Campus Network Design and Direct Engineering Assistance

Dale Smith
Network Startup Resource Center
dsmith@nsrc.org

This document is a result of work by the Network Startup Resource Center (NSRC at http://www.nsrc.org). This document may be freely copied, modified, and otherwise re-used on the condition that any re-use acknowledge the NSRC as the original source.

UNIVERSITY OF OREGON

NSRC
Network Startup Resource Center

Campus Network Challenges

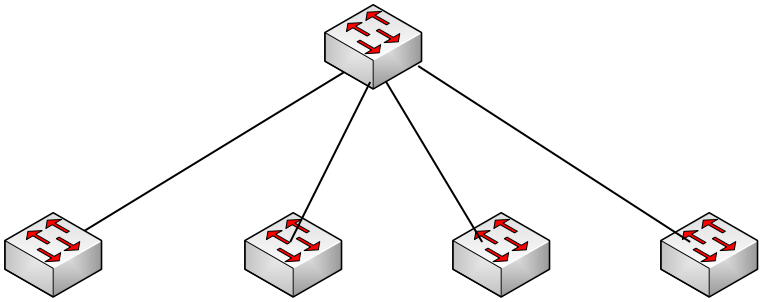
- Many are not structured properly and can't effectively utilize high bandwidth connections
- Many make heavy use of NAT and firewalls that limit performance
- Many are built with unmanaged network equipment that provide no ability for monitoring or tuning the network

Campus Network Rules

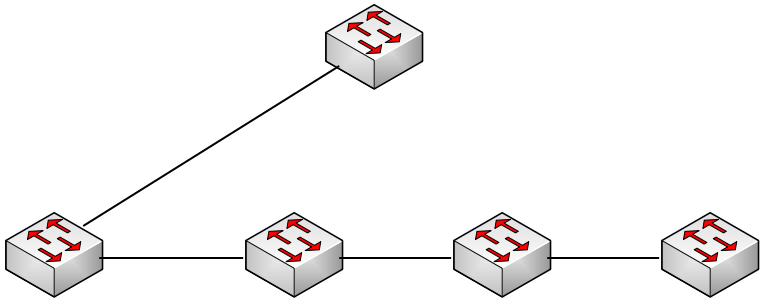
- Minimize number of network devices in any path
- Use standard solutions for common situations
- Build Separate Core and Edge Networks
- Provide services near the core
- Separate border routers from core
- Provide opportunities to firewall and shape network traffic

Minimize Number of Network Devices in the Path

- Build star networks



- Not daisy chained networks

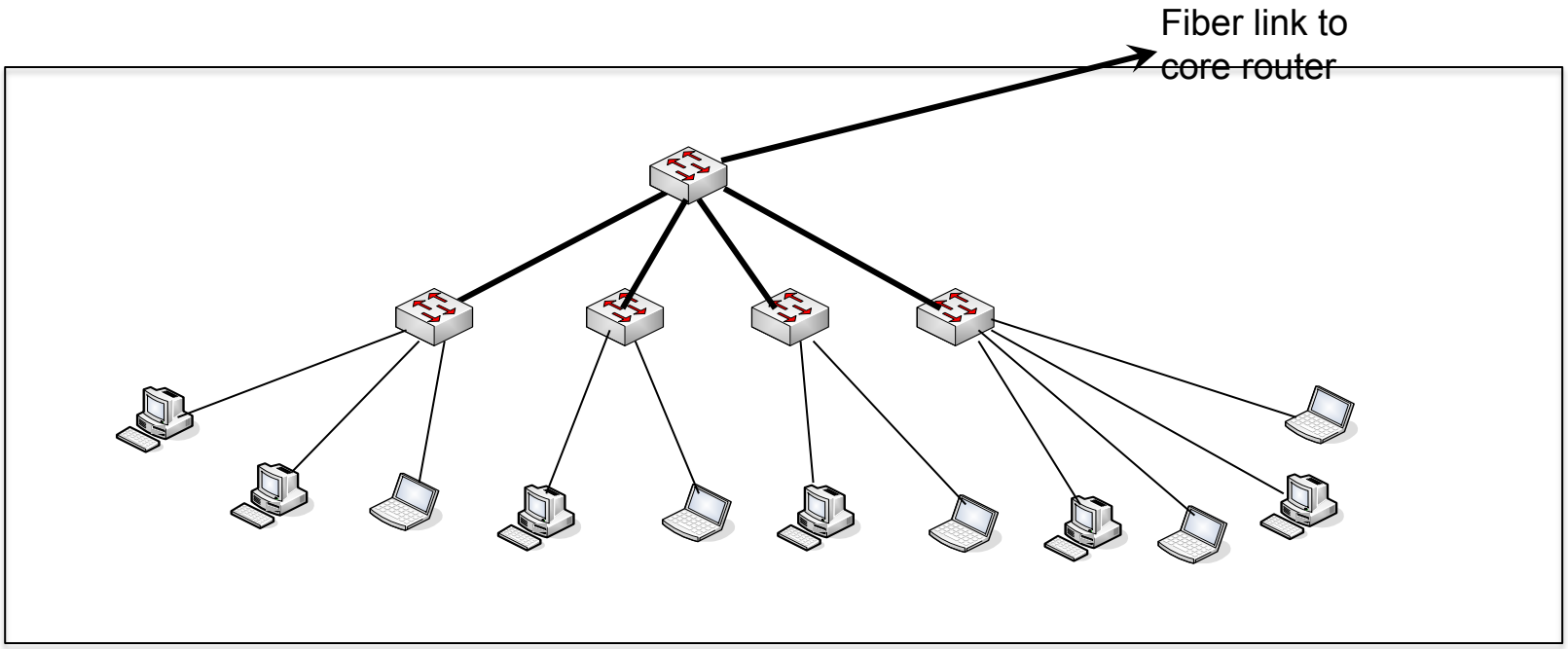


Edge Networks (Layer 2 LANs)

- Provides Service to end users
- Each of these networks will be an IP subnet
- Plan for no more than 250 Computers at maximum
- Should be one of these for every reasonable sized building
- This network should only be switched
- Always buy switches that are managed – no unmanaged switches!

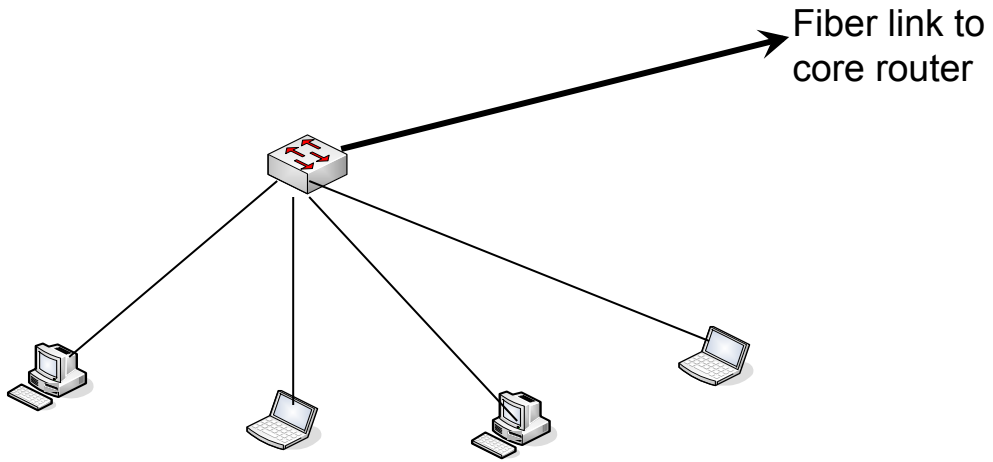
Edge Networks

- Make every network look like this:



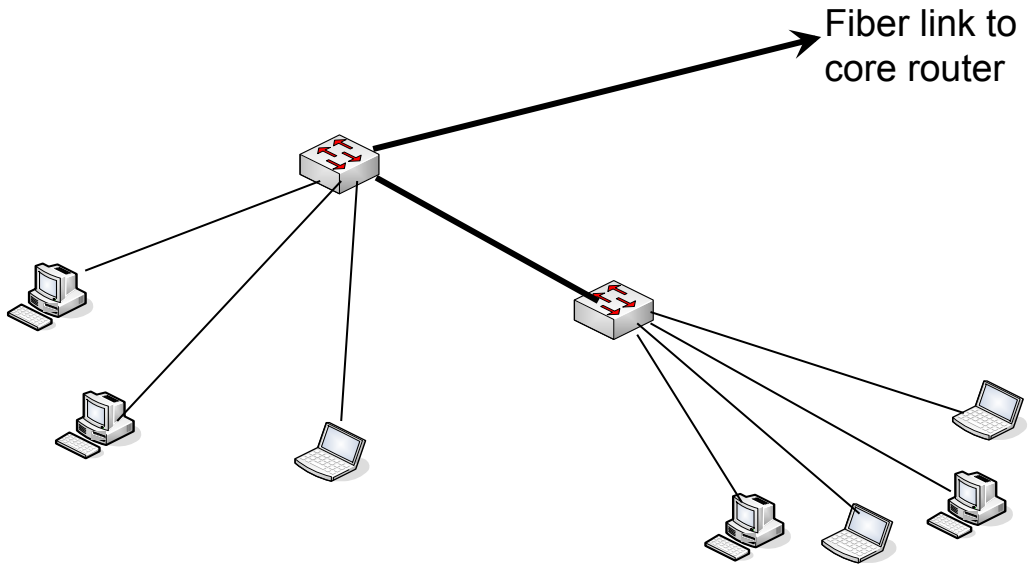
Edge Networks Continued

- Build Edge network incrementally as you have demand and money
- Start Small:



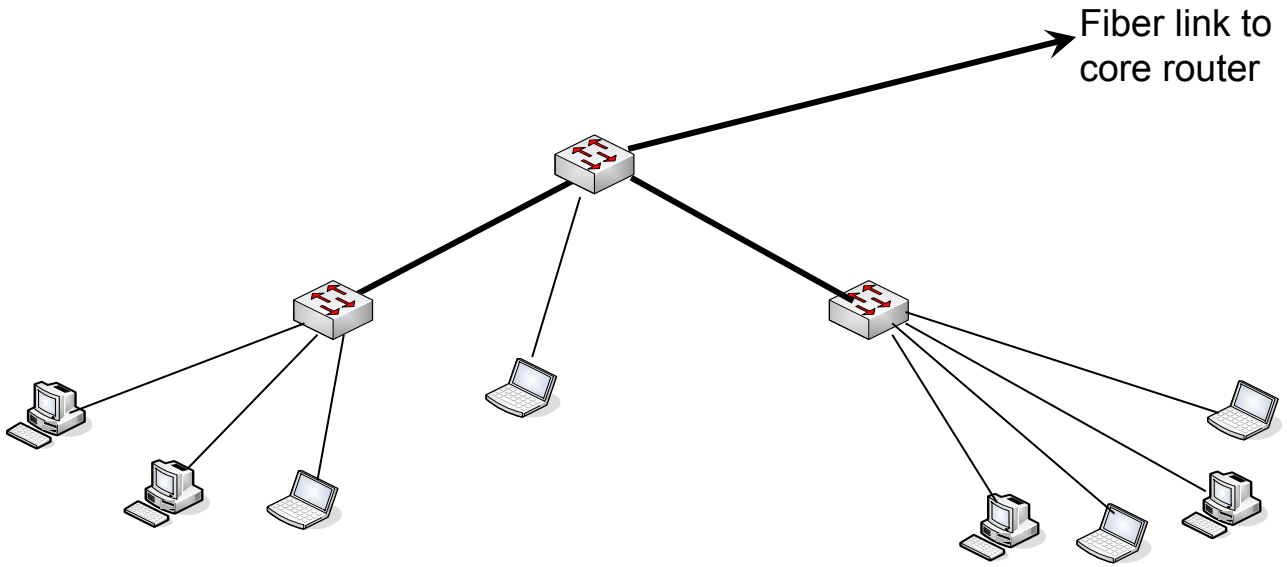
Edge Networks Continued

- Then as you need to add machines to the network, add a switch to get this:



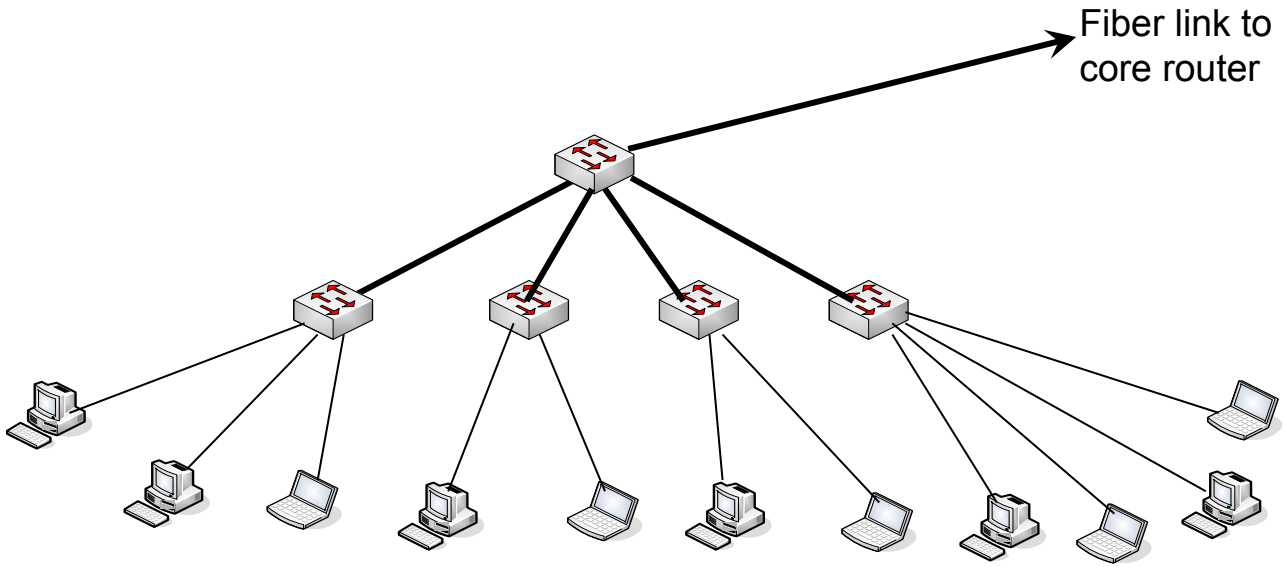
Edge Networks Continued

- And keep adding switches to get to the final configuration



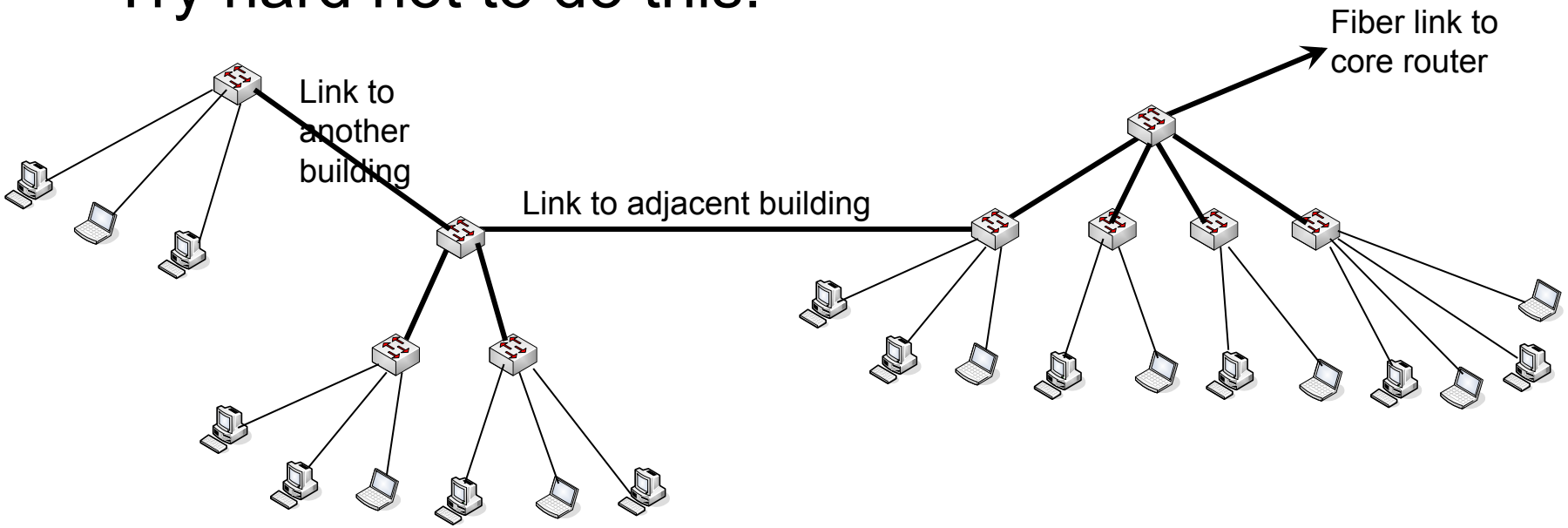
Edge Networks Continued

- And keep adding switches to get to the final configuration



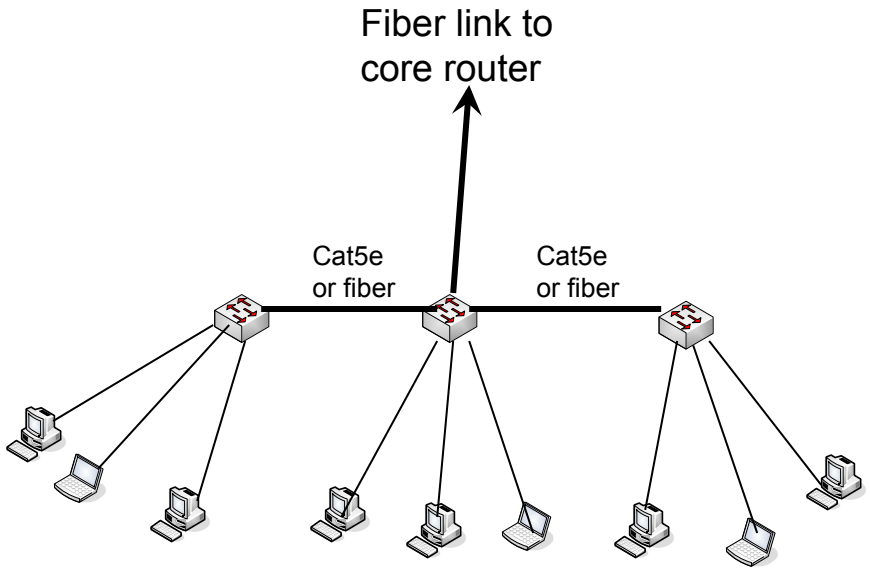
Edge Networks Continued

- Resist the urge to save money by breaking this model and daisy chaining networks or buildings together
- Try hard not to do this:



Edge Networks Continued

- There are cases where you can serve multiple small buildings with one subnet.
- Do it carefully.



Routing versus Switching Layer 2 versus Layer 3

- Routers provide more isolation between devices (they stop broadcasts)
- Routing is more complicated, but also more sophisticated and can make more efficient use of the network, particularly if there are redundancy elements such as loops

Layer 3 Switches

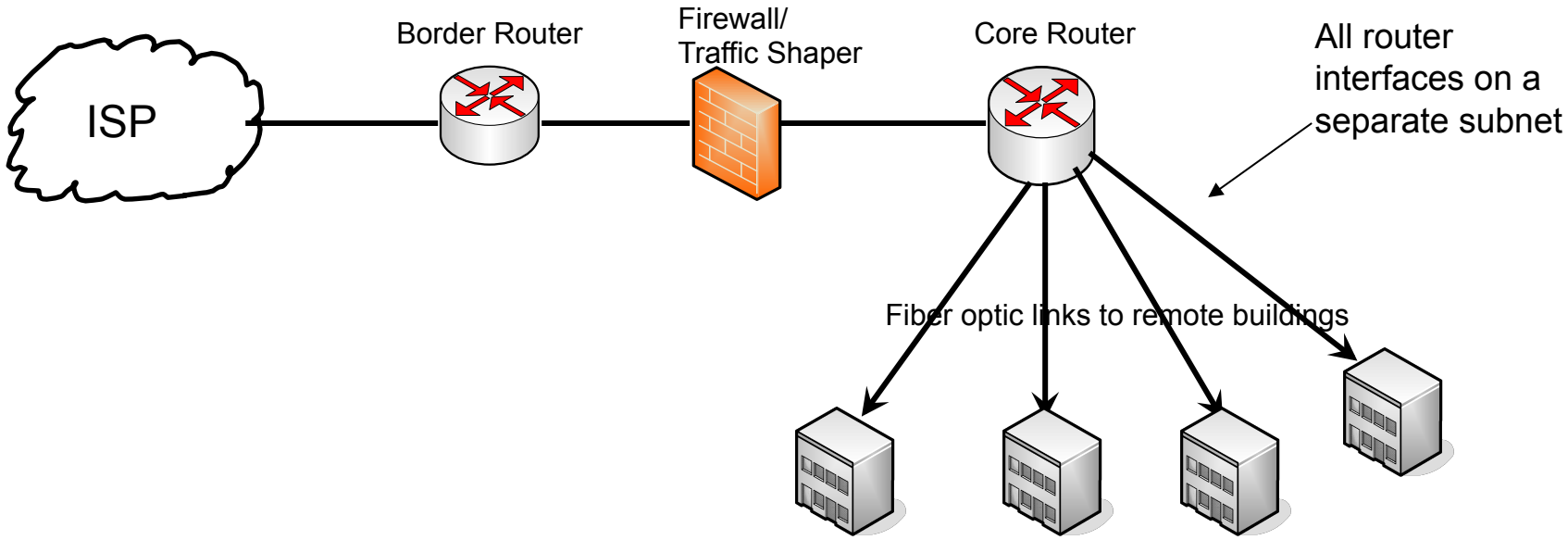
- Many vendors use the term “Layer 3 Switch”.
- These are contradictory terms
  - Layer 3 = Routing
  - Switch = Layer 2
- What vendors mean is that it is a device that can be configured as a router or a switch or possibly both at the same time.

Core Network

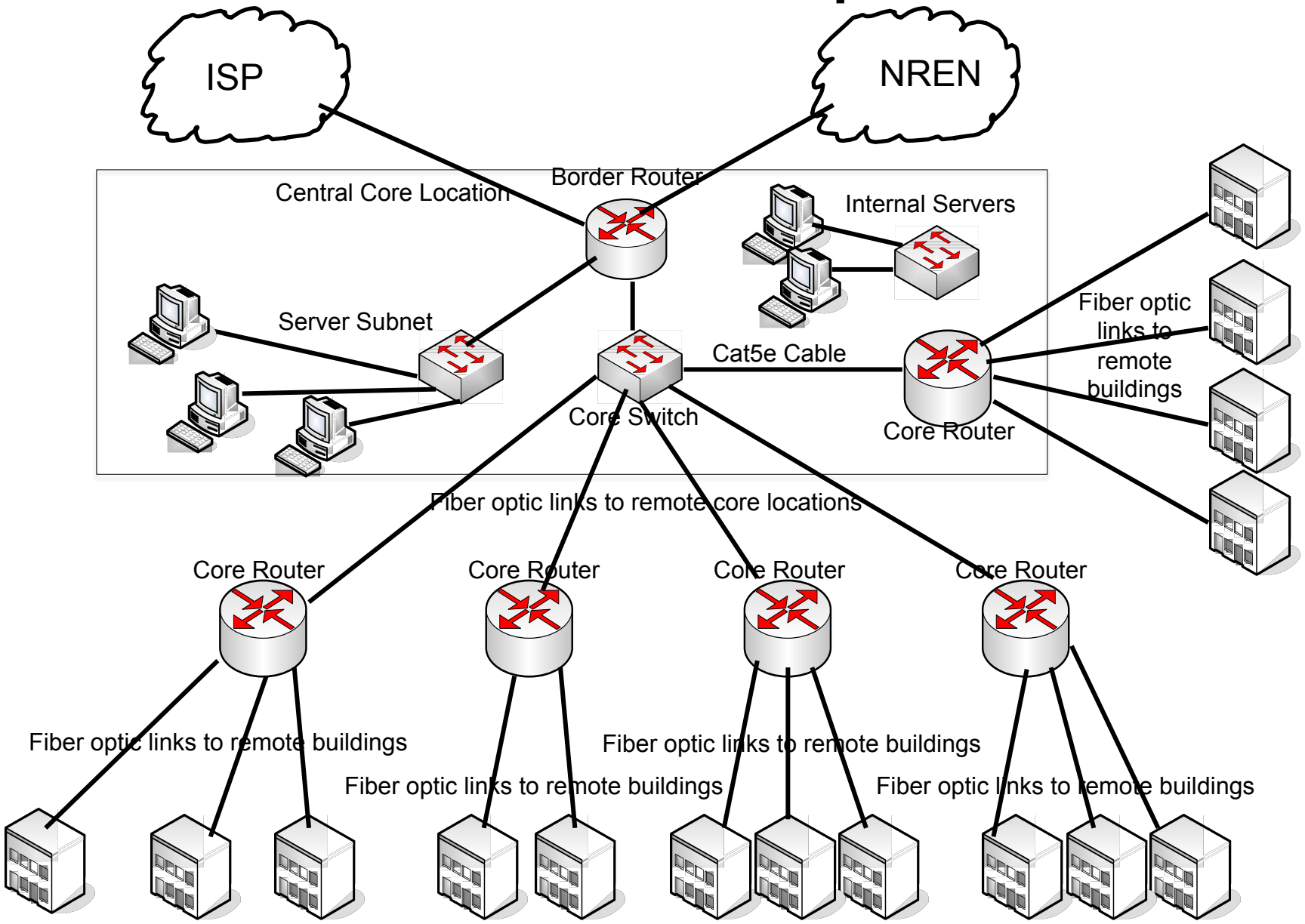
- Reliability is the key
  - remember many users and possibly your whole network relies on the core
- May have one or more network core locations
- Core location must have reliable power
  - UPS battery backup (redundant UPS as your network evolves)
  - Generator
  - Grounding and bonding
- Core location must have reliable air conditioning

Typical Campus Network

- Route in the core
- Switch at the edge
- Firewall in-line between border and campus core



Can be More Complicated

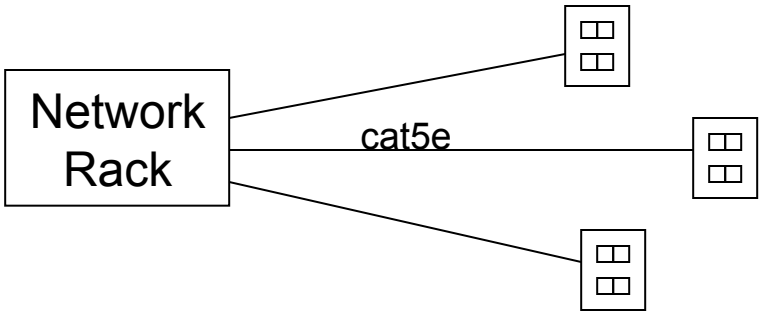


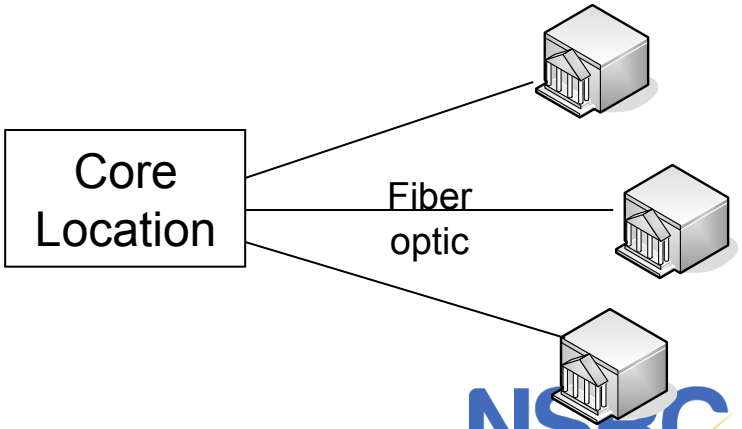
What about Cabling?

- The campus cabling plant is the underlying infrastructure that supports the network
- Similar rules apply to cabling as to network design
- People can waste money by not picking the right types of fiber optic cabling or unshielded twisted pair

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 (don't daisychain)



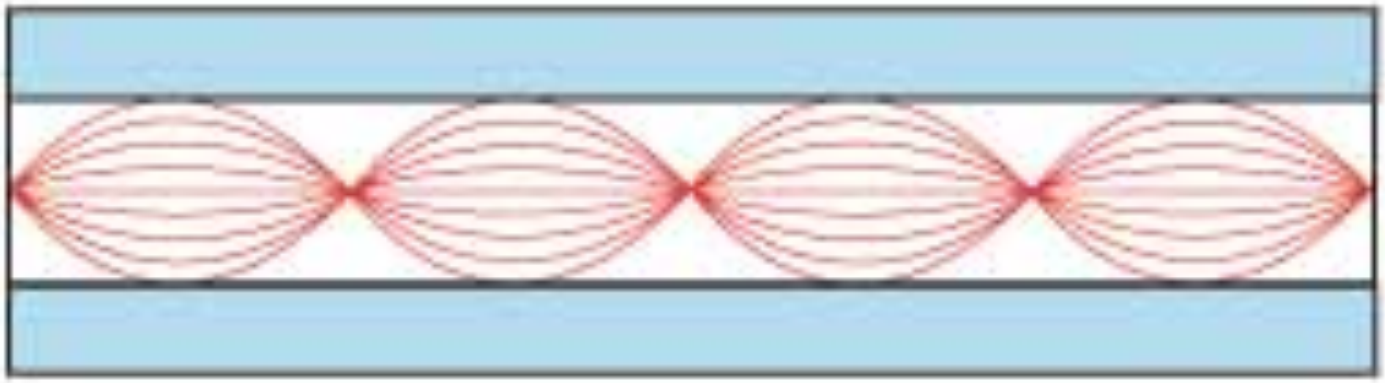


Unshielded Twisted Pair Cable

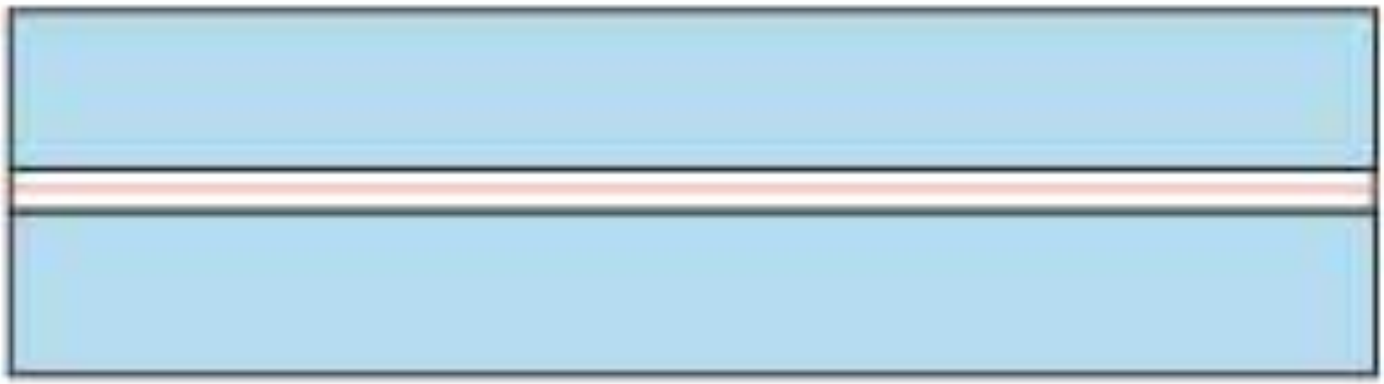
- Run in star configuration from network rack location to individual outlets in offices or labs.
- Run at least 2 cables to every outlet – I recommend 4 if you can afford it.
- Run 4 to 6 cables between network racks if the distance is less than 90 meters
- Question: what type of cable to run? Cat5, cat5e, Cat6, Cat6A?

Fiber Optic Cabling

- 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 to be aware
  - OSI/IEC 11801 OM1 – 62.5
  - OSI/IEC 11801 OM2 – 50 micron
  - OSI/IEC 11801 OM3 – 50 micron laser optimized
  - OSI/IEC 11801 OM4 – 50 micron higher bw

Single Mode Fiber

- All have core between 8 and 10 micron
- Standard types:
  - OS1 and OS2 (OSI/IEC 11801 types)
  - ITU G.652 (A, B, C, D)
  - ITU G.653 – 1310/1550 with EDFA amps
  - ITU G.654 – 1550 only
  - ITU G.655 – 1550/1625 for long haul DWDM
  - ITU G.656 – 1460/1625 for long haul DWDM
- You want G.652.D or OS2 single mode

Types of Optical Interfaces

Standard	Speed	Fiber Type
100baseFX	100Mbs	MM
1000baseSX	1Gbs	MM
1000baseLX/LH	1Gbs	MM or SM
10GbaseSR	10Gbs	MM
10GbaseLRM	10Gbs	MM
10GbaseLR	10Gbs	SM
10GbaseER	10Gbs	SM

Optical Interfaces: Cost & Distance

Standard	Cost*	OM1	OM2	OM3	OM4	G.652.D
100baseFX	$125	2km	2km	2km	2km	No
1000baseSX	$100	275m	550m	1km	1.1km	No
1000baseLX/LH	$169	500m	500m	500m	500m	10km
10GbaseSR	$475	33m	82m	300m	550m	No
10GbaseLRM	$785	220m	220m	300m	400m	No
10GbaseLR	$495	No	No	No	No	10km
10GbaseER	$6050	No	No	No	No	40km

*pricing for genuine Cisco products from networkhardwareoutlet.com.
In the USA, these products can be purchased cheaper than shown.

UNIVERSITY OF OREGON

NSRC
Network Startup Resource Center

Fiber Price Comparison

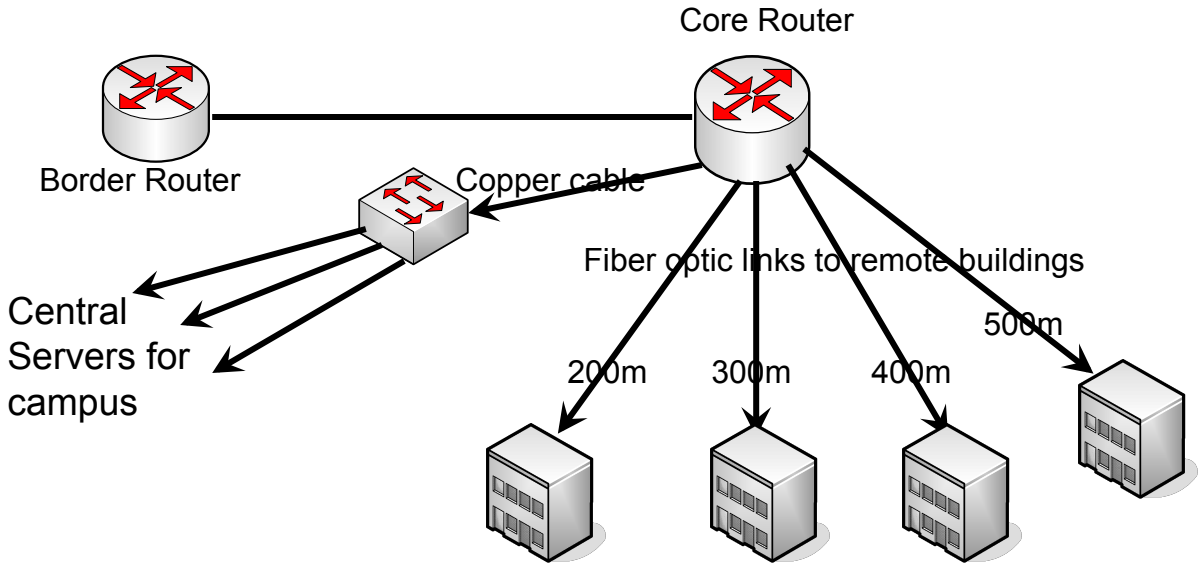
- Single mode fiber cabling is cheaper
- Multi mode optical interfaces are cheaper
- What makes sense for your campus?

Fiber Type	Cost per km*
OM1 (62.5 legacy)	$4,270
OM2 (50 legacy)	$2,854
OM3 (50 laser optimized)	$7,248
OM4 (new std)	$7,990
G.652.D (single mode)	$938

*Pricing based on 12-fiber outdoor cable, Corning 012TU4-T41xxD20, quote obtained in April, 2013

Simple Fiber Pricing Example

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



Pricing Example – 1Gig Links

- Use cheapest optical interface possible, but note that cheap interface is distance limited based on fiber type

Fiber Type	Fiber Cost	Optics	Total Cost
OM1	$5,978	2x1000baseSX@100 6x1000baseLX@169 = $1,214	$7,192
OM2	$3,996	8x1000baseSX@100 = $800	$4,796
OM3	$10,147	8x1000baseSX@100 = $800	$10,947
OM4	$11,186	8x1000baseSX@100 = $800	$11,986
G.652.D	$1,313	8x1000baseLX@169 = $1,352	$2,665

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	$5,978	Can't do do 10G farther than 220m	No
OM2	$3,996	Can't do do 10G farther than 220m	No
OM3	$10,147	Can't do do 10G farther than 300m	No
OM4	$11,186	8x10GbaseSR@475 = $3,800	$14,986
G.652.D	$1,313	8x10GbaseLR@495 = $3,960	$5,273

Fiber Optic Recommendations

- Multi mode is only good for 200m or less
- Install Single mode everywhere
- Run in star configuration from core network location to individual buildings
- Recommend: 6 fiber cores per building

Why DEA for Campuses?

- Helping campus network administrators design and build good networks is a key to the success of your NREN
- You can have the best NREN in the world, but if the campus network is bad, the experience of the staff and students will be bad

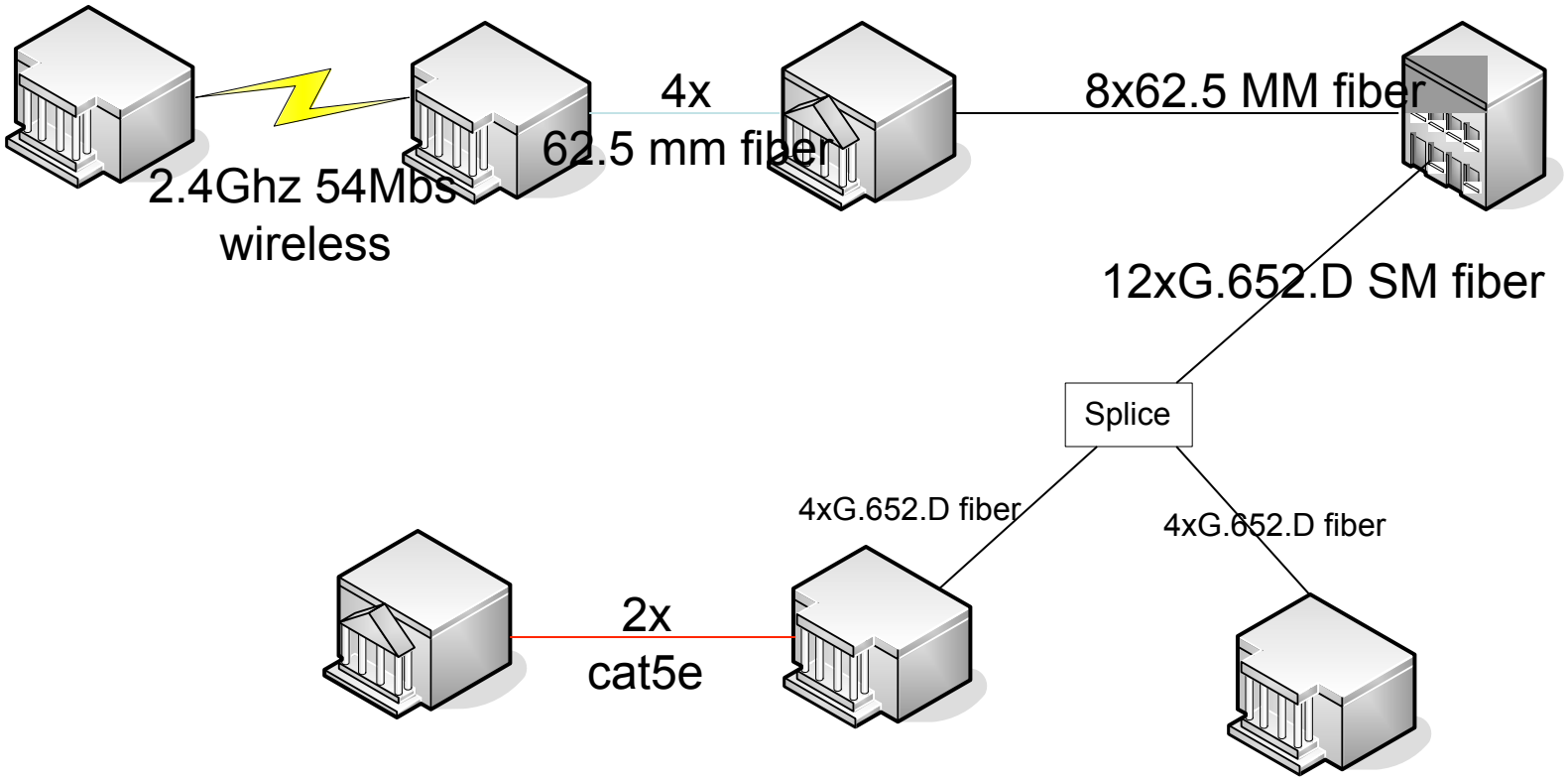
Direct Engineering Assistance

- Get campus network diagrams
- Difficult to get good diagrams that show everything you care about. Sometimes need three diagrams
  - A diagram showing fiber cabling
  - A diagram showing how equipment is connected together
  - A diagram showing the subnet/IP routing layout

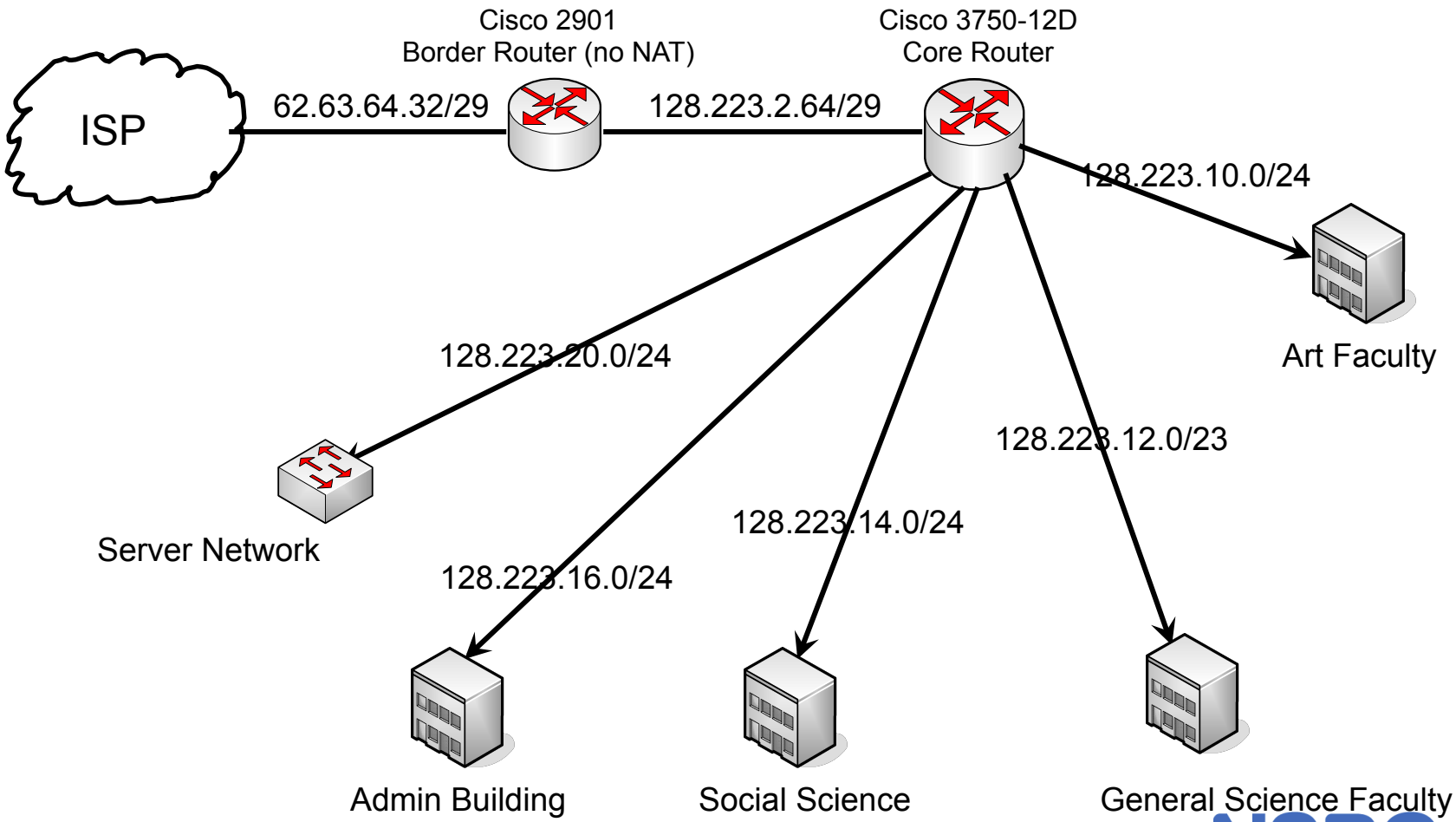
Network Diagrams

- Use separate diagrams for separate layers
  - Physical (cabling)
  - Switching (layer 2)
  - Routing (layer 3)
  - Frequently can combine Switching/Routing
- Helpful to have the physical diagram be an overlay on your campus map to show relations and distances between buildings
- If you combine layer 2/3, make it clear where you are switching and where you are routing

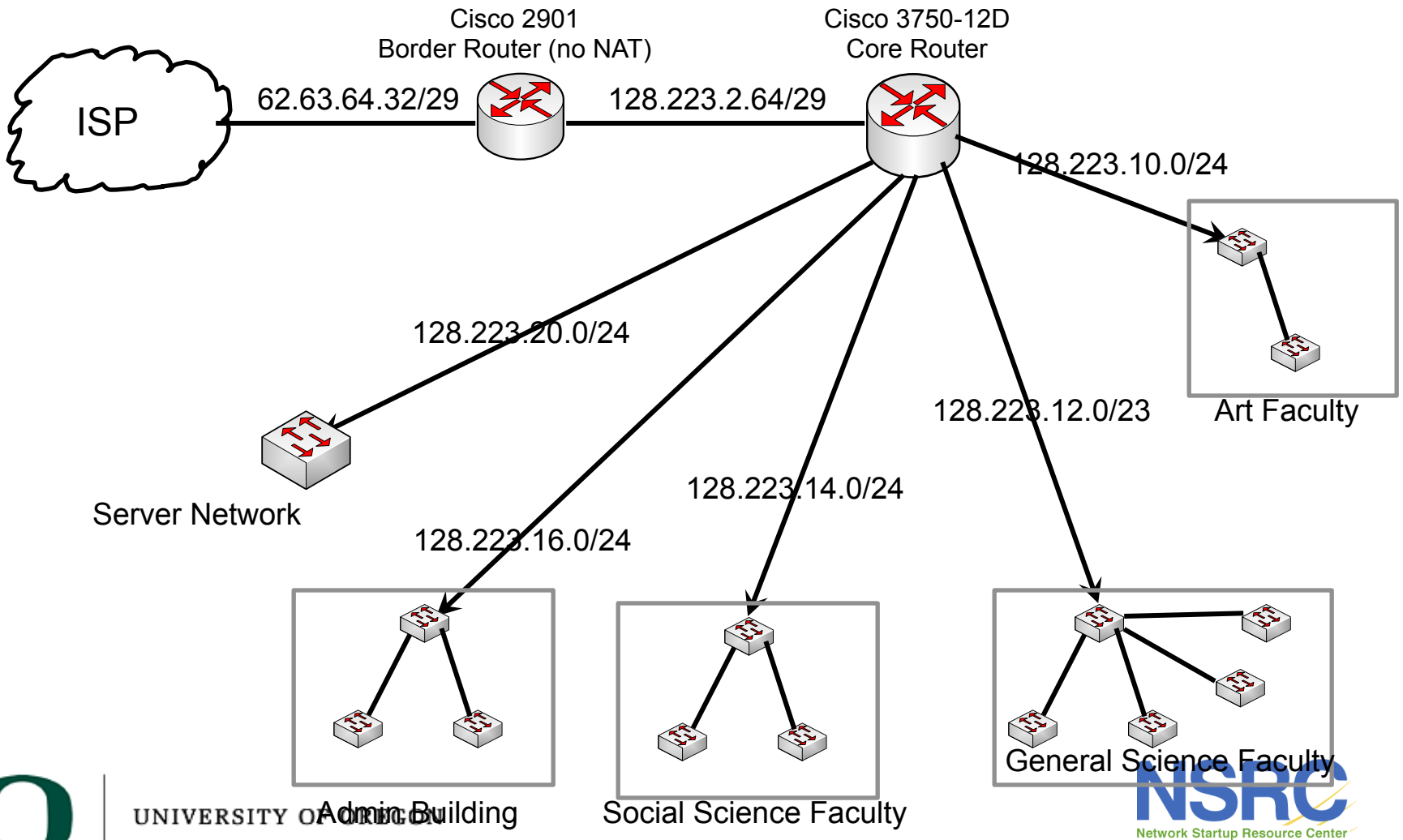
Sample Physical Diagram



Sample Layer 3 Diagram



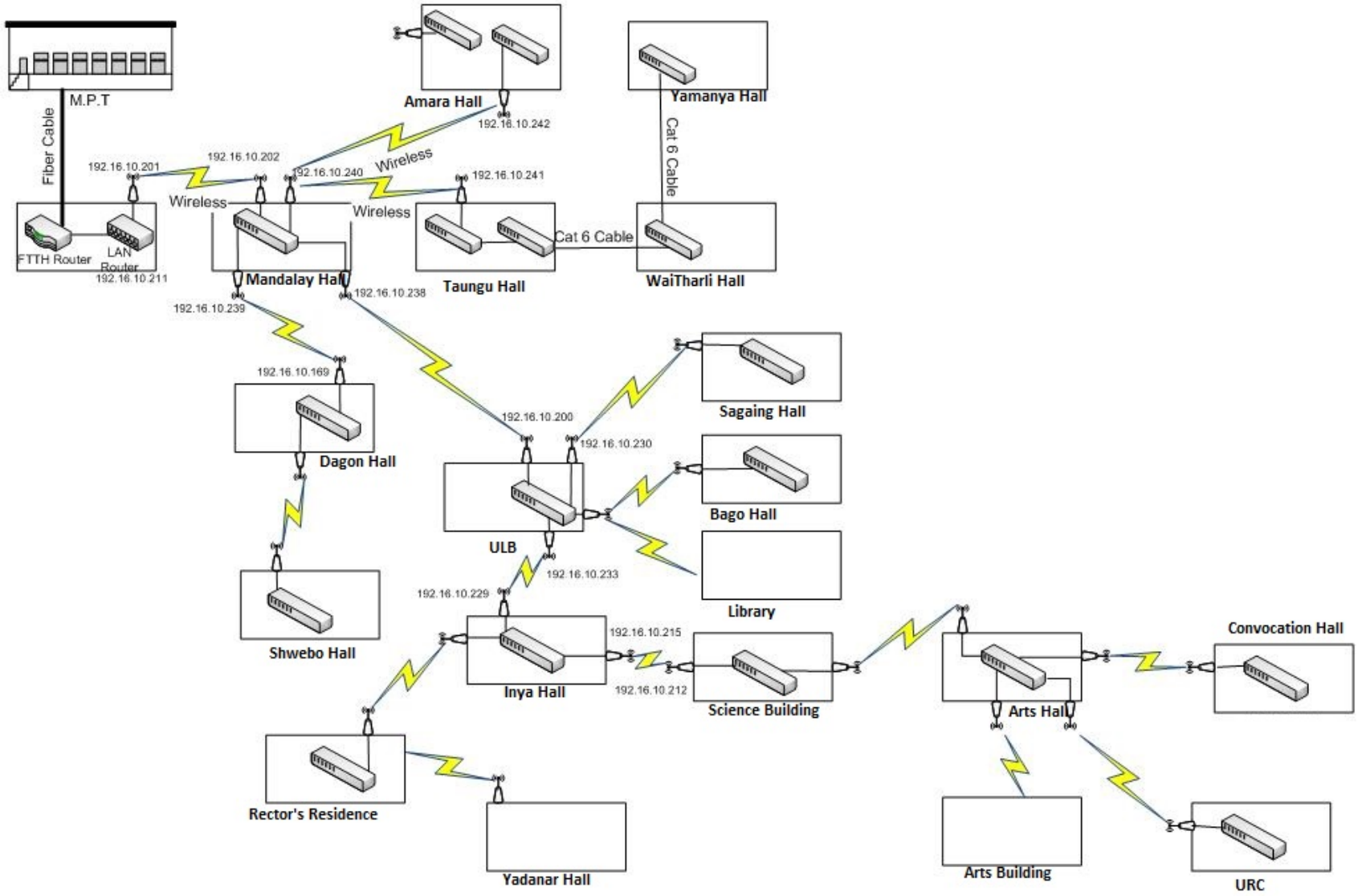
Sample Layer 2/3 Diagram



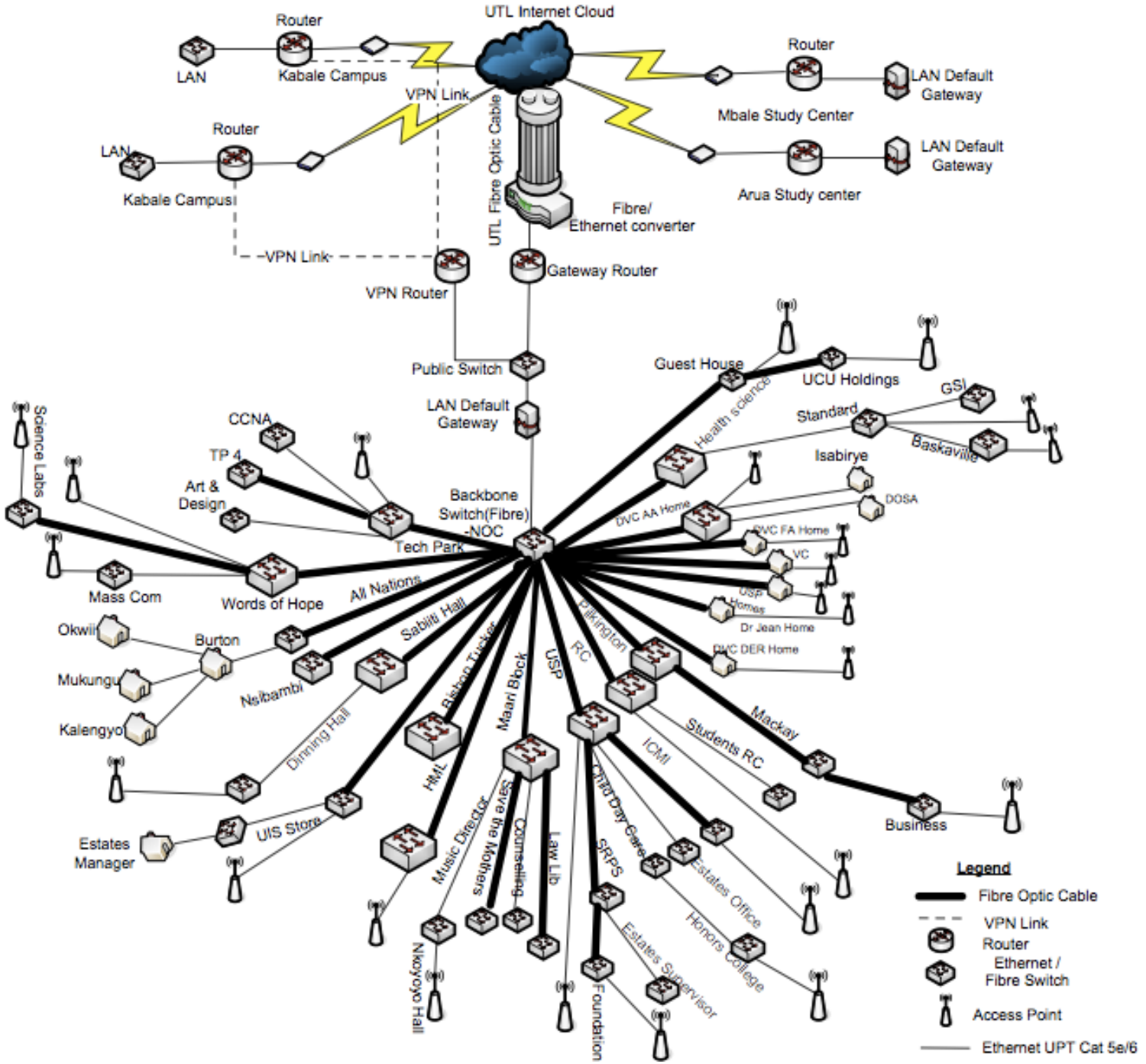
DEA “Touch Points”

- Route in the core
- Switch at the edge
- Build star networks – don’t daisy chain
- Managed switches
- Watch for heavily filtered networks that only allow web traffic – pay attention to firewalls
- Single mode fiber, not multi mode

Layer 2/3 Diagram for UY Campus Network



UCU PHYSICAL NETWORK SETUP/TOPOLOGY AS OF 11/02/2013



Questions?

This document is a result of work by the Network Startup Resource Center (NSRC at http://www.nsrc.org). This document may be freely copied, modified, and otherwise re-used on the condition that any re-use acknowledge the NSRC as the original source.

UNIVERSITY OF OREGON

NSRC
Network Startup Resource Center