“Here is more rough stuff on the ALTO ALOHA network.”


Bob Metcalfe’s 1972 sketch of his original “ethernet” vision
Image provided courtesy of Palo Alto Research Center Inc., a Xerox Company

EVOLUTION OF ETHERNET SPEEDS
WHAT’S NEW AND WHAT’S NEXT

Greg Hankins <greg.hankins@alcatel-lucent.com>
APRICOT 2014
AGENDA

1. Ethernet Speed Developments
2. 40 GE
3. 100 GE
4. 400 GE
KEY INDUSTRY DEVELOPMENTS FOR THE NEXT COUPLE OF YEAR

**IEEE Ethernet Standards**
- P802.3bj 100 Gb/s Backplane and Copper Cable Task Force
- P802.3bm 40 Gb/s and 100 Gb/s Operation Over Fiber Optic Cables Task Force
- P802.3bq 40GBASE-T Task Force
- 802.3 400 Gb/s Ethernet Study Group

**Higher Speed Ethernet**

**MSAs**
- Next-generation form factors
- CFP4, QSFP28, CDFP

**OIF ASIC to Pluggable Module Electrical Signaling**
- 25 Gb/s (CEI-28G-VSR)
- 50 Gb/s (CEI-56G-VSR)
ETHERNET STANDARDS DEVELOPMENT SUMMARY
CONTINUING TECHNOLOGY EVOLUTION

• IEEE 802.3ba standard for 40 GE and 100 GE approved June 17, 2010
  - 340 pages added to IEEE Std 802.3-2012
• Shipping 1st generation 40 GE and 100 GE media, test equipment, router interfaces, and optical transport gear in 2011/2012
  - Mature, interoperable technology with broad vendor support
• 2nd generation technology projects for both 40 GE and 100 GE are nearly finished
  - Available on the market this year
• 400 GE under development as the next Ethernet speed
  - Expected on the market in 2016+
**40 GE Applications**
- Data Center Aggregation and Core
- Data Center Access
- Server NICs
- Metro Core

**100 GE Applications**
- Service Provider Aggregation and Core
- Data Center Core
- Metro Core

**400 GE Applications (2016+)**
- Service Provider Core
- Large Data Center Core
- Large Metro Core
MPO CABLE ASSEMBLIES
HIGH DENSITY RIBBON FIBER CABLING

• 40 GE and 100 GE short reach pluggable modules use a multifiber push on (MPO) cable assembly to interconnect network devices
  - Also called MTP by US Conec
• Widely available in a variety of high density multimode fiber (MMF) and single-mode fiber (SMF) cabling options for data centers
  - MPO to MPO
  - MPO cassette for patch panels with into LC, SC, etc
  - Keyed connectors maintain correct transmit/receive orientation
• 40GBASE-SR4 uses a 12-fiber OM3 or OM4 MMF MPO cable
  - 8 fibers used, left 4 for transmit and right 4 for receive
  - 4 middle fibers are unused
• 100GBASE-SR10 uses a 24-fiber OM3 or OM4 MMF MPO cable
  - 20 fibers used, top middle 10 for receive and bottom middle 10 for transmit
  - 2 fibers on each end are unused
AGENDA

1. Ethernet Speed Developments
2. 40 GE
3. 100 GE
4. 400 GE
40 GE TRANSMISSION
MULTIMODE AND SINGLE-MODE FIBER

• Multimode ribbon fiber
  - Used for distances of 100 m on OM3 and 150 m on OM4 MMF
  - Data is sent using multiple 850 nm lasers transmitting over multiple parallel fibers
  - MPO cables provide multiple separate transmit and receive strands of multimode fiber in a ribbon cable assembly

• Single-mode duplex fiber
  - Used for distances of 2 km, 10 km and 40 km on standard duplex SMF
  - WDM component in the pluggable module multiplexes four transmit lanes over one strand of fiber and four receive lanes over the other strand of fiber for 40GBASE-LR4 and 40GBASE-ER4
  - 40 Gb/s serial transmit over one strand of fiber and receive over the other strand of fiber is used for 40GBASE-FR
40 GB/S QSFP+ MODULES OVERVIEW
QUAD SMALL FORM-FACTOR PLUGGABLE+

• Created for high density interfaces primarily short reach interfaces for data center applications
  - Small compact form factor enables low power consumption and high density
  - Also used for longer reach 40 GE
• Used for a variety of Ethernet, Fibre Channel and InfiniBand applications
  - 40 GE uses 4 x 10 Gb/s bidirectional channels
• Supports a variety of copper and fiber 40 GE interfaces
  - Breakout from 40 GE to 4 x 10 GE
• Same faceplate size as an XFP but slightly shorter (8.5 mm high x 18.35 mm wide x 52.4 mm long)

Images courtesy of Finisar.
### 40 GBE QSFP+ PLUGGABLE MODULES

#### Data Center Server and Access

<table>
<thead>
<tr>
<th>Physical Layer Reach</th>
<th>10 m Passive Copper Cable</th>
<th>100 m OM3/OM4</th>
<th>7 m Passive Copper Cable</th>
<th>100 m OM3/150 m OM4</th>
<th>10 km SMF</th>
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<tbody>
<tr>
<td><strong>Module</strong></td>
<td>10GSFP+Cu</td>
<td>10GBASE-SR</td>
<td>40BASE-CR4</td>
<td>40BASE-SR4</td>
<td>40BASE-LR4</td>
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<tr>
<td><strong>Media</strong></td>
<td>Integrated Twinax (QSFP+ to 4 x SFP+)</td>
<td>Parallel MMF (12-Fiber MPO to 4 x Duplex LC)</td>
<td>Integrated Twinax (QSFP+ to QSFP+)</td>
<td>Parallel MMF (12-Fiber MPO)</td>
<td>Duplex SMF (LC)</td>
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<td><strong>Standard</strong></td>
<td>July 2009 SFF-8431</td>
<td>June 2002 IEEE 802.3ae</td>
<td>June 2010 IEEE 802.3ba</td>
<td>June 2010 IEEE 802.3ba</td>
<td>June 2010 IEEE 802.3ba</td>
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40GBASE-SR4 and 40GBASE-LR4 QSFP+ images courtesy of Finisar.
RECENT 40 GE DEVELOPMENTS

• IEEE P802.3bj 100 Gb/s Backplane and Copper Cable Task Force started in September 2011
  - Optional Energy Efficient Ethernet (EEE) operation for 40 GE backplane links and copper cable interfaces
  - Standard expected in June 2014

• IEEE P802.3bm 40 Gb/s and 100 Gb/s Operation Over Fiber Optic Cables Task Force started in September 2012
  - 40GBASE-ER4: 4 x 10 Gb/s over 40 km SMF
  - Optional EEE operation for 40 GE and 100 GE fiber interfaces
  - Standard expected in March 2015

• IEEE P802.3bq 40GBASE-T Task Force started in May 2013
  - 40GBASE-T: 4 x 10 Gb/s over 30 m 4-pair balanced twisted-pair copper cabling (ISO/IEC JTC1 SC25 WG3 and TIA TR-42.7)
  - Task Force web page http://www.ieee802.org/3/bq/
  - Standard expected in September 2015
## 40 GE TECHNOLOGY REFERENCE

<table>
<thead>
<tr>
<th>Physical Layer Reach</th>
<th>1 m</th>
<th>7 m</th>
<th>30 m *TP</th>
<th>100 m OM3 / 150 m OM4</th>
<th>2 km SMF</th>
<th>10 km SMF</th>
<th>40 km SMF</th>
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<td><strong>Name</strong></td>
<td>40GBASE-KR4</td>
<td>40GBASE-CR4</td>
<td>40GBASE-T</td>
<td>40GBASE-SR4</td>
<td>40GBASE-FR</td>
<td>40GBASE-LR4</td>
<td>40GBASE-ER4</td>
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<td>September 2015 IEEE 802.3baq</td>
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<td>March 2011 IEEE 802.3ba</td>
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<td>March 2015 IEEE 802.3bm</td>
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<td>4 x 10</td>
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<td>4 x 10</td>
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<td>4 x 10</td>
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<td>1 x 40 850 nm</td>
<td>1 x 40 1550 nm</td>
<td>1 x 40 1310 nm</td>
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<td>Backplane</td>
<td>Twinax</td>
<td>Cat 8.1 F/UTP? Cat 8.2 S/FTP?</td>
<td>Parallel MMF</td>
<td>Duplex SMF</td>
<td>Duplex SMF</td>
<td>Duplex SMF</td>
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<td><strong>Module Type</strong></td>
<td>Backplane</td>
<td>QSFP+</td>
<td>RJ45?, GG45?, TERA?</td>
<td>CFP, QSFP+</td>
<td>CFP</td>
<td>CFP, QSFP+</td>
<td>QSFP+</td>
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<td>2010</td>
<td>2012</td>
<td>CFP 2010</td>
<td>QSFP+ 2011</td>
<td>2015</td>
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</table>
AGENDA

1. Ethernet Speed Developments
2. 40 GE
3. 100 GE
4. 400 GE
100 GE TECHNOLOGY ADOPTION LIFECYCLE
CROSSING THE CHASM INTO 2\textsuperscript{ND} GENERATION 100 GE

<table>
<thead>
<tr>
<th>Pluggable module images courtesy of Finisar.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adoption lifecycle curve based on “Crossing the Chasm” by Geoffrey Moore.</td>
</tr>
</tbody>
</table>

2010/2011
1 - 2 Premium Ports/Slot
1\textsuperscript{st} Generation CFP Modules

2012/2013
2 - 4 Premium Ports/Slot
2\textsuperscript{nd} Generation CFP Modules

2014/2015
4 - 8 Lower-Cost Ports/Slot
CFP\textsubscript{2} Modules

2015+
8 - 16 Commodity Ports/Slot
CFP\textsubscript{4} and QSFP\textsubscript{28} Modules

2022+
24 - 48 Commodity Ports/Slot
Serial 100 Gb/s Modules

1\textsuperscript{st} Generation 100 GE

2\textsuperscript{nd} Generation 100 GE

3\textsuperscript{rd} Generation 100 GE
100 GE TRANSMISSION
MULTIMODE AND SINGLE-MODE FIBER

• Multimode ribbon fiber
  - Used for distances of 100 m on OM3 and 150 m on OM4 MMF
  - Data is sent using multiple 850 nm lasers transmitting over multiple parallel fibers
  - MPO cables provide multiple separate transmit and receive strands of multimode fiber in a ribbon cable assembly

• Single-mode duplex fiber
  - Used for distances of 2 km, 10 km and 40 km on standard duplex SMF
  - WDM component in the pluggable module multiplexes all transmit lanes over one strand of fiber and all receive lanes over the other strand of fiber
    - 10x10 MSA standards use 10 x 10 Gb/s λs in the 1550 nm range
    - IEEE standards use 4 x 25 Gb/s λs in the 1310 nm range

10 x 10 Gb/s Over Parallel MMF
100GBASE-SR10

10 x 10 Gb/s Over Duplex SMF
10x10-2km, 10x10-10km and 10x10-40km

4 x 25 Gb/s Over Duplex SMF
100GBASE-LR4 and 100GBASE-ER4
100 GE PLUGGABLE MODULES OVERVIEW

CXP
C (100)  
X (10)  
Pluggable

- Designed for high-density short reach applications
  - Small compact form factor limits distance to MMF interfaces
- Used for 100GBASE-SR10 and InfiniBand 12X QDR
  - Provides 12 bidirectional channels over 24 parallel fibers
  - 100 GE uses 10 of the 12 channels
- Slightly wider and shorter than an XFP (27 mm wide x 45 mm long)

CFP
C (100)  
Form-Factor Pluggable

- New module optimized for 100 GE long reach applications, but also used for short reach applications
- Used for IEEE Ethernet and 10x10 MSA standards
- Complex electrical gearbox and optical components need a large module
  - Long reach modules contain an integrated WDM component for duplex SMF transmission
- Large size and power consumption limits front panel density
- Larger than an iPhone 4 (82 mm wide x 145 mm long)

CFP2
C (100)  
Form-Factor Pluggable 2

- 2nd generation 100 GE module
- Optional external universal gearbox can convert electrical signaling so that all current IEEE and MSA 100 GE standards can be supported in the CFP2 module
- Smaller size and lower cost, complexity and power consumption than the CFP
- Approximately ½ the width of a CFP (41.5 mm wide x 107.5 mm long)

Images courtesy of Finisar.
# 100 GE PLUGGABLE MODULES

<table>
<thead>
<tr>
<th>Module</th>
<th>100 m OM3 / 150 m OM4</th>
<th>10 km SMF</th>
<th>40 km SMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>100GBASE-SR10 CXP</td>
<td>100GBASE-SR10 CFP2</td>
<td>10x10-10km CFP</td>
<td>100GBASE-LR4 CFP</td>
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<tr>
<td>100GBASE-SR10 CFP</td>
<td>10x10-10km CFP</td>
<td>100GBASE-LR4 CFP2</td>
<td>10x10-40km CFP</td>
</tr>
<tr>
<td>100GBASE-SR10 CFP</td>
<td>10x10-10km CFP</td>
<td>100GBASE-LR4 CFP2</td>
<td>10x10-40km CFP</td>
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<td>100GBASE-LR4 CFP2</td>
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<td>100GBASE-ER4 CFP</td>
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<td>Parallel MMF (24-Fiber MPO)</td>
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<td>10 x 10 850 nm</td>
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<td><strong>Images courtesy of Finisar.</strong></td>
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<td><strong>Images courtesy of Finisar.</strong></td>
</tr>
</tbody>
</table>
1ST GENERATION 100 GE

• Fundamental 1st generation technology constraints limit higher 100 GE density and lower cost

• Electrical signaling to the CFP
  - 100 Gb/s Attachment Unit Interface (CAUI) uses 10 x 10 Gb/s lanes (CAUI-10)

• Optical signaling on the media
  - 100GBASE-SR10: 10 x 10 Gb/s parallel
  - 10x10 MSA: 10 x 10 Gb/s λs
  - 100GBASE-LR4 and 100GBASE-ER4: 4 x 25 Gb/s λs

• CFP module size, complexity and power consumption

• 2nd generation modules based on 4 x 25 Gb/s electrical signaling are available now

Image courtesy of Finisar.
1st Generation 100 GE
10 x 10 Gb/s Electrical and 4 x 25 Gb/s Optical

2nd Generation 100 GE
4 x 25 Gb/s Electrical and Optical

10 Gb/s Electrical Signaling and 10:4 Gearbox Adds Complexity, Cost, Space, and Consumes Power

## 100 GE Pluggable Module Evolution

Each module increases density, while reducing cost and power.

### Market Availability

<table>
<thead>
<tr>
<th></th>
<th>1st Generation</th>
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### Approximate Module Dimensions (Length x Width to Scale)

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### Front Panel Capacity (1 RU)

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<tr>
<td></td>
<td>4 Ports</td>
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<td>8 Ports</td>
<td>22/44 Ports</td>
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<td>16/32 Ports</td>
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### Electrical Signaling (Gb/s)

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### Media

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### Power Consumption (W)

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<td>&lt; 24 W (100GBASE-LR4)</td>
<td>&lt; 6 W (100GBASE-SR10)</td>
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<td></td>
<td>&lt; 14 W (2nd Generation CFP)</td>
<td>&lt; 12 W (100GBASE-LR4)</td>
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<td>&lt; 3.5 W (100GBASE-SR10)</td>
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<td>&lt; 6 W (100GBASE-LR4)</td>
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### Industry Standard Modules

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<td></td>
<td>CFP (82 mm Wide)</td>
<td>CXP (27 mm Wide)</td>
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<td></td>
<td>CFP2 (41.5 mm Wide)</td>
<td>QSFP28 (18.35 mm Wide)</td>
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<td>CFP4 (21.7 mm Wide)</td>
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### Cisco Proprietary Module

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<tbody>
<tr>
<td></td>
<td>CP4K (34.84 mm Wide)</td>
<td></td>
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</tbody>
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---

*Industry standard images courtesy of Finisar.*
• CFP2 supports electrical lanes that can run at multiple speeds
  - 10 x 10 Gb/s lanes (CAUI-10) for 100 GE
  - 8 x 25 Gb/s lanes (CAUI-4) for 100 GE
  - 8 x 50 Gb/s lanes (CDAUI-8) for 400 GE

• Optional external universal gearbox can convert electrical signaling so that all current IEEE and MSA 100 GE standards can be supported in the CFP2 module

• Smaller size and lower cost, complexity and power consumption than the CFP
100 GE MODULE EVOLUTION
GRAPHICAL VIEW OF MODULE FORM FACTORS

Diagrams courtesy of the CFP MSA.
CFP MODULE EVOLUTION FOR 100 GE AND 400 GE
HIGHER DENSITY CAGES AND FRONT PANEL DENSITY

CFP2
8 Ports Per Card
Front Panel Density

CFP4
16 Ports Per Card
Front Panel Density

Diagrams courtesy of the CFP MSA.
100 GE DEVELOPMENTS
BACKPLANE AND COPPER CABLE

• IEEE P802.3bj 100 Gb/s Backplane and Copper Cable Task Force started in September 2011
  - 100GBASE-KR4: 4 x 25 Gb/s NRZ 25 GBd on Megtron 6 backplane
  - 100GBASE-KP4: 4 x 25 Gb/s PAM-4 12.5 GBd on enhanced FR4 backplane
  - 100GBASE-CR4: 4 x 25 Gb/s over 5 m copper twinax cable
• Optional Energy Efficient Ethernet (EEE) operation for 40 GE and 100 GE backplane links and copper cable interfaces
• Task Force web page: http://www.ieee802.org/3/bj/
• Working on Draft 3.1 for 1st Sponsor recirculation ballot
• Standard expected in June 2014
100 GE DEVELOPMENTS
FIBER OPTIC CABLES

• IEEE P802.3bm 40 Gb/s and 100 Gb/s Operation Over Fiber Optic Cables Task Force started in September 2012
  
  - 40GBASE-ER4: 4 x 10 Gb/s over 40 km SMF
    - 4 x 25 Gb/s over 20 m MMF
      - Removed because there is not enough economic or technical advantage vs. existing MMF alternatives
  
  - 100GBASE-SR4: 4 x 25 Gb/s over 70 m OM3 and 100 m OM4 parallel MMF
    - 4 x 25 Gb/s over 500 m SMF
      - Removed due to lack of consensus that any of the proposals (CWDM, DMT, PAM-n, PSM4) provided sufficient size, cost and power reduction vs. existing SMF alternatives
  
  - CAUI-4 electrical signaling to the CFP2, CFP4 and QSFP28

• Optional Energy Efficient Ethernet (EEE) operation for 40 GE and 100 GE fiber interfaces

• Task Force web page http://www.ieee802.org/3/bm/

• Working on Draft 2.1 for 1st Working Group recirculation ballet

• Standard expected in March 2015
100 GE TECHNOLOGY GENERATIONS
PUTTING IT ALL TOGETHER

1st Generation 100 GE
10 Gb/s and 25 Gb/s Signaling

- Available in 2010
- More expensive, higher complexity and power consumption
- 400 Gb/s slot capacity
- Interfaces
  - 100GBASE-SR10
  - 10x10-2km
  - 100GBASE-LR4
  - 10x10-10km
  - 100GBASE-ER4
  - 10x10-40km

2nd Generation 100 GE
25 Gb/s Signaling

- Available in 2014
- Less expensive, lower complexity and power consumption
- 800 Gb/s slot capacity
- Supports existing interfaces plus 100GBASE-SR4

<table>
<thead>
<tr>
<th>CFP</th>
<th>CFP</th>
<th>CFP</th>
<th>ASIC</th>
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# 100 GE TECHNOLOGY REFERENCE

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<tr>
<th>Physical Layer Reach</th>
<th>1 m Backplane</th>
<th>5 m Copper Cable</th>
<th>7 m Copper Cable</th>
<th>70 m OM3 / 100 m OM4</th>
<th>100 m OM3 / 150 m OM4</th>
<th>2 km SMF</th>
<th>10 km SMF</th>
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<td>10x10-10km</td>
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<td>June 2010 IEEE 802.3ba</td>
<td>March 2015 IEEE 802.3bm</td>
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<td>June 2011 10x10 MSA</td>
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<td>June 2010 IEEE 802.3ba</td>
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<td><strong>Electrical Signaling (Gb/s)</strong></td>
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<td>4 x 25</td>
<td>10 x 10</td>
<td>4 x 25 850 nm</td>
<td>10 x 10 850 nm</td>
<td>10 x 10 1310 nm</td>
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<td><strong>Media Type</strong></td>
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<td>CFP, CFP2, CFP4, CPAK, QSFP28</td>
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</table>
AGENDA

1. Ethernet Speed Developments
2. 40 GE
3. 100 GE
4. 400 GE
IEEE BANDWIDTH REQUIREMENT PROJECTIONS

We are Here: 2014

Terabit Link Speeds are Needed Soon in Core Networks

INDUSTRY CHALLENGES FOR 400 GE AND BEYOND
SOLUTIONS ARE GOOD, FAST, OR CHEAP - PICK ANY TWO

Technical Feasibility

Market Requirements

Economics Dictate the Solution
IEEE Provides an Open Industry Forum to Make Decisions
WHY 400 GE? WHY NOT TERABIT SPEEDS?

• Given that Ethernet at terabit speeds is technically and economically impractical to develop until 2020+ we had to make a choice
  - Wait... for >10 years between Ethernet speed increases (100 GE June 2010)
  - Start a feasible higher speed Ethernet standard now that can be ready by 2016 when the market needs something faster
• IEEE 802.3 Ethernet Bandwidth Assessment (BWA) Ad Hoc and the IEEE 802.3 Higher Speed Ethernet (HSE) Consensus Ad Hoc spent a lot of time analyzing market demand and technical options
• High degree of consensus in the IEEE that 400 GE should be the next Ethernet speed
  - CFI straw poll: yes 132, no 0, abstain 1
  - Motion for Study Group: yes 87, no 0, abstain 4
• IEEE 802.3 Higher Speed Study Group first had to analyze market demand and technical options
  - Eventually decided on 40 GE and 100 GE
THEORETICAL M (1000) FORM-FACTOR PLUGGABLE USING TODAY’S TECHNOLOGY IS IMPractical

• Using current technology with 25 Gb/s electrical signaling, a TbE module (MFP) would use 40 channels
• The size of the module can be estimated at ½ sq. in. per W of power consumed
• If a CFP2 module consumes 7 W, then the MFP could consume 70 W
• This would require 45 sq. in. to cool and could make the module 5 in. by 9 in., which is too big to power and cool
IEEE 802.3 400 GB/S ETHERNET STUDY GROUP

• 400 GE Call for Interest (CFI) was presented at the March 2013 IEEE Plenary and approved to be an official IEEE Study Group

• Project Authorization Request (PAR) and Criteria for Standards Development (CSD) for P802.3bs adopted at the January 2014 IEEE Interim
  - Project approval request planned for March 27, 2014
  - 1st Task Force meeting expected in May, 2014

• Reach objectives adopted by Study Group at the November 2013 IEEE Plenary
  - 100 m MMF
  - 500 m SMF
  - 2 km SMF
  - 10 km SMF
  - Strong desire to support 400 GE to 4 x 100 GE breakout functionality based on 40 GE to 4 x 10 GE success

• 400 GE standard expected in 2016+

• First interfaces expected to be available in 2016+

• Study Group web page http://www.ieee802.org/3/400GSG/
### 400 GE Pluggable Module Evolution Estimates

Each module increases density, while reducing cost and power.

<table>
<thead>
<tr>
<th>Year</th>
<th>1st Generation</th>
<th>2nd Generation</th>
<th>3rd Generation</th>
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<td></td>
<td>2016+</td>
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<td><strong>Electrical Signaling</strong></td>
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<td>CDAUI-16</td>
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<td></td>
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<td>16 x 25 Gb/s</td>
<td>8 x 50 Gb/s</td>
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<td></td>
<td>CDAUI-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4 x 100 Gb/s</td>
</tr>
</tbody>
</table>

**Module**

- CDFP
- 4 x CFP4
- CFP2
- CFP4

*Ethernet at Terabit Speeds Becomes Feasible*

CDFP images courtesy of the CDFP MSA.
CFP images courtesy of Finisar and TE Connectivity.
**400 GB/S CDFP MODULE OVERVIEW**

**DESIGNED TO SUPPORT 4 TB/S PER SLOT**

- CD = 400 in Roman numerals, C = 100 and D = 500
- Optimized for short reaches and targeted for distances up to 500 m
- Supports copper cables, active optical cables and transceivers
- Initial focus is active optical cables

Images courtesy of TE Connectivity and the CDFP MSA.
ETHERNET SPEED EVOLUTION SUMMARY

• 10 GE is being widely deployed in every part of the network
  - 10 GE servers are driving the need for 40 GE and 100 GE in data centers
• 40 GE is increasingly deployed in data center networks
  - Popular in data centers for 40 GE and 4 x 10 GE breakout
• 100 GE is in transition to 2^{nd} generation technology
  - Still a couple of generations away from 100 Gb/s serial signaling
• 400 GE development has started and will leverage 100 GE
• Electrical signaling is increasingly challenging at higher speeds
  - Maturing 25 Gb/s technology, working on 50 Gb/s technology
• Ethernet at Terabit speeds is still unfeasible in the near future, but we’ll get there eventually (2022+)
MORE INFORMATION

- IEEE P802.3bj 100 Gb/s Backplane and Copper Cable Task Force
  - http://www.ieee802.org/3/bj/
- IEEE P802.3bm 40 Gb/s and 100 Gb/s Operation Over Fiber Optic Cables Task Force
- IEEE P802.3bq 40GBASE-T Task Force
  - http://www.ieee802.org/3/bq/
- IEEE 802.3 Higher Speed Study Group
- IEEE 802.3 Industry Connections Ethernet Bandwidth Assessment Ad Hoc
- IEEE 802.3 Industry Connections Higher Speed Ethernet Consensus Ad Hoc
- IEEE 400 GE Call-For-Interest presentation
- IEEE 802.3 400 Gb/s Ethernet Study Group
  - http://www.ieee802.org/3/400GSG/
- CFP MSA
  - http://www.cfp-msa.org/
- SFF Committee
  - http://www.sffcommittee.com/
- CDFP MSA
  - http://www.cdfp-msa.com/
www.alcatel-lucent.com

QUESTIONS?