Toward Convergence of FEC Interleaving Schemes for 400GE

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INTRODUCTION

- **This presentation discusses tradeofffs for different FEC interleaving schemes for 400GE.**
- **It aims to narrow down FEC interleaving options so that we can move forward to make the final decision soon.**

BASICS OF CODING THEORY

- It has been known for tens of years that multiple code words interleaving can increase burst error correction capability for RS, BCH, or other kind of FEC codes.

- To the best knowledge of author, the code word interleaving technique has not yet been used in Ethernet systems. Why?
  - Linearly increased latency is the major drawback.
  - The technique was used in OTN system(G.709) since interleaving latency is acceptable in that application.

- What does 400GE bring us?
  - Cons: higher cost in HW and higher power consumption
  - Pros: higher data rate, much reduced transmission latency. In fact one RS(544, 514) code word only takes 12.8ns to transmit.

- In brief, 400GE has brought us an unprecedented advantage in FEC coding that the latency penalty of multiple (2 ~ 4) code interleaving is not significant.

LATENCY COMAPRISON OF VARIOUS OPTIONS [1]

Summary

- Latency for interleave schemes with PMA Bit MUXing

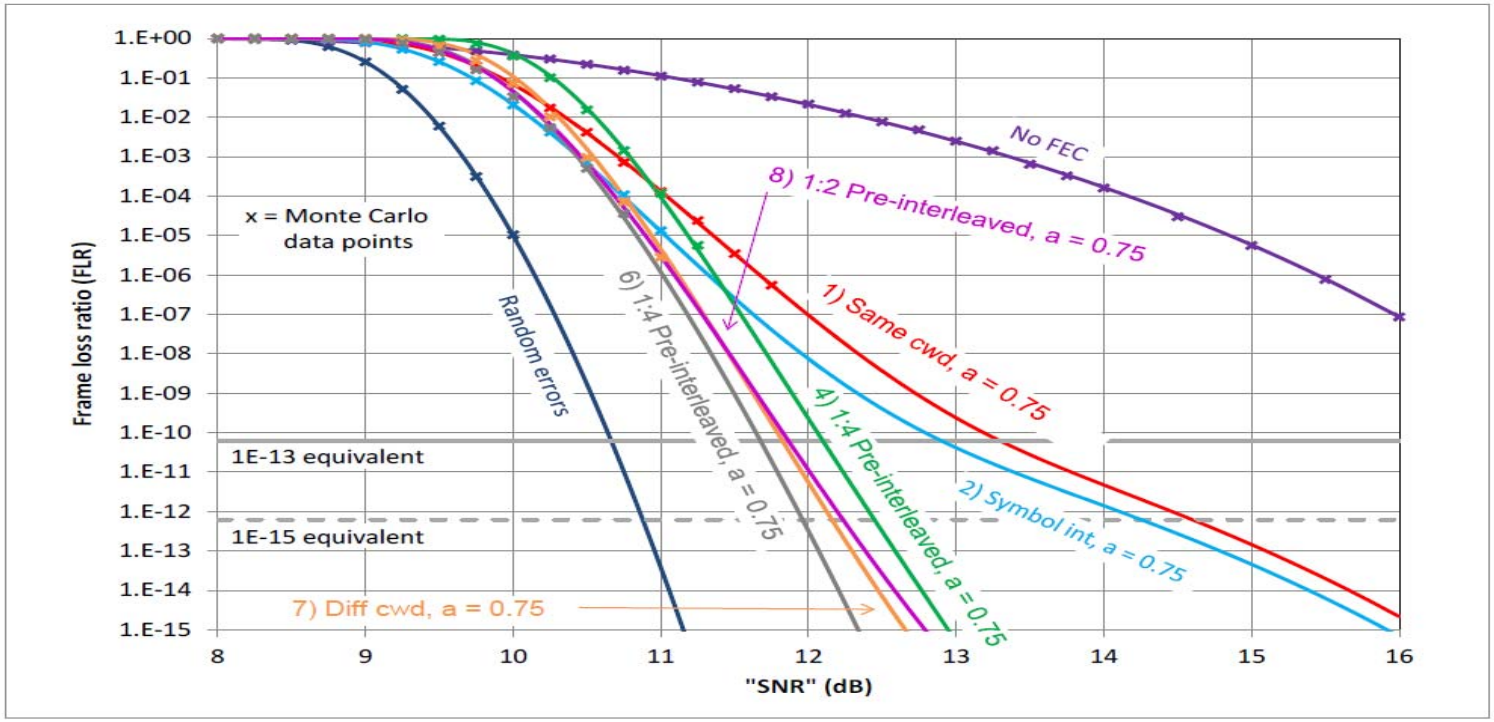
Schemes / FEC	**1,2,3** No pre-interleave	**6** 4-way Interleaving	**7** FOM	**8** 2-way Interleaving
1x400G	**75ns**	150ns	-	99ns
2x200G	87ns	138ns	-	**87ns**
4x100G	113ns	113ns	113ns	113ns

- From the above table, it can be seen that the latency penalty for 2-code interleaving (over non-itlv case) is 12ns.
- The latency penalty for 4-code interleaving is 38ns.
- The difference between HW complexity is not significant [1].

[1] from Phil Sun's presentation on 08-24-2015 (FEC group weekly meeting)

PERFORMANCE COMPARISON OF VARIOUS OPTIONS [2]

RS(544,514) All 1:2 results



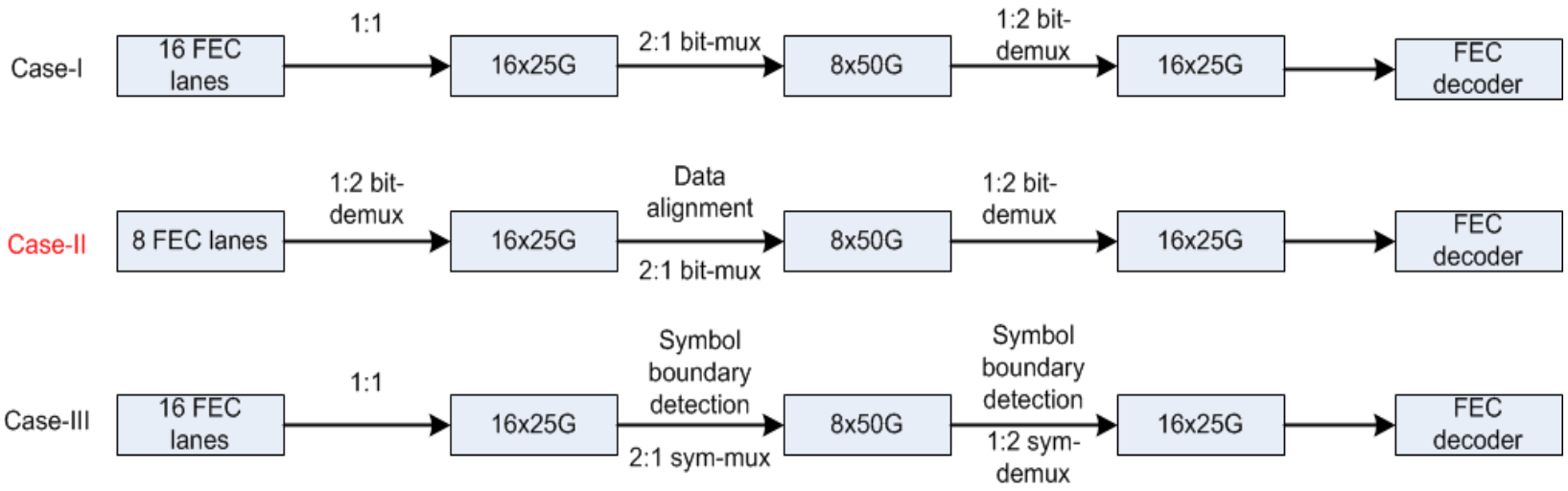
- From the above figure, it can be seen that the performance gain of 2-code interleaving is about 1.6 dB for target BER=1e-13 in the simulated case.
- The performance gain from 4-code interleaving is about 1.8 dB.

[2] from Peter Anslow's presentation in 08-14-2015(FEC group weekly meeting)

ANALYSES

- From the previous comparison on latency and performance, we may want to narrow down our selection between options 6 and 8.
- On the other hand, since both schemes used bit-muxing and code distribution over all lanes, we have cleared other implementation concerns such as easy optical module and occurrence of one bad channel.

ALTERNATIVE DATA STRIPING METHODS

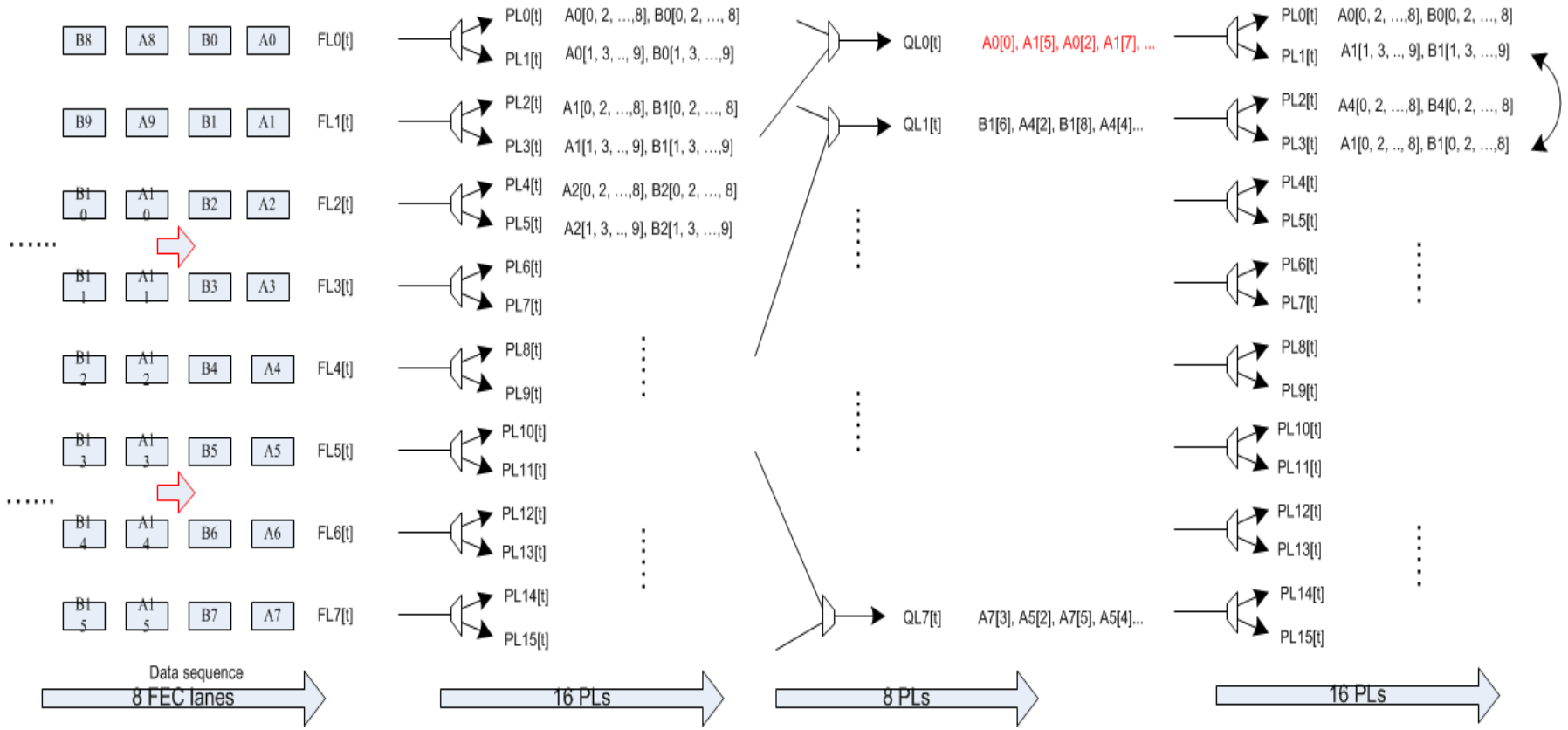


- In the above, Case-I shows bit-muxing scheme. Case-III shows RS symbol-muxing.
- The Case-II is based on 8 FEC lanes [3] with data alignment in the middle. Otherwise it is impossible to ensure RS symbol interleaving over 8 lanes.
- Roughly speaking, the implementation complexity increases from Case-I to III while the performance improves with same trend.

[3] Will Blise's slides on 08-24-2015 (sent to FEC group)

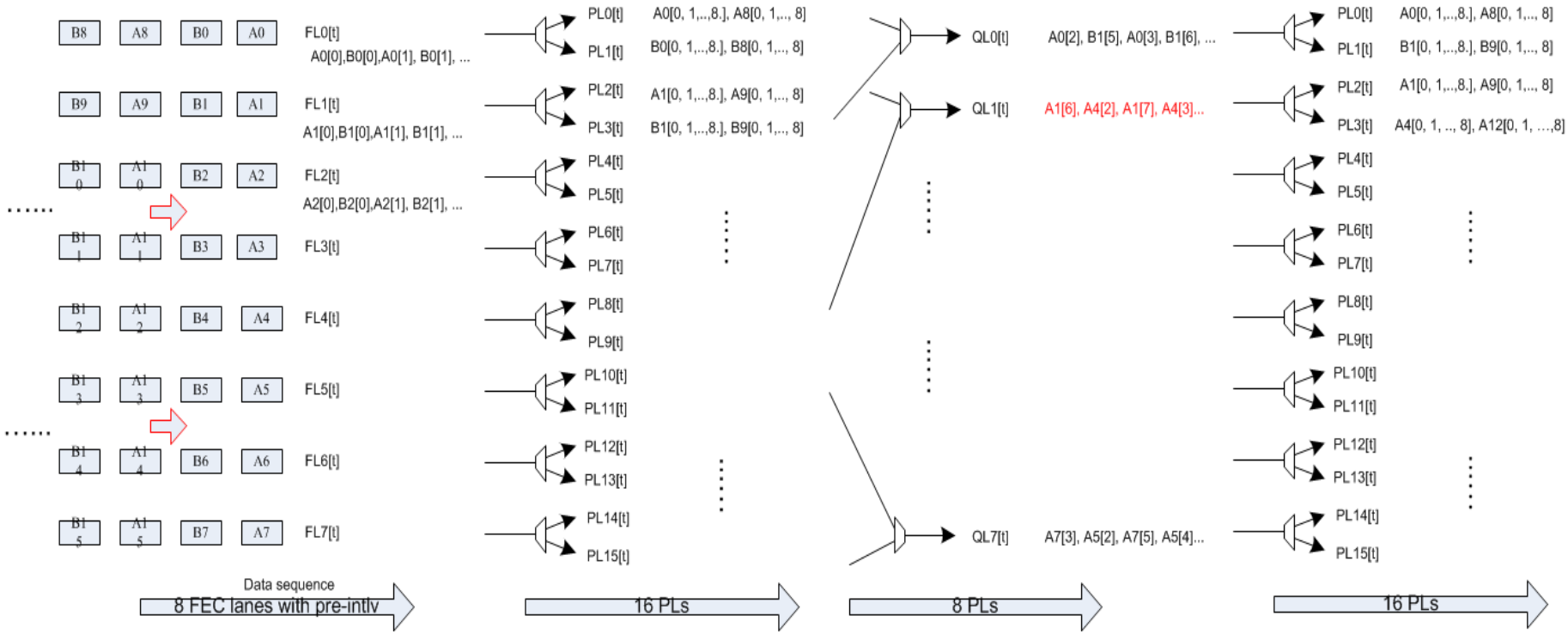
OPTION-A FOR STRIPING DATA OVER 8 LANES

- This is same as what Will proposed.
- Without data alignment in the middle, symbol interleaving is not guaranteed over 8 lanes.

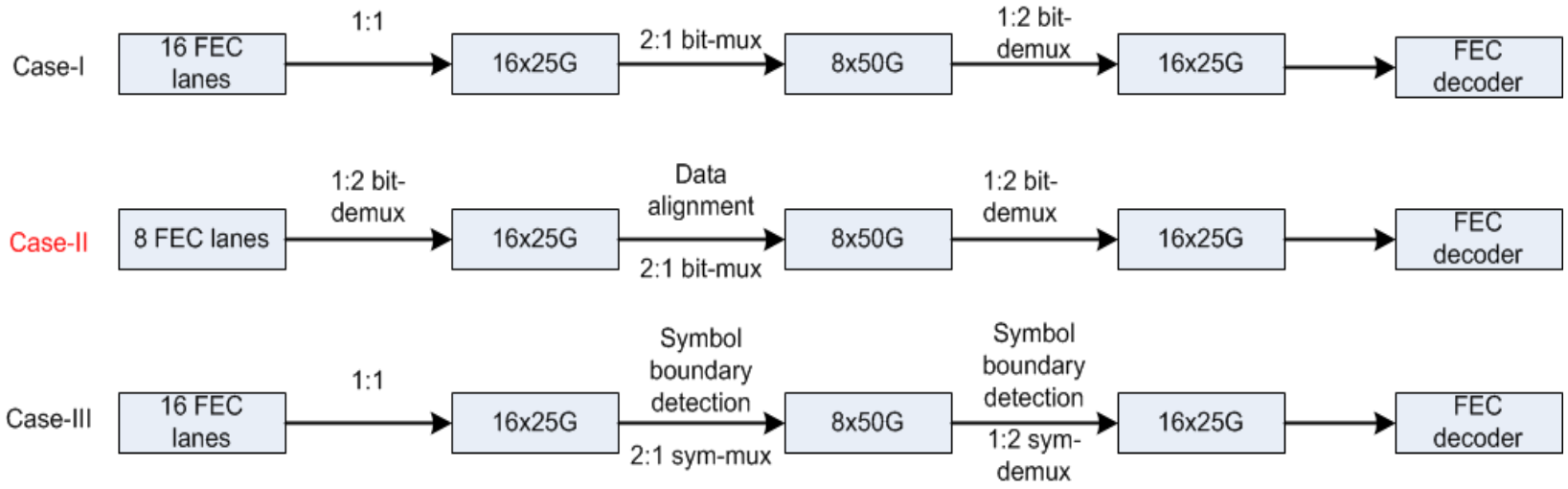


OPTION-B FOR STRIPING DATA OVER 8 LANES

- Pre-bit-interleaving is used.
- Without data alignment in the middle, RS symbol interleaving is not guaranteed over 8 lanes.



PERFORMANCE (ROUGH) ESTIMATION



- Assume 2-code interleaving:
  - The performance gap between case-I and case-III should be smaller than the difference between bit-muxing and symbol-muxing of 1 code.
  - Thus, the gap between case-I and case-II is likely << 0.3dB (consider multi-segment error accumulation).
- Assume 4-code interleaving:
  - The gap between case-I and case-II (or case-III) should be smaller than the gap with 2-code interleaving case.
- Detailed simulation can be provided for more accurate estimation. However, the performance with 2-code interleaving with bit-muxing may be sufficient.

FINAL REMARK

- Based on previous analyses and existing simulation results, we should narrow down our selection to option 6 (4-code interleaving) and 8 (2-code interleaving).