The bridge to possible

Improve Your Network Efficiency with 400G Optics

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BRKOPT-2806

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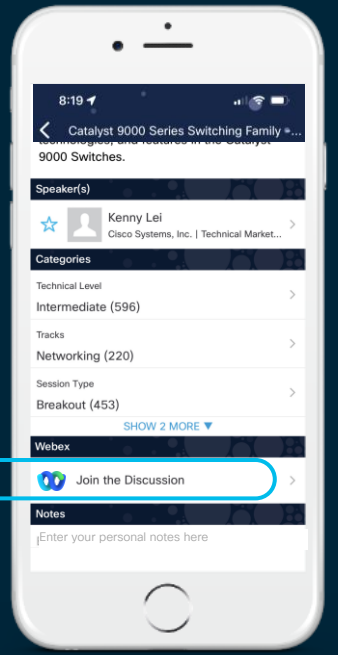

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Agenda

- Introduction
- Enabling Technologies
- Architectural Impact
- Operational Flexibility
- Deployment Considerations
- Summary

Optics innovation is indispensable to your network

Increasing demands for network performance

- *29 billion devices will access the internet*
- *300% more apps will run in data center and edge locations*
- *Over 500 million new apps will be written*

*by 2023

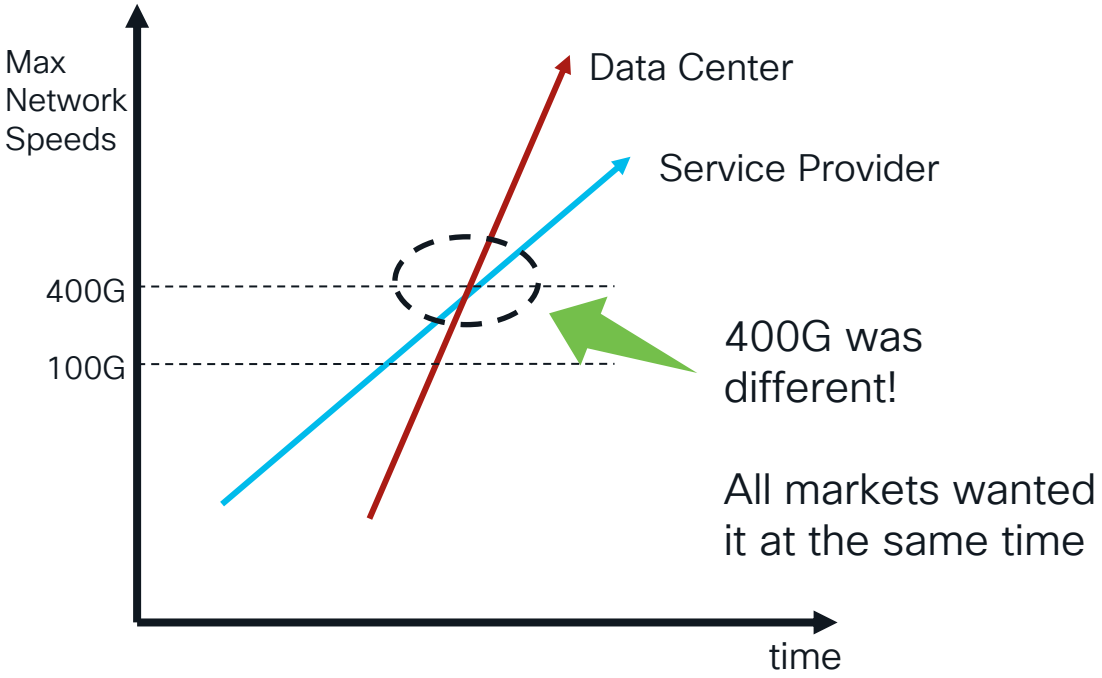
Strategic importance to delivering connectivity

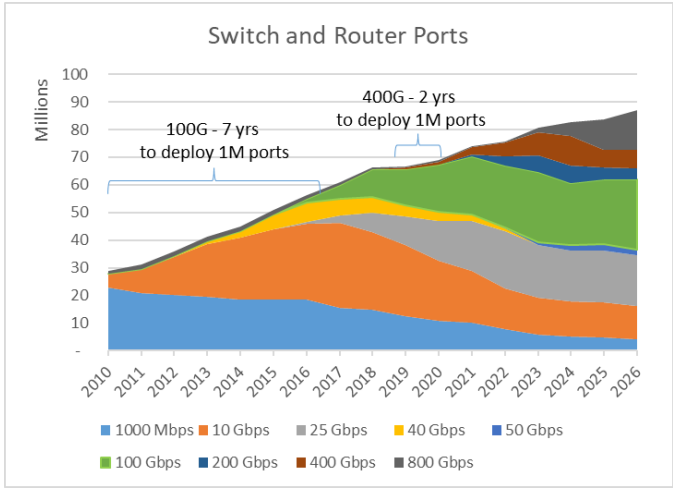
- *Capacity transitions to 100G/400G*
- *Flexibility across fiber infrastructure and distance requirements*
- *Growing percent of hardware BOM as speeds increase*

Growing sophistication in technology and production

- *Integrating more capability with Silicon Photonics*
- *Wafer-scale manufacturing, quality, and cost points*
- *Improved thermal efficiency*

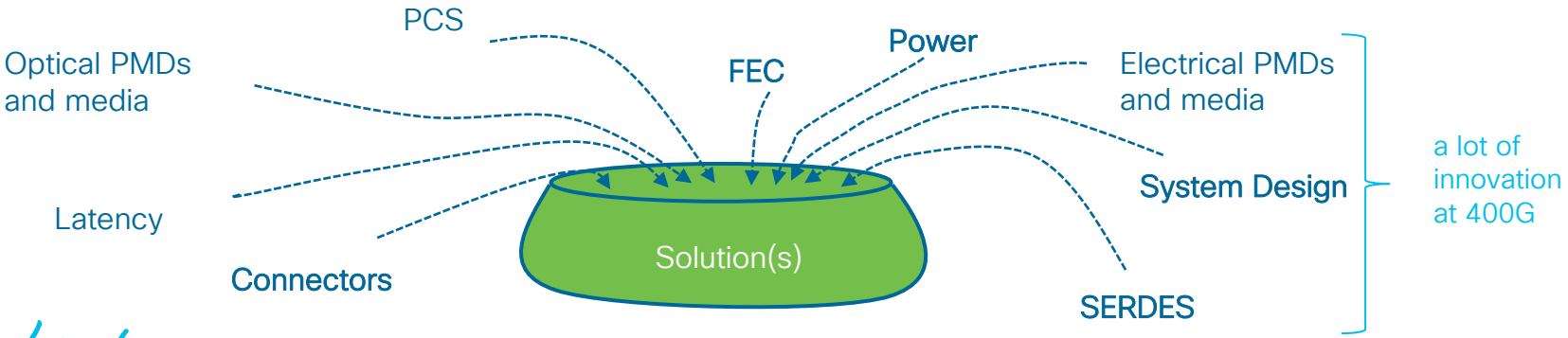
Market Intersecting at 400G



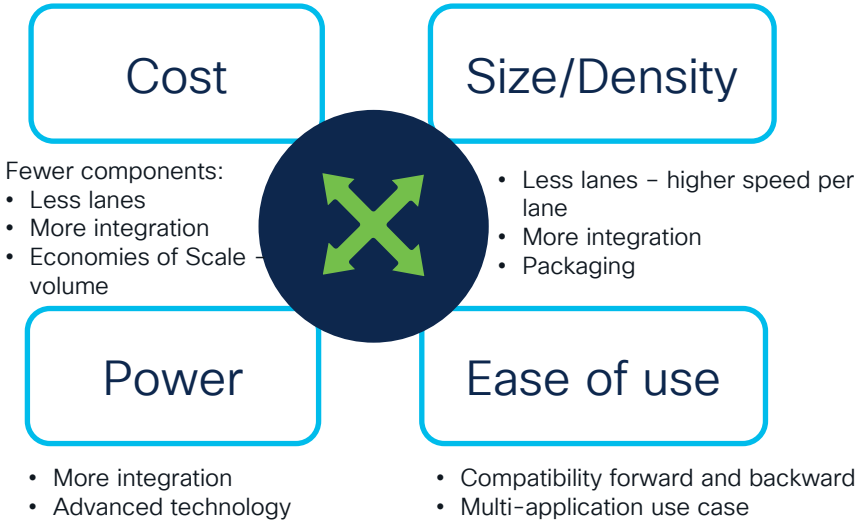


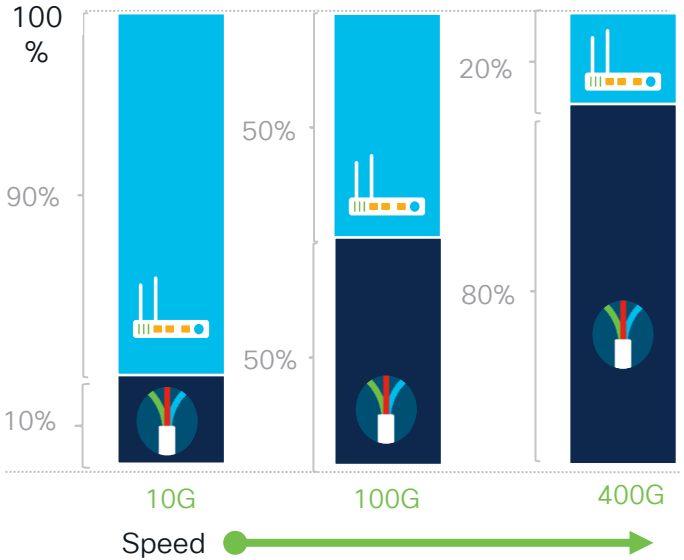
400G: Everything, all at once

- All the major markets wanted 400G in the same design cycle
- Tremendous pressure on just about everything
  - High density – ports in 1RU
  - All reaches – copper cable to DWDM long-haul (aka coherent)
  - Low cost – high volume adoption
- Several independent technology tracks necessary to make it all possible – IEEE, MSA, ..



400G Pluggable module – foundational to efficiency





Your network's efficiency is highly dependent on optics

Platform

Pluggable Optics

Improving Network Efficiency w/400G

Technology

Silicon Photonics
- Cost, power, size, integration
- Wafer level testing and module yield
- Enabling higher speed
- Density

Pluggable Form Factor

Pluggable Coherent

Architecture

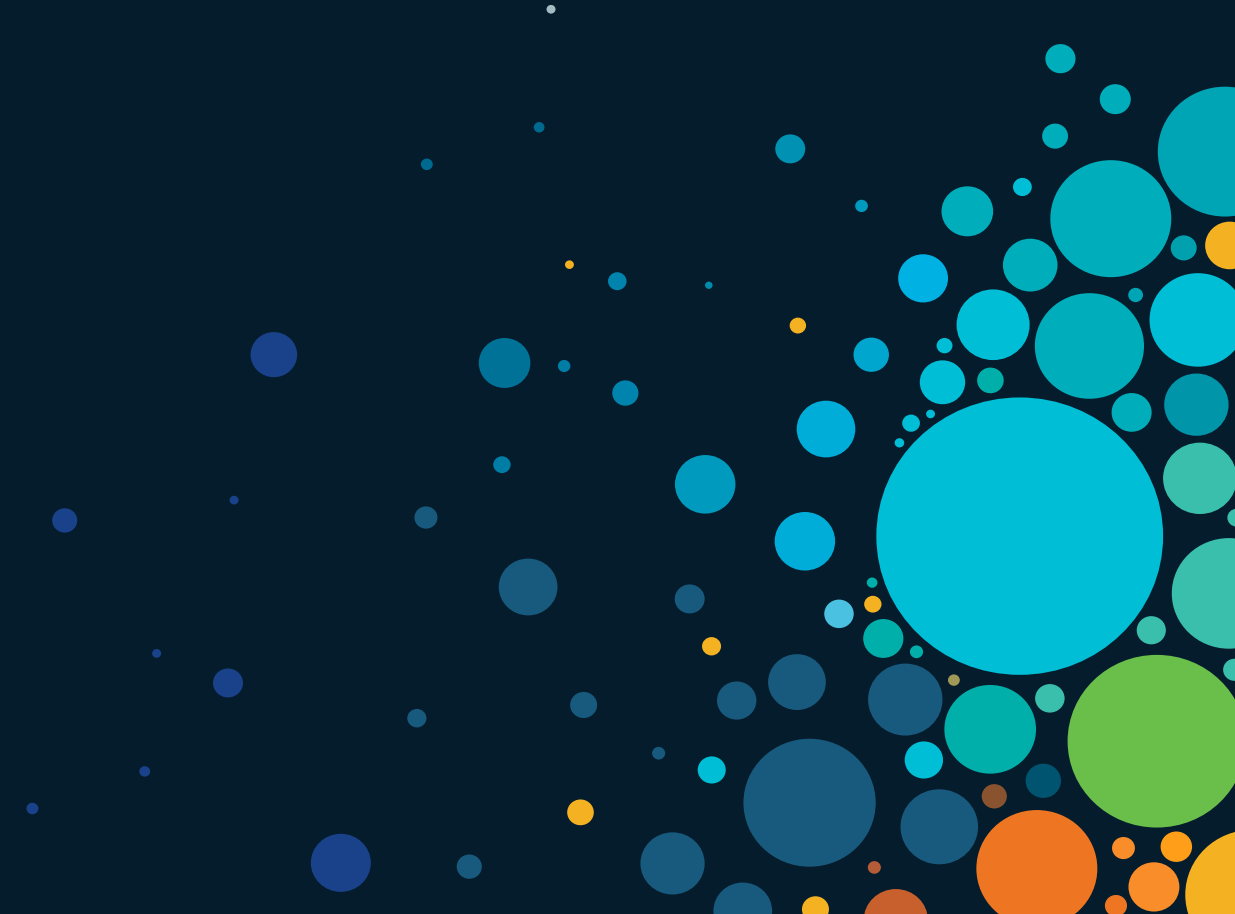
Zero density trade off
- Flexible ports-client or line

Multiple Applications
- Routed Optical Networks
- DC network fabrics
- DCI
- Enterprise

Operation & Deployment

- Standardization
- Management & Monitoring
- Deployment flexibility
- Breakout
- Improved reliability

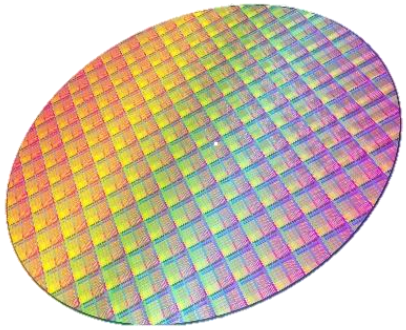
Enabling Technologies



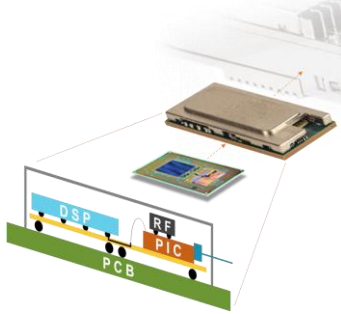
Silicon Photonics Drives Efficiency

Integration	Many optical functions on a single monolithic die with high yield
Temp Insensitive	Avoids the power and cost of thermo-electric coolers. Optics can be placed close to heat source (DSP)
CMOS Fab Model	Operationally scalable without fixed in-house fab cost
Non-Hermetic	Eliminate costly gold boxes, simplifies manufacturing and improves reliability

Non-coherent optical transceiver



Wafer Scale Photonics Manufacturing
Highly automated assembly & test



Coherent optical transceiver

Technology Innovation for 400G Pluggable Optics

Speeds

Faster optical modulation speeds. All based on advanced modulation.

100 Gb/s PAM4 single lane direct detect modulation

400G 16QAM Coherent modulation

Required more complex receivers & mandatory FEC (DSPs & added power)

Form Factors

Higher powers needed to be supported in pluggables

New 8x electrical interface required a new pluggable form factor

Two form factors emerged:

- QSFP-DD
- OSFP

Integration

SiPhotonics became a mainstream approach

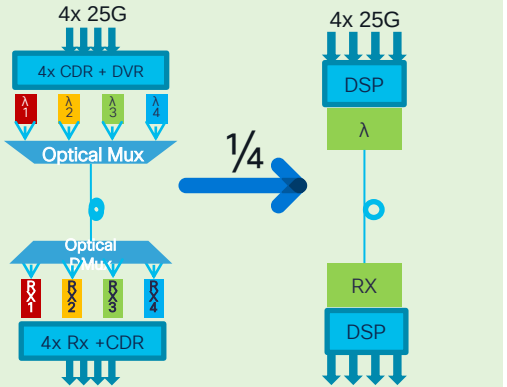
- enables the necessary integration
- Critical for DCO coherent optics
- Accelerated optical breakout usage

QSFP DD Provides Ultimate Efficiency / Flexibility

- Form factor provide ultimate flexibility – AOC, copper, coherent
- QSFP-DD MSA has very broad industry support
- Port is backward compatible to QSFP+, QSFP28, QSFP56
  - Ease migration to 400G
- Leverages industry cost structure and QSFP production capability
  - Over 100M QSFP ports have been deployed to date
  - Industry has invested in roughly 60M QSFP modules
- Support 2x100G designs
- QSFP-DD will support over 25W of power dissipation
  - Supports pluggable coherent modules (ZR & ZR+)
- Broad product offering from copper cable to coherent
- Evolves to 800G (QSFP-DD800)

100 Gb/s Modulation for efficient 400 GbE

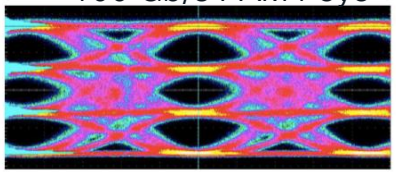
100 GbE

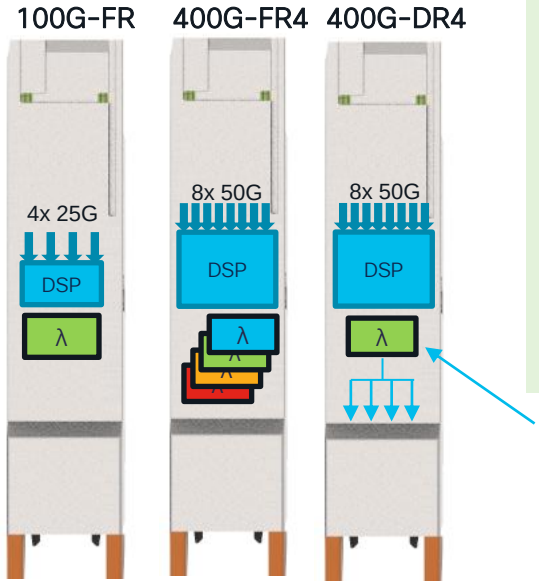


100G-SR4
100G-CWDM4
100G-LR4

100GBASE-DR
100GBASE-FR
100GBASE-LR

100 Gb/s PAM4 eye

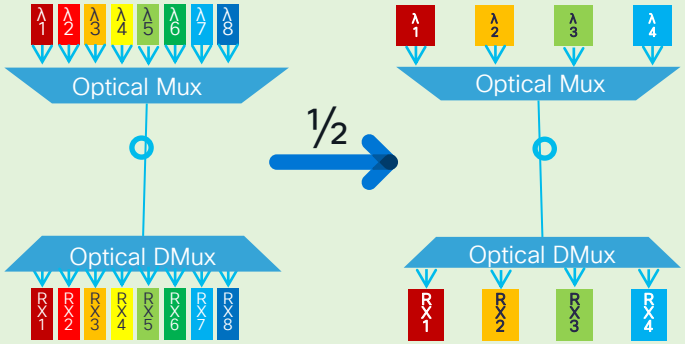




QSFP28

QSFP-DD

400 GbE

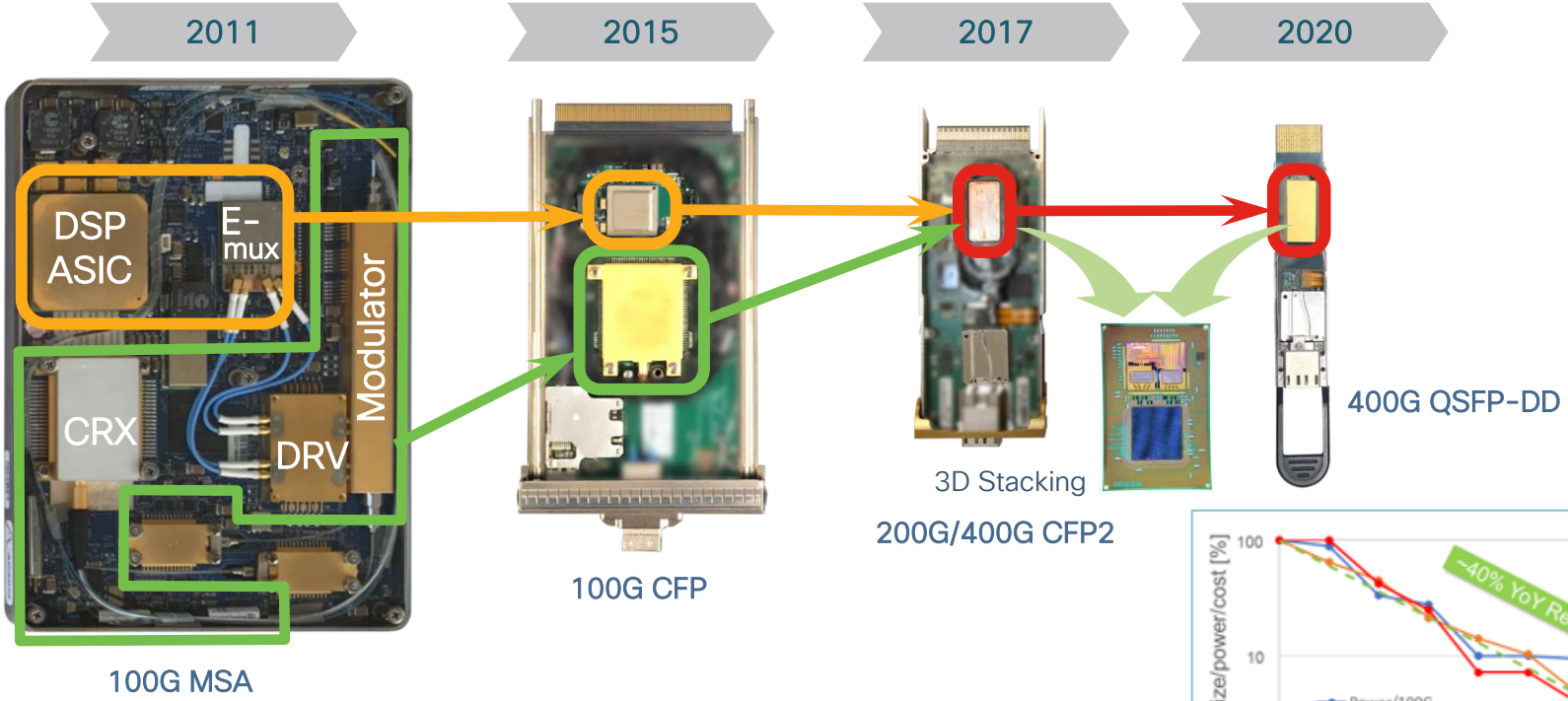


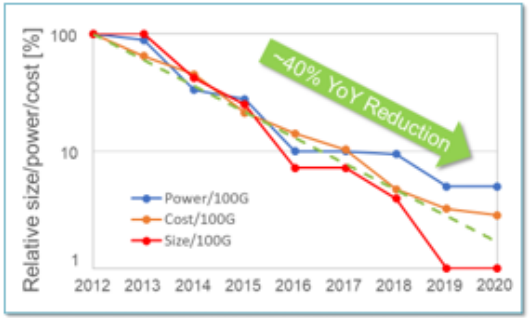
400GBASE-LR8

400GBASE-LR4

Bonus:
in SiPhotonics a single laser power can be split across 4 lanes

The Efficiency of Siliconization – 400G Coherent





Reducing Power, Size & Cost through Silicon Photonics integration

Pluggable Coherent Module Standardization – 400ZR

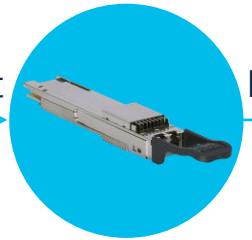
- Advanced Coherent optics – long distance DWDM
- QSFP-DD 400 GbE pluggable
- Compatible with DWDM line systems or dark fiber
- Focused on multivendor interoperability and power optimization
  - OIF driven DWDM I/F specification
  - Standard form factors: QSFP-DD, OSFP or CFP2
- Supports multiple use cases:
  - Campus and metro applications
  - Data Center Interconnect, Peering, Core, Edge, Aggregation networks
  - Enterprise, Wireline, Mobile and Cable markets

Standardization Drives Efficiency

Combines the best of two standardization efforts

OIF 400ZR

Simplified functionality
Edge optimized FEC (C-FEC)

400GE → Client →  Line → *400ZR – 120km*

Open ROADM

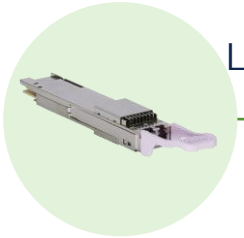
Flexible Client Mapping +
High Performance FEC (oFEC)

100G
200G
300G
400G
Ethernet
OTN
FlexO

Client →  Line → *100G*
200G
300G
400G
OpenROADM

OpenZR+ MULTI-SOURCE AGREEMENT

100GE
200GE
400GE
Nx 100GE
(Muxponder Mode)

Client →  Line → *100G*
200G
300G
400G

Simplified functionality +
High performance FEC (oFEC)

High performance pluggable modules
Multi-vendor interoperability

Cisco Blog: OpenZR+ Delivers 400G Coherent Optics for Multi-Haul Networks

Cisco and 400 GbE Industry Activities

✓ Complete

Cisco-led

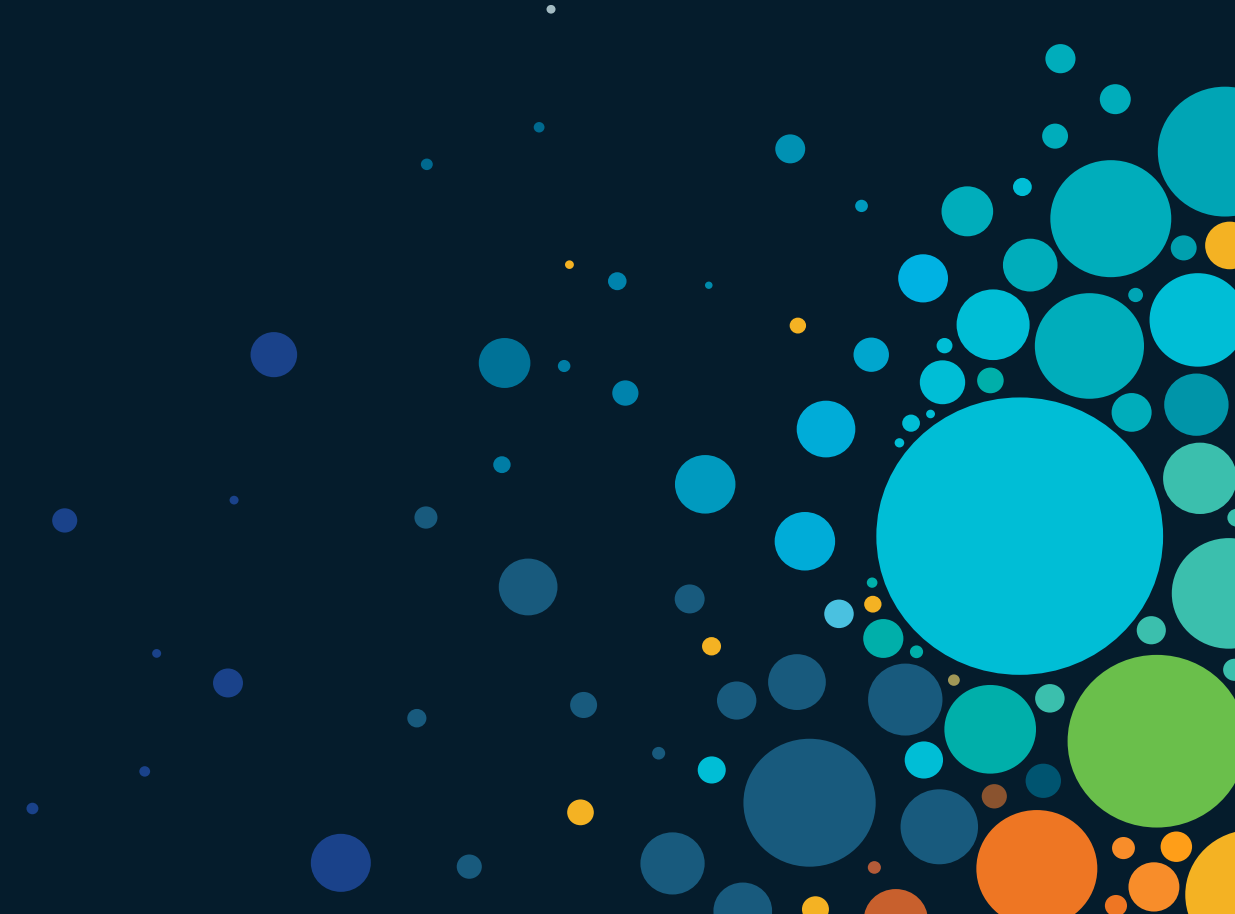
Standards	IEEE 802.3bs ✓ Cisco IEEE 802.3cd ✓ Cisco IEEE 802.3cm ✓ IEEE 802.3cn ✓ IEEE 802.3ct ✓ IEEE 802.3cu ✓ Cisco		400 GbE & 200 GbE MAC & Initial Interfaces 50 GbE MAC & Interfaces (also 100 GbE & 200 GbE PMDs) 400 GbE MMF (BiDi and SR8) Extended reach (40km) 50 GbE, 200 GbE, 400 GbE 100GbE Coherent 80km 100G-FR, 100G-LR, 400G-FR4, 400G-LR4-6
	OIF400ZR 802.3cw	Cisco	400 GbE Coherent 120km / 400 GbE Coherent 80km
	802.3ck	Cisco	100GE serdes
	802.3db		100/200/400GE MMF (100Gb/s short wavelength)
	802.3df	Cisco	200 Gb/s, 400 Gb/s, 800 Gb/s, and 1.6 Tb/s Ethernet Task Force
MSAs*	100G Lambda MSA	Cisco	100G-FR, 100G-LR, 400G-FR4, 400G-LR4-10
	QSFP-DD MSA	Cisco	400G Form factor
	OSFP MSA		400G Form factor
	SFP-DD MSA		100G Form factor
	400G-BiDi MSA	Cisco	400 GbE MMF BiDi
	OpenZR+ MSA	Cisco	OpenZR+ Interoperability specifications
	QSFP-DD800 MSA		800G Form Factor

Summary: Enabling technologies

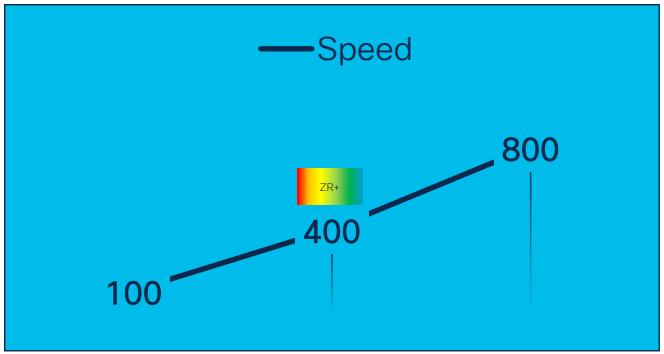
400 GbE brought about new technologies that can then be used to improve the efficiency of your network deployment:

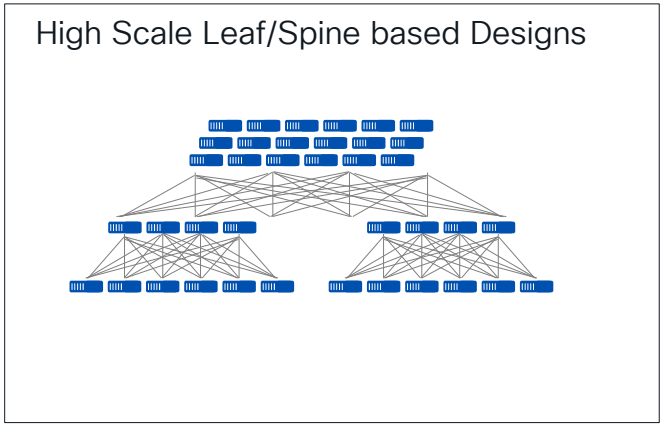
- High-speed, low power optical technology
  - Enabled by SiPhotonics
- New common form factor – QSFP-DD
  - Copper to coherent reaches supported
- Breakout – system density
- Coherent in a pluggable (form factors QSFP-DD, CFP2, O-SFP)
  - Standardization: providing multi-vendor interop ZR, ZR+
  - Industry first for coherent interfaces (400ZR)
  - Multi-application w/ZR and ZR+
    - Metro, regional, simple LH,
    - Campus, Data Center Interconnect, Peering, Core, Edge, Aggregation networks
    - Enterprise, Wireline, Mobile and Cable markets
- Standardization – common technologies at scale

Architectural Impact



400G Impact to DC Network Fabric

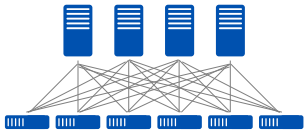




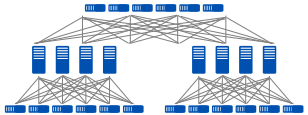
- Common network architecture between 100G and 400G enabling simple upgrade.
  - Same port densities, same media reaches.
- Flexibility to adopt 400G breakout for high radix 100 GbE design
  - Connect to legacy 100 GbE equipment
- Design flexibility
  - high bandwidth, high port density platform flexibility w/ fixed, modular
  - Link speed flexibility
  - Port flexibility – non / coherent use cases
  - Cabling flexibility – reduce fibers
- Backward and forward compatibility
  - 100G, 400G, 800G

Adoption of 400G in DC Designs

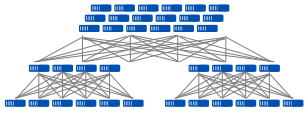
2-Tier Leaf/Spine



3-Tier Leaf/Spine



Evolved 3-Tier Leaf/Spine



- Increasing Scale-Out in all Tiers
- Dense 400G Switch Platform Flexibility
- Same port density 4x the capacity
- Further Possibility for Cost Optimization
- Latency optimization – fixed platforms
- Improved application performance – High bandwidth 400G fabric
  - Improved ECMP performance – bigger flows, larger flow buckets

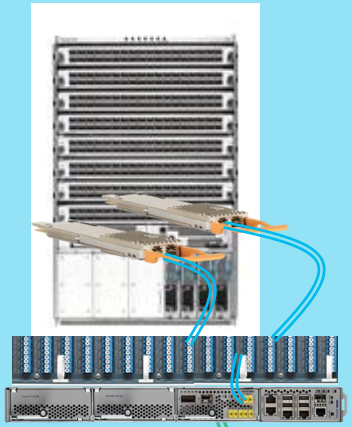
400ZR enables simplified DCI

DC A

Router / QDD-ZR/ZR+

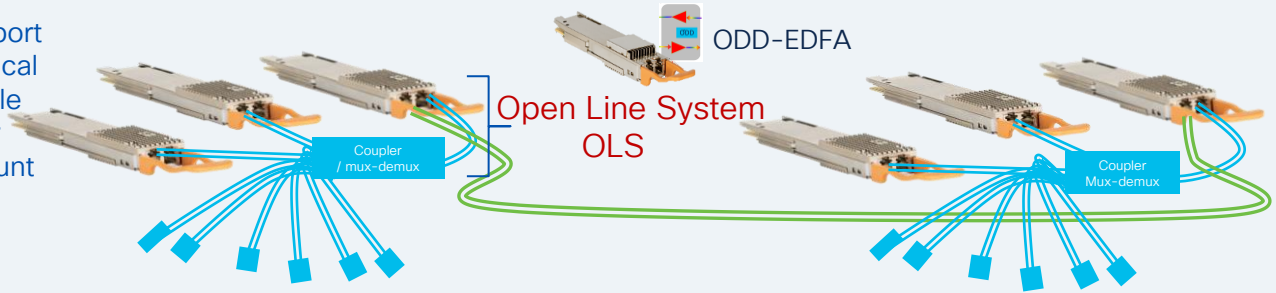
ZR or ZR+ for DCI
QSFP-DD form for
Transport
Optimization

DC B



Up to 140km*

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

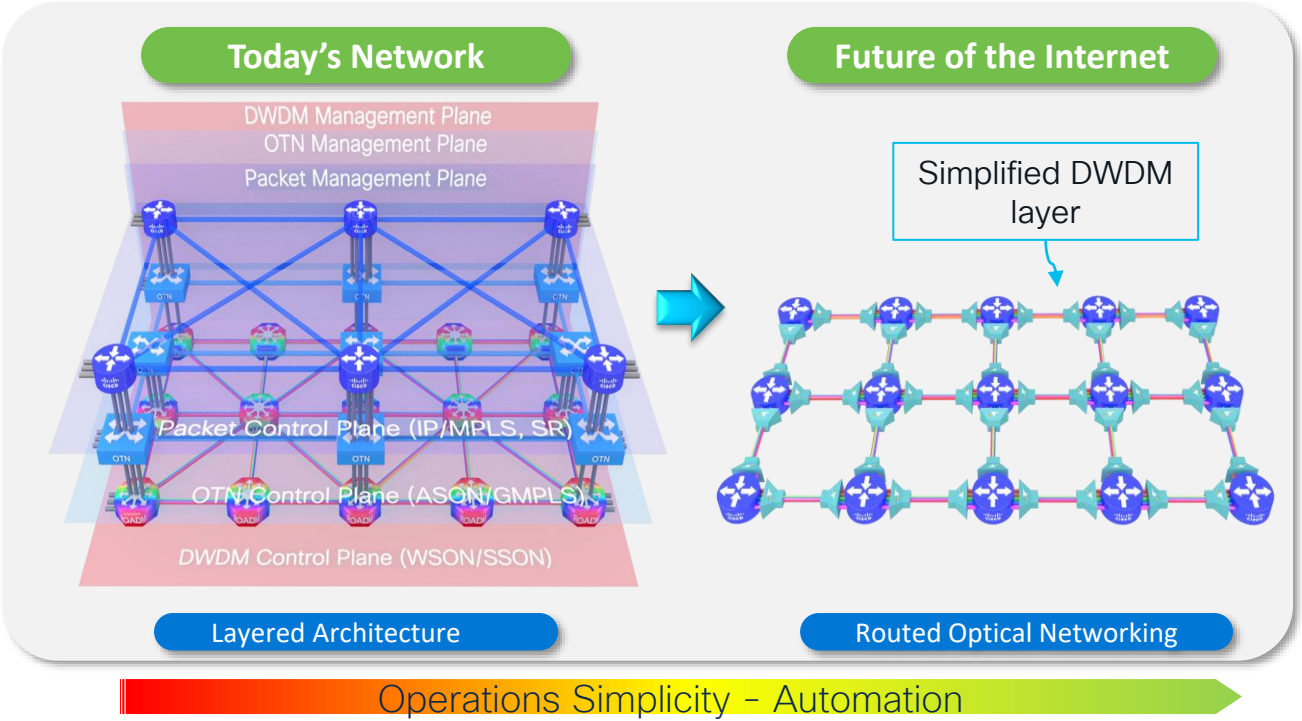


400G Coherent pluggable enables Routed Optical Network

DWDM interfaces directly off switch/router with no loss of density

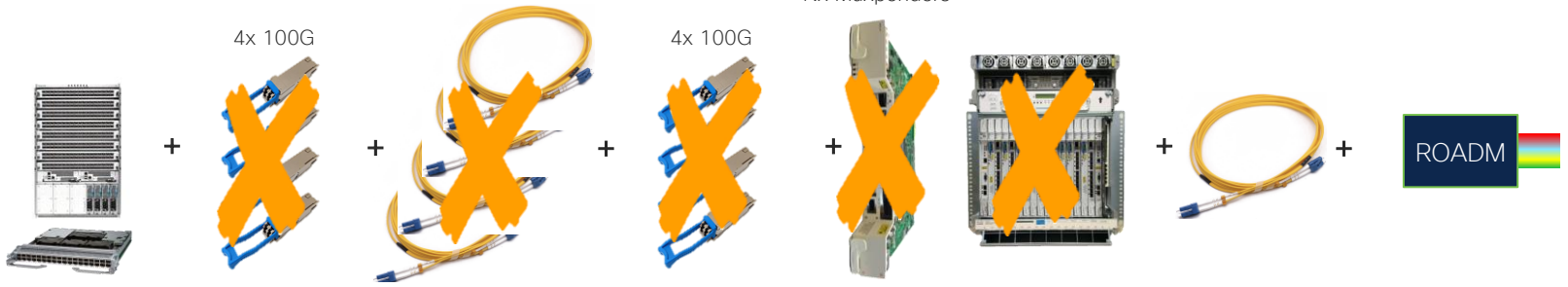
Flattened network architecture

Significantly lower TCO

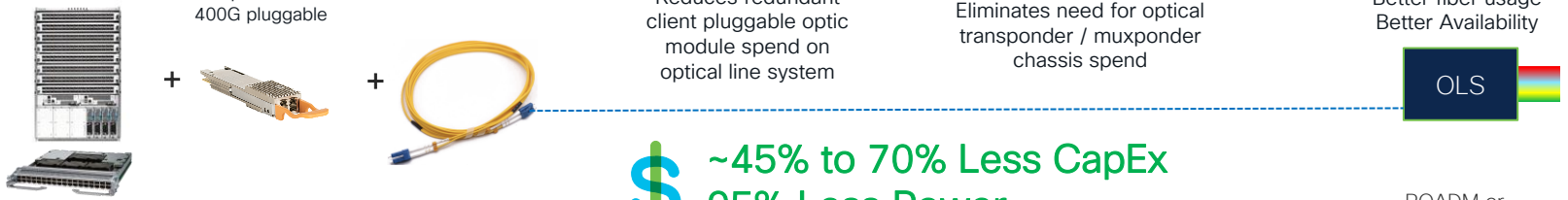


Routed Optical Networking: Removing Complexity

Previous



Today



Routed Optical Networking Solution Pillars

Converges Services: L1, L2 and L3 services with rich SLAs over IP/MPLS
Private Line Emulation for transparent services over packet switching*

Mass-Scale Routing Platforms

Multi Tbps NPUs and line cards
(Cisco and Merchant)

Less space/power per bit

Cost-effective for all services
(Port + Optics, OTN + IP)

Common Hardware

No dedicated or specialized hardware

Zero port density trade-offs

No hidden hardware costs

Standardized Optics

Digital Coherent Optics over QSFP-DD form factor
Standardized
Re-usable

Multi-vendor ecosystem

Gains of scale

Simplified Operations

Single IP/MPLS control plane with Segment Routing

End-to-end model-driven, and programmable

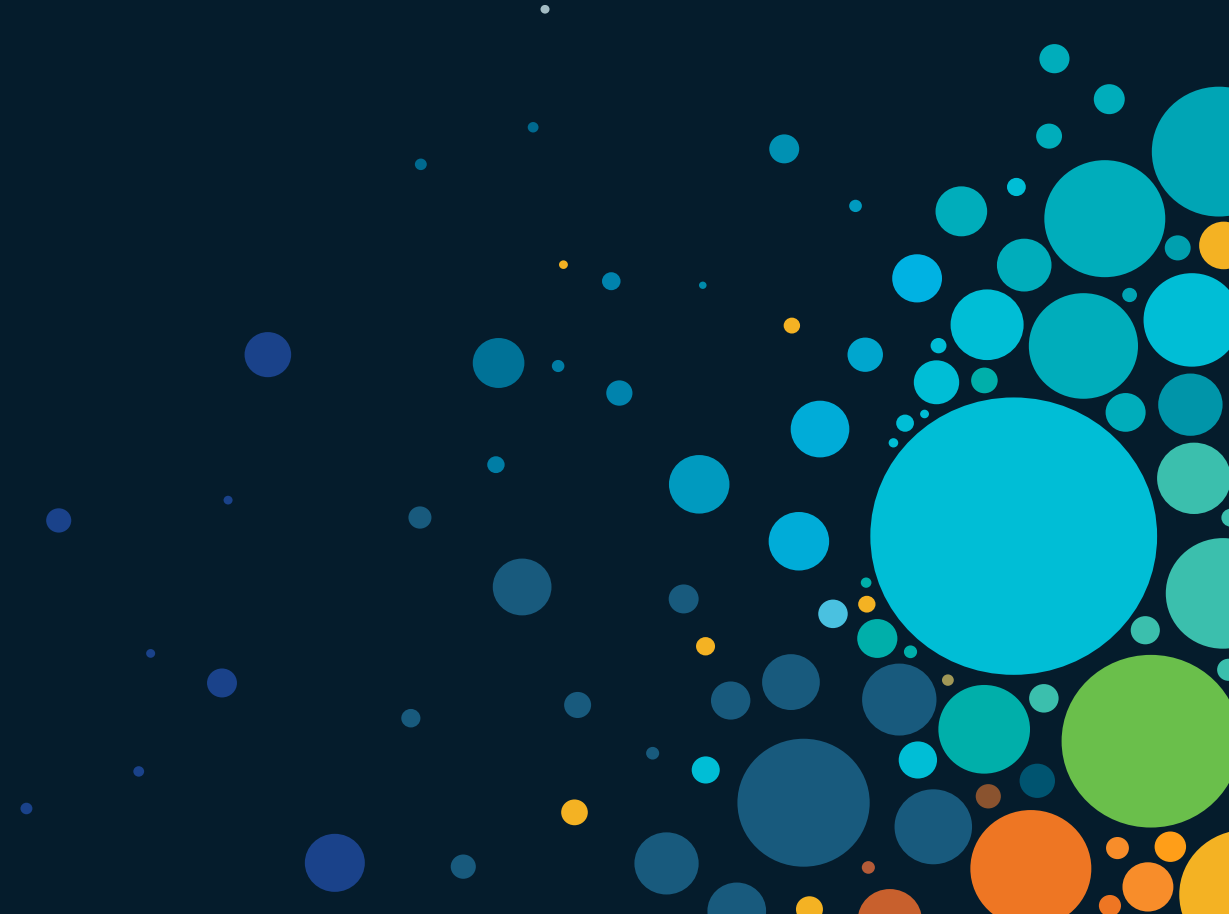
Hierarchical Controller architecture

** Private Line Emulation is a Cisco innovation which is currently under development.*

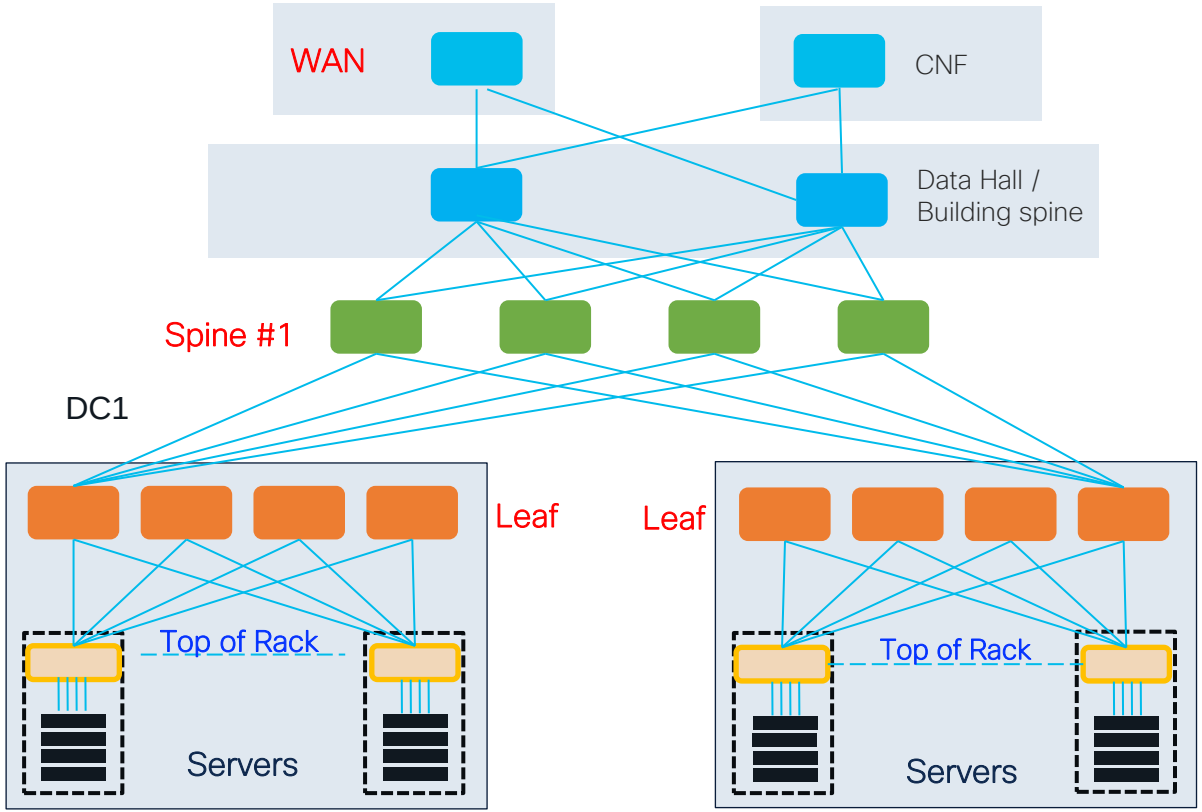
Summary: Architectural simplification

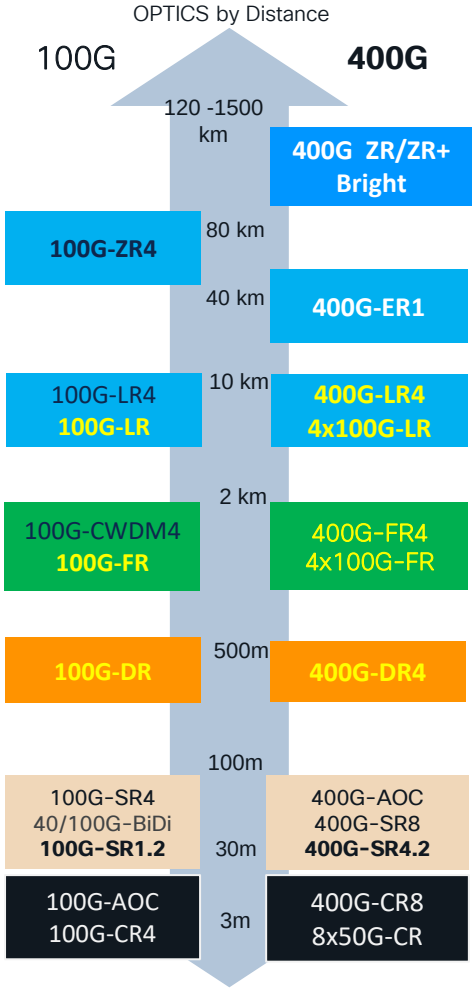
- 400G allows for design commonality & flexibility – link, port, fabric, cabling, breakout …
- Provide architecture scale, cost optimization and simplification
- Optimized DCI solutions
- New architecture – Routed Optical Networking
- Elimination of Network Elements

Operational Flexibility

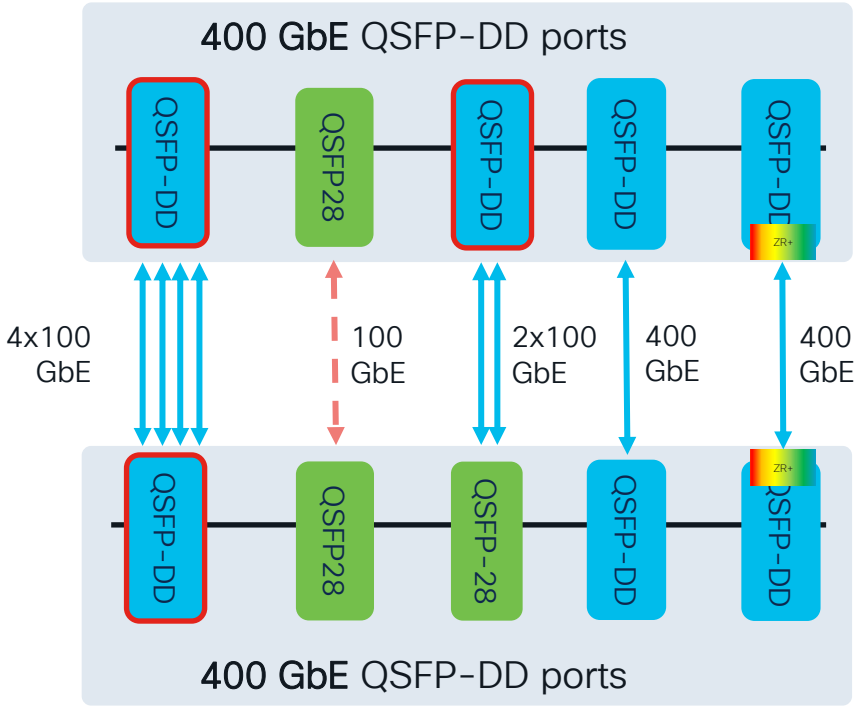


400G Optics covers the entire network solution





400 GbE Flexibility



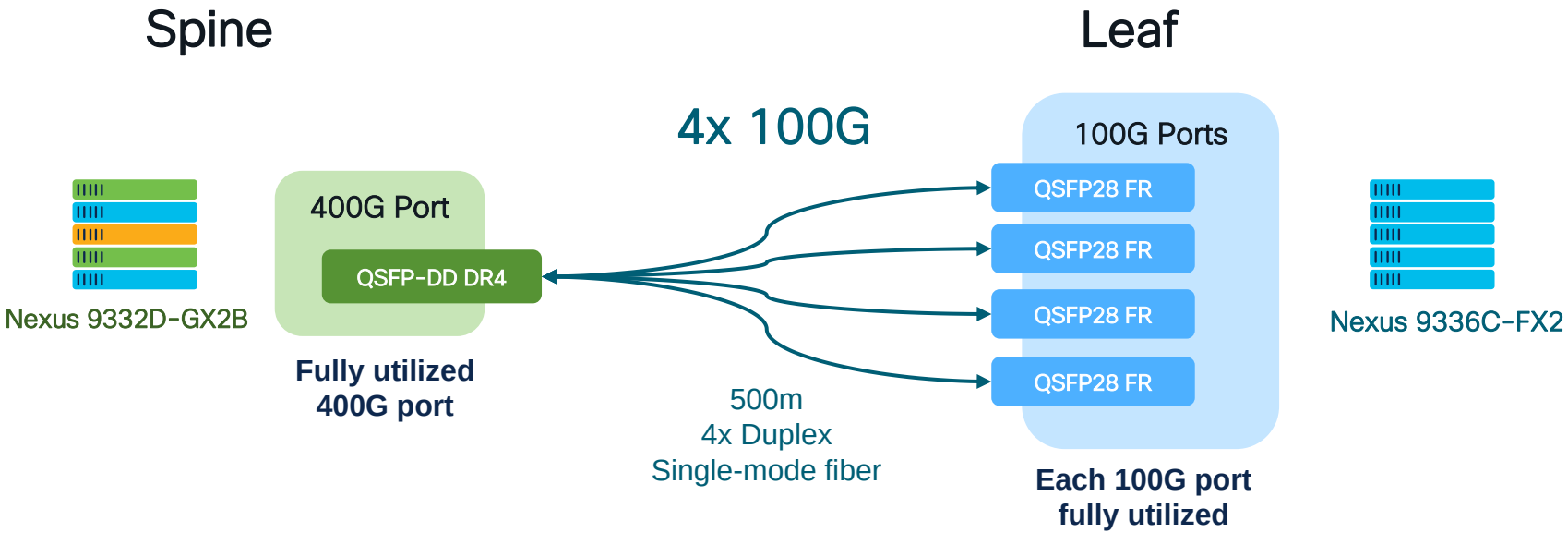
400 GbE

- Less ports manage vs n x 100 GbE links
- Improved system performance
- Fewer cables – improve airflow
- Connectivity to existing and new platforms
- ZR/ZR+ coherent – extended reach

Full switch port bandwidth

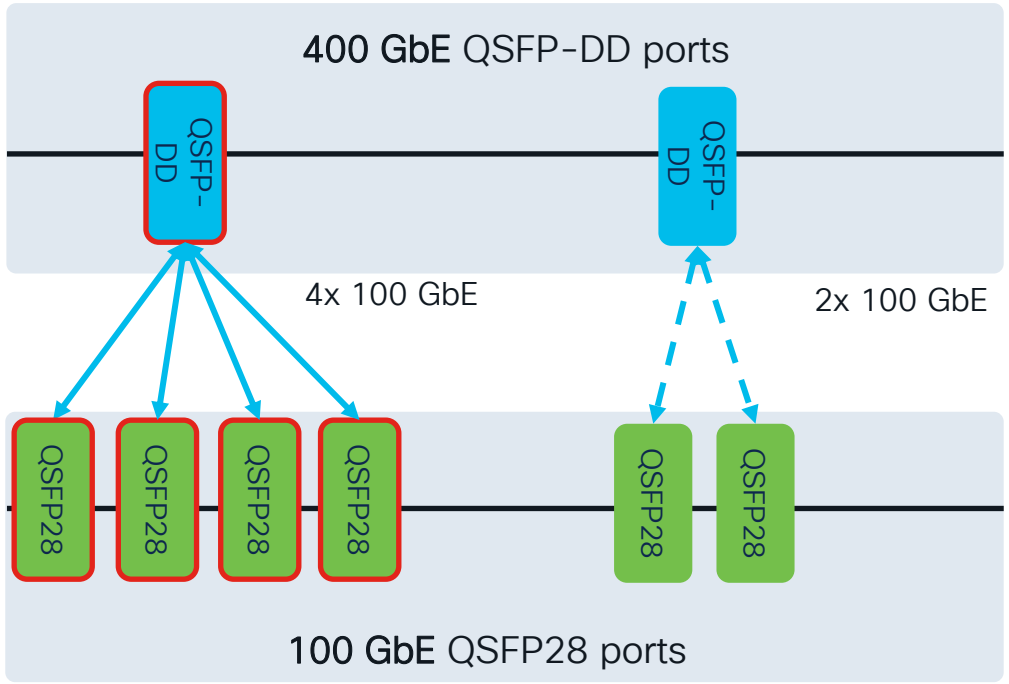
Reduced switch port bandwidth

Breakout capabilities with 400G optics



4x 100G breakout for single-mode fiber is only possible with the new QSFP28 Single Lambda 100G optics, not with first generation of QSFP28 SMF optics

Connecting to existing 100 GbE Equipment



Forward compatibility with newer switch systems is possible using the 100G single λ optics.

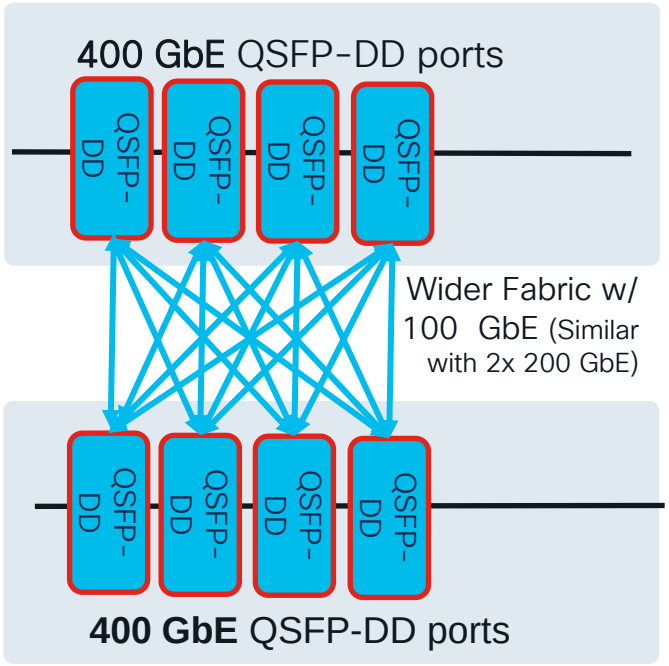
QSFP28 SR4, LR4, CWDM4

QSFP28 100G-DR/FR

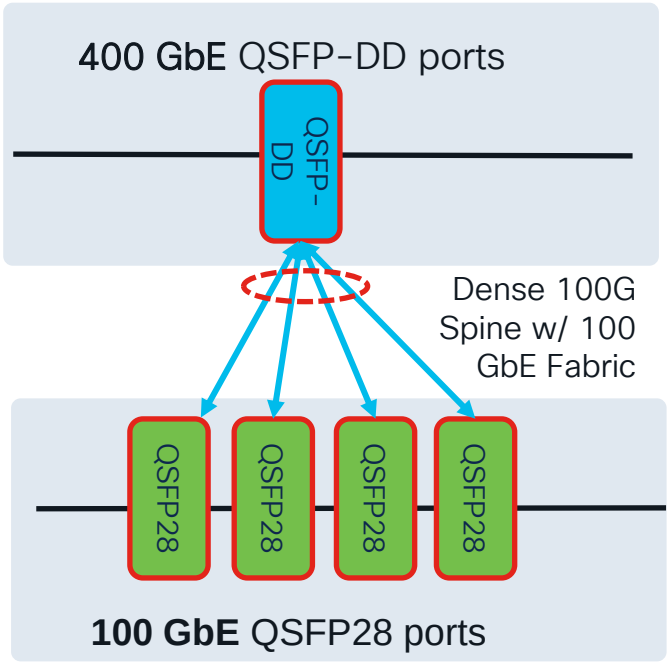
Full port bandwidth

Reduced port bandwidth

400G breakout for dense 100 GbE connectivity



Wider fabric – each port a diff switch



Port aggregation

400G ZR/ZR+ Remote Routers/Switches

In case of symmetric 400G routers interconnect multiple option can be considered – assuming a WDM system in the middle 3 major use cases are possible

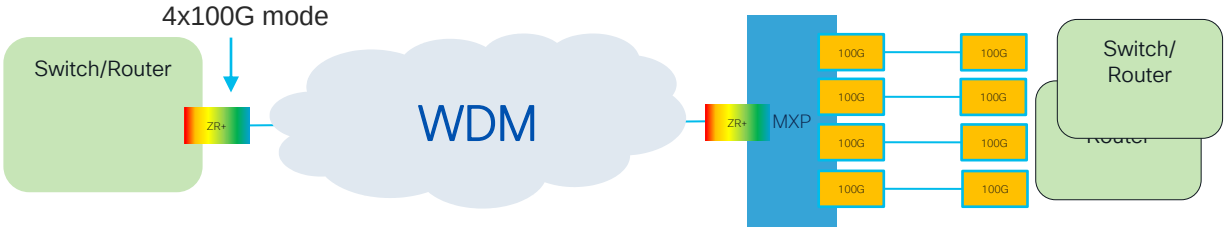
1. WDM ZR/ZR+ optics embedded on the router
   a) Sub case 1: Cisco WDM system
   b) Sub case 2: Third party WDM system

2. 400GE Interconnection with a 400GE capable TXP

3. 4x100GE fan out with a 100GE capable TXP

400G ZR/ZR+ Remote Routers/Switches

- The best option to interconnect a 400G router to a legacy 100G router is leverage 400G ZR+ optics embedded in the router (also ZR is OK if distance is less than 120km)
- Router 400G port is configured as 4x 100G fanout mode as ZR+ pluggable will transport those 100GE streams onto a single wavelength at 400G
- On the remote location, an interoperable mux-ponder (MXP) will break out 4 individual 100G interfaces to the 100G router



All the variant of 100G clients are available pending the selected muxponder

Summary: Operational Flexibility

- Common network architecture between 100G, 400G enabling simple upgrade
  - Same port densities, media reaches, coherent and non coherent mix deployment
  - Improved system switch capacity
- Maximize bandwidth with port flexibility
- Flexibility to adopt 400GE breakout for high radix 100GE design
  - Connect to legacy 100G equipment
  - Server breakout connectivity
- Backward and forward compatibility for 100G, 400G, 800G
- Improved reliability (fewer components or network elements = higher reliability)
- Improved application performance
- 400ZR+ provides speed/reach flexibility which can aid deployment

Deployment Considerations (Bonus Content)

Deployment considerations

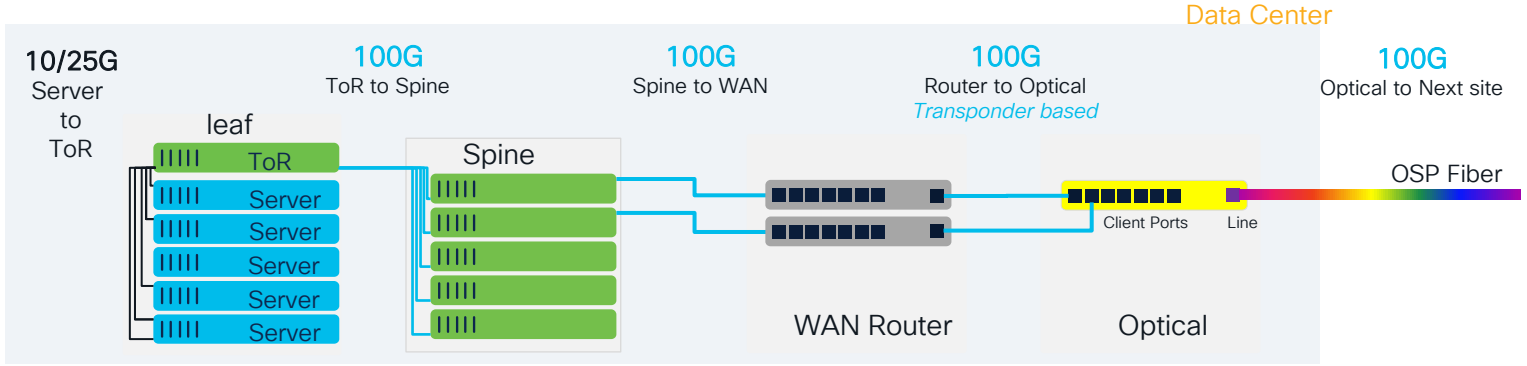
- Any transition to higher speed has a lot of deployment considerations which can help simplify the transition and more quickly realize the efficiencies
- The slides in this section are included for further reading to help with that transition. Contact Cisco or Partner team for deployment optimization at ask-optics@cisco.com
- Topics include:

Considering new 100G NICs ?	Switch Placement: ToR, MoR, EoR
Transition to 100G Single Lambda Optics for 400G Ready?	4x100G Breakouts save Power & Money
Cabling: SMF / MMF	Transition to 400ZR to recover Transponder

Key: Optimize Transition to 400G

10/25G NIC Servers

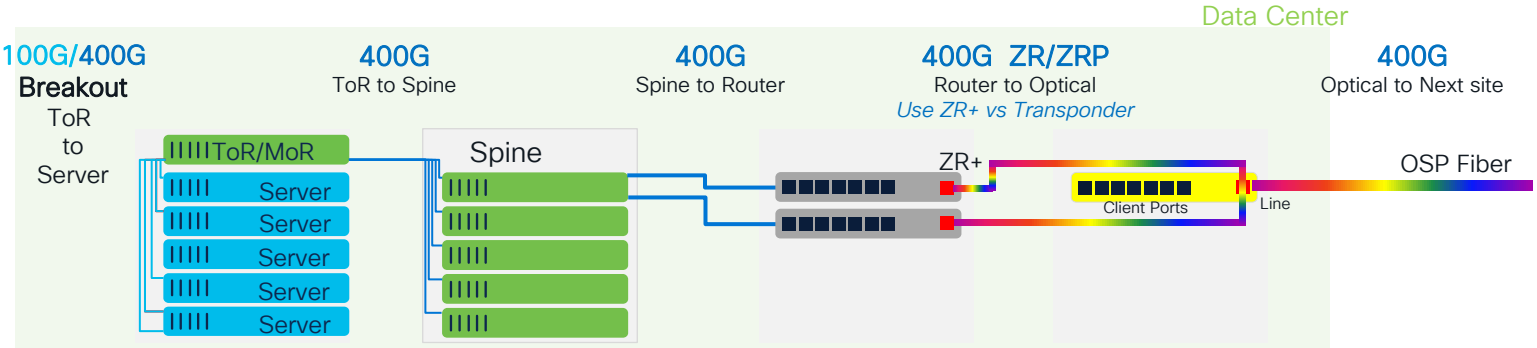
Now



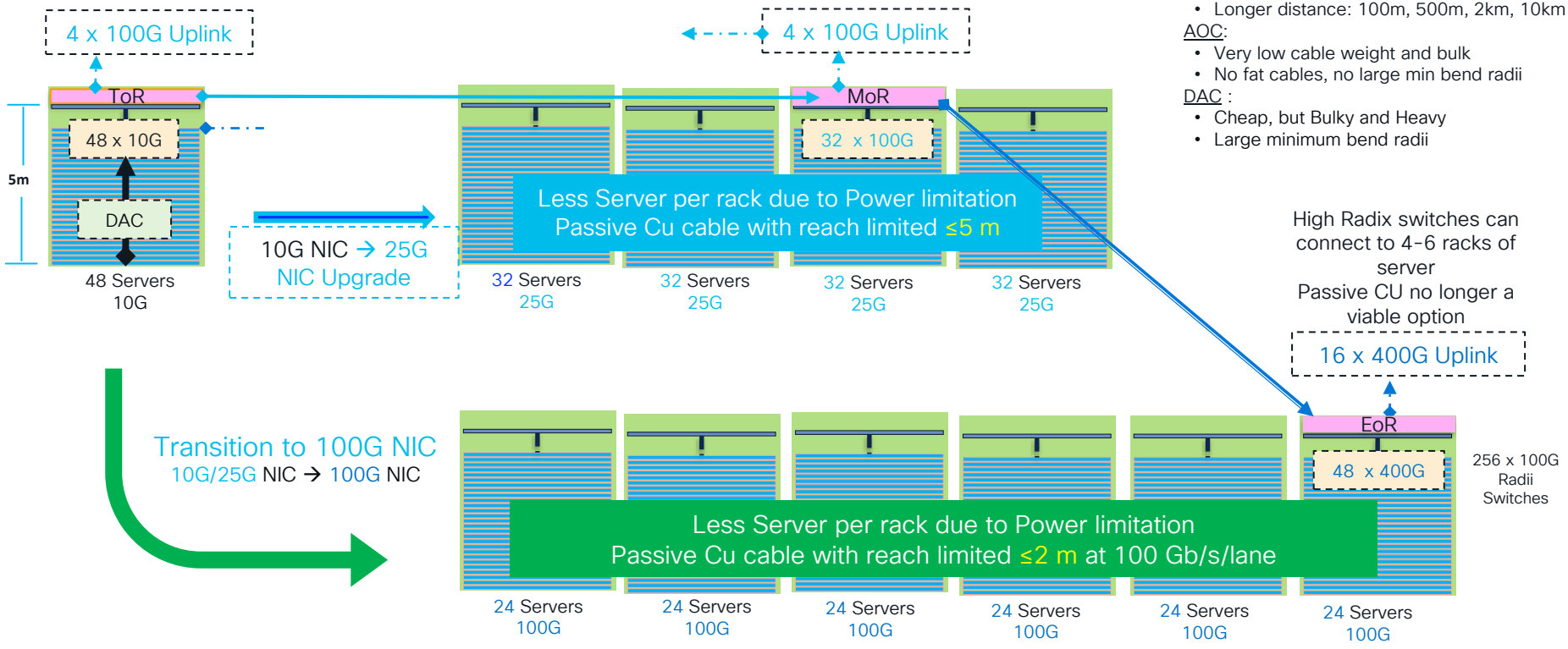
Sustainability: every 400G saves 5watts over 4x 100G, $, space, A/C
Tip: Save with 4x100G breakouts
Tip: Operationally align physical infra, sever, DC and WAN teams

Future

100G NIC Servers

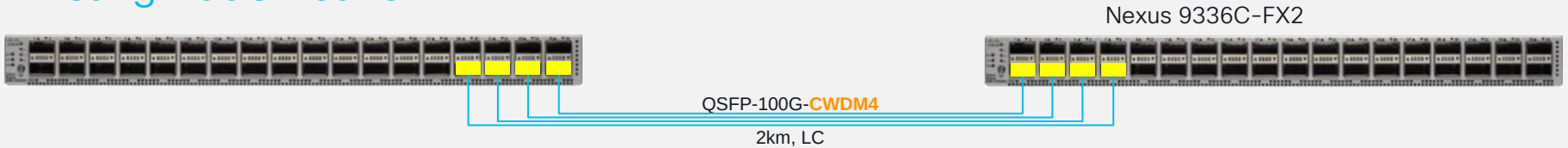


Opportunity: optimize ToR, MoR, EoR



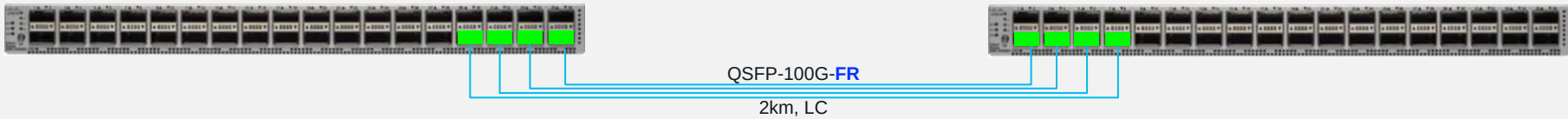
Prepare for 400G with 100G Single Lambda optics

1. Existing 100G network



- SMF Cabling, LC Connector
- 100G Legacy & Single Lambda: DR, FR, LR

2. Transition to 100G Single Lambda, 400G/800G ready



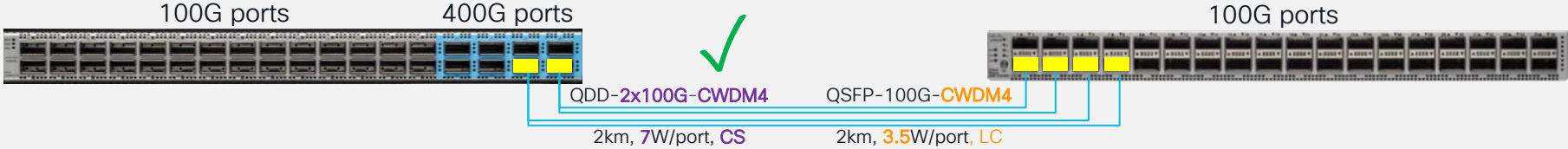
- Transition to QSFP-100G-FR-S
- Reuse SMF cabling, LC connector

Maximize your port with 4x100G or 2x100G breakout

✓ Maximize Ports with 4x100G breakout

- Transition to 400G Optics, maximize efficiency
- CAUTION: 400G port is MPO-12 connector, use Breakout cable for MPO to LC conversion
- Save 5W per 400G. 12W on QDD-4x100G-FR vs 17.2W for QSFP-100G-FR
- Save 3 ports

✓ If you must use Legacy, maximize with 2x100G



- Use when remote end only supports Legacy optics
- CAUTION: 2x100G optic is CS connector, use Breakout cable for CS to LC conversion
- Saves 2 ports

Side by side: Options to deliver 100G

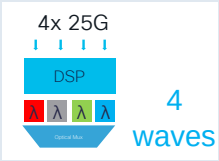
Cost per 100G: $$$

PID: QSFP-100G-CWDM4-S

Speed: 100G
Reach: 2 km, 1.2mi
Type: QSFP28
Power: 3.5W

Fiber: SMF
Connector: Duplex LC
Standard: CWDM MSA

4 Waves (nm):
1271, 1291, 1311, 1331
Xmt Power: -6.5 to +2.5
Rcv Power: -11.5 to +2.5



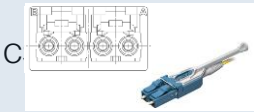
Breakout: to 2x100G CWDM LC LC — CS

Cost per 100G: $$

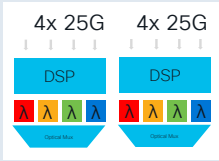
PID: QDD-2x100G-CWDM4-S

Speed: 2x 100G
Reach: 2 km, 1.2mi
Type: QSFP-DD
Power: 7W

Fiber: SMF
Connector: Dual Duplex C
Standard: CWDM MSA



8 Waves (nm):
1271, 1291, 1311, 1331
Xmt Power: -6.5 to +2.5
Rcv Power: -11.5 to +2.5



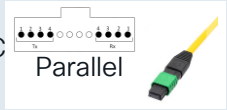
Breakout: to 100G-CWDM CS — LC LC

Cost per 100G: $

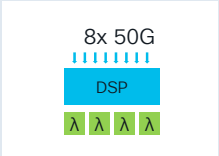
PID: QDD-4x100G-FR-S

Speed: 4x 100G
Reach: 2 km, 1.2mi
Type: QSFP-DD
Power: 12W

Fiber: SMF
Connector: MPO-12 (APC
Standard: 4x IEEE 100GBASE FR1



1 Wave (nm): 1310
Xmt Power: -3.1 to +4
Rcv Power: -7.1 to +4
400GAUI-8/CEI-56G- VSR- PAM4

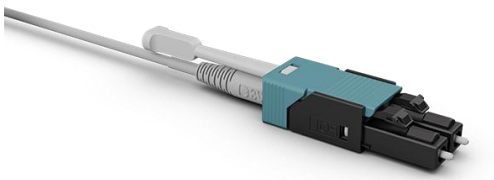


Breakout: to 4x 100G-FR

High Efficiency Optical Connectors

Two dominant ferrule/connector types

LC
single fiber ferrule

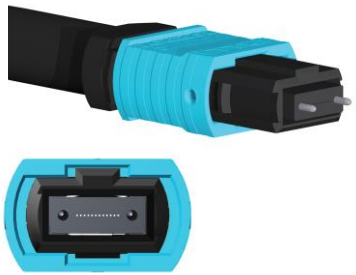


Uni-boot designs are common

Courtesy USCONEC

Used for all duplex fiber applications – SFP, QSFP, QSFP-DD etc

MPO/MTP
multiple fiber ferrule

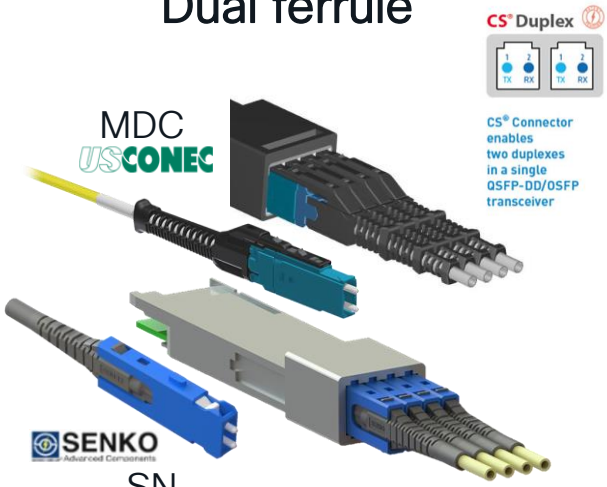


Courtesy USCONEC

Traditionally used for all parallel fiber applications – QSFP, QSFP-DD etc

New

Dual ferrule

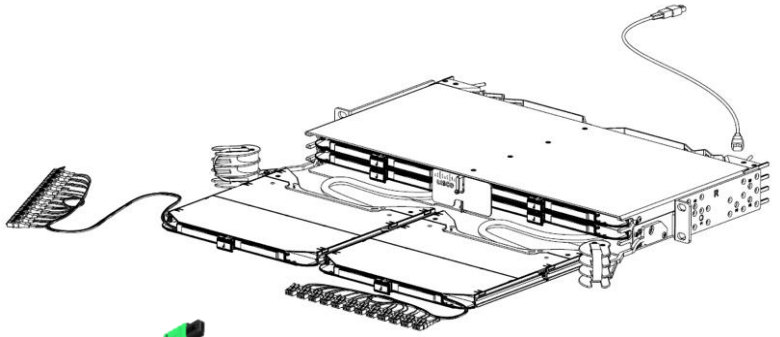


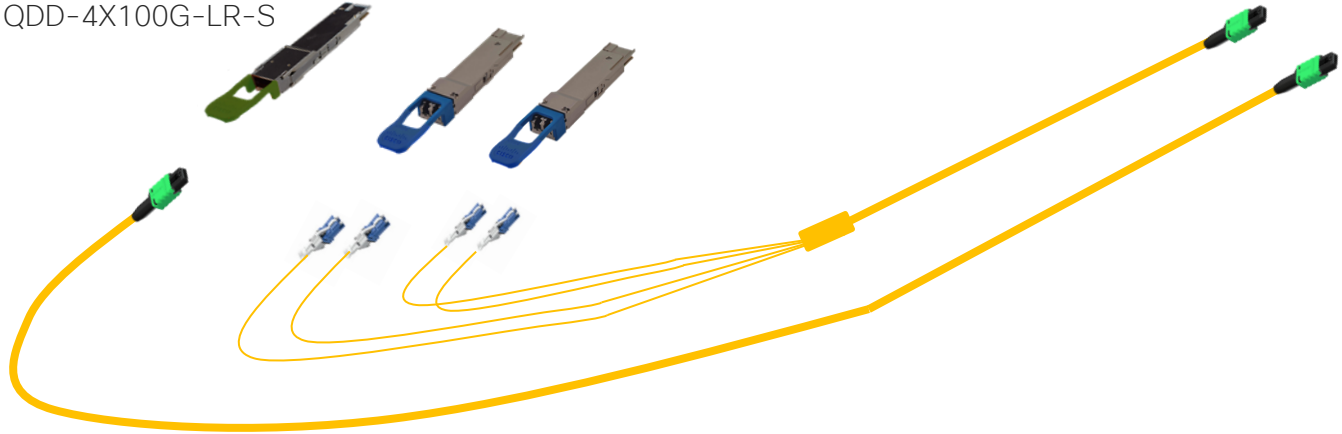
New high-density connectors for breakout applications (market adoption pending…)

Cabling Efficiency

MPO-12 Modules
QDD-400G-DR4-S
QDD-4X100G-FR-S
QDD-4X100G-LR-S

CS Connector Modules
QDD-2X100-LR4-S
QDD-2X100-CWDM4-S





Optics – All reaches across 100 GbE & 400 GbE

in a common pluggable

	100 m	500 m	2 km	10 km	40-100+ km
100G Optics	100G-SR4 100G-BiDi 100G-SR1.2*	100G-PSM4 100G-DR1	100G-CWDM4 100G-FR1	100G-LR4 100G-LR	100ZR 100ZR4
400G Optics	400G-SR8 400G-SR4.2 (aka 400G BiDi) 400G-SR4*	400G-DR4	400G-FR4 4X100G-FR1	400G-LR4 4x100G-LR	400G-ER1 (40km) 400ZR 400ZR+

* Still being standardized

How to Transition from 100G to 400G Optics

400G optics on both ends of the link

Reach	Optic today	Next Gen	Fiber Type; Breakout
100m MMF	100G SR4	400G SR4.2	Parallel fiber; supports breakout
500m SMF	100G PSM4	400G DR4 (500m) 4x100G FR (2km)	Parallel fiber; supports breakout
500m/2km SMF	100G SM-SR 100G CWDM4	400G FR4	Duplex fiber, no breakout
10km SMF	100G LR4	400G LR4	Duplex fiber, no breakout
80km SMF	100G DCO	400G ZR	Duplex fiber, no breakout
>120km SMF	Transponder	400G ZR+	Requires Optical, no breakout
<30m	100G AOC	400G AOC	
<3m	100G DAC	400G DAC	

Cisco's portfolio of QSFP-DD modules makes it easy to upgrade to 400G in many cases with the current fiber infrastructure

Upgrading only one end of the link to QSFP-DD?

QSFP-DD breakout options provide backwards optical compatibility to QSFP28

	Reach	QSFP 100G end	QSFP-DD end	Connect up to:
Legacy 100G 4x25G	100m MMF	100G SR4	2x100G SR4	TWO 100G-SR4 to a QSFP-DD port, use QDD-2X100-SR4-S
	2km SMF	100G CWDM4	2x100G CWDM4	TWO 100G-CWDM4 to a QSFP-DD port, use QDD-2X100-CWDM4-S
	10km SMF	100G LR4	2x100G LR4	TWO 100G-LR4 to a QSFP-DD port, use QDD-2x100-LR4-S
Single Lambda 1x 100G	500m SMF	100G-DR	400G DR4	FOUR 100G-DR to a QSFP-DD port, use QDD-400G-DR4-S
	2km SMF	100G FR	4x100G FR	FOUR 100G-FR to a QSFP-DD port, use QDD-4x100G-FR-S
	10km SMF	100G LR	4x100G LR	FOUR 100G-LR to a QSFP-DD port, use QDD-4x100G-LR-S
	100m MMF	100G BiDi	400G SR4.2	FOUR 100G-BiDi to a QSFP-DD port, use QDD-400G-SR4.2-BD

Cisco's portfolio of QSFP-DD provides efficient connectivity solutions between platforms for almost any interface

Summary

Summary

- 400G drove a lot of innovation. The market is growing & the technology is developed
  - New form factors, coherent pluggables, standardization, new architecture solutions
- These new technologies improve the efficiency of network deployments
- Simplified network upgrade from 100G to 400G possible due to transparency of network infrastructure
- Broader industry adoption of breakout:
  - High density deployment
  - Legacy network connectivity and migration
- New efficient architectures. Example: Routed Optical Networking
- Smooth path forward to 800G. [For more info see: BRKOPT-2699 “Optics is heading into the Terabit Era” on Wednesday]

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