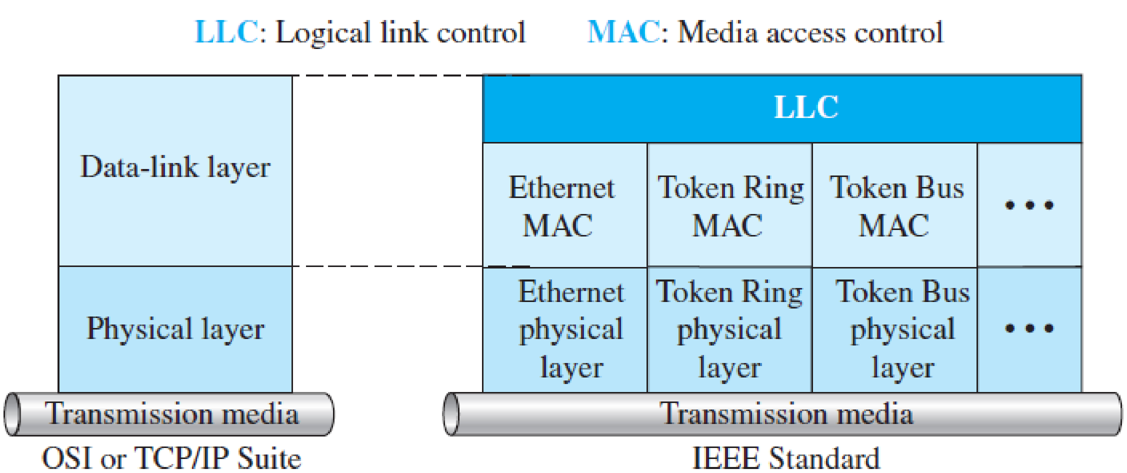
ETHERNET PROTOCOL

IEEE Project 802

- In 1985, the Computer Society of the IEEE started a project, called Project 802, to set standards to enable intercommunication among equipment from a variety of manufacturers.
- The relationship of the 802 Standard to the TCP/IP protocol suite is shown in below Figure.
- The IEEE has subdivided the data-link layer into two sublayers: logical link control (LLC) and media access control (MAC). IEEE has also created several physical-layer standards for different LAN protocols



Logical Link Control (LLC)

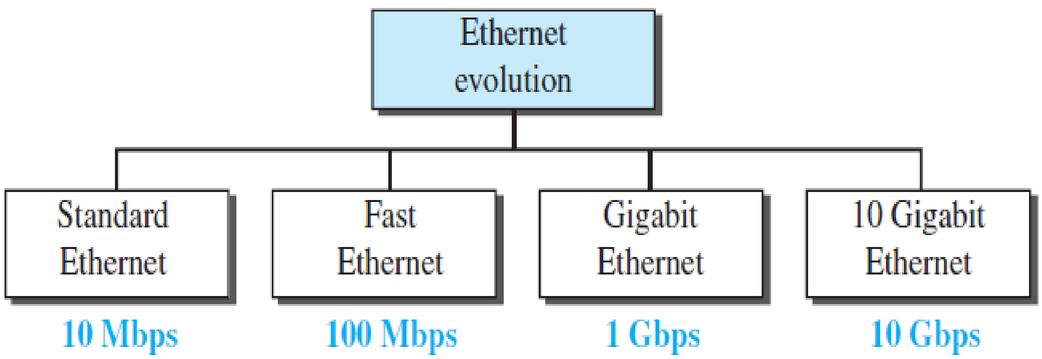
- Data link control handles framing, flow control, and error control. In IEEE Project 802, flow control, error control, and part of the framing duties are collected into one sublayer called the logical link control (LLC).
- Framing is handled in both the LLC sublayer and the MAC sublayer.

Media Access Control (MAC)

- IEEE Project 802 has created a sublayer called media access control that defines the specific access method for each LAN.

Ethernet Evolution

- Has four generations: Standard Ethernet (10 Mbps), Fast Ethernet (100 Mbps), Gigabit Ethernet (1 Gbps), and 10 Gigabit Ethernet (10 Gbps), as shown in Figure below.



STANDARD ETHERNET

- Original Ethernet technology with the data rate of 10 Mbps as the Standard Ethernet.

Characteristics

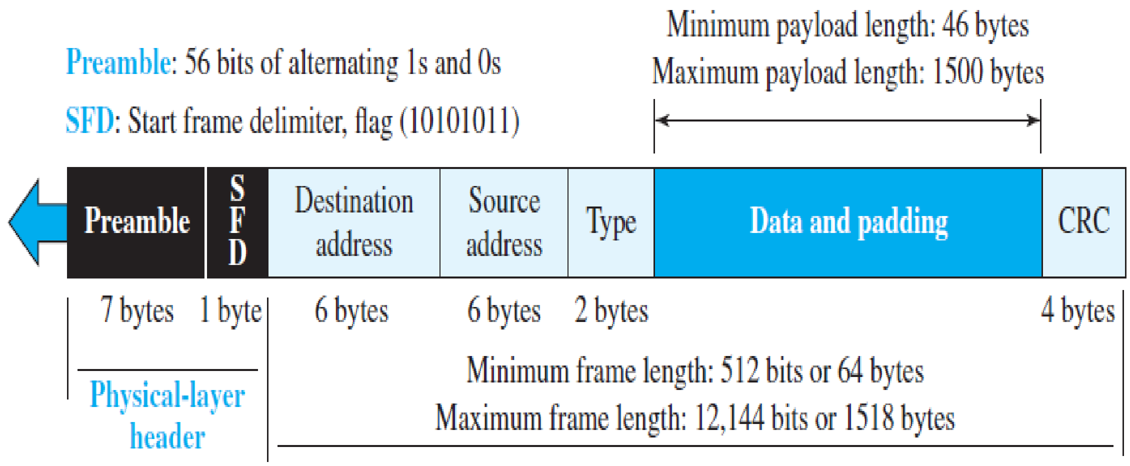
Connectionless and Unreliable Service

- 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.
- Ethernet is also unreliable like IP and UDP. If a frame is corrupted during transmission

and the receiver finds out about the corruption, which has a high level of probability of happening because of the CRC-32, the receiver drops the frame silently.

Frame Format

- ❖ The Ethernet frame contains seven fields, as shown in Figure below



Preamble.

- ❖ This field contains 7 bytes (56 bits) of alternating 0s and 1s that alert the receiving system to the coming frame and enable it to synchronize its clock if it's out of synchronization.
- ❖ The pattern provides only an alert and a timing pulse.
- ❖ The 56-bit pattern allows the stations to miss some bits at the beginning of the frame.

Start frame delimiter (SFD).

- ❖ This 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.
- ❖ The last 2 bits are (11)2 and alert the receiver that the next field is the destination address. This field is actually a flag that defines the beginning of the frame.

Destination address (DA).

- ❖ This field is six bytes (48 bits) and contains the link layer address of the destination station or stations to receive the packet.

Source address (SA).

- This field is also six bytes and contains the link-layer address of the sender of the packet. We will discuss addressing shortly.

Type.

- This field defines the upper-layer protocol whose packet is encapsulated in the frame.
- This protocol can be IP, ARP, OSPF, and so on.

Data.

- This field carries data encapsulated from the upper-layer protocols. It is a minimum of 46 and a maximum of 1500 bytes.
- If the data coming from the upper layer is more than 1500 bytes, it should be fragmented and encapsulated in more than one frame.
- If it is less than 46 bytes, it needs to be padded with extra 0s.

CRC.

- The last field contains error detection information, in this case a CRC-32. The CRC is calculated over the addresses, types, and data field.
- If the receiver calculates the CRC and finds that it is not zero (corruption in transmission), it discards the frame.

Frame Length

- Ethernet has imposed restrictions on both the minimum and maximum lengths of a frame.
- The minimum length restriction is required for the correct operation of CSMA/CD, as we will see shortly.
- An Ethernet frame needs to have a minimum length of 512 bits or 64 bytes. Part of this length is the header and the trailer.
    - **Minimum frame length: 64 bytes**
    - **Maximum frame length: 1518 bytes**
    - **Minimum data length: 46 bytes**

- **Maximum data length: 1500 bytes**

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.

4A: 30:10:21: 10:1A

Transmission of Address Bits

- The way the addresses are sent out online is different from the way they are written in hexadecimal notation. The transmission is left to right, byte by byte.

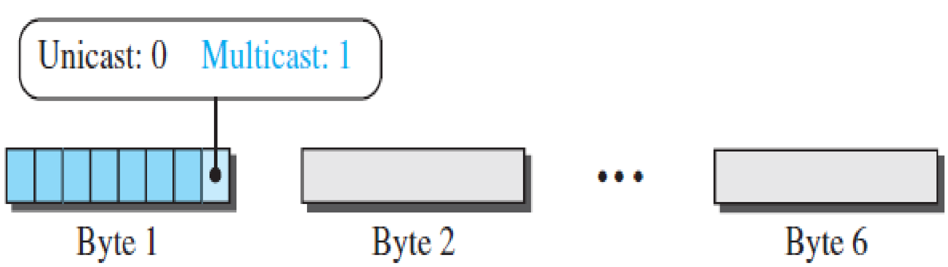
Example

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

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

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 as shown below figure.



Example:- 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 Fs, 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 Fs in hexadecimal.

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

  Efficiency =1 / (1 + 6.4 X a)

- in which the parameter "a" is the number of frames that can fit on the medium. It can be calculated as a = (propagation delay)/(transmission delay)

Example

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 × 108 m/s.

Propagation delay 5 2500/(2 3 108) 5 12.5 μs	Transmission delay 5 512/(107) 5 51.2 μs
a = 12.5/51.2 = 0.24	Efficiency = 39%

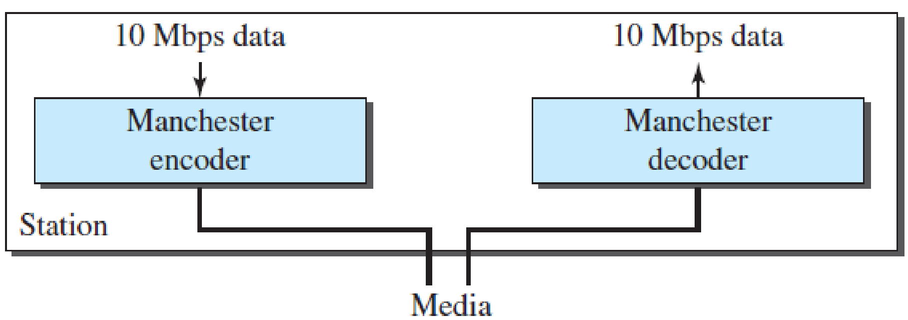
Implementation

- The Standard Ethernet defined several implementations, but only four of them became popular during the 1980s. Table shows a summary of Standard Ethernet implementation.

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

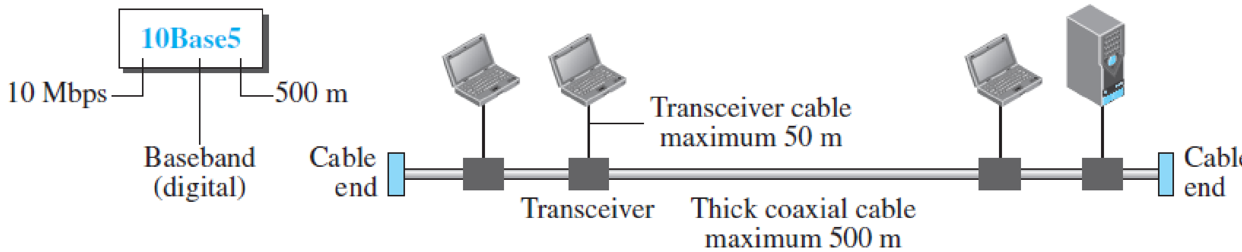
Encoding and Decoding

- All standard implementations use digital signaling (baseband) at 10 Mbps. At the sender, data are converted to a digital signal using the Manchester scheme at the receiver, the received signal is interpreted as Manchester and decoded into data.
- Figure below shows the encoding scheme for Standard Ethernet



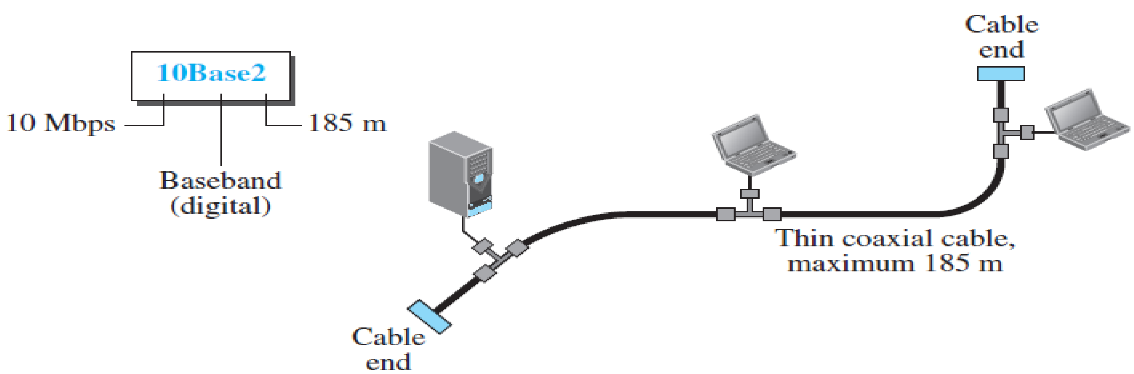
10Base5: Thick Ethernet

- The first implementation is called 10Base5, thick Ethernet, or Thicknet. Figure below shows a schematic diagram of a 10Base5 implementation.



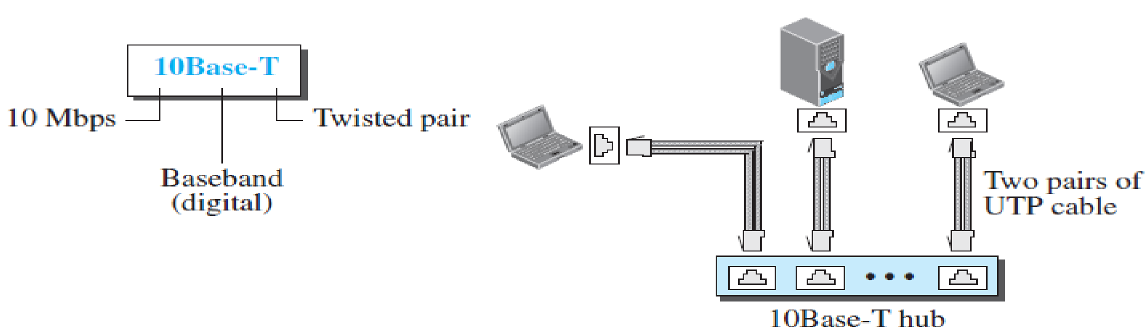
10Base2: Thin Ethernet

- ❖ The second implementation is called 10Base2, thin Ethernet, or Cheapernet.
- ❖ 10Base2 also uses a bus topology, but the cable is much thinner and more flexible. Figure below shows the schematic diagram of a 10Base2 implementation.



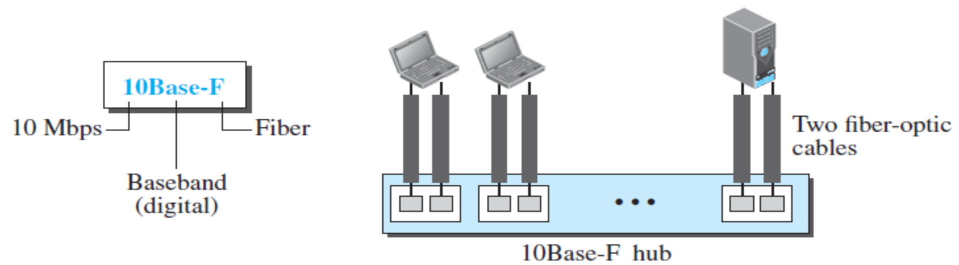
10Base-T: Twisted-Pair Ethernet

- ❖ The third implementation is called 10Base-T or twisted-pair Ethernet. 10Base-T uses a physical star topology. The stations are connected to a hub via two pairs of twisted cable, as shown in Figure below.



10Base-F: Fiber Ethernet

❖ Although there are several types of optical fiber 10-Mbps Ethernet, the most common is called 10Base-F. 10Base-F uses a star topology to connect stations to a hub. The stations are connected to the hub using two fiber-optic cables, as shown in below Figure.



Changes in the Standard

Bridged Ethernet

❖ The first step in the Ethernet evolution was the division of a LAN by bridges.

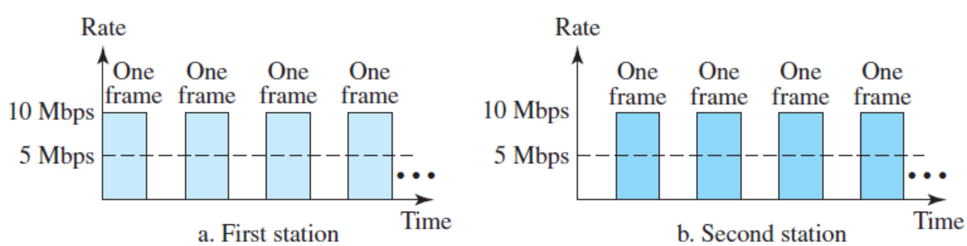
❖ Bridges have two effects on an Ethernet LAN.

Raising the Bandwidth

❖ 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.

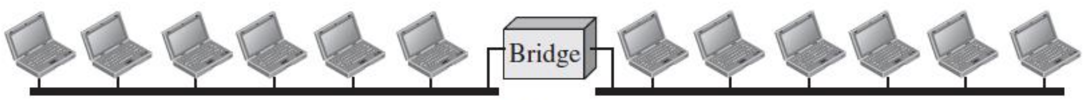
❖ If only one station has frames to send, it benefits from the total capacity (10 Mbps). But if more than one station needs to use the network, the capacity is shared.

❖ When one station is sending, the other one refrains from sending. We can say that, in this case, each station on average sends at a rate of 5 Mbps. Below Figure shows the situation.



- A bridge divides the network into two or more networks.
- Band widthwise, each network is independent is as shown in Figure below

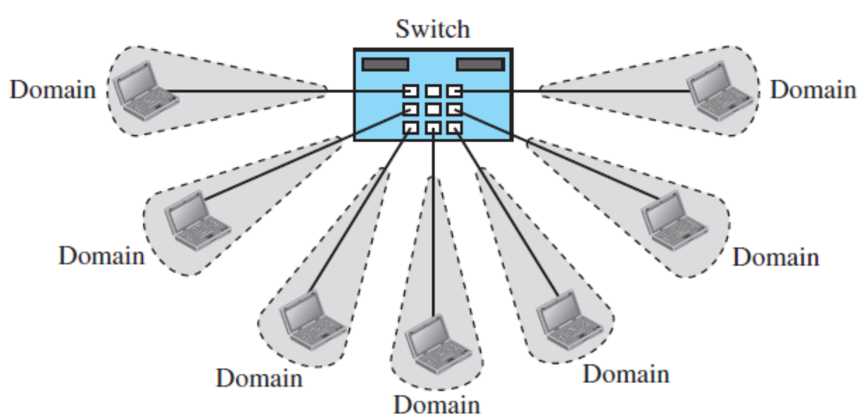
a. Without bridging



b. With bridging

Switched Ethernet

- The idea of a bridged LAN can be extended to a switched LAN.
- Instead of having two to four networks, A layer-2 switch is an N-port bridge with additional sophistication that allows faster handling of the packets as shown below Figure.



FAST ETHERNET (100 MBPS)

1. The goals of Fast Ethernet can be summarized as follows:
2. Upgrade the data rate to 100 Mbps.

3. Make it compatible with Standard Ethernet.
4. Keep the same 48-bit address.
5. Keep the same frame format.

GIGABIT ETHERNET

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 auto negotiation as defined in Fast Ethernet.

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.

Architectural Comparison

Medium

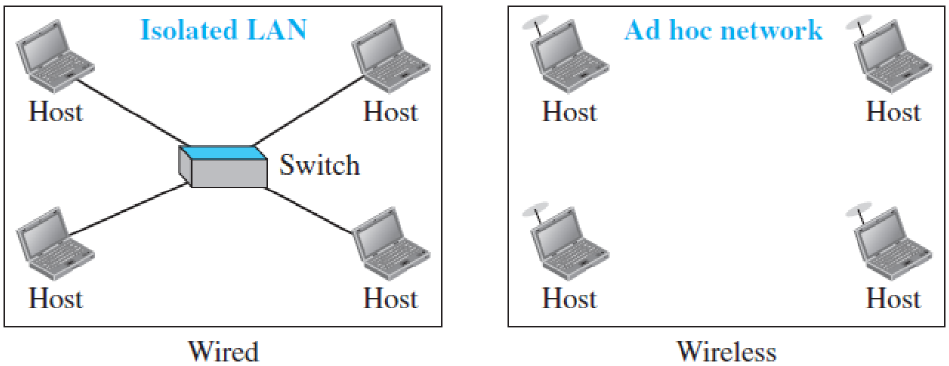
- The first difference we can see between a wired and a wireless LAN is the medium. In a wired LAN

Hosts

- In a wired LAN, a host is always connected to its network at a point with a fixed link layer address related to its network interface card (NIC).

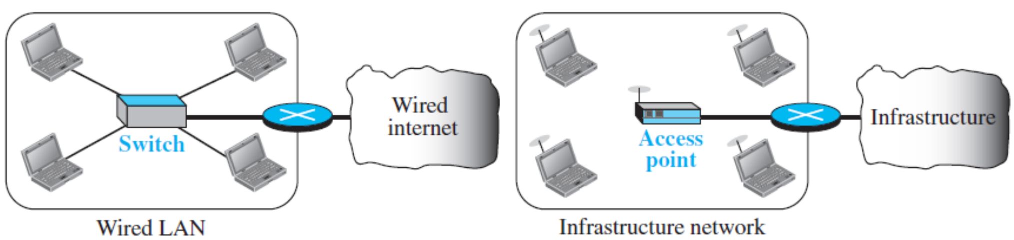
Isolated LANs

❖ The concept of a wired isolated LAN also differs from that of a wireless isolated LAN. A wired isolated LAN is a set of hosts connected via a link-layer switch as shown below figure.



Connection to Other Networks

❖ A wired LAN can be connected to another network or an internetwork such as the Internet using a router.



Characteristics

- ✓ **Attenuation**
- ✓ **Interference**
- ✓ **Multipath Propagation**
- ✓ **Error**

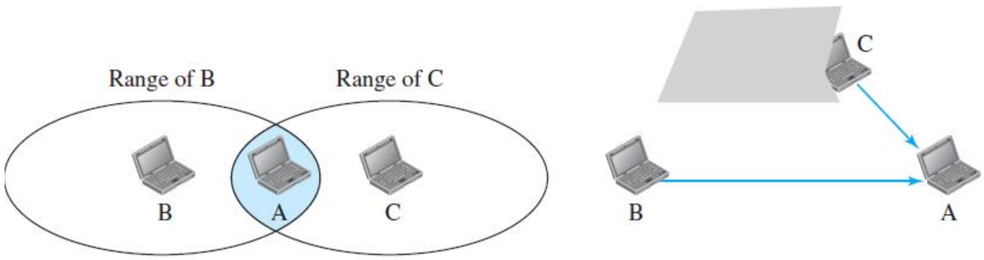
Access Control

❖ The CSMA/CD algorithm does not work in wireless LANs for three reasons:

1. To detect a collision, a host needs to send and receive at the same time (sending the

frame and receiving the collision signal), which means the host needs to work in a duplex mode. They can only send or receive at one time.

2. Because of the hidden station problem, in which a station may not be aware of another station's transmission due to some obstacles or range problems, collision may occur but not be detected as shown in below Figure.



a. Stations B and C are not in each other's range.

b. Stations B and C are hidden from each other.

3. The distance between stations can be great. Signal fading could prevent a station at one end from hearing a collision at the other end.

IEEE 802.11 PROJECT

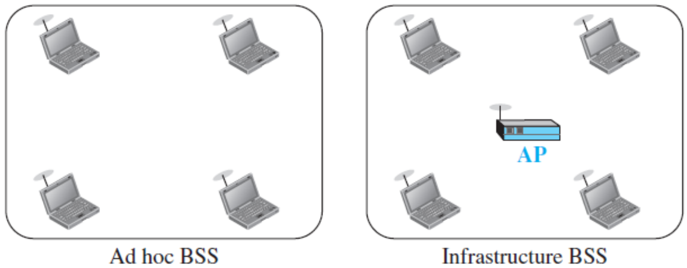
- EEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data-link layers. It is sometimes called wireless Ethernet.

Architecture

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

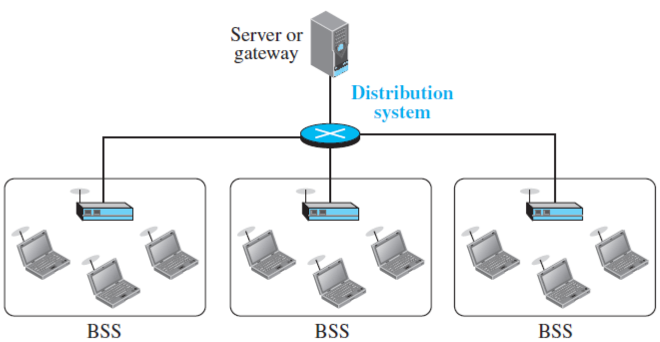
Basic Service Set

- 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) as shown below Figure.
- The BSS without an AP is a stand-alone network and cannot send data to other BSSs. It is called an ad hoc architecture.
- A BSS with an AP is sometimes referred to as an infrastructure BSS.



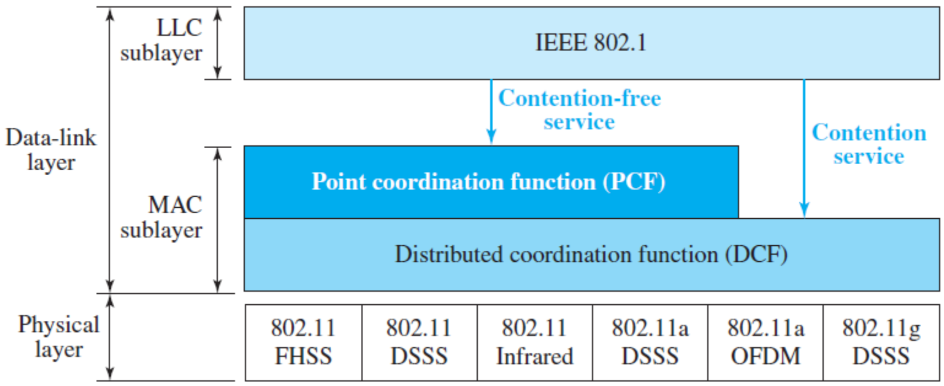
Extended Service Set

- 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.
- 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 as shown in figure below.



MAC Sublayer

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

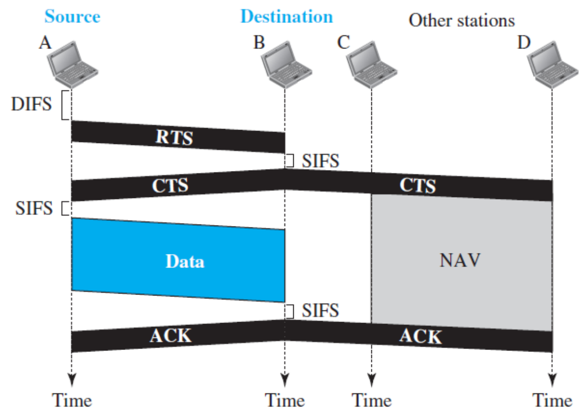


Distributed Coordination Function

- One of the two protocols defined by IEEE at the MAC sublayer is called the distributed coordination function (DCF).

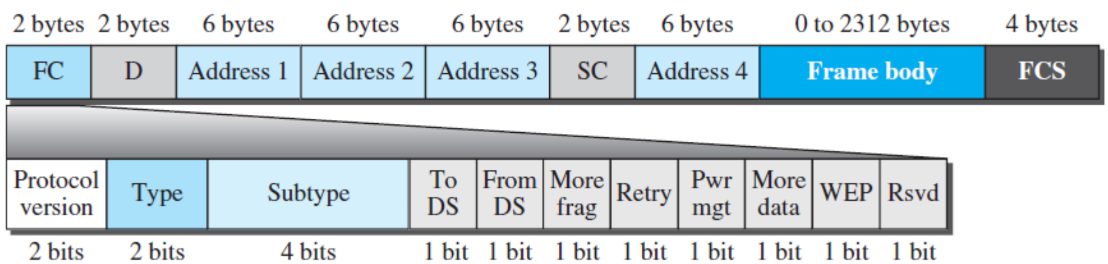
Frame Exchange Time Line

- Figure below shows the exchange of data and control frames in time.
  1. Before sending a frame, the source station senses the medium by checking the energy level at the carrier frequency.
     a. The channel uses a persistence strategy with backoff until the channel is idle.
     b. After the station is found to be idle, the station waits for a period of time called the distributed interframe space (DIFS); then the station sends a control frame called the request to send (RTS).
  2. After receiving the RTS and waiting a period of time called the short interframe space (SIFS), the destination station sends a control frame, called the clear to send (CTS), to the source station. This control frame indicates that the destination station is ready to receive data.
  3. The source station sends data after waiting an amount of time equal to SIFS.
  4. The destination station, after waiting an amount of time equal to SIFS, sends an acknowledgment to show that the frame has been received.



Frame Format

- The MAC layer frame consists of nine fields, as shown in Figure below.



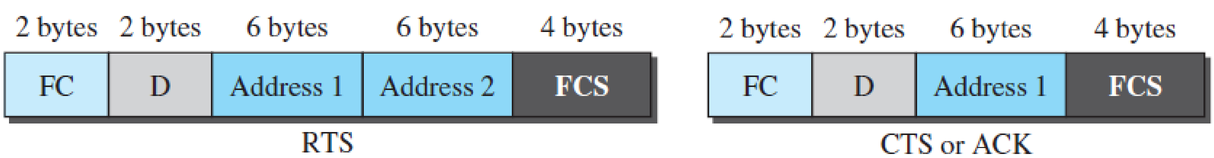
- Frame control (FC). The FC field is 2 bytes long and defines the type of frame and some control information. Table below describes the subfields.

Field	*Explanation*
Version	Current version is 0
Type	Type of information: management (00), control (01), or data (10)
Subtype	Subtype of each type (see Table 15.2)
To DS	Defined later
From DS	Defined later
More frag	When set to 1, means more fragments
Retry	When set to 1, means retransmitted frame
Pwr mgt	When set to 1, means station is in power management mode
More data	When set to 1, means station has more data to send
WEP	Wired equivalent privacy (encryption implemented)
Rsvd	Reserved

- D. This field defines the duration of the transmission that is used to set the value of NAV. In one control frame, it defines the ID of the frame.
- Addresses. There are four address fields, each 6 bytes long. The meaning of each address field depends on the value of the To DS and From DS subfields and will be discussed later.
- Sequence control. This field, often called the SC field, defines a 16-bit value. The first four bits define the fragment number; the last 12 bits define the sequence number, which is the same in all fragments.
- Frame body. This field, which can be between 0 and 2312 bytes, contains information based on the type and the subtype defined in the FC field.
- FCS. The FCS field is 4 bytes long and contains a CRC-32 error-detection sequence.

Frame Types

- A wireless LAN defined by IEEE 802.11 has three categories of frames: management frames, control frames, and data frames.
- Management Frames Management frames are used for the initial communication between stations and access points.
- Control Frames Control frames are used for accessing the channel and acknowledging frames. Figure below shows the format.



- For control frames the value of the type field is 01; the values of the subtype fields for frames we have discussed are shown in Table below.

Subtype	*Meaning*
1011	Request to send (RTS)
1100	Clear to send (CTS)
1101	Acknowledgment (ACK)

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 below Table

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

Case 1: 00

- In this case, To DS = 0 and From DS = 0. This means that the frame is not going to a distribution system (To DS = 0) and is not coming from a distribution system (From DS = 0). The frame is going from one station in a BSS to another without passing through the distribution system. The addresses are shown in below Figure.

Case 2: 01

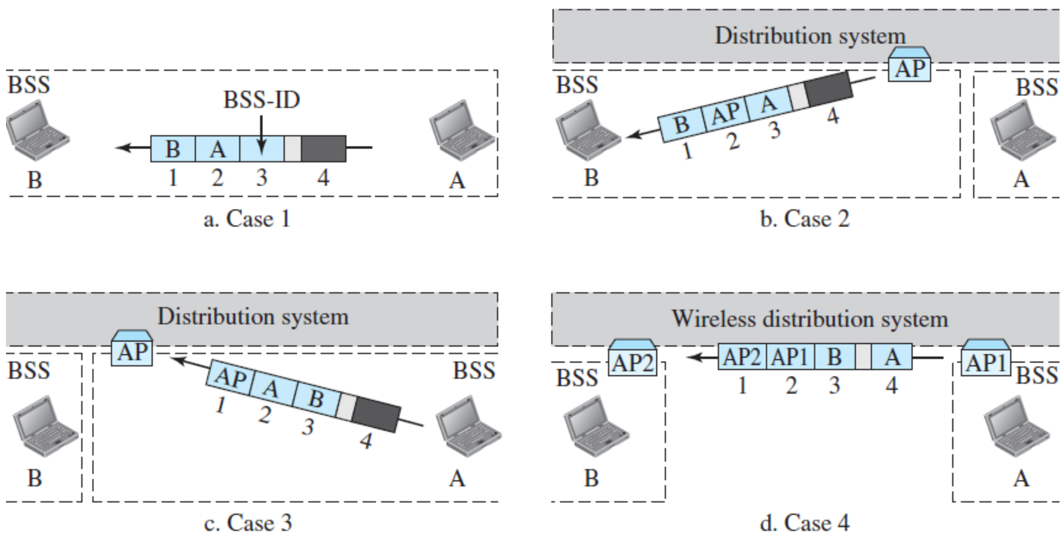
- In this case, To DS = 0 and From DS = 1. This means that the frame is coming from a distribution system (From DS = 1). The frame is coming from AP and going to a station. The addresses are as shown in below Figure.

Case 3: 10

- In this case, To DS = 1 and From DS = 0. This means that the frame is going to a distribution system (To DS = 1). The frame is going from a station to an AP. The addresses are as shown in below Figure.

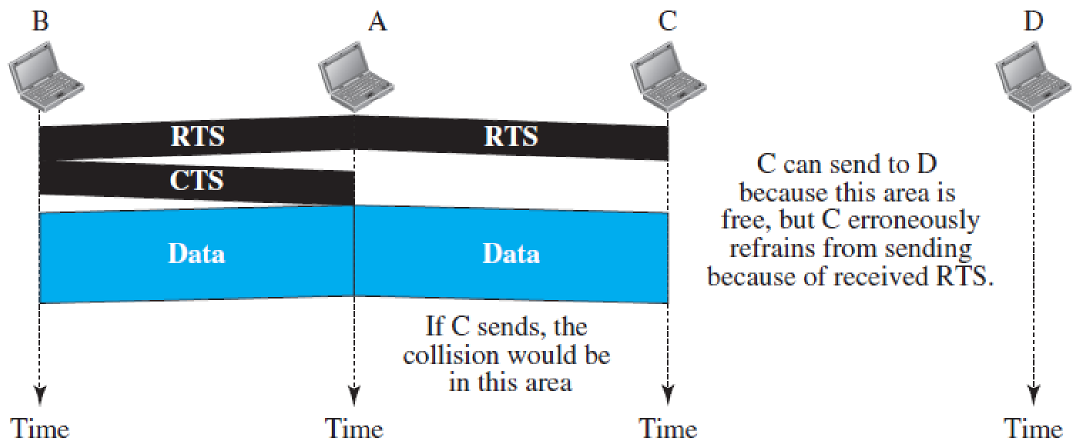
Case 4: 11

- In this case, To DS = 1 and From DS = 1. This is the case in which the distribution system is also wireless. The frame is going from one AP to another AP in a wireless distribution system. Below Figure shows the situation.



Exposed Station Problem

- In this problem a station refrains from using a channel when it is, in fact, available.
- In Figure below station A is transmitting to station B. Station C has some data to send to station D, which can be sent without interfering with the transmission from A to B.
- However, station C is exposed to transmission from A; it hears what A is sending and thus refrains from sending.
- The handshaking messages RTS and CTS cannot help in this case. Station C hears the RTS from A and refrains from sending, even though the communication between C and D cannot cause a collision in the zone between A and C
- Station C cannot know that station A's transmission does not affect the zone between C and D.



BLUETOOTH

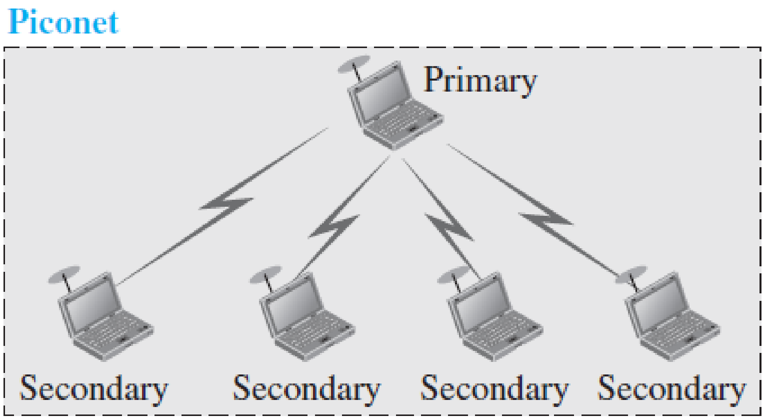
- ❖ Bluetooth is a wireless LAN technology designed to connect devices of different functions such as telephones, notebooks, computers (desktop and laptop), cameras, printers, and even coffee makers when they are at a short distance from each other.
- ❖ A Bluetooth LAN is an ad hoc network, which means that the network is formed spontaneously, the devices, sometimes called gadgets, find each other and make a network called a piconet.

Architecture

- ❖ Bluetooth defines two types of networks: piconet and scatternet.

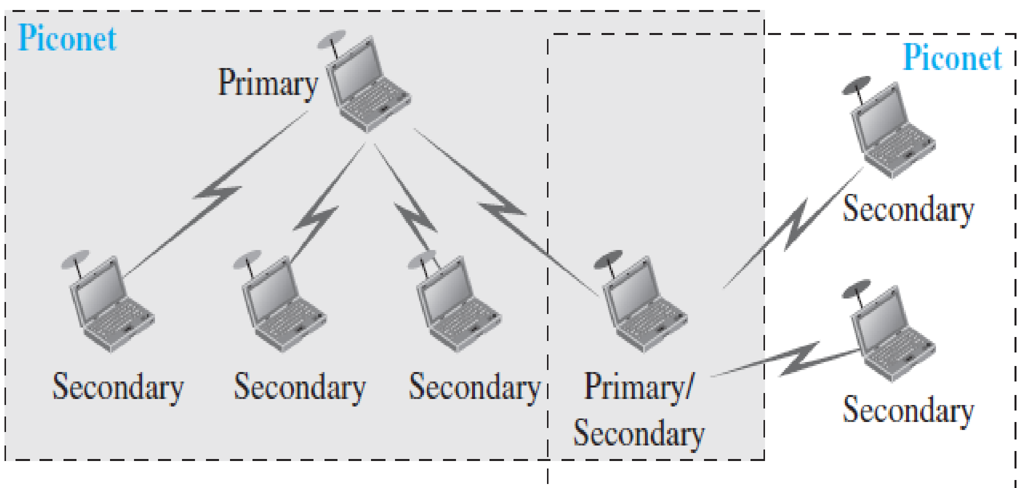
Piconets

- ❖ 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. The communication between the primary and secondary stations can be one-to-one or one-to-many. Below Figure shows a piconet.



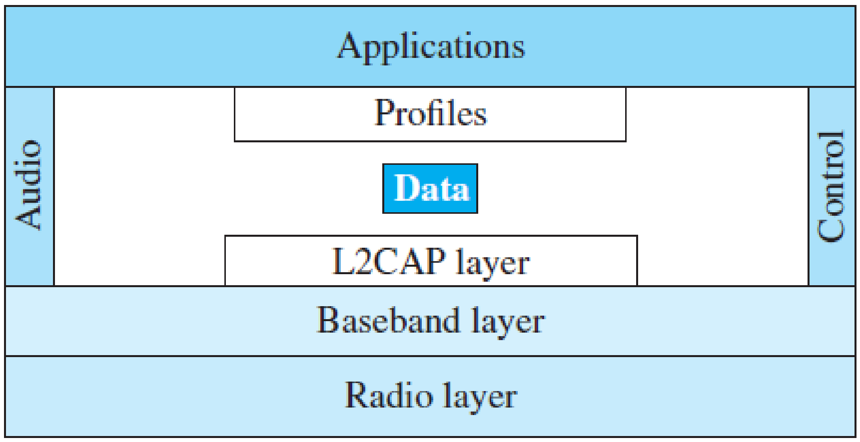
Scatternet

- 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 below illustrates a scatternet

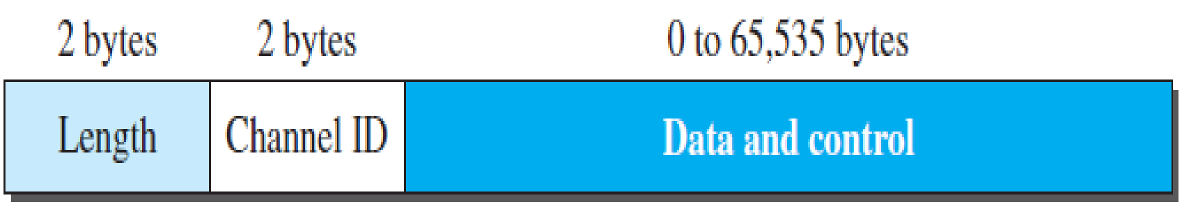


Bluetooth Layers

- Bluetooth uses several layers that do not exactly match those of the Internet model we have defined in this book. Figure belpw shows these layers



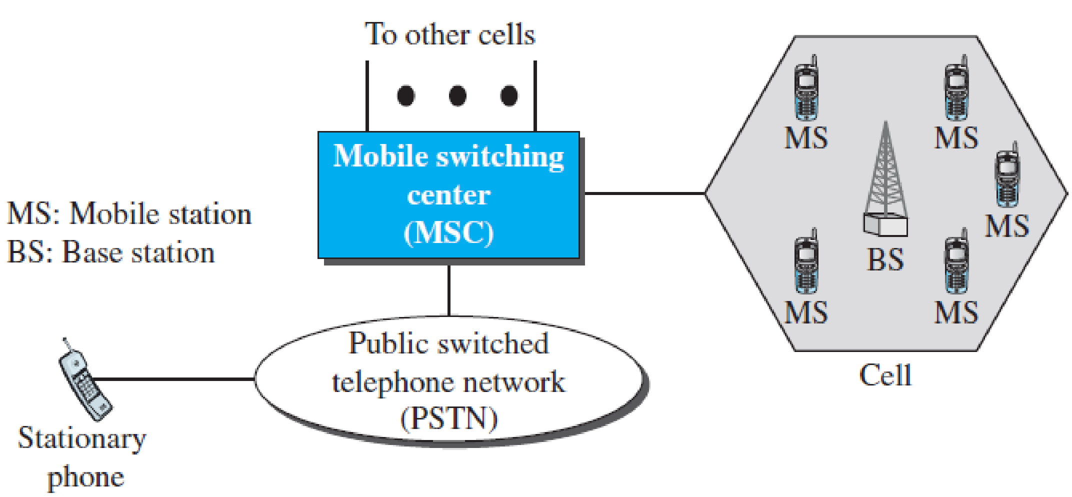
- L2CAP The Logical Link Control and Adaptation Protocol, or L2CAP (L2 here means LL), is roughly equivalent to the LLC sublayer in LANs.
- Figure below shows the format of the data packet at this level.



- The 16-bit length field defines the size of the data, in bytes, coming from the upper layers. Data can be up to 65,535 bytes

CELLULAR TELEPHONY

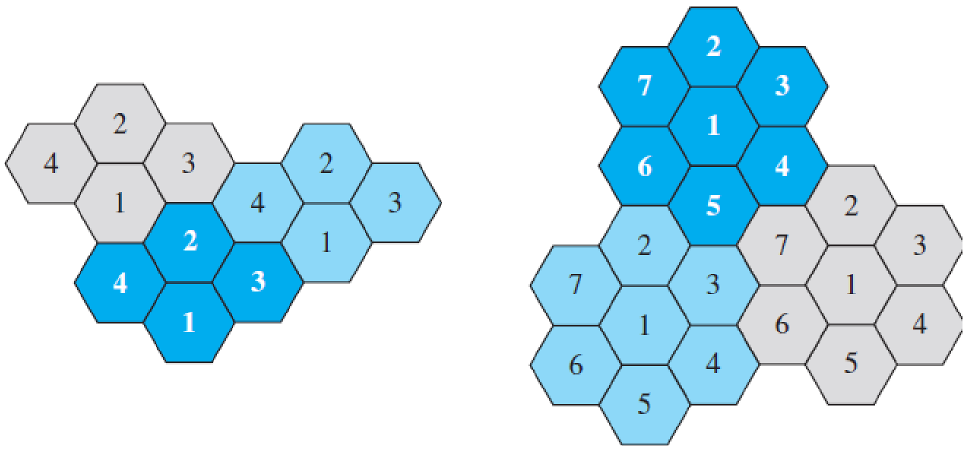
- ❖ Cellular telephony is designed to provide communications between two moving units, called mobile stations (MSs), or between one mobile unit and one stationary unit, often called a land unit.
- ❖ A service provider must be able to locate and track a caller, assign a channel to the call, and transfer 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).
- ❖ 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 below Figure.



- ❖ Cell size is not fixed and can be increased or decreased depending on the population of the area. The typical radius of a cell is 1 to 12 mi.
- ❖ High-density areas require more, geographically smaller cells to meet traffic demands than do low-density areas.
- ❖ Once determined, cell size is optimized to prevent the interference of adjacent cell signals.
- ❖ The transmission power of each cell is kept low to prevent its signal from interfering with those of other cells.

Frequency-Reuse Principle

- ❖ In general, neighboring cells cannot use the same set of frequencies for communication because doing so may create interference for the users located near the cell boundaries.
- ❖ A frequency reuse pattern is a configuration of N cells, N being the reuse factor, in which each cell uses a unique set of frequencies.
- ❖ When the pattern is repeated, the frequencies can be reused.
- ❖ There are several different patterns as shown in below Figure.
- ❖ The numbers in the cells define the pattern.
- ❖ The cells with the same number in a pattern can use the same set of frequencies. We call these cells the reusing cells.
- ❖ As Figure below shows, in a pattern with reuse factor 4, only one cell separates the cells using the same set of frequencies. In a pattern with reuse factor 7, two cells separate the reusing cells.



a. Reuse factor of 4 b. Reuse factor of 7

Transmitting

- To place a call from a mobile station, the caller enters a code of 7 or 10 digits (a phone number) and presses the send button.
- The mobile station then scans the band, seeking a setup channel with a strong signal, and sends the data (phone number) to the closest base station using that channel. The base station relays the data to the MSC.
- The MSC sends the data on to the telephone central office. If the called party is available, a connection is made and the result is relayed back to the MSC

Receiving

- When a mobile phone is called, the telephone central office sends the number to the MSC.
- The MSC searches for the location of the mobile station by sending query signals to each cell in a process called paging. Once the mobile station is found, the MSC transmits a ringing signal and, when the mobile station answers, assigns a voice channel to the call, allowing voice communication to begin.

Handoff

- It may happen that, during a conversation, the mobile station moves from one cell to another. When it does, the signal may become weak.
- To solve this problem, the MSC monitors the level of the signal every few seconds.
- If the strength of the signal diminishes, the MSC seeks a new cell that can better accommodate the communication.
- The MSC then changes the channel carrying the call.

Hard Handoff

- Early systems used a hard handoff. In a hard handoff, a mobile station only communicates with one base station.
- When the MS moves from one cell to another, communication must first be broken with the previous base station

Soft Handoff

- New systems use a soft handoff. In this case, a mobile station can communicate with two base stations at the same time.
- This means that, during handoff, a mobile station may continue with the new base station before breaking off from the old one.

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. Neighboring service providers can provide extended coverage through a roaming contract.
- The situation is similar to snail mail between countries. The charge for delivery of a letter between two countries can be divided upon agreement by the two countries.