LSI

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Receiver BER target for 32GFC

Adam Healey

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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 $\underline{10^{-6}}$."

…

"A TxRx Connection bit error rate (BER) of $\leq \underline{10^{-6}}$ 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)

$$p_{we} = 1 - (1 - p_{be})^{58+66} \cong 124 p_{be}$$

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

  $p_{we} \cong 81 p_{ce}$

  p_{ce} is the probability of an uncorrected codeword

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

  $p_{ce} = (124/81) p_{be}$

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Probability of codeword error

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

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

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

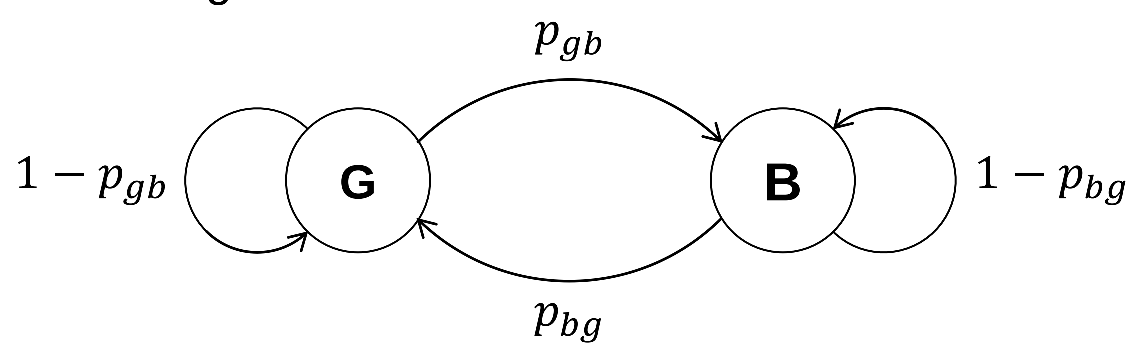
- Gilbert-Elliot channel to model 1-tap decision feedback equalizer (DFE)

$$p_g = p_{be}$$

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

where $Q = \sqrt{2}\operatorname{erfc}^{-1}(2p_{be})$
and b_1/b_0 is the normalized magnitude of the DFE coefficient

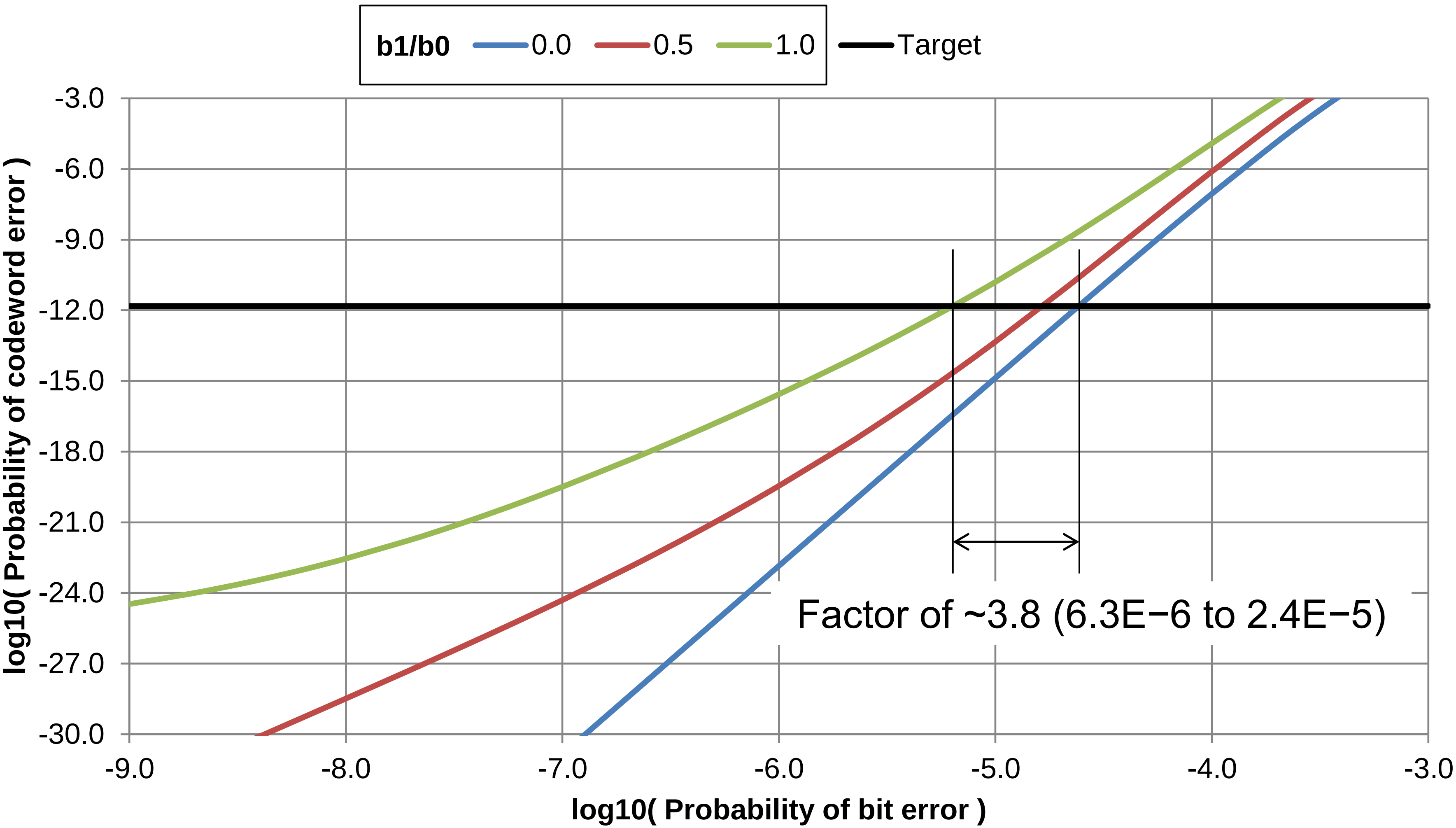
$$p_{gb} = p_g$$
$$p_{bg} = 1 - p_b$$



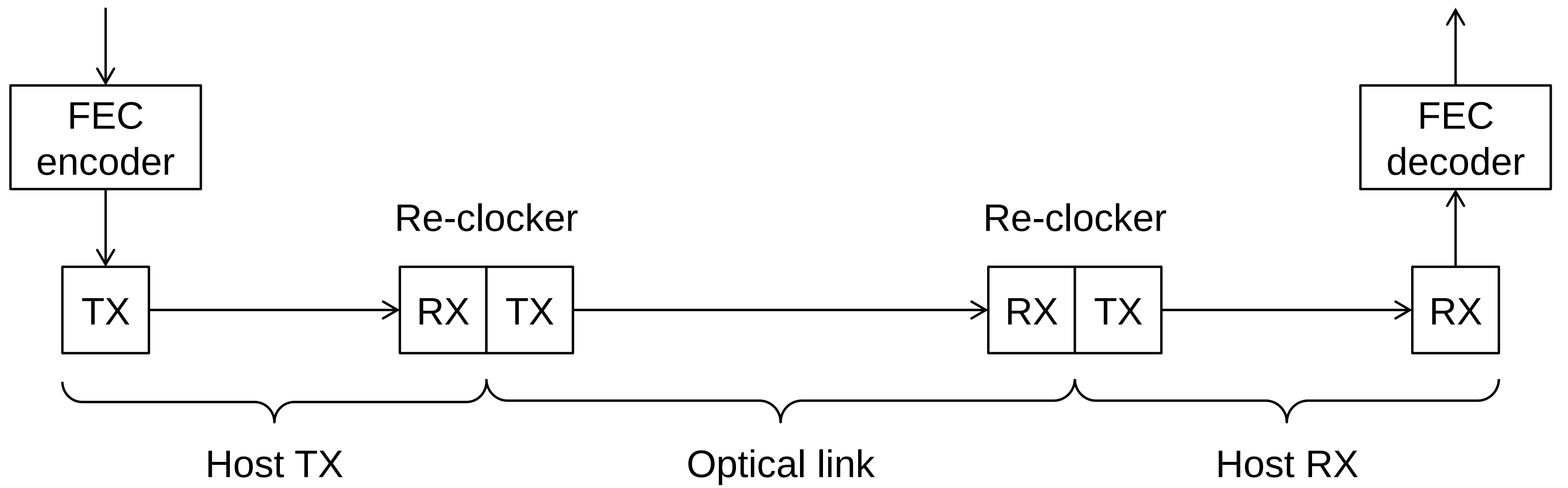
- Solve the probability of codeword error per reference [3]

- Note $b_1 = 0$ corresponds to the binary symmetric channel

Probability of codeword error



Application to 32GFC optical links



- BER ≤ 2.4E−5 at input to the FEC decoder assuming binary symmetric channel
- For each section (host transmitter, optical link, host receiver), require BER ≤ 8E−6
- If host receiver employs DFE, require BER ≤ 2E−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

1. M. Brown, “100GBASE-CR4/KR4/KP4 Receiver Performance Target”, IEEE P802.3bj™ Task Force interim meeting, September 2012. (link)

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

3. C. Pimentel, "Generating series for error statistics of block codes on channels with memory", Revista da Sociedade Brasileira de Telecomunicacoes, vol. 13, no. 2, pp. 78-81, December 1998.