Chapter 3: Cabling and Topology

Learning Objectives

This chapter introduces students to the concept of network topologies, and how they apply to the physical connections as well as to the flow of signals in a network. Then they will explore the different types of network cabling. The chapter closes with an overview of the industry-wide standards that promote the use and implementation of technology. At the end of this chapter, the student should be able to

- Explain the various types of network topology
- Describe the various types of network cabling
- Describe the IEEE networking standards

Estimated Time for Module: 1 to 2 hours

Preparing for Class

Instructors should have a good understanding and knowledge base of the CompTIA Network+ Exam in general. Specifically, the instructor should be well versed in the objectives of this chapter, especially in explaining the types of topologies, physical cables, and IEEE standards. Help the students to understand that the information studied in this chapter is standard, and applies to all networks, regardless of operating system.

Prerequisites for Class

Ensure that the students are

- In a computer lab, if possible, for access to the Internet
- Arranged in the classroom advantageously to ensure maximum participation
- Fundamentally sound with networking fundamentals

Class Preparation Notes

For this class the students will need
Key Terms

bandwidth  The maximum amount of data that can go through a cable.

BNC connectors  Bayonet-style connectors used to connect coaxial cable to computers.

bus topology  A network topology in which all computers connect to the network via a single cable that connects all of the computers in line.

category (CAT) rating  A rating system that grades cables based on the highest frequency in megahertz (MHz) a cable can handle, which, in turn, helps network installers get the right cable for the right network technology.

cladding  The part of a fiber-optic cable that makes the light reflect down the fiber.

coaxial cable  A type of cable that contains a central conductor wire surrounded by an insulating material, surrounded by a braided metal shield, which together effectively shield data transmissions from electromagnetic interference.

core  In fiber-optic cable, the glass fiber at the center of the cable.

crosstalk  Interference experienced on one cable or channel from signals transmitted on a neighboring cable or channel.

electromagnetic interference (EMI)  An electrical current generated along a network wire when a metal wire encounters the magnetic fields generated by items within an office.

fault tolerance  The ability to survive a failure.

fiber-optic cable  Transmits light rather than electricity, making it very attractive for both high-EMI areas and long-distance transmissions.

fully meshed topology  A mesh topology in which every computer connects directly to every other computer.
hybrid topology Any form of network topology that combines a physical topology with a signaling topology.

Institute of Electrical and Electronics Engineers (IEEE) The organization that establishes and promotes standards, including networking standards.

IEEE 1284 An IEEE committee that sets the standards for parallel communication.

IEEE 1394 An IEEE committee that sets the standards for a type of point-to-point connection often referred to as FireWire.

insulating jacket The outer part of a fiber-optic cable.

mesh topology A network topology in which every computer connects to every other computer via two or more routes, making mesh topology the most fault tolerant.

modal distortion A problem unique to multimode fiber-optic cables that use LEDs as the light source for the signal.

multimode Fiber-optic cable that uses LEDs as the light source for the signal.

network topology Describes how cables and other pieces of hardware connect to each other in a network.

Ohm rating A relative measurement of impedance on a cable.

partially meshed topology A network topology in which at least two machines have redundant connections, but in which every machine doesn’t have to connect to every other machine.

physical topology How cables physically connect networked components.

plenum The space between the acoustical tile ceiling in an office building and the actual concrete ceiling above; also used to indicate plenum-rated cable, which creates much less smoke and fumes when burned than other cabling types.

point-to-multipoint topology A topology in which a single system acts as a common source through which all members of the network converse.

point-to-point topology A topology in which two computer connect directly together with no need for a central hub or box of any kind.
polyvinyl chloride (PVC)  A cabling fire rating assigned to cable made from polyvinyl chloride and which has no significant fire protection, creating lots of smoke and noxious fumes when it burns.

RG rating  A rating for coaxial cable developed by the U.S. military.

ring topology  A topology that connects all computers on the network with a central ring of cable.

riser  A fire rating that designates the proper cabling to use for vertical runs between floors of a building, indicating that the cable provides less protection than plenum-rated cabling.

RJ-11  A registered jack (RJ) connector used for telephones, designed to support up to two pairs of wires.

RJ-45  A registered jack (RJ) connector used for computer networks, designed to support up to four pairs of wires.

RS-232  A recommended (RC) standard for serial cabling that dates from 1969. The most common RS-232 connector is a 90pin, male D-subminiature connector.

segment  A portion of a network in which all devices are directly connected to common physical-layer components, such as a hub or repeater. [Note definition is an enhancement to that provided within Chapter 3.]

shielded twisted pair (STP)  Consists of twisted pairs of wires surrounded by shielding to protect them from EMI.

signaling topology  How the signals travel electronically in a network.

single-mode  A designation for fiber-optic cable that uses lasers to generate the signal.

star topology  A network topology in which the computers on the network connect to a central wiring point (usually called a hub).

star-bus topology  A network topology that uses a physical star design, while the actual signals travel on a bus.
star-ring topology  A network topology that uses a physical star design, while the actual signals travel on a ring.

unshielded twisted pair (UTP)  A commonly used type of cabling consisting of twisted pairs of wires without shielding to protect the wires from EMI.

Lecture Outline

I. Topology

   A. Bus and Ring

      1. Bus topology: All computers connect in a line via a single cable.

      2. Ring topology: All computers attach to a central ring of cable.

      3. Problem: with both topologies, if the cable breaks, the entire network stops working.

   B. Star

      1. The computers connect to a central wiring point (hub)

      2. Offers fault tolerance not available with bus or ring

   C. Hybrids

      1. Hybrid topology combines a physical topology (usually star) with a signaling topology such as ring or bus.

      2. Star-ring: ring shrunk into a small box to which computers connect in a physical star (when viewed from outside the box).

      3. Star-bus: bus shrunk into a small box to which computers connect in a physical star (when viewed from outside the box).

   D. Mesh and Point-to-Multipoint

      1. Mesh

         i. Each computer connects to every other computer via two or more routes.
ii. Partially meshed topology: at least two machines have redundant connections. Every machine doesn’t have to connect to every other.

iii. Fully meshed topology: Every computer connects directly to every other computer.

iv. Fully meshed topology very expensive, yet impractical if using physical wire.

v. Very practical and often used in wireless networks.

vi. Formula to calculate the number of connections needed to make a fully meshed network, given a certain number of computers:

\[
y = \text{number of computers} \\
\text{number of connections} = \frac{y(y-1)}{2}
\]

**Teaching Tip**

First, define a “connection” as the means of communicating directly between two computers. For a wired mesh network, you can use the term “cables.” Then, have the students calculate the total number of connections needed to make a fully meshed network, given a certain number of computers. Then ask them why the number of connections is significant. They should conclude that in a wired network, this would require several (four in Figure 3-10) network cards in each computer to complete the connections. This leads to the point that mesh networks are normally used for wireless networks.

2. Point-to-Multipoint

i. Single system acts as a common source through which all members of the network converse.

ii. Differs from star topology in that an intelligent device is in the center, while star topology only has a device that can send a signal to all connections.
iii. Mesh or point-to-multipoint are more commonly used in wireless networks

E. Point-to-Point

1. Two computers connected directly together without a central hub or box.

2. Used in both wired and wireless networks.

F. Parameters of a Topology

1. Topology alone does not describe all features necessary to enable a network.

2. Network technology is a practical application of a topology and other critical technologies required to provide a method to get data from one computer to another.

   i. Examples of network technologies (details in the next two chapters)

      a. 10BaseT
      b. 1000BaseF
      c. 10GBaseLX

II. Cabling

A. Coaxial Cable

1. Contains a central conductor wire surrounded by an insulating material, which is surrounded by a braided metal shield

2. Referred to as coaxial (coax for short) because the center wire and the braided metal shield share a common axis or center line

3. Shields data transmissions from EMI

4. Coaxial cable connector

   i. BNC connectors: bayonet-style
ii. Vampire taps: pierce the cable

iii. F-type connector:
   a. Screw connector
   b. Used on cable Modems and televisions

5. Types of coax
   i. RG ratings developed by U.S. military
   ii. Only important measure of coax cabling is Ohm rating
      a. Ohm ratings printed on the cables
      b. RB-6 and RG-59 are rated at 75 Ohms

6. Easy to split coaxial cable to accommodate both television and Internet

7. Extend coaxial cabling with barrel connectors

B. Twisted pair
   1. The most common type of networking cable used today
   2. Composed of multiple pairs of wires twisted around each other at specific intervals
      i. Twists serve to reduce interference, called crosstalk
      ii. The more twists, the less crosstalk
   3. Shielded twisted pair (STP)
      i. Twisted pairs of wires are surrounded by shielding to protect them from EMI
      ii. Used in locations with excessive electronic noise
STP is used today for cable that is run in walls and into ceilings, because both areas have other items that can cause extreme EMI, such as lights, heating and air ducts, motors, and so on.

4. Unshielded twisted pair (UTP)
   i. Most common type of twisted-pair cabling used today
   ii. Other technologies (telephones) use UTP
   iii. Telephone has two pairs (four wires)
   iv. Network has four pairs (eight wires)

5. Category (CAT) ratings
   i. Rated in MHz: Each cycle (hertz) accounts for one bit of data
   ii. Maximum amount of data per second is called the bandwidth
   iii. CAT 3 max frequency 16 MHz, Max Bandwidth 16 Mbps in older existing network installations
   iv. CAT 5 max frequency 100 MHz, max bandwidth 100 Mbps, also in older existing network installations
   v. CAT 5e max frequency 100 Mbps, max bandwidth 1000 Mbps, in more recent networks
   vi. CAT 6 max frequency 250 MHz, max bandwidth 10000 Mbps, in most recent networks
   vii. Bandwidth-efficient encoding schemes squeeze more bits into same signal
        a. Enables CAT 5e cable, at 100 MHz, to handle 1000 Mbps
C. Fiber-Optic

1. Transmits light rather than electricity

2. Has four components: the fiber, cladding, buffer material, and insulating jacket

3. Can reach up to tens of kilometers

4. The most common fiber-optic cable size is 62.5/125 µm

**Teaching Tip**

*Point out the note on page 53 regarding symbol “µ,” (Greek letter “Mu”). As it says, this represents the value 1/1,000,000. Therefore, “µm” represents 1/1,000,000 of a meter, or a micrometer.*

5. Most network technologies that use fiber-optic require pairs of fibers

   i. One fiber for sending

   ii. Another fiber for receiving

6. Light can be sent down a fiber-optic cable as regular light or as laser light

   i. Fiber-optic cables that use LEDs are known as *multimode*

      a. Subject to modal distortion problem

      b. Transmit 850-nm wavelength

   ii. Fiber-optic cables that use lasers are known as *single-mode*

      a. Transmit 1350-nm or 1550-nm wavelength

   iii. Wavelength of light used is measured in nanometers.
Teaching Tip

Ask students if they are familiar with the term “nanometer” or “nm.” A nanometer (nm) measures one billionth of a meter.

7. Connector types on CompTIA Network+ exam
   i. ST
   ii. SC
   iii. LC: a duplex connector for two fiber cables

Teaching Tip

The Tech Tip on page 53 may be the students’ best hope for remembering the fiber-optic connector types for the exam. The explanation matches up nicely with Figure 3.28. If you do not have lengths of fiber-optic cable as examples, tell the students that any well-stocked computer store will have this cable in stock for them to see. A trip to the store is educational in this case.

D. Other Cables

1. Classic Serial
   i. RS-232
      a. Recommend Standard (RS), dating to 1969
      b. Most common: 9-pin, male D-subminiature connector
      c. Slow: only about 56,000 bps
      d. Only for point-to-point connections
      e. Rarely found on new PCs

2. Parallel
   i. Almost as old as RS-232
   ii. Up to 2 Mbps
iii. Limited to point-to-point topology

iv. 25-pin female DB type connector

v. IEEE 1284 committee sets standards for parallel

3. FireWire

i. Based on the IEEE 1394 standard

ii. Only viable alternative cabling option to fiber-optic or UTP

iii. Restricted to point-to-point connections (not supported by Windows Vista)

iv. Very fast (up to 800 Mbps)

v. Unique connector

**Teaching Tip**

*It may be too soon to mention this, but you can also use UTP for point-to-point connections. For instance, you can connect two computers directly (point-to-point) via the Ethernet connector on each computer. This means that no hub or switch is required. The trick is in using a cross-over cable.*

E. Fire Ratings

1. Developed by Underwriters Laboratories

2. Developed to reduce risk of network cables burning and creating noxious fumes and smoke

3. Two most common fire ratings

i. Polyvinyl chloride (PVC)

   a. No significant fire protection

   b. When burned creates lots of smoke and noxious fumes

ii. Plenum-rated cable
a. Creates much less smoke and fumes
b. Costs about 3 to 5 times as much as PVC-rated cable.
c. Required by most city ordinances

4. Riser-rated cabling used for vertical runs between floors

III. Network Industry Standards: IEEE

A. Defines industry-wide standards that promote the use and implementation of technology

B. IEEE 802

1. Defines frames, speed, distances, and types of cabling to use in a network environment

2. Sets the standards for networking

3. Divided into subcommittees (802.3, 802.5, etc.)

Teaching Tip

Refer to Table 3.2 for the currently recognized IEEE 802 subcommittees and their areas of jurisdiction. You may also want to ask the students to go online at www.ieee.org Web site and read more about how the different subcommittees are working on establishing standards.

Chapter Review

Teaching Tip

The following directly maps to the Summary in the Chapter. In some cases, the bulleted items are briefer than in the book; an additional note in brackets follows some items.

Explain the Different Types of Network Topology

- A network’s topology describes how computers connect to each other in that network.
  The most common network topologies are called bus, ring, star, and mesh.
In a bus topology, all computers connect to the network via a main line.

In a ring topology, all computers on the network attach to a central ring of cable.

In a star topology, the computers on the network connect to a central wiring point, which provides fault tolerance.

Modern networks use one of two hybrid topologies: star bus or star ring. Star bus is overwhelmingly the most common topology used today.

In a mesh topology, each computer has a dedicated line to every other computer. Mesh networks can be further categorized as partially meshed or fully meshed. [Ask the students to provide the formula for calculating the number of connections in a fully meshed network, found on page 42]

In a point-to-multipoint topology, a single system acts as a common source through which all members of the network converse.

Mesh and point-to-multipoint topologies are common among wireless networks.

In a point-to-point topology, two computers connect directly together.

Describe the Different Types of Network Cabling

Coaxial cable, or coax, shields data transmissions from EMI. Coax was widely used in early bus networks and it used BNC connectors.

Coax cables have an RG rating, with RG-6 being the predominant coax in use today.

Twisted pair cabling, which comes shielded or unshielded, is the most common type of networking cable today. UTP is less expensive and more popular than STP, thought it doesn’t offer any protections from EMI.

UTP is classified by its CAT rating, with CAT 5, CAT 5e, and CAT 6 being the most commonly used today.

Telephones use RJ-11 connectors, while UTP uses RJ-45 connectors.
Fiber-optic cable transmits light instead of the electricity used in CAT cable or coax. It is thin and more expensive, yet less flexible and more delicate, than other types of network cabling.

There are two types of fiber-optic cable based on what type of light is used. LEDs require multimode cable, while lasers generally require single-mode cable.

All fiber-optic cable has three parts: the fiber itself, the cladding, and the outer insulating jacket. Additionally, there are over one hundred types of connectors for fiber-optic cable, but ST, SC, and LC are the most common for computer networking.

Plenum-rated UTP is required by most cities for network installations.

Serial cables adhering to the RS-232 standard, and parallel cables adhering to the IEEE-1284 standard, may be used to network two computers directly together. You can also use IEEE 1394 (FireWire) connections for direct connection, although not with Windows Vista.

Describe the IEEE Networking Standards

Networking standards are established and promoted by the Institute of Electrical and Electronics Engineers (IEEE).

The IEEE 802 committee defines frames, speeds, distances, and types of cabling to use in networks. IEEE 802 is split into several subcommittees, indicated by a suffix of a dot, followed by the subcommittee number, such as IEEE 802.3 and IEEE 802.11.

The IEEE 1284 committee defines the standards for parallel communications, while the IEEE 1394 committee defines the standards for FireWire High-Performance Serial Bus.

Key Terms Quiz

Questions

1. A network topology where all computers connect to the network via a main line is called a _____________________.

2. ____________ is the ability to survive a problem.

3. The most commonly used type of network cabling, consisting of twisted pairs of wires, but no shielding, is ________________.

4. A network topology where the computers on the network connect to a central wiring point (usually called a hub) is a ________________.

5. A ________________ uses a physical star design that provides improved reliability and a logical bus to maintain compatibility with existing bus topology.

6. ________________ is the designation for fiber-optic cable that uses lasers to generate the signal.

7. A(n) ________________ is a relative measurement of impedance on a cable.

8. A topology that is the most fault tolerant, and has the most redundancy, is a ________________ topology.

9. A ________________ is a cable rating in megahertz that help network installers get the right cable for the right network technology.

10. The part of a fiber-optic cable that makes the light reflect down the fiber is the ________________.

**Answers**

1. A network topology where all computers connect to the network via a main line is called a *bus topology*

2. *Fault tolerance* is the ability to survive a problem.

3. The most commonly used type of network cabling, consisting of twisted pairs of wires, but no shielding, is *unshielded twisted pair (UTP)*.

4. A network topology where the computers on the network connect to a central wiring point (usually called a hub) is a *star topology*.

5. A *star bus topology* uses a physical star design that provides improved reliability and a logical bus to maintain compatibility with existing bus topology.
6. *Single-mode* is a designation for fiber-optic cable that uses lasers to generate the signal.

7. A(n) *Ohm rating* is a relative measurement of impedance on a cable.

8. A topology that is the most fault tolerant and has the most redundancy is a *fully meshed* topology.

9. A *category CAT rating* is a cable rating in megahertz that help network installers get the right cable for the right network technology.

10. The part of a fiber-optic cable that makes the light reflect down the fiber is the *cladding*.

**Lab Projects**

**Lab Project 4.1**

Using the information you have learned regarding networking topologies, create a table, and list the advantages and disadvantages to each one. Be sure to include bus, ring, star, partially meshed, fully meshed, point-to-multipoint, and point-to-point topologies.

**Lab Project 4.2**

Do some research about the various IEEE subcommittees in existence. Choose one of the 802 committees, and write a one-page report explaining that particular committee’s purpose and how it applies to the world of networking.

**Lab Project Solutions**

**Lab Project 4.1 Solution**

Tables will vary between students based on what they feel the advantages and disadvantages are. However, they should resemble the following:

<table>
<thead>
<tr>
<th>Topology</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>Inexpensive early solution.</td>
<td>Fails if not properly terminated. If one point</td>
</tr>
<tr>
<td></td>
<td>Simple network only,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Requires proper network cards and cabling. A small network does not require other special equipment. [The chapter did not explicitly state this.]</td>
<td>Breaks, the entire network fails.</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Ring</td>
<td>Does not need termination.</td>
<td>If one point breaks, the entire network fails.</td>
</tr>
<tr>
<td>Star</td>
<td>Fault-tolerant: if one cable breaks, all the other computers can still communicate.</td>
<td>Old-style star (before the advent of hubs containing the bus or ring) was not adopted for sites that already had a bus or ring network in place.</td>
</tr>
<tr>
<td>Star-ring hybrid</td>
<td>Adds advantage of star fault tolerance to a ring network.</td>
<td>[Not mentioned in chapter: uses more cable than ring.]</td>
</tr>
<tr>
<td>Star-bus hybrid</td>
<td>Adds advantage of star fault tolerance to a bus network.</td>
<td>[Not mentioned in chapter: uses more cable than simple bus topology.]</td>
</tr>
<tr>
<td>Partially meshed</td>
<td>Every machine does not have to connect to every other machine.</td>
<td>At least two computers must have redundant connections. Requires lots of cables. Not practical for a cabled network.</td>
</tr>
<tr>
<td>Full meshed</td>
<td>Lots of redundancy for fault tolerance.</td>
<td>Requires lots of cables, and lots of connections. Extremely unpractical for a cabled network.</td>
</tr>
</tbody>
</table>
### Point-to-multipoint

| Similar to star, with intelligent device in the middle. Devices can communicate with more than one other network segment. | Requires lots of cables, and lots of connections. Extremely unpractical for a cabled network. |

### Point-to-point

| No need for a central hub. | Can only connect two computers (or devices). |

---

**Lab Project 4.2 Solution**

This information will vary per student based on what 802 subcommittee they choose to write about. The IEEE publishes information on these various subcommittees at their Website, www.ieee802.org/. Find specific information by appending the subcommittee suffix (found in Table 3.2) to the end of the url. For instance, to learn about the 802.22 subcommittee, simply add “/22” to the end of the URL: http://www.ieee802.org/22/. For additional information, enter the full subcommittee identifier into any Internet search engine.