Roadmap to 400G Optics *…and Beyond* Green & Sustainable

Salim Janbeh RCDD®/ DCDC®/NTS®/CDCDP®/ATD®

Physical Infrastructure Consultant

PANDUIT™

BICSI® ENDORSED EVENT

Agenda

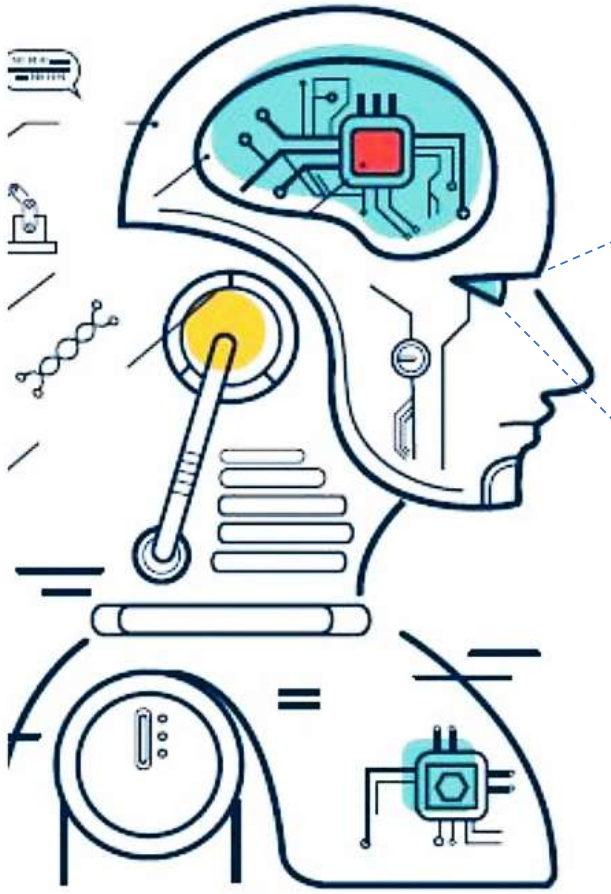
- Ethernet Roadmap
- VSFF Connector & Transceiver Update
- 400G Market/Technology Update
- 400G & 400G+ Roadmap
- Switch/Server Breakout Application
- Structured Cabling Support
- Q&A

BICSI ENDORSED EVENT

Ethernet Roadmap

Bicsi
ENDORSED EVENT

Bandwidth Growth Drivers



AI traffic** (such as ML) accounts for **more than 50% of the total traffic'.

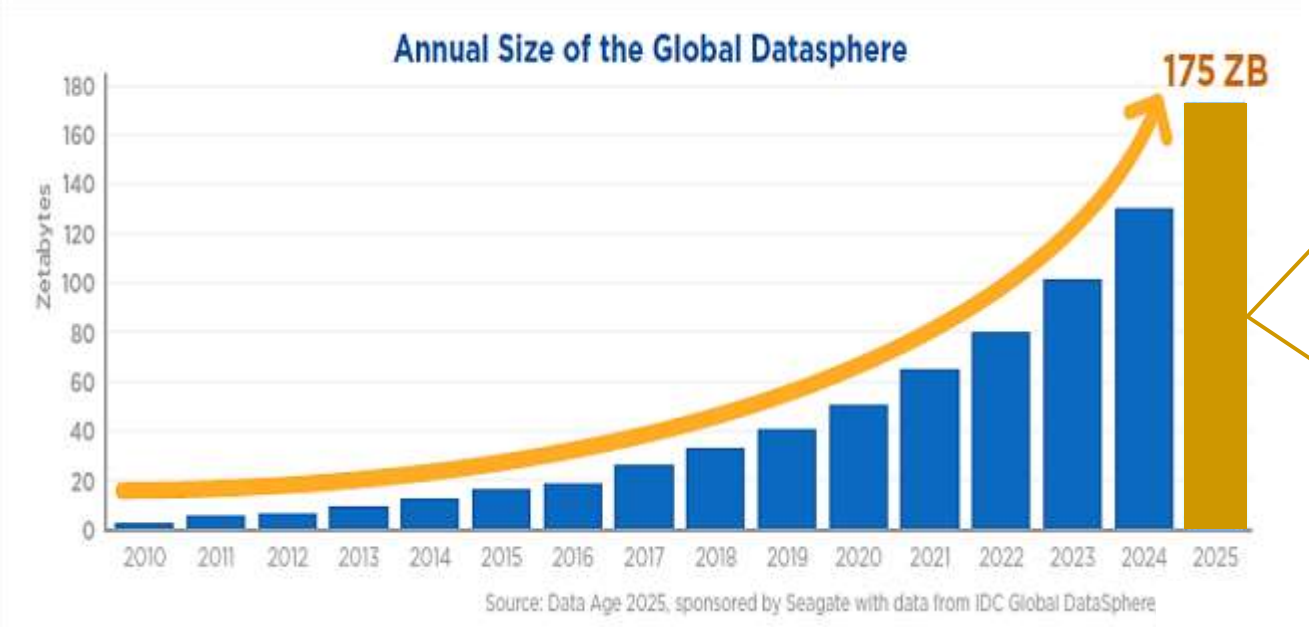
*'Google; networks shows **40% server traffic growth***

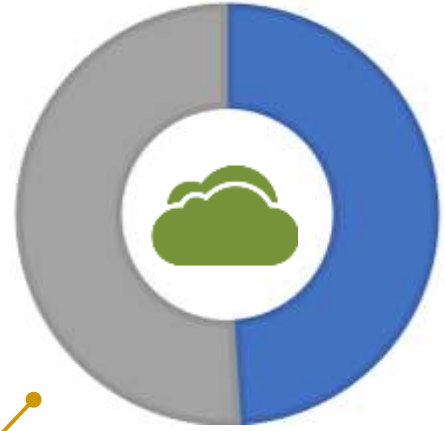
Source: Lightcounting

Bicsi® ENDORSED EVENT

Global Datasphere – Digital Transformation

"All Rivers flow to the Ocean"





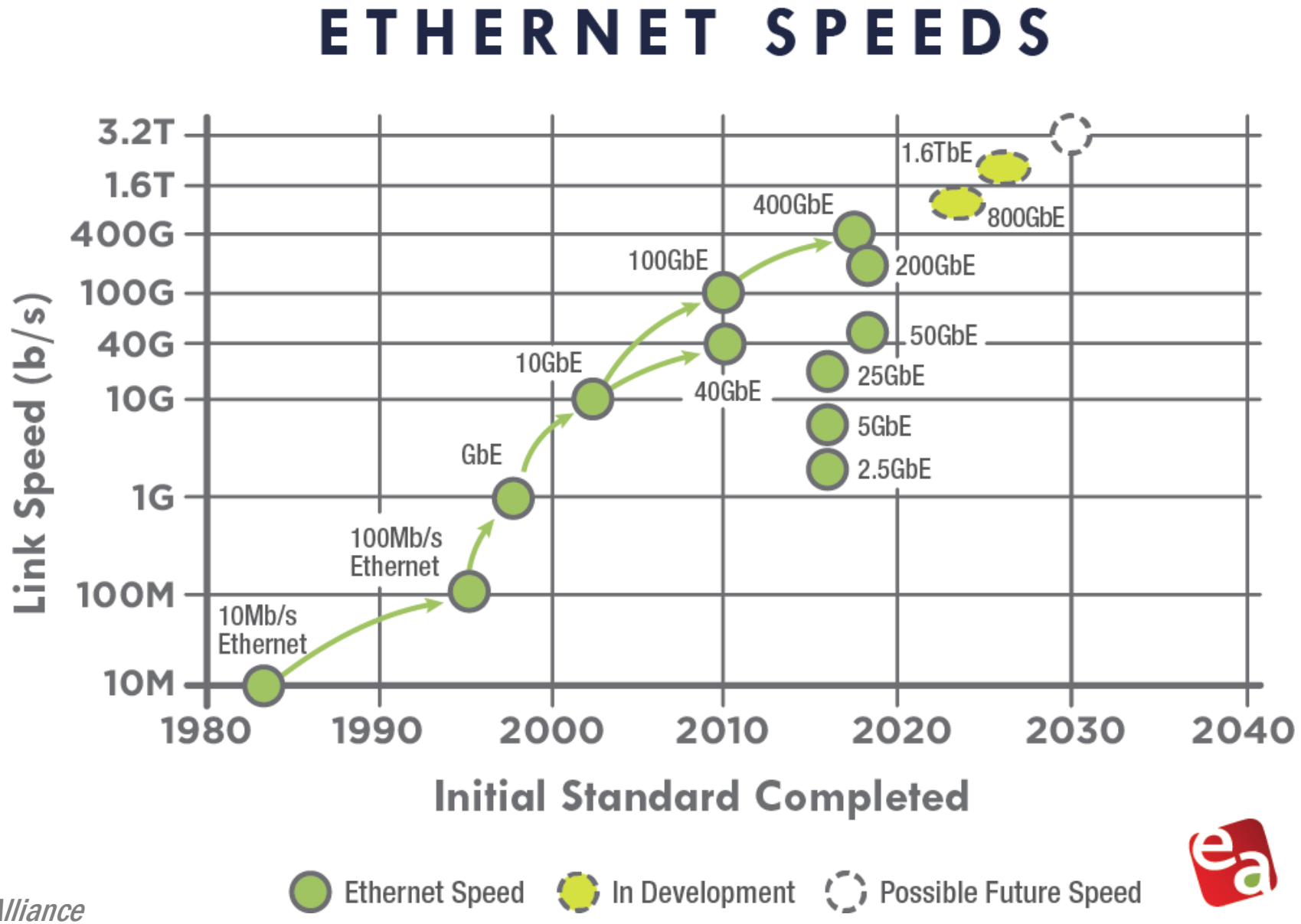
49% of global data will reside in public cloud

30% of global data will need real-time processing as 'Edge' role grows

By 2025, >50% of global data will be driven by analytics, AI, deep learning, and increase # of IoT devices.

Bicsi® ENDORSED EVENT

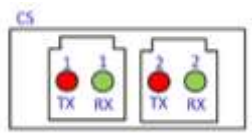
Ethernet Roadmap

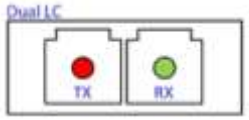


Source: Ethernet Alliance

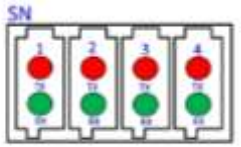
VSFF Fiber Connector & Transceiver Update

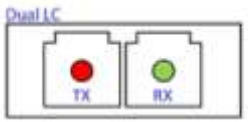
Duplex **CS**



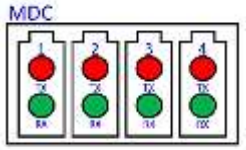


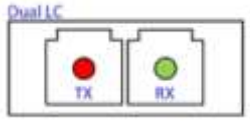
Duplex **SN**





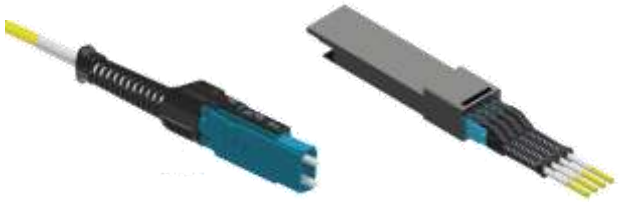
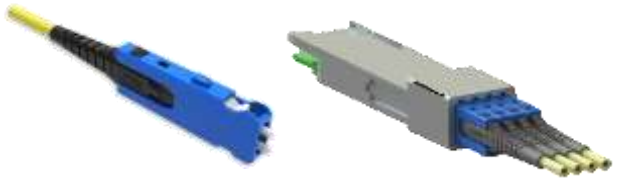
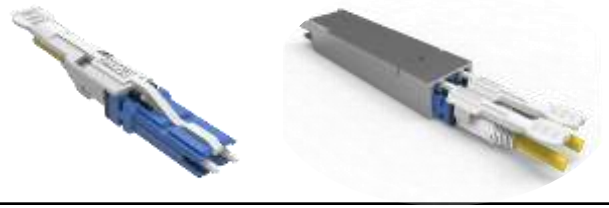
Duplex **MDC**





Bicsi ENDORSED EVENT

Very Small Form Factor (VSSF) Connectors

Name	Image	TIA	IEC	MSA
MDC		○	IEC 61754-37 ●	●
SN		○	IEC 61754-36 ●	●
CS		TIA-604-19 ●	○	●
MPO	 MPO24 MPO12 (or 8) MPO16	TIA-604-18 ●	IEC 61754-7-4 ●	●

KEY

- ● Published Standard
- ● Standard in Process
- ○ No Published Standard

MSA – Multi Source Agreement. Including QSFP-DD & OSFP
TIA – Telecommunication Industry Association. TIA FOCIS' connector standards
IEC – International Electrotechnical Commission. Connector standards

Bicsi® ENDORSED EVENT

‘Secret’ Decoder Pin

wGBASE-xRy.z **example: 400GBASE-SR4.2**

w = data rate :
- 10 Gbit/s
- 25 Gbit/s
- 50 Gbit/s
- 100 Gbit/s
- 200 Gbit/s
- 400 Gbit/s
- 800 Gbit/s

x = reach :

MMF
- S = 100m
- V = 30-50m

SMF
- D = 500m
- F = 2km
- L = 10km
- E = 40km
- Z = 80km

y.z = lane count (fiber/wavelength) :
- y = number of fiber pairs
- y = 4 fiber pairs (8 fibers Tx/Rx)
- z = number of wavelengths

Bicsi ENDORSED EVENT

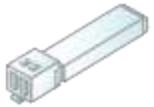
Optical transceiver module

	Backplane	Twinax Cable	15-40m(OT) Single Twisted Pair	>100m (OT) Single Twisted Pair	100m (IT) Twisted Pair (2/4 Pair)	MMF	500m PSM4	2km SMF	10km SMF	20km SMF	40km SMF	80km SMF	Electrical Interface	Pluggable Module
10BASE–	T1S		T1S	T1L	T									
100BASE–			T1	T1L	T									
1000BASE–			T1		T									SFP
2.5GBASE–	KX		T1		T									SFP
5GBASE–	KR		T1		T									SFP
10GBASE–			T1		T	SR			-BR10-D/U LR	-BR20-D/U	-BR40-D/U ER			SFP
25GBASE–	KR1 KR	CR1 CR/CR-S	T1		T (30m)	SR			LR EPON -BR10-D/U	EPON -BR20-D/U	ER -BR40-D/U		25GAUI	SFP
40GBASE–	KR4	CR4			T (30m)	SR4/eSR4	PSM4	FR	LR4		ER4		XLAUI XLPPI	QSFP
50GBASE–	KR2 KR	CR2 CR				SR		FR	EPON LR -BR10-D/U	EPON -BR20-D/U	ER -BR40-D/U		LAUI-2/50GAUI-2 50GAUI-1	SFP/QSFP
100GBASE–	KR4 KR2 KR1	CR10 CR4 CR2 CR1				SR10 SR4 SR2 VR1 SR1	PSM4 DR	CWDM4 FR1	LR4 4WDM-10 LR1	4WDM-20	ER4/ 4WDM-40	ZR	CAUI-10 CPPI CAUI-4/100GAUI-4 100GAUI-2 100GAUI-1	SFP/SFP-DD QSFP/QSFP-DD OSFP
200GBASE–	KR4 KR2	CR4 CR2 CR1				SR4 VR2 SR2	DR4 DR1	FR4 FR1	LR4		ER4		200GAUI-4 200GAUI-2 200GAUI-1	QSFP/QSFP-DD SFP-DD
400GBASE–	KR4	CR4 CR2				SR16 SR8/SR4.2 VR4 SR4	DR4 DR2	FR8 FR4 400G-FR4 DR4-2	LR8 LR4-6 400G-LR4-10		ER8	ZR	400GAUI-16 400GAUI-8 400GAUI-4 400GAUI-2	QSFP/QSFP-DD OSFP
800GBASE-	ETC-KR8 KR8	ETC-CR8 CR8 CR4				VR8 SR8	DR8 DR4	DR8-2 DR4-2 FR4	TBD		TBD		800GAUI-8 800GAUI-4	
1.6TBASE-		CR8					DR8	DR8-2					1.6TAUI-16 1.6TAUI-8	QSFP/QSFP-DD OSFP/OSFP-XD


SFP


QSFP


QSFP-DD


SFP-DD


OSFP


OSFP-XD

Gray Text = IEEE Standard Red Text = In Task Force Green Text = In Study Group

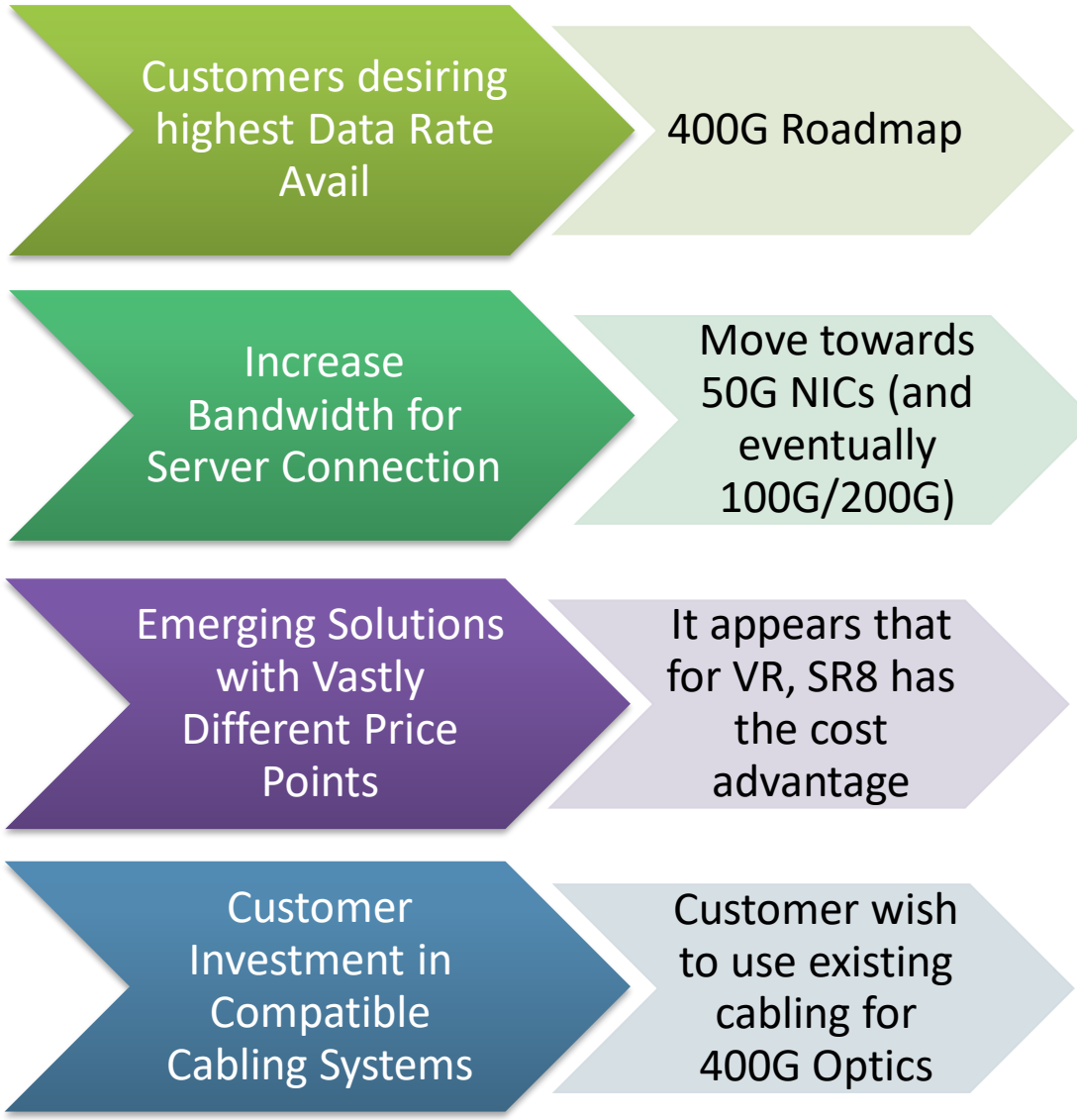
Blue Text = Non-IEEE standard but complies to IEEE electrical interfaces * Note: As of publication, subject to change

Source: Ethernet Alliance

400G Market/Technology Update

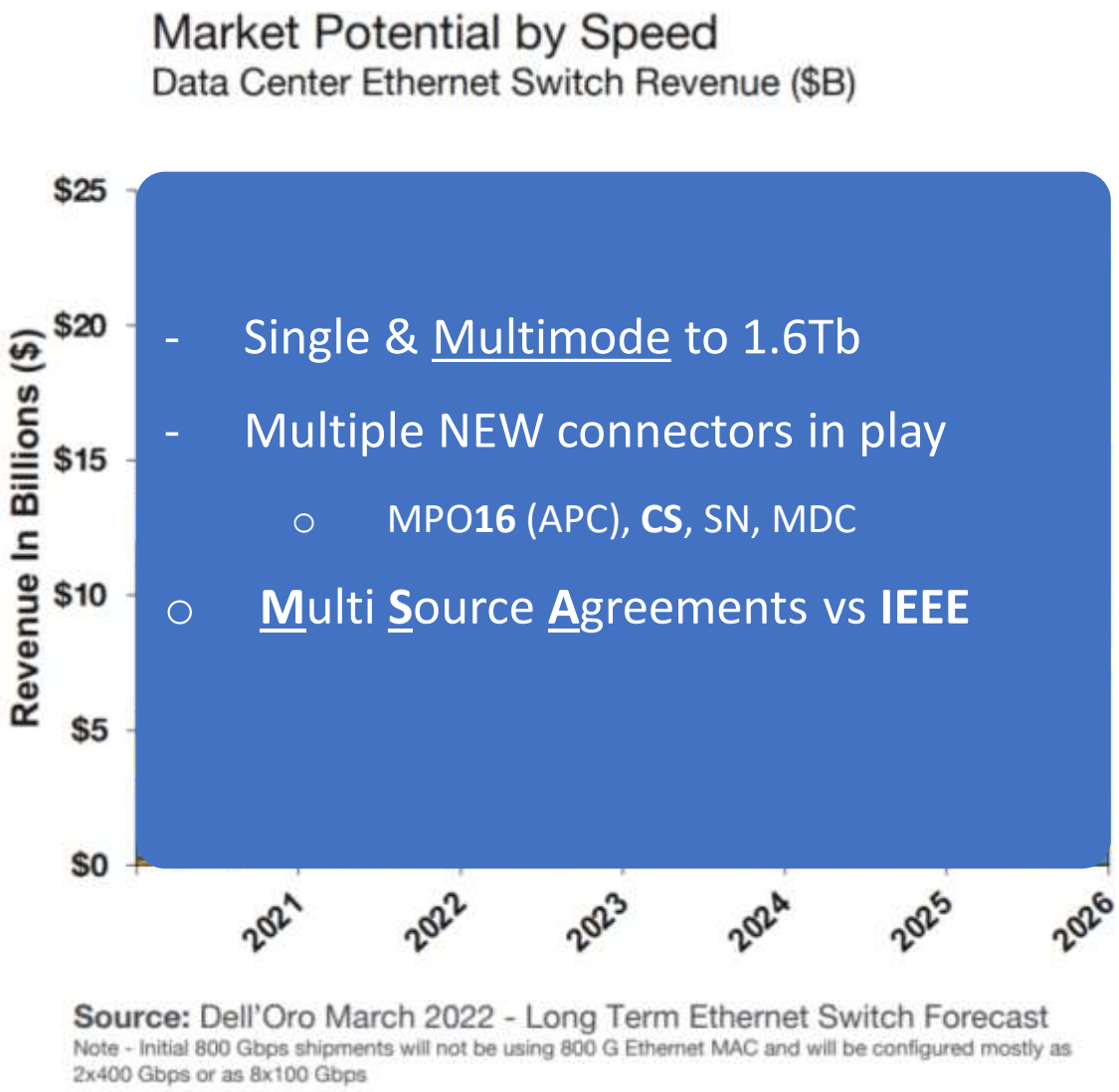
Bicsi®
ENDORSED EVENT

40G/100G/400G Market Insights



Bicsi® ENDORSED EVENT

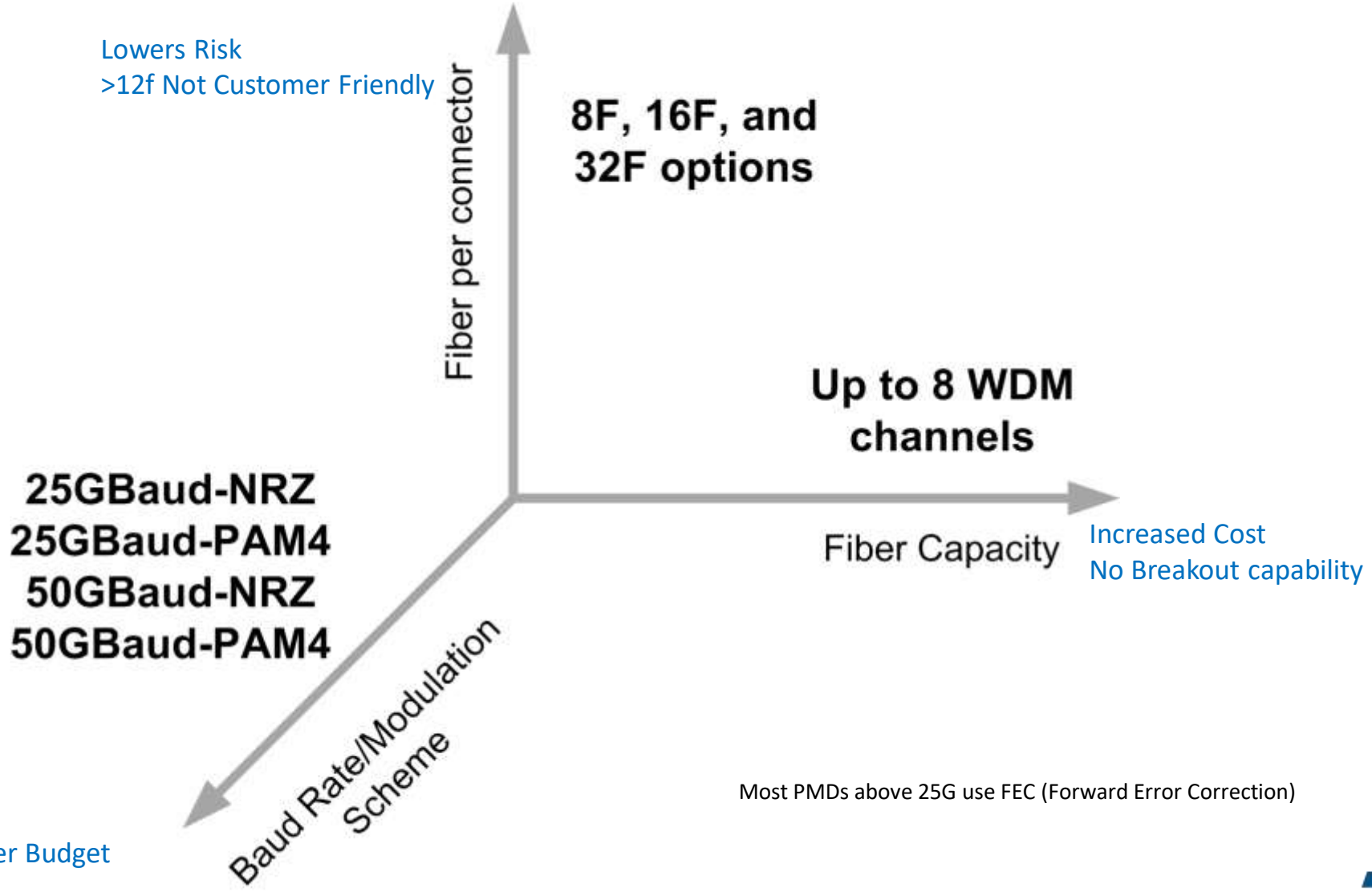
High Speed Ethernet Switch Forecast



- **Hyperscale** drives early adoption
- **Breakout** mode efficiencies
  - **Lowest cost** per **Gb**
  - Save space
  - Save time
  - Save power $'s (green)

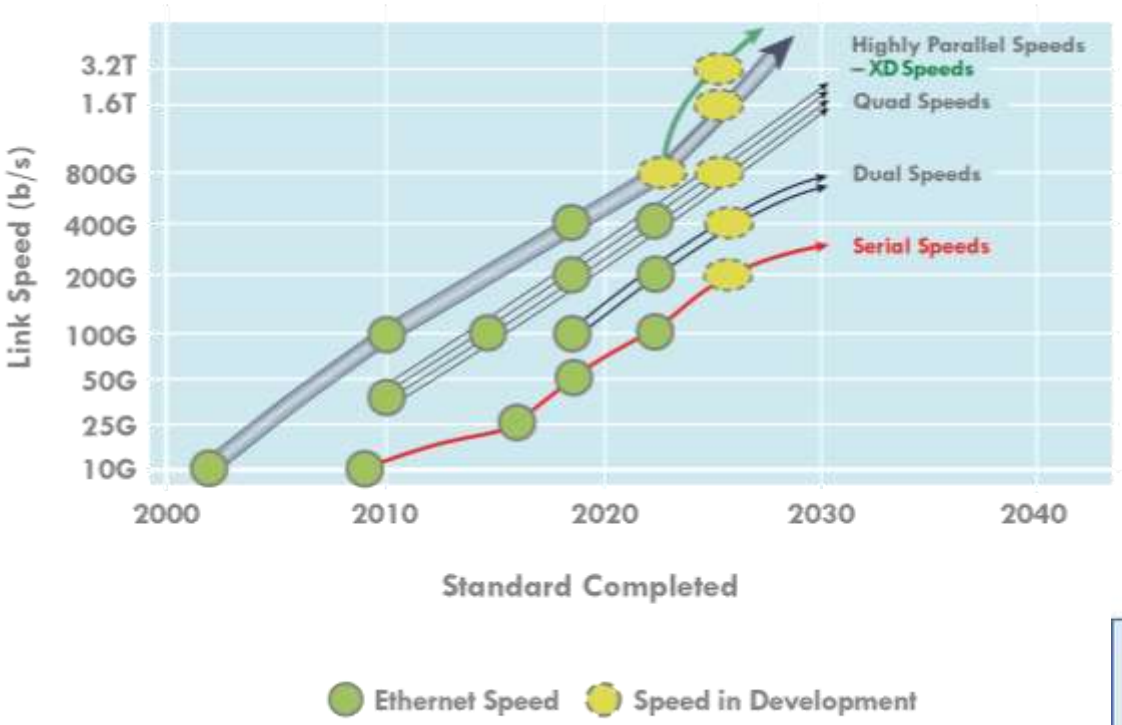
Bicsi ENDORSED EVENT

>10G ‘Toolbox’



Most PMDs above 25G use FEC (Forward Error Correction)

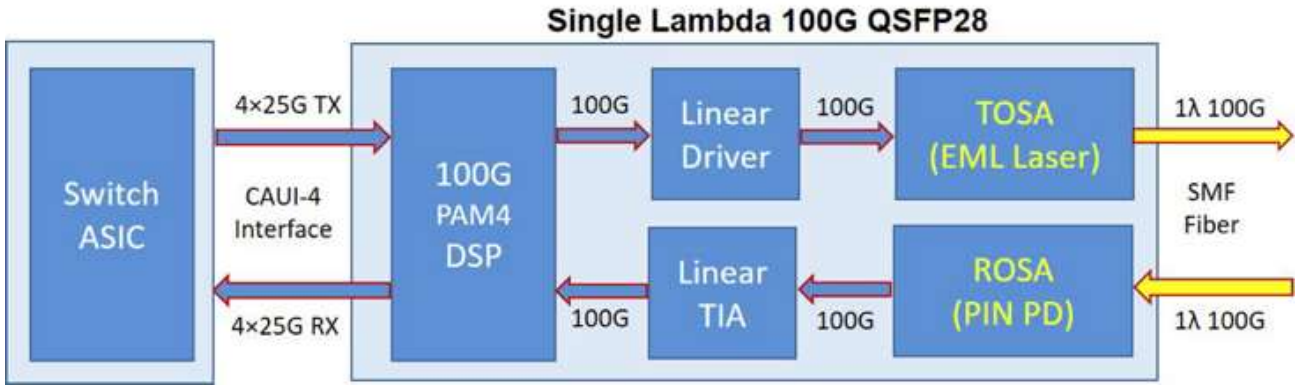
100G QSFP28 “Single Lambda”



100G Lambda
MULTI-SOURCE AGREEMENT

Ethernet Alliance prize to be awarded to the first company who publicly demonstrates a <3.5 W QSFP28+ 100 Gb/s transceiver module with CAUI-4 electrical interface using a single wavelength of light (100 GBASE-FR1/100 GBASE-SR1).

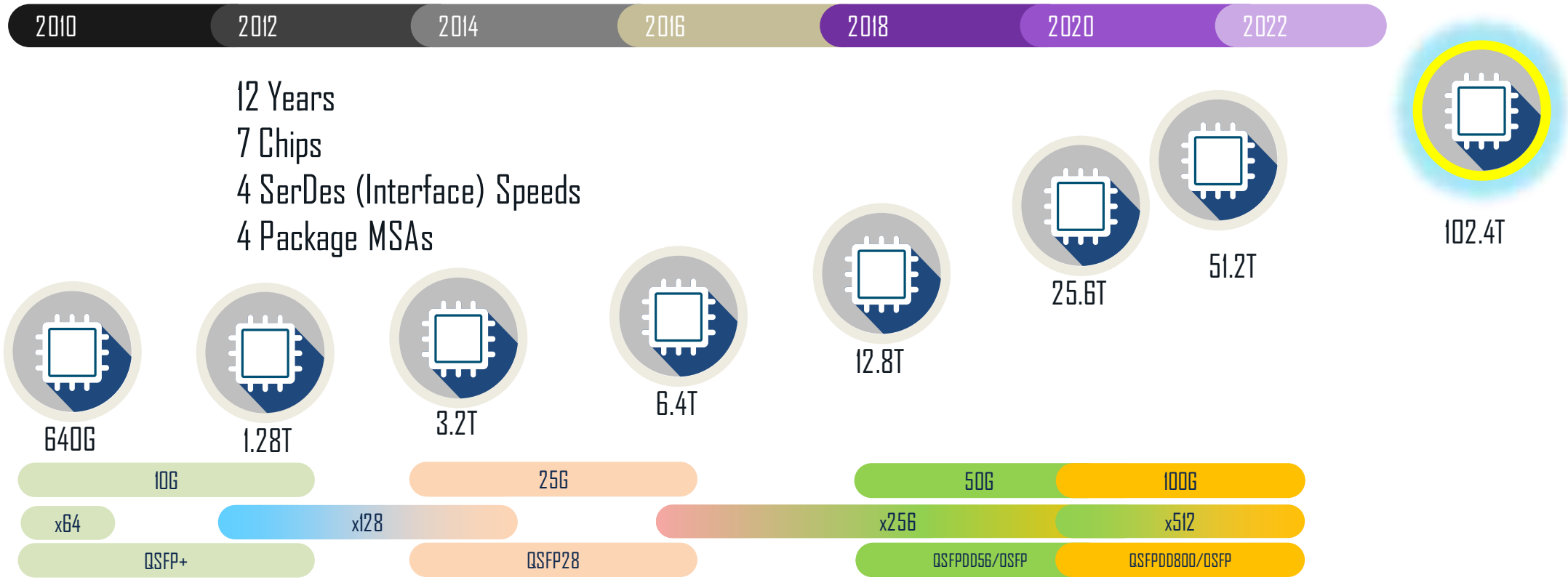
100G single lambda offers the simplest architecture, reliability/upgrade path to 400G optical Ethernet while enabling commercially viable lowest cost 100G pluggables.



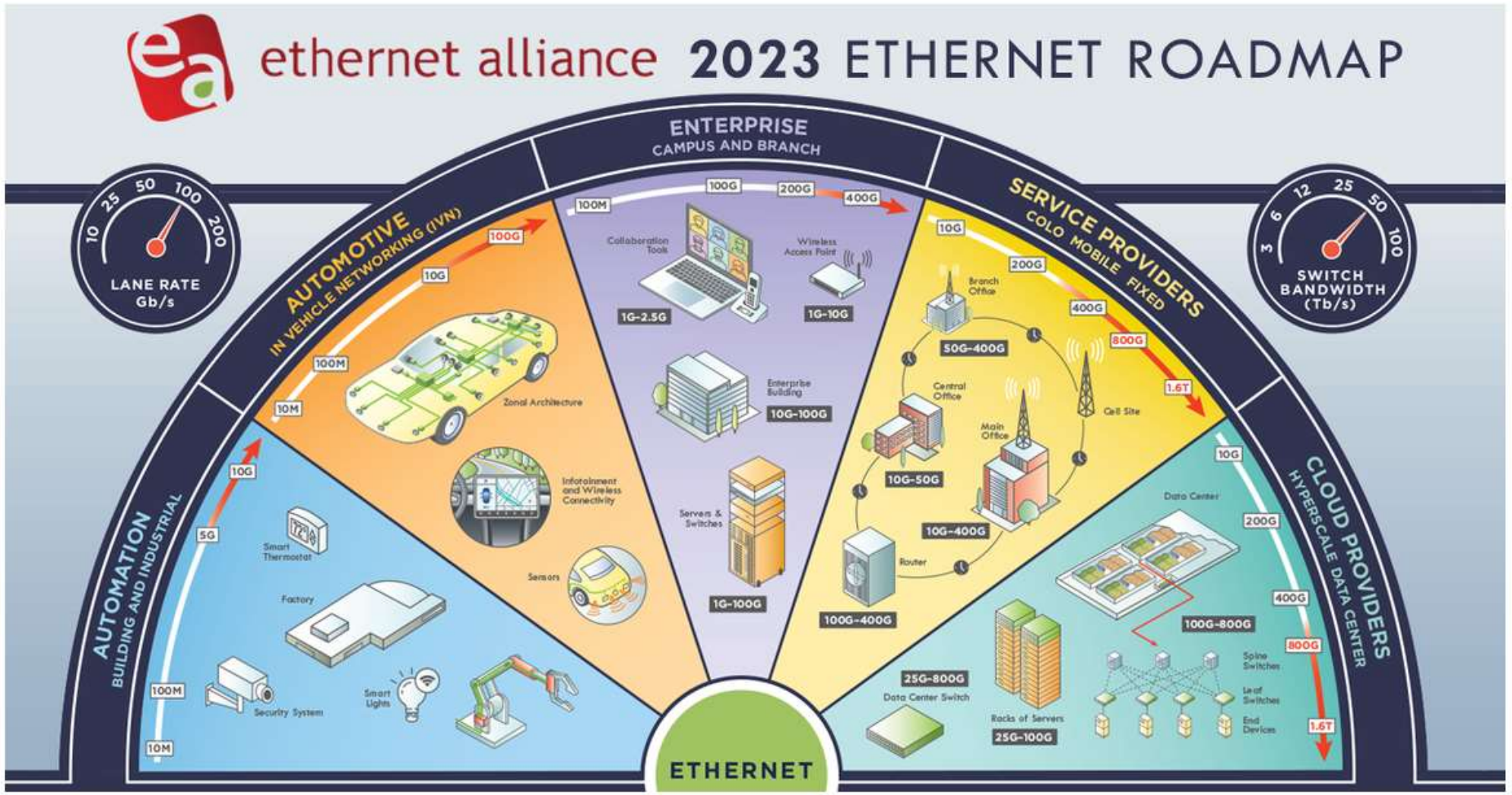
IEEE P802.3cu Working group for SMF
PAR Approved for MMF:
http://www.ieee802.org/3/100GSR/Objectives_Approved_by_100GSR_SG_Jan_2020.pdf

Bicsi
ENDORSED EVENT

Switch ASIC Advancement



400G & 400G+ Roadmap



BICSI ENDORSED EVENT

MMF Higher Data Rates = Higher Fiber Counts

Technology (per fiber) Lane Rate	1 Fiber Pair	2 Fiber Pairs	4 Fiber Pairs	8 Fiber Pairs
25G-λ NRZ	25G-SR		100G-SR4	
50G-λ PAM4	50G-SR	100G-SR2	200G-SR4	400G-SR8
2x50G-λ PAM4			400G-SR4.2 (BiDi)	
100G-λ NRZ	100G-SR	200G-SR2	400G-SR4	800G-SR8
2x100G-λ PAM4	200G-SR1.2	400G-SR2.2	800G-SR4.2	1.6T-SR8.2

Existing IEEE Standards

In Progress (est. 2022)

In Progress (est. 2025)

In Progress (est. 2027)

SRm.n

m = # of Fiber Pairs

n = # of Wavelengths

Bicsi® ENDORSED EVENT

400G/800G & Beyond Module Roadmap

Focus on Low-Cost/Shorter Reach Options for L-S & Server Interconnect

	Lane Rate Gb/s	Nomenclature	Lane Rate Gb/s	Number of Fiber Pairs	Connector	Number of Wavelengths	Year Standardized	Max. Reach meters (OM4)
Multimode	400	400GBASE-SR4	100	4	MPO-12	1 (850 nm)	TBD	TBD
	800	800GBASE-VR8	100	8	MPO-16	1 (850 or 940)	2025	50
	800	800GBASE-SR8	100	8	MPO-16	1 (850 nm)	802.3df	100
	800	800G-VR4.2	100	4	MPO-12	2 (850 and 910 nm)	2023	50
	800	800G-SR4.2	100	4	MPO-12	2 (850 and 910 nm)	Terabit BiDi MSA	70
	1600	1.6T-SR8.2	100	8	MPO-16 or 2xMPO-12	2 (850 and 910 nm)	Terabit BiDi MSA	70
Singlemode	800	800GBASE-DR8	100	8	MPO-16	1	2025 802.3df	500
	800	800GBASE-DR8-2	100	8	MPO-16	1	2025 802.3df	2000
	800	800GBASE-DR4	200	4	MPO-12	1	2026 802.3dj	500
	800	800GBASE-DR4-2	200	4	MPO-12	1	2026 802.3dj	2000
	800	800GBASE-FR4	200	1	Duplex	4	2026 802.3dj	2000
	1600	1.6TBASE-DR8	200	8	MPO-16	1	2026 802.3dj	500
	1600	1.6TBASE-DR8-2	200	8	MPO-16	1	2026 802.3dj	2000

Need to monitor DR4 (400G/800G) optics prices, as this is high volume PMD for L-S interconnect at Hyperscale entities (today & going forward)

400G/800G & Beyond Module Roadmap

Observations/Notes/Stream of Consciousness

- SR8 & VR8 PMDs are targeted at **displacing copper solutions** in switch to server applications at 50G or greater
- All the multimode 800G PMDs depend on 100G single lambda optics (ecosystem not mature & reach unknown...very much behind the maturity of single lambda singlemode optics)
- DR8 optics are taking hold in Hyperscale
- 200G single lambda singlemode optics is and will ultimately drive the majority of shorter reach Leaf-Spline application that require 800G/1.6T

Next Generation Standard, 802.3df (MMF)*

Physical Medium Dependent (PMD) sublayer and Media Type:

VR (Very short reach)	**SR (Short reach)**
100GBASE-VR1	100GBASE-SR1
200GBASE-VR2	200GBASE-SR2
400GBASE-VR4	400GBASE-SR4
800GBASE-VR8	800GBASE-SR8

**All dependent of arrival of cost-effective MMF "Single Lambda Optics"*

400G Module Lineup

DELL EMC TRANSCEIVERS

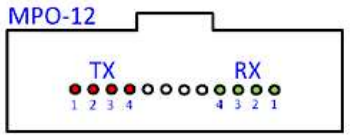
Model	Connector Type	Wavelength(s) (nm)	Transmission Medium	Distance (max.)	Transmitter Power (dBm)	Receiver Power (dBm)	Power Dissipation (max.; W)	Notes
400-Gigabit Ethernet QSFP56-DD transceivers								
Q56DD-400G-SR8	MPO-12DD	850	MMF OM3 MMF OM4	70 m 100 m	-6.0 to +4.0 /lane	-8.4 to +4.0 /lane	12.0	MPO-12DD is a two-row double density MPO-12
Q56DD-400G-SR4.2-ON*	MPO-12	850 910	MMF OM3 MMF OM4 MMF OM5	70 m 100 m 150 m	-6.2 to +4.0 /lane	-8.2 to +4.0 /lane	10.0	compatible with Q28-100G-BIDI-ON for 1 × 4 breakout
Q56DD-400G-EDR4	MPO-12	1310	SMF	2 km	-2.4 to +4.0 /lane	-6.4 to +4.5 /lane	12.0	compatible with Q28-100G-FR for 1 × 4 breakout
Q56DD-400G-FR4	duplex LC	1271 1291 1311 1331	SMF	2 km	-3.3 to +3.5 /lane	-7.3 to +3.5 /lane	12.0	

MPO24

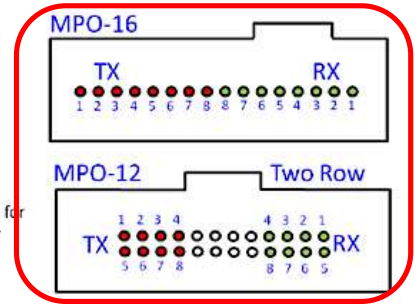
MPO12

MPO16

MPO8



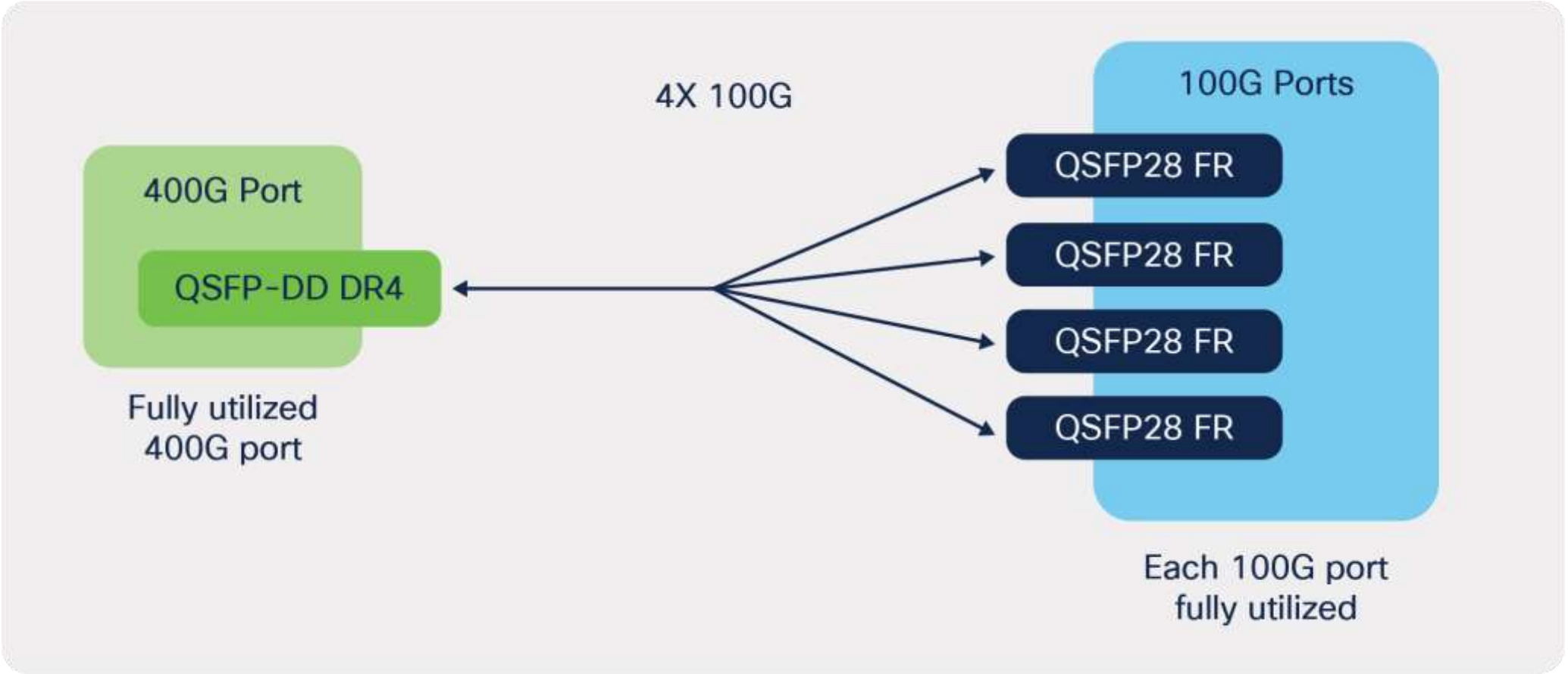
Note: The MPO 12, 2 row optical MDI is used for breakout applications and is not intended for structured cabling applications.



*ON: This module is designed for use in an "open network" environment, meaning that it is not tied to any specific vendor or proprietary technology.

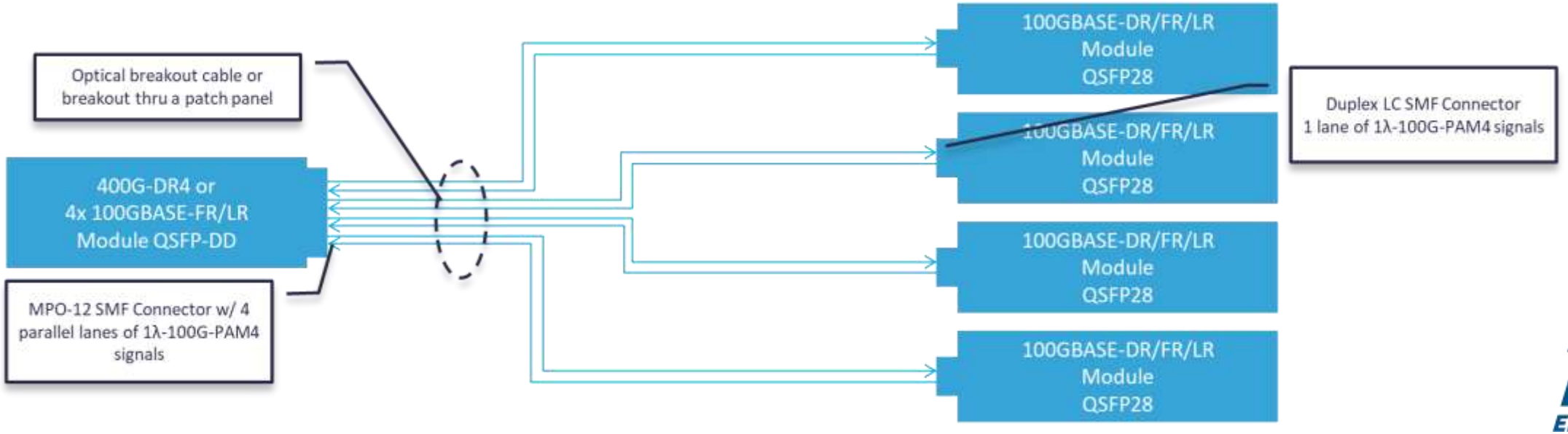
Bicsi® ENDORSED EVENT

Switch/Server Breakout Application



What is a Breakout?

- Breakouts are when an Ethernet port on a line card is configured as a multiple number of lower speed interfaces
- Breakouts are typically enabled by a pluggable module that can support multiple fiber connections
- Each fiber pair operates as an individual Ethernet connection
  - 400G-DR4 module can be used as four 100G modules in a single port

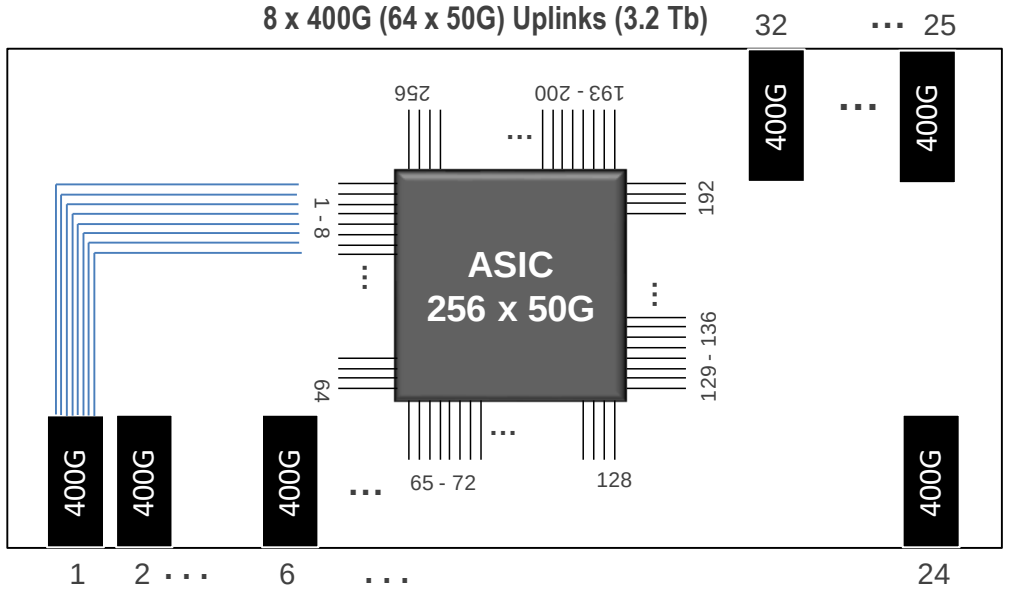


Why Breakout?

- Manage the migration to next gen platform
- Breakouts can increase the Radix of a switch, providing the opportunity to flatten network architecture
- High front panel density
  - A 400G QSFP-DD 400G-DR4 provides the highest density 100G module available on the market
  - Capability of 4x 100G modules in 18mm wide module more than twice the density of an SFP112 module (13mm width)
  - 32 port switch can aggregate 128 x 100GE lanes in a single RU

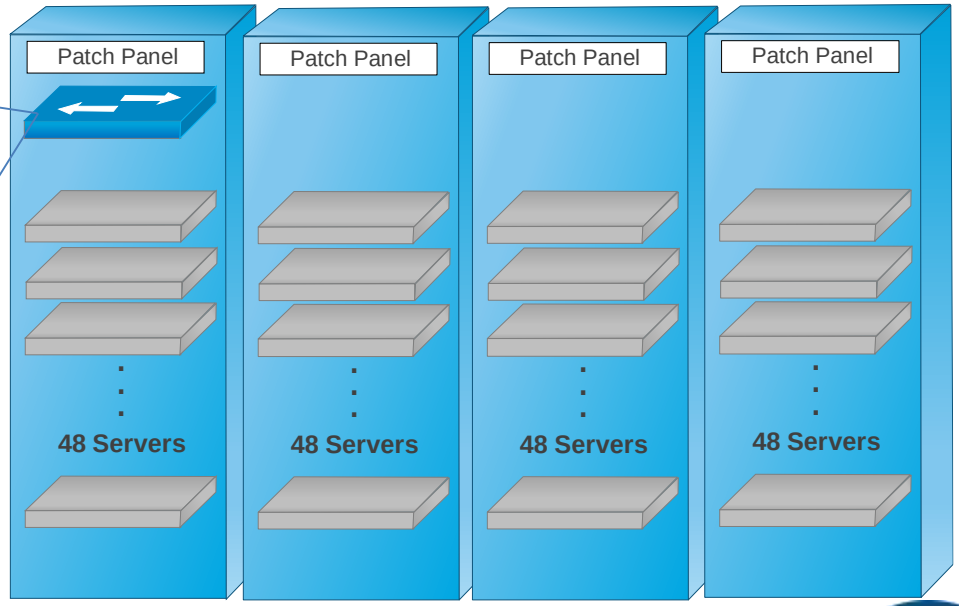
Application: 256 x 50G Switch Radix – 3:1 over subscription

- High density 32x400G port switch
- 50G servers supported by
  - 400G-SR8 to 50G-SR breakout



6 x 8 = 48
50G servers

6 switch ports / Rack
6x 16f MPO to 48 duplex LCs

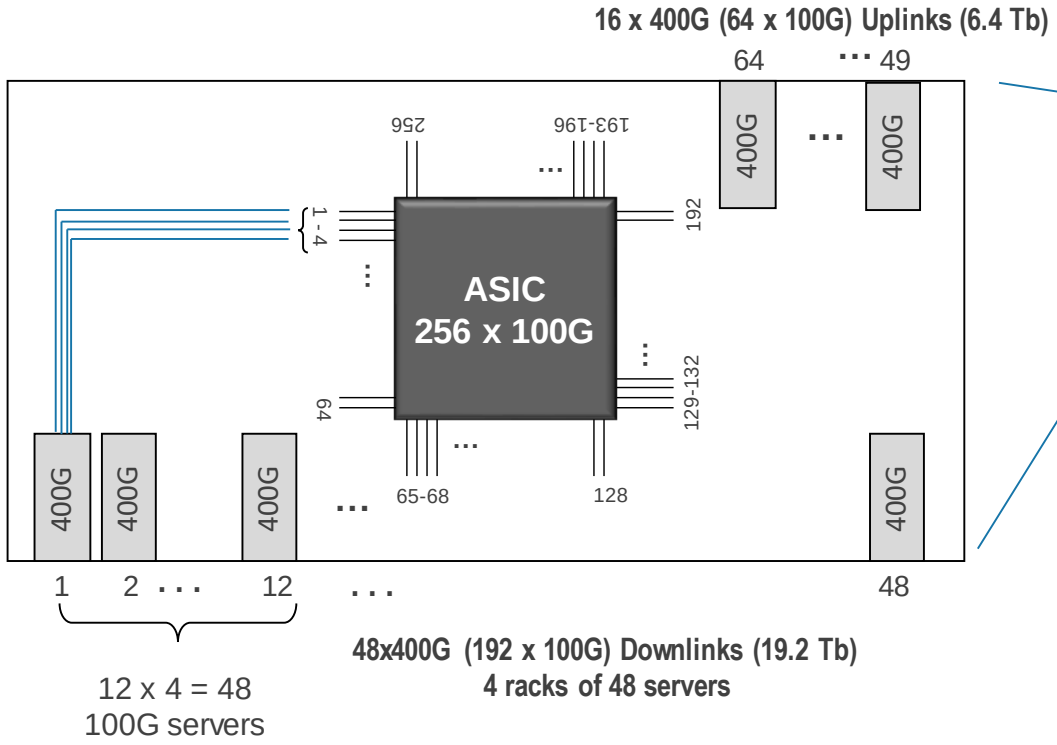


4 rack of 48 servers
or
8 racks of 24 servers

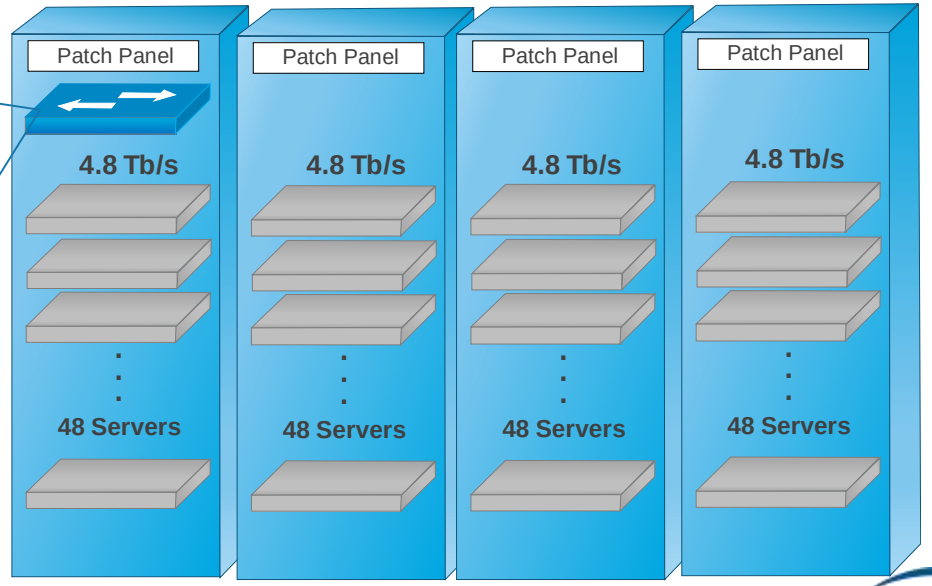
BICSI ENDORSED EVENT

Next-gen application: 256 x 100G Radix Switches

- High density 64 x 400G port spine switch (25.6 Tb/s)
- 100G servers supported by single-mode PMDs
  - 400GBASE-DR4 (802.3bs) & 100GBASE-DR (802.3cd) breakout
- Maximum required reach: 30m
- 800G PMD reduces number of ports to 32



12x 8f MPO to 48 duplex LCs per rack



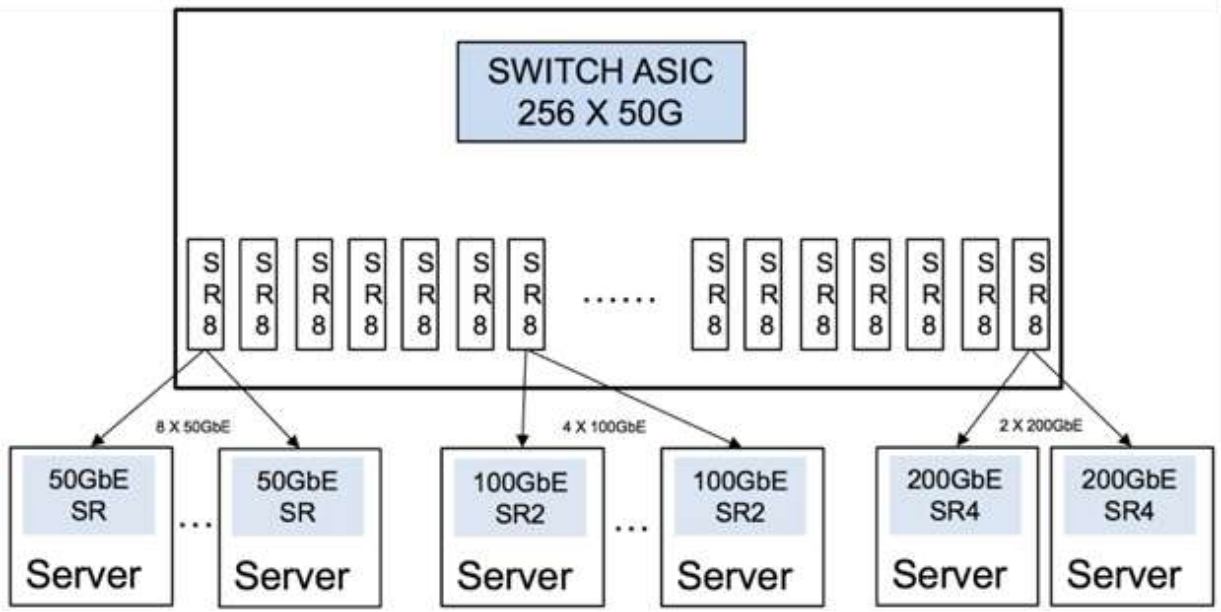
4 rack of 48 servers
or
8 racks of 24 servers

Bicsi ENDORSED EVENT

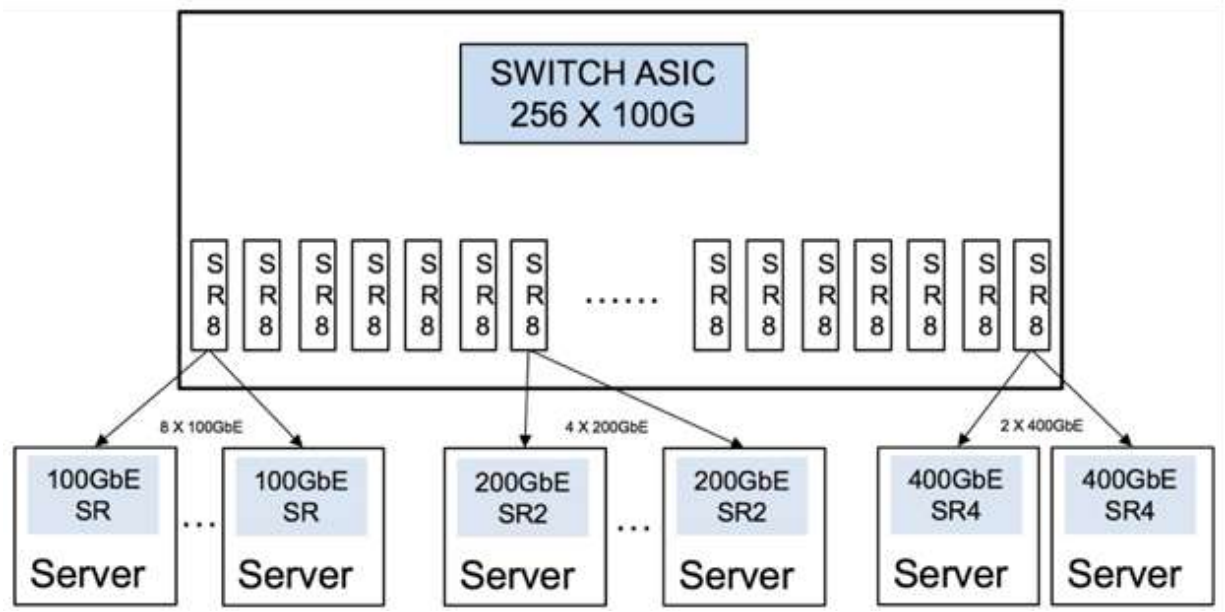
SR8 Optics Switch Port Consolidation for Breakout

Switch Radix over the last 9 years has increased from 64x10G, 128x25G, now to 256x50G, 256x100G and soon to 512x100G

50G



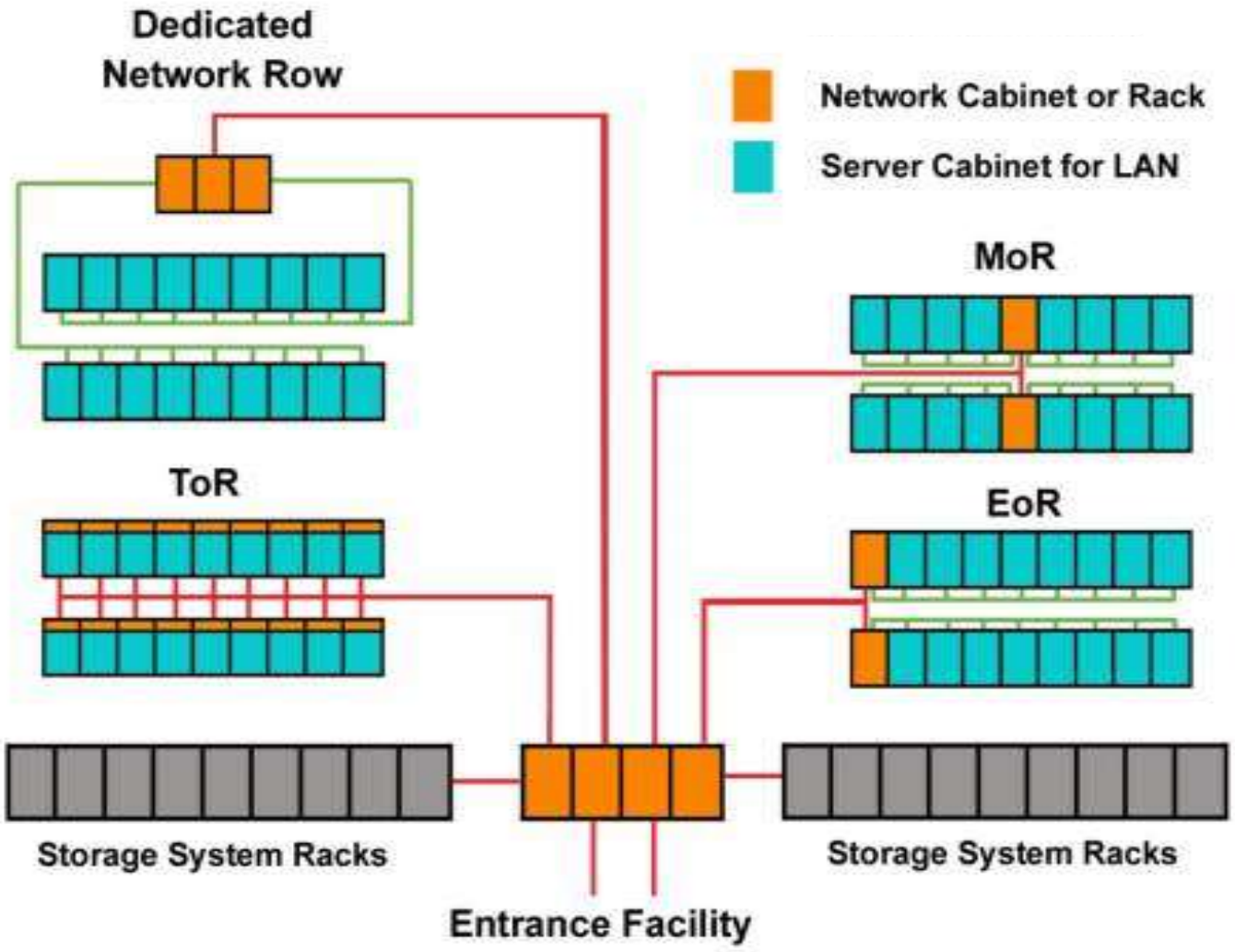
100G



Server attachment rates can be selected by grouping a number of SR8 ports together as required with structured cabling and this cabling becomes migratable as lane rates increase

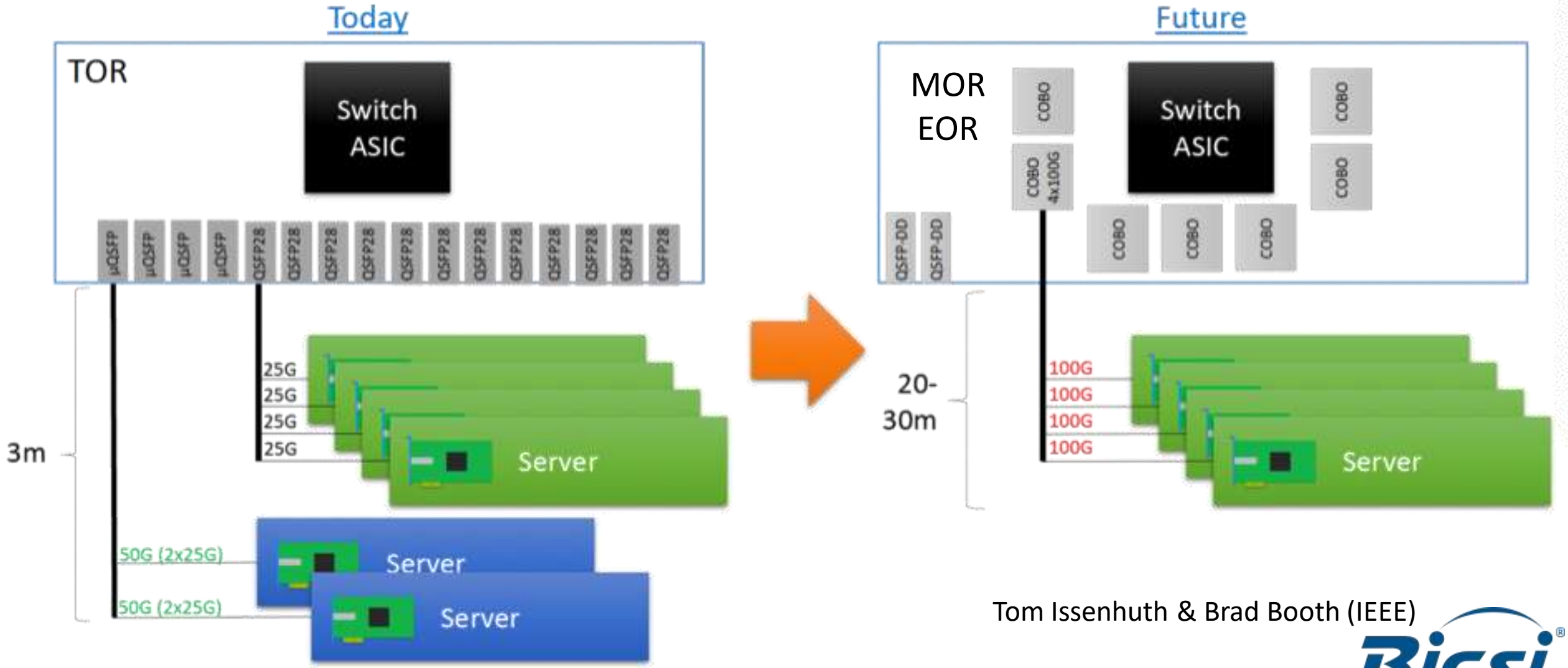
Structured Cabling Support

Leaf/Spine and Switch/Server Use Cases for Optical Modules



Bicsi
ENDORSED EVENT

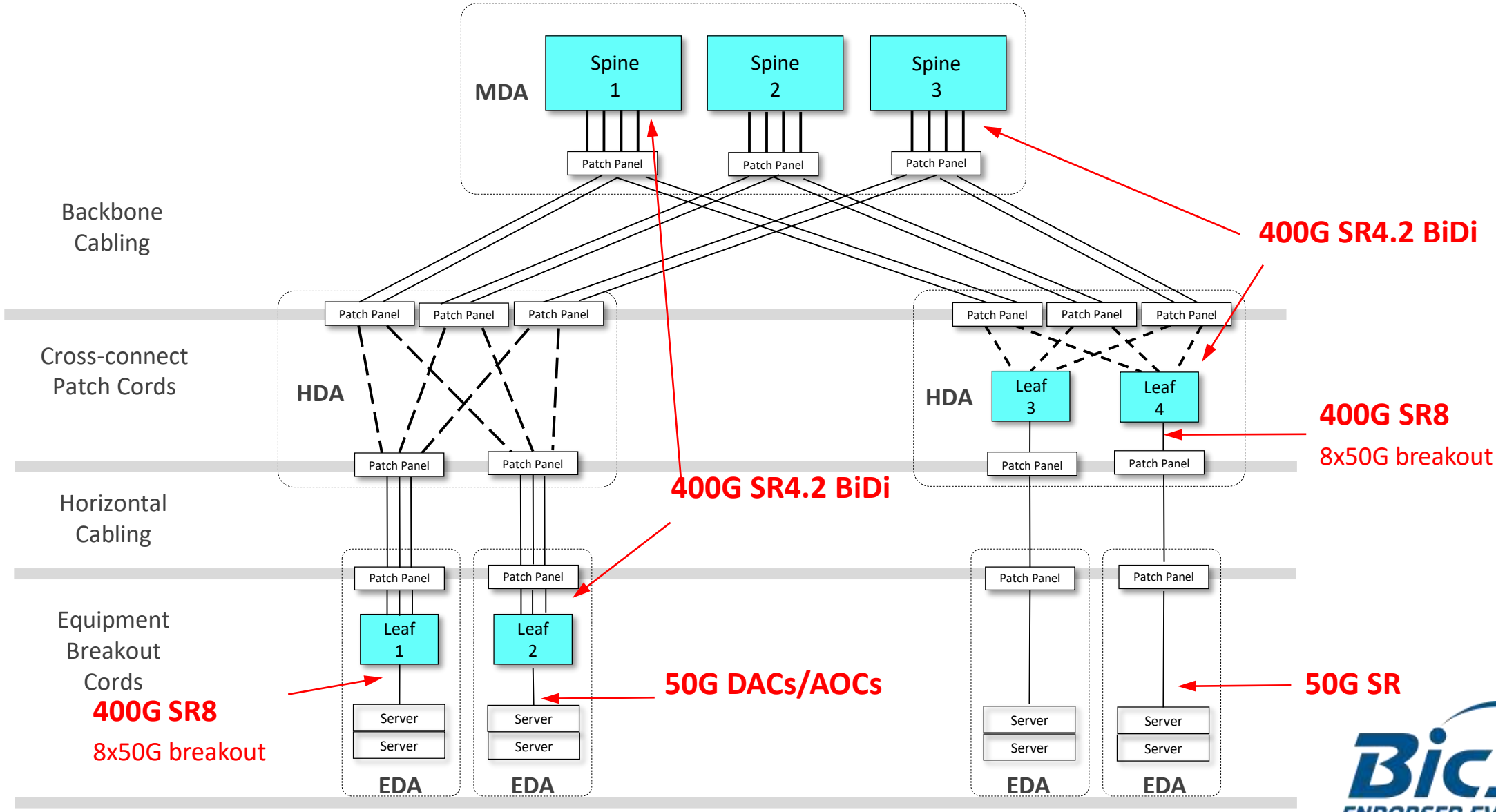
Breakout Use Case - Servers



Tom Issenhuth & Brad Booth (IEEE)

Bicsi ENDORSED EVENT

50G/400G Future PAM-4 Ecosystem for MMF



BICSI ENDORSED EVENT

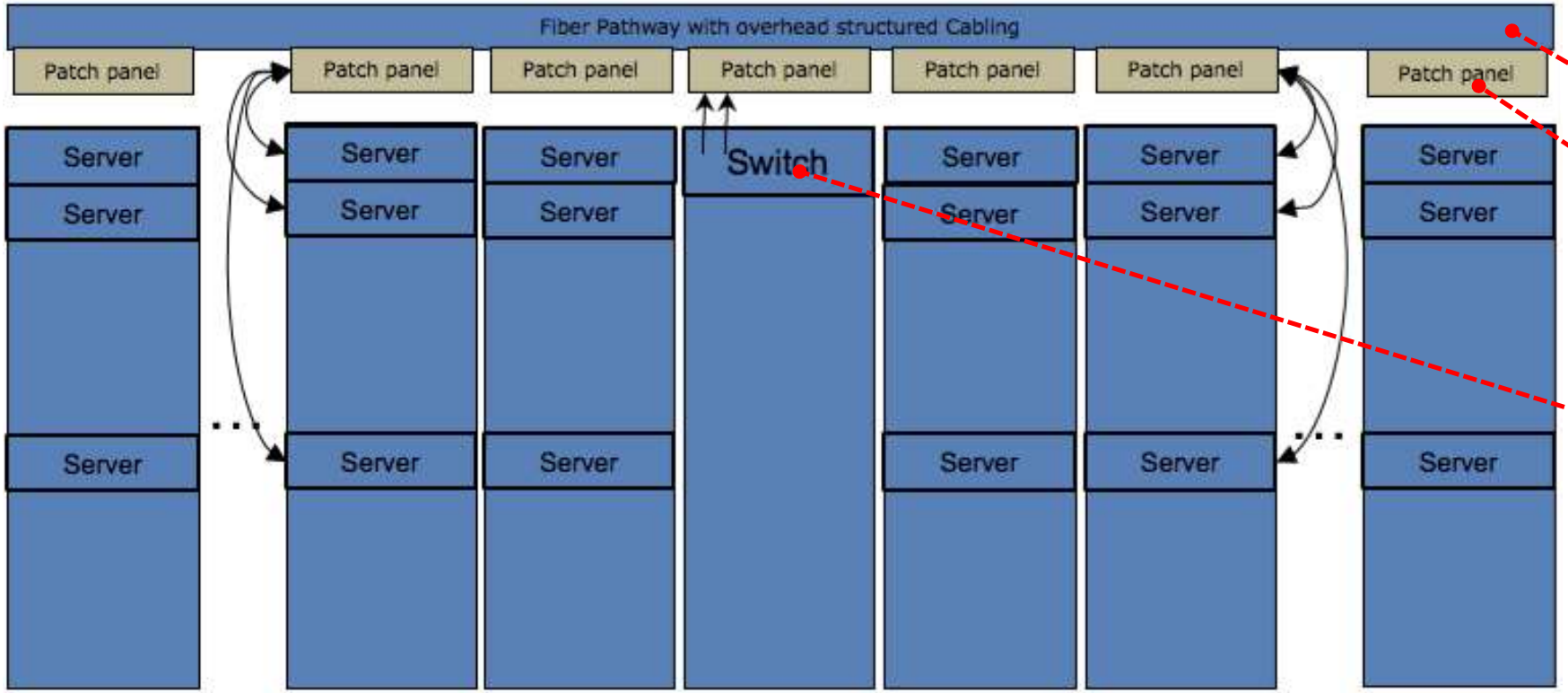
Customer Benefits of 400G SR8

- Enables higher density 50G server ports using 8:1 breakouts from a 400G SR8 optic (e.g.- a single 32 port 1RU modular 400G switch can enable 256, 50G ports/RU - High Radix)
- A reduction of the number of optical links and supporting cable plant (patch panels and connectors) by factor of 8 when compared to 50G switches
- A 4-fold increase in aggregate switch bandwidth
- A 2-4X lower initial installed cost and significant reduction operating expenses (dramatically lower power per gigabit)

SR8 Technology Simplifies Server Pod Build

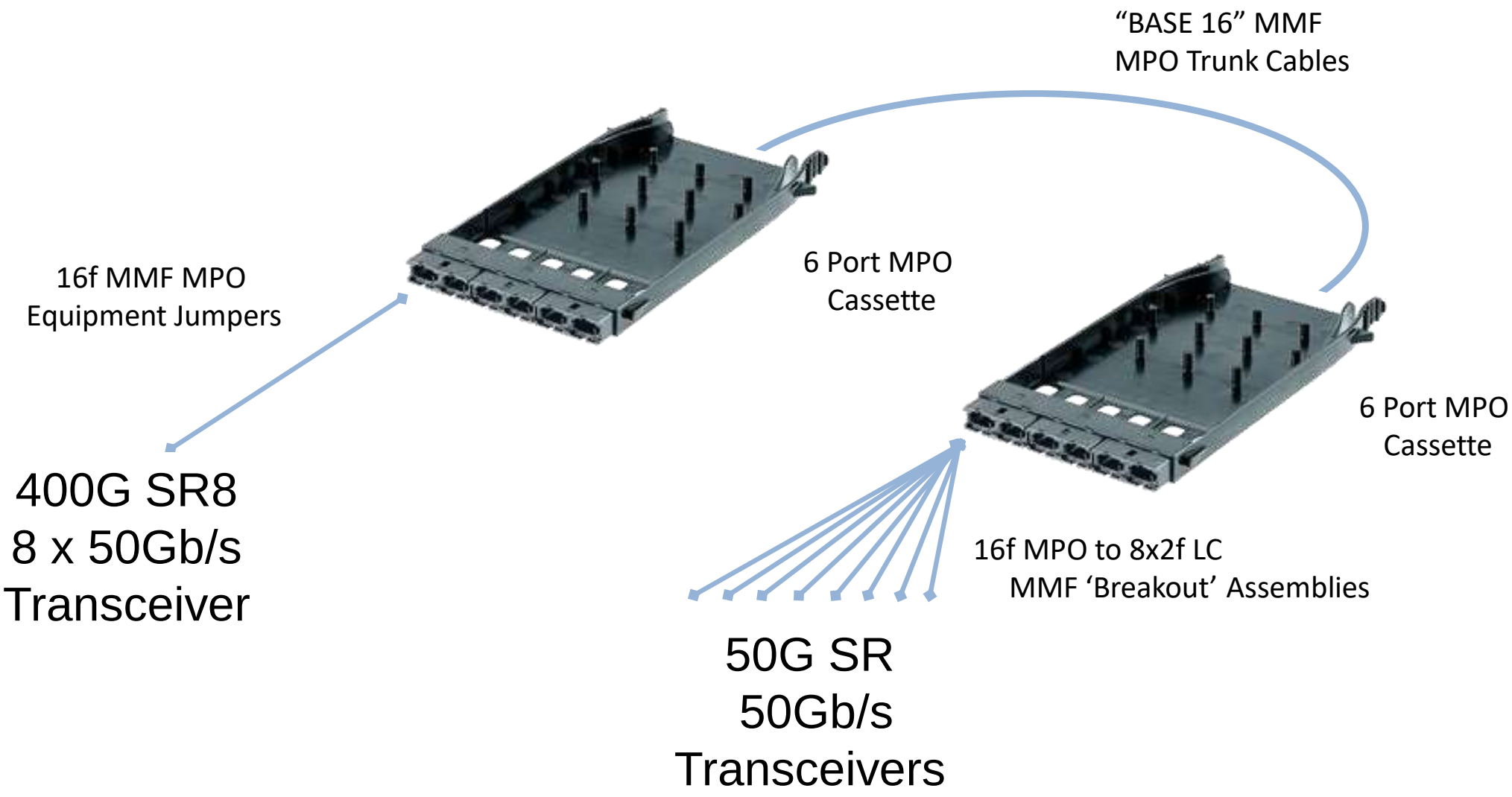
Move switch from ToR to EoR/MoR to more efficiently consume Radix

- Reduce Number of switch (Go Green)
- Agile Network by Simplifying architect
- Enables pre-terminated distribution cabling supporting multiple line rate generations
- Allow breakouts in cassettes to support various server data rates (50/100/200G)



Bicsi ENDORSED EVENT

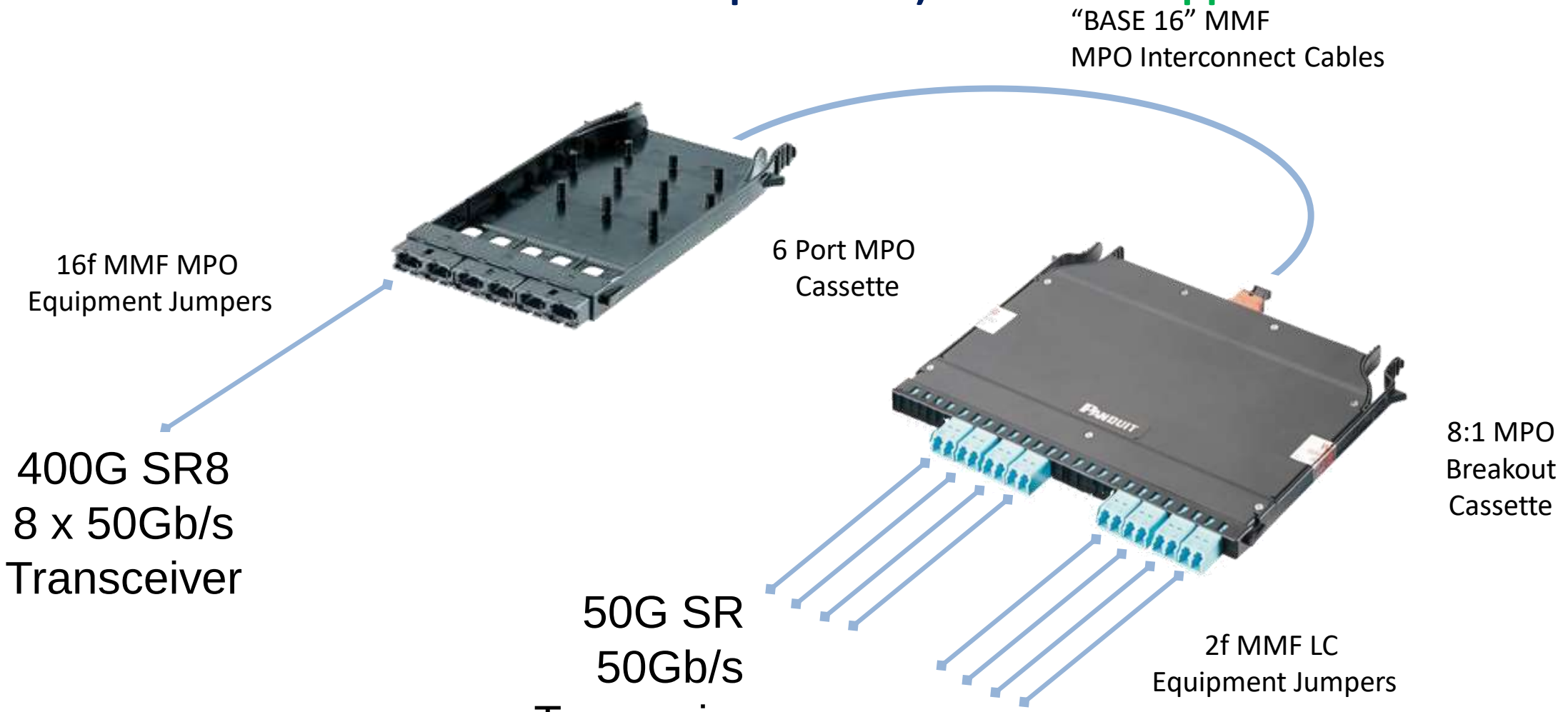
400G-SR8 to 50G SR1 Server NIC Breakout



Bicsi
ENDORSED EVENT

400G-SR8 to 50G SR1 Server NIC Breakout

(16f MMF infrastructure with 16f & LC Duplex EDAs) - Preferred Approach



BICSI ENDORSED EVENT

Connectivity spotlight

Consider **small diameter** cabling

X4

more glass
Parallel
(vs Duplex)

Stay flexible/ modular

Solve **fibre densification** challenge.
Mitigate circuit risk

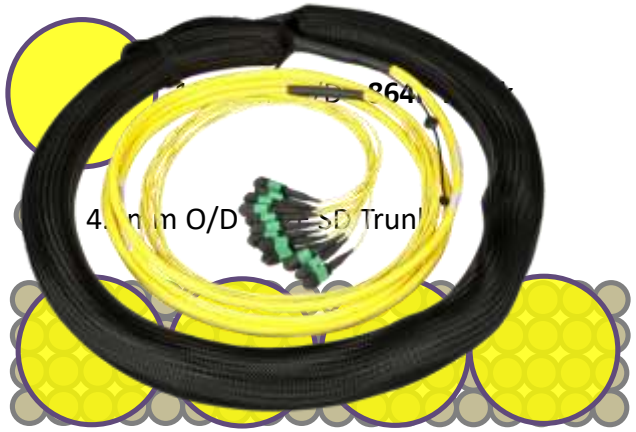
Pre-terminated/ pre-configured

Increase density
up to **50%**
144F/192F/ **216F per RU**

Go ‘white’

Save energy
power (lighting) efficiency

MMF the strong contender <150m



864F (72x**12F** trunks) VS **3,456F** (4x**864F** Trunks)

PanMPO 2.0™
MMF/SMF

HD Flex™
Split tray ½ circuit risk

CS Connector
Family SMF/MMF

HD Flex™
Zone/Floor Box

Bicsi ENDORSED EVENT

Wrap Up

- 400G is needed and will produce more efficient data centers links needed for the high traffic expected in this decade
- 400G deployment take off in 2020
  - Dell'Oro group indicates by 2023 to reach 15 million ports
- Start with Hyperscale but as cost reduces, deployment for colocation and premises data center expected
- 400G and beyond will eventually reduce number of deployed leaf switches (Cutting Power/operation cost, save space and simplify Switch to server Network Architect)
- Continues research for higher speed MMF connections started almost a decade ago
  - Currently developing faster solutions (2X) to be deployed in 2025
  - We expect future applications MMF at higher speeds

Q&A

Thank you

Bicsi®
ENDORSED EVENT

PANDUIT®

building a smarter, unified business foundation

Bicsi®
ENDORSED EVENT