HI_BER PARAMETERS

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Addressing comments 58, 59, 111, 112, 164 against D1.0

Introduction

- In D1.0, 107.1.2 lists different values hi_ber parameters compared to previous PCS clause
  - “hi_ber is asserted if ber_cnt reaches 97 in a 2 millisecond period”
- This gave rise to several comments against D1.0.
- Text is based on my comment #13 against D0.1…
  - Comment was accepted in March after verbal discussion, but no documented explanation.
  - I have taken an action item to provide justification for these values.

Rationale behind hi_ber

- BER monitor was introduced in 802.3ae as part of the PCS synchronization mechanism (walker_1_0500)
  - Guard against false packet acceptance in bad links (BER > 1e-4)
  - Should never trigger in a good link (BER < 1e-9)
  - Initial locking uses a faster method to trigger SLIP.
- With FEC, especially in a separate device, link restart should be triggered when the FEC has high uncorrectable codewords rate (severe degradation, lost sync, etc.)
  - FEC marks errors using sync headers, which can trigger hi_ber or de-assert rx_block_lock.

(If errors are not marked, something else should be done)

Original idea

Frame sync criteria

If misaligned, then sync error rate will be 50%. We must quickly assert loss of sync and "slip" our alignment to another candidate location

If already aligned with good BER (<10e-9), then we want to stay in sync with very high reliability

If BER is worse than10e-4 we should suppress sync, to avoid likelyhood of False Packet Acceptance due to CRC failures

Large gap stabilizes the lock state

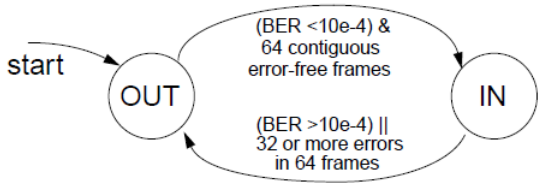
BER	current sync state	next sync state	notes
~50%	in	out	should be fast
>10e-4	in	out	prevents MTTFPA events, can be relatively slow to trigger
<10e-9	out	in	should be fast

Source: walker_1_0500

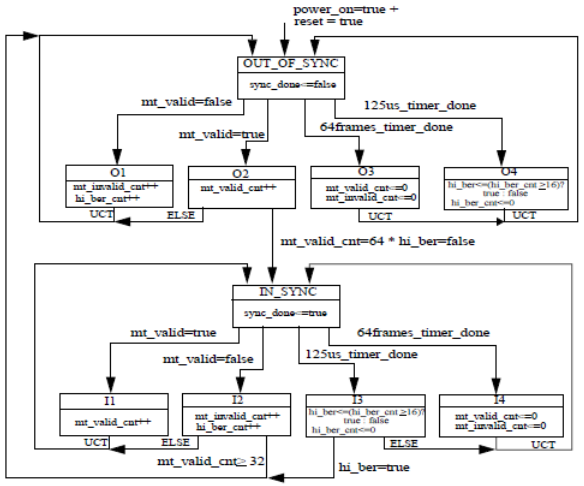
Original state diagrams

Frame sync algorithm

- frame sync is acquired after 64 contiguous frames have been received with valid “01” or “10” sync headers
- frame sync is declared lost after 32 “11” or “00” sync patterns have been declared in any block of 64 frames
- In addition, if there are 16 or more errors within any 125us time interval (~10e-4 BER), then frame sync is inhibited



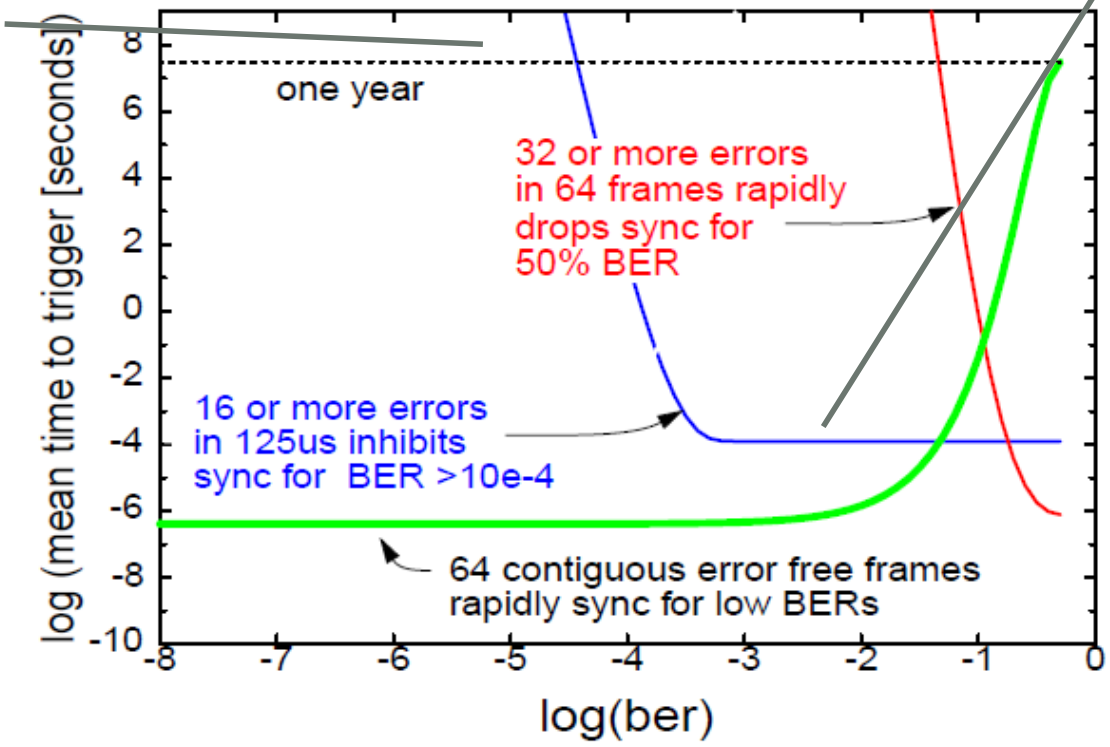
Synchronization state machine



Source: walker_1_0500

64/66 frame sync performance

Hi_ber will seldom trigger in this region



Hi_ber will trigger quickly in this region

Probability of hi_ber vs. BER

- Notation:
  - T_{hb} = the measurement window
  - N_{hb} = the number of blocks in the measurement window
  - K_{hb} = the threshold value
- Invalid sync header occurs when an error hits one of two bits in a 66-bit block. Probability in a specific block (p_{ish}) is approximately 2*BER.
- Probability of getting k hits out of N_{hb} trials follows the Binomial distribution $p(k) = \binom{N_{hb}}{k} p_{ish}^{k} (1 - p_{ish})^{N_{hb}-k}$
- For this distribution, assuming BER is low, the expectation and standard deviation are:

$$E[k] = N_{hb} \cdot p_{ish} \cong 2N_{hb} \cdot BER, \qquad \sigma_k \cong \sqrt{E[k]} = \sqrt{2N_{hb}} \cdot \sqrt{BER}$$

- Probability of hi_ber becomes very small when K_{hb} is a few σ_k higher than the expected value…

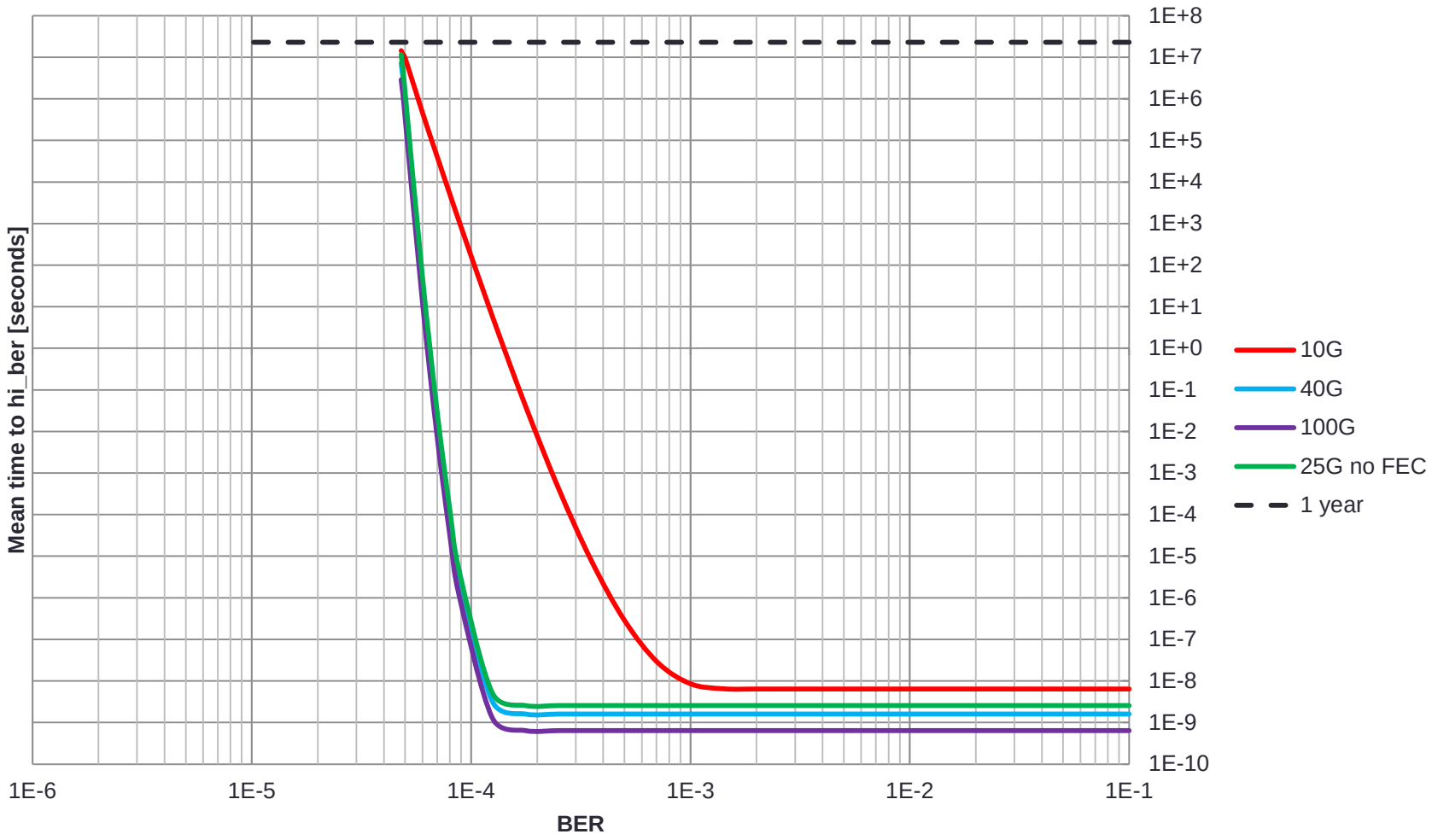
Summary of PCS characteristics

PCS	Hi_ber window T_{hb}	# blocks in window N_{hb}	Hi_ber threshold K_{hb}	Expected count $E[k]$	Standard deviation σ_k
10G (Clause 49)	125 µs	~19,500	16	$\sim 2e4 \cdot BER$	$197\sqrt{BER}$
40G (Clause 82)	1250 µs	~780,000	97	$\sim 1.6e6 \cdot BER$	$1250\sqrt{BER}$
100G (clause 82)	500 µs	~780,000	97	$\sim 1.6e6 \cdot BER$	$1250\sqrt{BER}$
25G (clause 107)	2000 µs	~780,000	97	$\sim 1.6e6 \cdot BER$	$1250\sqrt{BER}$

Difference between PCSs

- 10G PCS cliff:
  - For BER=1e-4, we get $E[k] \cong 2, \sigma_k \cong 2$, so 16 is 6σ away from mean (low probability to get hi_ber).
  - For BER=4e-4, we get $E[k] \cong 8, \sigma_k \cong 4$, so 16 is only 2σ away from mean (high probability to get hi_ber).
- 40G PCS cliff:
  - For BER=3e-5, we get $E[k] \cong 47, \sigma_k \cong 7$, so 97 is 7σ away from mean (low probability to get hi_ber).
  - For BER=5e-5, we get $E[k] \cong 78, \sigma_k \cong 9$, so 97 is only 2σ away from mean (high probability to get hi_ber).
  - ➔Cliff is at lower BER, but is more steep.
- 100G PCS and 25G PCS have proportionally scaled T_{hb} (same N_{hb}) and same K_{hb} – so similar behavior to 40G.

Mean time to hi_her for each PCS



The effect of FEC

- If FEC marks errors:
  - The “hit event” is an *uncorrected codeword* rather than a bad SH.
  - CER – codeword error ratio (replaces p_{ish})
  - N_{hb} = the number of *codewords* in the measurement window
  - K_{hb} = the threshold value
- Probability of getting k hits out of N_{hb} trials follows the Binomial distribution $p(k) = \binom{N_{hb}}{k} CER^k (1 - CER)^{N_{hb}-k}$
- CER can be calculated from BER and the code properties (for example, see ran_020415_25GE_adhoc)
- Note that every uncorrected codeword corrupts several SHs, so every hit “contributes” C>1 “steps” towards K_{hb}
  - In BASE-R FEC: C=5
  - In RS-FEC: C=12
- Effective threshold is $K'_{hb} = \lceil K_{hb}/C \rceil$
- The remaining calculation is similar…

Summary of FEC characteristics (25G)

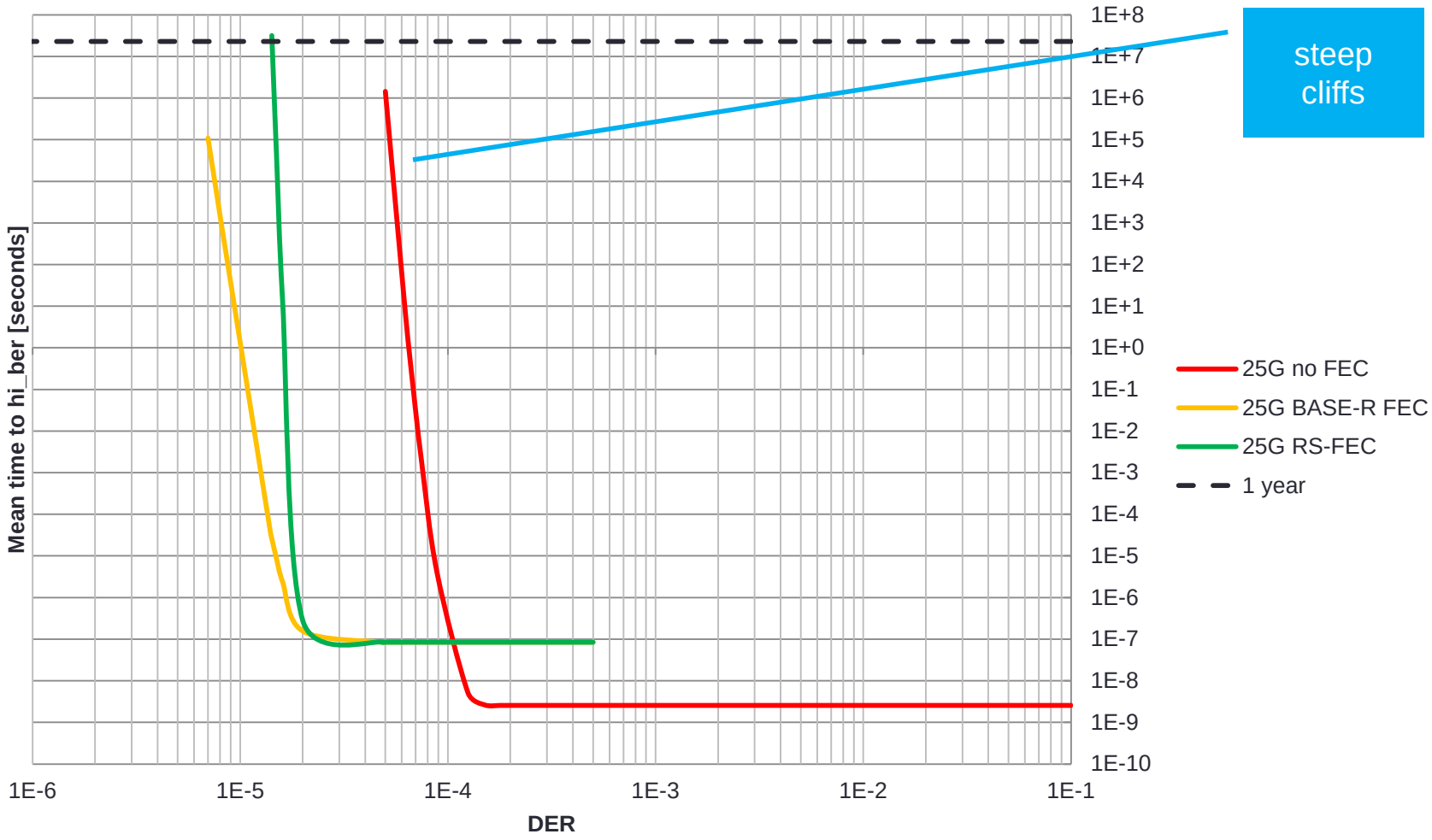
FEC mode	# blocks/ codewords in window N_{hb}	Contribution of each hit C	Hi_ber threshold K'_{hb}	Expected count $E[k]$	Standard deviation σ_k
No-FEC	~780,000	1	97	$\sim 1.6e6 \cdot BER$	$1250\sqrt{BER}$
Base-R FEC	~24,000	5	20	$\sim 4.7e4 \cdot CER$	$\sim 218\sqrt{CER}$
RS-FEC	~9,500	12	9	$\sim 1.9e4 \cdot CER$	$\sim 138\sqrt{CER}$

hi_ber cliff:

- In No-FEC: between BER=1e-4 and BER=4e-4
- In BASE-R FEC: between CER=1e-4 and CER=2e-4
  - To meet FLR target, we need CER<4.7e-10 (ran_020415_25GE_adhoc)
- In RS-FEC: between CER=8e-5 and CER=1e-4
  - To meet FLR target, we need CER<5.5e-10 (ran_020415_25GE_adhoc)

Cliffs are far enough from assumed performance; on reasonable links, hi_ber will practically never occur.

Mean time to hi_her for each FEC



Conclusion

- The hi_ber parameters in 107.1.2 provide the same features as in previous PCS cases:
  - hi_ber is practically never triggered in good or slightly degraded links
  - Extremely bad links will trigger hi_ber (similar conditions)
- All 3 FEC modes can work with the same parameters
- No need to change this subclause.

BACKUP

What if clause 49 values were used?