AUI error rate specifications

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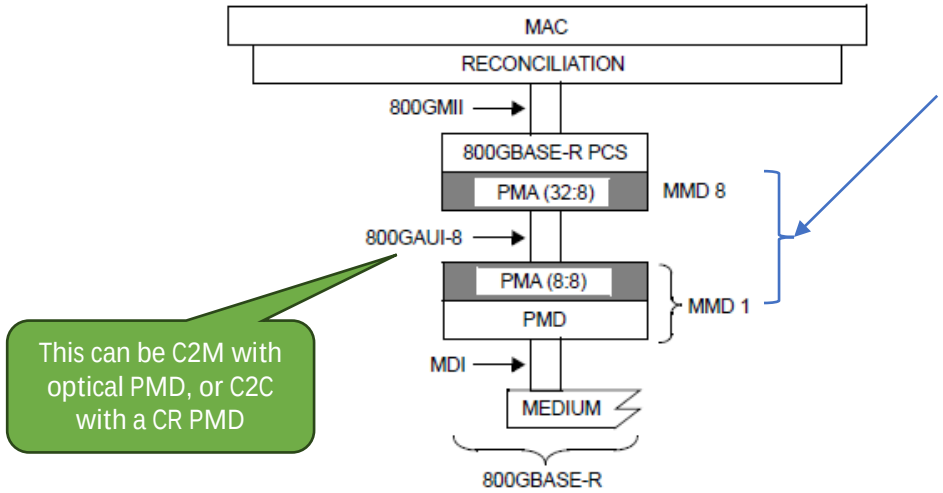
Outline

- Error budgeting
- Existing specifications
- Allocation of FLR/CER and random BER
- Verifying error requirements
- Proposed detailed text and tables

Background – AUIs within a PHY

- In ran_3dj_elec_02_230622 it was noted that:
  - A DER_0 value of 2.67e-5 was adopted for the higher-loss AUIs within a PHY (see motion #8 and ran_3dj_02_2305)
  - This corresponds to BER of 2e-5 with uncorrelated errors, or measured BER of 4e-5 with precoding ON
  - As part of that decision, **BER division between C2C and C2M** and measurement method were left to be determined
- Options for allocating the BER budget between AUI-C2C and AUI-C2M were presented in ran_3dj_01a_2307.
  - Straw polls #1 and #2 following the presentation (see motions_3dfdj_230720) indicated that more information is needed.

Recap: possible PHY structures (diagrams from 802.3df D2.1)



800GAUI = 800 Gb/s ATTACHMENT UNIT INTERFACE
800GMII = 800 Gb/s MEDIA INDEPENDENT INTERFACE
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE
MMD = MDIO MANAGEABLE DEVICE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 173A–1—Example PMA layering with eight-lane PMD and single 800GAUI-8

DER_0=2.67e-5 was adopted for both cases

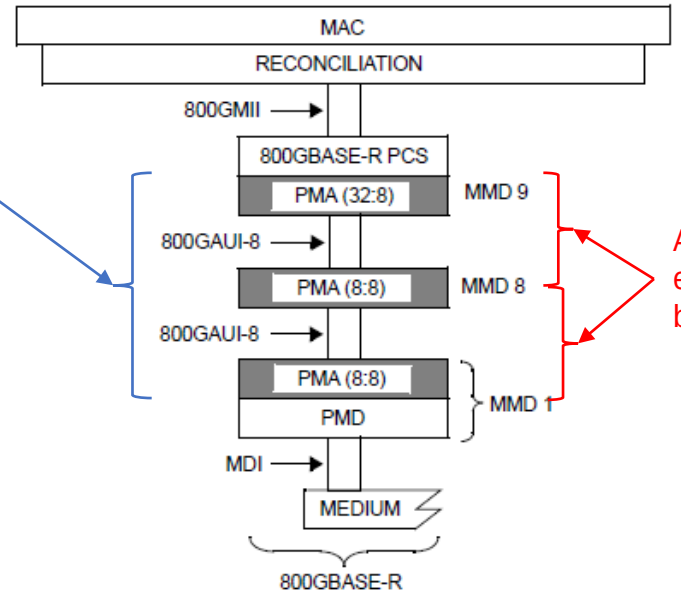


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Figure 173A–2—Example PMA layering with eight-lane PMD and two 800GAUI-8

Existing AUI BER specifications

AUI-C2M BER specifications

- Annex 120G specifies the bit error ratio as 10^{-5} in 120G.1.1.
- BER requirements for host and module stressed input tolerance are specified in 120G.3.3.5 and 120G.3.4.3, respectively, by reference to 120G.1.1.
- There are additional instances where the number 10^{-5} appears explicitly in the specifications:
  - Definition of signal level in 120G.5.1
  - Definitions of eye opening measurement method in 120G.5.2
  - These definitions pertain to host output and module output specifications, and to calibration of the stressed signal for host input and module input.
- All specifications are implicitly for measured BER, and correlated errors (for input) or noise (for output) are not addressed.
- AUI-C2M within an Extender is not addressed (could be given a much higher BER).

AUI-C2C BER specifications

- Annex 120F does not have a general bit error ratio specification.
- There are several places where the number 10^{-5} appears explicitly or implicitly in the specifications:
  - Definition of AC common-mode voltage in 120F.3.1.1 (differential pk-pk definition refers to clause 93 which does not mention the probability)
  - Transmitter jitter (through the definition of J4u)
  - Receiver tests (through FEC symbol error ratio)
  - The parameter DER_0 (for COM and ERL, also affects signal calibration in receiver test)
- Receiver interference tolerance is specified in terms of FEC symbol error ratio ($<10^{-4}$), with BER ($<10^{-5}$) suggested as an alternative, noting that BER measurement may be more stringent
  - This may be a hint of addressing correlated errors?
  - Other than that, correlated errors (for input) or noise (for output) are not addressed.
- AUI-C2C within an Extender is not addressed (could be given a much higher error ratio).

Outline of this proposal

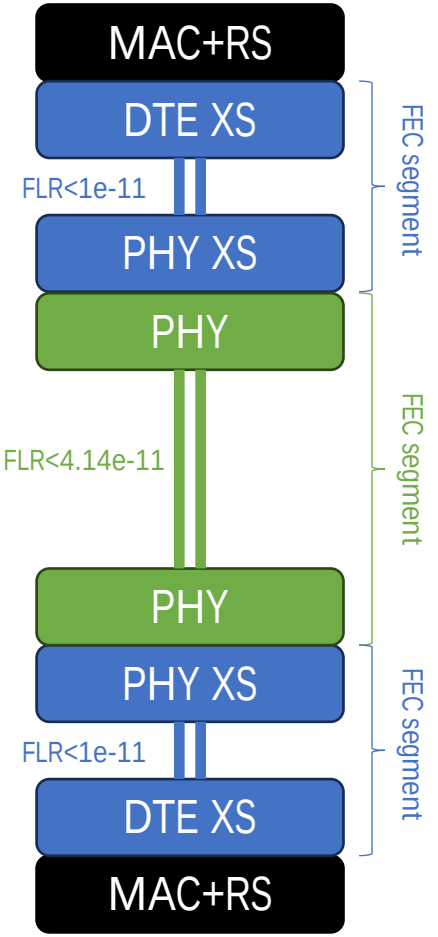
- This presentation includes a detailed proposal for error rate specifications for AUI-C2C and AUI-C2M within a PHY and within an Extender.
- The general idea is:
  - Budget the FLR between the RS-FEC segments of the link (PHY-to-PHY, and Extenders).
  - For each RS-FEC segment, calculate the BER that allows achieving the allocated FLR assuming uncorrelated errors ("random BER" or RBER).
  - AUIs within a PHY are allocated a small part of the RBER, 2e-5, corresponding to DER_0=2.67e-5 (as already adopted).
  - AUIs within an Extender are given the RBER that results in the full FLR allocated to the Extender.
- Normative requirements:
  - Measured BER is not a good metric; the measured BER that would be equivalent to the specified RBER in terms of FLR can be higher or lower (implementation dependent).
  - For the time being, it is proposed that the requirement for each AUI is to have an error rate and distribution that are equivalent to a specified RBER or lower, in terms of the effect on FLR.
  - Ways to verify this requirement will be proposed.

AUIs within an Extender

- The adopted BER objective is interpreted as FLR < 6.2e-11 at the MAC/PLS service interface (equivalent to BER<1e-13).
  - This is a MAC-to-MAC link.
  - An addition to the link between PHYs, this link can include an xGMII Extender on each end.
  - An xGMII Extender has a separate RS-FEC. Uncorrectable errors in that FEC will contribute to the FLR.
- The **FLR budget** should be divided between the PHY-to-PHY FEC segment and two xGMII Extenders, each of which can include one or two AUIs.
- It is assumed that the Extenders are less challenging than the PHY-to-PHY FEC segment and can be allocated a small portion of the FLR.
- The FLR allocation would result in a BER budget for the Extenders. The BER budget needs to be divided between the AUIs within the Extender.
- Other than the BER value, all AUI specifications remain the same as for an AUI within a PHY.

FLR/CER allocation

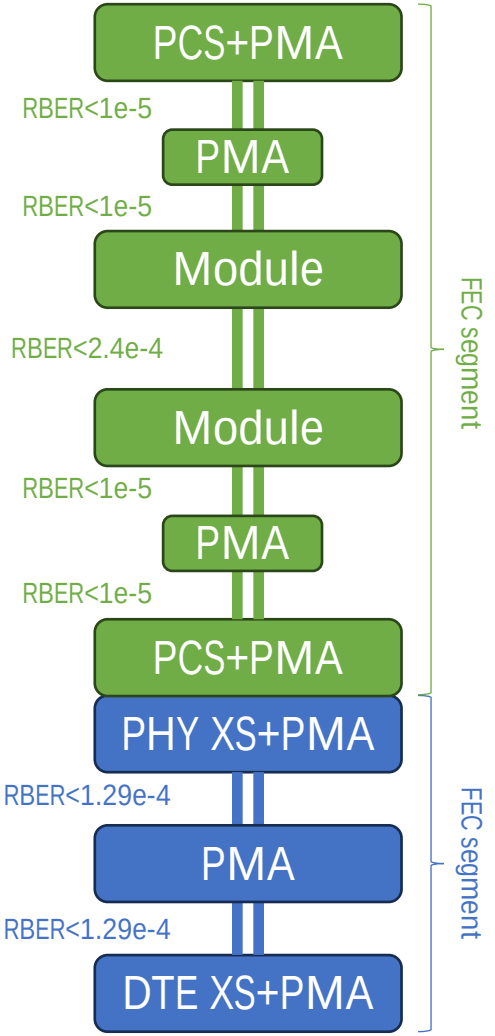
- To reach an FLR lower than 6.2e-11 in the MAC link, with 4-way interleaved RS544 in all FEC segments, the total codeword error ratio (CER) should be less than 1.5e-11 (=6.2e-11/4.125).
  - With 2-way RS544 interleaving, the same CER would result in FLR=3.2e-11, which is ok too.
  - It is suggested that all specifications will use the same CER and BER values, which are independent of traffic type. In the remainder I assume 4-way interleaving and budget the 1.5e-11 CER.
- It is suggested to divide the CER budget of 1.5e-11 between the PHY-to-PHY and the two Extenders as follows:
  - PHY-to-PHY: CER<1e-11, resulting in FLR<**4.14e-11**
  - Extender: CER<2.5e-12, resulting in FLR<**1e-11** (2e-11 if there are two)
  - 4.14e-11 + 2 × 1e-11 = 6.14e-11



FLR of the link is the sum of the FLRs on the FEC segments.

Random BER (RBER) allocation

- To achieve CER<1e-11 in the PHY link (PCS to PCS), with uncorrelated errors, we need RBER<2.85e-4.
  - Out of this RBER we allocated 2e-5 for AUIs within each host. An even split between C2C and C2M would result in **1e-5** for each.
  - RBER of 2.4e-4 can be allocated for the module-to-module link.
  - 2.4e-4 + 2 × 2e-5 = **2.8e-5**
- To achieve CER<2.5e-12 in the Extender link (PHY XS to DTE XS), with random uncorrelated errors, we need RBER<2.58e-4.
  - This RBER can be split between the AUIs within the Extender. An even split between C2C and C2M would result in **1.29e-4** for each.



RBER of a FEC segment is the sum of the RBERs on the interfaces within that segment.

How to divide the RBER within a FEC segment?

- Option 1 – a fixed allocation:
  - AUIs within a PHY are allocated a RBER of 2e-5 (corresponding to the adopted DER_0=2.67e-5). Dividing it evenly, both C2C and C2M specifications are RBER<1e-5.
  - AUIs within an Extender are allocated a RBER of 2.58e-4. Dividing it evenly, both C2C and C2M specifications are RBER<1.29e-4.
- Option 2 – a conditional allocation:
  - Within a PHY:
    - When a host has only one AUI (either C2M or C2C), that AUI is allocated a RBER of 2e-5.
    - When a host has two AUIs, C2M and C2C, each AUI is allocated an RBER of 1e-5.
  - Within an Extender:
    - When a host has only one AUI (either C2M or C2C), that AUI is allocated an RBER of 2.58e-4.
    - When a host has two AUIs, C2M and C2C, each AUI is allocated an RBER of 1.29e-4.
  - For C2M, module specifications should be unconditional – so it is suggested that only host input BER is dependent.

Verifying the error requirements

- In this proposal the BER allocations are in terms of RBER. Devices need to show equivalent or better performance.
- A possible way to verify that a device meets this requirement is to meet the FLR/CER allocated to the RS-FEC segment in the presence of **additional random errors** representing other interfaces within the that segment.
- Alternatively, error statistics (number of symbol errors per codeword) can be analyzed by test equipment.
- Measurement or validation methods may be proposed in the future. These are beyond the scope of this proposal.

Detailed proposed text for C2M

- Subclause in the introduction:

<Annex>.1.1 Bit Error ratio allocation

Several specifications in this annex are dependent on the bit error ratio (BER) allocated to the interface.

For a C2M interface within a PHY, the BER allocations assume errors generated by the receive function of the PMA and noise generated by the transmit function of the PMA are random and uncorrelated such that **with an additional BER due to external errors** (which can be introduced by other components of the same FEC segment), the uncorrectable codeword ratio of the PCS FEC (Clause 119, Clause 172, or Clause XXX) is less than 10^{-11}. This enables achieving a frame loss ratio (see 1.4.233) lower than 4.14×10^{-11} at the PCS service interface for 64-octet frames with minimum interpacket gap. The external errors are assumed to be uncorrelated.

For a C2M interface within a 200GMII, 400GMII, 800GMII or 1.6TMII Extender, the BER allocations assume errors generated by the receive function of the PMA and noise generated by the transmit function of the PMA are random and uncorrelated such that **with an additional BER due to external errors** (which can be introduced by an adjacent C2C interface), the uncorrectable codeword ratio of the Extender Sublayer FEC (Clause 118, Clause 171, or Clause YYY) is less than 2.5×10^{-12}. Combined with the frame loss allocation of the PHY, this enables achieving a frame loss ratio lower than 6.2×10^{-11} at the MAC service interface for 64-octet frames with minimum interpacket gap. The external errors are assumed to be uncorrelated.

If we choose conditional allocation

For host input, the allocated BER depends on whether or not the host includes a chip-to-chip Attachment Unit Interface (see <Annex>).

The allocated BER and the additional BER for external errors are summarized in <Table on next slide>.

Due to the FEC function in the PCS and the XS, if the errors or noise of a component are not random and uncorrelated, then the measured average BER required to meet the uncorrectable codeword requirements may be different from the allocated BER. Test methods that include the effect of FEC may be used to verify the requirements.

Bit error ratio allocation table for C2M

Specification	BER allocated to the C2M interface		BER assumed for external errors	
	Within a PHY	Within an Extender	Within a PHY	Within an Extender
Host output	10^{-5}	1.29×10^{-4}	2.7×10^{-4}	1.29×10^{-4}
Host input, for a host that includes an additional AUI-C2C	10^{-5}	1.29×10^{-4}	2.7×10^{-4}	1.29×10^{-4}
Host input, for a host that does not include an additional AUI-C2C	2×10^{-5}	2.6×10^{-4}	2.6×10^{-4}	0
Module output	10^{-5}	1.29×10^{-4}	2.7×10^{-4}	1.29×10^{-4}
Module input	10^{-5}	1.29×10^{-4}	2.7×10^{-4}	1.29×10^{-4}

Specifications within the AUI-C2M Annex that are dependent of the BER will refer to values in this table instead of using explicit numbers.

Detailed proposed text for C2C

- Subclause in the introduction:

<Annex>.1.1 Bit Error ratio allocation

Several specifications in this annex are dependent on the bit error ratio (BER) allocated to the interface.

For a C2C interface within a PHY, the BER allocations assume errors generated by the receive function of the PMA and noise generated by the transmit function of the PMA are random and uncorrelated such that **with an additional BER due to external errors** (which can be introduced by other components of the same FEC segment), the uncorrectable codeword ratio of the PCS FEC (Clause 119, Clause 172, or Clause XXX) is less than 10^{-11}. This enables achieving a frame loss ratio (see 1.4.233) lower than 4.14×10^{-11} at the PCS service interface for 64-octet frames with minimum interpacket gap. The external errors are assumed to be uncorrelated.

For a C2C interface within a 200GMII, 400GMII, 800GMII or 1.6TMII Extender, the BER allocations assume errors generated by the receive function of the PMA and noise generated by the transmit function of the PMA are random and uncorrelated such that **with an additional BER due to external errors** (which can be introduced by an adjacent C2M interface), the uncorrectable codeword ratio of the Extender Sublayer FEC (Clause 118, Clause 171, or Clause YYY) is less than 2.5×10^{-12}. Combined with the frame loss allocation of the PHY, this enables achieving a frame loss ratio lower than 6.2×10^{-11} at the MAC service interface for 64-octet frames with minimum interpacket gap. The external errors are assumed to be uncorrelated.

If we choose conditional allocation

The allocated BER depends on whether or not the PHY or the Extender includes a chip-to-module Attachment Unit Interface (see <Annex>).

The allocated BER and the additional BER for external errors are summarized in <Table on next slide>.

Due to the FEC function in the PCS and the XS, if the errors or noise of a component are not random and uncorrelated, then the measured average BER required to meet the uncorrectable codeword requirements may be different from the allocated BER. Test methods that include the effect of FEC may be used to verify the requirements.

Bit error ratio allocation table for C2C

Specification	BER allocated to the C2C interface		BER assumed for external errors	
	Within a PHY	Within an Extender	Within a PHY	Within an Extender
Transmitter, receiver, and channel electrical characteristics, for a host that includes an additional AUI-C2M	10^{-5}	1.29×10^{-4}	2.7×10^{-4}	1.29×10^{-4}
Transmitter, receiver, and channel electrical characteristics, for a host that does not include an additional AUI-C2M	2×10^{-5}	2.6×10^{-4}	2.6×10^{-4}	0

Specifications within the AUI-C2C Annex that are dependent of the BER will refer to values in this table instead of using explicit numbers.

That’s all

Questions? Discussion?