Interconnect Beyond 50Gb/s Panel
- Full Optical Interconnect

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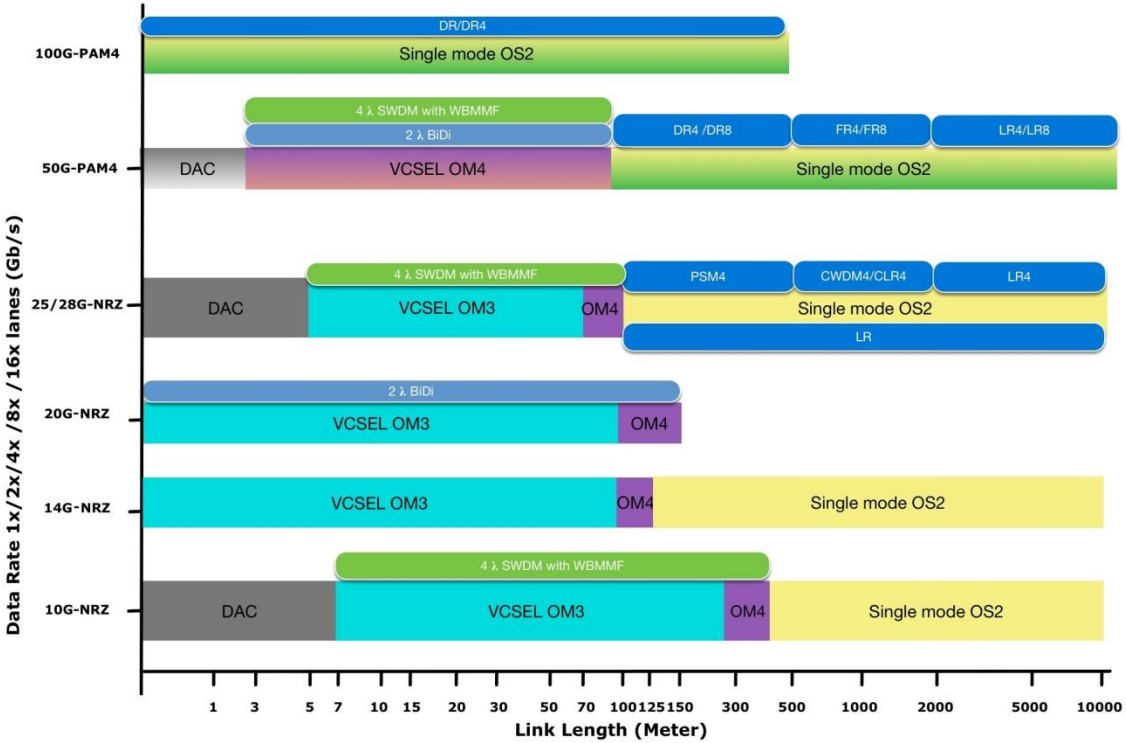
System Interconnect Speed & Media



High speed migration challenges

- Power efficiency (pj/bit or mW/Gb/s)
- Port density (Gb/s/mm^2)
- Reach (M or KM)
- Cost efficiency ($/Gb/s)
- Sustainability (infrastructure reusability)
- Product availability (Standards, multiple vendors)
- System scalability (pay-as-you-go)
- System resilience (failure tolerance/recovery)

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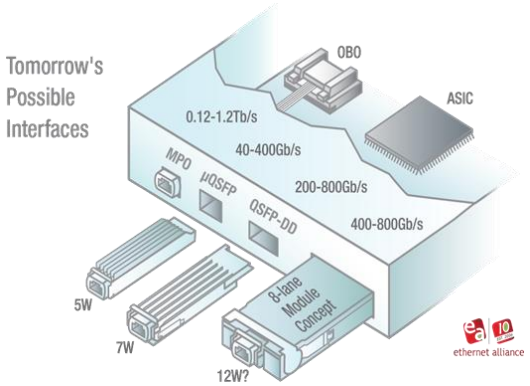
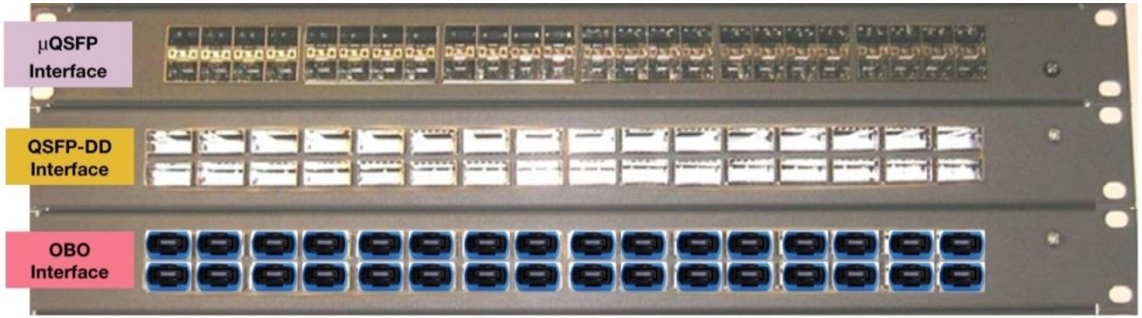
Merchant Switch ASIC Evolution & Emerging Interfaces

- Beyond 50G
  - New applications
  - New interfaces
  - More diversified form factors and speeds
  - New system architectures

Switch ASIC	Lane speed	Number of lanes	Number of Ports						Year Standard
			10Gb/s SFP+	25Gb/s SFP28	40G/s QSFP+	100G/s QSFP28	200G/s QSFP56 µQSFP	400G/s QSFP-DD OBO	
640Gb/s	10Gb/s	64	48		4				2010
			40		6				
					16				
1.28Tb/s	10Gb/s	128			32				2013
3.2Tb/s	25Gb/s	128		112		4			2015
						32			
4.8Tb/s	25Gb/s	192				48			2016
6.4Tb/s	25/50Gb/s	256/128					32		2017/2018
9.6Tb/s	50Gb/s	192					48		2018
12.8Tb/s	50/100Gb/s	256/128						32	2020





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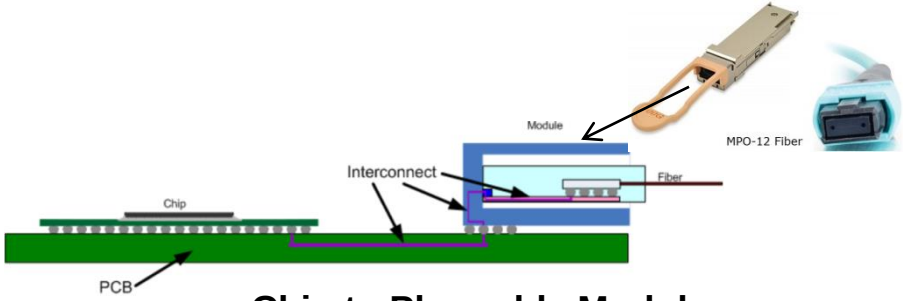
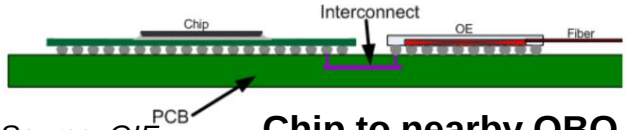
All Optical Interconnect & Data Center Architecture

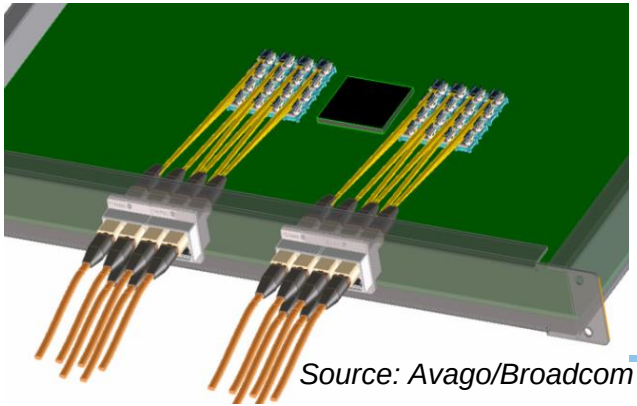


Chip to Pluggable Module

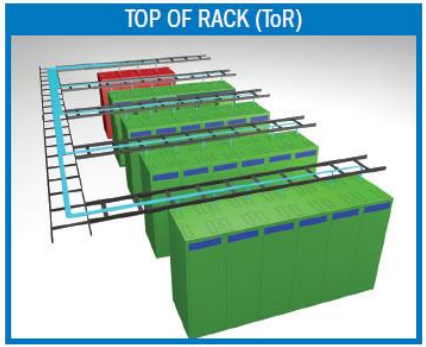


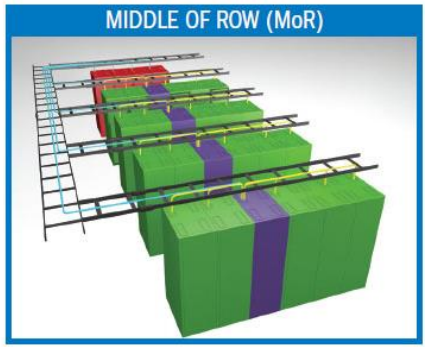
Chip to nearby OBO

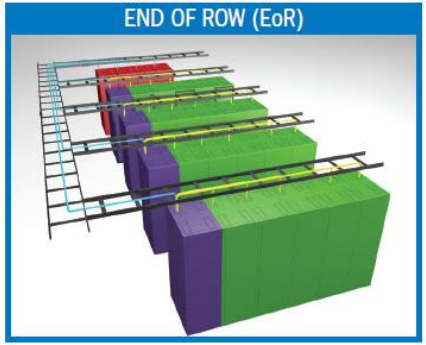
Source: OIF

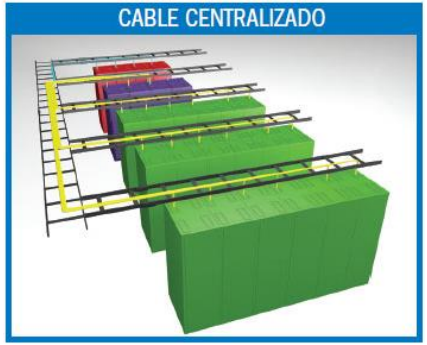


Source: Avago/Broadcom





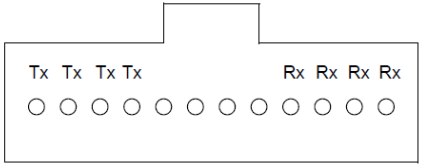




Source: Anixter

Improved Fiber Performance and Interfaces

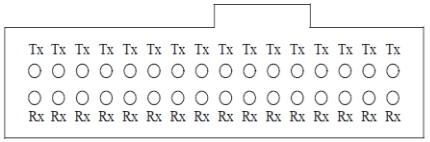
Wide Band MMF		OS2
Reduce fiber footprint for 100G and 400G	?	Longer reach (0.5km, 2km, 10km, 30/40km)
Lower cabling cost (SWDM)		Lower transceiver cost (PSM, CWDM)
4 λ per fiber, 50G-PAM4 per λ		Greater future potential ≥ 32 λ per fiber DWDM 50G-PAM4, 100G-PAM4 per λ



MPO-12

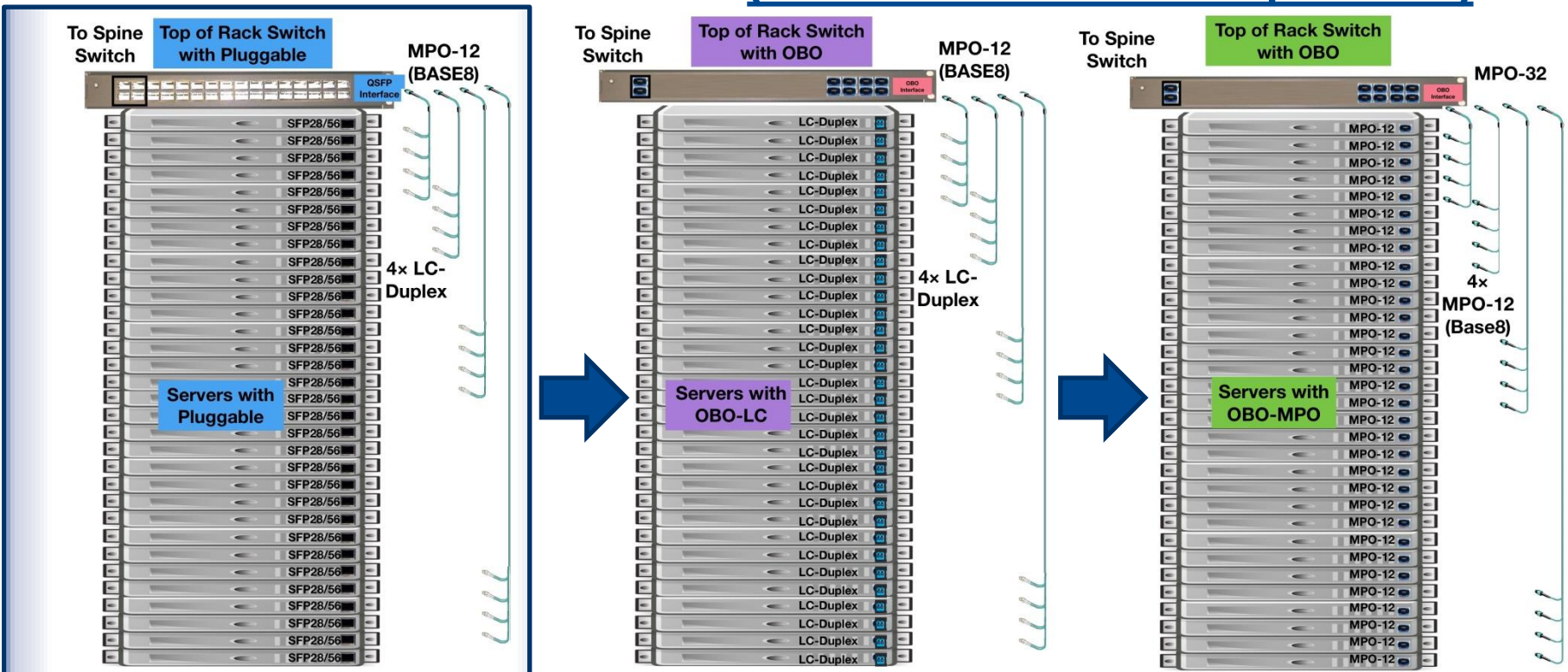
?

MPO-32



Better aligns with 200G/400G and beyond

ToR Server Rack with OBO (25G NRZ or 50G PAM4 per Lane)



Server I/O 25G to 50G (1-λ)
Switch I/O up to 200G, total BW 6.4T
25G/50G per fiber with 1- λ

Server I/O 25G to 200G (4-λ)
Switch I/O up to 800G, total BW 6.4T
25G/50G per fiber with 1-λ
100G/200G per fiber with 4-λ

Server I/O 100G to 800G (4-λ)
Switch I/O up to 3.2T, total BW 25.6T
25G/50G per fiber with 1-λ
100G/200G per fiber with 4-λ

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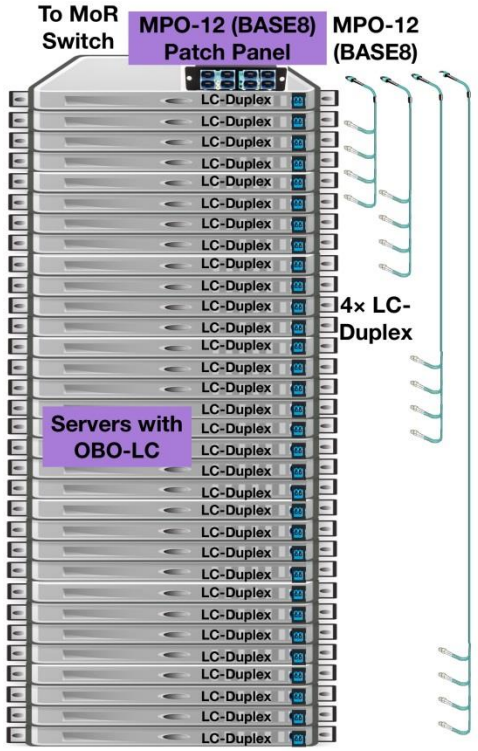
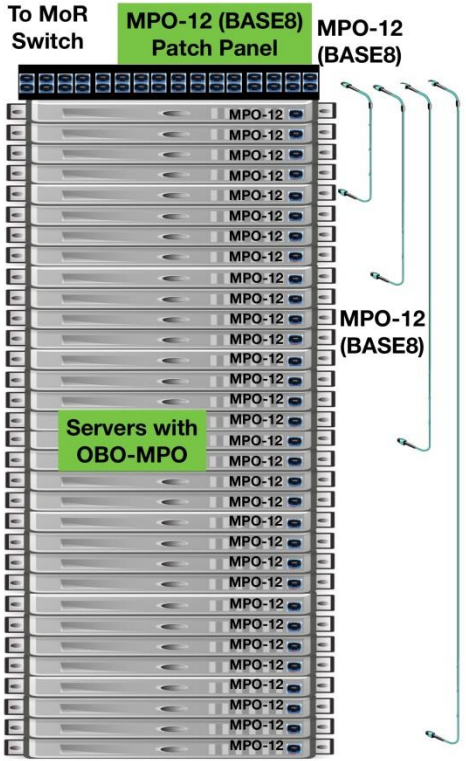
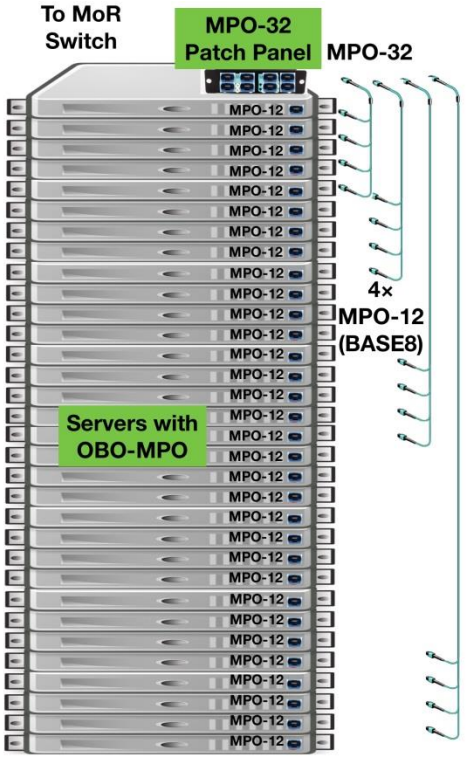
MoR Server Rack with OBO (25G NRZ or 50G PAM4 per Lane)



Server I/O 25G to 200G (4-λ)
32× 1RU server total BW 0.8T to 6.4T
25G/50G per fiber with 1-λ
100G/200G per fiber with 4-λ

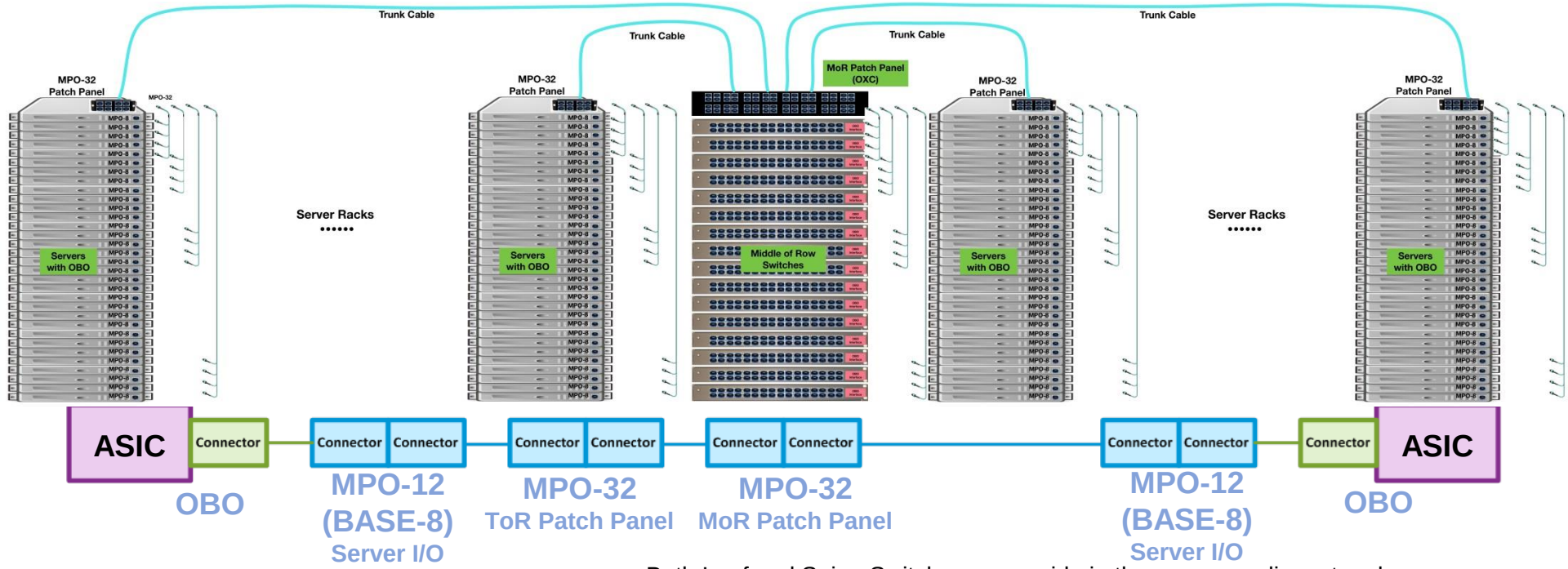


Server I/O 100G to 800G (4-λ)
32× 1RU server total BW 3.2T to 25.6T
25G/50G per fiber with 1-λ
100G/200G per fiber with 4-λ



Server I/O 100G to 800G (4-λ)
32× 1RU server total BW 3.2T to 25.6T
25G/50G per fiber with 1-λ
100G/200G per fiber with 4-λ

MoR Server-Switch (Leaf & Spine)



- Middle-of-Row makes more sense for high density

- Both Leaf and Spine Switches can reside in the same or adjacent racks
- All optical interfaces (single-λ, SWDM/CWDM, SMF/MMF)
- Switch ASIC BW up to 25.6T (32× MPO-12), up to ~102.4T (32× MPO-32)
- 4-Point connection, or up to 6-Point connection if use ZDA, cross-connect

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Standard & Best In Class Optical Fiber Interfaces

Current Standard

Fiber Type	Fiber Cable loss	MPO-12 Max IL (dB/Mated Pair)	LC Max IL (dB/Mated Pair)
OM3	3.5dB/km	0.50 dB	0.25 dB
OM4/ WBMMF	3.5dB/km	0.50 dB	0.25 dB
OS2	0.5dB/km	0.75 dB	0.35 dB

- Complex and costly using physical contact MPO-32
- Non-contact more suitable for multi-row connector (expended beam/lensed), but IL ~1.2-1.5dB

Best In Class

Fiber Type	Fiber Cable loss	MPO-12 Max IL (dB/Mated Pair)	LC Max IL (dB/Mated Pair)
OM3	3dB/km	0.35 dB	0.25 dB
OM4/ WBMMF	3dB/km	0.20 dB	0.15 dB
OS2	0.4dB/km	0.35 dB	0.15 dB

- Need considerable efforts and improvement for multi-row connector

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OBO ToR VS MoR

Top of Rack Architecture

OBO types	Interconnects	# Total Connection		Connection Loss	
		# MPO	#LC	Min IL	Max IL
single λ VCSEL	SE-Leaf SW	2	-	0.4dB	1.0dB
	Leaf-Spine SW	4	-	0.8dB	2.0dB
	SW-Core SW	4 to 6	-	0.8-1.2dB	2.0-3.0dB
multi-λ VCSEL	SE-Leaf SW	1	1	0.35dB	0.75dB
	Leaf-Spine SW	4	-	0.8dB	2.0dB
	SW-Core SW	4 to 6	-	0.8-1.2dB	2.0-3.0dB
single λ PSM	SE-Leaf SW	2	-	0.7dB	1.5dB
	Leaf-Spine SW	4	-	1.4dB	3.0dB
	SW-Core SW	4 to 6	-	1.4-2.1dB	3-4.5dB
single λ CWDM	SE-Leaf SW	1	1	0.5dB	1.1dB
	Leaf-Spine SW	4	-	1.4dB	3dB
	SW-Core SW	4 to 6	-	1.4-2.1dB	3-4.5dB

Midde of Row Architecture

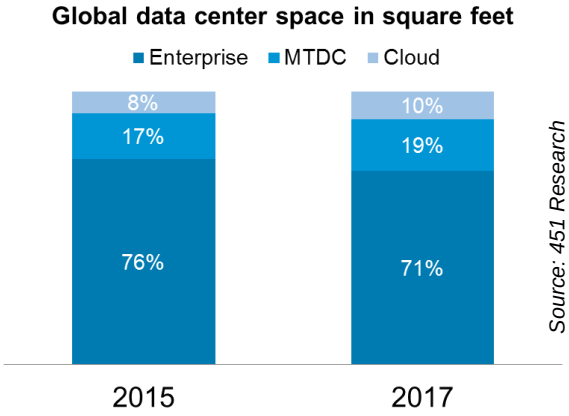
OBO types	Interconnects	# Total Connection		Connection Loss	
		# MPO	#LC	Min IL	Max IL
single λ VCSEL	SE-Leaf SW	4	-	0.8dB	2.0dB
	Leaf-Spine SW	2	-	0.4dB	1.0dB
	SW-Core SW	4 to 6	-	0.8-1.2dB	2.0-3.0dB
multi-λ VCSEL	SE-Leaf SW	3	1	0.75dB	1.75dB
	Leaf-Spine SW	2	-	0.4dB	1.0dB
	SW-Core SW	4 to 6	-	0.8-1.2dB	2.0-3.0dB
single λ PSM	SE-Leaf SW	4	-	1.4dB	3.0dB
	Leaf-Spine SW	2	-	0.7dB	1.5dB
	SW-Core SW	4 to 6	-	1.4-2.1dB	3-4.5dB
single λ CWDM	SE-Leaf SW	3	1	1.2dB	2.6dB
	Leaf-Spine SW	2	-	0.7dB	1.5dB
	SW-Core SW	4 to 6	-	1.4-2.1dB	3-4.5dB

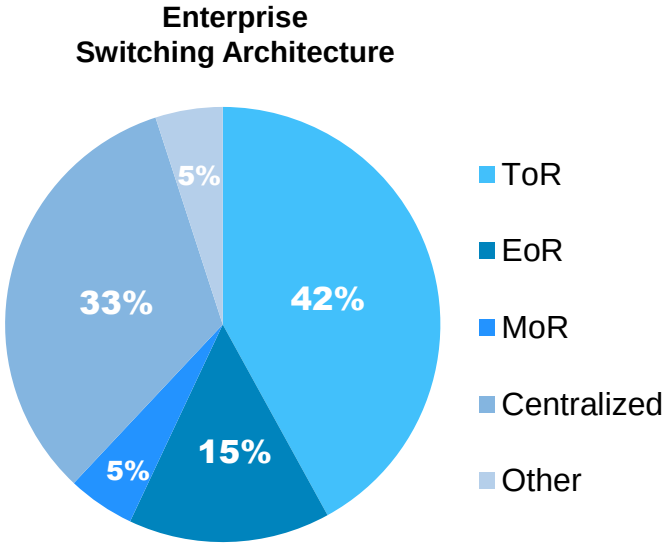
- Server optical I/O:
  - MPO-12 for single-λ, LC-Duplex for multi-λ
- Switch: MPO-12 or MPO-32 ?
- Patch Panel: MPO-12 or MPO-32 ?

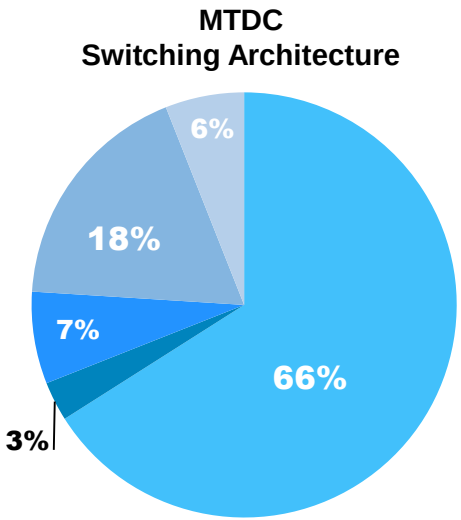
?

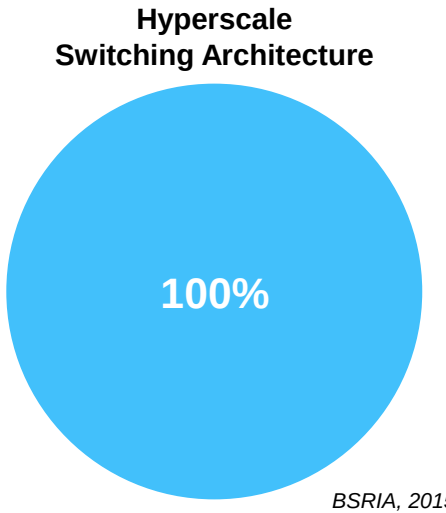
- Link Budget Must be Met with <u>reasonable cost</u>
- MoR and ToR are suitable for different architectures
- OXC and OCS in the MoR ?
  - 2-3dB additional insertion loss

Data Center Architecture
Switch to Server Links









BSRIA, 2015

Conclusions

- New HD optical interfaces will support ASIC with growing BW
- MMF/SMF both have sweet spots
  - Parallel for breakout configuration, SWDM/CWDM for aggregation
- On-board optics will eventually take over for speed >50G
  - With new design consideration, and industrial standards
  - Middle-of-row may become attractive again
  - Data center architecture will be more diversified
  - New opportunity for OCS
  - Cabling and connectivity performance/cost are also critical