4X25G Optical Modules and Future Optics

EA Panel Moderator
Daniel Dove - Applied Micro
The views expressed today on this presentation are the personal views of the participants and should not be considered the views or positions of Ethernet Alliance.
Panel Speakers & Topics

- Dan Dove, Applied Micro
  - IEEE 802.3™ Optical Standards Update
- Brad Booth, Dell
  - Short Reach Optics for Data Center Racks
- Jeffery Maki, Juniper
  - 100G link infrastructure requirements to support future 400G PMDs
- Matt Traverso, Cisco
  - Next Generation Optics - Advanced Modulation
IEEE 802.3 Standards

IEEE 802.3bm

- Next Generation 40 Gb/s and 100 Gb/s Optical Ethernet
  - Defining 40GBASE-ER4 (40km) solution
  - Defining 100GBASE-SR4 solution
  - Defining 100GBASE-nR4 solution
  - Defining a 4x25G Electrical Interface CAUI-4

Industry Connections (at the end of presentation)

- Bandwidth Assessment Ad hoc
  - Identified industry trends and bandwidth growth
- Consensus Building for Higher Speed of Ethernet
  - Forum for building consensus towards an 802.3 Call For Interest
40GBASE-ER4

Plan to modify Clause 87 to enable 40 km reach

- Allow low cost 40G adoption in metropolitan applications
- CWDM grid leveraged from 40GBASE-LR4
- Anticipate early baseline proposal to allow industry adoption with low risk of change
- Anticipate stable parameters early in 2013
**40GBASE-ER4**

A 40km 40GBASE standard can simplify networks

**Existing Solution – bulky & costly**
- Requires sophisticated user base
- Requires additional equipment
- Optimized for ‘00s to ‘000s of km

* Added 40GBASE-FR

**Proposed Solution – simple...**
- New PMD only
- Lack of point to point definition in telecom allows for additional Ethernet application

Ref: cfi_0312_2.pdf

ECOC 2012 - Amsterdam
CAUI-4

100G (C) Attachment Unit Interface

- Four lanes @ 25G data rate
- Reduces width/cost/power of I/O to module
- Potentially will leverage OIF CEI-VSR-28G
- Common electrical channel with 802.3bj
  - Single host budget for copper cables, optics

Fundamental to reducing cost/power and increasing density of 100G optics

- Eliminates need for 10:4 mux/demux (aka: Gearbox) in optical modules
100GBASE-SR4

4x25G optical interface for MMF

- Compatible with new 25G I/O
- Reduce cost, power of transceivers, solution
- Reduce # of fibers per link
- Focus on Data Center application
  - May be a single PMD capable of >100m
  - May be two PMDs, one shorter reach (>20m) cost-focused and one >100m
  - Task Force will decide based on cost/performance difference between longer/shorter reach alternatives
85% or more server/switch ports are < 20m
Areas for consideration

• Equalization; To compensate for BW limitations of VCSELs, PDs, TIAs, traces
• Forward Error Correction (FEC); To increase reach while maintaining BER
• Mode Partition Noise – Effects of higher speed links on existing channel models
• Re-timed vs Un-retimed interfaces
100GBASE-nR4

4x25G optical interface for SMF

- Reduce cost, power of transceivers, solution
- Focus on Data Center application
  - May be a new PMD capable of ≥ 500m
  - May be LR4 with 4x25G electrical interface
  - Decision to add a new PMD will be based on cost
- Alternatives under consideration
  - Multi-pair (4x25G) SMF (eliminate TEC, optical mux/demux)
  - Complex Modulation (reduce optics, move $ to DSP)
  - CWDM grid spacing (eliminate TEC)
For Massive Data Centers, these links are anticipated to be between 30m and 500m.

Lot of links

Very cost sensitive
P802.3bm Schedule (tentative)
Questions Will Be Taken at the end of all presentations
Short Reach Optics for Data Center Racks

Brad Booth
Dir., Network Architecture
Dell
Data Center Topology

- Leaf Switch
- Top of Rack Switch

>100 m reach

20-30 m Reach (Pod)

3 m Reach (Rack)
Pod Examples
Open Compute Rack Example
Server Motherboard

Optics require greater area

• SFP+ depth is 2x RJ45 MagJack

Server motherboard is space limited

• CPU and RAM get priority

* Measurements are in metric.
Optical Form Factors

Not designed for server motherboards

Board area
  • HD significantly better than other options

Faceplate protrusion
  • CXP and HD far greater

* Diagram from http://tinyurl.com/8l8emdj
Server Connectivity Trends

Copper not keeping pace
  • Increasing cable diameter to support higher data rates
  • Shorter reach capabilities

Optics could be the future
  • Not a simple win
  • Form factors impediment to deployment on server motherboards
Optics into Data Center Racks

Standards based commodity
  • Volume drives down price
  • Interoperability fosters competition

Form factor
  • MSA’s typically used
  • Size often dictated by broad module support
  • Compact form factors needed to penetrate volume server market
Questions Will Be Taken
at the end of all presentations
100G Link Infrastructure Requirements to Support Future 400G PMDs

Jeffery Maki
Distinguished Engineer
# 100G Ethernet Standard and Upcoming Standardization

<table>
<thead>
<tr>
<th>PMD Support</th>
<th>10G Media Lanes</th>
<th>25G Media Lanes</th>
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</thead>
<tbody>
<tr>
<td>Backplane</td>
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<td>100GBASE-KR4/KP4 (802.3bj-Draft Clause 93/94)</td>
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<tr>
<td>Copper Cable Assembly</td>
<td>100GBASE-CR10 (802.3 Clause 85)</td>
<td>100GBASE-CR4 (802.3bj-Draft Clause 92)</td>
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<td>MMF</td>
<td>100GBASE-SR10 (802.3 Clause 86)</td>
<td>Two Objectives (NG 40G/100G SG)</td>
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<td>Objective (NG 40G/100G SG)</td>
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<td>100GBASE-LR4 (802.3 Clause 88)</td>
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CFP(LC), CFP2(LC) and CFP4(LC) for SMF Applications


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Example: CFP, CFP2, and CFP4 for 100GBASE-LR4/ER4 SMF PMD

100GBASE-nR4
- A new **500-m** reach SMF PMD for 100GE is actively being considered in the 802.3 NG 40G/100G Optical Ethernet Study Group
- Character “n” is a place holder
- 100GBASE-LR4 is the current option
Projection of Form Factor Evolution to 400G

Roman Numerals
XL = 40
C = 100
CD = 400
400G Optical Ethernet

• First-generation PMDs have to be implementable that meet and eventually do better than these requirements
  – Size (Width): ≤ 82 mm (CFP width, ~4 x CFP4)
  – Cost: ≤ 4 x CFP4
  – Power: ≤ 24 W (4 x 6 W power profile of CFP4)

• Improved bandwidth density PMDs will need higher rate optical and/or electrical lane technologies such as 50 to 56 Gbps
Possible SMF Road Map: 100G, 400G, 1.6T

Early Adopter 400G
4 x 100GBASE-nR4
or
400GBASE-PSM4

Mature 400G
400GBASE-???

Early Adopter 1.6T
4 x 400GBASE-???
or
1600GBASE-PSM4

Parallel Single Mode, 4 Lanes (PSM4)
4, Tx and 4, Rx
1x12 MPO Connector

(Ethernet Alliance)
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Parallel fiber Infrastructure
Paradigm Example: QSFP(MPO) for Parallel Fiber Applications

40GBASE-SR4
High-Density 10GE Based on QSFP(MPO): 4 x 10GBASE-SR
Example: Structured Cabling for 10G/40G

**QSFP (1x12 MPO)**

- 1 x 12 Fiber Patch Cable
- 2 x 12 Fiber Trunk Cable
- 40G

**SFP+ (LC Duplex)**

- 10G
- LC-Duplex Patch Cable

Use SMF for 100G/400G
Summary

• CFP MSA form factors for bandwidth evolution
• Early adopter 400GE using 100GE module and SMF cabling infrastructure
• Possible common module for 400GE and high-density (i.e., 4-port) 100GE
Questions Will Be Taken at the end of all presentations
Next Generation Optics
Advanced Modulation

Matt Traverso
CISCO
Beyond the Building

Campus Distribution
- Vertical Cabling/Building Backbone (typically Multimode Fiber)
- Campus Backbone (typically single mode fiber)

Metro Aggregation
- P2P Access Switch
- Central Office

Core Network
- IP / MPLS
- Single mode fiber
- Non-DWDM

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Too Far Beyond the Building for this talk...

**DWDM Application different than Client Optics**

- Some Parameters are important for both
- Spectral/Transmission are critical for DWDM
- Density, Link Budget & Latency are critical for Client

<table>
<thead>
<tr>
<th></th>
<th>Client Optics</th>
<th>DWDM</th>
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<tr>
<td>Cost</td>
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<td>Port Density</td>
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<td>1</td>
</tr>
<tr>
<td>Optical Loss Budget</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Arbitrary Weighting of some interface parameters with 3 being “important” and 0 being “not important”
Advanced Modulation – what it is... (1)

Encoding widely used for Long Haul & Metro over the past few years
- 40G: Duobinary, DQPSK, QPSK, BPSK
- 100G: QPSK and more...
- Client Advanced Modulation has different drivers than Long Haul & Metro

At 100GE/802.3bm, IEEE is studying advanced modulation

Widely anticipated that beyond 100G – *Encoding is coming to client optics*

Client optics defined by their density
Advanced Modulation – what it is... (2)

4 ways to increase optical data-rate:

- Increase the transmission frequency, or
- Increase the number of fibers, or
- Increase number of optical wavelengths, or
- Increase number of bits per symbol

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**PAM-2**

1-bit Symbols

- 1 (1 level)
- 0 (0 level)

**PAM-4**

2-bit Symbols

- 1 1 (3 level)
- 1 0 (2 level)
- 0 1 (1 level)
- 0 0 (0 level)
Advanced Mod – Background and Drivers

Underlying assumption is that optical component count, associated packaging, and number of fibers are the dominant cost driver.

• “Reduction of number of components is key to achieve the lowest cost solution for data center application”  (Source: anderson_01_1111*)

The goal of advanced modulation is to move complexity into the electronics in an attempt to simplify the optics,

It is anticipated that this reduction in optical component count and associated packaging complexity (ideally to a single laser and receiver) drives down the cost.

*See: http://www.ieee802.org/3/100GNOPTX/public/nov11/anderson_01_1111_NG100GOPTX.pdf
Proposal leverages WDM and Advanced Modulation to enable high bit rate transmission @ low cost

2 bits per Symbol

4 Wavelengths

Use lower cost DMLs

These results highlight a PAM-8 implementation

3 bits per Symbol

DAC (Digital to Analog Convertor)

Using EML as light source & modulator

Spectral shaping investigated

Multipulse Modulation is proposed leveraging transversal filters to create orthogonal signals.
Multipulse Modulation is proposed leveraging transversal filters to create orthogonal signals

Directly modulated lasers

Published at ECOC’11

**Experimental result**

- Three-pulse (30 Gb/s aggregate) experiment presented at ECOC 2011 [2]

- VCSEL BW ~ 18 GHz; PIN-TIA BW ~ 15 GHz; transversal filter BW ~ 12 GHz

- 30 Gb/s aggregate suggests that 100 Gb/s aggregate would be feasible if these BW limitations were scaled by ~ 3

Silicon Photonics enables an Optical DAC

- DAC (Digital to Analog Convertor)
- Low cost CW laser light source
- DAC defined via lithography

Sample Proposal @ July IEEE (4b)
nicholl_01_0712_optx.pdf *

- Demonstrated PAM16 modulation using a segmented MZI, driven by an inverter based digital driver – **Optical DAC!**
- Power consumption for MZI Driver and MZI is 10mW (250 fJ/bit)
- Power consumption for whole transmit datapath including CDR, MZI, CW Laser (complete transmit solution) is 450mW
- PRBS-31 Eye Noisy – Currently under investigation
  - Excessive optical noise at the scope – 112uW each level with 17G optical filter
  - Rise time / fall time larger than design intent due to modeling error - 48-54ps instead of target 30-33ps – need to size inverter correctly

Summary:
Advanced Modulation is the (Right) Way Forward!

IEEE Objective is to develop a new SMF PMD that provides a ‘step function reduction’ in cost over 100GBASE-LR4

Going forward to rates >100G, Advanced Modulation provides a path to lower cost via reduced optical component count and associated packaging

Advanced modulation is a promising approach to reduce optical complexity/cost while not sacrificing data rate increases
Questions Will Be Taken at the end of all presentations
Industry Connections

Daniel Dove - Applied Micro
Industry Connections (BWA)

Consensus Building process within IEEE

Charter and Scope

- Evaluate Ethernet wire-line bandwidth needs of the industry
- Reference material for a future activity
- The role of this ad hoc is to gather information, not make recommendations or create a CFI

Webpage -

Chair, John D’Ambrosia, Dell (jdambrosia@ieee.org)
Findings of the IEEE 802.3 BWA

Figure 40—Relative traffic increase normalized to 2010

Industry Connections – Higher Speed Ethernet

Chair – John D’Ambrosia, Dell


HSE ICAID: [http://www.ieee802.org/3/ad_hoc/hse/ec-12-0033-01-00ec.pdf](http://www.ieee802.org/3/ad_hoc/hse/ec-12-0033-01-00ec.pdf)

Background and Purpose

- The completion of the IEEE 802.3 Industry Connections Ethernet Bandwidth Assessment Ad hoc has demonstrated that the bandwidth requirements of multiple application spaces are continuing an exponential climb with the forecasted growth in 2020 to reach a level 100x the bandwidth required in 2010. The purpose of the IEEE 802.3 Industry Connection’s Higher Speed Ethernet Consensus activity will be to build consensus related to initiating a new effort targeting the next speed of Ethernet for wireline applications, which will be used for the evaluation and possible development of a Call-For-Interest for the next IEEE 802.3 Higher Speed Study Group.

- Related Standards – IEEE Std 802.3-2008 and IEEE Std 802.3ba-2010
- Related Sponsor – IEEE 802

Charter and Scope

- The scope of this IC activity will focus on building consensus related to the next speed of Ethernet for wireline applications, which will be used for the evaluation and possible development of a Call-For-Interest for the next IEEE 802.3 Higher Speed Study Group. The requested duration for this Industry Connections activity is 12 months.

Proposed Deliverables

- The proposed deliverables will be the historical records, i.e. meeting notes & presentations, of the meetings held by this Industry Connections activity.