802.3ba Cu specifications

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• Vivek Telang, Broadcom
Supporters

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• Shimon Muller, Sun Microsystems
Presentation objectives

• Considerations for 802.3ba Cu specifications for baseline proposal.

• Measurement models and simulation models in development to evaluate usage of 10GBASE-KR (Clause 72) for 10 Gb/s lane options for both 40GBASE-CR4 and 100GBASE-CR10 cable assemblies.

• QSFP cable connector and 10 meters of twinaxial cable considered for 40GBASE-CR4 cable assemblies.
802.3ba objectives

- Support full-duplex operation only
- Preserve the 802.3 / Ethernet frame format utilizing the 802.3 MAC
- Preserve minimum and maximum FrameSize of current 802.3 standard
- Support a BER better than or equal to $10^{-12}$ at the MAC/PLS service interface
- Provide appropriate support for OTN

- Support a MAC data rate of 40 Gb/s
  - Provide Physical Layer specifications which support 40 Gb/s operation over:
    - at least 100m on OM3 MMF
    - at least 10m over a copper cable assembly
    - at least 1m over a backplane

- Support a MAC data rate of 100 Gb/s
  - Provide Physical Layer specifications which support 100 Gb/s operation over:
    - at least 40km on SMF
    - at least 10km on SMF
    - at least 100m on OM3 MMF
    - at least 10m over a copper cable assembly
40GBASE-CR4 and 100GBASE-CRn link

- 100GBASE-CRn or 40GBASE-CR4 Transmits

- 40GBASE-CR4 Transmit Function

- 100GBASE-CRn or 40GBASE-CR4 Receive Function

- MDI

- Signal shield

- Signal p

- Signal n

- Lane n

- Link shield

- Cable assembly
Cu cable assembly baseline proposal

• Evaluate usage of 10GBASE-KR (Clause 72) and 10GBASE-CX4 to specify 40GBASE-CR4 and 100GBASE-CR10
  – For commonality with 40 Gb/s backplane proposal:
    • 64b/66b PCS
    • Signaling speed 10.3125 Gbd (per lane)
    • Optional FEC sublayer (TBD)

• Evaluate usage CX4 for commonality with twinaxial cable assembly usage and specifications (plug-and-play over all specified distances)
  • S-parameters (+ additional parameters i.e., group delay, etc..)

• QSFP MSA – 10 Gb/s lane operation demonstrated up to 10 meters of twinaxial cable

• Group delay differences between backplane and twinaxial cable assemblies (64b/66b spectra versus 8b/10b)
• Support a MAC data rate of 100 Gb/s
• Provide Physical Layer specifications which support 100 Gb/s operation over:
  – at least 10m over a copper cable assembly
  – 10 x 10 Gb/s lane
  – 4 x 25 Gb/s lane (TBD)
  – 5 x 20 Gb/s lane (TBD)

• Support a MAC data rate of 40 Gb/s
• Provide Physical Layer specifications which support 40 Gb/s operation over:
  – at least 10m over a copper cable assembly
  – 4 x 10 Gb/s lane
S-parameter interconnect specifications

• S-parameters are sufficient to specify interconnect-induced signal impairments e.g.,
  • Measured:
    - Insertion loss
    - Return loss
    - Crosstalk
      - NEXT
      - FEXT
  • Computed:
    - PSNEXT
    - PSELFEXT
  • Limits:
    - Measurement based
    - InfiniBand

10GBASE-CX4 Cable assembly

For 10GBASE-CX4 - All cable assembly measurements are to be made between TP1 and TP4 as shown in the Figure illustrated above.
802.3ap Channel Parameters

- Channel measurement reference: TP1 to TP4.

**Measured**
- Insertion Loss
- NEXT
- FEXT
- Return Loss

**Computed**
- Insertion loss deviation
- Insertion loss to crosstalk ratio
- PSNEXT, PSFEXT, PSXT

**Limits**
- To support existing platforms (ATCA)
Cable board connector – QSFP - 38 ckt

- Infiniband Copper

- Annex A5: Pluggable Interfaces: CATx, Copper and Optical
  - Pluggable QSFP FOR 4x, 8x and 12x
  - Multiple 4x QSFP pluggables used for 8x or 12x links

QSFP Module

QSFP Connector: 38-contact, right angle surface mount connector

Source: Molex

32 - QSFP Ports
1U rack space

Source: Molex
802.3ap – channel parameter comparisons

• Insertion loss to crosstalk ratio (ICR) computed from S-parameter measurements and models of QSFP 10 meter copper cable assembly (24 AWG).
802.3ap IL limits vs 10 m QSFP cable assembly 24 AWG including test fixtures

IEEE 802.3ba – Jan 2008
802.3ap ICR limits versus 10 m QSFP cable assembly
24 AWG including test fixture

A(f) max attenuation
f1=1.00 GHz
f2=6.00 GHz

ICRmin(f)
fa=.100 GHz
fb=5.15625 GHz

ICRfit(f)
fa=.100 GHz
fb=5.15625 GHz

PSNEXT(f) - 4 disturbers
PSFEXT(f) - 3 disturbers
PSXT(f) - 4 NEXT + 3 FEXT

802.3ap recommends that ICRfit(f) ≥ ICRmin(f)
fa=0.100 to f2=5.15625 GHz
802.3ap RL limits vs 10 m QSFP cable assembly 24 AWG including test fixture

GHz

SDD11-Tx2_RL

SDD11-Tx2_RL

RL(f)
802.3ap ILD vs 10 m QSFP cable assembly 24 AWG including test fixtures

ILD(f) ≤ ILD_{max}(f) = 1.0 \times 0.5 \times 10^{-9} f
ILD(f) ≥ ILD_{min}(f) = -1.0 \times 0.5 \times 10^{-9} f
Simulation Setup

• Insertion Loss, Return Loss, Crosstalk per data from Chris DiMinico
• Package models based on measured data
• Receiver architecture same as that used in KR group (802.3ap)
• MATLAB simulations
  – Pulse Response “Frequency-domain” Analysis, with MMSE optimization
• Performance evaluation based on detailed, worst-case error probabilities (not simple Gaussian assumption)
• On-chip impairments included
  – Clock jitter, Offsets, Front-end noise, Detailed analog circuit models, Detailed equalizer implementation penalties
• Worst-casing of ISI data patterns and crosstalk phase

Source: Vivek Telang, Broadcom
Channel models

Source: Vivek Telang, Broadcom
Simulation results

<table>
<thead>
<tr>
<th>Slicer SNR &amp; BER</th>
</tr>
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<tbody>
<tr>
<td><strong>SNR (dB)</strong></td>
</tr>
<tr>
<td>18.5</td>
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</tbody>
</table>

Source: Vivek Telang, Broadcom
### 40GBASE-CR4 and 100GBASE-CR10 cable assembly

- **Cable assembly differential parameters**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Insertion Loss</em> ( f ) ( \leq ) TBD ( \sqrt{f} ) + TBD ( \times f ) + ( \frac{TBD}{\sqrt{f}} )</td>
<td>TBD</td>
<td>dB</td>
</tr>
<tr>
<td><em>NextLoss</em> ( f ) ( \geq ) TBD – TBD ( \times \log \left( \frac{f}{TBD} \right) )</td>
<td>TBD</td>
<td>dB</td>
</tr>
<tr>
<td><em>ReturnLoss</em> ( f ) ( \geq ) TBD</td>
<td>TBD</td>
<td>dB</td>
</tr>
<tr>
<td><em>MDNextLoss</em> ( f ) ( \geq ) TBD – TBD ( \times \log \left( \frac{f}{TBD} \right) )</td>
<td>TBD</td>
<td>dB</td>
</tr>
<tr>
<td><em>ELFEXT</em> ( f ) ( \geq ) TBD – TBD ( \times \log \left( \frac{f}{TBD} \right) )</td>
<td>TBD</td>
<td>dB</td>
</tr>
<tr>
<td><em>MDELFE XT</em> ( f ) ( \geq ) TBD – TBD ( \times \log \left( \frac{f}{TBD} \right) )</td>
<td>TBD</td>
<td>dB</td>
</tr>
</tbody>
</table>
Possible 40 Gb/s Layer Diagram

- Possible layer diagram based on discussions in HSSG
- Assumptions
  - 4 lanes of 10G
  - R PCS (64b/66b coding)

Source: ganga_02_1107.pdf
Possible 100 Gb/s Layer Diagram

Source: ganga_02_1107.pdf
Cu link diagrams

PMD Service Interface

CRn transmit function

n pair Twinaxial cable n=4,10,…

cable assembly

PMD Service Interface

CRn receive function Including AC coupling

PMD Service Interface

TP1 MDI TP2

TP3 MDI TP4

PMD Service Interface

TP1 MDI

TP4 MDI

PMD

x4 backplane

backplane connector

KR4 transmit function

x4 backplane

Backplane channel

KR4 receive function Including AC coupling
40GBASE-?Rn optical link diagram – OM3 Fiber.

Diagram showing the connection between two devices using OM3 fiber. The diagram includes labels for TX bit, RX bit, MDI, TP2, TP3, and PMD service interface.
Conclusions

• Measurements of 10 meter QSFP cable assembly compared to 10GBASE-KR (Clause 72) channel parameter limits used to validate 10 Gb/s lane operation over 10 meter QSFP cable assembly for 40GBASE-CR4.

• CX4 twinaxial cable assembly differential parameters proposed as basis for 40GBASE-CR4 and 100GBASE-CR10 link specification (i.e., S-parameters).
Test points

- MDI
- Twinaxial cable
- TP1
- TP2
- TP3
- TP4
- Tx attributes e.g., Pre-emphasis
- Tx package
- pcb
- Tx driver
- Rx attributes e.g., equalization, AC coupling
- Rx slicer
- cable assembly
- backplane connector
- backplane channel
- backplane
- Rx package
- pcb
Cu cable assembly channel model

- Cable board connector – QSFP
- 10 meters - 24 AWG – twinaxial cable


Worst-case Package Model (*.zip) Richard Mellitz Spec_RL_pkg_802_3.s4p
Cable – 24 AWG twinaxial

Insertion Loss-10 m-24 AWG

MHz

dB