Designing a Flexible Network Infrastructure to support new optical technologies

Enterprise vs. Cloud Data Center Requirements

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2017 BICSI Winter Conference & Exhibition
January 22-26 • Tampa, FL
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
## Major Characteristics of Data Centers

<table>
<thead>
<tr>
<th></th>
<th>SMB</th>
<th>Large Enterprise</th>
<th>Cloud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Servers</td>
<td>&lt;500</td>
<td>10,000</td>
<td>&gt;100,000</td>
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<tr>
<td>Number of Customers</td>
<td>&gt;1,000,000</td>
<td>&lt;5,000</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Number of Top-of-Rack / Leaf Switches</td>
<td>&lt;25</td>
<td>&lt;500</td>
<td>&gt;2,000</td>
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<tr>
<td>Number of Spine / Aggregation Switches</td>
<td>1-2</td>
<td>&lt;25</td>
<td>&gt;100</td>
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<tr>
<td>Number of Core Switches</td>
<td>N/A</td>
<td>&lt;12</td>
<td>&gt;12</td>
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<tr>
<td>Deal Size</td>
<td>&lt;$100,000</td>
<td>&lt;$5,000,000</td>
<td>&gt;$20,000,000</td>
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<tr>
<td>Ethernet Switch Vendor Margin</td>
<td>&gt;60%</td>
<td>&gt;50%</td>
<td>&lt;25%</td>
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</tbody>
</table>

Source: Dell'Oro, 2015

### Total Ethernet Switch Data Center Revenue

- **Top 7 Cloud Providers**
- **Rest of Cloud and SPs**
- **Enterprise and SMB Market**

Source: Dell'Oro, 2015
PRIVATE

Used for a single organization.
Can be externally or internally hosted.

COMMUNITY

Shared by several organizations.
Typically externally hosted.

HYBRID

Two or more clouds bound together.
Usually part internally and part externally hosted.

PUBLIC

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

Transceiver modules by speed, percent of total

Dramatic Growth of 100G Expected...


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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
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

<table>
<thead>
<tr>
<th>Rate</th>
<th>Fiber Type</th>
<th># fibers</th>
<th>Connector</th>
<th>Reach</th>
<th>IEEE Std</th>
<th>Est. Release</th>
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</thead>
<tbody>
<tr>
<td>100GBASE-SR4</td>
<td>OM4</td>
<td>8</td>
<td>MPO</td>
<td>70m</td>
<td>802.3bm</td>
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<td>100m</td>
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<td>100GBASE-DR2</td>
<td>OS2</td>
<td>4</td>
<td>MPO</td>
<td>500m</td>
<td>802.3cd</td>
<td>Sep-18</td>
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<tr>
<td>100GBASE-FR2</td>
<td>OS2</td>
<td>2</td>
<td>LC</td>
<td>2km</td>
<td>802.3cd</td>
<td>Sep-18</td>
</tr>
<tr>
<td>200GBASE-DR4</td>
<td>OS2</td>
<td>8</td>
<td>MPO</td>
<td>500m</td>
<td>802.3bs</td>
<td>Dec-17</td>
</tr>
<tr>
<td>200GBASE-FR4</td>
<td>OS2</td>
<td>2</td>
<td>LC</td>
<td>2km</td>
<td>802.3bs</td>
<td>Dec-17</td>
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<tr>
<td>400GBASE-SR16</td>
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<td>32</td>
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<td>LC</td>
<td>2km</td>
<td>802.3bs</td>
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</table>
50G Lane Ecosystem is not far off – 100G/200G & 400G

- Most options use single-mode cabling

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<th>IEEE Std</th>
<th>Est. Release</th>
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<tbody>
<tr>
<td>100GBASE-DR</td>
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<td>2</td>
<td>LC</td>
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<td>802.3cd</td>
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<tr>
<td>100GBASE-FR</td>
<td>OS2</td>
<td>2</td>
<td>LC</td>
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<tr>
<td>200GBASE-SR4</td>
<td>OM4</td>
<td>8</td>
<td>MPO</td>
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<td>802.3cd</td>
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<td>400GBASE-FR8</td>
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<td>2km</td>
<td>802.3bs</td>
<td>Dec-17</td>
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</table>
Enterprise vs. Cloud Network Speeds

**Enterprise**
NOW: 1G Down/10G Up

10G Down/40G Up OR 10G Down/25G Up

**Cloud**
NOW: 10G Down/40G Up

25G Down/100G Up OR 50G Down/200G Up OR 100G Down/400G Up

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Multi-Sourcing Agreements (MSAs)

- In addition to IEEE standards, there are many technologies being developed thru MSAs with industry consortiums
  - 100G CLR4 Alliance – Duplex SMF
  - SWDM Alliance – Duplex MMF for 40 & 100G
  - 100G PSM4 MSA…Parallel SMF for 100G+
  - 10x10 MSA…Parallel SMF
  - CWDM4 MSA…Duplex SMF for 100G+
  - OpenOptics MSA – Duplex SMF for 100G & 400G
Sale of Ethernet Transceivers by Market

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SM vs. MM Transceiver Estimated Volumes

100G – 400G Ethernet

SM will account for 65% of volume

Market Leaders Setting an Example

99% Single-mode

2015

- Duplex single-mode: 1%
- AOC: 38%
- Parallel single-mode (e.g. PSM over MTP): 24%
- Multi-mode: 1%

Increased with CWDM4

2016

- Duplex single-mode: 5%
- AOC: 43%
- Parallel single-mode (e.g. PSM over MTP): 53%
- Multi-mode: 1%

Reducing multi-mode

Parallel continues to be #1 use-case

Source: The Next Platform

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Cost of SMF Optics expected to decline
Closer to MMF Optics

>10x

Source: Facebook presentation at IEEE Optical Interconnects Conference, 2016

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End-to-end 40G Channel Cost Comparison

MMF vs. SMF (August 2016)

- SR4: MM: Parallel, Dist.: 150m
- Bidi: MM: Duplex, Dist.: 150m
- UNIV: MM: Duplex, Dist.: 150m
- SWDM4: WBMMF: Duplex, Dist.: 150m
- LRL4: SM: Duplex, Dist.: 1km/2km
- PLRL4: SM: Parallel, Dist.: 1 km

SWDM4 40% more than Bidi
Parallel SM now 50% more than SR4

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Estimated List Prices: 100G Transceivers

SR4-MM & PSM4-SM are at the same price


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High Density 40/100G Switches

QSFP+ ports

Arista 7300 Series
Juniper 9214
Cisco Nexus 6004
Cisco Nexus 7700

<table>
<thead>
<tr>
<th>Transceiver</th>
<th>Switch Mfrs</th>
<th>Form Factor</th>
<th>IEEE Compliant</th>
<th>Fiber Type</th>
<th>Distance</th>
<th># of fibers</th>
<th>Connector</th>
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<tr>
<td>40G-SR4</td>
<td>All</td>
<td>QSFP+</td>
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<td>OM3/OM4</td>
<td>100m/150m</td>
<td>8</td>
<td>12F MTP</td>
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<tr>
<td>40G-C/X/ESR4</td>
<td>Cisco, Arista, Juniper</td>
<td>QSFP+</td>
<td>No</td>
<td>OM3/OM4</td>
<td>300m/400m</td>
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<td>12F MTP</td>
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<tr>
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<td>QSFP+</td>
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<td>OM3/OM4</td>
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<td>LC</td>
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<tr>
<td>40G-LX4</td>
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<td>100m/150m</td>
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<td>50G- UNIV</td>
<td>Arista</td>
<td>QSFP+</td>
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<td>OM3/OM4, OS2</td>
<td>100m, 500m</td>
<td>2</td>
<td>LC</td>
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<td>40G-LR4</td>
<td>All</td>
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<td>No</td>
<td>OS2</td>
<td>10 km</td>
<td>2</td>
<td>LC</td>
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<tr>
<td>40G-LRL4/IR4</td>
<td>Cisco, Arista, Juniper</td>
<td>QSFP+</td>
<td>Yes</td>
<td>OS2</td>
<td>1km/2km</td>
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<td>LC</td>
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<tr>
<td>40G-PLR4</td>
<td>Arista</td>
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<td>No</td>
<td>OS2</td>
<td>1 km</td>
<td>8</td>
<td>12F MTP</td>
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<tr>
<td>4x10G-IR</td>
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<td>QSFP+</td>
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<td>1.4 km</td>
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<td>12F MTP</td>
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<td>4x10G-LR- NEW</td>
<td>Cisco</td>
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<td>No</td>
<td>OS2</td>
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<td>8</td>
<td>12F MTP</td>
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<tr>
<td>40G-PLR4</td>
<td>Arista</td>
<td>QSFP+</td>
<td>No</td>
<td>OS2</td>
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<td>12F MTP</td>
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<td>40G-SWDM4 Coming Soon</td>
<td>TBD</td>
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<td>OM3/OM4/OM5</td>
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<td>2</td>
<td>LC</td>
</tr>
</tbody>
</table>

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**More Than 12 Choices Available!**

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Switches now have 100G ports available
High Density QSPF28 ports

<table>
<thead>
<tr>
<th>Transceiver</th>
<th>Switch Mfrs</th>
<th>Form Factor</th>
<th>IEEE Compliant</th>
<th>Fiber Type</th>
<th>Distance</th>
<th># of fibers</th>
<th>Connector</th>
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<tbody>
<tr>
<td>100G-SR10</td>
<td>All</td>
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<td>OM3/OM4</td>
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<td>20</td>
<td>24F MTP</td>
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<tr>
<td>100G-SR10 MXP</td>
<td>Arista</td>
<td>Embedded optics</td>
<td>No</td>
<td>OM3/OM4</td>
<td>100m/150m</td>
<td>24</td>
<td>24F MTP</td>
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<td>100G-XSR10</td>
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<td>CFP2</td>
<td>No</td>
<td>OM3/OM4</td>
<td>300/400m</td>
<td>20</td>
<td>24F MTP</td>
</tr>
<tr>
<td>100G-SR4</td>
<td>All</td>
<td>QSFP28</td>
<td>Yes</td>
<td>OM3/OM4</td>
<td>80m/100m</td>
<td>8</td>
<td>12F MTP</td>
</tr>
<tr>
<td>100G-XSR4 - NEW</td>
<td>Arista, Juniper</td>
<td>QSFP28</td>
<td>No</td>
<td>OM3/OM4</td>
<td>300m</td>
<td>8</td>
<td>12F MTP</td>
</tr>
<tr>
<td>100G-LRL4 - NEW</td>
<td>Arista, Juniper</td>
<td>QSFP28</td>
<td>Yes</td>
<td>OS2</td>
<td>2km</td>
<td>2</td>
<td>LC</td>
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<tr>
<td>100G-XW4 - NEW</td>
<td>Arista, Cisco</td>
<td>QSFP28</td>
<td>No</td>
<td>OS2</td>
<td>2km</td>
<td>2</td>
<td>LC</td>
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<tr>
<td>100G-LR4 – NEW FF</td>
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<td>CFP2/CPA2/ QSFP28</td>
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<td>2</td>
<td>LC/SC</td>
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<td>100G-PSM4- NEW</td>
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<td>No</td>
<td>OS2</td>
<td>500m</td>
<td>8</td>
<td>12F MTP</td>
</tr>
</tbody>
</table>

**Many New 100G Options Available**

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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

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

Colored-coded MTP Boots

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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
- Will support 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
- Will 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
• Will support 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
- Will support the following optics:
  - 10GbE in SFP+ form factor
  - 40GBASE-LR4/LRL4 in QSFP+ form factor
  - Arista 40G Universal in QSFP+ form factor
  - 100GBASE-LR4/LRL4 in CFP2/CPAK or QSFP28 form factors
- 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
- Will support the following optics:
  - 40GBASE-PLRL4/PLR4 in QSPF+ form factor
  - 40G: 4x10G-LR/IR in QSFP+ form factor
  - 100G-PSM4 in QSFP28 form factor

- Will support future applications of 200G-DR4, 400G-DR4

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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 form factor
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 1310nm and 1550nm
- Multi-channel tester required to test 12 and 24F MTPs
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