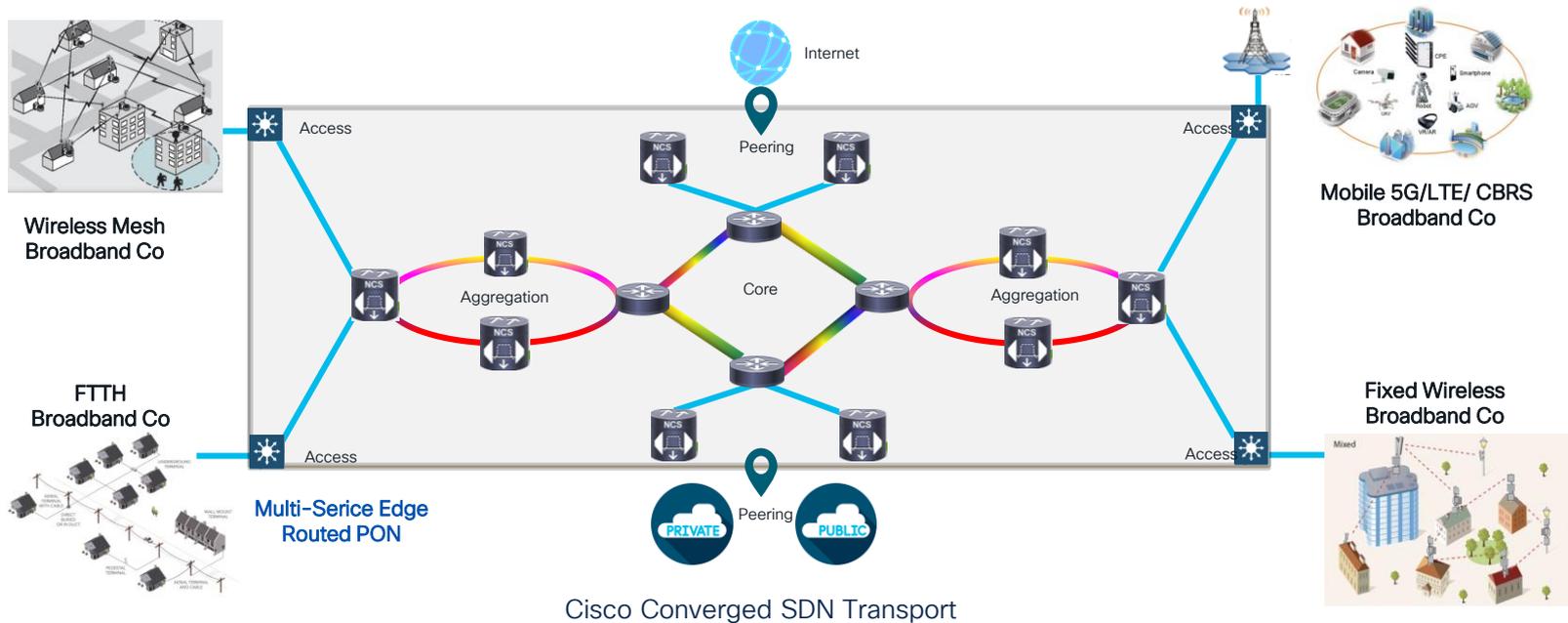


State Gov Department of Transportation



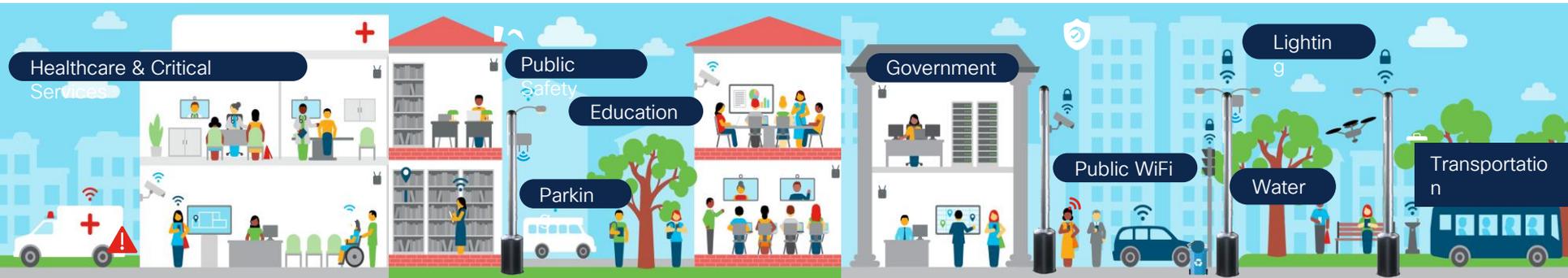
Middle Mile network : Affordable broadband

Automated end to end service creation and provisioning

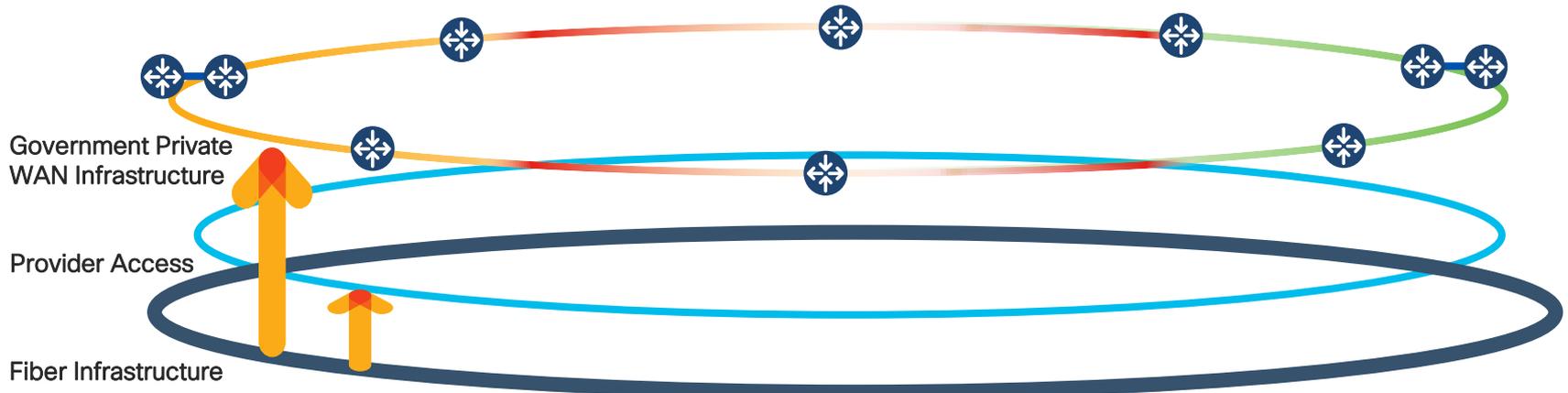


Cisco 8000 / ASR 9900 / NCS 5700 / NCS 540 XR router with integrated 400G BZR+ optics to provide backbone connectivity for last mile networks and anchor institutions eliminating the need for a DWDM transponder for bandwidth and reach

Government, Education and Public Services



Common infrastructure deployed once can be used for multiple use cases



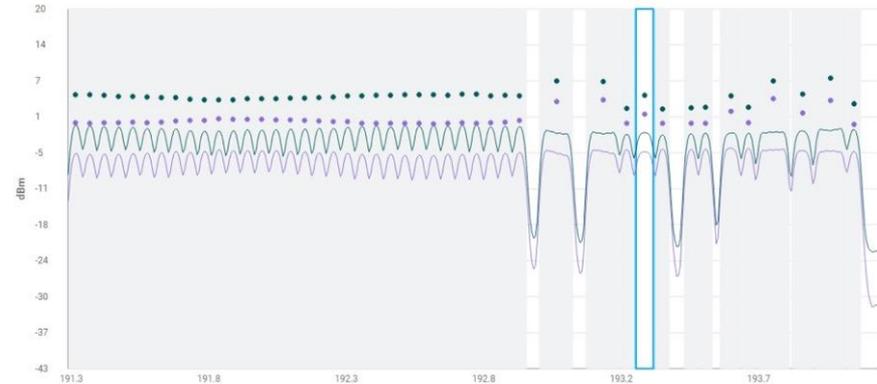
400GbE over 1337km with Bright ZR+



SP360: Service Provider
Cisco at OFC 2023: Announcing Successful Test with Sipartech to Deliver 400G Over 1,337 km
Bill Garner



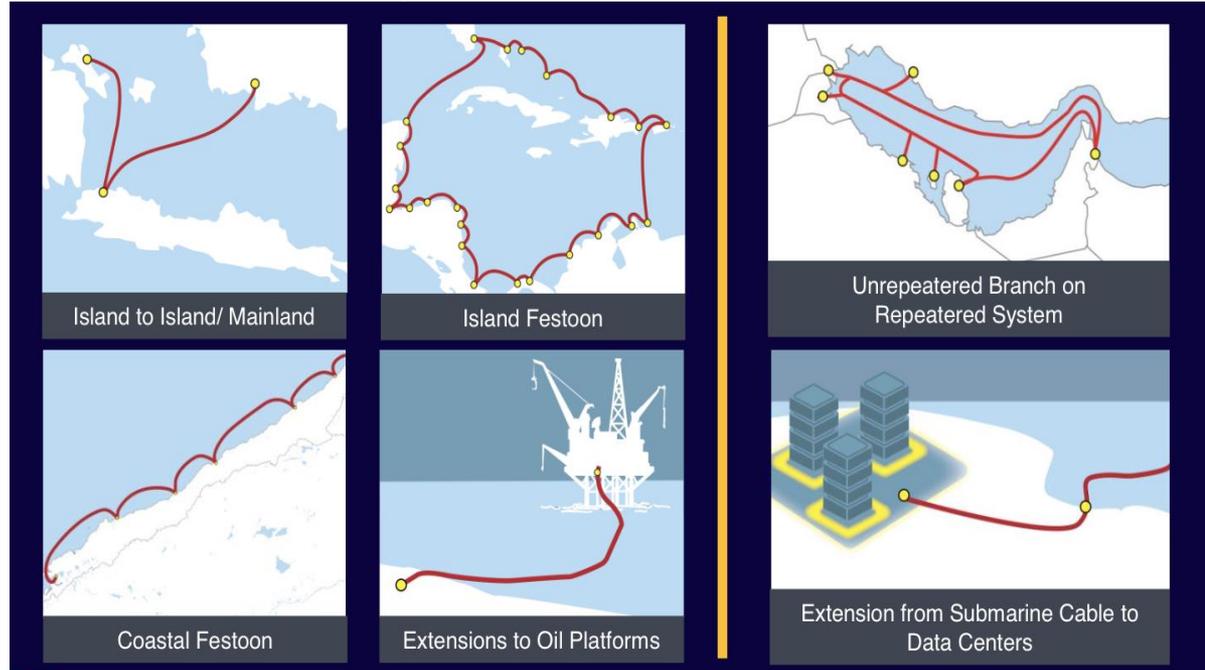
- Mixed SMF28 and E-LEAF fiber with 8 ROADM sites
- Alien λ over 3rd party CDC ROADM line system, plug and play!



“With the interoperability of Cisco’s equipment, we can deploy our next generation 400G+ services with speed, simplicity, and flexibility to meet our customers’ needs, while optimizing energy expenditure and our carbon footprint as part of our global strategy.” - Julien Santina, Sipartech CEO

Routed Optical Networking Subsea Applicable Markets

Oil & Gas platform connectivity
Island / Archipelago Connectivity
Data Center links <1000km
undersea links
Terrestrial backhaul



400G on long chains of Festoon

DCO on last segment
Data rate based on distance

Terrestrial backhaul
DCO on last segment

Recapping Routed Optical Networking Benefits

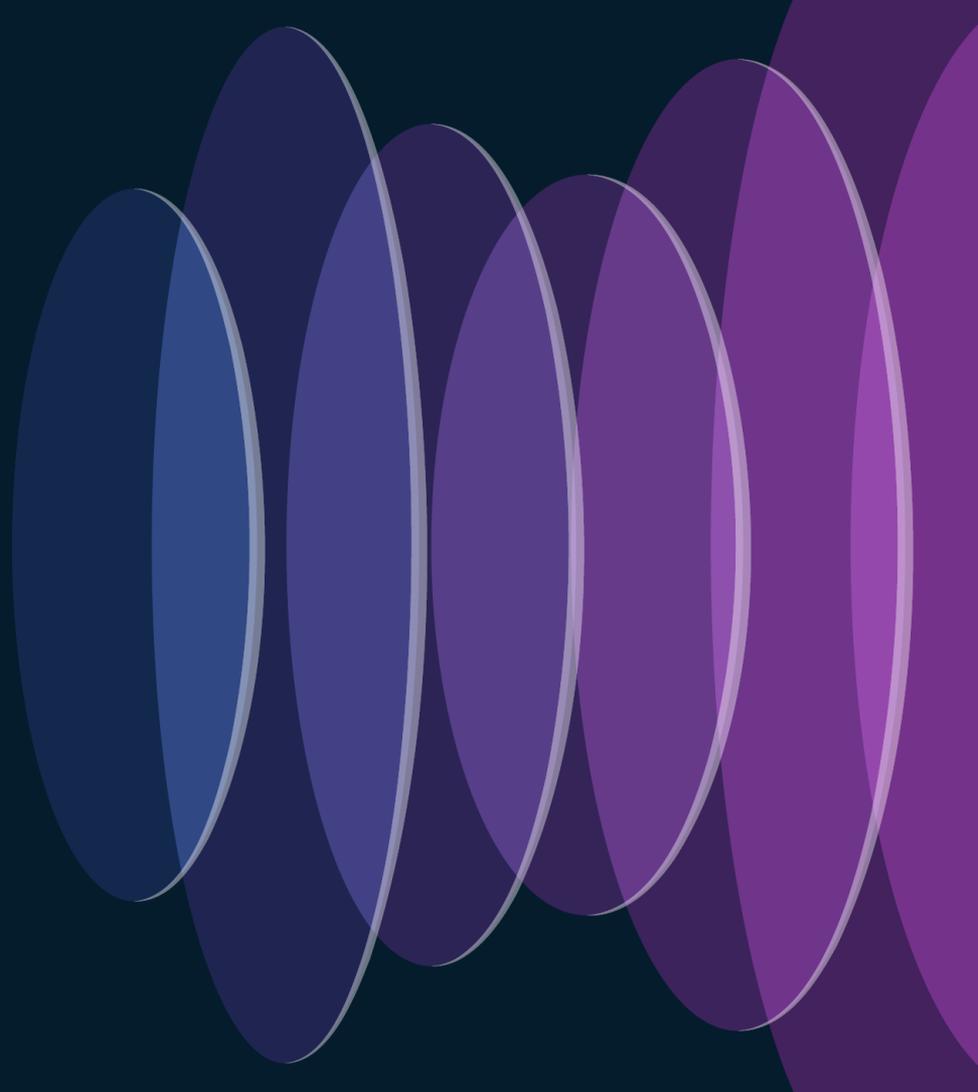
Layer Convergence	Converging through Digital Coherent Optics (DCO) in routers	Reduced complexity and lowered network cost
Service Convergence	Converging to a common packet transport by reducing dedicated infrastructure	Lowered cost and increased sustainability
Topology Convergence	Converging to greater congruency in IP, Photonic, and Fiber layers	Optimized network lifecycle management
Management Convergence	Converging orchestration and assurance into a unified view	Increased service agility and customer satisfaction
Operational Convergence	Converging business processes, operational practices and organizations	Higher productivity and efficiency and lower employee stress

Routed Optical Networking Evolution Path

Services & Hardware

	Build Faster Networks	Converge Services	Rearchitect Network and Transform Network Operations
Management Capabilities	<ul style="list-style-type: none"> • Visualization • RON link provisioning • RON link assurance 	<ul style="list-style-type: none"> • SR management • Network optimization • CS/PLE management • Service assurance 	<ul style="list-style-type: none"> • Deep service assurance • Integrated planning • Proactive & adaptive networking
Optical Services	Unchanged	CS/PLE services replacing optical Private Services	Increase bandwidth efficiency for CS/PLE services
Hardware	QDD pluggable variants (ZR to Bright-ZR+)	PLE UNI cards / CPE device	Simplified WDM layer (for greenfield apps)
Value	More capacity at lower cost	Maximize use of assets	Improved service availability & improved optical reach

Conclusion



Routed Optical Networking

Putting it All Together



Summary

- Routed Optical Networking enable a simplified converged network architecture
- Realize benefits today with deployment of DCO pluggable
- RON provides a toolbox to realize further benefits as appropriate
 - Segment Routing, PLE, Multivendor Automation, Simpler optical line system
- Addresses WAN network demand for scale, simplification, agility, scale, cost and sustainability
- Address all market segments and industry verticals

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Contact me at Webex space: “BRKOPT-1017: Scaling Wide Area Networks with Routed Optical Networking”



The bridge to possible

Thank you

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