BER statements in PMD clause introductions

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Introduction

- We currently have text related to BER in the “overview” section of all PMD clauses, which includes normative statements (“shall”), reflected in the PICS.
- This text is relatively new; before clause 95, the overview was more descriptive than normative, with no effect on PICS.
  - PMD clauses prior to 802.3bj (electrical and optical) did not mention BER in the overview at all. BER was only specified for the Rx (either directly or is a sensitivity parameter) and was a parameter for Tx specifications.
- There are several issues with this text being normative.
- What do we really want to say?

Brief history: Electrical PMDs that require FEC

- Clause 92 (100GBASE-CR4): overview includes BER and frame loss ratio as part of “guidelines”
  - Rx specifications are stated in terms of RS-FEC symbol error ratio in tolerance tests (92.8.4.4, 92.8.4.5)
  - PICS items are only related to these tests
- Clause 93 (100GBASE-KR4): overview includes BER as “link is required to operate with a BER…”
  - “In this context, a link consists of a compliant PMD transmitter, a compliant PMD receiver, and a channel meeting the requirements of 93.9.1”
  - Rx specifications are stated in terms of RS-FEC symbol error ratio in tolerance tests (93.8.2.3, 93.8.2.4)
  - PICS items are only related to these tests
- Clauses 110 and 111 use language similar to clause 93
  - “the link BER requirements depend on the FEC mode… the link is required to operate with a BER of X or better”
  - And similar Rx specifications and PICS

Optical PMDs that require FEC

- Started with clause 95

95.1.1 Bit error ratio

The bit error ratio (BER) shall be less than 5×10^{-5} provided that the error statistics are sufficiently random that this results in a frame loss ratio (see 1.4.223) of less than 6.2×10^{-10} for 64-octet frames with minimum interpacket gap when processed according to Clause 91.

If the error statistics are not sufficiently random to meet this requirement, then the BER shall be less than that required to give a frame loss ratio of less than 6.2×10^{-10} for 64-octet frames with minimum interpacket gap when processed according to Clause 91.

CF3	Bit error ratio	95.1.1	Meets the BER specified in 95.1.1	M	Yes [ ]

  - This is the first time there is a “shall” related to BER in the overview and a PICS item associated with it
    - It is unclear where BER is defined (should it be the service interface of the adjacent PMA? or the FEC input?), under what conditions (any compliant transmitter and channel? Stressed test conditions?), and how it can be measured to verify the “shall”
    - It is unclear what “sufficiently random” means and how it can be verified without a FEC decoder (and a CAUI interface)
    - Who is accountable for this requirement? (who should mark the PICS item?) Can any single component provider guarantee the BER of a Tx+channel+Rx system?
  - BER is a parameter of the SRS OMA spec (95.1.1 is referenced in a footnote in Table 95-7, also 95.8.1.1)
  - Transmitter parameter TDEC is also specified with reference to 95.1.1
  - BER is not mentioned in PICS items other than CF3 (shown above)
  - Unlike electrical PMDs which have clear Rx normative requirements for BER – here the BER is a “number to be met” (normatively) with many places referring to it; the result is confusing
- Clause 112 has language and structure identical to 95

PMD clauses in current drafts

- 802.3bs: all clauses (121, 122, 123, 124) use structure and language based on clause 95, and in addition, separate the error budget to optical and electrical interfaces
  - Still use “shall” in the overview
- 802.3cd:
  - Optical clauses follow 802.3bs (allowing additional errors on other interfaces)
  - Clauses 136 and 137 have:
    - Overview with “shall” statements about BER
    - Rx and Tx compliance tests (with “shall”) that are not aligned to the overview text

Thoughts

- The observable performance metric in Ethernet is FLR. The FLR objective is common for multiple PHYs of the same data rate.
- With FEC in the sublayer stack, FLR is dependent on FEC codeword error ratio, which depends on FEC-input metrics (such as FEC symbol error ratio and statistics).
  - This is measurable in a complete PHY, so can be used as a normative requirement
  - Rx normative specifications in the electrical PMDs use FEC counters, rather than BER
- FEC input metrics may depend on BER (defined at the PMA) and on detector error ratio (which is a PMD characteristic)
  - The dependence is complex when the errors are correlated, and meaningful measurements are difficult to define
  - We don’t want to make normative statements for something that is not well-defined and easy to measure
  - PMD/PMA performance metrics should serve as guidelines for achieving PHY-level performance
- Existing and suggested text for electrical PMD clauses are in following slides…
  - Considerations for the optical PMDs may be different; No change proposed there

Existing text in clause 136 overview

For the 50GBASE-CR and 100GBASE-CR2 PMDs, the link BER shall be less than 2.4×10^{-4} provided that the error statistics are sufficiently random that this results in a frame loss ratio (see 1.4.223) of less than 10^{-10} for 64-octet frames with minimum interpacket gap when additionally processed by the RS-FEC (Clause 134 or Clause 91) and the PCS (Clause 133 or Clause 82). For a complete Physical Layer, the frame loss ratio may be degraded to 6.2×10^{-10} for 64-octet frames with minimum interpacket gap due to additional errors from other electrical interfaces. If the error statistics are not sufficiently random to meet this requirement, then the BER shall be less than that required to give a frame loss ratio of less than 10^{-10} for 64-octet frames with minimum interpacket gap.

For the 200GBASE-CR4 PMD, the link BER shall be less than 2.4×10^{-4} provided that the error statistics are sufficiently random that this results in a frame loss ratio (see 1.4.223) of less than 1.7×10^{-12} for 64-octet frames with minimum interpacket gap when additionally processed by the PCS (Clause 119). For a complete Physical Layer, the frame loss ratio may be degraded to 6.2×10^{-11} for 64-octet frames with minimum interpacket gap due to additional errors from other electrical interfaces. If the error statistics are not sufficiently random to meet this requirement, then the BER shall be less than that required to give a frame loss ratio of less than 1.7×10^{-12} for 64-octet frames with minimum interpacket gap.

In this context, a link consists of a compliant transmitter (PMA and PMD), a compliant cable assembly, and a compliant receiver (PMD and PMA).

Clause 137 is similar

Proposed text for clause 136 overview

Clause 137 to be changed similarly

For the 50GBASE-CR and 100GBASE-CR2 PHYs, in order to support the required frame loss ratio (see 1.4.223) of less than 6.2×10^{-10} for 64-octet frames with minimum interpacket gap, the PMD and the adjacent PMA are required to detect bits from a compliant input signal at a BER lower than 2.4×10^{-4} assuming errors are sufficiently uncorrelated. This BER allocation enables a frame loss ratio lower than 10^{-10} after processing by the RS-FEC decoder (Clause 134 or Clause 91) and the PCS (Clause 133 or Clause 82) if there are negligible errors due to other electrical interfaces (50GAUI-n or 100GAUI-n). If the PMD and PMA create errors that are not sufficiently uncorrelated, the BER is required to be lower as appropriate to maintain a frame loss ratio lower than 10^{-10}.

For the 200GBASE-CR4 PHY, in order to support the required frame loss ratio (see 1.4.223) of less than 6.2×10^{-11} for 64-octet frames with minimum interpacket gap, the PMD and the adjacent PMA are required to detect bits from a compliant input signal at a BER lower than 2.4×10^{-4} assuming errors are sufficiently uncorrelated. This BER allocation enables a frame loss ratio lower than 9.2×10^{-13} after processing by the PCS (Clause 119) if there are negligible errors due to other electrical interfaces (200GAUI-n). If the PMD and PMA create errors that are not sufficiently uncorrelated, the BER is required to be lower as appropriate to maintain a frame loss ratio lower than 9.2×10^{-13}.

A compliant input signal is a transmitter output of a compliant PHY that has passed through a compliant cable assembly.

Where should performance be stated?

- “BER at the MAC/PLS service interface” or “Frame loss ratio” are common to multiple PHYs
- It makes sense to state them in the rate-specific introduction clauses
- Precedence exists… (next slide)
- Clauses 116 (200G and 400G) and 131 (50G) don’t mention BER/FLR at all.
- It is proposed to add the following statement (based on 105.1.1) to 131.1.1

  50 Gb/s Physical Layer entities, such as those specified in Table 131–1, provide a frame loss ratio (see 1.4.223) of less than 6.2×10^{-10} for 64-octet frames with minimum interpacket gap.

Existing introduction clauses

- Clause 44 (10G): BER mentioned in the “objectives” subclause
  - “Support a BER objective of 10^{-12}”
- Clause 80 (40G and 100G): BER statement as part of the overview
  - “40 Gb/s and 100 Gb/s Physical Layer entities, such as those specified in Table 80–1, provide a bit error ratio (BER) better than or equal to 10^{-12} at the MAC/PLS service interface”
- Clause 105 (25G): overview states the target FLR
  - “25 Gb/s Physical Layer entities, such as those specified in Table 105–1, provide a frame loss ratio (see 1.4.223) of less than 6.2×10^{-10} for 64-octet frames with minimum interpacket gap.”

Backup

How did older PMD clauses mention BER?

Older optical PMDs

- Clause 52 (10GBASE-S/L/E): no BER in overview
  - 52.9.9: “Receivers must operate with BER less than 10^{-12} when tested with a conditioned input signal that combines vertical eye closure and jitter according to this clause”
  - No BER-related PICS items
- Clause 53 (LX4): no BER in overview
  - 53.8.2: “The receiver shall operate at a BER less than 10^{-12} when tested with an input signal defined in 53.8.2.1 through 53.8.2.1”
  - “BER less than 10^{-12}” appears in PICS
- Clause 68 (LRM): no BER in overview
  - “shall” statements for BER in receiver sensitivity and jitter tolerance tests, and PICS items refer to the tests
- Clause 86 (SR4/SR10): no BER in overview
  - Receiver sensitivity follows clause 52, jitter tolerance follows clause 68; PICS items refer to the tests
- Clause 87 (40GBASE-LR4/ER4): no BER in overview
  - BER requirement only appears in a footnote to SRS in Table 87-8: “Measured with conformance test signal at TP3 (see 87.8.11) for BER = 10^{-12}”
  - PICS items related to this table, but not directly to BER
- Clause 88 (100GBASE-LR4/ER4) follows 87
- Clause 89 (40GBASE-FR): no BER in overview
  - BER is mentioned as part of receiver sensitivity and jitter tolerance definitions (which are specified in terms of power)
  - No PICS items directly related to BER

Older electrical PMDs

- Clause 54 (10GBASE-CX4): no BER in overview; BER defined as part of receiver characteristics
  - 54.6.4: ”The receiver shall operate with a BER of better than 10^{-12} when receiving a compliant transmit signal, as defined in 54.6.3, through a compliant cable assembly as defined in 54.7”
  - “BER of better than 10^{-12}” appears in PICS
- Clause 72 (KR): no BER in overview; BER requirement is part of receiver interference tolerance
  - PICS includes items for “receiver interference tolerance” which includes BER
- Clause 85 (CR4/CR10): no BER in overview
  - 85.8.4.2: Maximum BER in receiver interference tolerance is specified
  - 85.8.4.3: “The receiver shall operate with a BER 10^{-12} or better when receiving a compliant transmit signal, as defined in 85.8.3, through a compliant cable assembly as defined in 85.10.”
  - PICS has two items for the above