Applications on Fiber:

How to Guarantee with the New Architectures and the Strict Loss Budgets

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Applications

How does it work ?

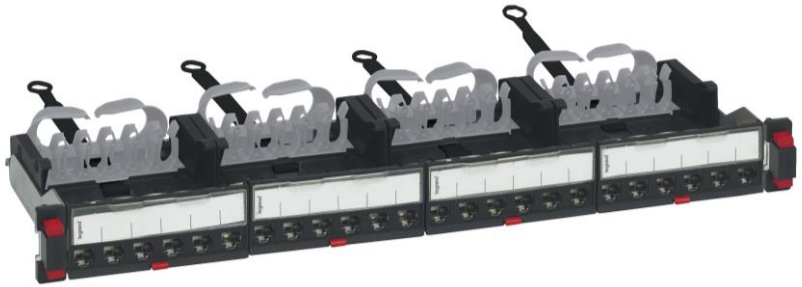
How does it work ?

- Data are carried by **light absence or presence of light** ("0" and "1")*
- An interface, **transceiver opto electric**, change the light signal into electric signal
- Need of **2 fibers** for emission and reception

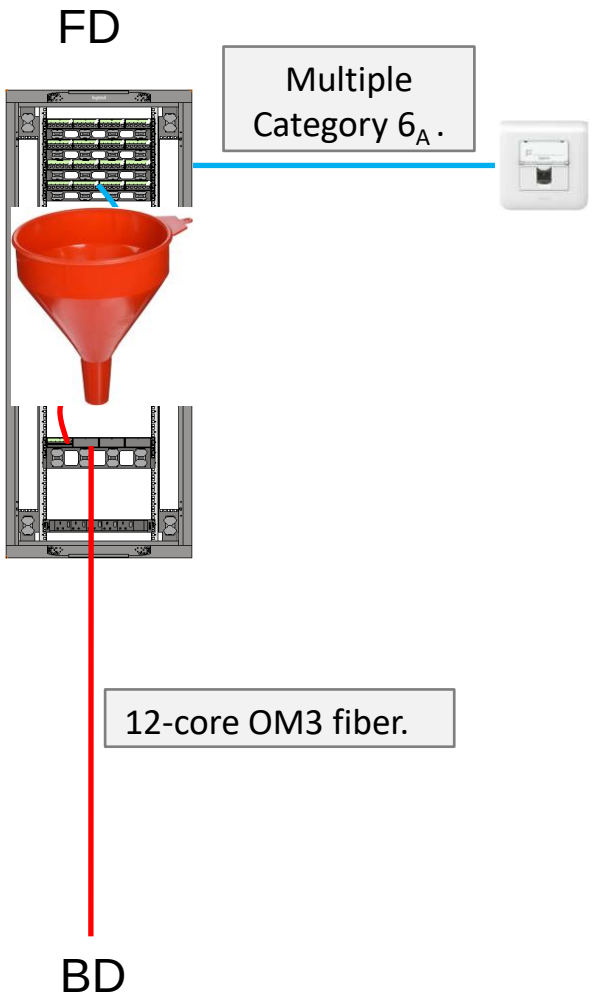
**Only recent technologies allow "levels "of light (PAM4)*

Horizontal vs. Vertical

Horizontal, Copper (4pair cables)		Backbone, Multimode fiber (2-core channels)	
Data Rate	Typical Cabling	Data Rate	Typical Cabling
10Mbps	Category 3	100Mbps	OM1
100Mbps	Category 5	1 000Mbps	OM2
1 Gbps	Category 6	10 000Mbps	OM3
10 Gbps	Category 6_A	?	?



The Bottleneck



The horizontal is 10G capable, yet most backbone installed today are limited to 10G. (OM3 duplex to 300m for example)

Let's consider the evolution of the needs:
More videoconferencing on larger screens of better definition
More cloud replication
More virtualization

WIFI-6 = 9.6Gbps

The evolution of WIFI is the most critical: a single access point, can require a 10G cabled connection.

A 10G backbone is not sufficient !

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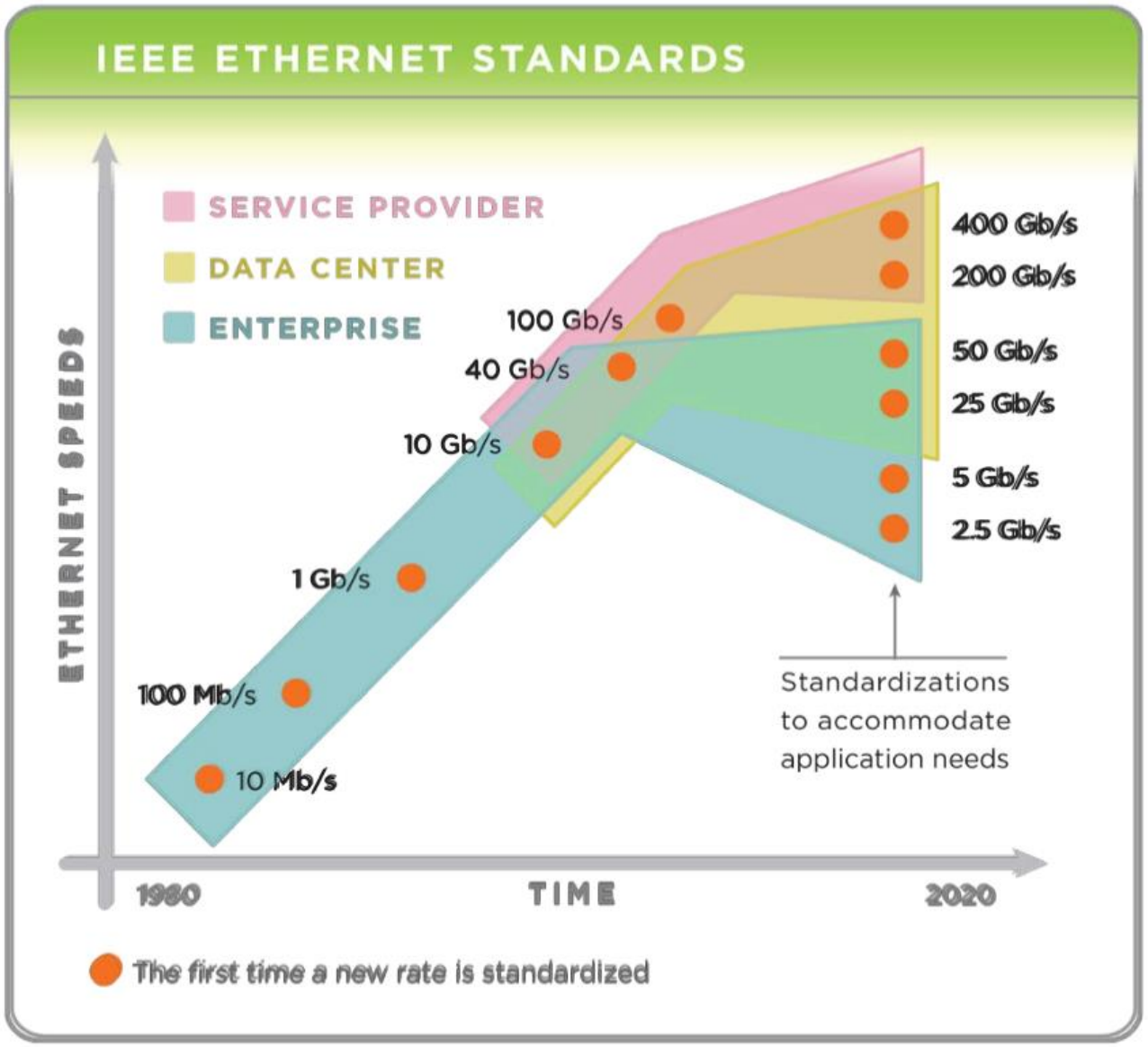
Trends



Source: Ethernet Alliance

Datarate Objectives

	LAN	Datacenter
Horizontal	≥ 10 Gbps	≥ 25 Gbps
Backbone	≥ 50 Gbps	≥ 100 Gbps

Target minimum performance for a new installation

Abandoning the ratio of 1:10:

LAN:

Not many ports are running full capacity
Provide more backbone connections

Datacenter:

New mesh topology, leading to more backbone connections.

Load balancing

Fiber Applications

Duplex applications, functioning on Duplex LC

Duplex	OM3	OM4	OM5	OS1a	OS2
1Gbps	550m	550m	550m	2km	5km
10Gbps	300m	400m	400m	2km	10km
25Gbps	70m	100m	100m	2km	10km
40Gbps	240m	350m	440m	2km	10km
50Gbps	70m	100m	100m	2km	10km
100Gbps	70m	100m	150m	2km	10km
200Gbps				2km	10km
400Gbps				2km	10km

Standard
Mutli-Source Agreement
Not available

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Fiber Applications

Parallel optics applications, functioning on 12-core MPO

Parallel	OM3	OM4	OM5	OS1a	OS2
10Gbps					
25Gbps					
40Gbps	100m	150m	150m		
50Gbps					
100Gbps	70m	100m	100m	500m	500m
200Gbps	70m	100m	100m	500m	500m
400Gbps	100m	100m	150m	500m	500m

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Selecting application compatibility

Duplex	OM3	OM4	OM5	OS1a	OS2
1Gbps	550m	550m	550m	2km	5km
10Gbps	300m	400m	400m	2km	10km
25Gbps	70m	100m	100m	2km	10km
40Gbps	240m	350m	440m	2km	10km
50Gbps	70m	100m	100m	2km	10km
100Gbps	70m	100m	150m	2km	10km
200Gbps				2km	10km
400Gbps				2km	10km

Parallel	OM3	OM4	OM5	OS1a	OS2
10Gbps					
25Gbps					
40Gbps	100m	150m	150m		
50Gbps					
100Gbps	70m	100m	100m	500m	500m
200Gbps	70m	100m	100m	500m	500m
400Gbps	100m	100m	150m	500m	500m

1200 €
Singlemode

200€
Multimode

1 generation of cabling goes through multiple generations of active.

Chose Multimode fiber whenever possible to save on the active.

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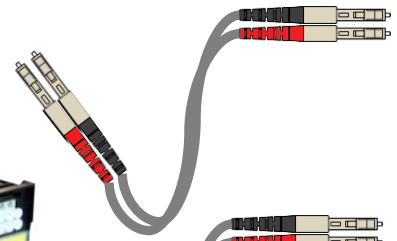
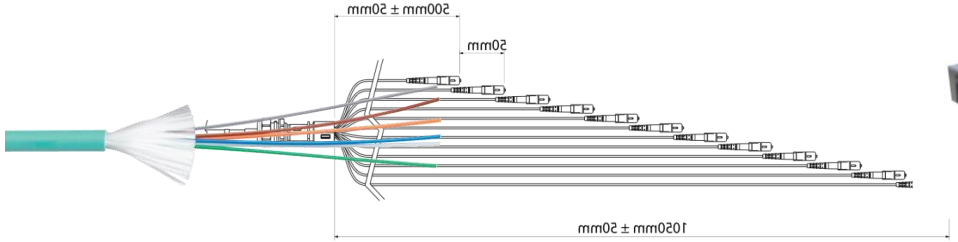
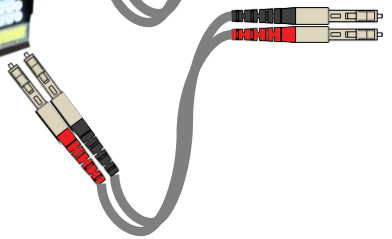
Connection Methods

Option 1: Splice



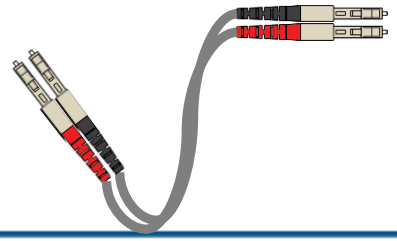
Option 2: Pre-term.





Option 3: MPO

Option 4: MPO



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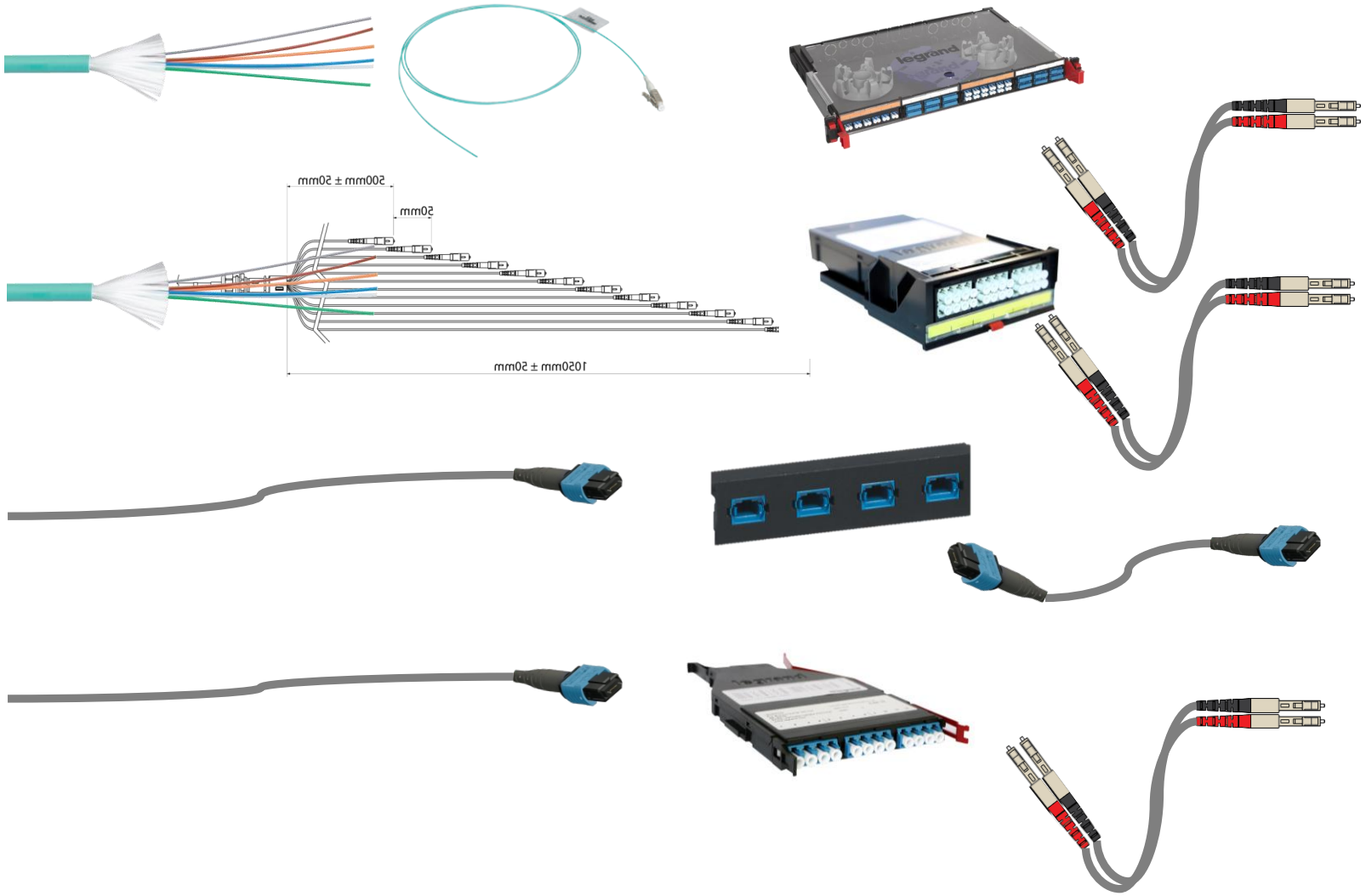
Performance per Type, Multimode



OM4:
- 10 to 50Gbps to 100m
- 10 to 100G (multi-source) to 100m

OM5
- 10 to 50Gbps to 100m
- 10 to 100G (multi-source) to 150m
- Future WDM 4x100G to 100m?

OM4:
- 40Gbps to 400G to 100m

OM5:
- 40 to 400G (multi-source) to 150m
- Future WDM 4x400G to 100m?

Allow duplex and breakout today, parallel tomorrow:
The best of both !!

Singlemode allows all, but at a higher cost. Parallel optics being intermediate

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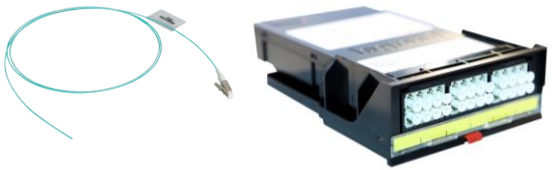
Flexibility and Future Proof

The use of MPO trunking with LC cassettes opens many opportunities as it allows:

- duplex,
- then breakout be replacing one cassette by an MPO coupler,
- then parallel optics by both cassette by an MPO couplers.

Beyond 500m, there is only singlemode with duplex LC.



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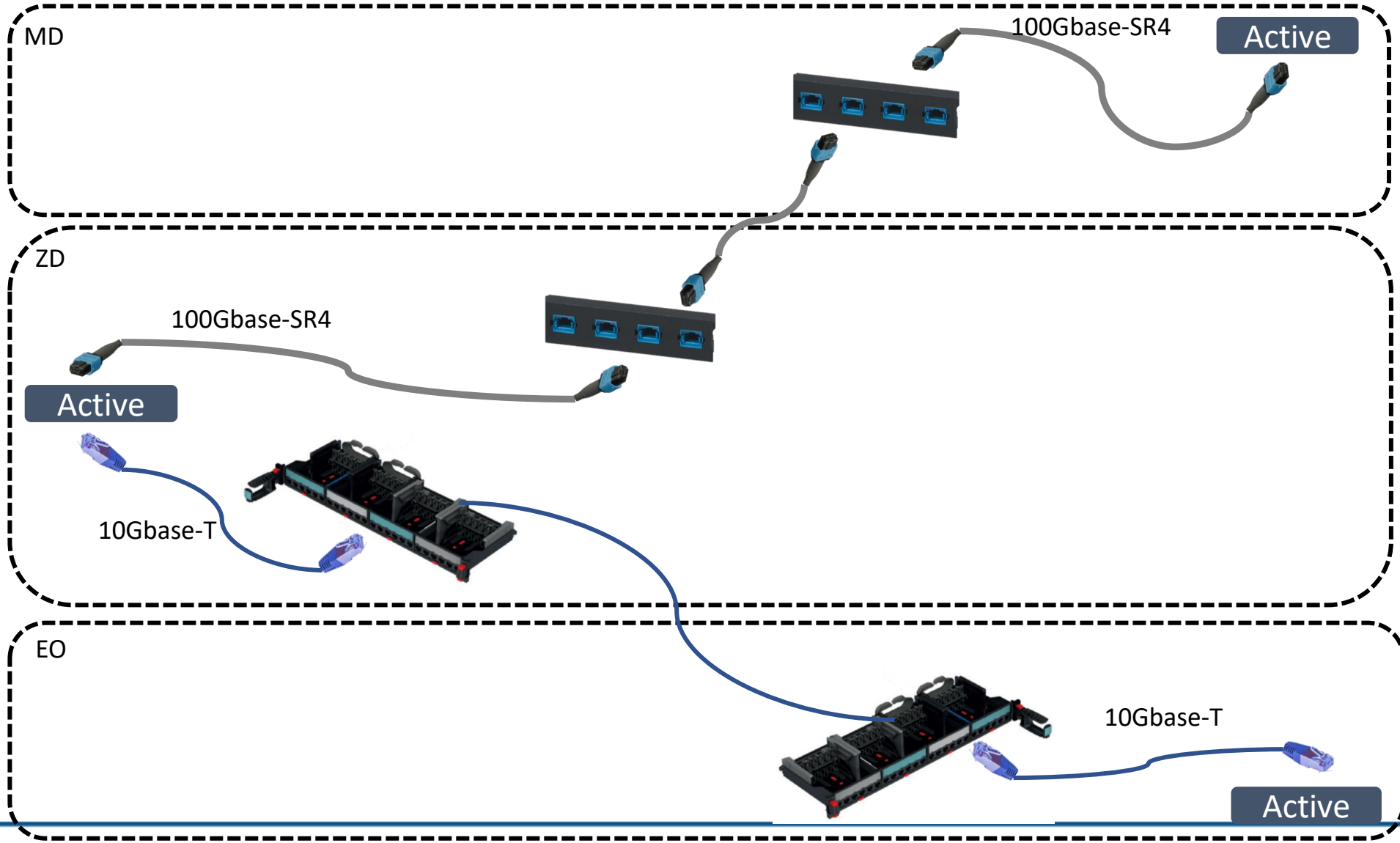
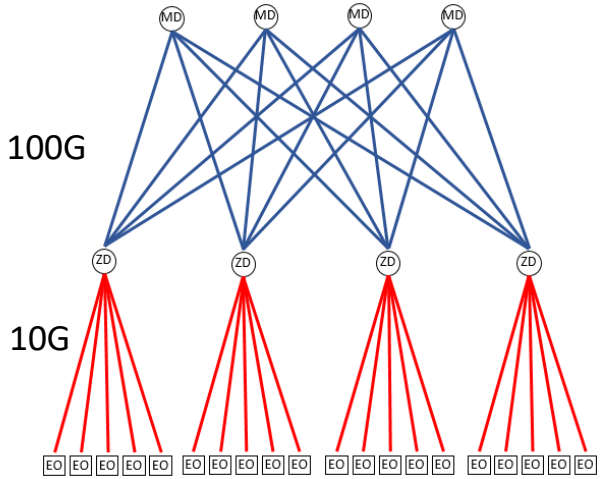
Architectures: Datacenters

Example: 10Gbase-T to the EO





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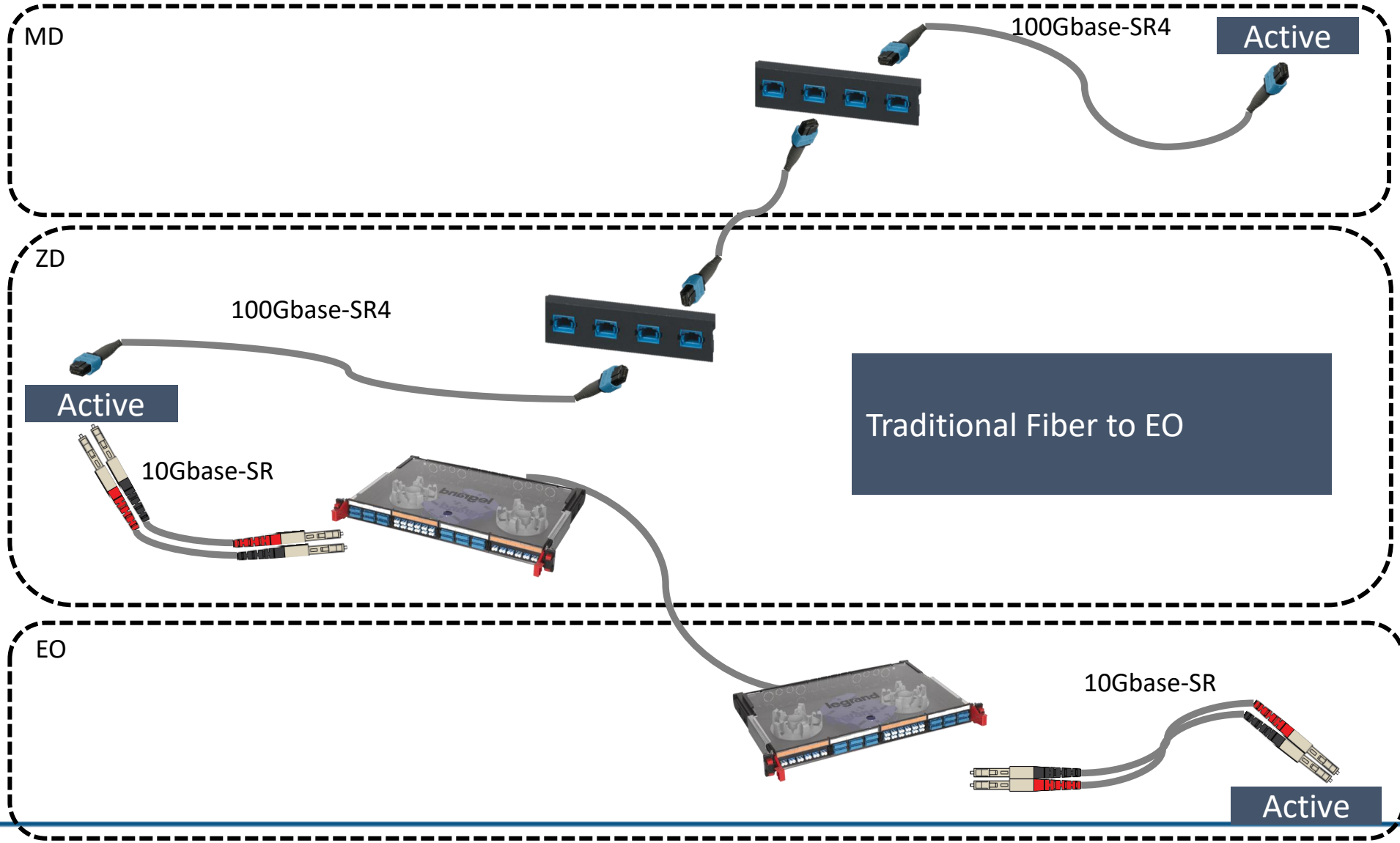
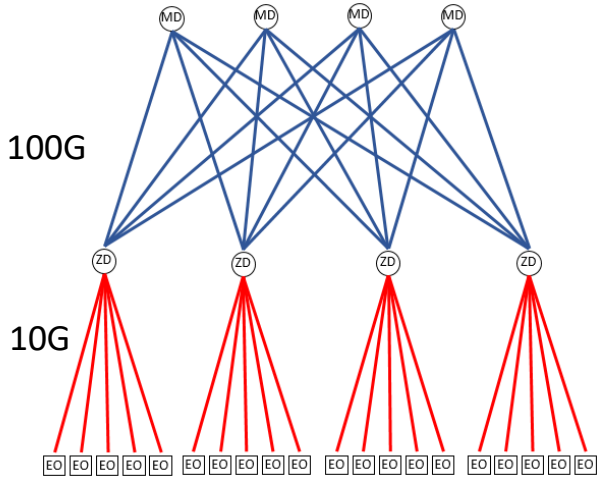
Example: 10Gbase-SR to the EO





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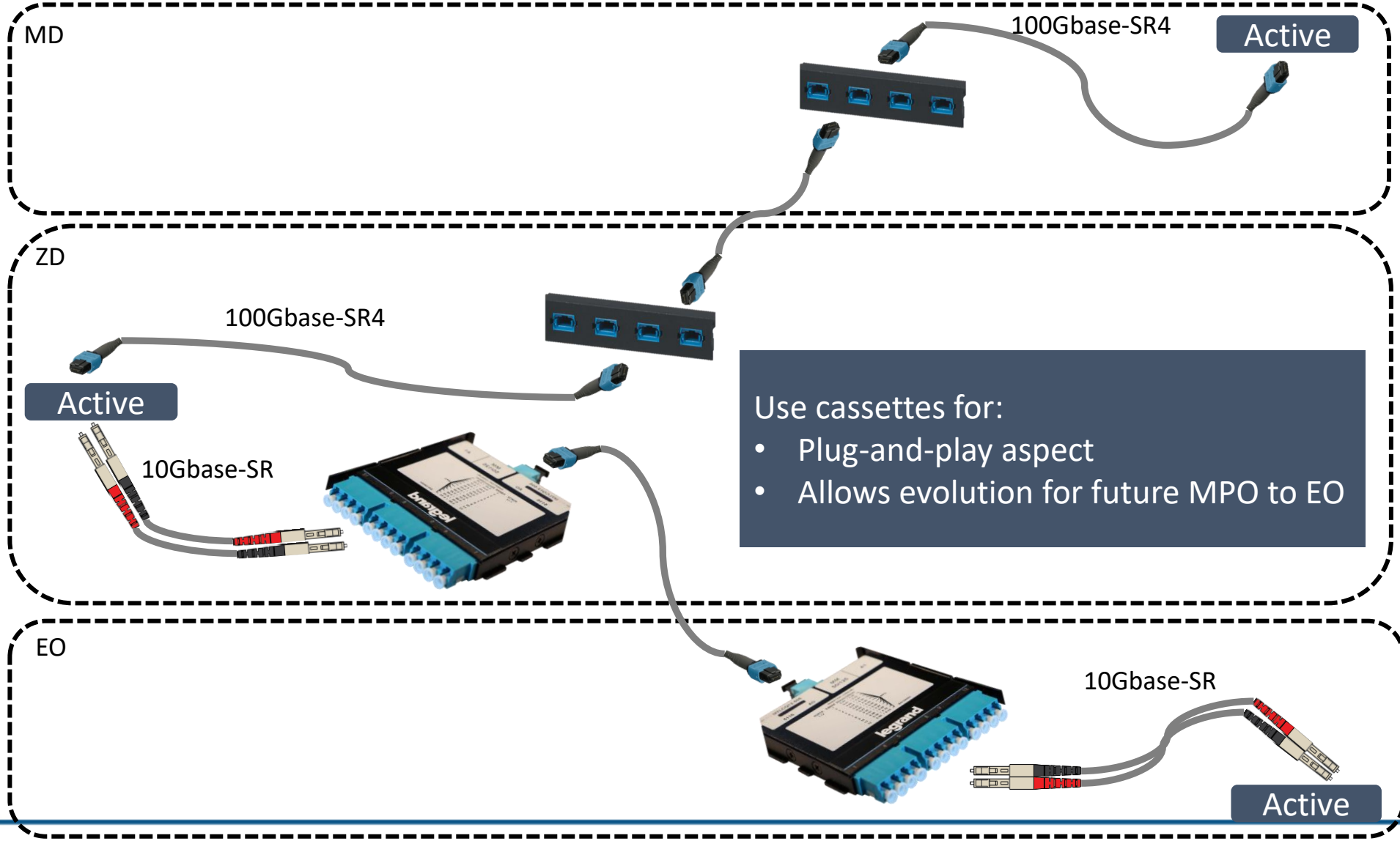
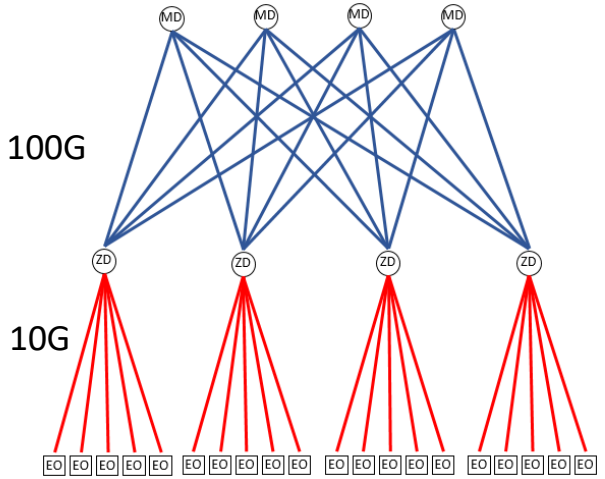
Example: 10Gbase-SR to the EO





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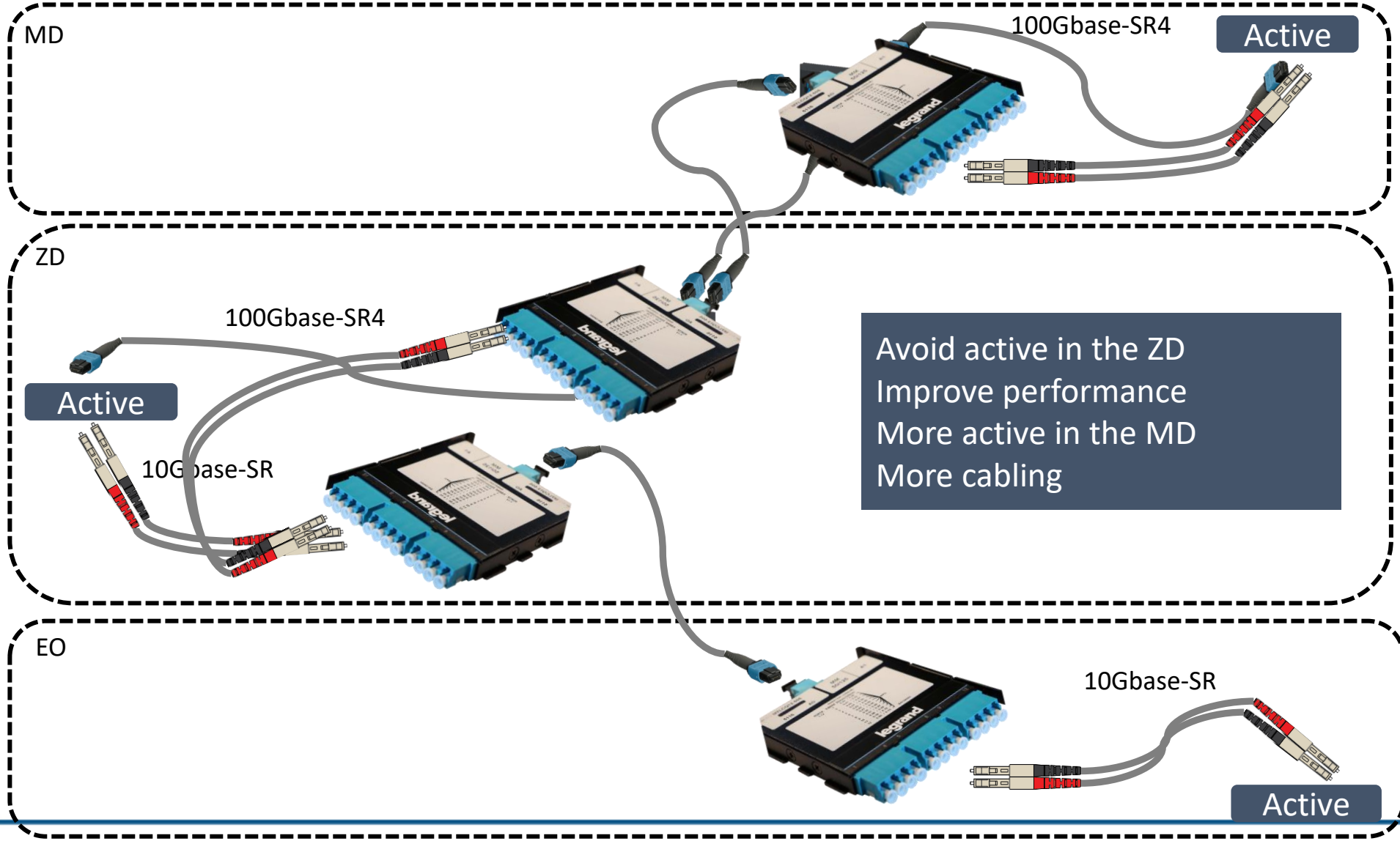
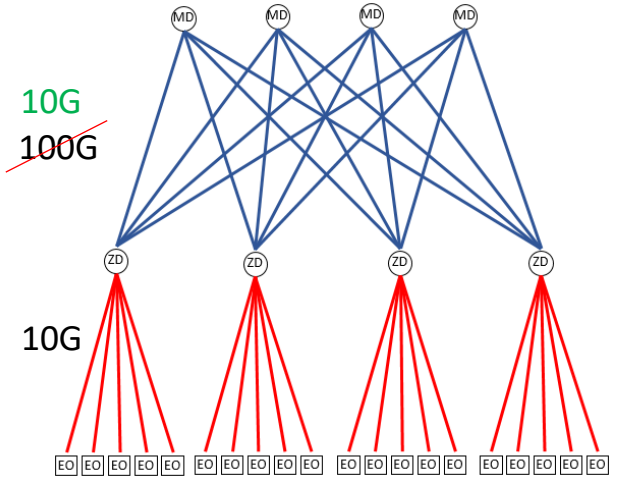
Example: 10Gbase-SR to the EO





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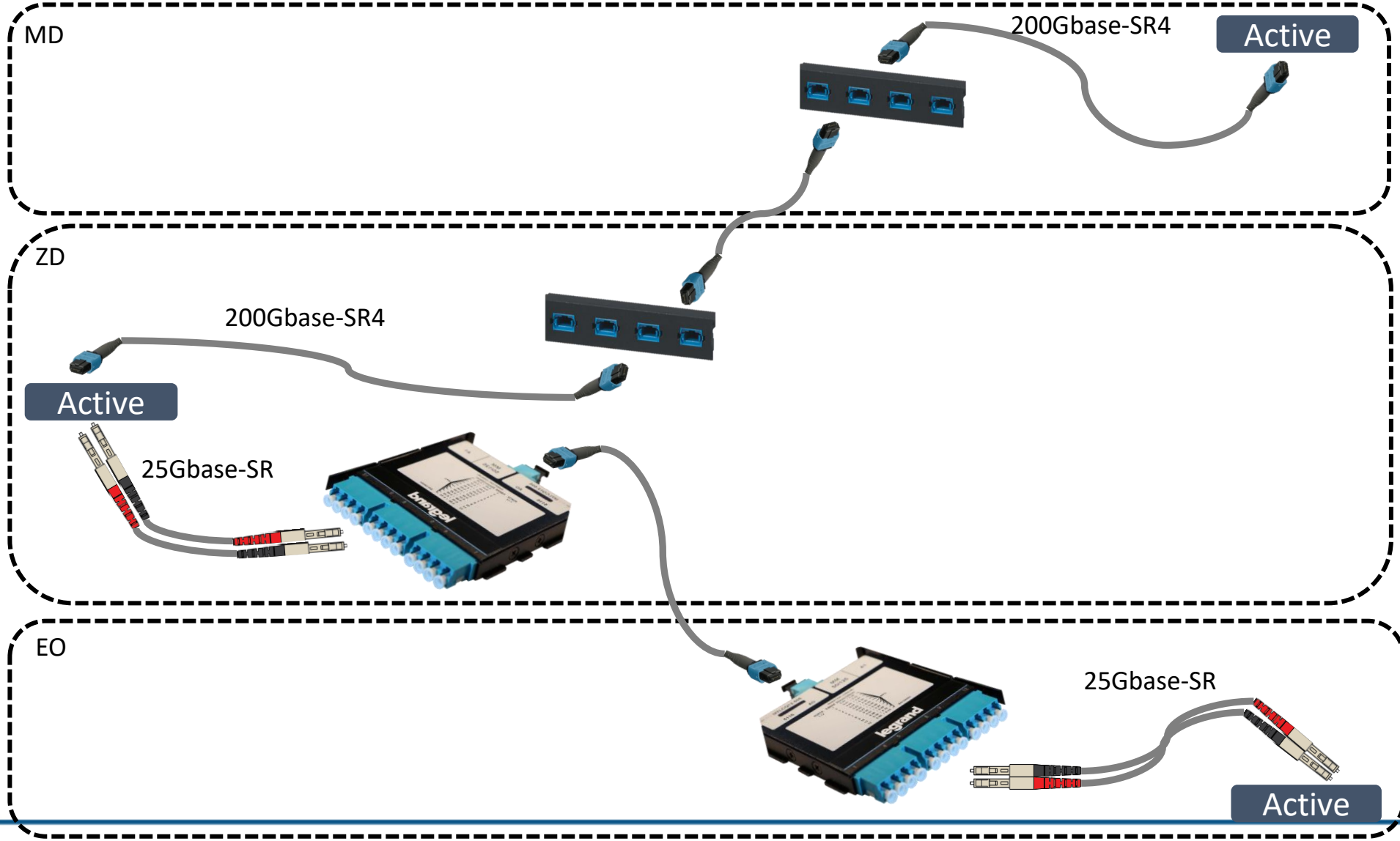
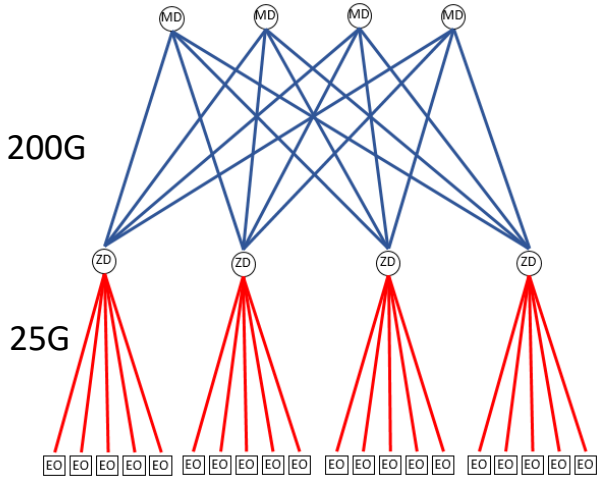
Example: 25Gbase-SR to the EO





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Example: 50Gbase-SR to the EO

MD

200Gbase-SR4

Active

Breakout mode 4 x 50G

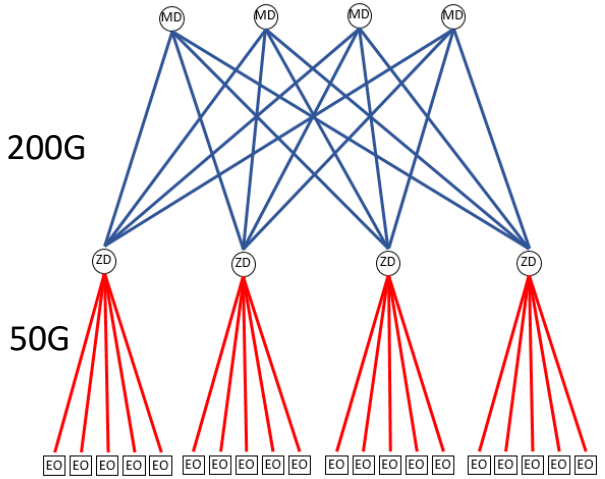
ZD

200Gbase-SR4

Active

50Gbase-SR

In breakout mode, consider using 8-core cassettes



EO

Max 4 per cassette
50Gbase-SR

Active

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Example: 100Gbase-SR4 to the EO

Draft IEEE 802.3dB:
100G on duplex
Multimode
(Designed for breakout 4 x 100G)

MD

100Gbase-SR4

Active

ZD

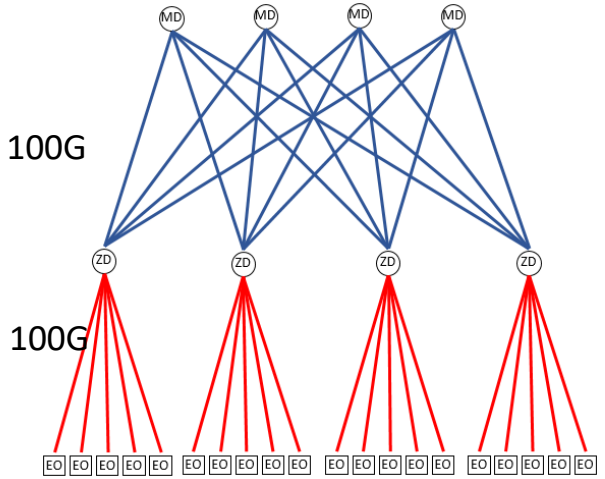
100Gbase-SR4

It’s also possible to connect directly servers in MPO.

EO

100Gbase-SR4

Active



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Example: 100Gbase-DR to the EO

If you need more than 100m distance

MD

400Gbase-DR4

Active

Breakout mode 4 x 100G

ZD

400Gbase-DR4

Active

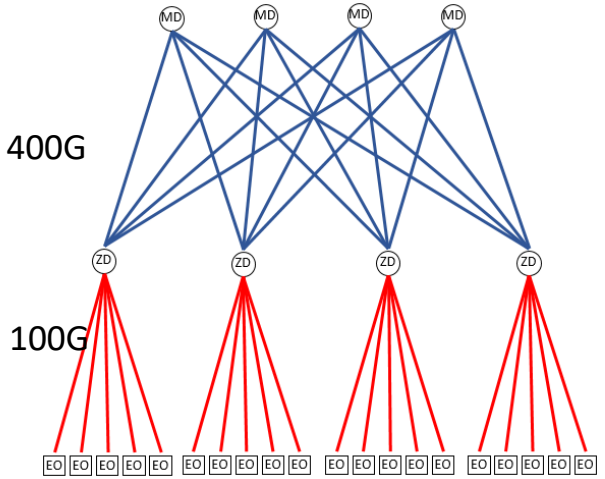
100Gbase-DR

You could also use singlemode

EO

100Gbase-DR

Active



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Applications Limits

Application Loss Limits :Multimode

	Application	Fiber Type	Maximum Distance	Maximum Channel Loss
2-core applications cable with SC, LC or other duplex connectors	10GBASE-SR	OM3	300m	2.6dB
		OM4 / OM5	400m	2.6dB
	25GBASE-SR	OM3	70m	1.8dB
		OM4 / OM5	100m	1.9dB
	40G-SWDM4(1)	OM3	240m	2.1dB
		OM4	350m	2.5dB
		OM5	440m	2.5dB
	50GBASE-SR	OM3	70	1.8dB
		OM4 / OM5	100	1.9dB
	100G-BiDi(1)	OM3	70m	1.8dB
		OM4	100m	1.9dB
		OM5	150m	2.0dB
	100G-SWDM4(1)	OM3	70m	1.8dB
		OM4	100m	1.9dB
		OM5	150m	2.0dB
4-core applications	100GBASE-SR2	OM3	70m	1.8dB
		OM4 / OM5	100m	1.9dB
8-core applications Typicaly MPO	40GBASE-SR4	OM3	100m	1.9dB
		OM4 / OM5	150m	1.5dB
	100GBASE-SR4	OM3	70m	1.8dB
		OM4 / OM5	100m	1.9dB
	200GBASE-SR4	OM3	70m	1.8dB
		OM4 / OM5	100m	1.9dB
	400G-BD4.2(1)	OM3	70m	1.8dB
		OM4	100m	1.9dB
		OM5	150m	2.0dB
	400GBASE-SR4.2	OM3	70m	1.8dB
		OM4	100m	1.9dB
		OM5	150m	2.0dB
16-core applications Typicaly MPO	400GBASE-SR8	OM3	70m	1.8dB
		OM4 / OM5	100m	1.9dB
20-core applications Typicaly MPO	100GBASE-SR10	OM3	100m	1.9dB
		OM4 / OM5	150m	1.5dB
32-core applications Typicaly MPO	400GBASE-SR16	OM3	70m	1.9dB
		OM4 / OM5	100m	1.9dB

(1): Not an IEEE standard. Application available as multi-source agreement

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Application Loss Limits: Singlemode

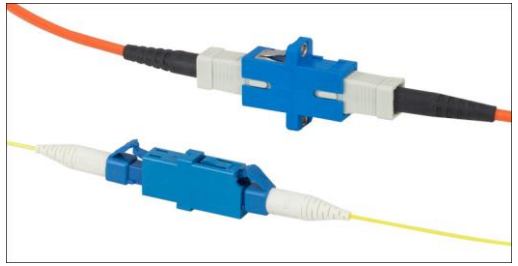
	Application	Fiber Type	Maximum Distance	Maximum Channel Loss
2-core applications cable with SC, LC or other duplex connectors	10GBASE-LX4	OS2	10km	6.6dB
	10GBASE-LR	OS2	10km	6.3dB
	25GBASE-LR	OS2	10km	6.3dB
	40GBASE-FR	OS1a / OS2	2km	4.0dB
	40GBASE-LR4	OS2	10km	6.37dB
	50GBASE-FR	OS1a / OS2	2km	4.0dB
	50GBASE-LR	OS2	10km	6.3dB
	100GBASE-FR1(1)	OS1a / OS2	2km	4.0dB
	100GBASE-LR1(1)	OS2	10km	6.3dB
	100GBASE-LR4	OS2	10km	6.3dB
	200GBASE-FR4	OS1a / OS2	2km	4.0dB
	200GBASE-LR4	OS2	10km	6.3dB
	400G-CWDM8-2(2)	OS2	2km	4.0dB
	400G-CWDM8-10(2)	OS2	10km	6.3dB
	400GBASE-FR4(1)	OS1a / OS2	2km	4.0dB
	400GBASE-LR4(1)	OS2	6km	6.3dB
	400GBASE-FR8	OS1a / OS2	2km	4.0dB
	400GBASE-LR8	OS2	10km	6.3dB
4-core applications	100GBASE-DR	OS1a / OS2	500m	3dB
8-core applications Typicaly MPO	200GBASE-DR4	OS1a / OS2	500m	3dB
	400GBASE-DR4	OS1a / OS2	500m	3dB

(1): Draft standard not yet ratified.
(2): Not an IEEE standard. Application available as multi-source agreement

Budget Calculations

Calculating the Insertion loss budget

Standard values



1 connection
= 2 connectors in a coupler

- Multimode*

Connector Attenuation	Cable attenuation	Splice attenuation
0.75dB / connection	3dB/km	0.3dB / splice

- Singlemode

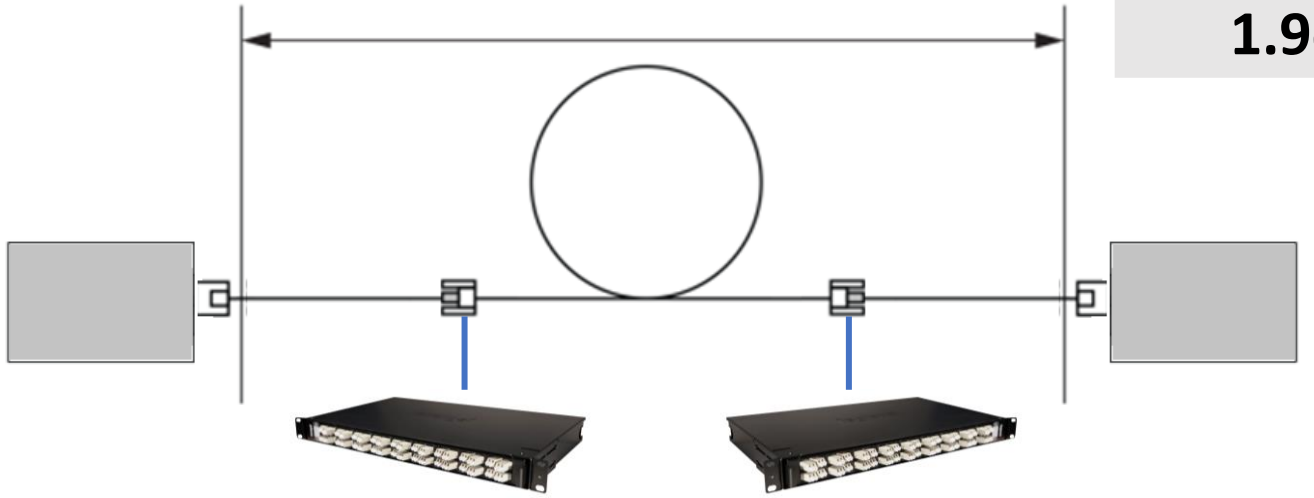
Connector Attenuation	Cable attenuation	Splice attenuation
0.75dB / connection	1dB/km (OS1a = indoor) 0.4dB/km (OS2 =Outdoor)	0.3dB / splice

**simplified for only 850nm, for legacy applications at 1300nm, other values apply*

Matching the application

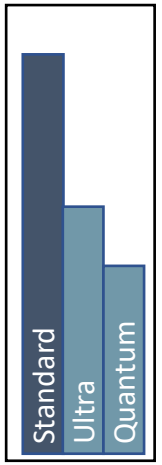
Example with 50Gbase-SR on OM5 on a standard channel with LC connectors

Loss Budget	Max. Distance
1.9dB	100m



Passed !!

Insertion Loss at 850nm			
Connectors	Splice	Cable	Total
0.75 x 2	0	3.0 x 0.1	
1.5dB	0.0dB	0.3dB	**1.8dB**



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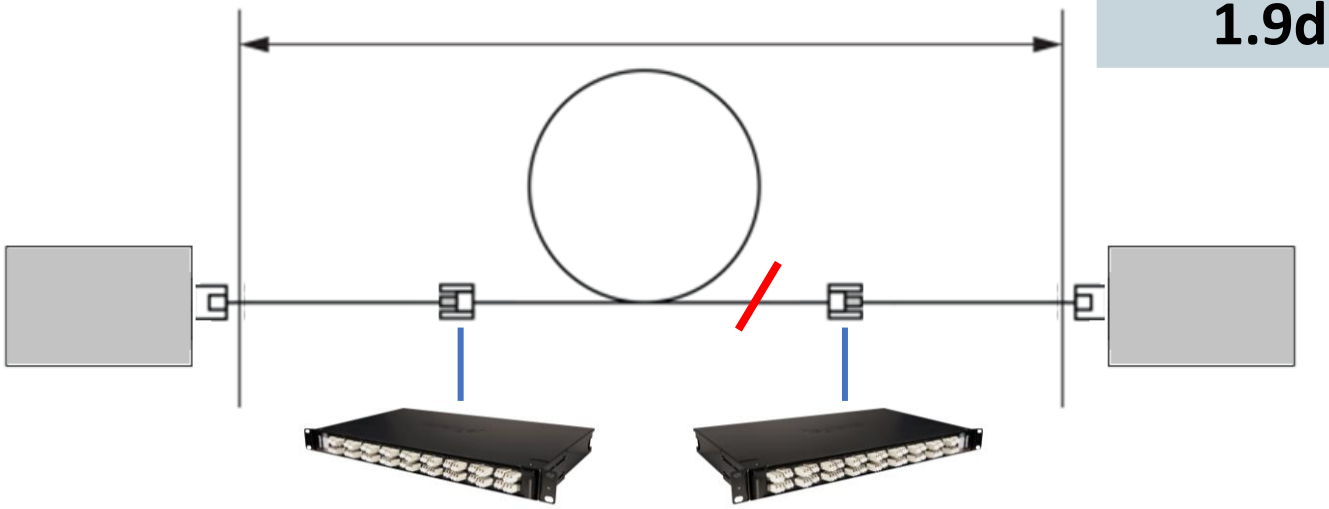
Matching the application

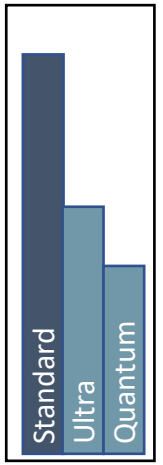
Example with 50Gbase-SR on OM5, adding a splice

Loss Budget	Max. Distance
1.9dB	100m



Failed !!

Insertion Loss at 850nm			
Connectors	Splice	Cable	Total
2 x 0.75	0.3	3.0 x 0.1	
1.5dB	0.3dB	0.3dB	**2.1dB**



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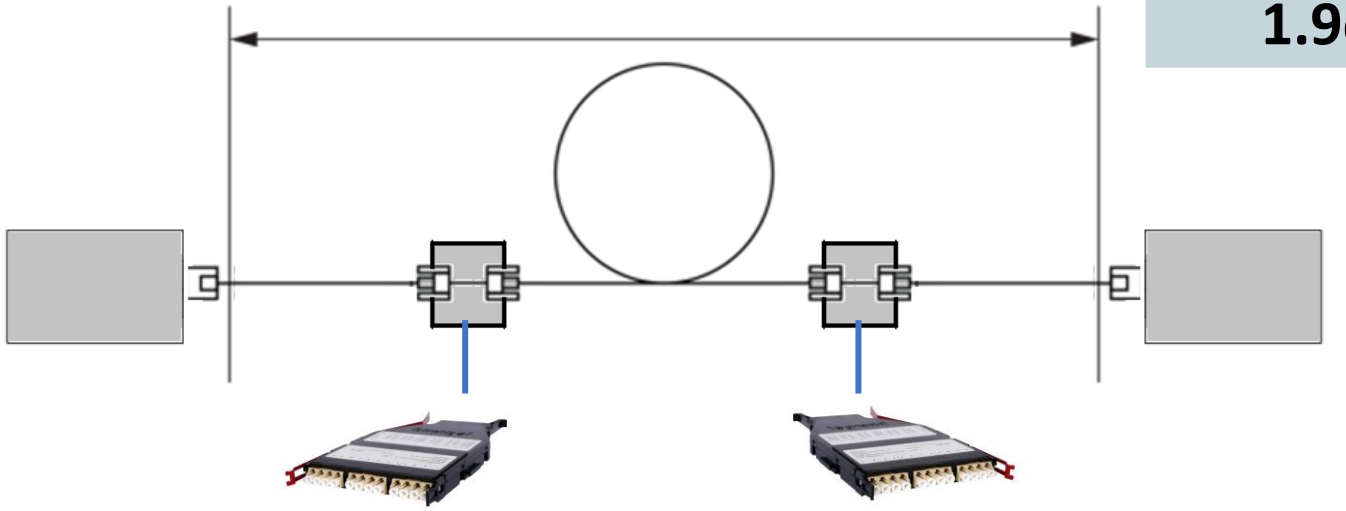
Matching the application

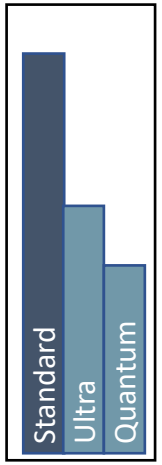
Example with 50Gbase-SR on OM5, using MPO to LC cassettes

Loss Budget	Max. Distance
1.9dB	100m



Failed !!

Insertion Loss at 850nm			
Connectors	Splice	Cable	Total
2 x 2 x 0.75	0	3.0 x 0.1	
3.0dB	0.0dB	0.3dB	**3.3dB**



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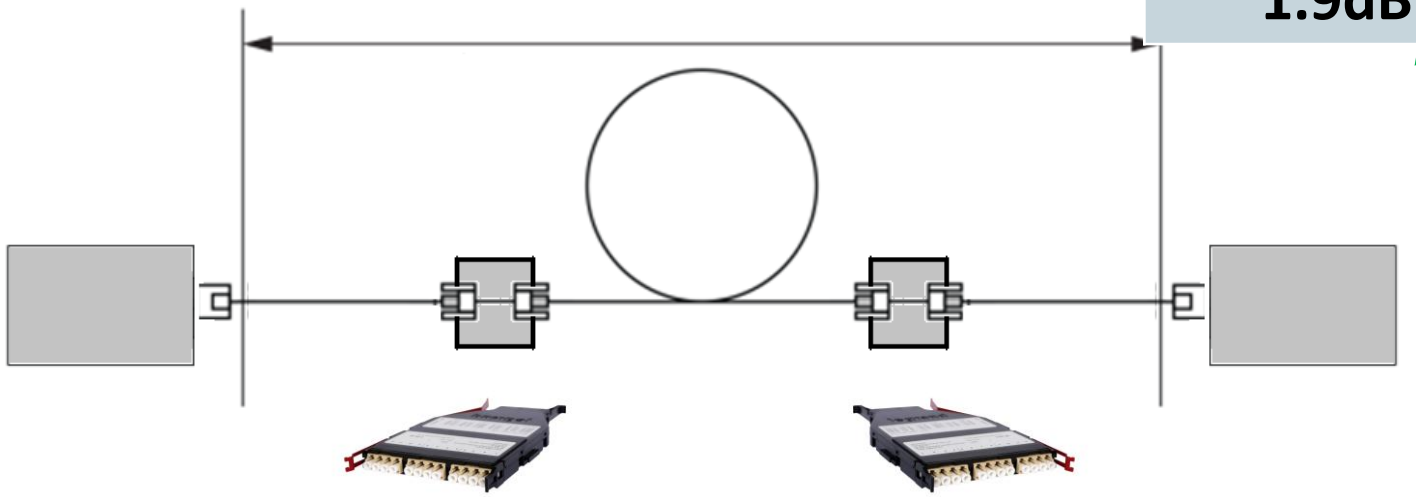
Matching the application

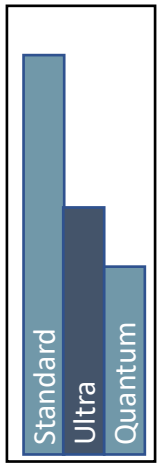
Example with 50Gbase-SR on OM5, with Ultra Low Loss cassettes

Loss Budget	Max. Distance
1.9dB	100m



Passed !!

Insertion Loss at 850nm			
Connectors	Splice	Cable	Total
2 x (0.35 + 0.20)	0	3.0 x 0.1	
1.1dB	0.0dB	0.3dB	**1.4dB**



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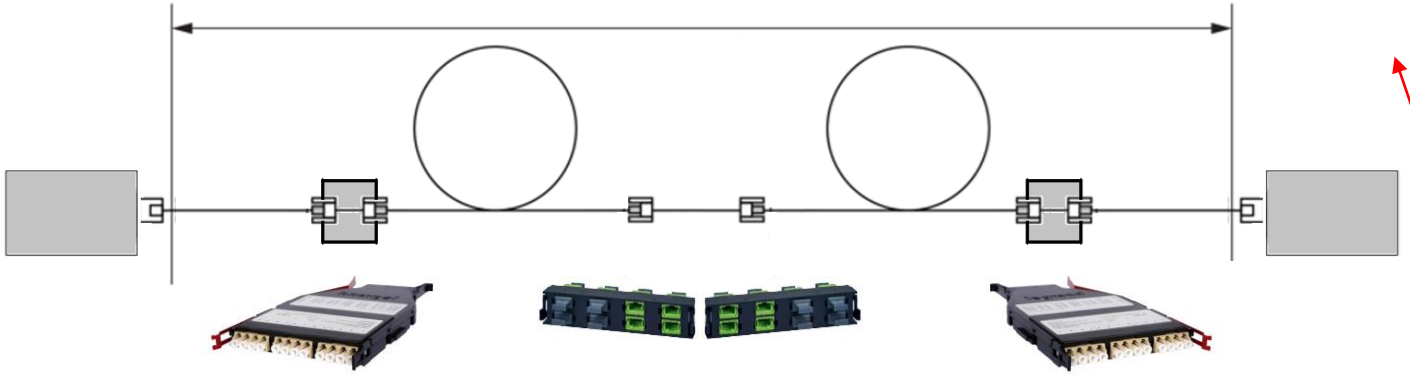
Matching the application

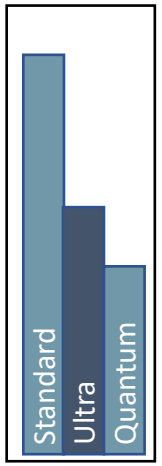
Example with 50Gbase-SR on OM5, with an added connection

Loss Budget	Max. Distance
1.9dB	100m



Failed !!

Insertion Loss at 850nm			
Connectors	Splice	Cable	Total
2 x (0.35 + 0.20) + 2 x 0.35	0	3.0 x 0.1	
1.8dB	0.0dB	0.3dB	**2.1dB**



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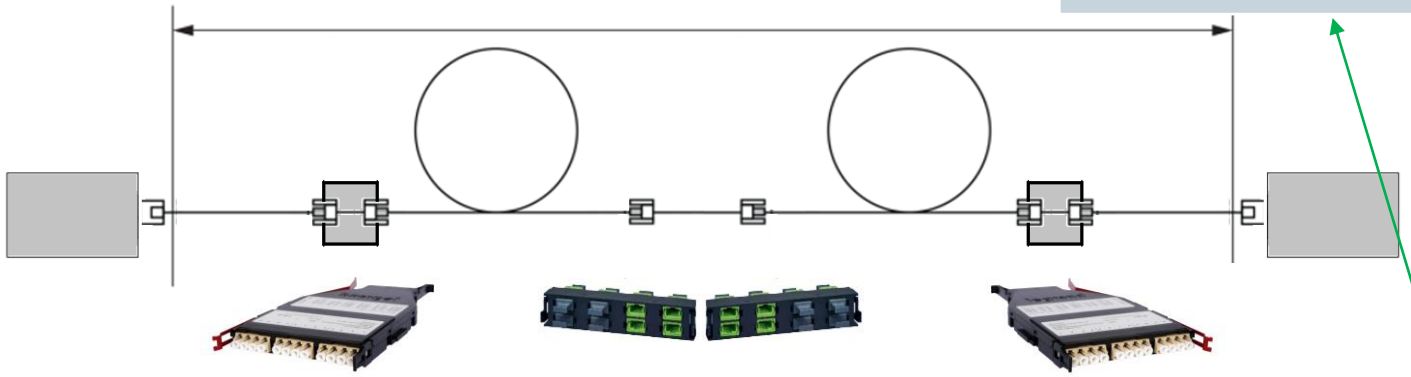
Matching the application

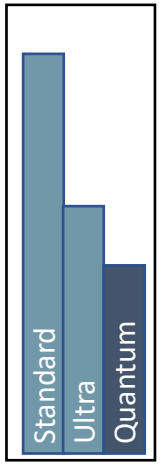
Example with 50Gbase-SR on OM5, with even better components

Loss Budget	Max. Distance
1.9dB	100m



Passed !!

Insertion Loss at 850nm			
Connectors	Splice	Cable	Total
2 x (0.275 + 0.1) + 2 x 0.275	0	3.0 x 0.1	
1.3dB	0.0dB	0.3dB	**1.6dB**



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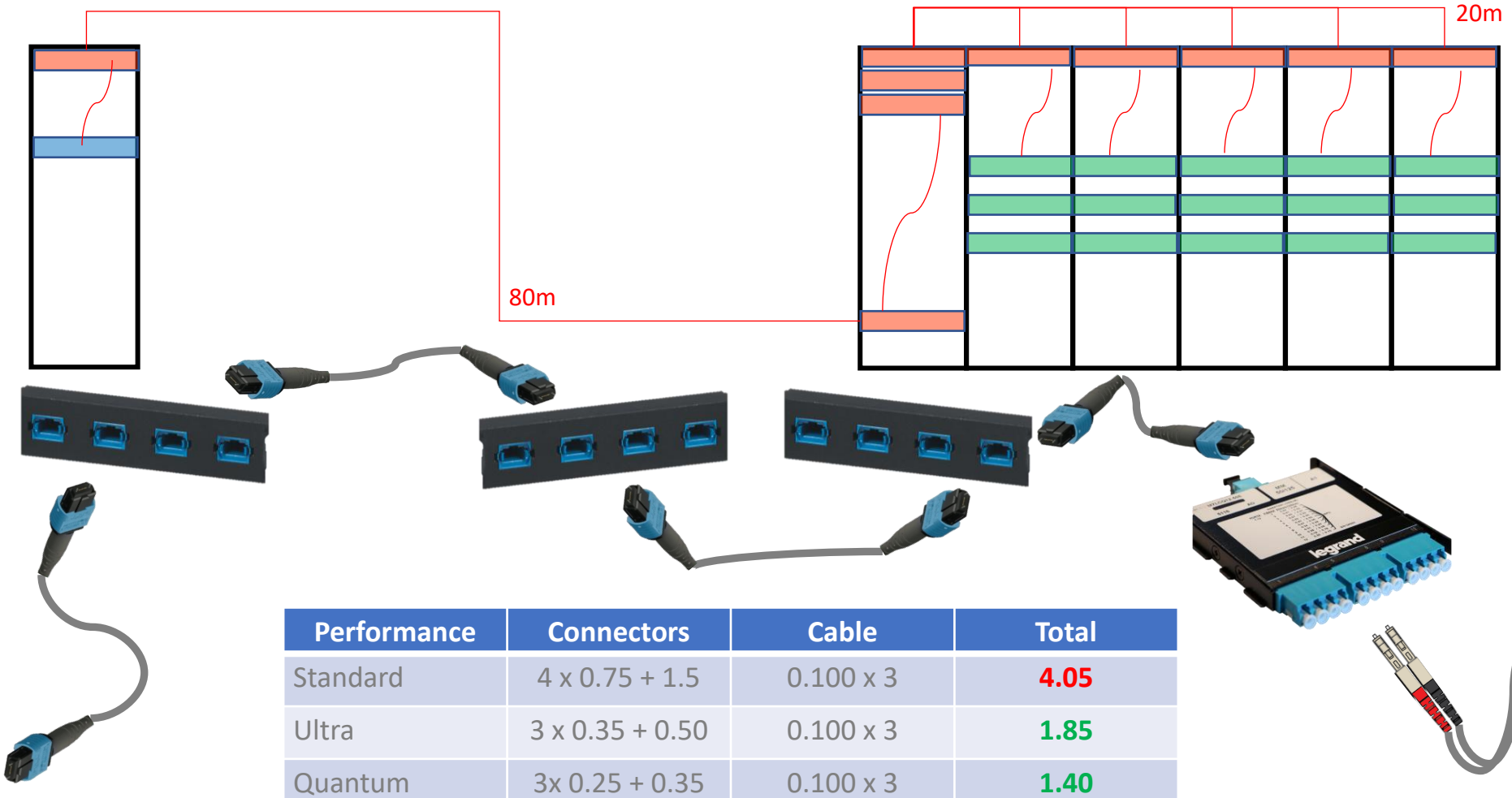
200Gbase-SR4 breakout to 4x 50G

Loss Budget	Max. Distance
1.9dB	100m



Performance	Connectors	Cable	Total
Standard	4 x 0.75 + 1.5	0.100 x 3	**4.05**
Ultra	3 x 0.35 + 0.50	0.100 x 3	**1.85**
Quantum	3x 0.25 + 0.35	0.100 x 3	**1.40**

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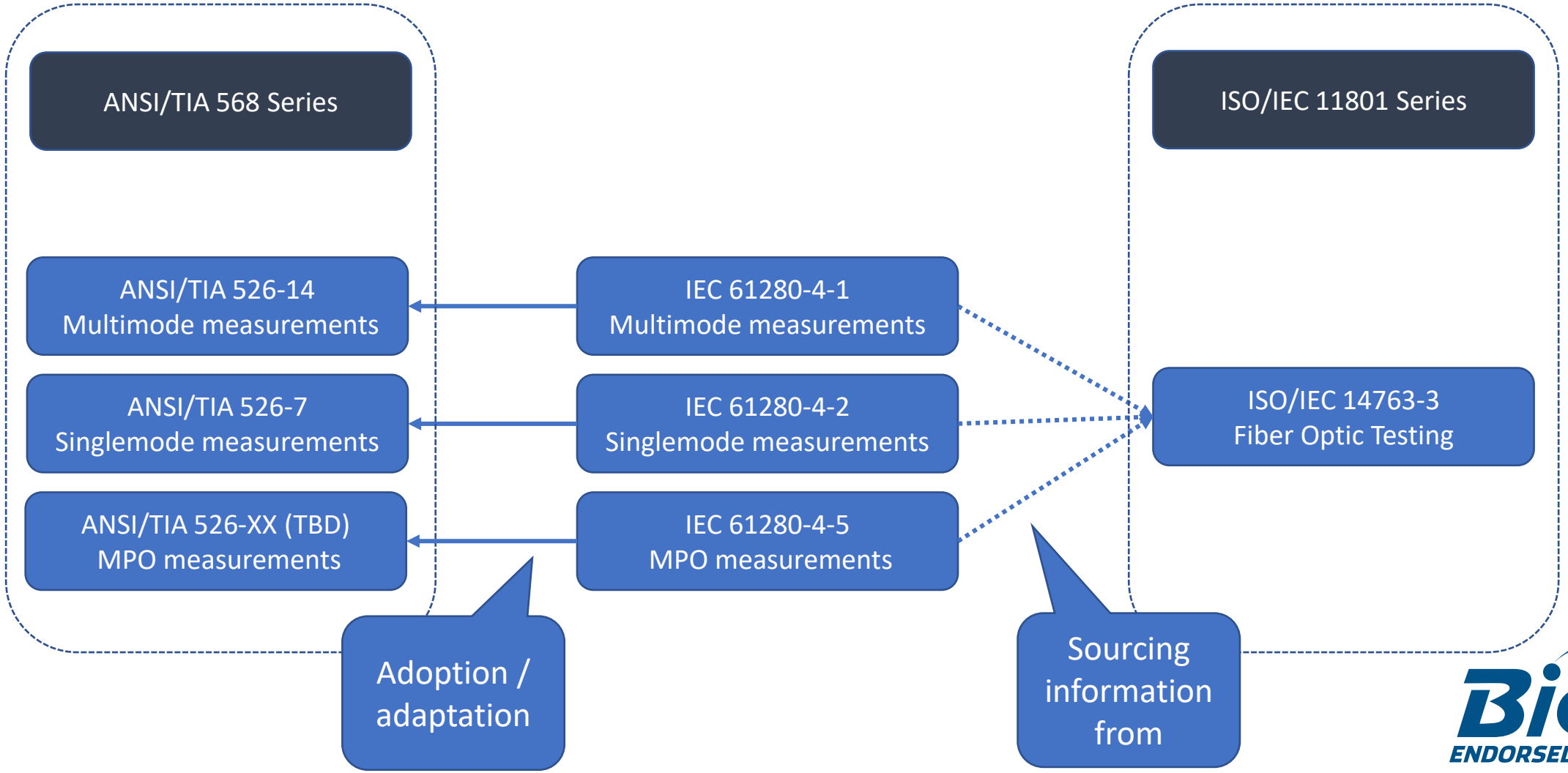
Testing

Testing Standards



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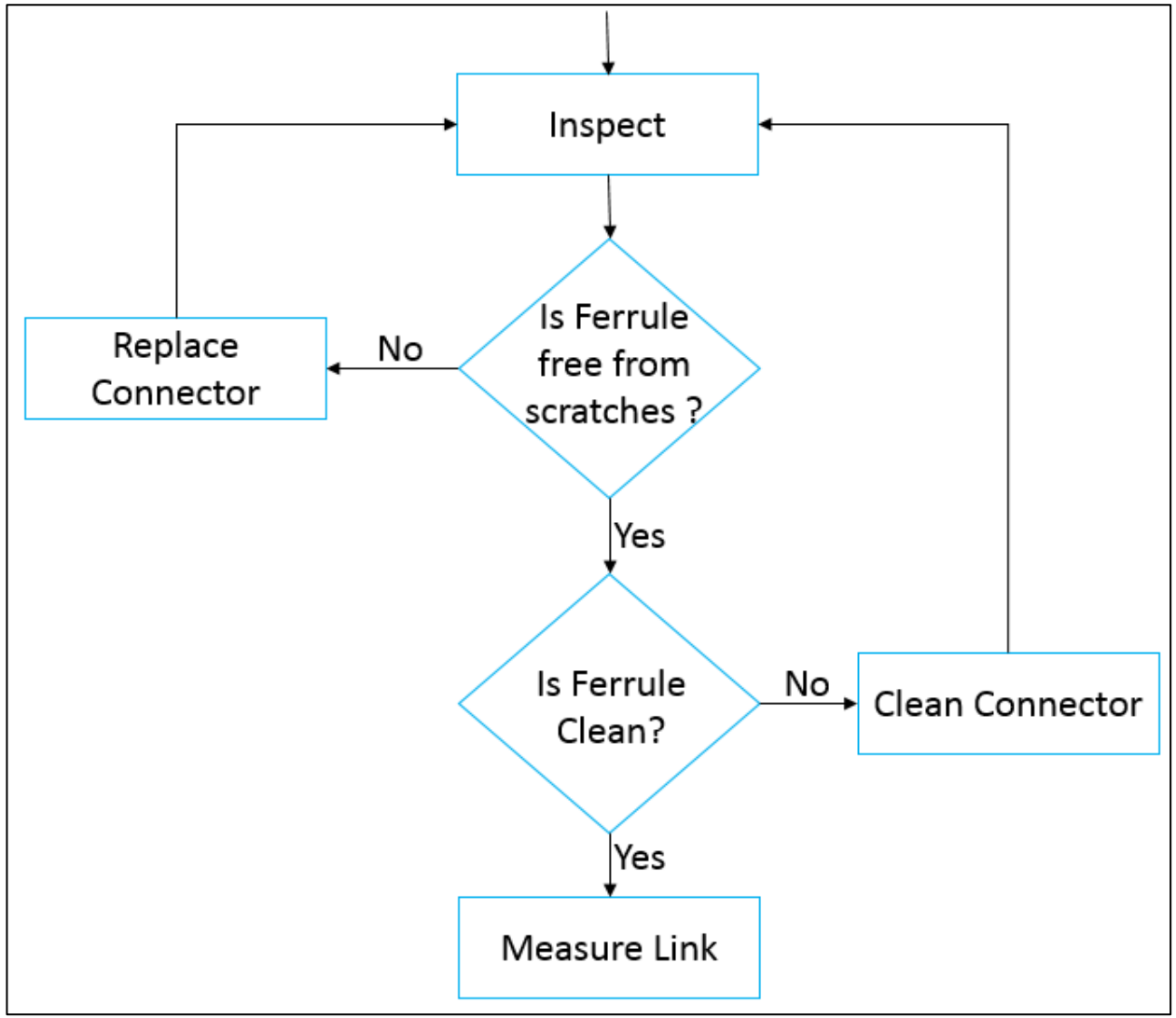
Test Procedure



Measurements

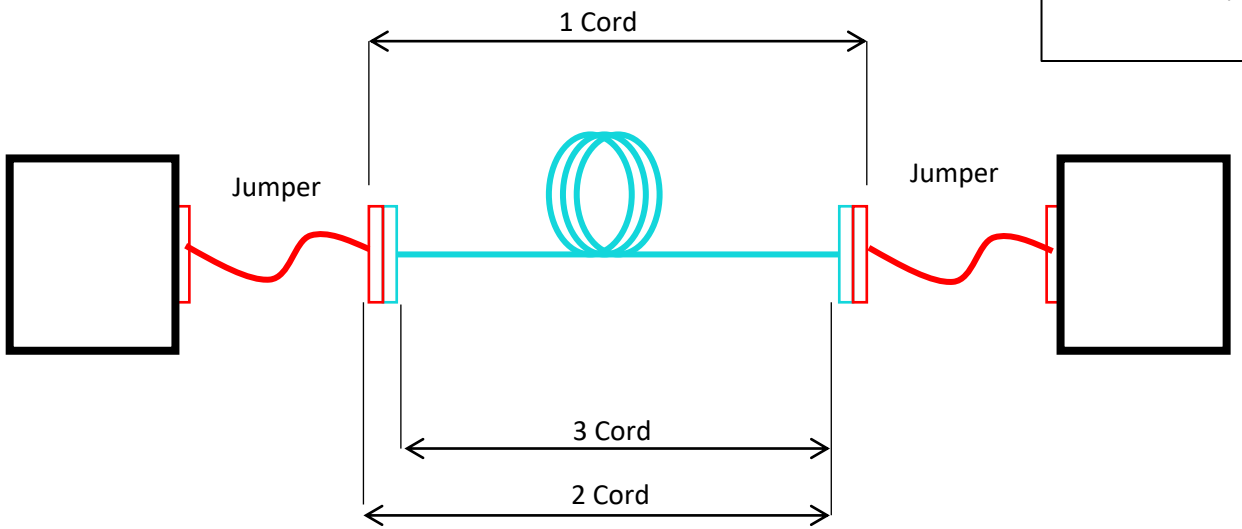
Standard	Fiber	Method		
ISO/IEC 14763-3: 2014	MM/SM	1 cord*	N/A	N/A
EIA/TIA-526-14: 2015	Multimode	1 cord	2 cord	3 cord
EIA/TIA-526-7: 2015	Singlemode	1 cord	2 cord	3 cord
IEC 61280-4-1: 2009	Multimode	1 cord	2 cord	3 cord
IEC 61280-4-2: 2014	Singlemode	1 cord	2 cord	3 cord

Permanent Link Certification

LSPM Required. OTDR is additional.

- Test both directions (some exceptions exist)
- Test both wavelengths

*Enhanced-3-cord is another version of the 1-cord method, when connectors tested are different from connectors on the testing device.



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Use Reference Cords

- Mandatory in ISO/IEC 14763-3, optional in other standards.

	LC, SC, etc..		MPO	
	Cylindrical connector styles		**Rectangular connector styles**	
	MMF	SMF	MMF	SMF
Eccentricity of core centre to ferrule outer diameter	<1 µm	<0,3 µm	N/A	N/A
True position of the fibre core	N/A	N/A	<1 µm	<0,3 µm
Exit angle	≤0,2°	≤0,2°	≤0,2°	≤0,2°
Accuracy of ferrule diameter	±0,5 µm	±0,5 µm	N/A	N/A
Attenuation of 2 reference connectors in a reference adapter	≤0,10 dB	≤0,20 dB	≤0,10 dB	≤0,20 dB

The Attenuation is not the objective, but only a consequence of the higher precision

Uncertainty of the measurement

IEC 61280-4-1

	Uncertainty Value at 95% using test cords with reference connectors dB			Uncertainty Value at 95% using test cords with standard connectors dB		
Measured loss dB	**Annex A (1 cord)**	**Annex C (2 cord)**	**Annex B (3 cord)**	**Annex A (1 cord)**	**Annex C (2 cord)**	**Annex B (3 cord)**
0,5	0,25	0,28	0,31	1,24	1,52	1,75
1,0	0,25	0,28	0,31	1,24	1,52	1,75
1,5	0,27	0,30	0,32	1,25	1,52	1,76
2,0	0,30	0,32	0,35	1,25	1,53	1,76
2,5	0,34	0,36	0,38	1,26	1,53	1,76
3,0	0,39	0,40	0,42	1,27	1,54	1,77
3,5	0,44	0,45	0,46	1,28	1,55	1,78

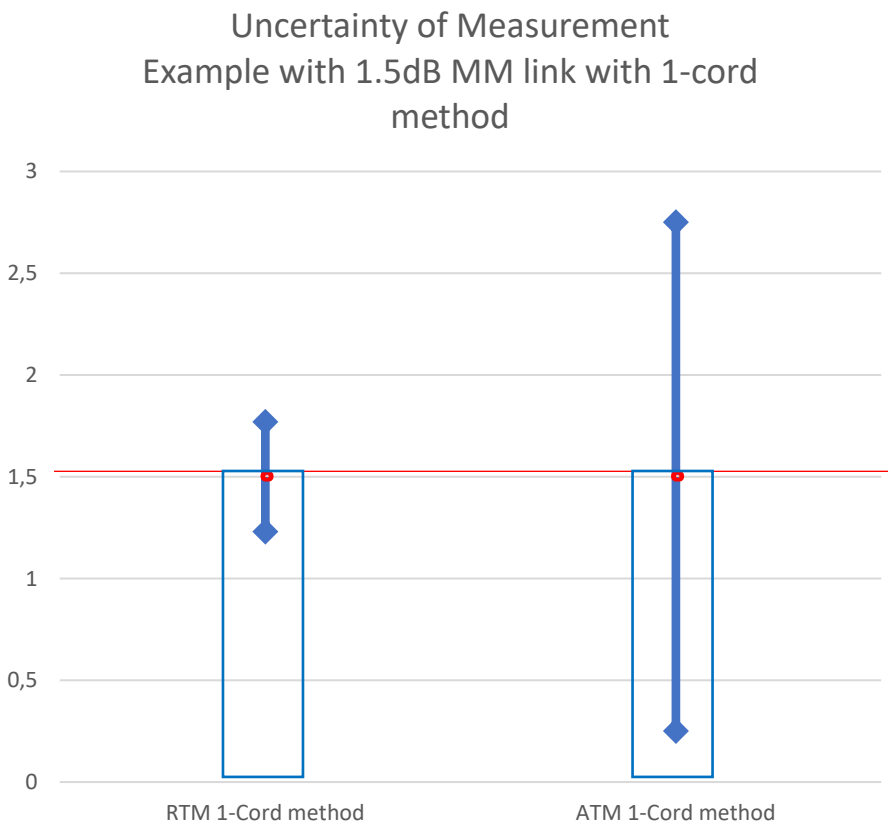
RTM with “reference quality” cord

ATM with “Standard” cord

Uncertainty is critical

Uncertainty is the assurance that the use of another cord will provide an IL within the specified range of values.

	dB			dB		
Measured loss dB	Annex A (1 cord)	Annex C (2 cord)	Annex B (3 cord)	Annex A (1 cord)	Annex C (2 cord)	Annex B (3 cord)
0,5	0,25	0,28	0,31	1,24	1,52	1,75
1,0	0,25	0,28	0,31	1,24	1,52	1,75
1,5	0,27	0,30	0,32	1,25	1,52	1,76
2,0	0,30	0,32	0,35	1,25	1,53	1,76
2,5	0,34	0,36	0,38	1,26	1,53	1,76
3,0	0,39	0,40	0,42	1,27	1,54	1,77
3,5	0,44	0,45	0,46	1,28	1,55	1,78



Uncertainty of test measurement using **reference grade** connectors (from ISO/IEC 14763-3 revision draft)

Uncertainty (dB)	MM	SM
Reference grade	0.27(1)	0.24(2)

(1) 0.14 x measured IL if the measured IL is more than 1.9dB
(2) Assuming the total length is less than 2km

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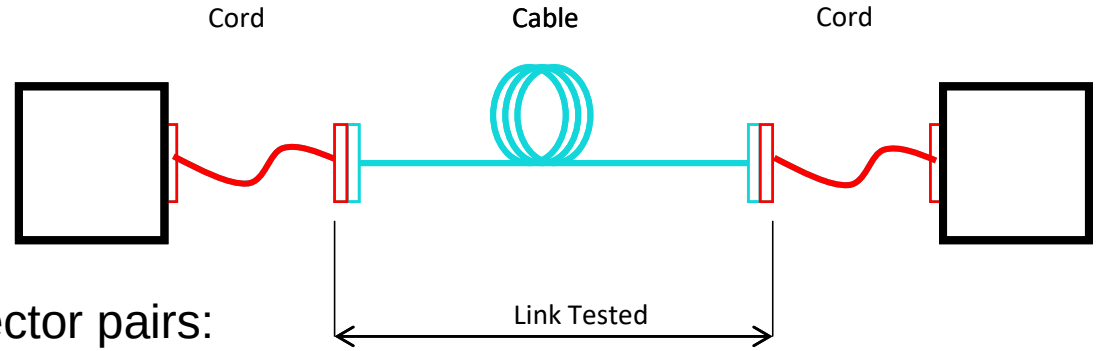
Set the Limits



Let's test a 100m of OM3 cable at 850nm, with 2 connector pairs:

Connector Attenuation	Cable attenuation	Splice attenuation
0.75dB / connection	3.0 dB/km	0.3dB / splice

Connector Attenuation	Cable attenuation	Splice attenuation	Total
~~0.75 x 2 = 1.50 dB~~	~~3.0 x 0.1 = 0.3dB~~	~~0~~	~~1.80dB~~

Attenuation with reference cords	Multimode
Reference Cord to Reference Cord	0.10 dB
Reference Cord to non-Reference Cord	0.50 dB
Non-Reference Cord to non-Reference Cord	0.75 dB

Values from ISO/IEC 14763-3 for cylindrical connector styles. Will be updated in the next revision

Connector Attenuation	Cable attenuation	Splice attenuation	Total
0.50 x 2 = 1.00 dB	3.0 x 0.1 = 0.3dB	0	1.30dB

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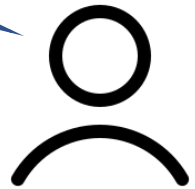
Selecting products

A word on components

Guaranteed 0.15dB

Great. So my connector will have this performance?



Lab testing is done with IEC 61300-3-4 → Vs. Reference connector !!!

Example

Measurement	Performance	Standard
IL / Master (measured)	0.15	IEC 61300-3-4
IL Typical / Master (expected)	0.12	IEC 61300-3-4
IL Typical / Random (expected)	0.14	IEC 61300-3-34
IL Max. / Random (expected)	0.25	IEC 61300-3-34

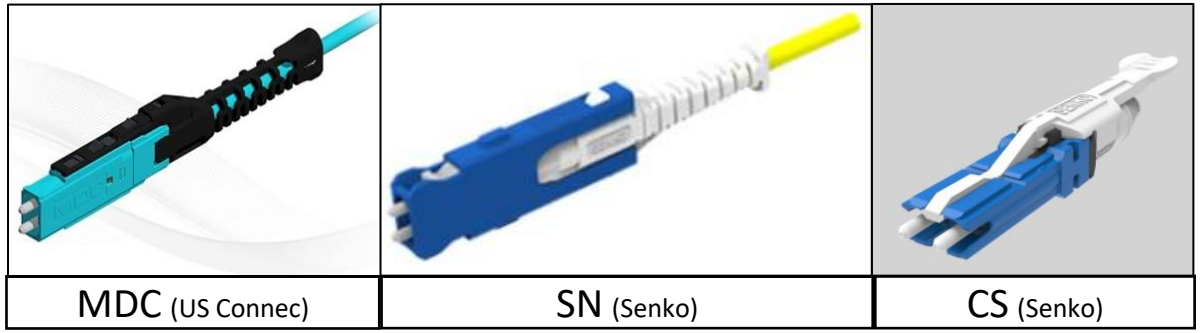
Key take-aways

What we've seen

Always define the applications needed before designing a fiber cabling, whether LAN or datacenter.	And don't forget to plan for the next generation of active equipment.
The applications define:	Types of cables (OM3, OM4, OM5, OS1a, OS2)
	Lengths of the links
	Types of connectors (duplex or parallel optics)
The architecture defines:	The performance of the connectors.
Use reference cords for testing	Otherwise the uncertainty is too high.
Set the right limits depending on your application requirements	Don't forget that the reference connectors provide lower IL than standard connectors.

Food for thought

With densities increasing, we need smaller than the LC



MDC (US Connec)	SN (Senko)	CS (Senko)

Channels are becoming more complex: we need higher performing connectivity

MPO don’t have a great performance.
Do we need to find a better connector for parallel optics?

?

Cassettes count double the IL.
They serve a good purpose, but could the industry find a better solution?

?

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Thank You

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