The Ethernet Rate Explosion

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Regarding the Views Expressed

My Industry Involvement

- **Senior Principal Engineer, IP Standards Team North America, Futurewei**
- **Chairman, Ethernet Alliance Board of Directors**
- **Chair, IEEE P802.3bs 400GbE Task Force**
- **Chair, IEEE 802.3 Next Generation Enterprise, Data Center, Campus Ad Hoc**
- **Recording Secretary, IEEE 802 Executive Committee**

ethernet alliance

The views I am expressing on IEEE standards and related products should NOT be considered the position, explanation, or interpretation of the Ethernet Alliance.

IEEE

Per IEEE-SA Standards Board Bylaws, Dec 2013 "At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE."

Where is Ethernet Going?

- Applications ???
- Rates ???
- Media ???
- Reaches ???
- Form Factors ???

A Word about Forecasting….

IEEE 802 Nov 2006 Plenary

HSSG Straw Poll

- I do not support a MAC rate of 40 Gb/s

Results: 89 / 104 people agreed

Flash forward (March 2016) –

- From 2010 – 2021, 40GbE is expected to ship >25,000,000 optical modules.

Dale Murray, LightCounting


Ethernet
Today

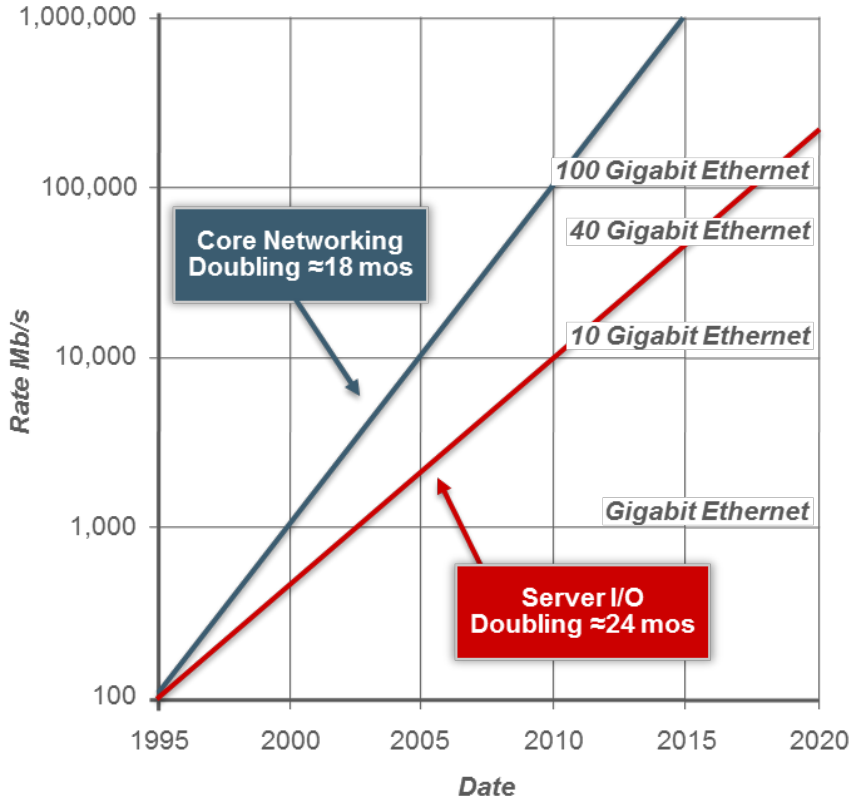
The “Exponential Factor”

“The greatest shortcoming of the human race is our inability to understand the exponential function.”

Albert Bartlett – American Scholar

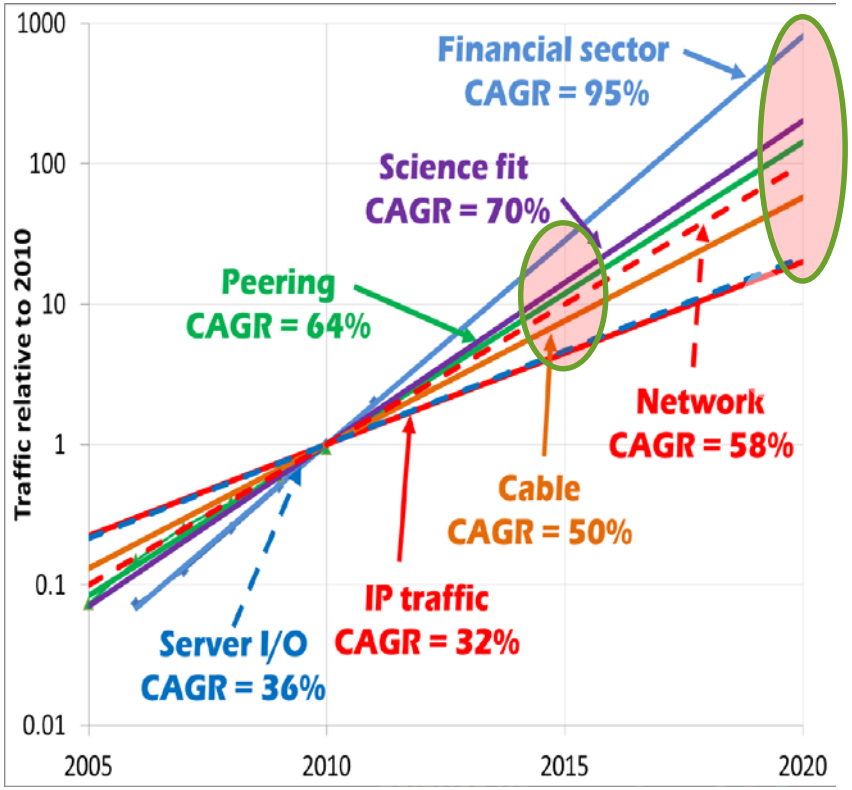
Market Diversity Examples

IEEE 802.3 HSSG - 2007



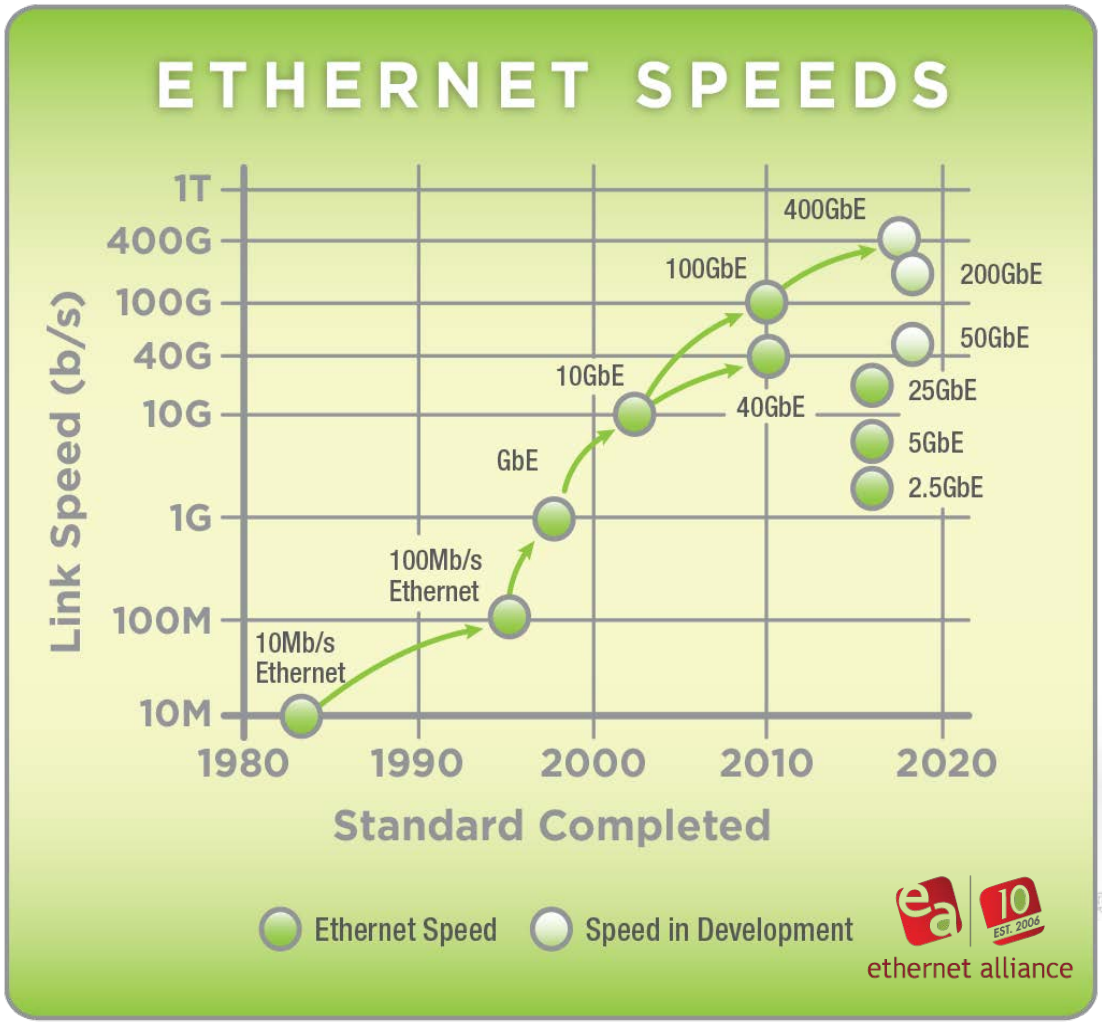
Source: http://www.ieee802.org/3/hssg/public/nov07/HSSG_Tutorial_1107.zip

IEEE 802.3 BWA - 2012

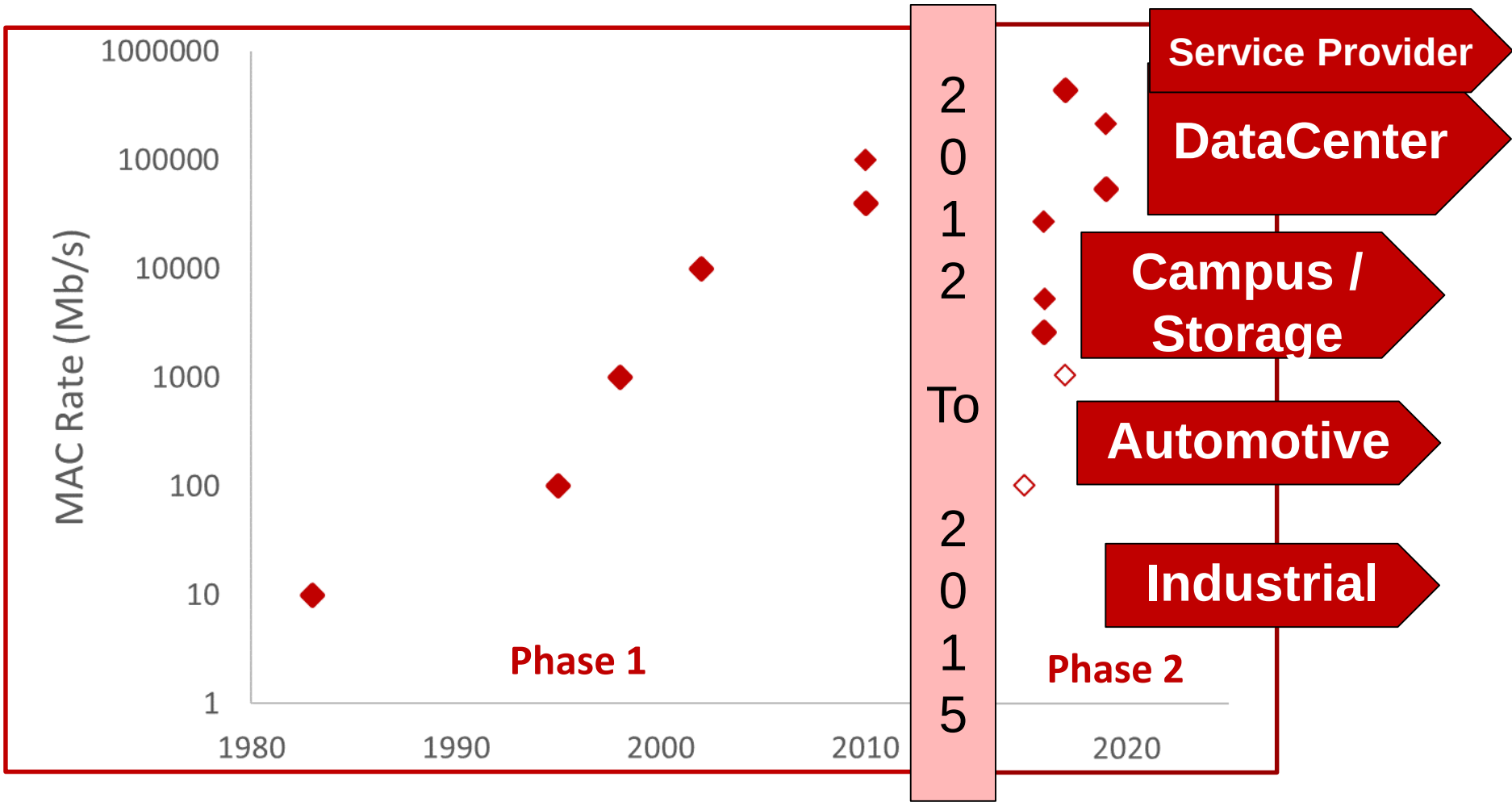


Source: http://www.ieee802.org/3/ad_hoc/bwa/BWA_Report.pdf

Ethernet Rates– What's Going On?



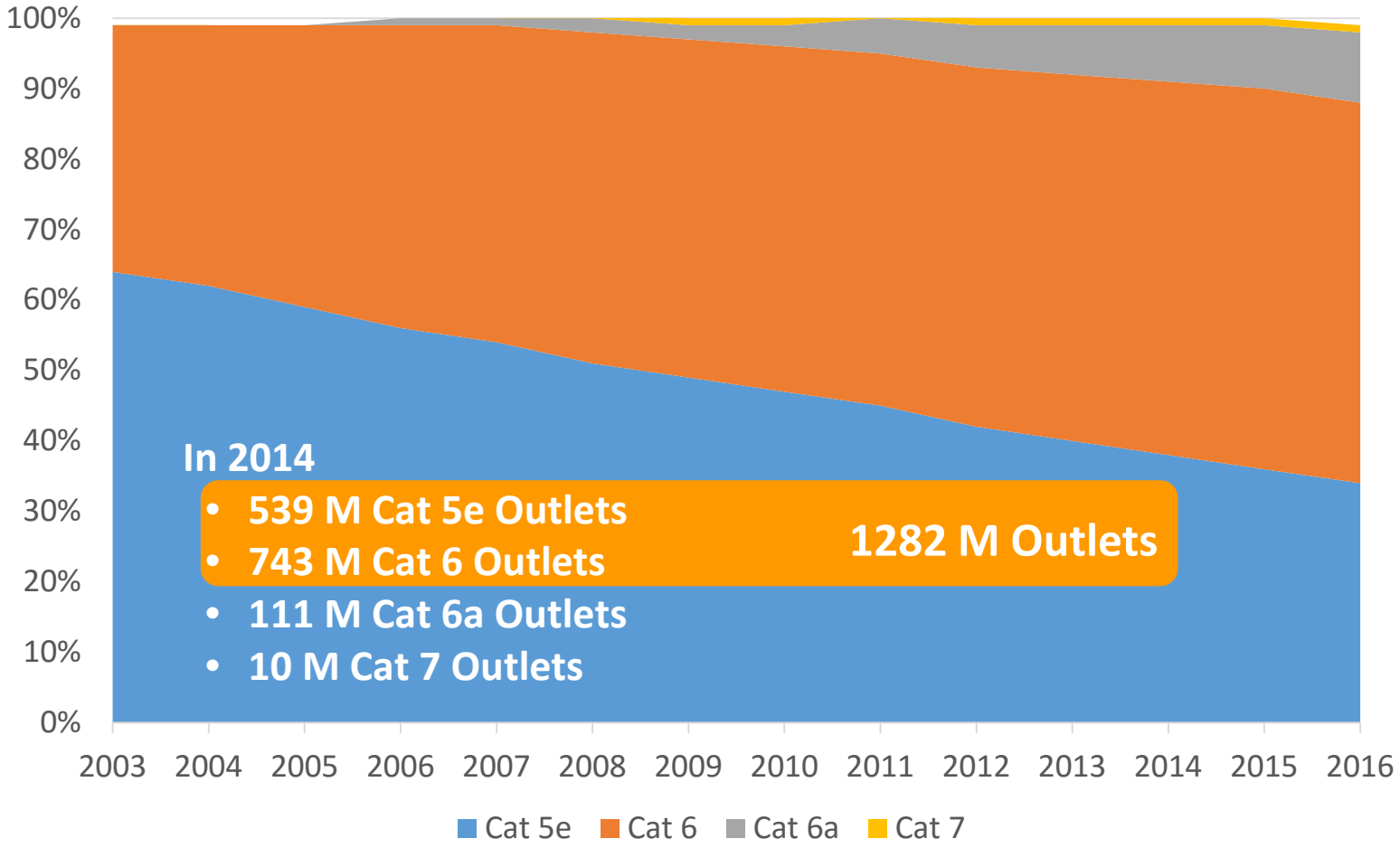
The “Phases” of Ethernet



Why 2.5G / 5G BASE-T?

- From 2003 to 2014 about 70 billion meters of Cat 5e and Cat 6 cabling were sold….
- The introduction of 802.11ac for wireless access points and > GbE needs
- 90% of ports outlets (≈1.3 B) are Cat 5e or Cat 6
- Customers want more value from this infrastructure.

What is Behind the Wall?



Source: NGEABT Study Group Cabling Installed Base Update (BSRIA),
http://www.ieee802.org/3/NGEBASET/public/jan15/jones_ngeabt_04c_0115.pdf

Why 25GbE Servers?

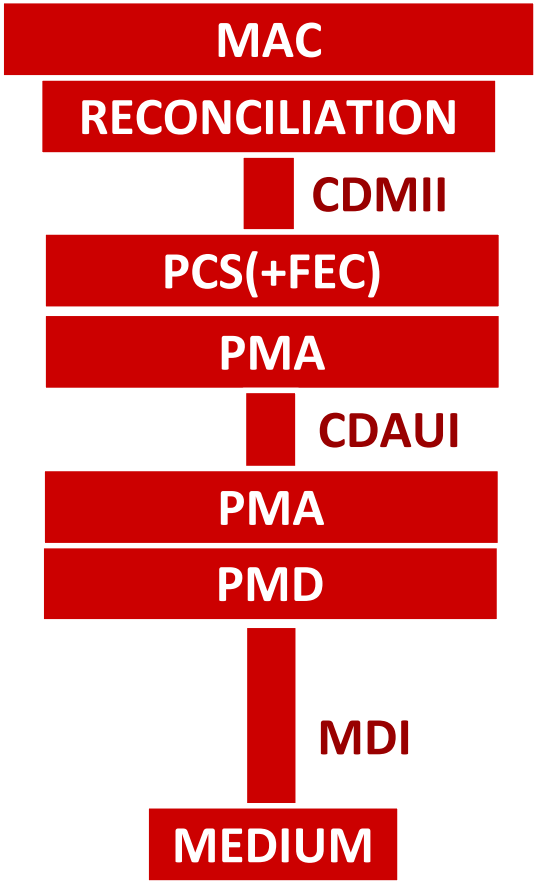
	3.2 Tb/s Switch Based on 32 QSFP Ports				# TORs for a 100K Server Data Center
Server I/O	Servers	100 GbE Uplinks	Throughput (Tb/s) per ToR Switch	Utilization (%)	
40GbE (4x10G)	28	4	1.52	47.5	3572
25GbE (Single Lane)	96	8	3.2	100	1042

Benefits of 25GbE

- Maximize Switch Throughput & Efficiency
- Minimize CAPEX
  - Minimize # of ToR switches
  - Minimize # of Cables
- Minimize OPEX
  - Less Power
  - Less Cooling
- Minimize Cost per Bit
- Technology Exists today!


400 GbE

The 400 GbE Architecture

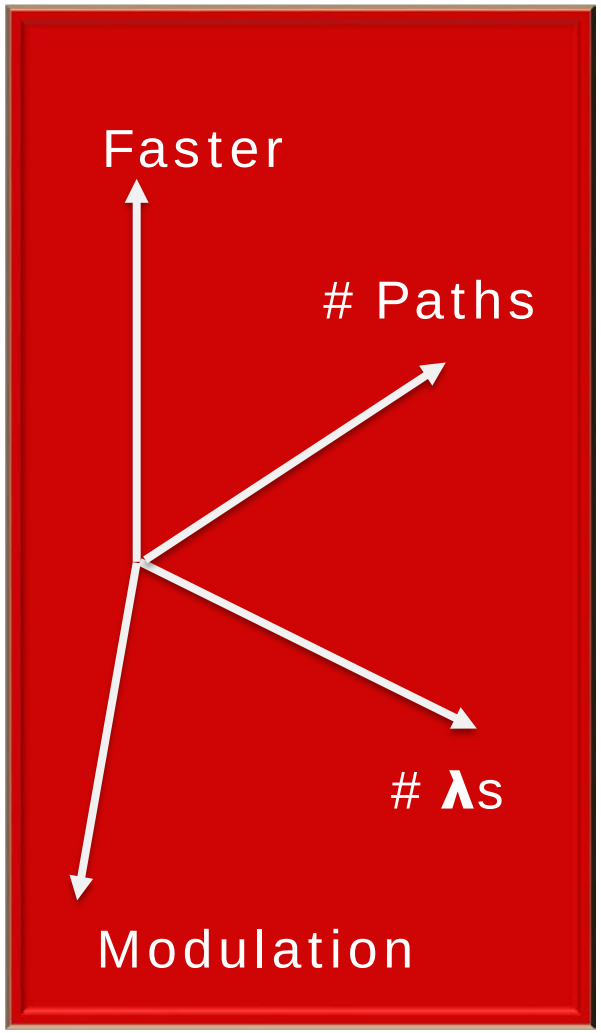


- CDMII Extender
  - Future proofing
  - Leverages current PCS / FEC, but enables future PCS / FEC
  - Leverages CDAUI Interface
- PCS
  - Coding, distribution, alignment
  - FEC RS(544,514)
    - Required for all PHYs
    - Embedded in PCS
    - Provides PCS / PCS protection
- CDAUI
  - Chip-to-Chip & Chip-to-Module
  - 16 lane 25Gb/s NRZ-based
  - 8 lane 50Gb/s PAM4-based

400 GbE Summary

400GBASE-	-SR16	-DR4	-FR4	-LR4
Modulation	NRZ	PAM4	PAM4	PAM4
BAUD Rate (GBd/s)	26.5625	53.125	26.5625	26.5625
Type of Fiber	MMF	SMF	SMF	SMF
# of Fibers (each way)	16	4	1	1
# λs per fiber	1	1	8	8
Reach	100 m	500 m	2 km	10 km

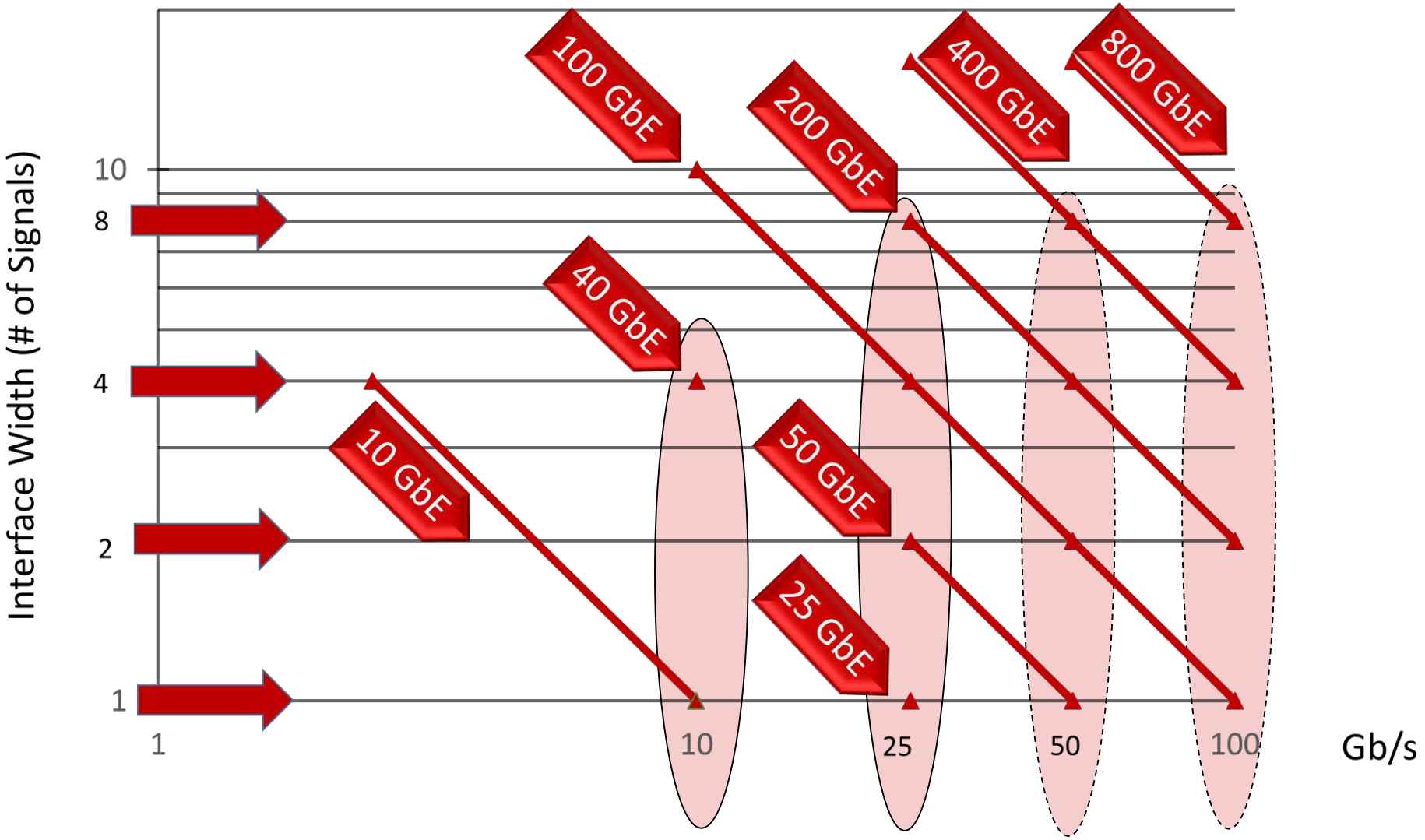
Achieving 400 GbE



- **Faster**
  - Introduction of 50GBaud
  - Mandatory Forward Error Correction
- **# [Physical] Paths**
  - Electrical Interfaces –8 and 16 lanes
  - MMF PHYs – 16 fibers
- **# λs**
  - 2km and 10km SMF PHYs: 8
- **Modulation ≥ 50 Gb/s**
  - NRZ transitions to PAM4


400 GbE
Influence

Families of Solutions



Ethernet Standards In-Development

Medium		25 G	50 G	NG 100G	200G	400G
AUI			2x25G 1x50G	2x50G	4x50G	16X25G* 8x50G *
BP			1x50G	2x50G	4x50G	
Cu Cable			1x50G	x50G	4x50G	
MMF	100 m		1x50G	2x50G	4x50G	16X25G *
SMF	500 m				4x50G	4x100G *
	2 km		1x50G		4x50G	8x50G *
	10 km	1x25G	1x50G		4x50G	8x50G *
	40 km	1x25G				

IEEE P802.3bs

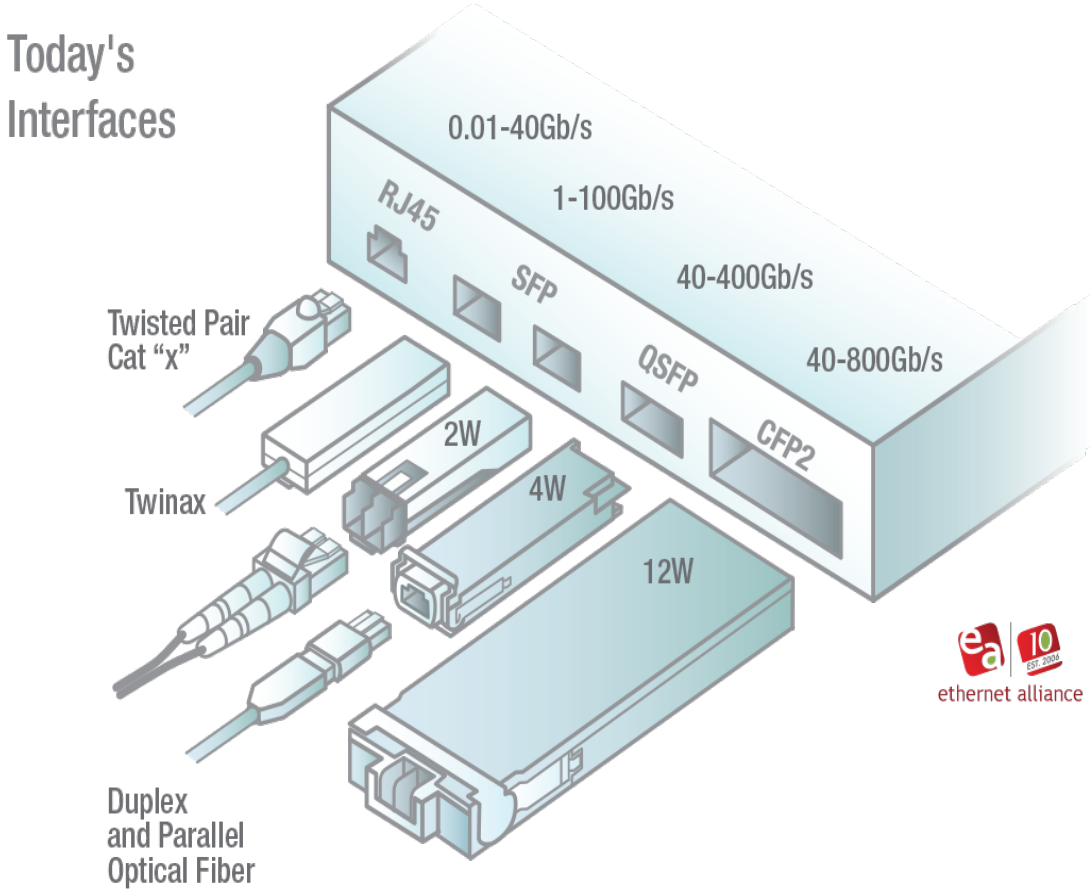
IEEE P802.cd

IEEE P802.3cc

* - baselines selected, if not marked, then baselines pending

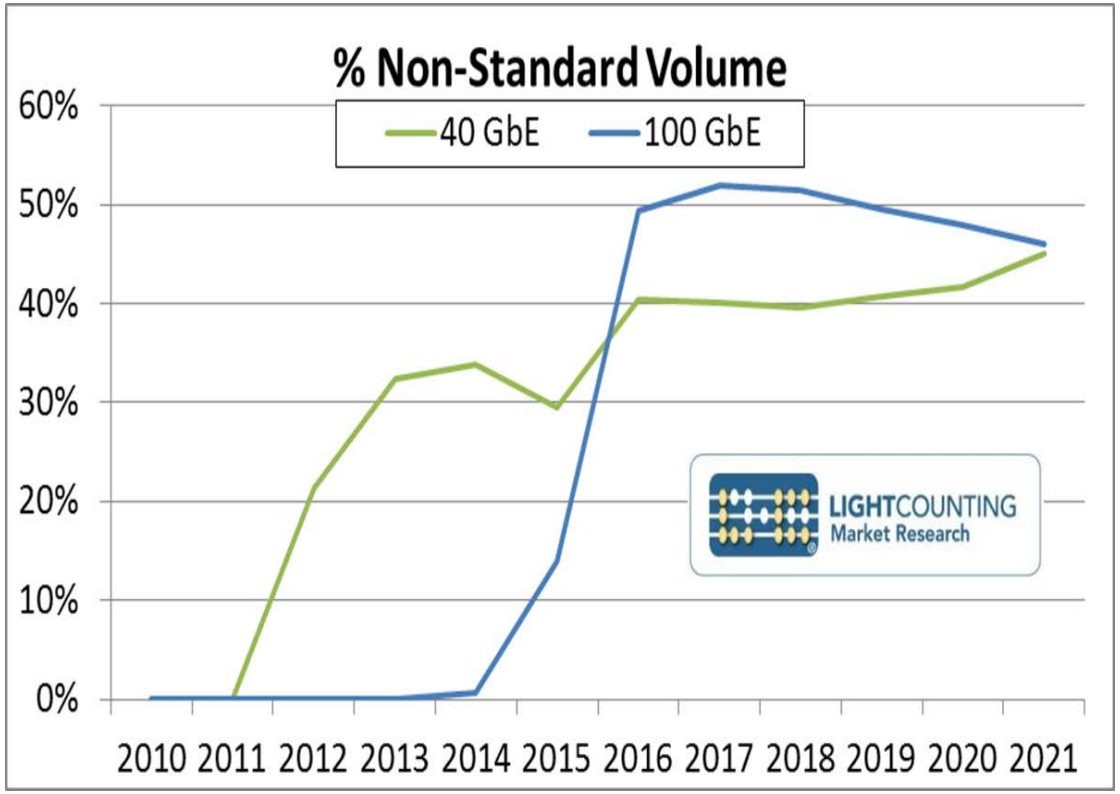

Realities
of Today

Optical Modules



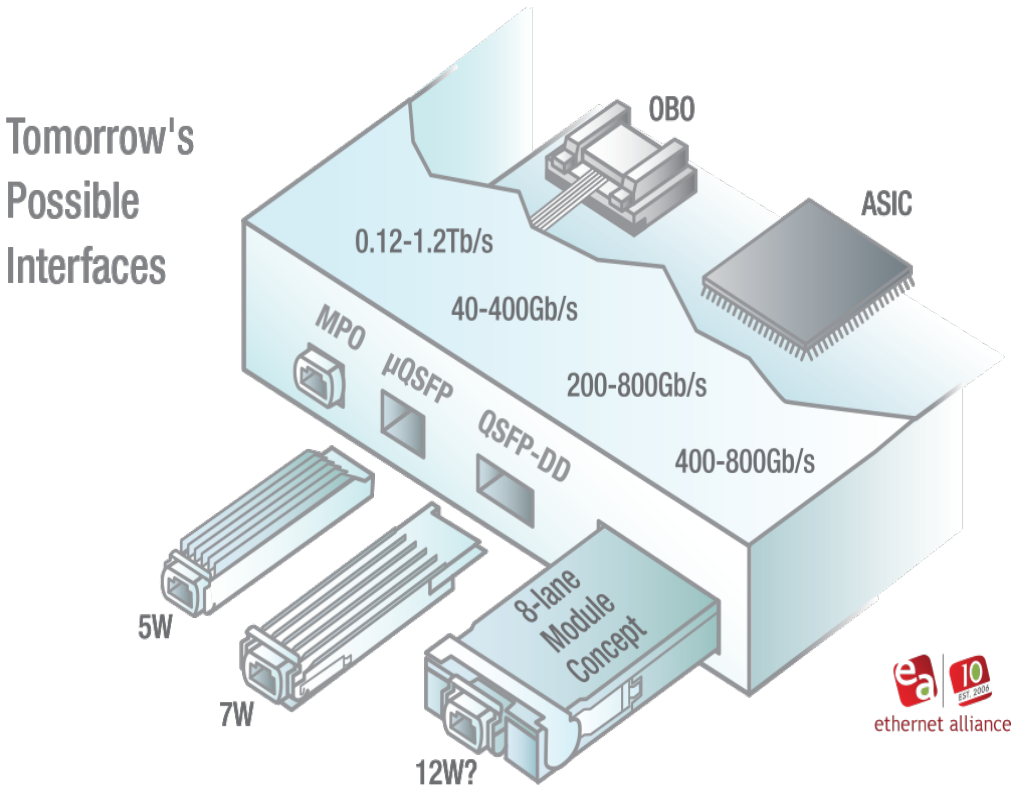
IEEE 802.3 defined C2M interfaces enabled non-IEEE 802.3 specified interconnect specifications for 40GbE and 100GbE ports

Non-Standard Optical Solutions



- **“Standardized” Ethernet ports**
- **Non-Standardized optical solutions**
- **Non-standardized optical solutions and multiple new form factors will continue**

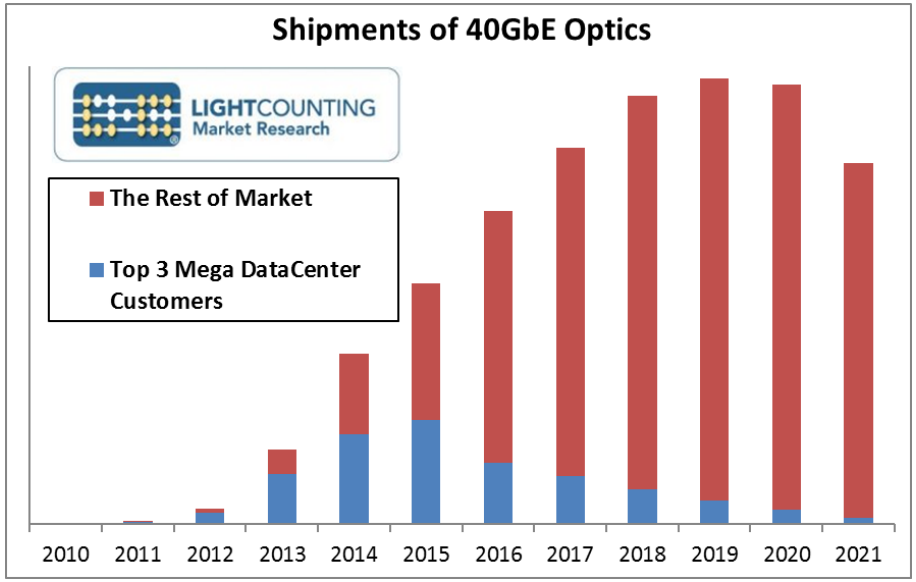
Future of Optical Modules

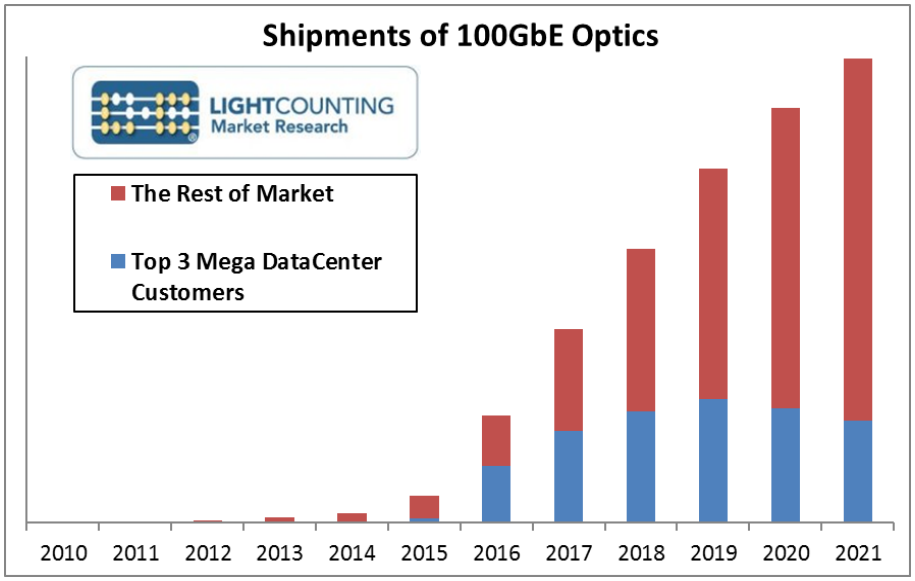


IEEE 802.3 defined C2M interfaces and Extender Sublayers will allow non-standardized interconnect to engage with "standardized" Ethernet ports

Moving Forward

- **Large hyperscale data centers will continue to lead the anticipated broad industry usage**



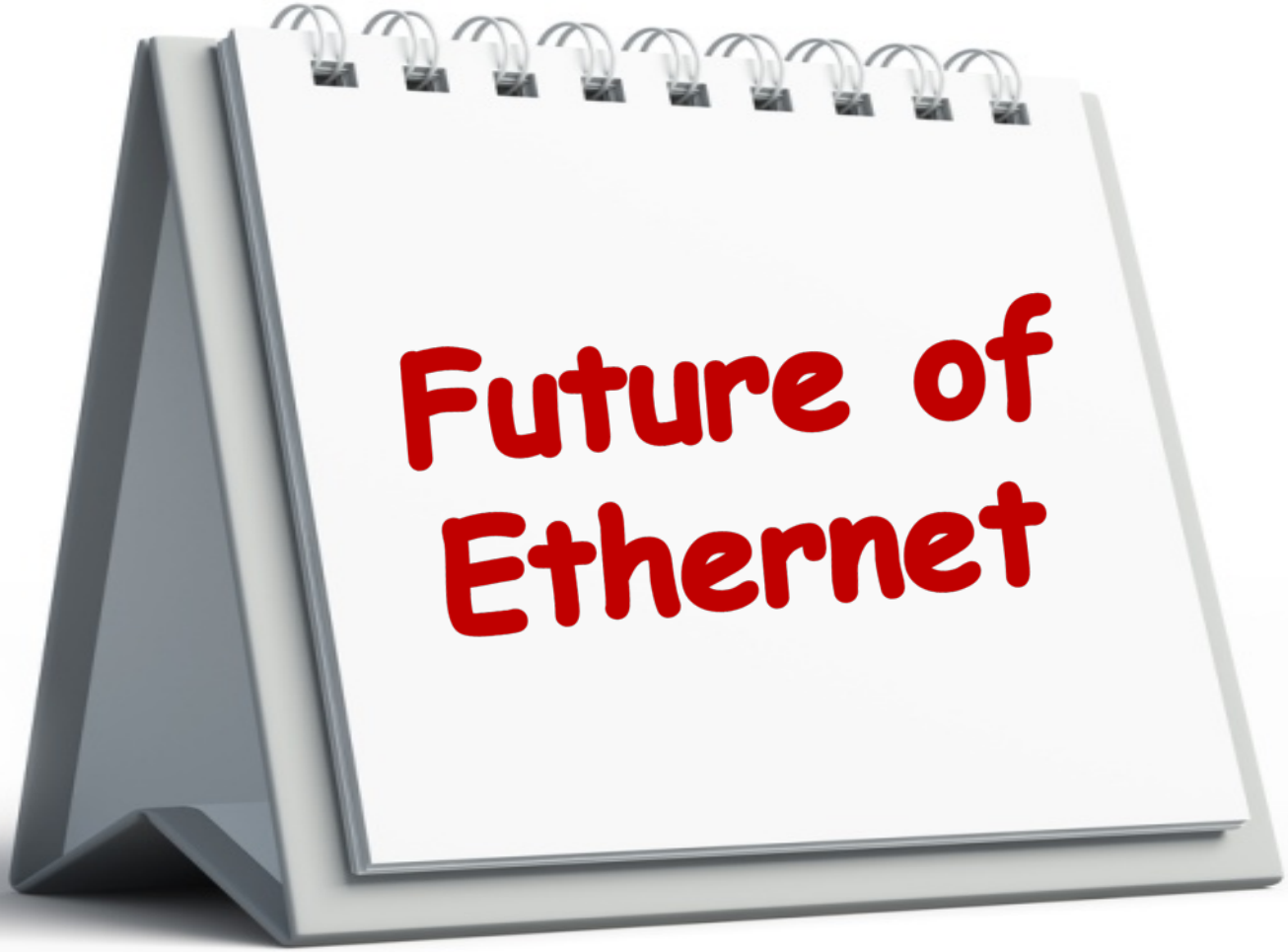


For 2010 - 2021

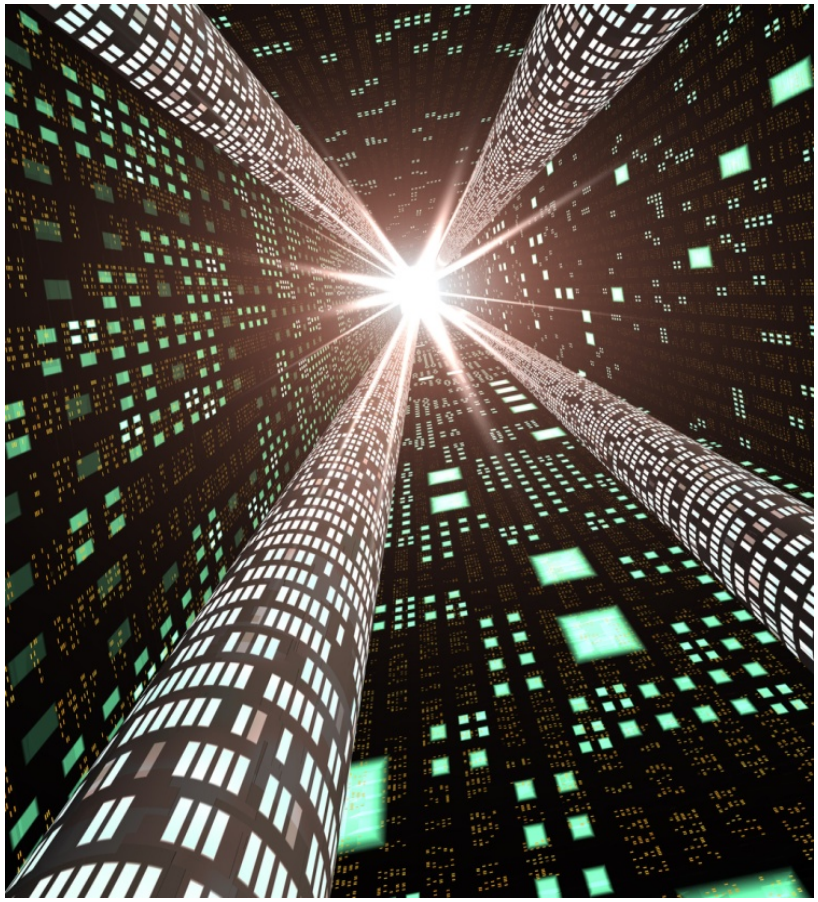
	Optical Modules	Top 3 DC's	Industry
40 GbE	≈25M	16%	84%
100 GbE	≈10M	33%	67%

Influence of Data Centers

- Data Center Needs
  - Faster Servers
  - Faster Networks
  - Faster Development Cycles
  - New architectures (i.e. Leaf / Spine)
- But....
  - Cost Sensitivity
  - Density Requirements
  - Willingness to go non-standard


Future of
Ethernet

Metcalfe’s Law



The value of a telecommunications network is proportional to the square of the number of connected users of the system

Has Ethernet Evolved?

YES

Meeting Industry Needs!

Technology Driver

New Rates

New Reaches

New Mediums

Thank You!

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- **IEEE P802.3bs 400GbE Task Force:**
  http://www.ieee802.org/3/bs/index.html