A Fork in the Road

OM5 vs. Single-Mode in the Data Center

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Outline

- Definition of Enterprise and Cloud Data Centers
- The Growth of Cloud Computing
- Market forecast for 25G/50G/100G/200G/400G Ethernet
- Trends with Multimode vs. Single-mode Optics
- Use case: 40G for Enterprise data centers
- Use case: 100G+ for Cloud data centers
- What about OM5?

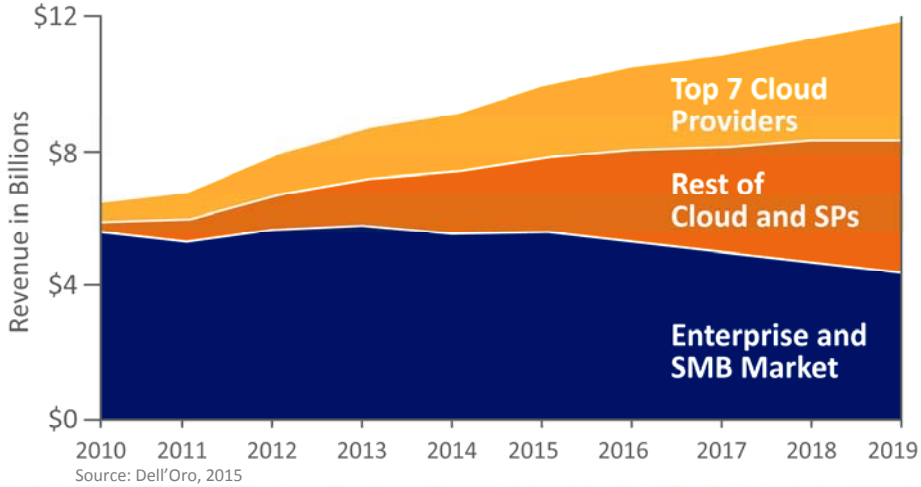
Enterprise vs. Cloud Data Centers

Major Characteristics of Data Centers

	SMB	Large Enterprise	Cloud
Number or Servers	<500	10,000	>100,000
Number Of Customers	>1,000,000	<5,000	<100
Number of Top-of-Rack / Leaf Switches	<25	<500	>2,000
Number of Spine / Aggregation Switches	1-2	<25	>100
Number of Core Switches	N/A	<12	>12
Deal Size	<$100,000	<$5,000,000	>$20,000,000
Ethernet Switch Vendor Margin	>60%	>50%	<25%

Total Ethernet Switch

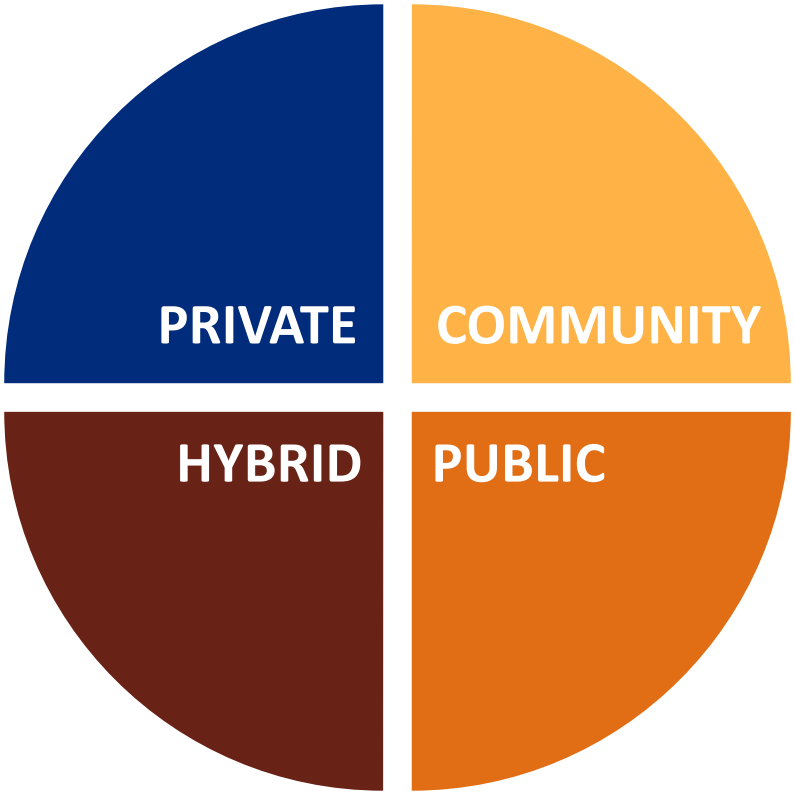
Data Center Revenue



Source: Dell'Oro, 2015

Used for a single organization.

Can be externally or internally hosted.



Shared by several organizations.

Typically externally hosted.

Two or more clouds bound together.

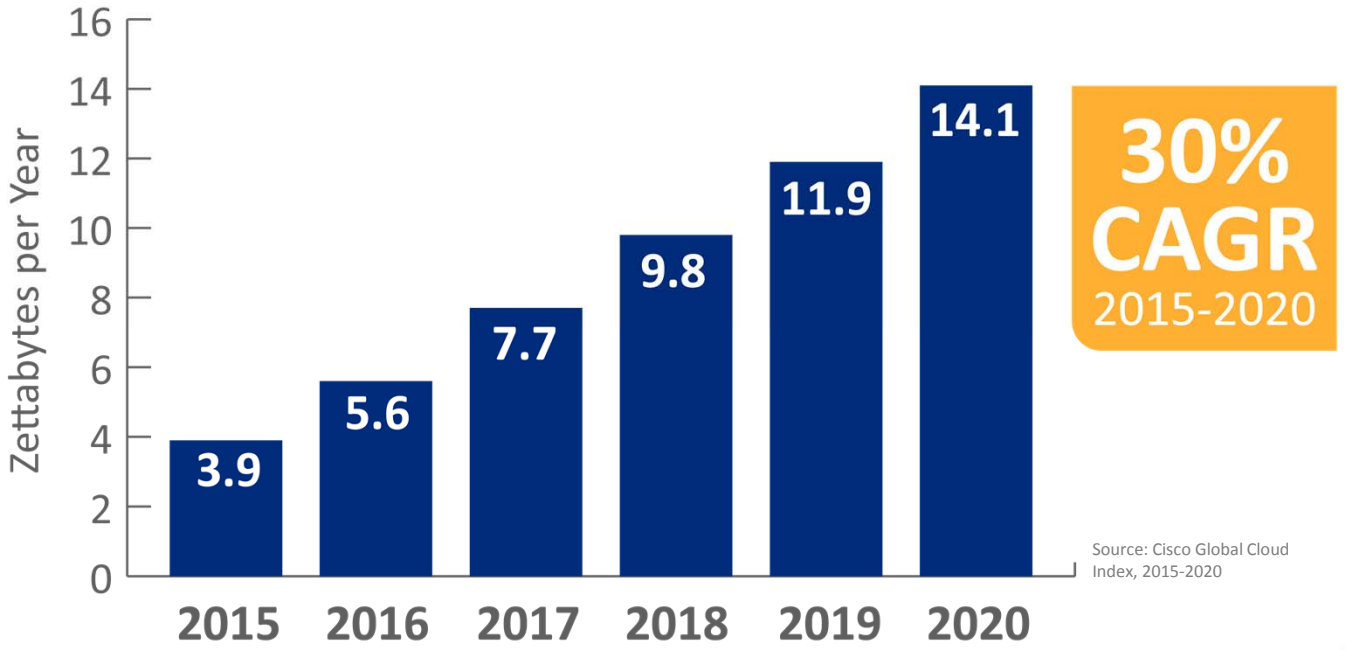
Usually part internally and part externally hosted.

Provisioned for open use by the hosting company which operates the data centers.

Global Cloud Traffic Growth

Cloud Traffic
Will Grow 3.7-Fold
from 2015 to 2020

Cloud Accounts for
92% of Traffic by 2020
up from 82% in 2015



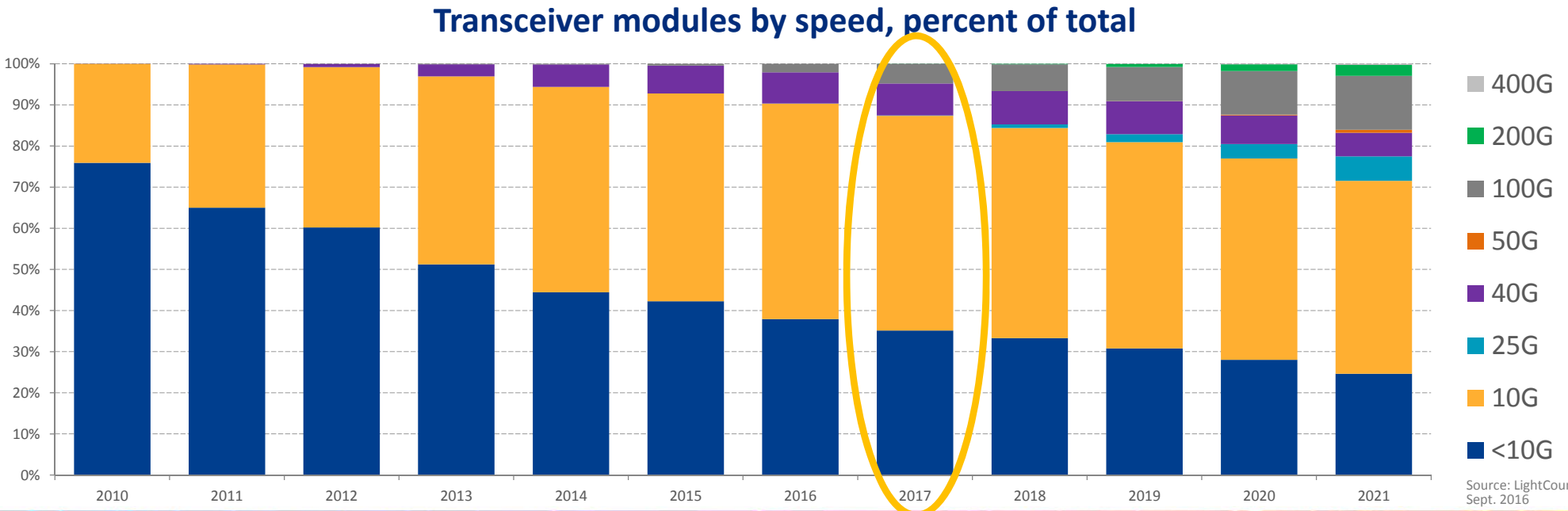
Source: Cisco Global Cloud Index, 2015-2020

Trends in the Data Center

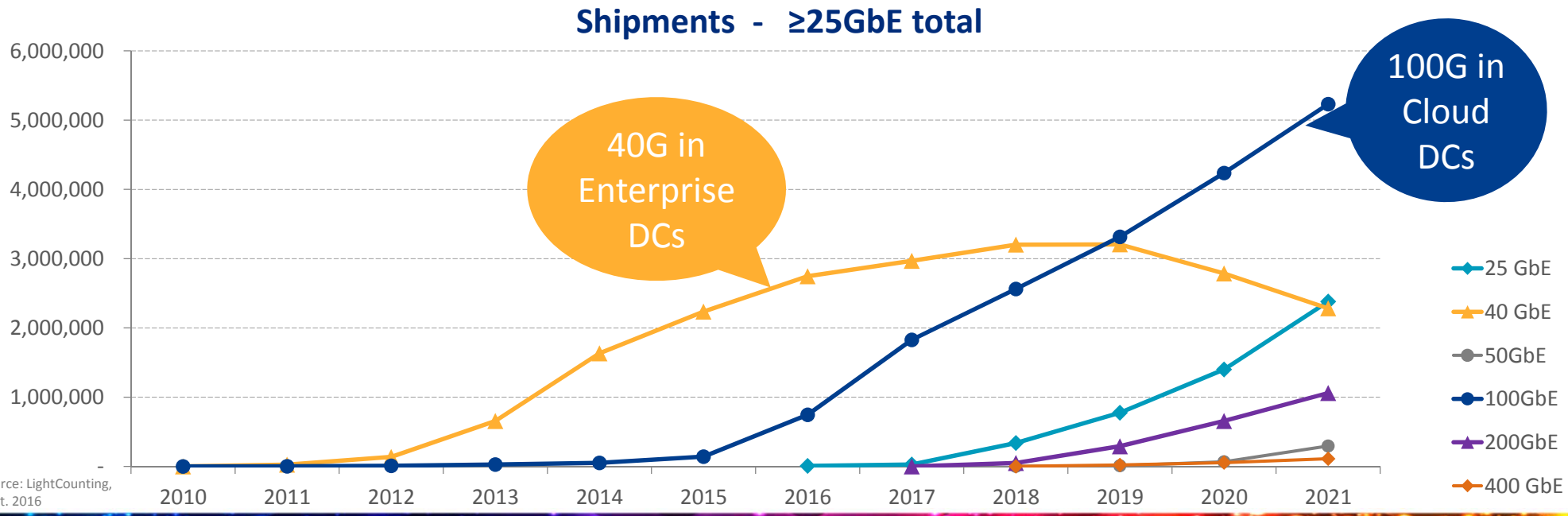
- Many traditional enterprise data centers are moving to the cloud
- Flatter network designs…3-tier to Leaf-Spine
- Data Centers are getting larger
- More companies are outsourcing to co-location providers
- Creation of a new 25Gb/s ecosystem
- New cost-effective 100G switches

The Need for Speed

Ethernet Speed Market Forecast



Dramatic Growth of 100G Expected…



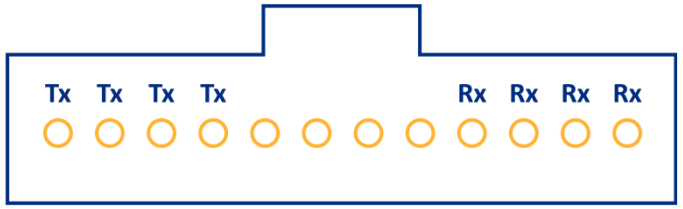
Source: LightCounting, Sept. 2016

25 Gb/s Lanes vs. 10Gb/s Lanes

- **The IEEE802.3ba standard, published in June 2010 defined 10Gb/s lanes for 40G & 100G transmission**
- **On April 29 2015, IEEE published the new IEEE802.3bm standard**
- **Primary objectives of standard**
  - Reduce cost of 100Gb/s
  - Reducing power requirements
  - Reduce # of lanes required

- **The standard defines 100G-SR4**
  - Uses 4 x 25Gb/s lanes in each direction
  - MTP connector with 8-fibers is required
  - Same requirements as 40G-SR4

IEEE Std 802.3bm-2015
Amendment 3 to IEEE Std 802.3-2012: Ethernet



100GBASE-SR4 Optical Lane Assignments

25G Lane Ecosystem is starting…

with 100G/200G & 400G

- **1st phase will likely use 25G down to server + 100G Uplinks**
- **75% of 100G options will utilize MPO connectors with 4 or 8 fibers**
- **Very little adoption of SR16 expected…no need for OM5**
- **Majority of options use single-mode**

Rate	Fiber Type	# fibers	Connector	Reach	IEEE Std	Est. Release
100GBASE-SR4	OM4	8	MPO	70m	802.3bm	Apr-15
100GBASE-SR2	OM4	4	MPO	100m	802.3cd	Sep-18
100GBASE-DR2	OS2	4	MPO	500m	802.3cd	Sep-18
100GBASE-FR2	OS2	2	LC	2km	802.3cd	Sep-18
200GBASE-DR4	OS2	8	MPO	500m	802.3bs	Dec-17
200GBASE-FR4	OS2	2	LC	2km	802.3bs	Dec-17
400GBASE-SR16	OM4 / OM5	32	MPO	100m	802.3bs	Dec-17
400GBASE-FR8	OS2	2	LC	2km	802.3bs	Dec-17

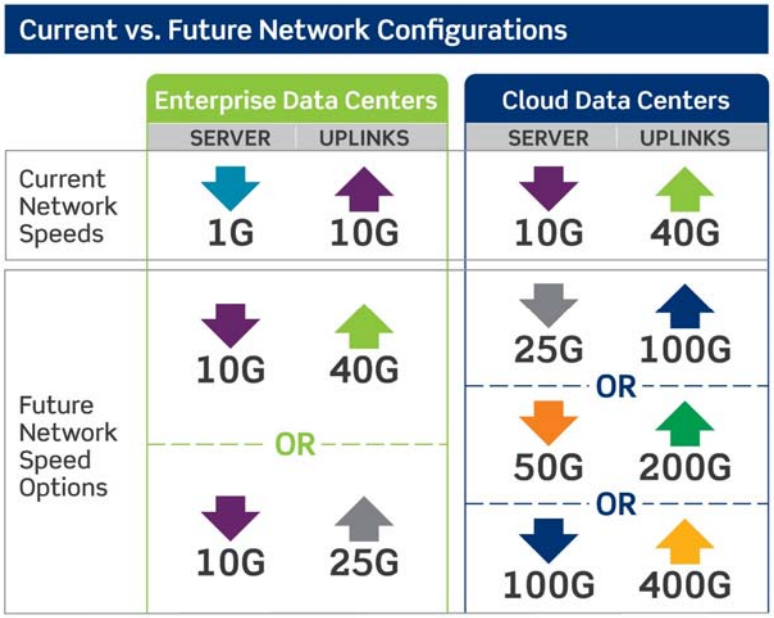
50G Lane Ecosystem is not far off

100G/200G & 400G

- **Most options use single-mode cabling**

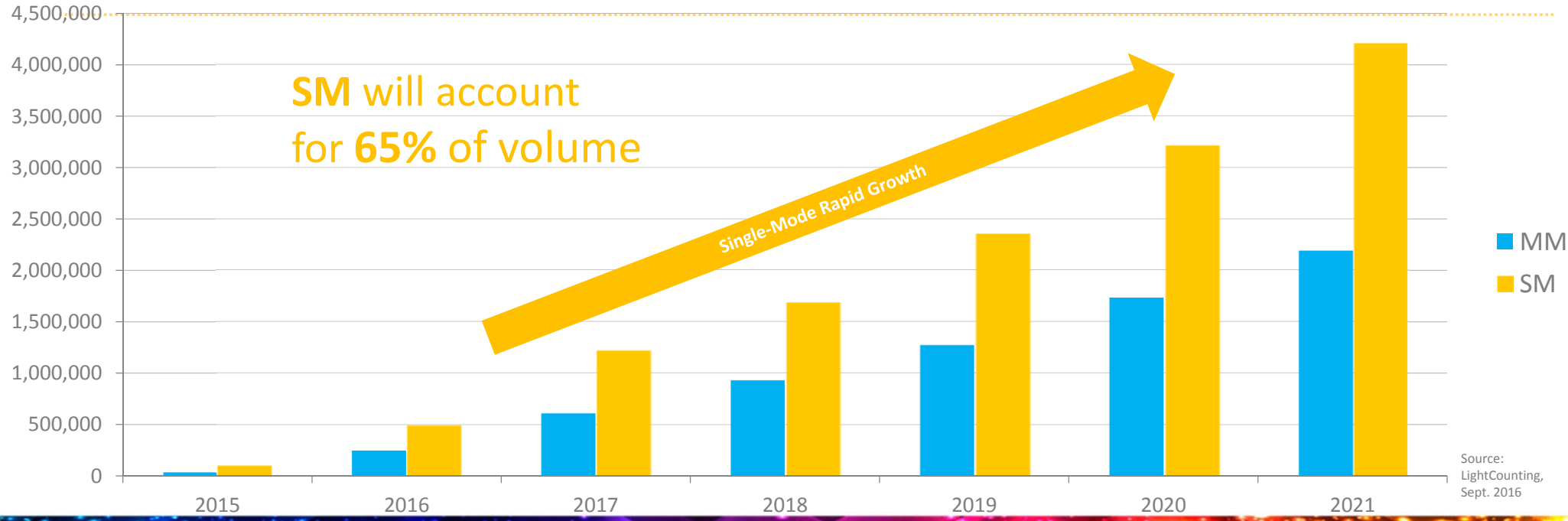
Rate	Fiber Type	# fibers	Connector	Reach	IEEE Std	Est. Release
100GBASE-DR	OS2	2	LC	500m	802.3cd	Sep-18
100GBASE-FR	OS2	2	LC	2km	802.3cd	Sep-18
200GBASE-SR4	OM4	8	MPO	100m	802.3cd	Sep-18
400GBASE-DR4	OS2	8	MPO	500m	802.3bs	Dec-17
400GBASE-FR8	OS2	2	LC	2km	802.3bs	Dec-17

Enterprise vs. Cloud Network Speeds



SM vs. MM Transceiver Estimated Volumes

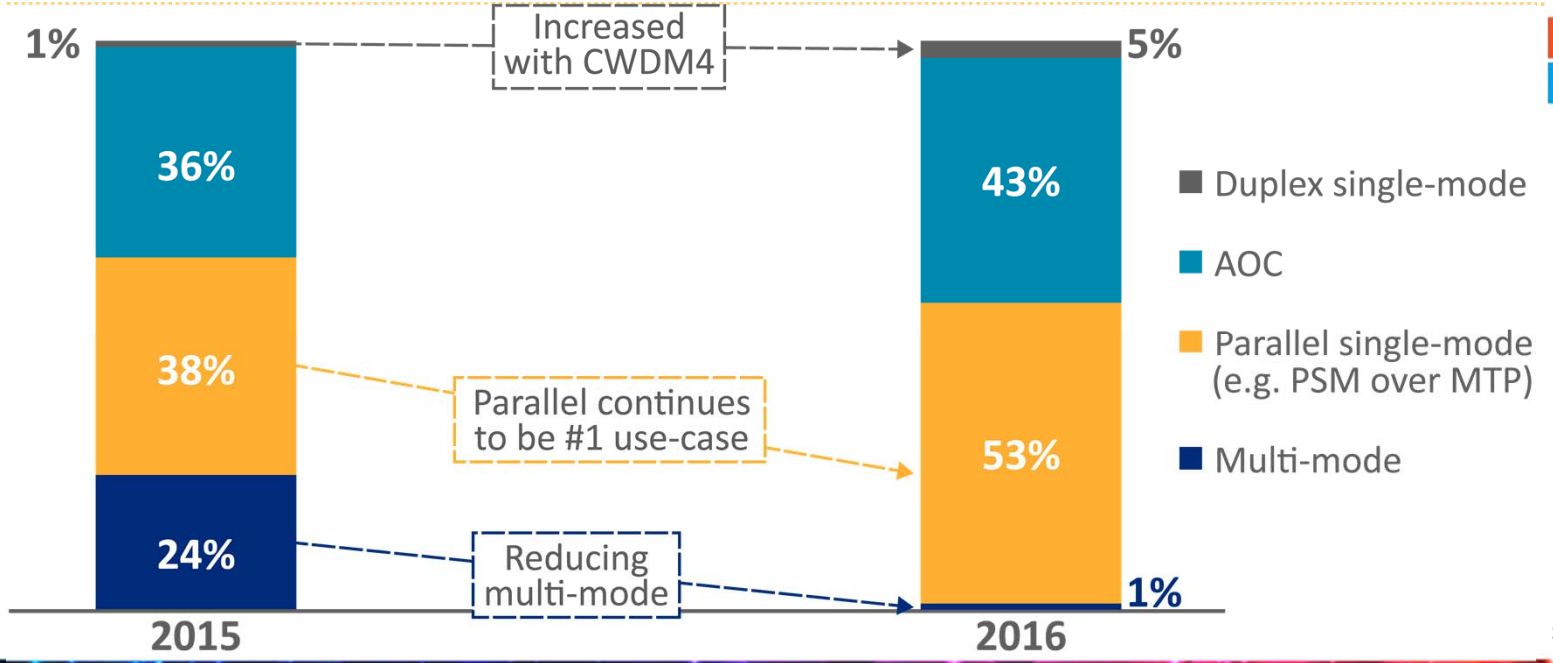
100G – 400G Ethernet



Source: LightCounting, Sept. 2016

Market Leaders Setting an Example

99% Single-mode

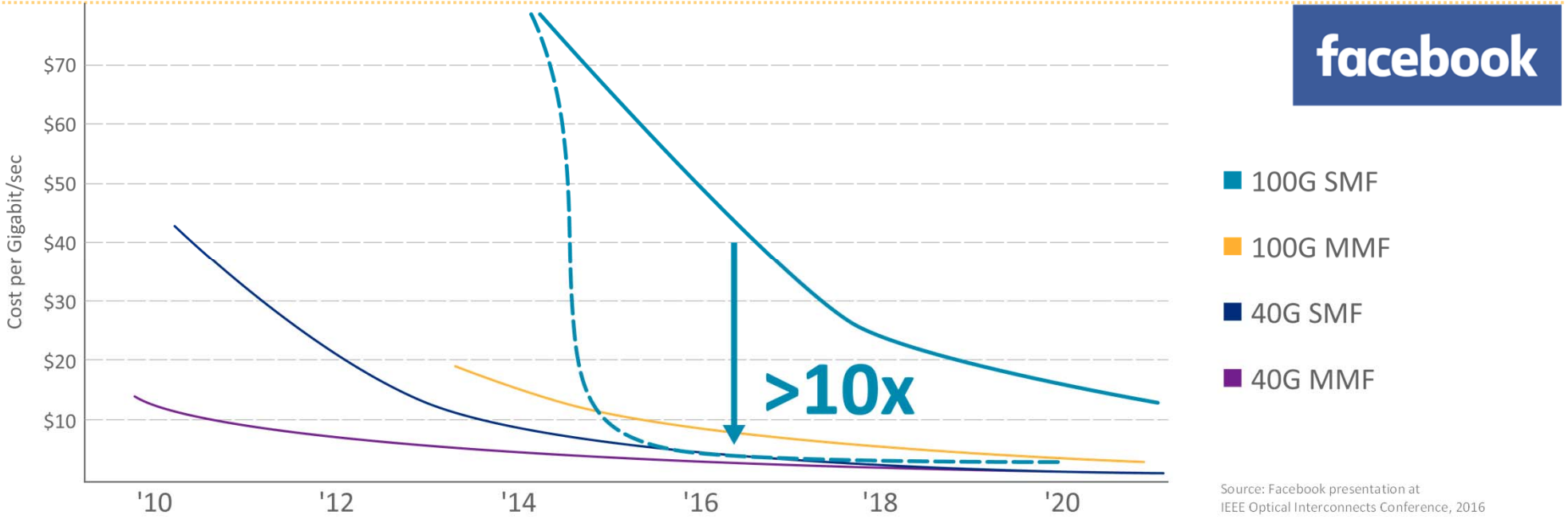


Microsoft

Source: The Next Platform

Cost of SMF Optics expected to decline

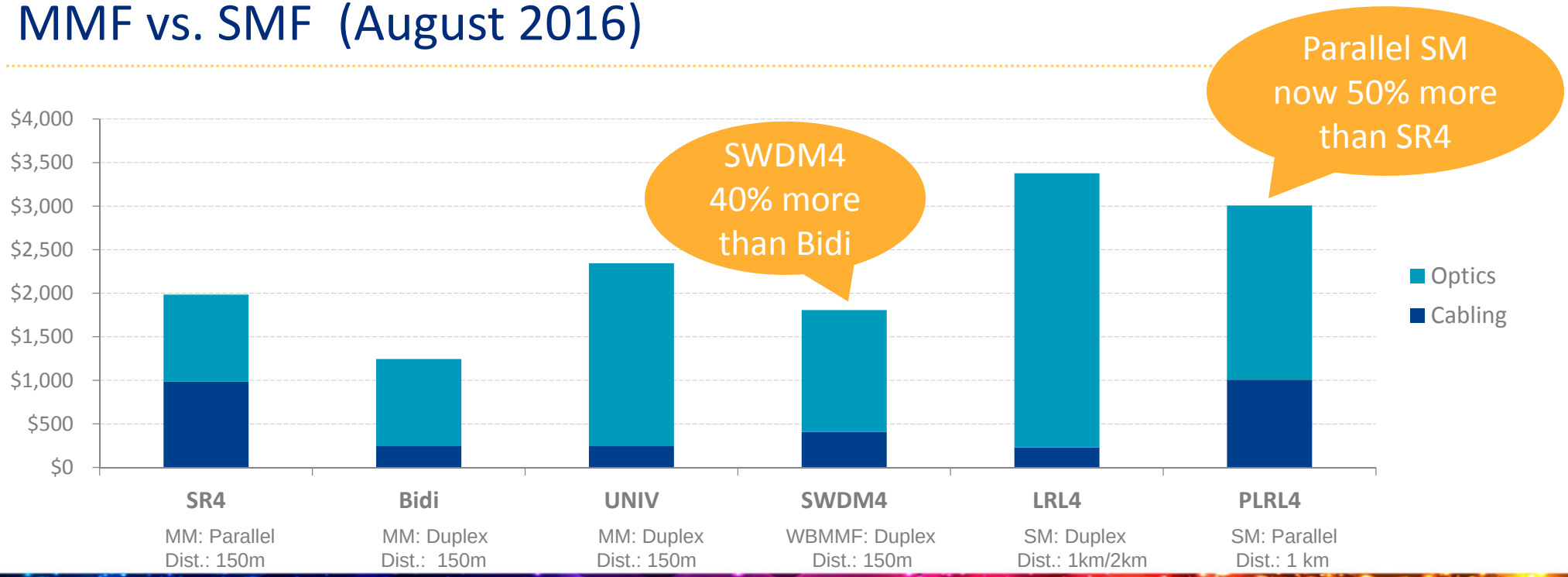
Closer to MMF Optics



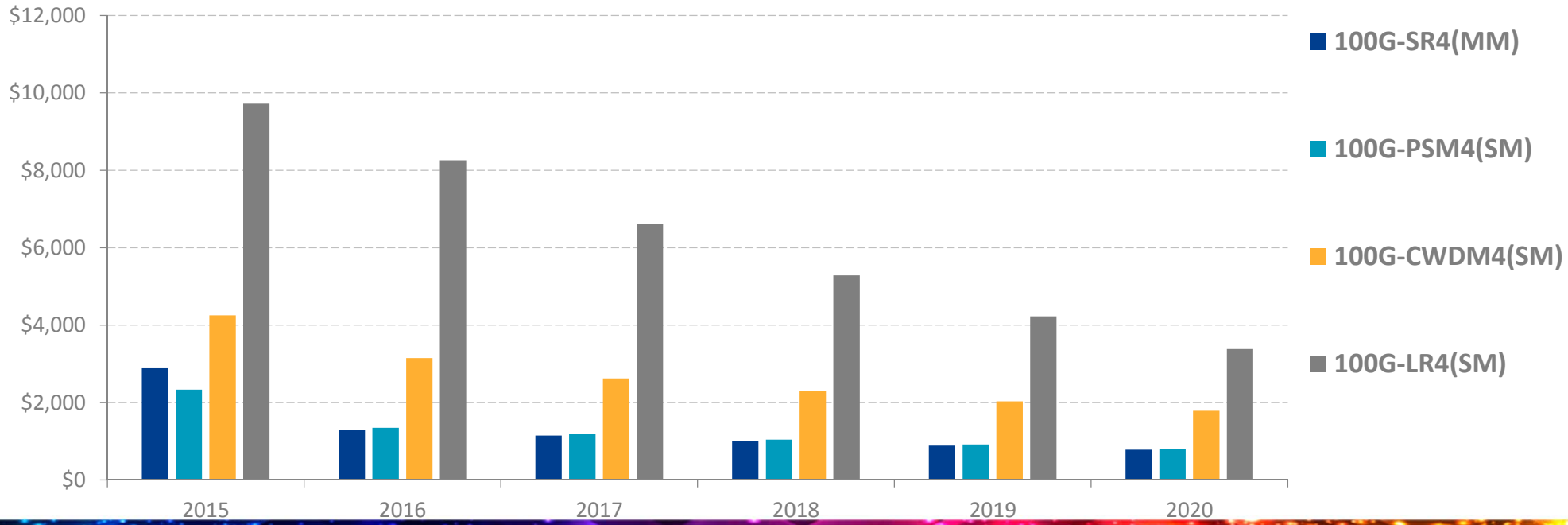
Source: Facebook presentation at
IEEE Optical Interconnects Conference, 2016

End-to-end 40G Channel Cost Comparison

MMF vs. SMF (August 2016)



Estimated List Prices: 100G Transceivers



Source: LightCounting, Sept. 2016

High Density 40/100G Switches

QSFP+ ports

Arista 7300 Series

Juniper 9214

Cisco Nexus 6004

Cisco Nexus 7700

40G Optical Transceivers – Aug 2017

	Transceiver	Switch Mfrs	Form Factor	IEEE Compliant	Fiber Type	Distance	# of fibers	Power (W)	Connector
1	40G-SR4	All	QSFP+	Yes	OM3/OM4	100m/150m	8	1.5	12F MTP
2	40G-C/X/ESR4	Cisco, Arista, Juniper	QSFP+	No	OM3/OM4	300m/400m	8	1.5	12F MTP
3	40G-BIDI	Cisco, Arista	QSFP+	No	OM3/OM4	100m/150m	2	1.5	LC
4	40G-LX4	Juniper	QSFP+	No	OM3/OM4	100m/150m	2	3.5	LC
5	40G- UNIV	Arista	QSFP+	Yes	OM3/OM4/OS2	150m, 500m	2	3.5	LC
6	40G-LR4	All	QSFP+	Yes	OS2	10 km	2	3.5	LC
7	40G-LRL4/IR4	Cisco, Arista, Juniper	QSFP+	Yes	OS2	1km/2km	2	3.5	LC
8	40G-PLRL4	Arista	QSFP+	No	OS2	1 km	8	3.5	12F MTP
9	4x10G-IR	Juniper	QSFP+	No	OS2	1.4 km	8	3.5	12F MTP
10	4x10G-LR	Cisco	QSFP+	No	OS2	10km	8	3.5	12F MTP
11	40G-PLR4	Arista	QSFP+	No	OS2	10 km	8	3.5	12F MTP
12	40G-SWDM4 TBA?	TBD	QSFP+	No	OM3/OM4/OM5	TBD	2	TBD	LC

More Than 12 Choices Available!

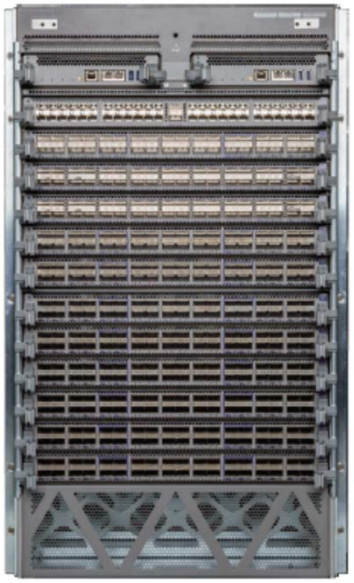
Switches now have 100G ports available

High Density QSPF28 ports

Cisco 3232C

Cisco 92160

Cisco 9508



Arista 7512R

100G Optical Transceivers – Aug 2017

	Transceiver	Switch Mfrs	Form Factor	IEEE Compliant	Fiber Type	Distance	# of fibers	Power (W)	Connector
1	100G-SR10	All	CFP/CFP2/CPAK	Yes	OM3/OM4	100m/150m	20	4.0-6.0	24F MTP
2	100G-SR10 MXP	Arista	Embedded optics	No	OM3/OM4	100m/150m	24	[illegible]	[illegible]F MTP
3	100G-XSR10	Arista	CFP2	No	OM3/OM4	300/400m	[illegible]	[illegible]	24 F MTP
4	100G-SR4	All	QSFP28/CPAK	Yes	[illegible]	70m/100m	8	3.5	12F MTP
5	100G-XSR4	Arista, Juniper	QSFP28	No	OM3/OM4	300m	8	3.5	12F MTP
6	100G-LRL4	Arista	QSFP28	Yes	OS2	2km	2	4.0	LC
7	100G-CWDM4	All	QSFP28/CPAK	No	OS2	2km	2	3.5	LC
8	100G-LR	All	CFP2/CPAK/ QSFP28	Yes	OS2	10km	2	4.5	LC/SC
9	10x10-LR	Cisco	CPAK	No	OS2	1 km	20	4.0	24F MTP
10	100G-PSM4- NEW	All	QSFP28	No	OS2	500m	8	3.5	12F MTP
11	40/100G-SRBD (BiDi), Est. Dec-2017	Cisco	QSFP28	No	OM3/OM4	TBD	2	TBD	LC

Many New 100G Options Available

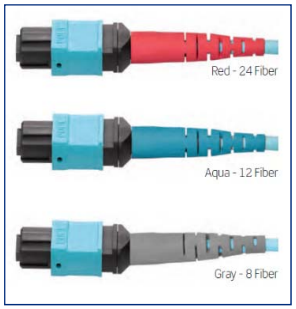
Enterprise Data Center Migration Strategy

Enterprise Data Centers

- Most are using 1G down to servers with 10G uplinks
- Considering to migrate to 10Gdown/40GUp
  or 25G/100G if costing looks attractive
- Majority of DCs have multi-mode cabling installed
- 85% of optical links are 150m or less

Migration Path for 40/100G Enterprise Networks

Multimode Solution



Colored-coded MTP Boots

10G

- MTP-LC Modules
- Duplex LC Patch Cords
- 10G-SR

40G

- MTP 24-F to 3x8-F Modules
- 8-Fiber MTP Array Cords
- 40G-SR4

100G

- MTP 24-F to 3x8-F Modules
- 8-Fiber MTP Array Cords
- 100G-SR4

Leviton introduced
January 2011
First in the Market

Multimode Migration Path

10G or 40G Duplex Channel

- 24-F MTP backbone
- Provides Duplex (2-fiber) connections at equipment
- Will support 1G/10GbE in SFP+ form factors
- Supports 40G using Wave Division Multiplexing Technology (WDM) like the Cisco/Arista BiDi in QSFP+ form factors

Multimode Migration Path

40G-SR4 Channel

- Same 24F MTP Backbone stays in place
- Swap out MTP-LC cassettes for MTP-MTP conversion cassettes
- Provides Parallel (8-fiber) connections at equipment
- 100% fiber utilization
- Support 40GBASE-SR4 in QSPF+

Multimode Migration Path

100G-SR4 Channel

- Same 24F MTP Backbone stays in place
- Swap out MTP-LC cassettes for MTP-MTP conversion cassettes
- Provides Parallel (8-fiber) connections at equipment
- 100% fiber utilization
- Supports 100GBASE-SR4 in QSFP+

Cloud Provider Migration Solution

Cabling Strategy for Cloud Providers

- **Most are either already using or planning to move to Single-mode**
  - 97% of single-mode links are 350m or less
- **Key reasons why single-mode is being selected:**
  - Requirements for reach beyond 150m
  - Transceivers costs have lowered significantly in last 2 years
  - Increasing bandwidth requirements
  - Majority of next gen speeds will use SMF
  - Need to "futureproof" cabling infrastructure
  - More flexibility to add more "hops" in channel

Single-Mode Migration Path

2-Fiber Channels: 10G, 40G, 100G, 200G or 400G

- 24-F MTP backbone
- Provides Duplex (2-fiber) connections at equipment

- Supports the following optics:
  - 10GbE in SFP+
  - 40GBASE-LR4/LRL4 in QSFP+
  - Arista 40G Universal in QSFP+
  - 100GBASE-LR4/LRL4 in CFP2/CPAK or QSFP28

- **Will support future applications of 100G-FR2, 200G-FR4,400G-FR8**

Single-Mode Migration Path

8-Fiber Channels: 40G, 100G, 200G or 400G

- Same 24F MTP Backbone stays in place
- Swap out MTP-LC cassettes for MTP-MTP conversion cassettes
- Provides Parallel (8-fiber) connections at equipment

- 100% fiber utilization
- Supports the following optics:
  - 40GBASE-PLRL4/PLR4 in QSPF+
  - 40G: 4x10G-LR/IR in QSFP+
  - 100G-PSM4 in QSFP28
- **Will support future applications of 200G-DR4, 400G-DR4**

Single-Mode Migration Path

20-Fiber Channel: 100G

- Same 24F MTP Backbone stays in place
- Swap out MTP-LC/MTP-MTP cassettes with MTP pass-thru cassettes
- Provides Parallel (20-fiber) connections at equipment
- Will support Cisco 10x10-LR in CPAK

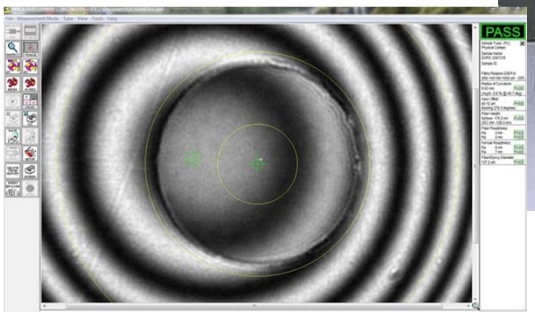
Single-Mode Cabling System

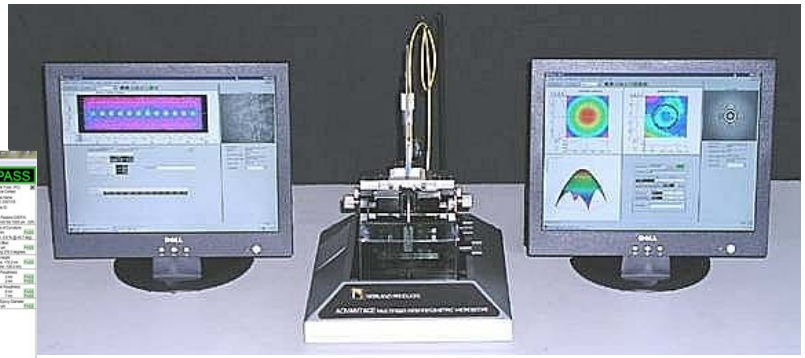
- MTP-MTP Low Loss Trunks – 12F MTP and 24F MTP/APC
- MTP-LC cassettes
- MTP-MTP conversion cassettes
- MTP pass-thru adapter plates
- MTP-MTP Array cords and harnesses
  - 8F, 12F, 24F

End-Face Geometry Testing is Required

for Single-Mode to Assure Consistent Quality

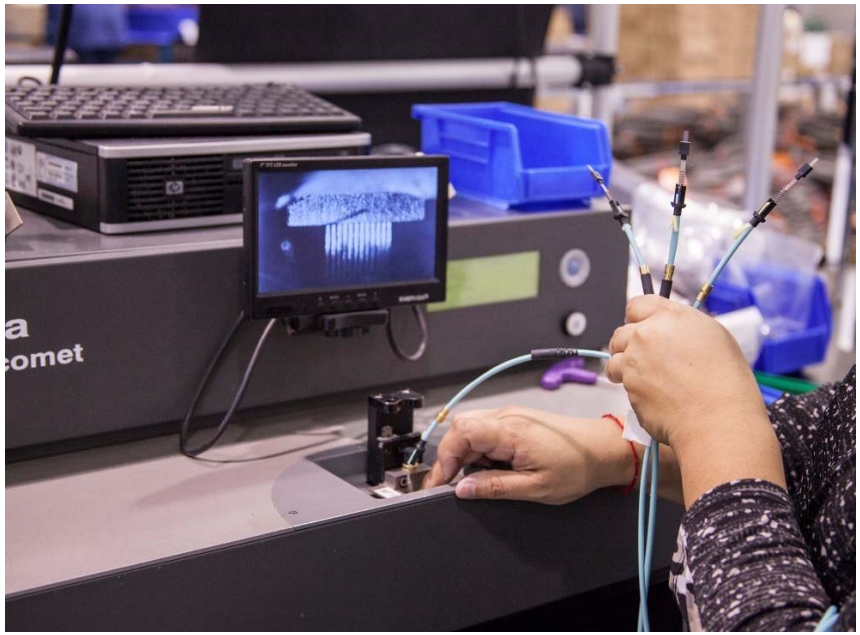
- **End-face geometry testing with Interferometer**
- **100% testing of single fiber single-mode connectors**
- **Tested to IEC-61755**
  - Apex offset
  - Radius of curvature
  - Fiber protrusion





Laser Cleaving Recommended for SMF

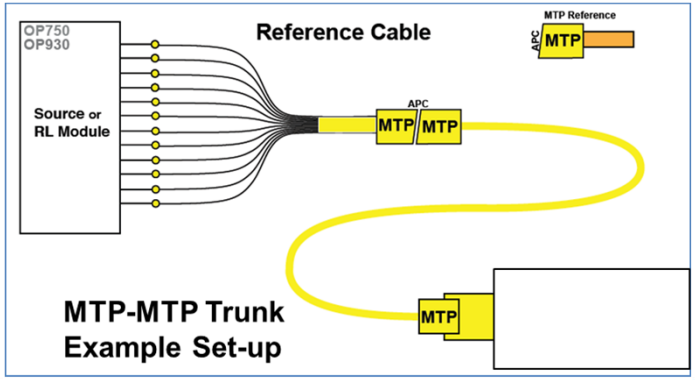
- High-precision equipment used for single and multi-fiber connectors
- Required for consistent, high-quality terminations
- Hand Cleaving 8.3 µm SMF very difficult



Single-Mode Test Equipment is Critical

Must Test Both IL and RL

- **Single-mode must be tested in both Return Loss & Insertion Loss**
- **Multi-channel tester required to test 12 and 24F MTPs**



What about OM5?

Is OM5 Fiber a Good
Solution for Data Centers?

Background on OM5 Fiber

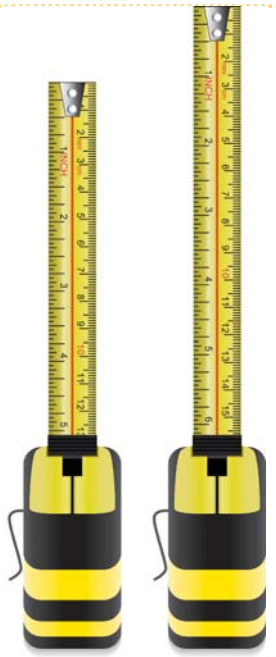
- Wideband multimode fiber (WBMMF) is a new fiber medium specified in ANSI/TIA-492AAAE, published in June 2016.
- ISO/IEC voted to use OM5 for WBMMF in the ISO/IEC 11801, 3rd edition.
- OM5 specifies wider range of wavelengths between 850nm and 953nm
- It was created to support Shortwave Wavelength Division Multiplexing (SWDM), which is being developed for 40 Gb/s, 100 Gb/s, and beyond.
- OM5 is being presented as a potential new option for data centers that require greater link distances and higher speeds.
- Many enterprise IT and data center managers are increasingly adopting single-mode fiber systems to solve these challenges

Why would a data center consider OM5?

- Longer cabling reach
- Reduce costs
- Required for higher speeds
- Higher density at switch ports

Does OM5 offer a longer reach than OM4?

- **Not true. The difference is minimal.**
  - OM5 and OM4 **max reach are the same** for current and future IEEE applications
    - Including 40GBASE-SR4, 100GBASE-SR4, 200GBASE-SR4, and 400GBASE-SR16
  - With 40G-SWDM4 transceivers OM4 supported 400-meter reach and OM5 supported 500-meter
  - With non-IEEE-compliant 100G-SWDM4 transceivers OM5 reach is 150-meters — only 50 meters more than OM4.
- **Most cloud data centers running 100 Gb/s or greater with cabling runs over *100 meters* are likely using single-mode already**



Does OM5 offer a longer reach than OM4?

- **SWDM Testing Shows OM4 Reach over 350m**

  - Leviton BER Testing done with Arista 40G SWDM4 modules had following results:
    - OM3 Channel: 300 meter reach
    - OM4 Channel: 390 meter reach
    - OM5 Channel: 500 meter reach
  - Most cloud data centers running 40 Gb/s with cabling runs over **300 meters** are likely using single-mode already

Does OM5 reduce costs?

- **It won't.**
  - **OM5 cabling costs about 60%-90%** more than OM4
  - 40G channel with SWDM transceivers, 50% more than 40GBidi/OM4 channel
  - Single-mode transceivers cost has declined considerably in last 12-18 months
    - Due to silicon photonics technologies and hyperscale data centers buying in volume

- **100G-PSM4 transceivers using single-mode fiber is the same price as 100GBASE-SR4 using multimode fiber.**

Is OM5 required for higher speeds?

- **Not true.**
  - All IEEE standards for 100/200/400 Gb/s will work with either single-mode (OS2) or multimode (OM4)
  - The majority of **next-generation speeds will require single-mode**
  - IEEE strives to develop future standards that work with the primary installed base of cabling infrastructure so customers can easily migrate to new speeds

- **None of the active IEEE standards addressing next-gen speeds (802.3bs or 802.3cd) will use SWDM technology.**

Does OM5 allow higher density from switch ports?

- **It won't.**
  - Data centers commonly use 40GBASE-SR4 to increase port density by breaking out 40 Gb/s ports into 10 Gb/s channels
  - This is also a benefit of new 100GBASE-SR4 modules, which use OM4 cabling

- **With 100G-SWDM4 modules, OM5 cabling cannot break out into 25 Gb/s channels. This would become a real issue as the 25 Gb/s ecosystem fully develops with more 25 Gb/s to the server.**

Leviton Recommendation to Clients on OM5…

- Leviton sees no reason to recommend OM5 for large data centers
- For enterprise data centers looking at migrating to 40GBASE-SR4 or 100GBASE-SR4, OM5 offers no additional benefit over OM4 or OM4+.
- Cloud data centers are either already using single-mode or planning to move to single-mode for migration to 800 Gb/s and 1 Tb/s without changing out their cabling

Summary

- Enterprise and Cloud DCs are very different
- 25G and 50G ecosystems are coming soon
- MMF and SMF Transceiver costs are getting closer
- Cloud data centers are migrating to single-mode