



400GBASE-LR4 Baseline Proposal

IEEE 802.3cu Task Force
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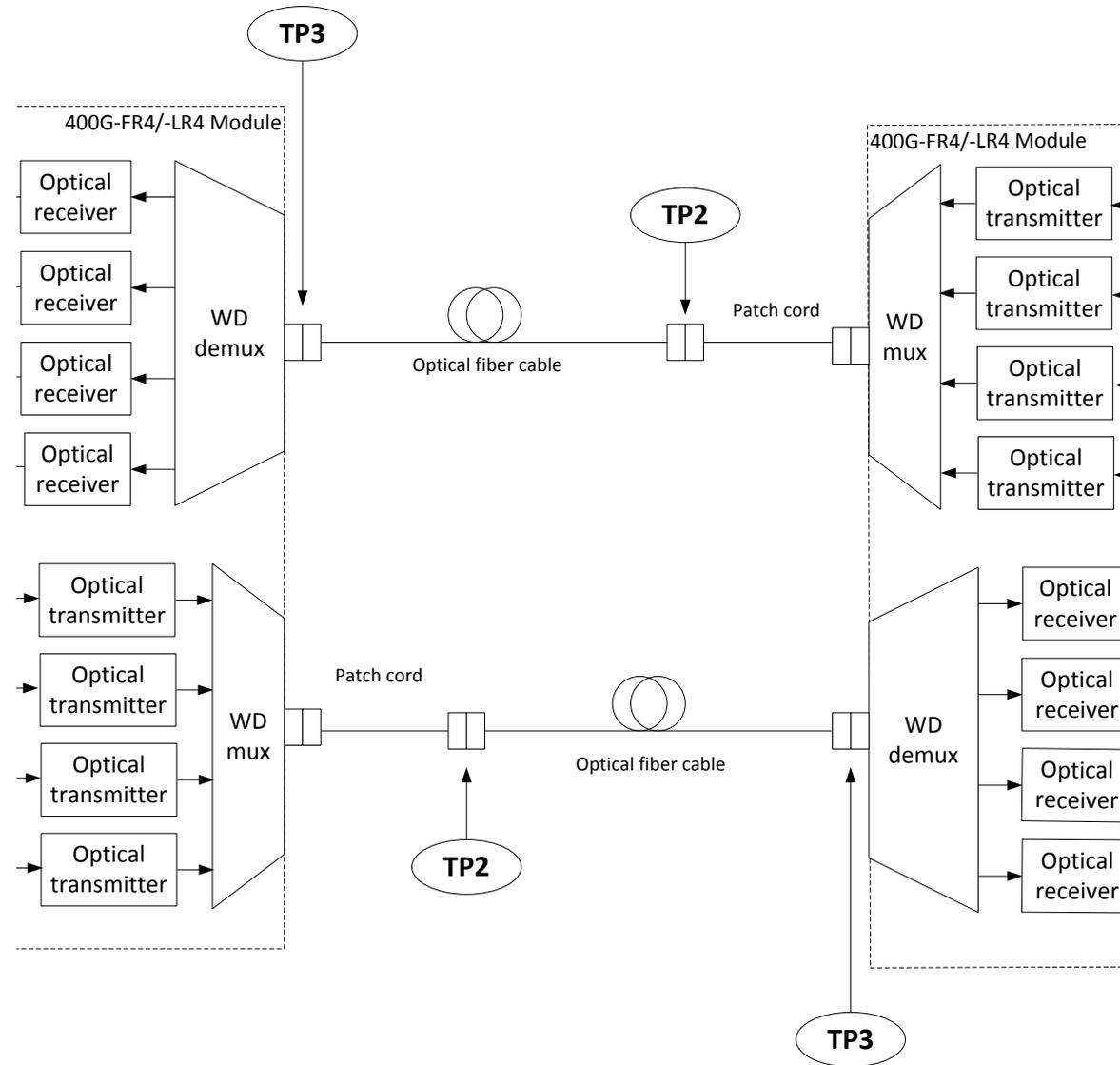
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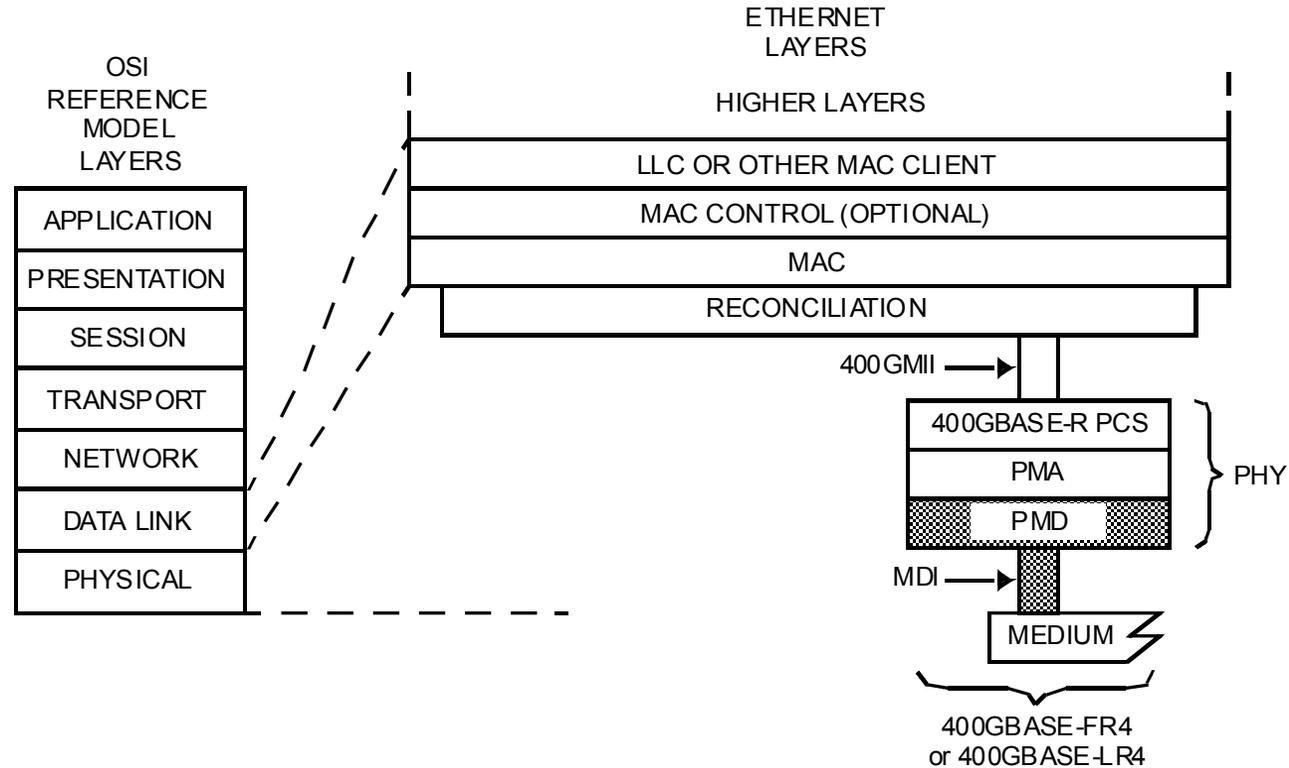
400GBASE-LR4 Baseline Proposal

- Task Force adopted objective:
Define a four-wavelength 400 Gb/s PHY for operation over SMF with lengths up to at least 10 km
- 100 Gb/s PAM4 signaling on each of four CWDM wavelengths
- FEC in 400GBASE-R PCS layer
- 10 km reach on ITU-T G.652 category G.652.B or G.652.D SMF

Block Diagram



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

FR4 = PMD FOR SINGLE-MODE FIBER — 2 km
 LR4 = PMD FOR SINGLE-MODE FIBER — 10 km

Transmit Characteristics

Description	400GBASE-LR4	Unit
PAM4 Signaling rate, each lane (range)	53.125 ± 100 ppm	GBd
Lane wavelengths (range)	1264.5 to 1277.5	nm
	1284.5 to 1297.5	
	1304.5 to 1317.5	
	1324.5 to 1337.5	
Side-mode suppression ratio (SMSR), (min)	30	dB
Total average launch power (max)	12.2	dBm
Average launch power, each lane (max)	6.2	dBm
Average launch power, each lane ^a (min)	-2.5	dBm
Outer Optical Modulation Amplitude (OMA _{outer}), each lane (max)	5.0	dBm
Outer Optical Modulation Amplitude (OMA _{outer}), each lane ^b (min)	0.5	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	-0.9	dBm
for extinction ratio < 4.5 dB	-0.8	
Transmitter and dispersion penalty eye closure for PAM4 (TDECQ), each lane (max)	3.9	dB
TDECQ – 10*log ₁₀ (C _{eq}), each lane (max) ^c	3.9	dB
Average launch power of OFF transmitter, each lane (max)	-20	dBm
Extinction ratio (min)	3.5	dB
Transmitter transition time (max)	17	ps
RIN _{15,6} OMA (max)	-136	
Optical return loss tolerance (max)	15.6	dB
Transmitter reflectance ^d (max)	-26	dB

^a 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.

^b Even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 4.5 dB or TDECQ < 1.3 dB for an extinction ratio of < 4.5 dB, the OMA_{outer} (min) must exceed this value.

^c C_{eq} is a coefficient defined in 121.8.5.3, which accounts for reference equalizer noise enhancement.

^d Transmitter reflectance is defined looking into the transmitter.

Receive Characteristics

Description	400GBASE-LR4	Unit
PAM4 Signaling rate, each lane (range)	53.125 ± 100 ppm	GBd
Lane wavelengths (range)	1264.5 to 1277.5	nm
	1284.5 to 1297.5	
	1304.5 to 1317.5	
	1324.5 to 1337.5	
Damage threshold, each lane (min) ^a	7.2	dBm
Average receive power, each lane (max)	6.2	dBm
Average receive power, each lane ^b (min)	-8.8	dBm
Receive power, each lane (OMA _{outer}) (max)	5.0	dBm
Difference in receive power between any two lanes (OMA _{outer}) (max)	4.6	dB
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMA _{outer}), each lane ^c (max)	$RS = \max(-6.6, SECQ - 8.0)$	
Stressed receiver sensitivity (OMA _{outer}), each lane ^d (max)	-4.1	dBm
Conditions of stressed receiver sensitivity test^e:		
Stressed eye closure for PAM4 (SECQ), lane under test	3.9	dB
SECQ – 10*log ₁₀ (C _{eq}), lane under test (max)	3.9	dB
OMA _{outer} of each aggressor lane	0.5	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 Receiver sensitivity (OMA_{outer}), each lane (max) is informative and is defined for a transmitter with a value of SECQ up to 3.4 dB for 400GBASE-FR4 and 3.9 dB for 400GBASE-LR4.

^d Measured with conformance test signal at TP3 (see 200.8.10) for the BER specified in 200.1.1.

^e These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

Illustrative Link Power Budget

Table 151–9—400GBASE-FR4 and 400GBASE-LR4 (new column) illustrative link power budgets

Description	400GBASE-LR4	Unit
Power budget (for max TDECQ) for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	11.0 11.1	dB
Operating distance	10.0	km
Channel insertion loss ^a	6.3	dB
Maximum discrete reflectance	See Table 151-15	dB
Allocation for penalties ^b (for max TDECQ) for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	4.7 4.8	dB
Additional insertion loss allowed	0	dB

^a The channel insertion loss is calculated using the maximum distance specified in Table 151–6 for 400GBASE-LR4 and fiber attenuation of 0.43 dB/km plus an allocation for connection and splice loss given in 151.11.2.1.

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

Table 151-15 (add new column for 400GBASE-LR4)

Number of discrete reflectance above -55dB	Maximum value for each discrete reflectance
	400GBASE-LR4
1	-22 dB
2	-29 dB
4	-33 dB
6	-35 dB
8	-37 dB
10	-39 dB

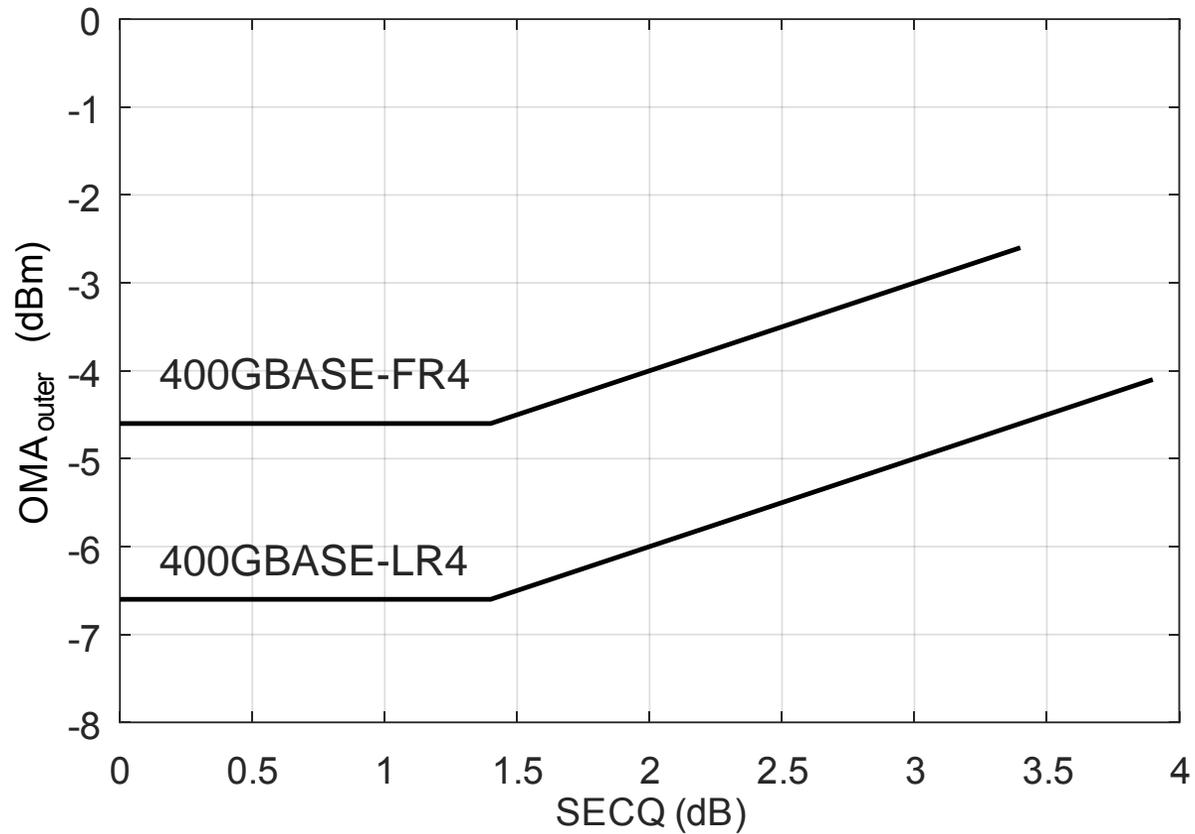
Transmitter compliance channel*

Type	Dispersion ^a (ps/nm)		Insertion loss ^b	Optical return loss ^c	Max mean DGD
	Minimum	Maximum			
400GBASE-LR4	$0.23 * \lambda * [1 - (1324/\lambda)^4]$	$0.23 * \lambda * [1 - (1300/\lambda)^4]$	Minimum	15.6 dB	0.8 ps

*for TDECQ test

Note that 0.23 multiplier is based on a slope of 0.092 ps/nm/km

Illustration of receiver sensitivity mask



Fiber optic cabling (channel) characteristics

Description	400GBASE-LR4		Unit
Operating distance (max)		10	km
Channel insertion loss ^{a,b} (max)		6.3	dB
Channel insertion loss (min)	0		dB
Positive dispersion ^b (max)		33.1	ps/nm
Negative dispersion ^b (min)		-58.7	ps/nm
DGD_max ^c		5	ps
Optical return loss (min)		22	dB
^a These channel loss values include cable, connectors and splices.			
^b Over the wavelength range 1264.5 to 1337.5 nm.			
^c Differential Group Delay (DGD) is the time difference at reception between the fractions of a pulse that were transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.			

Optical fiber and cable characteristics

Current text (from 122.11.1)

The fiber optic cable requirements are satisfied by cables containing IEC 60793-2-50 type B1.1 (dispersion un-shifted single-mode), type B1.3 (low water peak single-mode), or type B6_a (bend insensitive) fibers or the requirements in Table 122–18 where they differ.

Proposed text with reference to 2016 version of ITU-T G.652

The fiber optic cable requirements are satisfied by cables containing ITU-T G.652.B (dispersion unshifted), type G.652.D (low water peak, dispersion unshifted), or type G.657.A1, or type G.657.A2 (bend insensitive) fibers, or the requirements in Table 200–14 where they differ.

Description	Value	Unit
Nominal fiber specification wavelength	1310	nm
Cabled optical fiber attenuation (max)	0.47 ^a or 0.5 ^b	dB/km
Zero dispersion wavelength (λ_0)	$1300 \leq \lambda_0 \leq 1324$	nm
Dispersion slope (max) (S_0)	0.092	ps/nm ² km

^a The 0.47 dB/km attenuation for optical fiber cables is derived from Appendix I of ITU-T G.695.
^b The 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA 568-C.3.

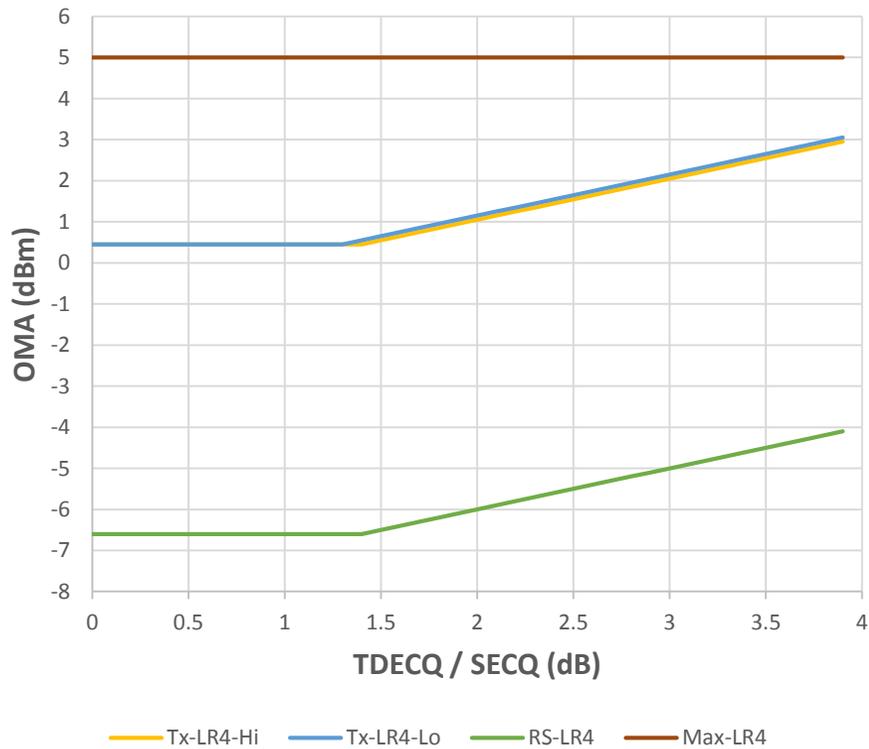
400GBASE-LR4 Baseline

Thank you

Backup - Compare LR4 with FR4

LR4 requires 2.8 dB additional link budget compared to FR4. This is allocated 0.8 dB to the Tx and 2.0 dB to the Rx.

400GBASE-LR4 TxOMA (min) and RS (max)
versus TDECQ/SECQ



400GBASE-FR4 TxOMA (min) and RS
(max) versus TDECQ/SECQ

