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The bridge to possible

400G to Terabit Optics

What you need to know!

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BRKOPT-2699

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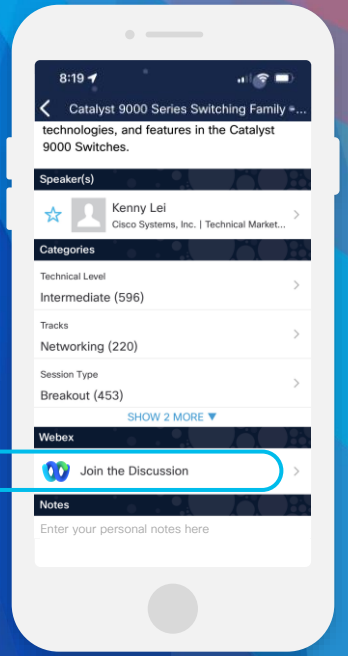


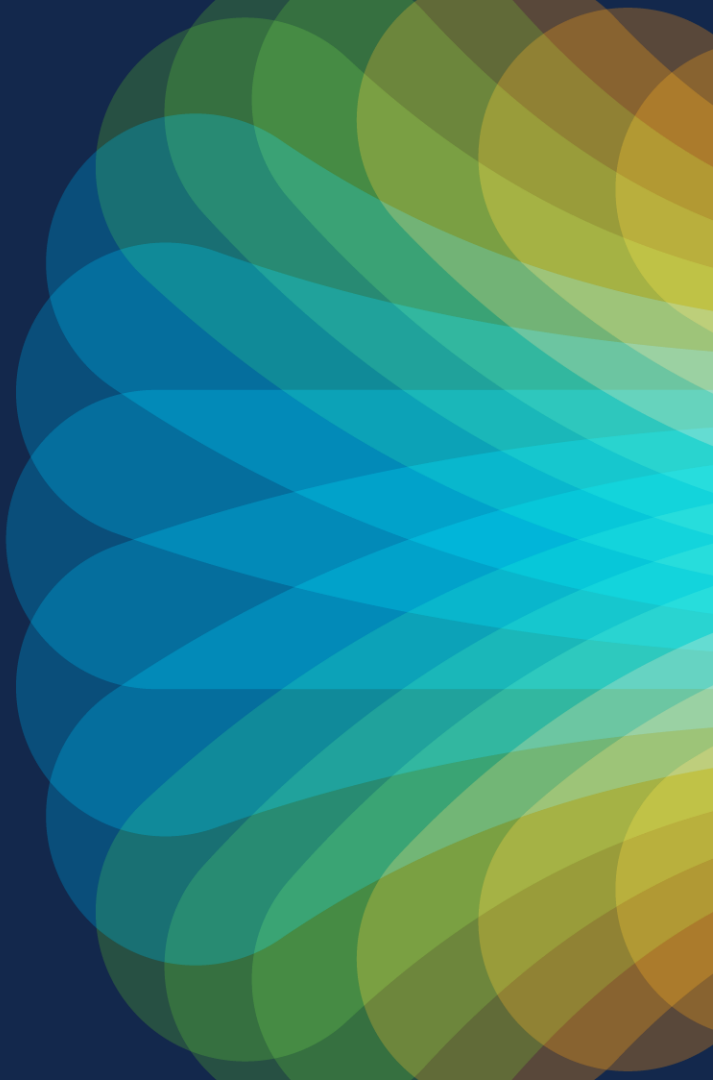
https://ciscolive.ciscoevents.com/ciscolivebot/#BRKOPT-2699

Agenda

- The current state of 400G market adoption
- Successfully deploying 400G
  - Considerations and challenges
- Going beyond 400G
  - New Implementations
  - New Technology
- Where are the standards going?
- Conclusion

Acknowledgements: This presentation would not exist without the inputs, expertise, and patience of many of our Cisco colleagues!

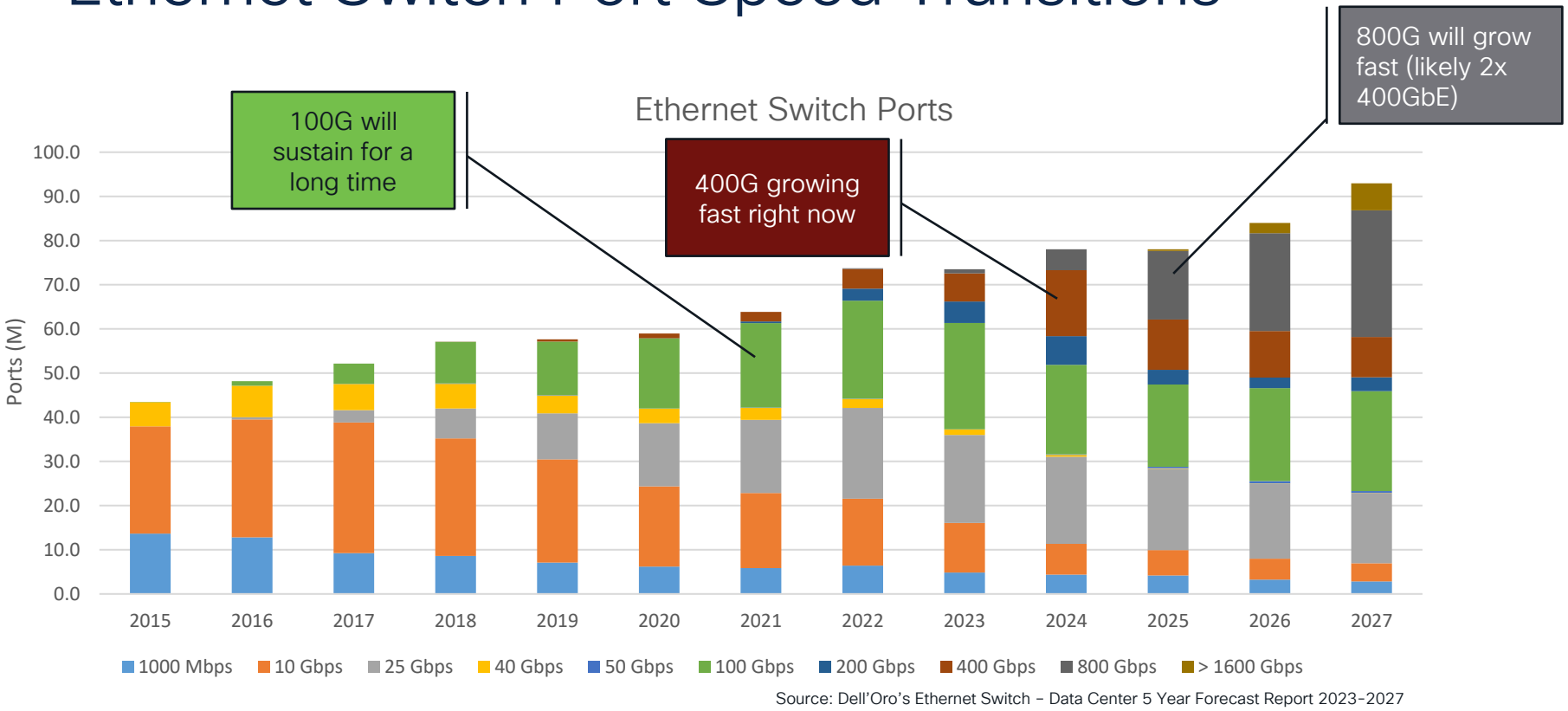
Market dynamics



Network operator top of mind

- Increasing capacity and sustainability
- Preserve investments in existing optics infrastructure and cabling
- Simplify operations and management of optical links
- Preparing for capacity expansion

Ethernet Switch Port Speed Transitions



Source: Dell'Oro's Ethernet Switch – Data Center 5 Year Forecast Report 2023-2027

Market segments adopting higher speeds

400G/800G

Hyperscalers

100G/400G/800G fabrics

AI/ML compute clusters

Disaggregation

Webscalers

Scale-out fabrics

25/50/100G server NICs

Vendor NOS supporting open, API-based automation

100G/400G

Enterprise

High performance IO

AI/ML compute clusters

Automation/ Monitoring

Media providers

Fabric for Media (IPFM)

8K uncompressed video driving 100G endpoints

Need for 400G uplinks

Telco service providers

100G/400G fabrics

Space constrained SP DC and edge locations

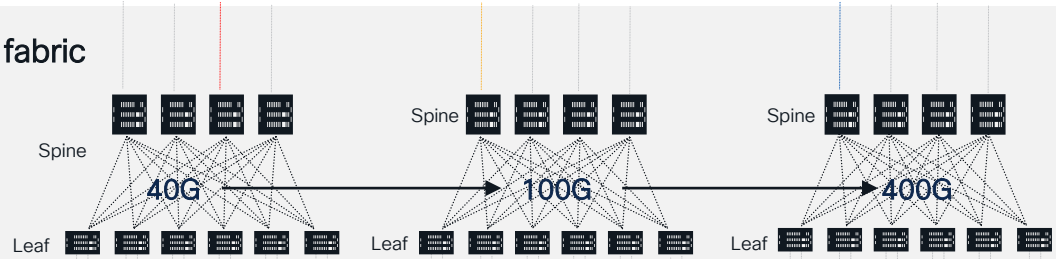
Ready for NFV/5G adoption cycle

Speed evolution in the data center

Inter-Data Center

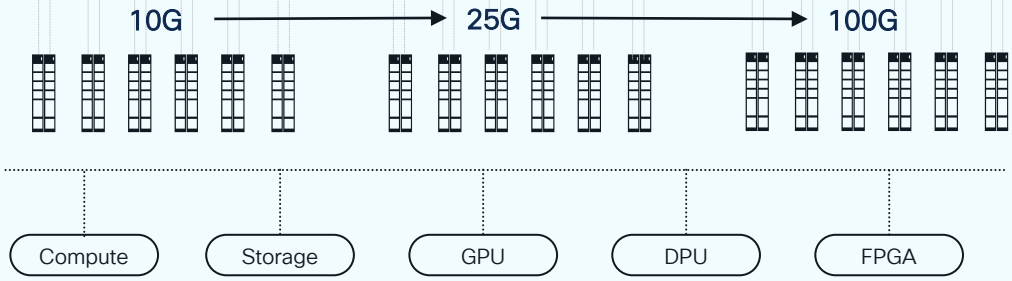
- Transitioning to pluggable DCI (DWDM coherent)
- Open Line System

Switch fabric



- Switch silicon bandwidth growing due to higher Radix and faster Serdes speeds
- Switch ASIC throughput growing: 6.4 Tbps to 12.8 Tbps to 25.6 Tbps to 51.2 Tbps (future)
- Optics increasing from 40Gbps to 100G Gbps to 400Gbps to 800Gbps

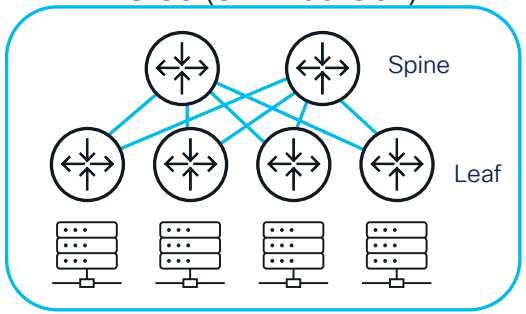
Access



- Server network connectivity evolves with server processor upgrade cycles as data center traffic grows
- Server port speed is transitioning from 1/10 Gbps to 25 Gbps to 100 Gbps
- Storage, GPU, DPU, FPGA driving connectivity bandwidth, PCIe speed increase

Why move to higher speeds?
400G → 800G example (same is true for 100G→ 400G)

25.6T user capacity using multiple switches with 12.8T ASICs (32x 400 GbE)



50 Gb/s ASIC IO (SerDes)
64 ports of 400GbE
(256 ports of 100 GbE)

~3000 Watts
26,280 kWh/year

=

25.6T user capacity using single switch with 25.6T ASIC (32x 800 GbE)

100 Gb/s ASIC IO (SerDes)
32 ports of 800G
(64 ports of 400 GbE
256ports of 100 GbE)

~400 Watts
3,504 kWh/year

=

Up to 87%
Energy Savings

83% less space/fans

Current state of 400G optics

Cisco and 400 GbE Industry Activities

✅ Complete @ 400G
Cisco-led

Standards	IEEE 802.3bs ✅ Cisco IEEE 802.3cd ✅ Cisco IEEE 802.3cm ✅ IEEE 802.3cn ✅ IEEE 802.3ct ✅ IEEE 802.3cu ✅ Cisco IEEE 802.3ck ✅ Cisco IEEE 802.3db ✅	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 100GE serdes 100/200/400GE MMF (100Gb/s short wavelength)
	OIF400ZR ✅ / 802.3cw Cisco	400 GbE Coherent 120km / 400 GbE Coherent 80km
	802.3df Cisco	200G/400G/, 800G Ethernet Task Force @ 100Gb/s per lane
	802.3dj Cisco	200G/400G/800G/1.6T Ethernet Task Force @ 200Gb/s per lane
	802.3dk	Greater than 50 Gb/s Bidirectional Optical Access PHYs Task Force.
MSAs*	100G Lambda MSA ✅	100G-FR, 100G-LR, 400G-FR4, 400G-LR4
	QSFP-DD MSA ✅ Cisco	400G/800G/1.6T Form factor
	OSFP MSA ✅ Cisco	400G/800G/1.6T Form factor
	SFP-DD MSA ✅	100G Form factor
	DSFP MSA. ✅	Alternative 100G Form Factor (Mobile)
	400G-BiDi MSA ✅ Cisco	400 GbE MMF BiDi

* Multi-Source Agreements – new ones all the time. Not all get wide industry adoption

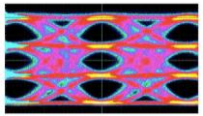
Flexibility of 400G pluggable modules

- Copper cables
- Multimode Fiber – 100m
- Single Mode Fiber inside DC – 500m & 2km
- Single Mode Fiber Campus – 10 km
- Outside plant, DCI – 100-1000 km

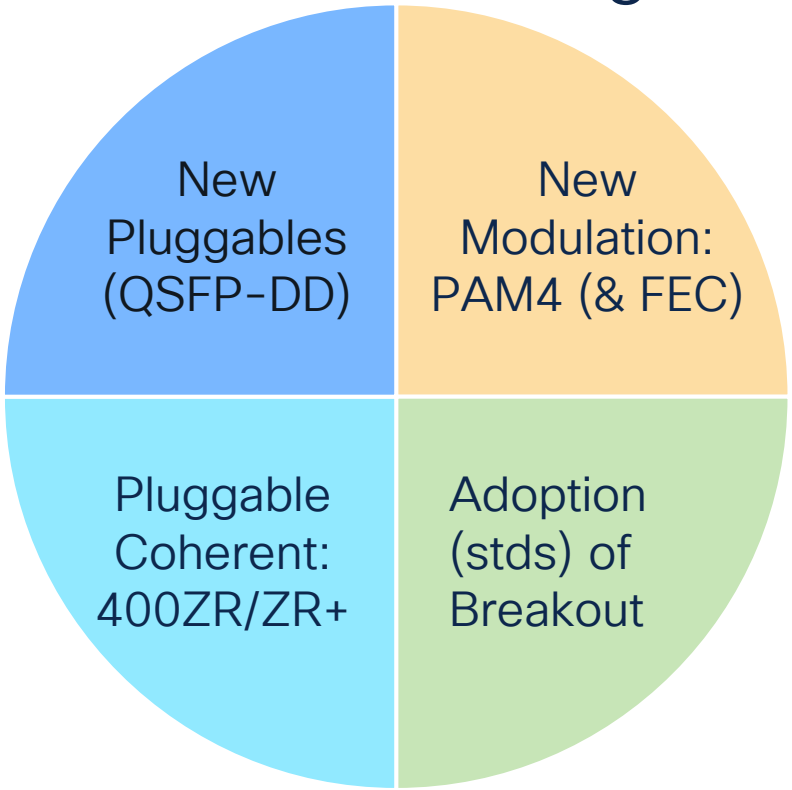
400 GbE modules and use cases
Full portfolio of interfaces available for use

What innovations did 400G bring?

New pluggable required to support 400G ports (8-wide)



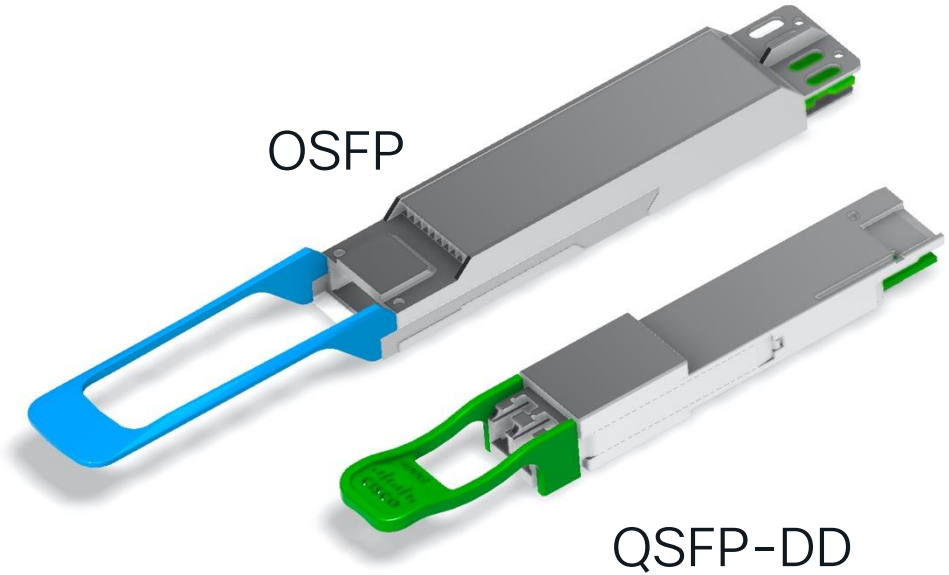
Higher speed interfaces adopted PAM4 modulation. Ubiquitous use of FEC.



Long reach coherent without any system port density reduction → Routed Optical Networking

Pluggable modules supporting multiple lower speed interfaces

400G Optical Modules: QSFP-DD or OSFP



Initiated by Cisco, QSFP-DD was proven to address all the technical and market requirements for a successful 400 GbE roll-out.

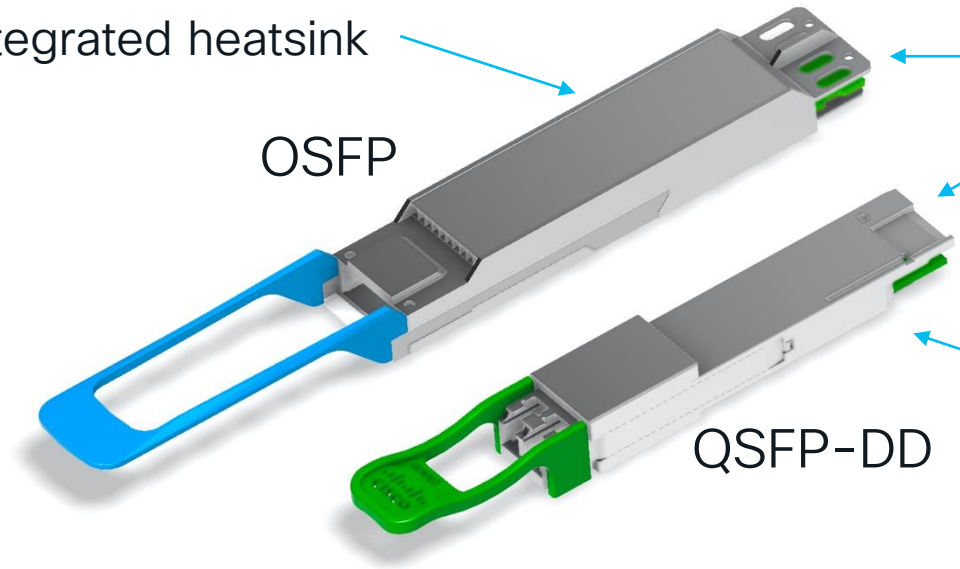
QSFP-DD is supported by every system vendor and module vendor. Drives economies of scale.

Ultimately, both modules meet all technical requirements (power, cooling, signal integrity). Differences are in alignment to market needs.

400G Optical Modules: QSFP-DD or OSFP

Integrated heatsink

OSFP



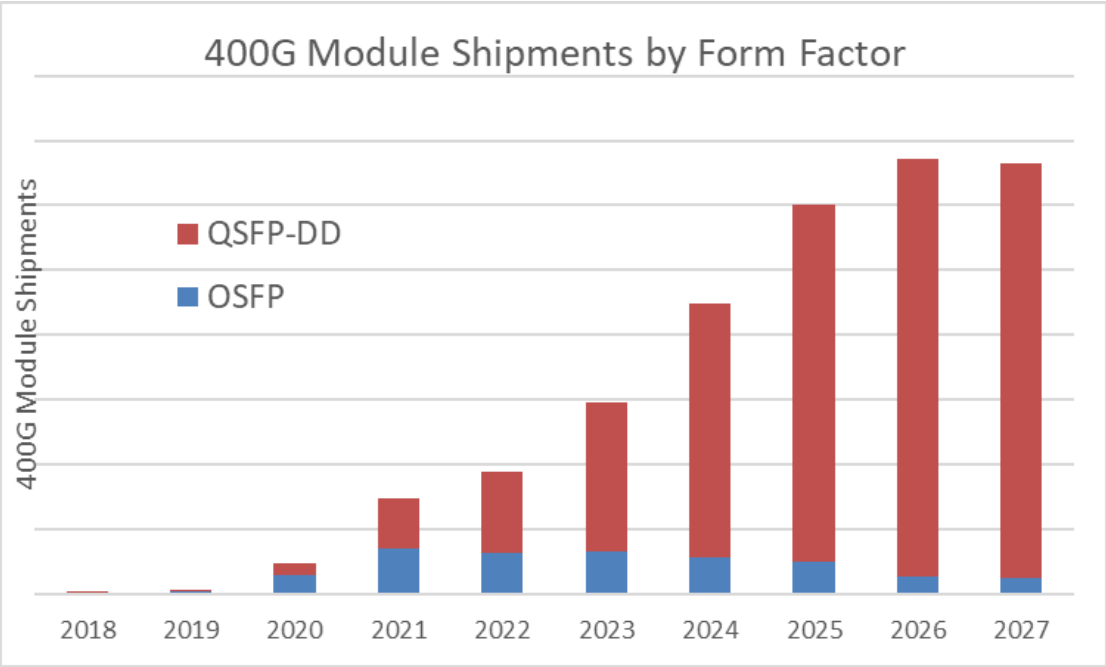
QSFP-DD

8x electrical interface support:

- OSFP – new connector
- QSFP-DD – novel double density approach allowing backwards compatibility with 100G modules (4x interface)

Backwards compatible with 100G QSFP28.
Riding heatsinks inside line card slides on top of the module's flat surface.

Market share and forecast: QSFP-DD vs OSFP



LightCounting Mega Datacenter Report Database , Aug 2'22

QSFP-DD Dominates 400G

Two phases in module adoption:

1. Early (Hyperscaler) adoption
2. Broad market adoption

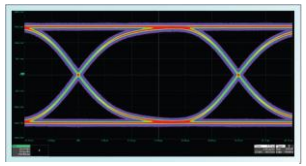
QSFP-DD's backwards compatibility is the key factor to explain wide adoption

Technologies used for 400G optics

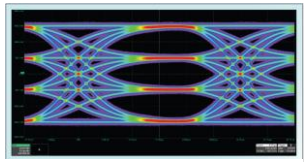
- Enabling higher performance but lowering cost

Modulation

Client optics

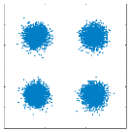


NRZ
1 bit/sec/symbol

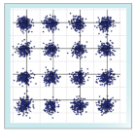


PAM4
2 bit/sec/symbol

Coherent optics



Coherent QPSK
2 bit/sec/symbol



Coherent 16-QAM
4 bit/sec/symbol

Using more complex modulation allows us to increase the data rate (Gb/s) without increasing the signaling speed (Gbaud)

Forward Error Correction (FEC)

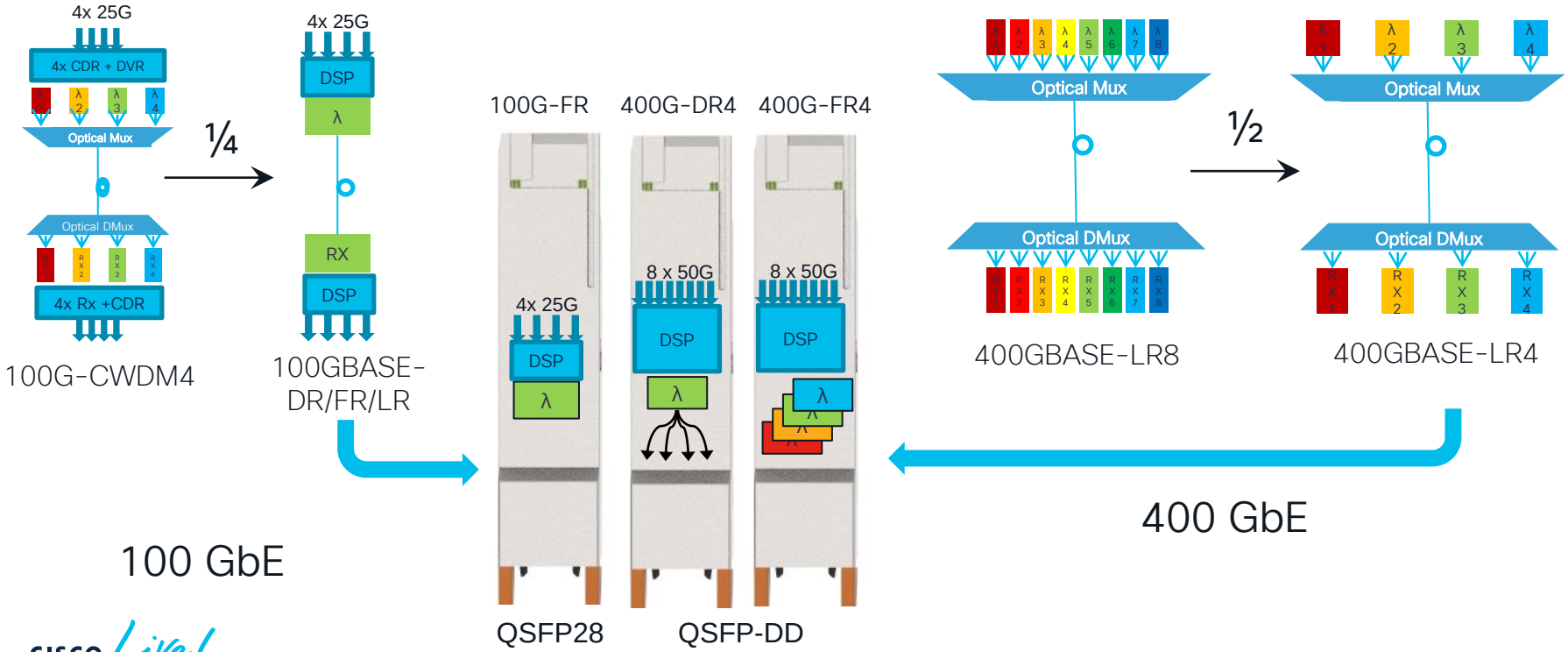
Allows correction of errors at receiver

Enables use of relaxed specs (saves $) to get same performance or enables much higher performance.

Usually embedded in Ethernet switch ASIC

100 Gb/s per wavelength optics

Simplifying 100 GbE and 400 GbE

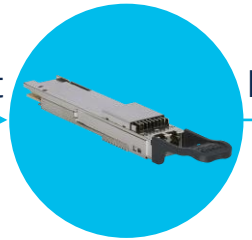


Standardization

400G Pluggable Coherent – 100+ km to 1000+ km

OIF 400ZR

Simplified functionality
Edge optimized FEC (C-FEC)

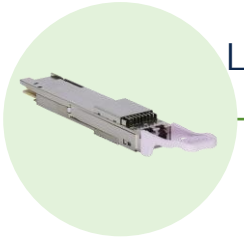
400GE → Client →  Line → *400ZR – 120km*

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

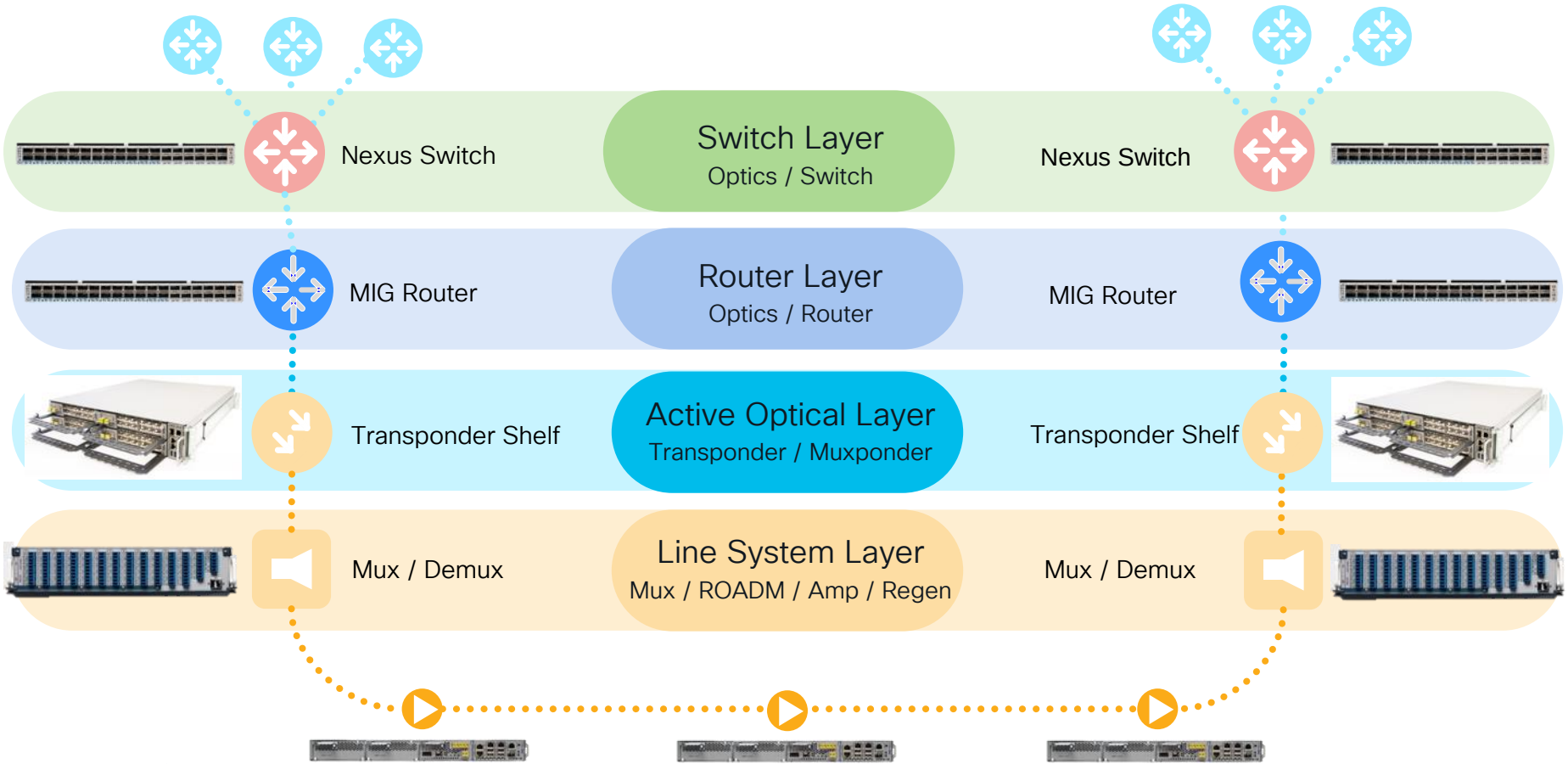
100GE
200GE
400GE
Nx 100GE
(Muxponder Mode)
→ Client →  Line → *100G*
200G
300G
400G

Simplified functionality +
High performance FEC (oFEC)

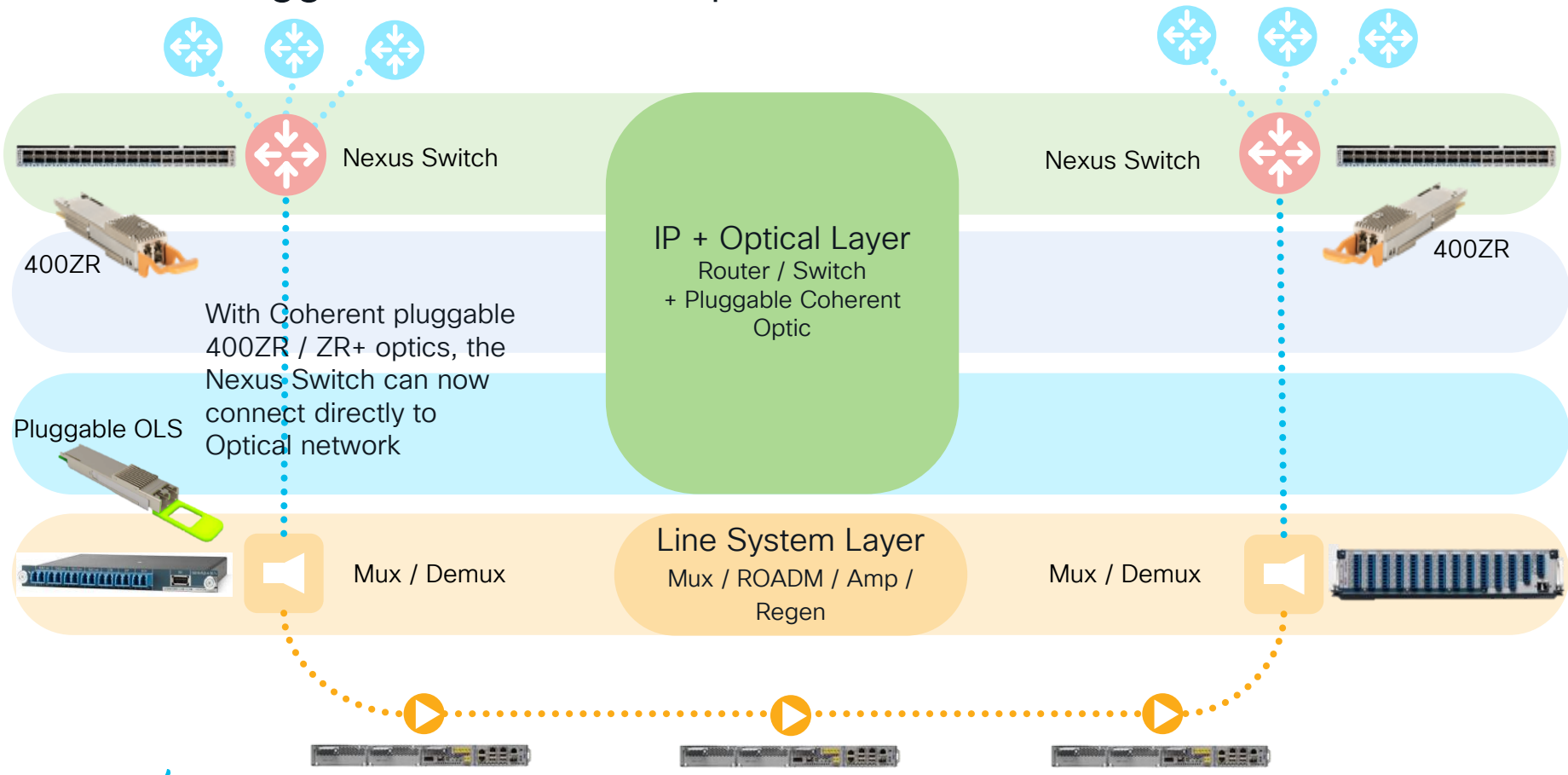
High performance pluggable modules
Multi-vendor interoperability

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

Traditional DCI Network Architecture



Coherent Pluggable enables a simplified Network Architecture

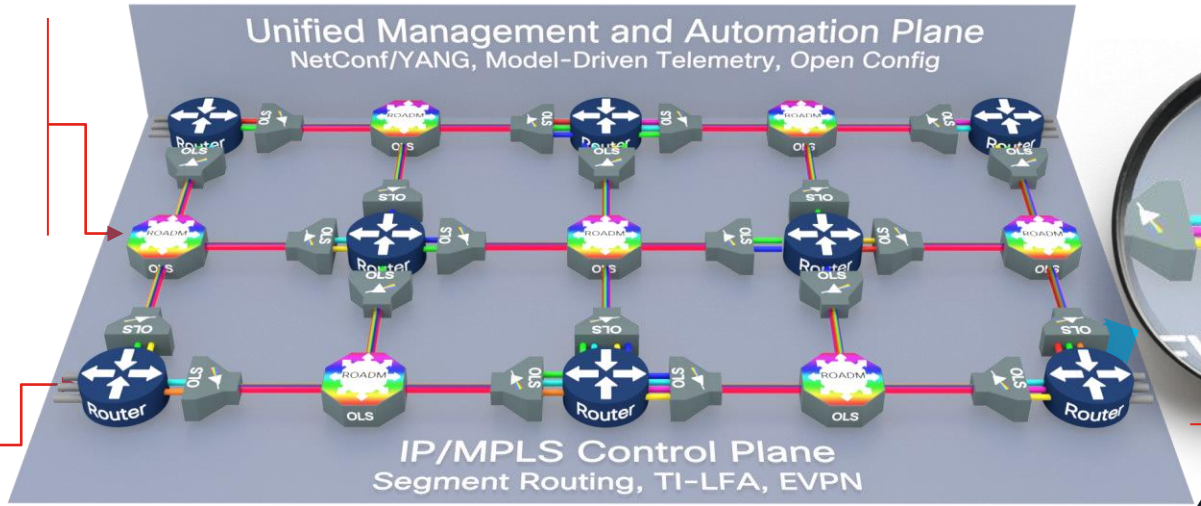


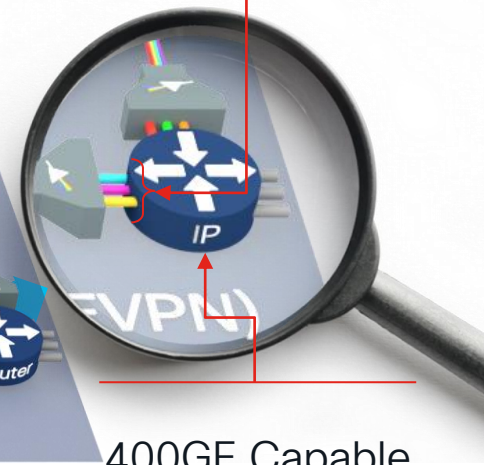
Coherent pluggable enabling Routed Optical Networking

400ZR/ZR+
QSFP-DD DCO
Pluggable Optics

75GHz min. width DWDM: ROADM, FOADM or Terminals

L3 VPN
L2 VPN
TDM
(via L1 PLE*)





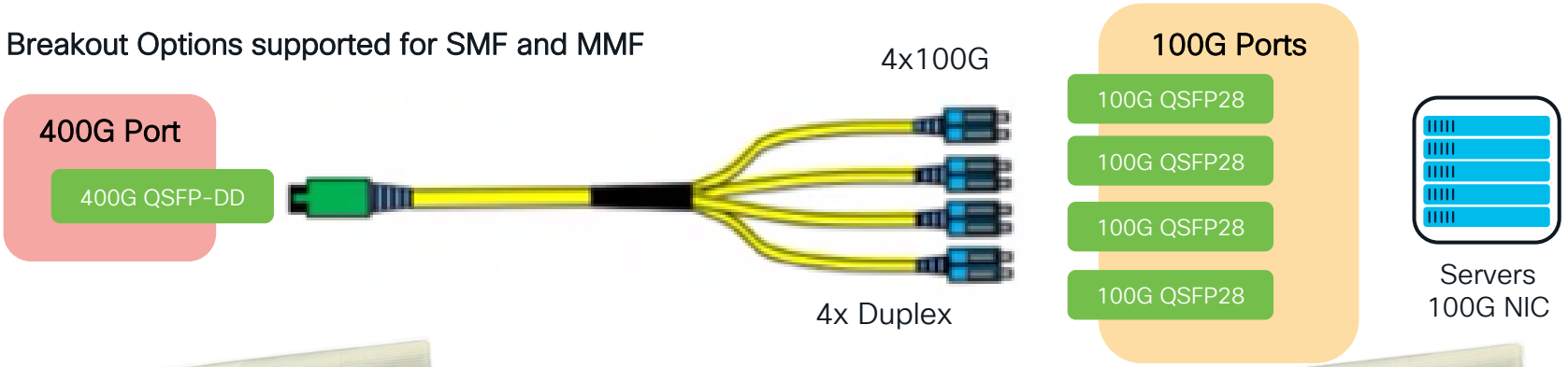
400GE Capable Router: Modular, Fixed

*PLE: Private Line Emulation

Breakout: 400G to 100G connectivity

Maximize port efficiency + forward compatibility with 100G single lambda

Breakout Options supported for SMF and MMF

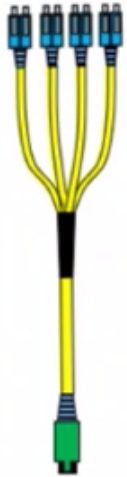


400G DR4 optics
Power: 12W
Space: 1 port

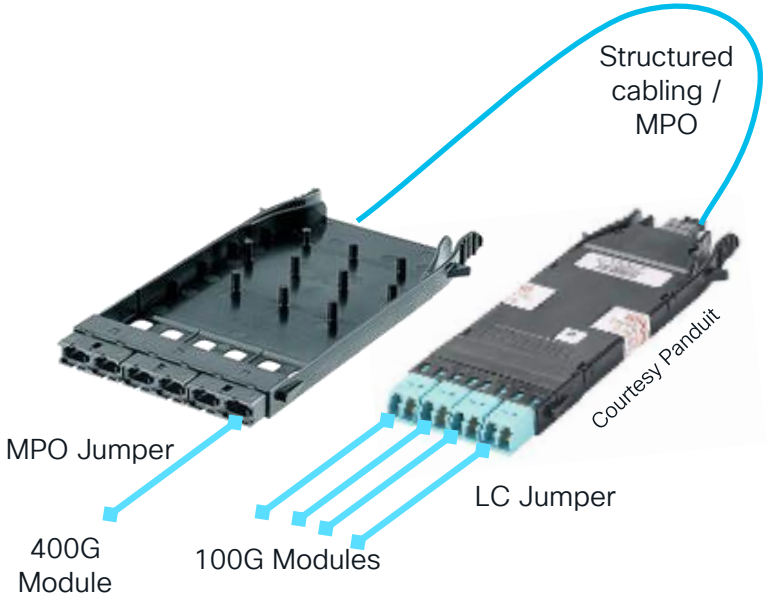
100G DR optics
Power: 4.3W x 4 = 17.3W
Space: 1 port x4 = 4 ports

Deploying Breakout

Multiple options exist

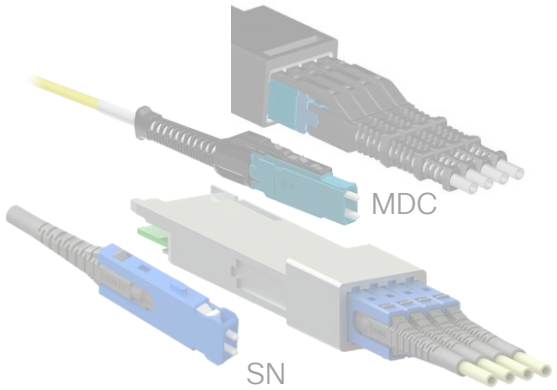


Breakout cables



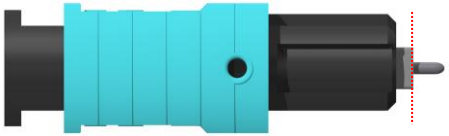
Using structured cabling and breakout cassettes

Small fingers required

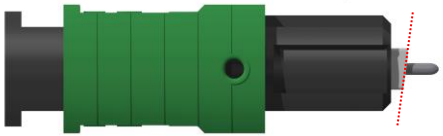


New dense VSFF connectors in module nose

Deployment considerations:
Multi-fiber (MPO) connectors: Angled (APC) vs flat polish (UPC)



Ultra Polish (UPC)
- all single SMF/MMF fiber connectors (LC)
- Vast majority of MMF MPO (MPO-12)

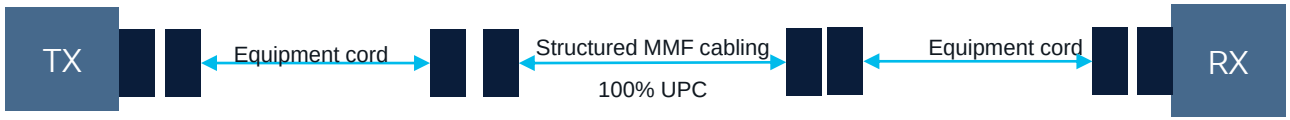


Courtesy USConnec

Angled Polish (APC)
- All SMF MPO
- Some recent introduction for MPO-16 MMF (SR8 use cases)

Some recent 400G MMF specs defined use of MPO APC. Awareness will prevent deployment issues

APC vs UPC deployment usage in MMF



Current Structure

Risk that network installer doesn't realize to change equipment cord

- Incorrect mismatch of PC and APC results in out of spec fiber plant (air gap). Damage risk exists
- MMF modules with APC is limited to MPO-16 based connectors and are being used in Hyperscaler environments for SR8 optics
- Everywhere else uses MPO-12 based connectors using UPC

400G summary

400G pluggable technology is mature today. Standards are complete.

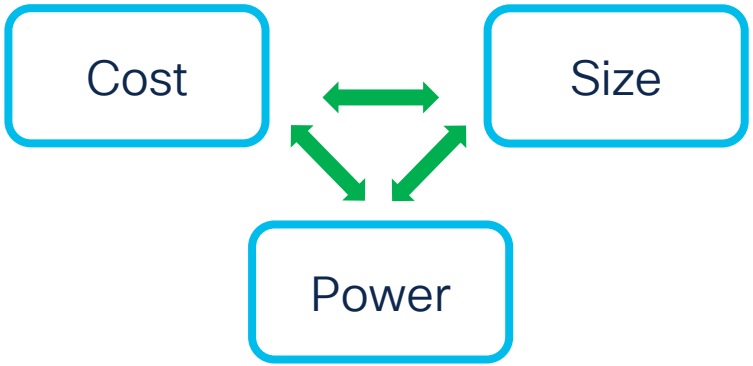
400G brought a lot of innovation that will be extended into next gen

- New QSFP-DD form factor(s) capable of supporting high density at all reaches. Backwards compatible with 100G QSFP28
- High-speed PAM4 optics. Higher integration, lower cost
- Coherent pluggable: 400ZR and 400ZR+ Enables Routed Optical Network architectures
- Mainstream adoption of breakout
  - 400G module as 4x100G (SMF) or 8x 50G (MMF). DAC too.
  - Some deployment considerations with breakout

Beyond 400G pluggable and 400 GbE

The function of optics

- The only function of Optics is to extend the interfaces from one ASIC/Switch to another
- Therefore, it is the ASIC roadmaps which primarily matter, and the role of optics is to keep up – without causing too many issues
- Unfortunately, optics does have challenges that affect what can be built:



It’s all about ASICs, SerDes, and Optics

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

640G | 1.28T | 3.2T | 6.4T | 12.8T | 25.6T | 51.2T | 102.4T | 204.8T

← 204.8T is 16x the bandwidth of 12.8T

320x increase in switching bandwidth over 16 years

Switching Capacity

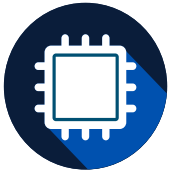
Cisco One ASICs

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 PAM4		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	128	

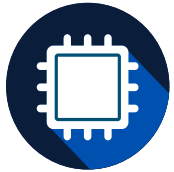
ASIC density continues to redefine how products are built.
Gates & GHz. SerDes & Interconnect. Optics & wavelengths.

Credit: adapted from slide by Rakesh Chopra & John Chapman
https://blogs.cisco.com/sp/co-packaged-optics-and-an-open-ecosystem

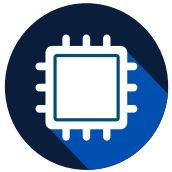
Optics (ports) follow ASIC roadmap



25.6T



51.2T



102.4T

SERDES

100G	100G	200G
X256	x512	x512

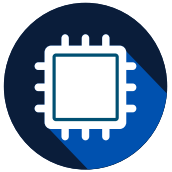
Fixed Configs

1 RU*	32p @ 800G
	QSFP-DD800, $OSFP_{800G}$
2 RU	64p @ 400G
	QSFP112

1 RU	32p @ 1.6T
	1.6T pluggable
2 RU	64p @ 800G
	QSFP-DD800, $OSFP_{800G}$

1 RU	32p @ 3.2T
	3.2T pluggable
2 RU	64p @ 1.6T
	1.6T pluggable

800G does not necessarily mean 800 GbE



25.6T

SERDES

100G

X256

Fixed Configs

1 RU	32p @ 800G
	QSFP-DD800, $OSFP_{800G}$
2 RU	64p @ 400G
	QSFP112

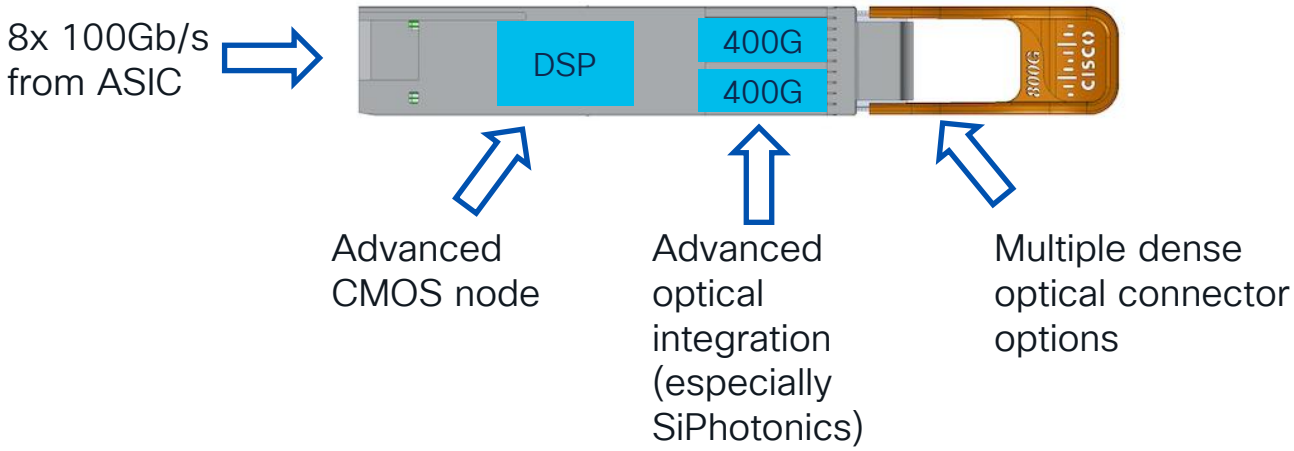
25.6T ASIC roadmap and system density requirements drive to 800G ports

- Dominant interest in 800G module today is to support 2x 400 GbE breakout
- No immediate network need for 800 GbE
  - Although IEEE working on it (more later)
- 800G modules have the same issues:
  - Thermals and Signal integrity
  - Backwards compatibility?

QSFP-DD800 supporting dense 400 GbE (aka breakout)

QSFP-DD

- 800G form factor enables an economical way to implement 400 GbE
  - Maximize the return on investment on the 400 GbE building blocks



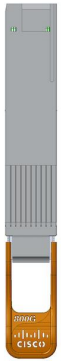
Implementing Dense 400 GbE

The QSFP module story continues

100 Gb/s
25 Gb/s SerDes
QSFP28

400 Gb/s
50 Gb/s SerDes
QSFP56-DD

400 Gb/s
100 Gb/s SerDes
QSFP112



800 Gb/s
100 Gb/s SerDes
QSFP-DD800

Powerful backwards compatibility

QSFP-DD800

Thermals

- 30W confirmed. No issues with any variant

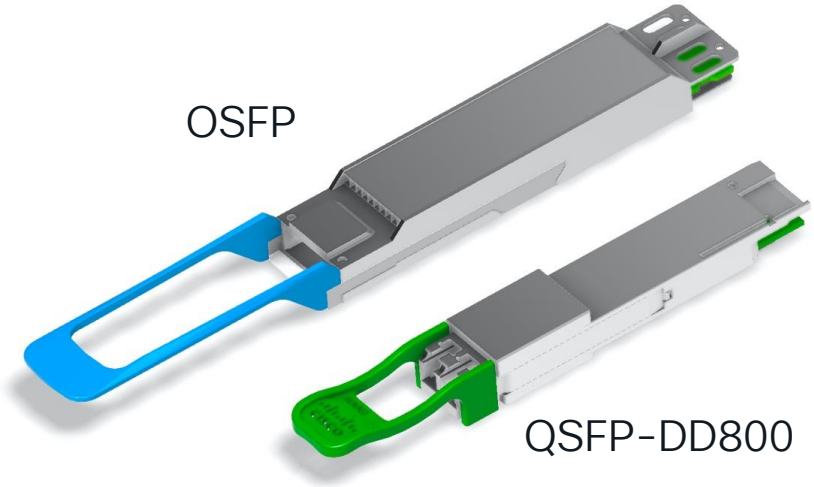
Electrical

- 100 Gb/s confirmed

Integration

- Continued CMOS node migration: 7nm → 5nm
- SiPhotonics continues to mature

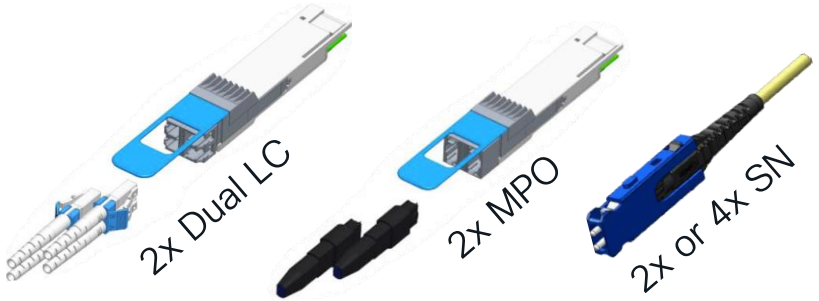
800G Optical Modules: QSFP-DD or OSFP (again)



Both variants support all the technical requirements:

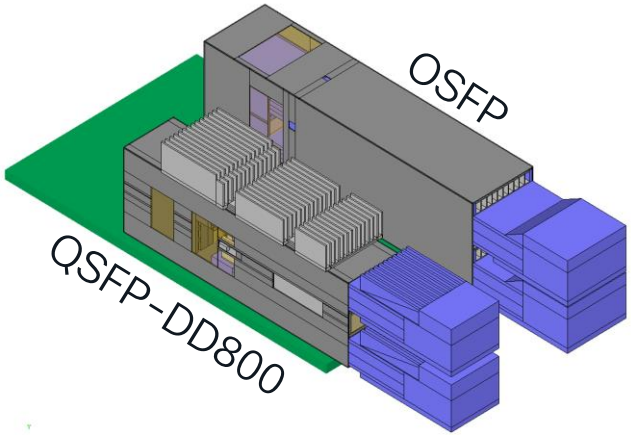
- 32 ports in 1 RU is feasible
- Electrical signal integrity @ 8x 100 Gb/s
- Thermal cooling capabilities up to 30W

Breakout optical connector options[1]



[1] only QSFP-DD shown but similar on OSFP

800G Optical Modules: QSFP-DD or OSFP (again)



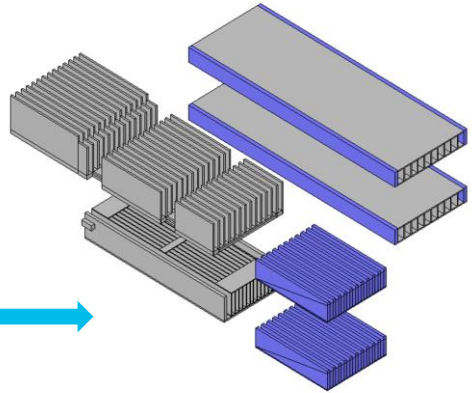
Showing two modules inserted into upper and lower ports in a cage.

External heatsinks as part of cage (QSFP-DD) or integrated (OSFP)

800G Optical Modules: QSFP-DD or OSFP (again)

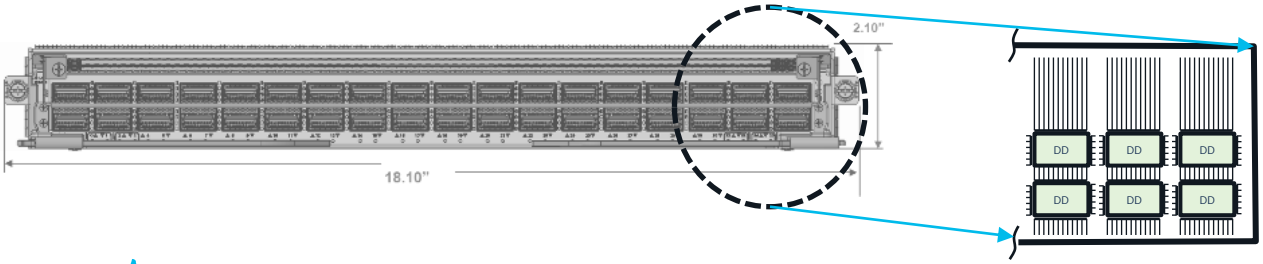
Removing modules and cages to just show the heatsink differences.

QSFP-DD based system can provide a much higher heatsink volume. Easier to cool.



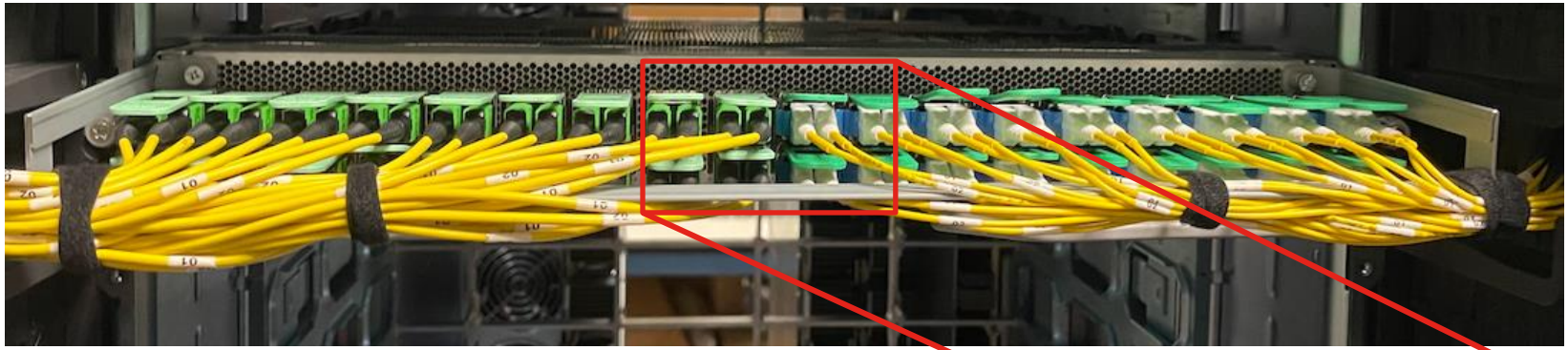
Heatsink tradeoffs:
QSFP-DD allows heatsinks to scale with thermal design need

OSFP design was developed before coherent pluggable modules or 800G/1600G were considered viable



Every linecard can be optimally designed to match user needs

25.6T Systems using QSFP-DD800



1RU 32 port
QSFP-DD800

2x400G
Dual MPO
Dual LC

Market adoption forecast for 800G modules

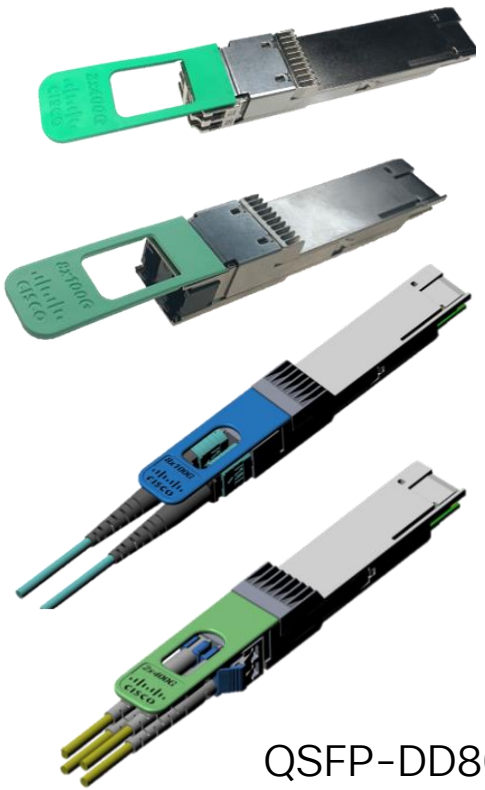
Market alignment

	QSFP-DD800	OSFP 800
400G adoption	✔	✕
Backwards Compatibility	✔	Only to OSFP 400
Thermal performance	Adaptable	Fixed
Electrical performance	✔	✔
2x optical connector support	✔	✔

Technical details – equivalent

Expect QSFP-DD800 broad adoption

QSFP-DD800 Ready for the Next Generation

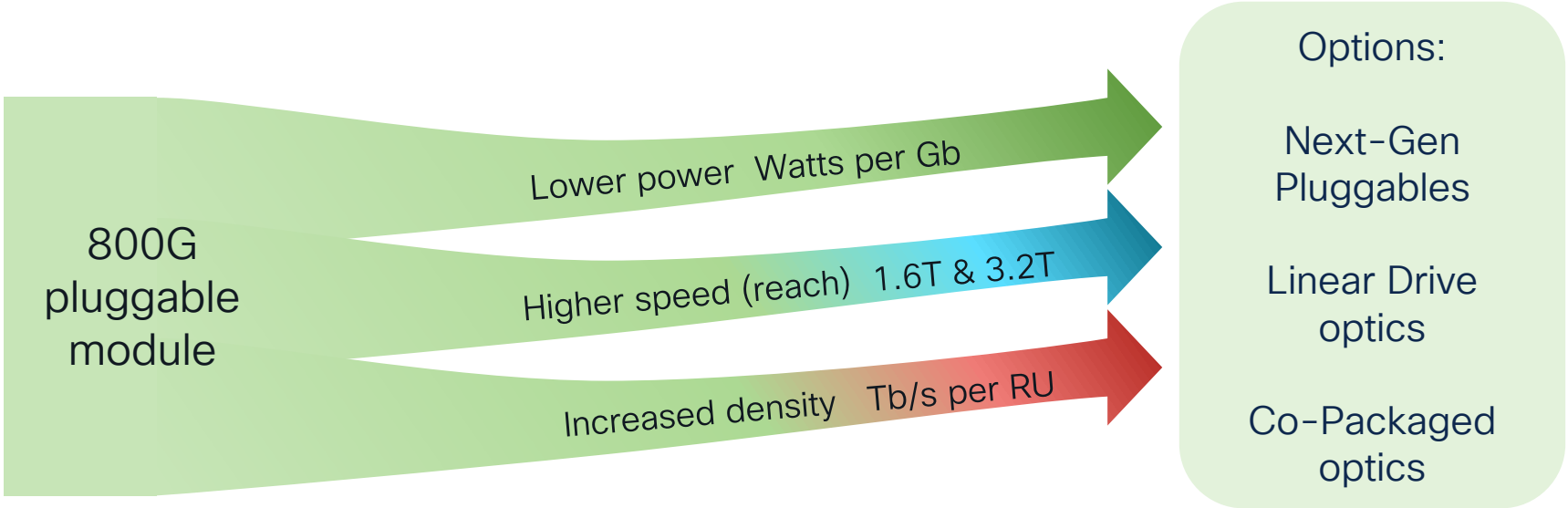


- Port is backward compatible to QSFP+, QSFP28, QSFP56, QSFP112, QSFP-DD
- Support 2x400G, 8x100G designs
- QSFP-DD will support over 30W of power dissipation
- Flexibility of a riding heatsink
- Increased heatsinking area for more power handling
- Wide variety of optical connector options
- Supports Dual MPO-12 & Dual Duplex LC to leverage existing cabling
- Availability of all variants is in progress
  - 8x 100 GbE (SMF and Copper Cables)
  - 2x 400 GbE (SMF and Copper Cables)
  - MMF still under investigation

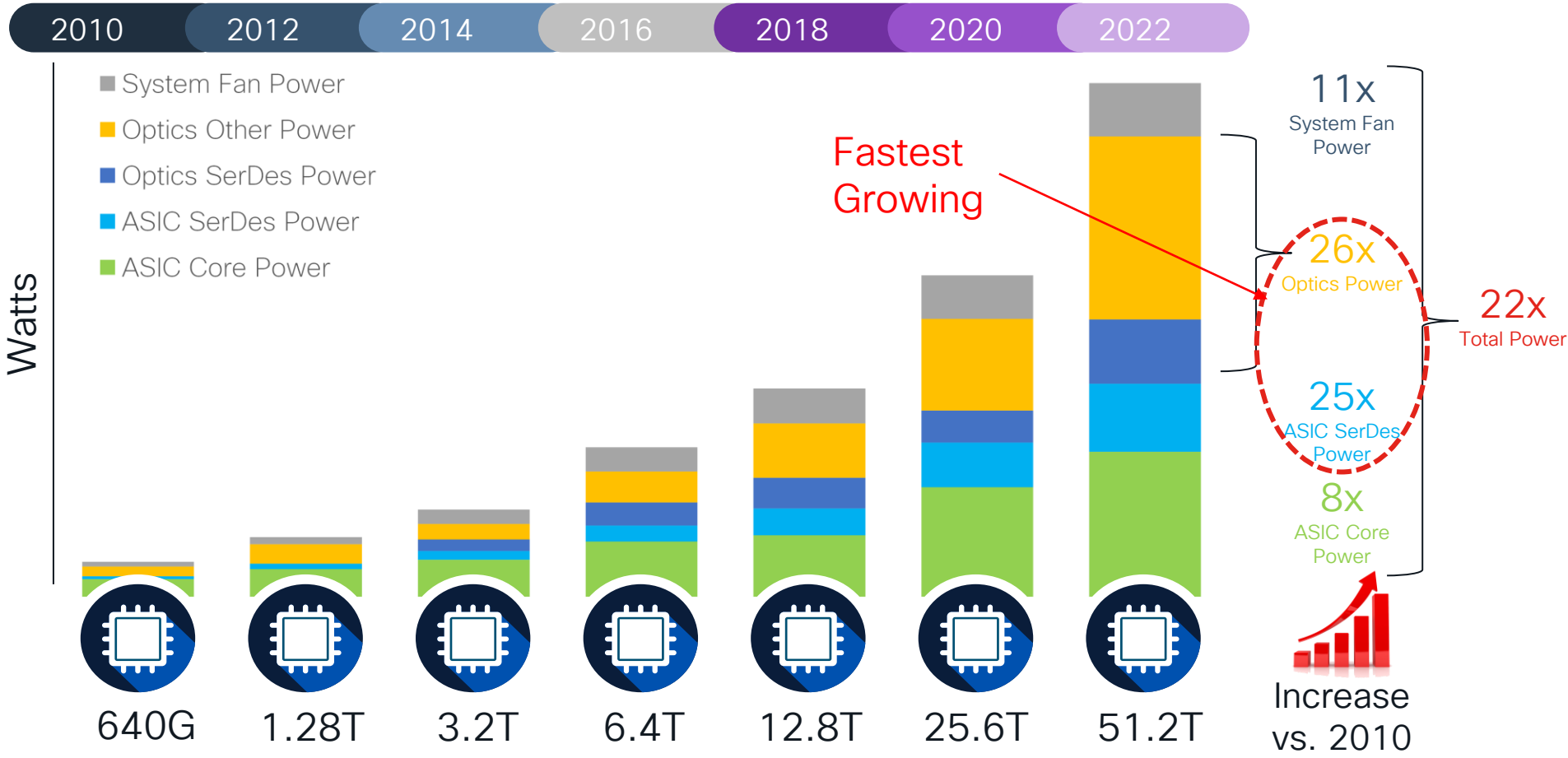
QSFP-DD800 leverages QSFP the industry's cornerstone high speed form factor for the next generation of networking equipment

What's next for optical interconnect?

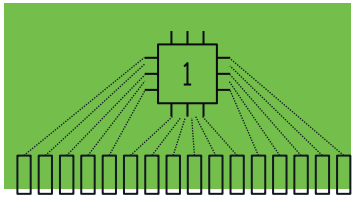
Going faster has some challenges



Relentless Advancement – 80x BW over 12 Years



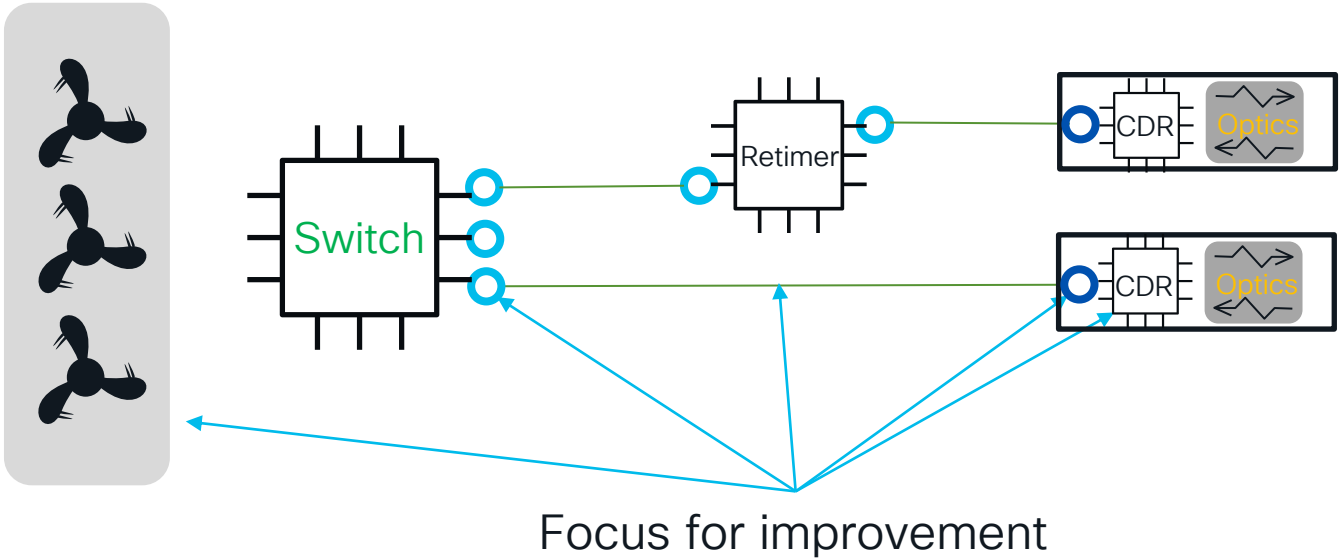
Interconnect and power



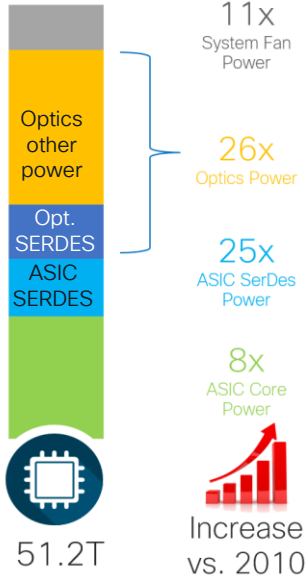
Switch ASICS

Retimers

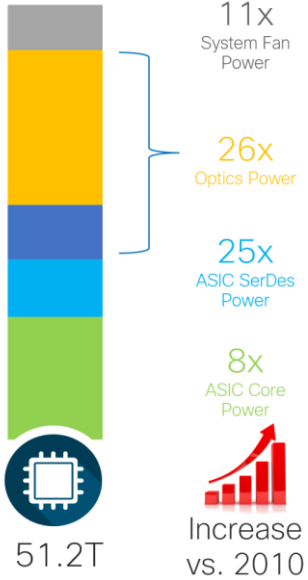
Pluggables



Focus for improvement

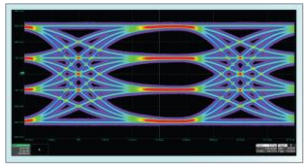


Addressing > 800G



Growing power remains a challenge

IO speeds: 100G to 200G (Distance?)



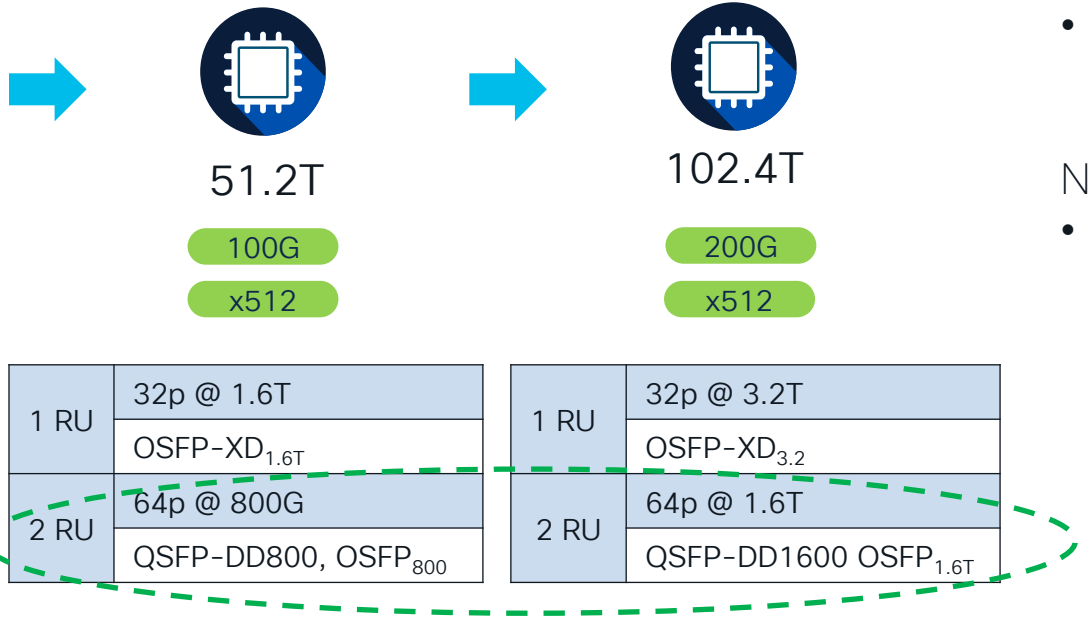
200G PAM4

Is this the time for Co-packaged optics?

Can pluggables continue?

Requirements for 1.6T pluggable

2x800 GbE, 4x400 GbE



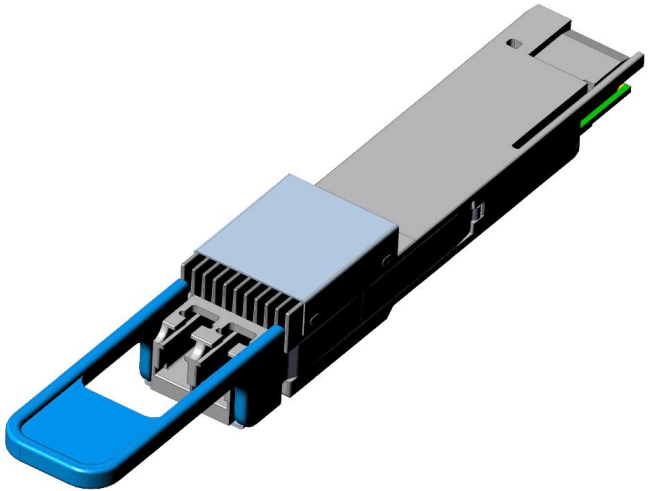
Same system design density and speed requirements with 200Gb/s SERDES.

- QSFP-DD and OSFP roadmaps will extend to 1.6T

New entrant (just to add to the mix)

- OSFP-XD
  - New 16x100G connector
  - Despite name – not compatible with OSFP
  - Solves the 51.2T 1RU “problem” but market shifting to 2RU
  - Some good design work that may be useful in future

The good news: Clear path to QSFP-DD1600



QSFP-DD MSA already working on QSFP-DD1600

Module form factor allows innovation on:

- Connector optimization
- Cage design
- Heatsink and thermal design
- System design

QSFP28 → QSFP-DD → QSFP-DD800 → QSFP-DD1600

Path ahead

Pluggable optics roadmap continues and extends beyond 800G

QSFP-DD

All QSFP

400G (8x 50G)

800G (8x 100G)

1.6T (8x 200G)

OSFP

400G (8x 50G)

800G (8x 100G)

1.6T (8x 200G)

Differences exist in system design and support of large current installed base

XD

1.6T (16x 100G)

No compatibility between OSFP & OSFP-XD (despite initial intent)
Market adoption unclear

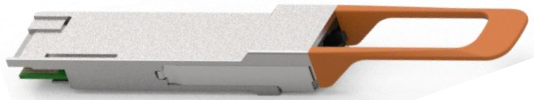
8x

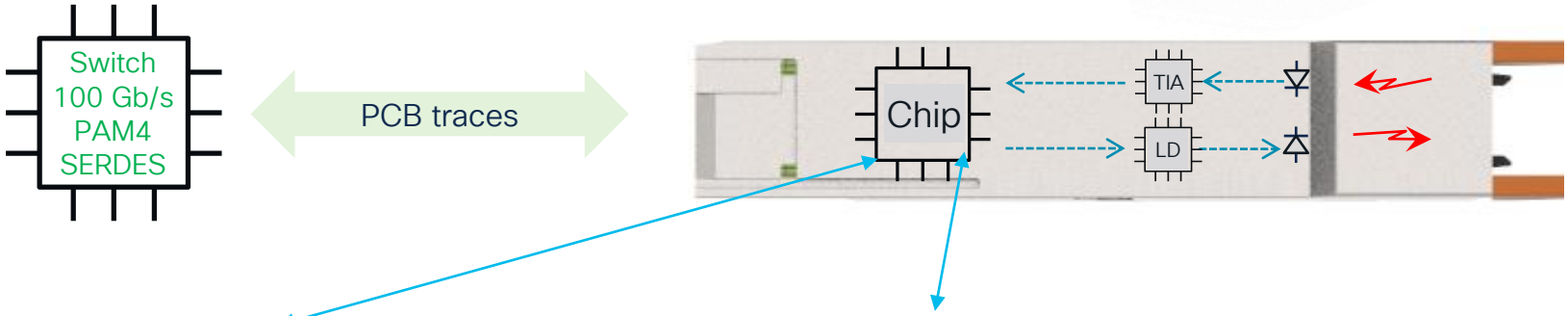
16x

Host side interface width

Market demand (time)

Linear drive optics





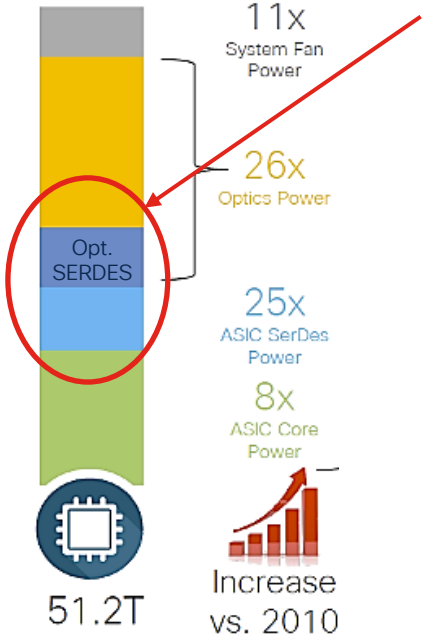
Current (Retimed)

- DSP fully equalizes electrical & optical signals
- Enables broad interoperability
  - Host/Port/Module
- Full telemetry & loopbacks possible
- FEC Monitoring or Partitioning possible
- But this adds power

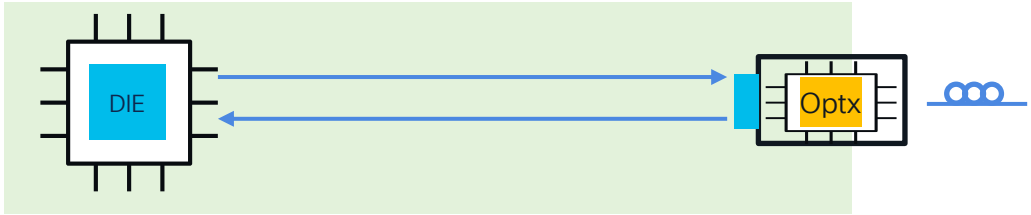
Linear (Non-retimed)

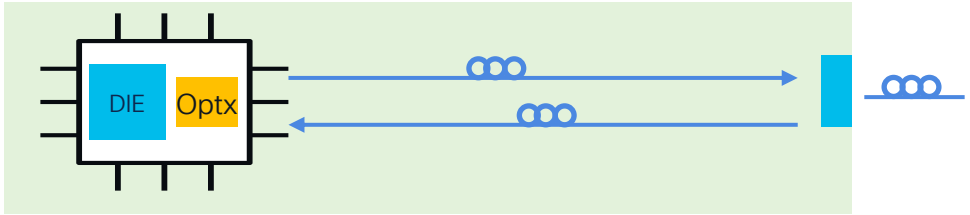
- Power reduction due to absence of equalization
- Performance is based on quality of every component in link (engineered link)
  - Optics, Serdes, PCB, connectors
  - Varies port to port
- Interoperability isn't "broad" any more
- No telemetry or loopback

Beyond Pluggable: Co-Packaged Optics

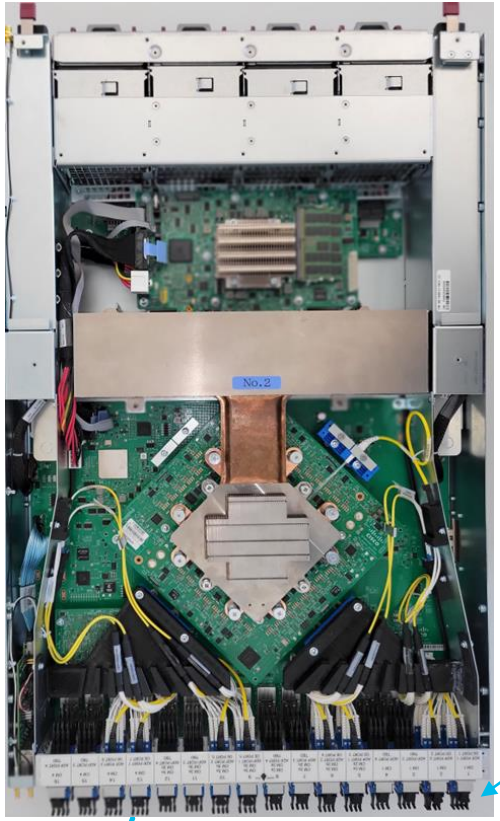


Focus is on reducing this power





Beyond Pluggable: Co-Packaged Optics

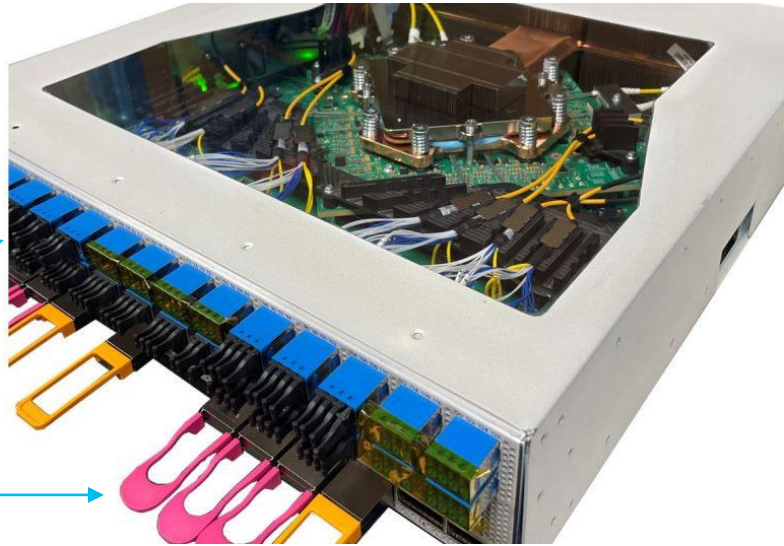


Cisco 25.6T CPO system demonstrated @ OFC'23

- 25-30% power reduction

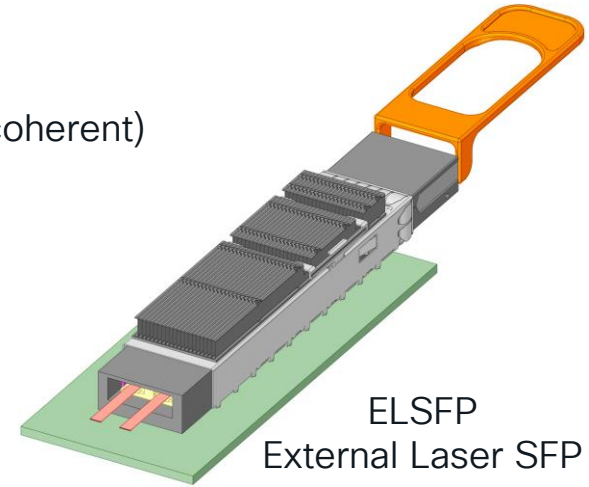
Fiber connectors

Optical power source (ELSFP)



Co-Packaged Optics

- Co-packaged (CPO) and Near-packaged (NPO) variants can provide power reductions. Silicon Photonics required.
- Some early industry standardization in flight. Goal to establish interoperable components → new “ecosystem”
- System configs would likely be:
  - 100% optics
  - 50% co-packaged optics / 50% pluggable ports (copper cables, coherent)
- Operational considerations:
  - Pluggable external laser power sources (reliability, thermals)
  - Reduced overall power
  - Reduced port flexibility



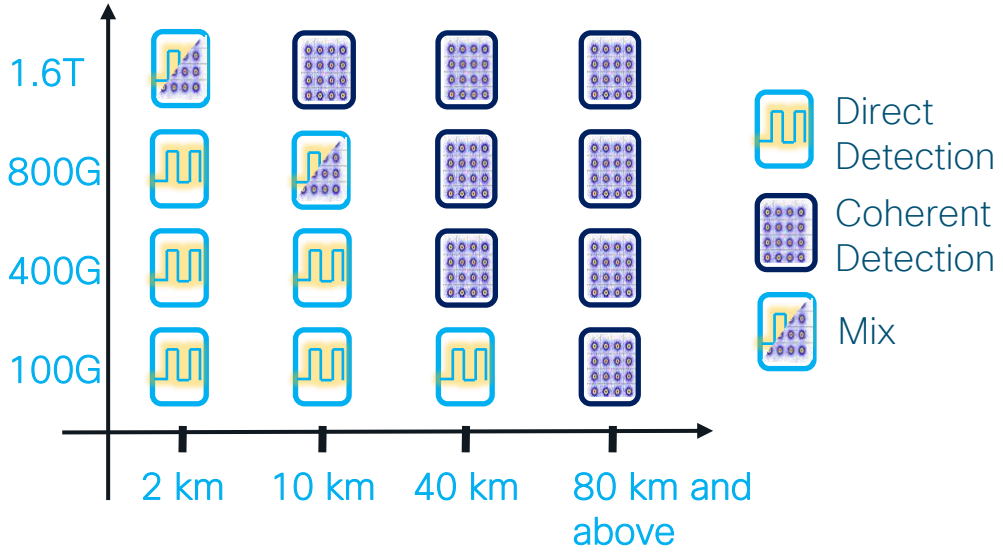
ELSFP
External Laser SFP

Maintaining reach at higher speeds

Direct Detect and Coherent technology will continue to be used

- 800G, 1.6T and beyond
- Coherent pushing towards shorter reaches. Not only in DWDM but also Grey applications
- Focus shifting from performance enhancements ($$$) to interoperable interfaces and pluggables

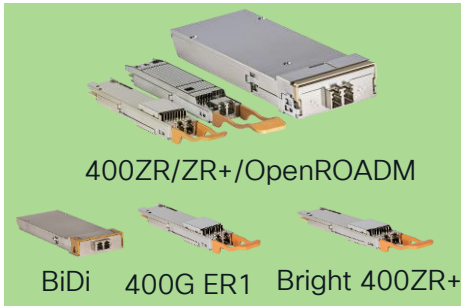
- Coherent multivendor Interop more and more prevalent
  - 100G DWDM interop, OIF 400ZR, OpenZR+, OpenROADM, ITU SG15/Q11



Road ahead for Coherent MSA pluggable

Today | Future

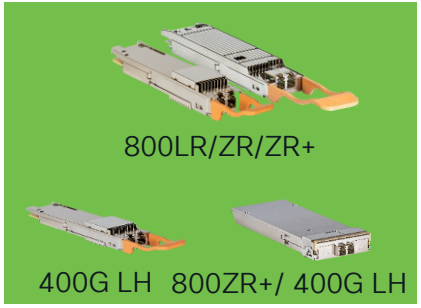
Expanding applications for 400G pluggables



50G SerDes

16-22W

Next-Gen 800G and 400G LH pluggables



50G/100G SerDes

22-30W

1.6T Coherent for DC, carrier networks

100G/200G SerDes

25-40W

Where are the standards going?

Cisco’s Focus: Compatibility and Standards

- Network operators require compatibility as they transition and adopt next generation technologies
- Cisco focuses on standard interfaces as much as possible to enable these smooth transitions

Standards Landscape

The interconnect industry is working to standardize what is needed. Standardization required to ensure interoperability

Optical Internetworking Forum

- Extending the 400ZR work
- 800ZR in definition (targets same application as 400ZR)
- New: 800LR – shorter reach coherent (10km)
- Module management (CMIS)

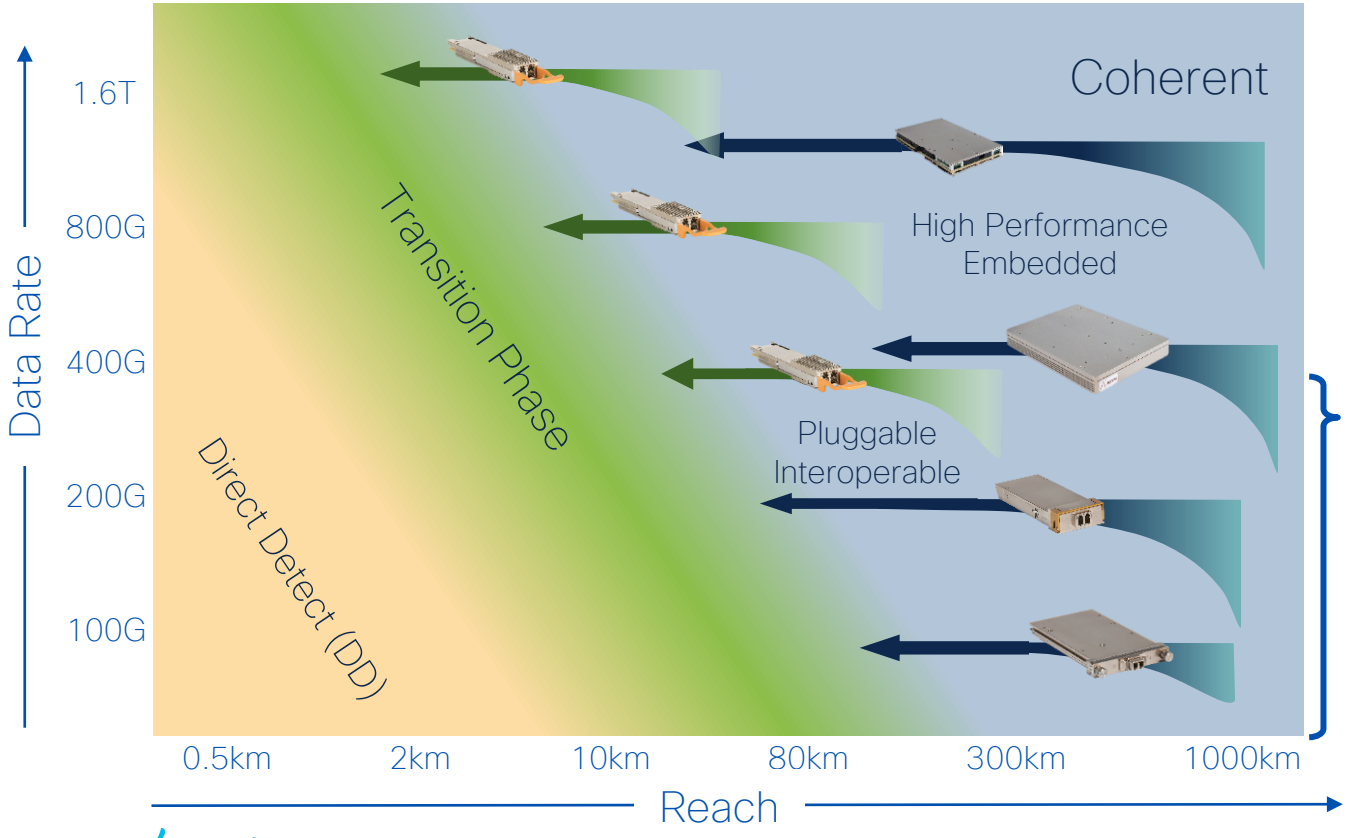
IEEE 802.3df and 802.3dj

- The foundational Ethernet standards for 800 GbE and 1.6 TbE

Form factors

- Form factor MSAs as we have covered already:
  - QSFP-DD, OSFP-XD, OSFP
- OIF is working on co-packaging implementation definitions

Coherent Technology Trends – Shorter Reaches



Edge applications driving transition towards shorter reach coherent solutions & industry standardization

Industry Momentum for Pluggable DCO Driven by Edge and Access

- OIF
  - Metro DCI 400ZR standard
  - 800LR 10KM in works
- IEEE
  - 100GbE & 400GbE beyond 80km reach
  - 800 GbE –10km & 40km
- CableLabs
  - Adopted 100G & 200G Coherent Access Standard
- Open ROADM
  - 100G/200G/300G/400G

IEEE 802.3df/3dj are working on 800 GbE and 1.6 TbE

Task Force underway. Initial specs being adopted.

Major themes:

1) 100 Gb/s based. (P802.3df)
   - 800 GbE based on an 8x 100 Gb/s approach (optical and electrical)
2) 200 Gb/s based (P802.3dj)
   - 800 GbE (4x 200 Gb/s) and 1.6 TbE (8x 200 Gb/s) (optical and electrical)
   - Will include 200 GbE and 400 GbE variations (useful for breakout)
3) Coherent solutions will be defined for 10 km and 40km
4) New standard reach – 2km parallel SMF

802.3df & 802.3dj: Adopted Objectives

Ethernet Rate	Assumed Signaling Rate	AUI	Cu Cable	MMF 50m	MMF 100m	SMF 500m	SMF 2km	SMF 10km	SMF 40km
200 Gb/s	200 Gb/s	Over 1 lane	Over 1 pair			Over 1 Pair	Over 1 Pair		
400 Gb/s	100 Gb/s						Over 4 Pair		
	200 Gb/s	Over 2 lanes	Over 2 pairs			Over 2 Pair			
800 Gb/s	100 Gb/s	Over 8 lanes	Over 8 pairs	Over 8 pairs	Over 8 pairs	Over 8 pairs	Over 8 pairs		
	200 Gb/s	Over 4 lanes	Over 4 pairs			Over 4 pairs	1) Over 4 pairs 2) Over 4 λ's		
	800 Gb/s							Over 1 pair	Over 1 pair
1.6 Tb/s	100 Gb/s	Over 16 lanes							
	200 Gb/s	Over 8 lanes	Over 8 pairs			Over 8 pairs	Over 8 pairs		

Technology Reuse

802.3df

Leverage existing or work-in-progress 100 Gb/s per lane (e.g. 3cu, 3ck, 3db) to higher lane counts

802.3dj

Develop 200 Gb/s per lane electrical signaling for 1/2/4/8 lane variants of AUIs and electrical PMDs

Develop 200 Gb/s per optical fiber for 1/2/4/8 fiber based optical PMDs and 4 lambda WDM optical PMD

Coherent signaling technology

https://www.ieee802.org/3/B400G/proj_doc/objectives_b400g_210826.pdf

800 GbE/1.6 TbE Timelines

IEEE 802.3df and 802.3dj timelines

- 8x 100 Gb/s variants: Specifications mature now. Std complete mid-2024
- 4x 200Gb/s variants: Baselines adopted later this year, Std complete 2026
- Coherent variants: Baselines later this year, Std complete 2026

OIF is making good progress on standardizing 800G coherent for:

- ZR (~100km) – estimated completion 1H'24
- LR (~10km) – estimated completion 1H'25

Wrap up

Summary

- 400G forced a lot of innovation. Today the market is growing & the technology is mature
  - Wide adoption QSFP-DD pluggable form factor for non-coherent and coherent interfaces. Enables new network architectures (routed optical networking)
- 800G is building on that innovation fully using 100 Gb/s technology. Market is starting to deploy.
  - Power is a dominant challenge, Breakout becoming the norm (2x 400 GbE etc.)
  - Reuse existing fiber infrastructure
  - Continued backward compatibility with QSFP-DD800
- Beyond 800G – prediction of the death of pluggables is premature
  - 1.6T → QSFP-DD1600 will continue to support.
  - New implementations under development (co-packaged, linear).
- IEEE defining next phase of foundational specifications today – 800 GbE & 1.6 TbE

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- Attend the interactive education with DevNet, Capture the Flag, and Walk-in Labs
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The bridge to possible

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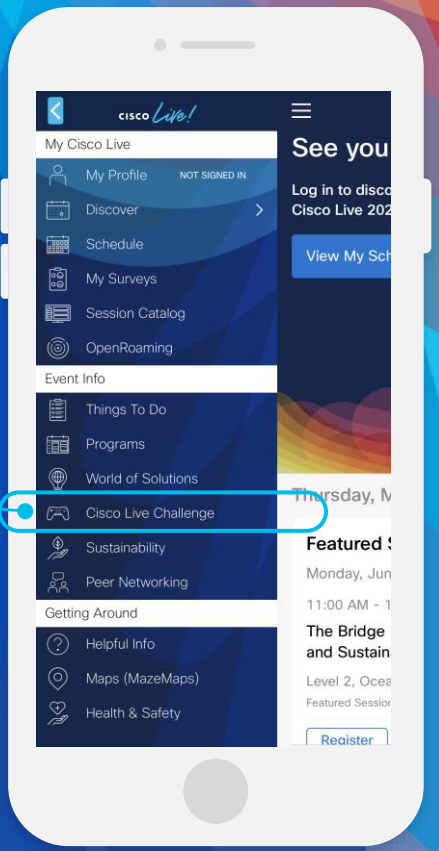

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