



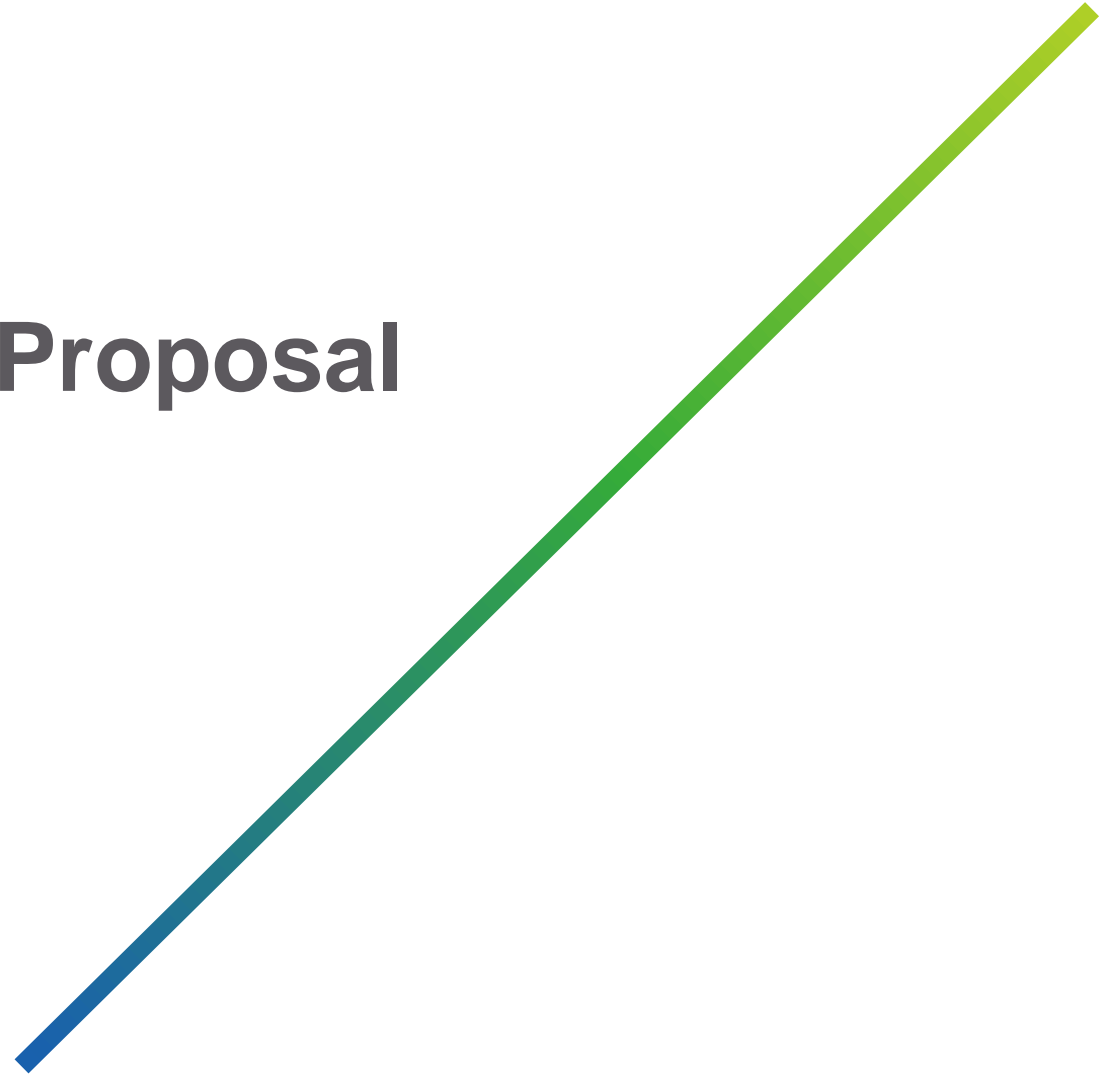
400GBASE-LR4 Baseline Proposal

IEEE P802.3cu ad hoc meeting

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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
- This proposal is for a single 400GBASE-LR4 PHY, with a single set of transmit and receive specifications, a single power budget and a single TDECQ transmitter compliance test.
 - Transmit and receive characteristics are the same as [lewis_3cu_01_0719](#) and are shown in slides 10-11 in the backup section of this presentation.
- The single 400GBASE-LR4 PHY proposal supports operation over the following channels:
 - 7 km reach on worst-case ITU-T G.652 SMF; assuming 0.5 dB/km loss and worst-case chromatic dispersion (-41 ps/nm to + 23 ps/nm)
 - 10 km reach on an engineered link; assuming 0.43 dB/km loss and same chromatic dispersion specs as for the 7 km link (-41 ps/nm to + 23 ps/nm)

Power Budgets

Single power budget

Table 151-9—400GBASE-FR4 and 400GBASE-LR4 illustrative link power budgets

Parameter	400GBASE-FR4	400GBASE-LR4		Unit
Power budget (for maximum TDECQ): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	7.7 7.8	11 11.1		dB dB
Operating distance	2	7	10^a	km
Channel insertion loss	4^b	5.5^c	6.3^d	dB
Maximum discrete reflectance	See 151.11.2.2			dB
Allocation for penalties ^e (for maximum TDECQ): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	3.7 3.8	4.7 4.8		dB dB
Additional insertion loss allowed	0	0.8	0	dB

^a Links longer than 7 km for the same power budget are considered engineered links. Attenuation and chromatic dispersion needs to be less than the worst case specified for ITU-T G.652.B, G.652.D, G.657.A1 or G.657.A2 single-mode fibers.

^b The channel insertion loss is calculated using the maximum distance specified in Table 151-6 for 400GBASE-FR4 and fiber attenuation of 0.5 dB/km plus an allocation for connection and splice loss given in 151.11.2.1.

^c The channel insertion loss is calculated using the maximum distance specified in Table 151-6 for 400GBASE-LR4 and fiber attenuation of 0.5 dB/km plus an allocation for connection and splice loss given in 151.11.2.1.

^d 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.

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

Transmitter compliance channels

Table 151–12—Transmitter compliance channel specifications

PMD type	Dispersion ^a (ps/nm)		Insertion loss ^b	Optical return loss ^c	Max mean DGD
	Minimum	Maximum			
400GBASE-FR4	$0.0465 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.0465 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	17.1 dB	0.8 ps
400GBASE-LR4	$0.161 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.161 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	15.6 dB	0.8 ps

^a The dispersion is measured for the wavelength of the device under test (λ in nm). The coefficient assumes 2 km for 400GBASE-FR4 and 7 km for 400GBASE-LR4.

^b There is no intent to stress the sensitivity of the O/E converter associated with the oscilloscope.

^c The optical return loss is applied at TP2.

*Single TDECQ test –
Translates to a min/max of -41.1/+23.2 ps/nm for
operating wavelengths from 1264.5 to 1337.5 nm.*

Fiber optic cabling (channel)

Single set of channel characteristics

Table 151-13—Fiber optic cabling (channel) characteristics

Description	400GBASE-FR4	400GBASE-LR4		Unit
Operating distance (max)	2	7	10	km
Channel insertion loss ^{a,b} (max)	4	6.3		dB
Channel insertion loss (min)	0	0		dB
Positive dispersion ^b (max)	6.7	23		ps/nm
Negative dispersion ^b (min)	-11.9	-41		ps/nm
DGD_max ^c	2.3	5		ps
Optical return loss (min)	25	22		dB

^a These channel insertion loss values include cable, connectors, and splices.

^b Over the wavelength range 1264.5 nm to 1337.5 nm for 400GBASE-FR4 and 400GBASE-LR4. Values for 400GBASE-LR4 are based on 7 km of G.652.B, G.652.D, G.657.A1, or G.657.A2 single-mode fiber.

^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. The value for 400GBASE-LR4 is based on 10 km of G.652.B, G.652.D, G.657.A1, or G.657.A2 single-mode fiber.

Optical fiber and cable

Standard fiber and cables

Table 151-14—Optical fiber and cable characteristics

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 at 1264.5 nm attenuation for optical fiber cables is derived from Appendix I of ITU-T G.695. Using 0.47 dB/km may not support operation at 10 km for 400GBASE-LR4.

^b The 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA 568-C.3. Using 0.5 dB/km may not support operation at 10 km for 400GBASE-LR4.

Summary

- This proposal is for a single 400GBASE-LR4 PHY, with a single set of transmit and receive specifications, a single power budget and a single TDECQ transmitter compliance test.
- The proposal supports operation over 7 km of worst-case fiber and 10 km on an engineered link (with the same -41 ps/nm to $+23$ ps/nm as the worst-case 7 km link)
- 7 km was chosen to limit dispersion to the range resulting in a 2 dB CD penalty as illustrated in [stassar_cu_adhoc_041719](#), based on data from [yu_optx_01a_0319](#). With more data we can revisit the reach to perhaps go up to 8 km.

400GBASE-LR4 Baseline

Thank you

Backup slides follow

Operating ranges

Table 151–6—400GBASE-FR4 and 400GBASE-LR4 operating ranges

PMD type	Required operating range
400GBASE-FR4	2 m to 2 km
400GBASE-LR4	2 m to 7 km
	2 m to 10 km ^a

^aLinks longer than 7 km for the same power budget are considered engineered links. Attenuation and chromatic dispersion needs to be less than the worst case specified for ITU-T G.652.B, G.652.D, G.657.A1 or G.657.A2 single-mode fibers.

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.

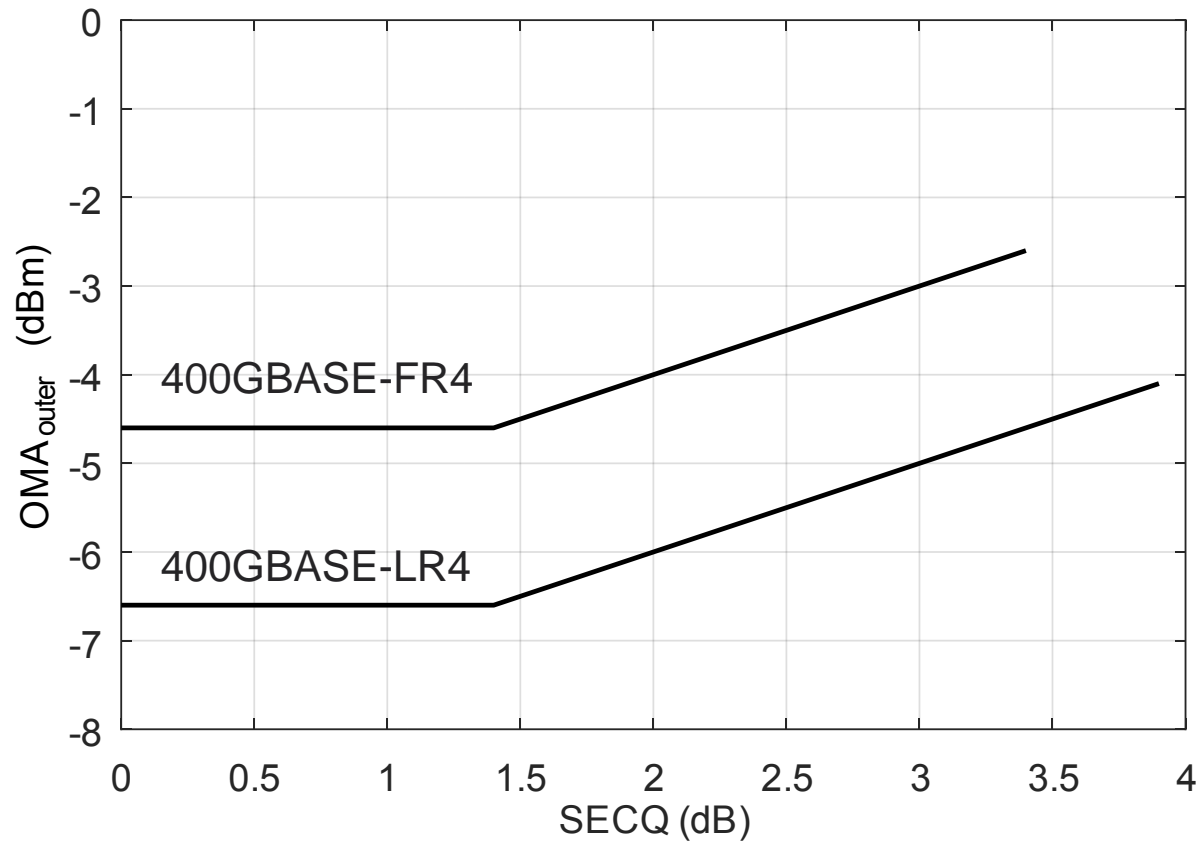
^b Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.

^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.

Illustration of receiver sensitivity mask



Additional link margin with new proposal

[mazzini_3cu_adhoc_082119](#)

