

# Upper Bound Based MPI Penalty Analysis

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Jan. 18, 2016

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# Problem Statement

- While a number of MPI analyses exist, no single method that has been agreed upon to determine the MPI penalty for all PMDs
- There is no agreed upon return loss specs for connectors(LC/MPO)/TOSA/ROSA
- Number of connectors has not been explicitly defined

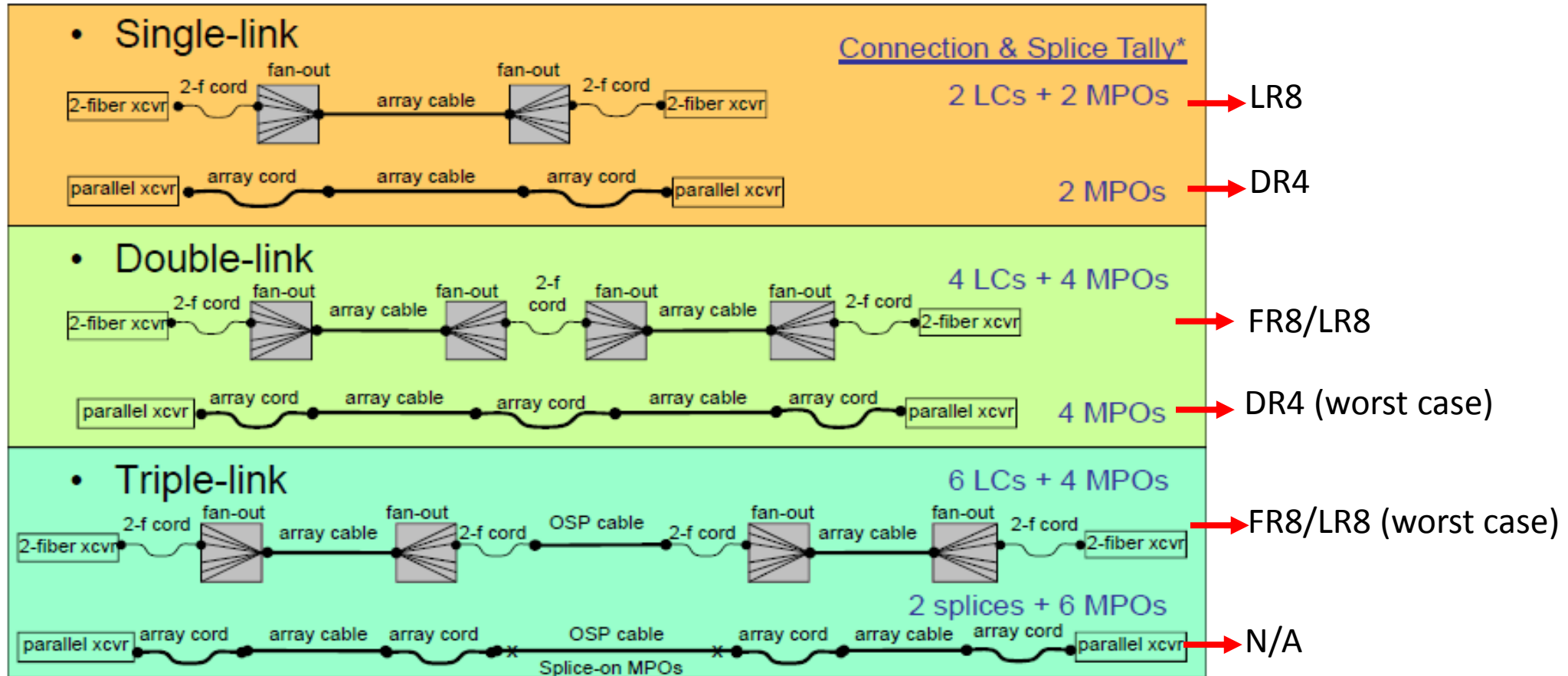
This presentation is to apply the upper bound MPI analysis to various links to facilitate consensus building towards

- The method to determine MPI penalty across all PMDs
- Connectors/TOSA/ROSA return loss specs
- Link model for each PMD

# Agenda

- Links under consideration
- Upper bound / Statistical upper bound MPI penalty analyses
  - Double link w/parallel transceivers
  - Double link w/duplex transceivers
  - Triple link w/duplex transceivers
- MPI penalty reduction by mid-span link loss
- Discussion/Summary

# Links Under Consideration



**Focus the worst case links proposed by Paul Kolesar**

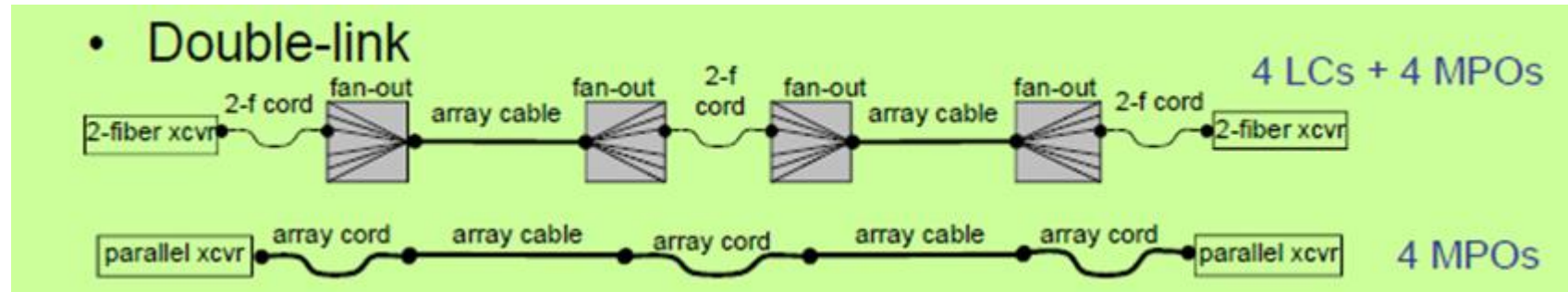
[http://www.ieee802.org/3/bs/public/14\\_05/kolesar\\_3bs\\_01\\_0514.pdf](http://www.ieee802.org/3/bs/public/14_05/kolesar_3bs_01_0514.pdf)

# Upper Bound Analysis (from Bhatt\_01\_0512)

## Assumptions

- No fiber loss and no connector loss
  - All interfering optical signals are perfectly aligned in polarization
  - All interfering optical signals are constructively added
  - All interfering terms are of highest PAM amplitude
    - Random amplitude is considered by Statistical upper bound analysis
- [http://www.ieee802.org/3/bm/public/nov12/farhood\\_01\\_1112\\_optx.pdf](http://www.ieee802.org/3/bm/public/nov12/farhood_01_1112_optx.pdf)
- All higher order terms are ignored
  - Optical signal ER = 5 dB (DR4) and, ER = 4.5 dB (FR8/LR8)

# Double Links – DR4



FR8/LR8

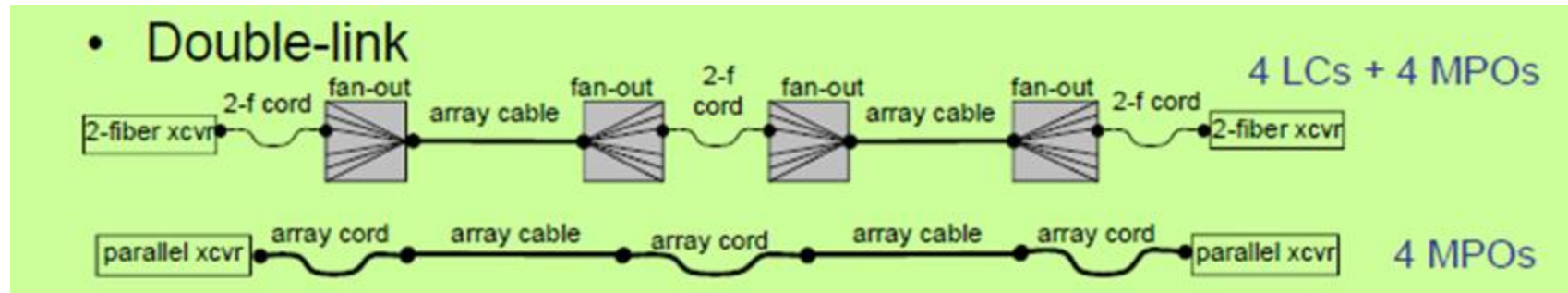
DR4

DR4 = 4 MPOs + TOSA + ROSA Total 15 possible reflection paths

Double DR4	$R_{\text{conn}}$ (dB)	$R_{\text{Tosa}}$ (dB)	$R_{\text{Rosa}}$ (dB)	Upper Bound MPI Penalty (dB)	Statistical Upper Bound Penalty (dB)
Case A	26	26	26	4.70	3.24
Case B	26	20	26	9.24	5.23
Case C	35	26	26	0.98	0.76
Case D	35	35	35	0.38	0.30
Case E	55	26	26	0.25	0.20
Case F	45	26	26	0.40	0.31
Case G	55	20	26	0.49	0.39
Case H	45	20	26	0.71	0.55

55 dB MPO  
 $\Rightarrow < 0.25$  dB MPI penalty

# Double Links – FR8/LR8



FR8 = 4 MPO + 4 LC + TOSA + ROSA      Total 45 possible reflection paths

FR8/LR8

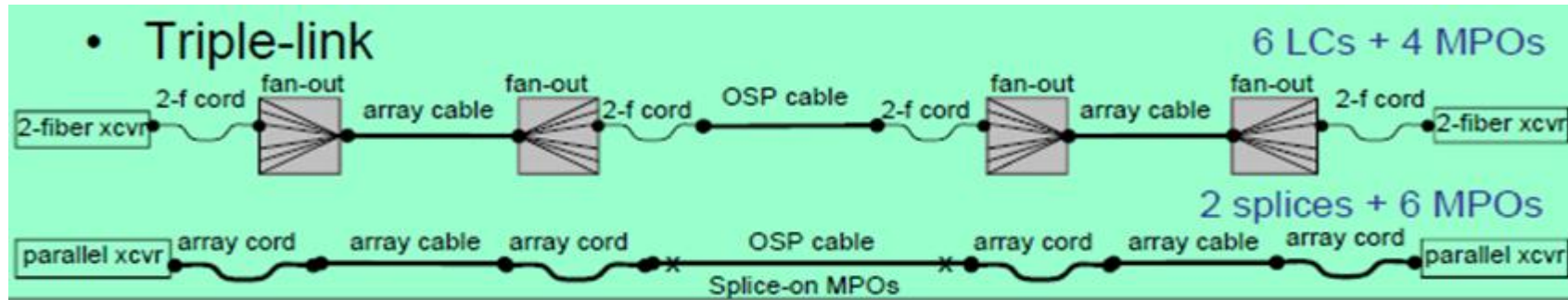
DR4

Double Link	$R_{LC}$ (dB)	$R_{MPO}$ (dB)	$R_{Tosa}$ (dB)	$R_{Rosa}$ (dB)	Upper Bound MPI Penalty (dB)	Statistical Upper Bound Penalty (dB)
Case A	26	35	26	26	-	10.83
Case B	26	45	26	26	7.70	4.84
Case C	26	55	26	26	5.87	3.97
Case D	35	35	26	26	2.81	2.12
Case E	35	45	26	26	1.49	1.16
Case F	35	55	26	26	1.18	0.93
Case G	45	45	26	26	0.69	0.55
Case H	45	55	26	26	0.50	0.40

26 dB LC unacceptable

35dB LC, 55dB MPO  
 $\Rightarrow$  ~ 1 dB MPI penalty

# Triple Link – FR8/LR8



FR8/LR8

TOSA + ROSA + 6 LC + 4 MPO  $\Rightarrow$  Total of 66 possible reflection paths

Triple-Link	$R_{LC}$ (dB)	$R_{MPO}$ (dB)	$R_{Tosa}$ (dB)	$R_{Rosa}$ (dB)	Upper Bound MPI Penalty (dB)	Statistical Upper Bound Penalty (dB)
Case A	26	35	26	26	-	-
Case B	26	45	26	26	-	-
Case C	26	55	26	26	-	-
Case D	35	35	26	26	4.47	3.19
Case E	35	45	26	26	2.40	1.82
Case F	35	55	26	26	1.95	1.50
Case G	45	45	26	26	0.85	0.68
Case H	45	55	26	26	0.64	0.51

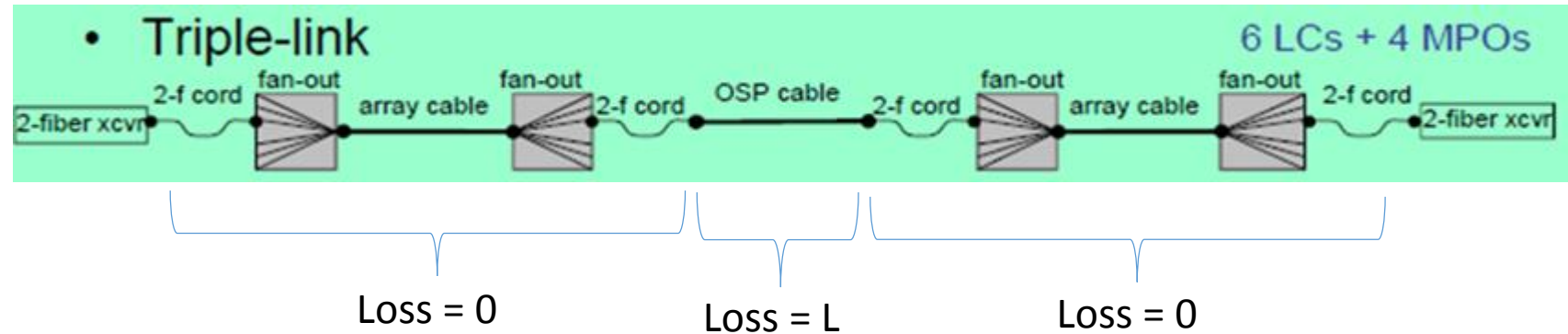
26 dB LC unacceptable

MPI penalty > 1 dB



# MPI Penalty Reduction by Mid-Span Link Loss

Mid-span model



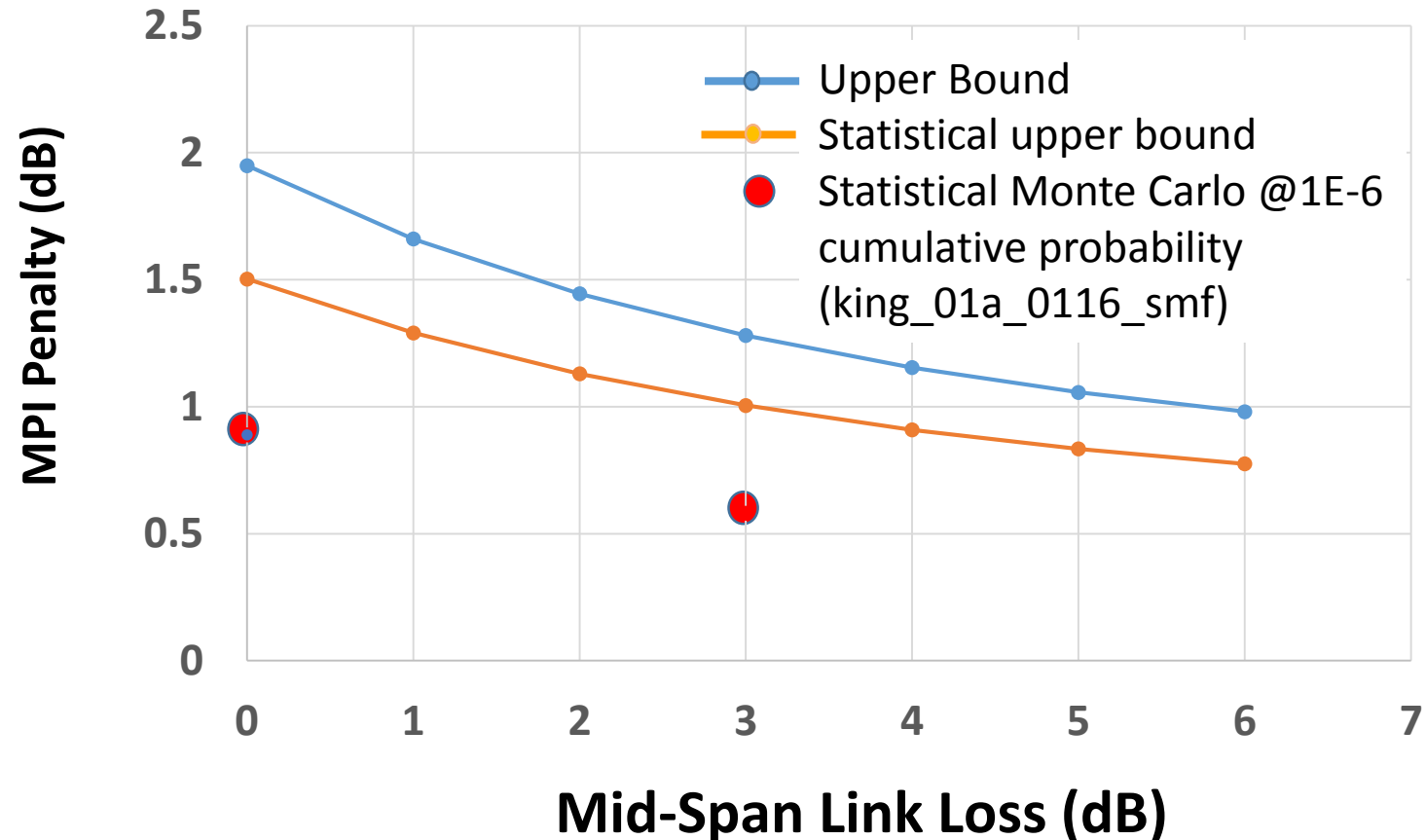
LR8	$R_{LC}$ (dB)	$R_{MPO}$ (dB)	$R_{Tosa}$ (dB)	$R_{Rosa}$ (dB)	Upper Bound MPI Penalty (dB)					Statistical Upper Bound Penalty (dB)				
					L=0 dB	L=1 dB	L=2 dB	L=3 dB	L=4 dB	L=0 dB	L=1 dB	L=2 dB	L=3 dB	L=4 dB
Case E	35	45	26	26	2.40	2.03	1.76	1.56	1.21	1.82	1.56	1.37	1.22	0.95
Case F	35	55	26	26	1.95	1.66	1.44	1.28	1.15	1.50	1.29	1.13	1.01	0.91
Case G	45	45	26	26	0.85	0.73	0.63	0.56	0.50	0.68	0.58	0.51	0.45	0.40
Case H	45	55	26	26	0.64	0.54	0.47	0.41	0.37	0.51	0.43	0.38	0.33	0.29

- MPI penalty reduces significantly as the link loss increases
- Maximum (MPI penalty + Link loss) occurs when the link loss is as maximum

# Comparison to Statistical Monte Carlo Simulations

[http://www.ieee802.org/3/bs/public/adhoc/smf/16\\_01\\_07/king\\_01a\\_0116\\_smf.pdf](http://www.ieee802.org/3/bs/public/adhoc/smf/16_01_07/king_01a_0116_smf.pdf)

Triple Link Case F (LC = 35 dB, MPO = 55 dB, TOSA = 26 dB, ROSA = 26 dB RL)



- Results are converging as the link loss goes higher
- At 3 dB link loss, the MPI penalty delta is ~ 0.4 dB.

# Discussion/Summary

- The conservative upper bound analysis provides the worst case MPI penalties
  - Calculated exemplary penalty assuming Tx/Rx = 26 dB, MPO = 55 dB, and LC = 35 dB RL
    - Parallel Double link (DR4): < 0.25 dB
    - Double link (FR8): ~ 1 dB
    - Triple link (FR8/LR8): 1.5 - 2 dB
- Upper bound MPI analysis and relaxed connector reflectance specs (LC = 26dB and MPO = 35dB) does not support a viable link budget for 400GBASE-FR8/LR8
- Duplex double/triple links have much higher MPI penalty than parallel double links
- Link loss can reduce the MPI penalty significantly. MPI penalty for a triple link (w/ 26 dB PMD, 35dB LC and 55dB MPO RL connectors) is ~ 1 dB with 3 dB link loss (vs. 0.6 dB from statistical Monte Carlo @1E-6 cumulative probability)

## Next steps:

- Need to agree on a method to calculate MPI penalty, link models, and connector specs consistent for all PMDs

# Thank You