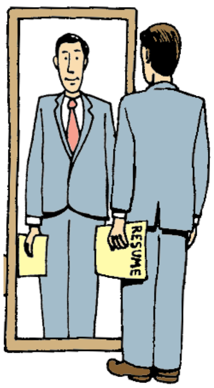
Lesson 2: ATM and Advanced Switching Techniques

At a Glance



So far in this course on switching, you have focused primarily on frame switching, also known as LAN switching. Cell switching is a second major type of switching becoming more widely used as its cost decreases. Cell switched networks use a combination of very fast switches and high-speed digital links to achieve extremely fast transmission speeds. ATM is the most popular and rapidly growing cell-switching technology. In this lesson, you will look at ATM and how it compares to other data transmission technologies.

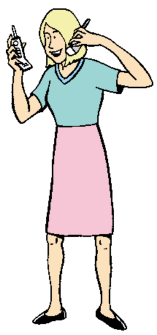
What You Will Learn

After completing this lesson, you will be able to:

- Describe the characteristics of ATM
- Describe three transfer modes used in switching technologies
- Describe the basic operation of an ATM network
- Compare ATM with traditional networking technologies
- Explain how LANE and MPOA enable ATM to integrate with legacy networks

Student Notes:

Tech Talk



- **Data Exchange Interface (DXI)**—A specification (by the ATM Forum) that defines how special data transfer frames can be used to connect non-ATM equipment with ATM switches.
- **Hardwiring**—Designing an integrated circuit so that it automatically performs certain functions instead of retrieving instructions from memory.
- **LAN Emulation (LANE)**—A specification that allows ATM networks to connect traditional (IEEE 802.x) LANs.
- **Legacy**—An existing network using older technology.
- **Multiprotocol Over ATM (MPOA)**— A specification for routing Layer 3 protocols over ATM networks.
- **Multiplexing**—The process of combining signals of multiple channels into one channel. Signals can either be modulated onto separate carrier frequencies (analog), or each signal can be transmitted at different time frames of equal duration (digital).
- **Next Hop Resolution Protocol (NHRP)**—The protocol used to match IP addresses with ATM addresses.
- **Private Network to Network Interface (PNNI)**—PNNI is an ATM standard for connecting ATM switches within a private network.
- **Transfer mode**——A method of transmitting, multiplexing, and switching data in a network.
- **Permanent Virtual Circuit (PVC)**—A permanent circuit that is established for the transmission of data between two devices.
- **Switched Virtual Circuit (SVC)**—A temporary circuit that is established between two devices only for the duration of the data transmission.
- **Quality of Service (QoS)**—The ability of a network to provide better and more consistent service to selected packets and network traffic based on pre-established criteria.

Characteristics of ATM

Asynchronous transfer mode (ATM) is a method of transmitting data using fixed length (53 bytes) data units, called cells, over circuits that can support not only traditional data requirements, but also voice and video. Since it operates at the MAC sublayer of the data link layer of the OSI model, which is above the physical layer, it can convert any type of packet into these fixed-length cells. Unlike other packet switching, ATM cells arrive at the destination point in the correct sequence.

- ATM is a high-speed data transmission technology that can be used for LANs and WANs.
- Primarily because of its bandwidth and quality of service capabilities, ATM could form the basis of a unified network. One that is capable of sending data, voice, graphic, and video.
- If ATM were as widely used as IP, anyone could connect with anyone else whether they were on a LAN or a WAN. Interoperability would not be an issue.
- ATM is connection-oriented.
- Cell switching has many advantages over frame switching.
- ATM requires special ATM switches and interfaces to connect ATM switches to one another and to LANs.
- ATM is scalable. As an ATM network grows, more bandwidth can be added to handle more traffic. ATM operates from 25 Mbps to 2.46 Gbps
- ATM is independent of the transmission medium, though the medium can limit how fast ATM can operate. ATM can run on already existing T1 and T3 lines, although SONET is a typical choice endorsed by many network managers.
- It is possible but still rare to have an all-ATM LAN. It is more common to connect an Ethernet network to an ATM backbone. LAN Emulation (LANE) specifies a way to do this.
- MPOA defines how to run IP and other Layer 3 transmission protocols over ATM. It enhances LANE, especially in the use of VLANs.

On the negative side, ATM is still quite expensive and networks must have ATM devices that are interoperable. This requires new equipment.

Check Your Understanding

- What is ATM?
- ATM runs on already existing T1 and T3 lines. Why might this be an important consideration when choosing WAN connections?
- What makes ATM a good choice for video and voice?
- Why might a network manager not want to install ATM?
- Describe at least six characteristics of ATM.

Why ATM Use is Growing

Every day, more people are logging onto networks. They are creating, storing, and retrieving more and more data. They are using more powerful computers and sending more sound, images, video, and multimedia. Applications that used to be resident on each person's desktop computer can now be run on a server with all users accessing them through a network. People are shopping, chatting, holding conferences, and publishing everything and anything on the Internet. All of this explosive growth translates into a huge demand for more bandwidth. ATM offers a way to satisfy this demand.

Review of Transfer Modes

Asynchronous Transfer Mode (ATM) is a high speed switching technology that uses short, fixed size packets called cells (53 bytes). It is a cell-switching technique that combines the advantages of circuit switching and packet switching. Circuit switching and packet switching correspond to two transfer modes for transmitting, multiplexing, and switching data in a network: synchronous transfer mode and packet transfer mode.

Synchronous Transfer Mode

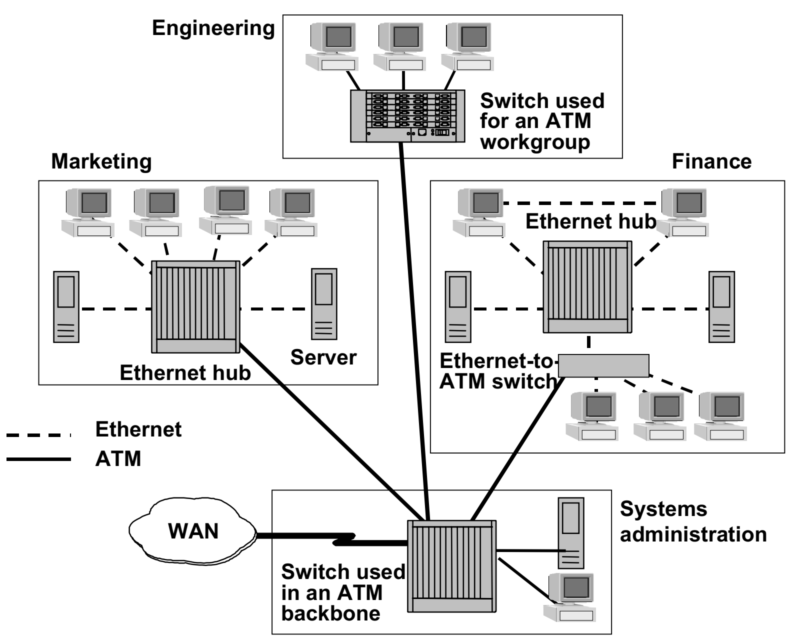
Circuit switching is also knows as synchronous transfer mode (STM). With STM, each transmission frame is divided into a series of time slots. You can think of each frame as a seat on a train. The schedule for the train is set up in advance (when the circuit is established) and from then on, the receiving end knows how fast the train will be moving and what will be in each seat of each car. Each seat on each car of the train is a time-slot and each time-slot is reserved for a certain user. The train stays on its fixed regular schedule, whether or not the user has data to send in his or her time slot. The time-slots are synchronous and the contents of the time slot are synchronous as well.

For a continuous data stream such as video or voice, STM works well. The receiver of a voice or video data stream would immediately notice if packets were delayed or interrupted. STM ensures that this doesn't happen by guaranteeing that there is always a time-slot available. For data, however, STM is not very efficient. Because data comes in bursts rather than a continuous stream, the time-slots go empty much of the time.

Packet Transfer Mode

As you know, packet switching, or packet transfer mode (PTM), overcomes the inefficiency of STM by allowing empty time-slots to be used by other users who need them. In PTM, each data packet has a header, which contains information about its source and destination. Ethernet, token ring, X.25, and Frame Relay all use PTM. PTM transmission is like a highway on which the data travels like individual vehicles. When a particular user has no data to send, another user can be sending. This makes PTM efficient for burst data transmission. A drawback to PTM is that each packet must have a header and this means a lot of additional data must be transmitted. In addition, because many users are contending to use the transmission path, PTM doesn't guarantee that data will arrive at a particular time (or even that it will arrive at all). A long transmission from one user may delay transmissions from other users because the others may take a different path. This makes PTM difficult to use for voice or video.

High Speed ATM Network



Asynchronous Transfer Mode

ATM combines the strengths of STM and PTM. Like STM, ATM is connection-oriented. ATM sets up a circuit first and transmits data according to a fixed schedule so that the receiving end knows when data will arrive. This makes ATM suitable for carrying voice or video.

Like PTM, ATM transmits data as packets and never reserves empty space for a user who is not transmitting. ATM gives available bandwidth to the user who requests it. ATM cells are transmitted synchronously but their contents are determined by need. This is where the term asynchronous comes from: the contents are asynchronously allocated.

This makes ATM suitable for burst data transmission. Another advantage to ATM is that it is easier to increase the amount of bandwidth available than it is with STM or PTM.

Check Your Understanding

- Which transfer mode does circuit switching use?
- Which transfer mode does cell switching use?
- Complete the table that compares STM, PTM, and ATM:

Capability	STM	PTM	ATM
Unit of data transmitted, length			
How the data unit is addressed			
How the bandwidth is allocated to users			
Kinds of transmissions best suited for			

How ATM Works

ATM cell switching has the advantages of circuit switching because it is connection oriented. Devices that use cell switching establish connections through virtual channels and paths rather than physical channels and paths. The connections are virtual because the bandwidth isn't actually created for each particular transmission; it is just allocated from bandwidth on the network that already exists.

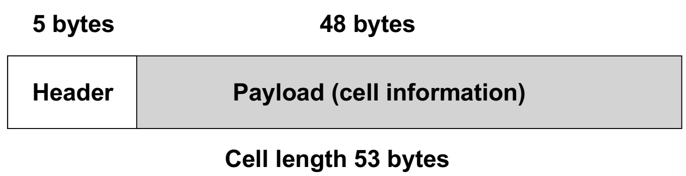
Virtual circuits can be permanent (PVC) so that they are always available. Of course, this means that the bandwidth could go unused when there is no data to transmit. Virtual circuits can also be switched so that each time a transmission is made, a circuit is set up and then broken down.

To begin ATM communication, the sending station transmits a connection request. The connection request includes (among other things) the following:

- The destination
- The average bandwidth that will be required
- The peak bandwidth that will be required during the transmission
- Maximum acceptable cell loss
- Maximum available variation in delay

The last two items specify the quality of service requirement. QoS is a way for the network to make sure that certain types of transmissions receive the bandwidth they need for the entire time they take to transmit. If a transmission doesn't receive adequate bandwidth there can be two primary results: different packets will be delayed by different amounts or packets will be dropped altogether. Voice and video transmissions can tolerate some cell loss; your brain will fill in the gaps if a cell in the middle of a stream is dropped. But voice and video cannot tolerate changing delay from one cell to the next. This will cause a voice signal to break up or a video signal to be jumpy or unintelligible. Data, on the other hand, can tolerate variation in delay; it's not so important that data cells arrive at regular intervals. But data cannot tolerate cell loss.

ATM Cell

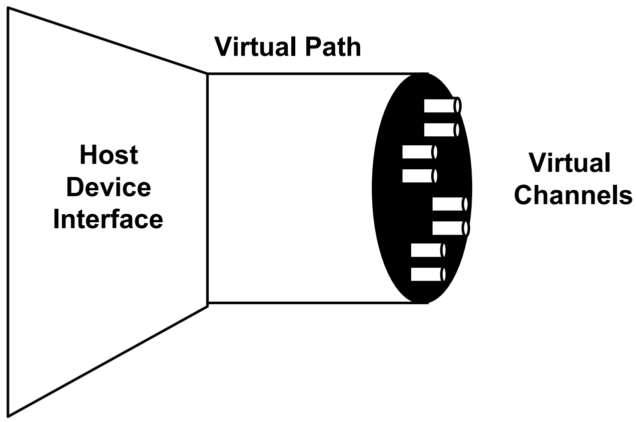


When it receives a connection request, the ATM switch first determines which physical link can be used. The switch makes sure that the physical link will be able to handle the new connection, with the quality of service requested, as well as all the connections it is already carrying. If the switch can handle the new transmission it becomes part off the path and sends the request on to the next switch in the direction of the destination. If the switch cannot handle the additional transmission, another switch is "asked." Because the arrangement of switches is a mesh, there are many possible paths to connect any two switches. This process continues until the path is complete and a virtual circuit is established. A typical switch can set up 100 to 200 virtual circuits per second.

ATM virtual circuits come in two forms:

- A *virtual channel* is the logical path connecting one station and another through the ATM network.
- A *virtual path* is a bundle of virtual channels.

Virtual Circuits



Like a trunk line in the public phone system, virtual paths make it more efficient to manage virtual circuits. If a switch along the path goes down, the circuits can be re-routed by changing the virtual path rather than redirecting each channel individually.

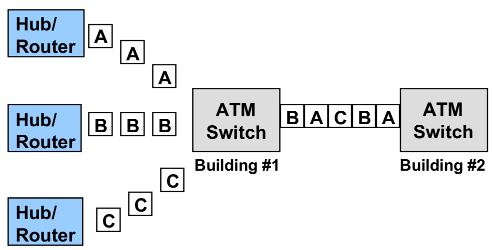
The ATM Cell

ATM cells are a fixed 53 bytes (or octets) in length with 5 of those octets used for the header.

ATM Cell Based Transmissions

- 25 Mb/s, 155 Mb/s, or 622 Mb/s
- Cell-based transmissions
  - 53 byte cells
- Negotiated service connection
  - End-to-end connections
  - Virtual circuits

Switch-based
Dedicated capacity
ATM Forum

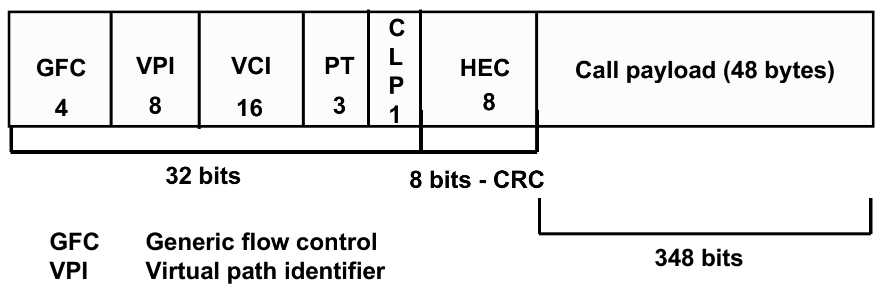


The small fixed-size ATM cells solve many problems. From the discussion of ASICs in Lesson 2-2, you may recall that the integrated circuits in switches can operate much faster if their instructions are hardwired. ATM takes advantage of this fact. Because all of the cells are the same size, the ATM switch needs fewer instructions. For example, the ATM switch does not need instructions, as a typical PTM switch does, for what to do with smaller and larger packets. Because the same ATM instructions are followed each time the switch processes data, those instructions can be hardwired.

Small fixed-size ATM cells also overcome the problem of variation in delay from packet to packet. Because all the cells are the same size, there is never a larger cell that can delay the cells that follow it.

Each cell header contains information that tells which virtual path (VP Identifier) and which virtual channel (VC Identifier) the cell should use. This means that once the circuit is established, the only processing a switch must do is to read the VPI and VCI from the header and forward the packet to the correct port, whether the transmission is travelling across the office, the country, or the world. This makes ATM very fast.

ATM Cell Header with VPI and VCI



GFC	Generic flow control
VPI	Virtual path identifier
VCI	Virtual channel identifier
PT	Payload type
CLP	Cell loss priority
HEC	Header error control

Segmentation and Reassembly

The packets used by TCP/IP and other popular Layer 3 communications protocols are almost always larger than ATM cells. For ATM devices to communicate with these existing networks, packets must be *segmented* into cell-sized pieces before entering the ATM network and then *reassembled* into larger packets when leaving the ATM network. These are the steps:

- An ATM node receives a higher layer data frame.
- Remove the packet's cyclic redundancy check (CRC). This is the error-checking portion of the packet.
- Add a header and trailer to the packet that contains information for the end ATM node.
- Add padding (meaningless data) to make the packet size a multiple of 32 bits.
- Add a new CRC for the packet.
- Segment the packet into 48-bit pieces (including the packet overhead).
- Place each 48-bit segment into an ATM cell and add a header that includes the VCI.
- ATM switches along the VC only look at the VCI and the port that the cell arrived on, they consult a switching table that matches inbound port numbers to outbound port numbers and then send the cell onward.
- At the end ATM node, the cells are reassembled into packets following the reverse of the above steps.
- Once a packet is reassembled it is checked for errors by a higher level protocol.

Check Your Understanding

- How does the fixed size of an ATM improve data communications?
- In ATM communication what does the sending station transmit as port of its connection request?
- What is a virtual connection?
- What is a virtual circuit?
- Why are virtual connections more efficient than physical connections?
- Describe an ATM cell.
- Explain how the fixed-length of the ATM cell makes transmissions faster and more efficient?
- Why do packets used by TCP/IP generally have to be segmented and reassembled in order to communicate with ATM?
- What are the steps taken when segmenting and reassembling TCP/IP packets for transport over ATM devices?

ATM and Legacy Networks

It is possible to create an all ATM network, also known as "ATM to the desktop," but most organizations are not ready to scrap their entire network and start building from scratch, especially since ATM hardware can be very expensive. Instead, most uses of ATM involve integrating it into existing (legacy) networks that use established communications technology.

Earlier, you learned the steps in converting the larger data packets used by Ethernet, TCP/IP, and other transmission technologies into ATM cells. This section will focus on how those packets get to the correct destination.

The major difference between ATM and existing networks is that shared LANs, such as Ethernet or Fast Ethernet, transmit data by broadcasting. The individual user's computer doesn't need to know the path that the data should take to get to its destination. It simply broadcasts the data with its destination address to the entire network and only the addressed device responds.

In a WAN context, IP networks use ARP. A host sends out a broadcast asking which machine has the destination IP address, the device with that IP address responds by sending its MAC address. Connectionless IP networks are also called *broadcast networks*. ATM is known as a *nonbroadcast multiple access (NBMA)* network.

ATM uses point-to-point connections. ATM does not broadcast. An ATM cell carries in its header the identifier for a specific circuit along which it will travel. How does a station set up to use Ethernet and/or TCP/IP learn which ATM circuits to use when sending a message? LAN Emulation, MPOA, and I-PNNI offer three ways to solve this problem.

LANE

The job of LAN Emulation (LANE) is to make an ATM network act as though it is part of a traditional LAN. LANE allows Ethernet, Token Ring, and other frame-based connectionless to communicate over ATM virtual channels.

LANE enables ATM to seem like a LAN by adding a number of components to the ATM network that emulate LAN functions.

To make ATM act as if it is connectionless, LANE specifies that devices in the ATM network and in the legacy network be grouped together into one or more *emulated LANs (ELAN)*. An ELAN is really just a VLAN that also includes ATM devices. As you learned in Lesson 2-3, it VLANs have their own broadcast domain, even when the devices are not physically connected.

Legacy LAN and ATM Differences

Ethernet and token ring	**ATM**
Connectionless Service	Connection-oriented
MAC addresses	Network service access point (NSAP) addresses
Broadcast, multicast capable	No inherent broadcast, multicast capability
Variable length packets	Fixed-length cells
Contention access method (Ethernet)	No contention

ELAN provides for four functions: initialization, registration, address resolution, and data transfer. It does this by defining two components:

- LAN emulation client (LEC)
- LAN emulation services:
  - LAN emulation configuration server (LECs)
  - Broadcast and unknown server (BUS)

LAN Emulation Client (LEC)

The LAN emulation client is software that allows a device to participate in the emulated LAN. The LEC can be a device driver on a workstation or server. LEC must be run on a switch or a router that will go between the legacy LAN and the ATM network (also called an *edge device)*. ATM devices must also run LEC software. A single ATM device can belong to multiple ELANs.

The LEC handles data forwarding, address resolution, the interface between Layer 2 and Layer 3 protocols, and control functions.

LAN Emulation Server (LES)

LANE matches IP addresses to ATM circuits by maintaining a database. The LAN Emulation Server (also called the ATMARP server or the LE-ARP server) maintains this table. Each LEC tells its MAC address to the LES. A LES must be assigned to each ELAN. When a legacy device on an ELAN needs to connect with a device on another ELAN, it first checks the LES to get the ATM address of the destination device.

LAN Emulation Configuration Server (LECS)

The LECS allows a LEC to join or leave an ELAN. The LECS assigns each LEC to an ELAN. The LECS provides the LEC with the ATM address of the LES assigned to the ELAN. When it boots, each LEC calls the LECS to find out the ATM address of the LAN emulation server.

Broadcast/Unknown Server (BUS)

Shared networks must be able to broadcast. The broadcast/unknown server (BUS) is connected to every station in the ELAN and can perform broadcast and multicast operations over the ATM network.

Quality of Service

Applications at higher OSI layers that communicate with an ATM network through LANE are not yet able to specify Quality of Service (QoS). This is because ATM cells with their quality of service header information are not seen by the LAN applications.

MPOA

MPOA is another example of the "route first, then switch" technique used with VLANs and in Layer 3 switching. When a device on one VLAN sends a message to a device on another VLAN, the initial broadcast is routed. The routing might be handled by a router or by a Layer 3 switch. The *route server* creates a logical path through the network. Then the ATM connection manager converts the logical path into a virtual circuit.

Multiprotocol over ATM (MPOA) defines how to do Layer 3 routing over an ATM network. Using LANE, members of two different ELANs must use a router to communicate. But those devices are connected through the ATM network, so it would be more efficient if an outside router weren't necessary and the connections were made strictly through ATM. This is what MPOA adds to LANE.

MPOA gives the job of finding the logical path to a server that uses Next Hop Resolution Protocol (NHRP). NHRP matches IP addresses with ATM addresses. A series of servers running NHRP must extend across the IP network that overlays the ATM network. When a user tries to send data that could travel across the ATM network, the NHRP server at the source sends out a request for the ATM address of the destination machine. The request travels from NHRP server to NHRP server until it reaches one that knows the address of the destination user. This address is then passed back, server to server, until it reaches the source.

Once the destination ATM address is found and returned to the sending machine, ATM can set up a virtual circuit and transfer the rest of the transmission over the ATM circuit.

Of course, if the transmission is very short, it doesn't make sense to go through the process of resolving the ATM address and moving the transmission from routing to switching. It will probably be faster just to route the transmission across the IP network. But for longer transmissions, MPOA can be faster.

Additionally, MPOA lets the IP (or IPX or AppleTalk) network use ATM's quality of service capabilities.

I-PNNI

PNNI is an ATM standard for connecting ATM switches within a private network. I-PNNI extends PNNI to provide integrated routing.

MPOA uses route servers to find the path between two devices and a route server may not know the best current path for a particular packet to follow. Using I-PNNI, all the switching and routing devices at the edge of an ATM network perform *their own* route calculations and then share that information through the ATM network in order to calculate the best path through the network.

One drawback to I-PNNI is that switches that can do routing calculations are more expensive than non I-PNNI switches.

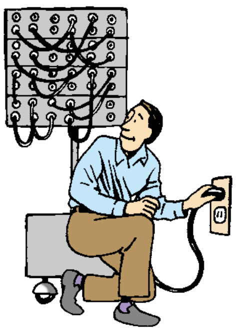
Check Your Understanding

- How does a station set up to use Ethernet and/or TCP/IP learn which ATM circuits to use when sending data?
- How does LANE make ATM act as though it were connectionless?
- What is LAN emulation client software?
- What is needed for LAN emulation software to function?
- What does a LAN emulation server (LES) do?
- What does a LAN emulation configuration server (LECS) do?
- Why is a Next Hop Resolution Protocol server used with Multiple Protocol over ATM?
- What is I-PNNI and what does it do?

Try It Out

Materials Needed:

- Networking research materials
- Internet connection (optional)



Create a Classroom Resource Book

During this activity, you will prepare a classroom resource book for the use of future students taking this course. Subsequent students will update this book each term with the most recent changes in communications technology. Internetworking is an evolving science and it is next to impossible to write, print, and distribute a resource that is current. A classroom resource book that is updated each term will contain the latest facts about recent advancements and developments in communications technology.

Work with at least three other students. Decide what the resource should contain. Distribute the tasks equally and create a professional quality resource. Make a copy for each student in the group to keep for their portfolio and for interview purposes for further education and/or the workplace.

You have learned a great deal during the time spent taking the NetKnowledge courses. This activity will help you compile and organize what you have learned to create a resource to be shared with future internetworking students.

Prepare a five-minute presentation about your classroom resource and contents. Explain why your group selected the specific materials/topics included in the resource.

After all groups have presented their projects, informally discuss group dynamics, include positive and negative aspects of group dynamics, ideas for how to handle difficult issues, etc.

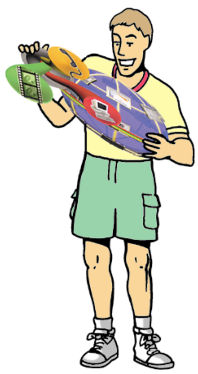
Rubric: Suggested Evaluation Criteria and Weightings:

Criteria	**%**	**Your Score**
Participation and ability to work in a professional manner as a team member	15	
Ability to prioritize, organize, and decide which information should be included, and that which should be excluded	10	
Creativity, attention to detail, grammar, spelling, organization, writing style, of the final product	15	
Accurate, comprehensive, understandable, and suitable for an internetworking classroom resource	25	
Ability to meet deadline with a completed, professional quality resource	15	
Quality of group presentation	10	
Contributes and actively participates in post-presentation discussion	10	
Other		
TOTAL	**100**	

Stretch Yourself

Materials Needed:

- RFP
- Classroom Network
- Internet connection
- Calculator (optional)



RFP Activity – Pricing Communications Networks

Lab Part 1: Read and Understand Requirements

In this section of the activity, you will read and understand a set of networking requirements in Exhibit A of the RFP.

You will be using the information provided in this table, reproduced from the RFP, to calculate the numbers of end user devices, components, and their costs.

Users	Routers	Switches	Hubs
1 per network port	1 per building link	1 per 8 hubs	12 port
1 NIC card + cable	1 LAN cable	Switch to hub cables	Hub to port cables
Distance to hub: 20 meters	Live backup router	Distance to router: 5 meters	Distance to switch: 50 meters

You will be using the information provided in this table, reproduced from the RFP, to calculate the number of communications lines, their lengths, the communications devices needed to support them, and their costs.

Building	LAN	Km to Center	User Ports	Link
a. Adams Hall	10baseT	7.6	230	T1
b. Jefferson Hall	100baseT	12.4	89	4 - T1
c. Lincoln Hall	10baseT	1.3	123	T1
d. Reagan Hall	1000baseT	5.0	498	12 – T1
e. VanBuren Hall	100baseT	2.8	205	2 - T1
f. Washington Hall	10baseT	14.6	37	2 - ISDN
e. Off Campus Users	Dial-Up	-	48	56K

Take some time to make sure you understand what each item in the table means.

Lab Part 2: Calculate components, average costs, total line item costs

In this section of the activity, you will calculate numbers of network components needed to meet a set of requirements.

1. First, you will calculate the number of users for planning purposes by multiplying the users in each building by 1.25. Round to nearest user.

Building	LAN	User Ports	Growt h	Design Users
a. Adams Hall	10baseT	230	1.25	288
b. Jefferson Hall	100baseT	89	1.25	111
c. Lincoln Hall	10baseT	123	1.25	154
d. Reagan Hall	1000baseT	498	1.25	623
e. VanBuren Hall	100baseT	205	1.25	256
f. Washington Hall	10baseT	37	1.25	46
e. Off Campus Users	Dial-Up	48 port	1.00	port

2. After getting the user count for each building, you will calculate each of the numbers listed below using the following formulas:

Users	Routers	Switches	Hubs
1 per network port	1 per building link	1 per 8 hubs	12 port
1 NIC card	1 LAN cable	Switch to hub cables	Hub to port cables
Port to computer NIC cables	Live backup router	Distance to router – 5 meters	Hub to switch cables – 50 meters

This is an example for Adams Hall of how you will do the calculations:

Adams 288 Users	1 Router	3 Switches	24 Hubs
288 network ports	1 per building link 1 Master switch if needed	Hubs/8	Users/12
288 NIC cards 288 cables	1 LAN cable – 6 meters	3 Switch to router switch cables	288 Hub to port cables - 20 meters
288 3 meter port to computer NIC cables	1 Live backup router	3 Router cables – 6 meters	24 Hub to switch cables – 50 meters

Now complete the calculations for each of the buildings:

N Jefferson Users	**Routers**	**Switches**	**Hubs**
N network ports	1 per building link 1 Master switch if needed	S =(N/12) / 8 switches	H = N/12 hubs
N NIC cards	1 LAN cable – 6 meters	S Switch to router switch cables	H Hub to port cables – 20 meters
N – 3 meter port to computer NIC cables	1 Live backup router	S router cables – 6 meters	H Hub to switch cables – 50 meters

N Lincoln Users	Routers	Switches	Hubs
N network ports	1 per building link 1 Master switch if needed	S =(N/12) / 8 switches	H = N/12 hubs
N NIC cards	1 LAN cable – @ 6 meters	S Switch to router switch cables	H Hub to port cables – 20 meters
N – 3 meter port to computer NIC cables	1 Live backup router	S router cables – 6 meters	H Hub to switch cables – 50 meters

N Reagan Users	Routers	Switches	Hubs
N network ports	1 per building link 1 Master switch if needed	S =(N/12) / 8 switches	H = N/12 hubs
N NIC cards	1 LAN cable – @ 6 meters	S Switch to router switch cables	H Hub to port cables – @ @ 20 meters
N – 3 meter port to computer NIC cables	1 Live backup router	S router cables – 6 meters	H Hub to switch cables – 50 meters

N VanBuren Users	**Routers**	**Switches**	**Hubs**
N network ports	1 per building link 1 Master switch if needed	S =(N/12) / 8 switches	H = N/12 hubs
N NIC cards	1 LAN cable – @ 6 meters	S Switch to router switch cables	H Hub to port cables – @ @ 20 meters
N – 3 meter port to computer NIC cables	1 Live backup router	S router cables – 6 meters	H Hub to switch cables – 50 meters

N Washington Users	**Routers**	**Switches**	**Hubs**
N network ports	1 per building link 1 Master switch if needed	S =(N/12) / 8 switches	H = N/12 hubs
N NIC cards	1 LAN cable – @ 6 meters	S Switch to router switch cables	H Hub to port cables – @ @ 20 meters
N – 3 meter port to computer NIC cables	1 Live backup router	S router cables – 6 meters	H Hub to switch cables – 50 meters

Item	Adams	Jefferson	Lincoln	Reagan	Van Buren	Wash-ington	Total	Price	Total
Users	288							-------	-------
Ports	288							5.99	
NIC 10	288							22.00	
NIC 100	0							32.00	
NIC 1000	0							112.00	
20m cables	288							8.88	
5 m cables	4							3.50	
50 m cables	24							33.00	
Hubs	24							134.00	
Switch	4							845.00	
Router	2							1200.00	
Dialup Ports	--	--	--	--	--	--	48	125.00	

This is an example of how you will do the calculations for the hardware and wiring components. You will use your own market prices for each item. Use www.shopper.com, or any other vendor on the Internet to determine average street prices for these items. You will fill this chart in for all buildings and calculate a final set of proposed costs.

Lab Part 3: Calculate communications line costs from tariffs

In this section of the activity, you will calculate line costs from a set of communication tariffs.

Building	LAN	Km to Center	User Ports	Link
a. Adams Hall	10baseT	7.6	230	T1
b. Jefferson Hall	100baseT	12.4	89	4 - T1
c. Lincoln Hall	10baseT	1.3	123	T1
d. Reagan Hall	1000baseT	5.0	498	12 – T1
e. VanBuren Hall	100baseT	2.8	205	2 - T1
f. Washington Hall	10baseT	14.6	37	2 - ISDN
e. Off Campus Users	Dial-Up	-	48 port	56K

You will use the following tariff table for the costs of telecommunications services in your proposal:

Tariff Service	$ / Km	Monthly Flat Rate	One Time
T3 45 Mbps Service	245.00	3400.00	9000.00
T1 1.544 Mbps Service	21.00	256.00	1200.00
ISDN 128 Kbps Service	-	75.00	675.00
Dial-up lines	-	28.00	43.00

Then you will extend and calculate all of the communications costs:

Building	Link	Km to Center	$ / Km	Monthly Distance Charges	Monthly Flat Rate Charges	One Time Charges
a. Adams Hall	T1	7.6				
b. Jefferson Hall	4 - T1	12.4				
c. Lincoln Hall	T1	1.3				
d. Reagan Hall	12 – T1	5.0				
e. VanBuren Hall	2 - T1	2.8				
f. Washington Hall	2 - ISDN	14.6				
e. Off Campus Users	48 - 56K	-				

Lab Part 4: Calculate hardware, software and other costs of Network Control Center

In this section of the activity, you will calculate the costs of servers and management components by getting estimates on the Internet

1. Make a list of the items you propose to incorporate into the Network Management Center.
2. Add the required Servers from Exhibit D.
3. Find estimates for each of the items and Servers on the Internet. Use www.shopper.com for pricing.
4. Document your costs.

Lab Part 5: Consolidate your calculations and report in RFP format

In this section of the activity, you will consolidate the results of your calculations into a concise set of costs. Prepare documentation for submission of pricing in your Network RFP Proposal in accordance with Exhibit E.

The pricing for the network should be based on the requirements contained in Exhibit A and shall include the following:

1. Cost of Link for shared access to the Internet from a State Approved Tier 1 Internet Backbone ISP from the main campus to at a predetermined location that is 43 miles from the main campus. The shared access to the Internet will support at least 40Mbps of data traffic. One-time charges, recurring monthly telecommunications charges, and Internet access charges shall be included.

Link	Link Type	Km to ISP	$ / Km	Monthly Distance Charges	Monthly Flat Rate Charges	One Time Charges
NMC to ISP	T3	43				

2. Dedicated connection of the following six buildings, and off-campus dial-up connections to the Millennium Network Control Center:

Link	Link	Km to Center	$ / Km	Monthly Distance Charges	Monthly Flat Rate Charges	One Time Charges
a. Adams Hall	T1	7.6				
b. Jefferson Hall	4 - T1	12.4				
c. Lincoln Hall	T1	1.3				
d. Reagan Hall	12 – T1	5.0				
e. VanBuren Hall	2 - T1	2.8				
f. Washington Hall	2 - ISDN	14.6				
e. Off Campus Users	48 - 56K	-				

Pricing for telecommunications connectivity shall include one-time charges and recurring monthly telecommunications charges for each link and the dial-up lines.

3. Design of a hierarchical hub and switch topology at each of the buildings using the following guidelines:

Users	Routers	Switches	Hubs
1 per network port	1 per building link	1 per 8 hubs	12 port
1 NIC card	1 LAN cable	Switch to hub cables	Hub to port cables
Port to computer NIC cables	Live backup router	Distance to router – 5 meters	Hub to switch cables – 50 meters

The network should be designed with 25% extra capacity. The number of switches and hubs should be based on the actual number of users plus 25% additional for growth and to cover labs.

Pricing for hardware and infrastructure shall include cabling costs, cost of port blocks, LAN cables, patch panels, hubs, switches, routers, NIC cards, and backup equipment.

Item	**Adams**	**Jefferson**	**Lincoln**	**Reagan**	**VanB uren**	**Wash-ington**	**Total**	**Price**	**Total**
Users	288							-------	-------
Ports	288							5.99	
NIC 10	288							22.00	
NIC 100	0							32.00	
NIC1000	0							112.00	
20 m cables	288							8.88	
5 m cables	4							3.50	
50 m cables	24							33.00	
Hubs	24							134.00	
Switch	4							845.00	
Router	2							1200.00	
Dialup Ports	--	--	--	--	--	--	48	125.00	

4. Design, specification, and equipment for Millennium Network Management Center. This equipment and software will be specified to enable the central network staff to diagnose, maintain, and support the campus wide network.

Pricing for the Network Control Center shall include hardware, software, cables, racks, and servers. Research Unit Prices on the Internet.

Item Description	Quantity	Unit Cost	Total Cost
Network File Server – Compaq 7000 or equivalent – 1 Gb RAM – with 750 Gb of RAID Storage	1		
Network Web Server – Compaq 3000 or equivalent – 512 Mb RAM – 50 Gb Storage	1		
Network Mail Server – Compaq 3000 or equivalent – 512 Mb RAM – 50 Gb Storage	1		
Network Firewall and Proxy Server – Compaq 3000 or equivalent – 512 Mb RAM – 50 Gb Storage	1		
Network Management Control Server – Compaq 1850 or equivalent – 256 Mb RAM – 36 Gb Storage	1		
Racks, cables, and miscellaneous equipment			
Network management tools and software			
Network operating systems licenses			
Other Items			

Rubric: Suggested Evaluation Criteria and Weightings:

Criteria	%	Your Score
Read and understand a set of networking requirements in the RFP	20	
Calculate numbers of network components to meet a set of requirements. Extend standard average costs for those components to calculate a set of line item costs	20	
Calculate line costs from a set of communication tariffs	20	
Calculate the costs of servers and management components by getting estimates on the Internet	20	
Consolidate the results of your calculations into a concise set of costs. Prepare documentation for submission in your Network RFP Proposal.	20	
Other		
TOTAL	**100**	

For Network Wizards

Materials Needed:

- Workstation connected to Internet
- NeoTrace 2.02 (or later) software

Packet Switching Across the Internet

NeoTrace is a multi-purpose Internet tool used for finding information and troubleshooting. At the simplest level, NeoTrace shows you how packets (data) get from your computer to another computer on the Internet. You see all the nodes (equipment of various types on the Internet that is passing traffic) between your computer and the trace target.

This activity is broken down into the following five parts:

- Download, install, and set up the NeoTrace software.
- Use the NeoTrace software to trace routes between your classroom and sites across the Internet
- Understand the technology used to trace, map, and document paths
- Utilize the trace technology to identify all switching nodes in a path and as a troubleshooting aid
- Print, store, and publish in HTML, your trace results

Part 1: Setup

In this section of your activity, you will download, install, and set up NeoTrace Version 2.02 (or later) *Shareware* on your system.

1. First you should visit this web site on the Internet to download the NeoTrace software to your IBM PC:

   http://www.neoworx.com/neotrace/

   The download is about 1.2 MB in size.

2. Next, you will get the software up and running. Just run the installation program that you downloaded. The installation program will automatically create the installation directory, start menu items, and an icon on your desktop. If you have a "quick launch" area on your Windows task bar, you can move this desktop shortcut there for easy access to NeoTrace.

3. The default configuration settings are sure to work on all systems. The only setting you need to make immediately is your Home Location. You will be prompted to enter information about your location. The zipcode is the most important data element which you will enter.

4. After you have installed your NeoTrace software, and are connected to the network, run the software by clicking on its icon.

5. If you have a firewall, then the following information will be of interest to you or your network administrator:

   It is possible to use NeoTrace through a firewall. If the firewall is not already configured to permit the use of PING or TRACERT through it (by use of ICMP packets) the firewall will need to be reconfigured.

   In order for NeoTrace (or ping for that matter) to operate through a firewall, two rules must be added to the firewall configuration. The first rule is to allow machines to send echo-requests. The second rule is to allow receipt of echo-replies. Depending on your particular firewall vendor, the terminology used may be different but the principle holds true

   NeoTrace makes use of ICMP (Internet Control Message Protocol) packets. ICMP packets are not associated with any particular port number.

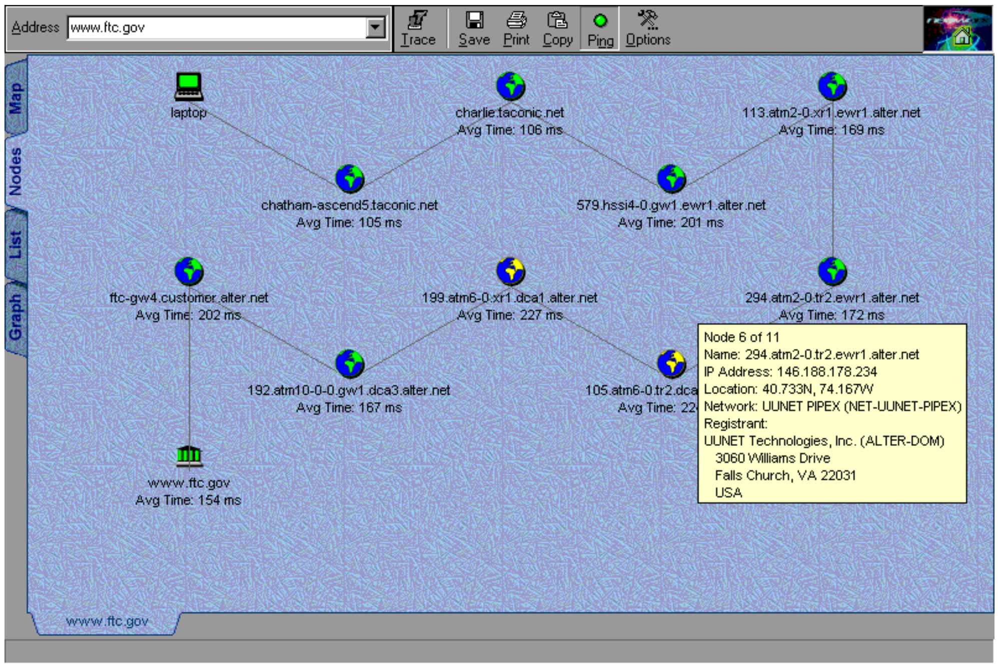
   Please note that changes to firewall configuration should only be made by a network administrator with an understanding of the characteristics of the firewall. Consult the documentation for your particular firewall for further information. Configuration changes that allow Ping to operate through the firewall will typically be documented, and these same procedures will allow use of NeoTrace.)

Part 2: Using NeoTrace

In this section of your activity, you will use the NeoTrace software to trace routes between your classroom and sites across the Internet

1. Using NeoTrace: Using NeoTrace is very simple. In the space provided at the top left of the NeoTrace window, enter the name of a computer to trace, and click the button labeled Trace. The name can be a logical domain name like news.cnn.com, or it can be an IP address like, 205.20.117.205. The software will now perform the trace, and it will also collect all the information available about nodes along the route.

2. Understanding the Node diagram**:** The default Node display diagram shows the name or IP address of each node between you and the location you entered, and the ping time to that node. Do not be surprised if you find many nodes between two points.



Ping time, as it is shown, indicates the length of time it takes for a packet of data to travel from your computer to that distant computer and back. The time only indicates the round trip to that one computer and is not directly related to the time on previous nodes.

It is possible to have a lower time on a more distant node and a high time on a closer node. The cause is the node with the higher time being efficient at routing traffic along but giving lower priority to responding to the ping request. This is not at all unusual.

3. Pinging Your Path**:** After the path diagram is fully drawn, click on the Ping button in the toolbar. NeoTrace will now start pinging the remote site, and you will see the Ping in light green as it traverses the network.

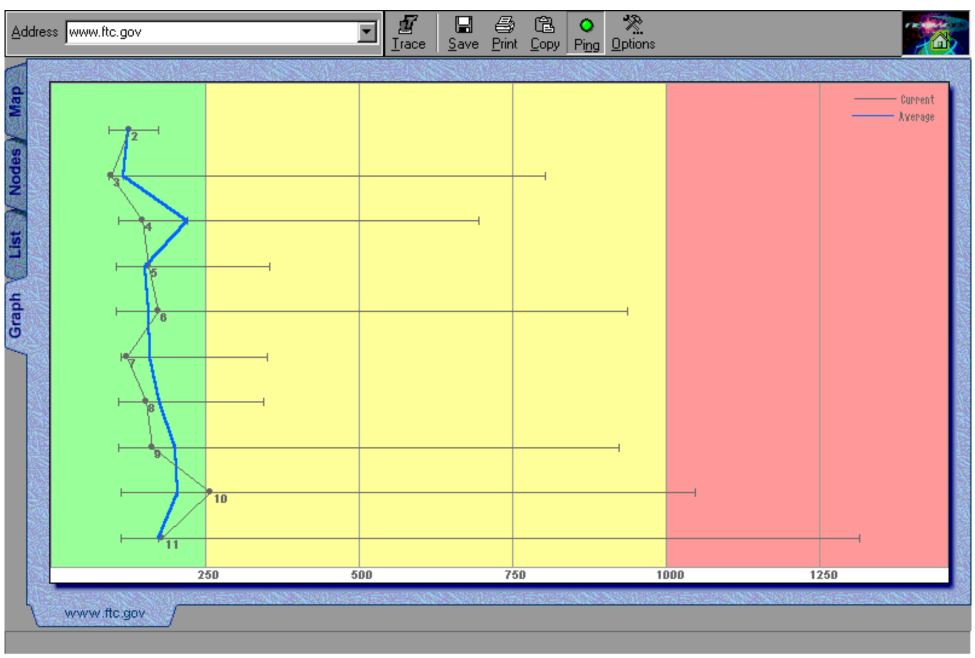
4. Multiple Traces: You can have up to fivetraces in memory at the same time. Tabs are added to the bottom of the window as new traces are started. Only the visible trace is active, all other traces are stopped when they are not visible.

   Continuous pinging is only active for the currently visible trace. Multiple pinging of routes would deliver inaccurate results, as the times would be affected by the traffic of pings to other routes.

   To close a trace result tab, double-click on it, or press Ctrl+D to remove the trace tab that is on top.

5. Understanding Ping Time and Traffic: The Ping Time is greatly affected by the amount of traffic on your connection. If you see a sudden and dramatic worsening of ping times it is usually due to a web page transfer, file download or email poll. The slower your connection the larger the effect traffic will have on the ping time.

6. Using the Graph View: When looking for trends in ping time, the Graph is the most useful view. Select it by clicking on the Graph tab on the left side of the NeoTrace window. You can easily see the overall results at a glance. When continuous pinging is turned on you can also see the low, high and average response times for each node.



A blue line indicates the average time. This is the average of the last three responses. The high and low response times are indicated by a range line and tick marks.

Vertical lines run at 250ms intervals and the background color corresponds to the node colors on the Node view to match the "node speed" ranges you have set in the Options.

Node 1 is not drawn on the graph; this is your computer and is always at a ping time of 0.

You will generally see a left to right trend in ping times. Ping times naturally increase as nodes are farther away. If you see high local ping times that decrease in the middle this often indicates high traffic on the local or ISP network. Nodes with high ping times are typically dealing with more traffic or are on the other side of a slower or lower-bandwidth link.

Sudden jumps in the ping time when tracing overseas generally indicates the point where the traffic moves over a long distance. The node on the short end of the jump is the last node in your country, and the next node is the first node in the next country. This is particularly apparent in traces that cross the Pacific or Atlantic.

7. Exploring Node Information**:** During the trace, information is returned the trace display is updated. If you move your mouse over the nodes, you will see pop-up windows that display further information about the nodes, including the name and address of the owner if available. If you wish to terminate a trace before it completes, press the Trace button again. Its appearance will indicate whether or not a trace is in progress.

8. Getting Additional Node Information**:** Once the trace is complete, you can get additional information and options through a contextual menu. Move the mouse pointer to the node you are interested in and right-click to view this menu.

Part 3: Understanding How NeoTrace Works

In this section of your activity, you will learn how the NeoTrace software is able to trace routes between your classroom and sites across the Internet

How NeoTrace Works

NeoTrace works by exploiting a feature of the Internet Protocol called TTL, or Time To Live. Originally, this data field in an IP packet header was supposed to contain a value representing the actual amount of time a packet could be flying around the Internet before a router would simply discard it. This was designed to eliminate packets that were endlessly looping around the network and therefore wasting bandwidth and router capability.

NeoTrace sends out a packet destined for the destination you specify. It sets the TTL field in the packet to 1. The first router in the path receives the packet, decrements the TTL value by 1, and if the resulting TTL value is 0, it discards the packet and sends a message back to the originating host to inform it that the packet has been discarded.

NeoTrace records the IP address and DNS name (if available) of that router, then sends out another packet with a TTL value of 2. This packet makes it through the first router, then times-out at the next router in the path. This second router also sends an error message back to the originating host. NeoTrace continues to do this, recording the IP address and name of each router until a packet finally reaches the target host, or until it decides that the host is unreachable. In the process, NeoTrace records the time it took for each packet to travel round trip to each router. Slow links are therefore pinpointed.

How NeoTrace is Used

There are many applications for this information. NeoTrace is a useful tool when troubleshooting connections or just verifying that everything is working OK. There is also a wealth of information presented by NeoTrace, including the domain owners, relative locations, and in some cases geographical location of nodes. Internet professionals, home users, law enforcement and many others use NeoTrace.

Why NeoTrace Route Timing Information is Important

All traffic on the Internet is made up of packets of data that travel between multiple computers or nodes from their destination to their source. The path that these packets traverse is called the route.

The structure of the Internet has a long history and many aspects of it are a result of the evolution it has made from the original network into the global data infrastructure it is used as today. One of these aspects is that there is no single route between any two distantly spaced nodes. Another aspect is that you are at the mercy of the intervening route for the performance of your traffic.

Regardless of how fast your connection to “the Internet” is, the slowest point in the route limits your overall connection to another site. The chain is only as strong as its weakest link.

Bandwidth is the amount of data that can travel through the connection in a given period of time.

What else can I use NeoTrace for?

Besides using NeoTrace to look for weak spots in a connection, you can use it to:

- Discover if you can’t reach a site due to a failure at your ISP or further into the Internet
- Determine the point of a network failure that is preventing you from reaching a web site
- Determine the geographic location of sites
- Track down the origin of unwanted e-mails (“spam”)
- Monitor performance.
- Discover the owners of a site
- Determine the type and quality of connection a site has to the net

Part 4: Use NeoTrace to Identify Paths and Map Routes

In this section of the activity, we will utilize the trace technology to identify all switching nodes in a path and as a troubleshooting aid.

1. Enter three addresses and create three separate traces. Your three IP addresses or domain names should include:
    - One site which is in the same town as your school
    - One site in Washington D.C.
    - One site on another continent

You may need to do a little research to select your sites. You could also pull down a list of sites in the NeoTrace window.

2. After you have completed your traces, look at the Map, Nodes, List, and Graph tabs on the left side of the NeoTrace window. Count the number of nodes in each path. Trace the longest path a few more times. Does the node count change? Why do you think it does?

3. As you investigate your paths, you will notice that nodes have different colors. The relative speed of nodes is indicated by their color. This is an indication of how long it takes a packet (data) to make a round trip between your computer and that particular computer. Note that the time can vary between traces, and may vary a great deal at different times of the day due to traffic conditions on the Internet. The color ranges can be adjusted in the configuration dialog.

4. See if you can identify any slow or bottleneck links, and any slow or bottleneck nodes. What can you speculate about slow links? What can you speculate about slow nodes?

Part 5: Printing, Storing, and Publishing Trace Results

In this section of the activity we will print, store, and publish in HTML, your trace results. Following are the directions to help you publish your findings.

The results of a trace can be output to the printer, a text file or to simple HTML format. You have three choices regarding the amount of information that you want included in the output:

A. Simple Report

Displays the node number, hostname, IP address and timing results (essentially the same as command line traceroute)

B. Standard Report

Also displays short WhoIs results (essentially the normal NeoTrace results)

C. Detailed Report

Includes detailed WhoIs results

To change the style of output, choose Options and make your selection.

To Save results, pick Save from the File menu or use the Save button on the tool bar. From the save dialog box, you can choose either HTML or TEXT format.

To Print results, choose Print from the File menu or the Print button on the tool bar.

Select ONE of your traces and print the details for it using the detailed reporting option.

1. Save the same report to a Web Page.
2. Use this printout, and the Web page you saved, to illustrate your example and the conclusions you came to about the network to other members of the class.

Rubric: Suggested Evaluation Criteria and Weightings:

Criteria	**%**	**Your Score**
Download, install, and set up the NeoTrace software	10	
Use the NeoTrace software to trace routes between your classroom and sites across the Internet	20	
Understand the technology used to trace, map, and document paths	20	
Capture and record statistics on the modeling and simulation of traffic	20	
Utilize the trace technology to identify all switching nodes in a path and as a troubleshooting aid	20	
Print, store, and publish in HTML, your trace results	10	
Other		
TOTAL	**100**	

Summary

Lesson 2: ATM and Advanced Switching Techniques

In this lesson, you learned how to do the following:

- Describe the characteristics of ATM
- Describe three transfer modes used in switching technologies
- Describe the basic operation of an ATM network
- Compare ATM with traditional networking technologies
- Explain how LANE and MPOA enable ATM to integrate with legacy networks

Review Questions

Lesson 2: ATM and Advanced Switching Techniques

1. ATM is
   a. Connectionless
   b. Cannot connect LANs and WANs
   c. Capable of sending data, voice, and video with no guarantee of quality of service
   d. Connection-oriented
2. Which transfer mode uses time-slot position for data addressing?
   a. STM
   b. PTM
   c. ATM
   d. All of the above
3. Which transfer mode allocates bandwidth whether it is used or not?
   a. STM
   b. PTM
   c. ATM
   d. All of the above
4. Which transfer mode is best suited for voice, video, and data?
   a. STM
   b. PTM
   c. ATM
   d. All of the above

5. Which of the following statements is false?
   a. ATM uses point-to-point connections
   b. ATM is know as a nonbroadcast multiple access network
   c. ATM cells have in their headers identifiers for specific circuits along which the data will travel
   d. ATM cells come in a variety of sizes
6. Synchronous transfer mode (STM) is also known as what?
   a. Packet switching
   b. Circuit switching
   c. Asynchronous transfer mode
   d. Data streaming
7. What are the four functions provided by ELAN?
   a. Initialization, connection orientation registration, and data transfer
   b. Initialization, registration, address resolution, and data transfer
   c. Initialization, quality of service, address resolution, and data transfer
   d. Initialization, cell segmentation and reassembly, quality of service, and data transfer
8. How does ELAN provide functions such as initialization?
   a. By defining STM
   b. By defining STM and LEC, and ATM
   c. By defining ATM and PVC, and BUS
   d. By defining LEC, LECS, and BUS

9. What is the name of the transfer mode that allows empty time-slots to be used by other users who need them?

   a. STM

   b. LAN

   c. ELAN

   d. PTM

10. Which of the following does not use packet switching technology?

    a. X.25

    b. Ethernet

    c. Frame Relay

    d. ATM

11. When are PVC circuits available for transferring ATM cells?

    a. When the destination is known

    b. Only when requested

    c. Always

    d. Varies according to time of day

12. Which of the following is not true about ATM?

    a. Connection-oriented

    b. No inherent broadcast, multicast capability

    c. Fixed-length cells

    d. Contention access method

13. How does LANE match IP addressees to ATM circuits?
    a. By maintaining a database
    b. By contention
    c. Information is contained in the ATM cell
    d. Through quality of service data
14. What makes ATM capable of handling voice, data, and video?
    a. It is a packet switching environment
    b. It is connectionless
    c. Because of its bandwidth and quality of service capabilities
    d. It requires interfaces to connect to LANs
15. What defines how IP and other Layer 3 protocols run over ATM?
    a. MPOA
    b. LANE
    c. LEC
    d. LECS
16. What is ATM?
    a. A high-speed packet switched network
    b. A high-speed cell switched network
    c. A data only transfer method
    d. A contention based network

17. Quality of service determines which of the following?
    a. Maximum acceptable cell loss
    b. The destination
    c. The average bandwidth requirements
    d. The peak bandwidth requirements
18. Why can ATM instructions be hardwired?
    a. The cells are the same size
    b. It uses the same set of instructions to process data
    c. It needs fewer instructions
    d. All of the above
19. What is connected to every station in an ELAN to perform broadcast and multicast operations over ATM?
    a. A LAN
    b. A LEC
    c. A QoS
    d. A BUS
20. What standards allow ATM to act as though it were connectionless by specifying that the devices in ATM and legacy networks be grouped together into one or more emulated LANs?
    a. LEC
    b. LECS
    c. LANE
    d. LES

Scoring

Criteria	Points	Your Score
Check Your Understanding		
Describe the characteristics of ATM	25	
Describe three transfer modes used in switching technologies	25	
Describe the basic operation of an ATM network	25	
Compare ATM with traditional networking technologies	25	
Explain how LANE and MPOA enable ATM to integrate with legacy networks	25	
Total	**100**	
Try It Out: Create a Classroom Resource Book	**100**	
Stretch Yourself: RFP Activity – Pricing Communications Networks	**100**	
Network Wizards: Packet Switching Across the Internet	**100**	
Lesson Review	**100**	
TOTAL	**500**	

Resources:

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The ATM Forum, http://www.atmforum.com/
The ATM Forum is an international non-profit organization with the goal of accelerating the use of ATM.