Loss Budgeting for Single-mode Channels

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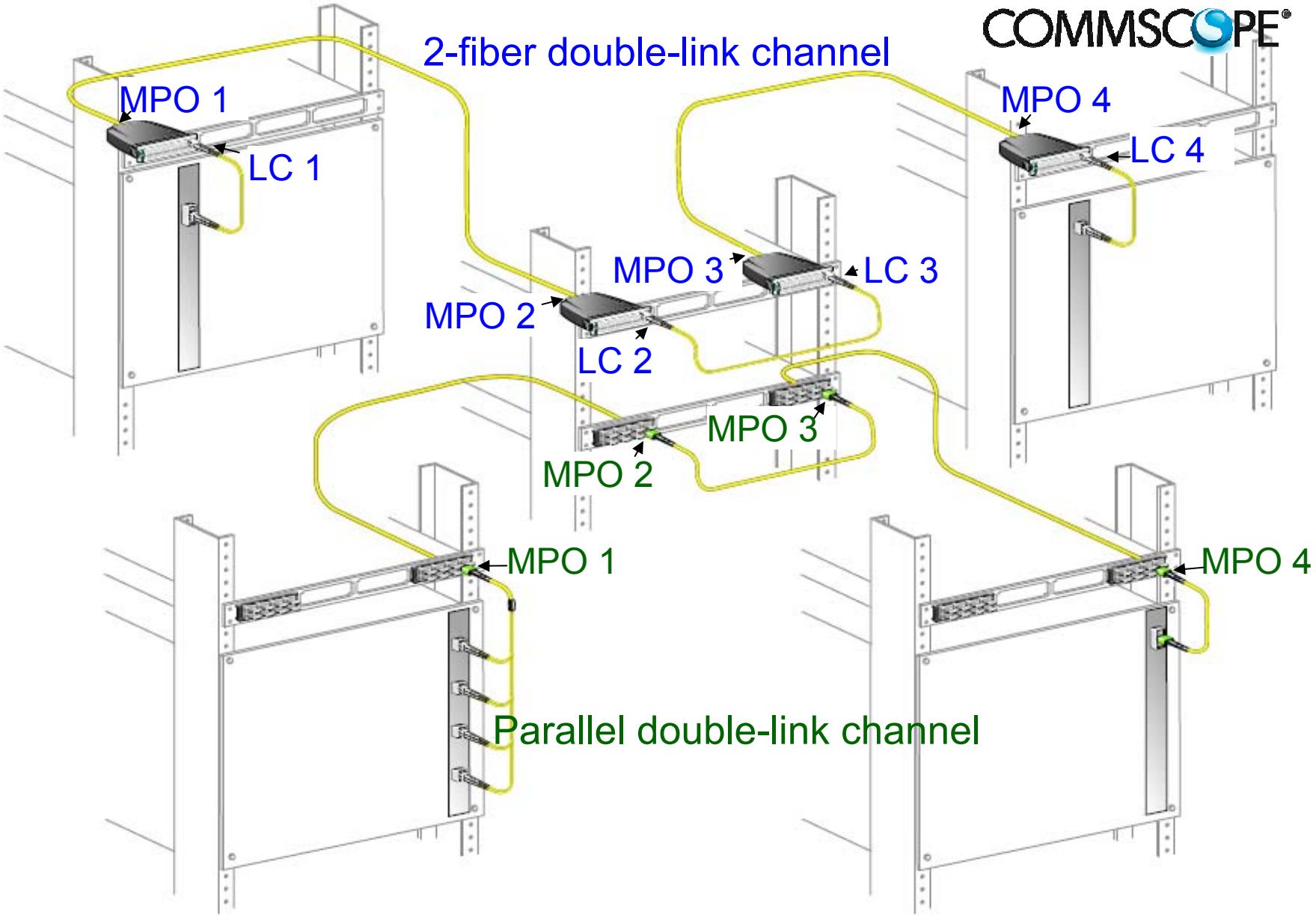
IEEE P802.3bm SMF Ad Hoc

Purpose and Approach

- To define a loss budget that
  - is appropriate for single-mode fiber data center channels up to 500 m in length
  - addresses differences between 2-fiber and parallel optics connectivity
  - supports double-link channels
  - supports the attenuation of cable constructions used inside buildings
- Use statistical approach
  - Following the lead from previous contribution to P802.3ba

Double-link cabling channels

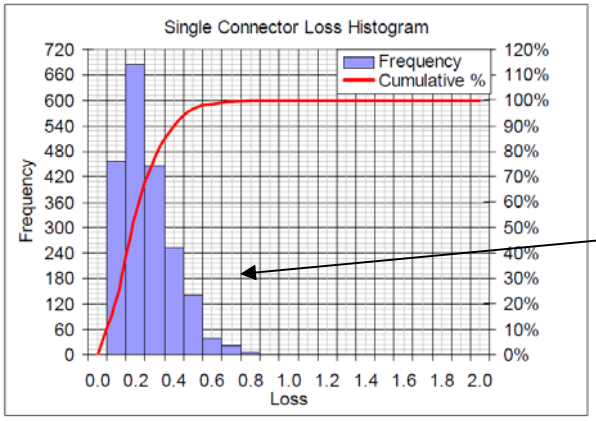


Channel Connectivity Characteristics

- Examining previous diagram we see that
  - 2-fiber channels have 8 connections
    - 4 LCs + 4 MPOs
    - Owing to the use of MPO pre-terminated cabling that employs fan-out cassettes
  - Parallel optic channels have 4 connections
    - 4 MPOs
    - Fan-out cassettes are not used

Connection Insertion Losses (1 of 5)

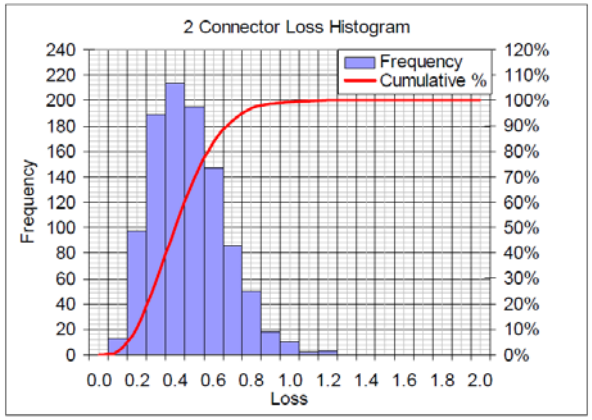
Single connector loss pdf



- mean loss=0.22 dB, s.d.=0.134 dB

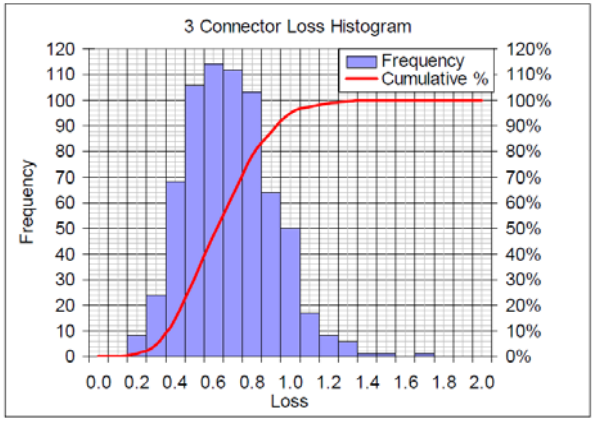
- Contribution king_01_0508 to P802.3ba
  - Insertion loss represented by Rayleigh distribution
  - Employed Monte Carlo method to sum connection losses

2 connectors loss pdf



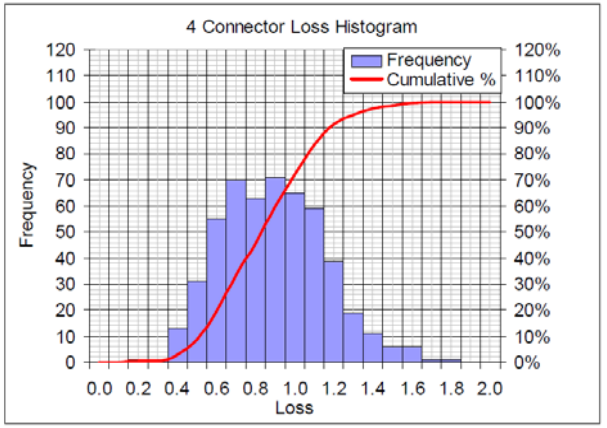
- mean loss=0.421dB, s.d.=0.187dB

3 connectors loss pdf



- mean loss=0.631 dB, s.d.=0.221 dB

4 connectors loss pdf



- mean loss=0.842 dB, s.d.=0.264 dB

Connection Insertion Losses (2 of 5)

Statistical characteristics comparison of king_01_0508 and Normal statistics

# conn.	King_01_0508		Normal Stats	
	Mean	Std. Dev.	Mean	Std. Dev.
1	0.220	0.134	0.220	0.134
2	0.421	0.187	0.440	0.190
3	0.631	0.221	0.660	0.232
4	0.842	0.264	0.880	0.268

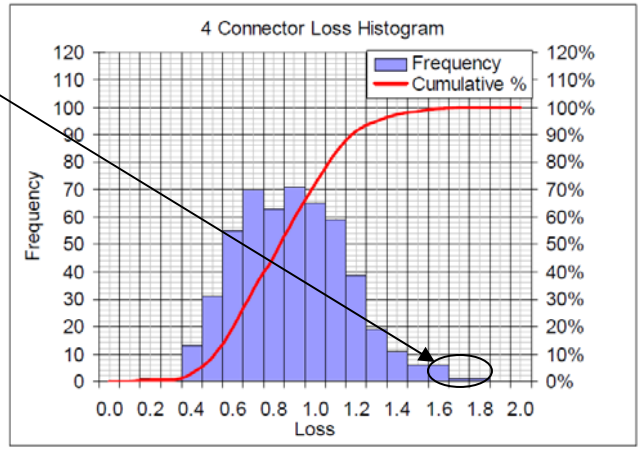
⇦ Start with the same values

- Means and Standard Deviations agree to within 5%
  - Good cross-check
  - Normal statistics can substitute for Monte Carlo simulation
- Normal statistics will be used going forward here
  - Their slightly higher values will help account for the accelerating trend of loss vs. offset not included in king_01_0508

Connection Insertion Losses (3 of 5)

- king_01_0508 asserted that 1.5 dB was sufficient to support 4 multimode MPO connections
  - 1.6% of connections would exceed 1.5 dB
  - Represents +2.5 std. dev. point in distribution
    - 0.842 + 2.5×0.264 = 1.5 dB
  - Represents +2.3 std. dev. in Normal dist.
    - 0.880 + 2.3×0.268 = 1.5 dB

4 connectors loss pdf



- mean loss=0.842 dB, s.d.=0.264 dB
- 95%<1.3dB loss, 98.4%<1.5 dB loss

Accepting Jonathan's assertions, all we need to know are the means and standard deviations for MPOs and LCs.

Sounds trivial, but…

Connection Insertion Losses (4 of 5)

- Connection loss is specified with various terms
  - Typical, average, maximum, sometimes mean & std. dev.
- And differing conditions
  - Random mate to like product
  - When mated to a reference-grade plug
  - When “tuned” (i.e. iteratively clocked for optimum alignment)

But what we need are practical values
for common data center deployments.

So here goes…

Connection Insertion Losses (5 of 5)

- Connection loss should be modeled using random-mate statistics for un-tuned assemblies
  - Random-mate stats represent actual deployment conditions
  - Un-tuned terminations are lower in cost and commonly used in DCs
- Good starting place for single-mode LCs
  - Mean = 0.20 dB; Std. Dev. = 0.15 dB
- Good starting place for single-mode MPOs
  - Mean = 0.35 dB; Std. Dev. = 0.25 dB

Using these values at +2.5 standard deviations we get:

2.65 dB for 4 MPOs
3.66 dB for 4 MPOs + 4 LCs

Note: these values are ~0.1 dB higher than what I stated on the reflector because I had used 2.3 standard deviations, but should have used 2.5 as in king_01_0508

Adding Cable Attenuation

- TIA 568 and ISO 11801 (and their related data center cabling counterparts) are predominantly used for premises and data center cabling specifications
  - Both specify single-mode cable attenuation that is dependent on construction
- TIA:
  - outside plant: 0.5 dB/km max @ 1310 nm, 1550 nm
  - indoor/outdoor: 0.5 dB/km max @ 1310 nm, 1550 nm
  - indoor: 1.0 dB/km max @ 1310 nm, 1550 nm
- ISO:
  - OS1 (original spec that included inside plant): 1.0 dB/km max @ 1310 nm, 1550 nm
  - OS2 (added to support 10 km outside plant applications): 0.4 dB/km max @ 1310 nm, 1383 nm, 1550 nm
- Advisable to use <u>at least</u> 0.5 dB/km for cabling that will often serve indoor deployments

Adding 0.25 dB for 500 m of cable attenuation to connection loss gives:

2.90 dB for parallel optics

3.91 dB for 2-fiber channels

These are recommended minimum budgets. Greater budgets will enable more flexibility in channel design regarding topologies and cable type.

Closing Perspectives

- The 100G-LR4 spec provides 6.3 dB of loss budget for 10 km reach
- These 500 m loss budgets are substantially smaller
  - Should enable cost reduction
- However, if trimmed further they will lose utility
  - Our efforts will be in vein
- Do not follow precedent of allocating only 2 dB connection and splice loss
  - Worked in past because substantial power was also allocated to overcome attenuation of cabling, e.g. at least 4 dB for 10 km reach
    - This attenuation budget is traded for insertion loss budget within data centers
    - This luxury will not be afforded to the short-reach solutions we are defining

Q & A