From 10G to 400G: analysis of the past, current and future cabling solutions

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Agenda

1- Standards
2- Copper Systems
3- PoE Compliant Installation
4- Fiber Systems
5- Single Pair Ethernet

IEEE for Ethernet

IEEE 802:
LAN / Man Standards

802.5: Token Ring (disbanded)

802.1: Higher LAN Protocols

802.15: WPAN (bluetooth, Zigbee,...)

IEEE 802: LAN / MAN standards	
802.3 Ethernet (CSMA / CD)	**802.11 Wireless (CSMA / CA)**
802.3j (1990) 10base-T, 10base-F	**802.11a (1999)** 54Mbps @ 5GHz
802.3u (1995) 100base-TX, 100base-T4, 100base-FX	**802.11b (1999** 11Mbps @ 2.4GHz
802.3z (1998) 1000base-X (Fiber optic)	**802.11g (2003** 54Mbps @ 2.4GHz
802.3ab (1999) 1000base-T	**802.11n (2012)** 150Mbps @ 2.4 and 5GHz, 600M w/MIMO 4
802.3ae (2003) 10G on fiber	**802.11ac (2012)** 867Mbps @ 5GHz , 6.77G w/ MIMO 8
802.3af (2003) Power over Ethernet, 15w	**802.11ad (2013)** 6.75Gbps @ 2.4, 5, and 60GHz
802.3an (2006) 10Gbase-T	**802.11ax (2019?)** improvement of 802.11ac for high density
802.3at "PoE+" 30W	
802.3ba (2010) 40G and 100G on fiber	
802.3bq (2016) 25Gbase-t and 40Gbase-T	
802.3bz (2016) 2.5Gbase-t and 5Gbase-T	
802.3bs (2018) 200G and 400G on fiber	
802.3bt (2018) "PoE++" 100W	

Customer premise cabling : ISO, International

Components

International Electrotechnical Commission

ISO Information Technology Generic Cabling Systems

Performance, Design	Implementation	Validation	Technical Reports
ISO/IEC 11801-1 (2017) General requirements	**ISO/IEC 14763-2** Planning and Installation Implementation	**ISO/IEC 61935-1** Testing of balanced twisted Pair Cabling	**ISO/IEC TR 24704 (2004)** Cabling for wireless access points
ISO/IEC 11801-2 (2017) Offices and commercial buildings	**ISO/IEC 30129** Bonding and Grounding	**ISO/IEC 14763-3** Testing of Fiber Optic Cabling	**ISO/IEC TR 24750 (2007)** Assessment and mitigation of installed balanced cabling channels in order to support 10GBASE-T
ISO/IEC 11801-3 (2017) Industrial premises		**ISO/IEC 14763-4 (Draft)** Measurement of E2E, MPT and DA links	**ISO/IEC TR 29125 (2010)** Requirements for RP of terminal equipment
ISO/IEC 11801-4 (2017) Homes			**ISO/IEC TS 29125 (2017)** Add. requirements for RP of terminal equipment
ISO/IEC 11801-5 (2017) Data centers			
ISO/IEC 11801-6 (2017) Distributed building services			

Revision 2 soon out

Amendment 1 ratified. Edition 2.1 in draft

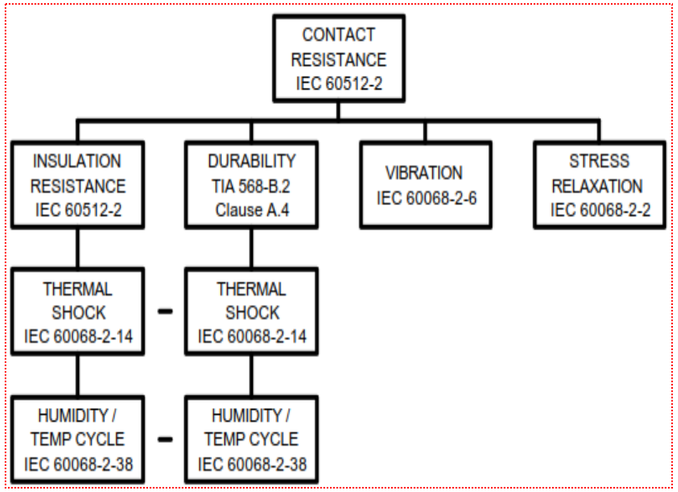
New types of channels: End-to-End, Modular Plug terminated, and Direct Attach.

Customer premise cabling :TIA, North American

ANSI/TIA: Telecommunications Cabling for Customer Premises

Components, Performance	Design	Implementation	Validation	Technical Reports
TIA - 568.2-D Balanced twisted-pair cabling (New)	**TIA - 568.0-D** Generic cabling	**TIA - 569-D** Telecommunications pathways and spaces	**TIA - 526-7-A** Single-mode fibre testing	**TIA - TSB-155-A** Support of 10Gbase-T on existing Cat.6
TIA - 568.3-D Optical fibre cabling	**TIA - 568.1-D** Commercial building	**TIA - 607-C** Bonding and grounding telecommunications	**TIA - 536- 14-C** Multi-mode fibre testing	**TIA - TSB - 184A** Supporting PoE over twisted pair
TIA - 568.4-D Broadband coaxial cabling and components	**TIA - 758-B** Customer-owned outside plant	**TIA - 606-C** Administration		**TIA - TSB-5021** Guidelines for 2.5G and 5G on Cat5e and Cat6
TIA - 568.5 (Draft) Single pair cabling	**TIA - 942-B** Data centers	**TIA - 862-B** Intelligent building systems		
	TIA - 1005-A Industrial premises	**TIA - 5017** Physical network security		
	TIA - 1179-A Healthcare facilities			
	TIA - 570-C Residential			
	TIA - 4966 Educational facilities			
	TIA - 162-A Cabling for wireless access points			
	TIA - 5018 Cabling for distributed antena systems			

IEC International Electrotechnical Commission



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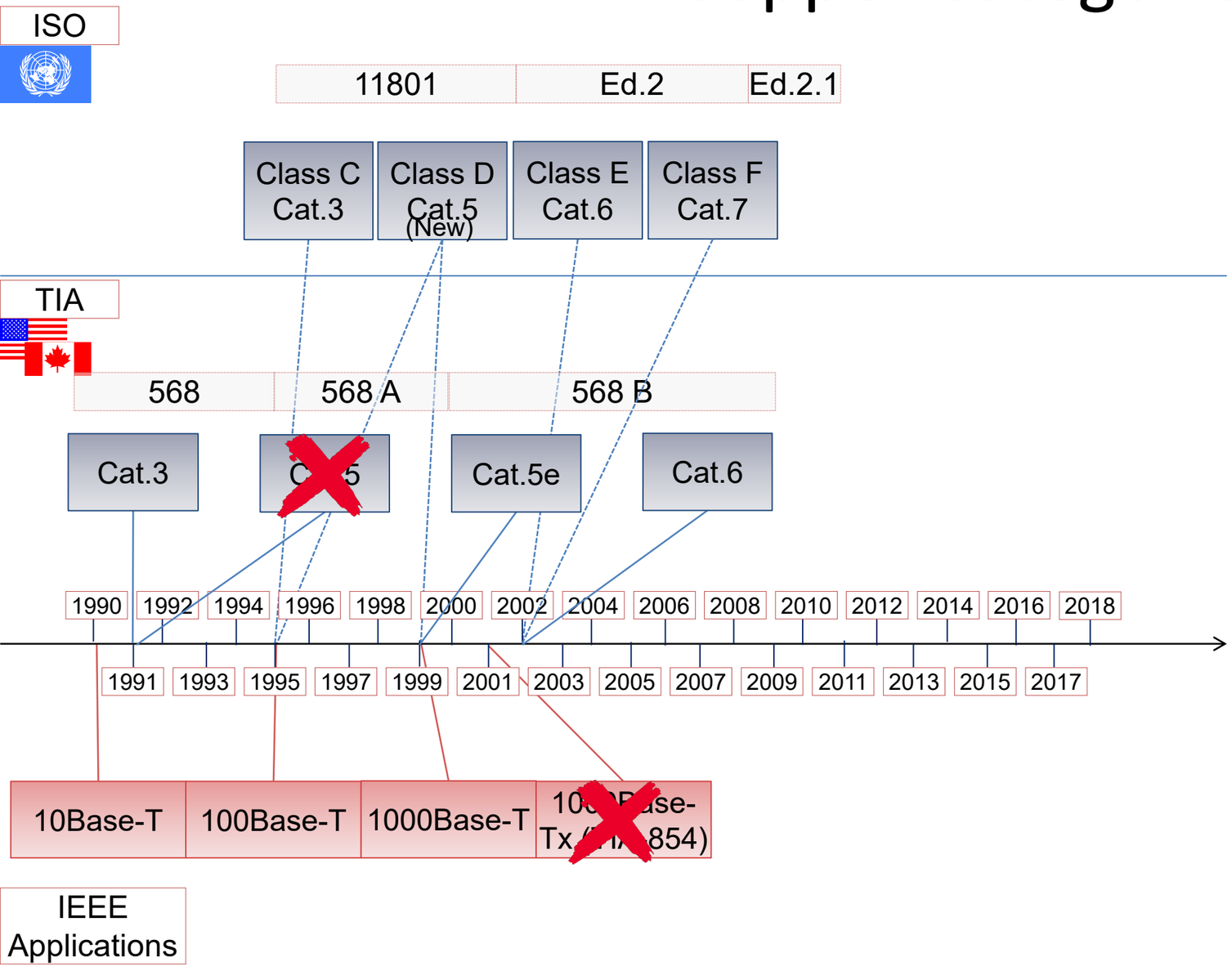
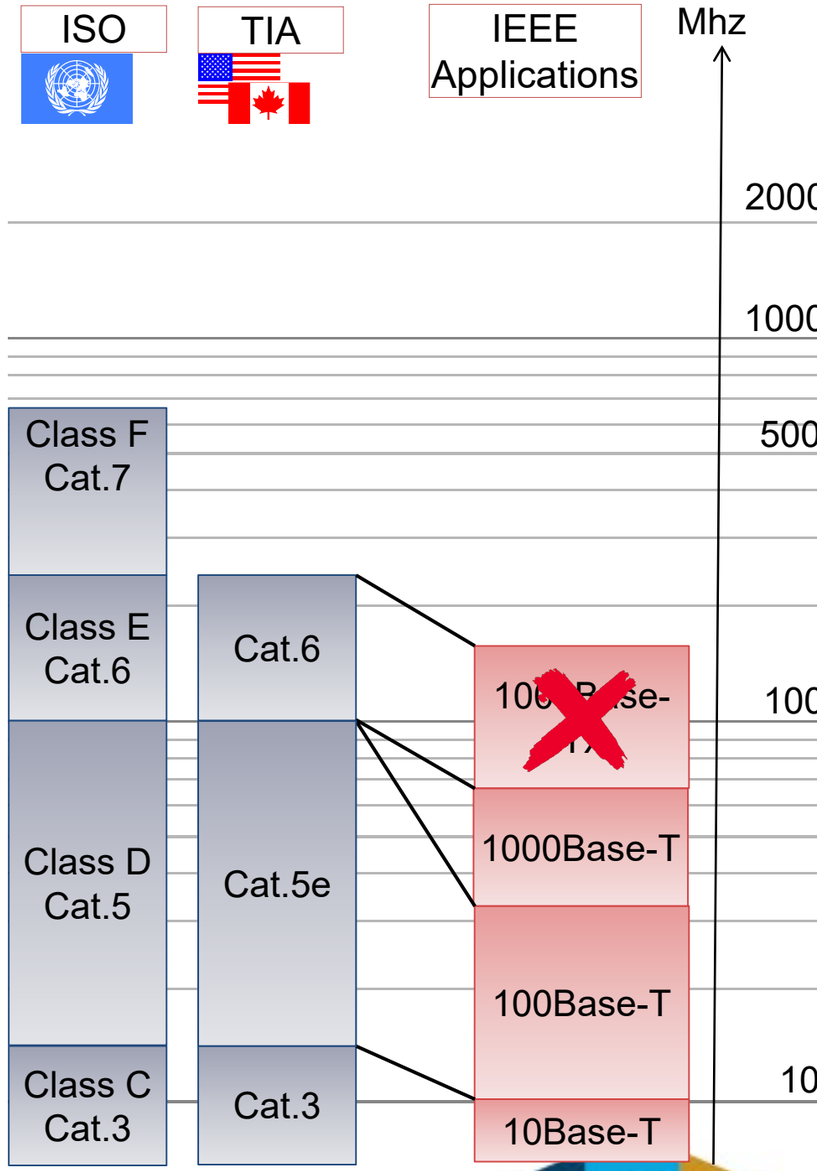
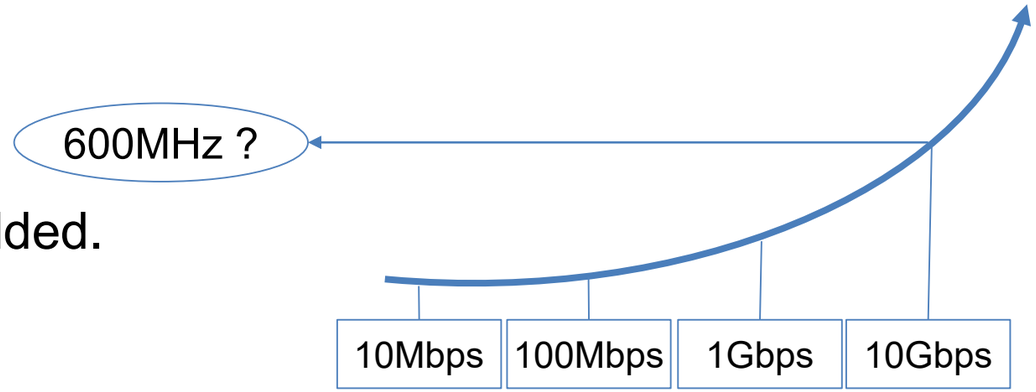
Copper Categories

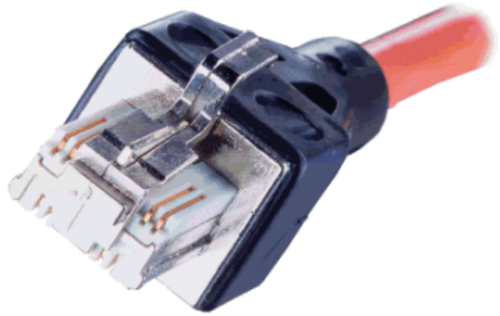




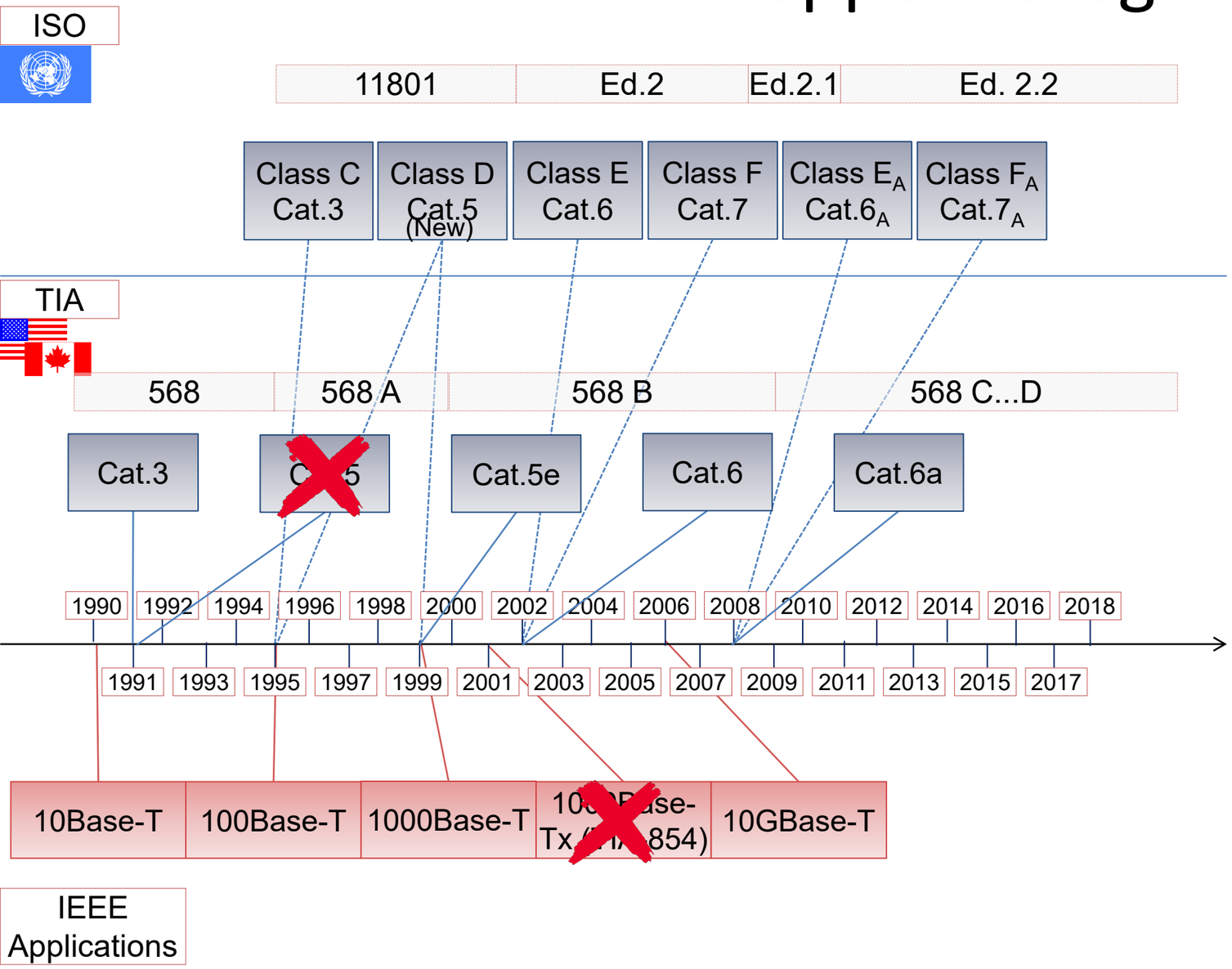
Category 7

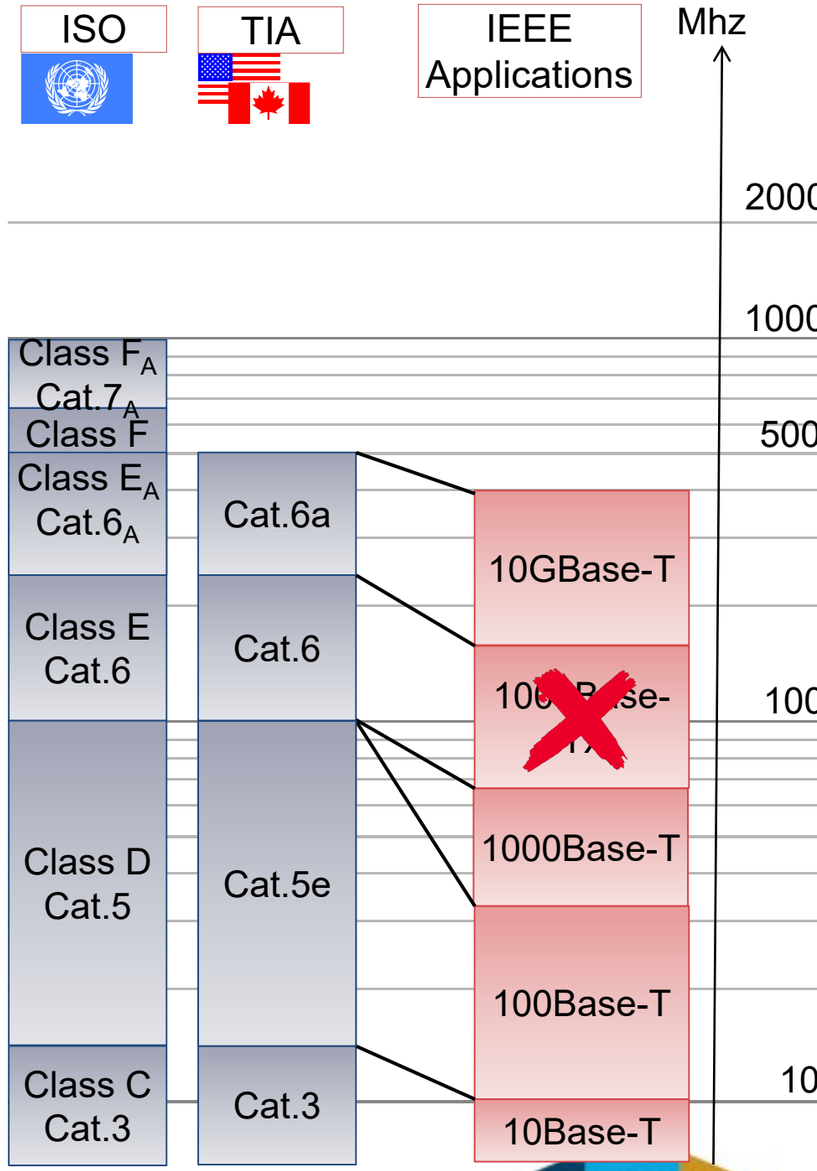
- Designed for a future 10 Gigabit Ethernet.
- 600MHz definition was a “best guess”.
- Technology for 600MHz cable was impossible unless fully shielded.
- Technology for 600MHz RJ45 was deemed impossible.
- Category 7 was created with “PIMF” cable and “non-RJ45” connectors.





Copper Categories





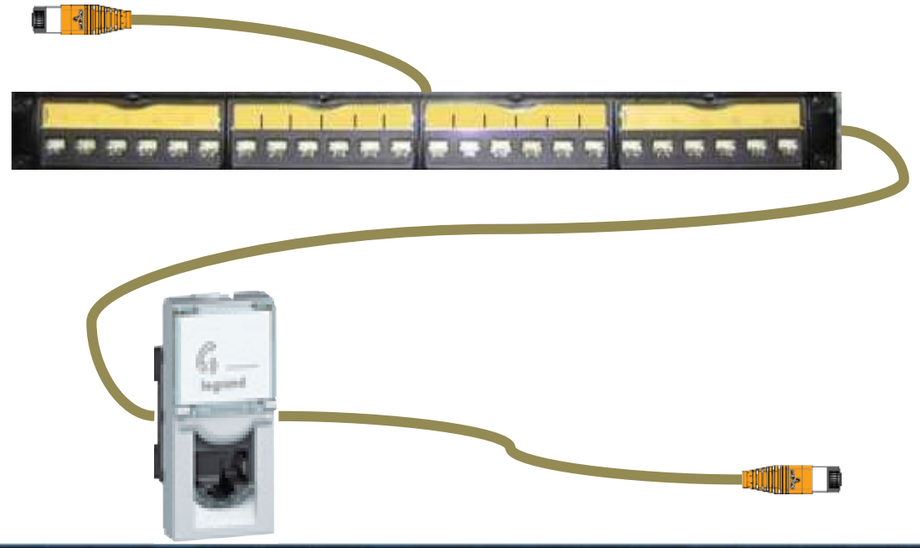
IEEE 802.3bg 10GBase-T

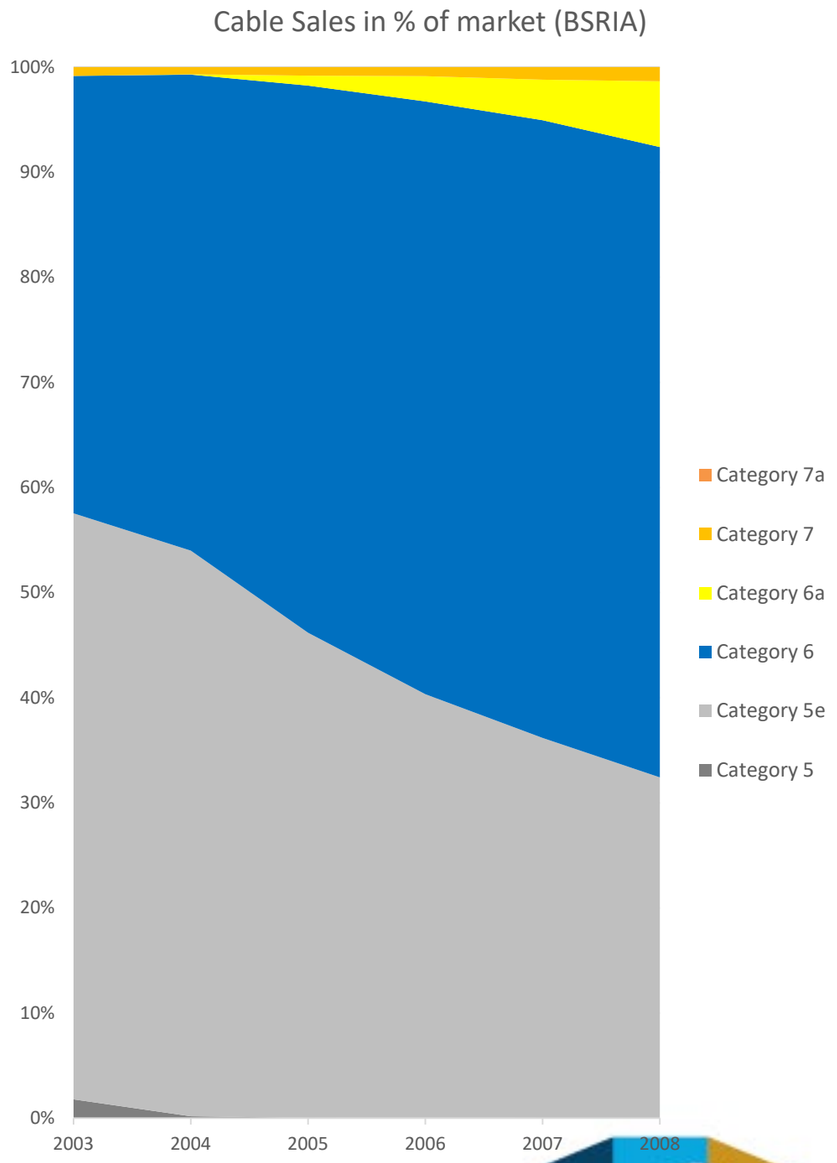
- 10G is ratified in 2006:

Category / Class	Compliance	Conditions
Cat.6 / Class E_A	Possible	Additional testing*
Cat. 6_A / Class E_A	Yes	RJ45 connector
Cat.7 / Class F	Yes	Non-RJ45 connector

** Only for existing cabling. Re-Test in-channel up to 500MHz, and test Alien noise*

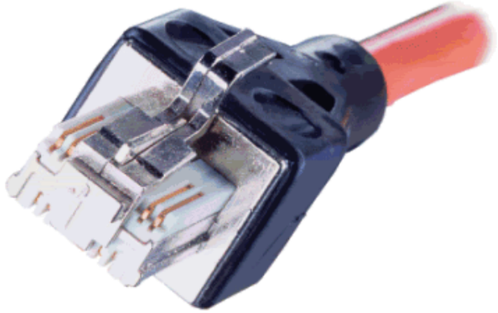
Disturbed Cable

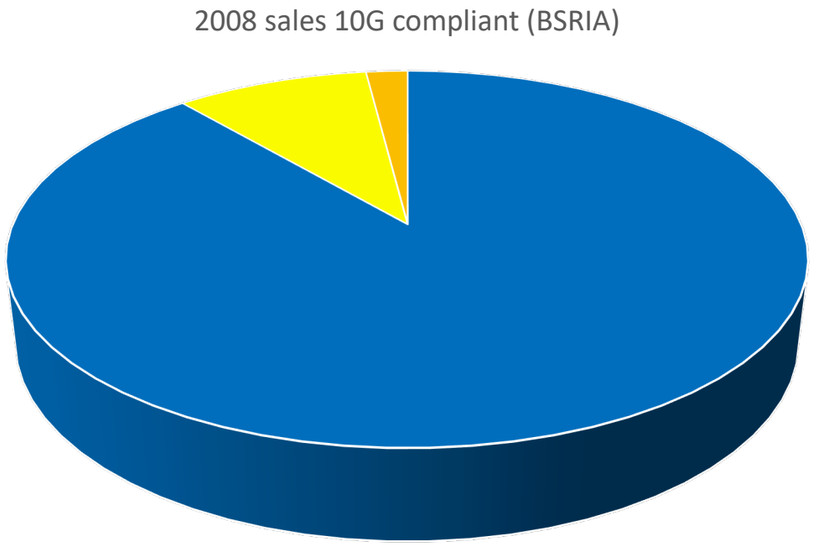


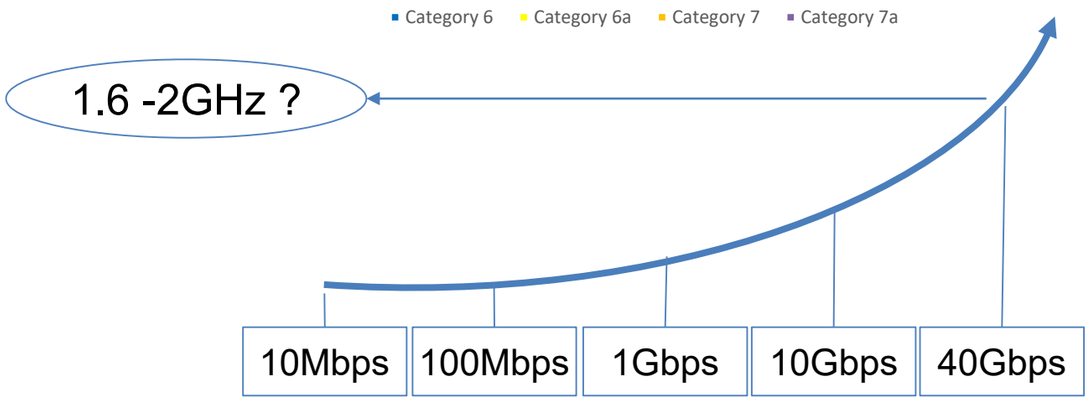


Category 7_A

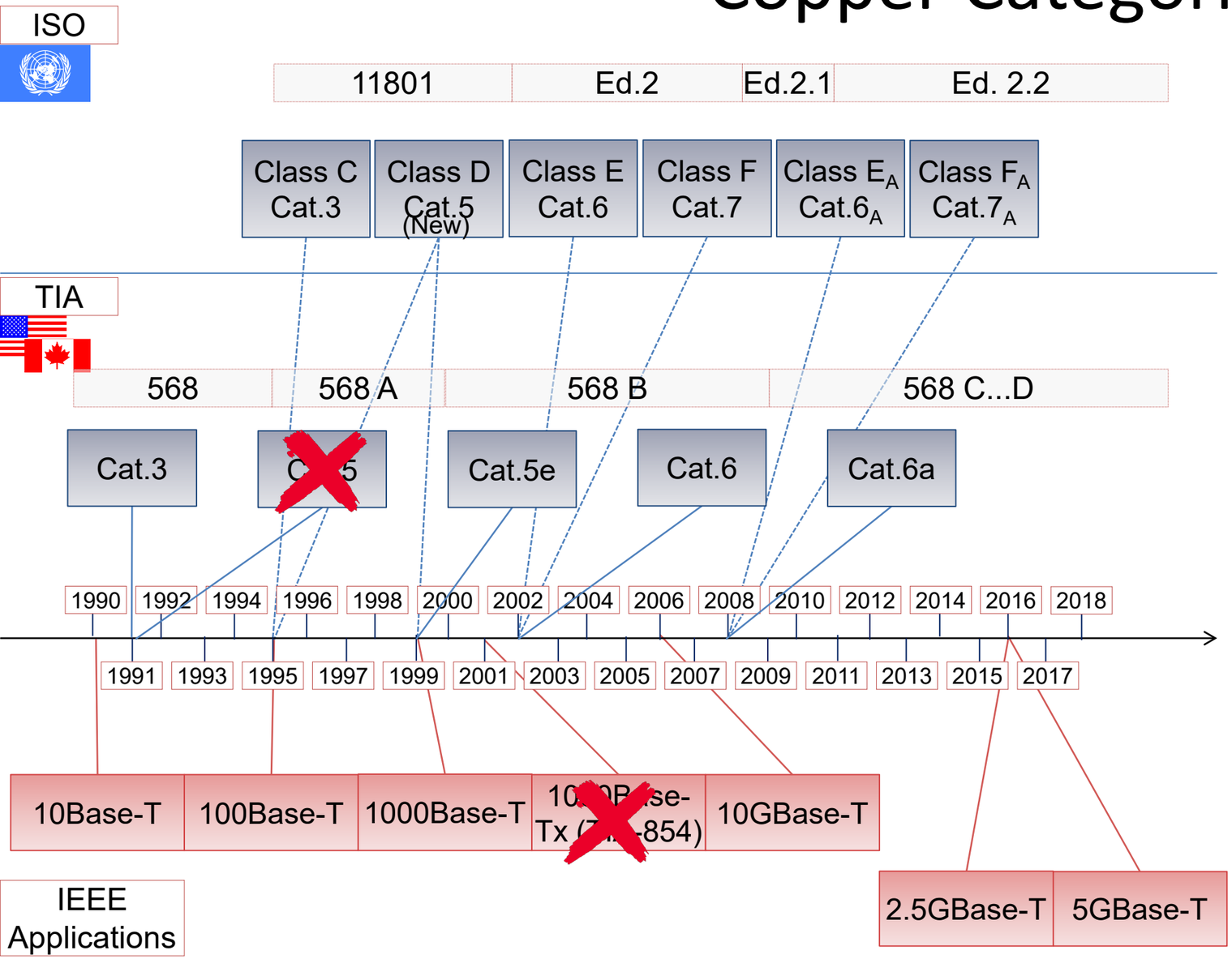
- No active equipment exists for 10G on Category 7 / Class F.
- So as soon as Cat6A is ratified, any cabling system for 10G but using connectors other than RJ45 is non competitive.
- Category 7A was created to offer a solution with the highest available frequency with the “non-RJ45”connectors. (about 1GHz in 2006)

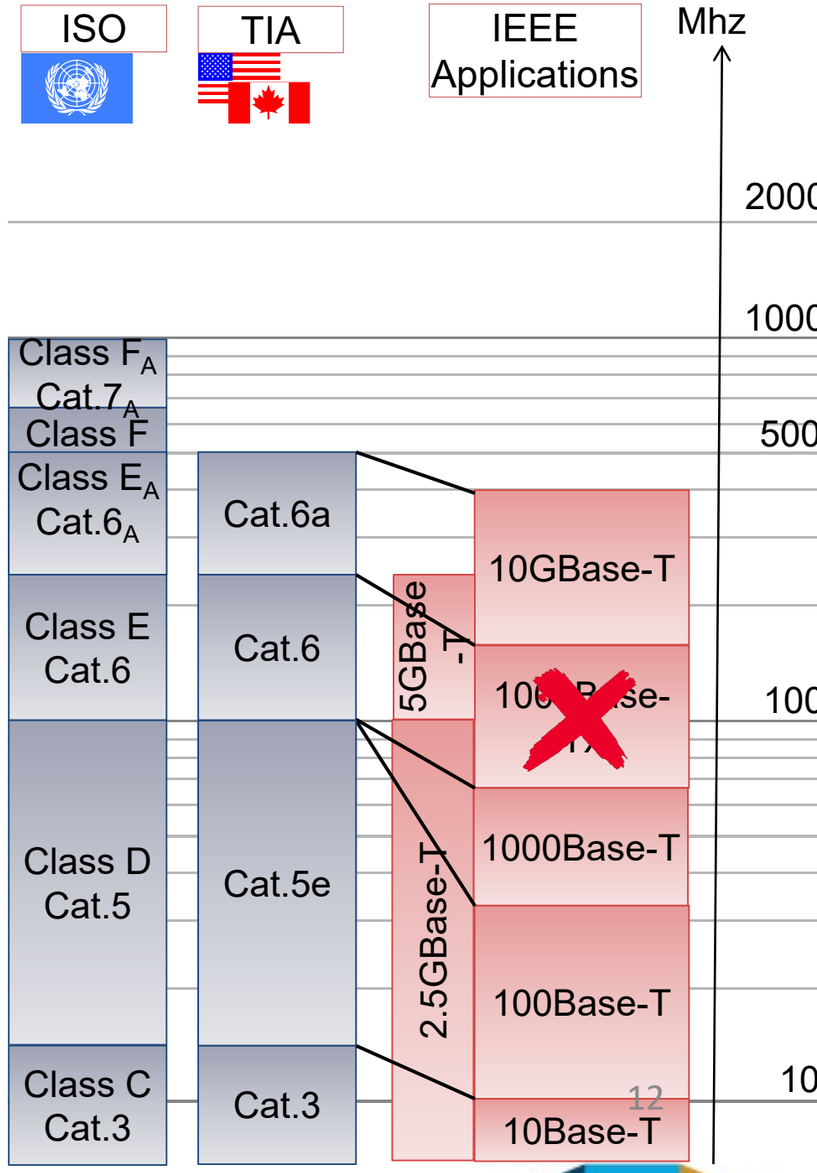






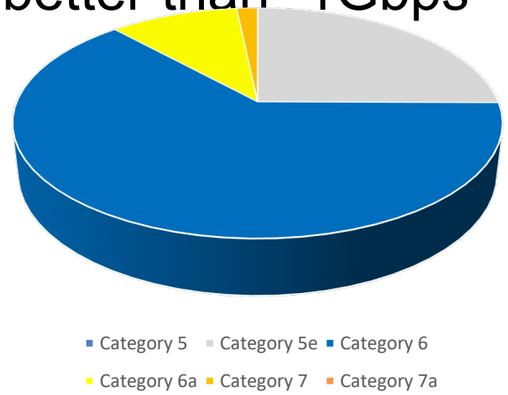
Copper Categories





Nbase-T 2.5G and 5G

- 802.11ac and 802.11ad, existing since 2013, offer 6.75Gbps wireless.
- Only Cat6a offers more than 1Gbps on cable.
- Wireless access points need to connect to existing cable with "better than" 1Gbps



Disturbed Cable

Bundled cabling length 0m to 50m	Category 5e	Category 6	Category 6A
2.5GBASE-T			Assured
5GBASE-T Assured			Assured

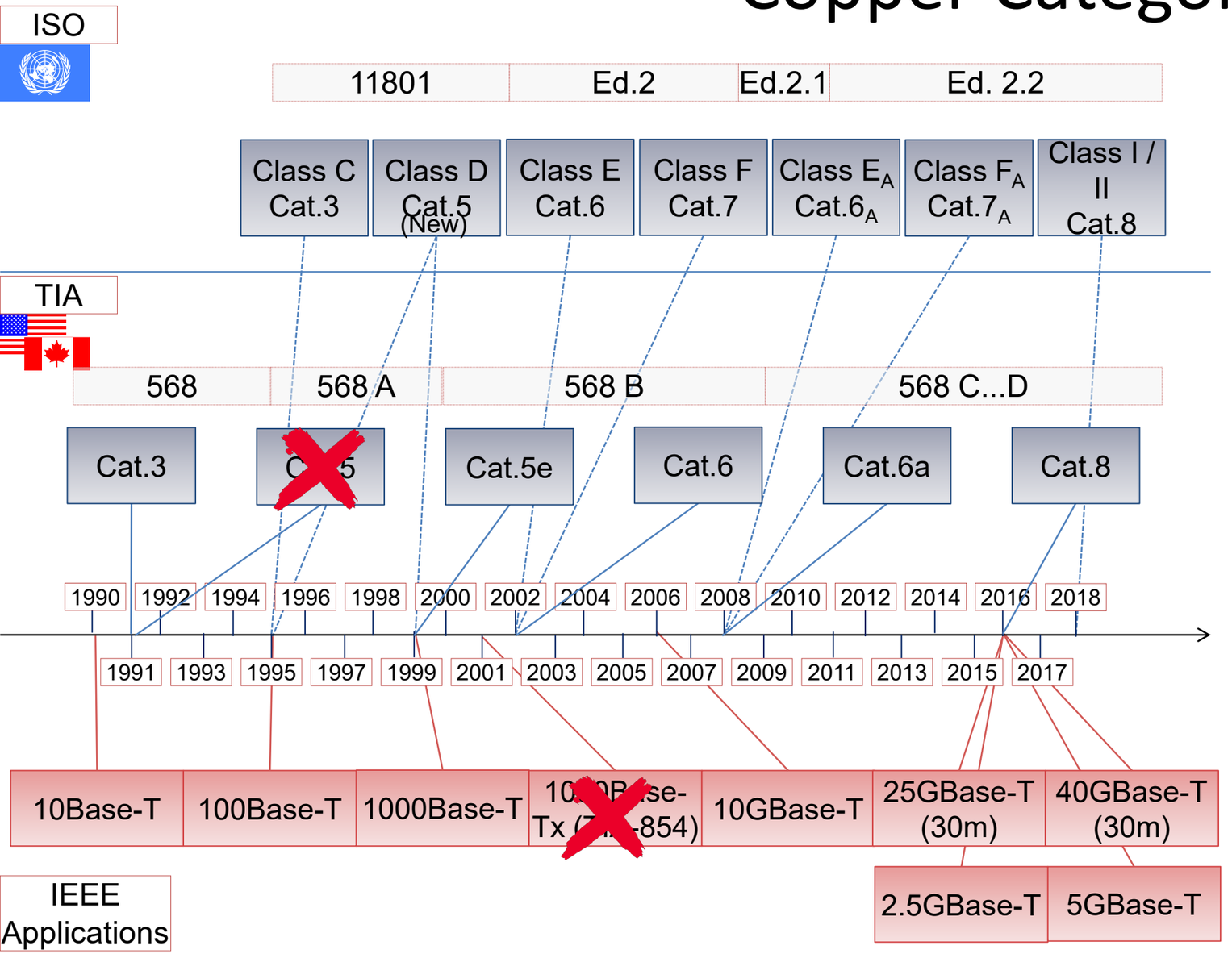
Bundled cabling length 50m to 75m	Category 5e	Category 6	Category 6A
2.5GBASE-T			Assured
5GBASE-T Assured			Assured

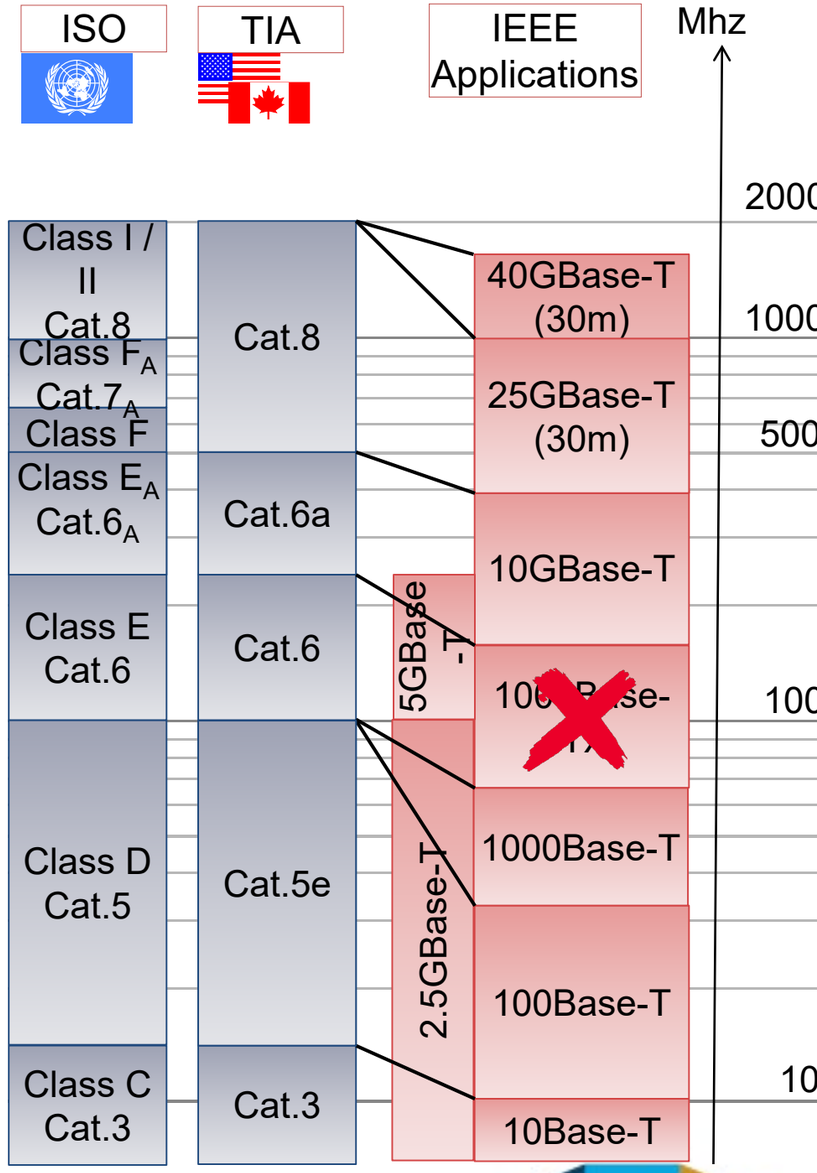
Bundled cabling length 75m to 100m	Category 5e	Category 6	Category 6A
2.5GBASE-T			Assured
5GBASE-T Assured			Assured

ALSNR Risk	High	Medium	Low

Table from NG-Base-T

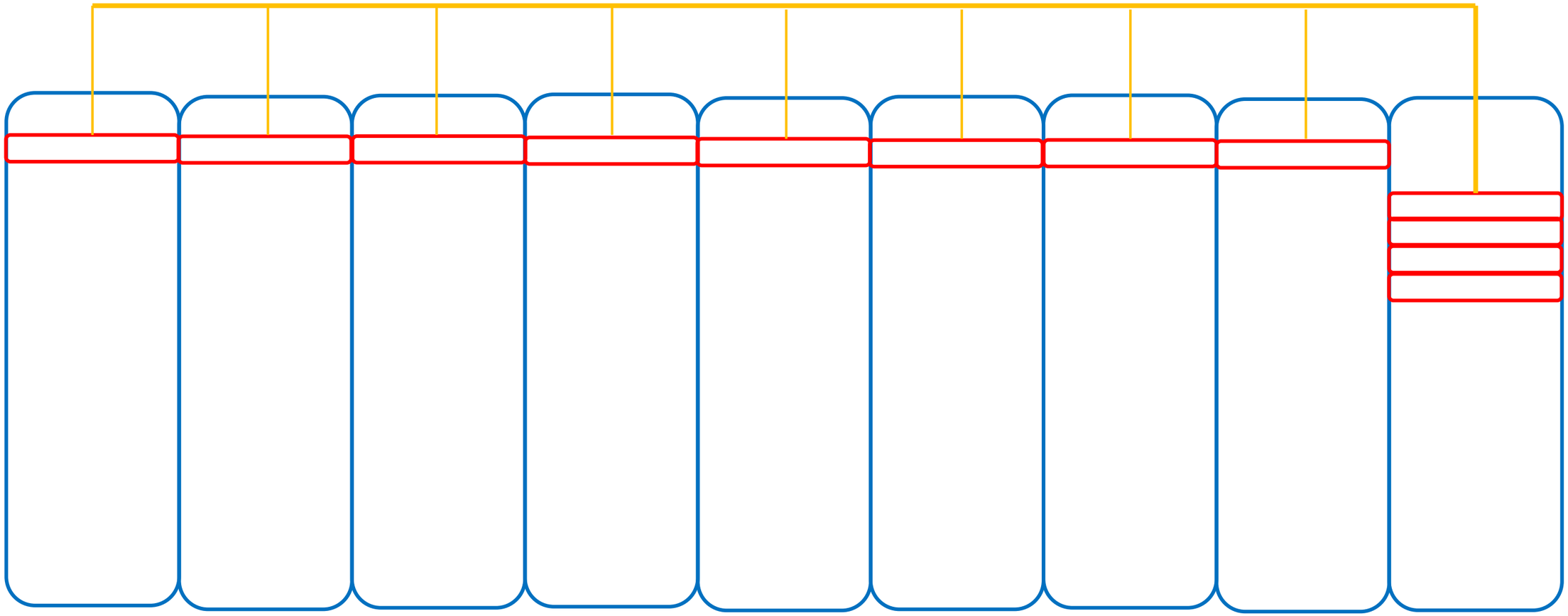
Copper Categories





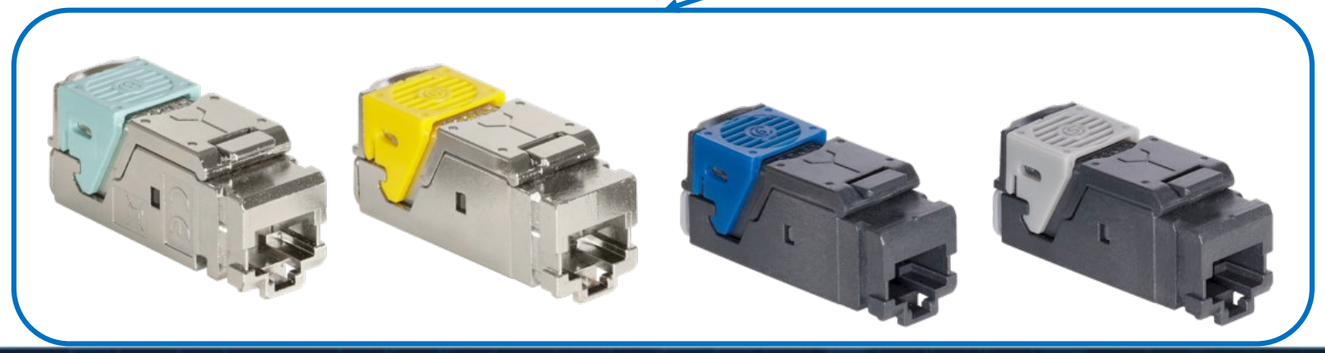
25G and 40G

- IEEE 802.3bq 25Gbase-T and 40Gbase-T is designed for the horizontal cabling in datacenters.
- The maximum distance is 30m.



Cat.8, Class I and Class II

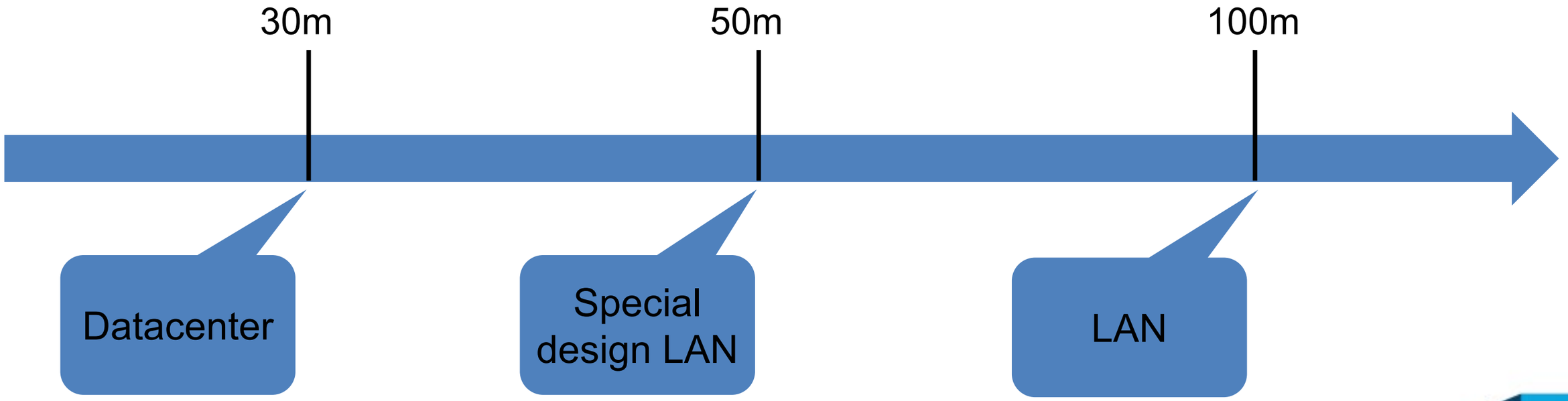
	Frequency	Distance	25 and 40 GBase-T	Cable	Connectors
TIA Cat.8	2 GHz	30m	Yes	F/UTP or S/FTP Cat.8	"RJ45" Cat.8
ISO Class I				Cat 8.1 = TIA Cat8	"RJ45" Cat.8.1 = TIA Cat.8
ISO Class II				S/FTP Cat.8.2	"Non-RJ45"



What's next?

- There is currently no work on any future Category 9.
- 40G is limited to 30m on category 8.
- Best solution for LAN is currently 10G, working on Category 6_A.
- But 25G could work for longer distance on Cat.8. (will <u>not</u> work on Cat.7_A1000MHz)
- Currently in development in the ISO/IEC standards: New 25G on Category 8 for 50m or more.

Caution: IEEE have announced that they are not interested is such development.



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PoE Standards

Published 2018

	IEEE		HDBase-T Alliance	IEC	ISO / IEC	CENELEC	TIA	NEC
Applications	802.3af	15.4W	HDBase-T					
	802.3at	30W						
	802.3bt	60W and 100W						
Cable testing under load				61156-1-4 (draft)				LP Rating
Connector testing under load				60512-99-001				
				60512-99-002 (draft)				
Cabling testing under load					TS-29125	TR 50174-99-1	TSB-184-A	
Conditions for new cabling					14763-2 (revision)	50174-2		

Existing

Final draft

CDV, almost final

published 2018

End customer purchases compliant equipment

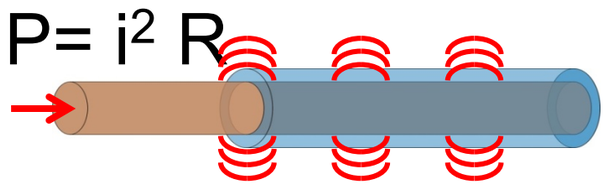
Manufacturer tests his components.

How to implement PoE on existing cabling

How to install new cabling PoE compliant

New ongoing from Electrical side of standards (safety aspects):
IEC 60364-7-716 Edition 1, Committee draft.

So what's so important about PoE in cabling?



- Power through a cable, because of resistance, creates heat.
- ISO/IEC 11801-1, chapter 9.3.2.3: Operating temperature of cables is -20°C to +60°C.
- Higher temperature = higher resistance = lower performance.

PoE compliance for new cabling

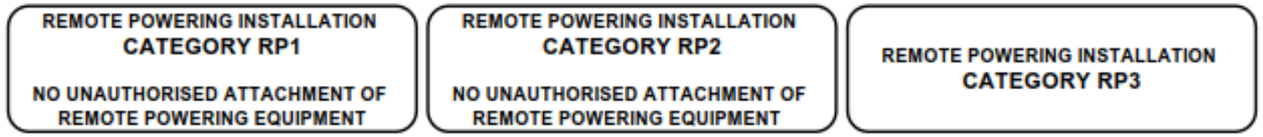
- ISO /IEC 14673-2 (draft), information Technology - Implementation and operation of customer premises cabling – Part 2: Planning and installation.
  - For balanced cabling in accordance with ISO/IEC 11801-1
  - Remote Powering equipment to supply no more than 500mA per conductor.
  - Installation must be designated in one of the following categories:

Draft. But the content on PoE is identical to EN 50174-2 which is already ratified.

Category	$i_{c\text{-}average}$	i_c	Controls required during	
			Attachment of remote powering equipment	Planning of subsequent cabling installation
RP1	≤ 212 mA	≤ 500 mA	Yes	Yes
RP2	> 212 mA < 500 mA	≤ 500 mA	Yes	Yes
RP3	-	≤ 500 mA	No	Yes

Mandatory to control before connecting a PoE device. Unless RP3.

-> Someone takes responsibility for the compliance during operation.



Labeling required to identify the type

For installation of cabling in accordance with ISO/IEC 11801-2, ISO/IEC 11801-3, ISO/IEC 11801-4 and ISO/IEC 11801-6 the planning, installation and administration requirements of Category RP3 shall be applied.

Correspondence Between Current and Power

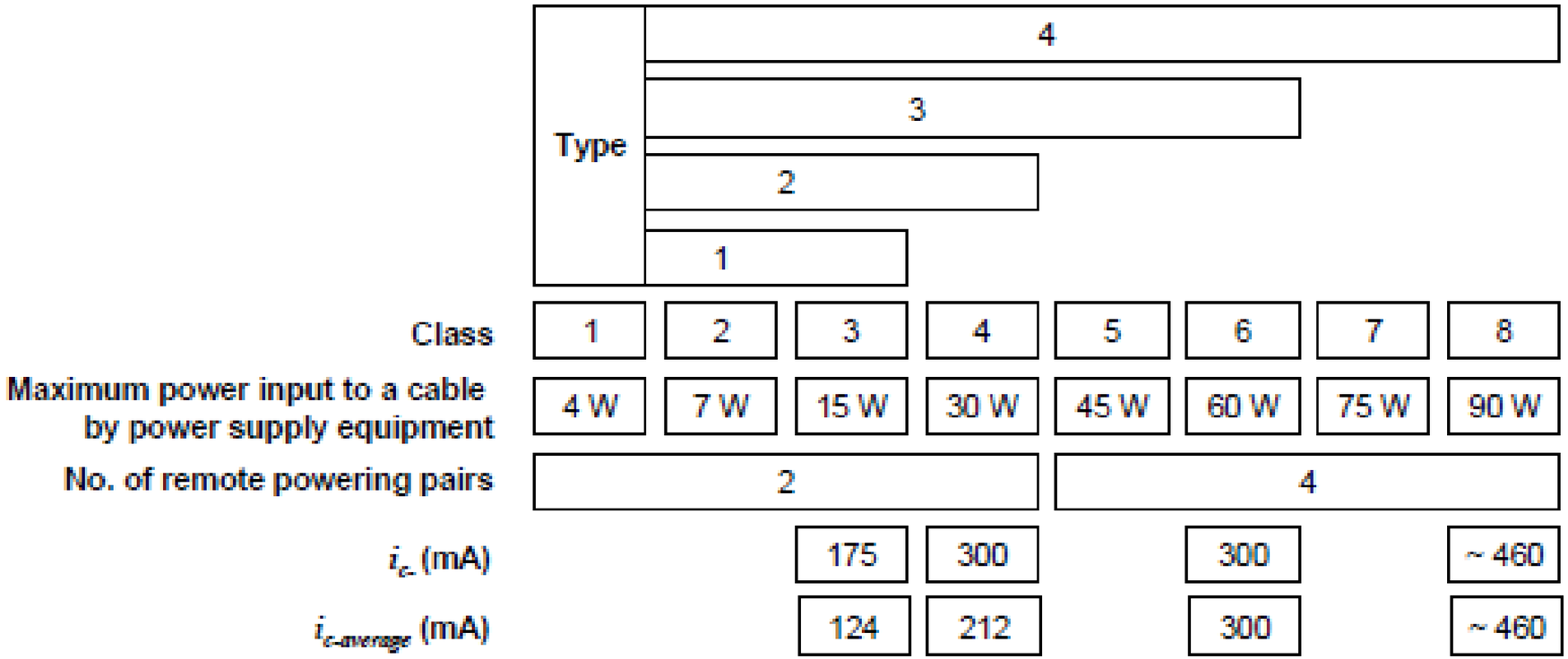
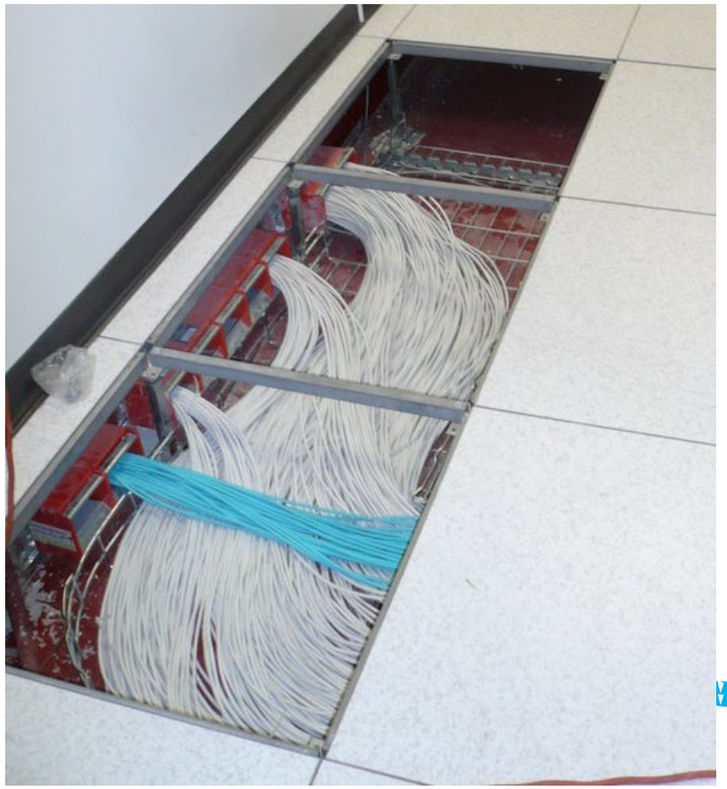


Figure A: Conductor currents for IEEE 802.3 remote powering applications

Calculate the heat increase

- Since you should comply to RP3, assume 500mA per conductor for 100% of the links (Type 4 100W everywhere).
- Irrelevant on PoE, the maximum number of cables in a bundle should be 24.
- However, bundles might join together in specific areas. For example through fire rated walls.



Calculate an average temperature

$$T_{\text{global}} = \frac{1}{L} \times \sum_{n=1}^{n} \left(T_{\text{ambient}-n} + \Delta T_n \right) \times L_n$$

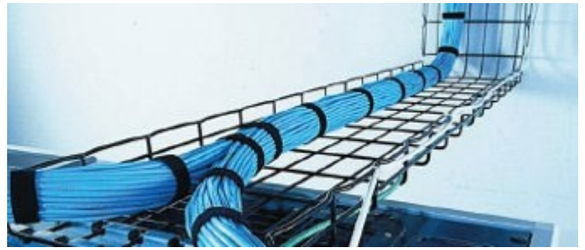
Suggestion: first only calculate worst case

Calculate the heat increase

- Calculate the temperature increase with the formula.

$$\Delta T\ ^{\circ}C = \left(0.8 \times N + \frac{K \times \sqrt{N}}{D}\right) \times R$$

N = number of cables
K = temperature coefficient of the cable management
D = diameter of the cables
R = resistance of the cables



ΔT Estimations

Table 19 - Temperature changes for various cable bundle sizes

Installation condition E/F - Ventilated								
No. of cables (N)	6	12	24	48	72	96	144	216
Cable R and D[a]	ΔT °C							
0,095 Ω/m 5,0 mm	3,0	5,0	7,0	11,0	15,0	18,0	24,0	32,5
0,075 Ω/m 7,0 mm	2,5	4,0	6,0	9,0	12,5	15,5	20,5	27,0
0,065 Ω/m 7,7 mm	2,0	3,5	5,5	8,0	11,0	13,5	18,0	24,0

[a] Wit

Installation condition C - Unperforated tray								
No. of cables (N)	6	12	24	48	72	96	144	216
Cable R and D[a]	ΔT °C							
0,095 Ω/m 5,0 mm	4,0	6,0	9,0	14,0	18,0	21,5	28,5	38,0
0,075 Ω								
0,065 Ω								

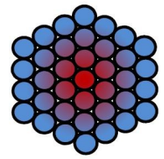
[a] Within

Installation condition A - Insulation								
No. of cables (N)	6	12	24	48	72	96	144	216
Cable R and D[a]	ΔT °C							
0,095 Ω/m 5,0 mm	13,0	18,5	27,0	39,0	**	**	**	**
0,075 Ω/m 7,0 mm	$\approx \left(0{,}8\times N+\frac{0{,}27\times\sqrt{N}}{D}\right)\times R$	7,5	10,5	15,5	23,0	29,0	34,0	**	**
0,065 Ω/m 7,7 mm		6,0	8,5	12,5	18,5	23,0	27,5	35,0	**

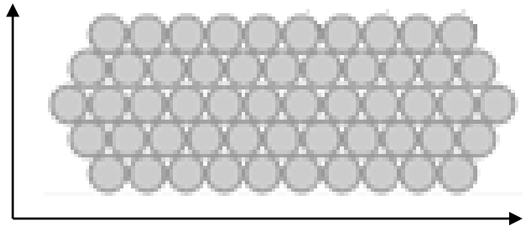
[a] Within the formula, D in metres e.g. for cable diameter 5 mm, D = 0,005

NOTE ** indicates a temperature in excess of 60 °C (assuming an ambient of 20 °C) which represent unacceptable localised heating

- You can estimate using the tables in the document.
- Or you could have a more precise using the annex I.
- Or most precise using the ISO/ IEC TS 29125
- Below is a simplification. (Caution: over – simplified. Add some extra margin)
- Adjust if the bundles are not round but rectangular



	Ventilated			Unperforated Tray			Trunking / Conduit			Insulation		
Typical Cat.	**24**	**72**	**216**	**24**	**72**	**216**	**24**	**72**	**216**	**24**	**72**	**216**
Cat.5	7.0	15.0	32.5	9.0	18.0	38.0	13.0	25.0	> 40	27.0	> 40	> 40
Cat.6	4.5	9.5	22.0	5.5	11.5	25.0	7.5	15.0	32.0	15.5	29.0	> 40
Cat.6A	4.0	8.0	18.5	4.5	9.5	21.0	6.0	12.5	26.0	12.5	23.0	> 40



Height to Width	1:1	1:2	1:3	1:4	1:5	1:6	1:7	1:8	1:9	1:10
ΔT multiplier	0.89	0.84	0.77	0.71	0.66	0.62	0.59	0.56	0.53	0.51

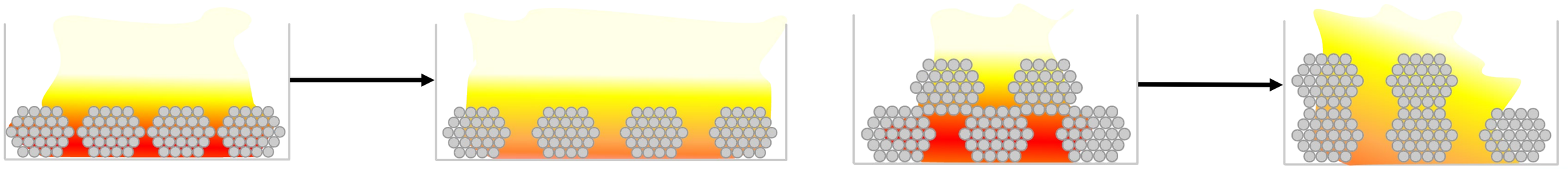
Verify the solution

- Estimate the temperature of the environment and add the two together.
- In any case T + ΔT should be maximum 60 °C for standard compliant cabling.
- Calculate your maximum lengths for permanent links adjusted with the temperature. Here is a simplified table.

T (°C)	Permanent Link (m)
20	90
25	88
30	85
35	83
40	80
45	78
50	75
55	73
60	70
Assuming 10m of cords with 50% extra attenuation	

Mitigate

- At this point you might be trying to find solutions to reach a lower temperature.
- Calculate more precisely instead of using only absolute worst case.
- Then look into:
  - Bundle separation
  - Smaller bundles
  - Cables with lower resistance
  - Cables with larger diameter
  - Changes to the environment
  - Reduction of the ambient temperature
- If all fails, lower to RP2 and check again.
- In all cases, good practice is to arrange the bundles to improve airflow



PoE compliance for new cabling

- **Do not design or install new cabling without considering the PoE needs.**
- **Use worst case, then improve with more accurate calculations.**
- **Forget the 90m permanent link limit. You'll always be lower.**

Agenda

1- Standards
2- Copper Systems
3- PoE Compliant Installation
4- Fiber Systems
5- Single Pair Ethernet

Multimode vs. Singlemode

10GBASE-LR SFP+ transceiver module for SMF, 1310-nm wavelength, 10km, LC duplex connector

Price: **$395.00**
Model/Part #: SFP-10G-LR
Availability: In Stock
Ships: In 24 hours
Warranty: Lifetime

Qty: 1 + Add to Cart - OR - Add to Wish List Add to Compare

☆☆☆☆☆ 0 reviews | Write a review

Singlemode for distance, multimode for price

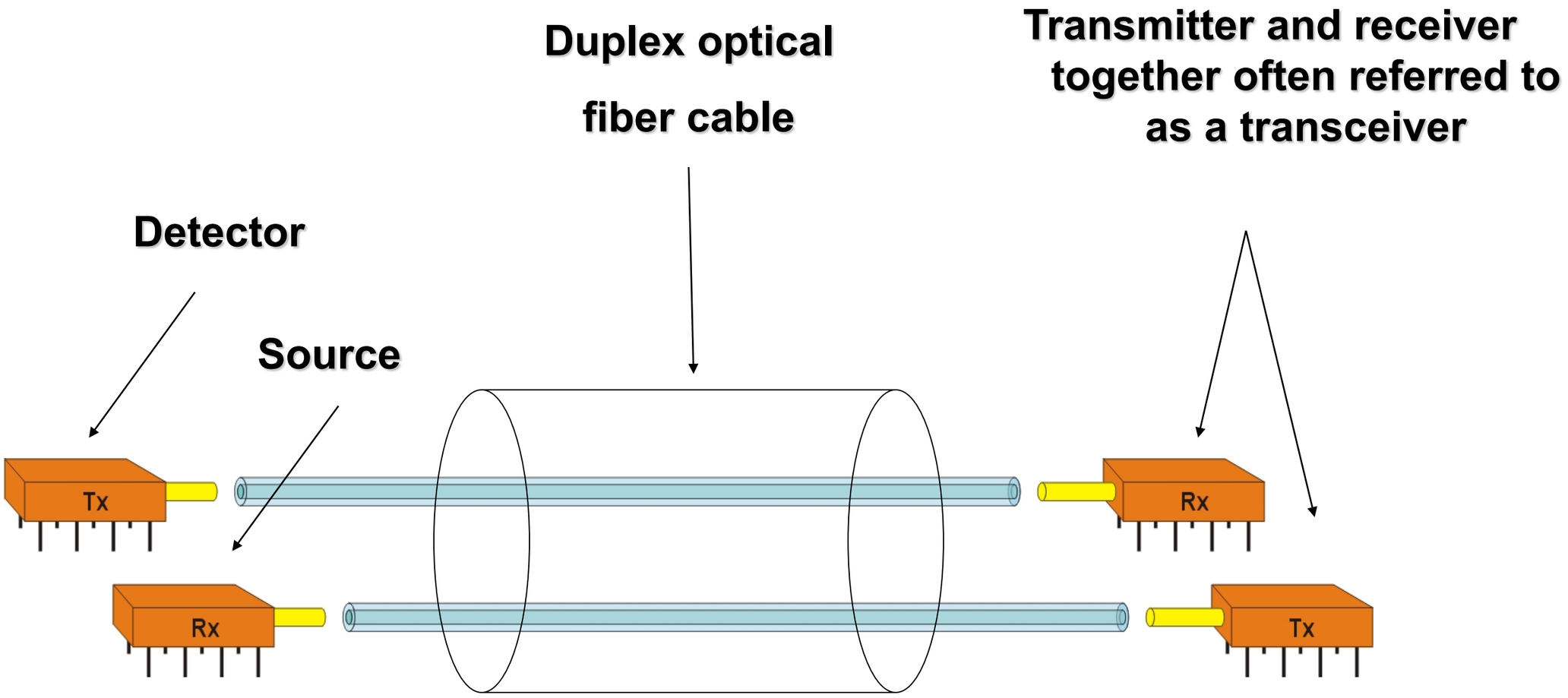
10GBASE-SR SFP+ transceiver module for MMF, 850-nm wavelength, 300m, LC duplex connector

Price: **$145.00**
Model/Part #: SFP-10G-SR
Availability: In Stock
Ships: In 24 hours
Warranty: Lifetime

Qty: 1 + Add to Cart - OR - Add to Wish List Add to Compare

☆☆☆☆☆ 0 reviews | Write a review

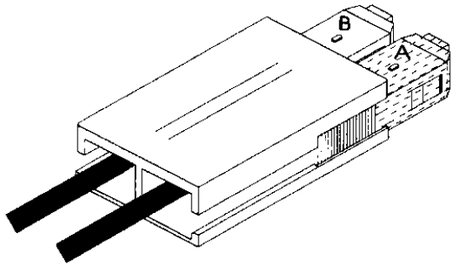
Duplex transmission



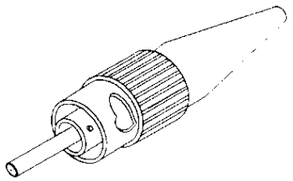
Connector choice

LC

Obsolete

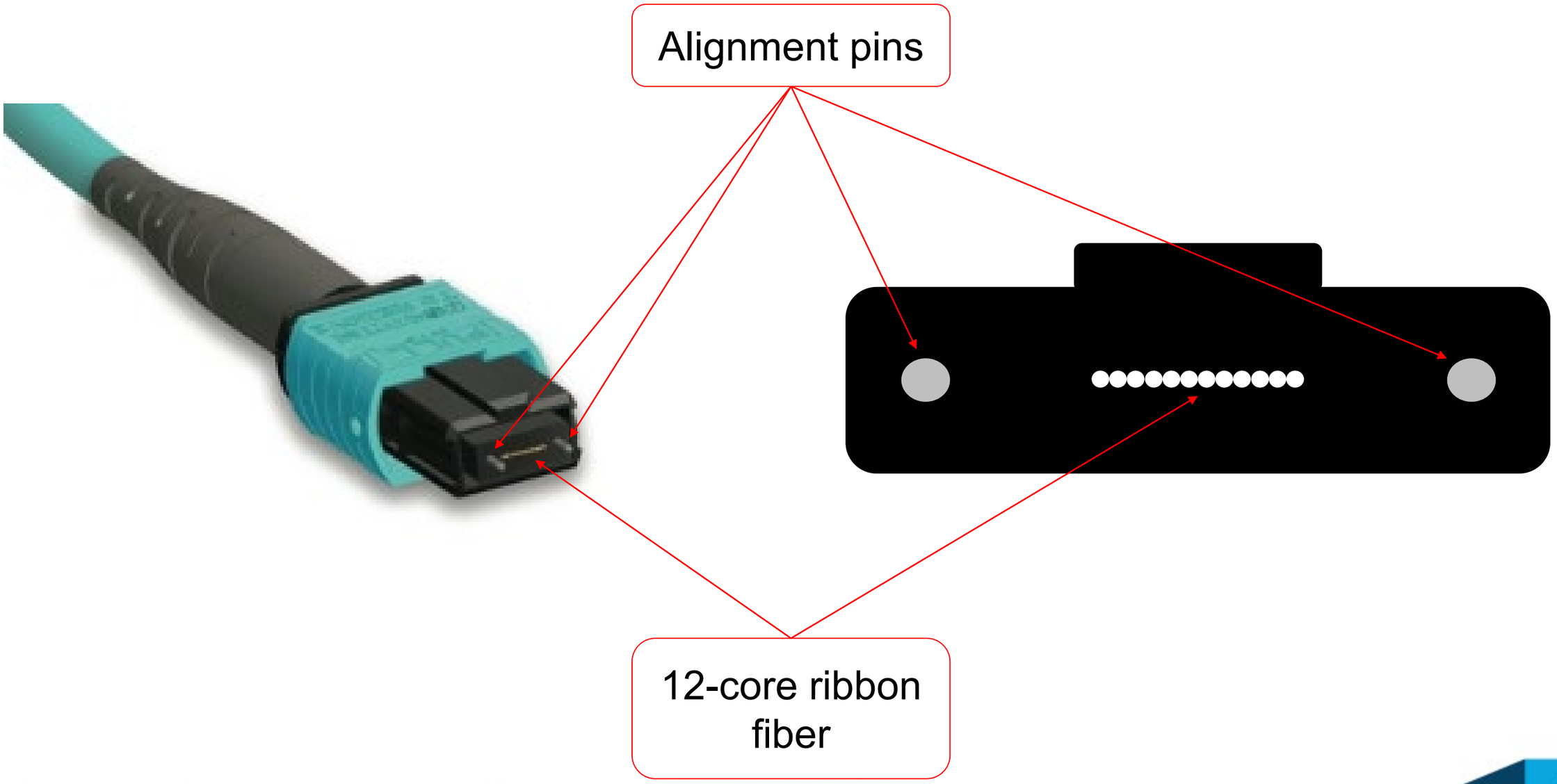


SC - Duplex



ST

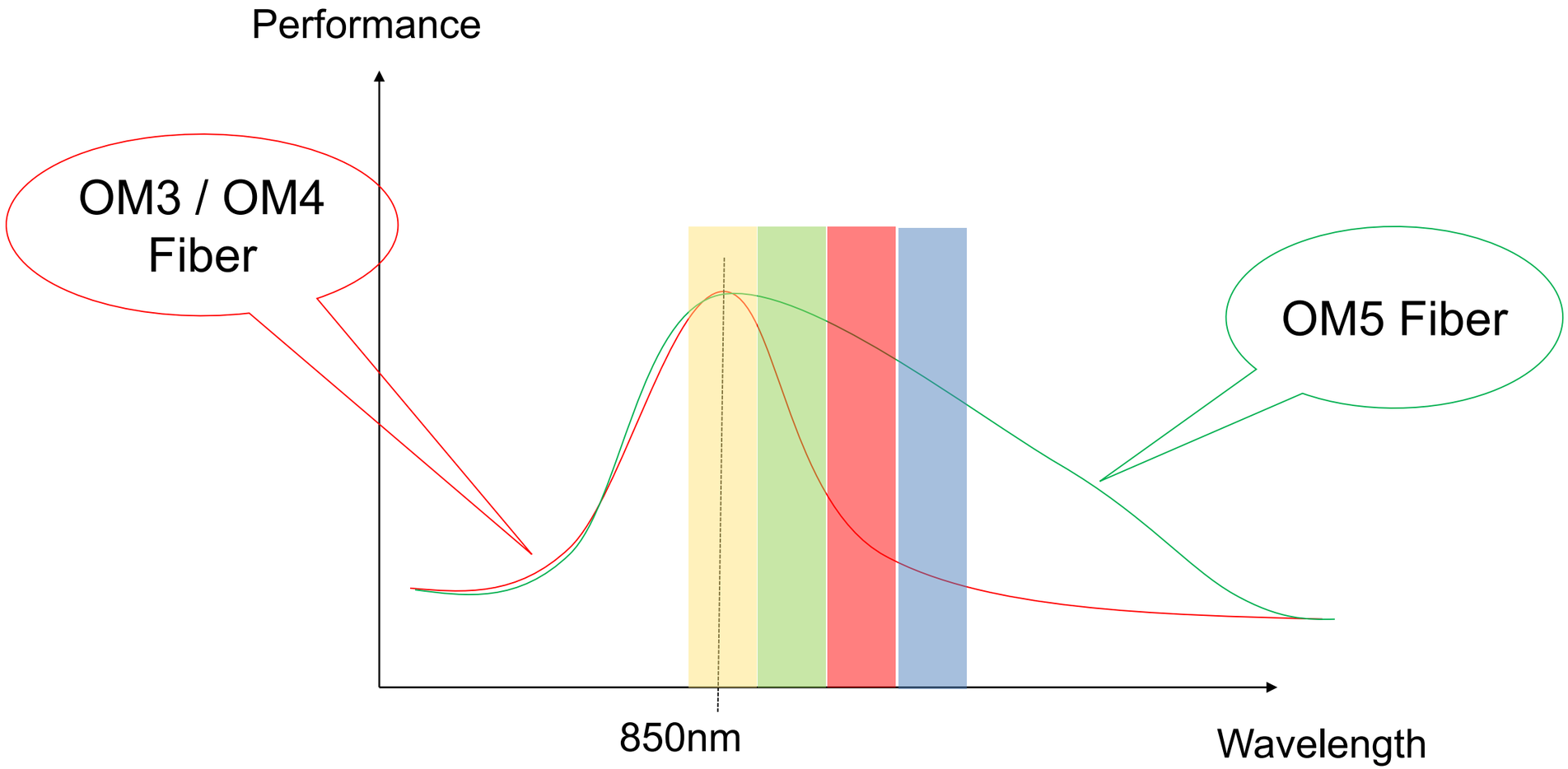
Alternate: the MPO



Increasing the performance on MM Fiber

	LAN 10G VCSEL (NRZ)	DC 10G VCSEL (NRZ)	DC 25G VCSEL (NRZ)	DC 50G VCSEL (PAM4)	DC 100G VCSEL (PAM4)
	OM3 300m / OM4 400m	OM3 100m / OM4 150m	OM3 70m / OM4 100m	OM3 70m / OM4 100m	
10G	●●				
25G			●●		
40G		●●●●●●●●●●●●			
		●● (WDM: Different distances)			
50G				●●	
100G		●●●●●●●●●●●● ●●●●●●●●●●●●	●●●●●●●●	●● (WDM: Different distances)	●●
			●● (WDM: Different distances)		
200G				●●●●●●●●	●●●●
				●● (WDM: Different distances)	
400G			●●●●●●●●●●●●●●●● ●●●●●●●●●●●●●●●●	●●●●●●●● ●●●●●●●●	●●●●●●●● ?
			●●●●●●●● (WDM: Different distances)	●●●●●●●● (WDM: Different distances)	

OM5 Fiber



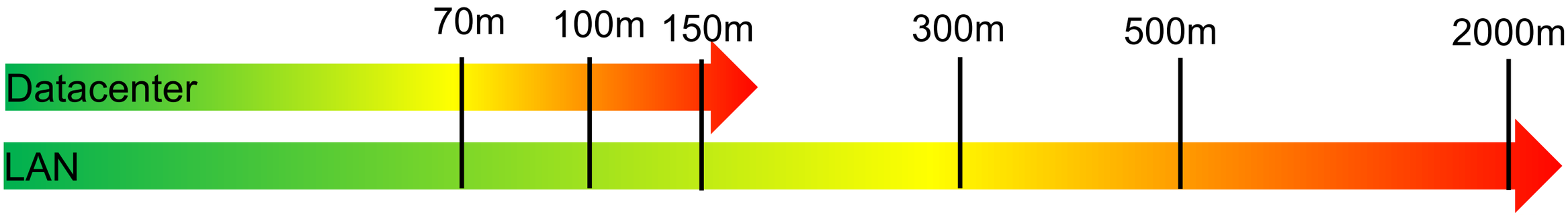
Singlemode New Developments

	25G LASER (NRZ)	40G LASER (NRZ)	50G LASER (PAM4)	100G LASER (NRZ)
10G				
25G	○○			
40G		○○		
50G			○○	
100G			○○○○	○○
200G			○○○○○○○○	
			◔◔	
400G		8 wavelengths		○○○○○○○○
			◔◔	◔◔

What's next?

- Continued Higher data rates in the datacenter.
- New applications based on signals of 25G, 50G and 100G, not on 40G.
- Parallel optics use 4, 8 16 cores instead of the base 12 originally in the MPO connectors.
- (Financial) Distance limit between parallel optics and wavelength multiplexing not clear yet.
- For backbone cabling based on 2-core cabling, OM5 seems to have far more probability of future application than OM3 or OM4.
- New work on bidirectional

Caution: OM3 and OM4 have changed to maximum IL = 3.0dB/km instead of 3.5dB/km, to align with OM5.



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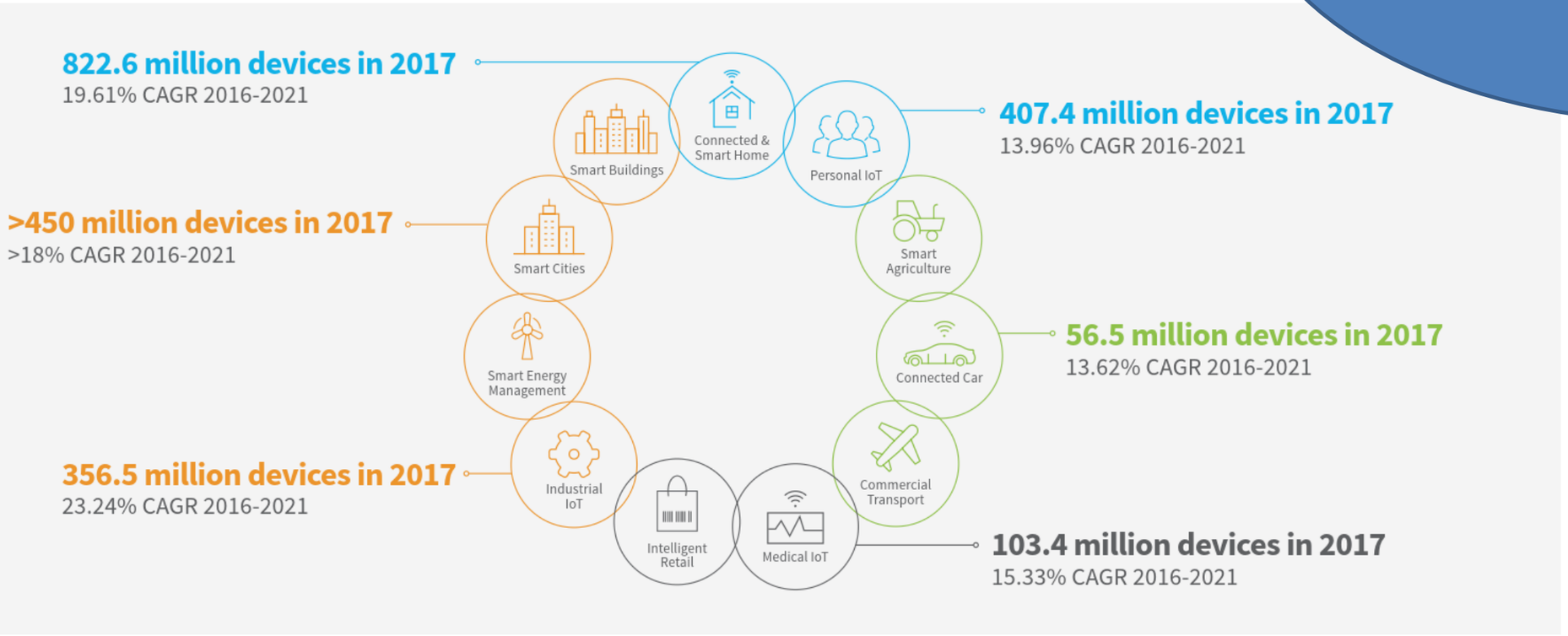
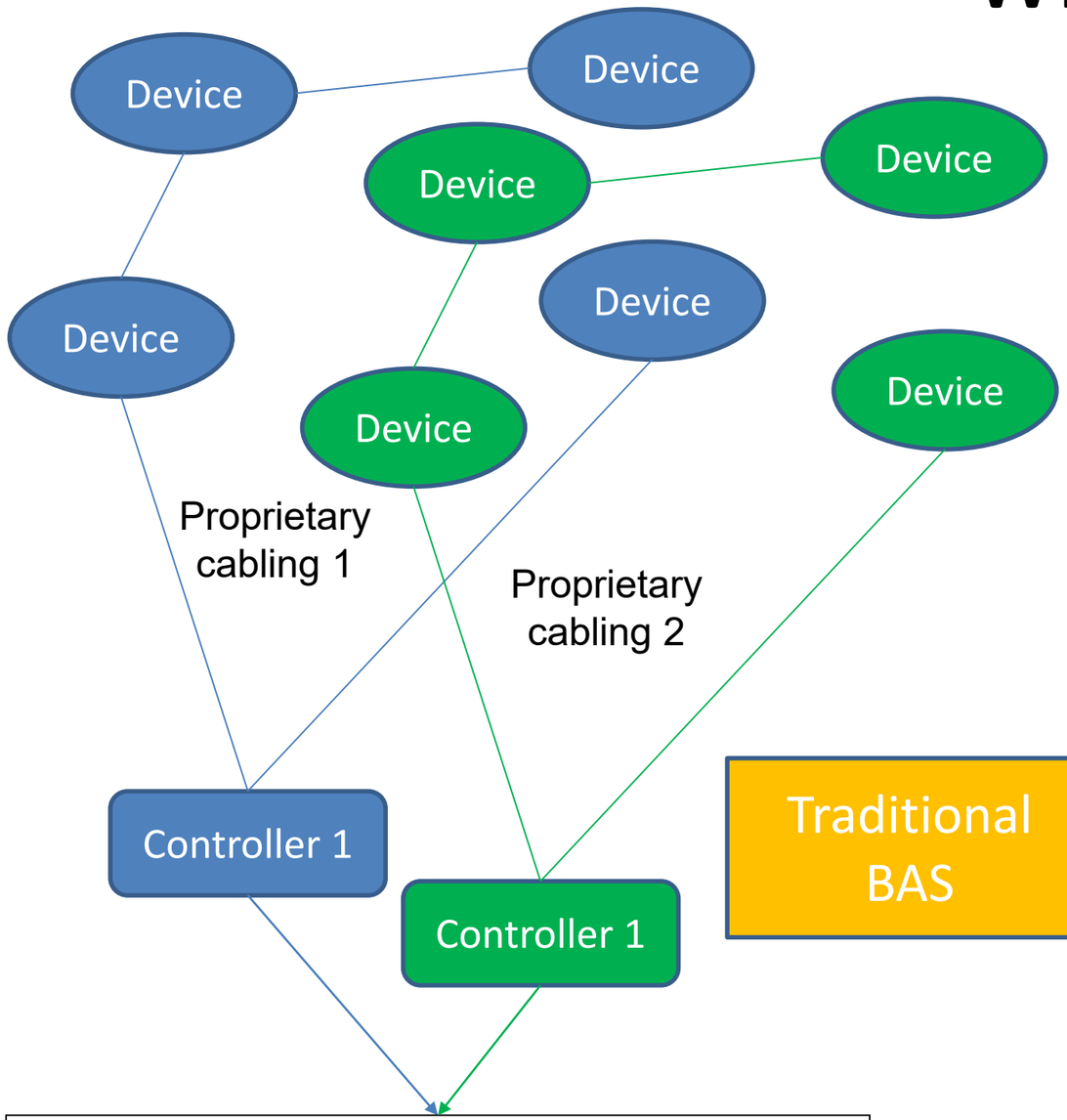
IoT

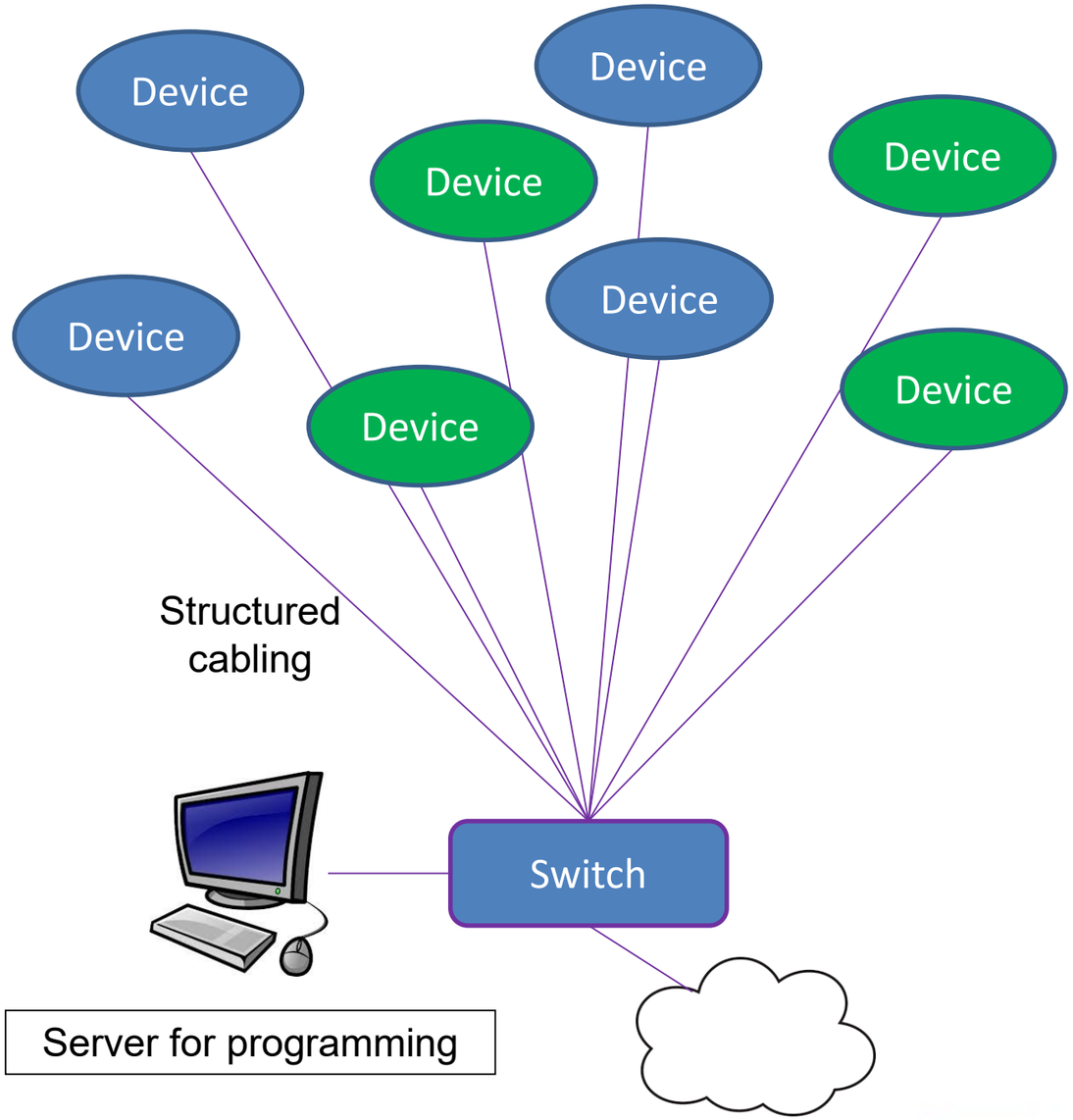
- From HIS Markit:

The number of connected IoT devices worldwide will jump 12% on average annually, from nearly 27 billion in 2017 to 125 billion in 2030.



Why Ethernet?



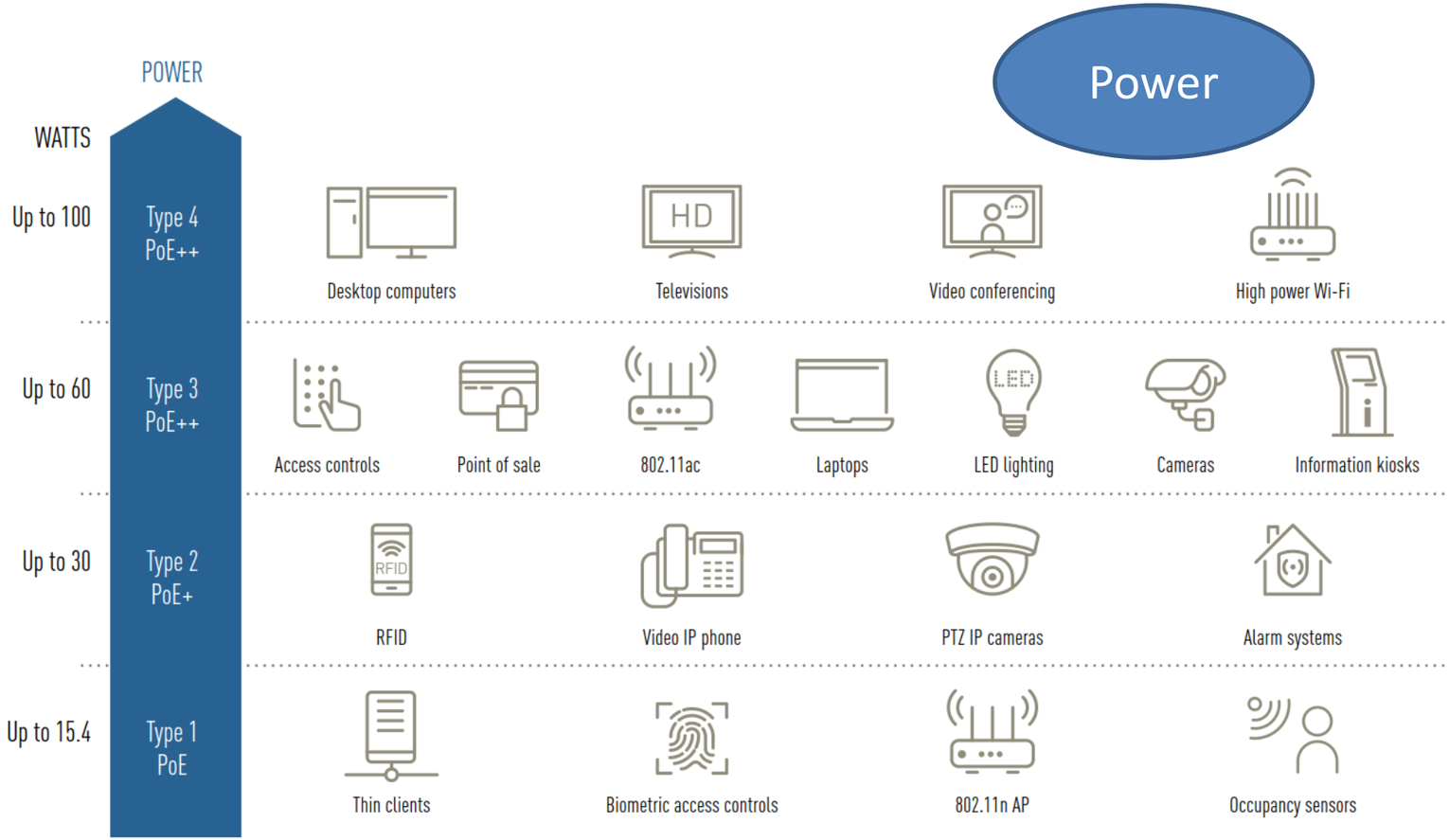


Why PoE ?

- Why would you pay for an electrical infrastructure that you are using at 5% capacity in IoE devices, plus a communication infrastructure (wired or wireless)
- PoE simply does it better and cheaper !

What we offer

- Our cabling systems can provide:



Data

Cat.5e → 1Gbps

Cat.6A → 10Gbps

Needs

Major Uses Cases ISO/IEC 11801-6 Distributed Services

Use Case	Application Data Rate (Mb/s)	In-Building Range of Reach (m)	Remote power (watts)	Remote Termination
IoT	< 10	15 - 100	< 5	NCP/device
BAS	< 10	15 - 100	15 - 30	NCP/device
WIFI (ac)	1000 – 10 G	< 15	15 - 50	NCP/AP
Lighting	< 10	15 - 100	10 - 50	NCP/device
Surveillance	100 - 1000	15 - 100	10 - 30	NCP/camera
VoIP phone	< 10	15 - 100	40	phones
Fire/smoke alarm	< 10	15 - 100	5 - 10	Console/speakers
Audio/speakers	< 10	15 - 100	5 - 10	speakers

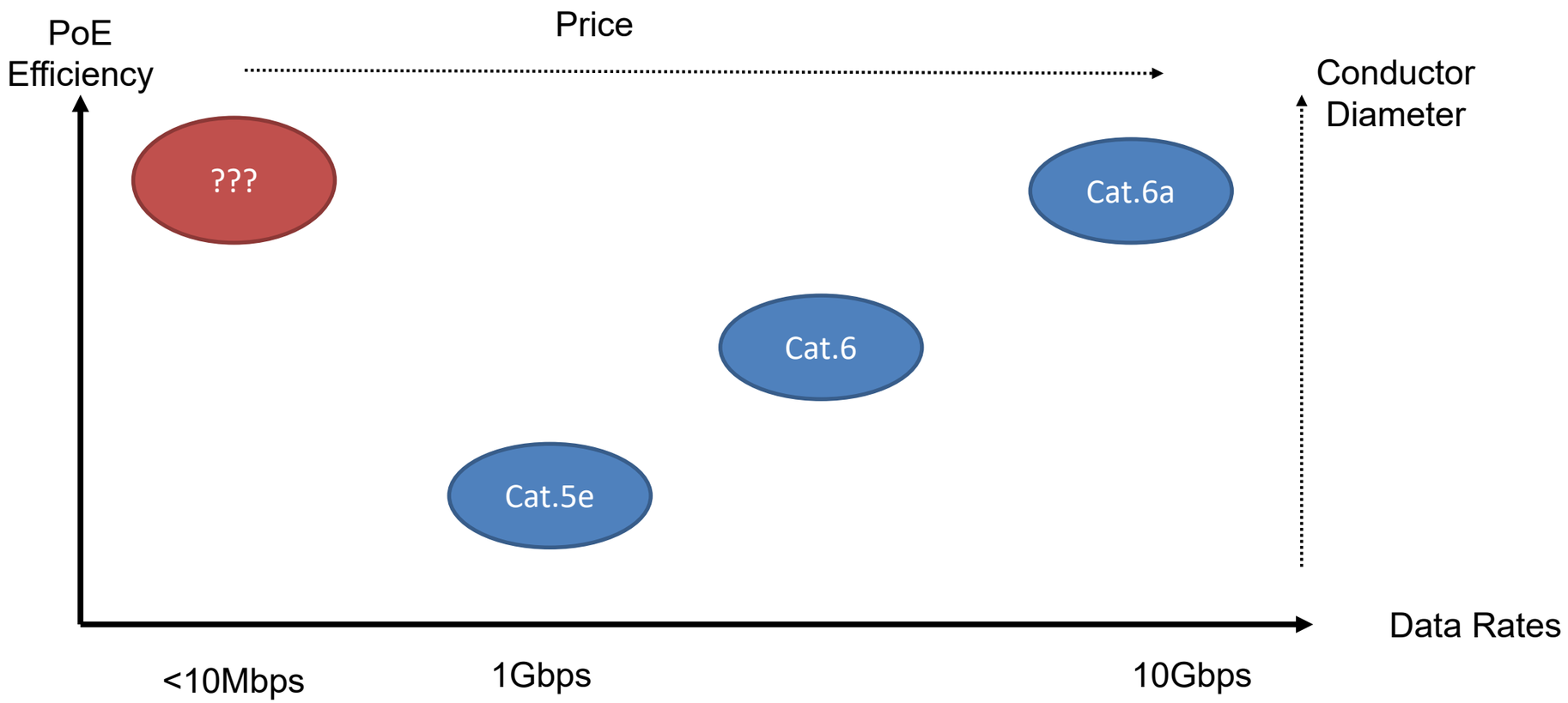
Building Controls Protocols

- BACnet: Physical Interface can be RS-485 (MS/TP), RS-232, LONTalk, Ethernet,
- LONTalk: Physical interface is twisted pair or Power Line
- MODBus: Physical Interface is RS-485 or RS-232
- Profibus/Fieldbus/ControlNet: Physical Interface is RS-485 or RS-232
- KNX (formerly EIB & BatiBus & EHS): Physical Interface is twisted pair, RF or Power Line
- DALI: Physical Interface for control signal is RS-485
- OPC (Open Platform Communications): can interface with LONTalk, BACnet or DALI

A new solution?

Our Current options

What we need



List of SPE Options

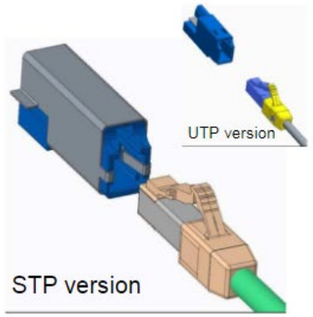
- IEEE Single Pair Ethernet

Standard	Content	Target	Distance	Specifics	Status
802.3bw	100mbps	Automotive	30m		Ratified
802.3bp (Type A)	1Gbps	Automotive	30m	4 connectors	Ratified
802.3bp (Type B)	1Gbps	Transport / industrial	40m		Ratified
802.3bu	PoDL	802.3 bw / bp	All	50V, 1.36Amp	Ratified
802.3cg (Short and Long)	10mbps + Power	Industrial / Commercial	S < 15m L < 1km	Up to 10 connectors	Draft Expected Sept 2019.
802.3ch Multi Gig	2.5G, 5G, 10G	Automotive	15m		Draft Expected 2020

Cabling

- ISO /IEC 11801 – Ongoing documents:
  - TR 11801-9906: Systems performance for single pair Ethernet applications
  - 11801-1 Amendment: addition of the single pair channels
  - 2 connectors have been chosen: one for commercial (variant 1), one for industrial. (variant 2) being defined in IEC 63171 series.
  - 2 Cables: 600MHz (IEC 61156-11 and 12) and 20MHz (IEC 61156-13 and 14).

Variant 1 – LC style for $M_1I_1C_1E_1$ acc. IEC 63171-1



Variant 2 – Industrial style for $M_2I_2C_2E_2$ and $M_3I_3C_3E_3$ acc. IEC 61076-3-125

IP20

M8 IP65/67

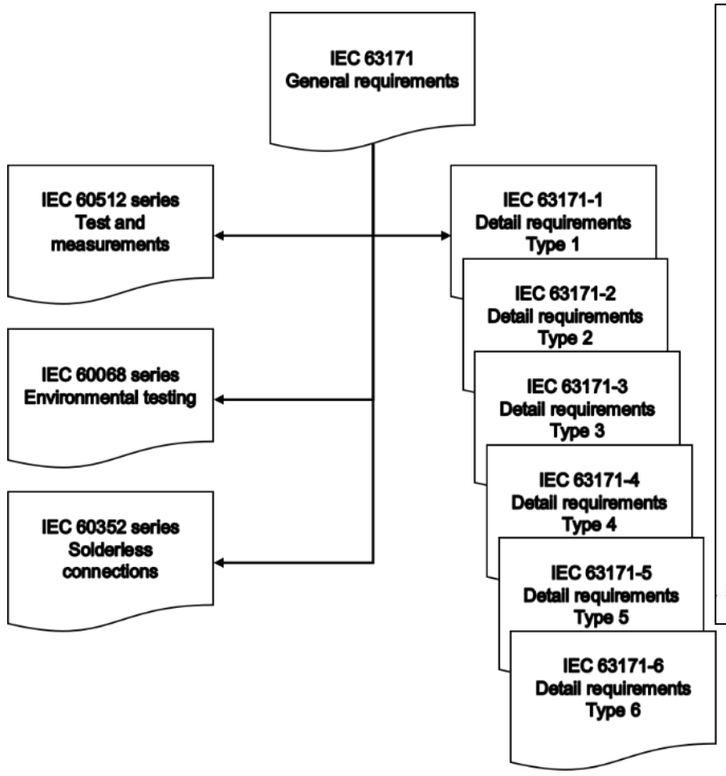
M12 IP65/67

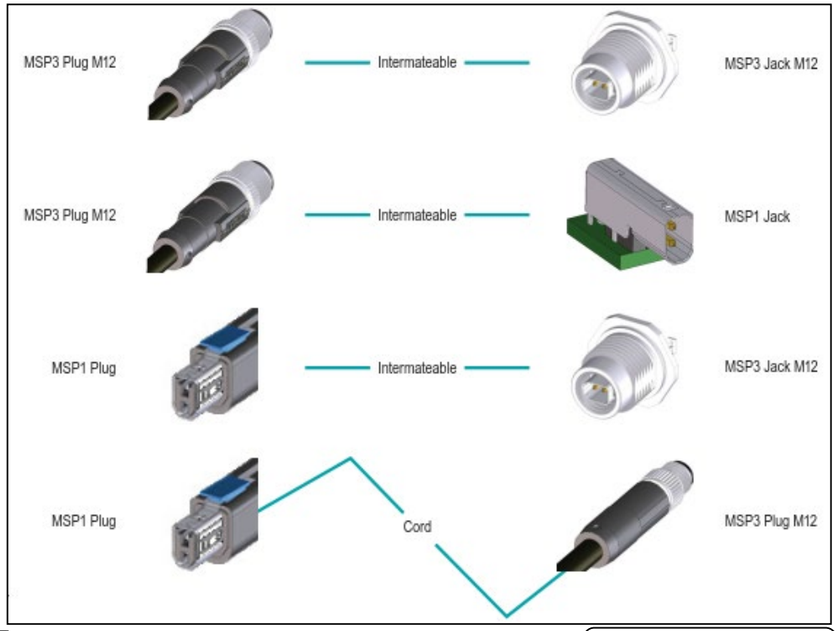
Multiple cable AWGs

Channel	Frequency	Length(s)
T1-A	20MHz	100m, 250m, 500m, 1000m
T1-B	600MHz	100m
T1-C	2.5MHz (?)	50m(?)

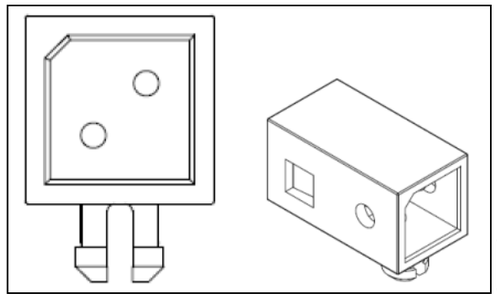
Cabling

- IEC - Drafts 63171-x
  - Connectors for single pair use (not limited to Ethernet)
  - All 6 variant will be defined



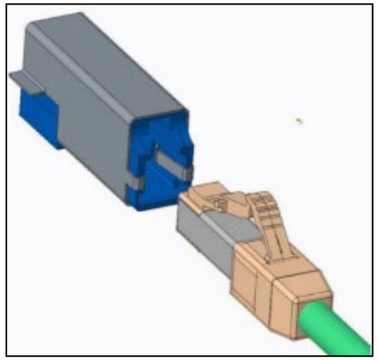


63171-5

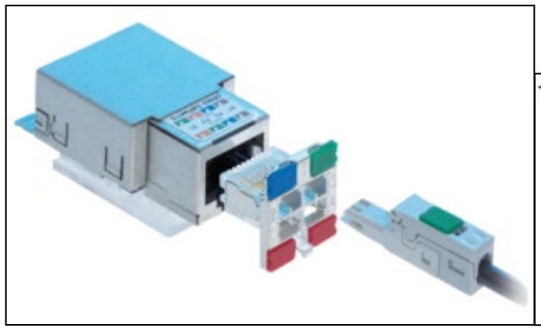


63171-4

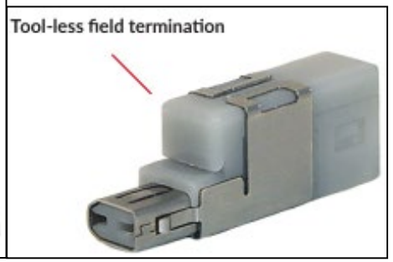
63171-1

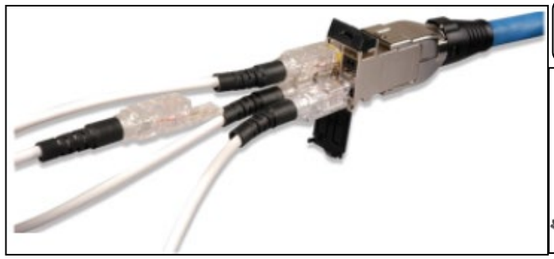


61076-3-25 -> 63171-6

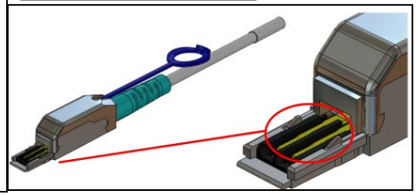


63171-2



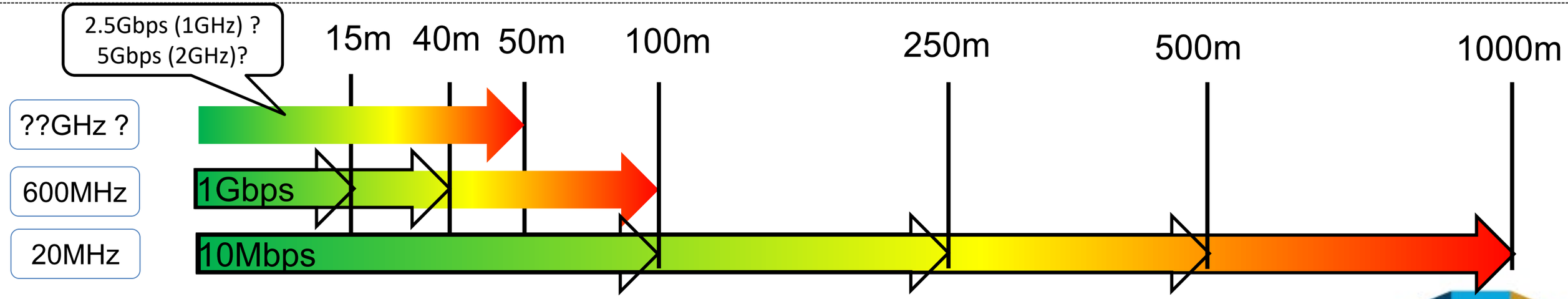


63171-3



What to expect?

- Single pair Ethernet is a whole new ecosystems with many options…
- Power to increase to 100w soon.
- The IEEE channels are almost all defined. The creation of channels to support them is almost defined in ISO/IEC TR 11801-9906.
- But there is still substantial work to be done in ISO/IEC 11801-1 Amd. To translate this into simpler options more in line with “traditional” channels, while offering future options.
- While the 20MHz channel is created to serve a market, the 600MHz channel is created to push existing products.
- **You can expect the 20MHz / 10Mbps version to be a major part of intelligent buildings**.



Thank You

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