Chapter 3

Underlying Technology

TCP/IP
Protocol Suite
Fourth Edition

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OBJECTIVES:

❑ **To briefly discuss the technology of dominant wired LANs, Ethernet, including traditional, fast, gigabit, and ten-gigabit Ethernet.**

❑ **To briefly discuss the technology of wireless WANs, including IEEE 802.11 LANs, and Bluetooth.**

❑ **To briefly discuss the technology of point-to-point WANs including 56K modems, DSL, cable modem, T-lines, and SONET.**

❑ **To briefly discuss the technology of switched WANs including X.25, Frame Relay, and ATM.**

❑ **To discuss the need and use of connecting devices such as repeaters (hubs), bridges (two-layer switches), and routers (three-layer switches).**
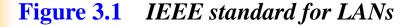
Chapter Outline

3-1 WIRED LOCAL AREA NETWORKS

A local area network (LAN) is a computer network that is designed for a limited geographic area such as a building or a campus. Although a LAN can be used as an isolated network to connect computers in an organization for the sole purpose of sharing resources, most LANs today are also linked to a wide area network (WAN) or the Internet.

The LAN market has seen several technologies such as Ethernet, token ring, token bus, FDDI, and ATM LAN, but Ethernet is by far the dominant technology.

Topics Discussed in the Section

- ✓ **IEEE Standards**
- ✓ **Frame Format**
- ✓ **Addressing**
- ✓ **Ethernet Evolution**
- ✓ **Standard Ethernet**
- ✓ **Fast Ethernet**
- ✓ **Gigabit Ethernet**
- ✓ **Ten-Gigabit Ethernet**

Figure 3.1 IEEE standard for LANs

LLC: Logical link control
MAC: Media access control
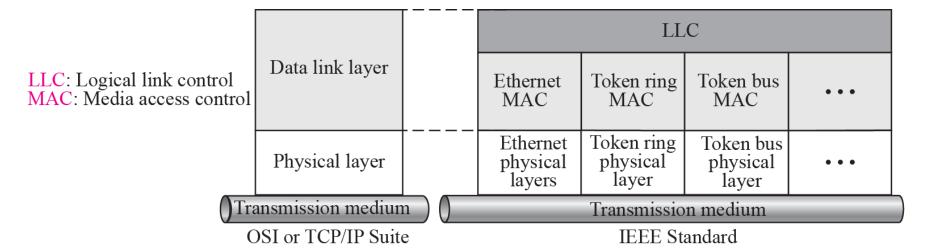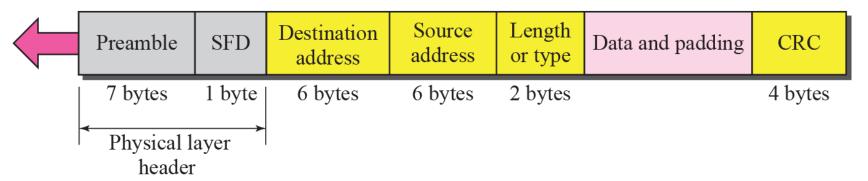

OSI or TCP/IP Suite   IEEE Standard

Figure 3.2   *Ethernet Frame*

Preamble: 56 bits of alternating 1s and 0s.

SFD: Start frame delimiter, flag (10101011)

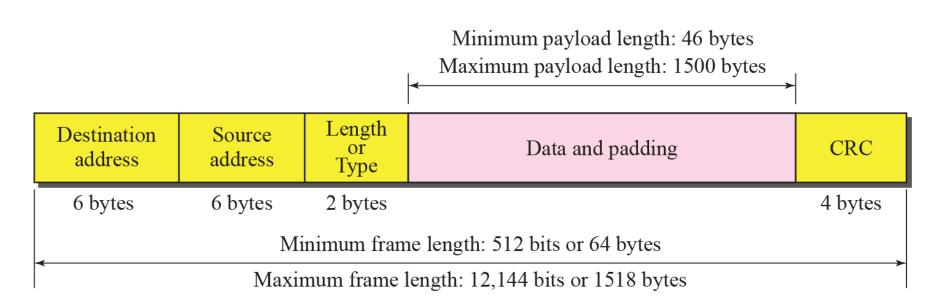| Preamble	SFD	Destination address	Source address	Length or type	Data and padding	CRC
7 bytes	1 byte	6 bytes	6 bytes	2 bytes		4 bytes

Physical layer
header

❑ **Preamble.** The first field of the 802.3 frame contains 7 bytes (56 bits) of alternating 0s and 1s that alerts the receiving system to the coming frame and enables it to synchronize its input timing.

❑ **Start frame delimiter (SFD).** The second field (1 byte: 10101011) signals the beginning of the frame. The SFD warns the station or stations that this is the last chance for synchronization.

❑ **Destination address (DA).** The DA field is 6 bytes and contains the physical address of the destination station or stations to receive the packet.

Figure 3.2 *Ethernet Frame*

❑ **Source address (SA).** The SA field is also 6 bytes and contains the physical address of the sender of the packet.

❑ **Length or type**. This field is defined as a type field or length field. The original Ethernet used this field as the type field to define the upper-layer protocol using the MAC frame.

❑ **Data.** This field carries data encapsulated from the upper-layer protocols. It is a minimum of 46 and a maximum of 1500 bytes.

❑ **CRC.** The last field contains error detection information.

Figure 3.3 *Maximum and minimum lengths*

Minimum payload length: 46 bytes
Maximum payload length: 1500 bytes

Destination address	Source address	Length or Type	Data and padding	CRC
6 bytes	6 bytes	2 bytes		4 bytes

Minimum frame length: 512 bits or 64 bytes
Maximum frame length: 12,144 bits or 1518 bytes

Note

Minimum length: 64 bytes (512 bits)
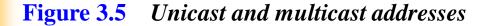
Maximum length: 1518 bytes (12,144 bits)
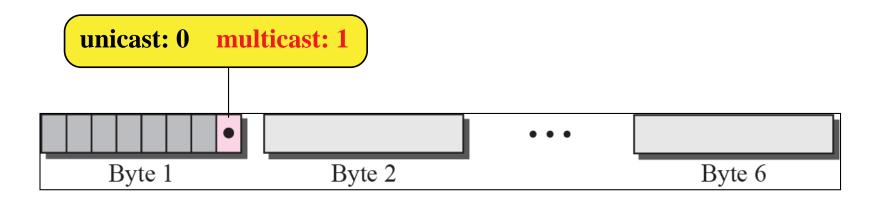
Figure 3.4 *Ethernet address in hexadecimal notation*

d: Hexadecimal digit

$$d_1 d_2 : d_3 d_4 : d_5 d_6 : d_7 d_8 : d_9 d_{10} : d_{11} d_{12}$$

6 bytes = 12 hexadecimal digits = 48 bits

Figure 3.5 *Unicast and multicast addresses*

unicast: 0   multicast: 1

Byte 1   Byte 2   . . .   Byte 6

❖ **A unicast destination address**: defines only one recipient; the relationship between the sender and the receiver is one-to-one.

❖ **A multicast destination address:** defines a group of addresses; the relationship between the sender and the receivers is one-to-many.

❖ **The broadcast address:** is a special case of the multicast address; the recipients are all the stations on the LAN. A broadcast destination address is forty-eight 1s.

Note

The broadcast destination address is a special case of the multicast address in which all bits are 1s.

Note

The least significant bit of the first byte defines the type of address. If the bit is 0, the address is unicast; otherwise, it is multicast.

Example 3.1

Define the type of the following destination addresses:
- a. 4A:30:10:21:10:1A
- b. 47:20:1B:2E:08:EE
- c. FF:FF:FF:FF:FF:FF

Solution

To find the type of the address, we need to look at the second hexadecimal digit from the left. If it is even, the address is unicast. If it is odd, the address is multicast. If all digits are F's, the address is broadcast. Therefore, we have the following:
- a. This is a unicast address because A in binary is 1010   (even).
- b. This is a multicast address because 7 in binary is 0111   (odd).
- c. This is a broadcast address because all digits are F's.
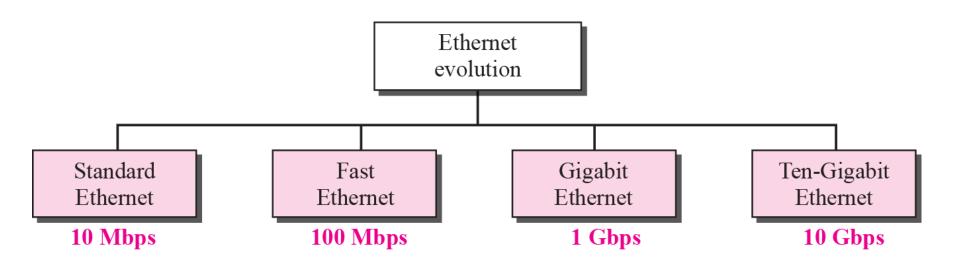
Example 3.2

Show how the address 47:20:1B:2E:08:EE is sent out on line.

Solution

The address is sent left-to-right, byte by byte; for each byte, it is sent right-to-left, bit by bit, as shown below:

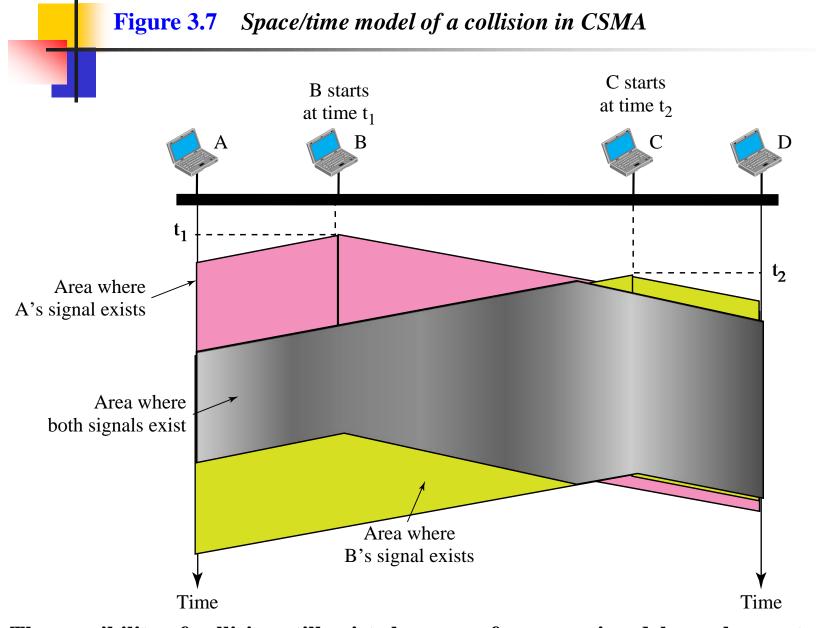←   11100010 00000100 11011000 01110100 00010000 01110111

Figure 3.6 *Ethernet evolution through four generations*

Ethernet evolution

| Standard Ethernet | Fast Ethernet | Gigabit Ethernet | Ten-Gigabit Ethernet |
| 10 Mbps | 100 Mbps | 1 Gbps | 10 Gbps |

The IEEE 802.3 standard defines carrier sense multiple access with collision detection **(CSMA/CD)** as the access method for traditional Ethernet. Stations on a traditional Ethernet can be connected together using a physical bus or star topology, but the logical topology is always a bus. By this, we mean that the medium (channel) is shared between stations and only one station at a time can use it. In this situation, how can we be sure that two stations are not using the medium at the same time? If they do, their frames will collide with each other.

Carrier sense multiple access (CSMA), requires that each station first listen to the medium (or check the state of the medium) before sending. In other words, CSMA is based on the principle "sense before transmit" or "listen before talk." CSMA can reduce the possibility of collision, but it cannot eliminate it.

Figure 3.7   Space/time model of a collision in CSMA

The possibility of collision still exists because of propagation delay; when a station sends a frame, it still takes time (although very short) for the first bit to reach every station and for every station to sense it.

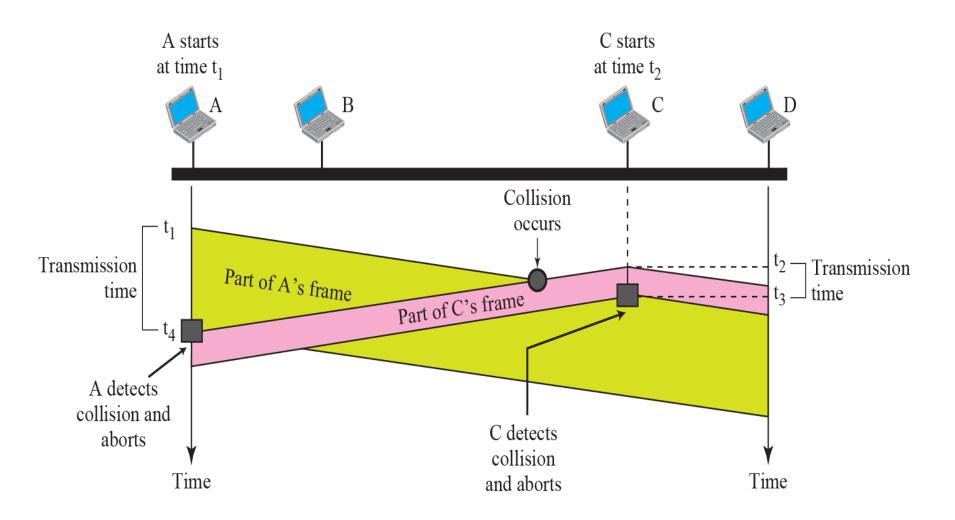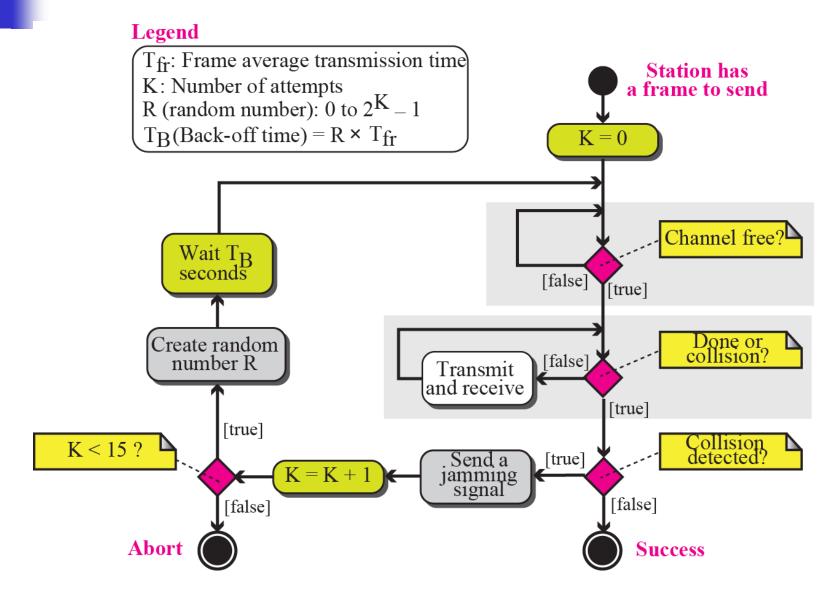**Figure 3.8** *Collision of the first bit in CSMA/CD*
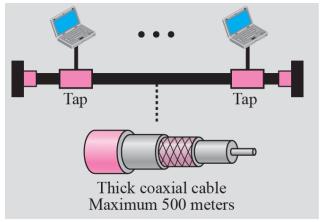
Figure 3.9 *CSMA/CD flow diagram*

Legend

T_{fr}: Frame average transmission time
K: Number of attempts
R (random number): 0 to $2^K - 1$
T_B (Back-off time) = $R \times T_{fr}$

Station has a frame to send

$K = 0$

Channel free?

[false]   [true]

Done or collision?

Transmit and receive

[false]

[true]

Wait T_B seconds

Create random number R

[true]

$K < 15$?

[false]

$K = K + 1$

Send a jamming signal

[true]

Collision detected?

[false]

Abort

Success

❖**Base** means baseband (digital), **signal X** approximately defines either the maximum size of the cable in 100 meters (for example 5 for 500 or 2 for 185 meters) or the type of the cable, **T** for unshielded twisted pair cable (UTP) and **F** for fiber-optic.
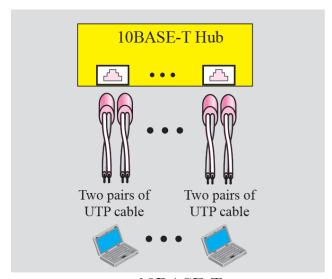
Table 3.1 *Summary of Standard Ethernet implementations*

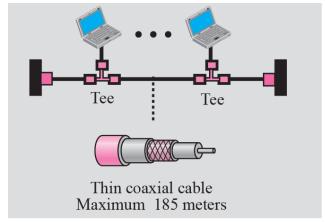| Characteristics	10Base5	10Base2	10Base-T	10Base-F
Medium	Thick coax	Thin coax	2 UTP	2 Fiber
Maximum length	500 m	185 m	100 m	2000 m

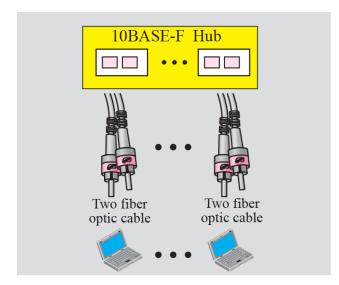# Figure 3.10 *Standard Ethernet implementation*

a. 10BASE5

b. 10BASE2

c. 10BASE-T

d. 10BASE-F

Fast Ethernet (100 Mbps)

❖ Fast Ethernet was designed to compete with LAN protocols such as FDDI or Fiber Channel. IEEE created Fast Ethernet under the name **802.3u.**

Table 3.2 *Summary of Fast Ethernet implementations*

Characteristics	100Base-TX	100Base-FX	100Base-T4
Media	STP	Fiber	UTP
Number of wires	2	2	4
Maximum length	100 m	100 m	100 m

❖ **The goals of Fast Ethernet can be summarized as follows:**
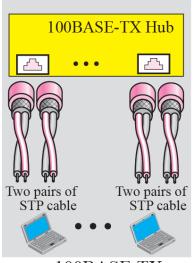 1. Upgrade the data rate to 100 Mbps.
  2. Make it compatible with Standard Ethernet.
  3. Keep the same 48-bit address.
  4. Keep the same frame format.
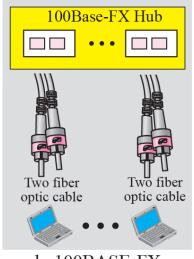 5. Keep the same minimum and maximum frame lengths.

Fast Ethernet (100 Mbps)

❖ A new feature added to Fast Ethernet is called **autonegotiation**. It allows two devices to negotiate the mode or data rate of operation.

❖ The access method is the same (CSMA/CD) for the half-duplex approach; for full-duplex Fast Ethernet, there is no need for CSMA/CD.

❖ The fast Ethernet drop the bus topologies and keep only the star topology. For the star topology, there are two choices: half duplex and full duplex. In the half-duplex approach, the stations are connected via a hub; in the full-duplex approach, the connection is made via a switch with buffers at
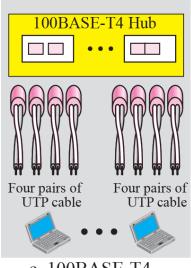
Figure 3.11   Fast Ethernet implementation

a. 100BASE-TX

b. 100BASE-FX

c. 100BASE-T4

Giga Ethernet (1 Gbps) :

❖ The need for an even higher data rate resulted in the design of the Gigabit Ethernet Protocol (1000 Mbps). The IEEE committee calls the Standard **802.3z.**

❖ **The goals of the Gigabit Ethernet design can be summarized as follows:**

1. Upgrade the data rate to 1 Gbps.
2. Make it compatible with Standard or Fast Ethernet.
3. Use the same 48-bit address.
4. Use the same frame format.
5. Keep the same minimum and maximum frame lengths.
6. To support auto-negotiation as defined in Fast Ethernet.

Giga Ethernet (1 Gbps) :

Note

In the full-duplex mode of Gigabit Ethernet, there is no collision; the maximum length of the cable is determined by the signal attenuation in the cable.
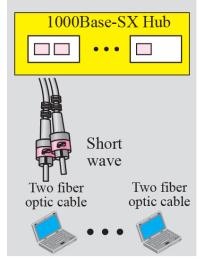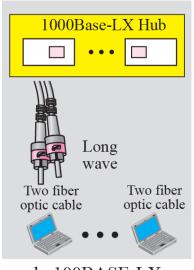
Giga Ethernet (1 Gbps) :

Table 3.3   *Summary of Gigabit Ethernet implementations*

Characteristics	1000Base-SX	1000Base-LX	1000Base-CX	1000Base-T4
Media	Fiber short-wave	Fiber long-wave	STP	Cat 5 UTP
Number of wires	2	2	2	4
Maximum length	550 m	5000 m	25 m	100 m
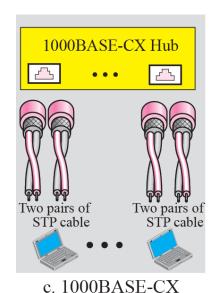
Figure 3.12   *Gigabit Ethernet implementation*

a. 1000BASE-SX

b. 100BASE-LX

c. 1000BASE-CX

d. 1000BASE-T4

Ten Giga Ethernet (10 Gbps):

❖ The IEEE committee created Ten-Gigabit Ethernet and called it Standard **802.3ae.**

❖ The goals of the Ten-Gigabit Ethernet design can be summarized as follows:
   1. Upgrade the data rate to 10 Gbps.
   2. Make it compatible with Standard, Fast, and Gigabit Ethernet.
   3. Use the same 48-bit address.
   4. Use the same frame format.
   5. Keep the same minimum and maximum frame lengths.
   6. Allow the interconnection of existing LANs into a metropolitan area network (MAN) or a wide area network (WAN).
   7. Make Ethernet compatible with technologies such as Frame Relay and ATM.

❖ Ten-Gigabit Ethernet operates only in full duplex mode, which means there is no need for contention; CSMA/CD is not used in Ten-Gigabit Ethernet.

Ten Giga Ethernet (10 Gbps):

❖ Ten-Gigabit Ethernet operates only in full duplex mode, which means there is no need for contention; CSMA/CD is not used in Ten-Gigabit Ethernet.

Table 3.4 *Ten-Gigabit Ethernet Implementation*

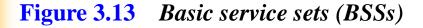| Characteristics	10GBase-S	10GBase-L	10GBase-E
Media	multi-mode fiber	single-mode fiber	single-mode fiber
Number of wires	2	2	2
Maximum length	300 m	10,000 m	40,000 m

3-2 WIRELESS LANS

Wireless communication is one of the fastest growing technologies. The demand for connecting devices without the use of cables is increasing everywhere. Wireless LANs can be found on college campuses, in office buildings, and in many public areas. In this section, we concentrate on two wireless technologies for LANs: IEEE 802.11 wireless LANs, sometimes called wireless Ethernet, and Bluetooth, a technology for small wireless LANs.
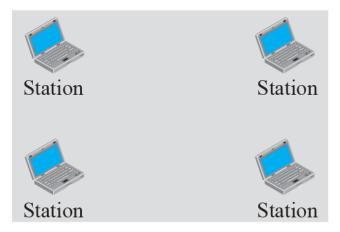
Topics Discussed in the Section

✓ **IEEE 802.11**

✓ **Bluetooth**

Wireless LAN (802.11)

❖ IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data link layers.

❖ The standard defines two kinds of services: the **basic service set (BSS) and the extended service set (ESS).** IEEE 802.11 defines the basic service set (BSS) as the building block of a wireless LAN.

➢ A basic service set is made of stationary or mobile wireless stations and an optional central base station, known as the **access point (AP).**

➢ The BSS without an AP is a stand-alone network and cannot send data to other BSSs. It is called an **ad hoc architecture**. In this architecture, stations can form a network without the need of an AP; they can locate one another and agree to be part of a BSS.

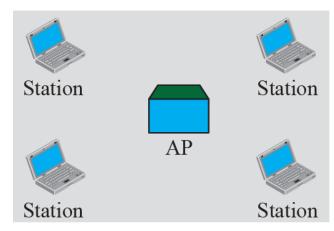❖ A BSS with an AP is sometimes referred to as an infrastructure network. Figure 3.13 shows two sets in this standard.

Figure 3.13   Basic service sets (BSSs)

BSS: Basic service set

Ad hoc network (BSS without an AP)

AP: Access point

Infrastructure (BSS with an AP)

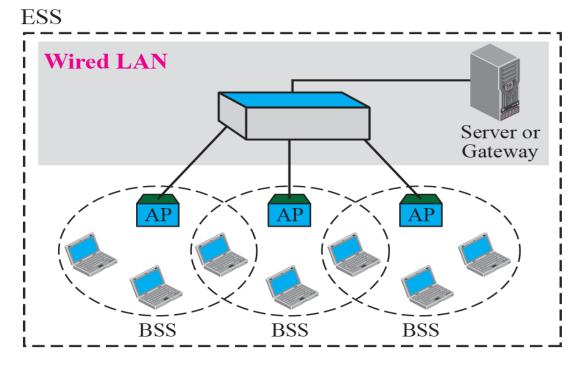**Figure 3.14   *Extended service sets (ESSs)***

Extended service set (ESS) is made up of two or more BSSs with APs. In this case, the BSSs are connected through a distribution system, which is usually a wired LAN. The distribution system connects the APs in the BSSs. IEEE 802.11 does not restrict the distribution system; it can be any IEEE LAN such as an Ethernet. Note that the extended service set uses two types of stations: mobile and stationary. The mobile stations are normal stations inside a BSS. The stationary stations are AP stations that are part of a wired LAN.

ESS

Wired LAN

ESS: Extended service set
BSS: Basic service set
AP: Access point

Server or Gateway

AP   AP   AP
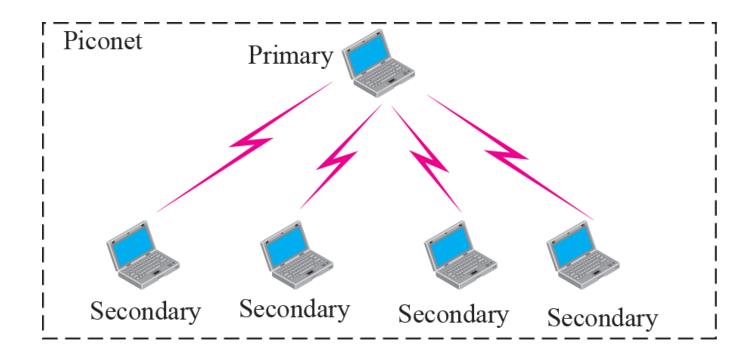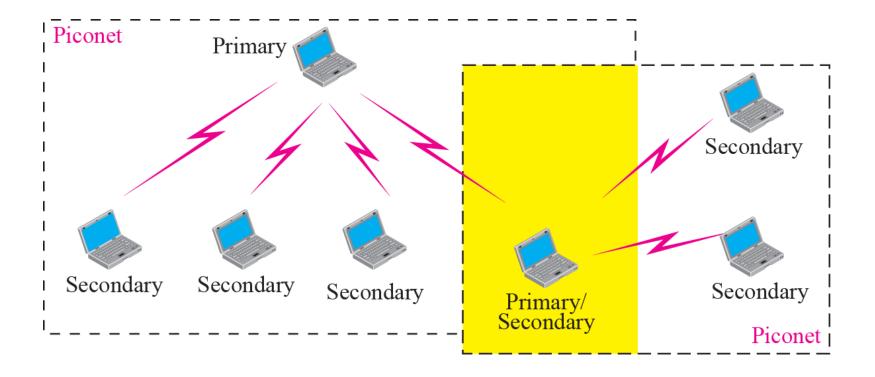
BSS   BSS   BSS

Wireless LANs (Bluetooth)

❖ **Bluetooth** is a wireless LAN technology designed to connect devices of different functions such as telephones, notebooks, computers (desktop and laptop), cameras, printers, coffee makers, and so on. A Bluetooth LAN is an ad hoc network, which means that the network is formed spontaneously; the devices, sometimes called gadgets, find each other and make a network called a piconet. A Bluetooth LAN can even be connected to the Internet if one of the gadgets has this capability. A Bluetooth LAN, by nature, cannot be large. If there are many gadgets that try to connect, there is chaos.

❖ Today, Bluetooth technology is the implementation of a protocol defined by the **IEEE 802.15 standard.** The standard defines a wireless personal area network (PAN) operable in an area the size of a room or a hall.

Wireless LANs (Bluetooth)

❖ Bluetooth defines two types of networks: **piconet and scatternet**:

➢ **Piconets**   A Bluetooth network is called a piconet, or a small net. A piconet can have up to eight stations, one of which is called the primary; the rest are called secondaries. All the secondary stations synchronize their clocks and hopping sequence with the primary. Note that a piconet can have only one primary station. The communication between the primary and the secondary can be one-to-one or one-to-many. Figure 3.23 shows a piconet.

➢ **Scatternet**   Piconets can be combined to form what is called a scatternet. A secondary station in one piconet can be the primary in another piconet. This station can receive messages from the primary in the first piconet (as a secondary) and, acting as a primary, deliver them to secondaries in the second piconet. A station can be a member of two piconets. Figure 3.24 illustrates a scatternet.

Figure 3.23   Piconet

Figure 3.24 *Scatternet*

3-3 POINT-TO-POINT WANS

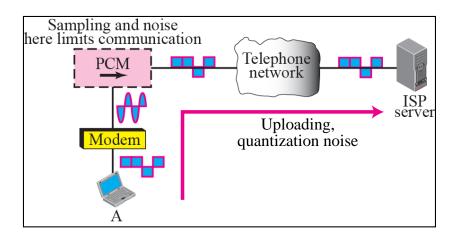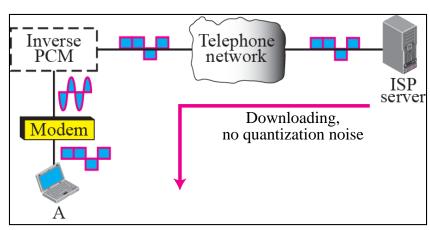A second type of network we encounter in the Internet is the point-to-point wide area network. A point-to-point WAN connects two remote devices using a line available from a public network such as a telephone network. We discuss traditional modem technology, DSL line, cable modem, T-lines, and SONET.

Topics Discussed in the Section

- ✓ **65K Modems**
- ✓ **DSL Technology**
- ✓ **Cable Modem**

POINT-TO-POINT WANS *(56K modem)*

❖ The maximum data rate in the uploading direction is 33.6 kbps, but the data rate in the downloading direction is 56 kbps.

❖ why 56 kbps? The telephone companies sample voice 8000 times per second with 8 bits per sample. One of the bits in each sample is used for control purposes, which means each sample is 7 bits. The rate is therefore 8000×7, or 56,000 bps or 56 kbps.

❖ **The DSL provide higher-speed access to the Internet. Digital subscriber line (DSL) technology is one of the most promising for supporting high-speed digital communication over the existing local loops (telephone line). DSL technology is a set of technologies, each differing in the first letter (ADSL, VDSL, HDSL, and SDSL). The set is often referred to as xDSL, where x can be replaced by A, V, H, or S.**

➢ **Asymmetric DSL (ADSL)** provides asymmetric(غيرمتماثل)communication. The downstream bit rate is much higher than the upstream bit rate. Although this feature meets the needs of most residential subscribers, it is not suitable for businesses that send and receive data in large volumes in both directions.

➢ **The symmetric digital subscriber line (SDSL)** is designed for these types of businesses. It divides the available bandwidth equally between the down-stream and upstream directions.

➢ **The very high bit rate digital subscriber line (VDSL),** an alternative approach that is similar to ADSL, uses coaxial, fiber-optic, or twisted-pair cable for short distances (300 to 1800 m).

Note

ADSL is an asymmetric communication technology designed for residential users; it is not suitable for businesses.

❖ DSL uses the existing unshielded twisted-pair cable, which is very susceptible to interference. This imposes an upper limit on the data rate. Another solution is the use of the **Cable TV network.**

❖ The traditional cable TV system used coaxial cable end to end.

❖ Cable TV started to distribute broadcast video signals to locations with poor or no reception.

3-4 SWITCHED WANS

The backbone networks in the Internet can be switched WANs. A switched WAN is a wide area network that covers a large area (a state or a country) and provides access at several points to the users. Inside the network, there is a mesh of point-to-point networks that connects switches. The switches, multiple port connectors, allow the connection of several inputs and outputs.

Switched WAN technology differs from LAN technology in many ways.

Topics Discussed in the Section

✓**X.25**

✓**Frame Relay**

✓**ATM**

WANS ITCHED WANS (X.25)

❖ **The X.25 protocol,** introduced in the 1970s, was the first switched WAN to become popular both in Europe and the United States. It was mostly used as a public network to connect individual computers or LANs. It provides an end-to-end service. **Although X.25 was used as the WAN to carry IP packets from one part of the world to another**, there was always a conflict between IP and X.25.

❖ The problem with X.25 is that it was designed at a time when transmission media were not very reliable (no use of optical fibers). For this reason, X.25 performs extensive error control. This makes transmission very slow and is not popular given the ever increasing demand for speed.

SWITCHED WANS (Frame Relay)

❖ The Frame Relay protocol, a switched technology that provides low-level (physical and data link layers) service, was designed to replace X.25. Frame Relay has some advantages over X.25:

➤ High Data Rate.
➤ Bursty Data.
➤ Less Overhead Due to Improved Transmission Media.

❖ Asynchronous Transfer Mode (ATM) is the cell relay protocol designed by the ATM Forum and adopted by the ITU-T.

❖ ATM is a cell network. A cell is a small data unit of fixed size that is the basic unit of data exchange in a cell network. In this type of network, all data are loaded into identical cells that can be transmitted with complete predictability and uniformity. Cells are multiplexed with other cells and routed through a cell network. Because each cell is the same size and all are small, any problems associated with multiplexing different-sized packets are avoided.

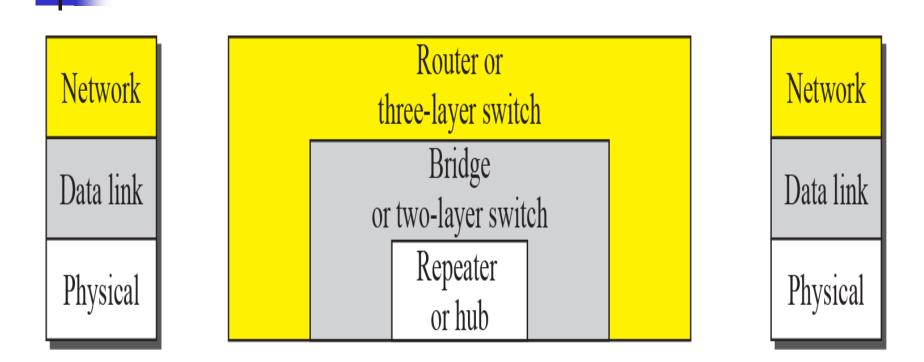**A cell network uses the cell as the basic unit of data exchange.**
A cell is defined as a small, fixed-size block of information.

3-5 CONNECTING DEVICES

LANs or WANs do not normally operate in isolation. They are connected to one another or to the Internet. To connect LANs and WANs together we use connecting devices. Connecting devices can operate in different layers of the Internet model. We discuss three kinds of connecting devices: repeaters (or hubs), bridges (or two-layer switches), and routers (or three-layer switches).
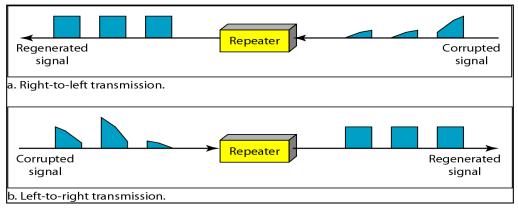
Topics Discussed in the Section

✓ **Repeaters**

✓ **Bridges**
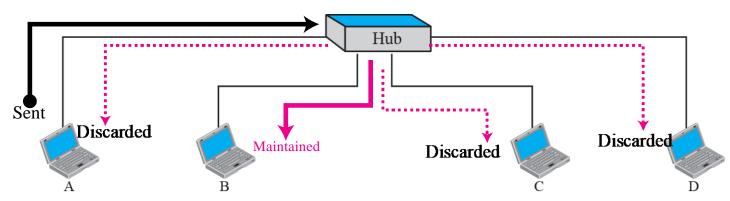
✓ **Routers**

Figure 3.40 *Connecting devices*

❖ Repeaters and hubs operate in the first layer of the Internet model. Bridges and two-layer switches operate in the first two layers. Routers and three-layer switches operate in the first three layers.

Figure 3.41 *Repeater or hub*

❖ A repeater receives a signal and, before it becomes too weak or corrupted, regenerates and retimes the original bit pattern. The repeater then sends the refreshed signal.

Function of a repeater

TCP/IP Protocol Suite   *Function of a Hub*   57

Repeater or hub Drvice

Note

A hub or a repeater do not have any data-link address and they do not check the data-link address of the received frame. They just regenerate the corrupted bits and send them out from every port.

Note

A repeater forwards every bit; it has no filtering capability.

TCP/IP Protocol Suite

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Bridge device

❖ A bridge operates in both the physical and the data link layers. As a physical-layer device, it regenerates the signal it receives. As a data link layer device, the bridge can check the MAC addresses (source and destination) contained in the frame.

Note

A bridge has a table used in filtering decisions.

❖ Bridge has filtering capability. It can check the destination address of a frame and can decide from which outgoing port the frame should be send out.

Note

A bridge does not change the physical (MAC) addresses in a frame.

Figure 3.42   Filtering of Bridge

Bridge table

Address	Port
71:2B:13:45:61:41	1
71:2B:13:45:61:42	2
64:2B:13:45:61:12	3
64:2B:13:45:61:13	4

Bridge

1   2   3   4

71:2B:13:45:61:41   71:2B:13:45:61:42   64:2B:13:45:61:12   64:2B:13:45:61:13
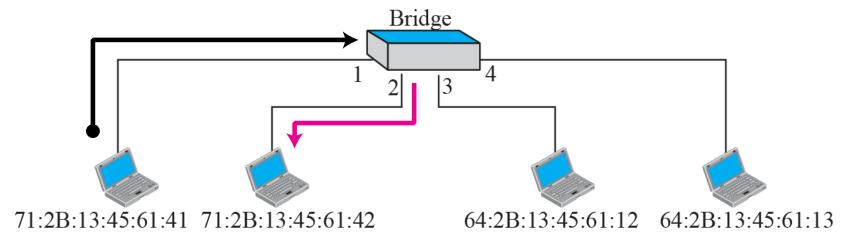
Figure 3.43   *Learning of bridge*

Gradual building of Table

Address	Port

a. Original

Address	Port
71:2B:13:45:61:41	1

b. After A sends a frame to D

Address	Port
71:2B:13:45:61:41	1
64:2B:13:45:61:13	4

c. After D sends a frame to B

Address	Port
71:2B:13:45:61:41	1
64:2B:13:45:61:13	4
71:2B:13:45:61:42	2
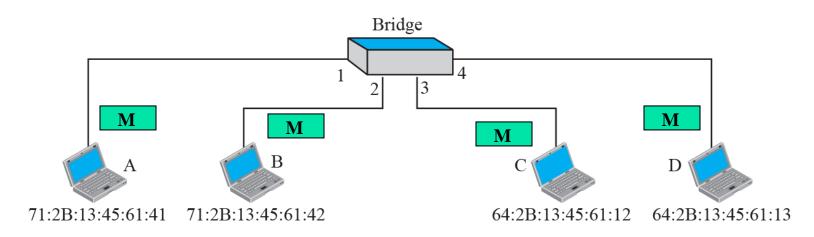
d. After B sends a frame to A

Address	Port
71:2B:13:45:61:41	1
64:2B:13:45:61:13	4
71:2B:13:45:61:42	2
64:2B:13:45:61:12	3

e. After C sends a frame to D

Bridge

1   2   3   4

M — A   71:2B:13:45:61:41
M — B   71:2B:13:45:61:42
M — C   64:2B:13:45:61:12
M — D   64:2B:13:45:61:13

Note

> *A transparent bridge is a bridge in which the stations are completely unaware of the bridge's existence. If a bridge is added or deleted from the system, reconfiguration of the stations is unnecessary.*

❖ A router is a three-layer device; it operates in the physical, data link, and network layers. As a physical layer device, it regenerates the signal it receives. As a data link layer device, the router checks the physical addresses (source and destination) contained in the packet. As a network layer device, a router checks the network layer addresses (addresses in the IP layer).

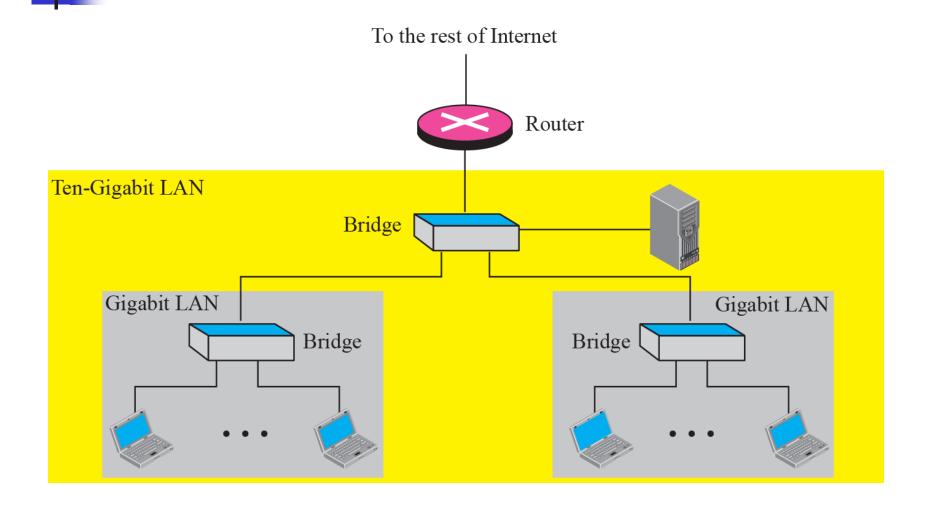❖ Note that bridges change collision domains, but routers limit broadcast domains.

Note

A router is a three-layer (physical, data link, and network) device.

Note

> **A repeater or a bridge connects segments of a LAN.**
> **A router connects independent LANs or WANs to create an internetwork (internet).**

Figure 3.44   Routing example

The Router Device

Note

A router changes the physical addresses in a packet.