Campus Network Cabling: Cabling Standards

Campus Network Design & Operations Workshop

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UNIVERSITY OF OREGON

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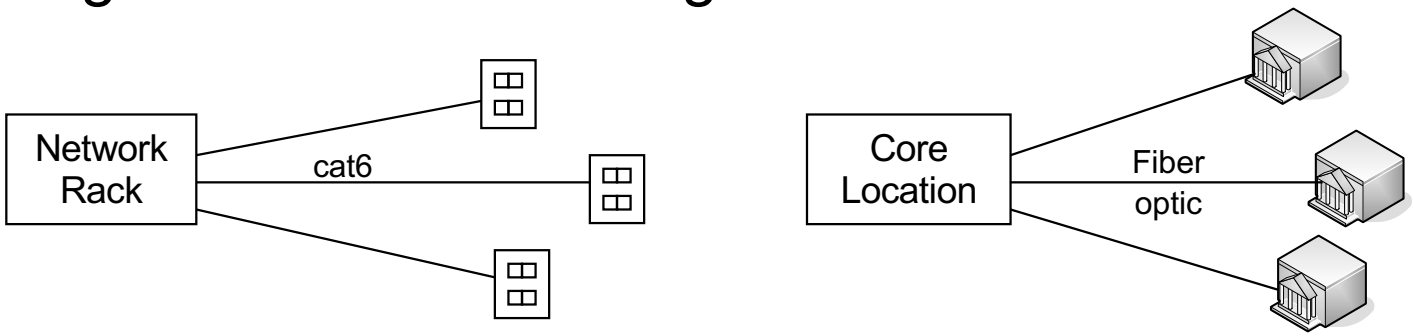
NSRC Network Startup Resource Center

Structured Cabling Systems

- Only two types of cabling:
  - Unshielded twisted pair copper – provides service to individual computers and between network racks
  - Fiber optic cabling – provides service to buildings and between network racks
- Everything is run in a star configuration



Unshielded Twisted Pair Cable

- Run in star configuration from network rack location to individual outlets in offices or labs.
- Run at least 2 cables to every outlet – 4 is recommended if you can afford it.
- Run 4 to 6 cables between network racks if the distance is less than 90 meters
- Question: what type of cable to run? Cat5, Cat5e, Cat6, Cat6A?

What type of UTP

- What speed does each type support?

Cable Type	Speed	Max Distance	Cost Factor*
Category 5**	100Mbps	100m	1x
Category 5e	1000Mbps	100m	1x
Category 5e	5000Mbps	100m	1x
Category 6	5000Mbps	100m	1.2x
Category 6	10,000Mbps	55m	1.2x
Category 6A	10,000Mbps	100m	1.4x
Category 8	40,000Mbps	30m	5x

* Prices in USA with USA contractors

** Most Category 5 cable meets Category 5e performance specifications

Don't buy anything that claims to be "Cat 7" – it is NOT an IEEE standard!

Twisted Pair Signaling Standards

- IEEE 802.3 Ethernet Signaling Standards over Twisted Pair

Standard	Speed	Minimum Cable Type*
100baseTX	100Mbps	Category 5
1000baseT	1Gbps	Category 5e
2.5GbaseT	2.5Gbps	Category 5e
5GbaseT**	5Gbps	Category 6
10GbaseT***	10Gbps	Category 6A
40GbaseT****	40Gbps	Category 8

* Minimum quality cable to support this standard. Better cables also will work

** 5GbaseT signals at 200MHz. Category 5e is minimally 100MHz, but many Category 5e installations utilize 200MHz or even 350MHz cable, so they will support 5GbaseT

*** Note that Category 6 will support 10GbaseT for a limited distance of 55 meters

**** Category 8 distance limited to 30 meters

Twisted Pair and Wireless

- We see lots of people say “I don’t need to do wiring – we will just provide wireless”
- For good wireless performance you must provide wiring to each access point
  - Do not use mesh unless it is not possible to do wiring
- Wireless standards are a moving target and as you move to newer standards that provide faster speeds, you need better cabling to support the faster speeds

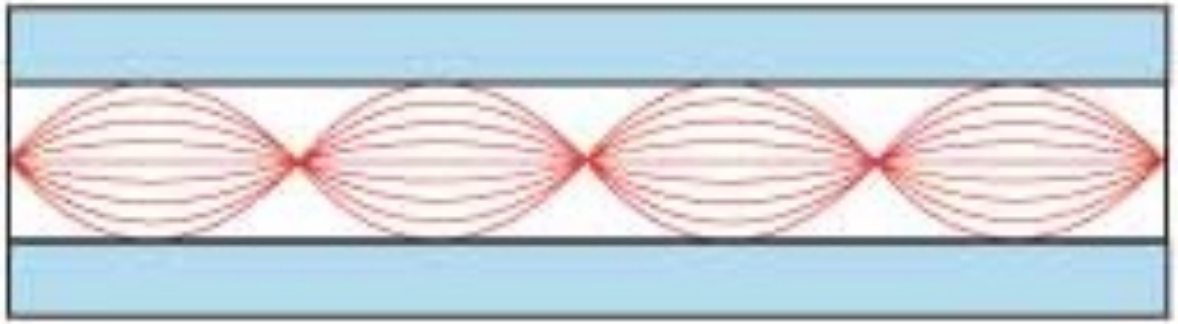
Wireless Standards and Cabling

IEEE Standard	Wi-Fi Alliance Name	Frequency Bands	Max Data Rate	Cabling Required
802.11n	Wi-Fi 4	2.4 or 5GHz	576Mbps	Cat 5e or Cat 6
802.11ac	Wi-Fi 5	5GHz	6.933Gbps	Cat 6A
802.11ax	Wi-Fi 6	2.4, 5GHz (Wi-Fi 6E supports 6GHz)	9.608Gbps	Cat 6A
802.11be	Wi-Fi 7	2.4, 5, and 6GHz	23.059Gbps	Two (2) Cat 6A
802.11bn (2028)	Wi-Fi 8	2.4, 6, and 6GHz	~100Gbps	Fiber!

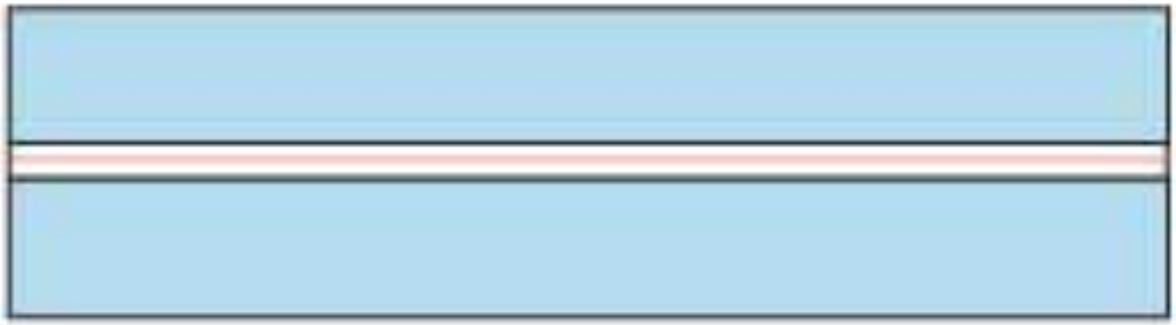
- Recommendation is four (4) Category 6A cables for each access point location
- Two (2) is sufficient, but when you move to using 6GHz with Wi-Fi 6E or Wi-Fi 7, you must have access points closer together and the four (4) cables allows you to use the extra two cables to run an additional access point nearby

Fiber Optic Cabling

- Two basic types of fiber
  - Multi Mode



  - Single Mode



Fiber Optic Cabling

- Multi Mode
  - Photons take different paths through the fiber, travelling slightly different distances
  - They arrive at different times and interfere with each other
  - This severely limits the distance over which communication works
  - The problem gets worse at higher transmission rates
- Single Mode
  - All photons take the same path
  - Works over much longer distances and higher speeds

Multi Mode Fiber

- Two basic types:
  - 62.5 micron core. Legacy, older style
  - 50 micron core. Newer
- Standards to be aware
  - OSI/IEC 11801 OM1 – 62.5 micron
  - OSI/IEC 11801 OM2 – 50 micron
  - OSI/IEC 11801 OM3 – 50 micron laser optimized
  - OSI/IEC 11801 OM4 – 50 micron higher bandwidth
  - OSI/IEC 11801 OM5 – 50 micron wideband optimized (for SWDM)

SWDM: short wavelength division multiplexing
http://www.swdm.org/about-swdm-technology/

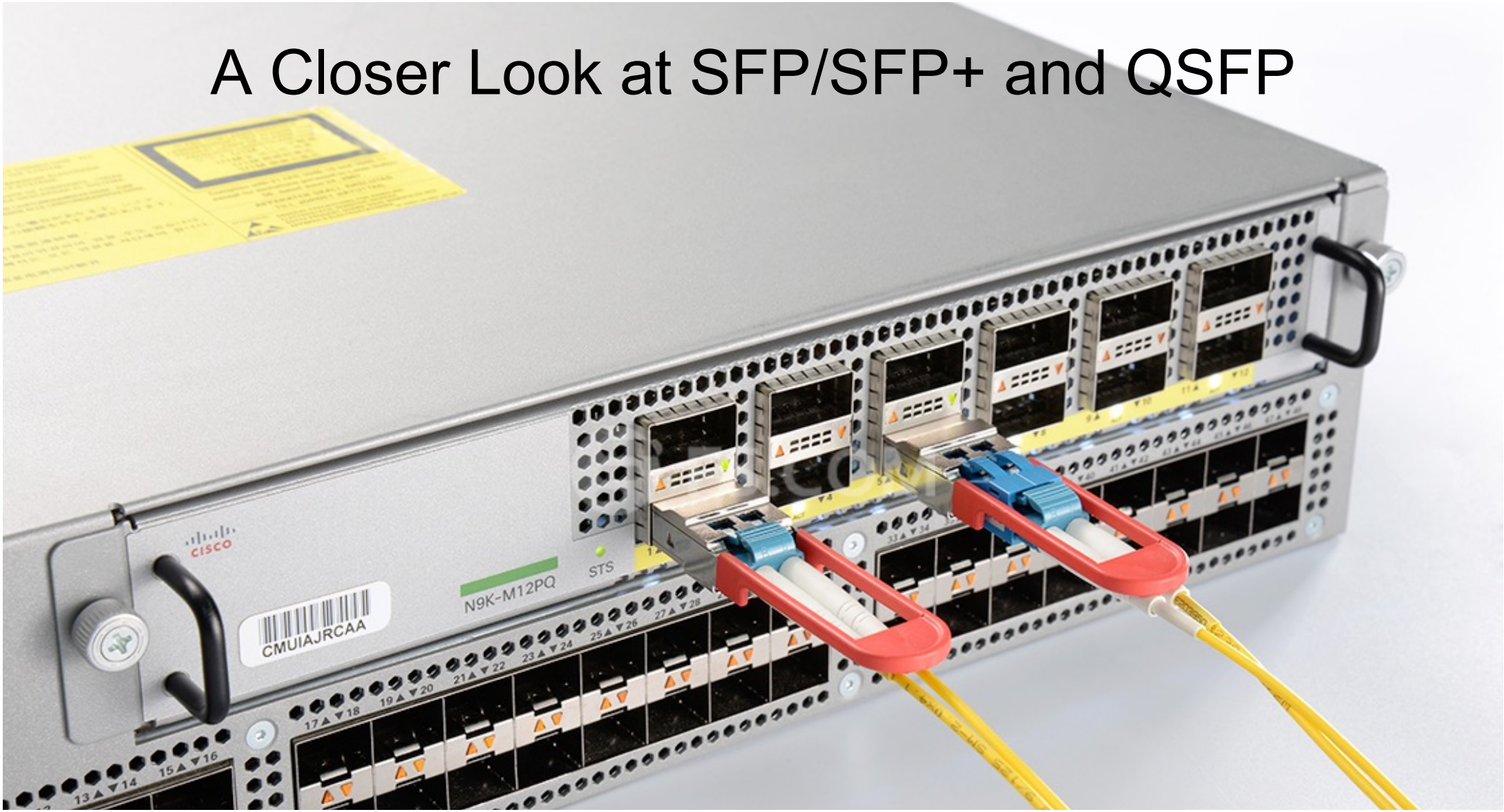
Single Mode Fiber

- All have core between 8 and 10 micron
- Different types:
  - OSI/IEC 11801 OS1 – legacy standard
  - OSI/IEC 24702 OS2 – newer standard
  - Lots of International Telecommunication Union (ITU) fiber types designed for long haul and telephony
    - Common is G.652 (A, B, C, D)
    - Other standards associated with long haul and wave division multiplexing
    - Most of the ITU standard fiber is not suitable for campus installations.
- You want OS2 single mode, which is the same as G.652.D

Optical Interfaces

- We refer to optical interfaces as the module that is placed in a switch or router to attach to fiber optic cable
- Most common types are SFP, SFP+ and QSFP

A Closer Look at SFP/SFP+ and QSFP



Common socket types

SFP	*1G*
SFP+	*10G*
SFP28	*25G*

QSFP	*40G (4x10G)*
QSFP28	*100G (4x25G)*

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

Multi mode

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	$111	2	40km

* List pricing for Cisco compatible SFP/SFP+ optics from flexoptix.net in September 2024.

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

Multi mode

Standard	Speed	Cost*	# of Fibers	OM1	OM2	OM3	OM4
40GbaseSR4***	40Gbps	$79	8**	No	No	100m	150m
100GbaseSR4***	100Gbps	$86	8**	No	No	70m	100m

Single mode

Standard	Speed	Cost*	# of Fibers	OS2
40GbaseLR4***	40Gbps	$301	2	10km
100GbaseLR4***	100Gbps	$502	2	10km

* List pricing for Cisco compatible QSFP/QSFP28 optics from flexoptix.net in September 2024.
** Connector used is a 12-fiber MPO connector, but the standard only uses 8 of the strands.
*** There are several 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 cable, non-armored cable.
- Manufacturer is Corning, part number 012TU4-T47xxD20, which is more expensive than many suppliers.
- Pricing obtained September 2020

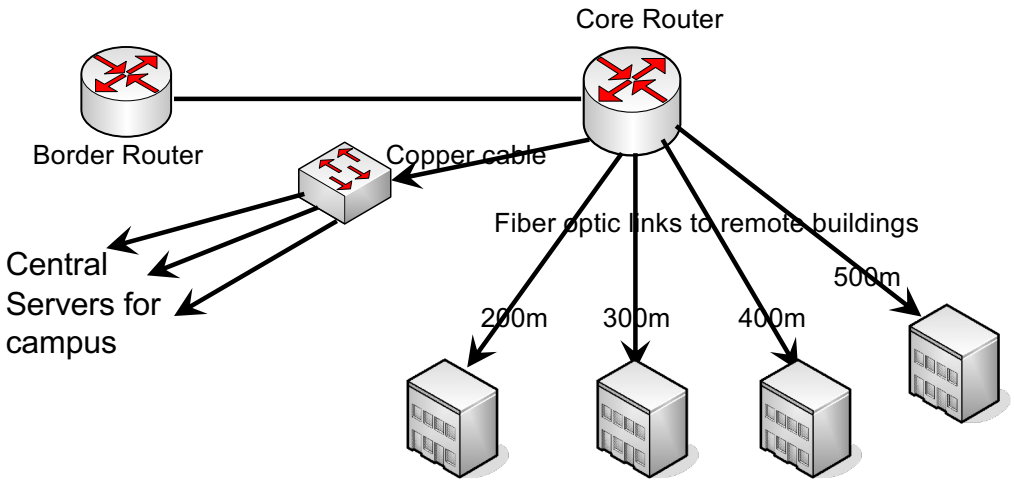
Fiber Type	Cost per km*
OM1 (62.5 legacy)	$4,921
OM2 (50 legacy)	$3,465
OM3 (50 laser optimized)	$8,147
OM4 (50 laser optimized)	$8,977
OS2 (single mode)	$922

Which Type of Fiber is Best?

- Single mode is clearly a winner in terms of cost, distance and speed
- Even though:
  - Multi mode optical interfaces may be less expensive than single mode optical interfaces (but not much)
- Equipment manufacturers and cable installers have traditionally tried to direct you to install multi mode fiber.
  - Don't do this. OS2 single mode is so much cheaper and has so much more capability that it is the obvious choice for virtually every application
- Note that our examples don't show the cost of the switch or router port to place the optical interface into.
  - A 10Gbps capable switch will be more expensive than a 1Gbps switch

Simple Example

- Consider the simple network below
  - Total fiber length 1400m
  - 8 optical interfaces



Example – 1Gbps Links

- Use cheapest optical interface possible, but note that the 1000BaseSX interface has different distance limitations than LX

Fiber Type	Fiber Cost	Optics	Total Cost
OM1	1.4*4921 = $6889	2x1000baseSX or LX @$24, plus 6x1000baseLX @$24 = $192	$7,081
OM2	1.4*3465 = $4851	8x1000baseSX or LX @$24 = $192	$5,043
OM3	1.4*8147 = $11406	8x1000baseSX or LX @$24 = $192	$11,598
OM4	1.4*8977 = $12568	8x1000baseSX or LX @$24 = $192	$12,760
OS2	1.4*922 = $1291	8x1000baseLX @$24 = $192	$1,483

- *SX interfaces have a lower range on OM1 fiber than LX, but longer range on OM2/OM3/OM4*
- *It used to be that SX interfaces were slightly cheaper than LX, but typically not any more*

Example – 10Gbps Links

- Note that some fiber types won't support 10Gbps over the required distances

Fiber Type	Fiber Cost	Optics	Total Cost
OM1	1.4*4921 = $6889	Can't do 10G further than 220m	N/A
OM2	1.4*3465 = $4851	Can't do 10G further than 220m	N/A
OM3	1.4*8147 = $11406	Can't do 10G further than 300m	N/A
OM4	1.4*8977 = $12568	8x10GbaseSR @$35 = $280	$12,848
OS2	1.4*922 = $1291	8x10GbaseLR @$45 = $360	$1,651

Example – 100Gbps Links

- Note that only OS2 Single Mode will support 100Gbps over the required distances

Fiber Type	Fiber Cost	Optics	Total Cost
OM1	1.4*4921 = $6889	Can't do 100G at all	N/A
OM2	1.4*3465 = $4851	Can't do 100G at all	N/A
OM3	1.4*8147 = $11406	Can't do 100G further than 70m	N/A
OM4	1.4*8977 = $12568	Can't do 100G further than 100m	N/A
OS2	1.4*922 = $1291	8x100GbaseLR4 @$502 = $4,432	$5,307

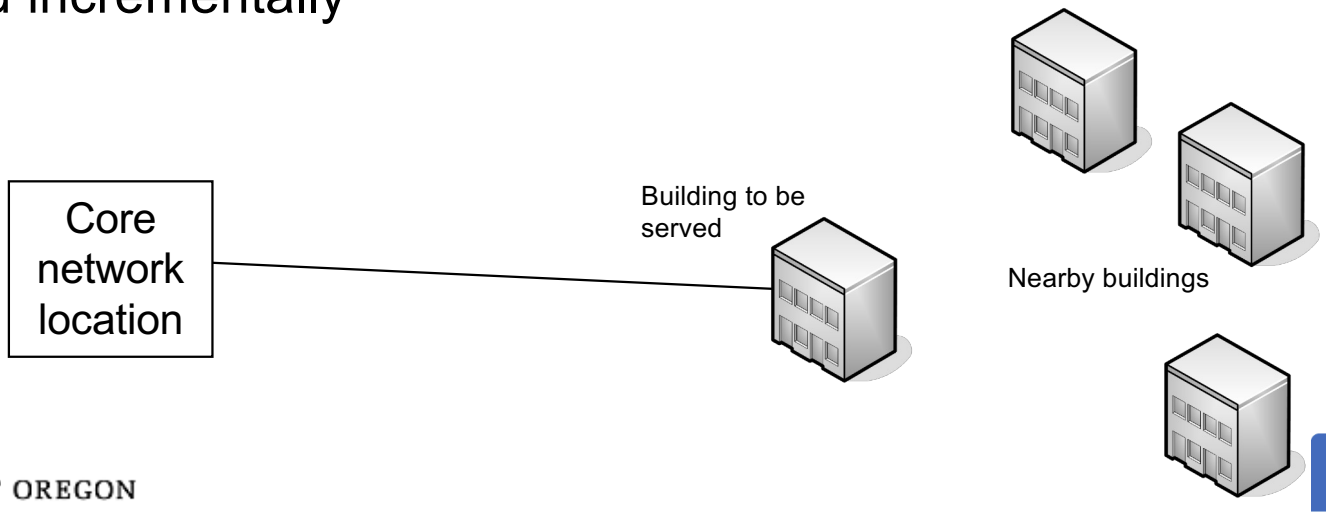
Conclusion: not only is OS2 far cheaper up-front, it's also future-proof

Fiber Optic Recommendations

- Don’t install any Multi mode
- Only install Single mode
- Run in star configuration from core network location to individual buildings
- Run in star configuration inside of buildings from main network rack to other network racks
- To reduce costs, can run large fiber cable from core to some remote location, then smaller cables from there to surrounding buildings

Star Configuration

- Plan for future – Install enough fiber
  - Between Buildings: 6 single mode from core to each building (consider 12/24 fibers if you can afford it)
  - Inside of buildings: 6 or more single mode between network racks
  - Can build incrementally



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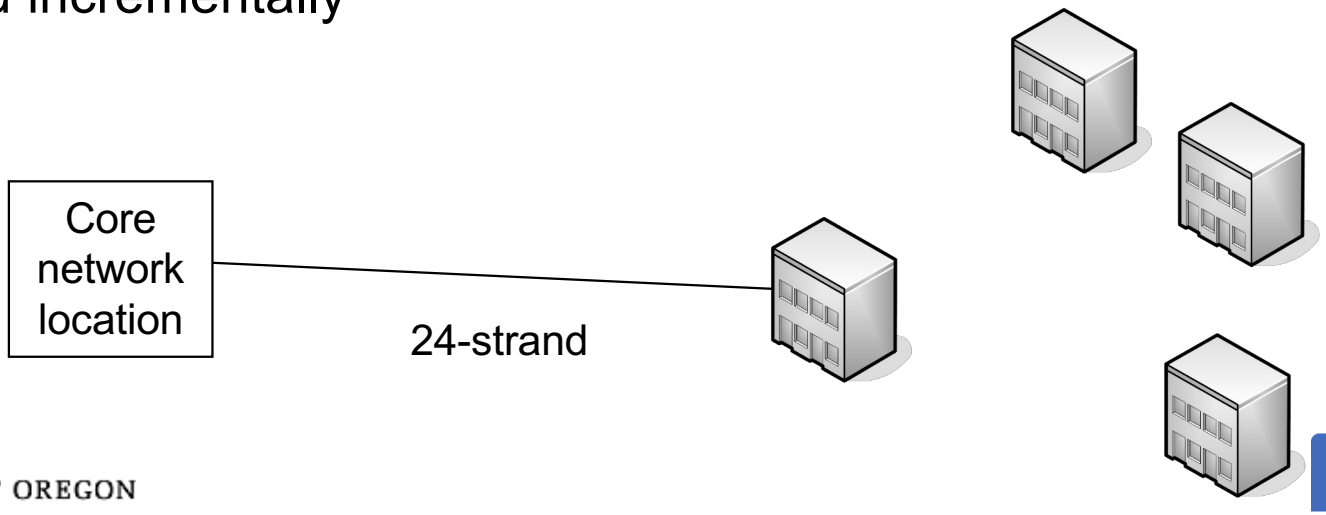

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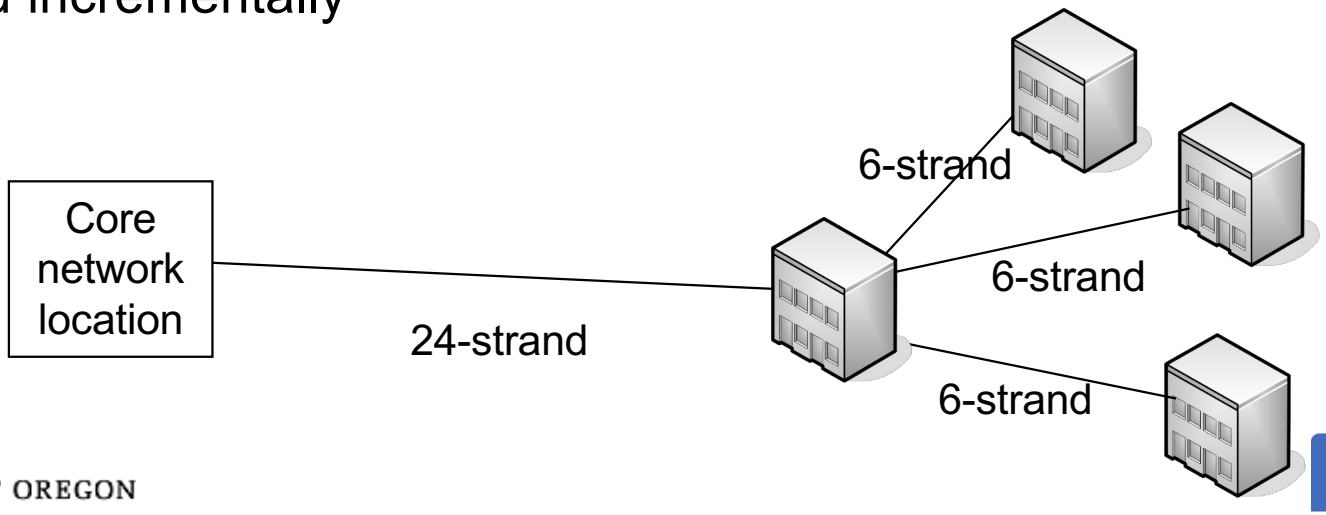
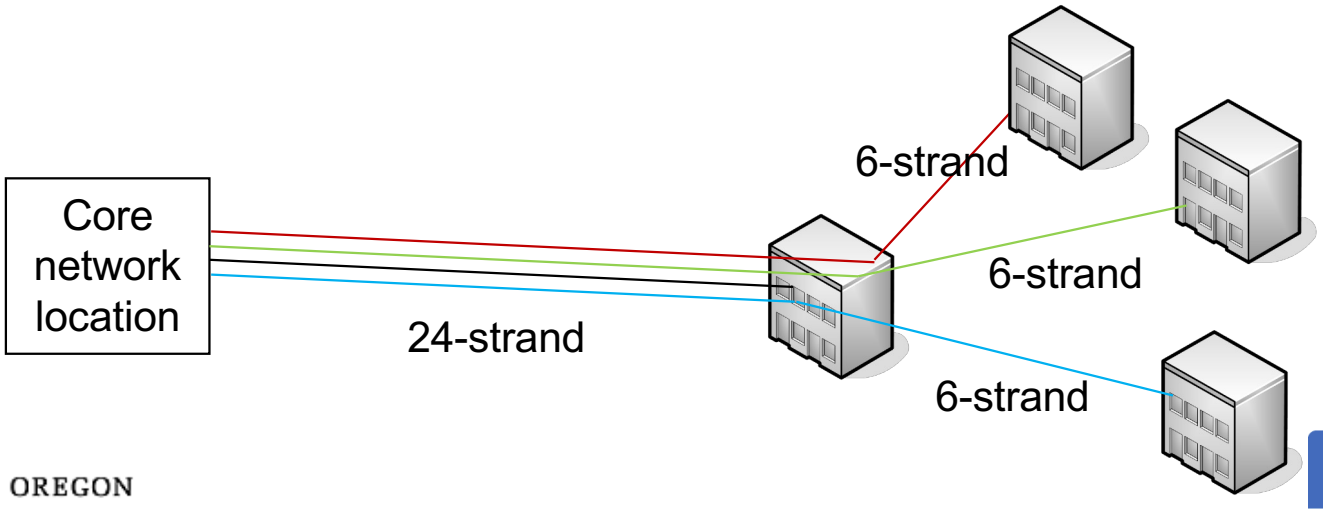
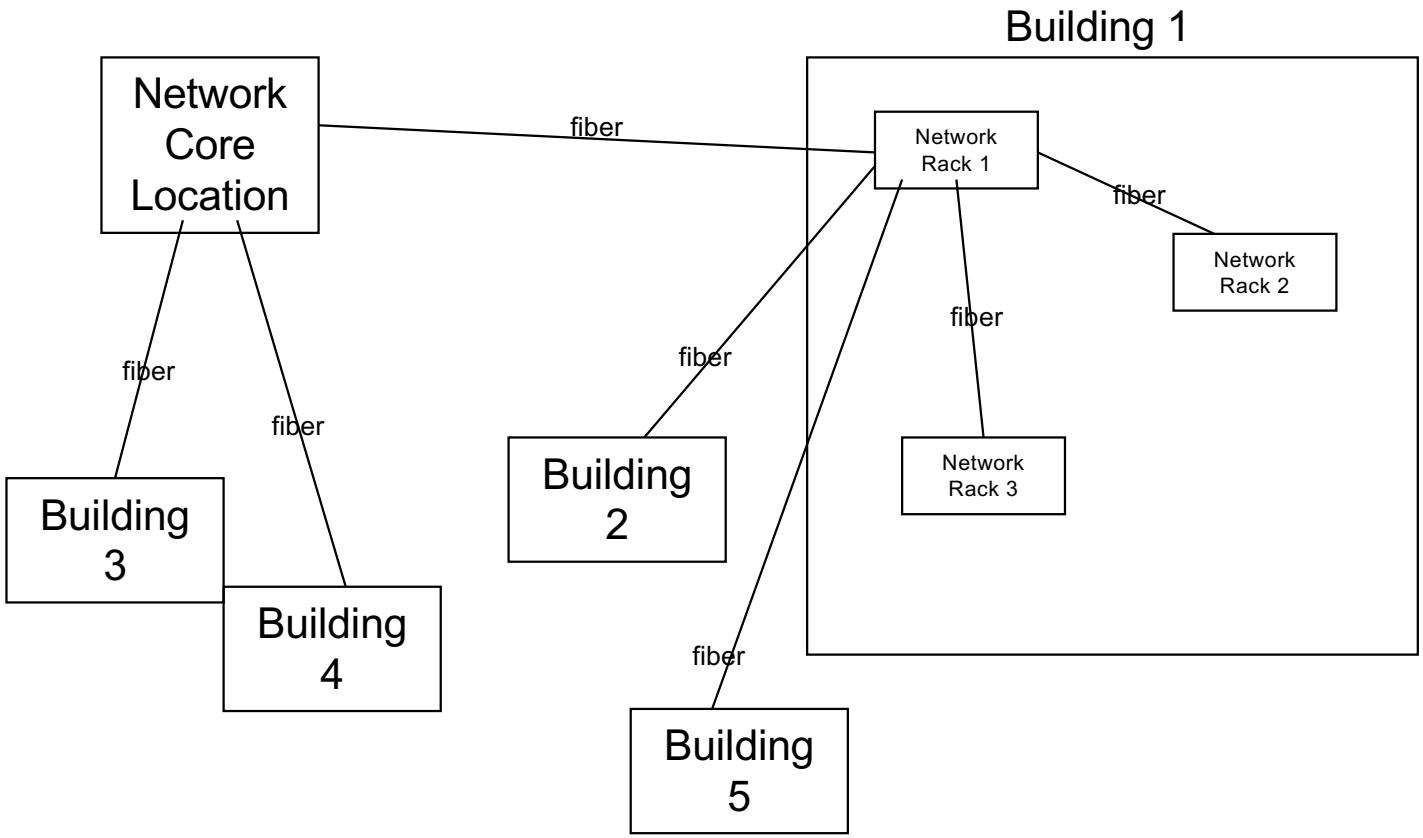


Star Configuration

- Note: this isn't the same as daisy-chaining
  - Fibers are patched or spliced together so that the edge buildings have a direct light path to the core
  - Hence they don't depend on the intervening building



Fiber Optic Topology



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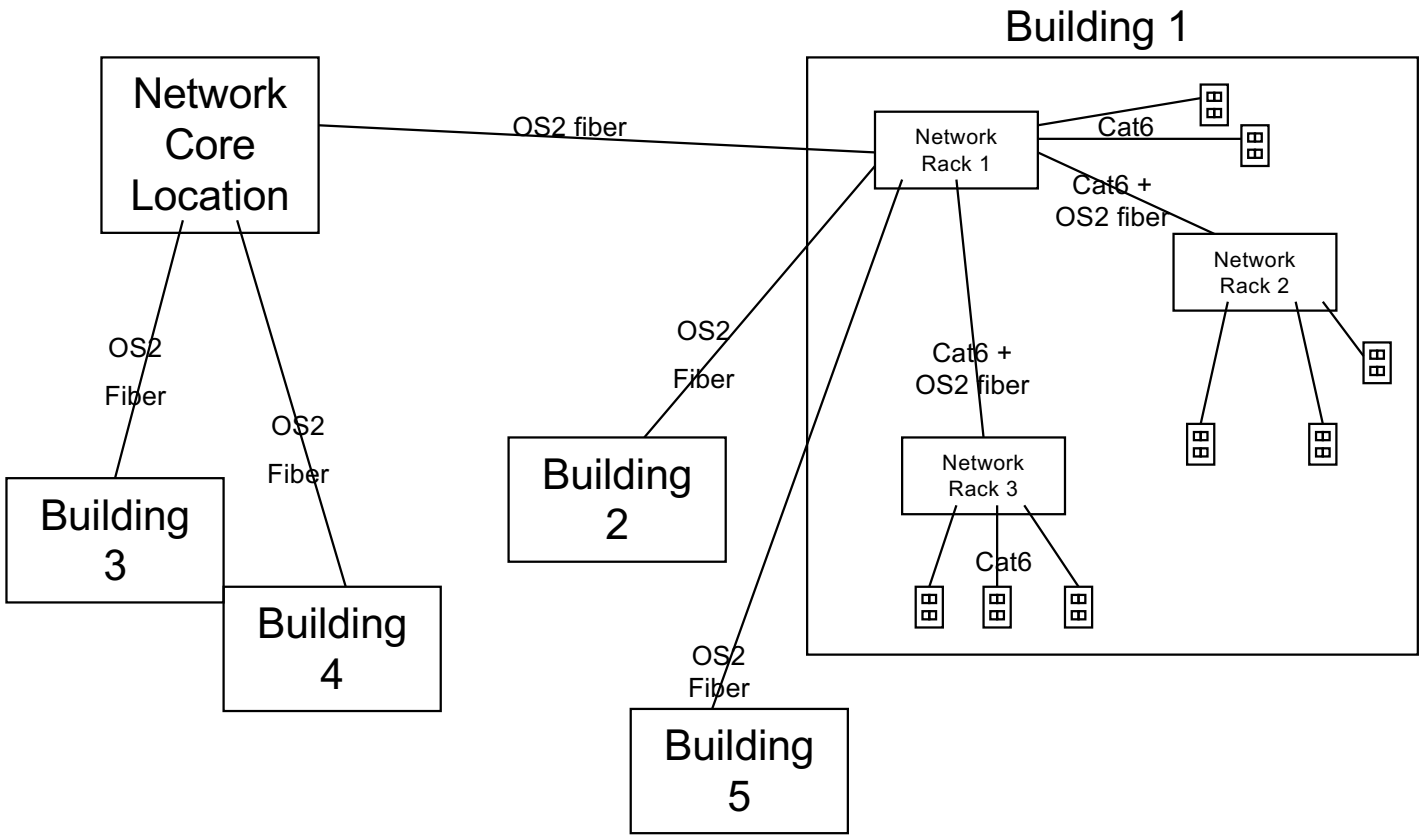
Putting it all Together



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