Helping With Direct Engineering Assistance

Dale Smith
Network Startup Resource Center
dsmith@nsrc.org

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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

Campus Network Challenges

- Many are not structured properly and can't effectively utilize high bandwidth connections (if a campus has 200Mbs, it is way different than 2Mbs)
- 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

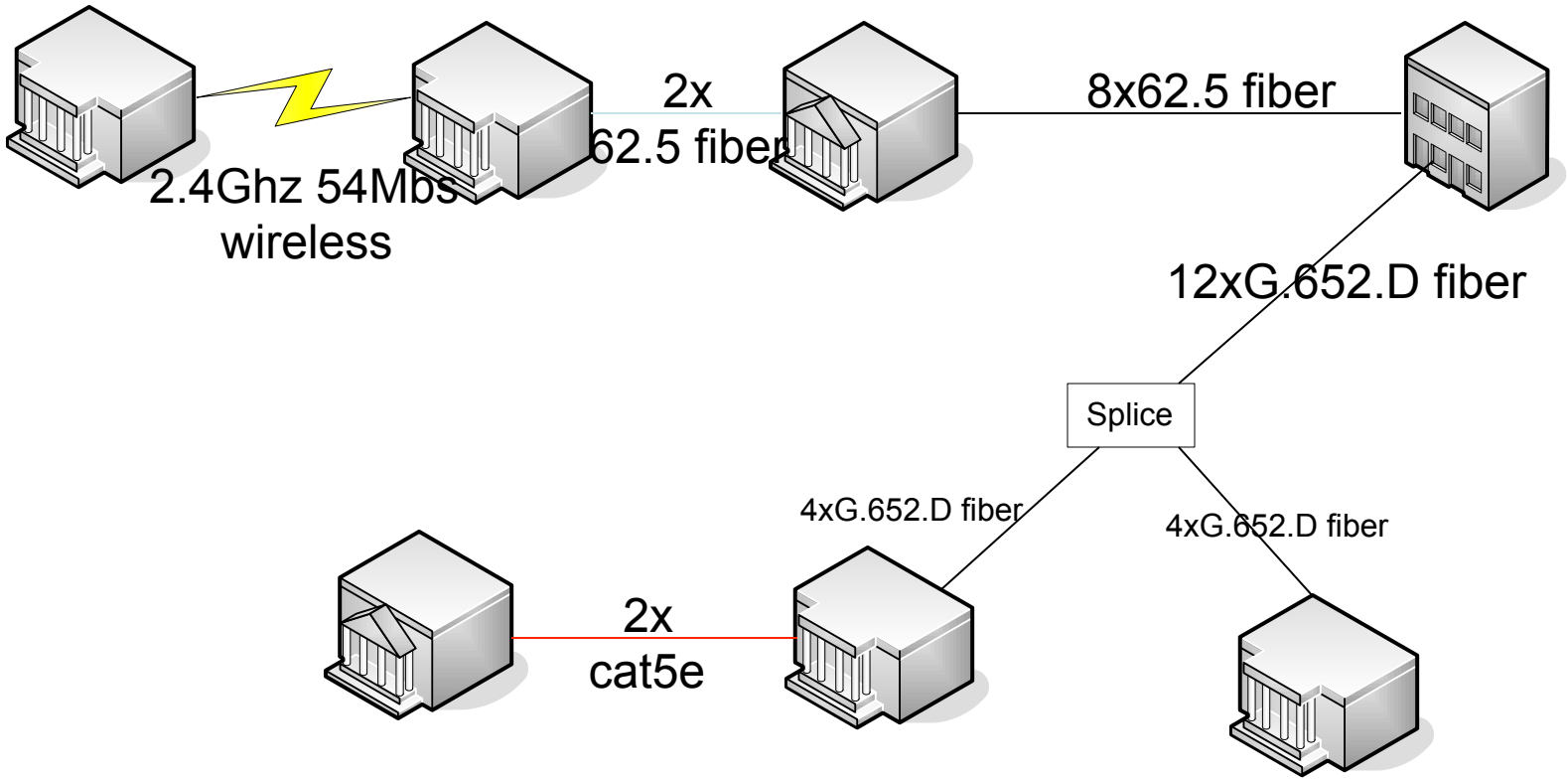
More Campus Network Thoughts

- We want to guide people to not do heavy firewalling and filtering
- Move people away from forced web proxies
- Networks that require every user to visit a help desk to connect is a losing proposition
- Encourage people to provide network diagrams to document their network – this provides a basis to begin to plan for improvements

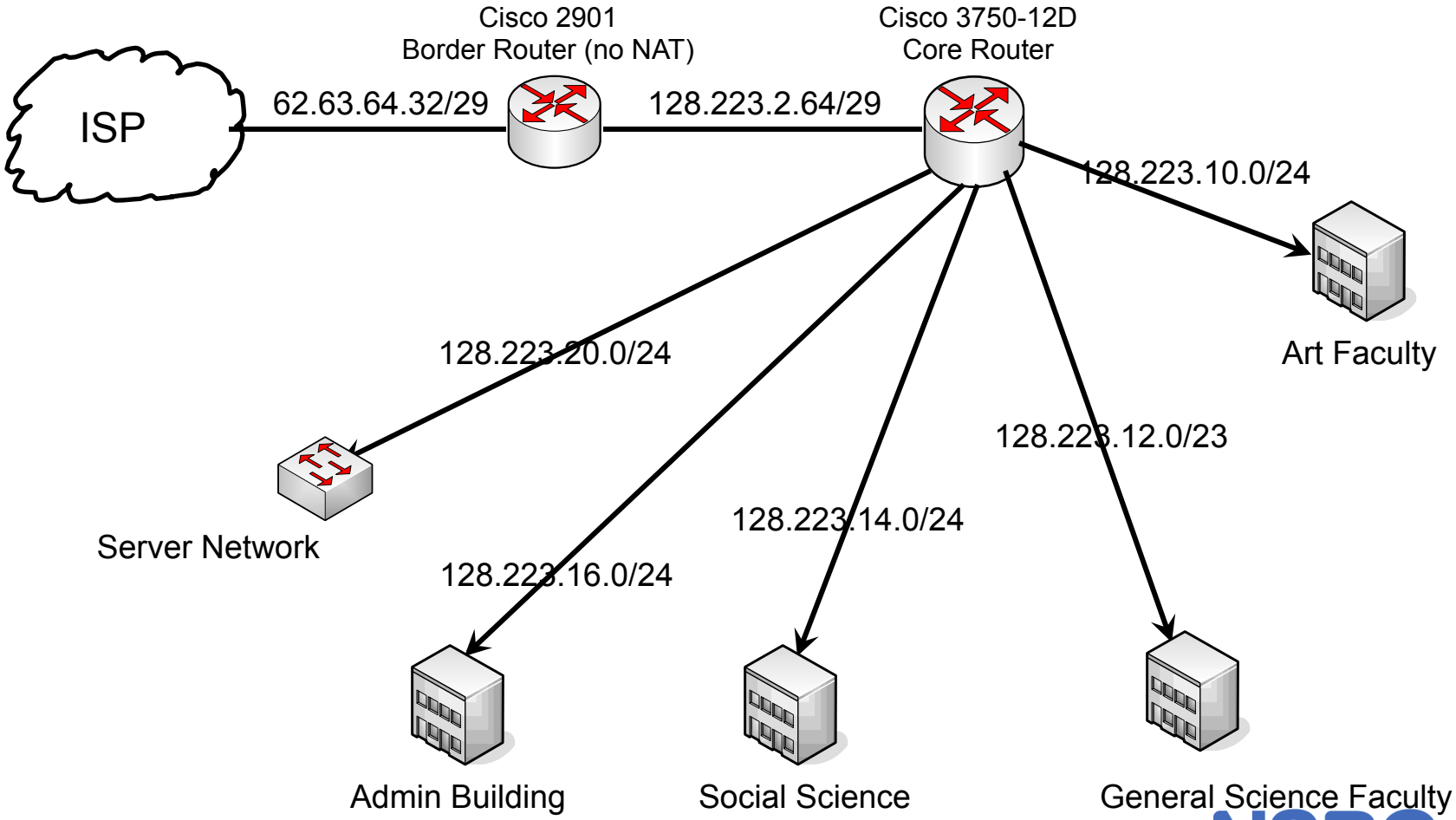
Network Diagrams

- 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

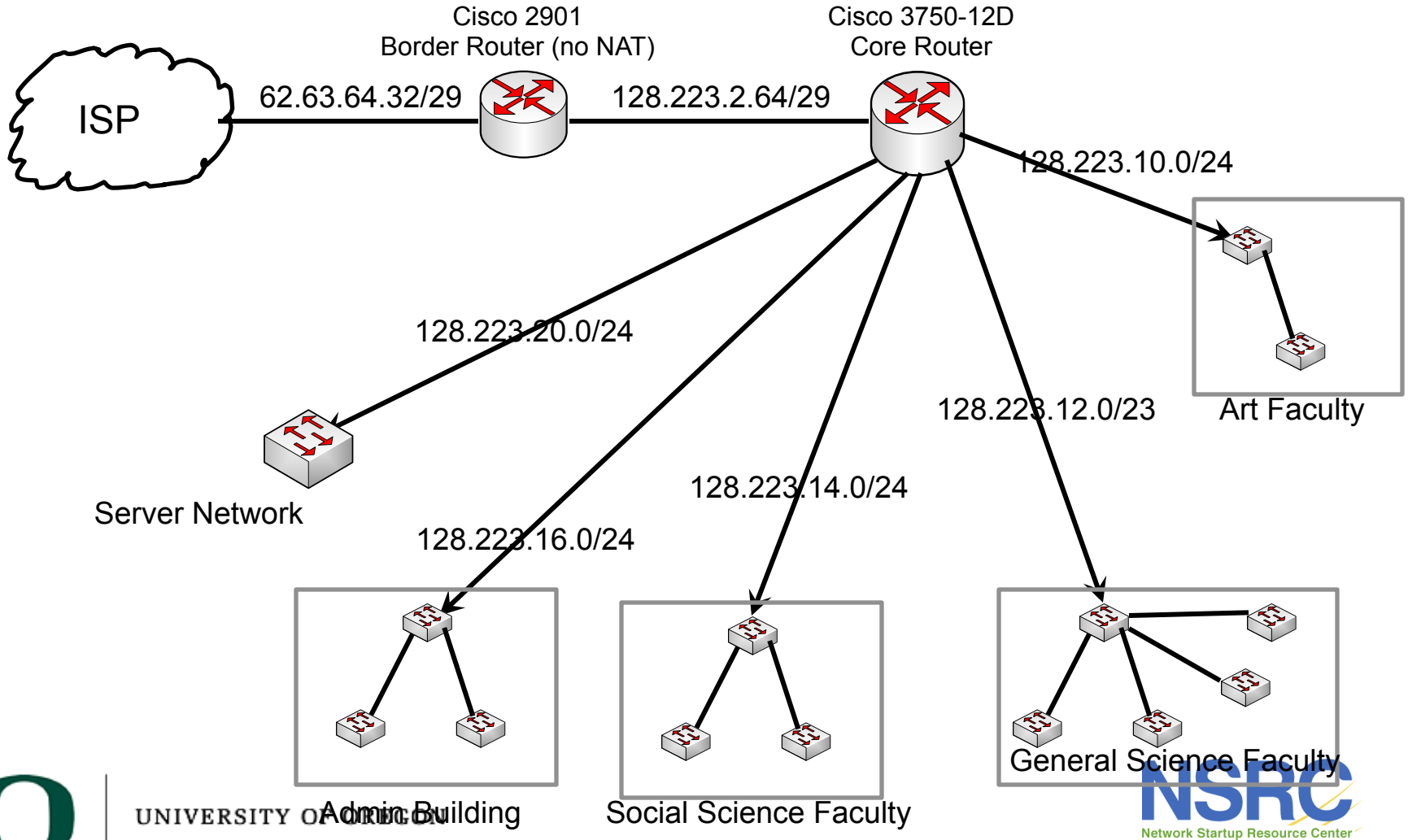
Sample Physical Diagram



Sample Layer 3 Diagram



Sample Layer 2/3 Diagram

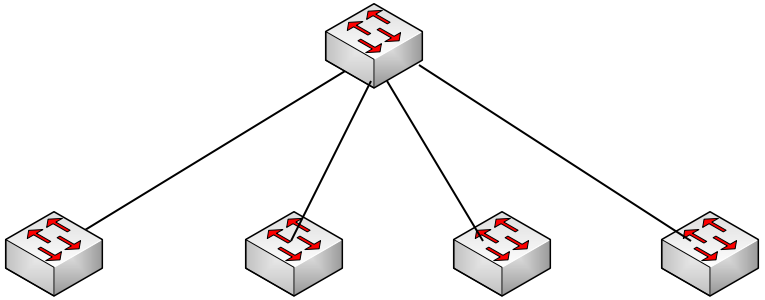


Basic Campus Network Rules

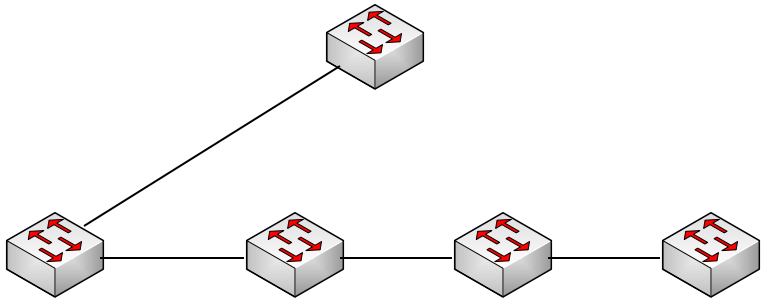
- Minimize number of network devices in any path
- Use standard solutions for common situations
- Build Separate Core and Edge Networks
- Route in the core of the network
- Switch on the edge of the network
- Provide services near the core
- Separate border routers from core routers
- Provide opportunities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

Minimize Number of Network Devices in the Path

- Build star networks



- Not daisy chained networks

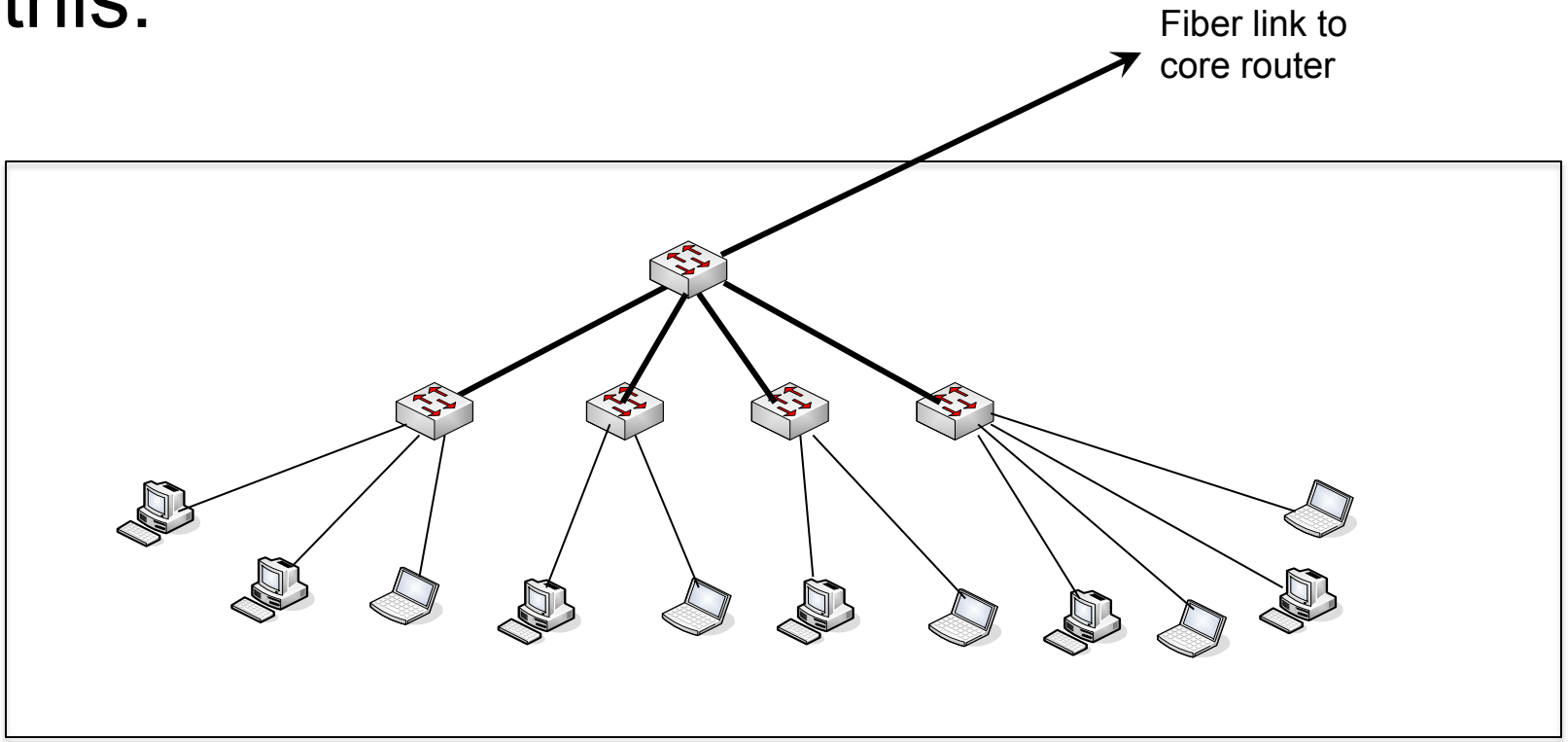


Each Building Should be a Subnet

- These are called edge networks
- Plan for no more than 250 computers
- Large computer labs may need separate subnet
- Can use VLANs for separation
  - Don't carry VLANs between buildings
- This network should only be switched
- Always buy switches that are managed – no unmanaged switches!

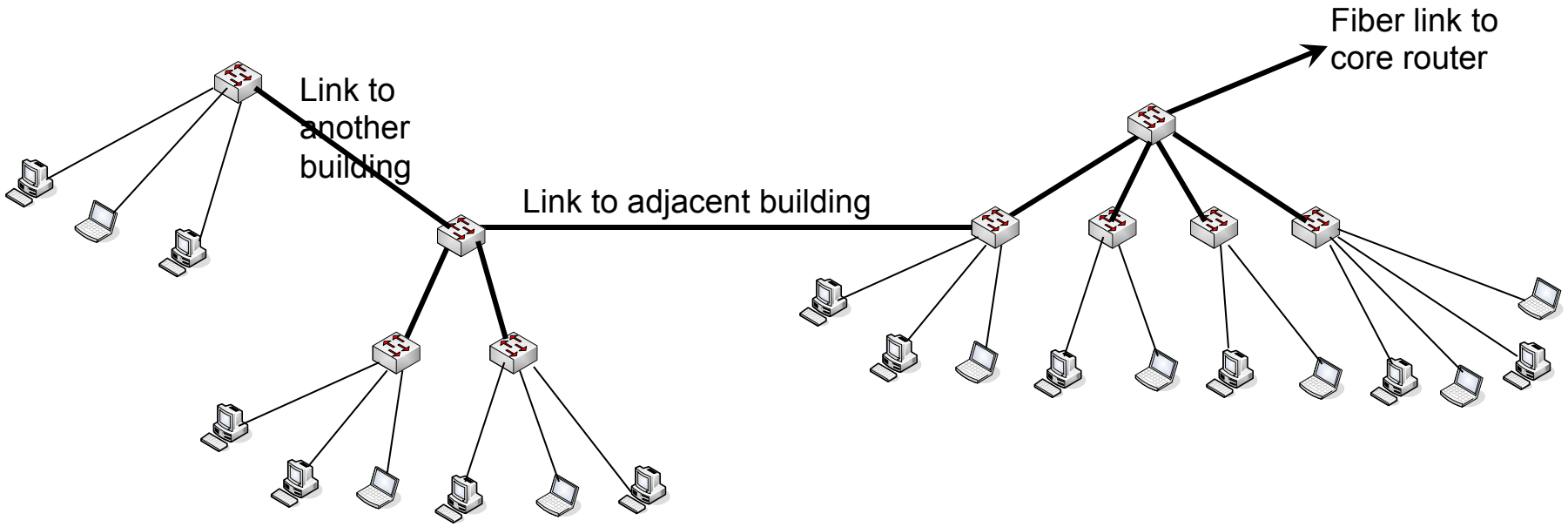
Edge Networks

- Every building should have a network like this:



Edge Networks Continued

- Watch out for networks that have daisy chained buildings together like this:



Routing versus Switching Layer 2 versus Layer 3

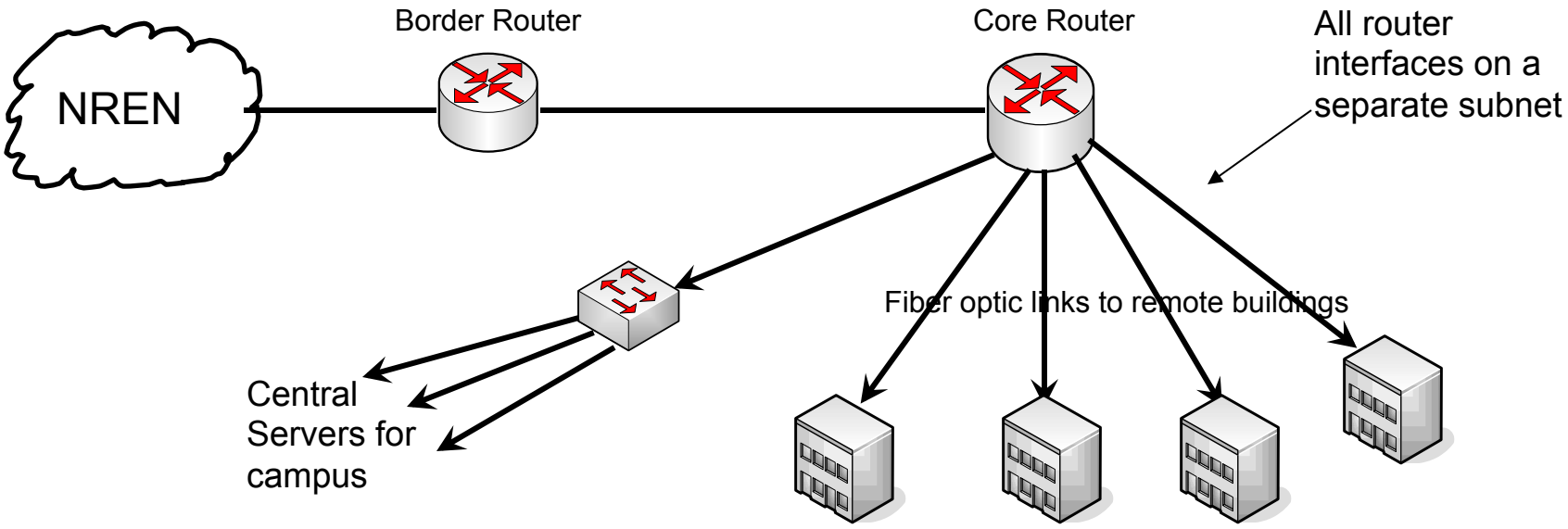
- Routers provide more isolation between devices (they stop broadcasts)
- Routing is more complicated, but also more sophisticated and can make more efficient use of the network, particularly if there are redundancy elements such as loops

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.

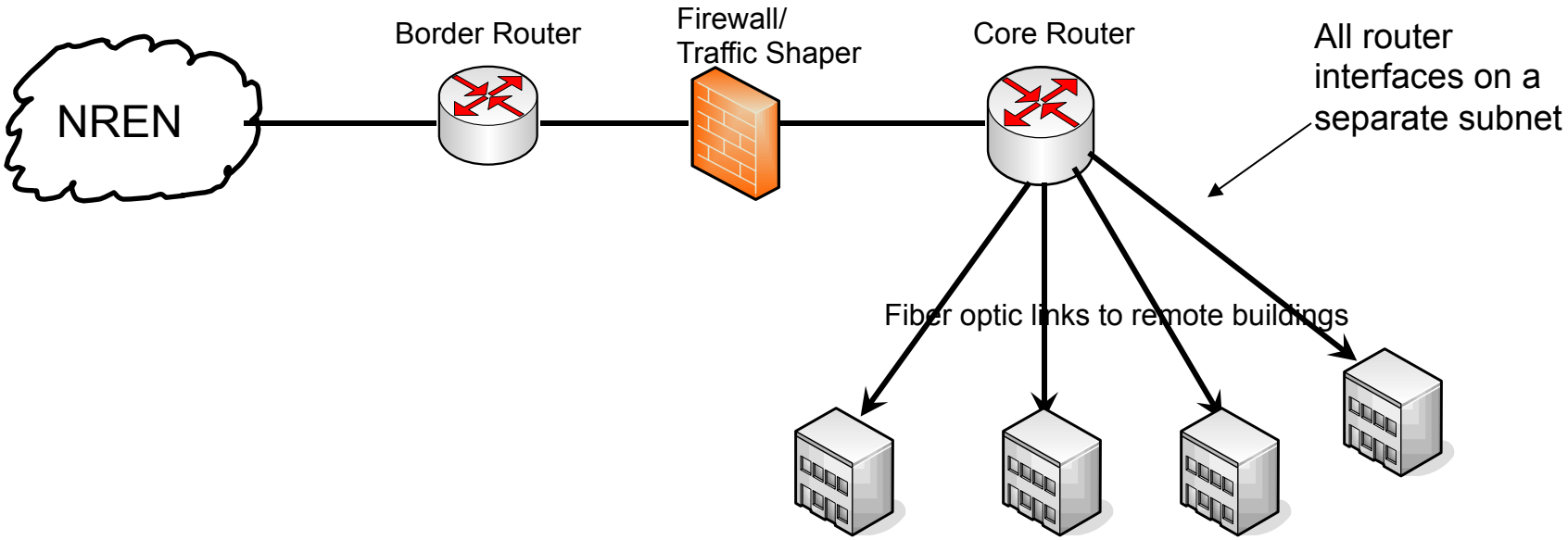
Core Network

- At the core of your network should be routers – you must route, not switch.
- Routers give isolation between subnets
- A simple core:



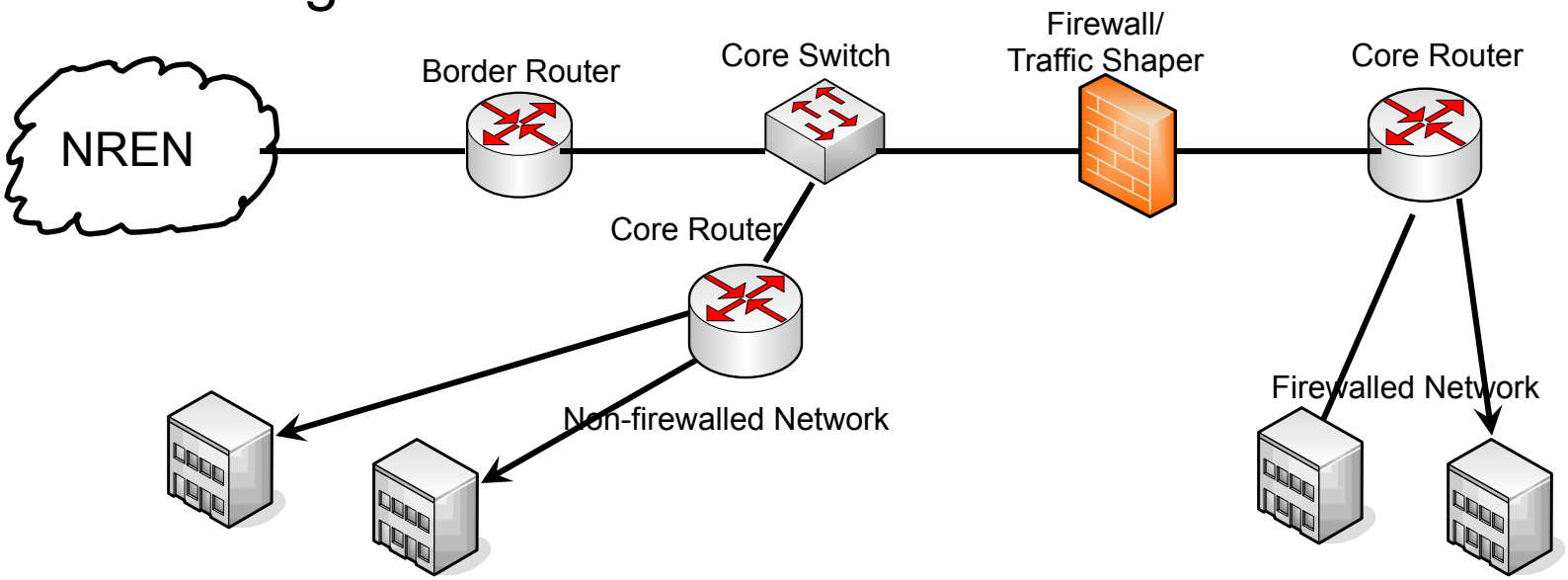
Where to put Firewalls

- Security devices must be placed “in line”
- This means that the speed of the firewall affects access to the outside world
- This is a typical design:



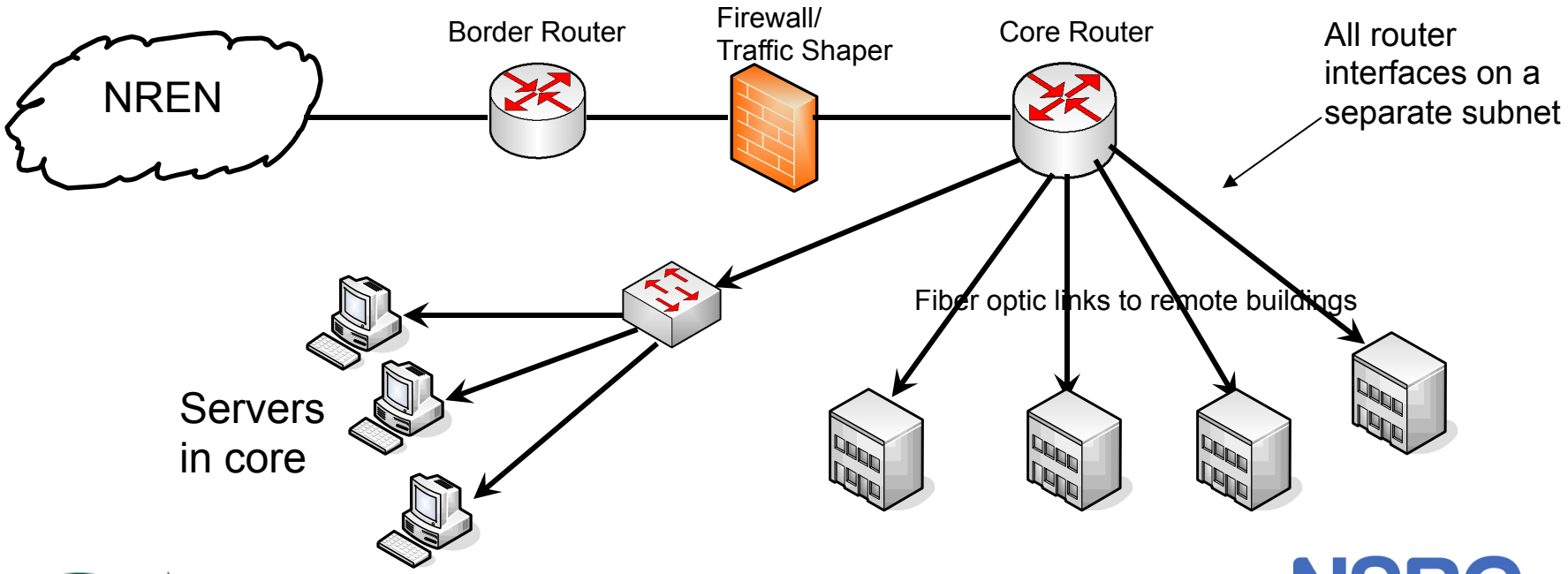
Where to put Firewalls

- As Campus Networks have gotten better bandwidth, the firewall becomes a bottleneck.
- Can move part of your network from behind the firewall to allow full bandwidth, un-filtered access to the Internet
- One configuration:



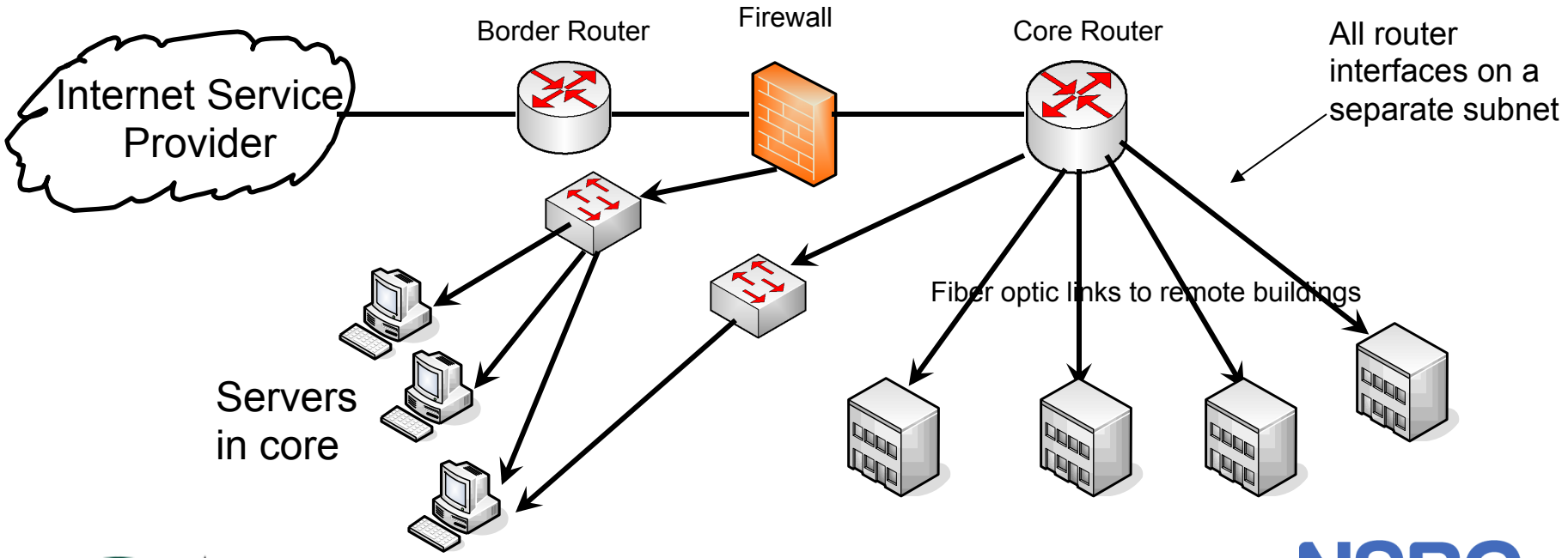
Where to put Servers?

- Servers should never be on the same subnet as users
- Should be on a separate subnet off of the core router
- Servers should be at your core location where there is good power and air conditioning



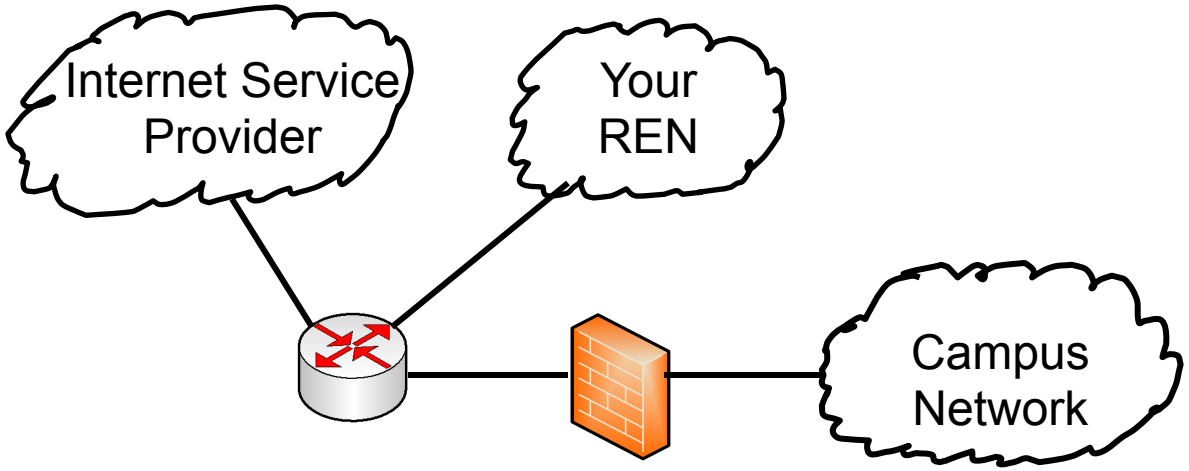
Where to put Servers?

- Sometimes you need servers that have public IP addresses
- Can put directly off of a firewall with no NAT
- Can have some servers with an interface on both the external network and an internal network

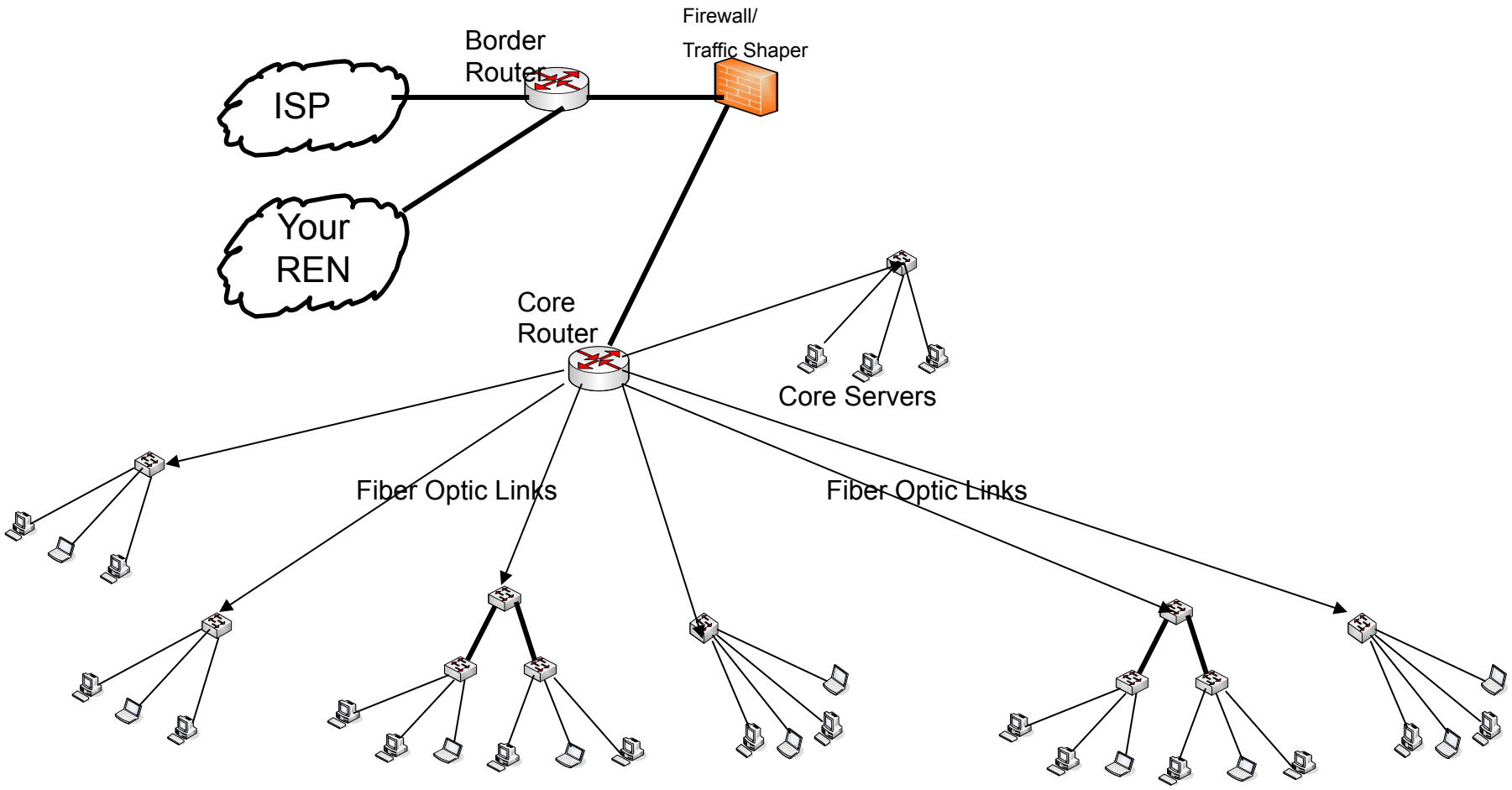


Border Router

- Connects to outside world
- RENs and Peering are the reason you need them
- Must get Provider Independent IP address space to really make this work right

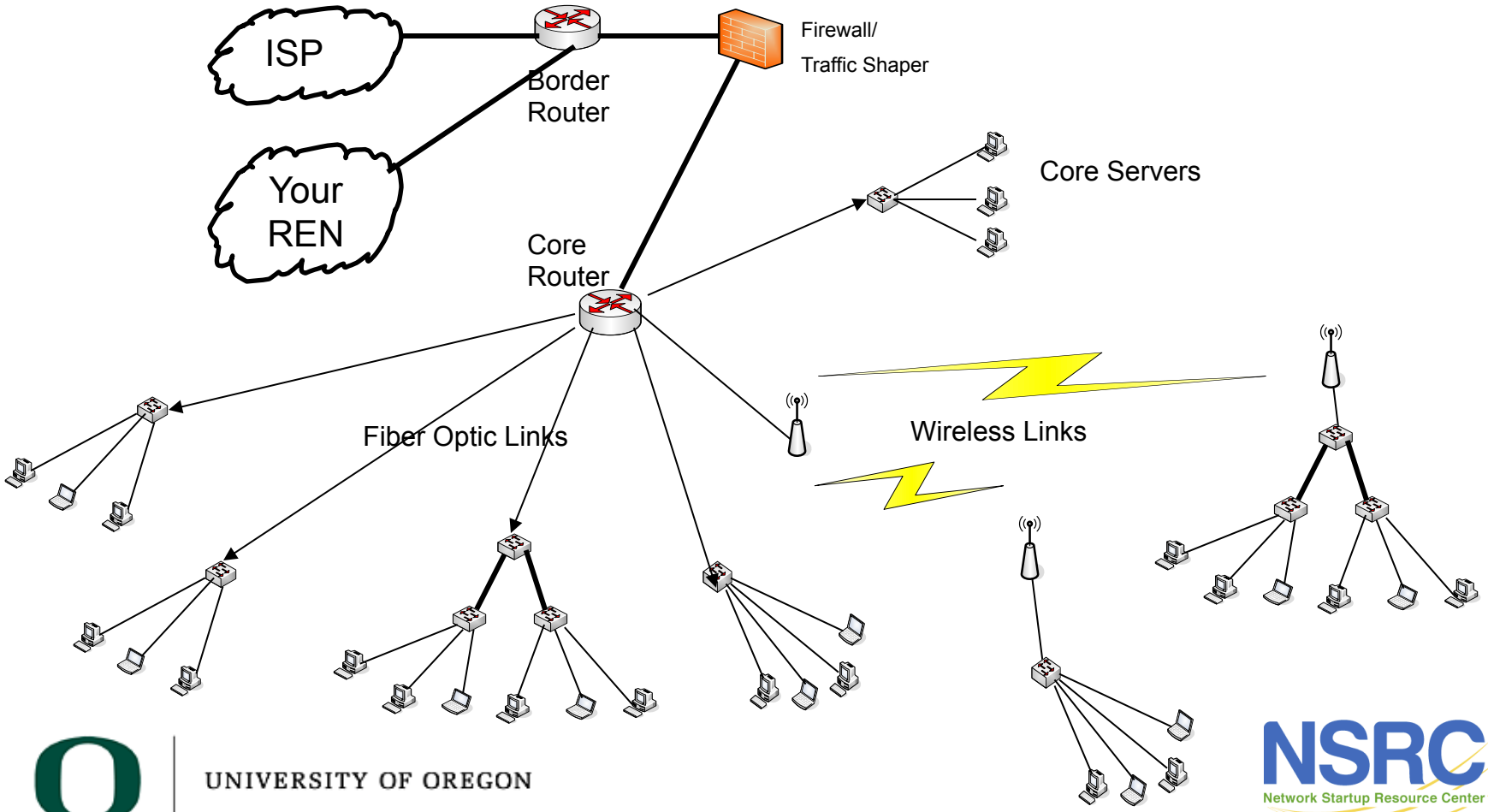


Putting it all Together



Alternative Core Designs

- Wireless Links versus Fiber

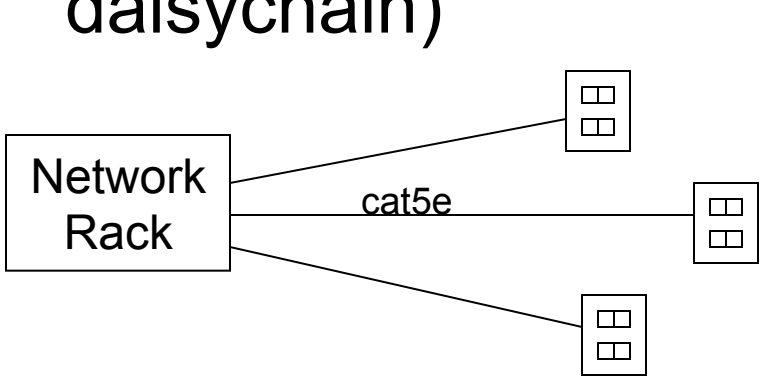


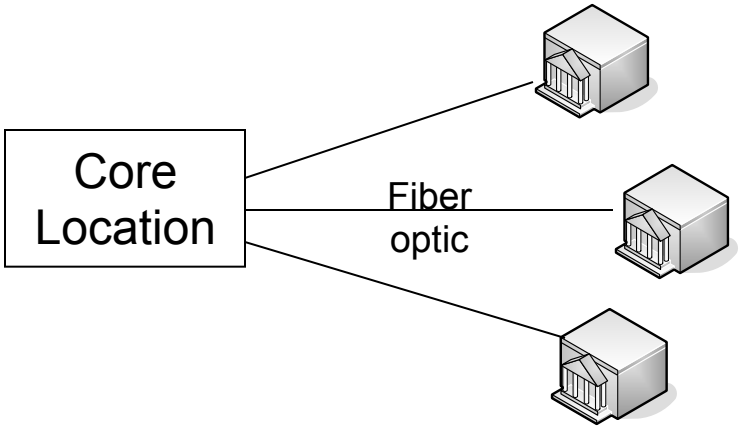
What about Cabling?

- 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, ???

What type of UTP

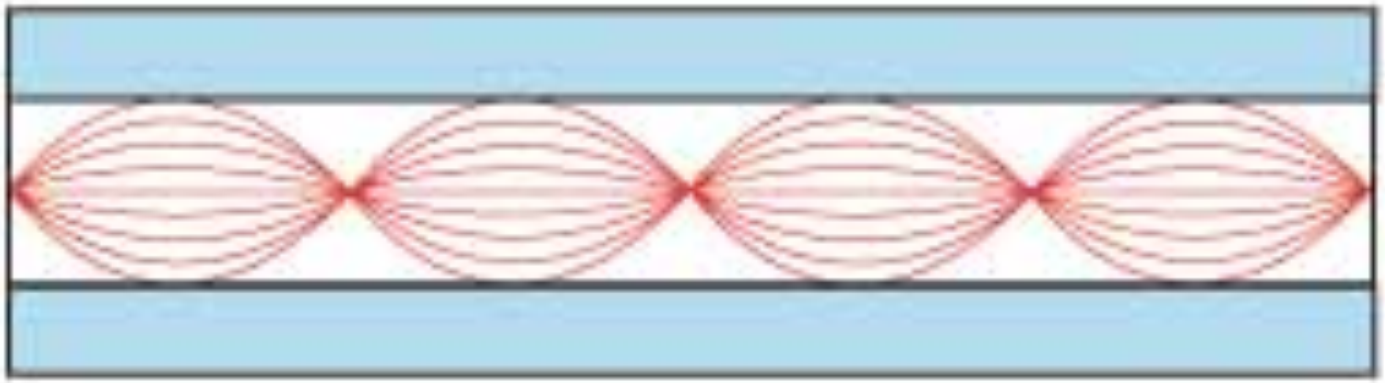
- What speed does each type support?

Cable Type	Max Speed	Max Distance	Cost Factor
Category 5	100Mbs	100m	1x
Category 5e	1000Mbs	100m	1x
Category 6	1000Mbs	100m	1.5x
Category 6	10,000Mbs	57m	1.5x
Category 6a	10,000Mbs	100m	3x

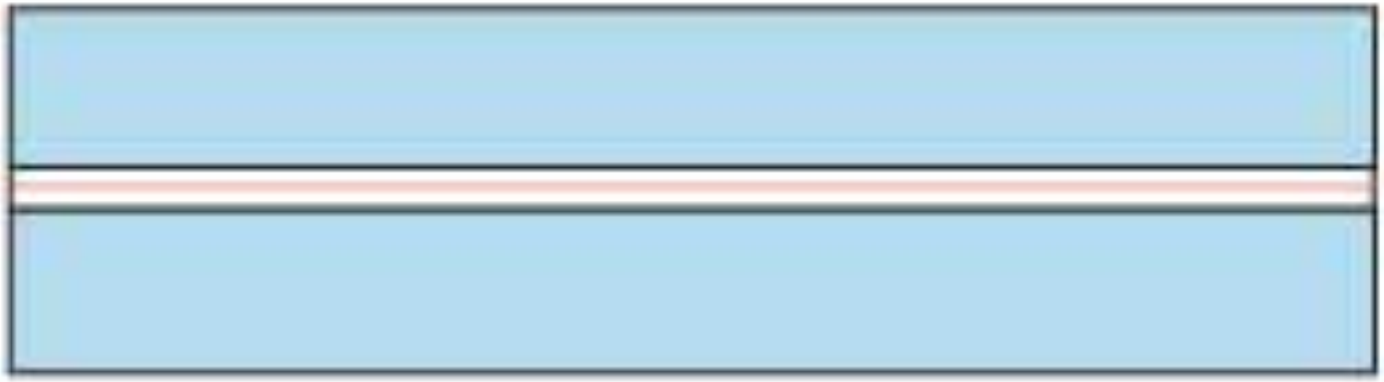
- Strongly recommend category 5e cabling.

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
  - G.651 – 50 micron
  - 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	?	?	10km
10GbaseSR	$475	33m	82m	300m	550m	No
10GbaseLRM	$785	220m	220m	220m	?	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.

Fiber Price Comparison

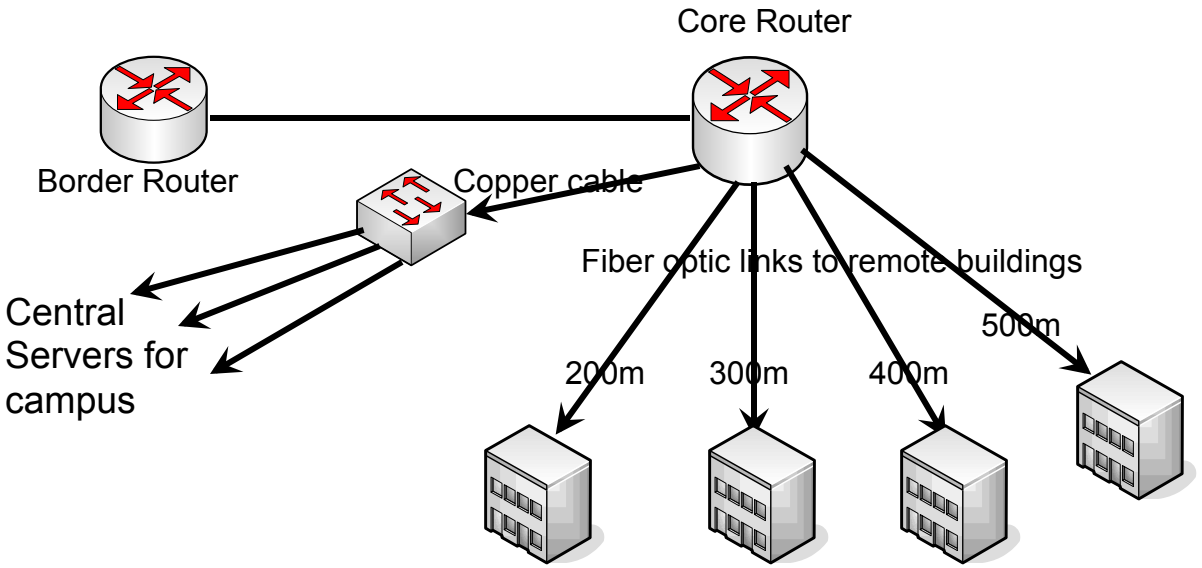
- Single mode fiber cabling is cheaper
- Multi mode optical interfaces are cheaper
- What makes sense for your campus?

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

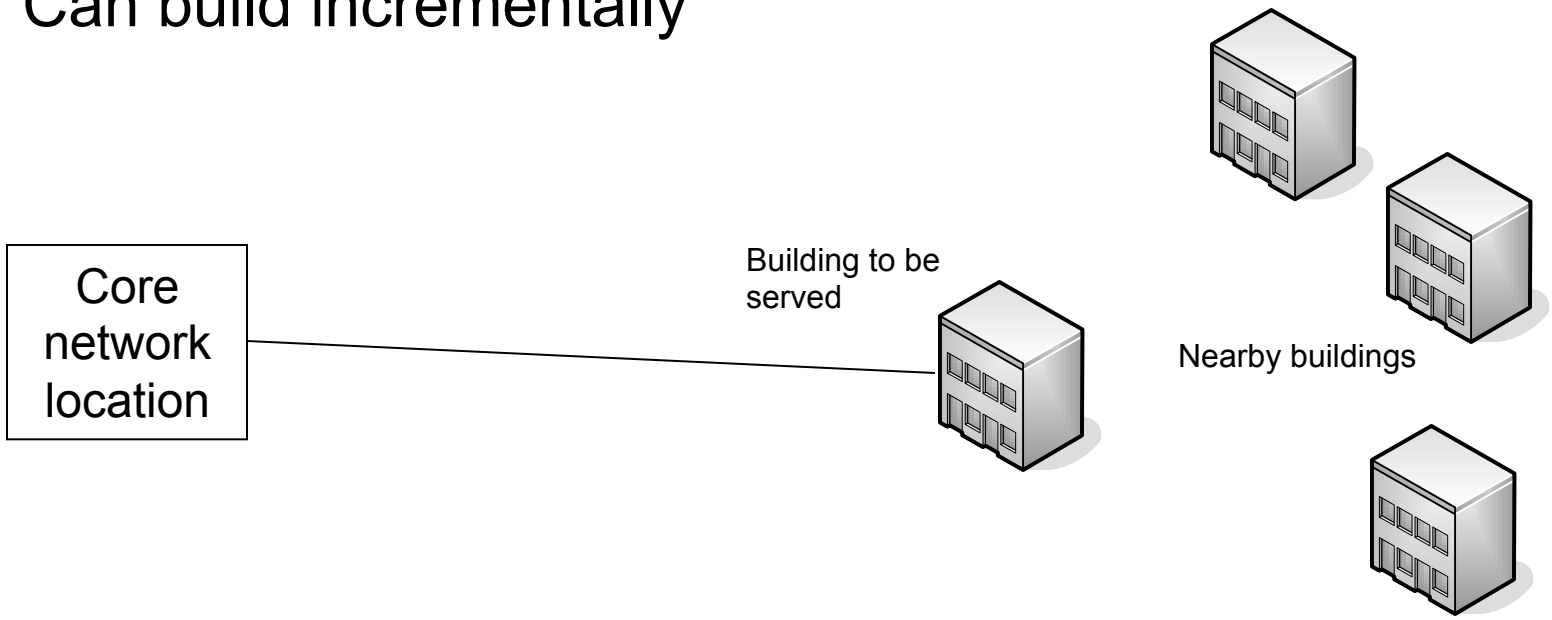
Fiber Type	Fiber Cost	Optics	Total Cost
OM1	$5,978	Can't do do 10G farther than 220m	No
OM2	$3,996	Can't do do 10G farther than 220m	No
OM3	$10,147	Can't do do 10G farther than 300m	No
OM4	$11,186	8x10GbaseSR@475 = $3,800	$14,986
G.652.D	$1,313	8x10GbaseLR@495 = $3,960	$5,273

Fiber Optic Recommendations

- Only install Multi Mode OM2 if distances are short
- Don't do OM1, OM3 or OM4 anywhere
- Install Single mode everywhere
- Run in star configuration from core network location to individual buildings
- Run in star configuration inside of buildings from main network closet to other closets
- 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 (multi mode OK if distances are short)
  - Inside of buildings: 6 single mode and 6 multi mode between network racks
  - Can build incrementally



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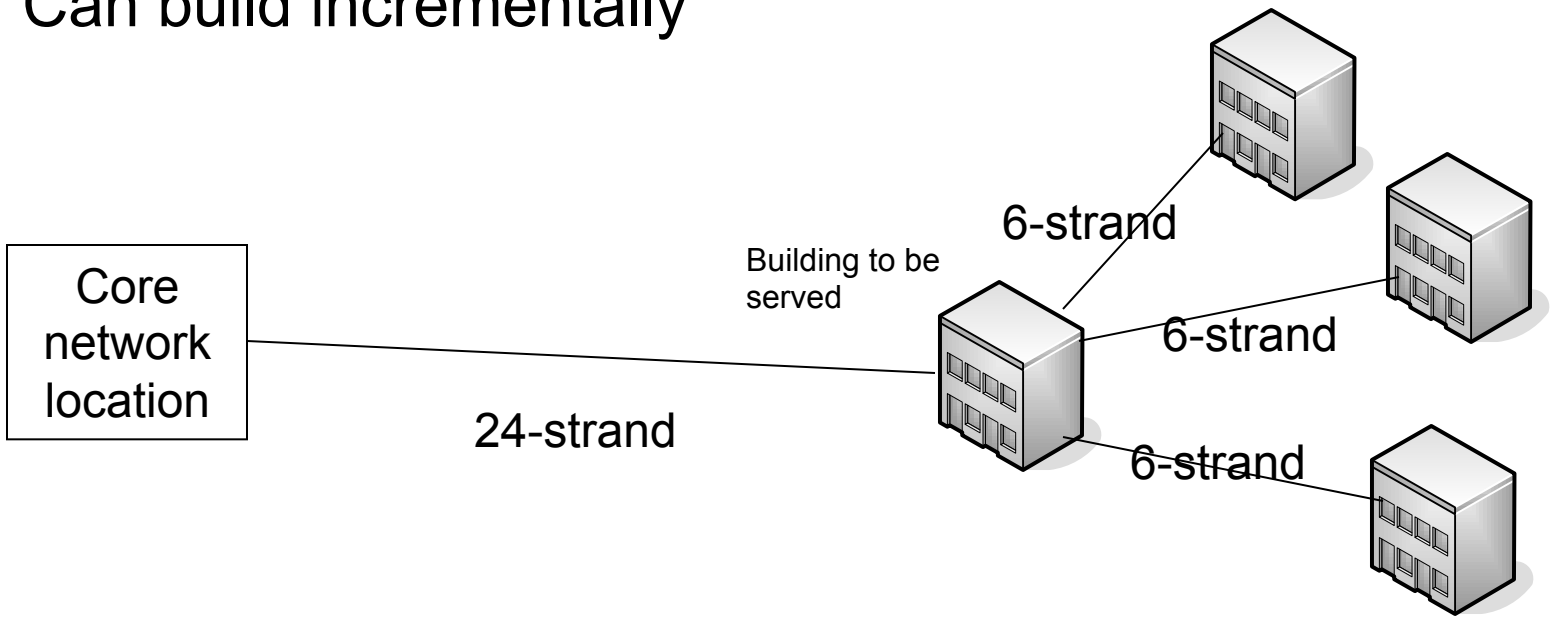
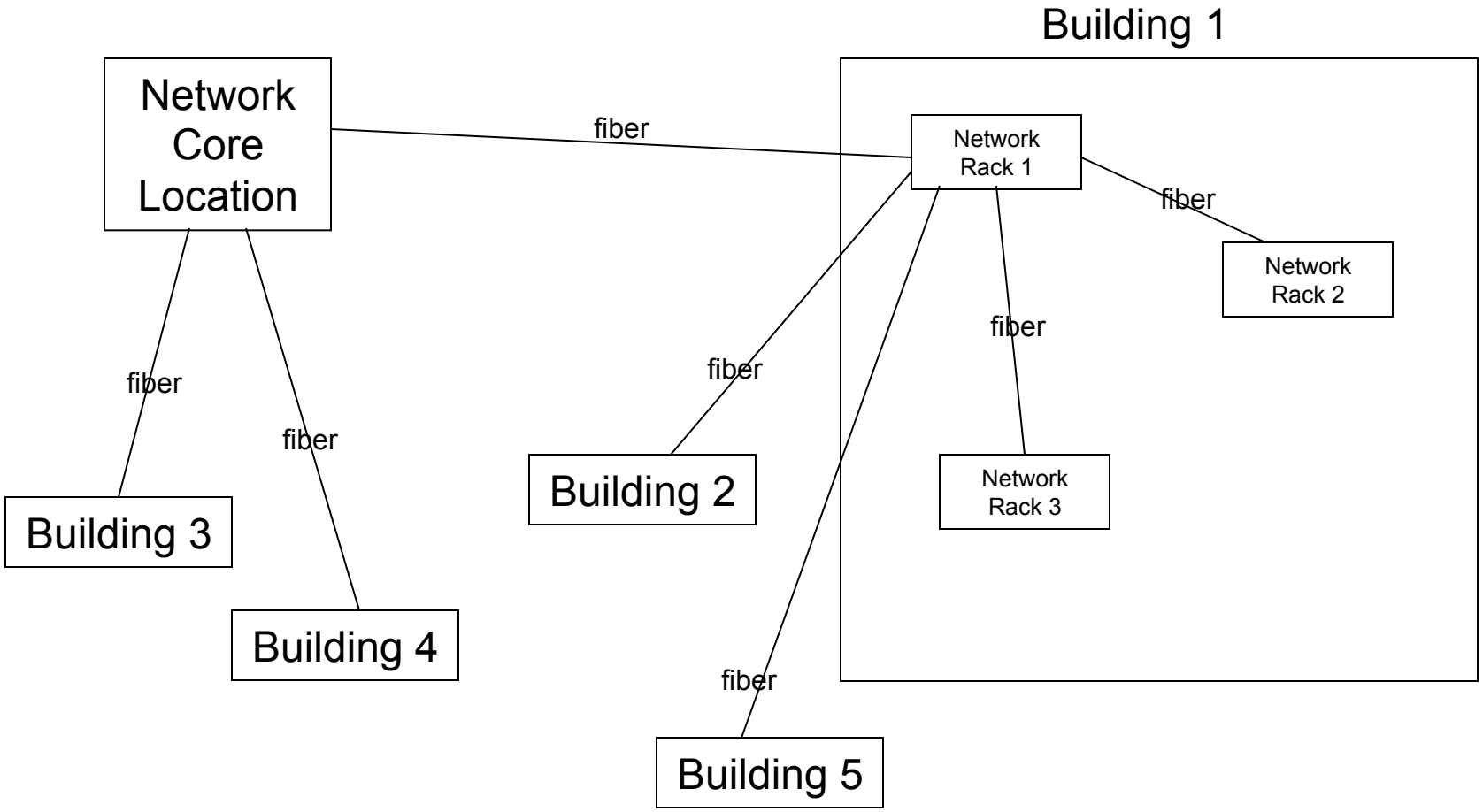


Fiber Optic Topology



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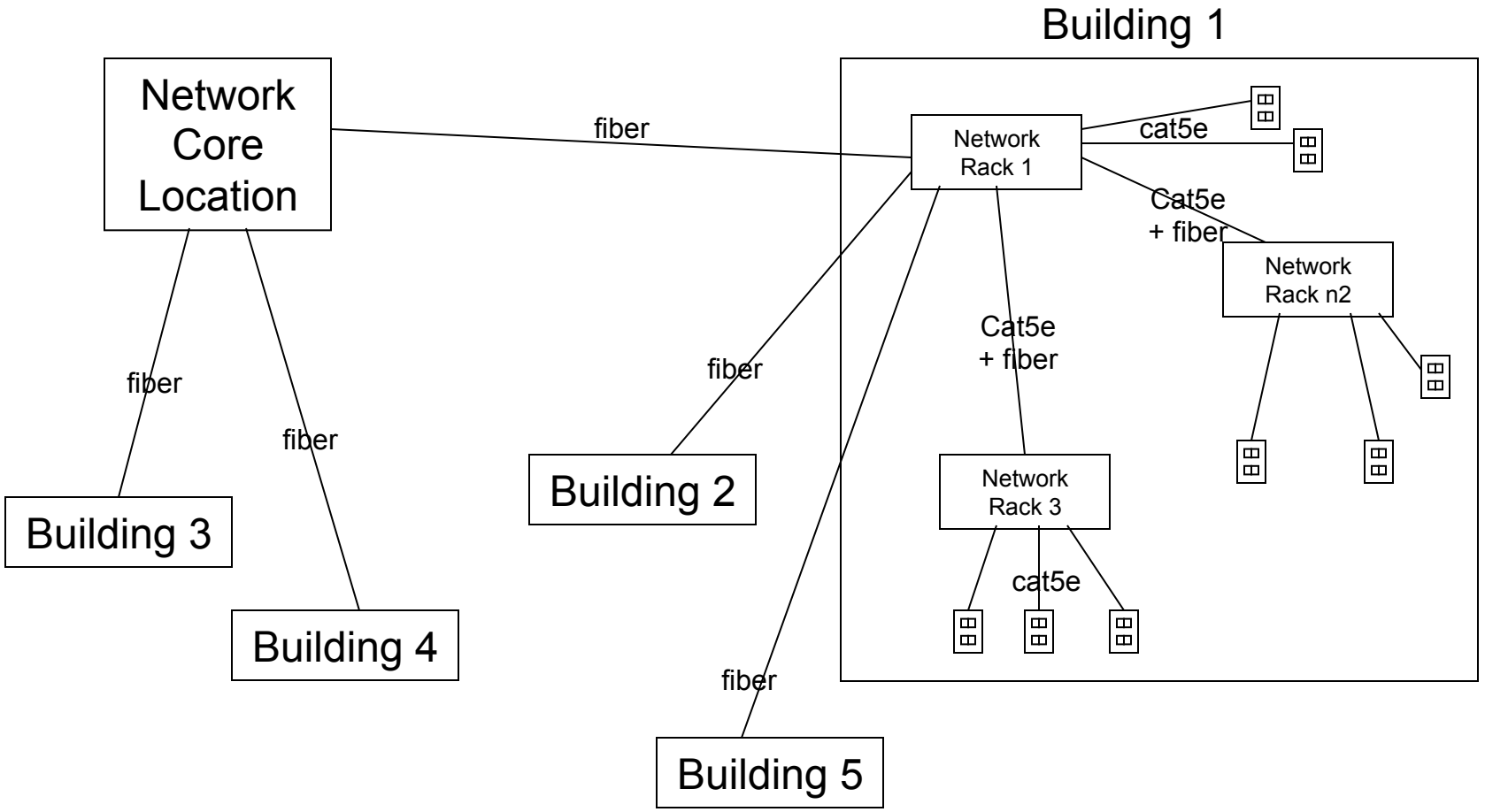

DEA “Touch Points”

- 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

Questions?

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