Broad market potential, economic feasibility, and distinct identity for an 400GBASE-SR4.2 objective

David Piehler (Dell EMC), Chongjin Xie (Alibaba), Robert Lingle Jr. (OFS)

IEEE 802.3 Next-gen 200G & 400G PHYs over fewer MMF Pairs Study Group

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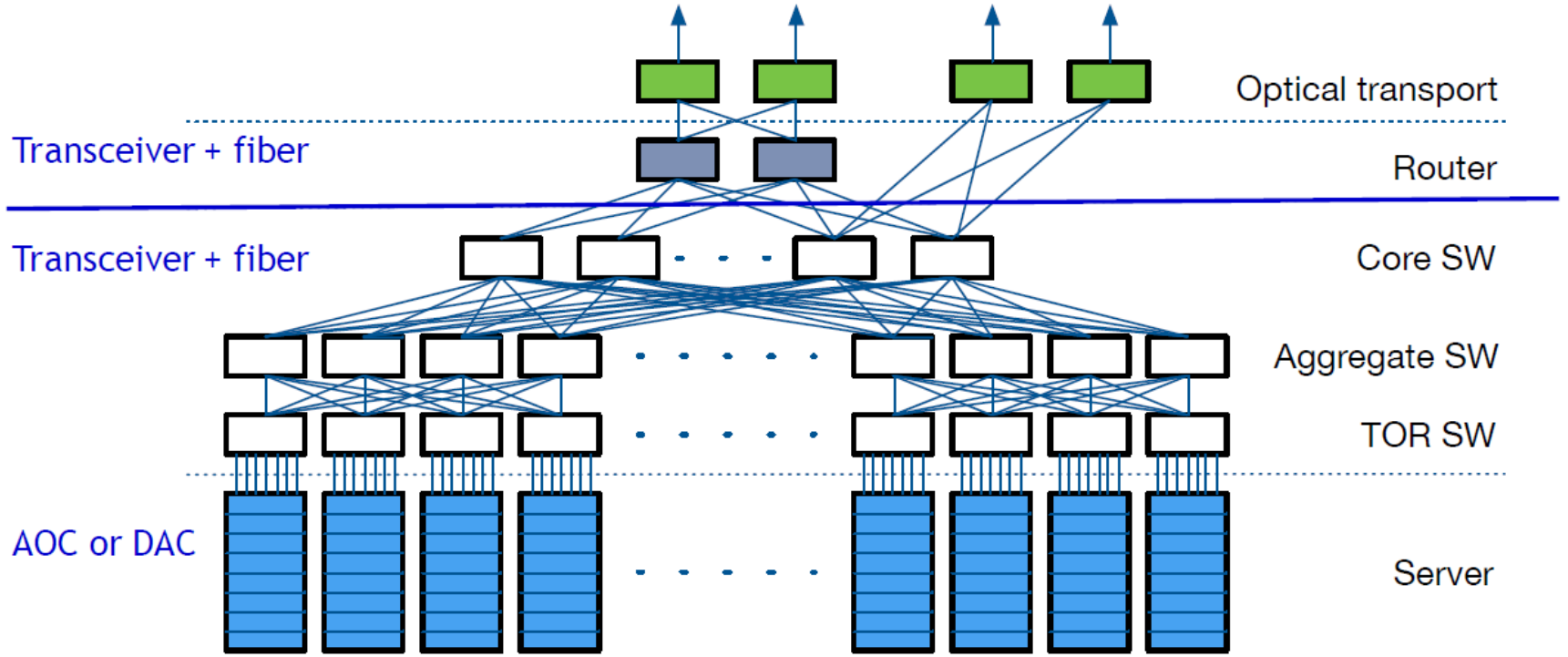
We project that 400GBASE-SR4.2 operating over 4 pairs of MMF will be a widely useful solution in cloud and large enterprise data centers, as well as CO Transformation in service providers



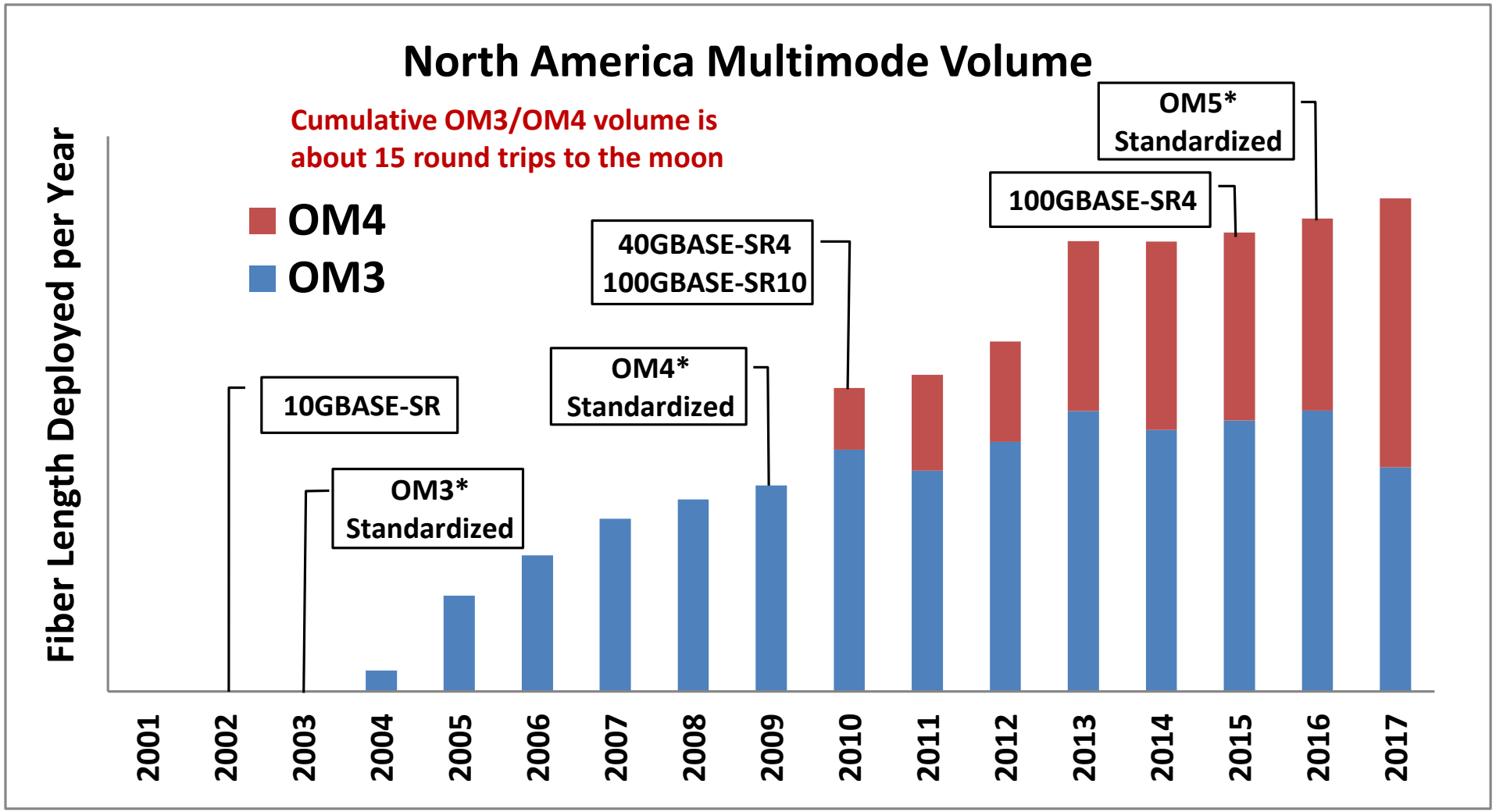
- switch-to-switch
- switch-to-router
- router-to-transport

- break out to 4x100G may find application in the future

Multi-Wavelength Nomenclature

SRm.n m = # fiber pairs n = # wavelengths

Deployment of OM3 MMF ramped up followed standards, with OM4 ramping up next following standards; Deployment has not slowed



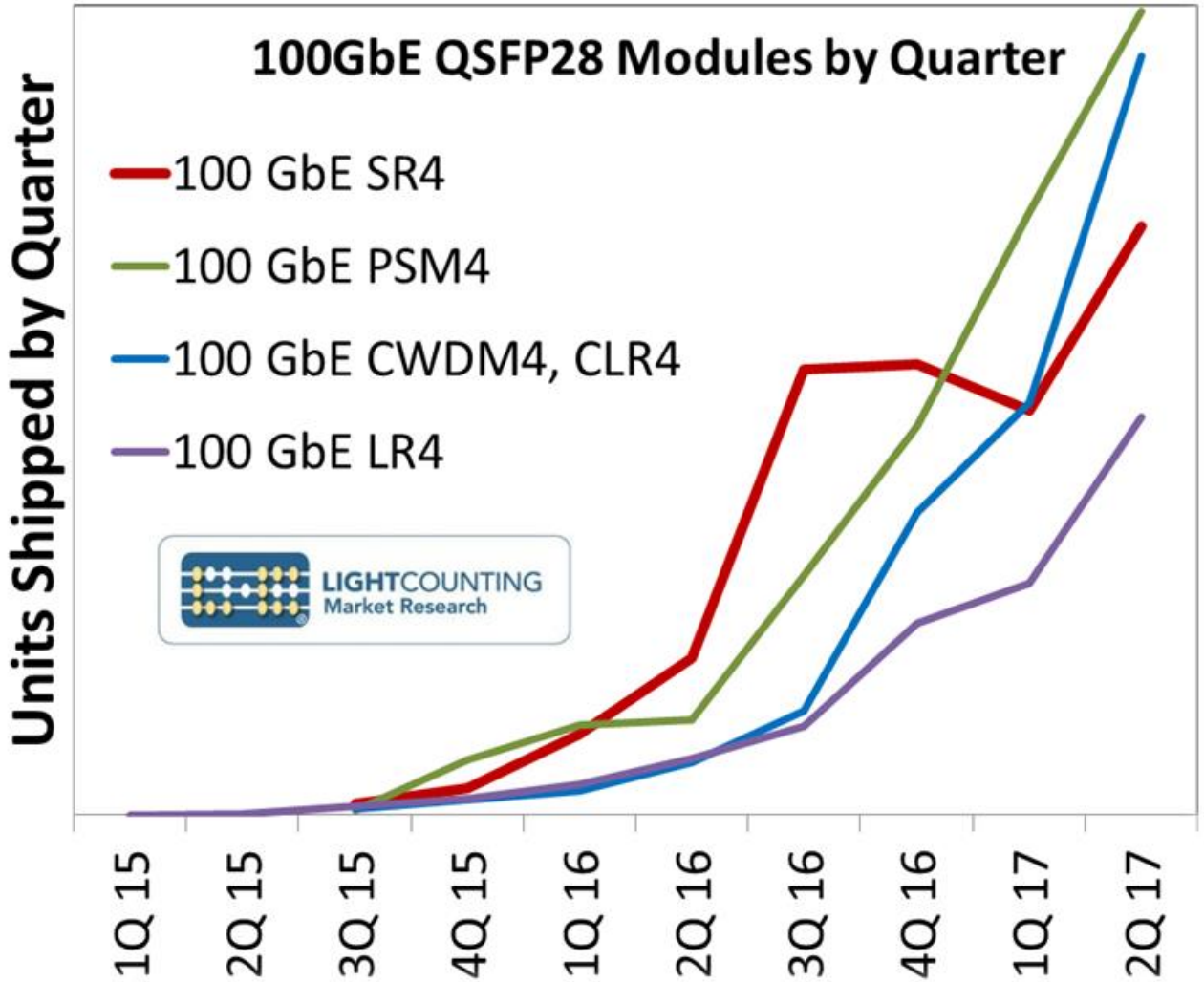
* Dates are ANSI/TIA standardization dates, not ISO/IEC
2017 estimated by annualizing 1H17 volume

Used with permission: Matthew Burroughs North America Multimode Reports

10/40/100G have been widely deployed over MMF

- Large installed base of duplex OM3/OM4 MMF deployed for 10GBASE-SR
- Large installed base of parallel OM3/OM4 MMF deployed for 40GBASE-SR4 and 100GBASE-SR4
- Industry investment in MMF cabling continues
- 400GBASE-SR16 does not operate on either of the common installed base cable types

100GBASE-SR4 in QSFP28 was required by web2.0 and largest enterprise data centers as soon as 100G switches entered the market



- Modules for MMF cabling had largest share of units shipped in 2016
- LightCounting predicts strong growth for all four module types.
- MMF is not dead!
- Deployment of 4-pair 100G links today suggests need for an upgrade path to 400G

from Nov 2017 CFI for Next-gen 200 & 400G MMF PHYs

As an example, Alibaba utilizes 100GBASE-SR4 in switch-to-switch connections

- 100GBASE-SR4 links over MMF cabling are lower cost for Alibaba today than PSM4 or CWDM4 links over SMF cabling

Alibaba Network & Optics: Current

Network speed	40G	100G	400G	1.6T?
SW-SW	40G eSR4 QSFP+	100G SR4, CWDM4 QSFP28	400G DR4 (FR4) SR4.2 QSFP56-DD	1.6T ?? OBO?? QSFP224-DD??
SW-Server	10G AOC SFP+	25G AOC SFP28	100G AOC SFP56-DD	400G OBO?? SFP224-DD??
Deployment	2013	2017	2019	2023?

Bandwidth density 40x in 10 years
Doubles ~ every 2 years

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10

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Existing 400GBASE-SR16 does not support 4f pair cabling used for SR4 links

Technology (per fiber)	1 fiber pair	2 fiber pairs	4 fiber pairs	8 fiber pairs	16 fiber pairs
25G-λ NRZ	25G-SR		100G-SR4		400G-SR16
50G-λ NRZ				400G-SR8	
50G-λ PAM4	50G-SR	100G-SR2	200G-SR4	400G-SR8	
100G-λ PAM4	200G-SR1.2	200G-SR2	400G-SR4		
2x50G-λ PAM4		200G-SR2.2	400G-SR4.2		
4x25G-λ NRZ		200G-SR2.4	400G-SR4.4		
4x50G-λ PAM4	200G-SR1.4	400G-SR2.4			
8x50G-λ PAM4	400G-SR1.8				

The module types shown in red would be formally within the scope of the SG, but many would lack technical feasibility or broad market potential

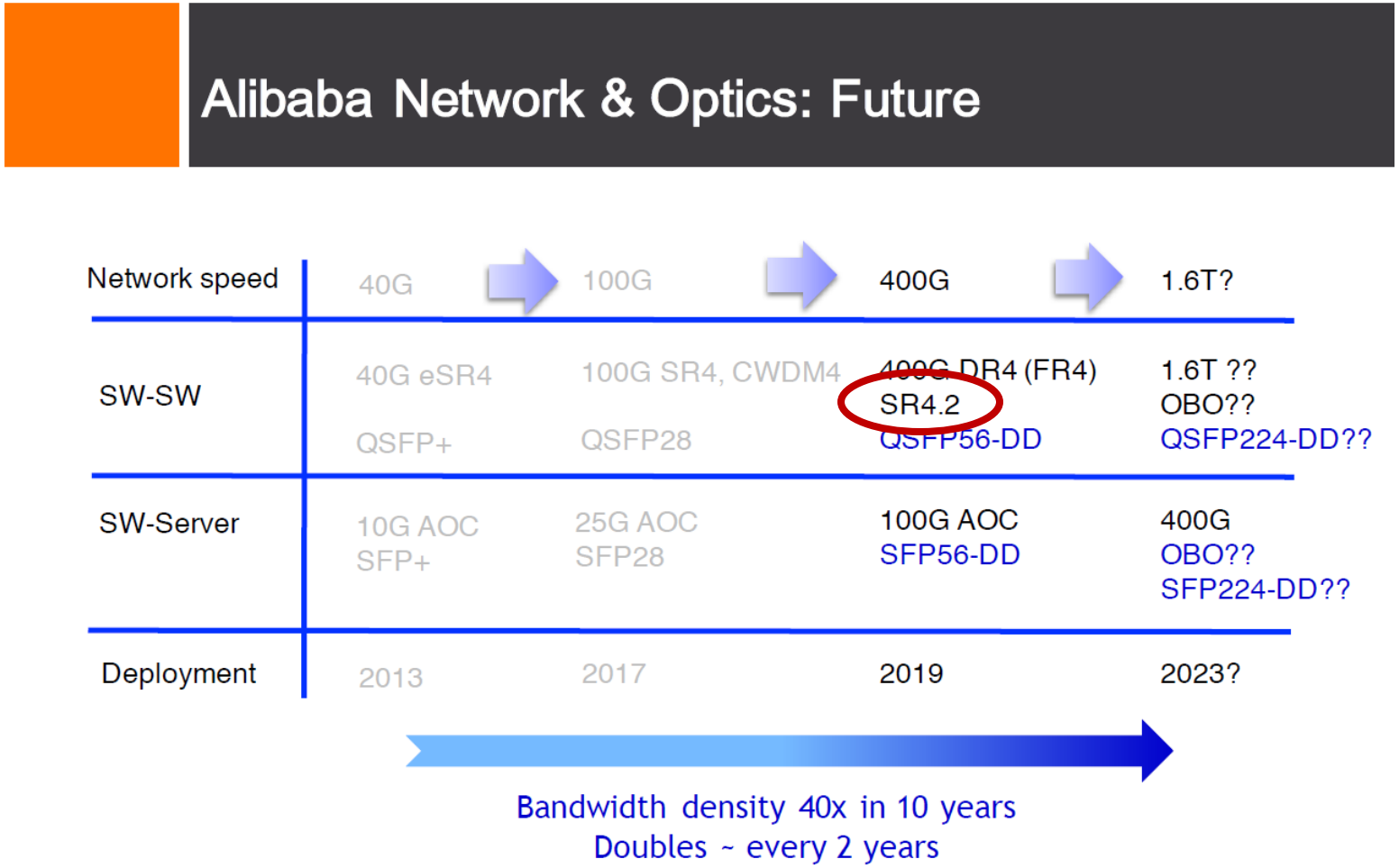
Existing or in-progress IEEE standard

Multi-Wavelength Nomenclature

SRm.n m = # fiber pairs n = # wavelengths

Use of SR4.2 over 4 pair MMF cable is anticipated for 400G

- 400GBASE-SR4.2 is on the Alibaba roadmap for 2019 and forward
- IEEE 802.3 should move quickly to define 400G SR4.2



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14

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Comments on a switch vendor's experience of demand relevant to 400GBASE-SR4.2, based on the consistent trend of reusing cable

- **There has been demand for 40G duplex MMF solutions (BI-DI and SWDM) from the earliest days of 40G to enable reuse of 10G MMF (duplex) cabling.**
- **Sold 100GBASE-SR4 into large enterprise DCs in 2016 as soon as switches with 100G ports became available.**
  - **Could have sold 100G duplex MMF solutions if available in 2016 also to enable reuse of 10G and 40G MMF duplex cabling.**
- **As switches with 400G ports become available, expect:**
  - **To see an immediate demand for 400G MMF solutions.**
  - **To see an immediate demand for a four-fiber pair 400G MMF solution that can reuse 40GBASE-SR4 and 100GBASE-SR4 cabling.**

The introduction of data center functionality into Service Provider central offices for NFV/SDN has created a new space for short reach interconnects in the ≤100m range

Central Office Floor

Datacom Gear Room

- **Datacom gear requires that room be upgraded for fire safety & cooling load**
- **Smaller size is friendly to <100m reach for standardized MMF links**
- **Deploying 40 & 100Gb/s MMF links now**
- **Higher speeds will follow in the future**

- **SMF often preferred in CO's in spite of higher link cost, since connections may be required between floors**
- **Telecom grade equipment allowed relaxed fire code rating and lower cooling load in traditional central offices**

400GBASE-SR4.2 is a better fit to the data center market than existing 400GBASE-SR16 and has Distinct Identity & Economic Feasibility

	400GBASE-SR16	400GBASE-SR4.2
Design Intent	400G with 25G SerDes; originally aimed at CDFP form factor, now CFP8	400G based on 50 Gb/s SerDes; fits into OSFP and QSFP-DD
Electrical Interface	Requires gearbox to operate with 400GAUI-8	Native to 400GAUI-8
Cabling Medium	Requires 16f pair cabling, not commonly available	Operates on commonly available 4f pair cabling, with one-fourth the pair count
Optical Connector	Atypical 32f MPO	Typical 12f MPO
Transceiver Form Factor	Incompatible with likely target form	Compatible with target forms
Cost Implications	Higher – more fibers, more ICs, low port availability	Lower – fewer fibers, fewer ICs, existing cabling

The cost factors for 400GBASE-SR4.2 are well known from industry experience in making parallel MMF modules & multi-wavelength MMF modules; 50 Gb/s PAM4 specifications are well-known from IEEEE 802.3cd

Conclusion & Recommendation

- We have demonstrated Broad Market Potential, Economic Feasibility, and Distinct Identity for 400GBASE-SR4.2, for applications in the cloud, large enterprise, and service provider space.

- Rapid progress towards 400 Gb/s in cloud data centers implies the need for rapid progress for a standard for 400GBASE-SR4.2

- Recommend the Study Group adopt as an objective:
  - "Provide not more than two physical layer specifications which support 400 Gb/s operation over fewer than 16 pairs of MMF with channel lengths up to at least 100 m."
  - [Note: this language would allow PMDs to be specified for four MMF pairs plus *one other* pair count, if the Study Group wishes to allow the Task Force that flexibility. If not, the objective could be collapsed to a single specification over four pairs]

Supporters

Back Up

Adding wavelengths & PAM4 to MMF modules preserves the historical cost & power advantage over SMF modules

- Tolerances for mux/demux are significantly more relaxed in the case of MMF than SMF
- More costly circuits are needed to implement PAM4 for both fiber types
- Reduction of laser RIN for PAM4 is not more difficult for VCSELs than for DFBs
- Packaging for VCSEL sources at 50Gb/s PAM4 is based on known technology, whereas packaging for 1310nm sources at 100 Gb/s per lane PAM4 has required significant development

from Nov 2017 CFI for Next-gen 200 & 400G MMF PHYs