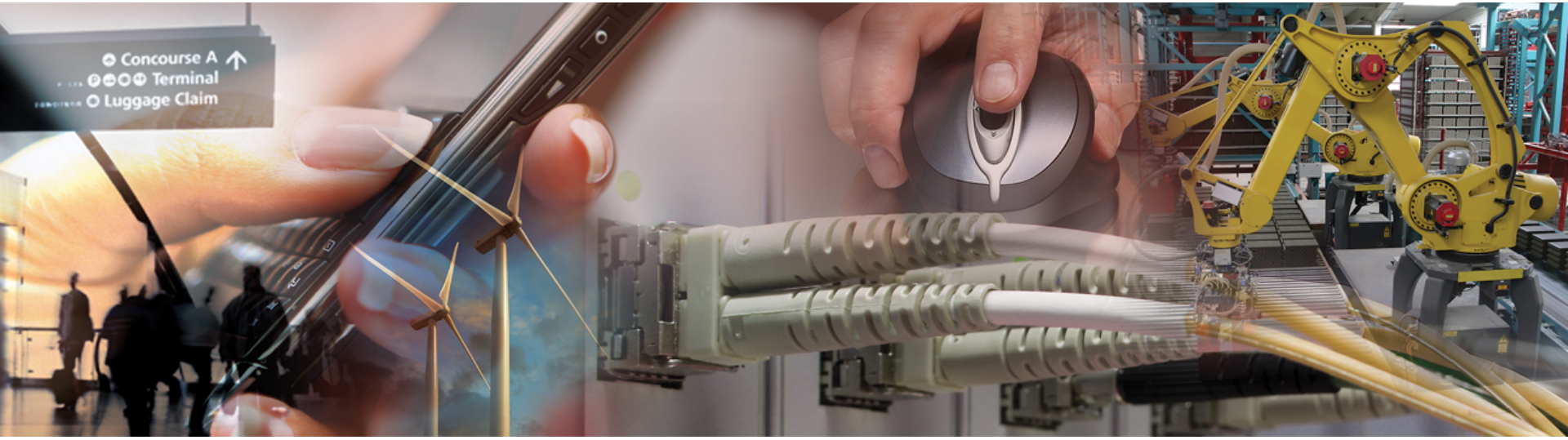
PMA muxing considerations



Jeff Slavick

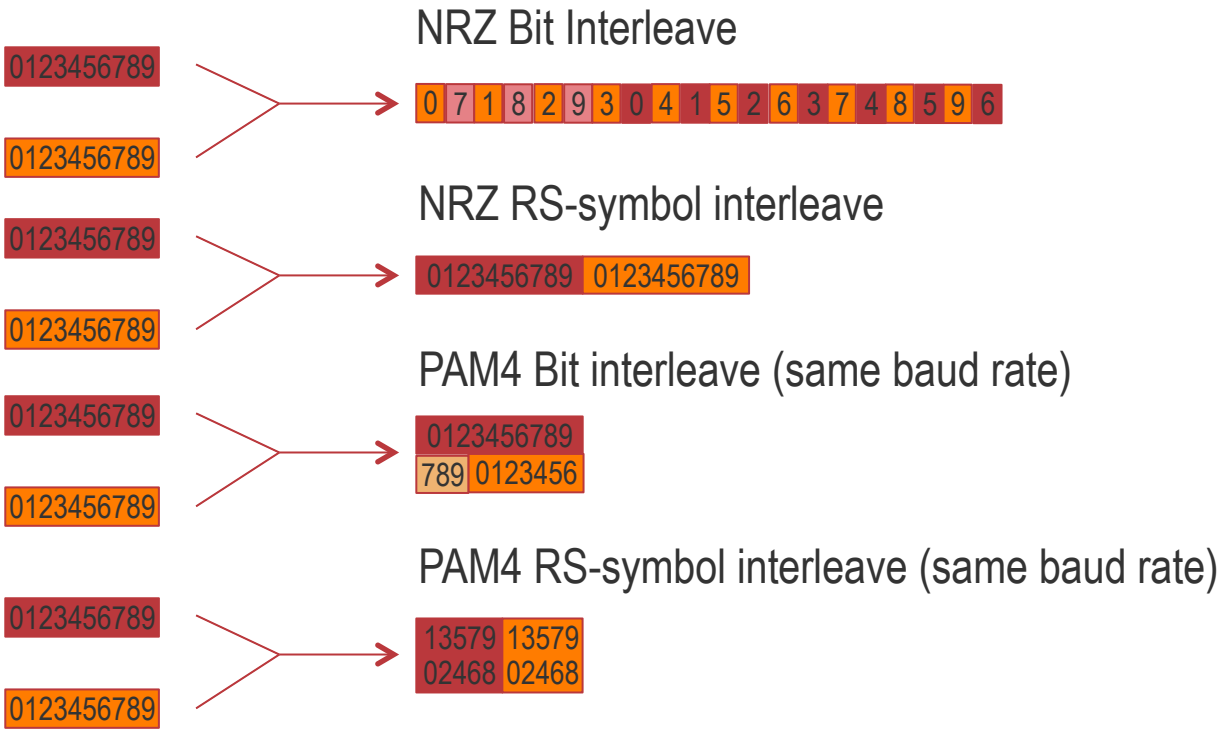
Supporters

- Tongtong Wang
- Xinyuan Wang

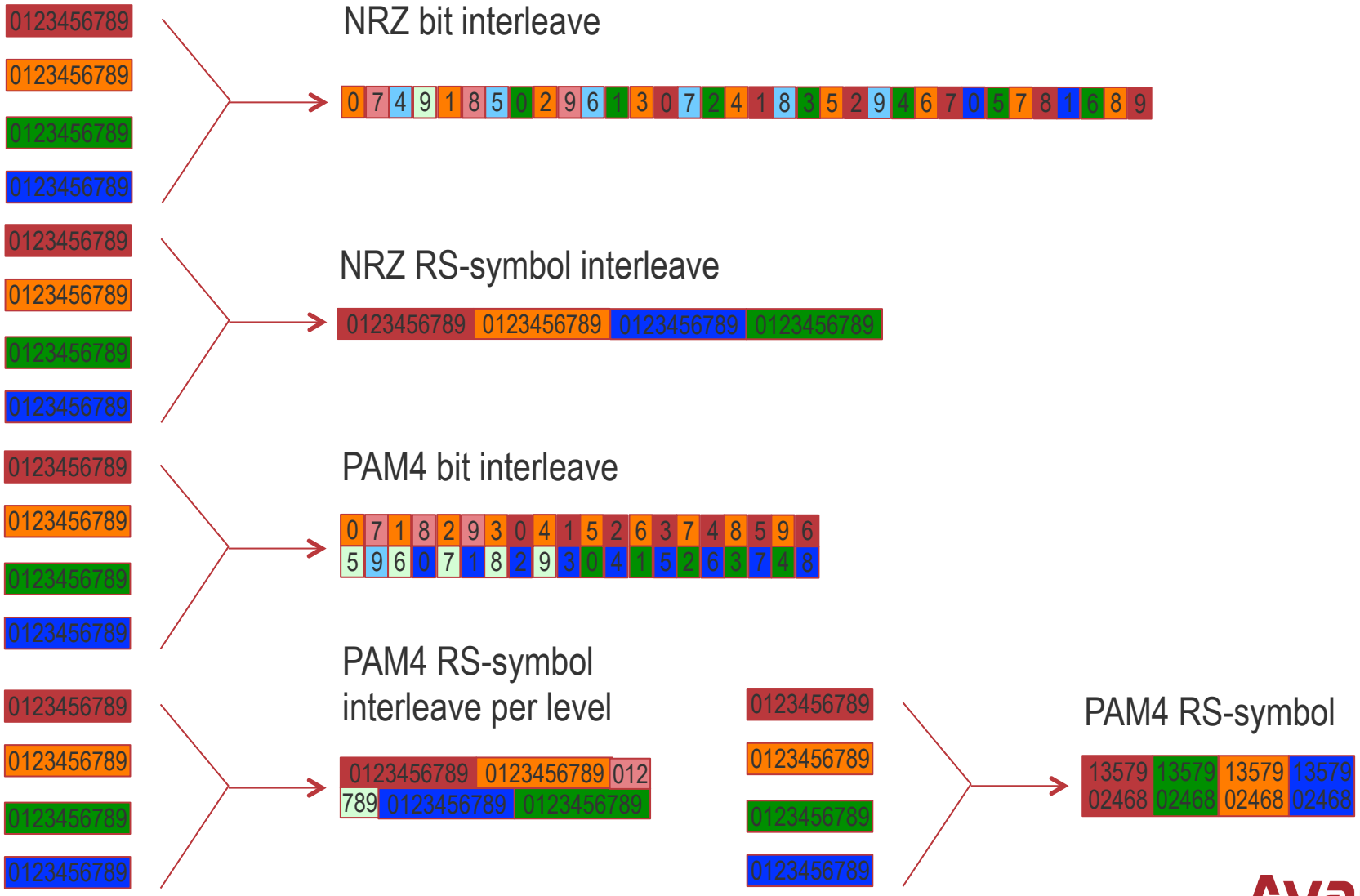
Assumptions

- **RS-FEC is used (10b RS-symbol)**
- **Gray encoding is used for PAM4 modulations**
  - Single level miss incurs only a single bit error

Double the data rate



Quadruple data rate from NRZ



Error Signatures

- **What do burst errors on a PAM4 link look like?**
  - Are they single level bursts
  - Do they toggle between levels
- **How does this affect the RS-FEC?**

Single Level burst Error

#1

#2

#3

#4

#5

#6

Pattern	Burst Length	Probability of RS FEC symbols in error due to single burst error				
		1	2	3	4	5
NRZ Bit (2 FEC lanes)	2b	100%	100%	-	-	-
	4b	100%	100%	19%	1%	-
	5b	100%	100%	28%	2%	-
	6b	100%	100%	36%	4%	-
NRZ RS (2 FEC lanes)	2b	100%	10%	-	-	-
	4b	100%	30%	-	-	-
	5b	100%	40%	-	-	-
	6b	100%	50%	-	-	-
PAM Bit (2 FEC lanes)	2b (1 level)	100%	10%	-	-	-
	4b (1 level)	100%	30%	-	-	-
	5b (1 level)	100%	40%	-	-	-
	6b (1 level)	100%	50%	-	-	-
PAM RS (2 FEC lanes)	2b (1 level)	100%	20%	-	-	-
	4b (1 level)	100%	60%	-	-	-
	5b (1 level)	100%	80%	-	-	-
	6b (1 level)	100%	100%	-	-	-
PAM Bit (4 FEC lanes)	2b (1 level)	100%	100%	-	-	-
	4b (1 level)	100%	100%	19%	1%	-
	5b (1 level)	100%	100%	28%	2%	-
	6b (1 level)	100%	100%	36%	4%	-
PAM RS (4 FEC lanes)	2b (1 level)	100%	20%	-	-	-
	4b (1 level)	100%	60%	-	-	-
	5b (1 level)	100%	80%	-	-	-
	6b (1 level)	100%	100%	-	-	-

Error type analyzed in http://www.ieee802.org/3/bs/public/14_11/anslow_3bs_02_1114.pdf and http://www.ieee802.org/3/bs/public/14_09/wang_t_3bs_01a_0914.pdf

Burst Error toggling between PAM levels

#3

#4

#7

#8

#9

#10

Pattern	Burst Length*	Probability of RS FEC symbols in error due to single burst error				
		1	2	3	4	5
PAM Bit (2 FEC lanes)	4b (1 level)	100%	30%	-	-	-
	5b (1 level)	100%	40%	-	-	-
	6b (1 level)	100%	50%	-	-	-
PAM RS (2 FEC lanes)	4b (1 level)	100%	60%	-	-	-
	5b (1 level)	100%	80%	-	-	-
	6b (1 level)	100%	100%	-	-	-
PAM Bit (2 FEC lanes)	4b (2 level)	100%	100%	37%	3%	-
	5b (2 level)	100%	100%	46%	4%	-
	6b (2 level)	100%	100%	55%	5%	-
PAM RS (2 FEC lanes)	4b (2 level)	100%	60%	-	-	-
	5b (2 level)	100%	80%	-	-	-
	6b (2 level)	100%	100%	-	-	-
PAM Bit (4 FEC lanes)	4b (2 level)	100%	100%	100%	100%	-
	5b (2 level)	100%	100%	100%	100%	20%
	6b (2 level)	100%	100%	100%	100%	28%/ 2% (6)
PAM RS (4 FEC lanes)	4b (2 level)	100%	60%	-	-	-
	5b (2 level)	100%	80%	-	-	-
	6b (2 level)	100%	100%	-	-	-

* 5b and 4b burst length dropped black entries 5 & 4

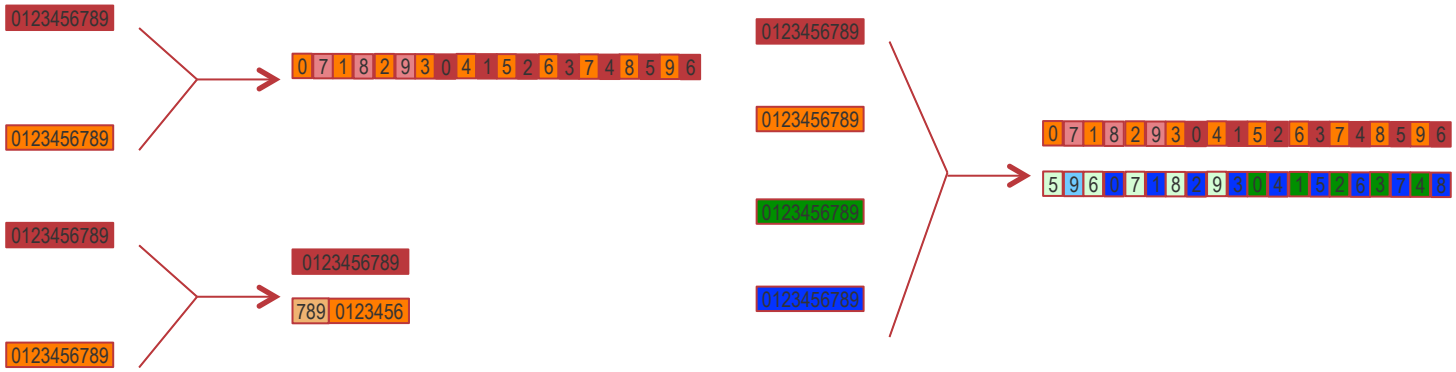
Error signatures affects

- NRZ bit interleave has been shown to require a higher BER floor then NRZ RS-symbol interleave in previous presentations to the group.*
- PAM bit interleave has higher probabilities of needing 3 and 4 RS-symbols of correction (#7) compared to NRZ bit interleave (#1) when a PAM burst error occurs. This could imply an additional increase in the BER floor to support this type of bit interleave.

* See http://www.ieee802.org/3/bs/public/14_11/anslow_3bs_02_1114.pdf and http://www.ieee802.org/3/bs/public/14_09/wang_t_3bs_01a_0914.pdf

PMA option 1

- Bit mux always

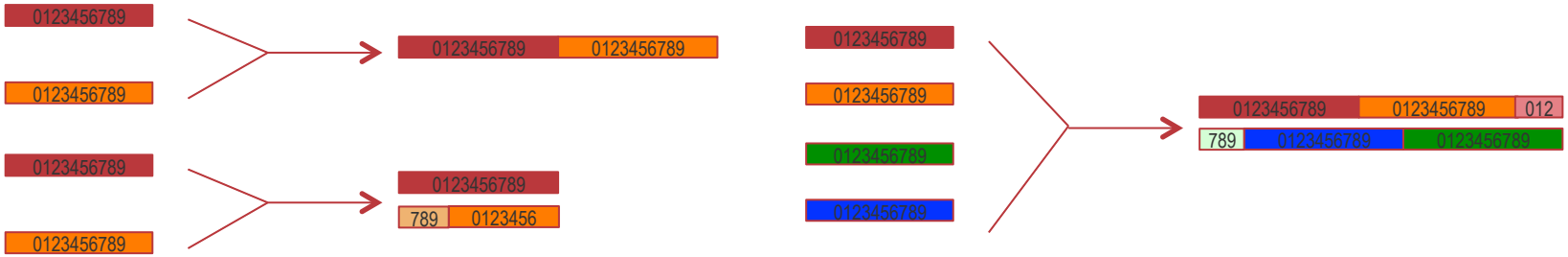


- Pro – simple

- Con – RS-FEC performance is degraded, increasing required BER floor. Single RS-FEC solution not viable must use a FOM design.

PMA option 2

- Bit mux when baud rate stays same. RS symbol mux when baud rate changes.



- PRO – simple for NRZ <-> PAM4 transitions at same baud rate. RS-FEC performance degraded (magnitude depends on error signature)
- Con – When baud-rate changes must RS-FEC symbol align
  - Ie. 25G NRZ -> 100G PAM4 requires alignment, 25G NRZ -> 50G PAM does not.

Option 3

- RS-FEC symbol interleave always

- Pro – Best FEC performance, supports both FOM and Single FEC implementations.

- Con – All rate changes (data or baud) require alignment to RS-FEC symbols

Conclusion

- **Selection of PMA muxing scheme is a tradeoff between**
  - BER operating floor
  - Number of FEC engines
  - Error signature of links
  - RS-FEC symbol framing when lane counts change
- **Option 1 requires more FEC engines and higher BER floor**
- **Option 2 requires symbol framing in some situations with a reduced BER floor**
- **Option 3 requires symbol framing in all situations but the lowest BER floor**