Campus Networks: Layer1 cabling

Copper Twisted Pair / Fiber Optics / Design recommendations

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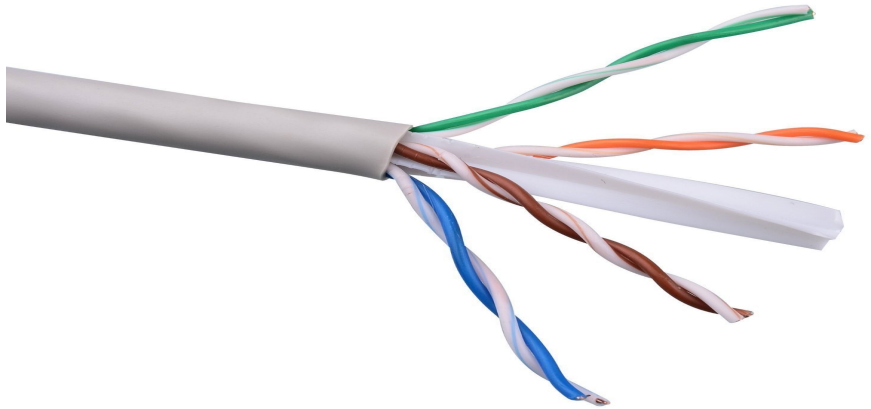
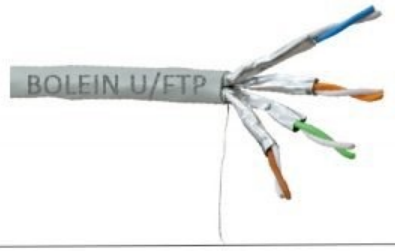
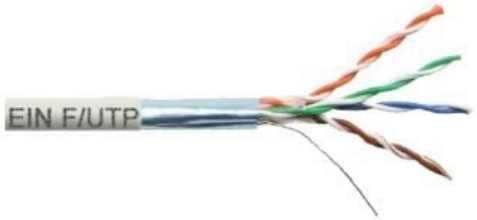
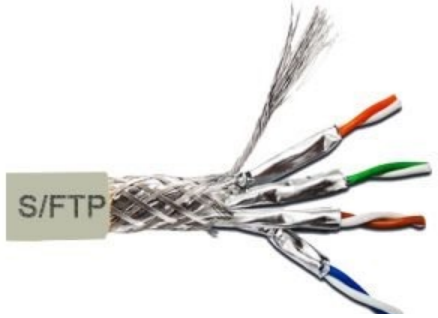
Types of cables

Two main categories used in today's networks

1- Copper Twisted Pair cables

- Unshielded (UTP)
- Shielded (STP): F/UTP, SF/UTP, U/FTP, F/FTP, S/FTP



	ISO/IEC 11801	Cable Shielding	Pair Shielding
	U/UTP	None	None
	U/FTP	None	Foil
	F/UTP	Foil	None
	F/FTP	Foil	Foil
	S/FTP	Braiding	Foil

Credit: https://www.bolein.net/wp-content/uploads/2020/06/UTP-STP-800x979.jpg

Copper Twisted Pair cable standards

Category	Maximum Speed	Max. Length	Frequency	SHIELDING	Application
CAT 1	Up to 1Mbps(Carry only Voice)	--	1MHz	Unshielded	Old telephone cabling
CAT 2	Up to 4Mbps	--	4MHz	Unshielded	Token Ring Network
CAT 3	Up to 10Mbps	100m	16MHz	Unshielded	Token Ring & 10BASE-T Network
CAT 4	Up to 16Mbps	100m	20MHz	Unshielded	Token Ring Network
CAT 5	Up to 100Mbps	100m	100MHz	Unshielded	Ethernet, Fast ethernet and Token Ring
CAT 5e	Up to 1Gbps	100m	100MHz	Unshielded or Shielded	Ethernet, Fast ethernet & Gigabit ethernet
CAT 6	Up to 10Gbps	100m	250MHz	Unshielded or Shielded	Ethernet, Fast ethernet, Gigabit ethernet & 10G Ethernet(37 - 55 meter)
CAT 6a	Up to 10Gbps	100m	500MHz	Shielded	Ethernet, Fast ethernet, Gigabit ethernet & 10G Ethernet(37 - 55 meter)
CAT 7	Up to 10Gbps	100m	600MHz	Shielded	Ethernet, Fast ethernet, Gigabit ethernet & 10G Ethernet(100 meter)
CAT 8	Up to 40Gbps	100m	2000MHz	Shielded	Ethernet, Fast ethernet, Gigabit ethernet & 25G-40G Ethernet(30 meter)

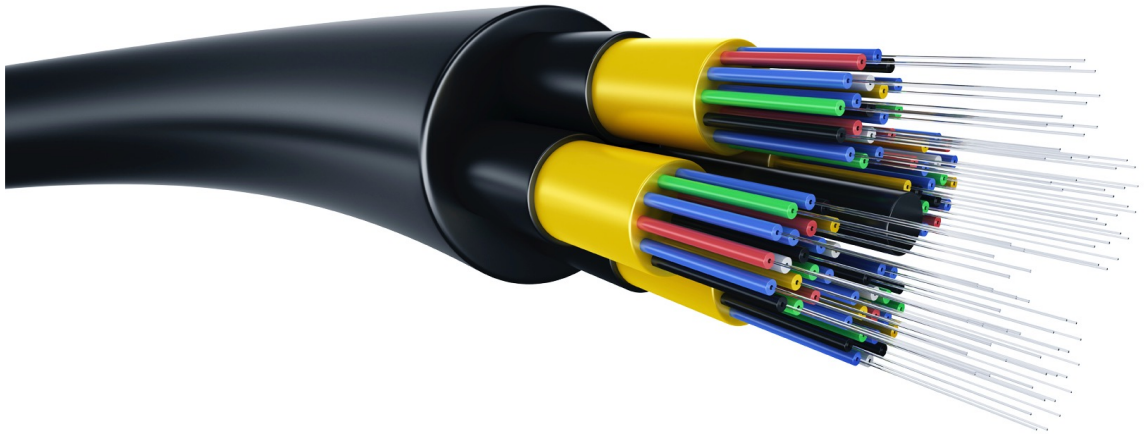
Credit: https://dc.mynetworkinsights.com/categories-of-copper-twisted-pair-cables/

Types of cables

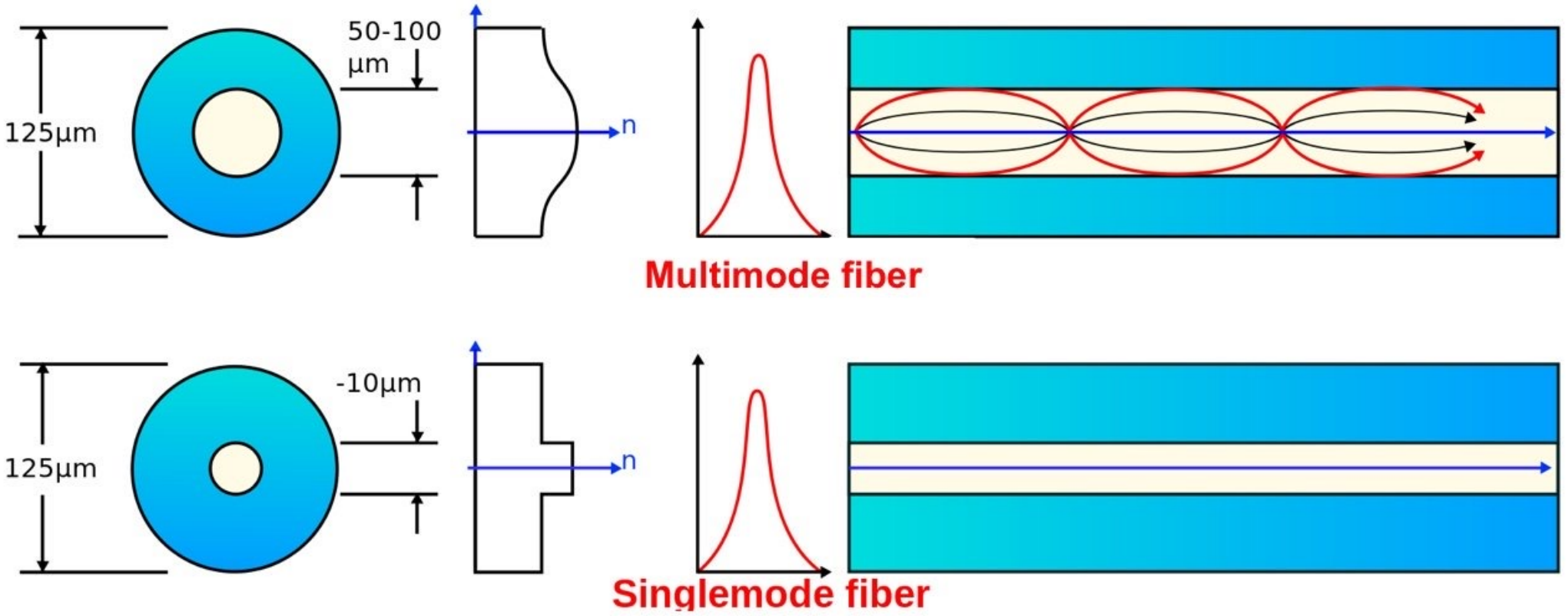
Two main categories used in today's networks

2- Fiber Optics cables

- Single mode
- Multimode



Single Mode VS Multimode Fiber



Credit: https://www.sfm.ca/multi-mode-vs-single-mode-fiber-optic-cable-debates-and-differences/

Fiber Optics cable types/colors

Multimode Fiber		Cable Jacket Color
(OM1)	62.5/125um	ORANGE
(OM2)	50/125um	ORANGE
(OM3)	50/125um	AQUA
(OM4)	50/125um	AQUA / VIOLET
(OM5)	50/125um	LIME GREEN

Single Mode		Cable Jacket Color
(OS2)	9/125um	YELLOW

Credit: https://www.blackbox.com/en-us/insights/blogs/detail/tps/2022/01/25/understanding-fiber-optic-cable-and-connector-colors

Fiber Optic connectors

Picturization	Connector Type	Coupling Type	Fiber Type	Polish	No. of Fibers	Typical Applications	Comment
	ST	Twist on	Single mode /Multimode	PC, UPC	1	LANs	Keyed
	FC	Screw on	Single mode /Multimode	PC, UPC, APC	1	Datacom, Telecommuni-cations	Keyed
	SC	Snap on	Single mode /Multimode	PC, UPC, APC	1	CATV, Test Equipment	Keyed
	LC	Snap on RJ45 style	Single mode /Multimode	PC, UPC, APC	1	Gigabit Ethernet, Video Multimedia	Small Form Factor (SFF)

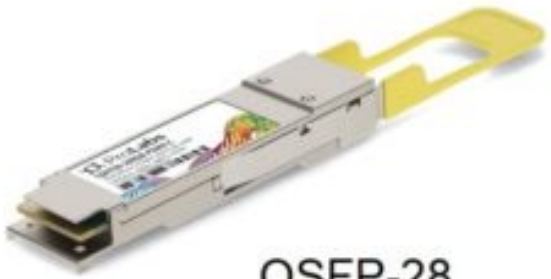
Credit: https://dc.mynetworkinsights.com/different-types-of-fiber-optic-cable-connectors/

Fiber Optic transceivers

SFP28

SFP+

SFP



QSFP-28

QSFP+

QSFP

Optical Interfaces: Cost & Distance (1-10G)

Multimode

Standard	Speed	Cost*	# of Fibers	OM1	OM2	OM3	OM4
1000baseSX	1Gbps	24$	2	275m	550m	1km	1.1km
1000baseLX	1Gbps	24$	2	500m	500m	500m	500m
10GbaseSR	10Gbps	35$	2	33m	82m	300m	550m
10GbaseLRM	10Gbps	55$	2	220m	220m	300m	400m

Single Mode

Standard	Speed	Cost*	# of Fibers	OS2
1000baseLX	1Gbps	24$	2	10km
10GbaseLR	10Gbps	45$	2	10km
10GbaseER	10Gbps	128$	2	40km

* pricing for Cisco compatible SFP/SFP+ optics from flexoptix.net in May, 2023

Optical Interfaces: Cost & Distance (40-100G)

Multimode

Standard	Speed	Cost*	# of Fibers	OM3	OM4
40GbaseSR4***	40Gbps	94$	**8	100m	150m
100GbaseSR4***	100Gbps	104$	**8	70m	100m

Single Mode

Standard	Speed	Cost*	# of Fibers	OS2
40GbaseLR4***	40Gbps	346$	2	10km
100GbaseLR4***	100Gbp s	554$	2	10km

* pricing for Cisco compatible QSFP/QSFP28 optics from flexoptix.net in May 2023
** Connector used is a 12-fiber MPO connector but the standard only uses 8 of the strands
*** There are a number of additional 40G and 100G standards, SR4 and LR4 are most common

Fiber Optic Cable Price Comparison

Below is a table outlining the pricing for a 12-fiber outdoor non-armored cable.

Fiber Type	Cost per km*
OM1 (62.5 legacy)	4,921$
OM2 (50 legacy)	3,465$
OM3 (50 laser optimized)	8,147$
OM4 (50 laser optimized)	8,977$
OS2 (single mode)	922$

(*) Manufacturer is Corning part number 012TU4-T47xxD20,
pricing obtained September 2020

Cabling recommendations

- Inside datacenter (distance<150m): twisted pair copper for 1GE or fiber for 10GE and more
- From network core to buildings and between building floors: Fiber Optic
- Single mode vs multimode ?

=> quick cost calculation on the board

Cabling recommendations

- From buildings to outlets: UTP Cat5e, Cat6 or Cat6A ?
- Things to consider when choosing cable type: distance, interference/loss, COST
- Remember that copper is prone to electromagnetic interference !

Cabling recommendations

- Redundancy is very important: always run additional cables
  - Example: Copper: run 2 to 4 cables to every outlet
  - Example: FO: run 6 strands (3 pairs) if you need 2 (1 pair)
    run 12 strands (6 pairs) if you need 4 or 6 (2-3 pairs)
- Don’t forget about labeling: On both sides of the cable !
- For contractor specifications: refer to a document made by NSRC at https://nsrc.org/activities/agendas/en/cndo/networking/cndo/en/labs/Cabling_Systems_Specifications.docx

Acknowledgment

This work is inspired from the NSRC campus networks workshop available here: https://nsrc.org/activities/agendas/en/cndo/

Questions ?