

# 100GBASE-DR Link Budget Considerations

Matt Traverso, Cisco

Hai-Feng Liu, Intel

Marco Mazzini, Cisco

Gary Nicholl, Cisco

Matt Sysak, Intel

# Supporters

- David Lewis, Lumentum
- Kohichi Tamura, Oclaro
- Atul Gupta, Macom
- Chris Cole, Finisar
- Jonathan King, Finisar
- Mark Kimber, Semtech
- Bharat Tailor, Semtech
- Kent Lusted, Intel
- Brian Welch, Luxtera
- Matt Brown, APM

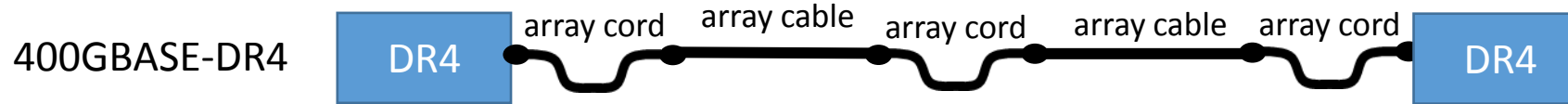
# Background and Motivation

- One of IEEE 802.3cd objectives is to *‘define a single lane 100 Gb/s PHY for operation over duplex SMF with lengths up to at least 500 m, consistent with IEEE P802.3bs Clause 124’* (400GBASE-DR4).
- In the adopted 100GBASE-DR baseline of [traverso 3cd 03a 0916](#), it was stated: “with penalties consistent with a channel allowing up to 4 discrete reflectances of -35 dB” – This means an additional ~0.2 dB MPI penalty needs to be included in the link budget.
- No consensus has been reached as how to allocate this ~0.2 dB between Tx and Rx.
- As the additional MPI penalty is primarily due to the high reflectance LC connectors in 100GBASE-DR links, which also have lower insertion loss, high MPI penalty and high link loss do not occur at the same time.
- In this presentation, we propose to use the total of link loss and MPI penalty for 100GBASE-DR link budget (vs. consider them separately), show this would support more usage cases with the same total budget as 400GBASE-DR4, and recommend changes to the Draft 1.0.

# Link Budget Based on Total Link Loss + MPI Penalty

- 1) Methodologies used
  - Referencing [kolesar 3bs 01 0514](#) for MPO/LC loss statistics and model
    - Assume MPO mean loss = 0.35 dB (stdev = 0.25 dB), and LC mean loss = 0.2 dB (stdev = 0.15 dB).
  - Referencing [anslow 03 1107.xls](#) for SMF attenuation
  - Referencing [king 01a 0116 smf](#) for MPI calculation
- 2) Compare the usage cases covered by 3 dB link loss and 0.3 dB MPI penalty vs. the usage cases covered by 3.1 dB total budget

# 400GBASE-DR4 Reference



## 500m Double link with 4 MPO connectors

Connector Losses = 2.65 dB,

Fiber loss = 0.25dB,

-> Link Loss = 2.9 dB (rounded to 3 dB)

MPI Penalty = 0.1 dB

Agreed Budget = 3.1 dB

# 500m Link Loss & MPI Penalties vs. # of LC/MPO Connectors

Link Loss	0 MPO	1 MPO	2 MPO	3 MPO	4 MPO	5 MPO
0 LC	0.25	1.23	1.83	2.38	2.9	3.4
1 LC	0.83	1.53	2.11	2.65	3.16	n.c.
2 LC	1.18	1.82	2.38	2.91	3.41	n.c.
3 LC	1.5	2.1	2.65	3.16	n.c.	n.c.
4 LC	1.8	2.38	2.91	3.42	3.91	n.c.
5 LC	2.09	2.65	3.17	n.c.	n.c.	n.c.
6 LC	2.37	2.91	3.42	n.c.	n.c.	n.c.
7 LC	2.64	3.17	n.c.	n.c.	n.c.	n.c.
8 LC	2.91	n.c.	n.c.	n.c.	n.c.	n.c.

MPI penalty	0 MPO	1 MPO	2 MPO	3 MPO	4 MPO	5 MPO
0 LC	n.c.	n.c.	n.c.	n.c.	0.1	n.c.
1 LC	n.c.	n.c.	n.c.	0.07	0.06	n.c.
2 LC	n.c.	n.c.	0.13	0.11	0.12	n.c.
3 LC	n.c.	0.2	0.19	0.18	n.c.	n.c.
4 LC	n.c.	0.33	0.26	n.c.	n.c.	n.c.
5 LC	n.c.	0.36	0.35	n.c.	n.c.	n.c.
6 LC	0.55	0.43	n.c.	n.c.	n.c.	n.c.
7 LC	0.55	n.c.	n.c.	n.c.	n.c.	n.c.
8 LC	0.55	n.c.	n.c.	n.c.	n.c.	n.c.

Green cells = Margins w/respect 3.0 dB link loss

Yellow cells = Less than 0.2dB margin w/respect 3.0dB Link loss

Orange cells = Not supported by 3.0dB link loss

Blue = 400GBASE-DR4 link loss

Red = considered main topology for 100GBASE-DR double link

Green cells = MPI penalty < 0.3dB

Orange cells = MPI penalty > 0.3dB

Blue = 400GBASE-DR4 agreed MPI penalty (calculated is < 0.1dB)

- High link loss and high MPI penalty not always occur at the same time

# Independent Link Loss & MPI Penalty vs. Total Budget

## 3.3 dB Total Budget (3 dB Loss + 0.3 dB MPI Penalty)

Loss only	0 MPO	1 MPO	2 MPO	3 MPO	4 MPO
0 LC	-	-	n.c.	n.c.	2.90
1 LC	-	n.c.	n.c.	2.65	3.16
2 LC	n.c.	n.c.	2.38	2.91	3.41
3 LC	n.c.	2.10	2.65	3.16	n.c.
4 LC	1.80	2.38	2.91	n.c.	n.c.
5 LC	2.09	2.65	3.17	n.c.	n.c.
6 LC	2.37	2.91	n.c.	n.c.	n.c.
7 LC	2.64	3.17	n.c.	n.c.	n.c.
8 LC	2.91	n.c.	n.c.	n.c.	n.c.

Green Cells: Meet both 3dB link loss and 0.3dB MPI Penalty

Orange cells: OK with 3dB link loss but MPI penalty > 0.3 dB

## 3.1 dB Total Budget

Loss+MPI	0 MPO	1 MPO	2 MPO	3 MPO	4 MPO
0 LC	-	-	n.c.	n.c.	3.00
1 LC	-	n.c.	n.c.	2.72	3.26
2 LC	n.c.	n.c.	2.51	3.02	3.53
3 LC	n.c.	2.30	2.84	3.34	n.c.
4 LC	n.c.	2.71	3.17	n.c.	n.c.
5 LC	n.c.	3.01	3.52	n.c.	n.c.
6 LC	2.92	3.34	n.c.	n.c.	n.c.
7 LC	3.19	n.c.	n.c.	n.c.	n.c.
8 LC	n.c.	n.c.	n.c.	n.c.	n.c.

Green Cells: Meeting 3.1 dB total budget

Yellow Cells: Can be covered with an extra 0.2 dB

- Consistent with previous methods
- Less usage case covered
- Different optical Tx OMA and Rx sensitivity specs for DR (4xDR) and DR4

- Consider the total budget of (loss + MPI penalty)
- More usage case covered
- Same optical Tx OMA and Rx sensitivity specs for DR, DR4 (4xDR)

# Optical Return Loss

- Field additions of all possible reflections including Rx (with -26 dB ORL) without link loss
- Forecasted Loss = 500m loss + Conn. Loss

# of -35 dB Discrete Reflectance	# -45 dB Reflectance MPO allowed	Optical Return Loss (dB)	MPI Penalty (dB)	Max. Link Loss (dB)	Forecasted Loss (dB)
0	4	22.8	0.1	3	2.9
1	3	21.4	0.1	3	2.65
2	3	19.8	0.11	3	2.9
3	2	18.8	0.19	3	2.65
4	1	17.9	0.33	3	2.38
5	1	16.8	0.36	3	2.65
6	0	16.1	0.55	3	2.37

**Recommend to use 16.1 dB for the worst case as the optical return loss specification**



# Proposed Addition of new table

MPI penalty	0 MPO	1 MPO	2 MPO	3 MPO	4 MPO	5 MPO
0 LC	n.c.	n.c.	n.c.	n.c.	0.1	n.c.
1 LC	n.c.	n.c.	n.c.	0.07	0.06	n.c.
2 LC	n.c.	n.c.	0.13	0.11	0.12	n.c.
3 LC	n.c.	0.2	0.19	0.18	n.c.	n.c.
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5 LC	n.c.	0.36	0.35	n.c.	n.c.	n.c.
6 LC	0.55	0.43	n.c.	n.c.	n.c.	n.c.
7 LC	0.55	n.c.	n.c.	n.c.	n.c.	n.c.
8 LC	0.55	n.c.	n.c.	n.c.	n.c.	n.c.

Green cells = MPI penalty < 0.3dB  
 Orange cells = MPI penalty > 0.3dB  
 Blue = 400GBASE-DR4 agreed MPI penalty (calculated is < 0.1dB)

		Number of 45 dB Reflectances										
		Max Link Loss	0	1	2	3	4					
Number of 35 dB Reflectances	0	3	3	3	3	3	3					
	1											
	2											
	3							2.90	2.9	2.9	n.c.	
	4							2.77	2.84	n.c.	n.c.	
	5							2.74	2.75	n.c.	n.c.	
	6							2.45	2.6	n.c.	n.c.	n.c.
	7							2.45	n.c.	n.c.	n.c.	n.c.

Green Cells: Support maximum link loss of 3dB  
 Yellow Cells: Maximum link loss permitted due to MPI penalty

Max. Link Loss =

3 dB, if Forecasted Loss + MPI Penalty < 3

3 – MPI Penalty, if Forecasted Loss + MPI Penalty < 3

# Recommended Changes to Draft 1.0 (I)

Table 140–6—100GBASE-DR transmit characteristics

Description	Value	Unit
Signaling rate (range)	53.125 ± 100 ppm	GBd
Modulation format	PAM4	—
Wavelength (range)	1304.5 to 1317.5	nm
Side-mode suppression ratio (SMSR), (min)	30	dB
Average launch power (max)	4	dBm
Average launch power <sup>a</sup> (min)	-2.4	dBm
Outer Optical Modulation Amplitude (OMA <sub>outer</sub> ) (max)	4.2	dBm
Outer Optical Modulation Amplitude (OMA <sub>outer</sub> ) (min) <sup>b</sup>	-0.3	dBm
Launch power in OMA <sub>outer</sub> minus TDECQ (min)	-1.3	dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ) (max)	2.5	dB
Average launch power of OFF transmitter (max)	-20	dBm
Extinction ratio (min)	5	dB
RIN <sub>21.4</sub> OMA (max)	-142	dB/Hz
Optical return loss tolerance (max)	21.4	dB
Transmitter reflectance <sup>c</sup> (max)	-26	dB

- Keep unchanged, same as in DR4
- Keep unchanged, same as in DR4
- Change to RIN<sub>16.1</sub>OMA
- Change to 16.1 dB

# Recommended Changes to Draft 1.0 (II)

Table 140-7—100GBASE-DR receive characteristics

Description	Value	Unit
Signaling rate (range)	53.125 ± 100 ppm	GBd
Modulation format	PAM4	—
Wavelengths (range)	1304.5 to 1317.5	nm
Damage threshold <sup>a</sup>	6.5	dBm
Average receive power (max)	4	dBm
Average receive power <sup>b</sup> (min)	-5.4	dBm
Receive power (OMA <sub>outer</sub> ) (max)	4.2	dBm
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMA <sub>outer</sub> ) <sup>c</sup> (max)	-4.4	dBm
Stressed receiver sensitivity (OMA <sub>outer</sub> ) <sup>d</sup> (max)	-1.9	dBm
Conditions of stressed receiver sensitivity test: <sup>e</sup>		
Stressed eye closure for PAM4 (SECQ)	2.5	dB

→ Keep unchanged

→ Keep unchanged

Table 140-8—100GBASE-DR illustrative link power budget

Parameter	Value	Unit
Power budget (for max TDECQ)	5.6	dB
Operating distance	500	m
Channel insertion loss <sup>a</sup>	3	dB
Maximum discrete reflectance	See 140.10.2.2	dB
Allocation for penalties <sup>b</sup> (for max TDECQ)	2.6	dB
Additional insertion loss allowed	0	dB

→ 5.6 dB as in 400GBASE-DR4

→ Add footnote stating, higher penalties may be supported with reduce link loss. See table 140-13.

# Recommended Changes to Draft 1.0 (III)

## replace table 140-13

~~Table 140-13—Maximum value of each discrete reflectance~~

Number of discrete reflectances above -55 dB	Maximum value for each discrete reflectance
	100GBASE-DR
1	-37 dB
2	-42 dB
4	-45 dB
6	-47 dB
8	-48 dB
10	-49 dB

Table 140-13 – Maximum link loss with different discrete reflectances topologies

		Number of 45 dB Reflectances					
		Max Link Loss	0	1	2	3	4
Number of 35 dB Reflectances	0						
	1			3	3	3	3
	2						
	3	3		2.9	2.9	2.9	n.c.
	4			2.8	2.8	n.c.	n.c.
	5			2.7	2.8	n.c.	n.c.
	6	2.45	2.6	n.c.	n.c.	n.c.	n.c.
	7	2.45	n.c.	n.c.	n.c.	n.c.	n.c.

Add footnote to explain 35 dB reflectance implies LC connector (IEC reference).  
 Add footnote to explain 45 dB reflectance implies MPO connector (IEC reference).

# Summary

- Proposed to use the total of link loss and MPI penalty in 100GBASE-DR link budget consideration, which would
  - resolve the issue of additional  $\sim 0.2$  dB MPI penalty in the link budget,
  - support more usage cases, and
  - keep the same Tx OMA(min) and Rx sensitivity specifications as those in 400GBASE-DR4.
  - enable tradeoff of MPI penalty and link loss
- Calculated optical return loss for 100GBASE-DR usage cases which gave 16.1 dB as the worst case ORL.
- Recommended changes in 100GBASE-DR link budget.

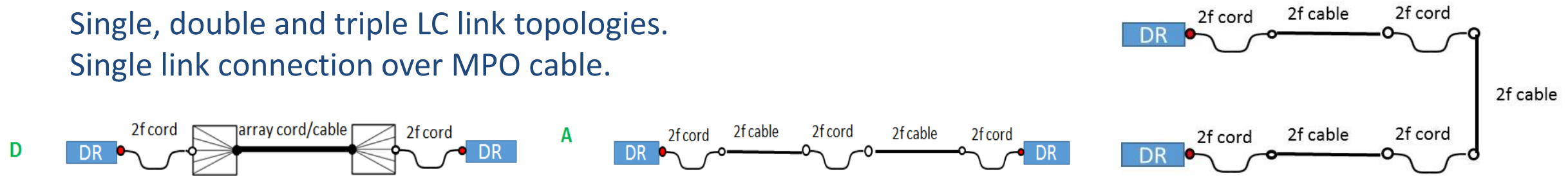
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# Main Link Topologies Supported by 3.1 dB Total Budget

Assuming 3.1dB total budget for 100GBASE-DR, we can include below topologies:

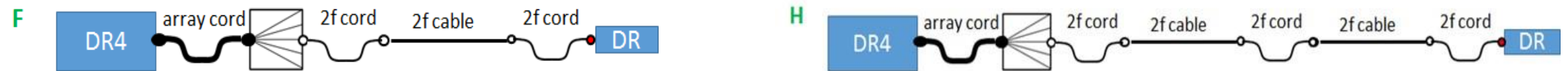
## 100GBASE-DR over 100GBASE-DR

Single, double and triple LC link topologies.  
Single link connection over MPO cable.



## Breakout: 4x100G-DR (DR4-like) over 100GBASE-DR

Single, double links connection for most representative break-out cases.



100GBASE-DR (4xDR) optical interface specifications identical to 400GBASE-DR4 specifications