C Band Baseline proposal for 800GBASE-LR1 and 800GBASE-ER1

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Overview

802.3dj includes the following 800Gb/s objectives that are for a coherent optical solution

- over 1 wavelength over a single SMF in each direction with lengths up to at least 10 km
- over a single SMF in each direction with lengths up to at least 40 km

A logical specification based on coherent modulation and BCH coding has been adopted for the 10km objective

- https://www.ieee802.org/3/dj/public/23_07/kota_3dj_01b_2307.pdf

The FEC for 40km and wavelengths for both 10 & 40km for these objectives need to be adopted

This contribution provides proposed baseline specifications to meet these objectives with C band operation

Historical view of 802.3 10 & 40km specs

Observation on IEEE and industry history around 10 km reaches

		2km	10km	40km
25GbE	Single λ	-	Single λ	Single λ [1]
50 GbE	Single λ	Single λ	Single λ	Single λ
100GbE	Single λ	Single λ	Single λ	Single λ [2]
	4 λ	CWDM	LAN WDM CWDM	LAN WDM
200 GbE	4 λ	CWDM	LAN WDM	LAN WDM
400GbE	4 λ	CWDM	CWDM	LAN WDM
	8 λ	LAN WDM	LAN WDM	LAN WDM

Notes:
[1] tighter wavelength range
[2] tighter spectral width

Observations:

- IEEE 802.3 has history of grouping technical solutions between reaches for leverage and economy of scale
- Lowest cost solution always used for highest volume reach (2km)
  - That solution generally extended to max reach possible
- History of grouping 10km & 40km when 2km solution not practical for those reaches (100G and 200G)
- No history of separate solutions for each reach

williams_3df_01_220222.pdf

nowell_3dj_02_2305.pdf

Using a compatible solution for 10 & 40 km is consistent with 802.3's historical approach of leveraging multiple reaches using a common solution

C Band vs O band optical specs

A review of the fiber losses used in 802.3 is presented in

- https://www.ieee802.org/3/dj/public/adhoc/optics/0423_OPTX/stassar_3dj_optx_01a_230427.pdf

For 10 km operation the following losses are used:

- C band: 0.28 dB/km

40km is typically treated as an engineered link, with reduced loss

At 10 km a C band solution has 1.5dB less loss than an O band solution

→ This loss can be used either to reduce laser power, or to provide additional unallocated margin

The 10 km solution is defined to support a 6.3dB loss budget consistent with existing 802.3 10km specifications – this is a topic that can be discussed

- A lower loss budget based on C band could also be a consideration based on additional analysis

800GBASE-LR1 and 800GBASE-ER1 C Band Link parameters

	800GBASE-LR1	800GBASE-ER1	
Operating Distance	10	40	km
Fiber Loss	2.8	10.9	dB
Additional Loss	3.5	1	dB [1, 2]
Chromatic Dispersion Max	200	800	ps/nm [3]
Chromatic Dispersion Min	0	0	ps/nm
Polarization Mode Dispersion	5	10	Ps [4]
Maximum Channel Loss	6.3	11.9	dB
Allocation for penalties	0.5	1	dB

Note 1: 800GBASE-LR1 is assumed to be designed for a 6.3dB loss budget

Note 2: 800GBASE-ER1 provides 1dB of allocation for patch panels.

Note 3: Chromatic Dispersion is allocated based on G.654 maximum CD value, which is greater than the worst-case G.652.D

Note 4: PMD spec is based on values adopted in 802.3cu

Laser options

Historically coherent solutions are designed for DWDM applications, using wavelength locked tunable lasers

- Tight wavelength control is needed to maximize fiber capacity

These locked lasers with < ± 1.8GHz frequency accuracy allow DSP compensation for worst case frequency offsets between the two ends' lasers

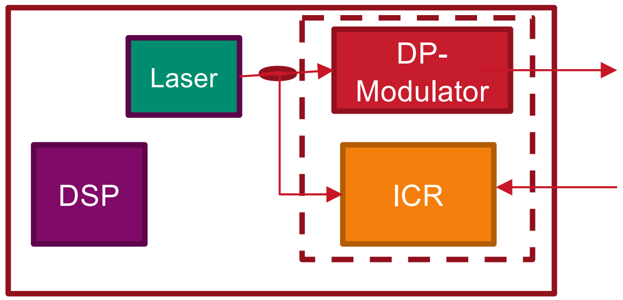
Single channel applications remove this tight-frequency requirement

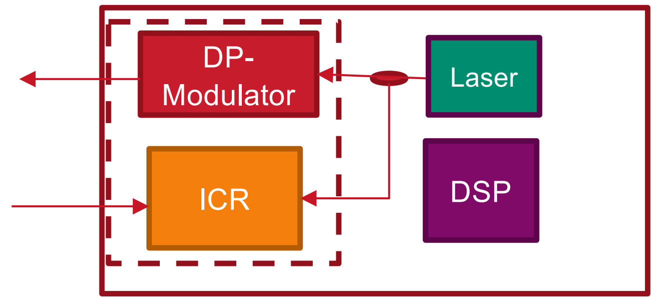
Unlocked lasers with frequency accuracies in the ± 12.5GHz range require some degree of laser control to minimize the frequency difference between the Tx and LO lasers

- Using a two-laser solution to separate Tx and Rx lasers allows independent Rx frequency acquisition and tracking
- A single laser solution with this frequency accuracy would require details of laser tracking to be defined to ensure stable interop

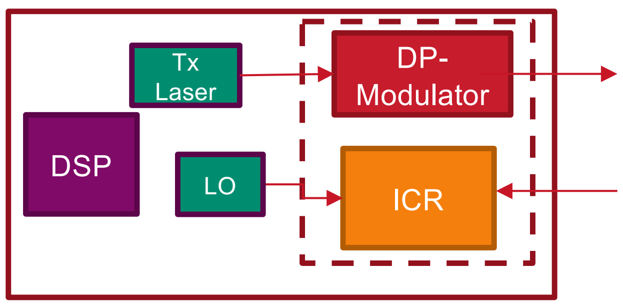
Coherent lasers / control overview

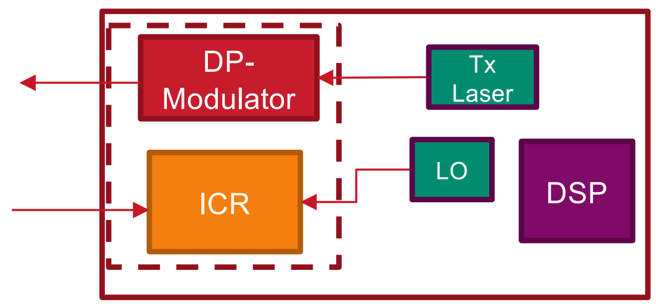
shared laser





Two laser





Typical coherent implementation uses a shared laser for both Tx & Rx (LO)

The optics design & specifications ensure that the frequency difference between the two lasers (IF) is small enough to be removed at the DSP Rx

LR and ER Interoperability

For the 10 km objective, the following optical power levels are used in this proposed baseline

- Tx Optical Power: -10 dBm
- Rx sensitivity (TP2): -16.8 dBm

Loss budgets for the two objectives are:

- 10km: 6.3 dBm, 40km: 11.9 dBm

Optical amplification in the 40km module will be implemented to allow the additional ~6 dB channel loss

- Current optical modules include amplification using SOA and µEDFA technologies to provide over 14 dB of optical gain, while meeting > 36dB Tx OSNR
- Increasing the 40km Tx optical power to -4dBm provides a straightforward path to interoperable 10 & 40km specifications

BCH FEC has sufficient coding gain for the 40km specification, providing a path to interoperability

- See: https://www.ieee802.org/3/dj/public/23_03/maniloff_3dj_01a_2303.pdf & https://www.ieee802.org/3/dj/public/23_07/stassar_3dj_01a_2307.pdf

Coherent Specification Methodology

Coherent specification for 100G in 802.3ct and ITU G698.2 are based on an approach using a reference receiver and EVM to specify optical budgets

802.3cw adds parametric specifications, in addition to EVM

802.3dj will be specified as a single channel specification, and will provide an opportunity to revisit the methodology

- A recent proposal to use Tx impairments into a reference receiver analogous to TECQ has been proposed: https://www.oiforum.com/get/53960

This is an important topic, but needs significant additional study

- Our current view is that initial specifications should be based on the approach used in 802.3cw
- As more data and analysis is presented this approach may evolve

800GBASE-LR1 and 800GBASE-ER1 Tx Parameters

	800GBASE-LR1	800GBASE-ER1	Unit
Signalling rate	123.7±50 ppm	123.7±50 ppm	Gbaud
Modulation Format	DP-16QAM	DP-16QAM	
Optical Frequency	193.7	193.7	THz
FEC	RS(544,514,10) +BCH(126,110)		
Average Launch Power (Max)	-6	0	dBm
Average Launch Power (Min)	-10	-4	dBm
Optical Frequency Accuracy	±12.5	±12.5	GHz [1]
Laser Linewidth	1	1	MHz
In Band OSNR	36	36	dB/12.5 GHz
Power difference between X and Y polarizations (max)	1.5	1.5	dB
Skew between X and Y polarizations (max)	5	5	ps
EVMmax (max)	TBD	TBD	%
Instantaneous I-Q offset per polarization (max)	-20	-20	dB
Mean I-Q offset per polarization (max)	-26	-26	dB
I-Q amplitude imbalance (mean)	1	1	dB
I-Q phase error magnitude (max)	5	5	deg
I-Q quadrature skew (max)	0.75	0.75	ps
Average launch power of OFF transmitter (max)	-20	-20	dBm
Transmitter reflectance (max)	-20	-20	dB
Transmit output power stability	± 1	± 1	dB
RIN average (max)	-145	-145	dB/Hz
RIN peak (max)	-140	-140	dB/Hz

[1] Assumes that the Rx LO laser will align to minimize frequency offset

800GBASE-LR1 and 800GBASE-ER1 C Band Rx Parameters

	800GBASE-LR1	800GBASE-ER1	Gbaud
Signalling rate	123.7±50 ppm	123.7±50 ppm	
Modulation Format	DP-16QAM	DP-16QAM	THz
Optical Frequency	193.7	193.7	GHz
Optical Frequency Tolerance	±12.5	±12.5	dBm [1]
Sensitivity at TP2	-16.8	-16.9	dBm [2]
Sensitivity at TP3	-16.3	-15.9	dBm
Optical Power (Max)	TBD	TBD	dB [3]
Damage Threshold	+5	+5	dBm
Receiver reflectance (max)	20	20	dB
Allocation for Penalties	0.5	1	dB

Note [1] Assumes that the Rx LO laser will align to Tx frequency to minimize frequency offset

Note [2] 800GBASE-LR1 and 800GBASE-ER1 are compliant over the 10km link

Note [3] X dB minimum loss included for ER Tx

Summary

Optical specifications are provided for operation over 10 & 40km SMF using a RS544/BCH(126,110) FEC code

C Band operation allows a common design and interoperability between LR and ER modules, consistent with 802.3 precedent

The proposed specification is based on fiber specifications consistent with previous IEEE 802.3 clauses

- Details of the loss specification can evolve based on further study of applications and implementations

Thanks!