

400GBASE-FR4 Baseline Proposal

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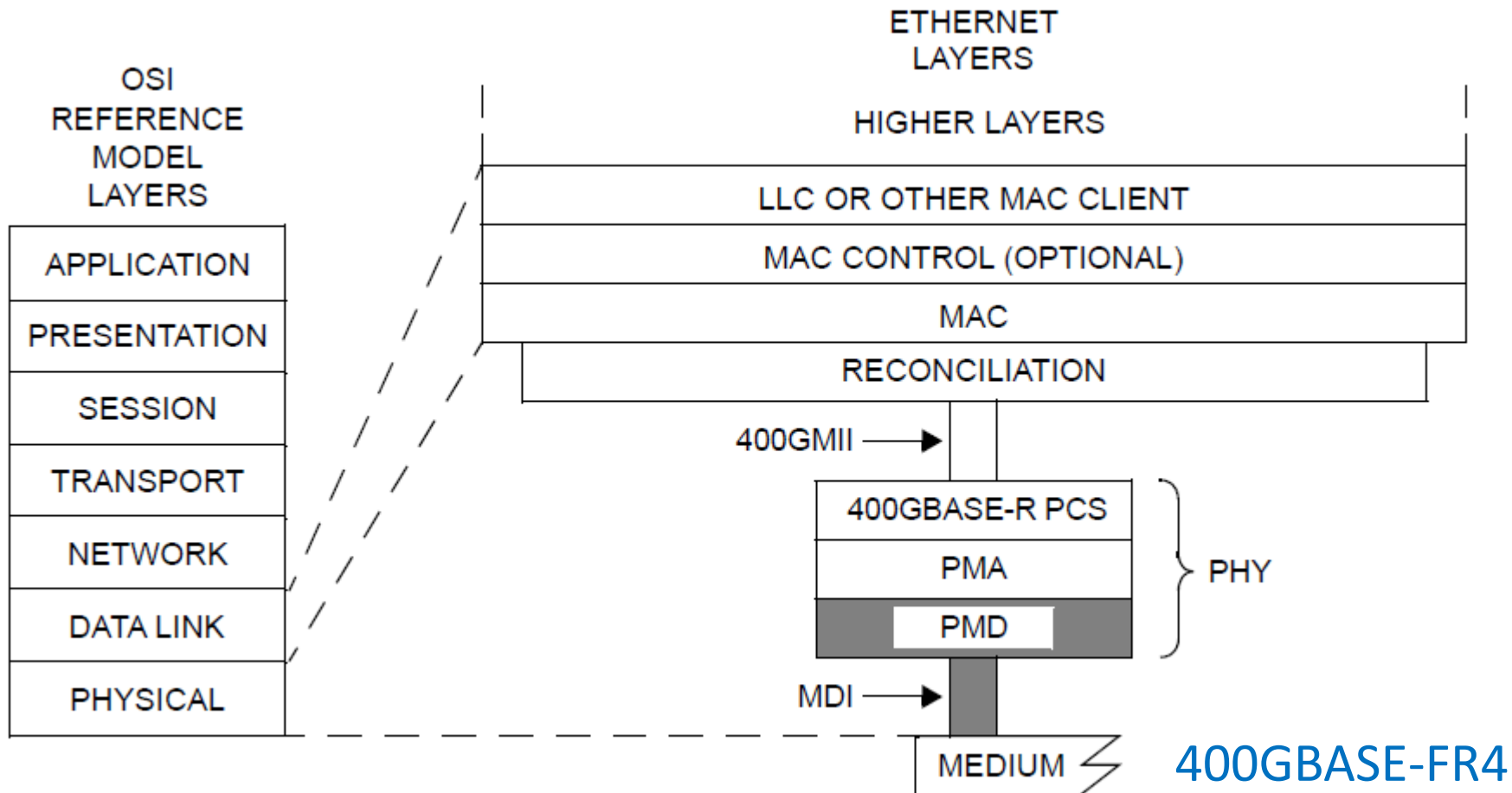
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Overview

- Present a baseline proposal to address the objective of *defining a four-wavelength 400 Gb/s PHY for operation over SMF with lengths up to at least 2 km*
- Approach is based on 100G/λ transmission on four CWDM wavelength lanes using PAM4 signaling
- Link budget is based on Clause 91 FEC

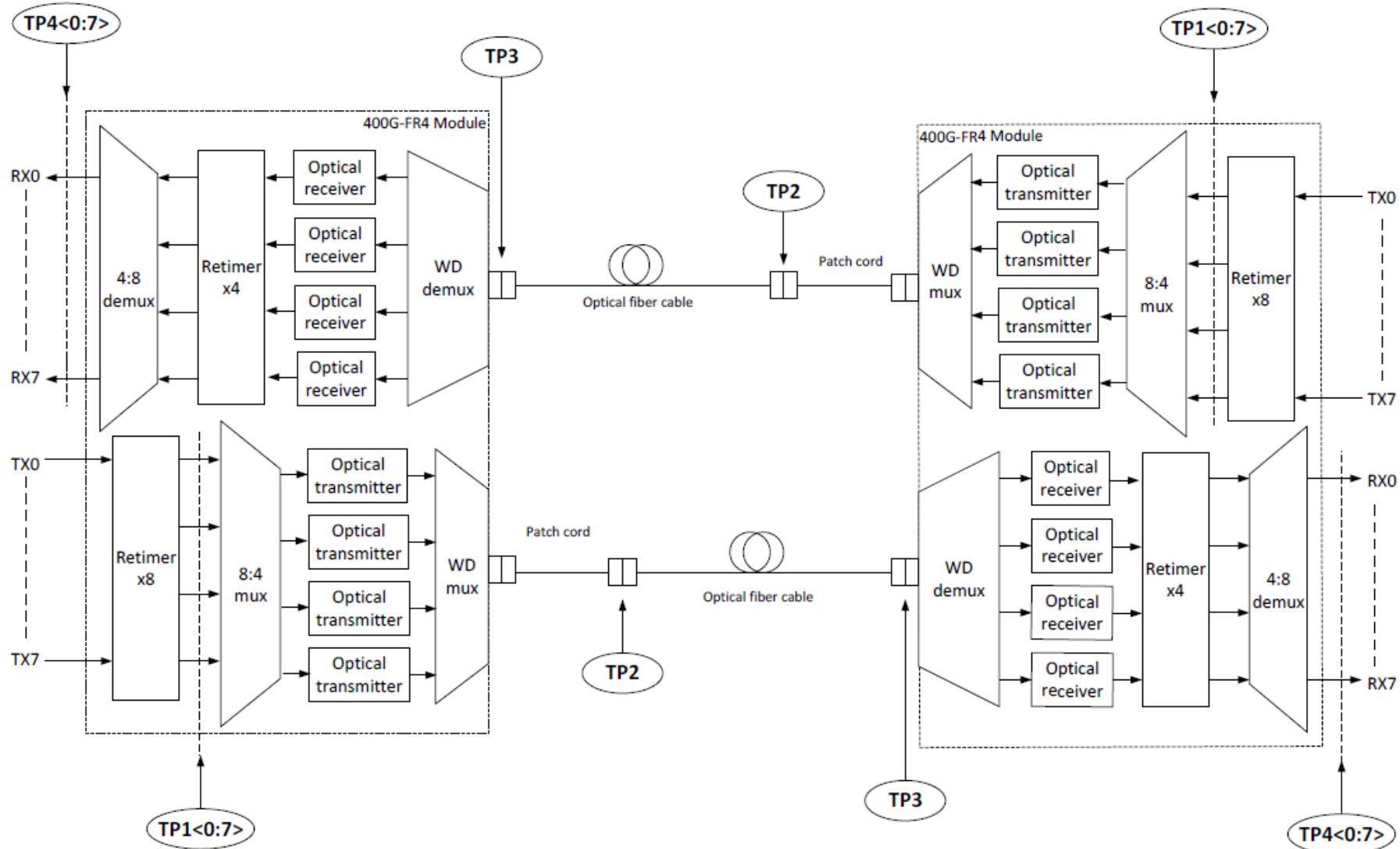
Position in IEEE 802.3 Ethernet Model



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
 FR = PMD FOR SINGLE-MODE FIBER — 2 km

Example PMD Block Diagram – for 2km Duplex SMF



Key Assumptions

- CWDM Wavelength Grid:

WDM Lane Assignment		
400GBASE-FR4 CWDM Lane	Center Wavelength (nm)	Wavelength Range (nm)
L0	1271	1264.5 to 1277.5
L1	1291	1284.5 to 1297.5
L2	1311	1304.5 to 1317.5
L3	1331	1324.5 to 1337.5

- 3.4 dB TDECQ as in 400GBASE-DR4
- Same FR link model for ORL calculations
- Split the 1.2 dB loss/penalty delta (relative to 400GBASE-DR4) between Tx & Rx
 - Increase Tx OMA_{outer} (min) – TDECQ by 0.5 dB
 - Lower max. SRS (OMA_{outer}) by 0.7 dB

4λ x 100G Optical Transmitter Specifications

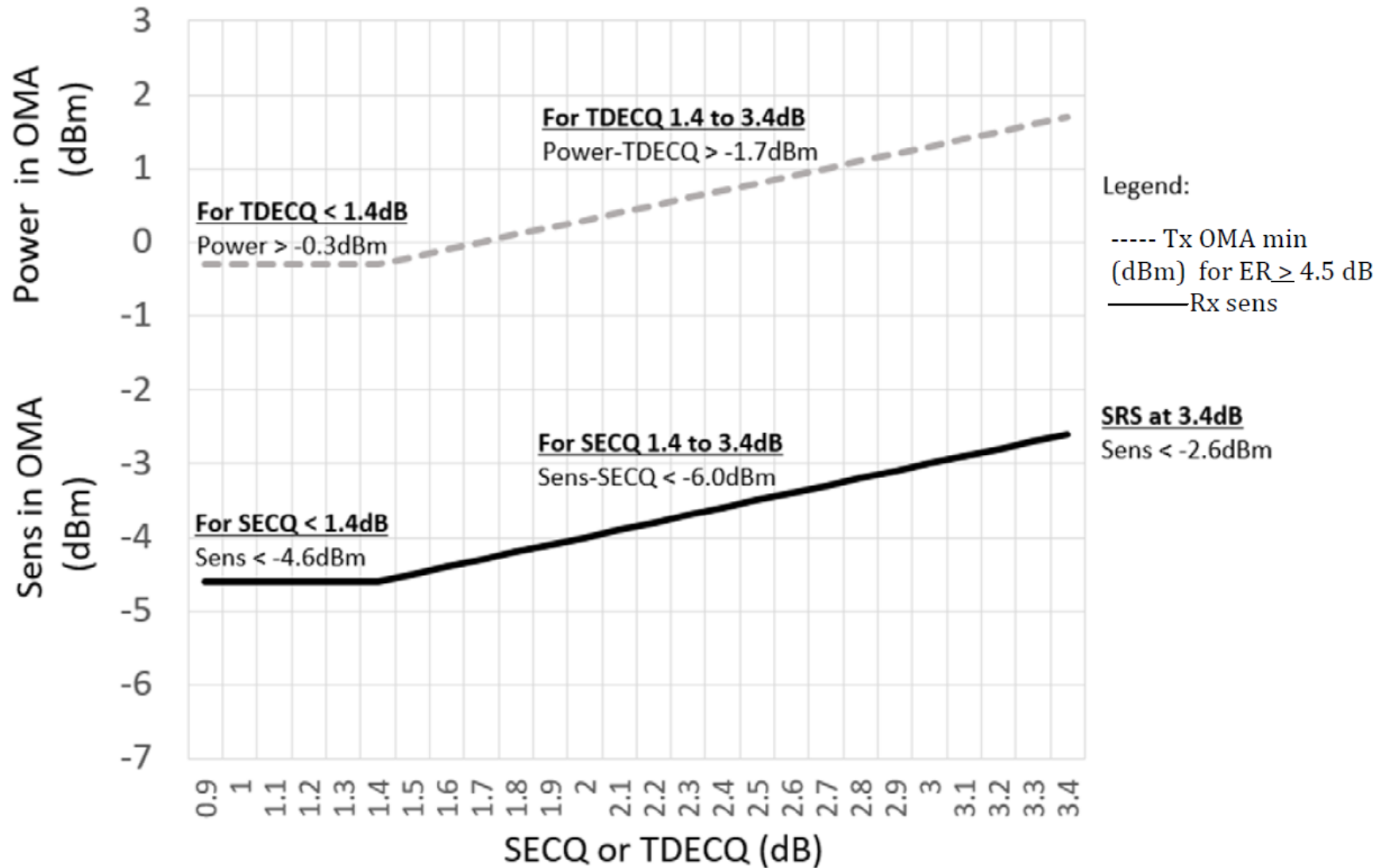
Description	400GBASE-FR4	Unit
PAM4 Signaling rate, each lane (range)	53.125 ± 100 ppm	GBd
Lane wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	nm
Side-mode suppression ration (SMSR), (min)	30	dB
Total average launch power (max.)	9.5	dBm
Average launch power, each lane (max)	3.5	dBm
Average launch power, each lane (min)	-3.3	dBm
Outer Optical Modulation Amplitude (OMA _{outer}), each lane (max)	3.7	dBm
Difference in launch power between any two lanes (OMA _{outer}) (max)	4	dB
Outer Optical Modulation Amplitude (OMA _{outer}), each lane (min)*	-0.3	dBm
Launch power in OMA _{outer} minus TDECQ, (min) for ER ≥ 4.5 dB	-1.7	dBm
for ER < 4.5 dB	-1.6	dBm
Transmitter & dispersion eye closure for PAM4 (TDECQ), each lane (max)	3.4	dB
TDECQ – 10*log ₁₀ (C _{eq}), each lane (max)	3.4	dB
Average launch power of Off transmitter, each lane (max)	-20	dBm
Extinction ratio, each lane (min)	3.5	dB
Transmitter transition time (ps)	17	ps
RIN _{17.1} OMA (max)	-136	dB/Hz
Optical return loss tolerance (max)	17.1	dB
Transmitter reflectance (max)	-26	dB

*Even if TDECQ < 1.4 dB, the OMA_{outer} (min) must exceed this value

4λ x 100G Optical Receiver Specifications

Description	400GBASE-FR4	Unit
PAM4 Signaling rate, each lane (range)	53.125 ± 100 ppm	GBd
Lane wavelength (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	nm
Damage threshold, each lane	4.5	dBm
Average receive power, each lane (max)	3.5	dBm
Average receive power, each lane (min)	-7.3	dBm
Receive power (OMA_{outer}), each lane (max)	3.7	dBm
Difference in receive power between any two lanes (OMA_{outer}) (max)	4.1	dB
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMA_{outer}), each lane (max)	Max (-4.6, $SECQ - 6.0$)	dBm
Stressed receiver sensitivity (OMA_{outer}) (max)	-2.6	dBm
Conditions of stressed receiver sensitivity test:		
Stressed eye closure for PAM4 (SECQ), lane under test	3.4	dB
SECQ – 10*log10(C_{eq}), lane under test (max)	3.4	dB
OMA_{outer} of each aggressor lane	1.5	dBm

400GBASE-FR4 Receiver Sensitivity Mask



Illustrative Optical Link Budget

Description	400GBASE-FR4	Unit
Power budget (for max TDECQ) for ER \geq 4.5 dB for ER < 4.5 dB	7.7 7.8	dB
Operating distance	2	km
Channel insertion loss	4	dB
Maximum discrete reflectance	See Table below	dB
Allocation for penalties (for max TDECQ) for ER \geq 4.5 dB for ER < 4.5 dB	3.7 3.8	dB
Additional insertion loss allowed	0	dB

Table — Maximum value of each discrete reflectance

Number of discrete reflectances above -55 dB	Maximum value for each discrete reflectance
1	-25 dB
2	-31 dB
4	-35 dB
6	-38 dB
8	-40 dB
10	-41 dB

Thank You