Data Center Cabling Technology and Trends

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Data Center Applications Engineer
Agenda: Data Center Cabling

- Market and Technology Trends
- Standards Impact on Structured Cabling
- Future Cabling Considerations
- Structured Cabling Best Practices
- Q&A
Data Centers
Market and Technology Trends
## Data Centers – 2007 Typical Installations

<table>
<thead>
<tr>
<th>Facility</th>
<th>Purpose</th>
<th>Typical Data Rates</th>
<th>Typical # of Racks</th>
<th>Typical Business</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR</td>
<td>Cross-Connections &amp; Switches</td>
<td>10/100 Mbps</td>
<td>&lt; 5</td>
<td>All</td>
</tr>
<tr>
<td>Small DC (Reduced)</td>
<td>Servers, CPU, UPS, Switches</td>
<td>1 Gbps</td>
<td>5 - 20</td>
<td>Small Financial Hospitals</td>
</tr>
<tr>
<td>Medium DC (Basic)</td>
<td>Servers, CPU, UPS, POE, Local SAN, Switches</td>
<td>1 - 10 Gbps</td>
<td>20 - 100</td>
<td>Banks Drug Co. Universities</td>
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<tr>
<td>Large DC (Distributed)</td>
<td>Servers, CPU, UPS, POE, Local &amp; Remote SANs, Switches, Asset Management</td>
<td>1 - 10 Gbps</td>
<td>&gt; 100</td>
<td>Large Financial Retail Insurance Large Research Labs</td>
</tr>
</tbody>
</table>
Data Center Cabling Mix

Data Center Media Mix

- Copper: 20%
- Fiber: 80%

Source: IDC and IEEE Task Group

SAN Media Mix

- Copper: 10%
- Fiber: 90%
Green Data Centers: Energy Efficient Ethernet (EEE)

- IEEE 802.3az Energy Efficient Ethernet Task Group
  - Established September 2007
  - Defining mechanism to reduce power consumption in Ethernet networks
  - Copper physical layers addressed:
    - 1000BASE-TX, 1000BASE-T; 10GBASE-T, KR, KX4
  - $450 million per year potential savings in energy costs
  - Rate restoration may be a few milliseconds
  - Requires minimum of CAT 6 cabling
  - Proposal to extend to fiber variants
Higher Speed Market Drivers

Higher Speed Ethernet Market Adopters

- Campus Backbones
- Corporate Backbones
- Corporate Data Centers
- ISP Aggregation
- High Performance Computing (HPC)
- Broadband Aggregation
- Internet eXchanges
- ISP Backbones
- Content Providers

06 07 08 09 10 11 12 13 14 15 16 17

Year 20—
High Performance Computing (HPC) - Timeline

- **2007**
  - Copper cabling favored at <10m
  - 850nm VCSELs favored for links greater than 10m
  - Commercial server systems follow HPC after ~3 yrs.
  - 20G InfiniBand
- **2008**
  - 40G InfiniBand for server-switch links
- **2009**
  - 100G required for switch-switch links
- **2011-2013**
  - 40G matches CPU/system bus
HPC InfiniBand

Switched fabric communications link primarily used in high-performance computing

<table>
<thead>
<tr>
<th></th>
<th>Single</th>
<th>Double</th>
<th>Quad</th>
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<tbody>
<tr>
<td>1X</td>
<td>2.5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>4X</td>
<td>10</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>12X</td>
<td>30</td>
<td>60</td>
<td>120</td>
</tr>
</tbody>
</table>
Server Trends

- Time after ratification to reach 1,000,000 ports
  - Fast Ethernet: 1 year
  - Gigabit: 2 years
  - 10G: after 6 years

- Optical Ethernet standards are out of step with broad server market requirements

- Premature use of higher speed both difficult & costly
Server Trends: Rationale for 40G Ethernet

- High cost relegates 10G primarily to aggregation
- Faster Ethernet taking longer to reach same penetration
  - Fast Ethernet: 5 years to 60% market penetration
  - Gigabit Ethernet: 9 years to 60% market penetration
  - 10G: may take over 10 years to 60% market penetration
- 40G Rationale
  - Better match to speed of next generation servers
    - PCIe
    - Significantly less expensive than 100G
    - Technology already developed
      - InfiniBand
      - SONET
Server Trends: Ethernet Ports

x86 Servers by Ethernet Connection Speed (40G and 100G)

- 10 year transition for 1G Ethernet
- 5 years for 10GBE
- 5 years for 40GBE

Source: Intel & Broadcom (April 2007)
Comparison of Gigabit Roadmaps

Source: LAN Technologies Consulting
Server Form Factors & Physical Networking

**Pedestal Server**
- Less than 100m to switch across DC
- Copper or fiber cabling
- Base-T or Base-SR/LR

**Rack Server**
- Less than 15m to switch at rack top or in row
- Copper cabling
- Base-CX4 or Base-T

**Blade Server**
- Less than 30 inches to switch in back of chassis
- Copper PCB
- Base-KX4 or Base-KR
Active Fiber Optic Cables (CMOS PHOTONICS)

• **Features & Benefits**
  – 4-Channel full-duplex
  – Multirate: 1.0Gb/s – 10.5Gb/s (per channel)
  – 1550nm wavelength solution
  – Up to 300 meters reach
  – High density QSFP form-factor

• **Impact on Market**
  – Direct challenge to copper & MMF
  – Demand for SM multi-fiber
  – More design freedom for data centers

Luxtera: Blazer LUXX5010
Higher Speed Ethernet

- **IEEE 802.3ba Higher Speed Ethernet Task Group**
  - Objectives
    - Support a BER of $> 10^{-12}$
    - Support 40G:
      - At least 100m on OM3 LOMF
      - At least 10m on copper cabling
      - At least 1m over a backplane
    - Support 100G:
      - At least 40km on SMF
      - At least 10km on SMF
      - At least 100m on OM3 LOMF
      - At least 10m on copper cabling
Higher Speed Ethernet Development Plan

- **CFI**
- **TF Review**
- **WG Ballot**
- **Sponsor Ballot**
- **Standard**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>2006</td>
<td>Study Group</td>
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<tr>
<td>2007</td>
<td>CFI approved</td>
</tr>
<tr>
<td>2008</td>
<td>Task Force approved</td>
</tr>
<tr>
<td>2009</td>
<td>D1.0 Baseline Proposal</td>
</tr>
<tr>
<td>2009</td>
<td>D2.0 Last Feature</td>
</tr>
<tr>
<td>2010</td>
<td>D3.0 Last Technical Change</td>
</tr>
</tbody>
</table>

BECAUSE YOUR BUSINESS RUNS THROUGH US
Higher Speed Ethernet Fiber Data Center Trends

- 850nm 12x10G devices may support 100-300m
- Utilization of 12-fiber cable & MPO connectors an important factor for technical and economic feasibility of 100G MMF
- Pre-terminated OM3 fiber cable is cost-effective
- SMF solutions are more costly (due to optics)

<table>
<thead>
<tr>
<th>Data Center Lengths (m)</th>
<th>Percentage of ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;150</td>
<td>90</td>
</tr>
<tr>
<td>&lt;200</td>
<td>96</td>
</tr>
<tr>
<td>&lt;300</td>
<td>100</td>
</tr>
</tbody>
</table>
High-Speed Optics Trends - Cost

- 10x speed/3x cost model broken at 10G
- Deployment of 10G in backbones and data centers just starting
- >10G lasers rare & prohibitively expensive
- 100G serial optics could be 10x speed @ 13x cost
- >10G links feasible with parallel optics today
- 100G = 10x10G WDM over a two-fiber link
- 100G = 10x10G arrays over 20-fiber link
Cabling for 40 & 100G

- Transmission method
  - Impact on number of fiber strands
  - Connector types
- OM3 fiber required for 100 meters
- What happened to OM2 fiber?
- Single mode versus multi-mode
- Preparing for 40G/100G today
Single Mode versus Multi-mode Fiber

- **Single Mode CWDM Systems**
  - Pro: Low cable cost
  - Con: High transceiver cost & development required

- **OM3 multi-mode parallel systems**
  - Pro: Low cost, readily available parts
  - Con: High cable cost and limited distance

- Traditionally, cost of opto-electronics drive cost comparisons between MM and SM

- Preliminary cost analysis for MM suggests lower cost up to ~200 meters
Transmission Methods

- SM option will likely use CWDM
  - 4 lasers (25-Gig) combined on to one fiber
  - 1 fiber Tx, 1 fiber Rx
- 40G lasers are too expensive
- 100G lasers do not exist outside of the lab and will be too expensive
- Low water peak SM fiber better suited to CWDM
Low/Zero Water Peak Fiber

Conventional SM Fiber

Lower loss

Coarse Wavelength Division Multiplexing (20 nm spacing ITU-T G.694.2)

Enables Full-Spectrum CWDM
Transmission Methods

12 Channel Duplex
100 Gb/s 850 VCSEL Array

- MM 1G/10G uses serial transmission scheme
  - One Tx, one Rx fiber
- 40G/100G to use parallel transmission
  - 10 fibers at 10G ea. Tx
  - 10 fibers at 10G ea. Rx
  - 12-fiber MTP/MPO connector
  - 24 fiber MM cable
- Possible 12F solution using CWDM (two wavelengths per fiber)
Parallel Optics Specifications – What happened to OM2?

• Parallel optics manufacturing process
  – Mounting 12 VCSELs on wafer difficult

• Transceiver manufacturers want a relaxed spec
  – Spectral width
  – Encircled flux

• Result may be increased DMD
  – Higher DMD results in shorter distance
  – OM2 distance with new VCSELs too short
  – OM3 becomes minimum bandwidth required
OM4 Fiber (OM3+)

- 4500 MHz·km targeted bandwidth
  - 500 meters at 10G
  - Targeted distance of over 200 meters for 40/100G
  - 4900 MHz·km current maximum bandwidth fiber available today
    - GIGAlite 10XB – 600m at 10G
    - Best shot at longer distance 40G/100G
Preparing for 40G/100G

• Specify minimum of OM3 fiber
  – OM4 (4500 MHz minimum) as an option
  – Add SM (low water peak) to cables
• Design data centers for 100 meters max lengths
• Be aware of higher fiber count requirements
  – 2 fibers per link becomes 24 fibers
• MTO/MTP connectors will likely become standard interfaces
Cable OD Important

- Smaller OD cables will become important
- Ribbon cables big and bulky

New 48F MDP Cable (0.231” OD)
24F (0.189” OD)

48F Stacked Ribbon Cable (0.520” OD)

48F LTP Cable (0.370” OD)
Storage Area Network: Fibre Channel

Fibre Channel Roadmap
Specification and Market Availability

Striped – FC-Base10 for ISLs Only
Solid – FC-Base2 for all end devices

Source: Fibre Channel Industry Association (FCIA)
The Future for Copper

- IEEE work just starting on 40G copper
- Preliminary modeling
  - Berk-Tek and Penn State University
  - Transceiver manufacturers
- Possible to look at UTP/FTP technology and draw reasonable conclusions about copper roadmap
Copper Cabling Technology

- Cabling design focused on minimizing noise susceptibility
  - Maximize signal strength
  - Decrease noise
- Cables can reduce noise
  - Twist rate, insulation, separation, precision reduce internal noise
  - Consistency and precision of manufacturing process and shielding can reduce external noise
Noise Susceptibility: Internal Crosstalk

- Internal noise is crosstalk from one pair to an adjacent pair
  - NEXT, FEXT, ELFEXT, PSNEXT, PSELFEXT
- Higher application speed are more susceptible to noise
- Gigabit and 10-Gig Ethernet use sophisticated internal noise cancellation techniques
- Can internal noise at 40G be reduced enough for UTP cable to work?
Noise Susceptibility: External Noise Sources

- Electromagnetic interference (EMI)
  - Narrow spikes of voltage
  - Generated by copy machines, air conditioning units, elevators, etc.

- Radio Frequency Interference (RFI)
  - Conflicting frequencies with Ethernet (60-400 MHz)

- Alien crosstalk
  - Unwanted emissions from cable to cable in a bundle
Noise Susceptibility: Cable Balance

- Precise manufacturing of the pairs will allow a cable to absorb some external noise
  - Concentricity of conductors
  - Even application of dielectric material
  - Consistent twist pattern
- Measured as LCL, ELTCL (cable balance)
- Efficient at reducing EMI and RFI to acceptable levels
Noise Susceptibility: External Noise

- Two options for reducing external noise
  - Shielding
  - Spacing
Noise Susceptibility: Alien Crosstalk

• FTP shows more margin over TIA spec than 6A, especially at higher frequencies.
Shielded Cable Designs

- Two approved versions
  - F/UTP or FTP (Class E)
    - IEEE requirements
    - TIA requirements
      - 6AFTP
  - Category 7 (Class F)
    - ISO 11801 European
    - Individually shielded pairs with an overall
Key Points for UTP

• UTP cable – signal strength versus noise
  – External and internal
  – The higher the application speed, the less tolerance for noise
  – Internal noise can be cancelled to acceptable levels
  – External noise a major design hurdle

• Spacing and shielding have been used to push UTP cable to 100m at 10G
## Copper Cabling

### Copper Cable Types

<table>
<thead>
<tr>
<th>Cable Type:</th>
<th>Category 5e</th>
<th>Category 6</th>
<th>Category 6FTP</th>
<th>Category 6A</th>
<th>Category 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWG size</td>
<td>24</td>
<td>23</td>
<td>23</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Shielding</td>
<td>no</td>
<td>no</td>
<td>yes, overall</td>
<td>no</td>
<td>yes, each pair plus overall</td>
</tr>
<tr>
<td>Frequency Rating</td>
<td>100 MHz</td>
<td>250 MHz</td>
<td>500 MHz</td>
<td>500 MHz</td>
<td>600 MHz</td>
</tr>
<tr>
<td>Ability to reduce internal noise</td>
<td>fair</td>
<td>good</td>
<td>good</td>
<td>high</td>
<td>very high</td>
</tr>
<tr>
<td>Ability to reduce external noise</td>
<td>low</td>
<td>fair</td>
<td>very high</td>
<td>high</td>
<td>very high</td>
</tr>
<tr>
<td>1 GbE Transmission distance (m)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>10GbE Transmission distance (m)</td>
<td>n/a</td>
<td>55M if criteria met</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
The future for outlets

- 4 Pairs on top
  - 250 MHz

- 8 top contacts
  - 100% RJ45 compatible

- 4 new contacts
  - For >600MHz

- 2 Pairs on top
  - 600 MHz

- 2 Pairs on bottom

Switch mechanism
- Only 8 contacts at a time
Data Center Cabling Best Practices
Data Center Best Practices

- Planning
- Cable Routing

Source: The Uptime Institute
Data Center Best Practices

Planning

- Determine cooling capacity and heat load up front
- Raised floor with hot and cold aisles to maximize cooling
- Monitor heat load
Data Center Best Practices

Cable Routing

- Minimize overhead cable routing in “hot aisles”
- Give 10% more headroom for IL than the requirement at 68°F in case of excess temperature rise
  - Temperatures measured at up to 104°F in some data centers
- Bundles should not impede air flow

Product Heat Density Trend Chart
Data Center Cooling and Cable Layout

CEILING

RAISED FLOOR

CABLE TRAYS or LADDER RACK

CABLE TRAYS or LADDER RACK

CABLE TRAYS or LADDER RACK

3’ - 4’

Front

Rear

Cabinet or Rack

Cabinet or Rack

Cabinet or Rack

CABLE TRAYS or LADDER RACK

PERFED TILES

PERFED TILES

POWER CABLES

POWER CABLES
Energy Efficiency
Cabling Best Practices

- Hot aisle/cold aisle arrangement
- Reduce cable congestion from under the raised floor to improve cold air movement
- Improve airflow with innovative rack designs
- Use thinner cables to reduce congestion
- Use blanking panels for open rack spaces
- Use occupancy sensor lighting
- Make sure static pressure in raised floor is adequate
Data Center Cabling per TIA-942

- **Backbone subsystem (fiber)**
  - Backbone cables
  - Main cross-connects
  - Horizontal cross-connects
  - Mechanical terminations
  - Patch cords

- **Horizontal subsystem (fiber or copper)**
  - Horizontal cables
  - Mechanical terminations
  - Patch cords
  - Zone outlet or consolidation point (optional)
Data Center Cabling per TIA-942

- 100-ohm twisted-pair copper cable
  - Category 5e
  - Category 6 or above - recommended
- Multi-mode fiber optic cable
  - 62.5/125 µm or 50/125 µm
  - 50/125 µm 850 nm laser optimized multimode fiber - recommended
- Single mode optical fiber cable
- 75-ohm coaxial cable
  - Type 734 & 735 cable
  - Type T1.404 coaxial connector
Cassette-Based Optical Cabling System

Main Distribution Area (MDA)
- Cable Management Rack
- Rack Mount Patch Fiber Cabinet
- Duplex Jumper Cable 50μm, LOMF
- Optical Cassette, 1U 50μm, LOMF
- Multi-fiber backbone cable
- Ribbon Cable with 50μm, LOMF

Horizontal Distribution Area (HDA)
- Cable Management Rack
- Optical Cassette, 2U 50μm, LOMF
- Rack Mount Patch Fiber Cabinet
- Duplex Jumper Cable 50μm, LOMF

Data Center Cabling Technology and Market Trends
Pre-Terminated Trunk Cable Solution

- 2 to 432 fiber cables
- Factory installed connectors
- Extend from the rear of an adapter panel to rear of another adapter panel in another rack/cabinet
New Micro Data Center Plenum Fiber Cable

- Developed specifically for the data center
- Optimized for use in pre-terminated assemblies
- Easy to install, easy to terminate
- 50% smaller than ribbon cables
- No preferential bending

New 48F MDP Cable (0.231” OD)
48F Stacked Ribbon Cable (0.520” OD)
48F LTP Cable (0.370” OD)
Copper Cabling Options

- **Category 6 (UTP)**
  - Vulnerable to alien crosstalk, thus limited to 55m max.
  - Must test compliance to 10GBASE-T
  - May require additional mitigation

- **Augmented Category 6 (UTP)**
  - Supports 100-meter 10GBASE-T operation
  - Addresses alien crosstalk by design
  - Standards completed and published

- **Shielded Category 6 (FTP)**
  - Overall tape shield – noise immunity
  - Supports 100-meter 10GBASE-T operation
  - Greater utilization in Europe
  - Installation cost premium over Cat. 6 UTP
Reducing Copper Cabling ODs

- **Current Product ODs**
  - LANmark 10G2 CMP = .300”
    - (Reduced from .350” Oct 1, 2007)
  - LANmark FTP-6 CMP = .290”
  - LANmark 6 = .190”
    - (Reduced from .220 June 1, 2006)
    - (Comparable to 5e @ .165”)

- **New Products**
  - LANmark FTP-6 CMP ≈ .245” (April)
    - Removing Filler
  - New 500MHz FTP ≈ .265” (March)
Pre-Terminated Copper Cabling

- Quick plug-in with modularity
  - Patch panel to patch panel
  - Patch panel to active blades
- Options customized for specific data center needs
  - Plug and play cassettes, plugs, jacks or un-terminated
- Minimizes installation and test times
Data Center Market and Technology Trends

Questions?