400 Gb/s 100-m 8-pair MMF objective baseline proposal

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IEEE P802.3cm, Pittsburgh, May 2018

Outline

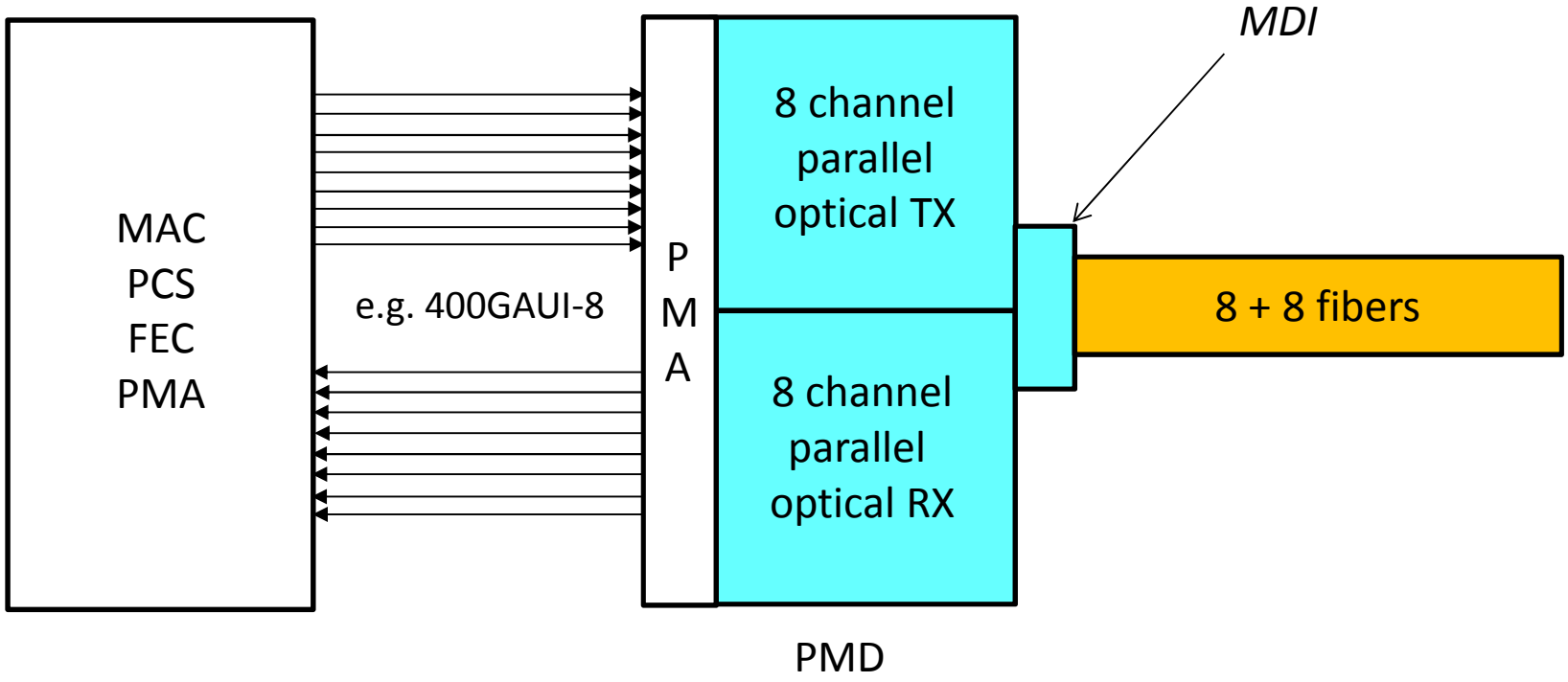
- Baseline proposal for a retimed PMD to address the 802.3cm objective “Define a physical layer specification that supports 400 Gb/s operation over 8 pairs of MMF with lengths up to at least 100m”
  - 8 lane parallel, short wavelength based PMD for 400GBASE-SR8.
  - Leveraging 200GBASE-SR4 optical technology and content of clause 138
  - Compatible with an 8 x 50Gb/s PAM4 electrical interface, and breakout applications.
  - Assumed use of 400GBASE-FR8 FEC (defined in 802.3bs), to enable 100 m reach.
  - Architecture, parameters and specifications for optical interfaces follow.
- General approach is to add 400GBASE-SR8 to the content of clause 138 by adopting the Tx, Rx and power budget specs verbatim.
  - Major content portions are discussed herein, but the addition of “and 400GBASE-SR8” or “or 400GBASE-SR8”, as appropriate, trailing other text that calls out the 200GBASE-SR4 PMD, is also included in this proposal.

Motivation

- 8 parallel links operating at 26.5625 GBd, using low cost, high performing multimode-fiber-compatible optics and electronics
  - Leverages 200GBASE-SR4 technology
  - FEC-supported, retimed interface enables a lowest power, lowest cost, 100m solution
  - Uses existing, viable semiconductor technologies and uncooled VCSELs
- The 8 optical lanes can directly map the 8 electrical lanes of 400GAUI-8, without requiring multiplexing, translation, or de-skewing inside the module.
- Compatible with ‘break out’ application.

Proposal

- 8 parallel lanes @ 26.5625 GBd for 400GBASE-SR8 over 100 m OM4 fiber.
  - Exact signaling rate is determined by project's choice of FEC.
  - This rate assumes reuse of 802.3bs KP FEC.
- 850 nm sources, re-use of 200GBASE-SR4 specifications.
  - Assumes PMD target BER (prior to error correction) of 2.4×10^{-4}



Clause by clause changes follow

Clause 138.1 Overview

Table 138–3—Physical Layer clauses associated with the 200GBASE-SR4 PMD

Associated clause	200GBASE-SR4
117—RS	Required
117—200GMII[a]	Optional
118—200GMII Extender	Optional
119—PCS for 200GBASE-R	Required
120—PMA for 200GBASE-R	Required
120B—200GAUI-8 C2C	Optional
120B—200GAUI-8 C2M	Optional
120D—200GAUI-4 C2C	Optional
120D—200GAUI-4 C2M	Optional
78—Energy Efficient Ethernet	Optional

[a]The 200GMII is an optional interface. However, if the 200GMII is not implemented, a conforming implementation must behave functionally as though the RS and 200GMII were present.

Add new table for 400GBASE-SR8 after Table 138-3 with content the same as Table 138-3 except as noted. Change each instance.

- Change 200G to 400G
- Change SR4 to SR8
- Change 120B to 120C for C2M
- Change AUI-8 to AUI-16
- Change 120D to 120E for C2M
- Change AUI-4 to AUI-8

Increment trailing table numbers.

ISO/IEC OSI reference model

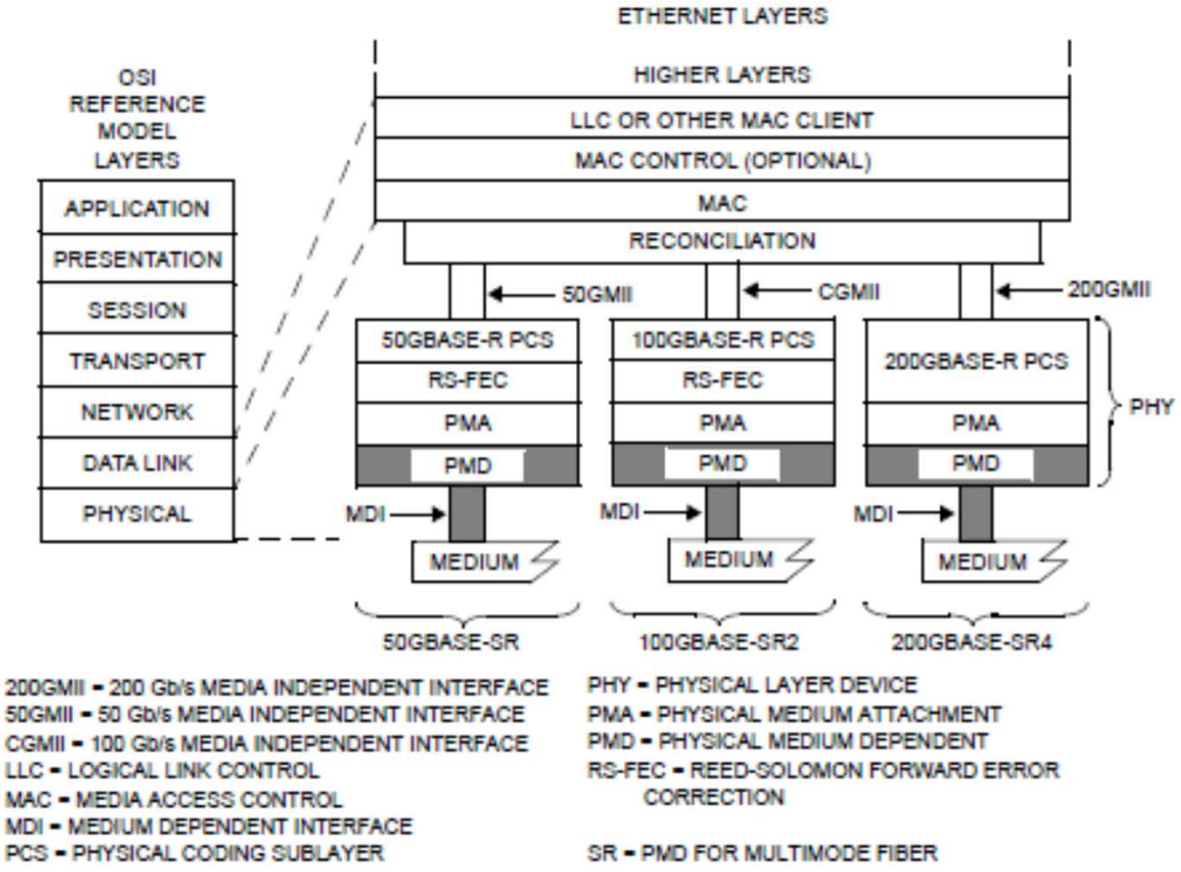


Figure 138–1—50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4 PMD relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

Add 400GBASE-SR8 stack to the right of 200GBASE-SR4 stack following 200G form.

138.1.1 Bit error ratio; 138.2 PMD service interface

For 138.1.1 change:

"200GBASE-SR4 PMD" to "200GBASE-SR4 and 400GBASE-SR8 PMDs".

For 138.2 add paragraphs as follows:

The 400GBASE-SR8 PMD service interface is an instance of the inter-sublayer service interface defined in 116.3, with eight parallel symbol streams (n = 8).

The 400GBASE-SR8 PMD has eight parallel symbol streams, hence *i* = 0 to 7.

138.3.1 Delay constraints; 138.5 PMD functional specs

For 138.3.1 add paragraph as follows:

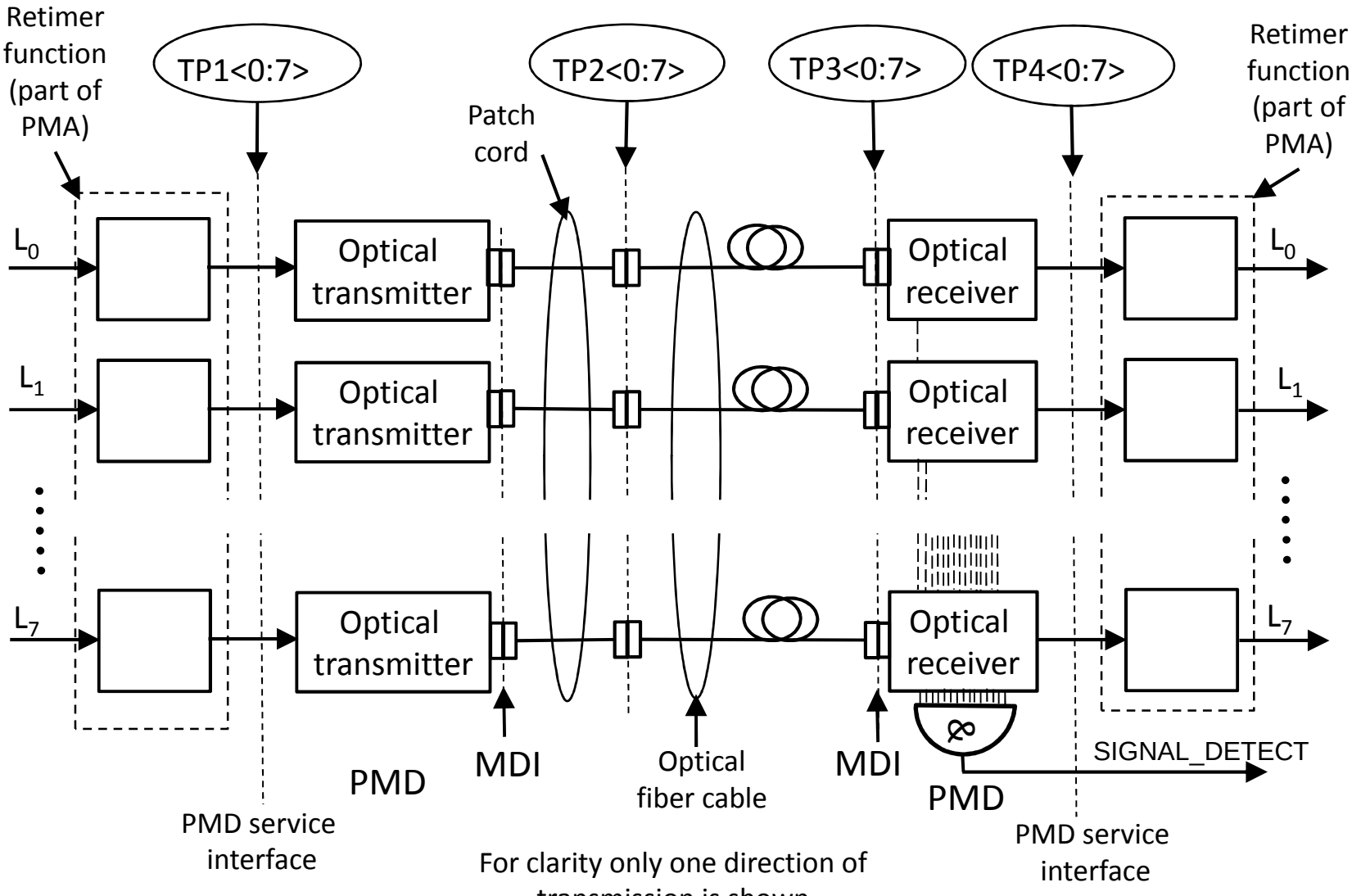
> The sum of the transmit and receive delays at one end of the link contributed by the 400GBASE-SR8 PMD including 2 m of fiber in one direction shall be no more than 8192 bit times (16 pause_quanta or 20.48 ns).

For 138.5.1 replace paragraph 1 with:

> The PMD block diagram for 400GBASE-SR8 is shown in Figure 138–2. The block diagrams for 200GBASE-SR4, 100GBASE-SR2 and 50GBASE-SR are equivalent to Figure 138–2, but for four lanes, two lanes and one lane per direction, respectively.

Replace Figure 138-2 with the diagram on the next slide.

Block diagram for 400GBASE-SR8 transmit/receive paths



138.5.2 PMD transmit function; Table 138-7

For 138.5.2 add the following sentence after the one on 200GBASE-SR4:

The 400GBASE-SR8 has eight parallel symbol streams, hence *i* = 0 to 7.

Add 400GBASE-SR8 to Table 138-7

Table 138–7—Operating range

PMD type	Required operating range[a]
50GBASE-SR 100GBASE-SR2 200GBASE-SR4	0.5 m to 70 m for OM3
	0.5 m to 100 m for OM4
	0.5 m to 100 m for OM5

[a]The PCS FEC correction function may not be bypassed for any operating distance.

138.7 PMD Optical specifications

- Add “and 400GBASE-SR8” to:
  - 138.7.1 Transmitter optical specifications
    in text introducing Table 138-8 - Transmit Characteristics
  - 138.7.2 Receiver optical specifications
    in text introducing Table 138-9 - Receive Characteristics
  - 138.7.3 Illustrative link power budget
    in text introducing Table 138-10 – Illustrative link power budget

Transmitter characteristics of clause 138.7.1 (D3.2 shown below for reference)

Table 138–8—Transmit characteristics

Description	Value	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm	GBd
Modulation format	PAM4	
Center wavelength (range)	840 to 860	nm
RMS spectral width[a] (max)	0.6	nm
Average launch power, each lane (max)	4	dBm
Average launch power, each lane (min)	–6	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	3	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (min)[b]	–4	dBm
Launch power in OMA_{outer} minus TDECQ (min)	–5.9	dBm
Transmitter and dispersion eye closure (TDECQ), each lane (max)	4.9	dB
Average launch power of OFF transmitter, each lane (max)	–30	dBm
Extinction ratio, each lane (min)	3	dB
Optical return loss tolerance (max)	12	dB
Encircled flux[c]	≥ 86% at 19 µm ≤ 30% at 4.5 µm	

[a]RMS spectral width is the standard deviation of the spectrum.
[b]Even if the TDECQ < 1.9 dB, the OMA (min) must exceed this value.
[c]If measured into type A1a.2 or type A1a.3, or A1a.4, 50 µm fiber, in accordance with IEC 61280-1-4.

Receiver characteristics of clause 138.7.2 (D3.2 shown below for reference)

Table 138–9—Receive characteristics

Description	Value	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm	GBd
Modulation format	PAM4	
Center wavelength (range)	840 to 860	nm
Damage threshold[a] (min)	5	dBm
Average receive power, each lane (max)	4	dBm
Average receive power, each lane[b] (min)	–7.9	dBm
Receive power, each lane (OMA_{outer}) (max)	3	dBm
Receiver reflectance (max)	–12	dB
Stressed receiver sensitivity (OMA_{outer}), each lane[c] (max)	–3	dBm
Receiver sensitivity (OMA_{outer}), each lane[d] (max)	Equation (138–1)	dBm
Conditions of stressed receiver sensitivity test:[e]		
Stressed eye closure (SECQ), lane under test	4.9	dB
OMA_{outer} of each aggressor lane[f]	3	dBm

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level on one lane. The receiver does not have to operate correctly at this input power.
[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]Measured with conformance test signal at TP3 (see 138.8.8) for the BER specified in 138.1.1.
[d]Receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to 4.9 dB.
[e]These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.
[f]Only applies to 100GBASE-SR2 and 200GBASE-SR4.

Illustrative link power budget of clause 138.7.3 (D3.2 shown below for reference)

Table 138–10—Illustrative link power budget

Parameter	OM3	OM4	OM5	Unit
Effective modal bandwidth at 850 nm[a]	2000	4700		MHz.km
Power budget (for max TDECQ)	6.9			dB
Operating distance	0.5 to 70	0.5 to 100		m
Channel insertion loss[b]	1.8	1.9		dB
Allocation for penalties[c] (for max TDECQ)	5			dB
Additional insertion loss allowed	0.1	0		dB

[a]Per IEC 60793-2-10.
[b]The channel insertion loss is calculated using the maximum distance specified in Table 138–7 and cabled optical fiber attenuation of 3.5 dB/km at 850 nm plus an allocation for connection and splice loss given in 138.10.2.2.1.
[c]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

138.8 Definitions of optical parameters and measurement methods

- Table 138-12:
  - Add “or 400GBASE-SR8” after three instances of 200GBASE-SR4 in Table 138-12 Test-pattern definitions and related subclauses.
- 138.8.5 TDECQ
  - Add “and 400GBASE-SR8” to last dash list.
- 138.8.5.1 TDECQ reference equalizer
  - Add “and 400GBASE-SR8” to first sentence.
- 138.8.8 Stressed receiver sensitivity
  - Add “and 400GBASE-SR8” to fourth dash list.

138.9 Safety, installation, environment, and labeling

- 138.9.2 Laser safety
  - Add “and 400GBASE-SR8” to first sentence.
- 138.9.4 Environment
  - Add “or 400GBASE-SR8” to first sentence.
- 138.9.5 Electromagnetic emission
  - Add “or 400GBASE-SR8” to first sentence.
- 138.9.7 PMD labeling requirements
  - Add “or 400GBASE-SR8” to first sentence.

138.10 Fiber optic cabling model

- Change first sentence as follows:
  - The fiber optic cabling (channel) contains 1, 2, 4 or 8 optical fibers for each direction to support 50GBASE-SR, 100GBASE-SR2, 200GBASE-SR4 or 400GBASE-SR8, respectively.

Medium Dependent Interface (MDI) for 400GBASE-SR8 and lane assignments

Follow will of Task Force to be determined after MDI contributions and discussions.