PMD BER requirements

Pete Anslow, Ciena

IEEE P802.3cd Task Force, October 2016

Introduction

The IEEE P802.3bs Task Force has adopted RS(544,514) FEC with interleaving of FEC symbols from two FEC codewords to give good burst error tolerance.

Concerns over the latency of codeword interleaving led to the adoption of optionally enabled precoding for 50 Gb/s and next generation 100 Gb/s Ethernet.

anslow_3cd_01_0716 analysed the performance of this scheme.

Because of:

- the uncertainty of whether or not precoding always converts a burst of errored symbols into just a pair of errored symbols (one at the beginning and the other at the end of the burst)
- 200G and 400G links have an advantage that they contain 4 or 8 lanes not all of which will be at the worst case simultaneously

anslow_3cd_01_0716 proposed to allocate all of the extra errors due to the BER = 1E-12 instead of BER = 1E-13 to the electrical sub-links and keep the BER requirement for the optical sub-link at 2.4E-4

FLR corresponding to 2.4E-4 for random errors

The FLR corresponding to a BER of 2.4E-4 for 50G and 100G using RS(544,514) FEC with random errors can be found according to the equations given on page 11 of anslow_3bs_02_1114 with MFC = 8 as per page 4 of anslow_01a_1112_mmf

This results in a FLR of 9.2×10^{-13}

Note that the processing specified for 200G and 400G in 119.2.5.3 for uncorrectable codewords requires the FEC decoder to:

"set every 66-bit block within the two associated codewords to an error block".

This means that the factor (1 + MFC)/MFC) in equation 4 of anslow_3bs_02_1114 should be replaced by (1 + 2*MFC)/MFC), which changes the FLR from 9.2×10^{-13} to 1.7×10^{-12}

Proposal 1

Change the text in 139.1.1 and 140.1.1 to:

The bit error ratio (BER) when processed by the PMA (Clause 135) 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 9.2×10^{-13} for 64-octet frames with minimum interpacket gap when additionally processed by the FEC (Clause 91) and PCS (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 the 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 9.2×10^{-13} for 64-octet frames with minimum interpacket gap.

Proposal 2

Change the text in 138.1.1 to:

For the 50GBASE-SR and 100GBASE-SR2 PMDs, the bit error ratio (BER) when processed by the PMA (Clause 135) 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 9.2×10^{-13} for 64-octet frames with minimum interpacket gap when additionally processed by the FEC (Clause 134 or Clause 91) and 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 the 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 9.2×10^{-13} for 64-octet frames with minimum interpacket gap.

For the 200GBASE-SR4 PMD, the bit error ratio (BER) when processed by the PMA (Clause 120) 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 the 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.

CR and KR clauses

The CR and KR clauses differ from the optical clauses in that it is expected that the error statistics will not be random.

Also, according to Tables 136-1, 136-2, 137-1, and 137-2 all of the CR and KR PMD types allow the optional use of a C2C interface that uses PAM4 coding.

According to the analysis in anslow_3cd_01_0716 if the precoding always converts a burst of errored symbols into just a pair of errored symbols, then if **all FEC gain is used on one sub-link** we have:

FLR = 6.2E-10	DER_0	BER with Gray decoding only	BER with precode removal
1:2 bit mux precoded, a=0.75	3E-4	6E-4*	3E-4
Precoded, a=0.75	3.2E-4	6.4E-4*	3.2E-4
Random errors	7.6E-4	3.8E-4	NA

FLR = 6.2E-11	DER_0	BER with Gray decoding
1:2 P802.3bs D2.1, a = 0.75	3.2E-4	6.4E-4*
P802.3bs D2.1, Random errors	6.2E-4	3.1E-4

Note – To account for burst errors, the values marked with “*” have been multiplied by 4 when a = 0.75.

50G and 100G CR and KR BERs

If the errors generated by the CR or KR link were random, then the fact that there could still be two C2C sub-links generating additional burst errors means that the arguments on pages 2 and 3 lead to a BER limit of 2.4E-4 after Gray decoding for the PMD (CR or KR) part of the link. These errors alone would result in a FLR of 9.2×10^{-13}.

However, if the errors generated by the CR or KR link were bursty with a=0.75 and precoding always converts a burst of errored symbols into just a pair of errored symbols, then a total BER budget of 3E-4 after precoding removal and Gray decoding has to be shared between the C2C sub-links and the PMD sub-link. If we allocate 1E-5 to each of two C2C sub-links (after precoding removal and Gray decoding), then this becomes a BER limit of 2.8E-4 after precoding removal and Gray decoding for the PMD alone.

In order to allow for some uncertainty as to whether or not precoding always converts a burst of errored symbols into just a pair of errored symbols, it is proposed to use a limit of 2.4E-4 here also. These errors alone would result in a FLR of 1×10^{-10}.

200G CR and KR BERs

If the errors generated by the CR or KR link were random, then the fact that there could still be two C2C sub-links generating additional burst errors means that the existing budgets for 200G lead to a BER limit of 2.4E-4 after Gray decoding for the PMD (CR or KR) part of the link. These errors alone would result in a FLR of 1.7×10^{-12}.

However, if the errors generated by the CR or KR link were bursty and use precoding as per the 50G and 100G, then an analysis of the performance with precoding and FEC codeword interleaving should be performed.

Proposal 3

Change the text in 136.1 to:

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 1×10^{-10} for 64-octet frames with minimum interpacket gap when additionally processed by the FEC (Clause 134 or Clause 91) and 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 1×10^{-10} for 64-octet frames with minimum interpacket gap.

For the 200GBASE-CR 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).

Proposal 4

Change the text in 137.1 to:

For the 50GBASE-KR and 100GBASE-KR2 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 1×10^{-10} for 64-octet frames with minimum interpacket gap when additionally processed by the FEC (Clause 134 or Clause 91) and 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 1×10^{-10} for 64-octet frames with minimum interpacket gap.

For the 200GBASE-KR 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).

Thanks!