Ethernet 102: The Physical Layer of Ethernet

Scott Kipp
President of the Ethernet Alliance (Brocade)

Frank Yang
Marketing Chair, Next Generation Cabling Subcommittee (CommScope)

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The Presenters

Scott G. Kipp
- President of the Ethernet Alliance
- Chair of the QSFP MSA and 10X10 MSA
- Officer of many Fibre Channel standards and IETF RFCs
- Senior Technologist at Brocade

Frank Yang
- Marketing Chair of Next Generation Ethernet Cabling
- Technical Marketing Manager at CommScope, Inc.
THE VIEWS WE ARE EXPRESSING IN THIS PRESENTATION ARE OUR OWN PERSONAL VIEWS AND SHOULD NOT BE CONSIDERED THE VIEWS OR POSITIONS OF THE ETHERNET ALLIANCE.
Overview

This presentation investigates:
• EA Introduction
• Link Speeds and Distances
• Copper and Optical Links
• Future Links
• Physical Port Form Factors
• This presentation does not explore Passive Optical Networking, wireless and historic links
Who is the Ethernet Alliance?

- A global community of end users, system vendors, component suppliers and academia
- Representing the spectrum of the Ethernet industry

83 member companies

- Carrier & end user: 5%
- Component Vendors: 37%
- Academia & Affiliates: 33%
- System Vendors: 25%
The Ethernet Alliance Strategic Vision

**Expand Ethernet Ecosystem**
- Facilitate interop testing
- Expand the market
- Go global

**Support Ethernet Development**
- Support consensus building
- Host Technology Exploration Forums (TEFs)
- Team with other orgs

**Promote Ethernet**
- Marketing
- Education
University of Ethernet Curriculum

- Completed and available online
- Planned
- Concept

Ethernet 101: Introduction to Ethernet

- Physical Layer x00 Series
  - Ethernet 102: The Physical Layer of Ethernet
  - Ethernet 202: 10GBASE-T Revamped
  - Ethernet 301: 40/100GbE Fiber Cabling and Migration Practices

- Protocols x10 Series
  - Ethernet 111: 802.1: Protocols of Ethernet
  - Ethernet 211: Data Center Convergence
  - Ethernet 311: Congestion Notification

- Applications x20 Series
  - Ethernet 121: The Applications of Ethernet
  - Ethernet 221: Data Center Applications
  - Ethernet 321: Industrial Applications

- Products x30 Series
  - Ethernet 131: Ethernet Products
  - Ethernet 231: Ethernet Switches
  - Ethernet 331: Ethernet Server Adapters

What do you want to present?
Faster and Farther

- 10BASE-5 was released in 1980 and used a coaxial cable at 10Mbps for 500 meters.
- In 2010, 100GBASE-ER4 supported 100 Gb/s over 40km of single-mode fiber.
The Physical Layer of Ethernet

Source: IEEE 802.3 Standard
- Download your free copy of IEEE 802.3-2008 standard here:
  http://standards.ieee.org/about/get/802/802.3.html

AN = AUTO-NEGOTIATION
CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE
GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER

PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
XGMII = 10 Gb/s MEDIA INDEPENDENT INTERFACE
XLGMII = 40 Gb/s MEDIA INDEPENDENT INTERFACE
Ethernet Port Shipments

- About 300 million ports shipped every year
- Over a billion ports shipped since 2007

Source: Dell’Oro Ethernet Switch Report Five Year Forecast 2011 – 2015.
Ethernet Speed Standards

- Logarithmic Growth in Speed

![Graph showing Ethernet speed standards from 1995 to 2010. The x-axis represents years (1995, 1998, 2002, 2010), and the y-axis represents Ethernet speed in Mbps (10, 100, 1,000, 10,000, 100,000). The graph includes different Ethernet standards such as Fast Ethernet, GbE, 10GbE, 40GbE, and 100GbE.]
Server Connectivity

• 10GbE Server Connectivity Transitioning Now

For server applications 100Gb/s solution should be cost-optimized for 2017 technology envelope.

The Ethernet Eco-System

- Ethernet spans backplanes up to 1m
- Twinax to 15m
- Twisted pair to 100m
- Multimode fiber to 5km
- Single-mode fiber to 40km
Ethernet Nomenclature

• This is an interpretation of Ethernet nomenclature
• Example: 100GBASE-LR4

nTYPE-LLLm

Data rate:
- 10 10 Mb/s
- 100 100Mb/s
- 1000 1000Mb/s
- 10G 10Gb/s
- 40G 40Gb/s
- 100G 100Gb/s

Modulation type:
- BASE Baseband

First letter (media or wavelength):
- C Twin axial Copper
- E Extra long wavelength (1550nm) / Extended Reach
- F Fiber
- K BacKplane
- L Long wavelength (1310nm) / Long Reach
- S Short wavelength (850nm) / Short Reach
- T Twisted pair

Second letter (reach or PCS encoding):
- R ScRambled coding (64B66B)
- X EXternal sourced coding (4B5B, 8B10B)

Last Number –
- “ “ 1 Pair or Lane
- 4 4 Pairs or Lanes
- 10 10 Pairs or Lanes or 10 kilometers

Third letter
- M Multimode

* The IEEE does not specify these letters discretely and defines a PHY by the combination of letters
Data Rate and Line Rate

- One of the more confusing aspects of networking is the data rate and the line rate
- End Users should be interested in the Data Rate

<table>
<thead>
<tr>
<th>Variant</th>
<th>Data Rate (Gb/s)</th>
<th>Line Rate (Gb/s)</th>
<th>Encoding</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000BASE-X</td>
<td>1</td>
<td>1 X 1.25</td>
<td>8B/10B</td>
<td>1000BASE-SX</td>
</tr>
<tr>
<td>10GBASE-X</td>
<td>10</td>
<td>4 X 3.125</td>
<td>8B/10B</td>
<td>10GBASE-LX</td>
</tr>
<tr>
<td>10GBASE-R</td>
<td>10</td>
<td>1 X 10.3125</td>
<td>64B/66B</td>
<td>10GBASE-ER</td>
</tr>
<tr>
<td>40GBASE-R</td>
<td>40</td>
<td>4 X 10.3125</td>
<td>64B/66B</td>
<td>40GBASE-LR4</td>
</tr>
<tr>
<td>100GBASE-R</td>
<td>100</td>
<td>10 X 10.3125</td>
<td>64B/66B</td>
<td>100GBASE-SR10</td>
</tr>
</tbody>
</table>
Balanced Twisted Pair Cabling

- Twisted pairs with RJ-45 terminations are the most commonly deployed form of Ethernet and include:
  - 10BASE-T – 10Mb/s to 100 meters
  - 100BASE-T – 100Mb/s to 100 meters
  - 1000BASE-T – 1Gb/s to 100 meters
  - 10GBASE-T – 10Gb/s to 100 meters
Category Cabling

- Category (CAT) cabling comes in several forms

<table>
<thead>
<tr>
<th>TIA/EIA Category</th>
<th>ISO/IEC Class</th>
<th>Application</th>
<th>Bandwidth (MHz)</th>
<th># of Wire Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAT 1</td>
<td>A</td>
<td>Obsolete. Used for telephones and door bells.</td>
<td>0.1</td>
<td>1 or 2</td>
</tr>
<tr>
<td>CAT 2</td>
<td>B</td>
<td>Obsolete. Used in ARCnet and 4 Mb/s Token Ring.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>CAT 3</td>
<td>C</td>
<td>10BASE-T</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>CAT 4</td>
<td>N/A</td>
<td>Not used in Ethernet. Copper cabling designed for Token Ring</td>
<td>N/A</td>
<td>4</td>
</tr>
<tr>
<td>CAT 5</td>
<td>N/A</td>
<td>Replaced by CAT 5e</td>
<td>N/A</td>
<td>4</td>
</tr>
<tr>
<td>CAT 5e</td>
<td>D</td>
<td>Enhanced CAT 5 screened for high bandwidth</td>
<td>100</td>
<td>4</td>
</tr>
<tr>
<td>CAT 6</td>
<td>E</td>
<td>1000BASE-T</td>
<td>250</td>
<td>4</td>
</tr>
<tr>
<td>CAT 6A</td>
<td>EA</td>
<td>10GBASE-T</td>
<td>500</td>
<td>4</td>
</tr>
<tr>
<td>CAT 7</td>
<td>F</td>
<td>10GBASE-T</td>
<td>600</td>
<td>4</td>
</tr>
<tr>
<td>CAT 7A</td>
<td>FA</td>
<td>10GBASE-T</td>
<td>1000</td>
<td>4</td>
</tr>
</tbody>
</table>
Structured Twisted Pair Cabling System

- Up to 4 connectors in the link
Optical Fiber Types

- Optical fibers used in Ethernet come in multiple types

<table>
<thead>
<tr>
<th>Type</th>
<th>Application</th>
<th>Bandwidth Length Product (MHz<em>km or GHz</em>m)</th>
<th>Core / Cladding Diameter (um)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OM1</td>
<td>Obsolete. Used for FDDI.</td>
<td>160-200</td>
<td>62.5/125</td>
</tr>
<tr>
<td>OM2</td>
<td>Used for 100BASE-FX to 1000BASE-SX.</td>
<td>400-500</td>
<td>50/125</td>
</tr>
<tr>
<td>OM3</td>
<td>Used for 10GBASE-SR and higher speeds.</td>
<td>2000</td>
<td>50/125</td>
</tr>
<tr>
<td>OM4</td>
<td>Used for 10GBASE-SR and higher speeds.</td>
<td>4700</td>
<td>50/125</td>
</tr>
<tr>
<td>OS1</td>
<td>Standard single-mode fiber.</td>
<td>Nearly infinite</td>
<td>9/125</td>
</tr>
<tr>
<td>OS2</td>
<td>Reduced loss fiber not typically used in Ethernet</td>
<td>Nearly infinite</td>
<td>9/125</td>
</tr>
</tbody>
</table>
Multimode Fiber Variants

• Multimode fiber has enabled longer distances at higher speeds within the data center such as:
  – 100BASE-FX – 100Mb/s up to 2 kilometers
  – 1000BASE-SX – 1Gb/s up to 550 meters
  – 10GBASE-SR – 10Gb/s up to 300 meters
  – 40GBASE-SR4 – 40Gb/s up to 100 meters of OM3
  – 100GBASE-SR10 – 100Gb/s up to 100 meters of OM3
  – 40GBASE-SR4 – 40Gb/s up to 150 meters of OM4
  – 100GBASE-SR10 – 100Gb/s up to 150 meters of OM4

SFP+ with blue latch to signify multimode
LC Patchcord
MPO-LC Fanout Patchcord
Active Optical Cables
Single-Mode Fiber Variants

• Single-mode fiber is used for long distance links within large data centers and for links in campus or metro areas such as:
  – 100BASE-LX – 100Mb/s to at least 5 kilometers
  – 1000BASE-LX – 1Gb/s to at least 5 kilometers
  – 10GBASE-LR – 10Gb/s to at least 10 kilometers
  – 10GBASE-ER – 10Gb/s to at least 40 kilometers
  – 40GBASE-FR – 40Gb/s to at least 2 kilometers
  – 40GBASE-LR – 40Gb/s to at least 10 kilometers
  – 100GBASE-LR – 100Gb/s to at least 10 kilometers
  – 100GBASE-ER – 100Gb/s to at least 40 kilometers
Structured Fiber Cabling System

- MPO Trunk Cables
- LC Jumpers
- MPO-LC Fanouts
- Network equipment
Twinax Copper Cable Assembly

- Twinax is a shielded copper cable that has twin conductors with good electrical properties that enables these short reach applications at high speed:
  - 1000BASE-CX – 1Gb/s up to 25 meters
  - 10GBASE-CX4 – 10Gb/s up to 15 meters
  - SFP+ Direct Attach Cable – 10Gb/s to 7 meters
  - 40GBASE-CR4 – 40Gb/s up to 7 meters
  - 100GBASE-CR10 – 100Gb/s up to 7 meters

- 802.3bj Task Force is defining copper links that delivers 100Gb/s over 4 pairs up to 5 meter:
  - Expected to be released in 2013
  - See http://www.ieee802.org/3/100GCU/index.html
Backplane Ethernet

- Backplane Ethernet enables interoperable solutions within a chassis and supports these applications:
  - 1000BASE-KX – 1Gb/s over 4 pairs up to 1 meter
  - 10GBASE-KX4 – 10Gb/s over 4 pairs up to 1 meter
  - 10GBASE-KR – 10Gb/s over 1 pair up to 1 meter
  - 40GBASE-KR – 40Gb/s over 4 pairs up to 1 meter
- 802.3bj is defining backplane links that delivers 100Gb/s over 4 pairs up to 1 meter:
  - Expected to be released in 2013
  - See http://www.ieee802.org/3/100GCU/index.html
Current 100GbE IEEE 802.3 Projects

- Two projects defining 100GbE optical and copper variants

<table>
<thead>
<tr>
<th>Medium</th>
<th>Description</th>
<th>40GbE</th>
<th>100GbE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Backplane</strong></td>
<td>4 x 25Gb/s</td>
<td>✓</td>
<td>802.3bj Task Force</td>
</tr>
<tr>
<td><strong>Twin-axial</strong></td>
<td>100GBASE-CR4 - 4 x 25Gb/s</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td><strong>Chip-to-Chip / Module</strong></td>
<td>CAUI-4 - 4 x 25Gb/s</td>
<td></td>
<td>Next Gen 100G Ethernet Study Group 2011</td>
</tr>
<tr>
<td><strong>Multimode Fiber</strong></td>
<td>100GBASE-SR4 = 4x25Gb/s on 12-fiber ribbons</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What reach?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Single-mode Fiber</strong></td>
<td>100GBASE-nR4 - Shorter reach than 10km?</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Parallel ribbon fibers?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Optical Form Factors

- Physical ports come in various form factors that change over time as the technology progresses

SFP = Small Form Factor Pluggable
QSFP = Quad Small Form Factor Pluggable
CXP = 100G (C) Form Factor Pluggable
CFP = 100G (C) Form Factor Pluggable
CFP2 = CFP generation 2
CFP4 not shown

Illustration courtesy of Molex
Summary

• Ethernet links have expanded reach and speed to cover a variety of applications
• From 1 meter to 40 kilometers, Ethernet supports high speed backplanes and inter-data center links
• From 10Mb/s to 100Gb/s, Ethernet supports laptops to Internet Exchanges
• IEEE 802.3 is currently defining several 4X25Gb/s interfaces that will define the second generation of 100GbE
Ways to Get Involved In EA

• Become A Member
• Attend A Plugfest
  • Data Center Bridging
  • High Speed Ethernet
  • Higher Speed Modular IO
  • Energy Efficient Ethernet

Join A Subcommittee
• Participate In An EA Booth At Trade Shows
  • OFC/NFOEC
  • Carrier Ethernet Congress
  • Interop
  • Supercomputing
  • European Conference on Optical Communication (ECOC)

• Participate In EA Sponsored Webinars
Discussion and Q&A
Thank you