400GBASE-ER8 40km SMF PMD Preliminary Specification Proposal*

IEEE P802.3cn Task Force

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Outline

- Adopted SMF objectives
- Introduction
- Selected references
- Baseline proposal for 400GBASE-ER8
  - Transmit characteristics
  - Receive characteristics
- Illustrative link power budgets
- Recommendations

802.3cn Adopted Objectives

- From Objectives_180712

400 Gb/s Ethernet

- 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***
- Provide a physical layer specification supporting 400 Gb/s operation on a single wavelength capable of at least 80 km over a DWDM system.***

*** - *Adopted by SG May 2018 Interim. Not approved by IEEE 802.3WG. Approved by IEEE802.3WG - July 2018 Plenary*

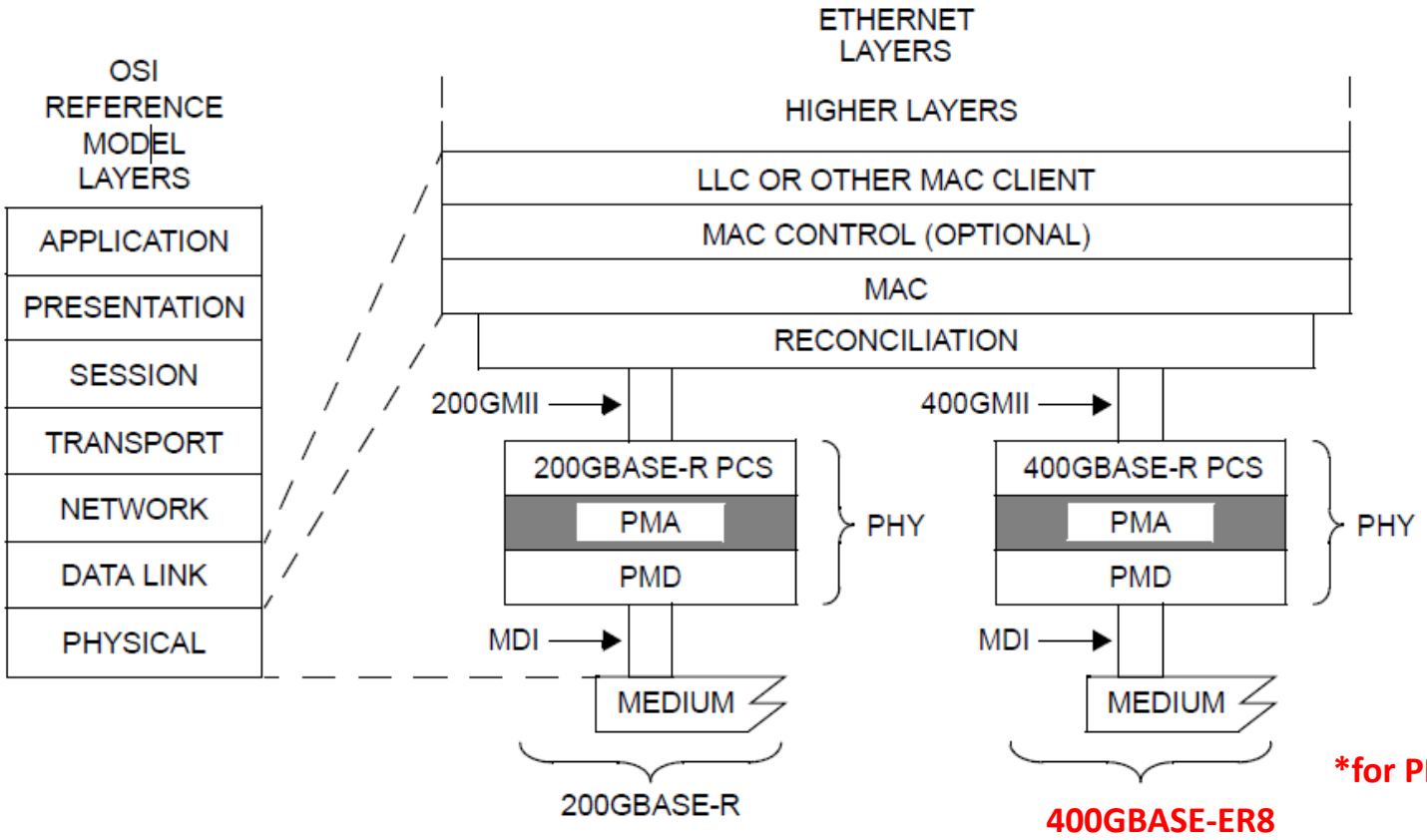
Introduction

- This presentation aim to address the preliminary 400G-ER8 baseline proposal as compared with existing 400G-LR8 developed by P802.3bs task force.
- 400G-ER8 leverage industry investment on mature 50Gb/s PAM4 as low cost and low power solution to enable OSFP and QSFP.
  - Major BOM difference from LR8 is to replace PIN by APD for higher sensitivity receiver.
  - Provide upgrade path for 50G-ER and 200G-ER4 through shared components.
- Technical feasibility to support 200/400GbE 40km (4/8x50G) SMF PMD objective was investigated and demonstrated by multiple vendors.
  - Multiple vendors offer high power EML and APD that can support 40km reach objective.

Selected References

- Sept 2018: 200G EML Fiber Propagation Results
  - jackson_b10k_01_0918
- Sept 2018: Single & quad channel APD receiver performance at 25GBd
  - huang_b10k_01a_0918
- July 2018: 400GBASE-LR8 measurement data for reaches >10km
  - cole_b10k_01_0718
- May 2018: Technical analysis to support 400GbE 40km objective
  - wang_b10k_01a_0518
- Mar. 2018: Technical feasibility to support 200GbE 40km objective
  - yu_b10k_01c_0318
- Jan. 2018: Investigation of technical feasibility for 200G/400G beyond 10km optical PHYs using high-power TOSA and APD-ROSA
  - yamamoto_b10k_01a_0118
- Jan. 2018: Technical feasibility to support 200GbE 40km objective
  - xu_b10k_01a_0118
- CFI, July 2017
  - CFI_01_0717; 100GbE-Beyond10km_CFI_D-final2
- Plus many industrial papers & pre-SG ad_hoc presentations
  - Chang OFC16, Th1G.2; Nada OFC15 M3C.2, Chan OFC15 Th3A.4 et al.

400GBASE-ER8: Position in 802.3 Layered Architecture*



*for PMD only

200GMII = 400 Gb/s MEDIA INDEPENDENT INTERFACE
400GMII = 400 Gb/s MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE

PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

ER8 = PMD FOR SINGLE-MODE FIBER - 40km

400GBASE-ER8: WDM Lane Assignments

- Based on LAN-WDM (800GHz) as 400GBASE FR8/LR8

Lane	Center Frequency THz	Center Wavelength nm	Wavelength Range nm
L0	235.4	1273.55	1272.55 to 1274.54
L1	234.6	1277.89	1276.89 to 1278.89
L2	233.8	1282.26	1281.25 to 1283.28
L3	233.0	1286.66	1285.65 to 1287.69
L4	231.4	1295.56	1294.53 to 1296.59
L5	230.6	1300.05	1299.02 to 1301.09
L6	229.8	1304.58	1303.54 to 1305.63
L7	229.0	1309.14	1308.09 to 1310.19

400GBASE-ER8 Operating Ranges

- Leverage the same fiber installments by 100GBASE-ER4

PMD type	Required operating range
400GBASE–LR8	2 m to 10 km
400GBASE–ER8	2 m to 30 km
	2 m to 40 km[a]

[a]Links longer than 30 km for the same link power budget are considered engineered links. Attenuation for such links needs to be less than the worst case specified for B1.1, B1.3, or B6_a single-mode fiber.

400G-ER8 Exemplary Link Budget

30/40km link budget proposal.			
Description(Outer Eye)	30km	40km	Unit
TxOMAouter (min)	2.4	2.4	dBm
TxOMAouter - TDECQmin	1	1	dBm
ER (min)		6	dB
TDECQ max		3.4	dB
Channel Insertion loss (min)		10	dB
Channel Insertion loss (max)	15	18	dB
MPI penalty	0.3	0.3	dB
DGD penalty		0.2	dB
URS @ SECQ = 1.4dB		-16.1	dBm
SRS @ SECQ = 3.4dB		-14.1	dBm
URS @ SECQ = 2dB		-15.5	dBm
OMAouter sens - SECQ=1.4dB		<-17.5	dBm

400G-ER8 Transmit Characteristics (TP2)

Description	400GBASE-LR8	400GBASE-ER8	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	14.7	dBm
Average launch power, each lane[a] (max)	5.3	5.6	dBm
Average launch power, each lane[b] (min)	–2.8	-0.1	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	5.7	6.4	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (min)	0.2	2.4	dBm
Difference in launch power between any two lanes (OMA_{outer}) (max)	4		dB
Launch power in OMA_{outer} minus TDECQ, each lane (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 –1.2 –1.1	 1.0 —	 dBm dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max)	3.3	3.4 (TBD)	dB
TDECQ - $10\log_{10}(C_{eq})$, *each lane* (max)	—	3.4 (TBD	
Average launch power of OFF transmitter, each lane (max)	–30		dBm
Extinction ratio, each lane (min)	3.5	6	dB
$RIN_{15.1}OMA$ (max)	–132	—	dB/Hz
$RIN_{xx.x}OMA$ (max)	—	TBD	dB/Hz
Optical return loss tolerance (max)	15.1	TBD	dB
Transmitter reflectance[c] (max)	–26		dB

[a] As the total average launch power limit has to be met, not all of the lanes can operate at the maximum average launch power, each lane.

[b] Average launch power, each lane (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.

[c] Transmitter reflectance is defined looking into the transmitter.

400G-ER8 Receive Characteristics (TP3)

Description	400GBASE-LR8	400GBASE-ER8	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	6.3	-3.4	dBm
Average receive power, each lane (max)	5.3	-4.4	dBm
Average receive power, each lane[b] (min)	–9.1	-18.1	dBm
Receive power (OMA_{outer}), each lane (max)	5.7	-3.6	dBm
Difference in receive power between any two lanes (OMA_{outer}) (max)	5.8		dB
Receiver reflectance (max)	–26		dB
Receiver sensitivity (OMA_{outer}), each lane (max)	max(-6.6, SECQ-8)	max(-16.1, SECQ-17.5)	dBm
Stressed receiver sensitivity (OMA_{outer}), each lane (max)	–4.7	–14.1	dBm
Conditions of stressed receiver sensitivity test:[c]			
Stressed eye closure for PAM4 (SECQ), lane under test	3.3	3.4	dB
OMA_{outer} of each aggressor lane	–0.2	–8.3	dBm

[a] The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level.
[b] Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[c] These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

400G-ER8 30/40km Link Power Budget

Parameter	400GBASE-LR8	400GBASE-ER8		Unit
Power budget (for maximum TDECQ) for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 10.1 10.2	 21.9 (TBD) –		 dB dB
Operating distance	10	30	40[a]	km
Channel insertion loss (max)	6.3	15	18	dB
Channel insertion loss (min)	0	10		dB
Maximum discrete reflectance	See 122.11.2.2	TBD		dB
Allocation for penalties[b] (for maximum TDECQ) for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 3.8 3.9	 3.9 (TBD) –		 dB dB
Additional insertion loss allowed	0	3	0	dB

[a]Links longer than 30 km are considered engineered links. Attenuation for such links needs to be less than the worst case for B1.1, B1.3, or B6_a single-mode cabled optical fiber

[b]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

Suggested penalty: MPI: 0.3dB (by simulation @40km transmission
DGD: 0.2dB (by simulation @ worst case)

400GBASE-ER8 Channel Specs

- G.652 40km worst case fiber loss and dispersion values
  - Max positive dispersion remain unchanged (1310nm) ~ 38ps/nm
  - Min negative dispersion shift (1295 to 1273nm) ~ -114 to -204ps/nm

PMD type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c]	Max mean DGD
	Minimum	Maximum			
100GBASE–ER4	$0.93 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.93 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	20 dB	0.8 ps
400GBASE–ER8	$0.93 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.93 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	TBD	0.8 ps

[a]The dispersion is measured for the wavelength of the device under test (λ in nm). The coefficient assumes 40 km for 100GBASE–ER4.

[b]There is no intent to stress the sensitivity of the BERT's optical receiver.

[c]The optical return loss is applied at TP2.

Recommendation

- Adopt the proposed 400GbE PMD based on 8x50Gb/s PAM4 with LAN-WDM spacing in support of P802.3cn 400G 40km SMF PMD objective
  - The proposed 400GbE PMD enables cost-effective solution for 40km reach by leveraging 400GBASE-LR8.
- The proposed 400GBASE-ER8 SMF PMD interoperable with 400GBASE-LR8.
  - The 400GBASE-ER8 interoperable with 400GBASE-LR8 will enable common deployment, and economies of scale through shared component volume.
- The 400GBASE-ER8 will use the same FEC, PMA, and common specification/compliance methodology.
- All baseline parameters and specifications are open to further analysis and are subject to change by the Task Force.

Thank YOU