Upper Bound Based MPI Penalty Analysis

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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

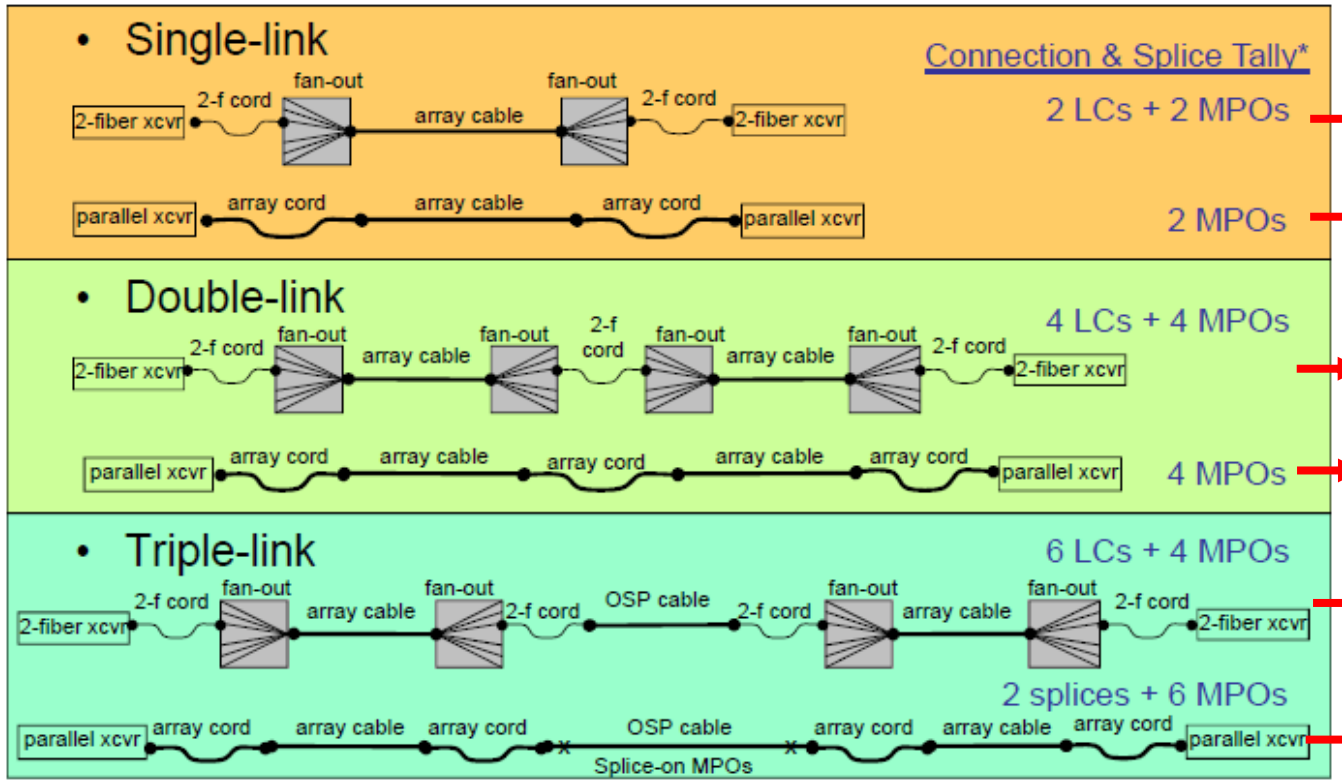
- The method to determine MPI penalty across all PMDs
- Connectors/TOSA/ROSA return loss specs
- Link model for each PMD

Agenda

- Links under consideration
- Upper bound MPI penalty analysis
  - Double link w/parallel transceivers
  - Double link w/duplex transceivers
  - Triple link w/duplex transceivers
  - Single link w/duplex transceivers
- Discussion/Conclusions

Links Under Consideration

Focus the links proposed by Paul Kolesar
http://www.ieee802.org/3/bs/public/14_05/kolesar_3bs_01_0514.pdf



Reach Objective ≥	Transmission & Channel	Insertion Losses	Attenuation	Total Loss Budget
100 m MM	2-fiber D-L	1.50 dB	0.35 dB	1.85 dB
	Parallel D-L	1.50 dB	0.35 dB	1.85 dB
500 m SM	2-fiber D-L	3.66 dB	≥ 0.25 dB	≥ 3.91 dB
	Parallel D-L	2.65 dB	≥ 0.25 dB	≥ 2.90 dB
2,000 m SM	2-fiber T-L	4.15 dB	≥ 0.92 dB	≥ 5.07 dB
	Parallel T-L	3.78 dB	≥ 0.92 dB	≥ 4.70 dB
10,000 m SM	2-fiber S-L	2.13 dB	≥ 4.26 dB	≥ 6.39 dB

Upper Bound Analysis (from Bhatt_01_0512)

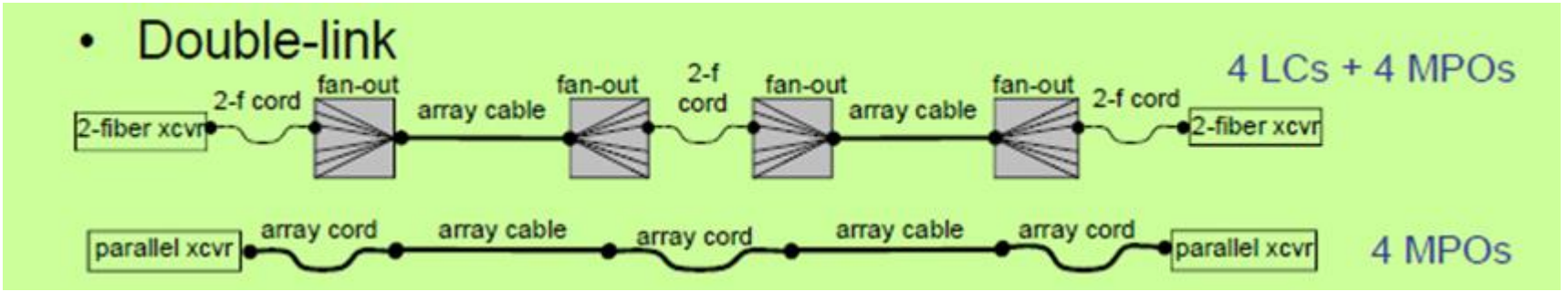
Assumptions

- 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

- All higher order terms are ignored
- Optical signal ER = 5 dB (DR4) and, ER = 4.5 dB (FR8/LR8)

Double Links – DR4

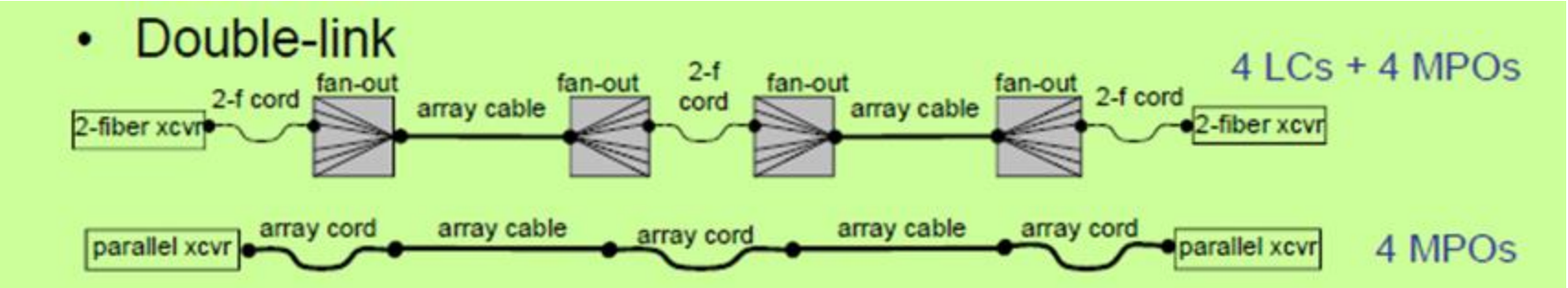


DR4 = 4 MPOs + TOSA + ROSA Total 15 possible reflection paths

Dounble DR4	R_{conn}(dB)	R_{Tosa} (dB)	R_{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
⇒ < 0.25 dB MPI penalty

Double Links – FR8



FR8

DR4

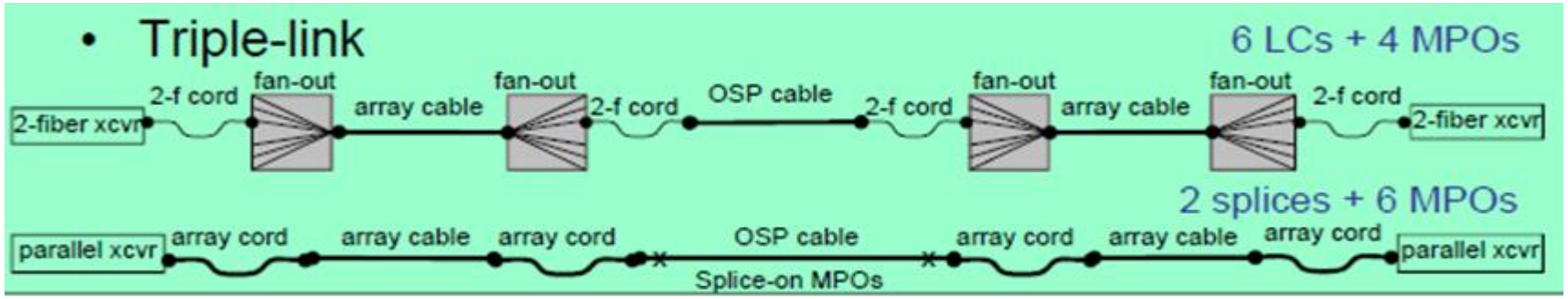
FR8 = 4 MPO + 4 LC + TOSA + ROSA Total 45 possible reflection paths

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
⇒ ~ 1 dB MPI penalty

Triple Link – FR8



FR8

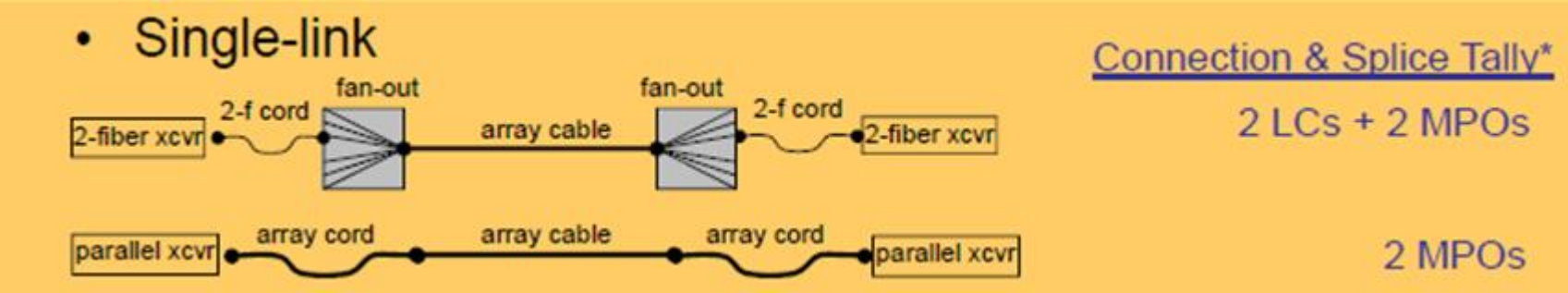
TOSA + ROSA + 6 LC + 4 MPO ⇒ Total of 66 possible reflection paths

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

Need lower connector RL to bring MPI penalty < 1 dB

Single Link - LR8



TOSA + ROSA + 2 LC + 2 MPO ⇒ Total of 15 possible reflection paths

Single 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	2.36	1.80
Case B	26	45	26	26	1.69	1.31
Case C	26	55	26	26	1.51	1.18
Case D	35	35	26	26	1.05	0.83
Case E	35	45	26	26	0.70	0.55
Case F	35	55	26	26	0.59	0.47
Case G	45	45	26	26	0.42	0.34
Case H	45	55	26	26	0.34	0.27

55 dB MPO
⇒ < 1 dB MPI Penalty

Discussion/Conclusions

- 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
    - Single link (LR8): < 0.6 dB
    - Double link (FR8): ~ 1 dB
    - Triple link (FR8): 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
- Duplex double/triple links have much higher MPI penalty than the parallel double link due to additional connectors used

Next steps:

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