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What's Hot In IP Optical Technology
Broadband for the Future

The Pace of Change is Increasing

Conquer Complexity with Confidence

– Muse Management Environment

Optical Transport Advances

– Broadband at the Speed of Light

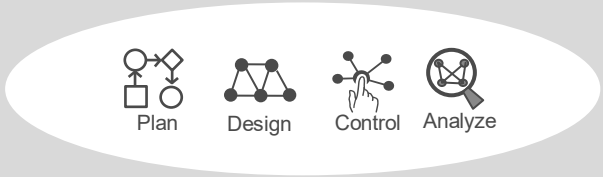
Routed Broadband

– Future Apps Will Require Advanced Layer 3 Transport Technology

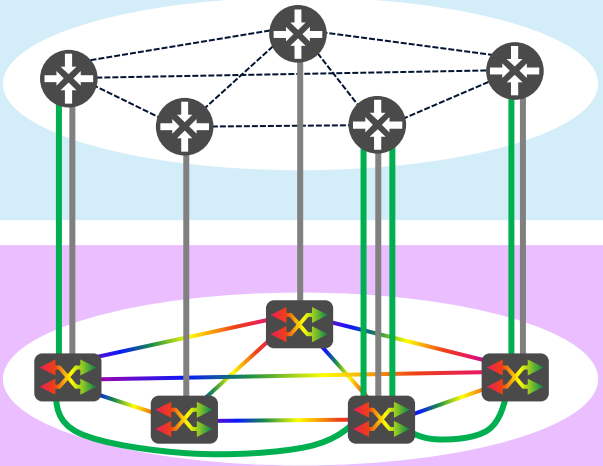
IPoDWDM evolution

IP Wave Portfolio

Muse
SDN Domain Orchestrator



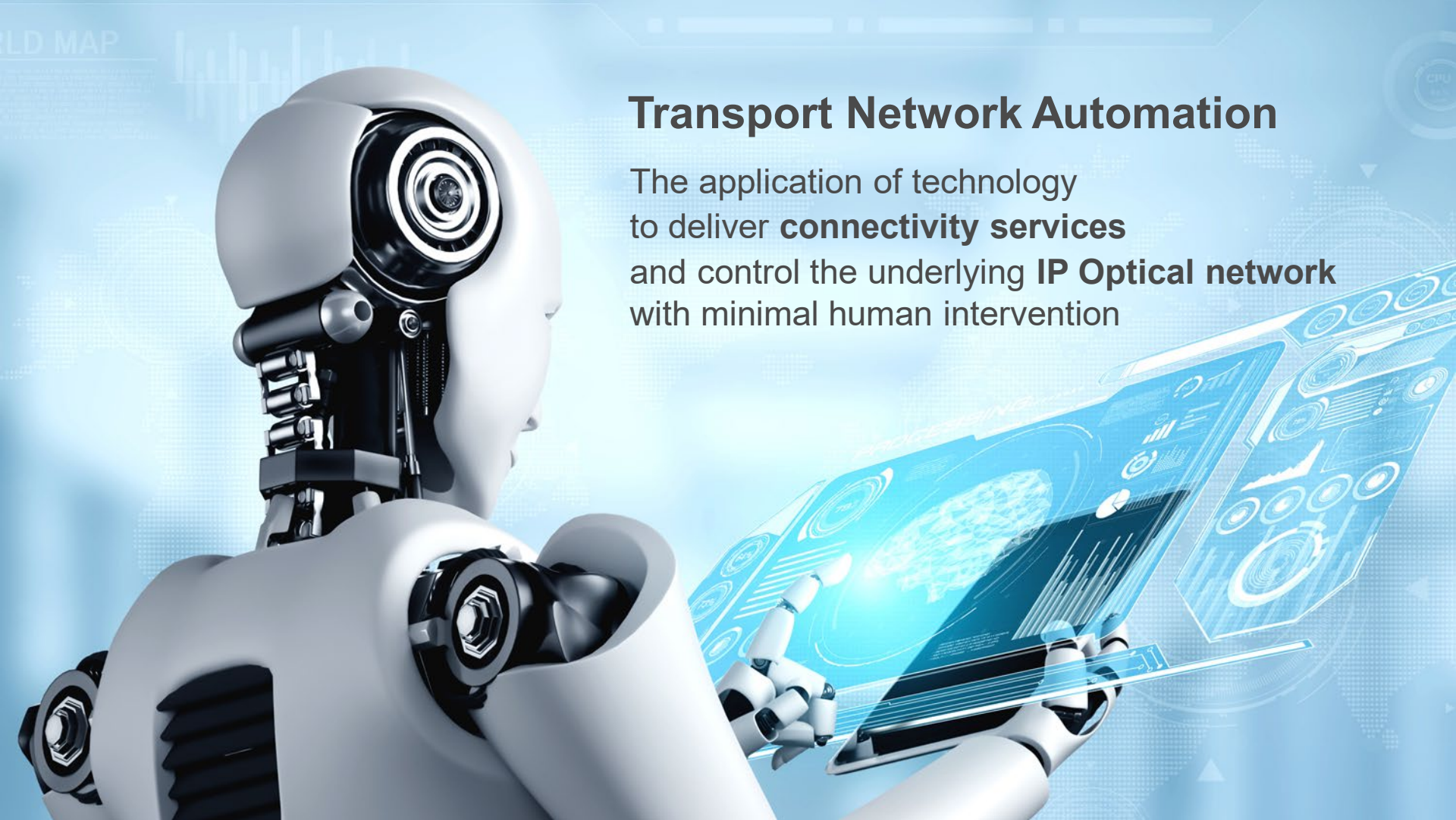
NPT
IP Routers



Apollo
Optical Networking Systems

Ribbon Professional Services

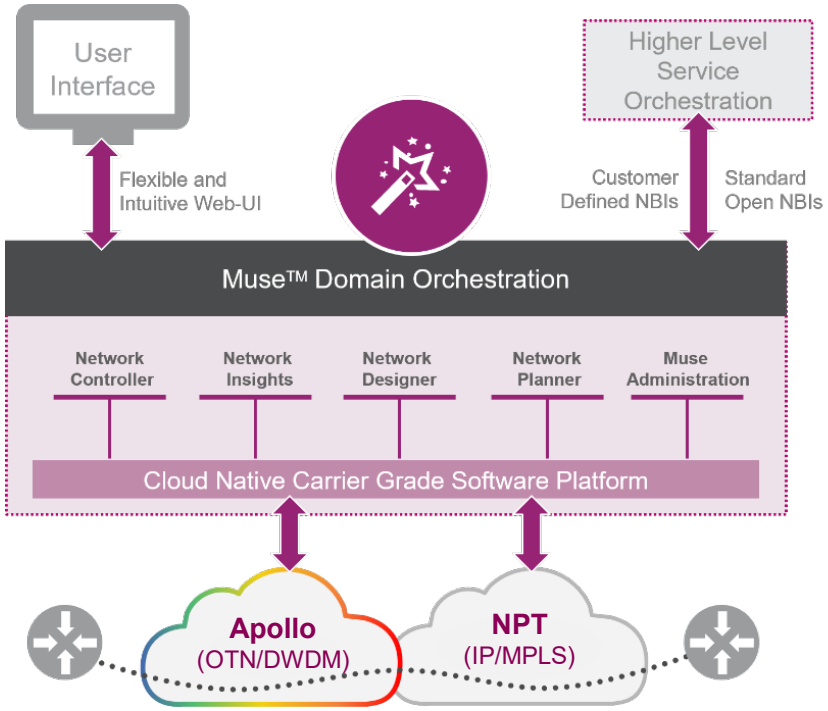
SDN Control



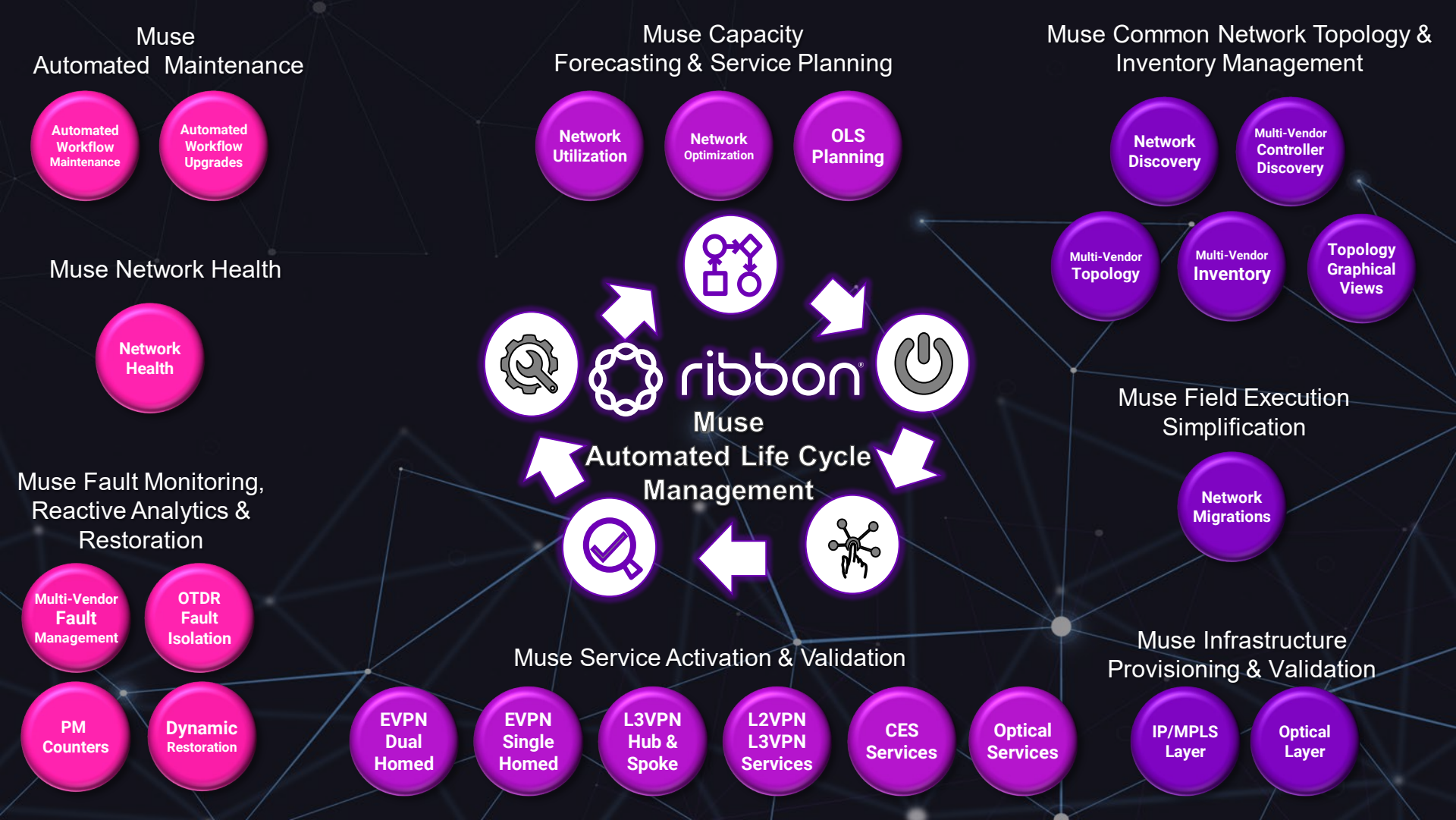
Transport Network Automation

The application of technology
to deliver **connectivity services**
and control the underlying **IP Optical network**
with minimal human intervention

Muse SDN Domain Orchestrator



Network Controller	Live network control for topology commissioning, service provisioning, fault management, maintenance and automations.
Network Insights	Self-Service BI application for analyzing the network inventory, performance, utilization and other KPIs.
Network Designer	Graphical Low-Code tools for designing service templates, network elements, tasks and automation workflows.
Network Planner	Topology design and optimization, optical services and equipment allocation, and export of required reports.
Muse Administration	User management, authentication and authorization, licensing, system health, and more.


Muse
Automated Maintenance
Automated Workflow Maintenance
Automated Workflow Upgrades
Muse Capacity
Forecasting & Service Planning
Network Utilization
Network Optimization
OLS Planning
Muse Common Network Topology &
Inventory Management
Network Discovery
Multi-Vendor Controller Discovery
Multi-Vendor Topology
Multi-Vendor Inventory
Topology Graphical Views
Muse Network Health
Network Health
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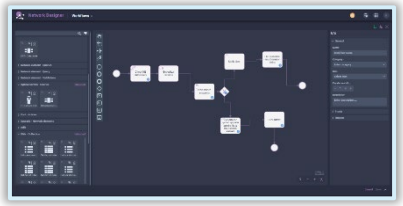
Muse
Automated Life Cycle
Management
Muse Field Execution
Simplification
Network Migrations
Muse Fault Monitoring,
Reactive Analytics &
Restoration
Multi-Vendor Fault Management
OTDR Fault Isolation
PM Counters
Dynamic Restoration
Muse Service Activation & Validation
EVPN Dual Homed
EVPN Single Homed
L3VPN Hub & Spoke
L2VPN L3VPN Services
CES Services
Optical Services
Muse Infrastructure
Provisioning & Validation
IP/MPLS Layer
Optical Layer

Muse Values

Intuitive Web UI

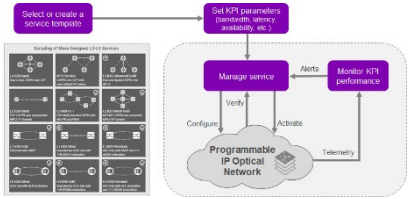
- Reduce mgmt complexity
- Tailor to NOC processes

Workflow Automation



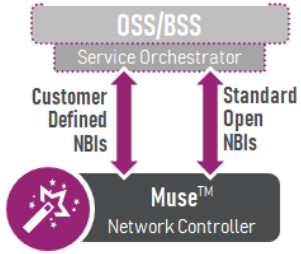
- Reduce OPEX
- Minimize human mistakes

Closed Loop Provisioning



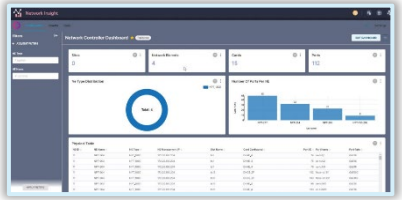
- Speed time to revenues
- Sell performance assured services

Flexible NBI



- Integrate within end-to-end SDN ecosystem

Insights & Analytics



- Better use of CAPEX
- Improve NOC efficiency

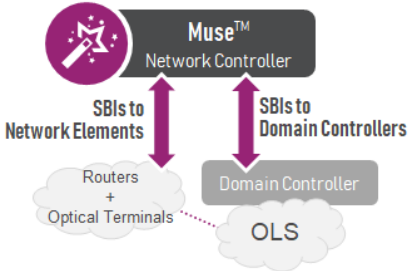
Network Health

- Predictive maintenance
- Fast-accurate fault finding

Cloud Native

- DevOps and Customization
- Performance and Security

Flexible Multi-Vendor SBI



- Disaggregated solutions
- Remove vendor lock-in

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Optical Networking Technologies

First-to-market

5nm-140Gbaud

With Lowest Power Use

Apollo 400G+ Transceiver Roadmap for 0dbm Optical Transport

Capacity-Reach (Performance) Optimized

Acacia

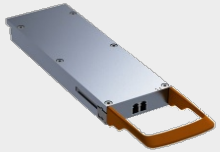
Low Power Consumption Optimized

Multisource pluggables

Open ROADM

Natural progression to meet 16QAM (metro/regional) and QPSK (LH/ULH) modulations at increasing Nx400G rates

CIM 8



16nm
2x600G
2x70Gbaud
Acacia Pico Module

5nm
1.2T
140Gbaud
Acacia Jannu CIM 8

Faster

2nm
2.4T
256+Gbaud
Acacia NN-2 CIM 10

QSFP-DD

7nm
400G
64Gbaud

Faster

4nm
800G
124Gbaud

CFP2 DCO

7nm
400G
64Gbaud

Smaller

Further

4nm
400G
124Gbaud

2021/2022 2023 2024 2025

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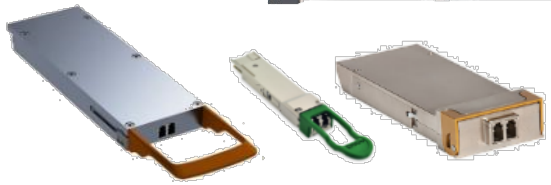
Suite of Solutions to Fulfill for All Optical Transport Needs

High Density
Front to back airflow

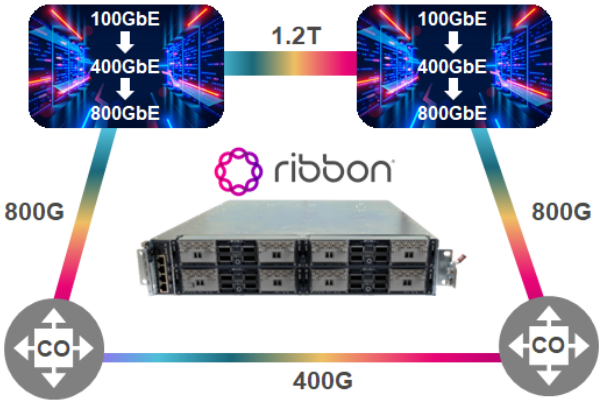
Modular Configurations
Side to side airflow



Exclusive use of pluggable transceivers
for pay-as-you-grow

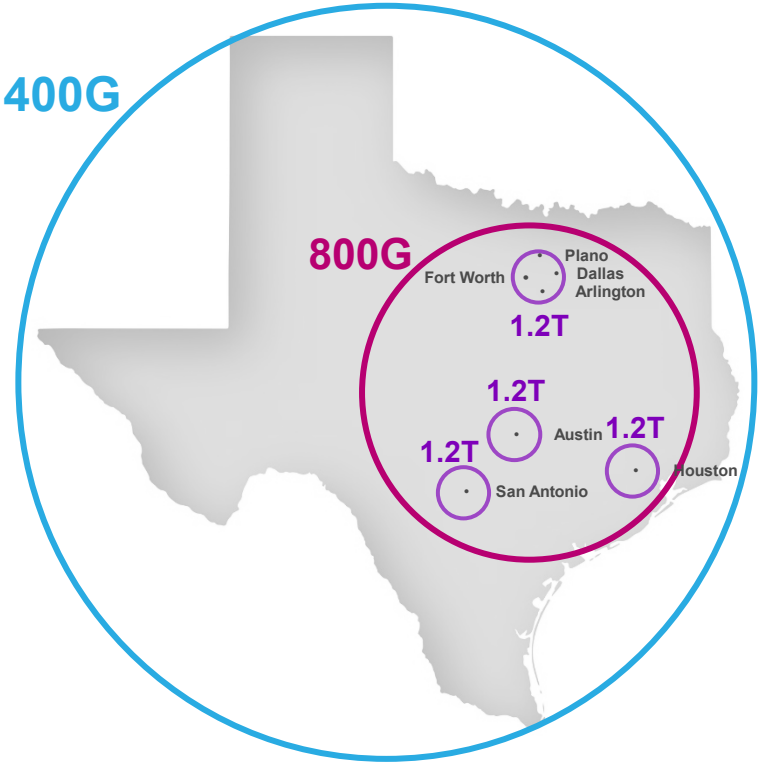
Across CDC ROADM Networks

Nx400G Lanes for Transporting 100GbE/400GbE Traffic



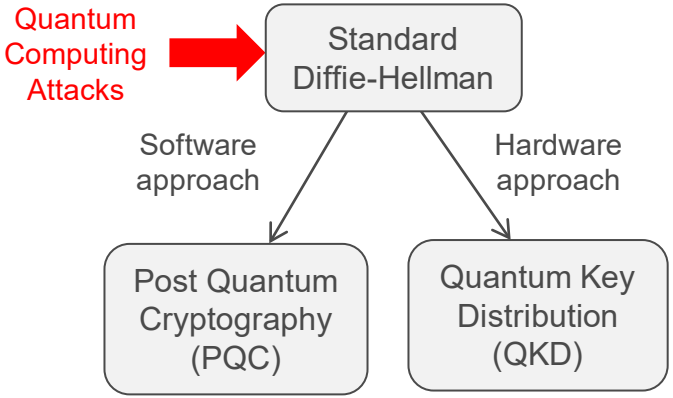
Ribbon “breaks down” data center walls with optical network transport of 100GbE, 400GbE and future 800GbE traffic with industry best:

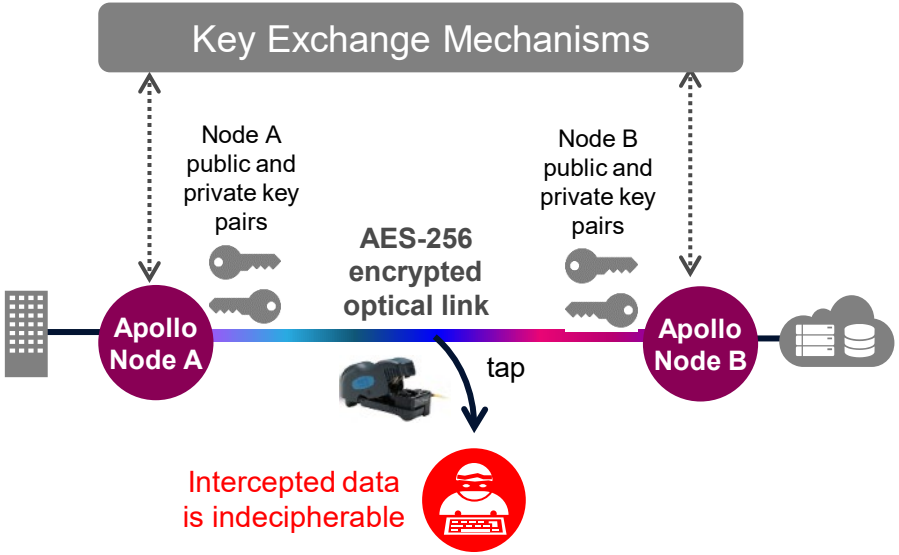
- 1.2T Short Haul (DCI)
- 800G Metro-Regional
- 400G Long Haul



Future Proof Layer 1 Optical Encryption

- Protects against data interception via fiber tapping with no added overhead or latency
- Non-crackable AES-256 encoding
- New key exchange mechanisms to deal with threat posed by quantum computing



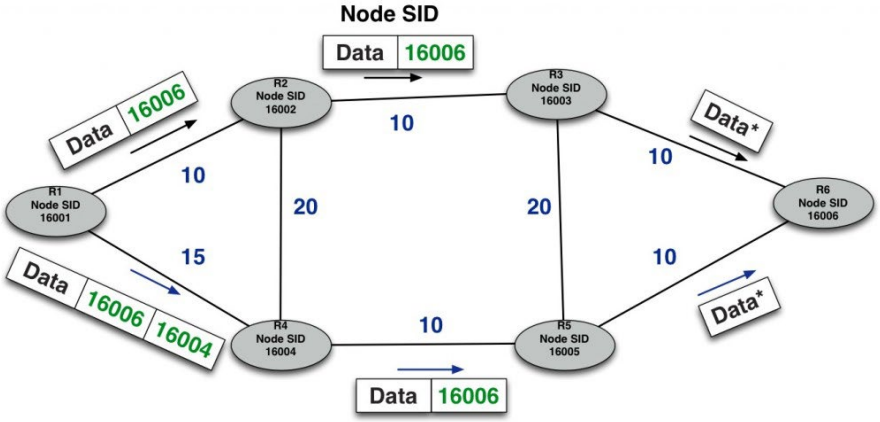


Packet Technologies evolution

What is Segment Routing?

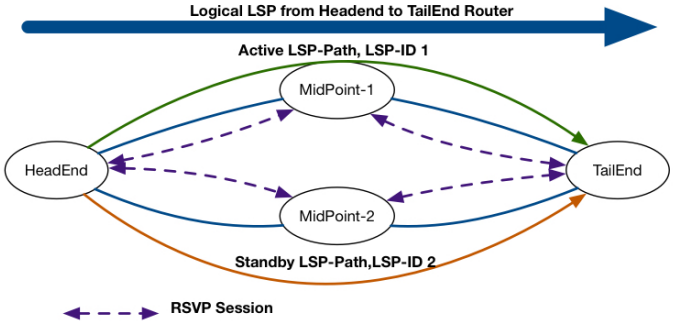
Multi-Protocol Label Switching

- MPLS uses labels to define “endpoints” on the network
- Label Distribution Protocol (LDP) used to distribute labels in traditional MPLS Network
- Segment Routing (SR) replaces LDP
  - Nodes get globally unique Node-SID
  - Adjacencies or “links” get locally significant Adjacency-SIDs
  - Traffic can be directed by specifying intermediate Node-SIDs

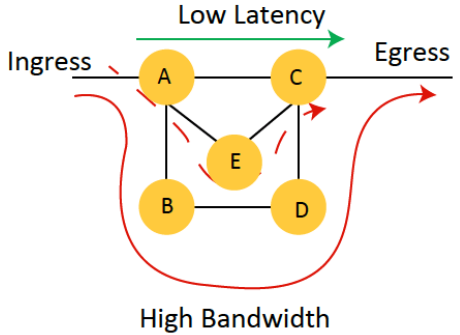


Advantages Over Other Protocols

- LDP is used with RSVP and RSVP-TE
  - Complicated traffic engineering
  - One-way tunnels tracked for each destination
  - Fast Re-Route has limitations

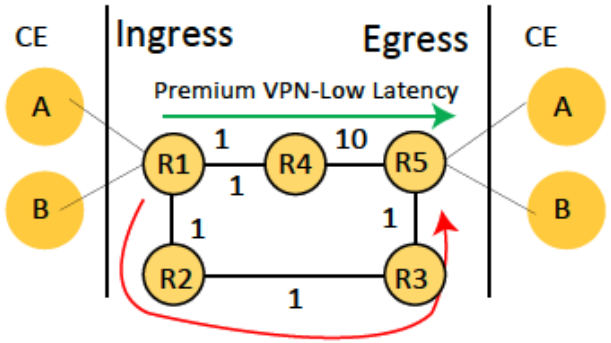


- SR Advantages
  - Simpler architecture to understand and operate
  - No directed paths needed; a “color” based algorithm can be used with specified constraints, like low latency, or high bandwidth
  - Topology Independent – Loop Free Alternative is a superior protection algorithm to Fast Re-Route

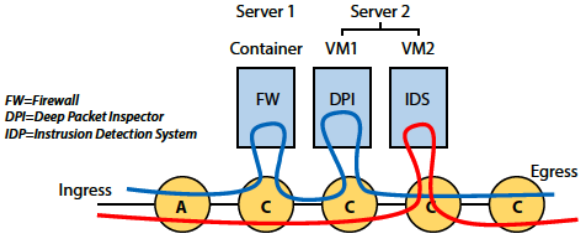


Traffic Engineering and SRv6

- Traffic Engineering can be done statically, or with a Path Computation Engine (PCE)
  - Static configs good for single IGP Domain
  - PCE used when multiple IGP Domains exist
  - Flex Algo Support can be used to isolate failure domains within a network

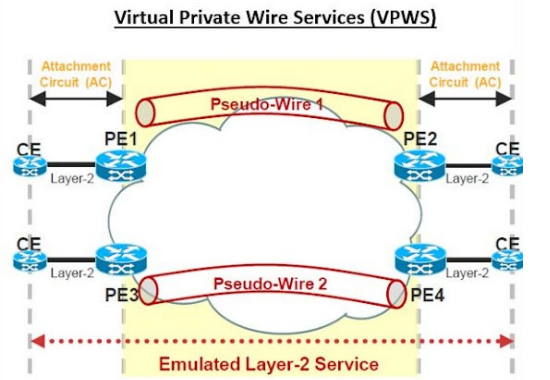


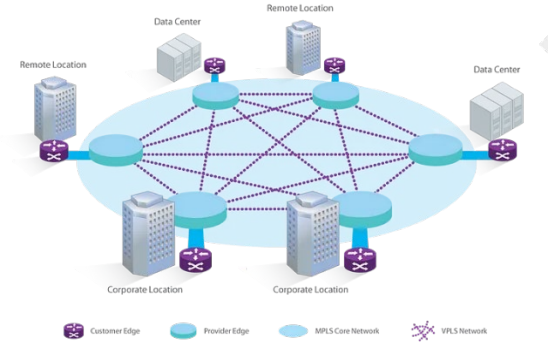
- SRv6
  - Adds programmability to the network path
  - Use headers to require traffic to access certain services on a path



Layer 2 VPNs – The Bread-and-Butter Offering

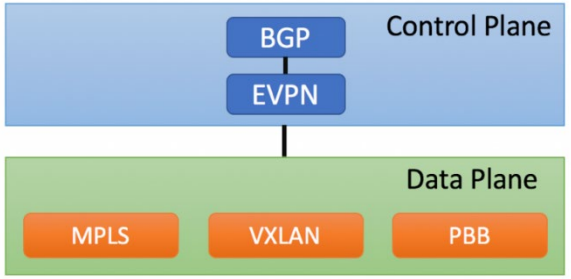
- MEF Type Circuits
  - Ethernet Private Line
  - Ethernet Private LAN
  - E-Tree
- Pseudowires and Tunnels
  - Typically delivered over Pseudowires/VPWS/VPLS or dedicated tunnel protocols
    - MPLS-TP
    - RSVP/RSVP-TE
    - SR with TI-LFA
- Has Downsides
  - MAC Learning is within the data plane
  - Poor support for multi-homing
  - Potential for Broadcast Storms



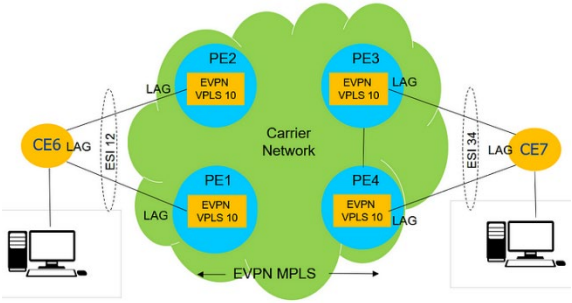


Ethernet VPN (EVPN) – How It Is Different

- Data Plane is separated from Control Plane
  - MAC Learning and Segment Identification is done via BGP
  - Traffic is forwarded over the MPLS data plane
  - No full mesh required for ELAN applications
  - Efficient handling of Broadcast, Unknown Unicast, and Multicast (BUM) traffic

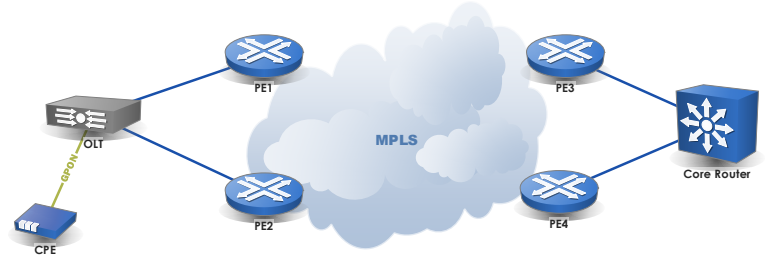


- Multi-Homing Advantage
  - All active multihoming allows CE-PE connections to different PEs to be identified by an Ethernet Segment ID (ESI)
  - MAC Address is associated in MP-BGP with the ESI
  - PEs that have not learned the MAC will still advertise the ESI availability
  - BUM traffic is handled by a single connected PE called the Designated Forwarder (DF)

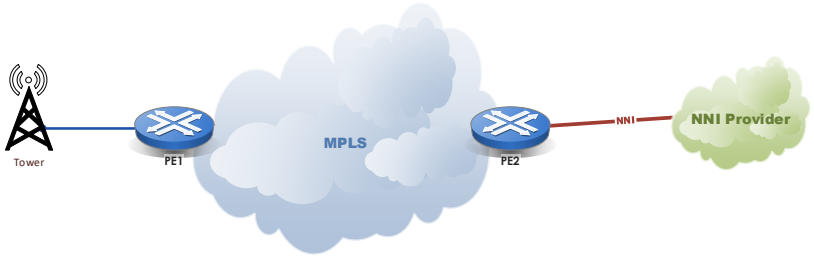


Typical Use Case

- Optical Line Terminal - Multihomed
  - All active multihomed connection with EVPN based L2VPN connected to Core Router
  - Resilient against failure of either link, or connected PE device
  - Development continues to expand use cases

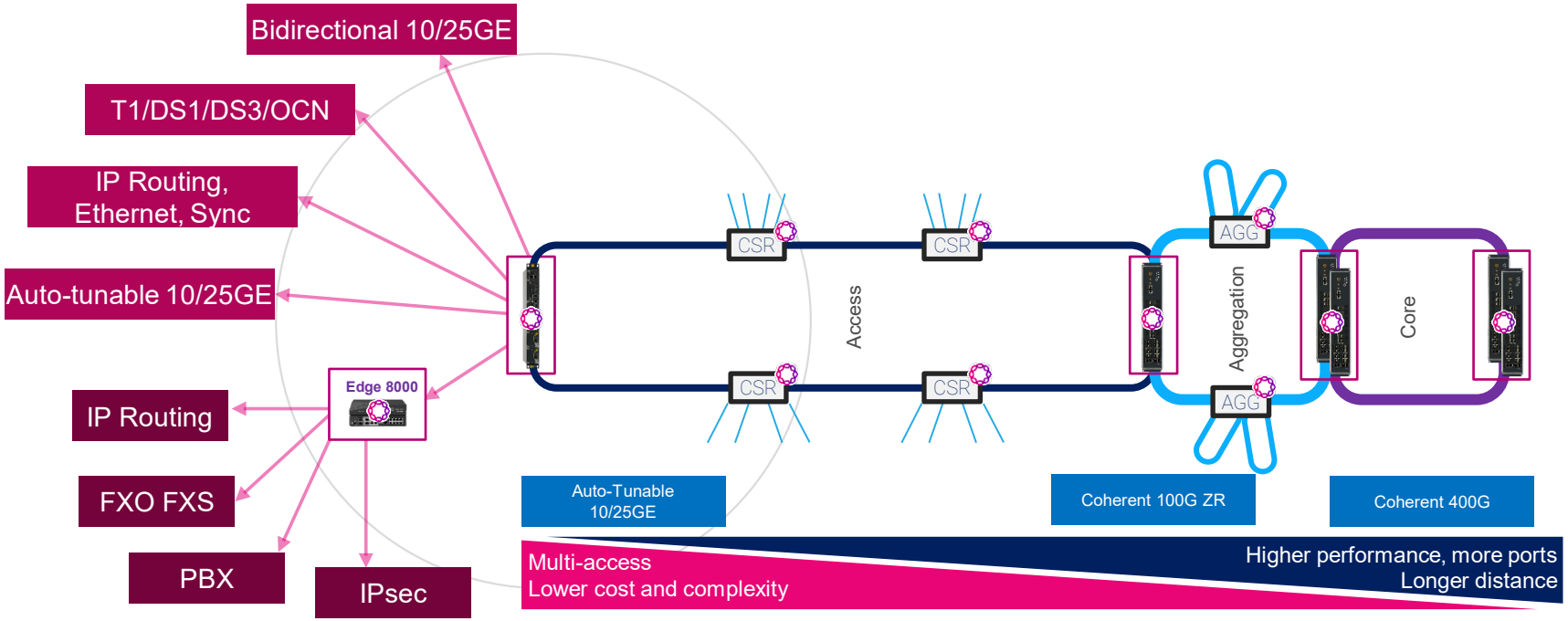


- Cellular Backhaul
  - VPWS over EVPN to build MEF E-Line service
  - All to one bundled connection at cell tower, traffic connected to NNI on customer specified VLAN



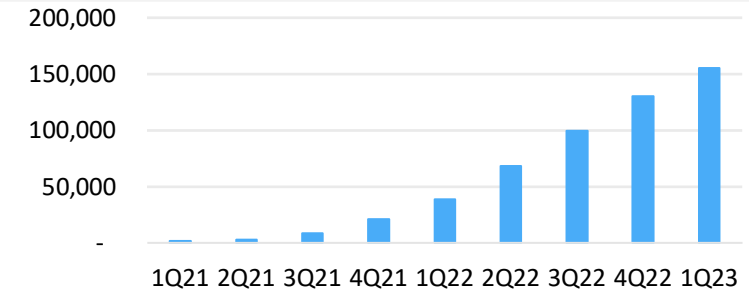
Evolution of optics

Comprehensive Technological Capabilities on the Edge



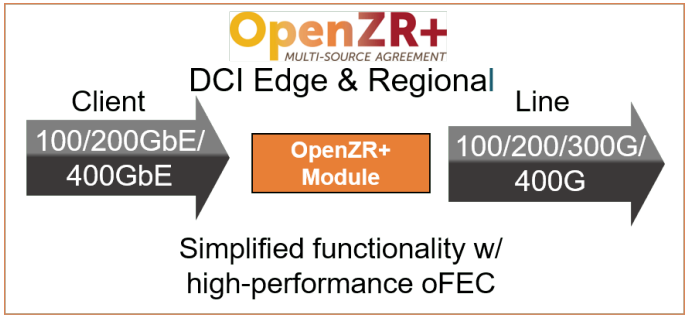
IPoDWDM with ZR / Open ZR+ modules

Growing Global 400G ZR cumulative shipments

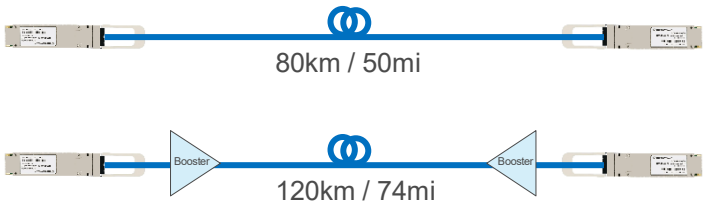


Source: Omdia

OpenZR+ Multi-Source Agreement (MSA)



400G ZR use cases

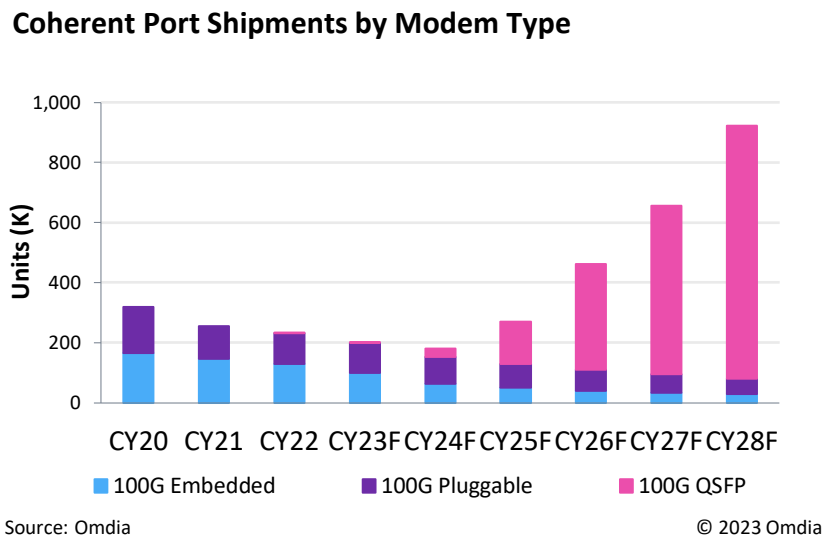


FEC - CFEC	Power 15W	Speed 400Gb	-10dbm	OFC standard	Gray

400G OpenZR use cases

FEC - oFEC	Power 25W	0dbm Coherent	Speed 100Gb / 200Gb/400Gb	OpenZR+ MSA standard	X5 higher price

100G: Transition from filling the core to equipping the edge



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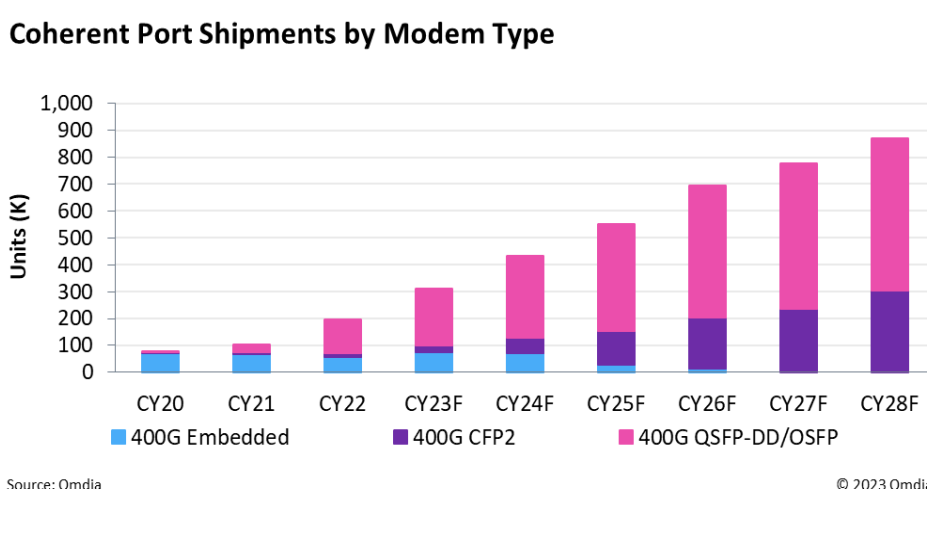

Source: Omdia

100G Embedded will continue to ship until every common equipment slot is filled.
400G ZR for cloud SPs a volume market now,

Optical breakout accessories

1RU Optical passive patch panel
Fits up to 8 connection modules per RU

Passive fiber connection modules
Front side and backside MPO cable connection

High-density 2RU Optical passive patch panel
Fits up to 18 connection modules per RU, 36 in total

High-density Passive fiber connection module
Backside MPO cable connection

Cost-effective break-out cable option
MTP12 - 8x LC

The Perfect Storm

Demand

Customer Requirements will Quickly Exceed the Ability to Deliver Without Proper Planning

Technology

Technology is Available Today to Scale and Support Future Demands

Funding

Make Every Dollar Count Extend Your ROI

Scale In 3-Dimensions
Capacity, Capability, Service Awareness


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