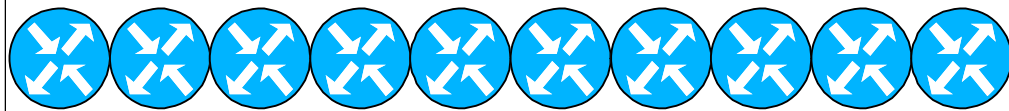


[Revision 1.0, file "s10.ppt", 05-Dec-2000 R.Curci]

Good afternoon. My name is Ray Curci. I am a computer science student in the computer network and system administration masters track. My project is entitled "FSU Computer Science Internet Teaching Lab" About 6 months ago, my good friend Mike Sloderbeck mentioned that he had read on the Computer Science web page that Computer Science and Information Studies will share a new Internet Teaching Laboratory, with routers provided by the Cooperative Association for Internet Data Analysis or CAIDA. I called the Computer Science chairman, Dr. Ted Baker, to find out more. Dr. Baker explained that some Cisco router equipment was donated and that renovations were underway in the Love building to build a new computer network lab. He encouraged me to talk with Jeff Bauer and Damon Snyder. Jeff Bauer suggested creating network assignments to supplement the assignments in his system administration class. The idea was to give students some hand-on exposure to network router equipment. I worked closely with him to develop labs to dovetail with his system administration class and we turned this effort into a masters degree project.

## OBJECTIVE

- Design, implement and document a highly flexible hands-on Internetwork Teaching Lab to augment systems administration and data communications courses including the creation of several sample lab exercises.



The objective of this project is to design, implement and document a highly flexible hands-on Internetwork Teaching Lab to augment systems administration and data communications courses including the creation of several sample lab exercises.



## DESIGN GOALS

- Low cost
- Secure design
- Extensible design
- Ease of soft reconfiguration
- Remote access
- Distributed design

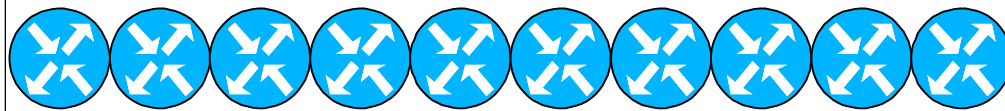
The design goals are as follows:

Low cost, secure design, extensible design, ease of soft reconfiguration, remote access, and distributed design.

I will revisit these design goals in more detail near the end of this presentation.

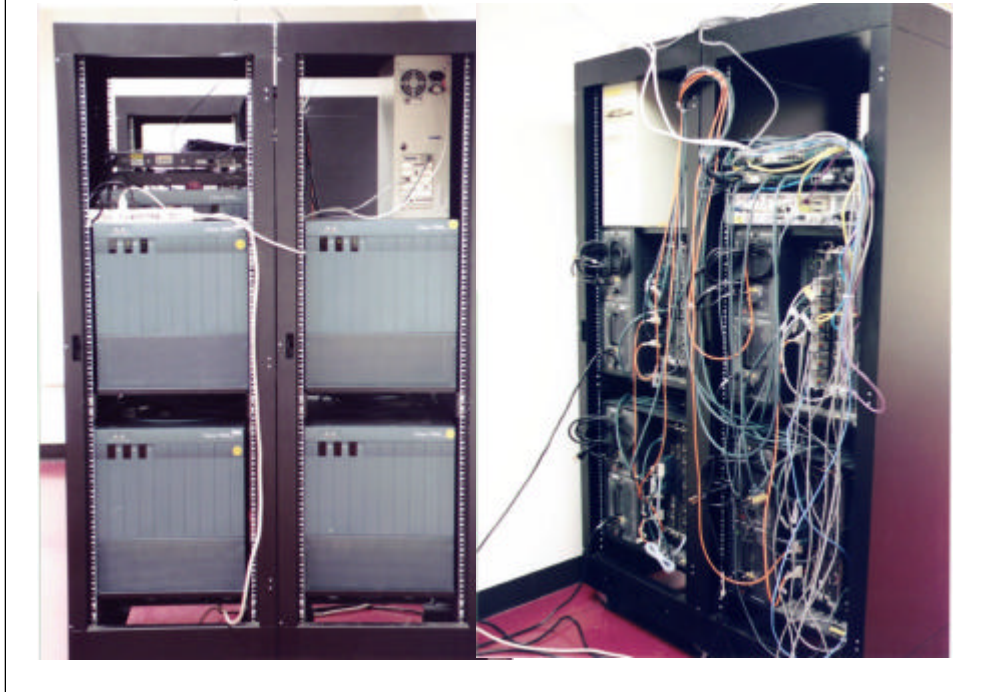
## FSU Computer Science Internet Teaching Lab Hardware

- Cisco 7000 routers (R1, R2, R3, R4)
- Cisco 4500 router (R5)
- Cisco 2511 router/firewall (R6)
- Cisco 35xxXL switches (CAT1, CAT2, CAT3)
- UNIX and NT computers



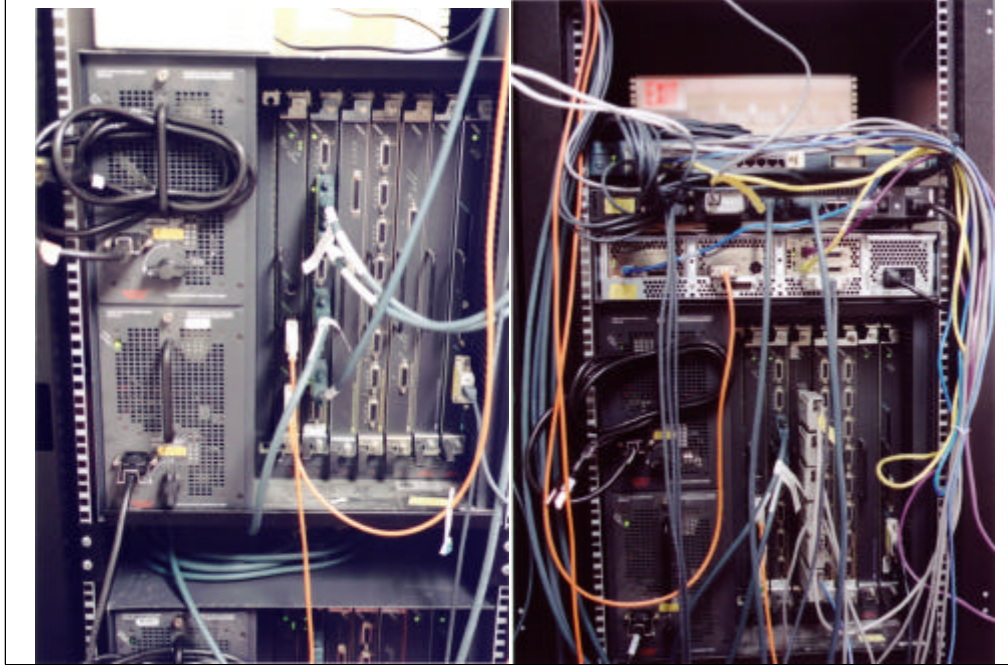
The lab hardware consists of four Cisco 7000 core routers labeled r1,r2,r3 and r4; one cisco 4500 router labeled r5, a cisco 2511 access router labeled r6, three Cisco catalyst 3500XL series layer 2 ethernet switches labeled cat1, cat2, and cat3; and several Linux, Sun, and Windows NT PCs.

## EQUIPMENT CABINETS




Here is what the equipment looks like at the front and rear. As you can see, it nearly fills two equipment cabinets. The four large 145 pound 7000s are the large routers on the bottom. As you can see, there are many cables. I tried to locate most equipment with connections to each other in a single cabinet to minimize the number of cables that span cabinets to make it easier to disconnect and move the cabinets individually. We also have some color-coded patch cables and wire management devices on order that have not yet been received to make the wiring more neat.

## EQUIPMENT CABINETS 2

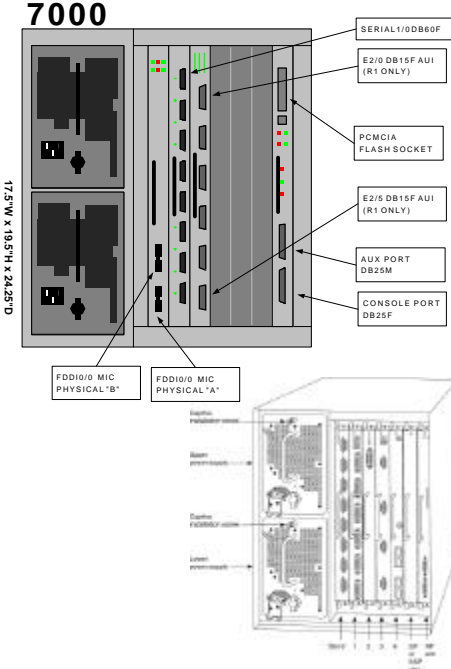


Here is a closer look.


## Cisco 7000 Routers (R1,R2,R3,R4)



- Donated by CAIDA
- FDDI and Serial WAN ports
- Single 6-port Ethernet card donated by Cisco
- End of life
- Previously deployed on InternetMCI backbone.
- 5 slots available for interface cards
- 145 lbs each

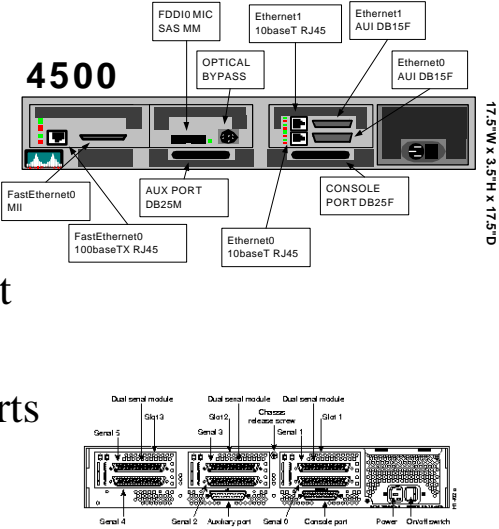


These are the four routers donated by CAIDA which included FDDI and serial WAN interface cards, but no ethernet cards. Phil Jensen, a systems engineer from the local Cisco office, donated a single 6-port EIP6 10Mbps ethernet card. The four routers are labeled “R1”, “R2”, “R3”, and “R4”. They are identically configured except that R1 has the additional 6-port ethernet card. These routers reached their end of life a few years ago and are no longer supported. The latest software is version 12.1 which no longer supports this architecture. We are using version 11.1 software which is about 5 years old. Several of the newer software features such as network address translation or NAT are not supported. These units were previously deployed on the MCI Internet backbone. Each chassis has 5 slots available for interface cards. Each has dual power supplies you can see on the left for redundancy. Each fully-loaded router weighs 145 pounds and were a struggle to set in the equipment cabinets. It took four people to carefully lift each router into place.



## Cisco 4500 Router (R5)

- Formerly CS Department Router with upgraded memory
- 1x FastEthernet port
- 2x Ethernet Ports
- 1x FDDI Port



For about the past 5 years, the Computer Science Department was connected to the FSU FDDI backbone network with a Cisco 4500 router. Its main purpose was to provide access lists to secure the departmental network. Recently, the department has installed a Cisco Catalyst 6000 switch with a multilayer switching feature card (MSFC) which replaced the 4500. After adding additional memory and upgrading the software, we have incorporated this router into the lab. This is still a current model and is supported by the latest IOS software. It has a fast ethernet port capable of ISL trunking, two 10 meg ethernet ports, and a single-attach FDDI port.



## Cisco 2511 Router/Firewall (R6)

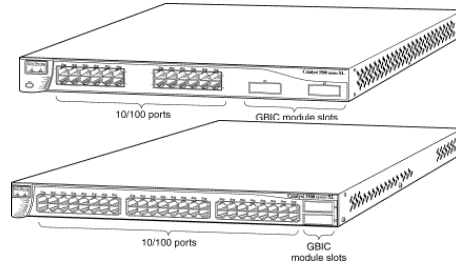
- Purchased used
- 1x Ethernet
- 2x Serial WAN
- 16x Async RS-232
- Out of band console access via “Inverse Telnet”
- Doubles as firewall

This cisco 2511 access router labeled “R6” is the only router that was purchased and we were able to find one used. It has an ethernet port for connecting to the computer science network, two serial WAN ports that connect to the other lab routers, and 16 asynchronous RS-232 ports. The RS-232 ports connect to the console ports on the other router and switch devices. You can TELNET to this router and use an IOS software feature called “inverse telnet” for an out-of-band connection to the other routers. Out of band access is very important since a lab network is often in flux where ordinary access through TELNET is not possible.



## Cisco Catalyst 3524XL & 3548XL Ethernet Switches (cat1, cat2, cat3)

- Layer 2 10/100 Ethernet Switches
- Gigabit Ethernet Uplinks with 1000baseSX GBICs
- Supports VLANs
- Supports ISL and 802.1Q Trunking

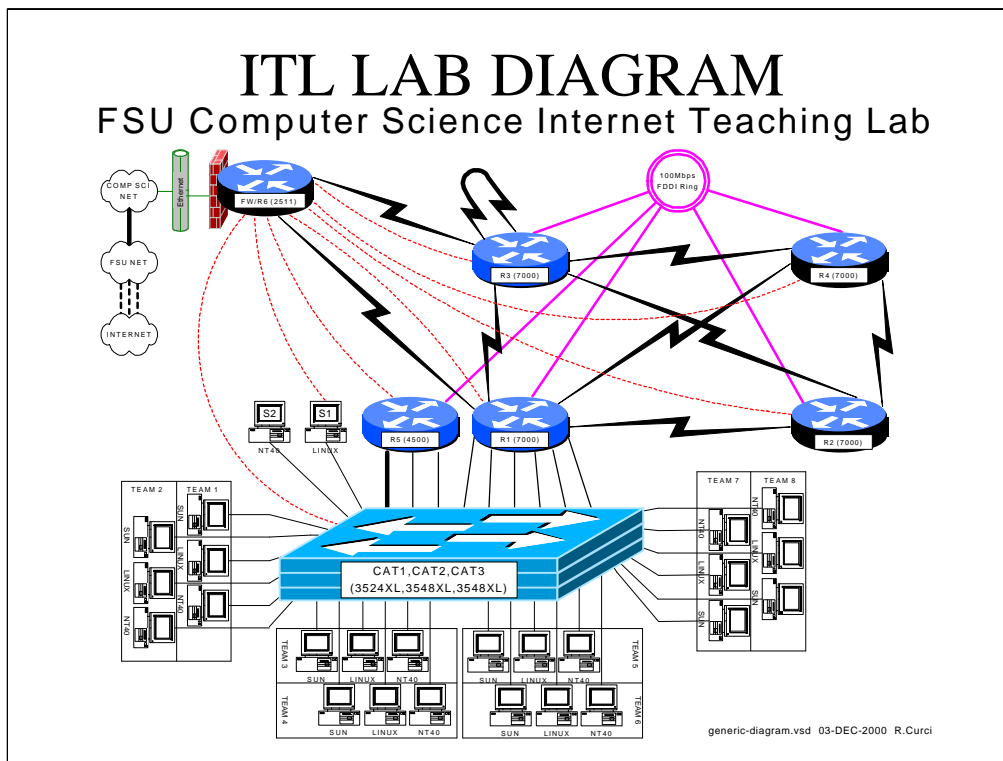


The Cisco catalyst 3500XL series is a layer 2 10/100 ethernet switch. Each has two gigabit ethernet uplinks. Each supports VLANs and trunking protocols. The 3524XL has 24 10/100 ports while the 3548XL has 48 10/100 ports. The 24-port switch labeled “cat1” is situated near the router equipment with connections to the ethernet and fast ethernet ports on routers R1 and R5 and will eventually be located in the computer machine room. Normally each of these ports would be in a separate VLAN corresponding to a student team. The two 48-port switches will be located in the network lab room with connections to the student PCs and instructor PC. These 96 ports will allow for approximately 15 teams with 3 PCs each. Gigabit 1000baseSX trunks between switches allow the VLANs to span switches. The location of the equipment in the computer machine room is partly to reduce the noise level in the network lab from the noisy 7000 routers and partly to improve the physical security of the equipment.

## UNIX and NT Computers

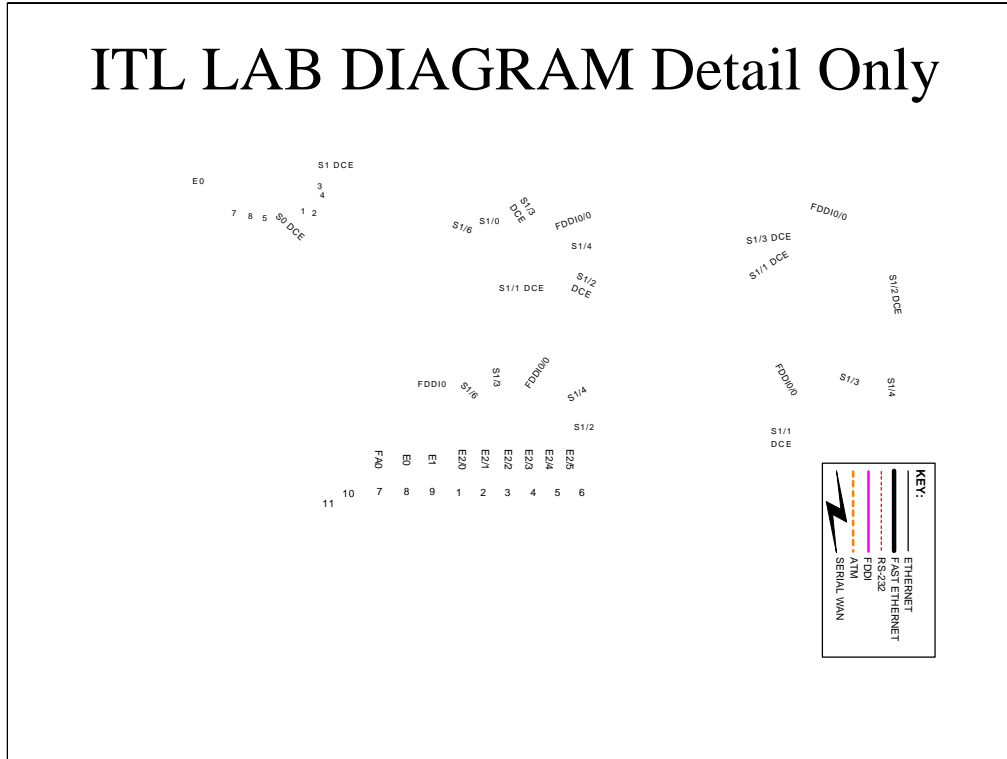


The student UNIX and NT PC computers are located in the newly renovated network lab in the basement of the LOVE building. These photos were taken before all the PCs were installed. There are 10 tables with 2 student team workspaces per table to handle 20 student teams with 3 PCs per team or 60 PCs total. The image in the bottom left corner shows how the lab PCs are depicted on many of the diagrams.



Here is a typical VISIO diagram depicting the lab. The six round dark blue icons are the routers. The rectangular light blue icon represents the stack of 3 catalyst ethernet switches. You can see two sample PC servers that I used for testing the sample lab exercises labeled “S1” and “S2”. You can also see near the bottom, several student PCs in groups of 3 representing teams that are only partially represented due to lack of space. Routers r1 through r4 are the 7000s; R5 is the 4500; and R6 is the 2511 firewall router. As you can see, the single choke point where the lab network connects to the outside computer science network ethernet has access lists depicted by the red brick “firewall”. The Computer Science Network connects to the FSU Network, which in turn connects through ATM to the Internet. As you can see, routers R1 through R5 connect to a common 100Mbps FDDI ring shown in purple. The black lightning bolts are serial WAN connections normally configured for 2Mbits/second and simulate T1 lines. The ethernet and fast ethernet ports on routers R1 and R5, as well as the PCs attach to catalyst switch ports that allows for a flexible grouping of VLANs that can be easily reconfigured in software. The red dashed lines are RS-232 serial links from the 2511 firewall to the routers and switches allowing for out-of-band communication with the console ports on the other devices even if the network is in a non-functional state.

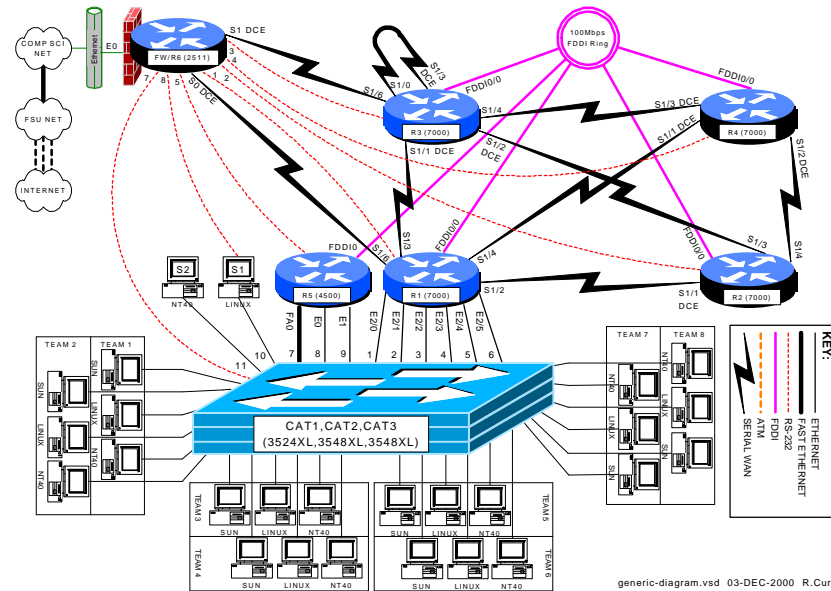
# ITL LAB DIAGRAM Detail Only



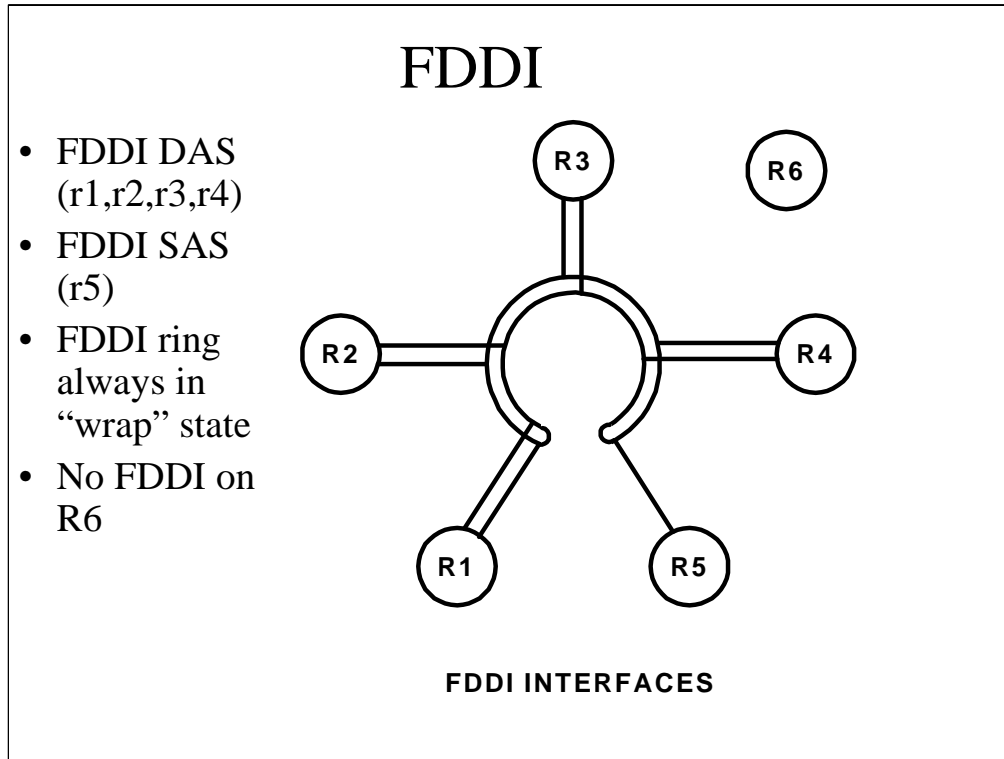
Here is a separate layer of the previous diagram with interface detail information which we will combine with the previous image in the next slide.

# ITL LAB DIAGRAM w/DETAIL

## FSU Computer Science Internet Teaching Lab



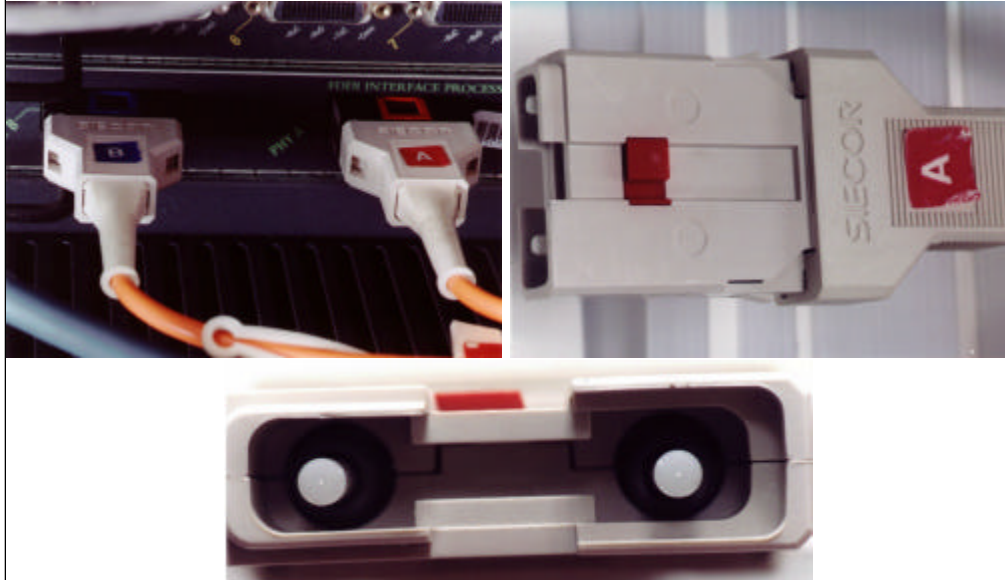
Here is the same diagram with interface details combined. This is actually the same VISIO drawing but with an extra layer containing the interface names and key displayed. This technique of using multiple drawing layers was handy in some cases for creating similar student and instructor versions of some of the sample lab diagrams.



I want to briefly discuss FDDI, serial WAN interfaces, and frame-relay because most people are not very familiar with them.

For those not familiar with FDDI, it utilizes fiber optic cable to normally build two counter-rotating rings for redundancy. When broken, the ring goes into what is called a “wrapped” state. As depicted on this diagram, you can see that router R5 is only singly attached to the ring because it has a single-attach interface whereas R1 through R4 have dual-attach FDDI interfaces. This means that our FDDI ring is always in the wrap state. Router R6 has no FDDI interfaces.

## FDDI 2

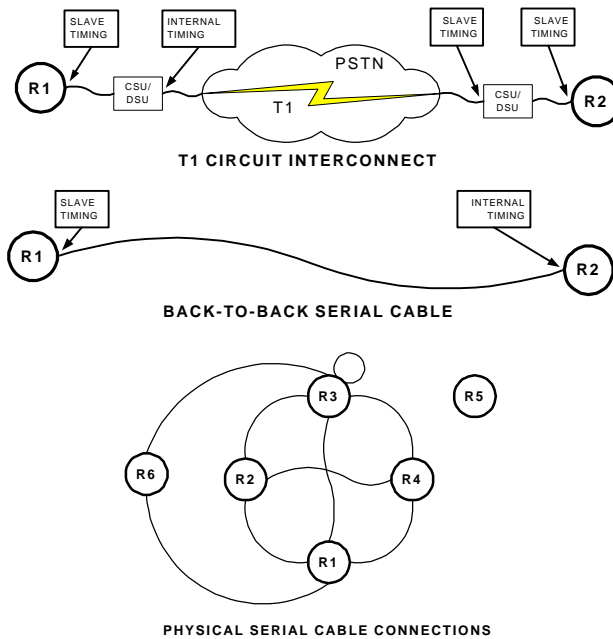


Here are what the FDDI MIC cables look like. Usually the cables are labeled “A” and “B”, color-coded, and keyed to get in the right order. On the photo on the bottom, you can see the 62.5 micron multimode fiber in the center of the fibers.



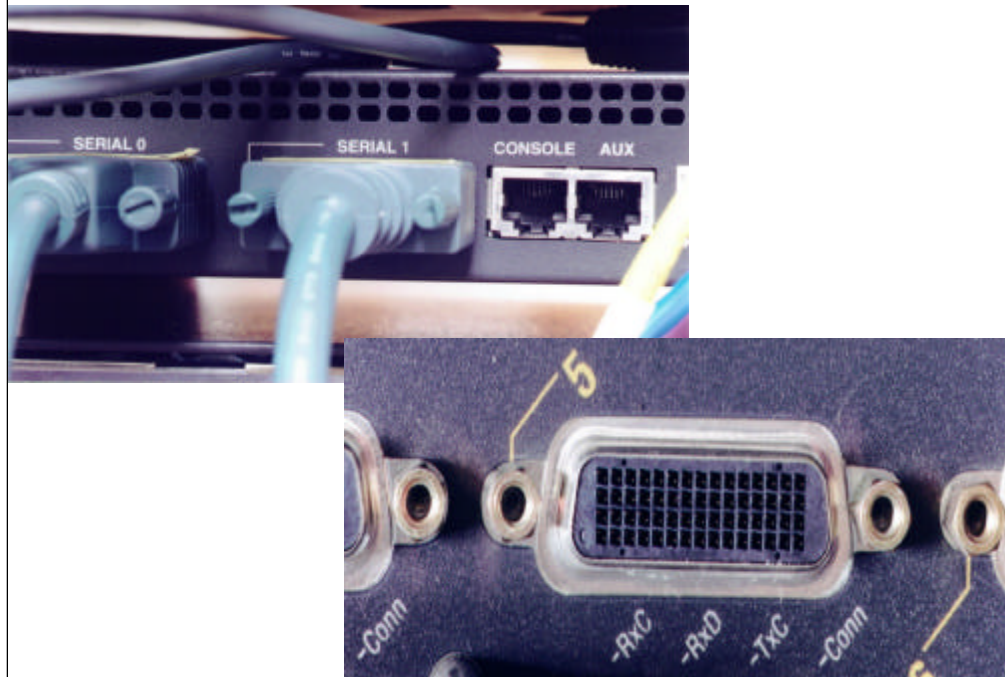
# Serial WAN

- CSU/DSUs used on 56K, T1, and T3 WAN data circuits.
- Lab uses special back-to-back serial cables without CSU/DSUs



For those not familiar with serial WAN interfaces, I'd like to talk about them a bit. Normally, WAN circuits are provided by the phone company in the form of 56K, T1, or T3 lines. Normally a channel service unit/data service unit or CSU/DSU sits on either end of the circuit. One end of the CSU/DSU connects to a router's synchronous serial WAN port using the V.35 protocol. The other end connects to the TELCO equipment. Telco equipment robs bits in the data stream for inband signaling, framing, and testing. The CSU/DSU converts between a stream of bits on the router side to the proper framing on the telco side. With CSU/DSUs, routers are normally configured as data terminal equipment or DTE and slave their clocks off the CSU/DSU. In this lab, since we have no CSU/DSUs, we are using special back-to-back serial cables which one router is configured as DTE and the other DCE. In this case, the DCE must supply the clocking.

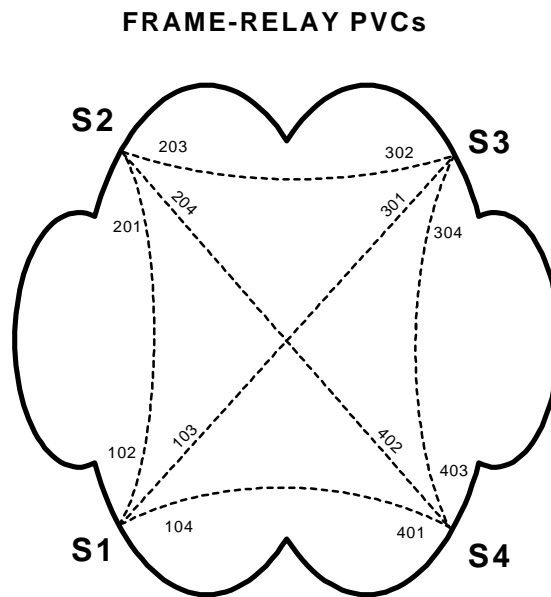
## Serial WAN 2



Here are two photos of the serial WAN back-to-back cables and router connector. The connectors are called “DB60” because they have 60 pins and are inside a shell shaped like the letter “D”. Electrically, they use the V.35 signaling standard.

# Frame-Relay

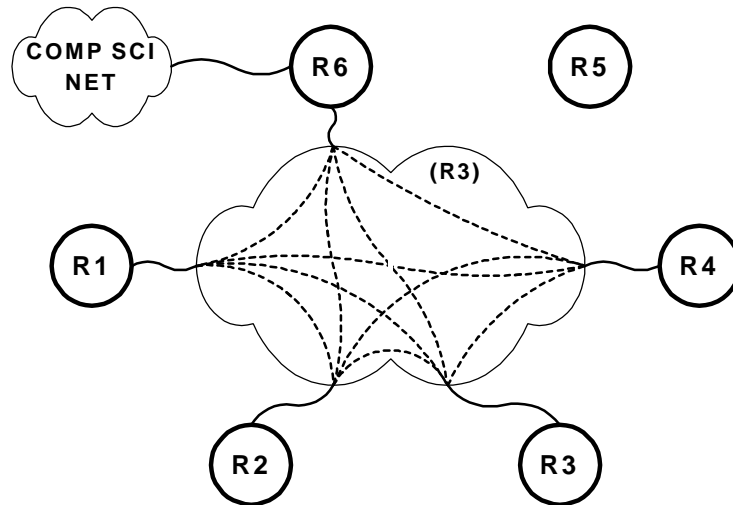
- WAN service sold by phone companies
- Physical data circuits connect routers to nearest frame switch
- PVCs are provisioned across the cloud between routers



Frame-Relay is a wide area network service sold by phone companies. A physical data circuit is established between routers and the nearest frame-relay switch in the cloud. Private virtual circuits are provisioned through the network to interconnect the routers. A full mesh of PVCs does not scale well and can be expensive due to  $N(N-1)/2$  PVCs. The most common configuration is a hub-and-spoke topology where the PVCs home back to a single router.

## Frame-Relay 2

- R3 can emulate Frame-Relay network
- All routers with serial WAN ports can participate, except R5



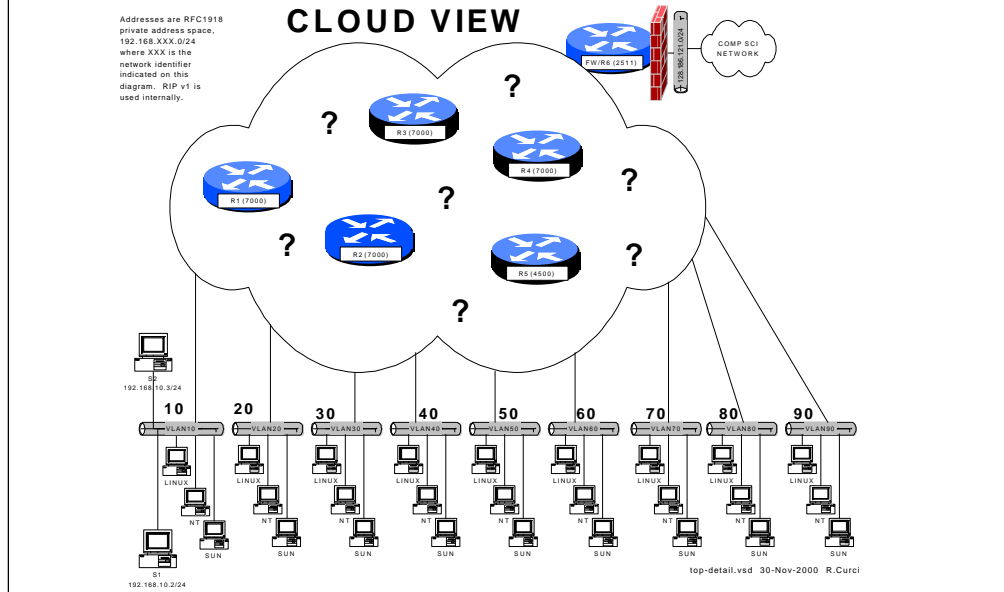
All routers with a serial WAN interface have a connection to router R3. Those ports on R3 can be configured to emulate a frame-relay switch network. The dotted lines in the figure represent PVCs provisioned in the network that can be created between any ports on the emulated frame-relay switch. Router R5 has no serial WAN interfaces and cannot participate. One of the labs explores frame-relay in detail.

## Sample Lab Exercises

- Cisco Router Basics
- Cisco Router Debugging
- **Topology Discovery Lab**
- **Start-From-Scratch Lab (RIP)**
- **RIP Lab**
- IGP Lab (RIP, OSPF, IGRP, EIGRP, IS-IS)
- **Variable Length Subnet Mask Lab with OSPF**
- **BGP Lab with Tunnels**
- **ACL Lab**
- **Frame-Relay Lab**
- **Multiprotocol Lab (IPX, Appletalk)**
- Spanning Tree Lab
- Count-To-Infinity (RIP) Lab

Here are some of the sample lab exercises developed. Most consist of a Visio diagram and Microsoft Word document. The Word documents use a special style applied to sections with sample solutions and instructor notes which uses hidden text. This allows a single document to be maintained that can be printed with the hidden text disabled or enabled to produce a student or teacher version of the document. We will look at the boldfaced labs in a bit more detail.

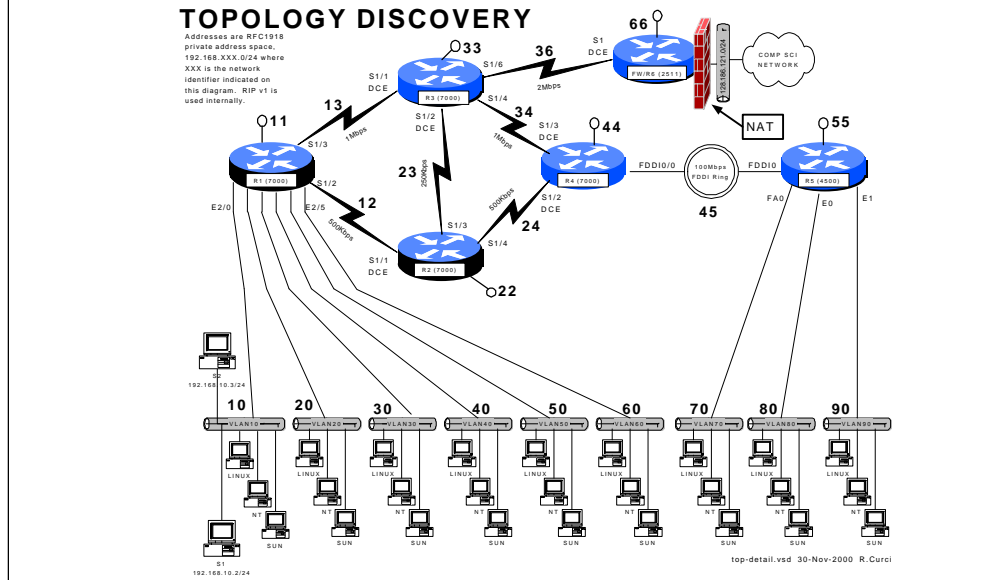
# Topology Discovery Diagram (Student Version)



In this lab, the student is not given access to the routers and is given very limited information on the network as shown above. There are several tasks where the students use tools on their PCs to figure out the topology. For example, students can listen to RIP routing announcements to learn which lab networks are present. Utilities like traceroute can be used to find the network path between two points. Tools such as IPERF and TTCPC can measure link bandwidth. SNMP can be used to query MIB variables to learn interface names, their bandwidth, system names, MAC addresses, routing table entries, etc. Normally, this lab would be used first before the student learns much detail about the lab equipment.

As you can see, we tell students the number of routers, that private class C IP networks beginning with 192.168 are used, that all networks use a 24-bit mask, and that RIP version 1 is deployed.

# Topology Discovery Diagram (Instructor Version)



Here is the teacher version of the diagram with details of router names, interface names, interface types, and bandwidth information present. Here is an example of where the Visio layering capability is used to produce two diagrams in a single document by selectively enabling layers.

## Sample Instructor Notes

For each of your routers, look up the following MIB variables:

`system.sysDescr.0`

`system.sysName.0`

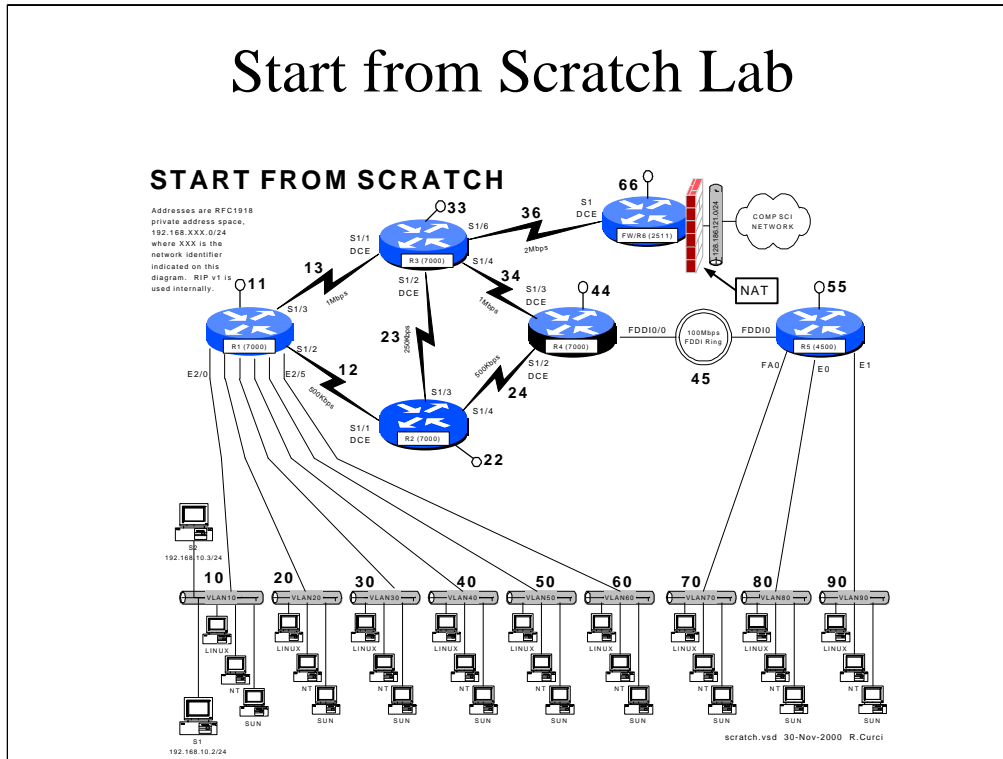
This will let you see the router names to eliminate any duplicates if you previously found more than one IP address for the same router. Using the system description, note the IOS software version of the router. You should now have enough information to draw a diagram of the six routers with the interface names, interface types (`ethernet`, `fdi`, `point-to-point`, `loopback`), how they connect to each other, and the IP addressing scheme.

```
# For each router, get the SNMP name and software version:
#
[root@sl top]# snmpget -v 1 192.168.11.1 public system.sysDescr.0
system.sysDescr.0 = Cisco Internetwork Operating System Software
IOS (tm) GS Software (GS7-J-M), Version 11.1(24), RELEASE SOFTWARE (fc1)
Copyright (c) 1986-1999 by cisco Systems, Inc.
Compiled Mon 04-Jan-99 21:19 by richv
[root@sl top]# snmpget -v 1 192.168.11.1 public system.sysName.0
system.sysName.0 = r1
#
# You can get the interface names along with their network address,
# IP address, and I/O stats:
#
```

Here is an example section of the instructor version of the topology discovery lab. Sections of text identified by the red bar on the right of the screen are hidden text not present in the student version of the lab document.



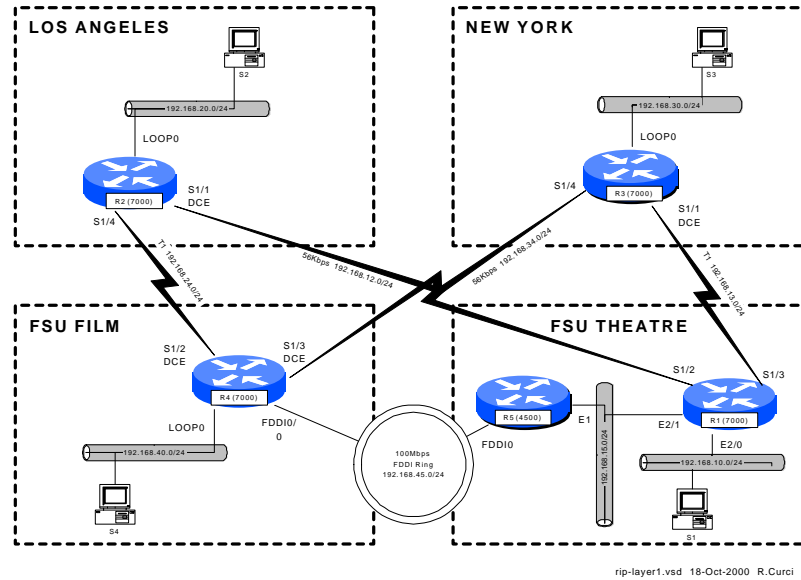
# Start from Scratch Lab



This is the start-from-scratch lab. Once exposed to the lab network, the instructor erases the router configurations and the students work as a team to configure the network to the specifications detailed in this diagram. This lab also introduces the student to configuring RIP protocol, virtual loopback interfaces, and to the network addressing scheme. Networks between routers, for example, are numbered by concatenating the router identifiers with the smaller identifier first. Team ethernet networks are numbered as 10 times the team number. Students are exposed to some network lab conventions that allow the students to focus less on the mechanics of memorizing identifiers and more on the interesting topics.

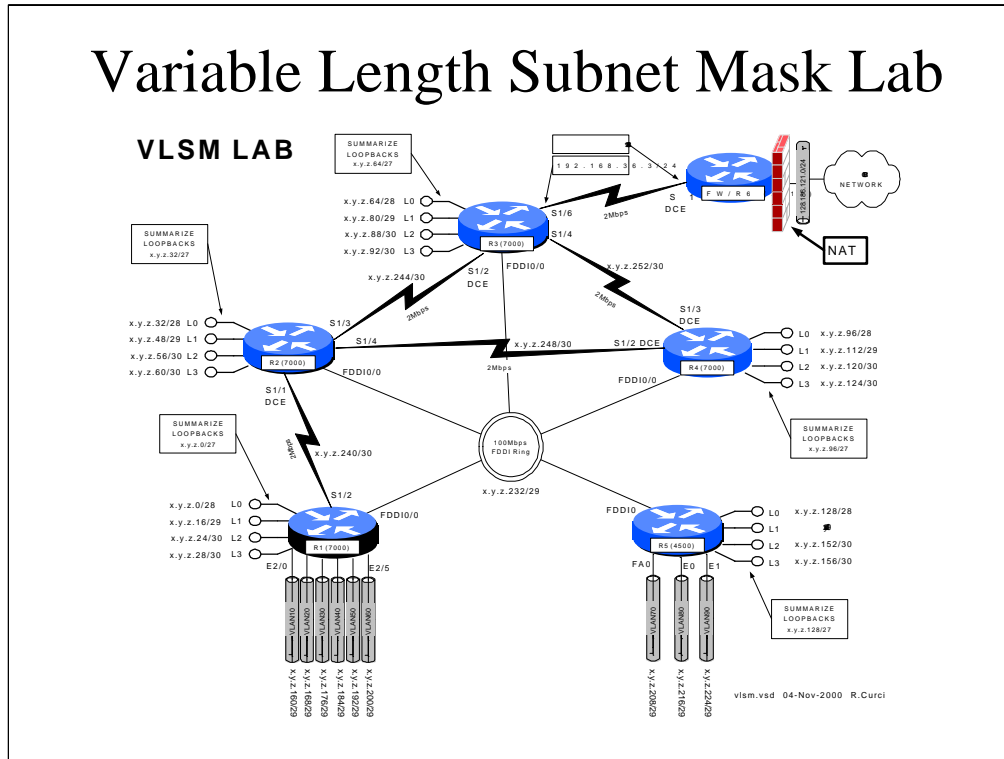
# Routing Information Protocol LAB

## CENTER FOR ENTERTAINMENT STUDIES



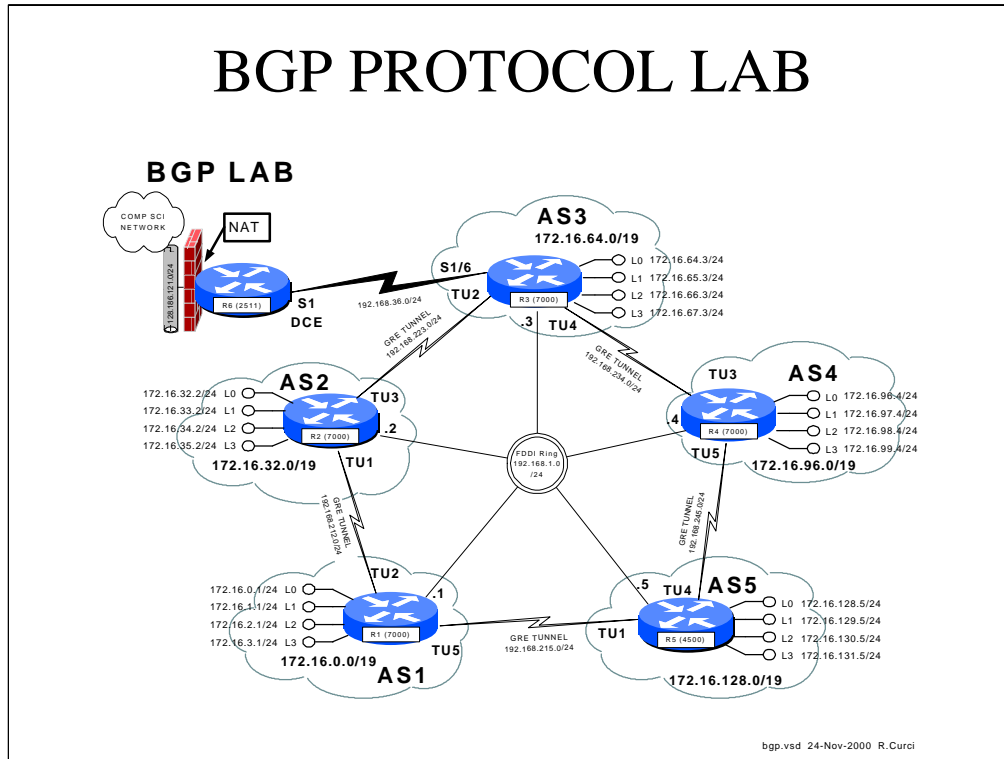
This lab explores the RIP routing protocol with a real-world example of a coast-to-coast network. Faculty from the FSU film school and theatre department help the governor improve his public speaking skills who is reelected. To show his appreciation, the governor convinces the legislature to fund the FSU center for entertainment studies including new branch campuses in Los Angeles CA (Hollywood) and New York City (Broadway). The students are network managers that must implement a cost effective wide area network to tie together the four locations. Things are arranged so that the limitations of the distance vector RIP protocol will cause problems. For example, traffic between the FSU theater department on campus and film school at the FSU University Center sometimes traverses slow WAN links to New York or Los Angeles. Students also have a monthly budget for WAN circuits and must figure out the best solution that balances cost, redundancy, and reliability. Even though this diagram looks very different than the previous one, only soft reconfiguration and use of virtual loopback interfaces is required with no physical lab cable moves.

# Variable Length Subnet Mask Lab



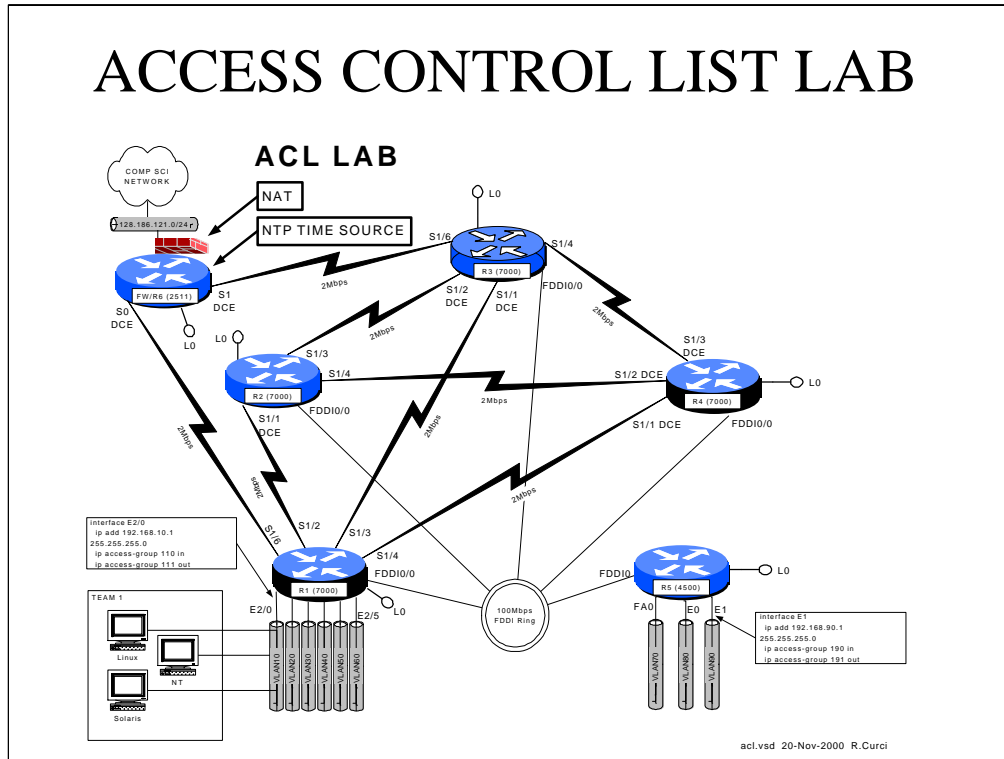
This lab explores variable length subnetting, OSPF areas, and route summarization. Most lab exercises use a class C network for each IP network which is convenient but a very inefficient use of IP address space. With the depletion of IP address space, techniques like VLSM and VLSM-aware routing protocols like OSPF are important to efficiently utilize IP address space. In this lab, the entire network must be readdressed using a single subnetted class C network. The lab is constructed so that the student must count the number of devices on each network segment to figure out the minimal size address block that will work and there are exactly enough addresses to solve the problem with none extra. Students also create virtual loopback addresses that are placed in different OSPF areas and summarized into OSPF area zero.

# BGP PROTOCOL LAB



The BGP protocol is used on the backbone of the Internet today. Networks are grouped into autonomous systems. BGP route attributes such as AS\_PATH are used to calculate the best routes. An AS\_PATH is an N-tuple listing the sequence of autonomous systems from the router's AS to the remote AS. Routers in different autonomous systems exchanging BGP routes are called "BGP peers." Because IP address summarization is crucial to the scalability of the Internet in reducing backbone router tables, this exercise has the students summarize the addresses on the virtual loopback interfaces into single advertisements to the BGP peers. This lab also explores the GRE tunnel interfaces. Tunnels are virtual point-to-point links between routers. They appear on the router similar to a serial interface. They are implemented in software and encapsulate the data payload inside an IP packet.

# ACCESS CONTROL LIST LAB

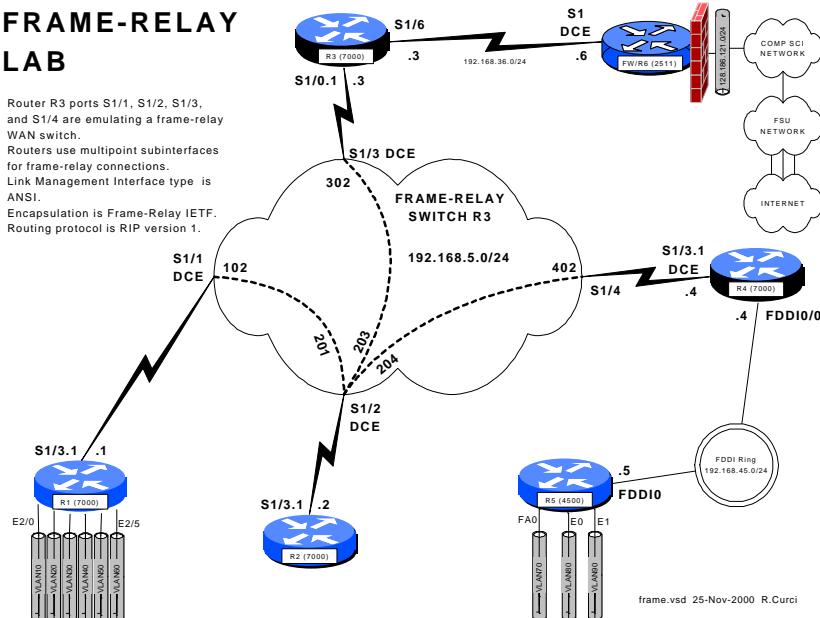


Access control lists or ACLs provide security. They can be applied to the input or output of an interface to selectively allow or deny particular traffic. In this lab, students must create and apply moderately complex access lists to their team's ethernet interface to allow traffic to pass according to a security policy. This helps give students an appreciation for the complexity of Internet firewalls.

# FRAME-RELAY LAB

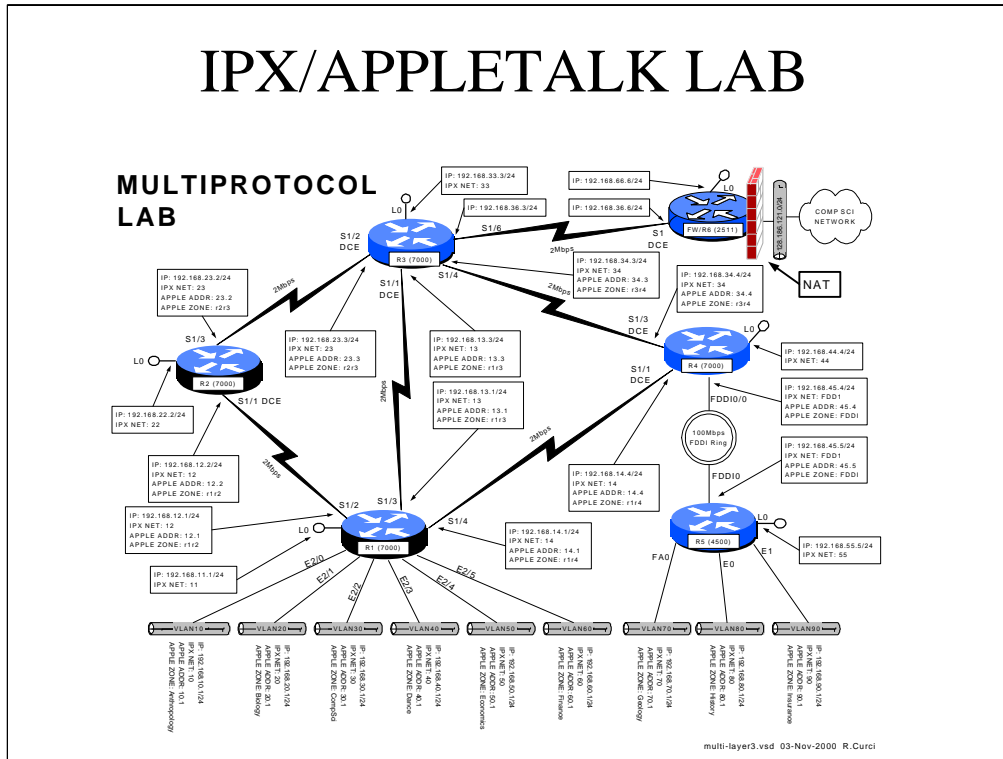
## FRAME-RELAY LAB

Router R3 ports S1/1, S1/2, S1/3, and S1/4 are emulating a frame-relay WAN switch.  
 Routers use multipoint subinterfaces for frame-relay connections.  
 Link Management Interface type is ANSI.  
 Encapsulation is Frame-Relay IETF.  
 Routing protocol is RIP version 1.

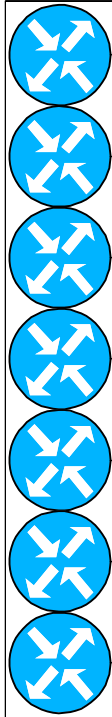


Cisco routers can emulate frame-relay WAN switches. Unused ports on router R3 are configured to emulate a frame-relay switch. Routers R1, R2, R3, and R4 then have a single WAN connection to the frame-relay network, but there is only a partial mesh of frame-relay PVCs in a hub-and-spoke configuration. In a business with offices in many cities, for example, the hub might connect to the headquarters site with spokes to the branch sites. This lab creates problems with frame-relay virtual circuit mappings and RIP split-horizon problems for the students to figure out.

# IPX/APPLETALK LAB



Although TCP/IP is the most popular network protocol, both IPX and Appletalk are also important. The IPX protocol is still widely used with Novell file servers, while Appletalk is widely used with Apple Macintosh computers for file sharing and printer sharing. For example, many of the networks at FSU have IPX and or Appletalk running on the same ethernet segments as TCP/IP. In this lab, students are exposed to IPX and Appletalk and configure these protocols on a TCP/IP only network.



## DESIGN GOALS

- Low cost
- Secure design
- Extensible design
- Ease of soft reconfiguration
- Remote access
- Distributed design

Let's review the design goals given earlier and elaborate on how they were achieved:

**Low Cost** – the cisco 7000 routers were donated by CAIDA and ethernet card by Cisco. The Cisco 4500 was taken out of service when the department upgraded their network connection. The main equipment costs are the cisco 2511 router which was purchased used, and the three cisco catalyst 3500XL layer 2 switches.

**Secure Design** – the cisco 2511 firewall router's ethernet port is the only connection between the lab to the outside network and provides a single choke point. Access lists and network address translation provide access security.

**Extensible Design** – The lab design can be easily extended, especially by adding additional PCs given the flexible VLAN design.

**Ease of Soft Reconfiguration-** All of the sample labs you will see later on in this presentation are constructed without the need to move any cables. Reconfiguration is accomplished by selectively enabling or disabling interfaces, through switch VLAN reconfiguration, frame-relay WAN emulation, and through creating of virtual loopback and tunnel interfaces.

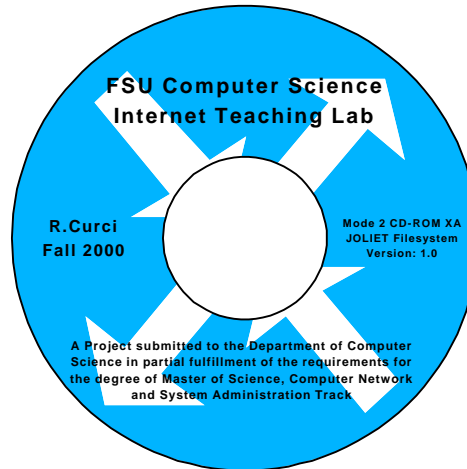
**Remote Access-** With the proper access, it is possible to log into the R6 firewall router and then connect to the routers or PCs.

**Distributed Design-** The gigabit trunking between ethernet switches allows the routers to be located in a different room than the student PCs to reduce the noise level and improve security.



# Project CD-ROM

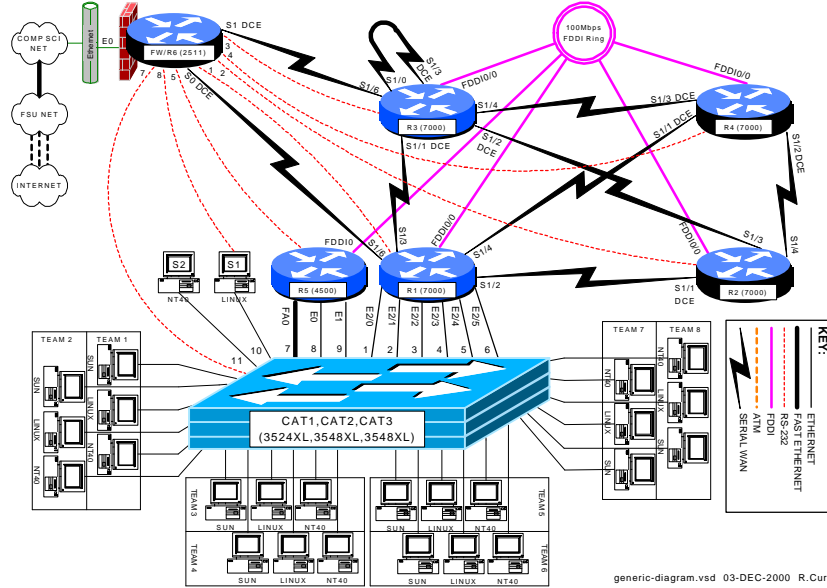
- Paper
- Slide show
- Labs
- Visio stencils
- Sysadm Utilities
- Instructor use only!



There is a project CD-ROM that contains the project paper, slide show, labs, Visio stencils, drawings, and many system admin utilities. The labs contain many extra files including router configurations, sample output from various SHOW commands, et.c. A lot of work went into this project and there are many additional files. This slideshow only scratches the surface.

# THE END

## FSU Computer Science Internet Teaching Lab



The End. Thank-You. Do you have any questions?