Technical Feasibility of optical PMDs with RS FEC

Yu Xu, Xinyuan Wang

Background and Introduction

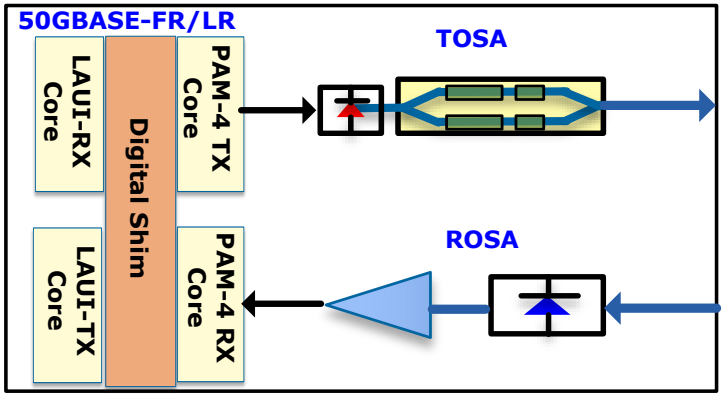
- In 50 Gb/s Ethernet Over a Single Lane and Next Generation 100 Gb/s & 200 Gb/s Ethernet Call For Interest Consensus Presentation, expect to leverage of Industry investment for PMD.

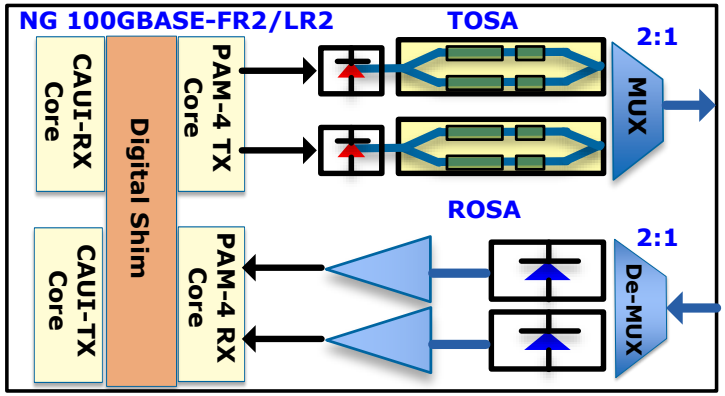
Technology	Nomenclature	Description	Status
Backplanes	100GBASE-KP4 & KR4 CEI-56G-LR-PAM4	4 x 25 Gb/s backplane 56 Gb/s PAM4	IEEE 802.3bj Published Straw Ballot
Chip-to-Module	CDAUI-8 CEI-56G-VSR-PAM4	8 x 50 Gb/s PAM4 60 Gb/s PAM4	IEEE P802.3bs in Task Force Rev Straw Ballot
Chip-to-Chip	CDAUI-8 CEI-56G-MR-PAM4	8 x 50 Gb/s PAM4 60 Gb/s PAM4	IEEE P802.3bs in Task Force Rev Straw Ballot
SMF Optical	400GBASE-FR8 & LR8 400GBASE-DR4	8 x 50 Gb/s PAM4 4 x 100 Gb/s PAM4	IEEE P802.3bs in Task Force Review
Module Form Factor	SFP56	1 x 50 Gb/s	Extension to Summary Document SFF-8402
	QSFP56	4 x 50 Gb/s	Extension to Summary Document SFF-8665

- There are different technical solutions to achieve at least 10km transmission for the new bitrates Ethernet.
- In this contribution, assuming to reuse technology from 802.3bs, we investigate the technical feasibilities of PMDs with RS FEC.

Reuse of bs SMF Solution

- If to share the same solution/platform from 400GBASE-FR8/LR8, the following block diagram could be used with MZ modulator could be imply DML or EML.





- Assuming share same optical solution/platform from 802.3bs 400GbE
  - **For 50GBASE-FR/LR:** No optical Mux/DeMux be required.
  - **For 100GBASE-FR2/LR2:** 2:1 optical Mux and 1:2 DeMux be required.
  - **For 200GBASE-FR2/LR2:** 4:1 optical Mux and 1:4 DeMux be required.

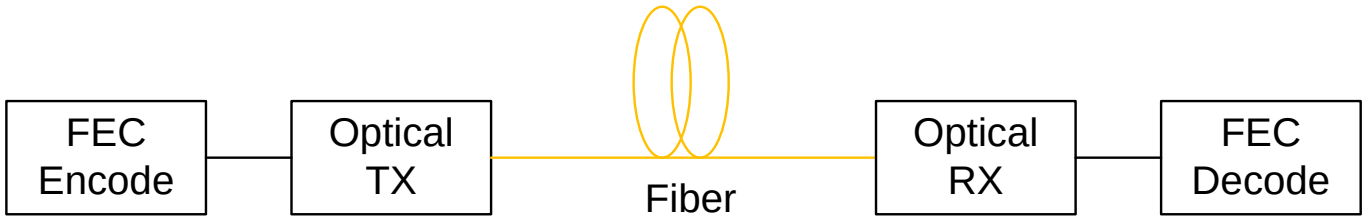
Insertion Loss of Optical Mux/DeMux

	MUX	DeMUx	Insertion loss reduction from 400GbE
400GBASE-FR8/LR8	3dB	3dB	0dB
200GBASE-FR4/LR4	2dB	2dB	2dB
100GBASE-FR2/LR2	1dB	1dB	4dB
50GBASE-FR/LR	0dB	0dB	6dB

- The extra additional link budget compared with 400GbE, could be used either to relax requirement of optical components or lower the requirement to RS FEC.
- Using 100GBASE-FR2/LR2 as example, 4dB additional insertion loss can be used to relax requirement for optical solution and RS FEC.
  - Conclusion of this analysis is still valid in 1X/4X 50Gbps PAM4 SMF solution.

Consideration of Extra Additional Link Budget

	Option 1	Option 2	Option 3
SMF reach	Extend the current length to 20/30/40km?	Keep the same as .bs with 2/10km	Keep the same as .bs with 2/10km
Tx/Rx optical spec	Keep the same as .bs	Relax the optical requirement	Hope the optical requirement also could be relax
FEC	Keep the same as .bs with KP4 RS FEC	Keep the same as .bs with KP4 RS FEC	Use a lower gain FEC
Further thinking	Could the extra margin support 40km? If not, do we need to define a 20km/30km transmission?	Need solid work to support. Choose the spec which can balance the cost (yield) and performance	Is KR4 RS FEC an option? What is the influence to optical side?



Analysis on Option 2

- P802.3bs transmit/receive characteristics are still evolving, but provides excellent starting point for the new PMDs.
- The extra budget can be used to relax the transmitter specification such as OMA reduction , extinction ratio relaxation, or relax the receiver sensitivity.
- Solid test results should be required to support any suggestion of modification.

Table 123–7—400GBASE-FR8 and 400GBASE-LR8 transmit characteristics

Description	400GBASE-FR8	400GBASE-LR8	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm		GBd
Modulation format	PAM4		—
Lane wavelengths (range)	1272.55 to 1274.54 1276.89 to 1278.89 1281.25 to 1283.27 1285.65 to 1287.68 1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19		nm
Side-mode suppression ratio (SMSR), (min)	30		dB
Total average launch power (max)	13.2		dBm
Average launch power, each lane (max)	4.2		dBm
Average launch power, each lane[a] (min)	–3	–2.5	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	5.5	5.7	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (min)[b]	0	0.5	dBm
Difference in launch power between any two lanes (OMA_{outer}) (max)	TBD	TBD	dB
Launch power in OMA_{outer} minus TDP, each lane (min)	–1	–0.5	dBm
Transmitter and dispersion penalty (TDP), each lane (max)	2.2	2.4	dB
Average launch power of OFF transmitter, each lane (max)	–30		dBm
Extinction ratio (min)	4.5		dB
$RIN_{xx}OMA$ (max)	TBD		dB/Hz
Optical return loss tolerance (max)	TBD		dB
Transmitter reflectance[c] (max)	TBD		dB
Transmitter eye mask definition	TBD		

Table 123–8—400GBASE-FR8 and 400GBASE-LR8 receive characteristics

Description	400GBASE-FR8	400GBASE-LR8	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm		GBd
Modulation format	PAM4		—
Lane wavelengths (range)	1272.55 to 1274.54 1276.89 to 1278.89 1281.25 to 1283.27 1285.65 to 1287.68 1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19		nm
Damage threshold[a], each lane	5.2		dBm
Average receive power, each lane (max)	4.2		dBm
Average receive power, each lane[b] (min)	–7	–8.8	dBm
Receive power, each lane (OMA_{outer}) (max)	5.7		dBm
Difference in receive power between any two lanes (OMA_{outer}) (max)	TBD	TBD	dB
Receiver reflectance (max)	TBD		dB
Receiver sensitivity (OMA_{inner}), each lane[c] (max)	–9.8	–11.6	dBm
Stressed receiver sensitivity (OMA_{inner}), each lane[d] (max)	TBD	TBD	dBm
Conditions of stressed receiver sensitivity test			
Condition 1[e]	TBD	TBD	
Condition 2[e]	TBD	TBD	

Analysis on Option 3

- For first order analysis, lets assume FEC coding gain only covers optical link with post FEC BER Objective=1E-12 in 50GbE/NG 100GbE
- Lets use the 400GBASE-LR8/FR8 KP4 FEC, which provide 3E-4 BER requirement.
- The extra margin gained could be allocated to the link to allow use of lower gain FEC, such as KR4 RS FEC.

RS FEC(n,k,t,m)	CG	NCG*	BERin	Overhead	SerDes Rate	Block Time	Latency**	Area Ratio
RS(528,514,7,10)	5.39	5.28	5.30E-05	0%	25.78125	102.4ns	~175ns	1X
RS(544,514,15,10)	6.64	6.39	3.60E-04	3.03%	26.5625	102.4ns	~197ns	2.9X

*: Block time and latency based on 50GbE

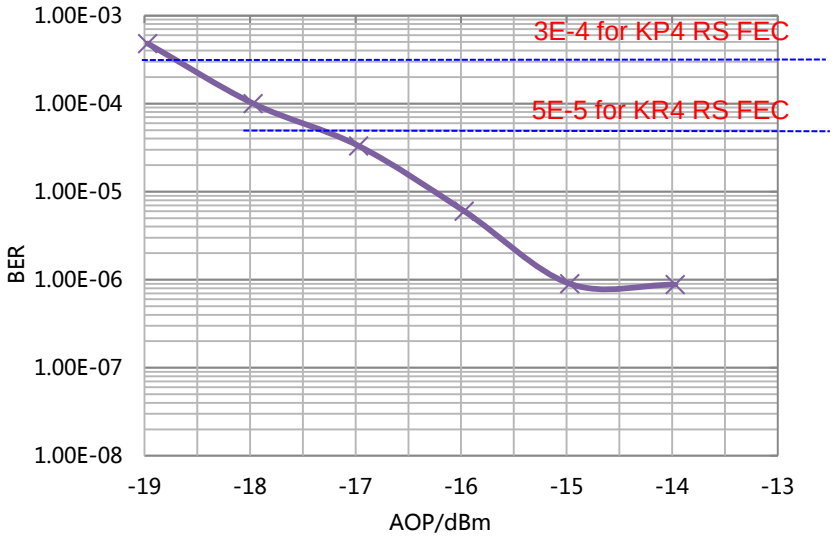
*: Refer to wang_x_3bs_01a_0115

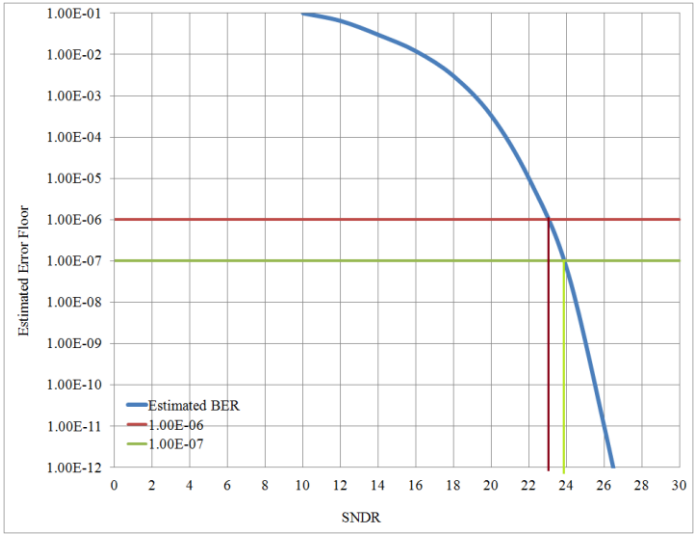
- Compare with KP4 RS FEC, the gain of KR4 RS FEC is **1.1dB** lower, corresponding to **0.55dB** in optical side.

	extra margin compare with 400GbE	FEC gain decreased	margin left
400GBASE-FR8/LR8	**0dB**	**-**	**-**
200GBASE-FR4/LR4	**2dB**	**0.55dB**	**1.45dB**
100GBASE-FR2/LR2	**4dB**	**0.55dB**	**3.45dB**
50GBASE-FR/LR	**6dB**	**0.55dB**	**5.45dB**

Optical side consideration of Option 3

- During 802.3.bs's discussion, the lowest BER suggested were 1E-6 with KP4 RS FEC.
- Assuming KR4 RS FEC, what should be the lowest pre-FEC 1E-6 or 1E-7?
- Theoretically BER would be limited by SNR transmitter, link impairments/attenuation, and sensitivity.
- Need to consider the lower latency of using KR4 FEC vs additional link budget reduction and potentially more strengthen optical requirements!





*: Refer to takai_3bs_01b_0515

Conclusion

- Leveraging 50 Gb/s PAM4 400GBASE-FR8/LR8 PMDs offers technically feasible implementation for all optical PMDs under consideration.
- Choosing 50Gb/s PAM4 offers extra margin for link budget which can be used to benefit relax transmitter, receivers, possible use KR4 RS FEC, and/or improve the yield of optical components.
- No matter which option we choose, lower cost, larger market share would have the highest priority.
- To consider which option we should choose, the following items are very important.
  - The technical feasibility for extend reach and its market volume.
  - The lowest pre-FEC BER requirement for given RS FEC meeting FLR
  - Other items that might need think through.

Thank You