Data Communications and Networking

Lecture 6

Dr. Su Mon Thu
Associate Professor
Department of Computer Engineering and Information Technology
Yangon Technological University

Outlines

- Wired LANs: Ethernet
- Other Wired Networks
- Wireless LANs
- Other Wireless Networks
- Connecting Devices and Virtual LANs

Lecture Objectives

- To introduce
  - Wired LANs: Ethernet
  - Other Wired Networks
  - Wireless LANs
  - Other Wireless Networks
  - Connecting Devices and Virtual LANs
- To understand Ethernet evolution through four generations
- To discuss telephone network, cable network, SONET and ATM
- To specify the characteristics of popular wireless transmission methods including 802.11, infrared and bluetooth
- discusses the WiMAX (a wireless access network), cellular telephone networks and satellite networks
- To discuss connecting devices and virtual LANs

Topic 1: Wired LANs: Ethernet

Wired LANs: Ethernet

Ethernet Protocol

- Ethernet is the traditional technology for connecting wired local area networks (LANs), enabling devices to communicate with each other via a protocol.

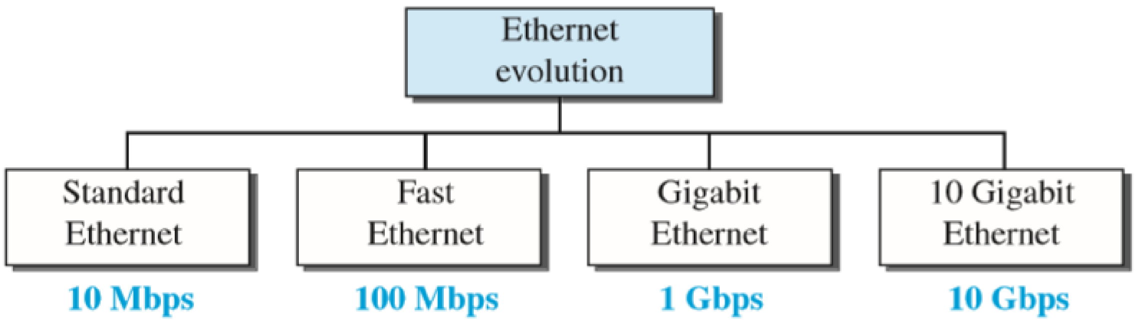


Figure 1. Ethernet Evolution Through Four Generations

Standard Ethernet

- It is referred to the original Ethernet technology with the data rate of 10 Mbps as the Standard Ethernet.
- Some characteristics of the Standard Ethernet are the followings.

Wired LANs: Ethernet (Continue)

Connectionless and Unreliable Service

- Ethernet provides a connectionless service, which means each frame sent is independent of the previous or next frame.
- Ethernet has no connection establishment or connection termination phases.
- The sender sends a frame whenever it has it; the receiver may or may not be ready for it.
- The sender may overwhelm the receiver with frames, which may result in dropping frames.
- If a frame drops, the sender will not know about it.
- Since IP, which is using the service of Ethernet, is also connectionless, it will not know about it either.

Wired LANs: Ethernet (Continue)

Frame Format

- The Ethernet frame contains seven fields, as shown in figure 2.

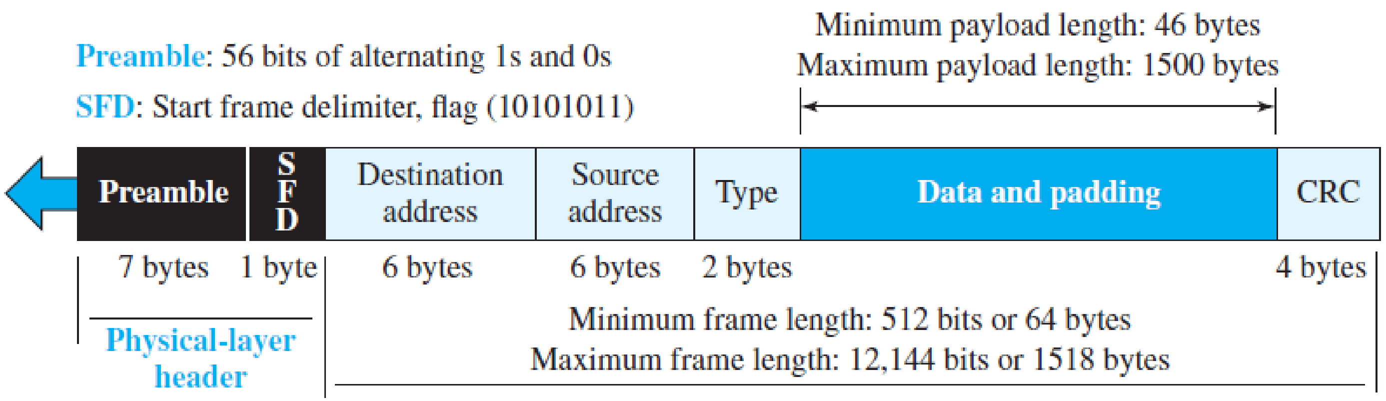


Figure 2. Ethernet Frame

Frame Length

- An Ethernet frame needs to have a minimum length of 512 bits or 64 bytes.

Wired LANs: Ethernet (Continue)

Addressing

- Each station on an Ethernet network (such as a PC, workstation, or printer) has its own network interface card (NIC).
- The NIC fits inside the station and provides the station with a link-layer address.
- The Ethernet address is 6 bytes (48 bits), normally written in hexadecimal notation, with a colon between the bytes. For example, the following shows an Ethernet MAC address: 4A:30:10:21:10:1A.

Transmission of Address Bits

- The transmission is left to right, byte by byte; however, for each byte, the least significant bit is sent first and the most significant bit is sent last.

Wired LANs: Ethernet (Continue)

- This means that the bit that defines an address as unicast or multicast arrives first at the receiver.
- This helps the receiver to immediately know if the packet is unicast or multicast.

Example 1

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

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:

Hexadecimal	47	20	1B	2E	08	EE
Binary	01000111	00100000	00011011	00101110	00001000	11101110
Transmitted ←	11100010	00000100	11011000	01110100	00010000	01110111

Wired LANs: Ethernet (Continue)

Unicast, Multicast, and Broadcast Addresses

- A source address is always a unicast address—the frame comes from only one station.
- The destination address, however, can be unicast, multicast, or broadcast.
- Figure 3 shows how to distinguish a unicast address from a multicast address.
- If the least significant bit of the first byte in a destination address is 0, the address is unicast; otherwise, it is multicast.

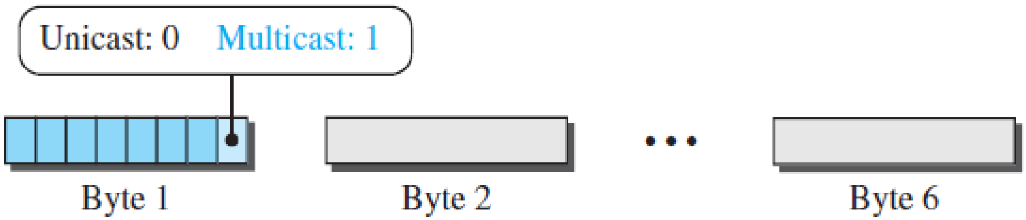


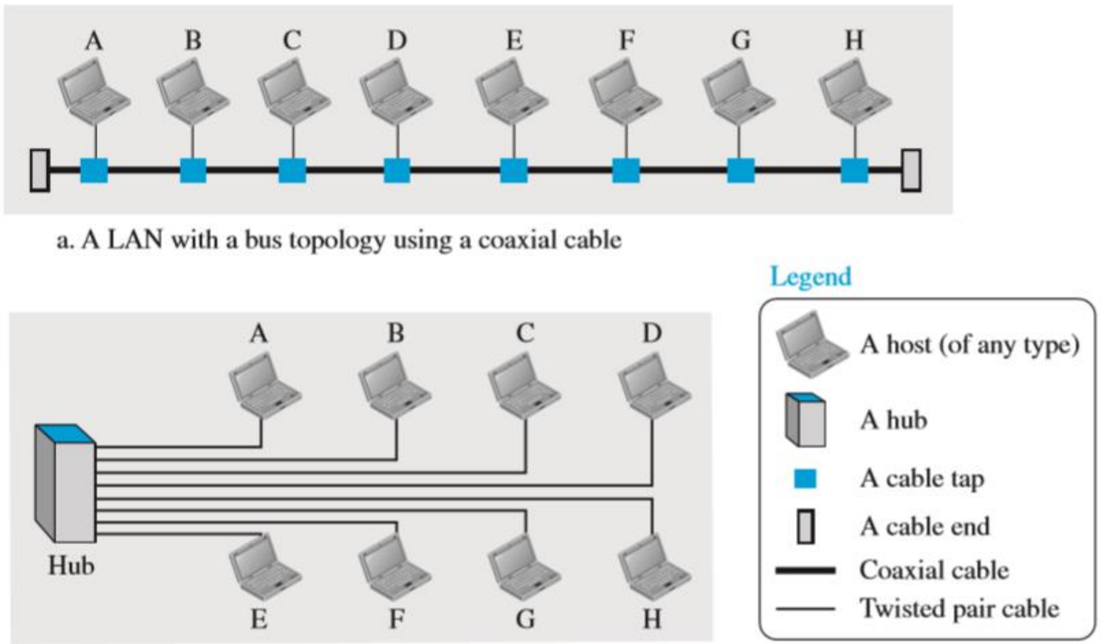
Figure 3. Unicast and Multicast Addresses

Wired LANs: Ethernet (Continue)

Distinguish Between Unicast, Multicast, and Broadcast Transmission

- Standard Ethernet uses a coaxial cable (bus topology) or a set of twisted-pair cables with a hub (star topology) as shown in Figure 4.
- In a unicast transmission, all stations will receive the frame, the intended recipient keeps and handles the frame; the rest discard it.
- In a multicast transmission, all stations will receive the frame, the stations that are members of the group keep and handle it; the rest discard it.
- In a broadcast transmission, all stations (except the sender) will receive the frame and all stations (except the sender) keep and handle it.

Wired LANs: Ethernet (Continue)



b. A LAN with a star topology using a hub

Figure 4. Implementation of standard Ethernet

Efficiency of Standard Ethernet

- The efficiency of the Ethernet is defined as the ratio of the time used by a station to send data to the time the medium is occupied by this station.

Wired LANs: Ethernet **(Continue)**

- The practical efficiency of standard Ethernet has been measured to be

$$\text{Efficiency} = 1 / (1 + 6.4 \times a)$$

- Where, the parameter "a" is the number of frames that can fit on the medium.

$$a = (\text{propagation delay})/(\text{transmission delay})$$

Example 2

In the Standard Ethernet with the transmission rate of 10 Mbps, we assume that the length of the medium is 2500 m and the size of the frame is 512 bits. The propagation speed of a signal in a cable is normally 2×10^8 m/s.

Solution

Propagation delay $= 2500/(2 \times 10^8) = 12.5\ \mu s$ Transmission delay $= 512/(10^7) = 51.2\ \mu s$

$a = 12.5/51.2 = 0.24$ Efficiency $= 39\%$

Wired LANs: Ethernet (Continue)

Implementation

- The Standard Ethernet defined several implementations, but only four of them became popular as shown in table 1.

Table 1: Summary of Standard Ethernet implementations

Implementation	*Medium*	*Medium Length*	*Encoding*
10Base5	Thick coax	500 m	Manchester
10Base2	Thin coax	185 m	Manchester
10Base-T	2 UTP	100 m	Manchester
10Base-F	2 Fiber	2000 m	Manchester

Bridged Ethernet

- In an unbridged Ethernet network, the total capacity (10 Mbps) is shared among all stations with a frame to send; the stations share the bandwidth of the network.
- When one station is sending, the other one refrains from sending.

***Wired LANs: Ethernet* (Continue)**

- A bridge divides the network into two or more networks. A network with 12 stations is divided into two networks, each with 6 stations.
- Now each network has a capacity of 10 Mbps as shown in figure 5.
- The 10-Mbps capacity in each segment is now shared between 6 stations (actually 7 because the bridge acts as a station in each segment), not 12 stations.
- In a network with a heavy load, eacsh station theoretically is offered 10/7 Mbps instead of 10/12 Mbps.
- The first step in the Ethernet evolution was the division of a LAN by bridges.
- Bridges have two effects on an Ethernet LAN: They raise the bandwidth and they separate collision domains.

Wired LANs: Ethernet (Continue)

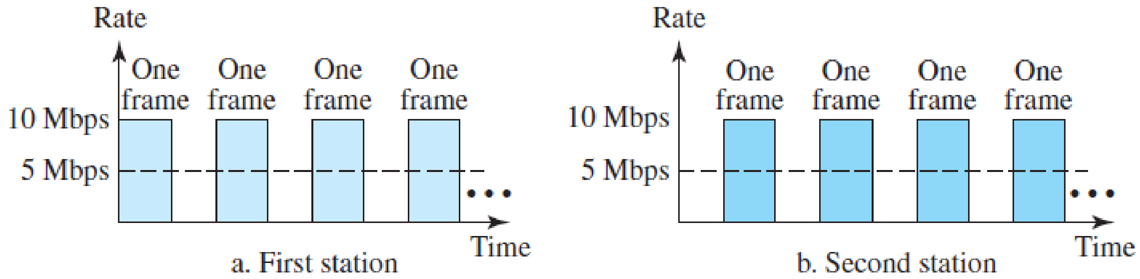


Figure 5. Sharing Bandwidth

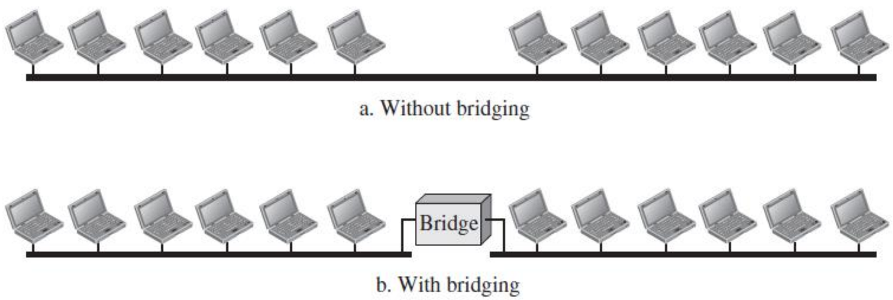


Figure 6. A Network with and Without A Bridge

Separating Collision Domains

- Another advantage of a bridge is the separation of the collision domain.
- Figure 7 shows the collision domains for an unbridged and a bridged network.

Wired LANs: Ethernet (Continue)

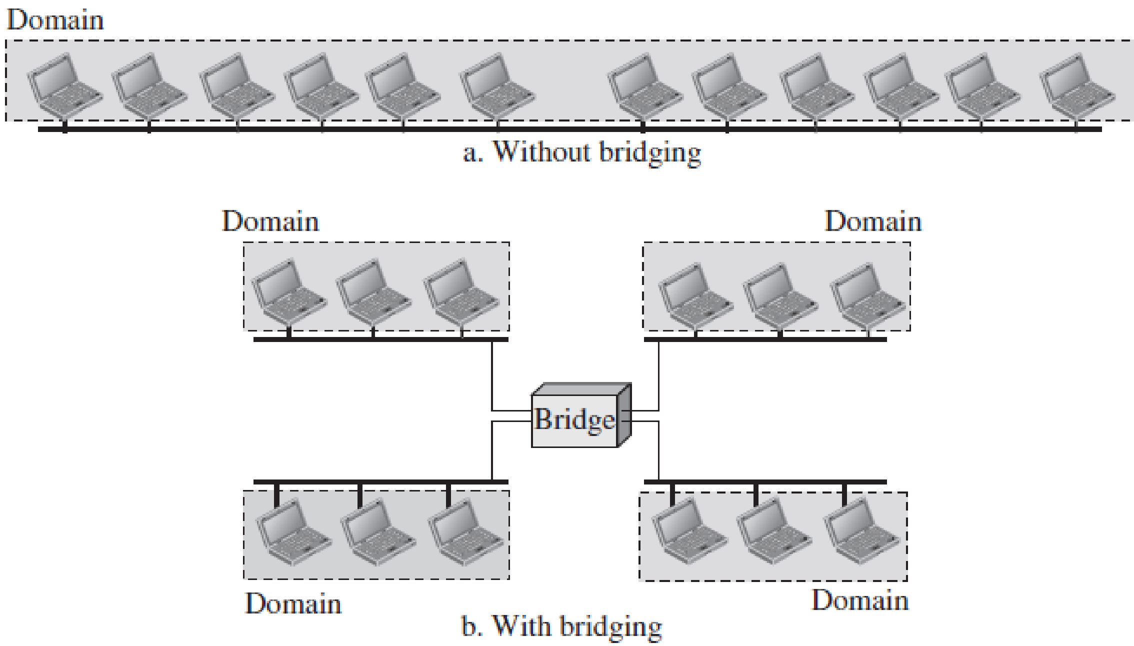


Figure 7. Collision Domains in an Unbridged Network and A Bridged Network

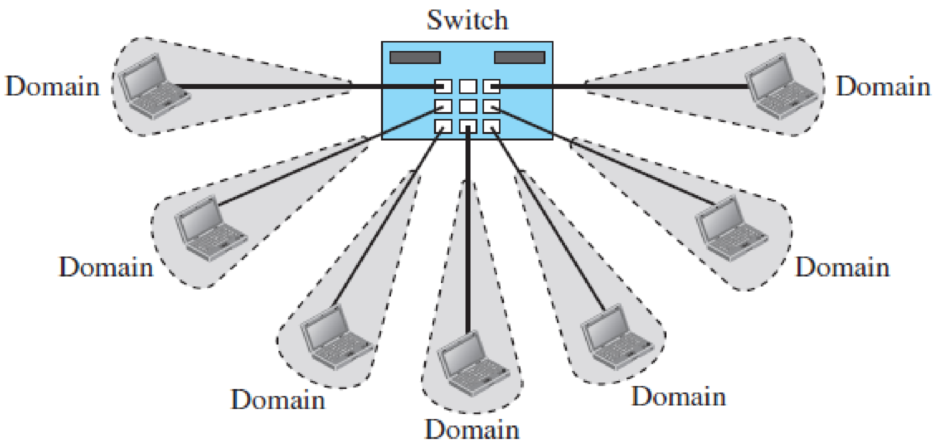


Figure 8. Switched Ethernet

Wired LANs: Ethernet (Continue)

Full-Duplex Ethernet

- One of the limitations of 10Base5 and 10Base2 is that communication is half-duplex (10Base-T is always full-duplex); a station can either send or receive, but may not do both at the same time.
- The next step in the evolution was to move from switched Ethernet to full-duplex switched Ethernet.
- The full-duplex mode increases the capacity of each domain from 10 to 20 Mbps.
- Figure 9 shows a switched Ethernet in full-duplex mode.

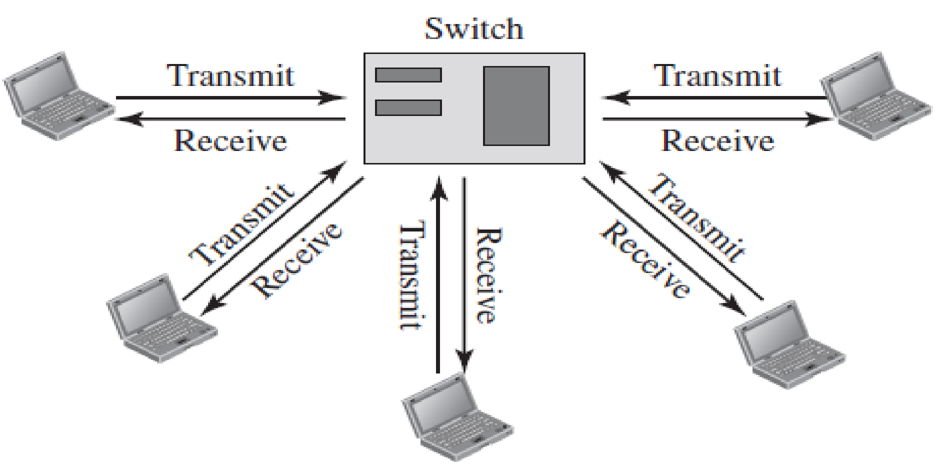


Figure 9. Full-Duplex Switched Ethernet

Wired LANs: Ethernet (Continue)

Fast Ethernet (100 Mbps)

- Ethernet made a big jump by increasing the transmission rate to 100 Mbps, and the new generation was called the Fast Ethernet.
- 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.

Gigabit Ethernet

- The goals of the Gigabit Ethernet were to upgrade the data rate to 1 Gbps, but keep the address length, the frame format, and the maximum and minimum frame length the same.

Wired LANs: Ethernet (Continue)

- 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. Support autonegotiation as defined in Fast Ethernet.

10 Gigabit Ethernet

- In recent years, there has been another look into the Ethernet for use in metropolitan areas.
- The idea is to extend the technology, the data rate, and the coverage distance so that the Ethernet can be used as LAN and MAN (metropolitan area network).

Wired LANs: Ethernet (Continue)

- The IEEE committee created 10 Gigabit Ethernet and called it Standard 802.3ae.
- The goals of the 10 Gigabit Ethernet design can be summarized as upgrading the data rate to 10 Gbps, keeping the same frame size and format, and allowing the interconnection of LANs, MANs, and WAN possible.

Table 2: Summary of 10 Gigabit Ethernet implementations

Implementation	*Medium*	*Medium Length*	*Number of wires*	*Encoding*
10GBase-SR	Fiber 850 nm	300 m	2	64B66B
10GBase-LR	Fiber 1310 nm	10 Km	2	64B66B
10GBase-EW	Fiber 1350 nm	40 Km	2	SONET
10GBase-X4	Fiber 1310 nm	300 m to 10 Km	2	8B10B

Topic 2: Other Wired Networks

Other Wired Networks

Telephone Networks

- The entire network, which is referred to as the plain old telephone system (POTS), was originally an analog system using analog signals to transmit voice.

Major Components

- The telephone network, as shown in figure 10, is made of three major components: local loops, trunks, and switching offices.
- The telephone network has several levels of switching offices such as end offices, tandem offices, and regional offices.

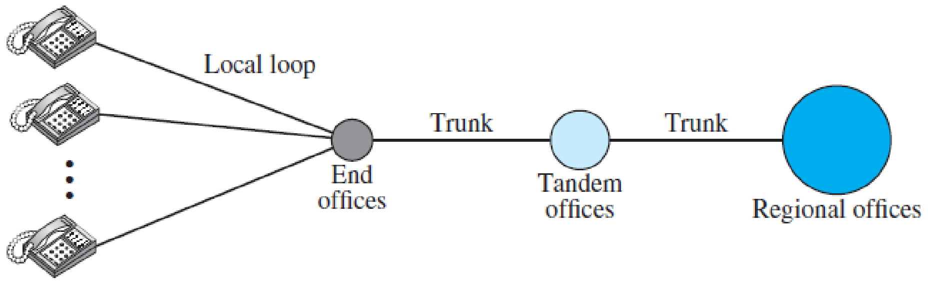


Figure 10. A Telephone System

Other Wired Networks (Continue)

Local Loops

- One component of the telephone network is the local loop, a twisted-pair cable that connects the subscriber telephone to the nearest end office or local central office.
- The local loop, when used for voice, has a bandwidth of 4000 Hz (4kHz).
- It is interesting to examine the telephone number associated with each local loop.
- The first three digits of a local telephone number define the office, and the next four digits define the local loop number.

Trunks

- Trunks are transmission media that handle the communication between offices.

Other Wired Networks (Continue)

- A trunk normally handles hundreds or thousands of connections through multiplexing.
- Transmission is usually through optical fibers or satellite links.

Switching Offices

- To avoid having a permanent physical link between any two subscribers, the telephone company has switches located in a switching office.
- A switch connects several local loops or trunks and allows a connection between different subscribers.

Signaling

- The signaling system became automatic.
- The switches in the telephone companies used the digital signals to create a connection between the caller and the called parties.

Other Wired Networks (Continue)

- Both in-band and out-of-band signaling were used.
- In in-band signaling, the 4-kHz voice channel was also used to provide signaling.
- In out-of-band signaling, a portion of the voice channel bandwidth was used for signaling; the voice bandwidth and the signaling bandwidth were separate.
- The signaling system was required to perform other tasks such as:
  1. Providing dial tone, ring tone, and busy tone.
  2. Transferring telephone numbers between offices.
  3. Maintaining and monitoring the call.

Other Wired Networks (Continue)

4. Keeping billing information.
5. Maintaining and monitoring the status of the telephone network equipment.
6. Providing other functions such as caller ID, voice mail, and so on.

Dial-Up Service

- The term modem is a composite word that refers to the two functional entities that make up the device: a signal modulator and a signal demodulator.
- A modulator creates a bandpass analog signal from binary data.
- A demodulator recovers the binary data from the modulated signal.

Other Wired Networks (Continue)

- Figure 11 shows the relationship of modems to a communications link.
- The computer on the left sends a digital signal to the modulator portion of the modem; the data are sent as an analog signal on the telephone lines.
- The modem on the right receives the analog signal, demodulates it through its demodulator, and delivers data to the computer on the right.
- The communication can be bidirectional, which means the computer on the right can simultaneously send data to the computer on the left, using the same modulation/demodulation processes.

Other Wired Networks (Continue)

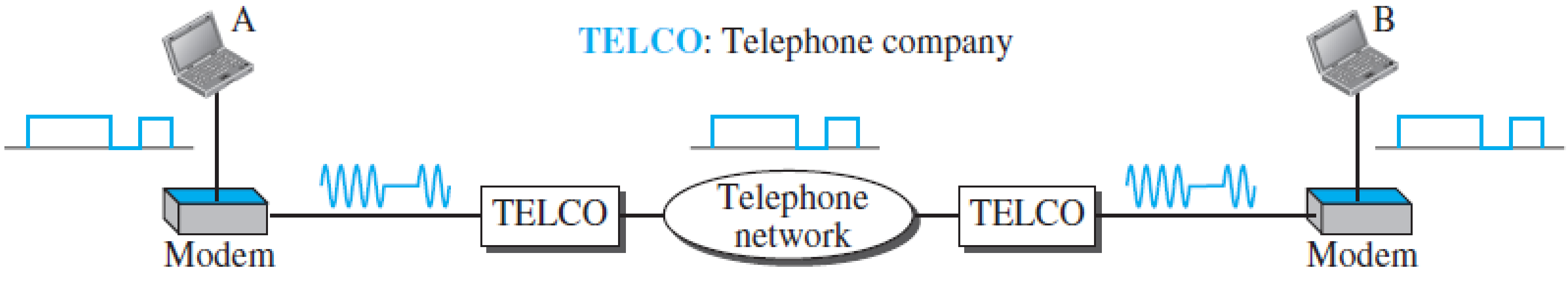


Figure 11. Modulation/Demodulation

Digital Subscriber Line (DSL)

- After traditional modems reached their peak data rate, telephone companies developed another technology, DSL, to 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 telephone.

Other Wired Networks (Continue)

- Asymmetric DSL (ADSL), like a 56K modem, provides higher speed (bit rate) in the downstream direction (from the Internet to the resident) than in the upstream direction (from the resident to the Internet).
- Typically, an available bandwidth of 1.104 MHz is divided into a voice channel, an upstream channel, and a downstream channel, as shown in figure 12.

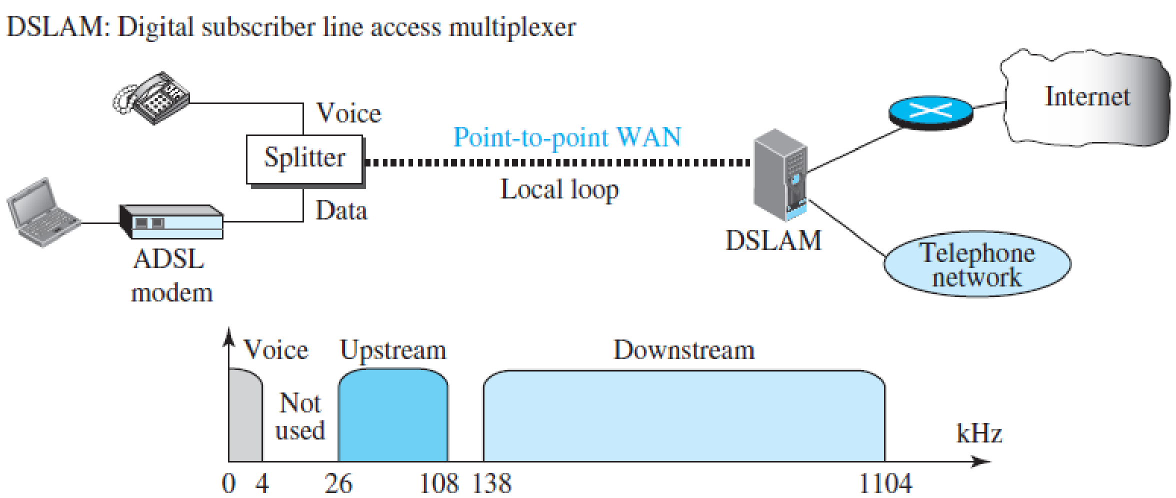


Figure 12. ADSL Point-to-Point Network

Other Wired Networks (Continue)

Cable Networks

- Cable TV networks were originally created to provide access to TV programs for those subscribers who had no reception because of natural obstructions such as mountains.
- In addition, cable networks enabled access to remote broadcasting stations via microwave connections.

Traditional Cable Networks

- It was called community antenna television (CATV) because an antenna at the top of a tall hill or building received the signals from the TV stations and distributed them, via coaxial cables, to the community.
- Figure 13 shows a schematic diagram of a traditional cable TV network.

Other Wired Networks (Continue)

- The cable TV office, called the head end, received video signals from broadcasting stations and fed the signals into coaxial cables.
- The signals became weaker and weaker with distance, so amplifiers were installed throughout the network to renew the signals.
- There could be up to 35 amplifiers between the head end and the subscriber premises.
- At the other end, splitters split the cable, and taps and drop cables made the connections to the subscriber premises.
- The traditional cable TV system used coaxial cable end to end.
- Due to attenuation of the signals and the use of a large number of amplifiers, communication in the traditional network was unidirectional (one-way).
- Video signals were transmitted downstream, from the head end to the subscriber premises.

Other Wired Networks (Continue)

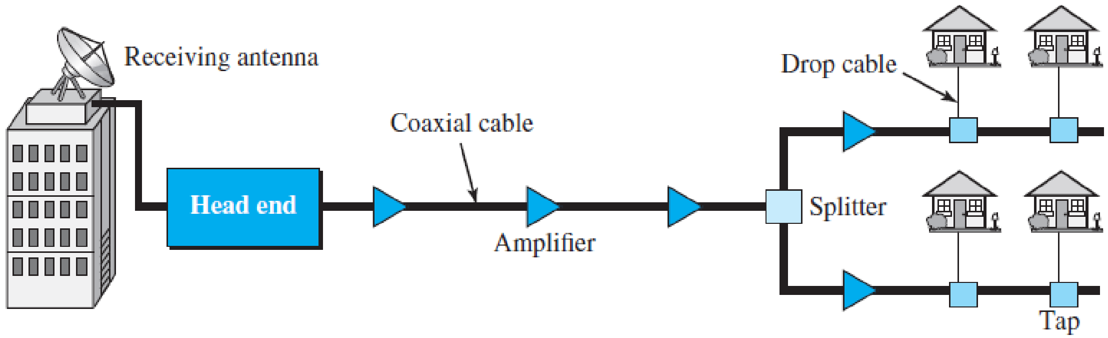


Figure 13. Traditional Cable TV Network

Synchronous Optical Network (SONET)

- SONET, that is used as a transport network to carry loads from other WANs.

Architecture

- The architecture of a SONET system is divided into signals, devices, and connections.

Signals

- SONET defines a hierarchy of electrical signaling levels called synchronous transport signals (STSs).

Other Wired Networks (Continue)

- Each STS level (STS-1 to STS-192) supports a certain data rate, specified in megabits per second .
- The corresponding optical signals are called optical carriers (OCs).

SONET Devices

- Figure 14 shows a simple link using SONET devices.
- SONET transmission relies on three basic devices: STS multiplexers/demultiplexers, regenerators, add/drop multiplexers and terminals.

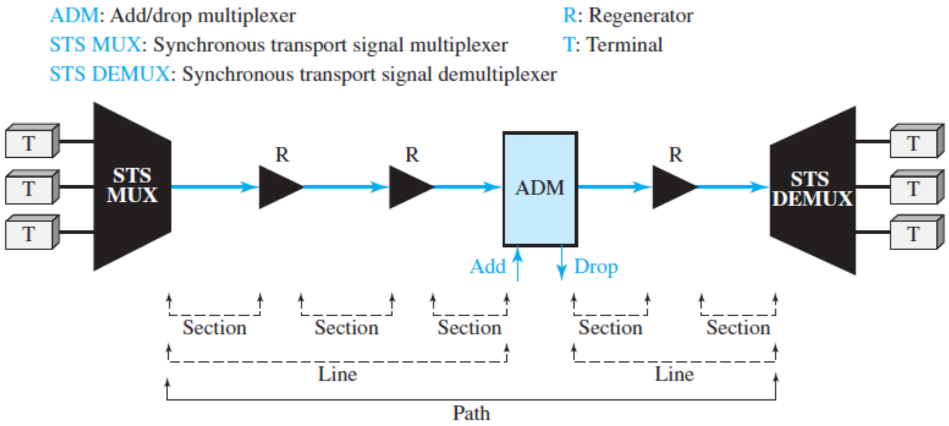


Figure 14. A Simple Network Using SONET Equipment

Other Wired Networks (Continue)

Connections

- The devices defined in the previous section are connected using sections, lines, and paths.

Sections

- A section is the optical link connecting two neighboring devices: multiplexer to multiplexer, multiplexer to regenerator, or regenerator to regenerator.

Lines

- A line is the portion of the network between two multiplexers: STS multiplexer to add/drop multiplexer, two add/drop multiplexers, or two STS multiplexers.

Paths

- A path is the end-to-end portion of the network between two STS multiplexers.

Other Wired Networks (Continue)

SONET Layers

- SONET defines four layers: path, line, section, and photonic as shown in figure 15.

Path Layer

- The path layer is responsible for the movement of a signal from its optical source to its optical destination.

Line Layer

- The line layer is responsible for the movement of a signal across a physical line.

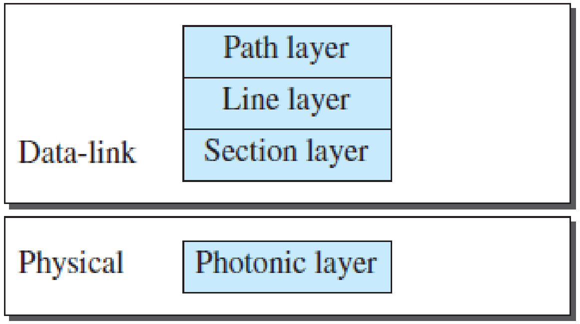


Figure 15. SONET Layers Compared with OSI or Internet layers

Other Wired Networks (Continue)

Section Layer

- The section layer is responsible for the movement of a signal across a physical section.

Photonic Layer

- The photonic layer corresponds to the physical layer of the OSI model.
- It includes physical specifications for the optical fiber channel, the sensitivity of the receiver, multiplexing functions, and so on.

SONET Frames

- Each synchronous transfer signal STS-n is composed of 8000 frames.
- Each frame is a two-dimensional matrix of bytes with 9 rows by 90 × n columns.
- For example, an STS-1 frame is 9 rows by 90 columns (810 bytes), and an STS-3 is 9 rows by 270 columns (2430 bytes).
- Figure 16 shows the general format of an STS-1 and an STS-n.

Other Wired Networks (Continue)

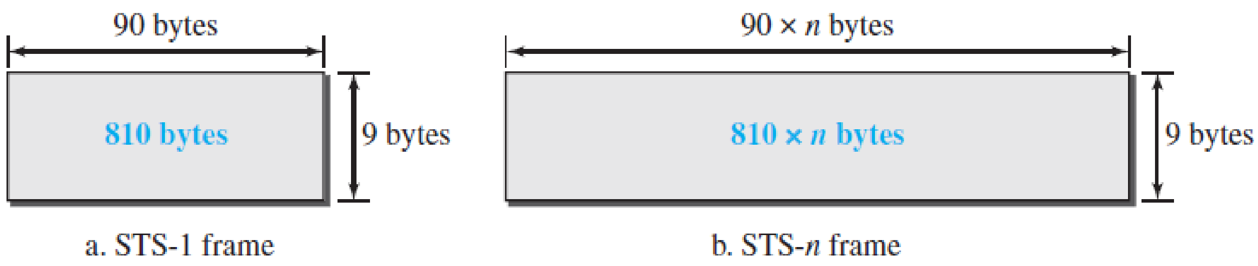


Figure 16. STS-1 and STS-n frames

Frame, Byte, and Bit Transmission

- One of the interesting points about SONET is that each STS-n signal is transmitted at a fixed rate of 8000 frames per second.
- This is the rate at which voice is digitized.
- For each frame the bytes are transmitted from the left to the right, top to the bottom.
- For each byte, the bits are transmitted from the most significant to the least significant (left to right).
- Figure 17 shows the order of frame and byte transmission.

Other Wired Networks (Continue)

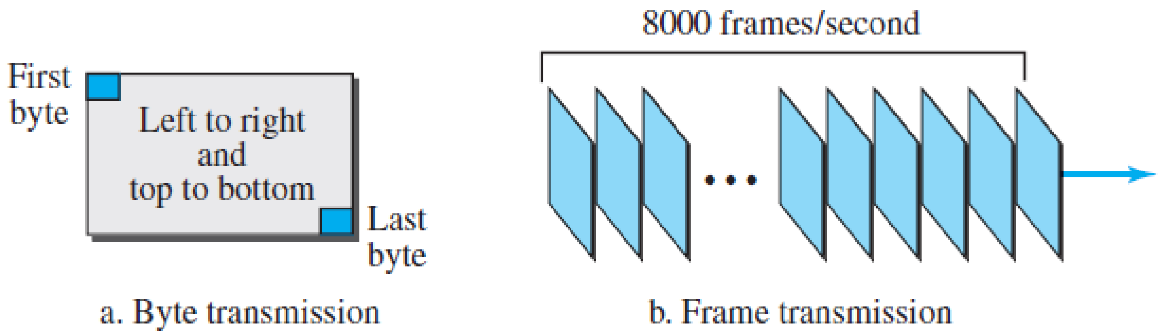


Figure 17. STS Frames in Transition

STS Multiplexing

- In SONET, frames of lower rate can be synchronously time-division multiplexed into a higher-rate frame.

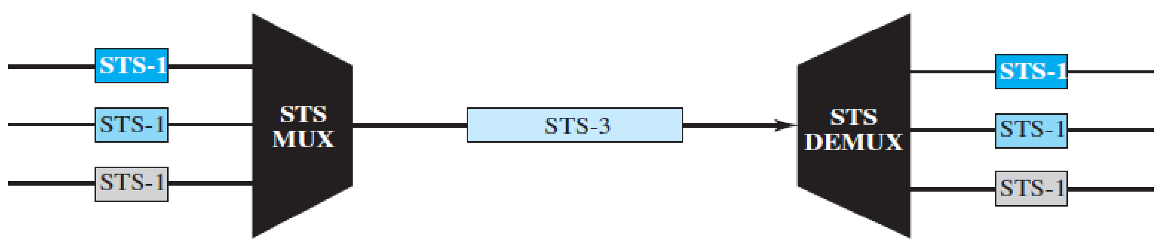


Figure 18. STS Multiplexing/Demultiplexing

Other Wired Networks (Continue)

Byte Interleaving

- Synchronous TDM multiplexing in SONET is achieved by using byte interleaving.
- For example, when three STS-1 signals are multliplexed into one STS-3 signal, each set of 3 bytes in the STS-3 signal is associated with 1 byte from each STS-1 signal.
- Figure 19 shows the interleaving.

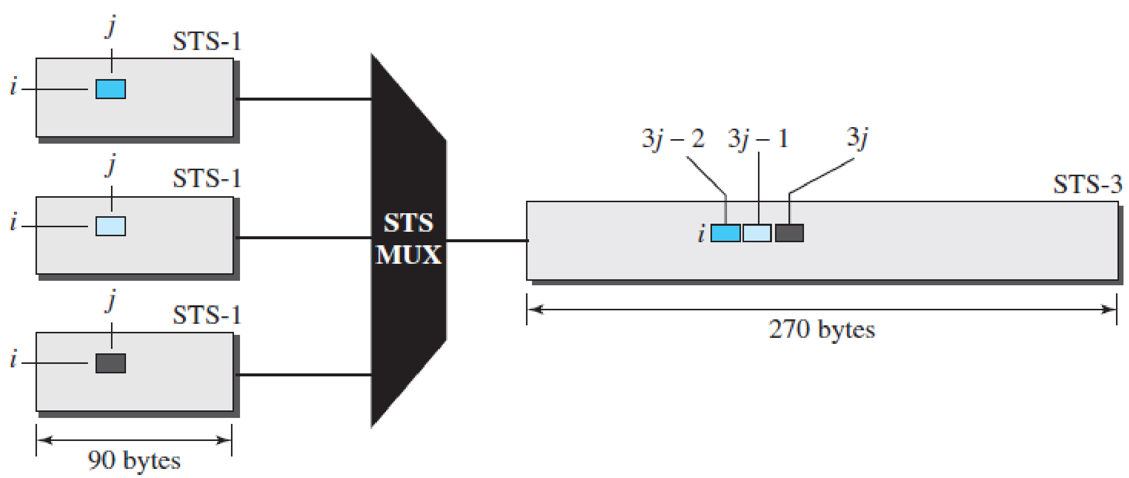


Figure 19. Byte Interleaving

Other Wired Networks (Continue)

SONET Networks

- Using SONET equipment, we can create a SONET network that can be used as a high-speed backbone carrying loads from other networks such as ATM or IP.
- SONET networks are divided into three categories: linear, ring, and mesh networks, as shown in figure 20.
- A linear SONET network can be point-to-point or multipoint.
- ADMs make it possible to have SONET ring networks.
- SONET rings can be used in either a unidirectional or a bidirectional configuration.
- One problem with ring networks is the lack of scalability.
- When the traffic in a ring increases, it is needed to upgrade not only the lines, but also the ADMs.
- In this situation, a mesh network with switches would probably give better performance.

Other Wired Networks (Continue)

ATM

- Asynchronous Transfer Mode (ATM) is a switched wide area network based on the *cell relay* protocol designed by the ATM forum and adopted by the ITU-T.
- ATM uses statistical (asynchronous) time-division multiplexing—that is why it is called *Asynchronous Transfer Mode*—to multiplex cells coming from different channels.
- It uses fixed-size slots (size of a cell).
- ATM multiplexers fill a slot with a cell from any input channel that has a cell; the slot is empty if none of the channels has a cell to send.
- Figure 20 shows how cells from three inputs are multiplexed.
- At the first tick of the clock, channel 2 has no cell (empty input slot), so the multiplexer fills the slot with a cell from the third channel.
- When all the cells from all the channels are multiplexed, the output slots are empty.

Other Wired Networks (Continue)

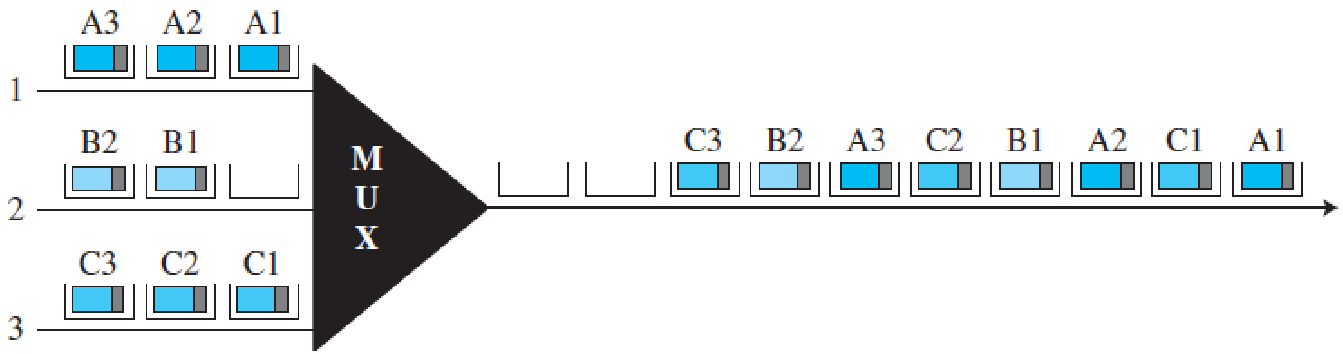


Figure 20. ATM multiplexing

Architecture

- ATM is a cell-switched network.
- The user access devices, called the endpoints, are connected through a user-to-network interface (UNI) to the switches inside the network.
- The switches are connected through network-to-network interfaces (NNIs).
- Figure 21shows an example of an ATM network.

Other Wired Networks (Continue)

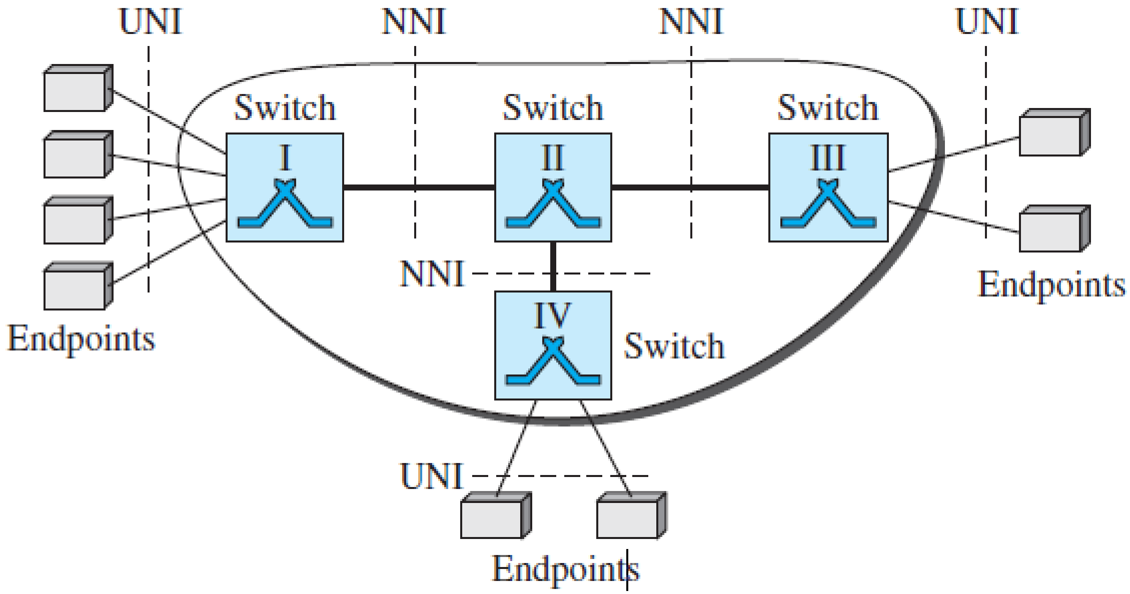


Figure 21. Architecture of an ATM network

Topic 3: Wireless LANs

Wireless LANs

Introduction

- 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.
- Figure 22 shows two isolated LANs, one wired and one wireless.

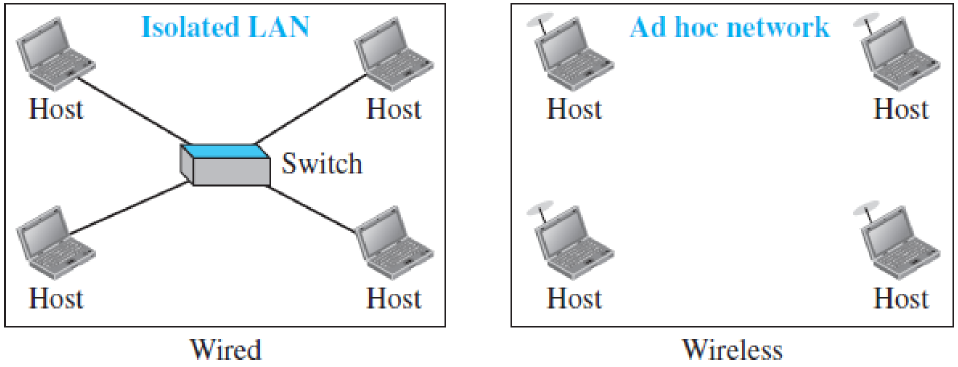


Figure 22. Isolated LANs: Wired Versus Wireless

Wireless LANs (Continue)

- A wired isolated LAN is a set of hosts connected via a link-layer switch.
- A wireless isolated LAN, called an ad hoc network in wireless LAN terminology, is a set of hosts that communicate freely with each other.
- The wireless LAN is referred to as an infrastructure network, and the connection to the wired infrastructure, such as the Internet, is done via a device called an access point (AP).

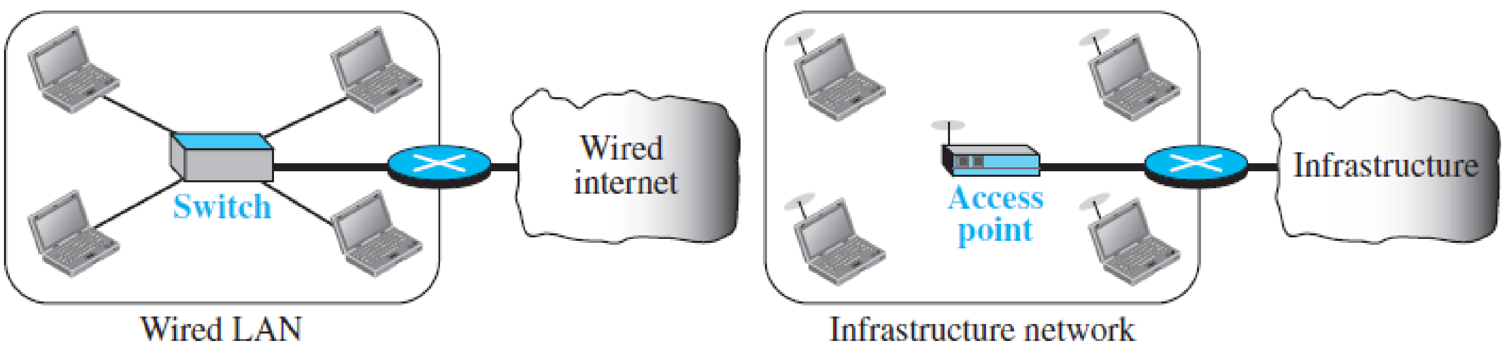


Figure 23. Connection of A Wired LAN and A Wireless LAN to Other Networks

Wireless LANs (Continue)

Characteristics

- There are several characteristics of wireless LANs that either do not apply to wired LANs or the existence of which is negligible and can be ignored.

Attenuation

- The strength of electromagnetic signals decreases rapidly because the signal disperses in all directions; only a small portion of it reaches the receiver.

Interference

- Another issue is that a receiver may receive signals not only from the intended sender, but also from other senders if they are using the same frequency band.

Wireless LANs (Continue)

Multipath Propagation

- A receiver may receive more than one signal from the same sender because electromagnetic waves can be reflected back from obstacles such as walls, the ground, or objects.

Error

- If it is about the error level as the measurement of signal-to-noise ratio (SNR), it can better understand why error detection and error correction and retransmission are more important in a wireless network.
- If SNR is high, it means that the signal is stronger than the noise, so it may be able to convert the signal to actual data.
- When SNR is low, the signal is corrupted by the noise and the data cannot be recovered.

Wireless LANs (Continue)

IEEE 802.11 PROJECT

- IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data-link layers.
- It is sometimes called wireless Ethernet.

Architecture

- The standard defines two kinds of services: the basic service set (BSS) and the extended service set (ESS).

Basic Service Set

- IEEE 802.11 defines the basic service set (BSS) as the building blocks 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).
- Figure 24 shows two sets in this standard.
- The BSS without an AP is a stand-alone network and cannot send data to other BSSs.

Wireless LANs (Continue)

- It is called an ad hoc architecture.
- A BSS with an AP is referred to as an infrastructures.

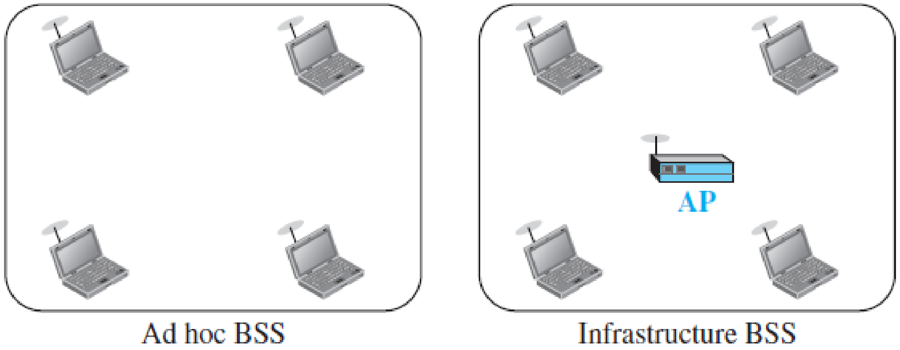


Figure 24. Basic Service Sets

Extended Service Set

- An 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 a wired or a wireless network.

Wireless LANs (Continue)

- The distribution system connects the APs in the BSSs.
- The stationary stations are AP stations that are part of a wired LAN as shown in figure 25.

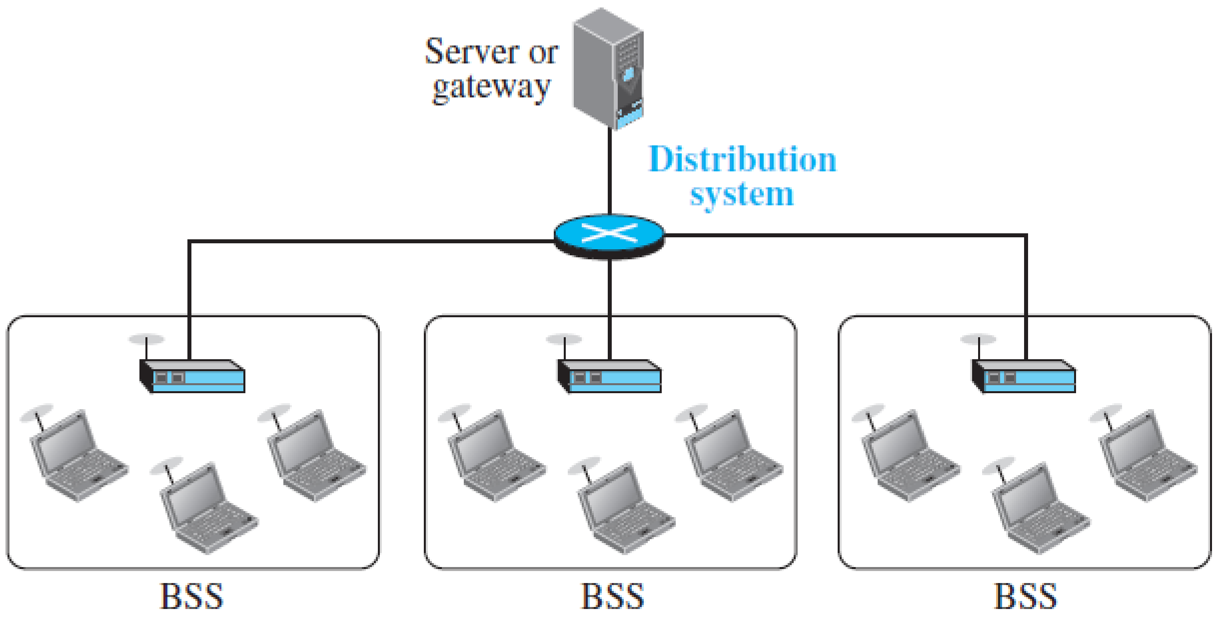


Figure 25. Extended Service Set (ESS)

Wireless LANs (Continue)

MAC Sublayer

- IEEE 802.11 defines two MAC sublayers: the distributed coordination function (DCF) and point coordination function (PCF).
- Figure 26 shows the relationship between the two MAC sublayers, the LLC sublayer, and the physical layer.

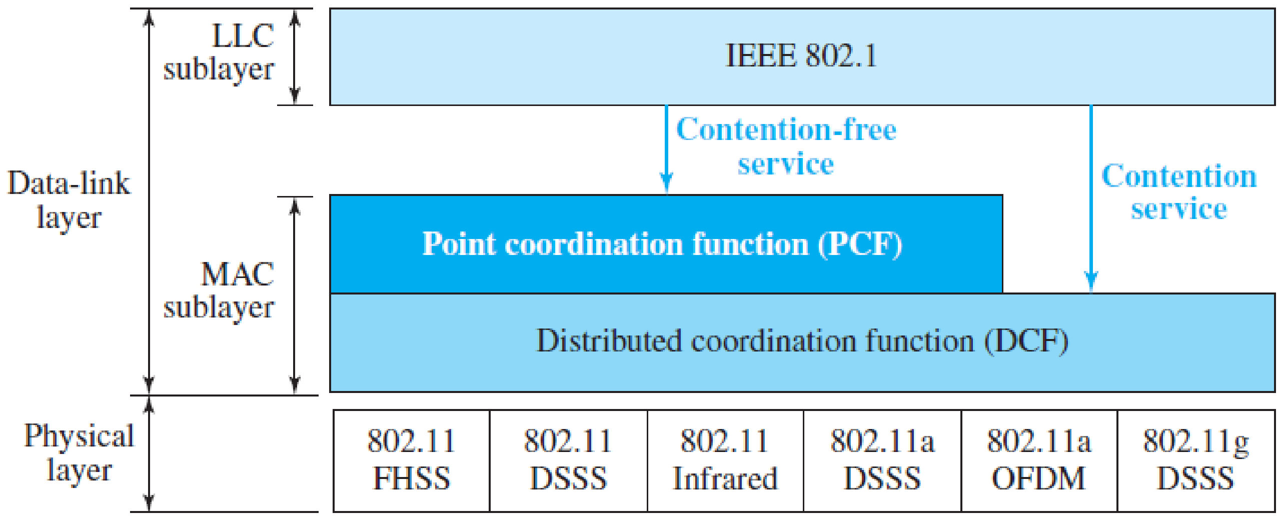


Figure 26. MAC layers in IEEE 802.11 standard

Wireless LANs (Continue)

Addressing Mechanism

- The IEEE 802.11 addressing mechanism specifies four cases, defined by the value of the two flags in the FC field, To DS and From DS.
- Each flag can be either 0 or 1, resulting in four different situations.
- The interpretation of the four addresses (address 1 to address 4) in the MAC frame depends on the value of these flags, as shown in Table 3.

Table 3: Addresses

To DS	*From DS*	*Address 1*	*Address 2*	*Address 3*	*Address 4*
0	0	Destination	Source	BSS ID	N/A
0	1	Destination	Sending AP	Source	N/A
1	0	Receiving AP	Source	Destination	N/A
1	1	Receiving AP	Sending AP	Destination	Source

Wireless LANs (Continue)

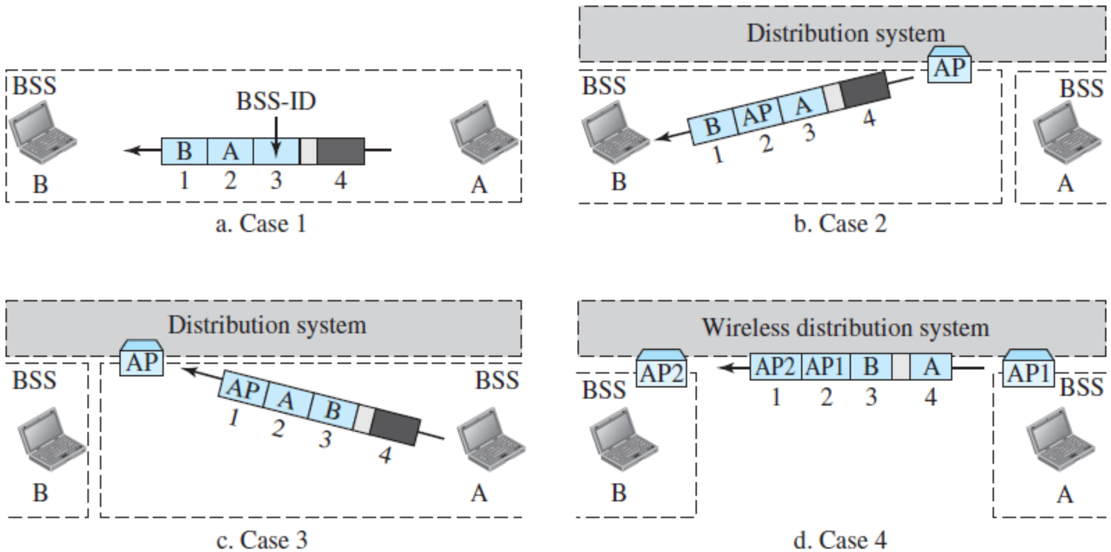


Figure 27. Addressing Mechanisms

Bluetooth

- Bluetooth is a wireless LAN technology designed to connect devices of different functions such as telephones, notebooks, computers (desktop and laptop), cameras, printers, and even coffee makers when they are at a short distance from each other.

Wireless LANs (Continue)

- A Bluetooth LAN, by nature, cannot be large.
- 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.
- The communication between the primary and secondary stations can be one-to-one or one-to-many.

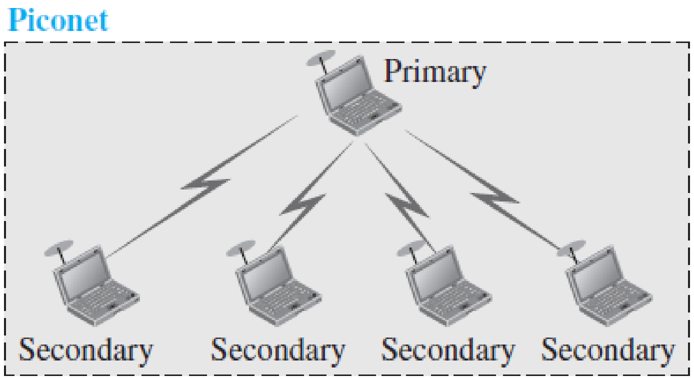


Figure 28. Piconet

Wireless LANs (Continue)

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.
- Figure 29 illustrates a scatternet.

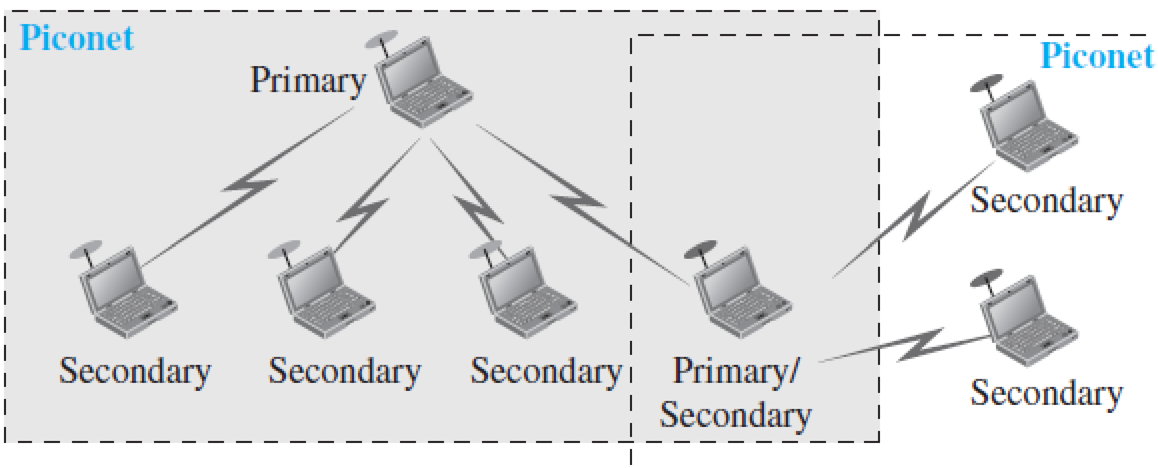


Figure 29. Scatternet

Topic 4: Other Wireless Networks

Other Wireless Networks

WiMAX

- The Worldwide Interoperability for Microwave Access (WiMAX) is a family of wireless broadband communication standard

Services

- WiMAX provides two types of services to subscribers: fixed and mobile.

Fixed WiMAX

- Figure 30 shows the idea behind a fixed service.
- A base station can use different types of antenna (omnidirectional, sector, or panel) to optimize the performance.
- WiMAX uses a beamsteering adaptive antenna system (AAS).
- While transmitting, it can focus its energy in the direction of the subscriber; while receiving, it can focus in the direction of the subscriber station to receive maximum energy sent by the subscriber.
- WiMAX also uses a MIMO antenna system, which can provide simultaneous transmitting and receiving.

Other Wireless Networks (Continue)

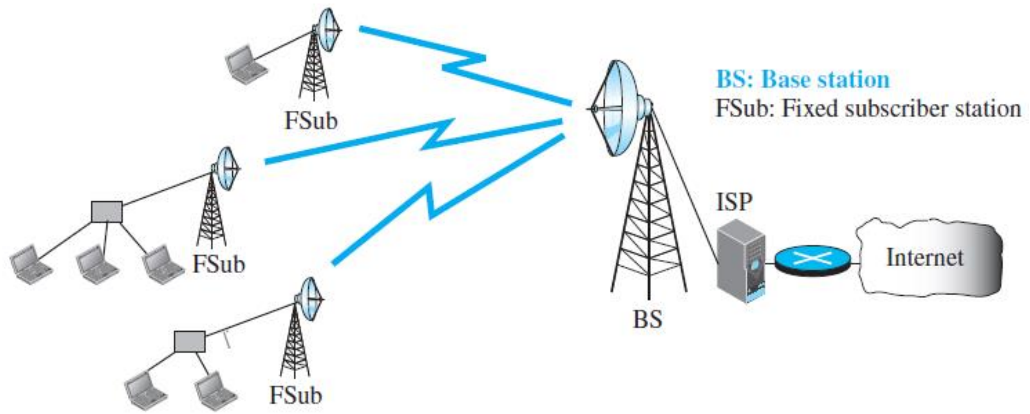


Figure 30. Fixed WiMAX

Mobile WiMAX

- Figure 31 shows the idea behind mobile service.
- It is the same as fixed service except.
- The subscribers are mobile stations that move from one place to another.

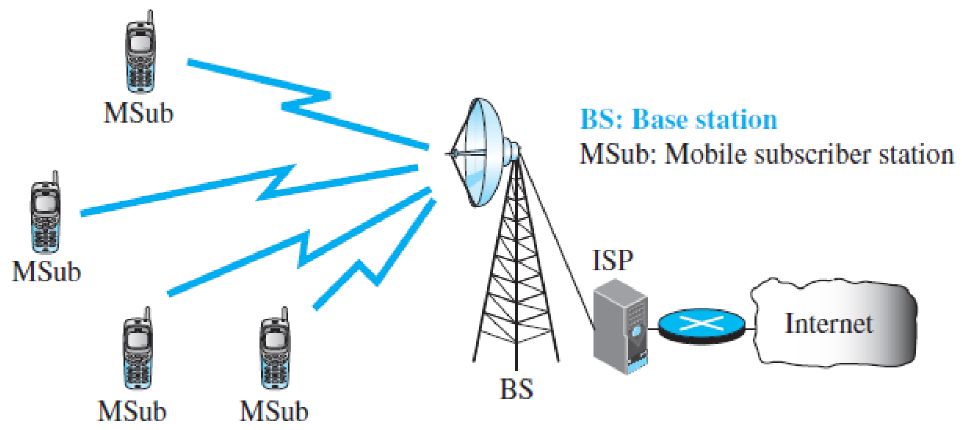


Figure 31. Mobile WiMAX

Other Wireless Networks (Continue)

Cellular Telephony

- Cellular telephony is designed to provide communications between two moving units, called mobile stations (MSs), or between one mobile unit and one stationary unit, often called a land unit.
- A service provider must be able to locate and track a caller, assign a channel to the call, and transfer the channel from base station to base station as the caller moves out of range.
- To make this tracking possible, each cellular service area is divided into small regions called cells.
- Each cell contains an antenna and is controlled by a solar- or AC powered network station, called the base station (BS).

Other Wireless Networks (Continue)

- Each base station, in turn, is controlled by a switching office, called a mobile switching center (MSC).
- The MSC coordinates communication between all the base stations and the telephone central office.
- It is a computerized center that is responsible for connecting calls, recording call information, and billing as shown in figure 32.

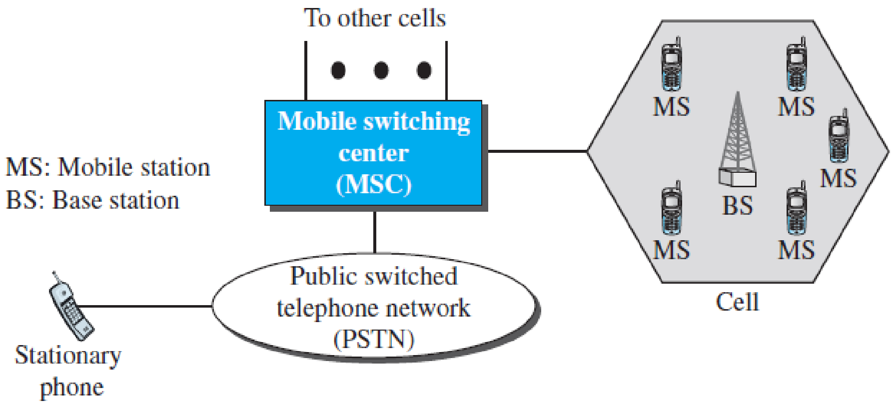


Figure 32. Cellular System

Other Wireless Networks (Continue)

Handoff

- Handoff refers to the process of transferring an active call or data session from one cell in a cellular network to another or from one channel in a cell to another.

Roaming

- One feature of cellular telephony is called roaming.
- Roaming means, in principle, that a user can have access to communication or can be reached where there is coverage.
- A service provider usually has limited coverage.

First Generation (1 G)

- The first generation was designed for voice communication using analog signals.
- Its speed up to 2.4 kbps.

Other Wireless Networks (Continue)

Second Generation (2 G)

- While the first generation was designed for analog voice communication, the second generation was mainly designed for digitized voice.
- It provides better quality and capacity
- Its data speed was up to 64kbps.

Third Generation (3G)

- 3G was introduced in 2000s
- Data transmission speed increased from 144kbps-2Mbps
- Send/receive large email messages
- Typically called smart phone and features increased its bandwidth and data transfer rates to accommodate web-base applications, audio and video files.

Other Wireless Networks (Continue)

Fourth Generation (4G)

- A 4G provides voice, date and streamed multimedia can be served on an "Any-time, Any-Where" basis at higher data rates than previous generations.
- Data rates speed from 50-100Mbps
- Wider bandwidth

Fifth Generation (5G)

- 5G technology was started from late 2010s
- Complete wireless communication with almost no limitations
- It is highly supportable to wwww (wireless world wide web).

Satellite Networks

- A satellite network is a combination of nodes, some of which are satellites, that provides communication from one point on the Earth to another.

Other Wireless Networks (Continue)

- A node in the network can be a satellite, an Earth station, or an end-user terminal or telephone.
- An artificial satellite needs to have an orbit, the path in which it travels around the Earth.
- The orbit can be equatorial, inclined, or polar, as shown in figure 33.

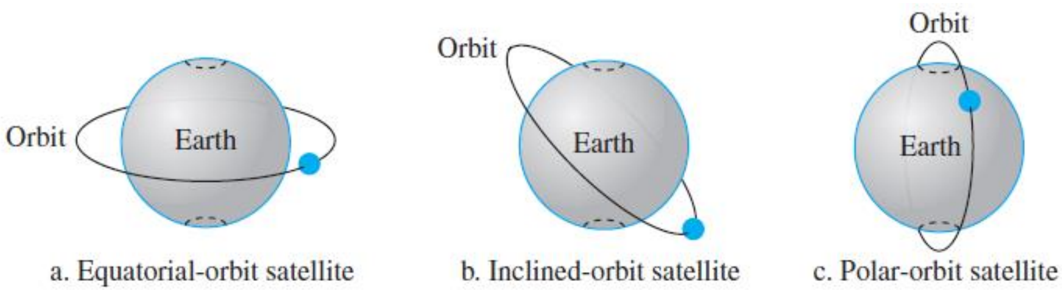


Figure 33. Satellite Orbits

Three Categories of Satellites

- Based on the location of the orbit, satellites can be divided into three categories: geostationary Earth orbit (GEO), low-Earth-orbit (LEO), and medium-Earth-orbit (MEO) as shown in figure 33.

Other Wireless Networks (Continue)

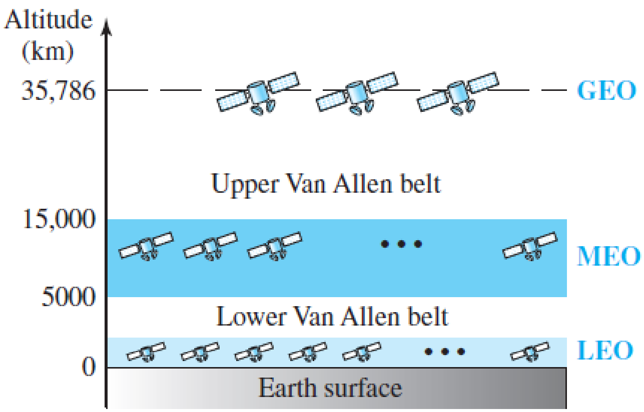


Figure 34. Satellite Orbit Altitudes

GEO

- A satellite that moves faster or slower than the earth's rotation is useful only for short periods.

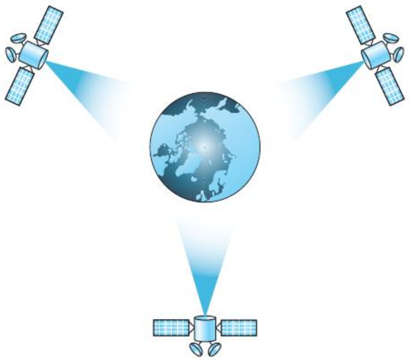


Figure 35. Satellites In Geostationary Orbit

Other Wireless Networks (Continue)

MEO Satellites

- Medium-Earth-orbit (MEO) satellites are positioned between the two Van Allen belts.
- A satellite at this orbit takes approximately 6 to 8 hours to circle the Earth.
- One example of a MEO satellite system is the Global Positioning System (GPS).
- GPS uses 24 satellites in six orbits, as shown in Figure 36.

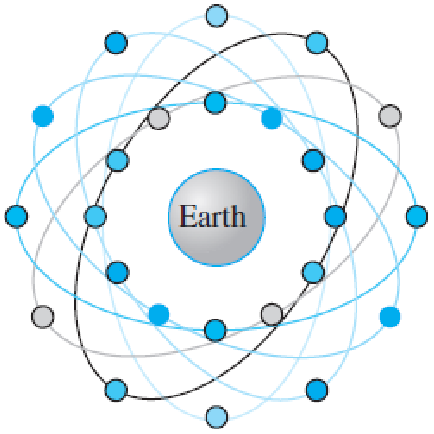


Figure 36. Orbits for Global Positioning System (GPS) Satellites

Other Wireless Networks (Continue)

LEO Satellites

- A LEO system is made of a constellation of satellites that work together as a network; each satellite acts as a switch.
- Satellites that are close to each other are connected through intersatellite links (ISLs).
- A mobile system communicates with the satellite through a user mobile link (UML).
- A satellite can also communicate with an Earth station (gateway) through a gateway link (GWL).
- Figure 37 shows a typical LEO satellite network.

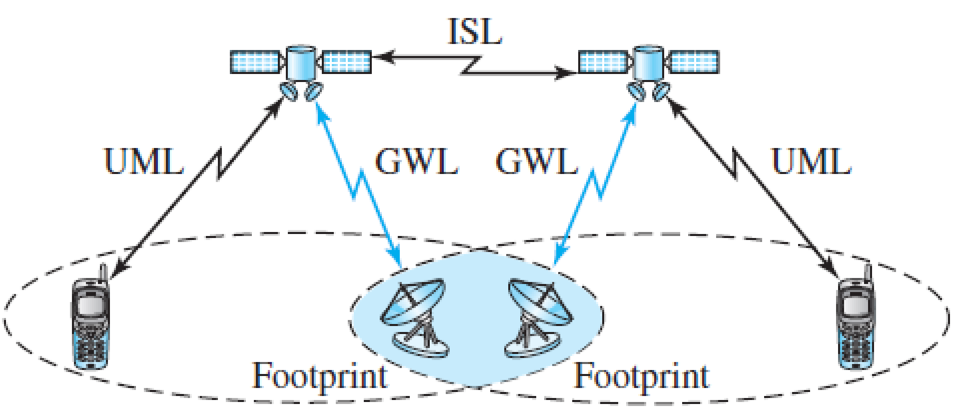


Figure 37. LEO satellite system

Topic 5: Connecting Devices and Virtual LANs

Connecting Devices and Virtual LANs

Connecting Devices

- Connecting devices can operate in different layers of the Internet model.
- Three kinds of connecting devices: hubs, link-layer switches, and routers.
- Hubs today operate in the first layer of the Internet model.
- Link-layer switches operate in the first two layers.
- Routers operate in the first three layers as shown in figure 38.

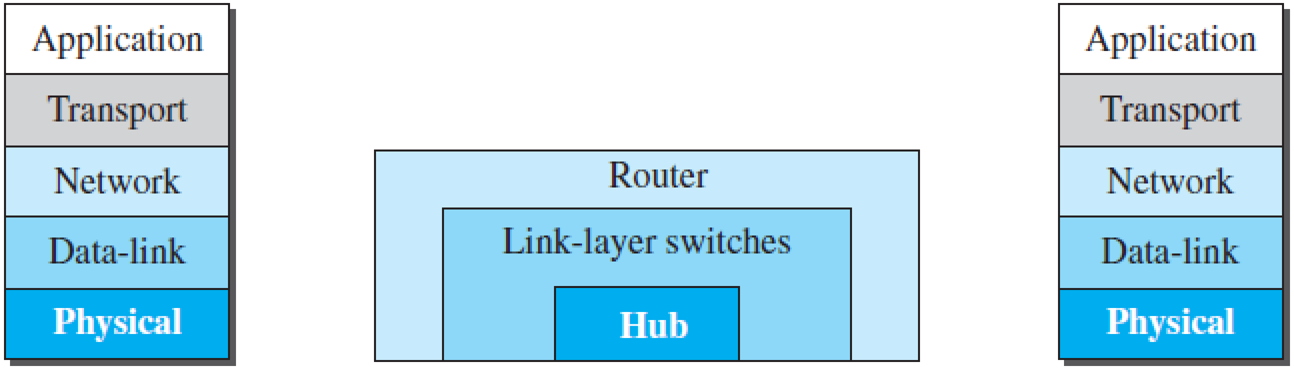


Figure 38. Three Categories of Connecting Devices

Connecting Devices and Virtual LANs (Continue)

Hub

- A hub is a device that operates only in the physical layer.
- Signals that carry information within a network can travel a fixed distance before attenuation endangers the integrity of the data.
- 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.
- In a star topology, a repeater is a multiport device, often called a hub.
- Figure 39 shows that when a packet from station A to station B arrives at the hub, the signal representing the frame is regenerated to remove any possible corrupting noise, but the hub forwards the packet from all outgoing ports except the one from which the signal was received.
- A repeater has no filtering capability.

Connecting Devices and Virtual LANs (Continue)

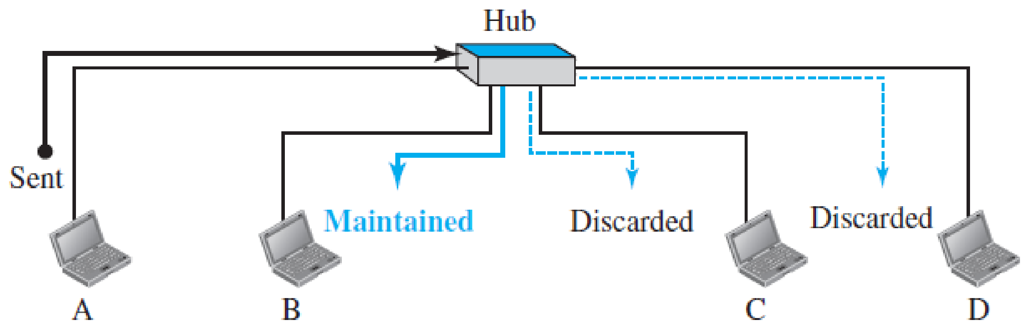


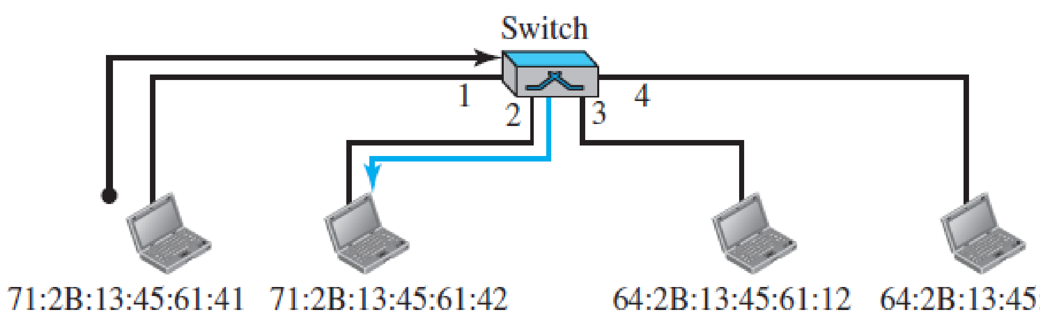
Figure 39. A Hub

Link-Layer Switches

- A link-layer switch (or switch) operates in both the physical and the data-link layers.
- As a physical-layer device, it regenerates the signal it receives.
- As a link-layer device, the link-layer switch can check the MAC addresses (source and destination) contained in the frame.
- A link-layer switch has a table used in filtering decisions.

Connecting Devices and Virtual LANs (Continue)

- A link-layer switch does not change the link-layer (MAC) addresses in a frame.
- A link-layer switch has filtering capability.
- It can check the destination address of a frame and can decide from which outgoing port the frame should be sent.



Switching 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

Figure 40. Link-Layer Switch

Connecting Devices and Virtual LANs (Continue)

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

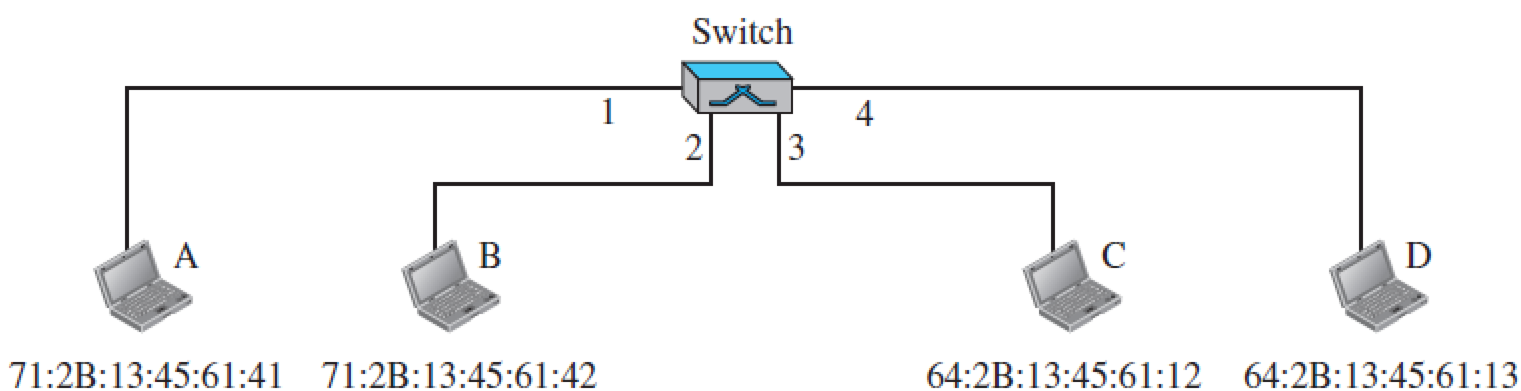


Figure 41. Learning Switch

Connecting Devices and Virtual LANs (Continue)

Loop Problem

- Transparent switches work fine as long as there are no redundant switches in the system.
- System administrators, however, like to have redundant switches (more than one switch between a pair of LANs) to make the system more reliable.
- If a switch fails, another switch takes over until the failed one is repaired or replaced.
- Redundancy can create loops in the system, which is very undesirable.
- Loops can be created only when two or more broadcasting LANs are connected by more than one switch.
- Figure 42 shows a very simple example of a loop created in a system with two LANs connected by two switches.

Connecting Devices and Virtual LANs (Continue)

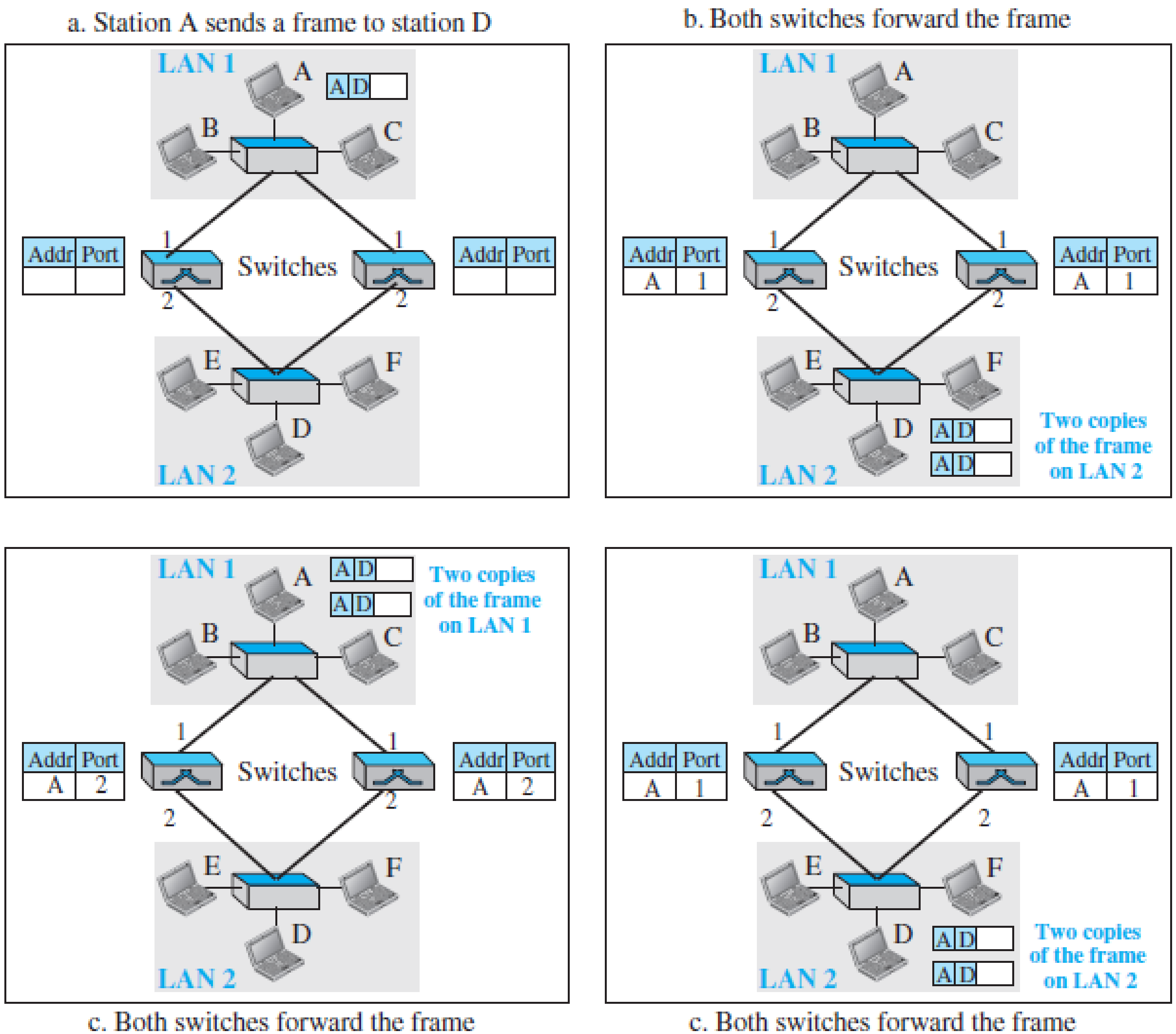


Figure 42. Loop Problem in A Learning Switch

Connecting Devices and Virtual LANs (Continue)

Spanning Tree Algorithm

- To solve the looping problem, switches use the spanning tree algorithm to create a loopless topology.
- In graph theory, a spanning tree is a graph in which there is no loop.
- In a switched LAN, this means creating a topology in which each LAN can be reached from any other LAN through one path only (no loop).
- Figure 43 shows a system with four LANs and five switches.
- To find the spanning tree, it is needed to assign a cost (metric) to each arc.
- The minimum hops are chosen.
- The hop count is normally 1 from a switch to the LAN and 0 in the reverse direction.

Connecting Devices and Virtual LANs (Continue)

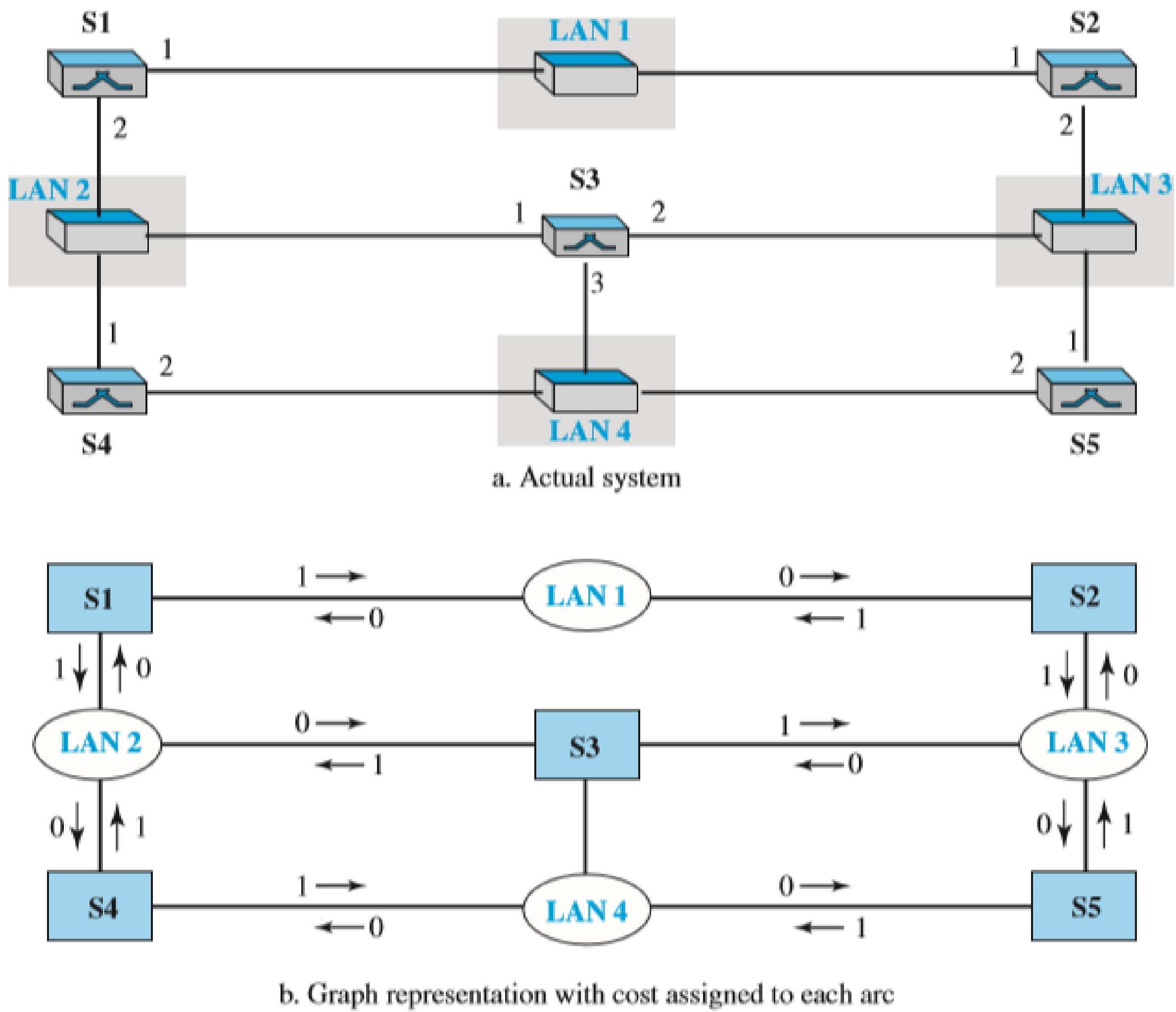


Figure 43. A System of Connected LANs and Its Graph Representation

Connecting Devices and Virtual LANs (Continue)

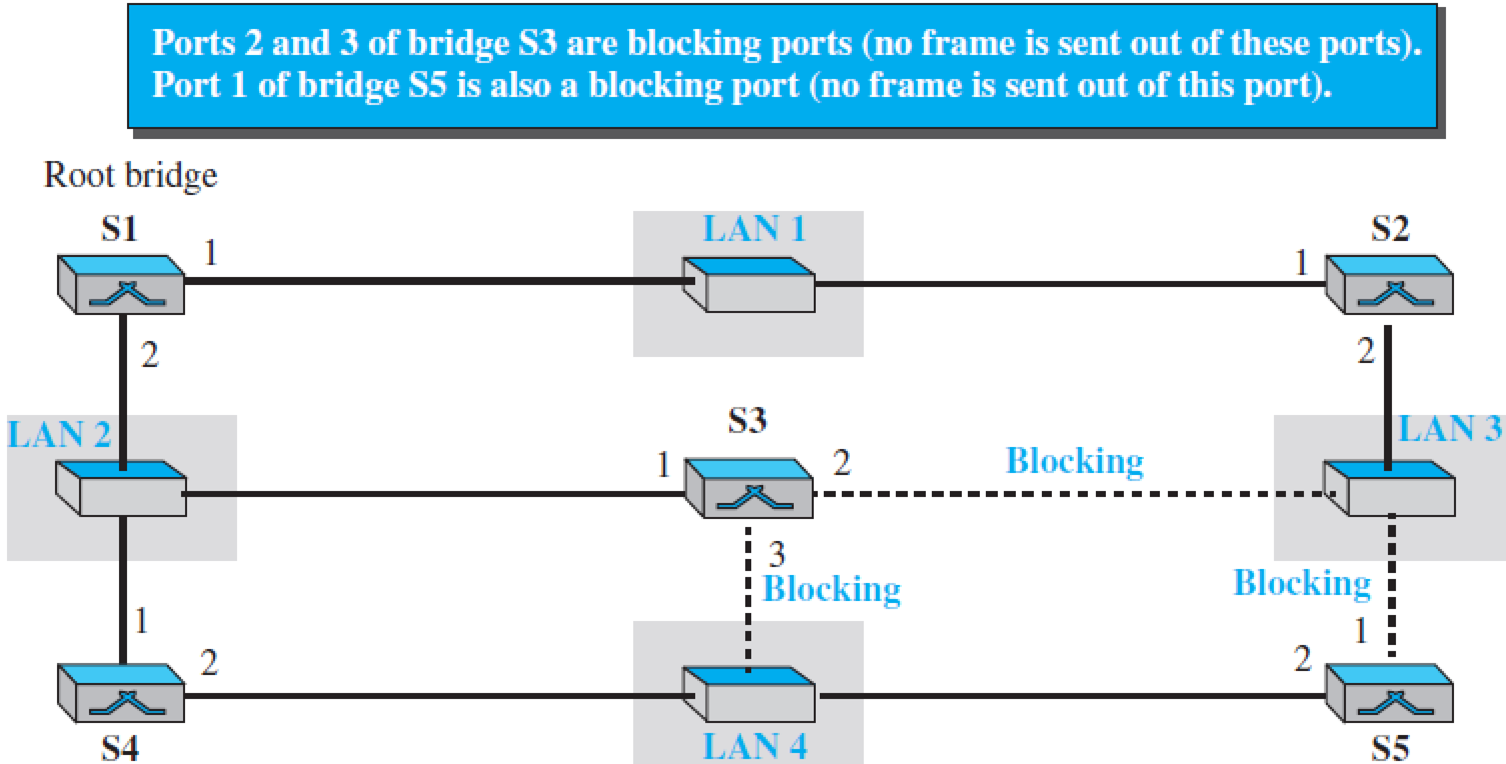


Figure 44. Forwarding and Blocking Ports After Using Spanning Tree Algorithm

Connecting Devices and Virtual LANs (Continue)

Routers

- A router is a three-layer (physical, data-link, and network) device.
- As a physical-layer device, it regenerates the signal it receives.
- As a 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.
- In figure 45, assume an organization has two separate buildings with a Gigabit Ethernet LAN installed in each building.

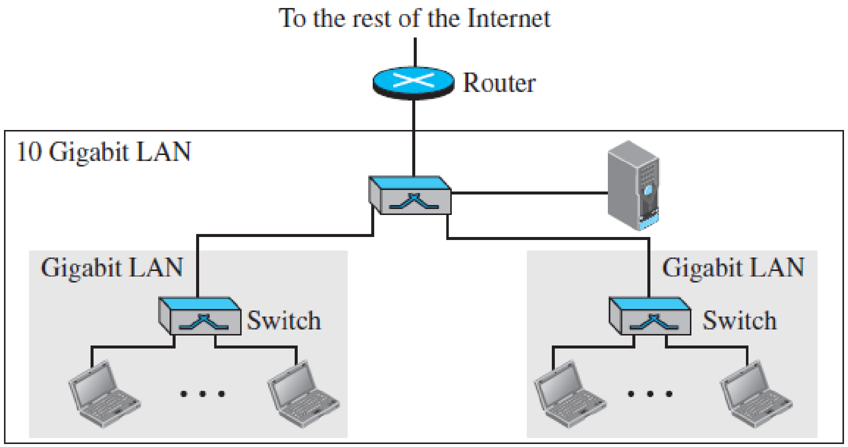


Figure 45. Routing Example

Connecting Devices and Virtual LANs (Continue)

Virtual LANs

- It can roughly define a virtual local area network (VLAN) as a local area network configured by software, not by physical wiring.
- Figure 46 shows a switched LAN in an engineering firm in which nine stations are grouped into three LANs that are connected by a switch.

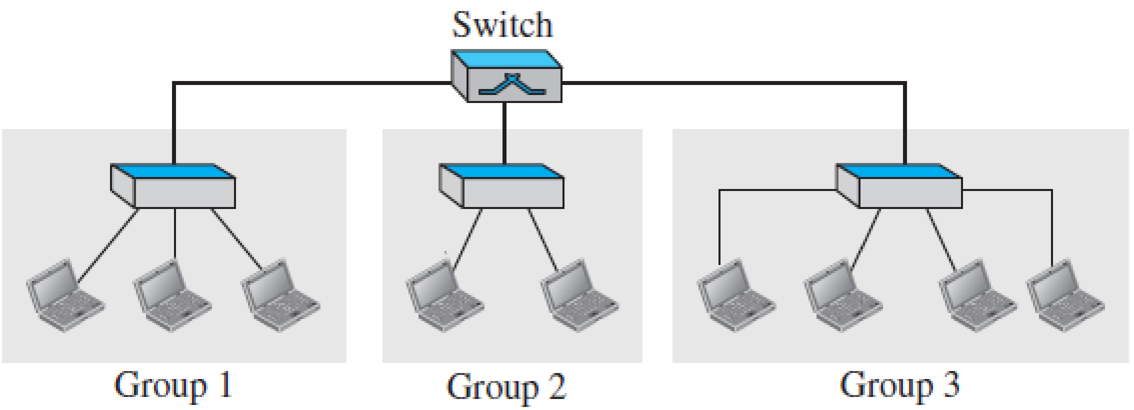


Figure 46. A Switch Connecting Three LANs

Connecting Devices and Virtual LANs (Continue)

- The whole idea of VLAN technology is to divide a LAN into logical, instead of physical, segments.
- A LAN can be divided into several logical LANs, called VLANs.
- Each VLAN is a work group in the organization.
- If a person moves from one group to another, there is no need to change the physical configuration.
- The group membership in VLANs is defined by software, not hardware.
- Any station can be logically moved to another VLAN.
- All members belonging to a VLAN can receive broadcast messages sent to that particular VLAN.
- Figure 47 shows the same switched LAN divided into VLANs.

Connecting Devices and Virtual LANs (Continue)

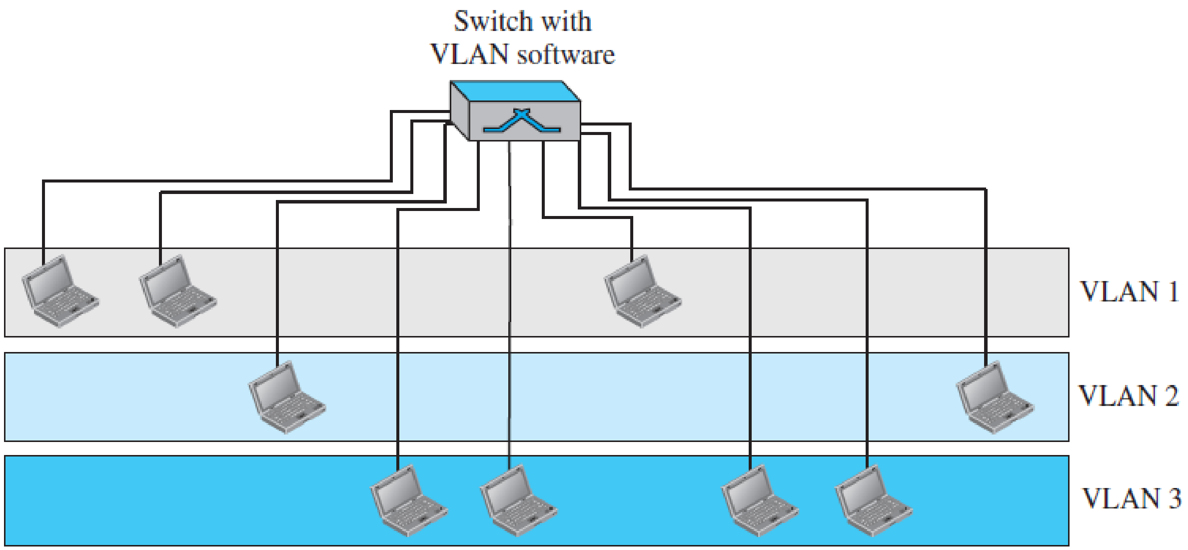


Figure 47. A switch using VLAN software

- VLAN technology even allows the grouping of stations connected to different switches in a VLAN.
- Figure 48 shows a backbone local area network with two switches and three VLANs.
- Stations from switches A and B belong to each VLAN.

Connecting Devices and Virtual LANs (Continue)

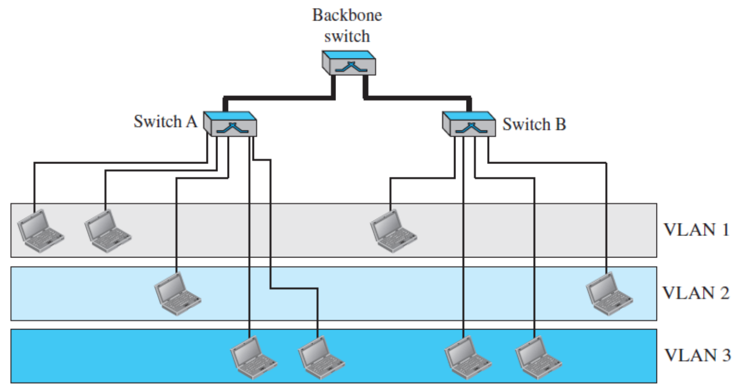


Figure 48. Two Switches In A Backbone Using VLAN Software

Membeship

- Vendors use different characteristics such as interface numbers, port numbers, MAC addresses, IP addresses, IP multicast addresses, or a combination of two or more of these.

Advantages

- There are several advantages to using VLANs.

Cost and Time Reduction

- VLANs can reduce the migration cost of stations going from one group to another.

Connecting Devices and Virtual LANs (Continue)

- Physical reconfiguration takes time and is costly.
- Instead of physically moving one station to another segment or even to another switch, it is much easier and quicker to move it by using software.

Creating Virtual Work Groups

- VLANs can be used to create virtual work groups.

Security

- VLANs provide an extra measure of security.
- People belonging to the same group can send broadcast messages with the guaranteed assurance that users in other groups will not receive these messages.

Next Week Lecture

- Network-Layer Services
- Packet Switching
- Network-Layer Performance
- IPv4 Addresses
- Forwarding of IP Packets

Thank You