Comments and proposals regarding SC-FEC sublayer lane alignment process

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References

- 100GBASE ZR Draft 802.3ct_D1p1.pdf, Private Area
- ITU-T G.709 - Interfaces for the optical transport network
- ITU-T G.798 - Characteristics of optical transport network hierarchy equipment functional blocks
- trowbridge_3cn_01a_0119.pdf, IEEE P802.3cn Task Force, Long Beach, January 2019

Introduction

- This contribution is in support of comments against the following D1.1 sections:
  - 153.2.4.1.1: Change fas_valid variable definition
  - 153.2.4.2: Change FAS_COMPARE function definition
  - 153.2.4.4: Update Figure 153-7 accordingly and add a new state diagram for lane identification

Lane synchronization

- State machine
  - fas_valid
    - Boolean variable that is set to true if the received 6-octet sequence is a valid frame alignment signal. The frame alignment signal consists of 40 known bits and 8 variable bits. *The sequence is considered to be valid if four of the first five octets match the known bits of the pattern described in 153.2.3.2.4, and the 6th octet represents a numerical value in the range 0 to 239 with the most-significant bit transmitted first.*
  - FAS_COMPARE
    - This function compares the values of first_fecl and current_fecl to determine if a valid frame alignment sequence has been detected and returns the result of the comparison using the variable fas_match. fas_match is true if *fas_valid* is true for first_fecl and current_fecl, and the 6th octet of first_fecl (interpreted with the most significant bit transmitted first) modulo 20 is equal to the 6th octet of current_fecl (interpreted with the most significant bit transmitted first) modulo 20. Otherwise, fas_match is false.

Lane alignment verification state machine

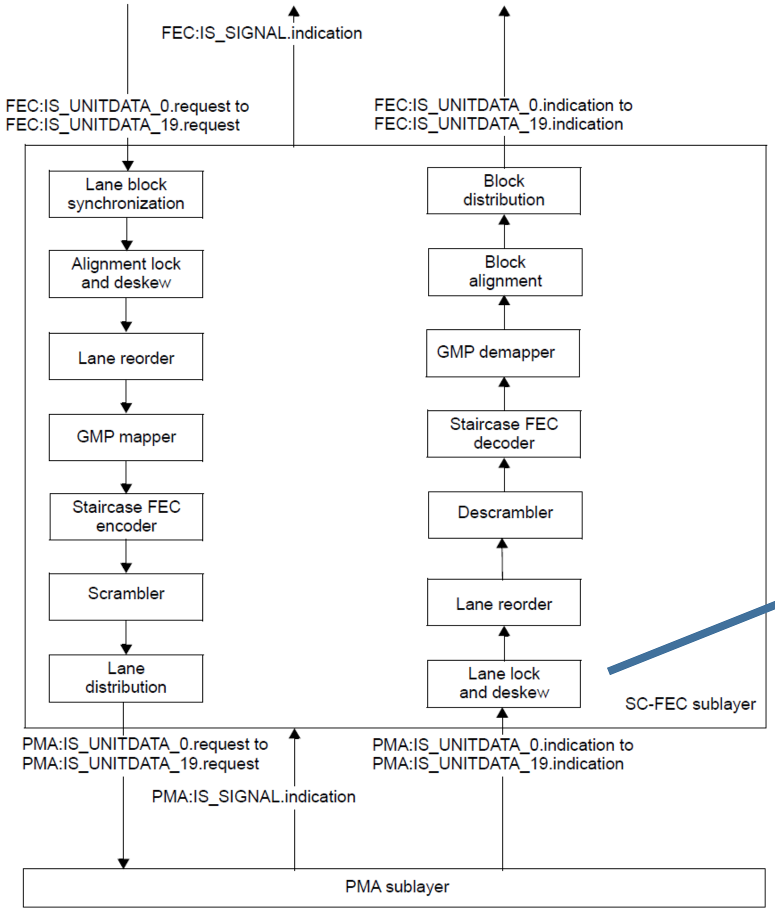
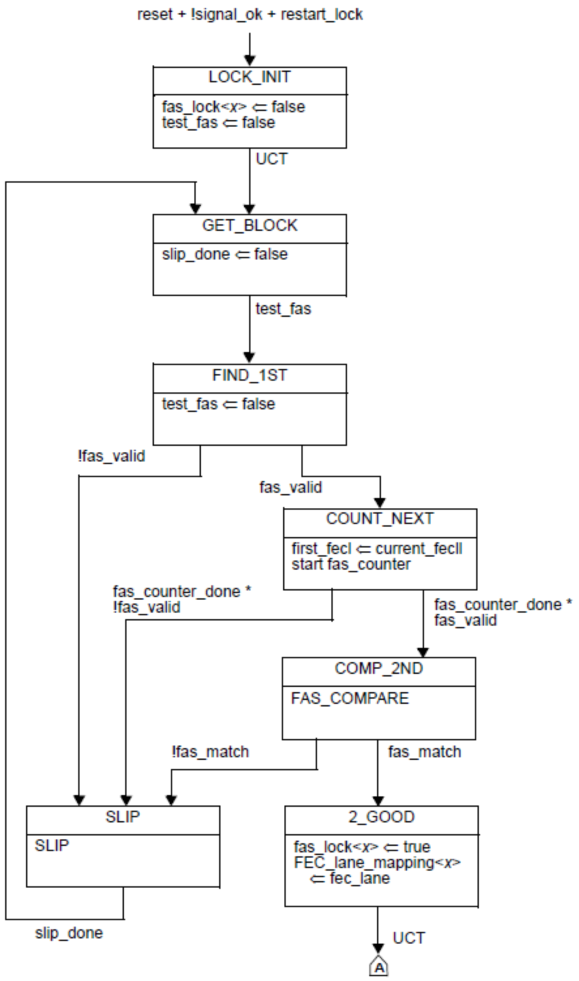


Figure 153–2—SC-FEC functional block diagram



Lane alignment loss verification state machine

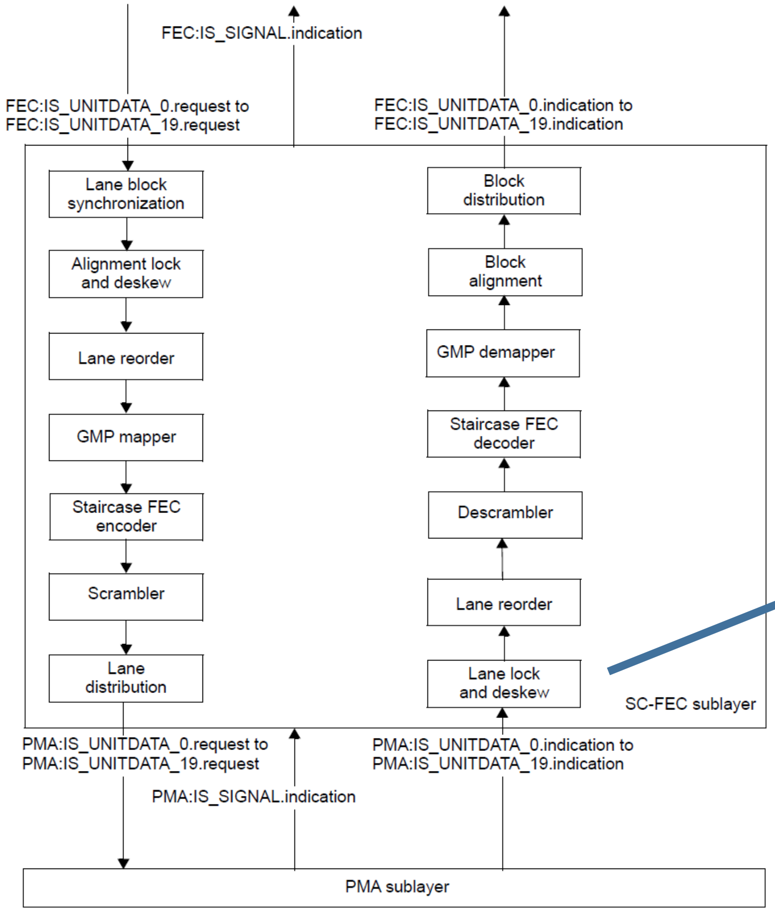
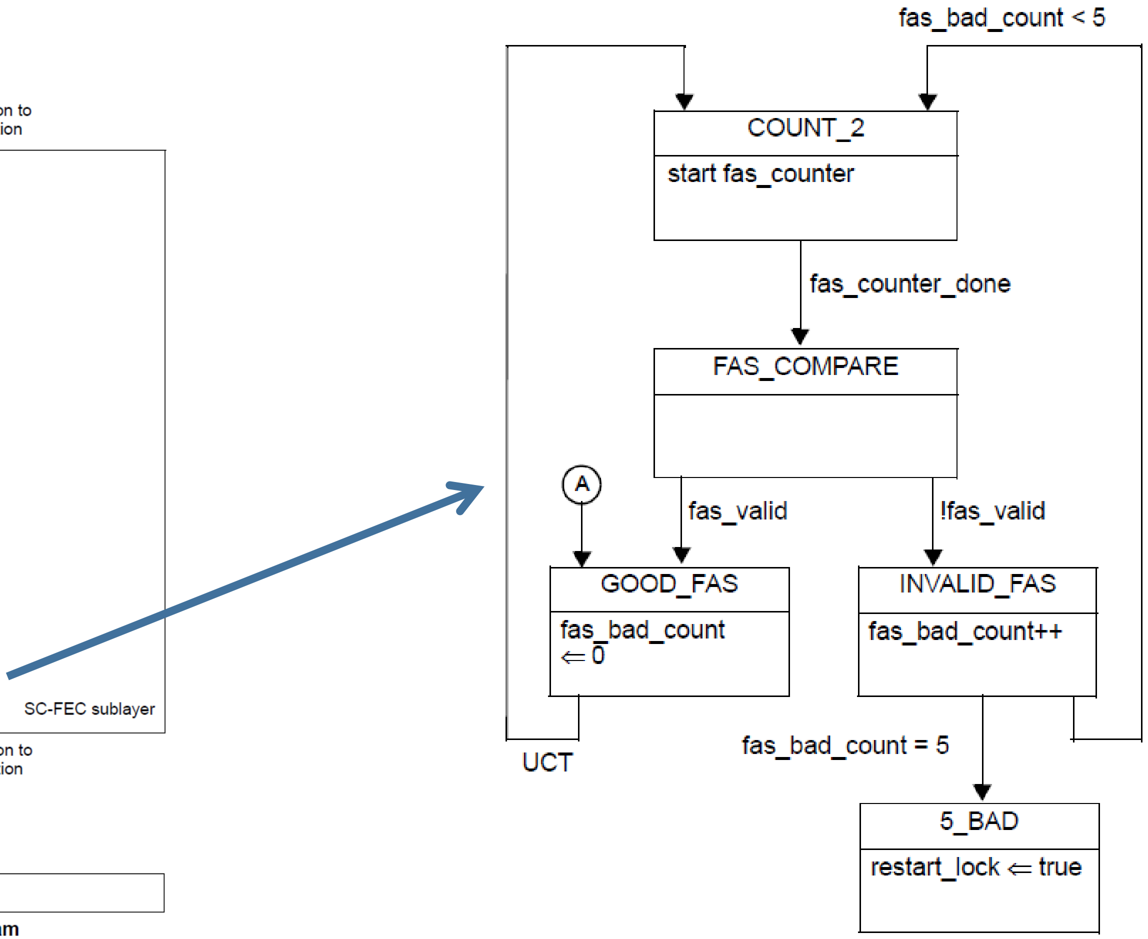


Figure 153–2—SC-FEC functional block diagram



Alignment procedures: 100GBASE-ZR vs. ITU-T G.798

Procedure	100GBASE-ZR	ITU-T G.798*
Alignment	Search for four octets that match four of the first five octets of the alignment (FAS) pattern + verify that the 6th octet value is <240. Count the bits to the next framing position candidate and verify again that four octets match four of the first five octets of the alignment (FAS) pattern and that the 6th octet value is the same as in the previous frame. If yes, then alignment is achieved.	In the OOF state (loss of alignment), the framing pattern searched for shall be a 4-byte subset of the FAS bytes. The IF state shall be entered if this subset is found and confirmed one frame period later.
Alignment loss	If for 5 consecutive frames there are more than four octets out of the first five octets of the FAS that do not match the pattern, OR the 6th octet value is not equal to the one detected during the alignment process, then alignment is lost.	The framing pattern checked for shall be the OA1OA2OA2 pattern (bytes 3, 4 and 5 of the FAS). The OOF state (loss of alignment) shall be entered if this subset is not found at the correct position in five consecutive frames.
Logical lane ID loss	Included in the alignment procedure	A new value of the logical lane marker is accepted when in five consecutive 16320 byte periods the same value is present in bits 7 and 8 of the MFAS byte (their equivalent to our lane identification).
Logical lane ID detection	Included in the alignment loss procedure	Recovery will be lost, when in each of five consecutive 16320-byte periods a value is received that is not the same as the accepted logical lane marker value

* ITU-T G.798 lane alignment requirements and procedures for OTU4-SC signal (the one our SC-FEC frame is based on) is for further study. Similar signals requirements and procedures are shown.

Proposal details

- Separate Lane marker procedures from alignment procedures
  - Option: Configurable detection and loss verification duration
  - Similar separation between block synchronization and alignment marker lock can be found in Figures 82-12 and 82-13.
- Alignment:
  - Detection based on 4 (fixed) FAS bytes OK
  - Loss detection based on: 3 (fixed) FAS bytes not OK
    - Option: Configurable loss verification duration
  - Note that usually alignment loss verification is relaxed compared with line alignment detection
- Advantage:
  - Developers will be able to reuse the same functions/hardware they developed for OTN similar signals.
    - We are “borrowing” the signal from OTN (simplified)
  - Testing for alignment problems simplified by separating functions

Loss of synchronization probability

- According to D1.1:
  - Per Lane: On average there will be an alignment loss every: ~ 1.5 min
  - If we separate the lane ID from synchronization: ~ 23 hours
  - *The main contributor to alignment loss is the lane ID verification*

- With the new proposed loss of alignment procedure (Y is the number of consecutive verification failures to lose alignment):

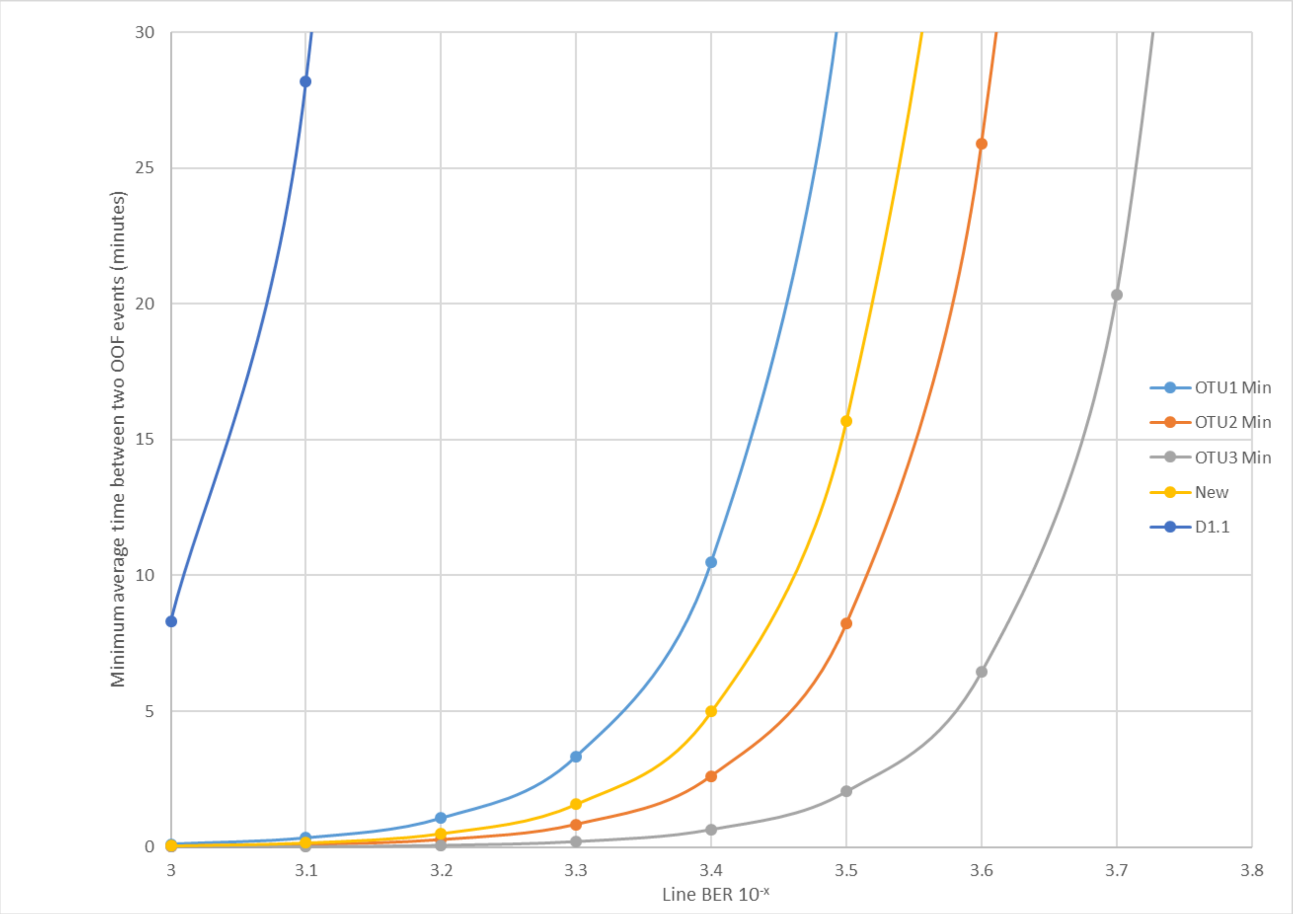
	Y=5	**Y=6**	**Y=7**
Per Lane [sec]	1.81	17.25	163.95

- In both cases, since the alarm is not integrated, the data path may be impaired.

Minimum average time between false out-of-frame events

- According to ITU-T G.798 Appendix III:
  - It is not possible to give the exact expression for the minimum average time between two out-of-frame events, due to it being a stochastic process. It is instead possible to give an approximate value for it.

Per Lane



Mean time to false frame acceptance (MTTFFA)

- According to ITU-T G.798 Appendix III:
  - The probability for false in-frame alignment can be obtained noting that the FAS is searched for up to one frame (FL bit long) with FL-1 possibilities for a false (simulated) FAS and confirmed the following δ frames.
  - The equation for computing MTTFFA is: $T_{frame}/(P_{fOOF} \times P_{fIF})$

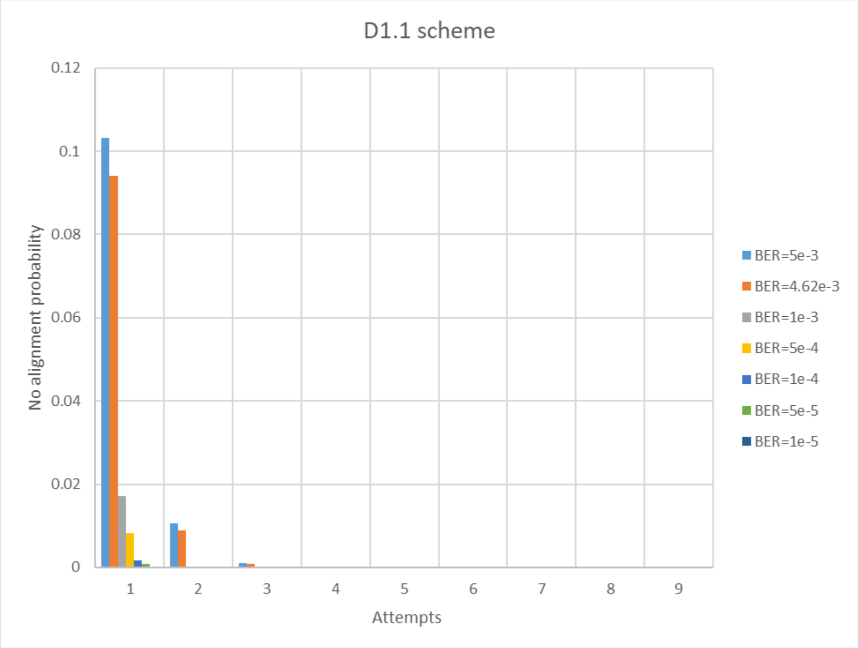
	OTU1	OTU2	OTU3	New	D1.1
MTTFFA (years) (BER = 5×10^{-3})	1.173×10^{7}	2.920×10^{6}	7.268×10^{5}	5.593×10^{6}	1.144×10^{7}
MTTFFA (years) (BER = 1×10^{-3})	2.918×10^{10}	7.265×10^{9}	1.809×10^{9}	1.392×10^{10}	1.023×10^{11}

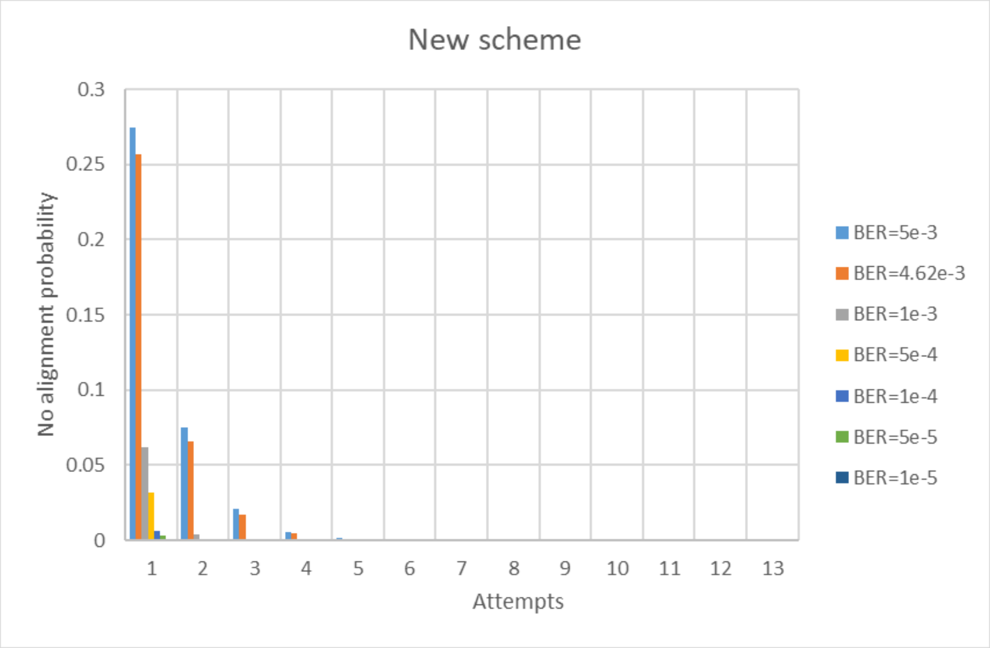
Frame lane alignment time

- According to ITU-T G.798 in our case:
  - The frame alignment time is computed using the following equation:
    - $T_{IF} = T_{frame} \times (1 + \delta + P_{fFAS} \times FAS_{Length})$
    - Where P_{fFAS} is the FAS emulation probability, FAS_{Length} is 32 and δ is 1 in our case

	OTU1	OTU2	OTU3	New
Alignment time [μsec]	97.94	24.38	6.07	46.71

- Taking BER into consideration (independent attempts):





New scheme adds two attempts: 46.71μsec

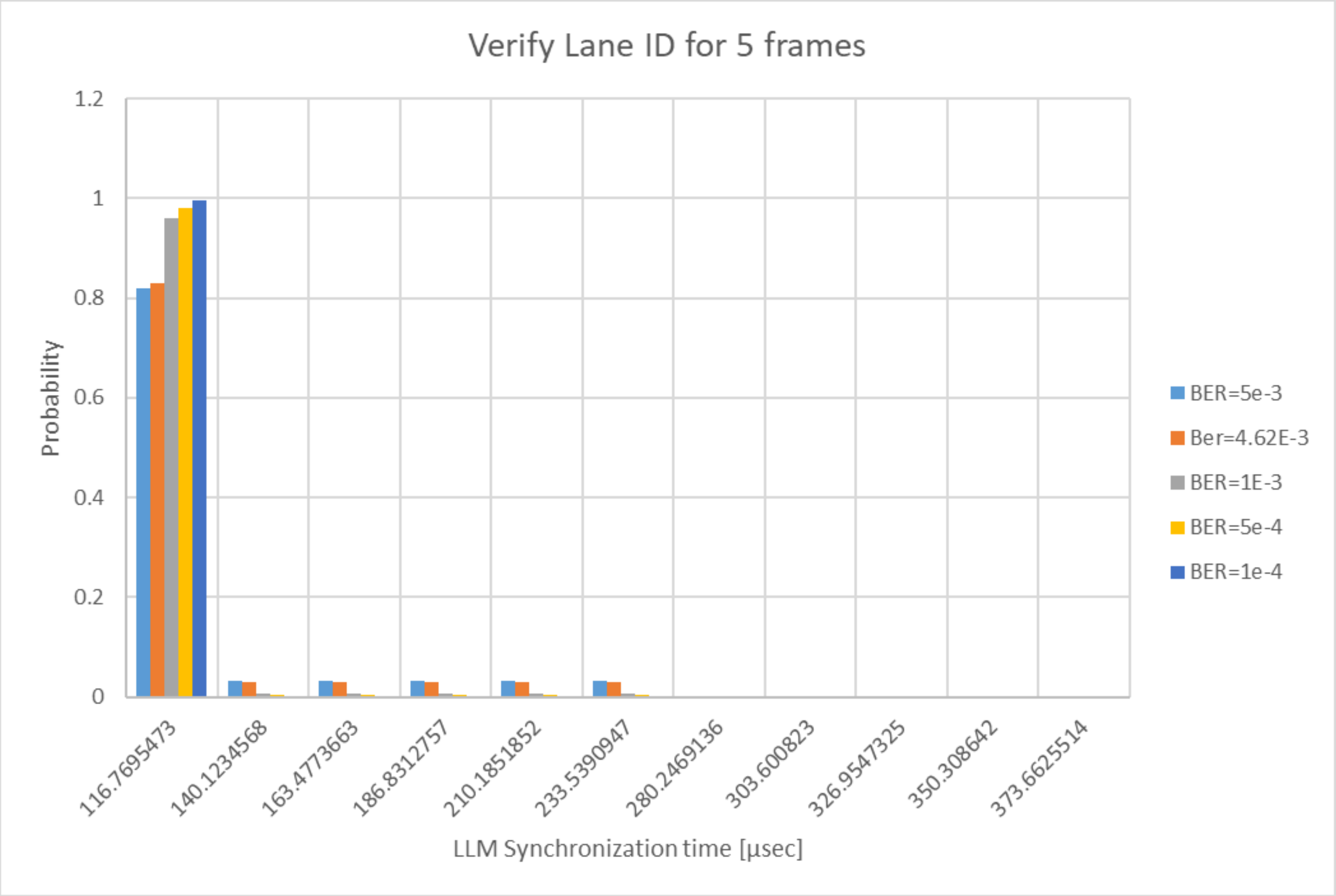
Alternative simpler alignment loss scheme

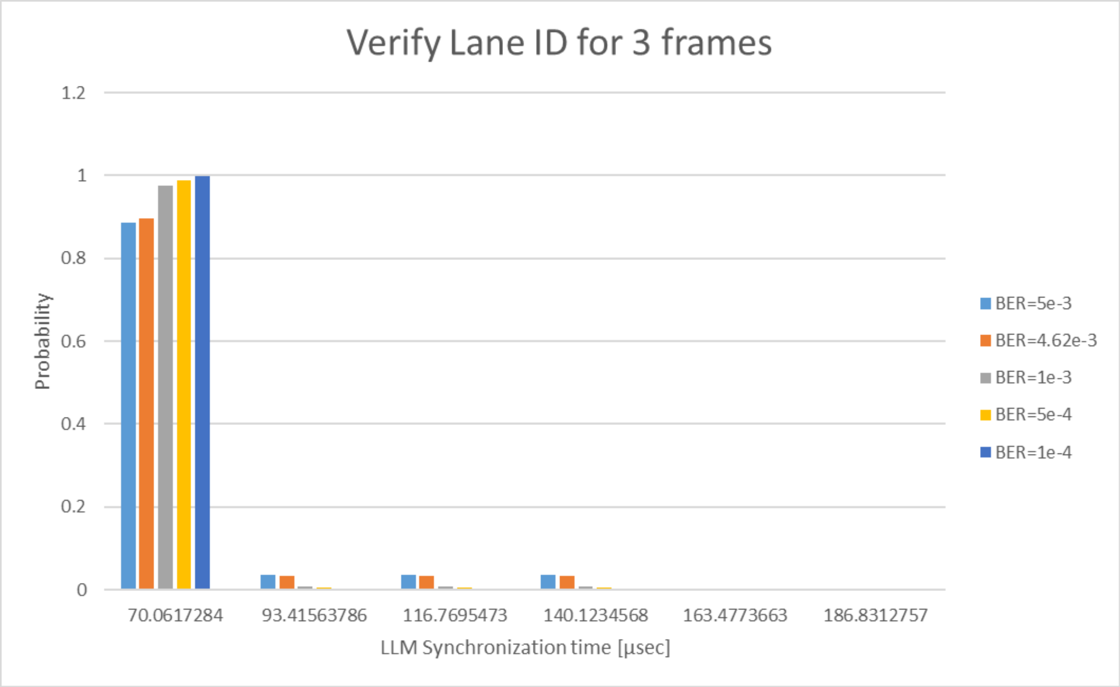
- fas_valid
  - Boolean variable that is set to true if the received 5-octet sequence is a valid frame alignment signal. The frame alignment signal consists of 40 known bits. The sequence is considered to be valid if a subset of 4 octets match the known bits of the pattern described in 153.2.3.2.4.
- FAS_COMPARE
  - This function determines if a valid frame alignment sequence has been detected and returns the result of the comparison using the variable fas_match. fas_match is true if the third, fourth and fifth octets match the known bits of the pattern described in 153.2.3.2.4. Otherwise, fas_match is false.
- Option: Configurable fas_bad_count.

Lane identification proposed process

- Independent lane alignment process
  - Note that in section 82 (PCS for 64B/66B, type 40GBASE-R and 100GBASE-R) the Block synchronization and the alignment marker lock are separate processes (Figures 82-12 and 82-13 respectively)
- Lane identification:
  - Start after FAS alignment, verify that the value is stable for X frames
- Lane identification loss:
  - Declared after Y consecutive frames the detected value is different from the accepted value
- In my comment I suggested X=Y=5.
  - Option: Configurable X and Y.

Lane identification alignment time





Conclusion

- Proposal:
  - Lane identification:
    - Separate from lane alignment process
    - Option: Configurable verification duration
  - Alignment:
    - Lane alignment: Fixed 4-octet subset of FAS searched for and verified
    - Lane alignment loss: Fixed 3-octet subset of FAS verified
  - Even if we stay with the D1.1 alignment/alignment loss process:
    - Lane alignment: 4 (or more) out of 5 FAS bytes OK searched for and verified
    - Lane alignment loss: 3 (or more) out of 5 FAS bytes Not OK searched for and verified 5 times
      - Caveat: Does not detect ±8 bit jumps