Optical Communication Trends in Data Centers
Dennis Kom | Director, Sales & Global Strategic Accounts | APAC Enterprise Networks
# Optical Communication Trends in Data Centers

<table>
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<td>• Ethernet Optical Transceiver Roadmap</td>
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<td>• Base-2, 8, 12 and 24</td>
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                                • Base-2,8,12 and 24                                                                                                                           |
| **Cabling Optimization** | • Fiber Utilization  
                                • Port Mapping  
                                • Port Breakouts  
                                • Integrated Port Tapping  
                                • High Fiber Count (HFC) Trunks                                                                                                               |
Increasing Bandwidth Demands
Global Data Center IP Traffic Growth

26% CAGR 2017–2022

Exabytes per Month

- 2017: 122
- 2018: 156
- 2019: 201
- 2020: 254
- 2021: 319
- 2022: 396

Source: Cisco VNI Global IP Traffic Forecast, 2017–2022
Increasing Bandwidth Demands
Preparing 5G with Optical Fiber

Sources: GrowthEnabler, market Pulse Report, IoT ; HIS Markit – 5G Strategies & Opportunities
Increasing Bandwidth Demands

Video is exploding!

How much bandwidth is required for transmission of uncompressed (raw) 4K video?

$$4096 \times 2160 \times 10 \times 25 = 2.2 \text{ Gbps}$$

Source: CNET

Source: Intel
Increasing Bandwidth Demands
DC Ethernet Switch: Total Port Shipments

Source: 650 Group, 2018
Increasing Bandwidth Demands
Server and Smart NICs: Connectivity Metrics

Source: 650 Group, 2018
WDM versus Parallel Transmission

- **Duplex**
  - Serial
  - 10G

- **WDM**
  - Wavelength Division Multiplexing
  - 40G, 100G

- **Parallel**
  - 40G, 100G, 400G

MTP Connector

Fibre Position

© 2019 Corning Incorporated
Ethernet Speed Roadmap
Ethernet Speed Roadmap
200G / 400G update

- Non-Return to Zero (NRZ), a 2-level modulation scheme has limitation to drive data rate beyond 25Gbps.
- Adoption of Pulse Amplitude Modulation (PAM4) for multi level signaling, to drive data rate at 50/100Gbps over a single fiber. PAM4 is expected to be the de facto standard for 100G connectivity. Read more: [http://100glambda.com](http://100glambda.com)
Ethernet Speed Roadmap

400G update

First generation standards guidance
- 32F parallel optics
- 400GBASE-SR16
- Tx 16x25G and Rx 16x25G (NRZ)
- CFP8 Transceiver
- 32F MPO connector, double array
- Minimal traction expected

2nd generation 400 Gb/s MMF PHYs Task Force - 400GBASE-SR8.
- eight pairs of MMF with reach of at least 100 m
- 16F Parallel Optics
- OM3 70m, OM4 100m and OM5 100m
- QSFP-DD / OSFP Transceiver
- 16F MPO Flat polish connector
- QSFP-DD / OSFP Transceivers
- TOR breakout cable for server interconnects

Figure 123-4—400GBASE-SR16 optical lane assignments
Ethernet Speed Roadmap
400G Pluggable Modules

- QSFP-DD and OSFP
- 32/36 ports per 1U line card
- 100/200G breakout capability
- Module power 10-12 w
- MPO, LC, CS or MDC connector
- MM and SM capable
- 2019-2020 availability

32 OSFP or 32 QSFP-DD Ports
12.8 Tb / 1U
## Ethernet Optical Transceiver Roadmap

Analyzing the benefits and tradeoffs of deploying structured cabling in a data center begins with the network equipment and its continuously evolving offerings from major transceiver, switch, server, and storage manufacturers.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Reach</th>
<th>40G</th>
<th>100G</th>
<th>200G</th>
<th>400G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duplex OM3/4/5</td>
<td>Short</td>
<td>BiDi (100m/200m)</td>
<td>BiDi (70m/100m)</td>
<td>To be defined</td>
<td>To be defined</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SWDM (240m/350m/440m)</td>
<td>SWDM (75m/100m/150m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parallel OM3/4/5</td>
<td>Short and Mid</td>
<td>SR4 (100m/150m/150m)</td>
<td>Gen1: SR10 10x10G (100m/150m/150m)</td>
<td>Gen1: SR8 8x25G (70m/100m/100m)</td>
<td>BiDi 4.2 (70m/100m/150m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>eSR4 4x10G (300m/400m)</td>
<td>Gen2: SR4 4x25G (70m/100m/100m)</td>
<td>Gen2: SR4 4x50G (70m/100m/100m)</td>
<td>Gen1: SR16 16x25G (70m/100m/100m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gen3: SR2 2x50G (70m/100m/100m)</td>
<td></td>
<td>Gen2: SR8 8x50G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gen3: SR4.2 4x50Gx2λ</td>
</tr>
<tr>
<td>Duplex SM</td>
<td>Long</td>
<td>LRL4 (2km)</td>
<td>CLR4 (2km)</td>
<td>FR4 WDM (2km)</td>
<td>FR8 WDM (2km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LR4 WDM (10km)</td>
<td>CWDM4 (2km)</td>
<td>LR4 WDM (10km)</td>
<td>LR8 WDM (10km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LR4 WDM (10km)</td>
<td>ER4 WDM (40km)</td>
<td>ER8 WDM (40km)</td>
</tr>
<tr>
<td>Parallel SM</td>
<td>Mid</td>
<td>PLR4 (10km)</td>
<td>DR 2x50G (500m)</td>
<td>DR4 4x50G (500m)</td>
<td>DR4 4x 100G (500m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSM4 (500m)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Black text = MSA or Proprietary
Green text = Approved IEEE 802.3 standards
Red text = In Progress IEEE 802.3 standards
All Roads Lead to 2F or 8F

Migration paths:

- 1G (SFP)
- 10G (SFP+)
- 40G (QSFP+)
- 100G (QSFP28)
- 400G (QSFP-DD)

SMF 2f Duplex:
- LX/LH 10 km → LR 10 km → LR4 10 km → LR4 10 km → LR4 10 km
- SMF 8f Parallel:
  - 4×10G LR 10 km → PSM4 500 m → DR4 500 m
- MMF 2f Duplex:
  - SX 2 km → SR 400 m → BiDi 150 m → BiDi 100 m
- MMF 8f Parallel:
  - SR 150 m → CSR4 400 m → SR4 100 m → 4×BiDi (SR4.2) 100 m
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                       • Base-2,8,12 and 24                                                    |
| **Cabling Optimization** | • Fiber Utilization  
                       • Port Mapping  
                       • Port Breakouts  
                       • Integrated Port Tapping  
                       • High Fiber Count (HFC) Trunks                                         |
Data Center Standards
TIA-942 Data Center Standard

- TIA-942 Telecommunications Infrastructure Standard for Data Centers
  - Provides information on the factors to be considered when planning and preparing the installation of a data center or computer room
    - Architectural design (door, floor, lightning, etc.)
    - Electrical and HVAC
    - Grounding and bonding
    - Structured wiring
  - Structured wiring guidance
    - Recognized media
    - Star topology
    - Cable types
    - Distances
    - Racks and spaces
    - Pathway and spaces
    - Redundancy
Data Center Standards
TIA-942 Data Center Standard

- Entrance Room
- Main Distribution Area (MDA)
- Horizontal Distribution Area (HDA)
- Zone Distribution Area (ZDA)
- Equipment Distribution Area (EDA)
Data Center Standards
TIA-942 Data Center Standard

<table>
<thead>
<tr>
<th>Unstructured Cabling:</th>
<th>Structured Cabling:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Point to point installation</td>
<td>- Star Topology</td>
</tr>
<tr>
<td>- Direct connections to all equipment via jumpers</td>
<td>- High fiber count trunks &amp; central patching locations</td>
</tr>
</tbody>
</table>

![Diagram showing unstructured and structured cabling systems in data center standards.](chart)
# Data Center Network Architecture
## Migration from Copper to Fiber

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Time</th>
<th>% Fiber</th>
<th>% CU</th>
<th>SW SAN Speed</th>
<th>Fiber Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>End of Row (EoR), Middle of Row (MoR)</td>
<td>2004-2007</td>
<td>20%</td>
<td>80%</td>
<td>10Mbps-100Mbps 2Gbps-4Gbps</td>
<td>OM1 15% OM2 12% OM3 63% OM4 10% SMF</td>
</tr>
<tr>
<td>Top of Rack (ToR)</td>
<td>2007-2010</td>
<td>40%</td>
<td>60%</td>
<td>100Mbps-1000Mbps 4Gbps-8Gbps</td>
<td>OM1 5% OM2 5% OM3 70% OM4 10% SMF</td>
</tr>
<tr>
<td>Spine and Leaf</td>
<td>2013-2017*</td>
<td>60%</td>
<td>40%</td>
<td>1000Mbps-10Gbps 8Gbps-16Gbps</td>
<td>OM1 2% OM2 55% OM3 30% OM4 13% SMF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SW SAN Speed</th>
<th>Fiber Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>10Gbps-100Gbps 16Gbps-32Gbps</td>
<td>OM1 18% OM2 16% OM3 23% OM4 59% SMF</td>
</tr>
</tbody>
</table>

*Source: Infonetics, Corning*
Data Center Network Architecture
Flattening Network Design

- Design for redundancy - spanning Tree Protocol (STP) cannot support parallel forwarding path.
- Adopt 80/20 rule where 80% of IP traffic is kept local, while 20% of IP traffic goes across the WAN.
- Poor utilization of links and difficult to scale.

- Design for resiliency and scalability with Two Tier Hierarchy Architecture using ECMP:
  - Non-blocking Spine-Leaf
  - Over-subscription Leaf to Server
- “east-west” layer 2 switch to server traffic flow:
  - Low network latency
  - Ease VM movement
- Transparent Interconnection of Lots of Links (TRILL) management increases overall network bandwidth and availability.
- Proliferation of DCI.
Data Center Network Architecture

Emergence of EDGE Computing

Source: Futuriom, 2018
Data Center Network Architecture
Fiber Across all Network Segments

<table>
<thead>
<tr>
<th>TOR / EOR</th>
<th>To Core</th>
<th>Campus</th>
<th>Metro/LH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cables</td>
<td>Transceivers</td>
<td>Transceivers</td>
<td>Transceivers</td>
</tr>
<tr>
<td>Cu / AOC</td>
<td>MMF, SMF</td>
<td>SMF</td>
<td></td>
</tr>
<tr>
<td>3m, 5m / 30m</td>
<td>100m, 300-500m</td>
<td>2 – 10km</td>
<td>&gt; 10km, up to 1000s of km</td>
</tr>
</tbody>
</table>

Bend Matters
Loss Matters
# Pre-Terminated Solutions
## EDGE8™ Solutions – Base 8 Wiring Configuration

<table>
<thead>
<tr>
<th>Product Family</th>
<th>Description</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDGE8™ Trunks</td>
<td>• 8-fiber MTP Trunks (pinned MTPs)</td>
<td>[Ex: 24F EDGE8™ Trunk]</td>
</tr>
<tr>
<td></td>
<td>• 8, 16, 24, 32, 48, 72, 96F (Plenum &amp; LSZH), 144F (Plenum)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• OM3, OM4, SM</td>
<td></td>
</tr>
<tr>
<td>EDGE8™ Housings</td>
<td>• EDGE8™ HD Housings with the usability &amp; density of EDGE using 6-slot trays</td>
<td>[4U Housing]</td>
</tr>
<tr>
<td></td>
<td>• 6-slot trays also available individually for field retrofit applications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 1U, 2U, 4U</td>
<td></td>
</tr>
<tr>
<td>EDGE8™ Modules &amp; Panels</td>
<td>• 8-fiber MTP-LC Module &amp; Pigtail Module</td>
<td>[8F Module]</td>
</tr>
<tr>
<td></td>
<td>• 1, 2, 4-port MTP Adapter Panels</td>
<td>[8F Piqtail Module]</td>
</tr>
<tr>
<td></td>
<td>• OM3/OM4, SM</td>
<td>[4-port MTP Panel]</td>
</tr>
<tr>
<td>EDGE8™ Harness</td>
<td>• 8-fiber MTP-LC Harness</td>
<td>[8F Harness]</td>
</tr>
<tr>
<td></td>
<td>• Staggered &amp; Uniform length LC UniBoot Legs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• OM3, OM4, SM</td>
<td></td>
</tr>
<tr>
<td>EDGE8™ Jumpers</td>
<td>• 2-fiber UniBoot LC Jumper</td>
<td>[LC UniBoo Jumper]</td>
</tr>
<tr>
<td></td>
<td>• 8-fiber MTP Jumper</td>
<td>[8F Jumper]</td>
</tr>
<tr>
<td></td>
<td>• OM3, OM4, SM</td>
<td></td>
</tr>
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</table>
Defining the Cabling System
Base Type is Determined by Trunk Cable & Connector Types

<table>
<thead>
<tr>
<th>System</th>
<th>Trunk Cable</th>
<th>Connector</th>
<th>Breakout to Base-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base-2</td>
<td>Multiples of 6 or 12</td>
<td>LC Duplex</td>
<td>N/A</td>
</tr>
<tr>
<td>Base-8</td>
<td>Multiples of 8</td>
<td>8F MPO</td>
<td>Module</td>
</tr>
<tr>
<td>Base-12</td>
<td>Multiples of 12</td>
<td>12F MPO</td>
<td>Module</td>
</tr>
<tr>
<td>Base-24</td>
<td>Multiples of 24</td>
<td>24F MPO</td>
<td>Module</td>
</tr>
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                              • Port Breakouts  
                              • Integrated Port Tapping  
                              • High Fiber Count (HFC) Trunks                                           |
Fiber Utilization
Base-12 vs. Base-8

- Base-8 systems enable 100% fiber utilization for 8-fiber transceivers (SR4, PLR4, PSM4)
Fiber Utilization
Achieving 100% Utilization from 10G to 400G

10G
(Duplex)

40G-4x10G
100G-4x25G
200G-4x50G
400G-4x100G
(Parallel Breakout)

40/100G/
200G/ 400G
(Parallel)
## Base Type Comparison Across Transceiver Options

<table>
<thead>
<tr>
<th>Ethernet</th>
<th>Fibers</th>
<th>Available</th>
<th>Base-2</th>
<th>Base-8</th>
<th>Base-12</th>
<th>Base-24</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10G</td>
<td>2</td>
<td>Yes</td>
<td>⬜️</td>
<td>⬜️</td>
<td>⬜️</td>
<td>⬜️</td>
</tr>
<tr>
<td>40G</td>
<td>8</td>
<td>Yes</td>
<td>⬠️</td>
<td>⬜️</td>
<td>⬠️</td>
<td>⬠️</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Yes</td>
<td>⬜️</td>
<td>⬜️</td>
<td>⬜️</td>
<td>⬜️</td>
</tr>
<tr>
<td>100G</td>
<td>20</td>
<td>Yes</td>
<td>⬠️</td>
<td>⬠️</td>
<td>⬠️</td>
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</tr>
<tr>
<td></td>
<td>8</td>
<td>Yes</td>
<td>⬠️</td>
<td>⬜️</td>
<td>⬠️</td>
<td>⬠️</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Yes</td>
<td>⬜️</td>
<td>⬜️</td>
<td>⬜️</td>
<td>⬜️</td>
</tr>
<tr>
<td>200G</td>
<td>16</td>
<td>Yes</td>
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<td>⬜️</td>
<td>⬠️</td>
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<td>8</td>
<td>Yes</td>
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<td>⬜️</td>
<td>⬠️</td>
<td>⬠️</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Yes</td>
<td>⬜️</td>
<td>⬜️</td>
<td>⬜️</td>
<td>⬜️</td>
</tr>
<tr>
<td>400G</td>
<td>32</td>
<td>Future</td>
<td>⬠️</td>
<td>⬜️</td>
<td>⬠️</td>
<td>⬠️</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Yes</td>
<td>⬠️</td>
<td>⬜️</td>
<td>⬠️</td>
<td>⬠️</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Yes</td>
<td>⬠️</td>
<td>⬜️</td>
<td>⬠️</td>
<td>⬠️</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Yes</td>
<td>⬜️</td>
<td>⬜️</td>
<td>⬜️</td>
<td>⬜️</td>
</tr>
</tbody>
</table>

- ⬜️ = 100% Fiber Utilization and good port organization
- ⬠️ = Not Optimized
Port Mapping

- Base-8 systems allow for 8, 16, 32 and 64-port line cards to be cabled cleanly without having unused connectors
Parallel Optics Port Break-out Applications

Active vs. Passive

24 port 40GE QSFP Line Card
Core Network

2X48 port 10GE SFP+ Line Card
TOR / MOR / EDGE Switch
Parallel Optics Port Break-out Applications

The Economies of Port Breakout

- Over half of 40GbE QSFP ports shipped are being used to break-out to 4x10G
- Why operate a 40GbE port in a “break-out” configuration?
  - 2-3x the 10G density per blade
  - 50% less power per port
  - 30% cost savings per port
  - Switch migration path (do not repurchase 40G optics or cards)
- Works for Parallel Optic Only

<table>
<thead>
<tr>
<th>Qty</th>
<th>Qty</th>
<th>Total List</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 Port 10GbE (SFP+) Line card</td>
<td>1</td>
<td>$44,000</td>
</tr>
<tr>
<td>10GBASE-SR SFP Module</td>
<td>48</td>
<td>$47,760</td>
</tr>
<tr>
<td>Cost/10G port (total of 48)</td>
<td></td>
<td>$1912/port</td>
</tr>
<tr>
<td>24 Port 40GbE (QSFP) Line card</td>
<td>1</td>
<td>$55,000</td>
</tr>
<tr>
<td>QSFP 4x10GBASE-SR Transceiver, MPO, 300M</td>
<td>24</td>
<td>$71,880</td>
</tr>
<tr>
<td>Cost/10G port (total of 96)</td>
<td></td>
<td>$1322/port</td>
</tr>
</tbody>
</table>
## Integrated Port Tapping

<table>
<thead>
<tr>
<th>Main Distribution Area (MDA)</th>
<th>EDA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elec</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Con</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Tap Area</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Con</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Structured Cabling Area</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Con</strong></td>
<td><strong>Elec</strong></td>
</tr>
</tbody>
</table>

- **Channel Link**

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### Diagram Description

**Main Distribution Area (MDA)**
- **Elec**
- **Con**
- **Tap Area**
- **Con**
- **Structured Cabling Area**

**EDA**
- **Con**
- **Elec**

- **Channel Link**

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**Monitor Device**

**Jumper**

**Harness**
High Fiber Count (HFC) Trunks
Improve Density. Reduce Deployment Time. Save Cost

4400 total fibers using 370 x 12-fiber MTP-to-MTP Edge trunks
13,680 total fibers using 95 x 144-fiber MTP-to-MTP Edge trunks
16,128 total fibers using 56 x 288-fiber MTP-to-MTP Edge trunks
Take Away

Helping Customers to Maximize their Network Infra Assets

Optimization
- 100% Utilization of Fiber
- Best-in-Class Density
- Improved Link Performance

Scalable & Modular Components
- Seamless migration to 400G
- Optical Port Tapping Monitoring
- Risk Mitigation

Total Cost of Ownership
- Reduction in Inventory
- Rapid Deployment