Baseline proposals for electrical interfaces at 200 Gb/s per lane

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Introduction

- We present baseline proposals for:
  - Two clauses for backplane (KR) and copper cable assembly (CR) PMDs with 1, 2, 4, and 8 lanes, at 200 Gb/s per lane
  - Two annexes for chip-to-module and chip-to-chip attachment unit interfaces (AUI-C2C, AUI-C2M) with 1, 2, 4, and 8 lanes, at 200 Gb/s per lane
- These proposals have been presented at the electrical ad hoc (ran_3dj_elec_01a_231207 and ran_3dj_elec_01a_240111).
  - Support for the proposal content was shown in straw polls taken at the ad hoc (3dj_elec_adhoc_Straw_Polls_240111):
    - Support adopting the CR proposal: Y: 50, N: 0, A: 11
    - Support adopting the KR proposal: Y: 50, N: 0, A: 10
    - Support adopting the AUI-C2C proposal: Y: 50, N: 0, A: 10
    - Support adopting the AUI-C2M proposal: Y: 45, N: 2, A: 13
- This presentation is planned for adoption and is ready for implementation in a draft.

Notation

- Areas that need decisions and TBD values are marked in magenta in this presentation.
  - Areas that still require major decisions are marked with ★
  - These do not preclude us from adopting a baseline proposal. The initial draft will include TBDs and editor's notes as necessary.
  - Technical completeness is required to progress to working group ballot (D2.0).
- Areas based on existing clauses without substantive changes are marked in blue.
- Magenta and blue notations are not intended to be used in drafts.

Proposal for CR PMDs

200GBASE-CR1, 400GBASE-CR2, 800GBASE-CR4, 1.6TBASE-CR8

CR clause outline

- CR PMDs will be specified in a single clause, 179.
- The proposed structure is based on existing CR PMD Clause 162 (IEEE Std 802.3ck-2022).
- The major subclauses are:
    1. Overview, including a general error rate specification
    2. Conventions
    3. Service interface
    4. PCS requirements for Auto-Negotiation (AN) service interface
    5. Delay constraints
    6. Skew constraints
    7. MDIO function mapping
    8. Functional specifications
    9. PMD electrical characteristics
    10. Channel characteristics
    11. Cable assembly characteristics
    12. MDI specifications
    13. Environmental specifications
    14. PICS
- Details on some of the subclauses are included in the following slides.

C179 (CR) Subclauses: the easy parts

- C179.1 Overview
  - Introductory text based on 162.1 with addition of description of the host types and cable types (motion #11 in motions_3cwdfdj_2311), nomenclature TBD
  - Tables of Physical layer clauses associated with the PMDs.
  - Architectural diagram (as in Figure 162-1).
- C179.2 Conventions
  - As in 162.2, n denotes number of lanes, i takes values 0 to n-1, "PMD" refers to any of the 4 defined PMDs.
- C179.3 Service interface
  - PMD:IS_UNITDATA_i.request and PMD:IS_UNITDATA_i.indication as PAM4 symbols. Add editor's note that these may be changed to sampled analog values.
  - PMD:IS_SIGNAL.indication as in clause 162.
- C179.4 PCS requirements for Auto-Negotiation (AN) service interface – as in clause 162
- C179.5 Delay constraints, C179.6 Skew constraints – based on Clause 162, with values scaled appropriately; Add editor's note that these values need confirmation
- C179.7 MDIO function mapping
- C179.8 Functional specifications – as in clause 162, except that the link diagram and test point table use TP0d and TP5d
- C179.12 MDI specifications: TBD (pending adoption of specific connectors)
- C179.13 environmental: boilerplate.

C179 (CR): Electrical characteristics (179.9)

- Structure and general content based on 162.9 with addition of host classes (tracy_3dj_01a_2311 slide 12); some parameters have separate specifications per class.
- Transmitter specifications at TP2:
  - Signal observation filter (Bessel-Thomson filter) bandwidth TBD
  - Signaling rate:
    - For 800GBASE-CR4 and 1.6TBASE-CR8, 106.25 GBd ± 50 ppm
    - For 200GBASE-CR1 and 400GBASE-CR2 PMDs in the same package as the PCS sublayer, 106.25 GBd ± 50 ppm; otherwise, derived from the adjacent PMA
  - ERL, RLcc (min) and RLdc (min) – values and equations TBD
  - Linear fit pulse peak ratio R_{peak} – per host class, values TBD
  - Jitter: parameters and values TBD
- Receiver specifications at TP3:
  - Signaling rate: For 800GBASE-CR4 and 1.6TBASE-CR8, 106.25 GBd ± 50 ppm; for 200GBASE-CR1 and 400GBASE-CR2, 106.25 GBd ± 100 ppm
  - ERL, RLcd (min) – value and equation TBD
  - Interference tolerance test channel and cable assembly losses – all per host class, values TBD
  - Test signal observation filter (Bessel-Thomson filter) bandwidth TBD
- For other parameters, use values from clause 162 (scaled to signaling rate where appropriate)

C179 (CR): Channel and cable assembly characteristics

- C179.10 Channel characteristics:
  - Structure based on 162.10
  - New content describing the concept of host types and cable types and their possible combinations (tracy_3dj_01a_2311 slide 12)
- C179.11 Cable assembly characteristics:
  - Structure based on 162.11 with 16 cable assembly types: 4 loss classes (CA-A, CA-B, CA-C, and CA-D)* × 4 lane widths (1,2, 4, and 8)
    - 162.11.2 will include an expanded loss table, with min/max loss equations and figures TBD
  - ERL, RLcd, ILcd, RLcc values/equations TBD
  - COM parameter values: see next slide.

* The cable loss classes are listed here using placeholder names per motion #11 from 11/23, nomenclature TBD

C179 (CR): COM parameter values (179.11.7)

- Signaling rate: 106.25 GBd
- Host device, package, and PCB parameters for signal/crosstalk path calculations:
  - New device and package models adopted only for KR/C2C
  - Division of the host loss budget between the components requires a separate proposal
  - For now, all these parameters are TBD
- COM reference receiver equalizer
  - CTLE parameters: scale existing parameters to the new signaling rate. Add editor's note that these need confirmation.
  - DER0 is 2e-4 (motion #12 in motions_3cwdfdj_2311)
  - η_0, T_r, and jitter values are TBD
  - FFE + 1-tap DFE has not been formally adopted but seems to be in consensus
    - Assuming we adopt FFE+DFE: tap setting algorithm, sampling point selection, and output pulse response calculation method are required (some existing presentations can be used); left as TBD until adopted
    - Length, fixed and floating taps (number and range), coefficient limits TBD
  - MLSE is considered necessary for CR receivers, but has not been adopted yet
    - If detailed proposal for MLSE in the COM reference receiver is adopted, we can consider keeping a minimum COM (implementation margin) of 3 dB.
    - Alternatively, the minimum COM can be reduced by the expected coding gain of the MLSE.
    - It is suggested that minimum COM is listed as TBD.
- Currently refer to Annex 93A; COM with FFE+DFE may become a new annex instead of amendment of 93A. Such annex is beyond the scope of this presentation.

Proposal for KR PMDs

200GBASE-KR1, 400GBASE-KR2, 800GBASE-KR4, 1.6TBASE-KR8

KR clause outline

- KR PMDs will be specified in a single clause, 178.
- The proposed structure is based on existing KR PMD Clause 163 (IEEE Std 802.3ck-2022).
- The major subclauses are:
    1. Overview, including a general error rate specification
    2. Conventions
    3. Service interface
    4. PCS requirements for Auto-Negotiation (AN) service interface
    5. Delay constraints
    6. Skew constraints
    7. MDIO function mapping
    8. Functional specifications
    9. PMD electrical characteristics
    10. Channel characteristics
    11. MDI specifications
    12. Environmental specifications
    13. PICS
- Details on some of the subclauses are included in the following slides.

C178 (KR) Subclauses: the easy parts

- C178.1 Overview
  - Introductory text based on 163.1 but with addition description of the two package classes.
  - Tables of Physical layer clauses associated with the PMDs.
  - Architectural diagram (as in Figure 163-1).
- C178.2 Conventions
  - As in 163.2, n denotes number of lanes, i takes values 0 to n-1, “PMD” refers to any of the 4 defined PMDs.
- C178.3 Service interface
  - PMD:IS_UNITDATA_i.request and PMD:IS_UNITDATA_i.indication as PAM4 symbols. Add editor’s note that these may be changed to sampled analog values.
  - PMD:IS_SIGNAL.indication as in clause 163.
- C178.4 PCS requirements for Auto-Negotiation (AN) service interface - as in clause 163
- C178.5 Delay constraints, C178.6 Skew constraints – based on Clause 163 with values scaled appropriately; Add editor’s note that these values need confirmation
- C178.7 MDIO function mapping, C178.8 Functional specifications – as in clause 163
- C178.12 MDI specifications – as in clause 163
- C178.13 environmental: boilerplate.

C178 (KR): Electrical characteristics (178.9)

- Structure and general content based on 163.9, including TP0v/TP5v methodology
- Transmitter specifications at TP0v:
  - Signal observation (Bessel-Thomson filter) bandwidth TBD
  - Signaling rate:
    - For 800GBASE-KR4 and 1.6TBASE-KR8, 106.25 GBd ± 50 ppm
    - For 200GBASE-KR1 and 400GBASE-KR2 PMDs in the same package as the PCS sublayer, 106.25 GBd ± 50 ppm; otherwise, derived from the adjacent PMA
  - Reference values ($ERL^{(ref)}$, $v_f^{(ref)}$, $R_{peak}^{(ref)}$) are calculated based on the Tx package class that the device adheres to
  - Jitter: parameters and values TBD
- Receiver specifications at TP5v:
  - Signaling rate: For 800GBASE-CR4 and 1.6TBASE-CR8, 106.25 GBd ± 50 ppm; for 200GBASE-CR1 and 400GBASE-CR2, 106.25 GBd ± 100 ppm
  - For dERL, the reference value $ERL^{(ref)}$ is calculated based on the Rx package class that the device adheres to
  - RLcd (min) – equation TBD
  - Receiver test parameters:
    - Test signal calibration to the channel minimum COM (TBD) with the parameters in this clause
    - Test signal observation filter (Bessel-Thomson filter) bandwidth TBD
    - Test channel ILdd at 53.125 GHz instead of 26.5625, separate for each Rx package class, values TBD
    - RSS_DFE4 not included (not adequate for FFE-based reference receiver). Add an editor's note that another metric TBD may be considered instead.
- For other parameters, use values from clause 163 (scaled to signaling rate where appropriate)

C178 (KR): Channel characteristics (178.10)

- Structure and general content based on 163.10
- New content describing the concept of package classes and how they affect channel compliance (motion #9 in motions_3cwdfdj_2311, lusted_3dj_02_2311 slide 7)
- Maximum ILdd at 53.125 GHz (recommended) – different per combination of package classes; values, equations and figures TBD
- ERL, RLcd, ILcd, ILdc: values/equations TBD
- COM parameter values: see next slide.

C178 (KR): COM parameter values (178.10.7)

- Signaling rate: 106.25 GBd
- Host device and package parameters for signal/crosstalk path calculations:
  - New device model (motion #1 in motions_3dfdj_230720, lim_3dj_01a_2307 slides 6-7), parameters TBD (not included in the motion)
  - Two package models and parameter values (motion #10 in motions_3cwdfdj_2311, lim_3dj_01a_2311 slides 8-9), trace lengths and test cases TBD (not included in the motion)
  - Package class on each end of the channel is selected as part of the invocation of the COM procedure.
- COM reference receiver equalizer and jitter parameter values TBD
  - Same as CR (see C179)
- Currently refer to Annex 93A; COM with FFE+DFE may become a new annex instead of amendment of 93A. Such annex is beyond the scope of this presentation.

Proposal for AUI-C2C

200GAUI-1 C2C, 400GAUI-2 C2C, 800GAUI-4 C2C, 1.6TAUI-8 C2C

AUI-C2C Annex outline

- AUI-C2C will be specified in Annex 176B.
- The proposed structure is based on existing AUI-C2C annex 120F.
- The major subclauses are:
  1. Overview, including a general error rate specification
  2. Compliance point definitions
  3. Electrical characteristics
  4. Channel characteristics
  5. PICS
- Details on each subclause are included in the following slides.

A176B (C2C): Overview (176B.1)

- General introductory text based on 120F.1, with the addition of Tx/Rx package classes, and interconnect length TBD
- Architectural diagram (as in Figure 120F-1), including usage within a PHY and within an xGMII Extender
- Composition of a C2C link, with a reference to the channel model subclause (176B.4)
- Nominal signaling rate 106.25 GBd, PAM4 modulation
- Transmitter output is adjustable (method TBD)
  - In-band training may be adopted as a separate proposal
- Error ratio specifications
  - Based on a BER allocation assuming random uncorrelated error events (see ran_3dj_01_230817)
    - For AUI-C2C within a PHY with AUI-C2M: event ratio <5e-6 (based on DER_0=0.67e-5; motions #1 and #2 in motions_3dj_230921)
    - For other cases: event ratio <TBD
  - Allowance of additional errors from other segments for each case
  - Measurement method and limits TBD (a separate annex is planned to explain BER interpretations and test methodology).

A176B (C2C): Compliance points (176B.2)

- Refer to the compliance points definitions in C178 (TP0v/TP5v methodology)
- Reference impedance: 100 Ω differential, 25 Ω common

A176B (C2C): Electrical characteristics (176B.3)

- Structure and general content based on 120F.3 (and similar to C178)
- Transmitter specifications at TP0v:
  - Signal observation (Bessel-Thomson filter) bandwidth TBD
  - Signaling rate: 106.25 GBd ±50 ppm (for 400GAUI-2 and 200GAUI-1, applies only for a PMA in the same package as the PCS; otherwise, derived from the adjacent PMA)
  - Reference values ($ERL^{(ref)}$, $v_f^{(ref)}$, $R_{peak}^{(ref)}$) calculated based on the Tx package class that the device adheres to
  - Jitter: parameters and values TBD
- Receiver specifications at TP5v:
  - Signaling rate: 106.25 GBd (±100 ppm for 400GAUI-2 and 200GAUI-1, ±50 PPM otherwise)
  - For dERL, reference value $ERL^{(ref)}$ calculated based on the Rx package class that the device adheres to
  - RLcd (min) – equation TBD
  - Receiver test parameters: generally, as in C178, except for:
    - Test signal calibration with the COM parameters of this annex
    - Different test channel ILdd at 53.125 GHz, values TBD
- For other parameters, use values from Annex 120F (scaled to signaling rate where appropriate)

A176B (C2C): Channel characteristics (176B.4)

- Based on the KR channel characteristics (C178) but with a separate table of parameters
  - Different DER_0 value – 0.67e-5 within a PHY with AUI-C2M, other cases TBD
  - Other parameters are suggested to be the same as those for KR in C178 (these may change later).

Proposal for AUI-C2M

200GAUI-1 C2M, 400GAUI-2 C2M, 800GAUI-4 C2M, 1.6TAUI-8 C2M

AUI-C2M Annex outline

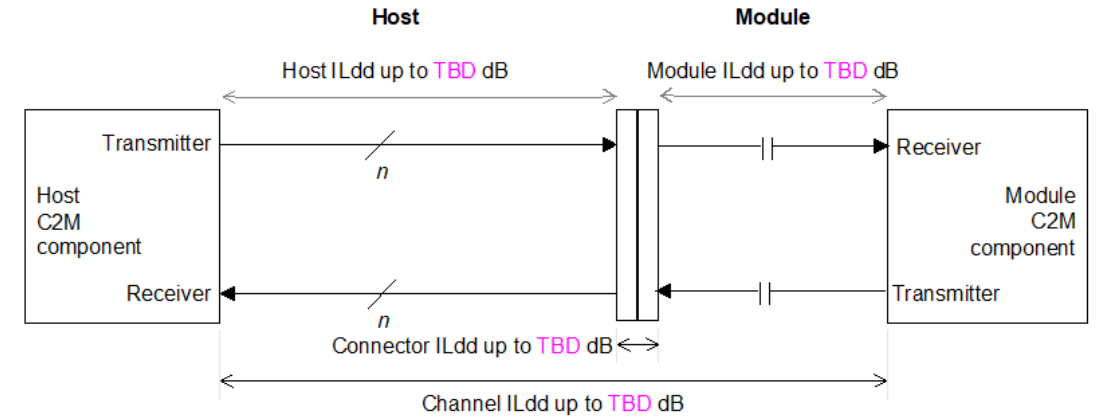
- AUI-C2M will be specified in Annex 176C.
- The proposed structure is based on existing AUI-C2M annexes, such as 120G, with some modifications.
- The major subclauses are:
  1. Overview, including a general error rate specification
  2. Channel model (including recommended insertion loss)
  3. Compliance point definitions
  4. Electrical characteristics: host/module, output/input
  5. Measurement methodology
  6. PICS
- Details on each subclause are included in the following slides.

A176C (C2M): Overview (176C.1)

- General introductory text based on 120G.1
- Architectural diagram (as in Figure 120G-1), including usage within a PHY and within an xGMII Extender
- Composition of a C2M link, with a reference to the channel model subclause (A176C.2)
- Nominal signaling rate 106.25 GBd, PAM4 modulation
- Output specification:
  - Adjustable output equalization and differential swing, with method TBD
  - Or – a small number of fixed settings (as in Annex 120G)
  - In-band training may be adopted as a separate proposal; if it is, it implies adjustable equalization. Otherwise, add editor's note that decision is needed.
- Error rate specifications
  - Based on BER allocation assuming random uncorrelated error events (see ran_3dj_01_230817)
    - For AUI-C2M within a PHY: event ratio <1.5e-5 (based on DER0=2e-5; motions #1 and #2 in motions_3dj_230921)
    - For AUI-C2M within an xGMII Extender: event ratio <TBD (options: 1e-4 / 2e-4)
  - Measurement method and limits TBD (a separate annex is planned to explain BER interpretations and test methodology).

A176C (C2M): Channel model (176C.2)

- Channel model figure with all losses TBD
  - Add text or graphics to clarify that host and module losses in the figure include packages



NOTE—The number of lanes *n* is equal to 1 for 200GAUI-1, 2 for 400GAUI-2, 4 for 800GAUI-4, and 8 for 1.6TAUI-8.
ILdd values are at 53.125 GHz.

Figure 999X–99—Channel model for AUI-C2M

- Channel insertion loss (recommended) TBD
  - Text, equation and figure based on 120G.4
- COM reference model (new) TBD
  - Reference transmitter and receiver for assumed capabilities (Tx FFE, CTLE, Rx FFE+1-tap DFE, MLSE?)
  - Same as those used for normative input/output requirements that include reference Tx/Rx
  - Channel characterization using COM is informative

A176C (C2M): Compliance point definitions (176C.3)

- Similar to 120G.2
- Reference to channel model in A176C.2
- HCB/MCB characteristics (similar to 120G.5.4)
  - Refer to another annex with detailed HCB/MCB/MTF specifications (modeled after Annex 162B) – assuming the same test fixtures are used
  - Content of that annex has not been adopted – will be TBD

A176C (C2M) Electrical characteristics: host/module, output/input (176C.4)

- Host and Module output:
  - Based on specifications in 120G, with the following exceptions:
    - Signaling rate value 106.25 GBd ± 50 ppm (for 400GAUI-2 and 200GAUI-1, ± 50 ppm applies only for a PMA in the same package as the PCS)
    - Transition time (min) value TBD
    - Steady-state voltage (max) defined with equalization off, value TBD
    - VEC and EH TBD; add editor's note that these may be replaced by output parameters for CR PMD (see "Measurement methodology")
    - ERL TBD
  - Details, equations, figures
- Host and Module input:
  - Based on specifications in 120G, with the following exceptions:
    - Signaling rate value 106.25 GBd
      - ± 50 ppm for 800GAUI-4 and 1.6TAUI-8
      - ± 100 ppm for 400GAUI-2 and 200GAUI-1
    - Stressed input tolerance
      - Calibration procedure and parameters TBD
      - These depend on decision between adjustable equalization and fixed settings; if the decision is not made, add editor's note
    - ERL TBD
  - Details, equations, figures

A176C (C2M): Measurement methodology (176C.5)

- Major decision to be made is whether output setting (equalization, swing, etc.) is adjustable using training, or selected from a small number of fixed settings.
  - This may affect both measurement methodology and stressed input calibration.
- This subclause is proposed to be TBD in the first draft.

Summary of the proposals

- Baseline proposal for CR PMDs: Slides 5-9
- Baseline proposal for KR PMDs: Slides 11-15
- Baseline proposal for AUI-C2C: Slides 17-21
- Baseline proposal for AUI-C2M: Slides 23-28

Decisions required for next steps

- CR, KR, C2C COM reference equalizer: DFE, or FFE + 1-tap DFE? other?
- COM model for C2M?
- MLSE in COM reference receiver, or reduction in minimum COM? other?
  - KR/CR only, or also AUIs?
- AUI-C2M – adjustable equalization or small number of fixed settings?
  - Big effect on host and module output and input methodology
  - Related question: in-band or out-of-band training over AUIs?
- BER measurement method