Loss Budgeting for 400GE Channels

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Purpose and Approach

- Lay groundwork (concepts, terminology)
- Define a loss budget that
  - is appropriate for each of the four “reach” objectives of the project
    - At least 100 m over MMF
    - At least 500 m over SMF
    - At least 2 km over SMF
    - At least 10 km over SMF
  - addresses differences between 2-fiber and parallel optics connectivity
  - supports double-link channels within a building
  - supports triple-link channels running between buildings
  - supports the higher attenuation of SM cable constructions used inside buildings
- Use statistical approach
  - Following the lead from previous contributions to P802.3ba, 3bm

Attributions

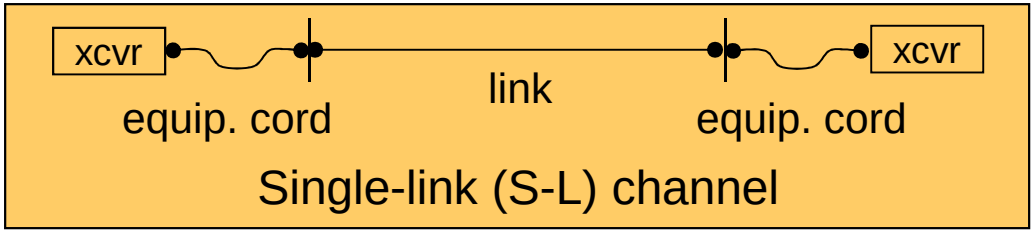
- References to prior related contributions
  - anslow_03_1107.xls / Fibre_characteristics_V_3_0.xls
  - king_01_0508
    “Connector loss budgeting methodology for parallel multimode PMDs”
  - kolesar_02_0911
    “Fiber Cabling Trends in Data Centers”
  - kolesar_02_0313
    “Loss Budgeting for Single-mode Channels”

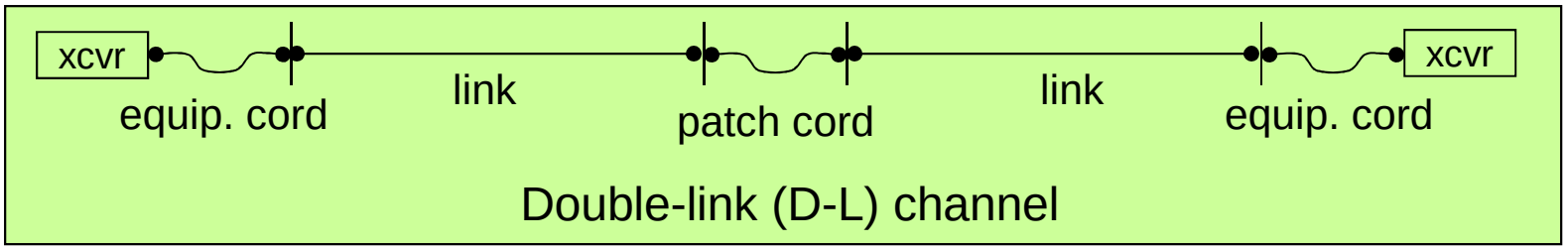
Cabling Terminology

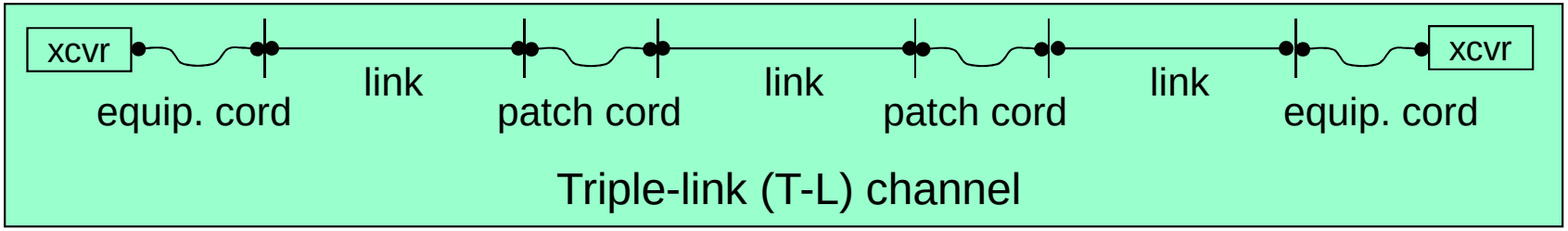
Cords – used to administer connectivity from:
1. equipment (transceivers) to patch panel, called equipment cords
2. patch panel to patch panel, called patch cords

Links – permanent cabling between two patch panels

Channels – complete end-to-end connectivity between equipment consisting of concatenations of cords and permanent link(s)

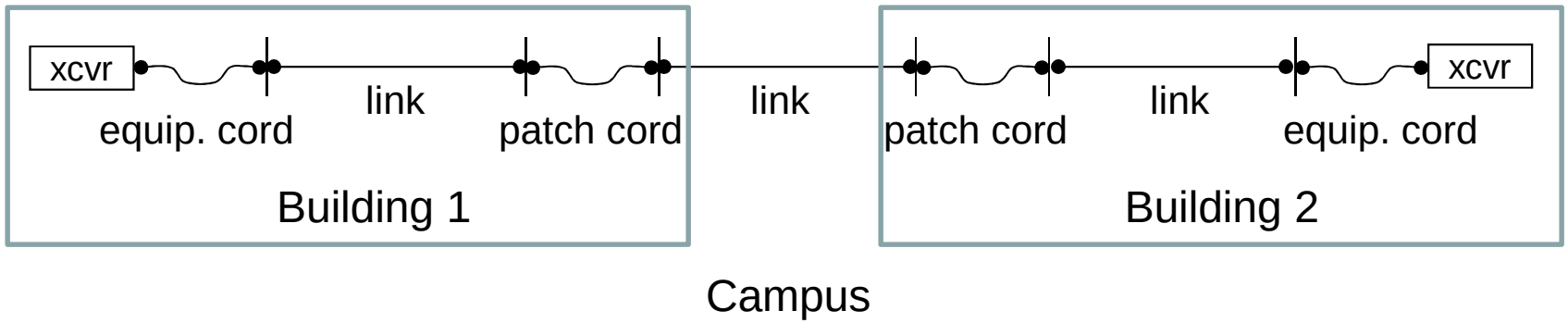




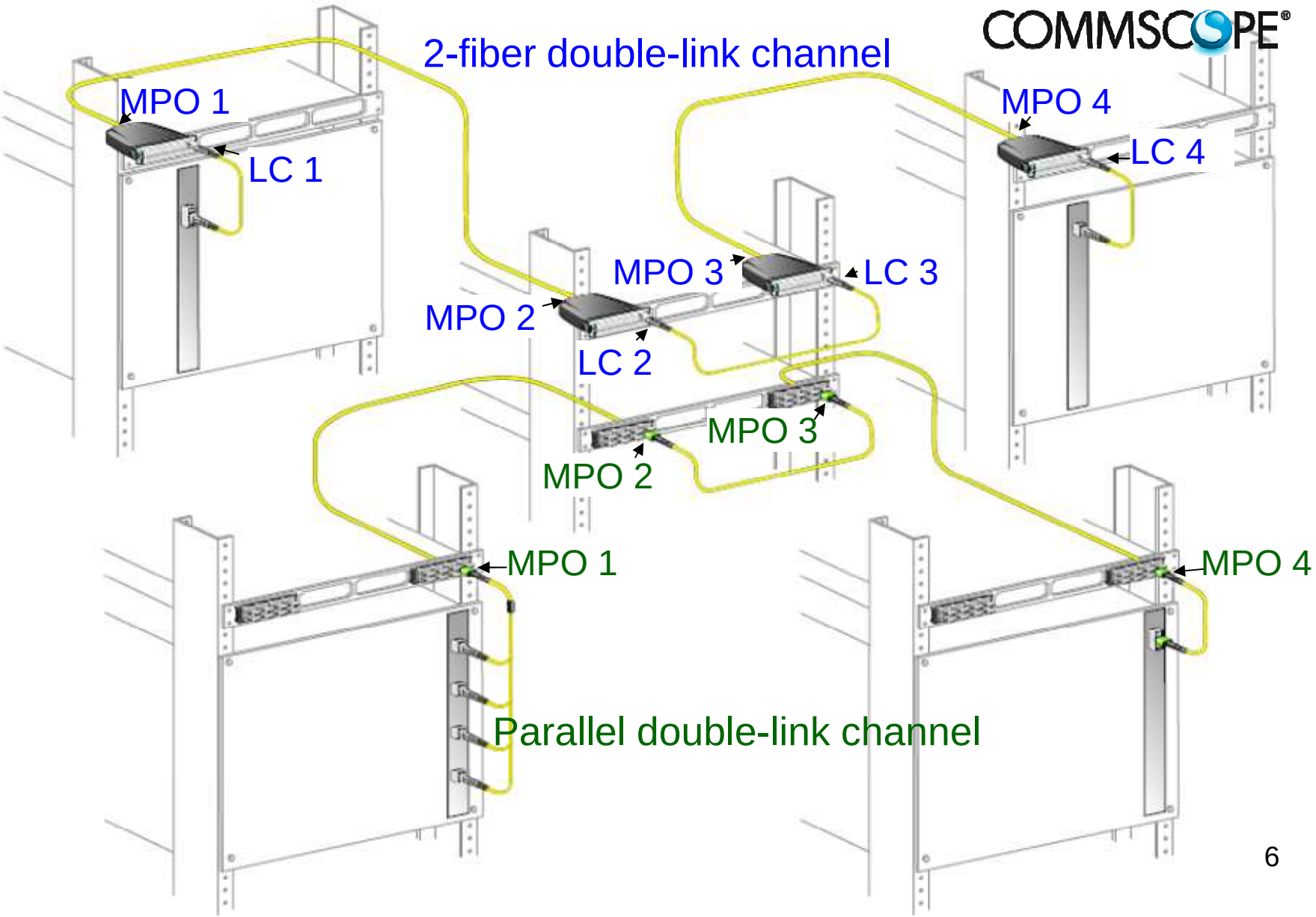


Triple-link Channels – Really?!

- Previous contributions modeled single-link and double-link
  - Suitable for topologies within a building (≤ 500 m)
- ≥ 2 km reach aims to span between buildings
  - Introduces additional campus link
- Supporting triple-link channels permits
  - One link in each building plus campus link

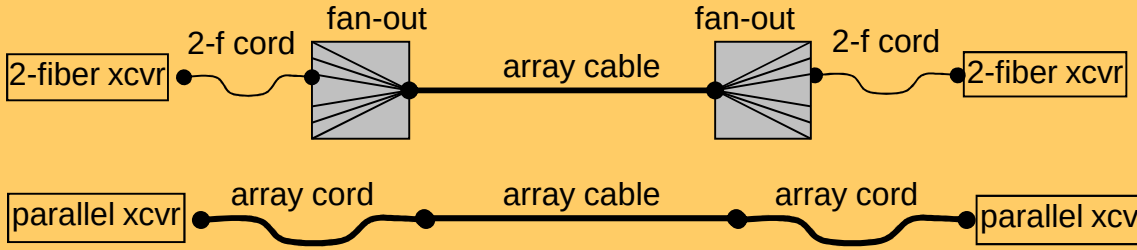


Double-link cabling channel examples



Common channel implementations

- Single-link

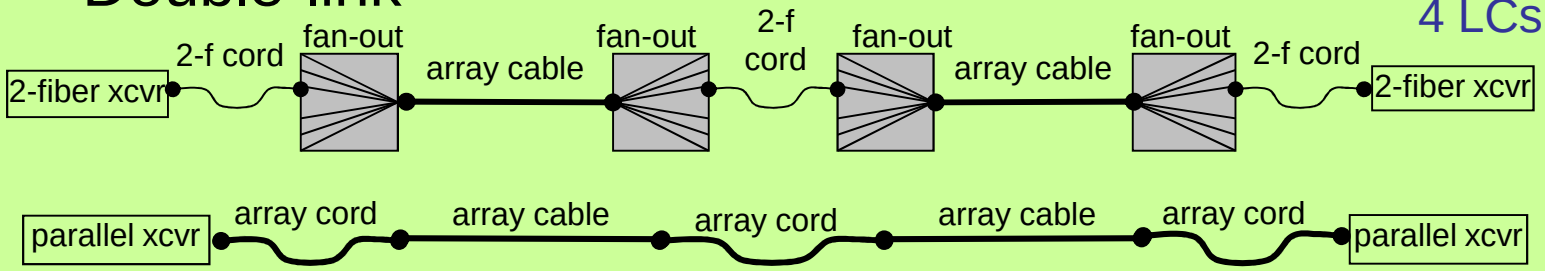


Connection & Splice Tally*

2 LCs + 2 MPOs

2 MPOs

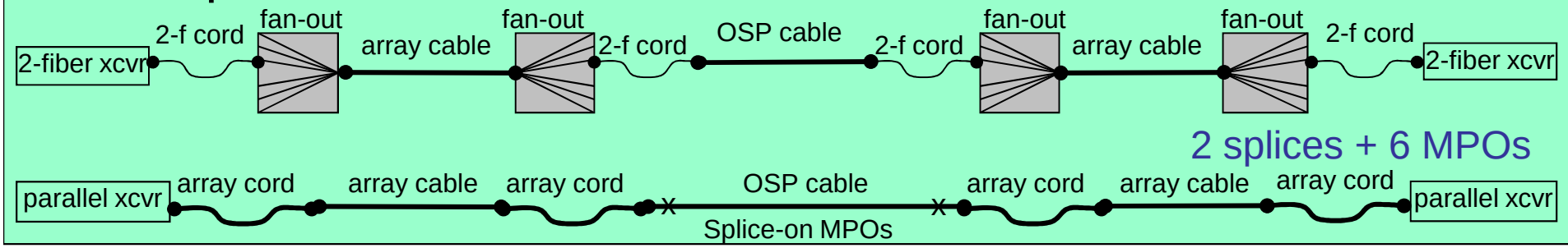
- Double-link



4 LCs + 4 MPOs

4 MPOs

- Triple-link



6 LCs + 4 MPOs

2 splices + 6 MPOs

* Connections to transceivers (at MDI) are not counted in standard loss budget

Channel Connectivity Characteristics

- Typical channel connection & splice count summary

Channel	Transmission	# LCs	# MPOs	# Splices*
Single-link	2-fiber	2	2	0
	Parallel fiber	0	2	0
Double-link	2-fiber	4	4	0
	Parallel fiber	0	4	0
Triple-link	2-fiber	6	4	0
	Parallel fiber	0	6	2

* Other splices along outside plant (OSP) cabling subsequently included in cable attenuation model via anslow_03_1107.xls / Fibre_characteristics_V_3_0.xls

SM Connection & Splice Insertion Loss

- Following approach in kolesar_02_0313 & king_01_0508
  - Calculate using normal statistics at +2.5 standard deviations
- 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
- Good starting place for single-mode fusion splices
  - Mean = 0.07 dB; Std. Dev. = 0.05 dB

Using these values at +2.5 standard deviations we get:

Channel	Transmission	# LCs	# MPOs	# splices	IL (dB)
Single-link	2-fiber	2	2	0	2.13
	Parallel fiber	0	2	0	1.58
Double-link	2-fiber	4	4	0	3.66
	Parallel fiber	0	4	0	2.65
Triple-link	2-fiber	6	4	0	4.15
	Parallel fiber	0	6	2	3.78

Cable Attenuation in Structured Cabling Standards

- 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 (OSP): 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 OSP applications): 0.4 dB/km max @ 1310 nm, 1383 nm, 1550 nm
- Advisable to use at least 0.5 dB/km for cabling that will serve indoor deployments
- Must separately account for splice losses along long lengths of OSP cabling

Cable Attenuation Budgets

- Indoor / Outdoor cabling length mixtures for reach objectives and attenuations
  - MM attenuation per IEEE 802.3 Link Model at 850 nm
  - SM attenuation per anslow_03_1107.xls / Fibre_characteristics_V_3_0.xls at 1310 nm

Reach Objective ≥	Indoor Length	Outdoor Length	Indoor Atten.	Outdoor Atten.	Total Atten.
100 m MM	100 m	0 m	0.35 dB	0 dB	0.35 dB
500 m SM	500 m	0 m	≥ 0.25 dB	0 dB	≥ 0.25 dB
2,000 m SM	1,000 m	1,000 m	≥ 0.50 dB	0.42 dB	≥ 0.92 dB
10,000 m SM	1,000 m	9,000 m	≥ 0.50 dB	3.76 dB	≥ 4.26 dB

Total Loss Budgets

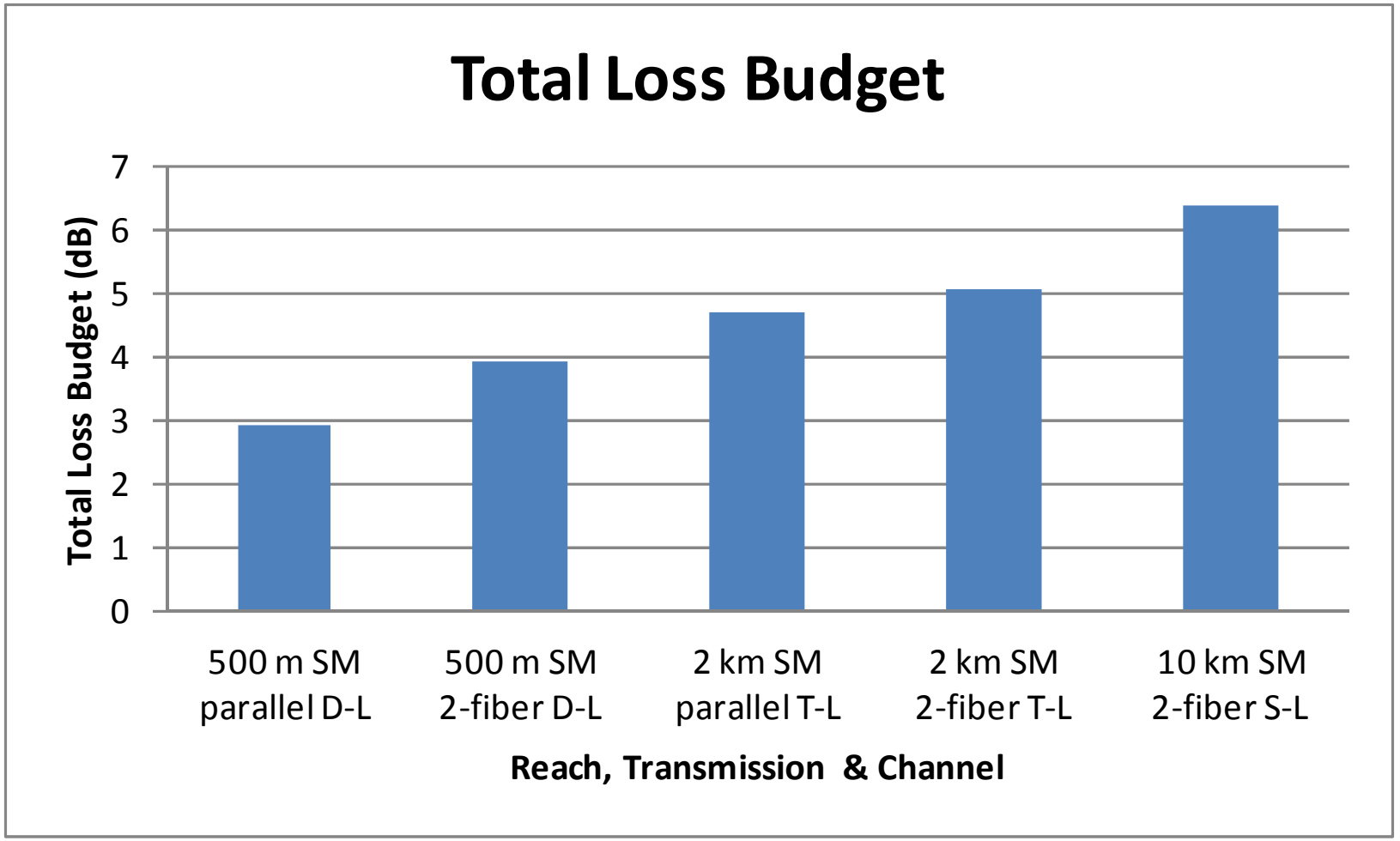
- Combining insertion losses and attenuations

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

Notes:

1. MM budgets follows traditional IEEE 802.3 allocations.
2. SM budgets combine models presented herein.
3. These are recommended minimum budgets. Greater budgets will enable more flexibility in channel design regarding topologies and cable type.

Total SM Loss Budgets at a Glance



Summary & Closing Perspectives

- 100G-LR4 provides 6.3 dB loss budget for 10 km reach
  - Supports single-link channels at maximum reach
  - Supports multi-link channels with reach reduction
- 2 km budget needs ~5 dB for loss
  - Moderately (~1.3 dB) smaller than for 10 km
  - Much budget (~4 dB) devoted to triple-link connectivity support
- 500 m budgets need ~3 dB for parallel or ~4 dB for 2-fiber
  - Substantially (~2.3 to 3.3 dB) smaller than for 10 km
  - Should enable cost reduction
- Trimming loss budgets further 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 these shorter-reach solutions

Q & A