The Impact of Emerging Data Rates on Layer One Fiber Cabling Infrastructures

Rick Dallmann
Senior Data Center Infrastructure Architect
CABLEExpress
36 Years of Experience

- CABLExpress is a manufacturer of custom-built structured cabling solutions focused on high-end data center, network and SAN environments
- RCDDs (Registered Communications Distribution Designer), DCDC, CDCD on staff
- Voting and contributing member of the TIA TR-42 board
- Subject matter expert presenters at AFCOM, BICSI, DatacenterDynamics (DCD), and FOSE conferences
- Expert structured connectivity data center design, spec and implementation according to TIA-942-A standards and IEEE 802.3 standards
- OEM and authorized solution provider for Brocade, Arista, HP and others
- ISO 9001:2008 process- and design-certified – qualification documented and verified by third party
Agenda

- Data Center Technology Trends
- The Optics and History
- Standards and Solutions
  - Ethernet (25/40/100/400 Gigabit)
  - Fiber Channel (16/32/64/128 Gigabit)
- Cabling Design Considerations and Challenges
  - Duplex/Serial
  - Parallel Optics
- Questions
The Need for Speed

- Rapid growth of server, network, and internet traffic
- Higher density requirements in the data center
- Low cost optical fiber Ethernet/SAN solutions
- Advances in technologies now allow the specification of the new 40/100/400G physical layer with reduced lane count and complexity... *Lower cost results!*
- 32/64/128 Gigabit Fiber Channel
Data Center Market Dynamics

Need for Higher Speed Interfaces

Bandwidth requirements for computing, core and storage networking require different data rates for next generation Ethernet & FC networks:
- 40 Gb/s Ethernet interface - Servers, high performance computing clusters, blade servers, storage area networks and network attached storage
- 100 Gb/s Ethernet interface - Core network switching, routing, and aggregation in data centers, internet exchanges and service provider peering points for high bandwidth applications such as video-on-demand
- >16G F Channel interface
  - *Base2 used throughout all applications for Fiber Channel infrastructure and devices. Each maintains backward compatibility with two previous generations
  - **Base10 commonly used for ISLs, core connections, and other high speed applications demanding maximum bandwidth

Source: IEEE P802.3ba Task Force
Data Center Trends: Data Rates

New Global Market Conditions/Challenges

• Newer network designs require more transmission media to enable scalable and higher density solutions

• Large Enterprise DCs are challenged to deal with significant transitions in the market to higher speed and longer reach channels

• Seamless infrastructure migration plans are necessary as data center port speeds are increasing
   (10Gb to 40Gb to 100Gb/s)(16Gb to 32Gb to 128Gb/s)
New Global Market Challenges

• Data center size continues to grow
1. Mega Data Centers will drive growth in market
• MMF/VCSEL solution will continue seeing pressure from competing
1. SMF/Long wavelength laser solutions
• VCSEL/MMF solutions offer several advantages worth preserving
1. Lowest energy consumption
2. Dust/debris immunity at connections (robust operation, MACs)
3. Support break-out via parallel optics (vs. WDM breakout)
4. Large installed base (>80% of DC fiber media)
• Benefits preserved for the bulk of 100G/128GFC/400G/512G channels by supporting 100m reach (even in break-out implementations)
  – using 4x parallel solutions

Source: BICSI
**The Optics**

**OFL (Overfilled Launch)**
- LEDs, not lasers
- Power distributed over 100% of the fiber core
- PRE 1 GIG Transceivers

**EMB (Effective Modal Bandwidth)**
- VCSELs
- Power distributed in a narrow region
- More accurate indication of performance in high-speed laser-based systems

Different VCELS fill a different set of modes in each fiber, which can affect pulse spreading.
Transceiver OEM Trends

- **Support of Installed Base**: Support for 16GFC, 32GFC, 40GbE, 100GbE, 128GFC and beyond on the existing installed MMF fiber plant.

- **Shortwave WDM (SWDM)**: The ability to multiplex multiple lanes onto a single fiber to reduce the fiber count and enable duplex-LC interfaces for 40GbE, 32GFC, 100GbE, 128GFC and beyond.

- **Lane rates > 25 Gb/s**: Developing and standardizing technology that enables multimode VCSELs to operate at 50 Gb/s and beyond, to enable future generations of both single-lane and multiple lane optical interfaces.

- **Wideband MMF**: Support for the definition and standardization of wideband multimode fiber to enable WDM transmission over links that are greater than 300m.

Source: Finisar
Next Generation Data Rates - Prepare Today, Avoid Upgrades Later

- **IEEE 802.3ba Standards**
  - OM3 glass support 40/100 gig speeds to 100 meters
  - OM4 glass support 40/100 gig speeds to 150 meters

- **IEEE 802.3bm Standards (Released 4-2015)**
  - 100GBase-SR
  - Transceiver speeds will jump from 10G per fiber to 25G
  - Duplex LC: Bi-Di and universal 40G Ethernet

- **IEEE 802.3bs Standards (In Committee 7-2015)**
  - 400GBase-SR; increase to 50G per fiber

- **Fiber Channel**
  - 32/64/128 Gigabit Fiber Channel
Fibre Channel Roadmap

1ₐGFC  2ₐGFC  4ₐGFC  8ₐGFC  16ₐGFC  32/128ₐGFC

The Optics

Non-standards based transceivers

• Bidi Technology over two fiber SFP

• “Universal” Optics – For SM & Legacy Cable Plant

• Parallel Singlemode Optics - 40GBASE-PLR4

• Embedded Optics Multispeed Ports
TIA TR-42.11 Optical Fiber Systems (Wide Band Multi-Mode)

- Support 4 or more wavelengths
- Possibly transmit 40G or 100G over a pair of fibers instead of four or ten pairs today

Bi-Directional Duplex SFPs

- BiDi – short for bidirectional
- 40G Ethernet over two fibers
- Allows use of existing LC infrastructure
- Uses Wavelength Division Multiplexing – 2 x 20 Gbps signals
Universal Optics - 40GBase-UNIV

- Addresses customer concerns around the reduced distances with 40GBASE-SR4
- Migrations from existing 10 to 40GbE networking without requiring a redesign or expansion of the fiber network
- Supports operation over a full 150 m of OM3 or OM4
- Can be used for up to 500 m and interconnected with both 40GBASE-LR4 and 40GBASE-LRL4
Parallel Single-Mode Optics - 40GBase-PLR4

- Parallel LR4 (PLRL4) supports distances compatible with 10GBASE-LR, (10km on SM fiber). ‘Lite’ Parallel LR4 (PLRL4) supports distances compatible with 10GBASE-LRL, (1km on SM fiber)
- Both modules can support 4 individual 10G-LR connections using a 4x10G mode and fiber breakout cables or cassettes for single mode fiber
- PLR4 and PLRL4 use an MTP-12 connector, and require an APC (Angle polished connector) single-mode MTP-12 cable
Embedded Optics Multi-Speed Ports (SR12)

12 Port MXP Triple-speed line card for Arista 7500E Series switch
Channel mapping for 24f MXP triple-speed port
Future 25G, 50G, and 100G Optics

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>No. of Lane Pairs</th>
<th>Lane Rate</th>
<th>SW code (MMF)</th>
<th>LW code (SMF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 Gb/s</td>
<td>1, 1</td>
<td>25 Gb/s</td>
<td>SR</td>
<td>LR</td>
</tr>
<tr>
<td>50 (＆40) Gb/s</td>
<td>1, 1</td>
<td>50 (＆40) Gb/s</td>
<td>SR</td>
<td>LR</td>
</tr>
<tr>
<td>100 Gb/s</td>
<td>2, 1</td>
<td>50 Gb/s</td>
<td>SR2</td>
<td>PSM2</td>
</tr>
<tr>
<td>100 Gb/s</td>
<td>1, 2</td>
<td>50 Gb/s</td>
<td>SWDM2</td>
<td>CWDM2</td>
</tr>
<tr>
<td>100 Gb/s</td>
<td>1, 1</td>
<td>100 Gb/s</td>
<td>FR</td>
<td></td>
</tr>
</tbody>
</table>

IEEE standards in **BOLD**: all other in *ITALICS* are proprietary

*Bicsi*
40G vs 50G Ethernet Deployment

- 40G Ethernet is now deployed in volume supported by 4x10G Parallel & WDM Transceivers
- Limited 40G Serial Transceiver deployment
- Limited 40G deployment using proprietary 2x20G ("BiDi")
- Future 40G & 50G Serial technology will be common
  40G Transceivers will likely be dual-rate 40/50G Transceivers
- 40G & 50G Serial Transceivers will have same cost:
  i.e. 50G will have 25% more bandwidth at same cost as 40G
- 50G Ethernet volume will quickly surpass 40G Ethernet volume because 25% more bandwidth will be "free"
- Total 40G Ethernet volume will plateau and decline
## Existing 40G & 100G Optics

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>No. of Lane Pairs</th>
<th>Lane Rate</th>
<th>SW code</th>
<th>LW code</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 Gb/s</td>
<td>4 Fiber 1</td>
<td>10 Gb/s</td>
<td>SR4</td>
<td>PSM4</td>
</tr>
<tr>
<td>40 Gb/s</td>
<td>1 Fiber 4</td>
<td>10 Gb/s</td>
<td>SWDM4</td>
<td>LR4</td>
</tr>
<tr>
<td>40 Gb/s</td>
<td>1 Fiber 1</td>
<td>40 Gb/s</td>
<td>FR</td>
<td></td>
</tr>
<tr>
<td>100 Gb/s</td>
<td>10 Fiber 1</td>
<td>10 Gb/s</td>
<td>SR10</td>
<td></td>
</tr>
<tr>
<td>100 Gb/s</td>
<td>4 Fiber 1</td>
<td>25 Gb/s</td>
<td>SR4</td>
<td>PSM4</td>
</tr>
<tr>
<td>100 Gb/s</td>
<td>1 Fiber 4</td>
<td>25 Gb/s</td>
<td>SWDM4</td>
<td>LR4 CWDM4</td>
</tr>
</tbody>
</table>

IEEE standards in **BOLD**: all other in *ITALICS* are proprietary.
# Future 200G and 400G Optics

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>No. of Lane Pairs</th>
<th>Lane Rate</th>
<th>SW code</th>
<th>LW code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gb/s</td>
<td>Fiber</td>
<td>λ</td>
<td>Gb/s</td>
<td>(MMF)</td>
</tr>
<tr>
<td>200</td>
<td>4</td>
<td>1</td>
<td>50</td>
<td><strong>SR4</strong></td>
</tr>
<tr>
<td>200</td>
<td>1</td>
<td>4</td>
<td>50</td>
<td><strong>SWDM4</strong></td>
</tr>
<tr>
<td>400</td>
<td>16</td>
<td>1</td>
<td>25</td>
<td><strong>SR16</strong></td>
</tr>
<tr>
<td>400</td>
<td>4</td>
<td>2</td>
<td>50</td>
<td><strong>SR4.2</strong></td>
</tr>
<tr>
<td>400</td>
<td>1</td>
<td>8</td>
<td>50</td>
<td><strong>SWDM8</strong></td>
</tr>
<tr>
<td>400</td>
<td>4</td>
<td>1</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>1</td>
<td>4</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

IEEE standards in **BOLD**: all other in *ITALICS* are proprietary
Take-Aways

• Standards Implementation of transceivers – multivendor support and interoperability for non-standards-based PMDs

• Wideband fiber, WDM, Bidi etc. are enablers of “customer-friendly” solutions that extend the lifetime of existing cable plant

• Breakout solutions for transceivers (BASE-4 ports) are most important for network scale in flat architectures (for both LAN & SAN)

• Network-ready status of cable plant for higher speeds and dark fiber can be mitigated by transceiver selection and the choice of cable plant
What happened to the 40G Ethernet standard?

- 100G Ethernet was first specified for core networking applications using forward looking 25G technology.
- 40G Ethernet was then added for cost sensitive Switch and Server applications using 4 lanes of existing 10G technology.
- Single lane 25G technology became more cost effective than 4 lanes of 10G technology.
- Single lane 50G technology is now in development and well enable low cost 50GbE offering more bandwidth than 40GbE.
Cabling for 40G and 100G Considerations

- Migration of existing cabling infrastructure or new install?

- How will DC infrastructure look or perform?
  - Direct Connect ISLs
  - Point to Point Cabling
  - Structured Cabling; Port replication
## Optical Infrastructure

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>1G</th>
<th>10G</th>
<th>40G</th>
<th>100G (10-lanes)</th>
<th>100G (4-lanes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTP-MTP backbone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LC-LC Backbone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IEEE STD</td>
<td>1000BASE-SX</td>
<td>1000BASE-LX</td>
<td>10GBASE-SR4</td>
<td>100GBASE-SR10</td>
<td>100GBASE-SR4</td>
</tr>
<tr>
<td>Transceiver Connector Type</td>
<td>LC</td>
<td>LC</td>
<td>12F MPO/MTP</td>
<td>24F MPO/MTP</td>
<td>12F MPO/MTP</td>
</tr>
</tbody>
</table>

![Star] = Requires **NO** Cabling Upgrade  
![Red] = Requires adding 12/24 MTP® trunk cabling
Optical Infrastructure

- 40/100/400G will operate over both duplex and parallel optics

- The majority of 40/100G initial implementations will be 4x10G or 4x25G breakouts
  - Fiber Channel data rates of 64G and 128G will also be supported by 4x16G and 4x32G breakouts

- **MTP®-based cabling** is the **most** effective way to future-proof structured cabling for future technologies and implementations
Cabling Methodologies

Point-to-Point...

*The wrong way*...

Let’s look...
Point-to-Point: No Structure
History has shown (hundreds of visited data centers) that loss is based on the design, installation, and product choices.
Loss that needs to be avoided

Let’s Examine
The Results
## dB Link Loss for Transmission

### Loss budget... Scary?

<table>
<thead>
<tr>
<th>Year</th>
<th>Application</th>
<th>Data Rate</th>
<th>Standard</th>
<th>Loss Budget (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>Ethernet</td>
<td>10 Mbps</td>
<td>IEEE 802.3</td>
<td>12.5</td>
</tr>
<tr>
<td>1991</td>
<td>Fast Ethernet</td>
<td>100 Mbps</td>
<td>IEEE 802.3</td>
<td>11.0</td>
</tr>
<tr>
<td>1998</td>
<td>Short Wavelength Fast Ethernet</td>
<td>10/100 Mbps</td>
<td>TIA/EIA-785</td>
<td>4.0</td>
</tr>
<tr>
<td>2000</td>
<td>1G Ethernet</td>
<td>1,000 Mbps</td>
<td>IEEE 802.3z</td>
<td>3.56</td>
</tr>
<tr>
<td>2004</td>
<td>8&amp;10G FC &amp; 10G Ethernet</td>
<td>10,000 Mbps</td>
<td>IEEE 802.3ae</td>
<td>2.60</td>
</tr>
<tr>
<td>2010</td>
<td>16G FC &amp; 40G Ethernet</td>
<td>40,000 Mbps</td>
<td>IEEE 802.3ba</td>
<td>1.9</td>
</tr>
<tr>
<td>2010</td>
<td>100G Ethernet</td>
<td>100,000 Mbps</td>
<td>IEEE 802.3ba</td>
<td>1.5</td>
</tr>
</tbody>
</table>
dB Link Loss for Transmission

- The optical loss budget, a/k/a “channel insertion loss,” or “power budget” of the link, is a measure of signal power loss measured in decibels (dB).
- Link loss is a combination of the fiber attenuation related to the distance of the link and the connectors or splices in the link.

**Critical! Understanding and “budgeting” potential link loss in a data center network is important:**

For 16G Fiber Channel and IEEE802.3ba and bm

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>Distance Spec</th>
<th>Channel Loss</th>
<th>Connector Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>OM3</td>
<td>100 meters</td>
<td>1.9dB</td>
<td>1.5dB</td>
</tr>
<tr>
<td>OM4</td>
<td>150 meters</td>
<td>1.5dB</td>
<td>1.0dB</td>
</tr>
</tbody>
</table>
# IEEE 802.3bm - OM3 versus OM4 Glass

## Standard Specified Distances

<table>
<thead>
<tr>
<th></th>
<th>850 nm Ethernet Distance (m)</th>
<th>850 nm Fibre Channel Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10G</td>
<td>40G</td>
</tr>
<tr>
<td>OM3</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>OM4</td>
<td>400 / 550*</td>
<td>150</td>
</tr>
</tbody>
</table>

*Engineered Length  ** 802.3ba10G/lane  *** 802.3bm 25G/lane
IEEE 802.3bm - OM3 versus OM4 Glass

Migration to OM4

Thoughts on how to reduce cost

- Limit link distance to bare minimum requirement
  - Focus specifications on OM4 fiber
- Include simple EDC in the receiver to reduce the requirements on the transmitter
  - Single FFE/DFE filter could significantly reduce transmitter requirements

Fibre Channel (32G) and Ethernet (100G) utilized OM4 to define distance objectives

Transmission and Cable Standards recommend OM4

Bicsi®
In 2005, Infrastructure Standards for Data Centers...

**TIA-942-A**

- Site and space layouts
- Tiered reliability
- Environmental considerations
- Cabling infrastructure
TIA-942: Distributed Data Center Topology

Entrance Room
  - Analogy: “Entrance Facility”

Main Distribution Area (MDA)
  - Analogy: “Equipment Room”

Horizontal Distribution Area (HDA)
  - Analogy: “Telecom Room”

Zone Distribution Area (ZDA)
  - Analogy: “Consolidation Point”

Equipment Distribution Area (EDA)
  - Analogy: “Work Area”
  - Tier 3 Data Center!!!
Leaf and Spine

Source: Cisco
TIA-942: Distributed Data Center Topology
Interconnect dB Loss

The Industry Standard
EIA/TIA 568-C.3

LC  **0.5dB/mated pair**
SC  **0.5dB/mated pair**
MTP® **0.75dB/mated pair**
Proper Product Selection is Key

- MTP® cassette modules
- MTP® conversion modules
- Various density enclosures
- MTP®-MTP® multi-fiber trunks
- MTP® to LC conversion harness
Proper Product Selection Is Key

Port Replication

MTP* to LC conversion harness

Bicsi
Loss and Attenuation Performance

Standard Product : Max/Mated Pair

• LC 0.15dB/mated pair
• MPO/MTP®- 12F 0.20db/mated pair
• MPO/MTP®- 24F 0.35db/mated pair
Using QSFP-40G Universal Transceiver

Cablexpress Skinny Trunk 24f Harness; (MTP 24fiber) to (LC 24fiber)

OR

Cablexpress Skinny Trunk 12f Harness; (MTP 12fiber) to (LC 12fiber)

Cablexpress Skinny Trunk 24f to 144 FIBER Trunk; (MTP 24fiber) to (MTP 24fiber)

Cablexpress Skinny Trunk 12f to 144 FIBER Trunk; (MTP 12fiber) to (MTP 12fiber)

Arista 7500E-series

Arista 7500E-series

10G Fabric Inter-switch Links

Cablexpress Skinny Trunk 24f Jumper; (MTP 24fiber) to (MTP 24fiber) FEMALE OMS/OMF Trace

Arista 7500E-series

Arista 7500E-series

40G Fabric Inter-switch Links

Cablexpress Skinny Trunk 12f Jumper; (MTP 12fiber) to (LC 12fiber)

Cablexpress Skinny Trunk 24f Jumper; (MTP 24fiber) to (LC 24fiber)

Arista 7150-series

Arista 7150-series

100G Inter-switch Links

Direct Connect Cabling Option

Cablexpress Skinny Trunk 24f Jumper; (MTP 24fiber) to (MTP 24fiber)

Cablexpress Skinny Trunk 12f Jumper; (MTP 12fiber) to (LC 12fiber)

Arista 7500E-series

Arista 7500E-series

40G Fabric Inter-switch Links

Cablexpress Skinny Trunk 24f Harness; (MTP 24fiber) to (12 Duplex LCs)

Cablexpress Skinny Trunk 12f Harness; (MTP 12fiber) to (12 Duplex LCs)

Arista 7150-series

Arista 7150-series

10G Fabric Inter-switch Links

Cablexpress LC-MTP Cassette/Patch Panel

Arista 7500E-series

Arista 7500E-series

Bicsi
120G to 10G Module
Adapts the 24-port MTP® to 12 LC connectors at 10G each

- Enables the programmable 120G MXP port to be converted into (12) standards-based 10GBASE-SR LC connectors when using SR or SRL optics over multi-mode OM4 fiber infrastructure
- Backwards compatible with existing hardware
- In compliance with TIA-942 standard design
- Better utilization of rack space
- Industry leading mated pair losses allows structured cabling options
Infrastructure Design

CABExpress
Skinny Vanck
Harness
MTP-MTP A port
direct per
director

SAN A(4) 64 port Cards

SAN B(4) 64 port Cards

MTP-MTP A Filter
(2-1 PER 100)
A & B Ports

(6) 12 Port
2 MTP-2x12
MTP-LC
A & B Ports

CABExpress
Skinny Vanck
Harness
MTP-MTP A port
direct per
director

FAB A
RESERVED Space

FAB B
RESERVED Space

MTP-MTP A Filter
(2-1 PER 100)
A & B Ports

(6) 12 Port
2 MTP-2x12
MTP-LC
A & B Ports

(6) 12 Port
2 MTP-2x12
MTP-LC
A & B Ports

CABExpress
Skinny Vanck
Harness
MTP-MTP A port
direct per
director

Cabinets 2 feet

80 feet

190 feet

Note: Dimensions and distances are approximate and should be verified for specific installation requirements.
Thank You!

Rick Dallmann
• Senior Data Center Infrastructure Architect

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• 315-430-9469