

Towards 400GBASE-FR4 Baseline Proposal

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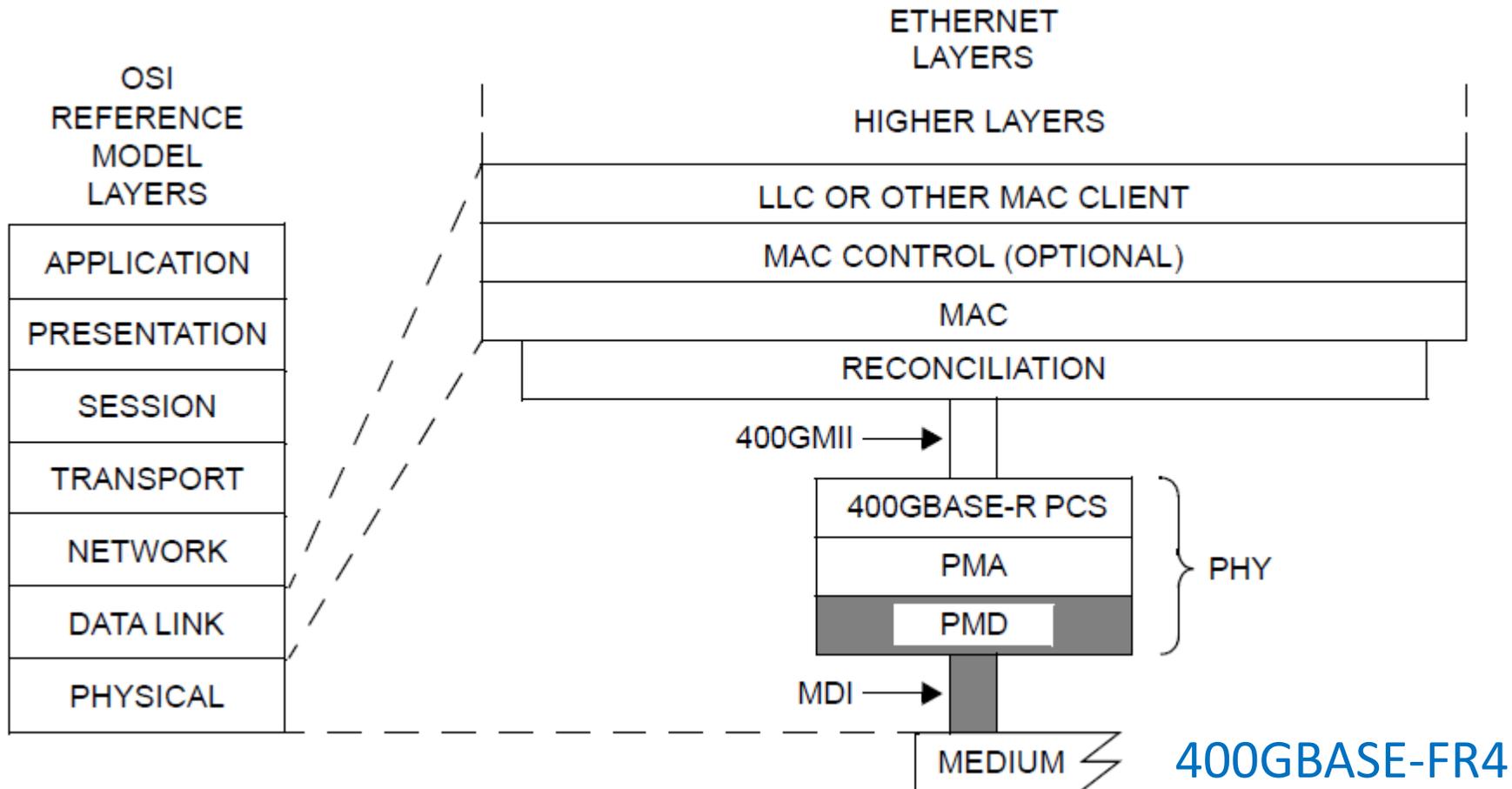
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Overview

- 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

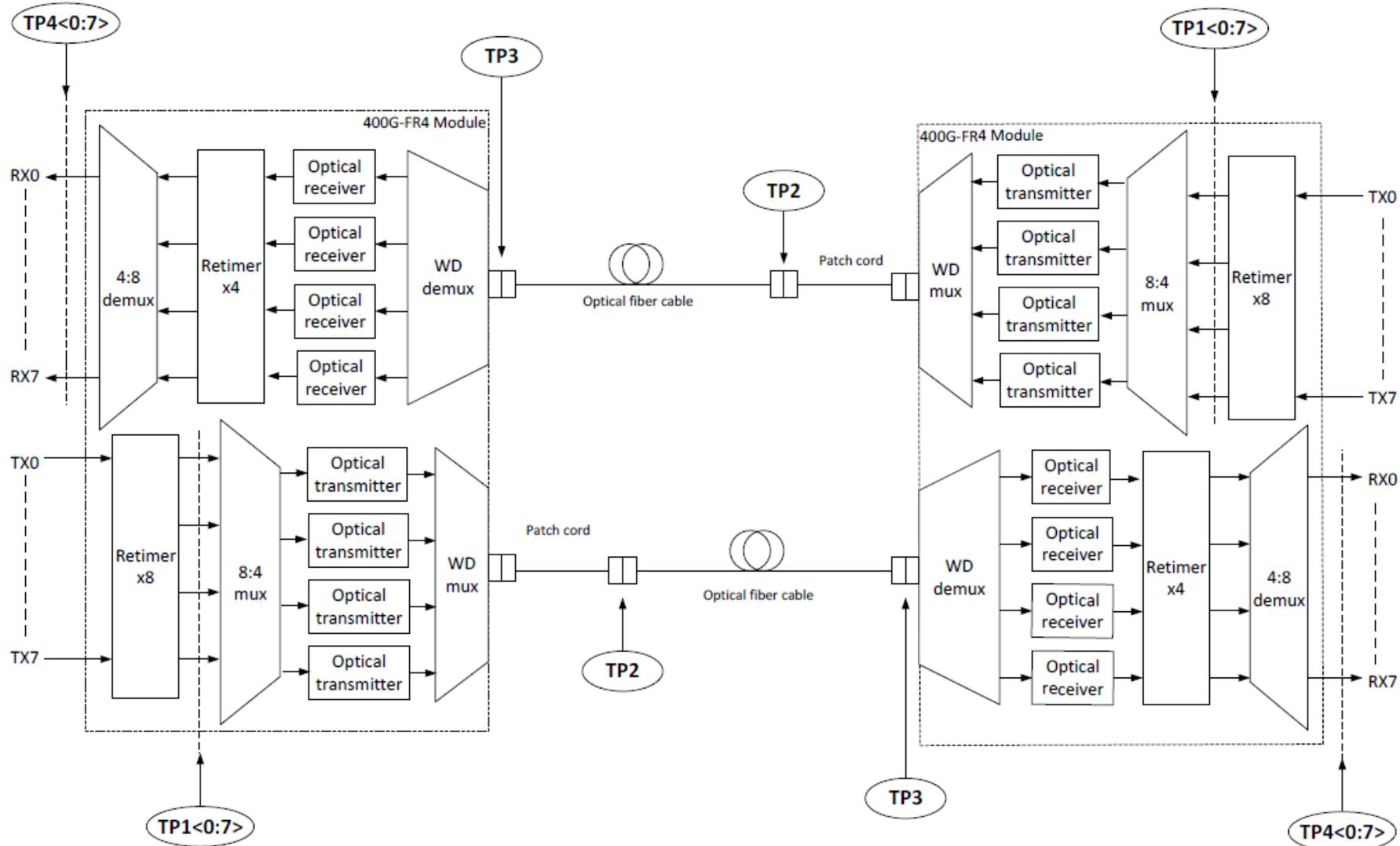
Position in IEEE 802.3 Ethernet Model



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 |
| $SECQ - 10 \cdot \log_{10}(C_{eq})$, 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 \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