Life at 1Gbs and Above
SANOG 33

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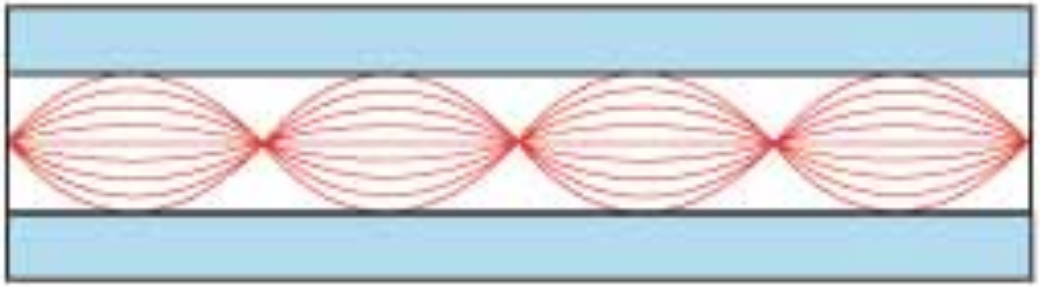
About This Talk

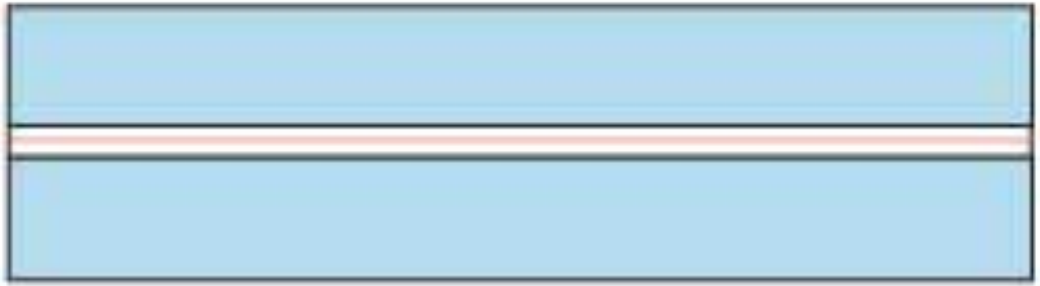
- Focus is campus or enterprise networks at 1Gbs and above
- Although there are data center issues included in this talk, the focus is on campus-size networks
- This talk does not address carrier networking issues
  - No wave division multiplexing (CWDM/DWDM) for long haul networks
  - No passive optical networking (EPON/GPON) for subscriber networks
- This talk does not discuss copper support of 1Gbs and above
  - Copper can support up to 40Gbs for limited distances
- Fiber is the media of choice for cabling between buildings

Fibre Optic Cabling Intro

- Two basic types of fiber
  - Multi Mode



  - Single Mode



Multi Mode Fiber

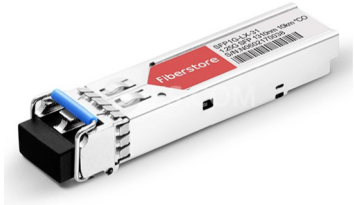
- Two basic types:
  - 62.5 micron core. Legacy, older style
  - 50 micron core. Newer
- A number of standards, but we will reference OSI/IEC 11801
  - OM1 – 62.5 micron
  - OM2 – 50 micron
  - OM3 – 50 micron laser optimized
  - OM4 – 50 micron higher bandwidth
  - OM5 – 50 micron optimized for short wave division multiplexing. This fiber is not in common use

Single Mode Fiber

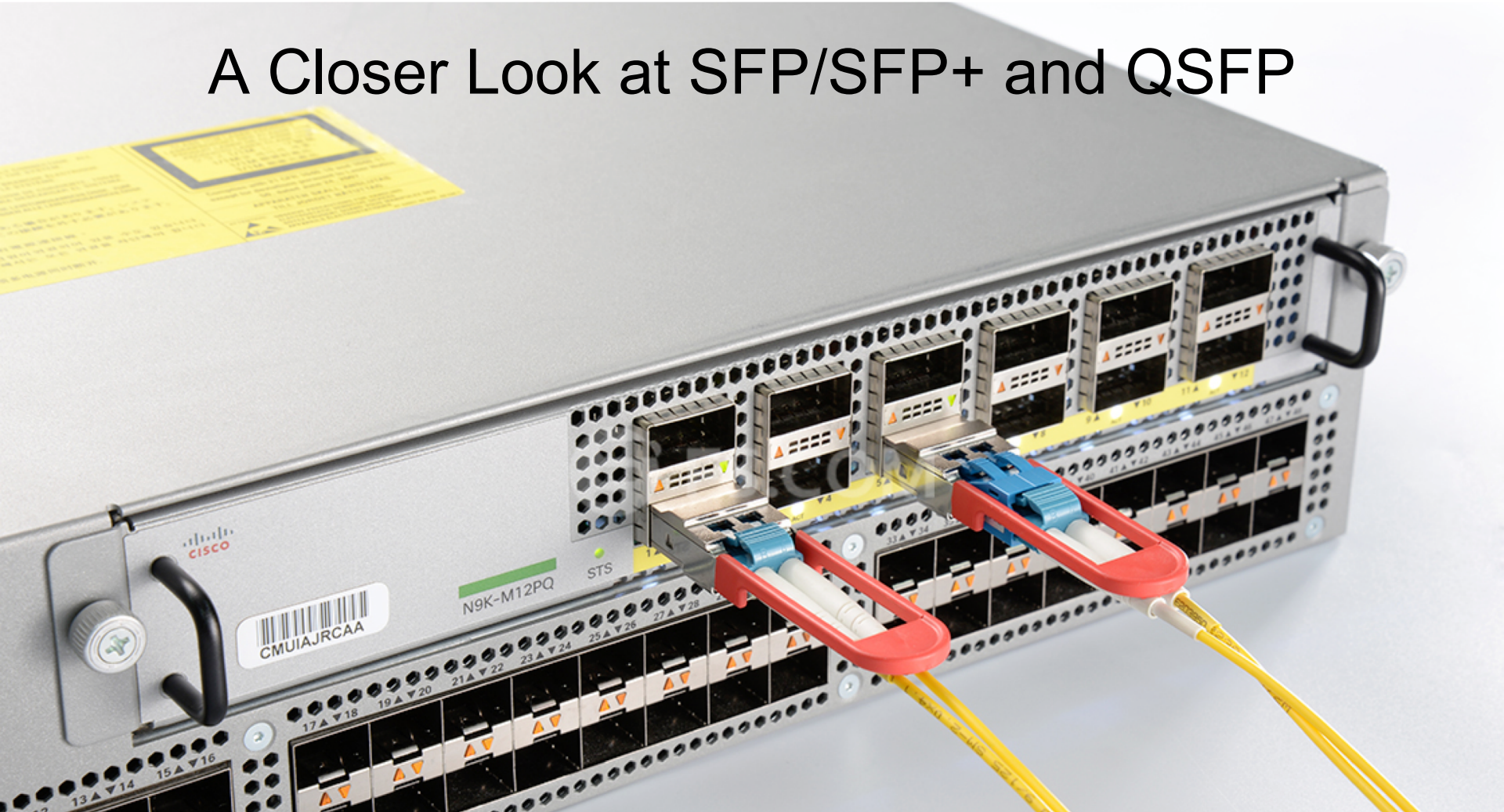
- All have core between 8 and 10 micron
- Standards by both ITU and OSI
- We will discuss OSI/IEC 11801 fiber types
  - OS1 – indoor fiber (data center), higher loss per km
  - OS2 – outdoor fiber, lower loss per km
- Typical campus and enterprise will use OS2 single mode, which is the same as ITU fiber type 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



Vendor Specific Optical Interfaces

- Vendors often “require” the use of the own brand of SFP/SFP+/QSFP modules
- Vendors often charge many times what these modules are worth
- For example, to purchase a Cisco Gigabit single mode 1000baseLX SFP (part number GLC-LH-SMD)
  - Cisco 2018 list price was USD $995.
  - The Fiber Store at fs.com sells equivalent equipment for USD $7
  - Flex Optics at flexoptix.com sells equivalent equipment for USD $27

1 Gigabit Ethernet on Fiber

Standard	Speed	Cost*	# of Fibers	OM1	OM2	OM3	OM4	OS2
1000baseSX	1Gbps	$6	2	275m	550m	1km	1.1km	No
1000baseLX	1Gbps	No	2	550m	550m	550m	550m	5km
1000baseLX10**	1Gbps	$7	2	550m	550m	550m	550m	10km
1000baseEX	1Gbps	$14	2	No	No	No	No	40km
1000baseZX	1Gbps	$24	2	No	No	No	No	70km
1000baseBX10	1Gbps	$9/$12	1	No	No	No	No	10km

*pricing for Cisco compatible SFP optics from http://fs.com in January 2019.
** Many vendors call this 1000baseLH, almost everyone incorrectly calls this 1000baseLX

10 Gigabit Ethernet on Fiber

Standard	Speed	Cost*	# of Fibers	OM1	OM2	OM3	OM4	OS2
10GbaseSR	10Gbps	$16	2	33m	82m	300m	550m	No
10GbaseLRM	10Gbps	$34	2	220m	220m	300m	400m	No
10GbaseLR	10Gbps	$34	2	No	No	No	No	10km
10GbaseER	10Gbps	$149	2	No	No	No	No	40km
10GbaseZR**	10Gbps	$299	2	No	No	No	No	80km
10GbaseBX***	10Gbps	$49	1	No	No	No	No	10km

*pricing for Cisco compatible SFP optics from http://fs.com in January 2019.
** Non-standard higher power 10GbaseER providing greater distance
***Non-standard single-fiber bi-directional version of 10GbaseLR

25 Gigabit Ethernet on Fiber

- 25 Gigabit is typically used in data centers
- Uses technology defined by the 100Gbps standard, which typically uses four lanes of 25Gbs

Standard	Speed	Cost*	# of Fibers	OM1	OM2	OM3	OM4	OS2
25GbaseSR	25Gbps	$79	2	No	No	70m	100m	No
25GbaseLR	25Gbps	$230	2	No	No	No	No	10km
25GbaseER	25Gbps	No**	2	No	No	No	No	40km

*pricing for Cisco compatible SFP optics from http://fs.com in January 2019.
** fs.com does not have a 25GbaseER optical interface

40 Gigabit Ethernet on Fiber

- 40 Gigabit standard is in “phase out” mode, which discourages the use
- Uses technology defined by the 10Gbps standard and uses four lanes of 10Gbps to achieve 40Gbps (note: 40GbaseFR is the exception to this)

Standard	Speed	Cost*	# of Fibers	OM1	OM2	OM3	OM4	OS2
40GbaseSR4	40Gbps	$39	8**	No	No	100m	150m	No
40GbaseLR4	40Gbps	$279	2	No	No	No	No	10km
40GbaseER4	40Gbps	$799	2	No	No	No	No	40km
40GbaseFR	40Gbs	No***	2	No	No	No	No	2km

*pricing for Cisco compatible optics from http://fs.com in January 2019.
** Connector used is a 12-fiber MPO connector but the standard only uses 8 of the strands (four in each direction).
***fs.com does not offer 40GbaseFR optical modules

100 Gigabit Ethernet on Fiber

- 100 Gigabit Ethernet typically uses four lanes of 25Gbs

Standard	Speed	Cost*	# of Fibers	OM1	OM2	OM3	OM4	OS2
100GbaseSR4	100Gbps	$99	8**	No	No	70m	100m	No
100GbaseSR2-BiDi***	100Gbps	No****	2	No	No	70m	100m	No
100GbaseLR4	100Gbps	$799	2	No	No	No	No	10km
100GbaseER4	100Gbps	$4,999	2	No	No	No	No	40km

*pricing for Cisco compatible optics from http://fs.com in January 2019.
** Connector used is a 12-fiber MPO connector but the standard only uses 8 of the strands (four in each direction).
*** Non-standard Bi-Directional version of 100GbaseSR using WDM on 2 fibers
**** fs.com does not provide this non-standard optical interface

Above 100Gbps

- Active standards work on what is being called TbE or Terabit Ethernet
- Two sets of active standards being developed
  - 200 Gigabit Ethernet (200G or 200GbE)
  - 400 Gigabit Ethernet (400G or 400GbE)
- Both will use multiple lanes, some variants via multiple strands of fiber and others will use multiple wavelengths
- At least 10km of single mode will be supported by at least some of the standards

What kind of fiber to install

- We see that the standards support both multi and single mode fiber.
- What type of fiber should we install?
- Note that the faster you go, that multi mode fiber supports shorter and shorter distances.
- Let’s think about campus networks

Think About the Cost of a Fiber Cable **System**

- Multi mode optical interfaces tend to be less expensive than single mode optical interfaces
  - Cost factor is significant as you look at higher speeds
- Single mode fiber cable is less expensive than multi mode fiber cable
- Don’t listen to your fiber installation contractor
- Don’t listen to your equipment provider
- They don’t know about the cost of the whole system
- What is the cost of the whole system?
  - Estimate how much the fiber cable costs
  - Estimate how much the optical interfaces will cost

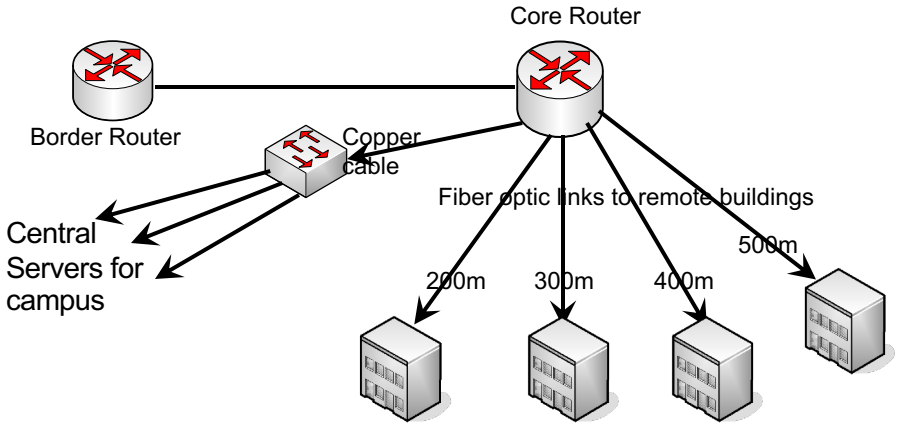
Fiber Optic Cable Price Comparison

- 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 in the USA from a common supplier in May, 2018

Fiber Type	Cost per km*
OM1 (62.5 legacy)	$4,921
OM2 (50 legacy)	$3,465
OM3 (50 laser optimized)	$8,147
OM4 (40 laser optimized)	$8,977
OS2 (single mode)	$1,010

Simple Fiber Pricing Example

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



Pricing Example – 1Gig Links

- Use all one type of fiber
- Use cheapest optical interface possible, but note that the cheaper 1000BaseSX interface is distance limited based on fiber type

Fiber Type	Fiber Cost	Optics	Total Cost
OM1	1.4*4921 = $6889	2x1000baseSX@6 6x1000baseLH@7 = $54	$6,943
OM2	1.4*3465 = $4851	8x1000baseSX@6 = $48	$4,899
OM3	1.4*8147 = $11406	8x1000baseSX@6 = $48	$11,454
OM4	1.4*8977 = $12568	8x1000baseSX@6 = $48	$12,616
OS2	1.4*1010 = $1414	8x1000baseLH@7 = $56	$1,470

Pricing Example – 10Gig Links

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

Fiber Type	Fiber Cost	Optics	Total Cost
OM1	1.4*4921 = $6889	Can't do 10G farther than 220m	N/A
OM2	1.4*3465 = $4851	Can't do 10G farther than 220m	N/A
OM3	1.4*8147 = $11406	Can't do 10G farther than 300m	N/A
OM4	1.4*8977 = $12568	8x10GbaseSR@34 = $272	$12,696
OS2	1.4*1010 = $1414	8x10GbaseLR@34 = $272	$1,686

Pricing Example – 100Gig Links

- Note that multi mode fiber won't support 100Gig for more than 100 meters

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 farther than 70m	N/A
OM4	1.4*8977 = $12568	Can't do 100G farther than 100m	N/A
OS2	1.4*1010 = $1414	8x100GbaseLR4@799 = $6392	$7,806

Summary

- Single mode fiber is the obvious cabling choice for enterprise campus networks
- 10Gbs is quite affordable and you should be installing this in all enterprise campus networks right now
- Don’t let vendors give you bad advice and sell you the expensive and possible even wrong solutions
- 100Gbs is coming, so pay attention as prices drop and routing and switching equipment becomes more available and affordable

Questions?