Technical Analysis to Support 400GbE 40km Objective

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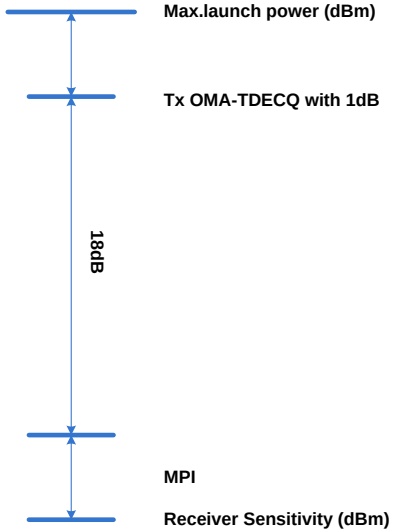
Background and Motivation

- Yu_b10k_01c_0318 presented the illustrative link budget for 200GE over 30/40km with updated definition of receiver sensitivity.
  - An four-lane 200 Gb/s operation over at least 40km of SMF objective is accepted in March meeting
- For 400GE 40km proposal, the straw poll on technical feasibility of 50 Gb/s PAM4, some indicated to want more information to cover the additional link budget from Mux/DeMux, CD penalty comparing to 200GE 40km, last Nov & Jan meeting.
- In this presentation, new test data and analysis based on previous work support the technical feasibility for 400GbE 30/40km to reach an proposed objective.

400GbE 40km Reach Link Budget

- To support the accepted 50 and 200GbE with 40km reach as objective in B10K study group, in the previous contributions, some test result of n*50G PAM4 from multi-vendors presented on BER, transmitter output power, dispersion penalty, Mux/DeMux loss, sensitivity of APD-based ROSA, fiber dispersion and so on.
  - http://www.ieee802.org/3/B10K/public/17_11/wang_b10k_01d_1117.pdf
  - http://www.ieee802.org/3/B10K/public/18_01/yamamoto_b10k_01a_0118.pdf
  - http://www.ieee802.org/3/B10K/public/18_01/xu_b10k_01a_0118.pdf
  - http://www.ieee802.org/3/B10K/public/18_03/yu_b10k_01c_0318.pdf
- Further investigation of ways to enhance link budget for 400GbE 40km with 50G PAM4 technology



	Type 1	Type 2	Type 3
Tx OMA-TDECQ (dBm)	3	1	1
Fiber + Connector Loss (dB)	18	18	18
MPI (dB)	0.5	0.5	0.5
Receiver Sensitivity(dBm)	-15.5 @ 2.4e-4	-17.5 @ 2.4e-4	-17.5 @ ~1e-3
FEC Gain dBo	3.2	3.2	4.5~5.2

- Type 1 approach: With enhanced EML
- Type 2 approach: With enhanced APD
- Type 3 approach: With enhanced FEC

Refer to: wang_b10k_01d_1117

New Test Data for Optical Solution

- Transmitter

Parameter	Vendor 1
Tx Output Power outer (After Mux)	6 dBm
ER	6.9 dB
SECQ	1.2 dB
Assumed CD Penalty	1 dB
Assumed TDECQ	2.2 dB

- Receiver

Parameter	Vendor 1
Receiver Sensitivity, (Before DeMux)	-16 dBm @1.2 dB SECQ

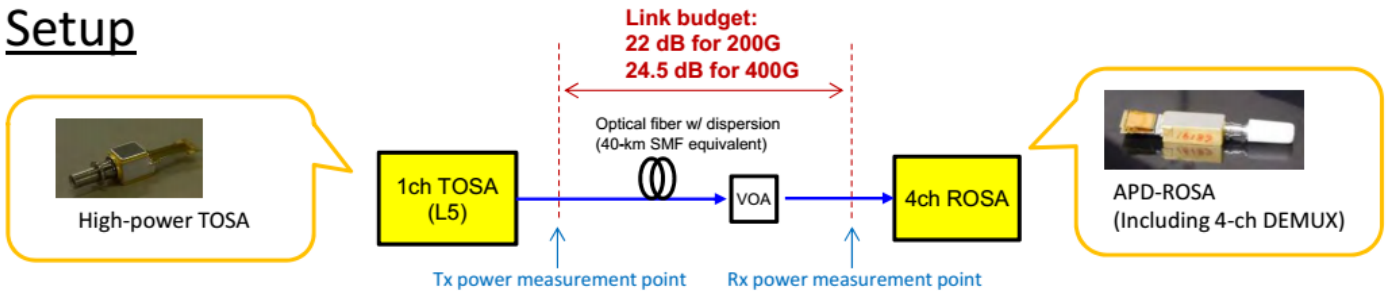
Tested Data from NTT to Support a 400GbE 40km Objective

- Yamamoto_b10k_01a_0118 investigated feasibility for 200G/400GbE beyond 10km optical PMD.

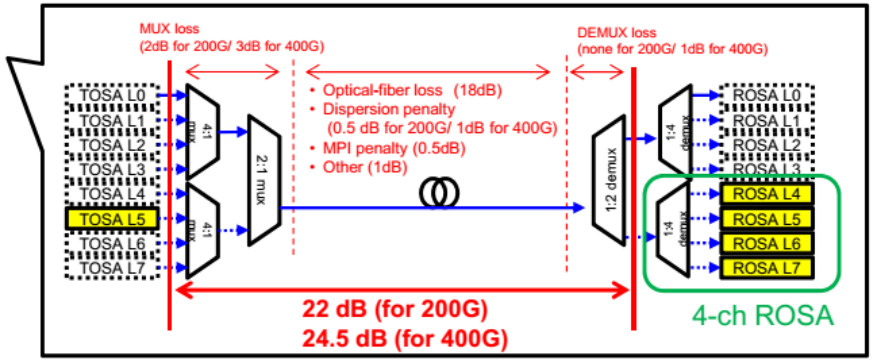
Experimental setup

Innovative R&D by NTT

Setup



- PAM4 signal is transmitted using 1-ch high-power TOSA and 4-ch APD-ROSA.
- Receiver sensitivity and dispersion penalty are evaluated assuming 8-lane LAN-WDM 40-km transmission.
- In the case with 4-ch ROSA including 4-ch DEMUX, the link budget is below;
  - 200G: 24 dB → 22 dB
  - 400G: 26.5 dB → 24.5 dB



- 200G/400G 40km transmissions have some margins.

	OMA margin	
	53 Gb/s (KP4-FEC)	56 Gb/s (Stronger FEC)
200G 40km	3.2 dB	4.2 dB
400G 40km	0.7 dB	1.7 dB

1-dB improvement

NTT

Potential Optical Margin of 400GbE 30/40km Link Budget

Description (Outer Eye)	Value	Unit
Tx OMA_{outer}, tested	6	dBm
Reach	30/40	km
SECQ tested Tx	1.2	dB
Insertion loss	18	dB
Assumed CD penalty	*1*	*dB*
MPI	0.5	dB
TDECQ assumed @ CD penalty=1dB	2.2	dB
Receiver sensitivity OMA_{outer} required @ SECQ = 0.9dB	-13.8	dBm
Receiver sensitivity tested @ SECQ = 1.2dB	-16	dBm
Receiver sensitivity calculated from tested value @ SECQ = 0.9dB	-16.3	dBm
Optical Margin for DGD penalty = 0	2.5	dB
Optical Margin for DGD penalty = 1dB	1.5	dB

- In this table, Tx OMA and Receiver sensitivity are tested numbers, this table is just to verify the feasibility, not for specification suggestion. In real product, those numbers could be traded off for yield.

Revisit Optical Margin from 802.3bs

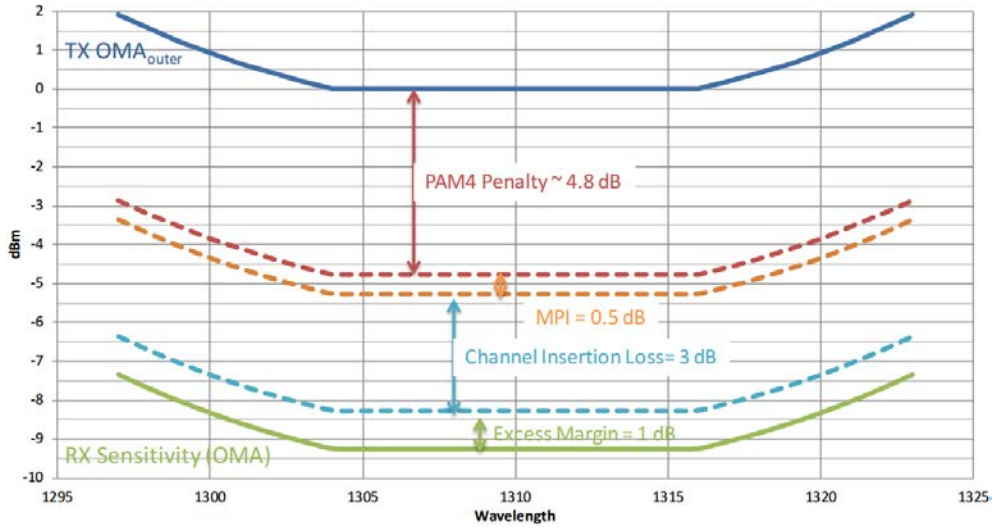
- In May 2015, we adopted baseline for 500m and 10km SMF objective of 400GbE based on following information from some TX and RX test result
- From "cole_3bs_01a_0515", adopted baseline for 400GBASE-LR8 10km SMF with 1.9dB Optical Margin.

Optical Margin

Description (Inner Eye)	400GBASE-FR8	400GBASE-LR8	Unit
Receiver Sensitivity (OMA), each lane, pre-DeMux (max)	-10.0	-11.8	dBm
DeMux Loss	3.0	3.0	dB
Cross-talk penalty	0.3	0.3	dB
Receiver Sensitivity (OMA), each lane, post-DeMux (max)	-13.3	-15.1	dBm
Receiver Sensitivity (OMA) single lane (typical measured)	-17	-17	dBm
Optical Margin	3.7	1.9	dB

- From "welch_3bs_01a_0515", adopted baseline for 400GBASE-DR4 500m SMF with ~1dB Optical Margin.

400G-PSM4 Link Budget (at TDP = 0.8 dB)

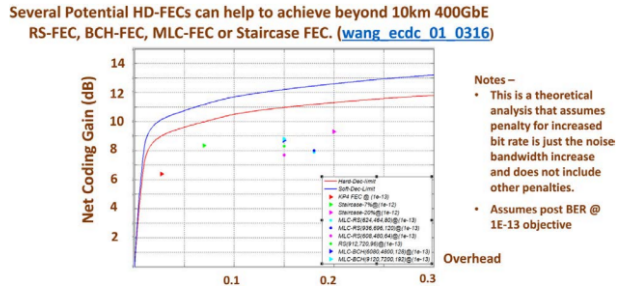


- Previous experience show data to support a feasibility objective with achievable margin at end of 802.3bs SG and output a comprehensive draft standard at TF.

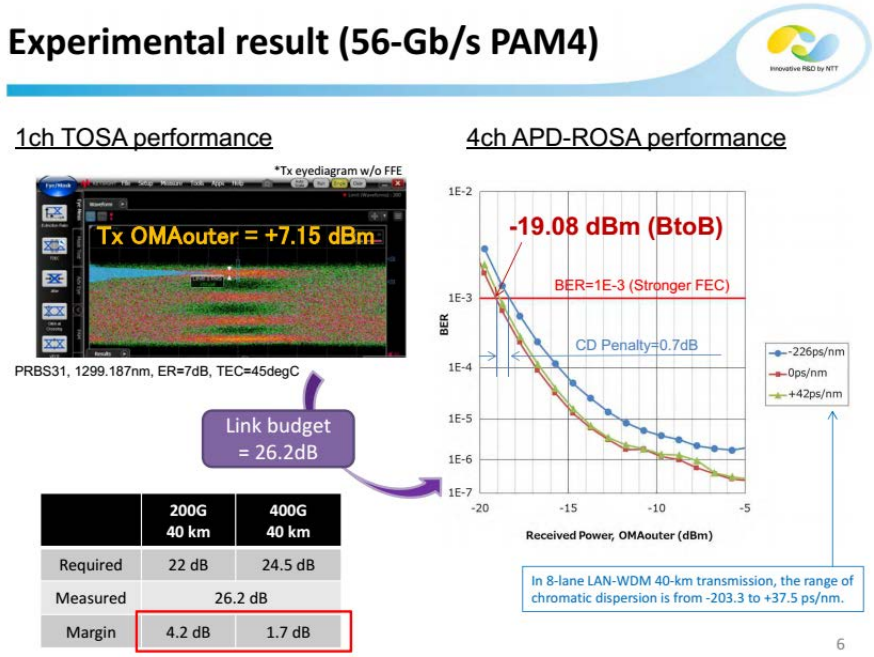
Type 3: Stronger FEC to Support Technical Feasibility

- During Nov 2017, feasibility of stronger FEC is also discussed as in wang_b10k_01d_1117.

- More capability from FEC to compensate link loss with APD receiver as in "effenberger_3ca_2_0316", assume Gain dB(Optical) = 0.75 Gain dB(Electrical/FEC)
- KP4 FEC with 6.4dB NCG and BER@2.4E-4 is assumed for 50/200GE-40km with 1X/4X 50G PAM4
- Stronger FEC offers 9-10 dB NCG or 3~4dB higher NCG compare to KP4 FEC
  - A FEC operating at BER@~1E-3 is off-the-shelf, agnostic to PMDs and can be used for PAM4 or Coherent
  - With the help of stronger FEC, the requirement for optical components could be relaxed by at least 2dB
  - The stronger FEC should be considered as backup option but does require a new design in silicon



- In yamamoto_b10k_01a_0118 , high data rate test result to support more optical margin and available of stronger FEC based on generic RS FEC.



	200G 40 km	400G 40 km
Required	22 dB	24.5 dB
Measured	26.2 dB	
Margin	4.2 dB	1.7 dB

- Even stronger FEC is not preferred approach due to new silicon and cost challenge, but it still available from technical feasibility perspective.

Summary:

- With as low as possible investment, reuse 50G PAM4 technology and eco-system in 400GbE 40km will benefit industry, and achieve Time to Market in Mobile backhaul etc.
- Based on the study, we would like to recommend the following objectives:
  - Support a MAC data rate of 400 Gb/s
  - Support a BER of better than or equal to 10^-13 at the MAC/PLS service interface (or the frame loss ratio equivalent) for 400 Gb/s
  - Provide a physical layer specification supporting 400 Gb/s operation over eight wavelengths capable of at least 40 km of SMF

thank you
danke
謝謝
ngiyabonga
teşekkür ederim
рахмат
Баярлалаа
спасибо
gracias
dank je
merci
obrigado
dziękuję
bedankt
hvala
mauruuru
sukriya
kop khun krap
go raibh maith agat
arigatō
dakujem
terima kasih
grazie
감사합니다
ありがとう
mochchakkeram
tapadh leat
takk
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blagodaram
misaotra
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Optical Margin of 200GbE 30/40km Link Budget, tested

Description (Outer Eye)	Value	Unit
Tx OMA_{outer}, tested	6.7	dBm
Reach	30/40	km
SECQ tested Tx	2	dB
Insertion loss	18	dB
CD penalty assumption	0.5	dB
MPI	0.5	dB
TDECQ assumed	2.5	dB
Receiver sensitivity OMA_{outer} required @ SECQ = 0.9dB	-13.4	dBm
Receiver sensitivity tested @ SECQ = 2.0dB	-16.6	dBm
Receiver sensitivity calculated from tested value @ SECQ = 0.9dB	-17.7	dBm
Optical Margin for DGD penalty = 0	4.3	dB
Optical Margin for DGD penalty = 1dB	3.3	dB

- In this table, Tx OMA and Receiver sensitivity are tested numbers, this table is just to verify the feasibility, not for specification suggestion. In real product, those numbers could be relaxed for yield.