Receiver BER target for 32GFC

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Background

**FC-PI-5, 5.1**
“The FC-FS-3 protocol is defined to operate across connections having a bit error ratio (BER) detected at the receiving port of less than or equal to $10^{-12}$.”

…
“A TxRx Connection bit error rate (BER) of $\leq 10^{-12}$ as measured at its receiver is supported. The basis for the BER is the encoded serial data stream on the transmission medium during system operation.”

**FC-PI-6, 4.1**
“The FC-FS-4 protocol is defined to operate across connections having a bit error ratio (BER) detected at the receiving port of less than or equal to $10^{-6}$.”

…
“A TxRx Connection bit error rate (BER) of $\leq 10^{-6}$ as measured at its receiver is supported. The basis for the BER is the encoded serial data stream on the transmission medium during system operation.”

**Question:** Is $10^{-6}$ the correct target for 32GFC receiver BER?
Probability of Transmission Word error for 16GFC

- A 64B/66B Transmission Word error occurs when one or more bit errors occur during the Transmission Word.

- A 64B/66B Transmission Word error occurs when one or more bit errors occur during the final 58 bits of the preceding Transmission Word (descrambler error propagation).

\[ p_{we} = 1 - (1 - p_{be})^{58+66} \approx 124p_{be} \]

\( p_{be} \) is the probability of a bit error (<< 1).
Probability of Transmission Word error for 32GFC

- 64B/66B to 256B/257B transcoding compresses 4 Transmission Words into a 257-bit block

- An RS(528,514) codeword contains 20 257-bit blocks or 80 Transmission Words

- Assume that all 80 Transmission Words are corrupted when the Reed-Solomon decoder fails to correct a codeword

- The first Transmission Word of the next codeword is also lost while recovering descrambler state

\[ p_{we} \approx 81p_{ce} \]

\[ p_{ce} \] is the probability of an uncorrected codeword

- Equate the probability of Transmission Word error for 16GFC and 32GFC

\[ p_{ce} = (124/81)p_{be} \]
Probability of codeword error

- Binary symmetric channel with input probability of bit error $p_{be}$

$$p_{se} = 1 - (1 - p_{be})^w \approx wp_{be}$$

$p_{se}$ is the probability of a Reed-Solomon symbol error, $w$-bit symbols (10)

$$p_{ce} = \sum_{i=t+1}^{n} \binom{n}{i} p_{se}^i (1 - p_{se})^{n-i}$$

$n$ is the codeword size in symbols (528)
$t$ is the error correcting capability in symbols (7)
Probability of codeword error, continued

- Gilbert-Elliot channel to model 1-tap decision feedback equalizer (DFE)

\[ p_g = p_{be} \]

\[ p_b = \frac{1}{4} \text{erfc} \left( \frac{Q}{\sqrt{2}} (1 - 2 b_1/b_0) \right) + \frac{1}{4} \text{erfc} \left( \frac{Q}{\sqrt{2}} (1 + 2 b_1/b_0) \right) \]

where \( Q = \sqrt{2} \text{erfc}^{-1}(2p_{be}) \)

and \( b_1/b_0 \) is the normalized magnitude of the DFE coefficient

\[ p_{gb} = p_g \]
\[ p_{bg} = 1 - p_b \]

- Solve the probability of codeword error per reference [3]

- Note \( b_1 = 0 \) corresponds to the binary symmetric channel
Probability of codeword error

Factor of ~3.8 (6.3E-6 to 2.4E-5)
Application to 32GFC optical links

- BER $\leq 2.4 \times 10^{-5}$ at input to the FEC decoder assuming binary symmetric channel

- For each section (host transmitter, optical link, host receiver), require BER $\leq 8 \times 10^{-6}$

- If host receiver employs DFE, require BER $\leq 2 \times 10^{-6}$ for that section to account for the possibility of error propagation
Application to 32GFC electrical links

- Backplane links should operate with a BER $\leq 6.3 \times 10^{-6}$ assuming a first DFE coefficient $b_1/b_0 = 1$ will dominate the performance of a multi-tap DFE
Summary

- Propose that 32GFC provide the same effective probability of Transmission Word error as 16GFC
- Ethernet has recently focused on the probability of frame error
- However, Fibre Channel also has primitive signals and sequences to consider
- A target of $10^{-6}$ can be generally applied to every use case with varying degrees of margin
References


2. P. Anslow, “BER and FER for 100GBASE-SR4”, IEEE P802.3bm™ MMF ad hoc meeting, November 2012. (link)