Lesson 1-4: Structured Cabling Systems

At a Glance

This lesson describes both physical and logical organization of networks. Topologies described include bus, ring, star, and hybrid. This unit also covers TIA/EIA 568 structured cabling standards, which govern the installation of local area networks. In order to design, install, troubleshoot, and maintain networks, administrators must have a solid understanding of these topologies and cabling standards.

What You Will Learn

After completing this lesson, you will be able to:

- Identify and describe the elements that are recommended for structured cabling networks.

- Diagram bus, star, ring, and hybrid topologies.

- Compare and contrast the advantages and disadvantages of bus, star, ring, and hybrid topologies.

- Select the appropriate topology for a particular set of network requirements.

- Create a questionnaire for an administrator to use when planning or expanding a network.

- Select and estimate the cost of cabling for a given network.

Tech Talk

- **Active Hub**—Type of hub that monitors, amplifies, and regenerates signals. Signals are strengthened in active hubs. The opposite of a passive hub.

- **Attenuation**—The weakening of a signal as it travels over connection media; also referred to as signal degradation.

- **Bus Topology**—Network topology where computer devices are connected in a row to a continuous length of cable segment. Each end of the cable segment must be terminated by means of a terminating resistor.

- **Logical Topology**—Logical topology describes the actual path of data signals through a network. It does not refer to the physical layout of the network.

- **Passive Hub**—Type of hub that does not take an active role in maintaining, processing, or regenerating signals. A passive hub serves only as a physical connection point for computer devices. The opposite of active hub.

- **Patch Panel**— Connection point located in a secure closet and used to terminate the horizontal and vertical cables.

- **Physical Topology**—The attributes and physical setup, not logical topology, of a network. Physical topology describes the physical connections and arrangement of the internetworking devices.

- **Redundancy**—Networking redundancy refers to the additional equipment or measures taken to ensure continuous operation of a network. One example is having an extra server available in case one goes down.

- **Ring Topology**—Closed network with no beginning or end point. Computer devices are all connected to one main cable segment in a continuous fashion. Termination devices are not necessary. All computers have equal access to the network.

- **Star Topology**—Topology that uses point-to-point wiring. There is a central hub, which receives and transmits signals over the network. Each computer device is connected to a hub, not directly to the other computers.

- **Terminator**—Device connected at the end of each wire segment in bus networks. Terminators absorb transmission signals, which prevent them from bouncing back and causing interference.

Elements of Structured Cabling Systems

When computer networks were first designed, future expansion and/or upgrading needs were not anticipated. Original networks were small, often as few as two or three computers and a printer connected together in the same office. Existing equipment was cabled together in a somewhat haphazard manner and networks that went beyond single-site locations were neither envisioned nor planned for. There was no need for cabling and networking standards.

As networks grew, and became common, it became apparent to vendors that standards needed to be implemented to provide interoperability. Initial structured cabling standards were vendor specific, for example, Token Ring networks by IBM and Ethernet networks by Digital Equipment Corporation. These standards were adequate at that time since networks still did not extend beyond single-site office locations and it was common to have equipment from only one vendor.

As networks expanded to include several offices and buildings, corporations became more dependent upon networking to conduct everyday business transactions. This created interoperability issues; one location may have IBM equipment, another Compaq, and so on. The inability to network with other locations became an economic issue. Also, vendor specific standards made worldwide internetworking nearly impossible. The need for permanent, interoperable, industry-wide structured cabling standards become necessary for a global economy.

In the early 90s, the Telecommunications Industry Association/Electronic Industries Association (TIA/EIA) developed industry-wide, internetworking, structured cabling standards. The TIA/EIA 568-standard, which you learned about in the Cabling lesson, attempts to make the installation of computer networks as efficient and consistent as the installation of telephone systems. The 568 standard breaks down the installation of wiring within a building into manageable pieces and governs wiring specifications for 10BASE-T, 100BASE-TX, 100BASE-T4, 100VG-AnyLAN, LocalTalk, Token Ring 4 and 16 Mb/s, and FDDI.

When designing or expanding networks, system administrators use current TIA/EIA 568 cabling specifications as a guide. This helps ensure both backward and forward compatibility for networks. Backward/forward compatibility means that new equipment functions with already existing networking devices and also takes into account future expansion requirements.

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Structured cabling specification 568 makes recommendations for the following basic elements of networks:

- **Building Entrance Requirements**—Specifications for the point at which outside cabling enters a building.

- **Equipment Room**—Storage area for the more expensive, complex equipment, often the existing telecommunications closets.

- **Backbone Cabling**—Cabling (often referred to as vertical) that carries the signals from equipment room to equipment room, between floors, and to and from the building entrance connections.

- **Horizontal Cabling**—Transmission media that carries signals from a same floor equipment room to the various work areas.

- **Work Area**—Any area where the computer workstations, printers, etc. are located, typically office space.

Building Entrance Requirements

The building entrance requirements are simply the specifications for the point at which the cabling enters a building. The specifications include recommendations for the type of connecting and surge protection devices. The standard also specifies the placement of the cabling used to connect the inside wiring to other buildings.

Equipment Room

The equipment room is typically the existing telecommunications closet. It can be any secure storage area where the communications racks, cables, and other more expensive hardware devices, such as patch panels, hubs, switches, and routers are located.

A locked equipment room helps prevent the theft of equipment and data security and also helps prevent accidental damage from untrained individuals.

The TIA/EIA 568 standards recommend that the equipment room be located in the middle of the office space, if possible. In this way, the cables that run from the equipment room to the work areas can be approximately the same lengths, and at the same time adhere to the maximum length standards. This helps ensure reliable transmission of data.

Backbone Cabling

Backbone cabling is the wiring that runs vertically between floors and/or between equipment rooms. Backbone cabling provides the interconnections between equipment rooms and the building entrance site, including cross-connects, patch cords, and terminators. Backbone cabling can also extend between buildings.

When planning a network it is a good idea to double or even triple the length of backbone cable that is needed for installation. This provides for expansion and the ability to run redundant connections.

Backbone Cabling Connects Equipment Rooms

Backbone Cable
Limit Depends on Cable Type

Patch Cable
6 Meter Limit
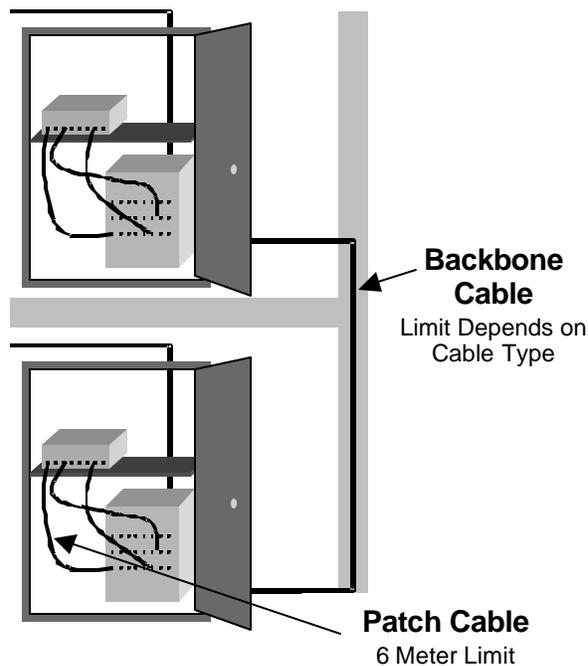
The wiring used for backbone cabling may be either copper or fiber optic.

Recommended backbone cable maximum distance limitations include:

- Voice grade 100 ohm UTP   800 meter limitation

- STP data grade 150 ohm   90 meter limitation

- Multimode 62.5/125μm fiber   2,000 meter limitation

- Patch cable   3 - 6 meter limitation

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When using copper wire for backbone cabling, avoid sources of high level electromagnetic or radio frequency interference (EMI/RFI). Fiber optic cable, although more expensive, has distinct advantages over copper since it can be run in locations such as elevator shafts or alongside power lines with no EMI/RFI affects. Since backbone cabling is stationary and there is less of it used, spending more money per unit length for high-speed backbone fiber optic cable is often the best choice. Recently, the price of fiber optic cable was reduced making this the current backbone cable of choice.

Horizontal Cabling

Horizontal cable is the physical media that runs from the wall jack at the workstation outlet to the termination in the equipment room. It also includes the cable run from the wall outlet to the workstation, and the cable in equipment closets that connects hubs, switches, and so on. These short pieces of cable are called patch cords or patch cable. There is a 3-meter limit from the wall jack to the workstation and a 6-meter limit between equipment in the telecommunications closet.

Horizontal Cabling
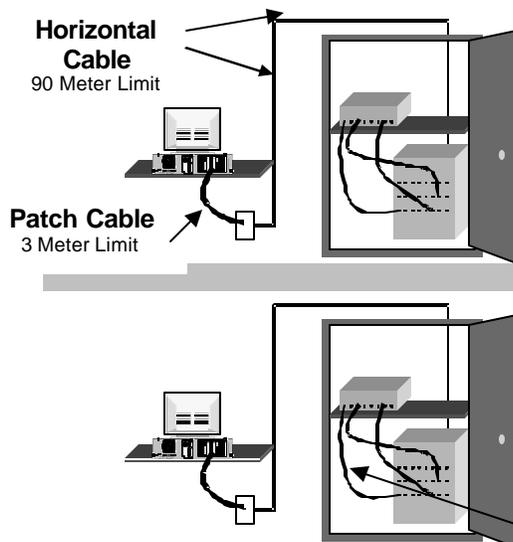
Most often, horizontal cable is routed directly from the wiring closet to the workstation, without splices, cable junctures, or taps. By eliminating splices, cable junctures and/or taps, the potential for faulty connections and electrical noise is reduced. Although not necessary, it is recommended that horizontal cabling be rated for category 5 use.

Maximum transmission speeds for horizontal cable are:

- Category 3 up to 16 MHz

- Category 4 up to 20 MHz

- Category 5 up to 100 MHz

Maximum recommended distance limitation for horizontal cable:

- 100 meters total

- Maximum of 3 meters from wall jack to workstation

- Maximum of 6 meters in the telecommunications closet

- Maximum of 90 meters from telecommunications closet to wall jack

Cable lengths from the computer workstation running to the hub in the equipment room may not exceed 100 meters, including the patch cable. The distance from the closet to the workstation should not exceed 90 meters. This leaves only 10 meters. It is strongly recommended that less than 3 meters be used for workstation-to-wall-outlet patch cable and less than 6 meters for patch cable in the wiring closet. The wall jack outlet must have a minimum of two ports, one for voice grade transmissions and one for data grade transmissions. Recommended horizontal cabling includes:

- 4-pair 100 ohm UTP

- 2-pair 150 ohm STP

- 2 fiber 62.5/125μm optical

When installing horizontal cable, it is important to avoid any sources of electromagnetic interference (EMI), such as elevator motors, portable heaters, electrical wiring, air conditioning, metal beams, and walls. Horizontal cable may be run under carpets, along ceiling tiles, over beams or frames, through wiring trays, through firewalls, or even as conduit back to the wiring closet. Cable lengths should be tested after installation and *before* equipment is attached.

Fiber optic cable is not subject to the same distance limitations, nor is it subject to EMI/RFI, however it is fragile and expensive and should only be installed by qualified technicians.

Work Area

The work area components include the computers, telephones, patch cables, adapters, and so on. Workstations are connected to the wall outlet by patch cables.

It is recommended that one wall jack be for category 5 wiring, and a second jack for UTP category 5, STP cable, or fiber optic cable. A network planned for future expansion often has six outlets. It is specified that category 5 cable be terminated with an 8-pin, RJ-45 wall jack; STP to a 4-position shielded token ring connector, and, fiber optic to a SCFOC/2.5 duplex connector. We will discuss these connectors later in the course.

Check Your Understanding

♦ Why are industry-wide, interoperable internetworking standards for cables important?

♦ List the elements of the TIA/EIA 568 structured cabling specification recommendations.

♦ What are building entrance requirements?

♦ Describe an equipment room/wiring closet.

♦ Fiber optic cabling is more expensive and more difficult to install than copper cabling. Why might a network administrator choose fiber optic cabling for backbone wiring?

♦ Name several sources of EMI.

♦ Wiring that runs from the equipment closet to the individual workstations is called what?

♦ Wiring that runs from the equipment closet on one floor to the equipment closet on other floors and to the building entrance point is called what?

♦ What is a work area? What are the recommendations for maximum cable lengths and wall jack outlets.

Network Topologies

Networking "physical" topology is simply where the workstations and cable are physically placed. The "logical" topology is not where the devices are physically positioned, it is the actual path the *data signal* takes when transmitted. You can see where workstations are located, but you cannot see the route taken by the data. When planning a reliable network, administrators must consider several factors p rior to selecting the physical and logical topology. Such factors include, ease of maintenance and management, cost, traffic, security, reliability, and redundancy. There are several topology choices, including bus, ring, star, and hybrid topology.

Bus Topology

When computers were first networked together, they were simply connected to one cable segment in a series. This physical setup is called bus topology. In bus topology, data signals travel the entire length of the cable from device to device. Each end of the cable is terminated, thus preventing signal bounce back. Data signals are transmitted to the entire network and devices can send data at any time. Small networks do well with this topology, but problems increase significantly when the network becomes too large.

Bus Topology


Terminator
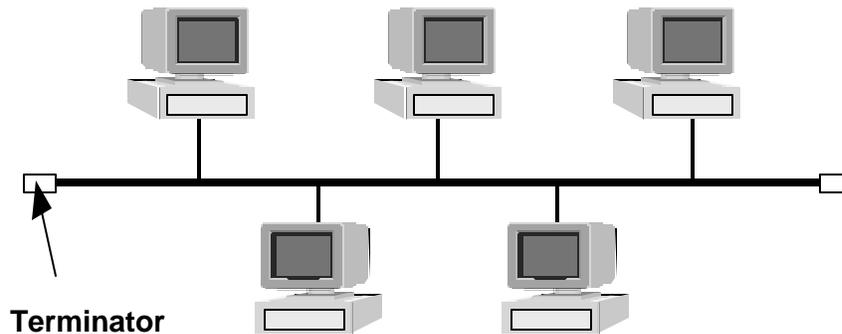
Bus topology advantages:

- Inexpensive to maintain

- Requires less cable

- Does not require extensive training

- Good choice for small networks

Bus topology disadvantages:

- Difficult to isolate malfunctions because of series connections

- When one device fails, all devices fail

- Heavy traffic causes considerable slowdowns and network crashes

Bus topology requires less cable than other topologies since it is a continuous series and not a point-to-point network. This keeps the costs down. Extending bus topology is accomplished by joining two cable segments with a connector or by adding repeaters. This can create transmission delays and errors. Technically speaking, bus networks are easy to use and understand and do not require extensive training. As networks grow, the excess traffic can slow the network or cause it to crash. All of these factors made it an excellent topology choice for small workplace and home networks in the preliminary stages of networking.

Bus Topology Extended with Repeater
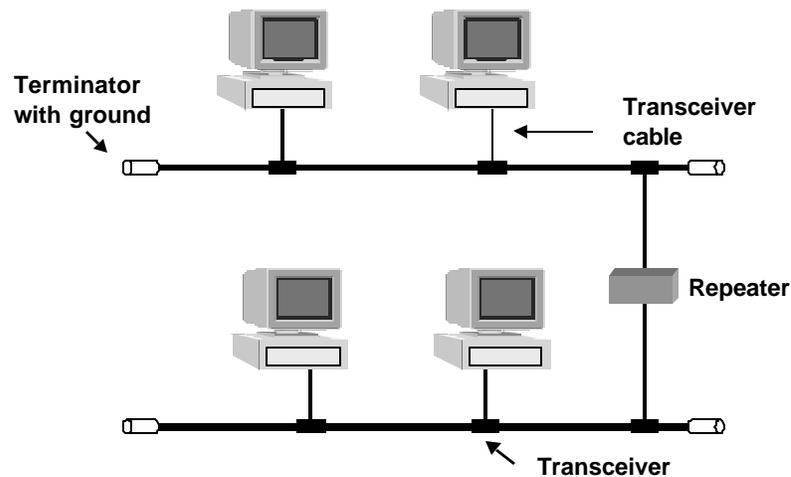
Troubleshooting bus topology is complicated because it is difficult to isolate problems. When one device malfunctions, that device can cause an entire network to fail. Expansion also creates problems. When making modifications to the network, the entire network must be disabled. Bus topology can make maintenance and troubleshooting challenging because it is difficult to isolate problems. This, in effect, cancels the inexpensive advantage. Although the easiest and least expensive, bus topology is not practical in large, multi-room, multi-floor, multi-building installations where frequent interruptions in service might be necessary and could cause considerable problems.

Of the various topology schemes, it uses the least amount of cable, because it is a continuous and not a point-to-point topology. If you are looking for a small inexpensive, easy to understand network, bus topology may be the answer.

Ring Topology

Like bus topology, all computer devices are connected to the same cable segment. However, it is one continuous connection with no beginning or end point. Termination is not required. The signal flows in only one direction in ring topology and each device in the ring receives the signal and examines it. If the transmission is not intended for that device, the signal is regenerated and passed on to the next device in the ring.

Ring topology advantages:

- Provides equal access for all devices on the ring

- Easier to manage and maintain than bus topology

- Very reliable

- Handles high volume traffic well

Ring topology disadvantages:

- Difficult to isolate malfunctions

- Expansion of network disrupts services for all

Each device has equal access to the network and is guaranteed access at regular intervals. This is important in a business where regular movement of data is essential, such as checks or other banking transactions.

Ring Topology
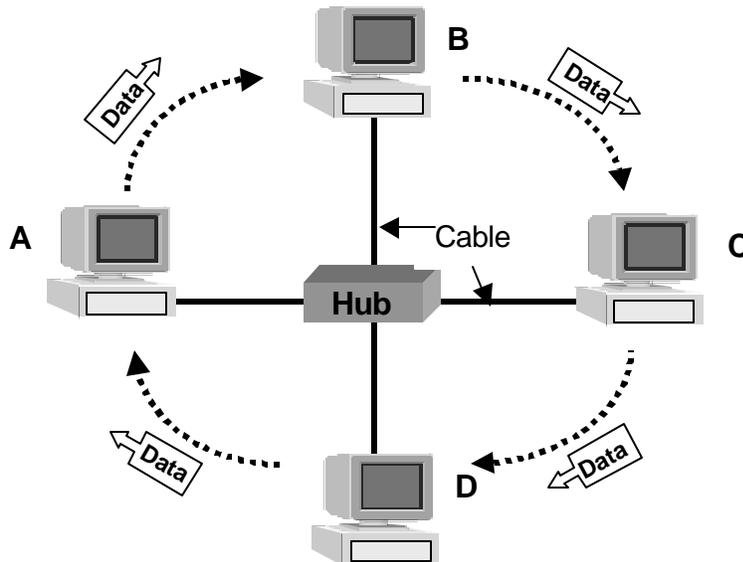
In ring topology, a token travels from computer to computer until it reaches a node waiting to transmit data. The data then attaches to the token and is delivered to the receiving device. The token then continues around the ring looking for another device waiting to send data.
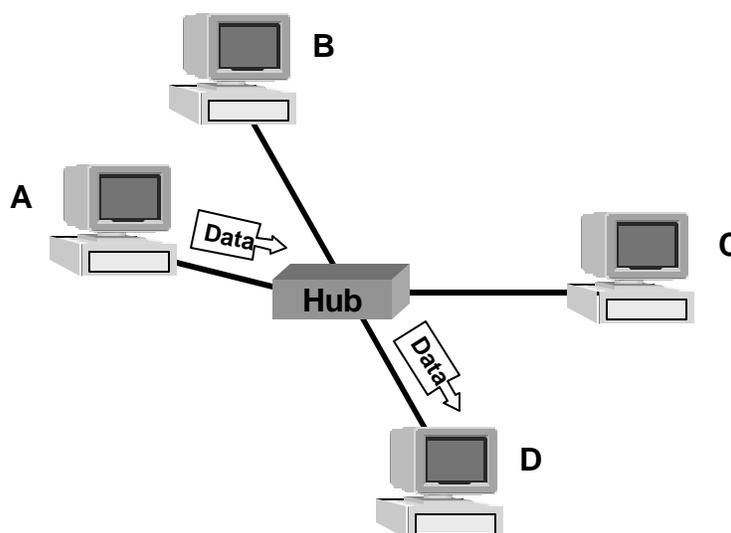
Ring topology is easier to manage and maintain than bus topology, is more reliable than a bus, and it handles traffic well. On the negative side, it does require more cabling than a bus, especially if the computer devices are far apart. Expansion of a ring network disrupts data transmission for all.

If your network has high traffic, and you are looking for a reliable network where each workstation has equal access, ring topology may be the answer. Token Ring and Fiber Distributed Data Interface (FDDI) networks use token passing ring topologies.

Star Topology

Star topology is a point-to-point architectural design where all computer devices are connected to a central hub, through which all data signals must travel. There are both active and passive hubs. Passive hubs send data without amplification; active hubs amplify data signals.

Star Topology

Star topology advantages:

- Easy to install and upgrade

- Easier to manage and maintain that bus and ring topologies

- Central hub makes troubleshooting easy

Star topology disadvantages:

- Hub failure causes entire network to go down

- More expensive for cabling

In star networks, the logical transmittal of data is similar to bus topology but only one computer can transmit data at a time. The physical topologies are quite different. The physical hub of the star acts to logically connect all devices as if to a single cable segment. Star is the easiest topology to install, upgrade, and manage.

Computer devices are attached directly to central hubs via patch cable. Each patch cable connects to a port on the hub. Small hubs usually have 4, 8, or 16 ports. Larger hubs may have up to 512 ports. Cabling is more expensive than for other topologies since each device must be connected directly to the hub

When a device on a star topology network fails, it does not disrupt the other computer devices. Similarly, if you add a new device, service to other nodes continues uninterrupted. However, if the hub fails, the entire network goes down. 10BASE-T is one of the most popular star topology networks.

Hybrid Network Topology

Hybrid topology is any combination of bus, star, and ring topology, for example, a star-bus configuration. With a star-bus network, several hubs can be connected on a bus segment to several star topology segments.

Hybrid Topology
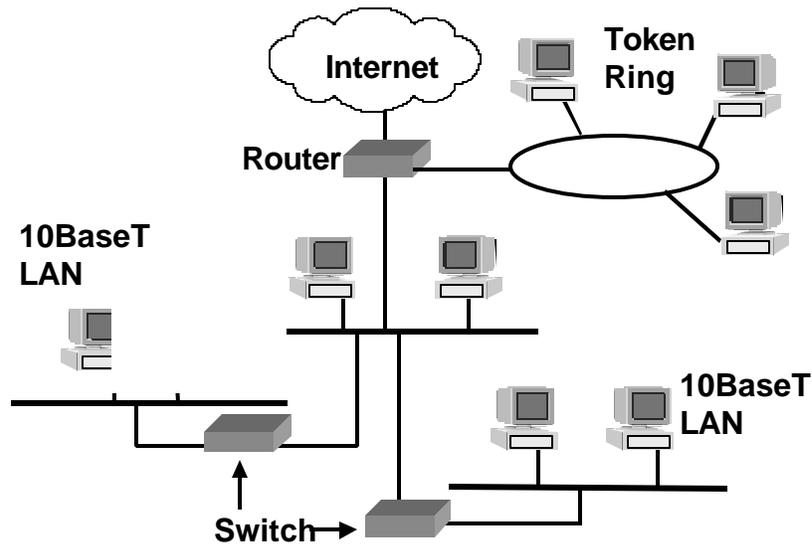
More often than not, hybrid topology is commonplace in large networks because it is allows combining subnetworks, each employing the least expensive, most efficient topology.

Check Your Understanding

♦ List several factors an administrator must consider when planning a network.

♦ Why must cable segments on a bus network be terminated?

♦ What are some advantages of bus topology?

♦ What is one major disadvantage of star topology?

Try It Out

Network Topologies

In the connectivity lesson, you diagramed all the devices and workstations connected to your network. When administrators design network topologies, they often use software applications to illustrate the topology. Using a computer, generate designs for four different network topologies, bus, ring, star, and hybrid topologies. Print out your networks and save in your portfolio.

Materials Needed

- Word processing application (e.g., MS Word)

- Network diagram from Lesson 2

- Actual network design from your instructor

Open a word processing application. Directions shown here are for Microsoft Word 6.0. (If you use another word processing application, check with your instructor for vendor specific directions.)

1. In the toolbar, click View. Scroll down to Toolbars and check Drawing.
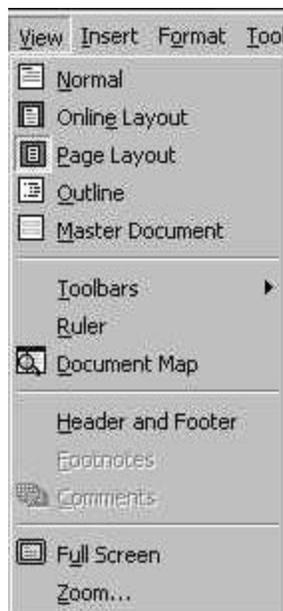
2. The following drawing toolbar will appear on the screen.

3. Diagram and label a bus topology with at least five nodes.

4. Highlight the Text box on the Drawing toolbar.

5. Move the pointer to where you want to draw a box, which will represent the computers. The pointer changes to a crosshair. Hold down the left mouse button and drag to create the box. For each computer device in your diagram, draw a textbox.

6. To move the textbox, bring the pointer to the edge of the box until it changes to a cross with arrows. Hold down the Shift key and move the box so it is where you want to place the computer.

7. You can size the text box by bringing the pointer to the edge or corner of the box until the pointer turns to a two-sided arrow. Hold down the left mouse button and size your text box.

8. Highlight the Line button on the Drawing toolbar.

9. Draw in lines to connect the computer devices. Use the lines to create a bus topology. Label the diagram Bus Topology.

10. Print your bus topology diagram and place it in your portfolio.

11. Create three more diagrams. One for star, one for ring, and one for a hybrid topology. Put them in your portfolio.

12. Contact your school's network administrator and ask what type of network topology the school uses.

13. Which type of topology does your school network use?

14. Using the hand drawn diagram you created for the connectivity lesson, and the information you received from the school network administrator, create a computer diagram of how your school may be wired.

15. Obtain the actual topology documentation for your school's network from your teacher.

16. Re-create the diagram to accurately reflect your school's topology.

Rubric: Suggested Evaluation Criteria and Weightings

Criteria	%	Your Score
Active engagement	15	
Accurate computer diagram of a bus, star, ring, and hybrid topology.	60	
Labeled diagrams placed in portfolio	10	
Diagram of your school's network topology	15	
TOTAL	**100**	
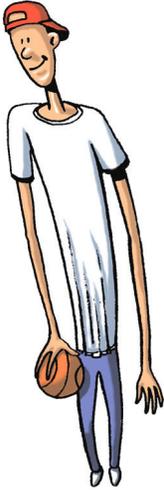
Stretch Yourself

Star Network

In this lesson, you learned the different types of wiring topology for networks. You have to be connected to the network in order to transmit data. In the connectivity lesson, you installed a NIC. In this activity, you will design a star and bus network topology and experience what happens when a network connection is broken.

Materials Needed

- Cables

- Networking equipment, e.g. a hub and several computers

- Computer file enabled for sharing

Star Network

Work in groups of four and set up a star network.

1. Verify that all four nodes are securely connected to the hub in a star format.

2. Check the NIC connection on each workstation to be sure there is a secure connection. Have your instructor check your star network.

3. Use one of the nodes as a server and the other three nodes as clients. Your instructor will tell you which computer will serve as the server and which will be the clients.

4. Clients should access a folder from the server. Make sure that you are able to access and use the shared folder as specified by your instructor.

5. Leave the folder open and remove the NIC connection from the server.

   ♦ Record in the space below what happens.

      Answer: The connection will fail.

   ♦ Explain why this happened. Are the other devices able to stay connected? Why?

      Answer: The computers are not longer connected together.

6. Reconnect the computer to the network.

   ♦ Are you still connected to the shared file?

Rubric: Suggested Evaluation Criteria and Weightings

Criteria	%	Your Score
Participation and teamwork	15	
Detailed notes of what happened when disconnected from the network	25	
Thoughtful analysis and comparison of bus and star networks	30	
Understanding of the OSI model and its relationship to this network activity	30	
TOTAL	**100**	
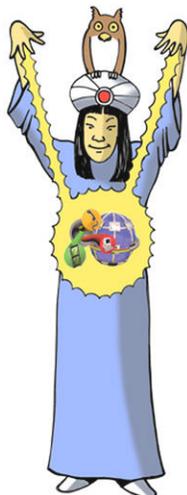
Network Wizards

Network Design

Materials Needed

- Spreadsheet application

- Drawing application

- Cable cost analysis prepared for Stretch Yourself, Lesson 3

Work with a partner to create a list of questions you should ask a client who has hired you to build a network. The client wants to know which type of cable you plan to use and why, how much the cable will cost, and why you selected the particular topology. The client also wants you to submit a proposal that defends your choice of cabling and network design.

After you create your questionnaire, role-play with your partner. One of you will assume the role of client, and the other the role of the network designer. The client will answer all the questions for a fictitious company of his/her choice. The network designer will record all of the answers.

When the questionnaire is complete, you will both analyze the requirements and determine the appropriate topology. Create a computer diagram of the proposed network for the client. Prepare a spreadsheet that shows a cost analysis of the cable needed to complete the job. The cost analysis should include the type of cable, length of cable, cost of each type of cable, and the total cable cost. Use the cost information you gathered in the cabling lesson.

Submit a proposal to the client indicating the suggested network topology. Include a summary to convince the client that this is the best, most cost efficient design for her/his needs. Your proposal must also defend your cable choices. Attach the computer diagram and cable cost analysis spreadsheet to your proposal.

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Rubric: Suggested Evaluation Criteria and Weightings

Criteria	%	Your Score
On time delivery of client proposal	10	
Computer diagram of proposed network	10	
Completeness of questionnaire	20	
Accurate analysis of client needs	20	
Accuracy and completeness of cable cost analysis spreadsheet	10	
Content and quality of client proposal	30	
TOTAL	**100**	

Summary

In this lesson, you learned the following:

- To identify and describe the elements that are recommended for structured cabling networks.

- To diagram bus, star, ring, and hybrid topologies.

- To compare and contrast the advantages and disadvantages of bus, star, ring, and hybrid topologies.

- To select the appropriate topology for a particular set of network requirements.

- To create a questionnaire for an administrator to use when planning or expanding a network.

- To select and estimate the cost of cabling for a given network.

Review Questions   Name

Lesson 1-4: Structured Cabling Systems

Part A

1. When planning a network, an administrator must

   a. Anticipate the potential for future growth.

   b. Take an inventory of existing hardware and software.

   c. Determine the needs of the organization.

   d. Determine the best physical and logical topology.

   e. All of the above.

2. Cabling that carries the signals from equipment room to equipment room, between floors and the building entrance cabling.

   a. Patch cable

   b. Backbone cable

   c. Horizontal cable

   d. All of the above

3. What is the office space where computers are located called?

   a. Work area

   b. Equipment room

   c. Building entrance

   d. Horizontal cabling room

   e. Backbone cabling room

4. The cabling that carries the signals from the equipment room to the various work areas.

   a. Workstation cabling

   b. Patch cabling

   c. Horizontal cabling

   d. Backbone cabling

5. Electromagnetic interference is not a problem for which cable?

   a. Category 5 UTP

   b. STP cable

   c. Coaxial cable

   d. Fiber optic cable

6. List five networking elements covered by the TIA/EIA 568 standards.

Part B

1. Diagram a bus network topology.

2. Diagram a star network topology.

3. Diagram a ring network topology.

Part C

1. List the advantages and disadvantages of bus network topology.

2. List the advantages and disadvantages of star topology.

3. List the advantages and disadvantages of ring topology.

Part D

1. You have been asked to create a network for five computers. Low cost is important and it is unlikely that the network will expand. Which network topology would you recommend and why?

2. Which topology would you recommend for a network that will be reconfigured frequently, must be very reliable, and is easy to troubleshoot without bringing down the entire network? Why?

3. You are designing a network for an automobile factory. There are lots of motors and fluorescent lights. Cost is not a factor. Each of the workstations must have equal access to the network. Which topology would you choose? Why?

4. Refer to question number 3. Which type of cable would you recommend for this network? Why?

Scoring

Rubric: Suggested Evaluation Criteria and Weightings

Criteria	%	Your Score
Part A: Identify and describe the elements that are recommended for structured cabling networks	25	
Part B: Diagram and explain bus, star, ring, and hybrid topologies.	25	
Part C: Compare and contrast the advantages and disadvantages of bus, star, ring, and hybrid topologies.	25	
Part D: Select the appropriate topology for a particular set of network requirements	25	
TOTAL	**100**	
Try It Out Diagram and explain bus, star, ring, and hybrid topologies.	**100**	
Stretch Yourself	**100**	
Network Wizards Questionnaire and estimate	**100**	
FINAL TOTAL	**400**	

References

Aschermann, Robert (1998). <u>MCSE Networking Essentials for Dummies.</u> *IDG Books Worldwide, Inc.* Foster City, California.

Bert, Glen (1998). <u>MCSE Networking Essentials: Next Generation Training</u> Second Edition. *New Riders Publishing* Indianapolis, Indiana.

Carol, J. T. & Love, R.D. (1995). Dedicated Token Ring. In <u>The Token Ring Consortium Report </u> [Online]. *University of New Hamphsire InterOperability Labs*. Available: www.iol.unh.edu/consortiums/tokenring/MACs_n_PHYs/Fall95/Special_Feature.html. [1999, April 30].

Chellis, James; Perkins, Charles; & Strebe, Matthew (1997). *MCSE* <u>Networking Essentials Study Guide</u>. *Sybex Inc.,* Alameda, California.

Derfler, Jr., Frank J., & Freed, L. (1998). <u>How Networks Work</u>, Fourth Edition. *Macmillan Computer Publishing/Que Corporation,* Indianapolis, Indiana.

Hayden, Matt. (1998). Sam's Teach Yourself Networking in 24 Hours. *Sam's Publishing,* Indianapolis, Indiana.

HDS Network Systems, Inc. (1996). IEEE 802.3 Ethernet type. In HDS @workStation System Administrator's Guide [Online]. Available: www.rzu.unizh.ch/nw/lwp/xhds/hdsdocs/netOS20/htmlsysadmin [1999, May 13].

Lantronix. (1999). Ethernet Tutorial. In Technology Tutorials [Online]. Available: www.lantronix.com/technology/tutorials [1999, April 20].

Lindsay, S., Rosenblum, D. & Walleigh, W. (1998). Token Ring Switching. In Technology [Online]. 3Com Corporation. Available: www.3com.com/nsc/500603.ntml [1999, April 30].

Lowe, Doug. (1998). Networking for Dummies. Third Edition. IDG Books Worldwide, Inc., Foster City, California.

Microsoft Corporation (1998). Dictionary of Computer Terms, *Microsoft Press*, Redmond, Washington.

Nortel Networks (1998). Internetworking Fundamentals: Student Guide. *Bay Networks Inc*. Billerica, Massachusetts.

Palmer, Michael J. (1998) Hands-On Networking Essentials with Projects, *Course Technology*, Inc. Cambridge, Massachusetts.

Spurgeon, Charles E. (1997). Practical Networking With Ethernet, *International Thomson Computer Press,* Boston, Massachusetts.

Spurgeon, Charles. (1993-1995). Quick Reference Guide to Ethernet [Online]. University of Texas Office of Telecommunications. Available: www.ots.utexas.edu/ethernet/descript-10quickref.html [1999, April 20].