Towards 400GBASE-FR4 Baseline Proposal

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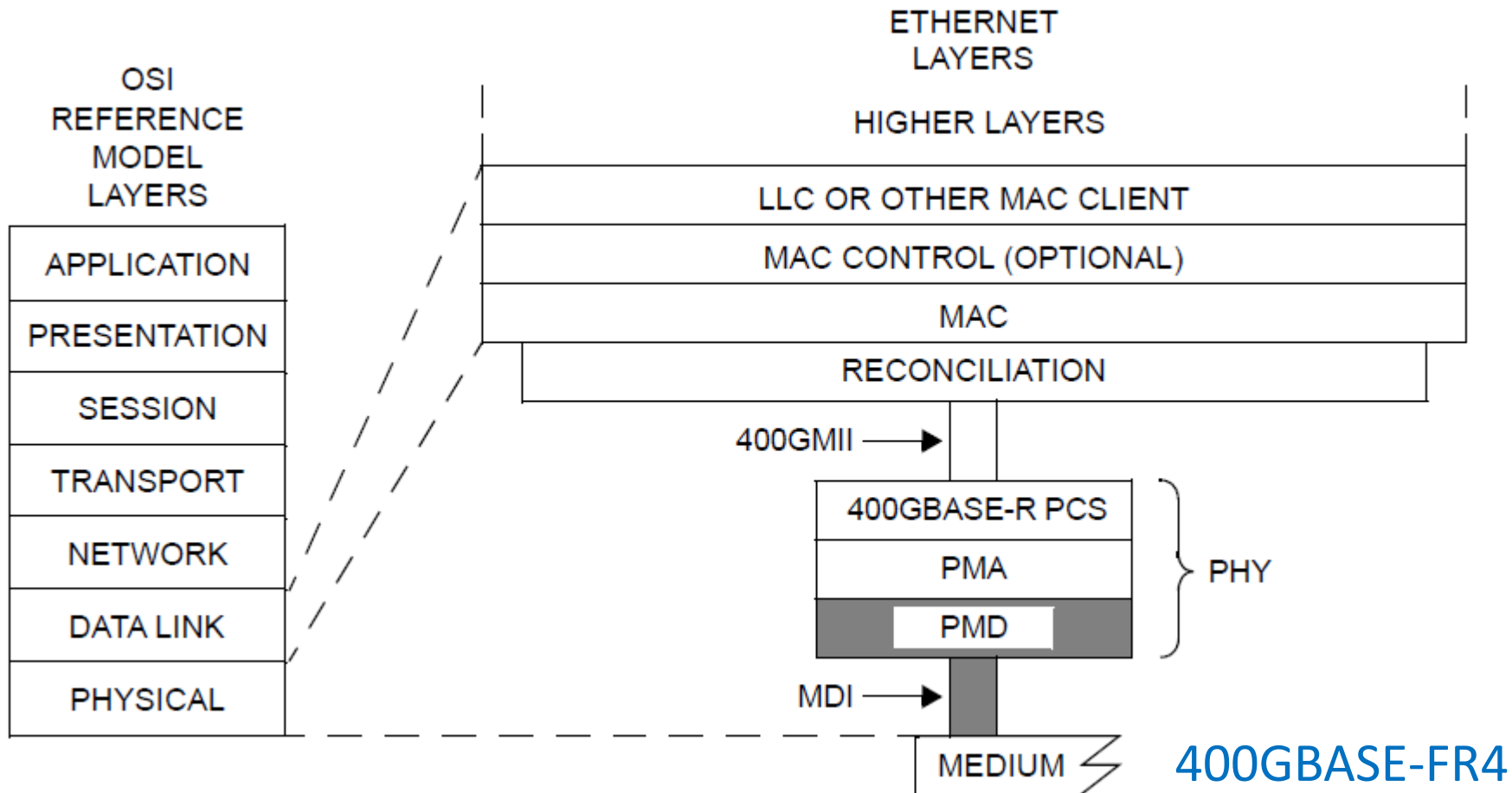
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Overview

- Present the work towards 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 KP4 FEC

Position in IEEE 802.3 Ethernet Model

ETHERNET LAYERS

HIGHER LAYERS

LLC OR OTHER MAC CLIENT

MAC CONTROL (OPTIONAL)

MAC

RECONCILIATION

400GMII →

| 400GBASE-R PCS |
| PMA |
| PMD |

} PHY

MDI →

MEDIUM

400GBASE-FR4

OSI REFERENCE MODEL LAYERS

APPLICATION
PRESENTATION
SESSION
TRANSPORT
NETWORK
DATA LINK
PHYSICAL

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
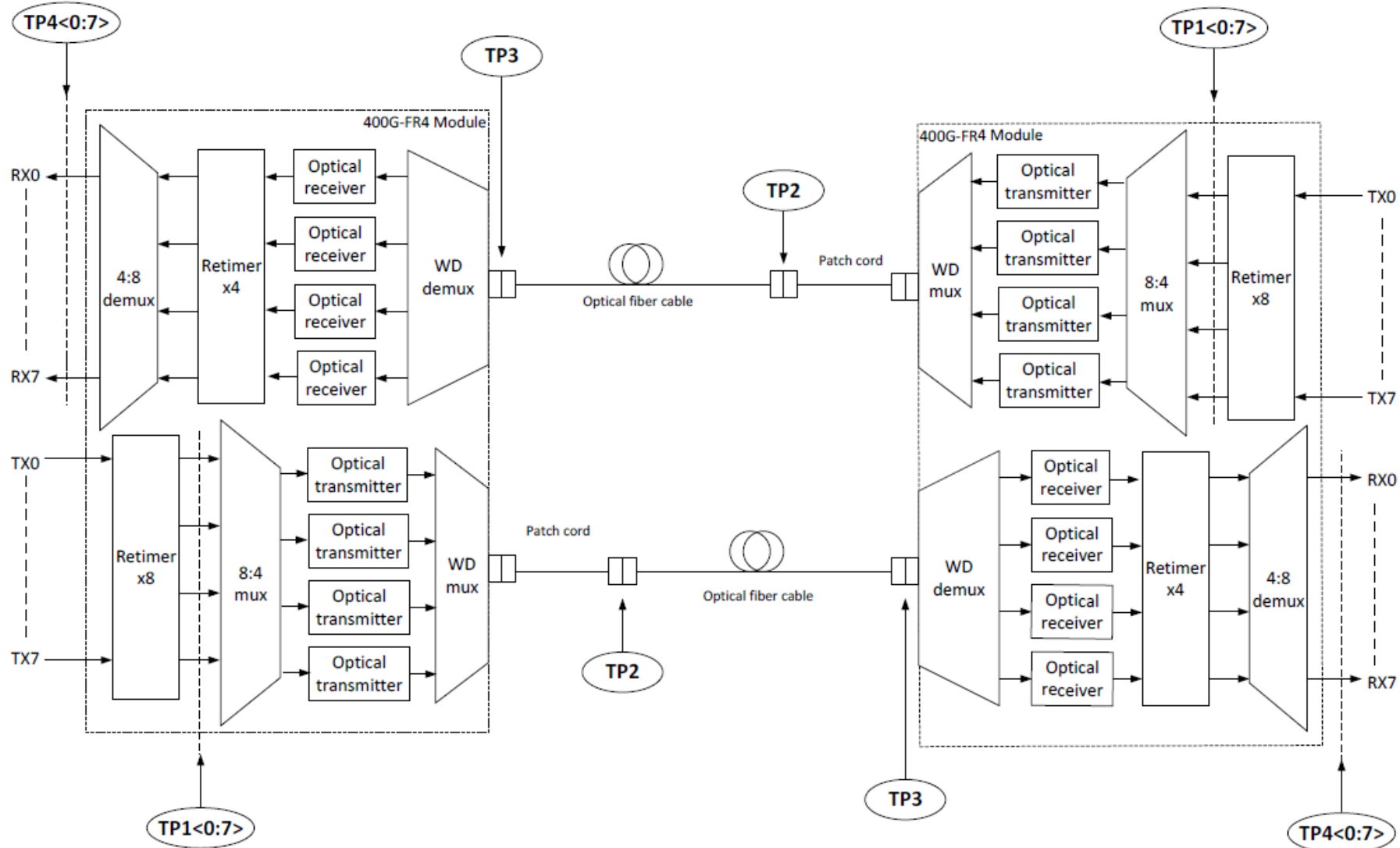
Key Assumptions

- 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 OMAouter 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*log10(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 OMAouter (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

Illustrative Optical Link Budget

Description	400GBASE-FR4	Unit
Power budget (for max TDECQ)		
for ER ≥ 4.5 dB	7.7	
for ER< 4.5 dB	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 ≥ 4.5 dB	3.7	
for ER< 4.5 dB	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