In Support of 200G MMF Ethernet PMDs

Broad Market Potential
Economic Feasibility

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NGMMF Study Group
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Similar logic applies to 200G MMF as it did for SMF

200G-PSM4/DR4 Broad Market Potential

- Share of SMF is growing vs. MMF
- 100G-PSM4 Interconnects are a considerable volume compared to other 100G Ethernet reaches
- 200G-PSM4/DR4 fits well in a 40G-100G-400G evolution of PSM4 interconnects
- 200G-PSM4/DR4 may extend the lifespan of the QSFP from factor

In support of a 500m objective For 200G Ethernet

Welch, Palkert, Murray

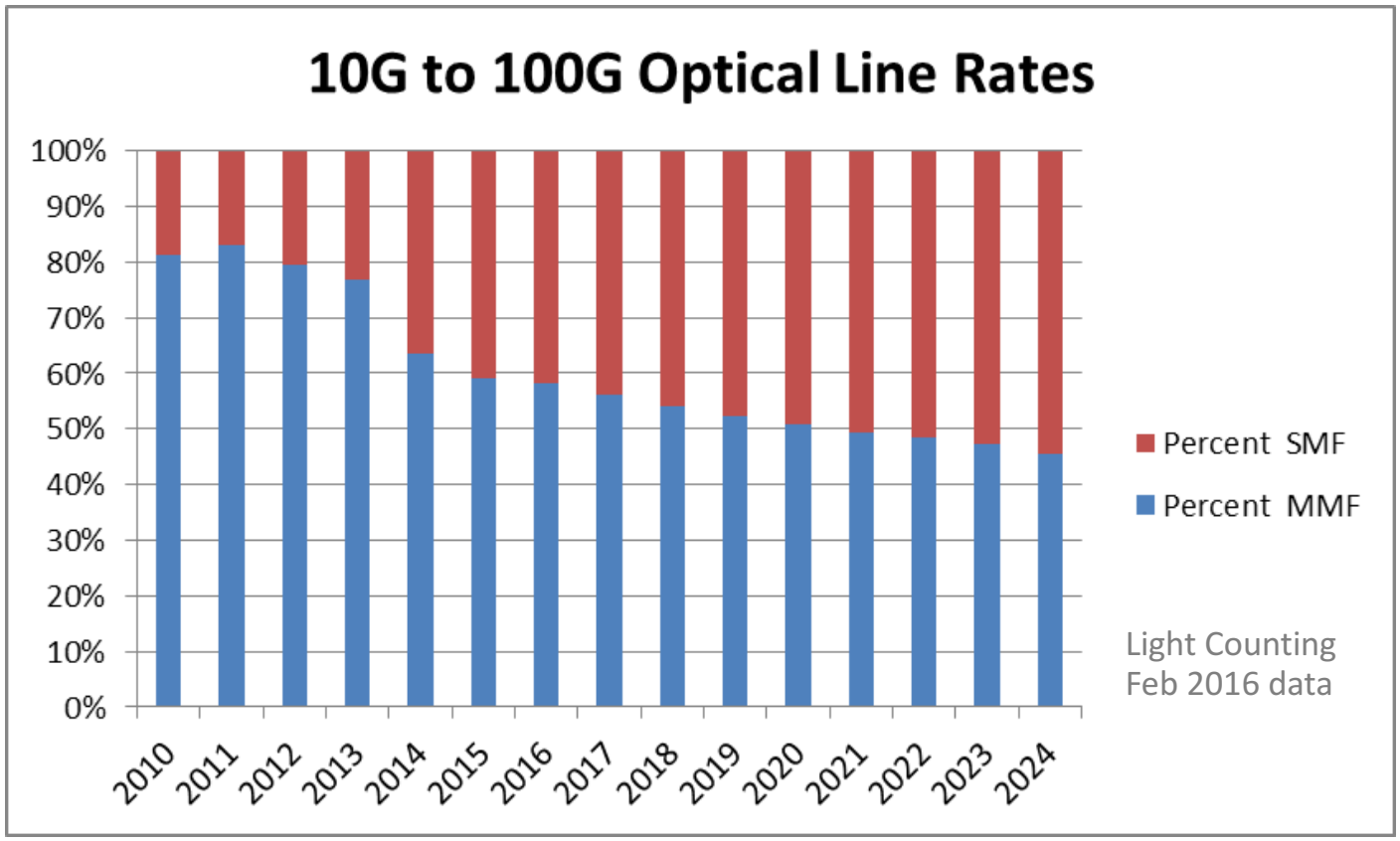
IEEE 50G NGOATH 3/2/2016

http://www.ieee802.org/3/50G/public/Mar16/welch_50GE_NGOATH_03b_0316.pdf

200G-SR1.n/? Broad Market Potential

- Multimode is a significant share of the market
- 40G Duplex (1-pair) links are a considerable and growing volume compared to other 40G solutions. 100G 1-pair links are expected to follow.
  - Extends the primarily Duplex enterprise topology
  - Offers cost advantage
- 200G-SR1.n fits well in the enterprise 40G-100G evolution of duplex switch interconnects, naturally following the server speed evolution from 10G to 25G and 50G
- Potentially provide server connectivity (multi-server chassis), well before individual servers reach 200G

MMF remains a large market through 2024



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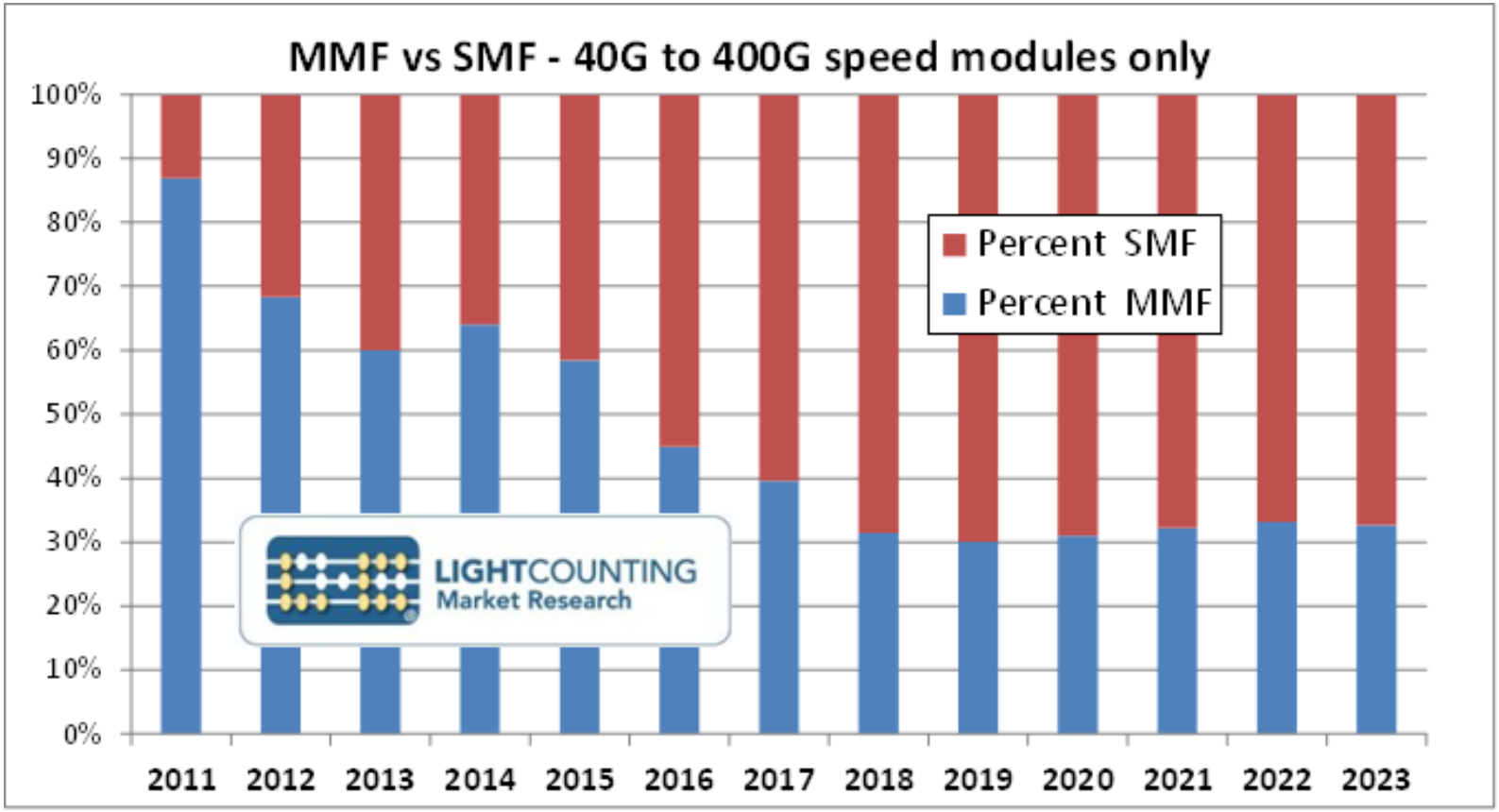
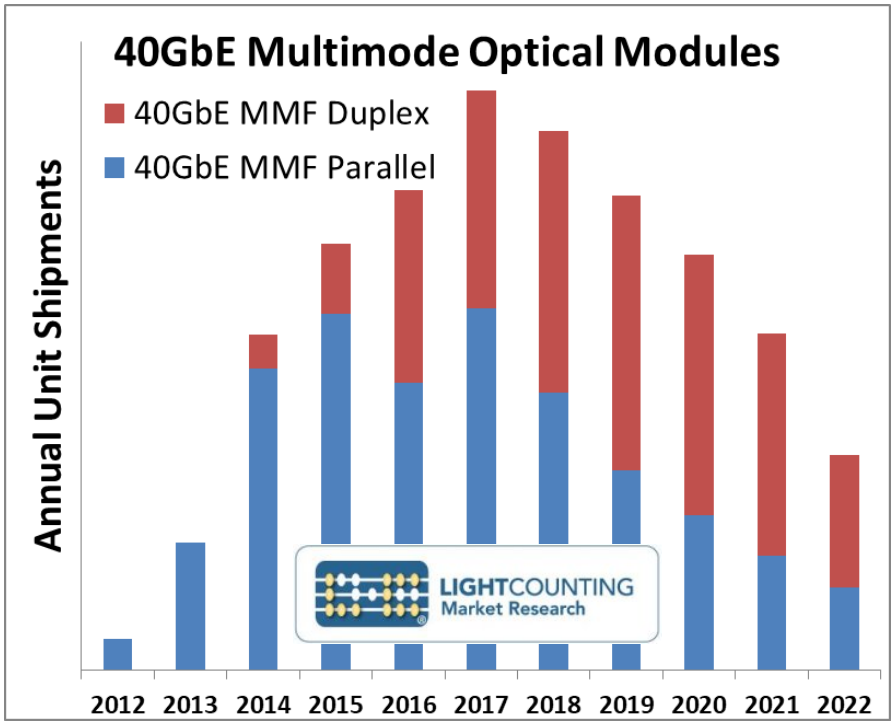
Higher Speed MMF share outlook



- Enterprise markets
- POD topologies
- Reach increasing

Data from LightCounting

Broad Market Potential for MMF Duplex



- Until 40GbE, all multimode Ethernet modules were duplex
- SR4 configuration helped launch the 40GbE market
- Duplex MMF still a desired solution, quickly reaching 38% of the 40GbE MMF market in 2017

LIGHTCOUNTING Market Research

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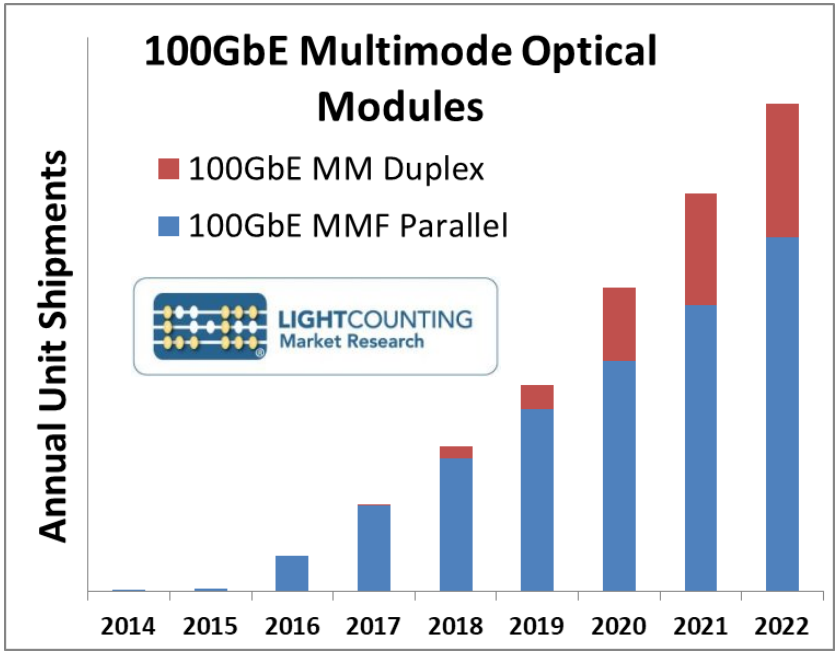
Broad Market Potential for MMF Duplex



At 100GbE:

- SR4 configuration again helped launch the market
  - SR10 never widely deployed
- Duplex MMF still a desired solution
  - Projecting a 27% share of the 100GbE MMF market by 2022

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MMF Duplex for Next-Gen Speeds

- Parallel and Duplex MMF modules serve essentially two different but complimentary markets
- LightCounting has documented solid success of MMF Duplex at 40GbE
- LightCounting is forecasting similar success for MMF Duplex at 100GbE
- There is no reason to believe this won't repeat at 200GbE, or even 400GbE
  - It would be a more difficult case to argue the duplex market will go away at faster speeds.

40G/100G Applications Multimode Fiber

Maximum reach based on Standards, MSAs and/or vendor specifications

	Standard	# fibers	maximum distance
40G	**40GBASE-SR4**	**(8)**	OM3 100 m OM4/OM5 150 m
	40G-BiDi	(2)	OM3 100 m OM4 150 m OM5 200 m
	40GBASE-eSR4	(8)	OM3 300 m OM4/OM5 400 m
	40G-SWDM4	(2)	OM3 240 m OM4 350 m OM5 440 m
100G	**100GBASE-SR4**	**(8)**	OM3 70 m OM4/OM5 100 m
	100GBASE-SR10	**(20)**	OM3 100 m OM4/OM5 150 m
	100GBASE-eSR4	(8)	OM3 200 m OM4/OM5 300 m
	100G-SWDM4	(2)	OM3 75 m OM4 100 m OM5 150 m eSWDM additional reach

Bold = standardized; regular = extended reach (super standard); green = WDM

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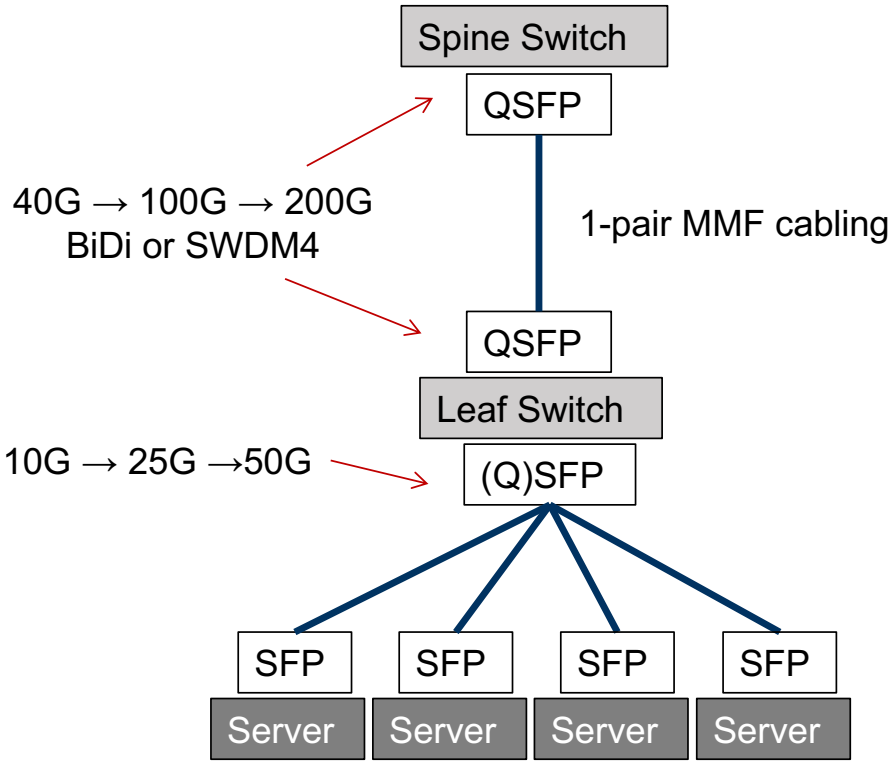
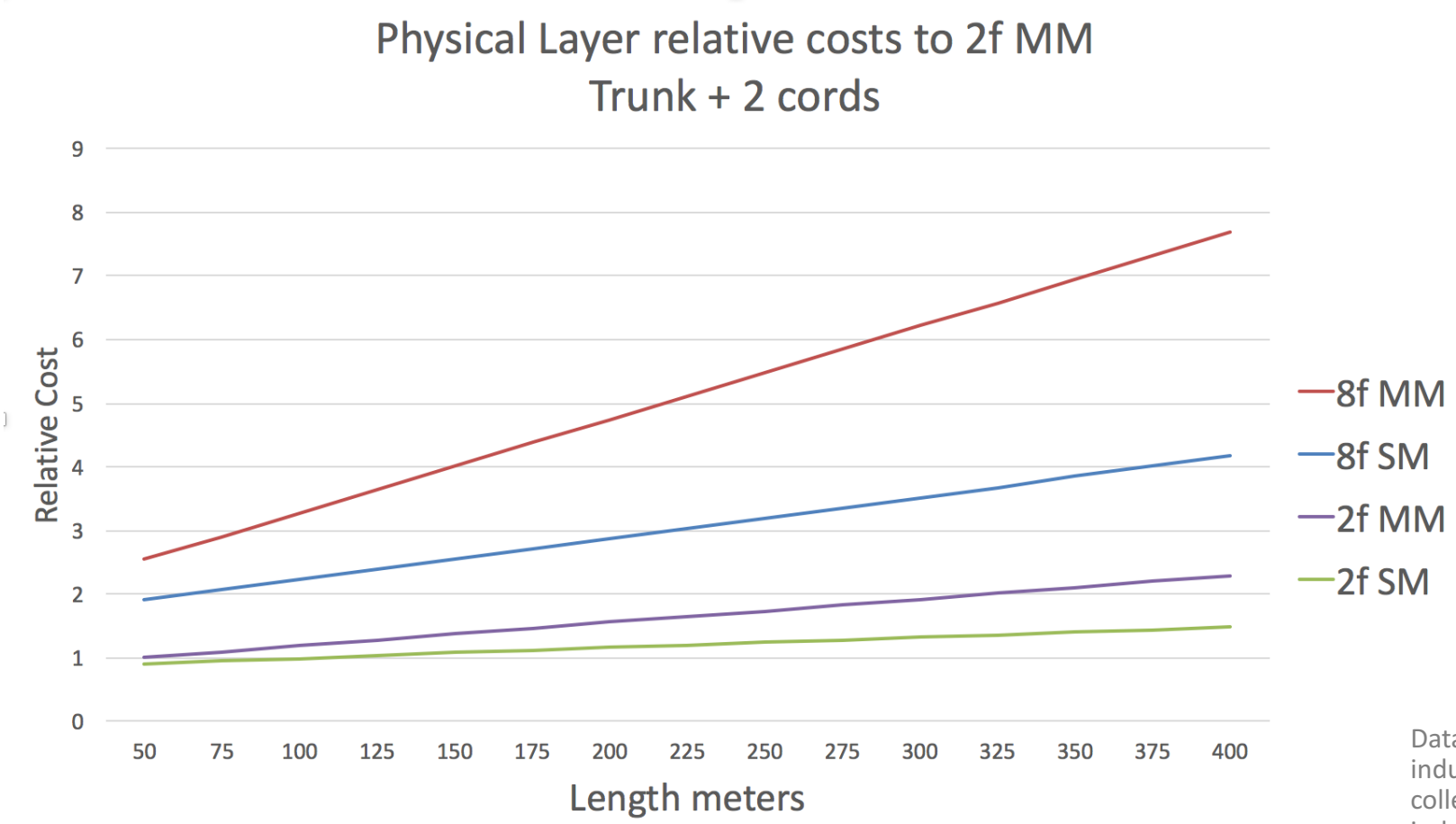
Enterprise Evolution



Generation	Server Rate	Up-link Rate
1	10G	40G->100G
2	25G	200G
3	50G	400G

- Large Enterprise L-S switch links migrating from 10G Duplex (port groups)
- MMF cabling infrastructure can serve at least three generations using 1-pair connectivity
- Server speeds will increase in the shorter term, 200G will help maintain contention ratios
- Continuing 1-pair infrastructure lowers the cost of upgrade – stated preference of several Enterprise operators

Physical Layer cost relationship



Data source – industry interviews, colleagues and industry experts

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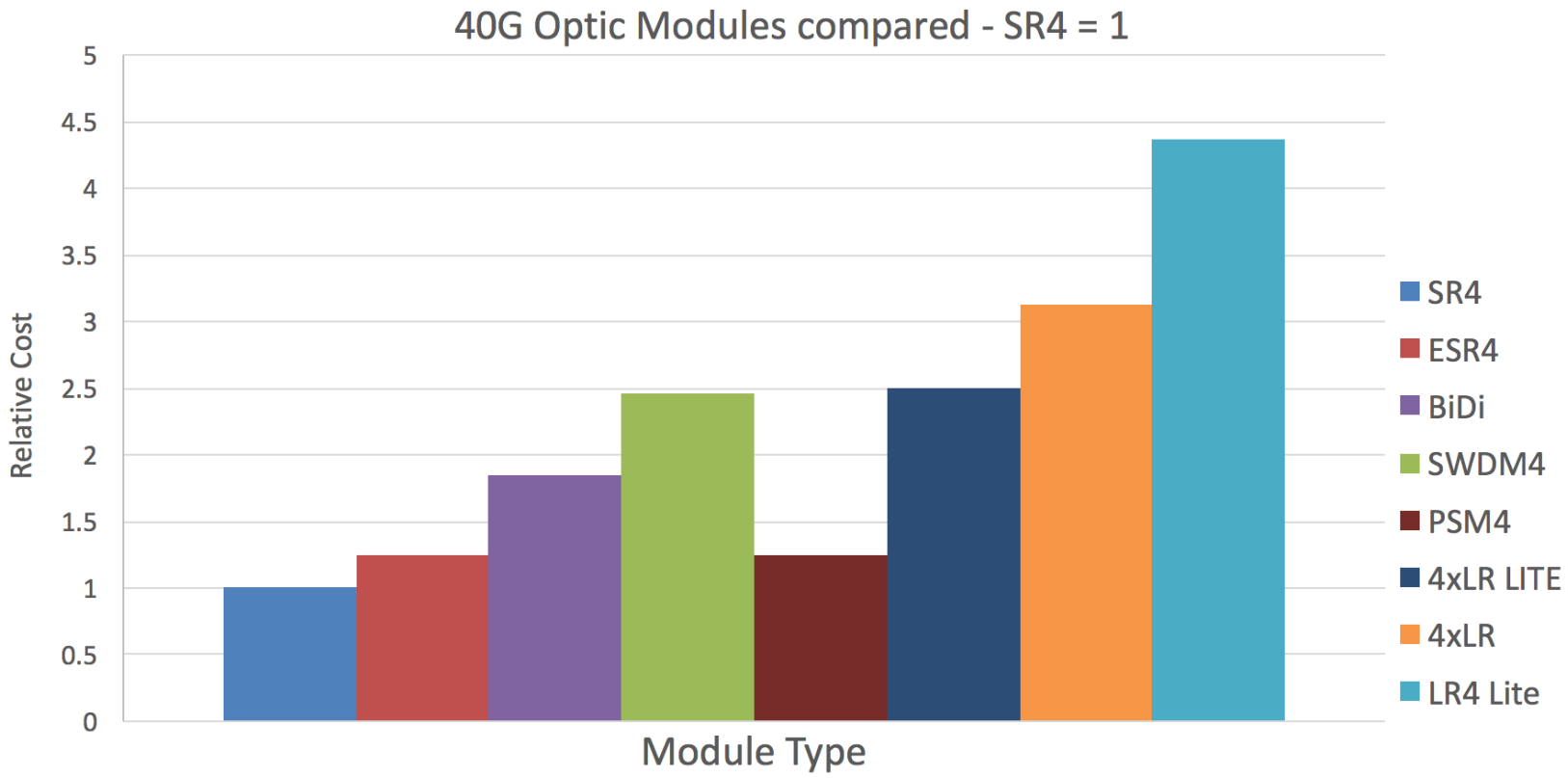
40G optic modules cost comparison

- Large volume market customer reports late 2017



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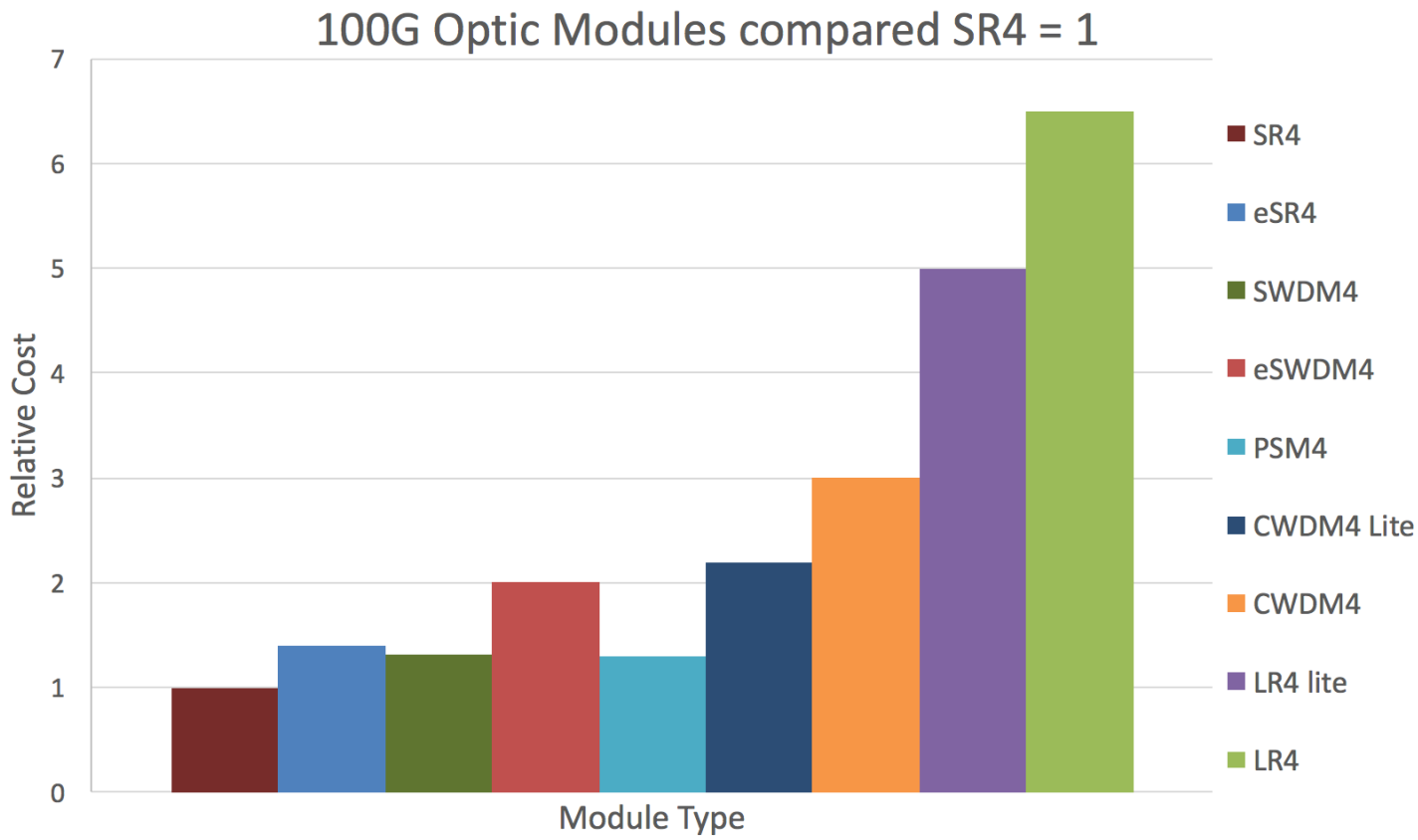
100G Optic Module cost comparison

- Large volume market customer reports late 2017



Data source – industry interviews, colleagues and industry experts

NG 200G & 400G PHYs over fewer MMF Pairs Study Group Jan 22, 2018

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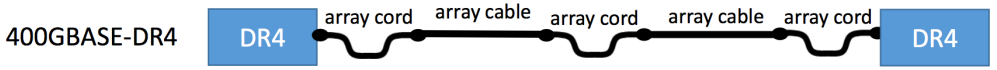
Short Reach link model examples

- Channel structures may require two or more concatenated links
- TRx : Passive component cost ratio has changed
  - Primarily TRx has decreased
- more connectivity = higher cable costs
  - one cable link shows lowest

  TRx : Cable cost ratio

400GBASE-DR4 Reference



500m Double link with 4 MPO connectors

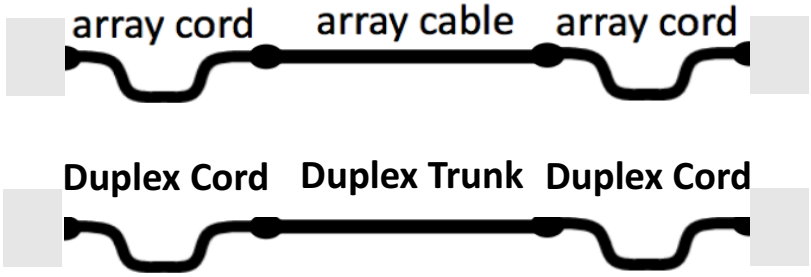
Connector Losses = 2.65 dB,
Fiber loss = 0.25dB,

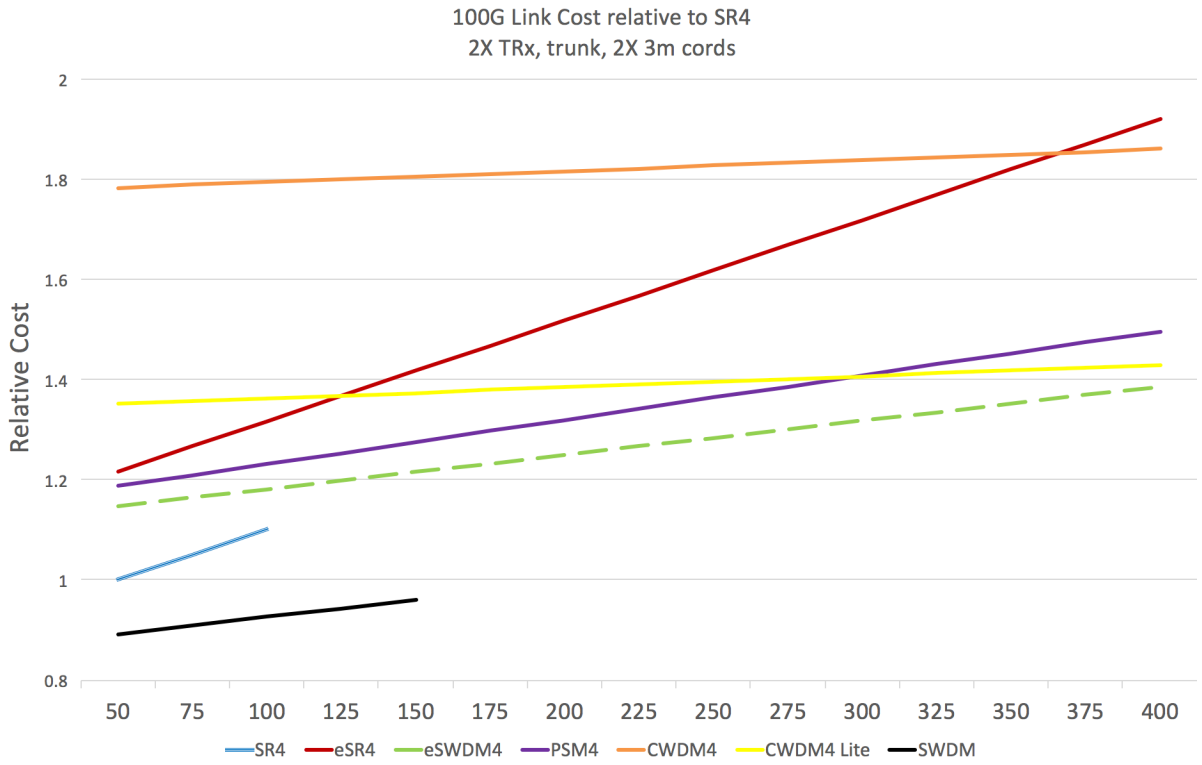
-> Link Loss = 2.9 dB (rounded to 3 dB)

http://www.ieee802.org/3/cd/public/Nov16/traverso_3cd_01_1116.pdf

Relative link costs for 100G Applications

- Link cost includes 2X Transceivers 1 Trunk, 2 Cords and 2f or 8f
- Parallel:Duplex Connector costs 1.7 – 2.1X
- MM:SM per fiber meter 2.3-3.1





eSWDM4– est. reach target announced

Data source – industry interviews, colleagues and industry experts

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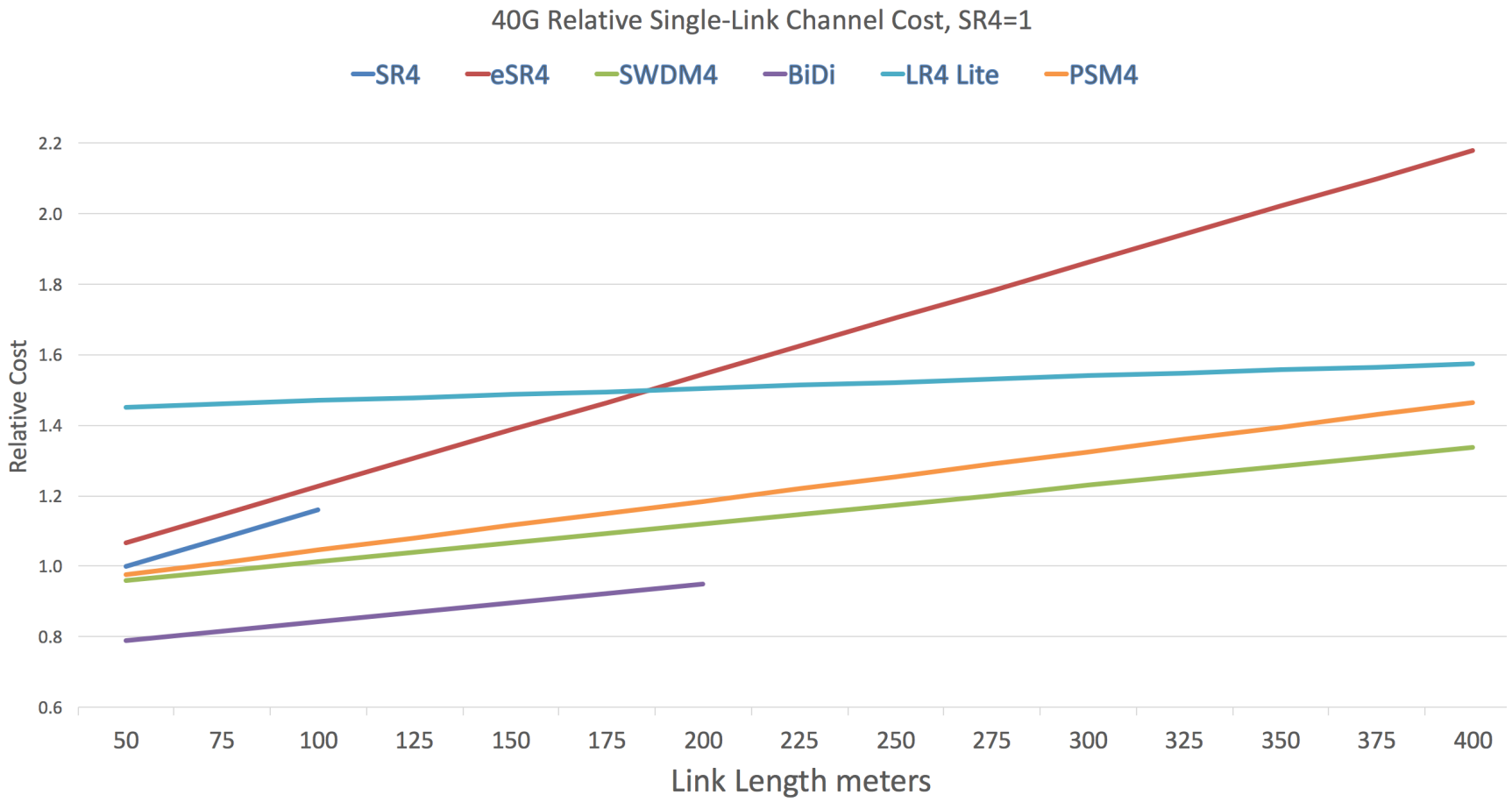
Relative link costs for 40G Applications



Data source – industry interviews, colleagues and industry experts

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Conclusions

- Deployment of 200G should fit well between 100G and 400G in the enterprise
  - Approximately 2 year cadence from 40G to 100G, 3-4 years for 100G to 400G (50G ad hoc)
  - 200G 1.n could extend the lifespan of QSFP and enable a common port type
- 40G MMF duplex quickly adopted
  - SR1.n modules produced increased reach and/or decreased cost
- LIGHTCOUNTING forecast predicts a similar adoption for 100G MMF duplex
- Physical infrastructure is now a significant component of data link costs
  - Duplex cabling would provide a cost advantage for 200G MMF links
- 40G and 100G data links are competitive with short reach SM data links for data center applications
  - Supportive of long term MMF market share in data centers