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Ethernet 102: The Physical Layer of Ethernet

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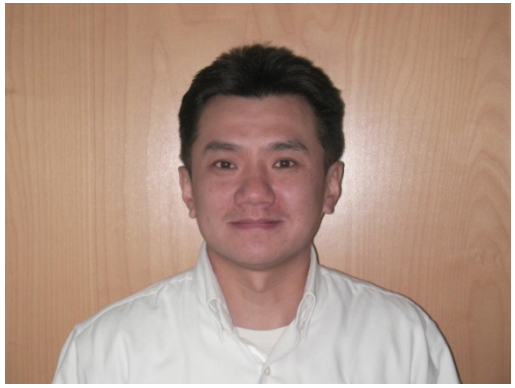
The Presenters

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.

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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.

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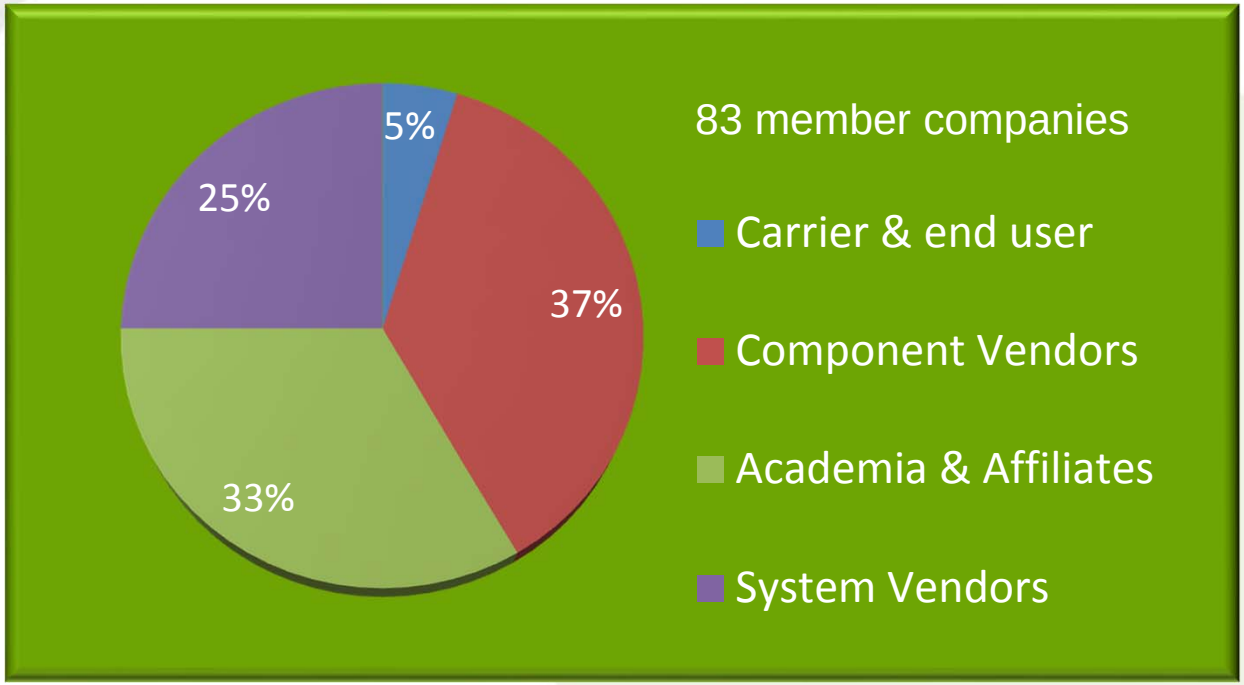
Overview

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



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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

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University of Ethernet Curriculum

- Completed and available online
- Planned
- Concept

Ethernet 101:
Introduction to Ethernet

Physical Layer x00 Series	Protocols x10 Series	Applications x20 Series	Products x30 Series
Ethernet 102: The Physical Layer Of Ethernet	Ethernet 111: 802.1:Protocols Of Ethernet	Ethernet 121: The Applications Of Ethernet	Ethernet 131: Ethernet Products
Ethernet 202: 10GBASE-T Revamped	Ethernet 211: Data Center Convergence	Ethernet 221: Data Center Applications	Ethernet 231: Ethernet Switches
Ethernet 301: 40/100GbE Fiber Cabling and Migration Practices	Ethernet 311: Congestion Notification	Ethernet 321: Industrial Applications	Ethernet 331: Ethernet Server Adapters

What do you want to present?

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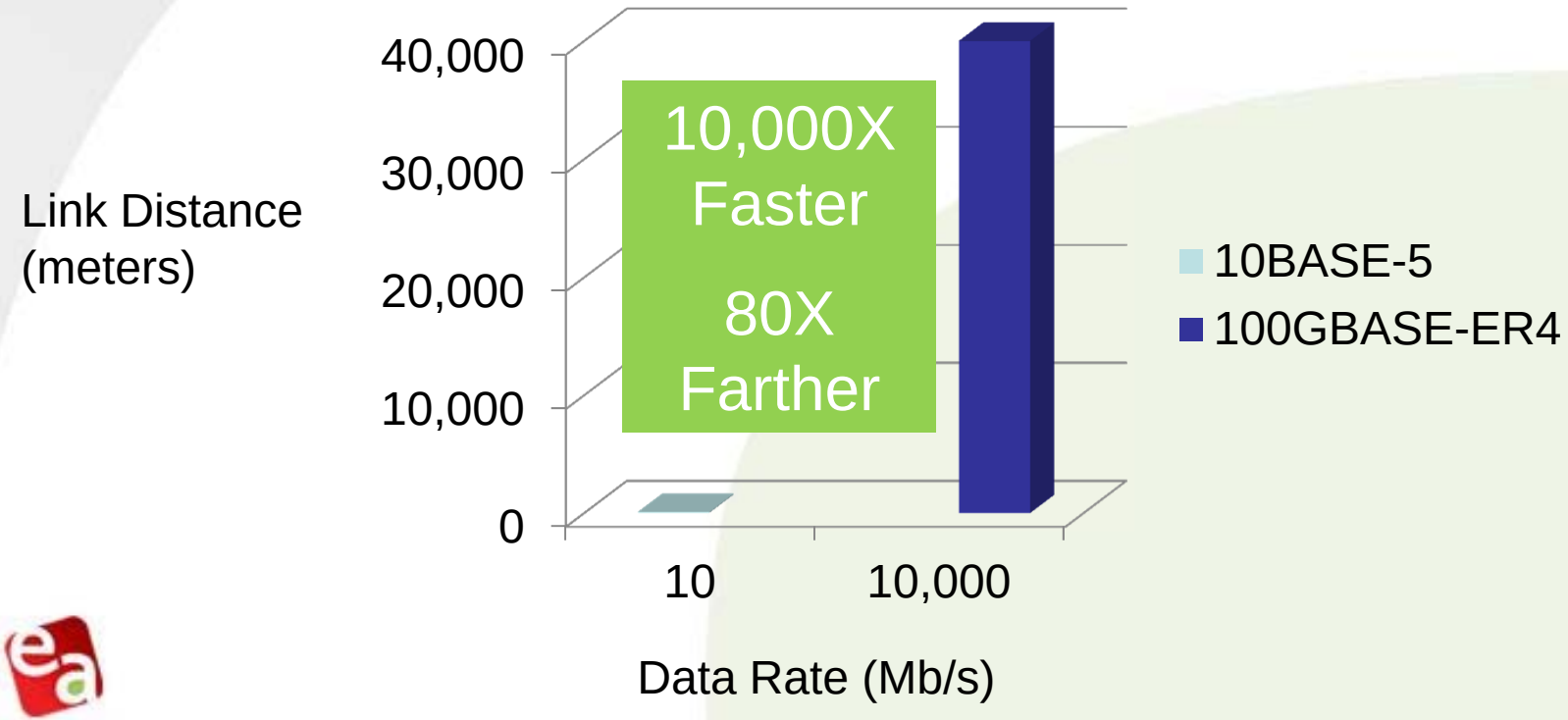
Faster and Farther

- 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



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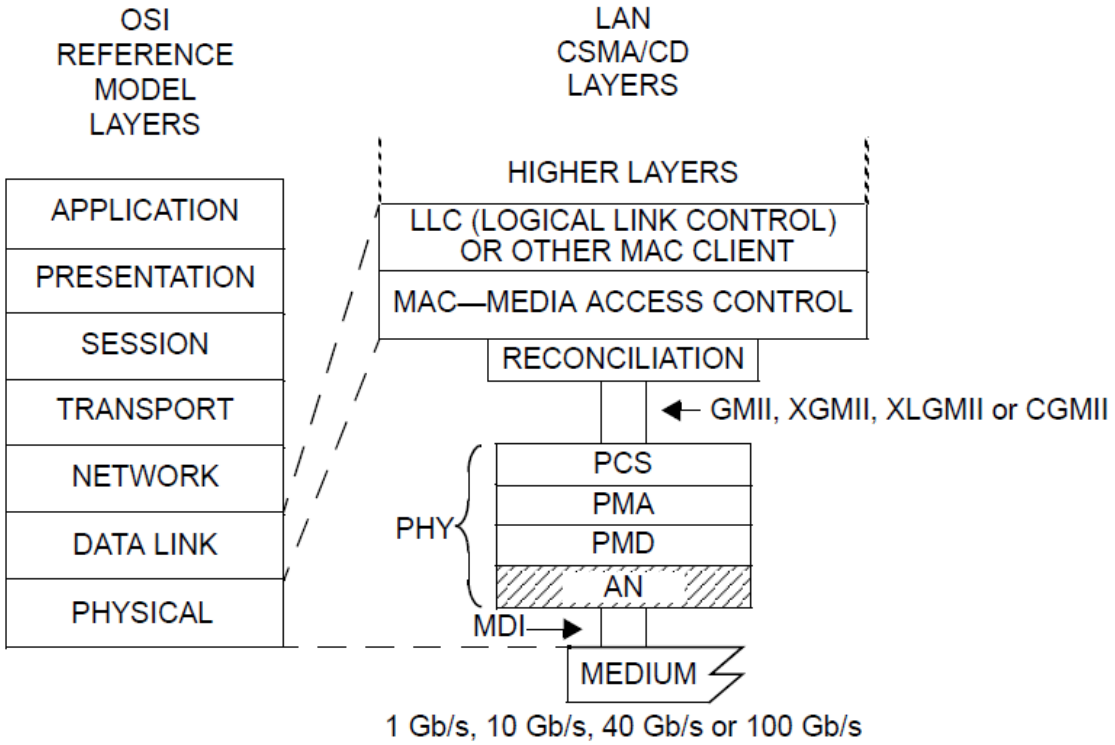
The Physical Layer of Ethernet



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

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

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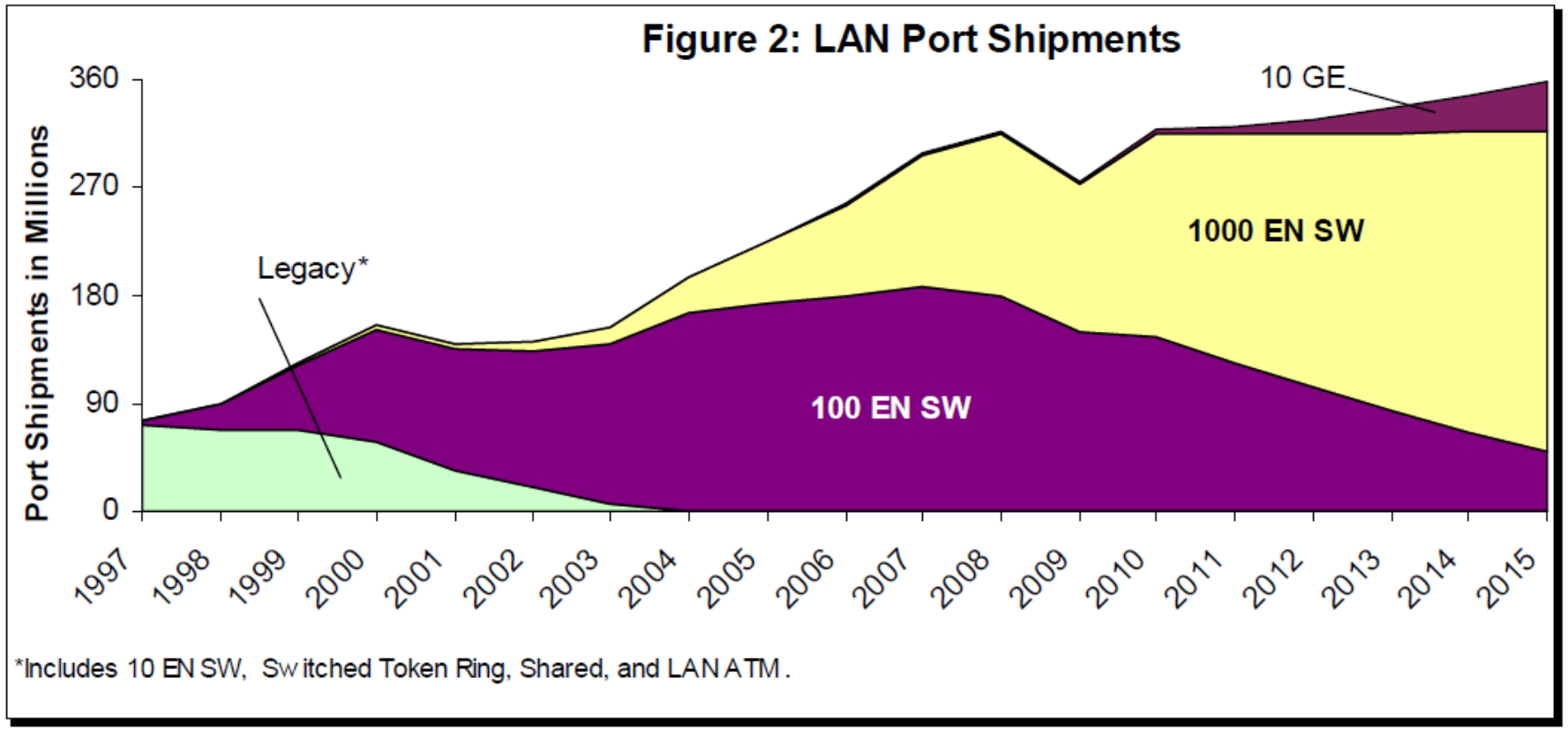
Ethernet Port Shipments

- 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.

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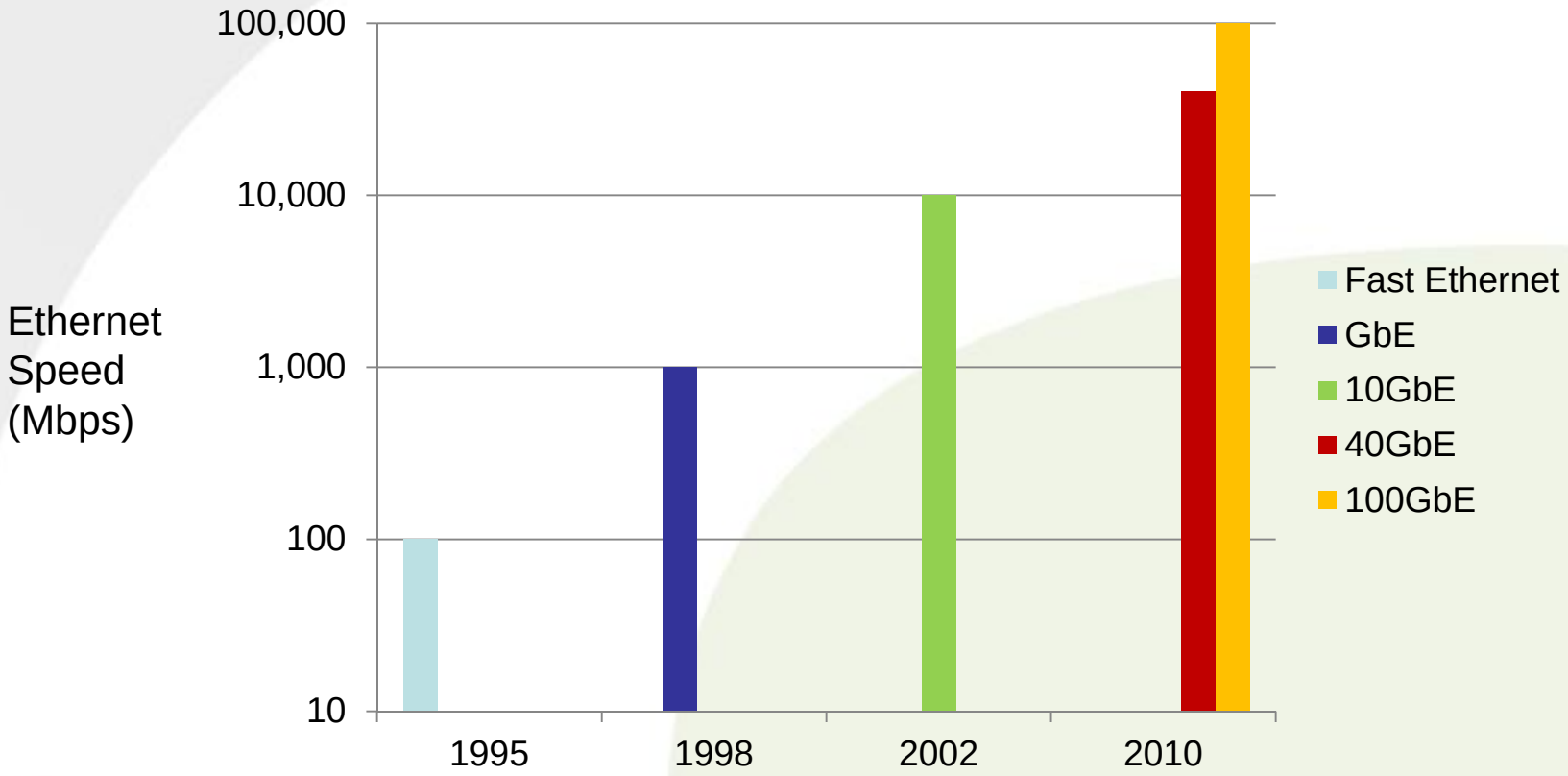
Ethernet Speed Standards

- Logarithmic Growth in Speed



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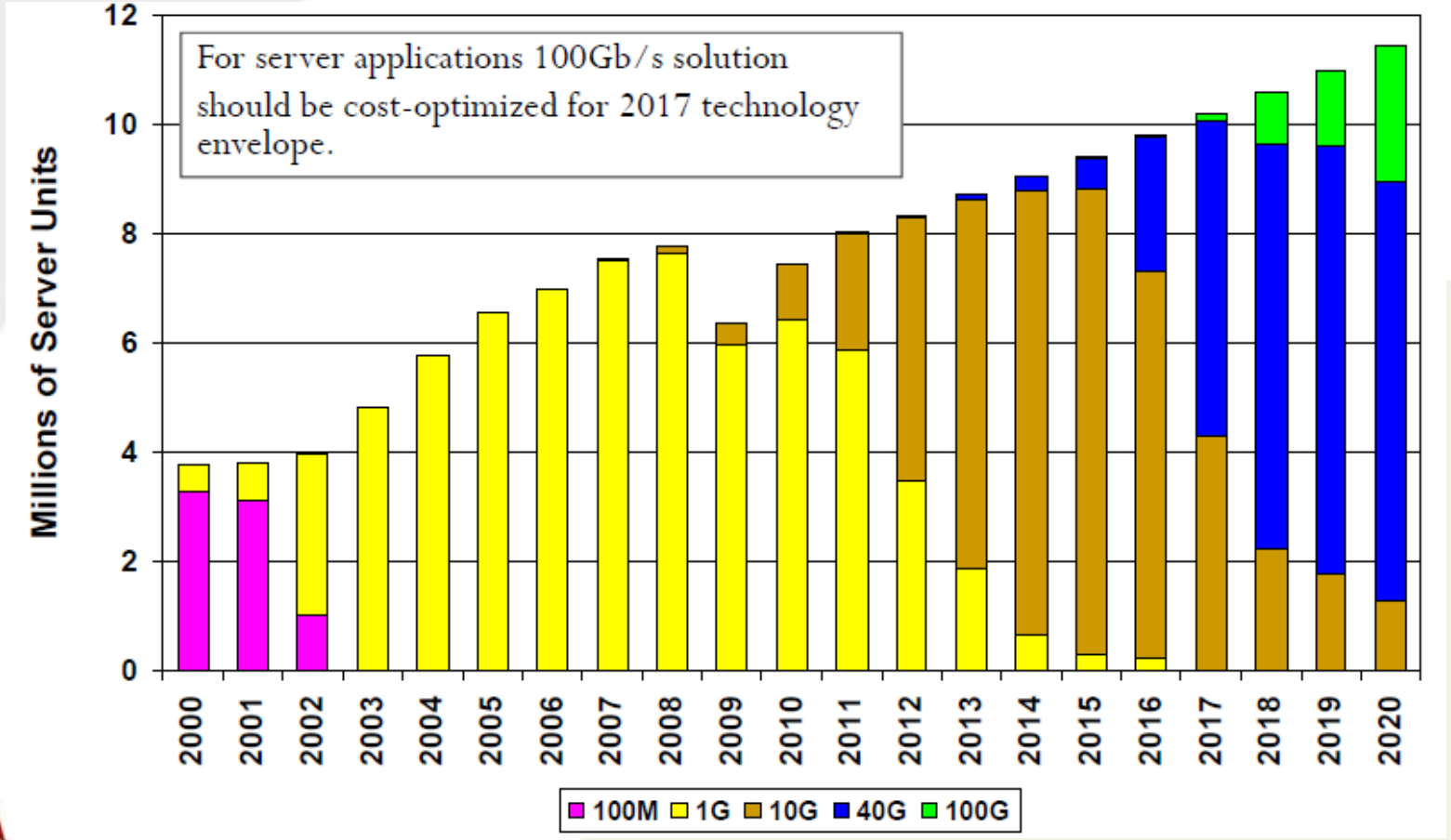
Server Connectivity

- 10GbE Server Connectivity Transitioning Now



Source: http://www.ieee802.org/3/100GCU/public/nov10/CFI_01_1110.pdf

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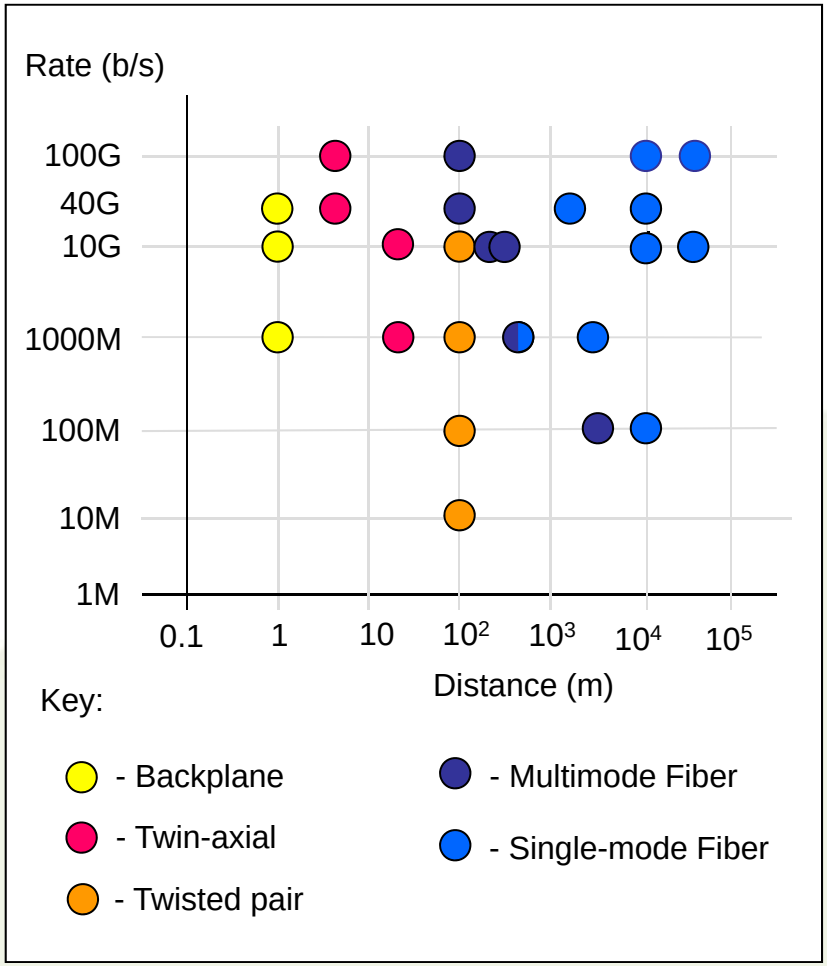
The Ethernet Eco-System

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



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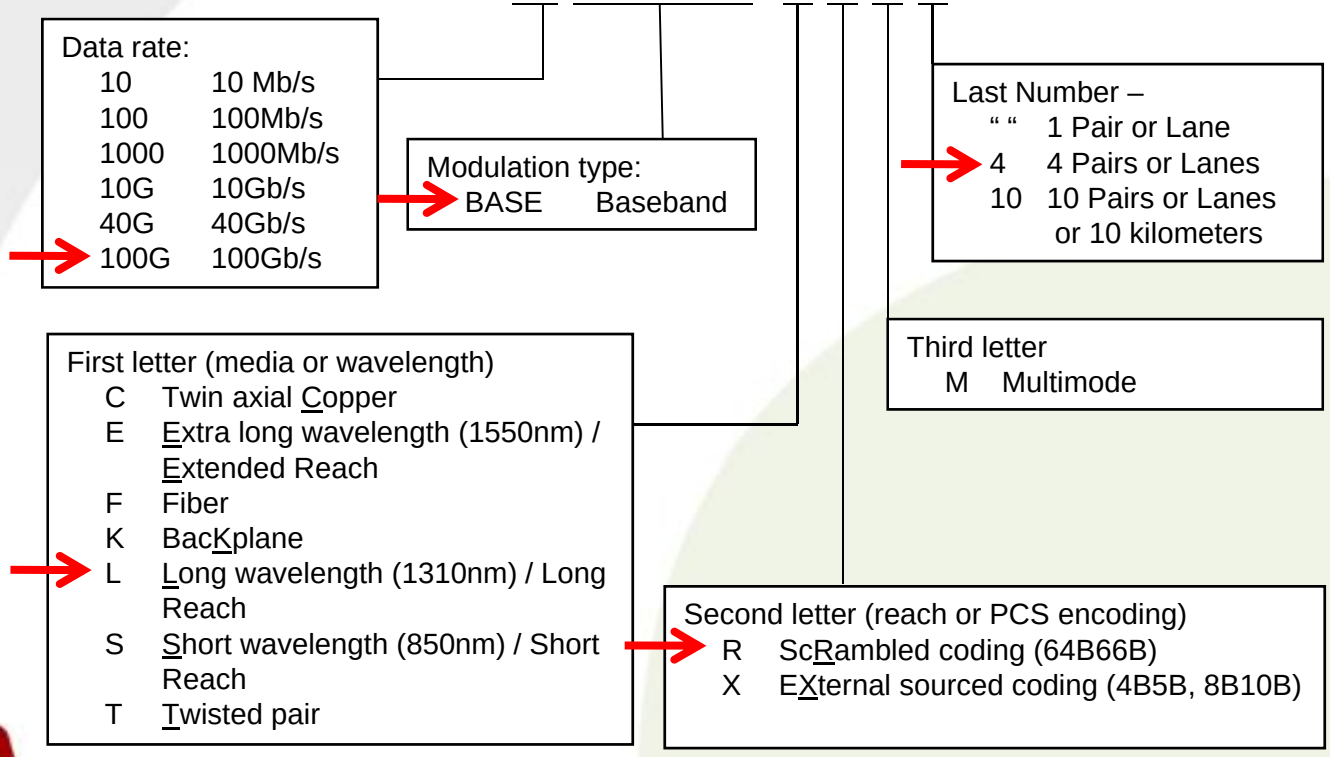
Ethernet Nomenclature

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

nTYPE-LLLm



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

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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

Variant	Data Rate (Gb/s)	Line Rate (Gb/s)	Encoding	Examples
1000BASE-X	1	1 X 1.25	8B/10B	**1000BASE-SX**
10GBASE-X	10	4 X 3.125	8B/10B	**10GBASE-LX**
10GBASE-R	10	1 X 10.3125	64B/66B	**10GBASE-ER**
40GBASE-R	40	4 X 10.3125	64B/66B	**40GBASE-LR4**
100GBASE-R	100	10 X 10.3125	64B/66B	**100GBASE-SR10**

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

RJ45 Jack

The ubiquitous RJ45 connector

RJ45 Plug

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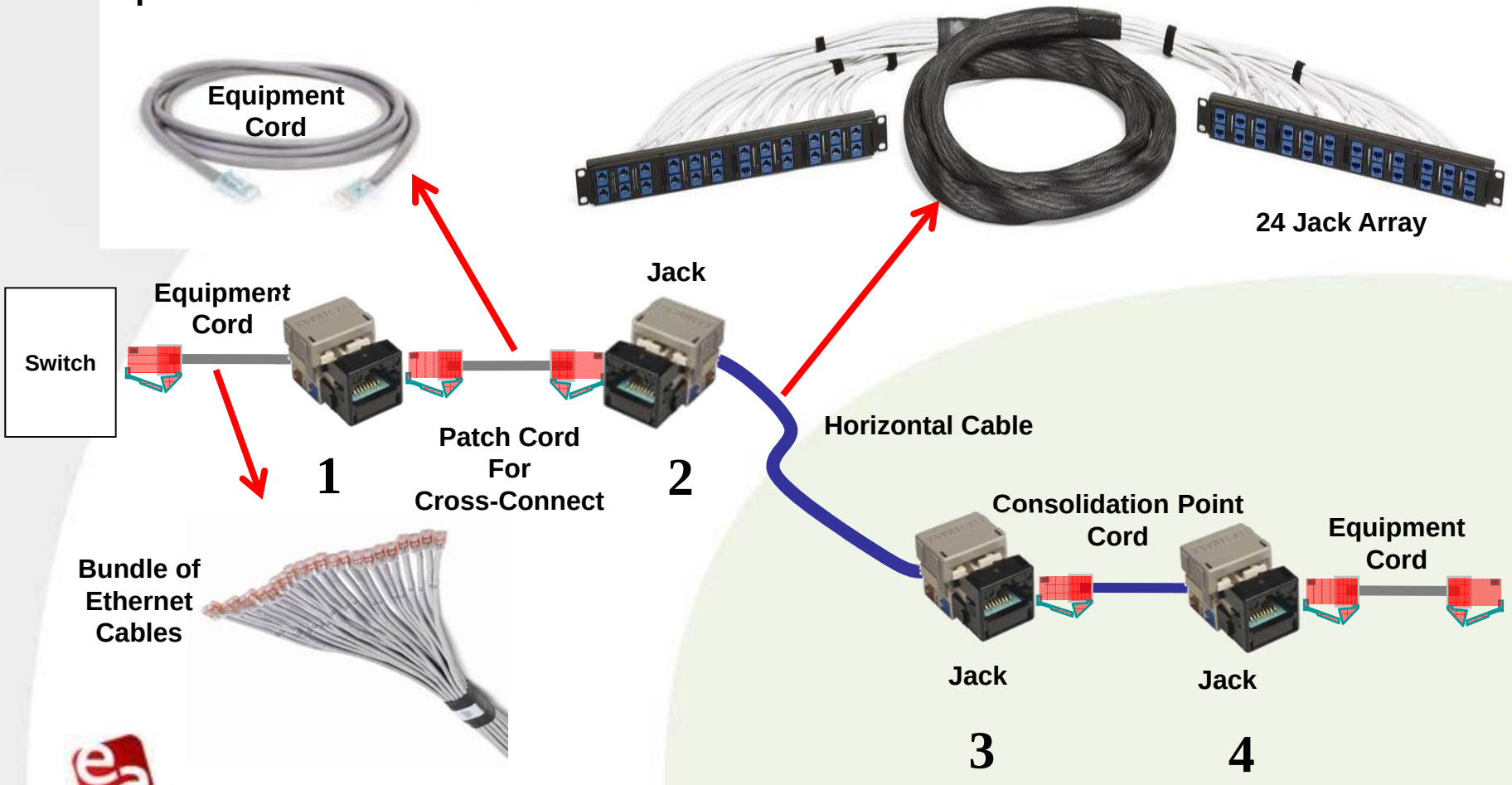
Category Cabling

- Category (CAT) cabling comes in several forms

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

Structured Twisted Pair Cabling System

- Up to 4 connectors in the link



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Optical Fiber Types

- Optical fibers used in Ethernet come in multiple types

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

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

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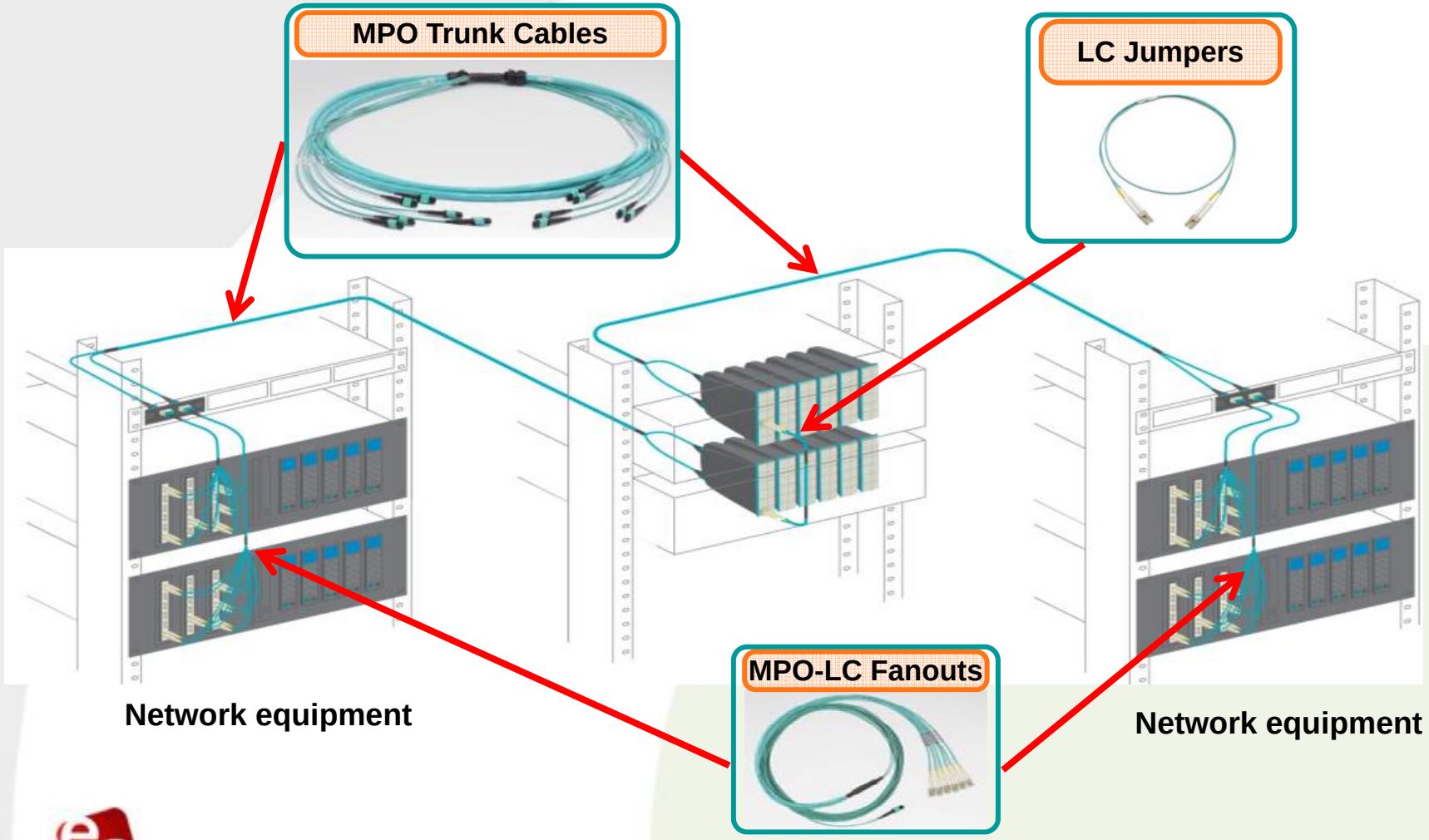
Single-Mode Fiber Variants

- 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



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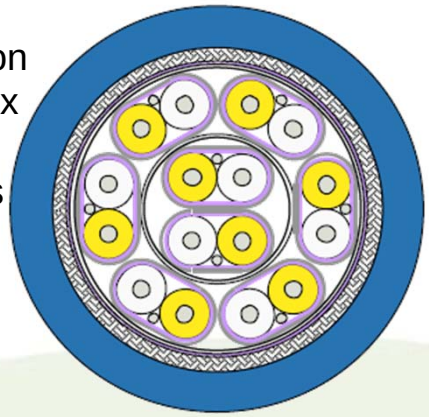
Twinax Copper Cable Assembly

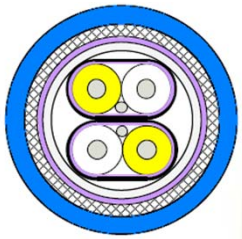
- Twinax is a shielded copper cable that has twin conductors with good electrical properties that enables these short reach applications at high speed:
  - 1000BASE-CX – 1Gb/s up to 25 meters
  - 10GBASE-CX4 – 10Gb/s up to 15 meters
  - SFP+ Direct Attach Cable – 10Gb/s to 7 meters
  - 40GBASE-CR4 –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

Cross-section
8 pair twinax
for
4 channels



- 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

Cross-section
2 pair twinax for SFP+



SFP+ Direct Attach Cable (DAC)

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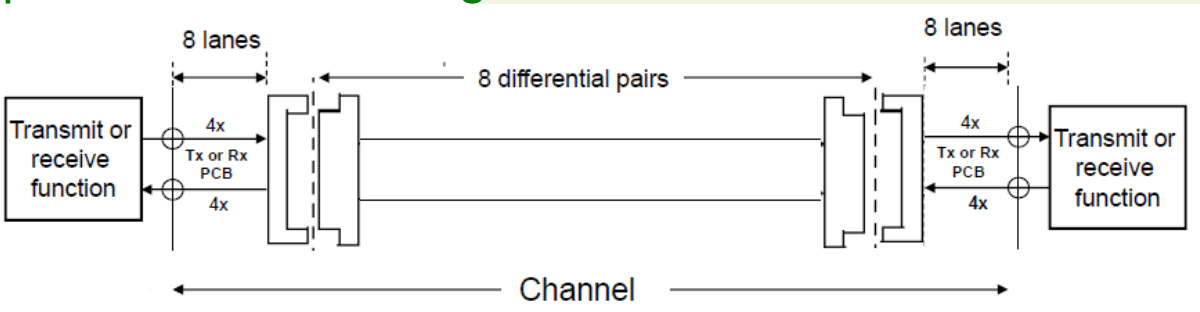
Backplane Ethernet

- 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



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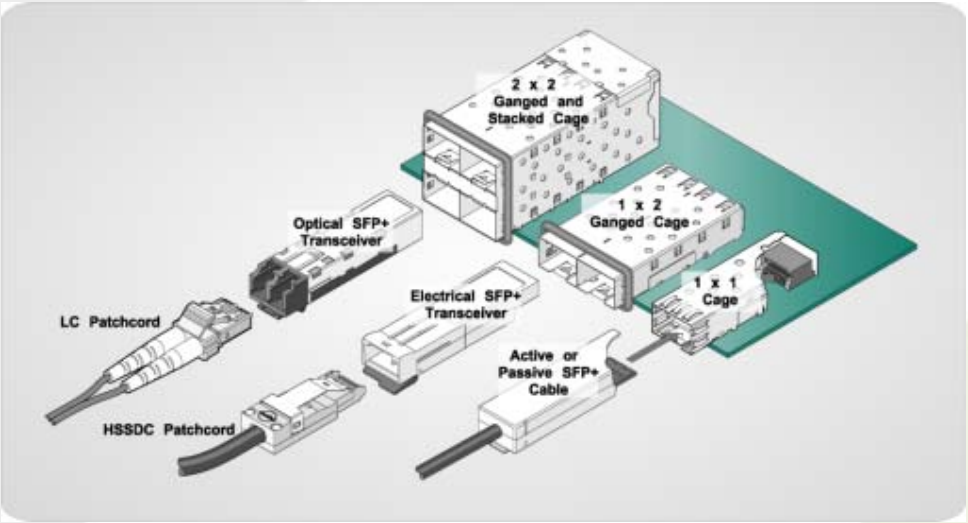
Current 100GbE IEEE 802.3 Projects

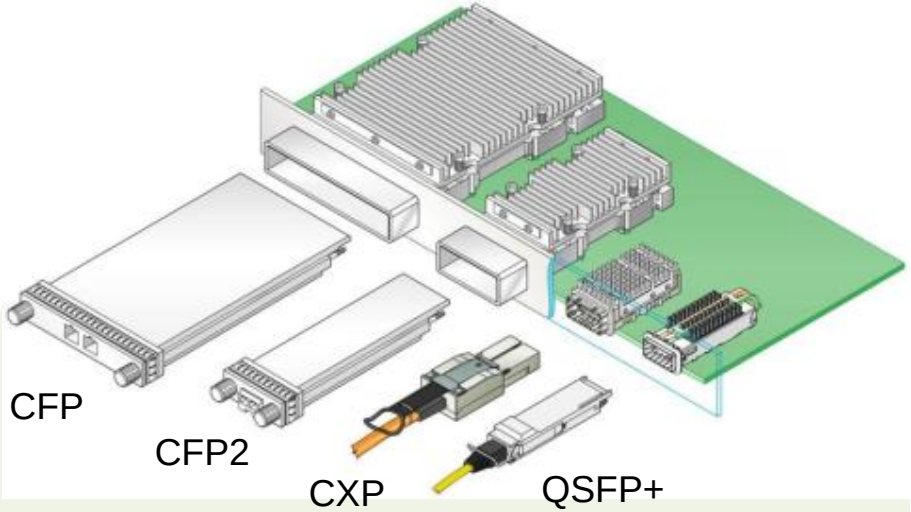
- Two projects defining 100GbE optical and copper variants

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

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

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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

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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

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Discussion and Q&A

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Thank you

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