Wireless &Wired LAN's

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IEEE STANDARDS

- 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. Project 802 does not seek to replace any part of the OSI or the Internet model.
- Instead, it is a way of specifying functions of the physical layer and the data link layer of major LAN protocols. The standard was adopted by the American National Standards Institute (ANSI). In 1987, the International Organization for Standardization (ISO) also approved it as an international standard under the designation ISO 8802.
- The IEEE has subdivided the **data link layer into two sub layers**: logical link control (LLC) and media access control (MAC). IEEE has also created several physical layer standards for different LAN protocols.

Wireless LAN

- Wi-Fi – Wireless Fidelity – IEEE 802.11
- Bluetooth- IEEE 802.15

Wireless MAN

- Wi-Max- Worldwide Interoperability for Microwave Access) -IEEE 802.16

Wireless WAN

- Cellular Telephony

Data Link Layer

- The data link layer in the IEEE standard is divided into two sublayers: LLC and MAC.

Logical Link Control (LLC)-

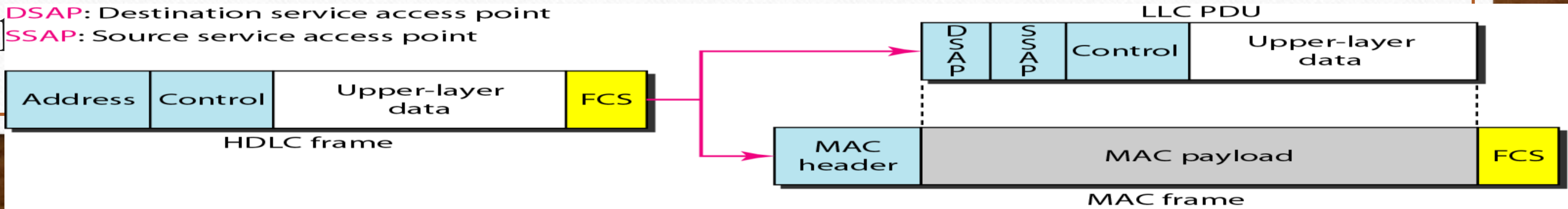
- Data link control handles framing, flow control, and error control. In IEEE Project 802, flow control, ~~error control, and part of the framing duties are collected into one sublayer called the logical link control.~~ Framing is handled in both the LLC sublayer and the MAC sublayer. The LLC provides one single data link control protocol for all IEEE LANs. In this way, the LLC is different from the media access control sublayer, which provides different protocols for different LANs. A single LLC protocol can provide interconnectivity between different LANs because it makes the MAC sublayer transparent.
- **Framing** - LLC defines a protocol data unit (PDU) that is somewhat similar to that of HDLC. These fields are called the destination service access point (DSAP) and the source service access point (SSAP). A frame defined in HDLC is divided into a PDU at the LLC sublayer and a frame at the MAC sublayer, as shown in Figure.
- **Need for LLC** The purpose of the LLC is to provide flow and error control for the upper-layer protocols that actually demand these services. For example, if a LAN or several LANs are used in an isolated system, LLC may be needed to provide flow and error control for the application layer protocols. However, most upper-layer protocols

Media Access Control (MAC)-

- Random access, controlled access, and channelization. IEEE Project 802 has created a sublayer called media access control that defines the specific access method for each LAN. For example, it defines *CSMA/CD* as the media access method for Ethernet LANs and the token passing method for Token Ring and Token Bus LANs. As we discussed in the previous section, part of the framing function is also handled by the MAC layer. In contrast to the LLC sublayer, the MAC sublayer contains a number of distinct modules; each defines the access method and the framing format specific to the corresponding LAN protocol.

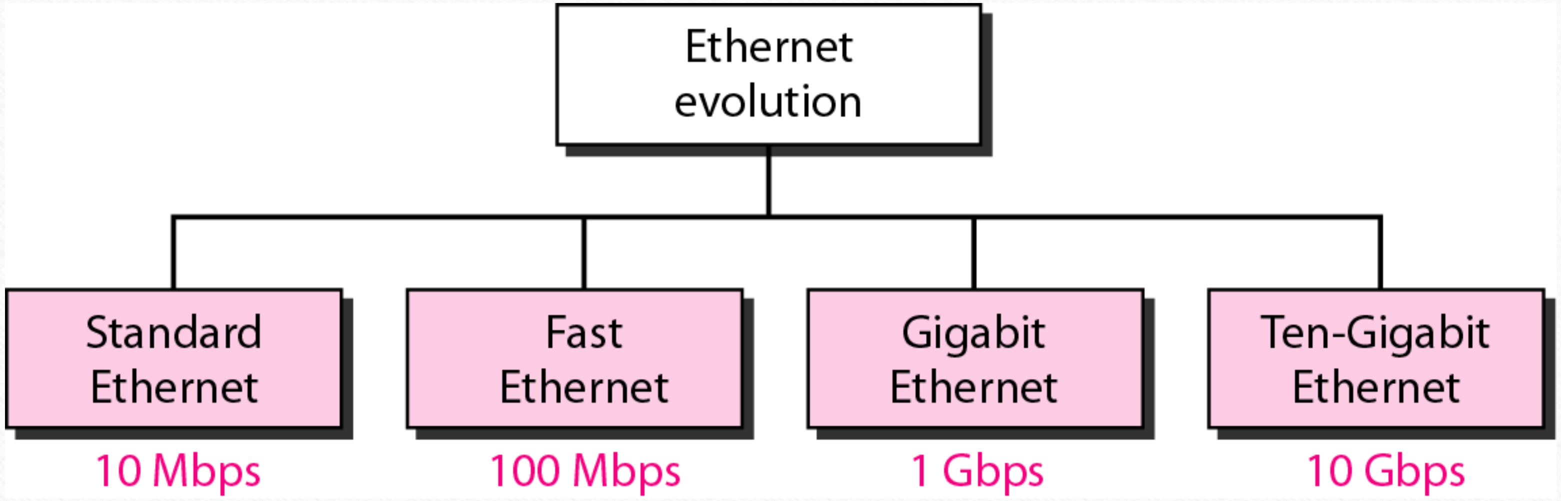
Physical Layer

- The physical layer is dependent on the implementation and type of physical media used. IEEE defines detailed specifications for each LAN implementation. For example, although there is only one MAC sublayer for Standard Ethernet, there is a different



STANDARD ETHERNET

- The original Ethernet was created in 1976 at Xerox's Palo Alto Research Center (PARC).Since then, it has gone through four generations: Standard Ethernet (10 Mbps), Fast Ethernet (100 Mbps), Gigabit Ethernet (1 Gbps), and Ten-Gigabit Ethernet (10 Gbps),as shown in Figure. We briefly discuss all these generations starting with the first, Standard (or traditional) Ethernet.



MAC Sublayer

- In Standard Ethernet, the MAC sublayer governs the operation of the access method. It also frames data received from the upper layer and passes them to the physical layer.

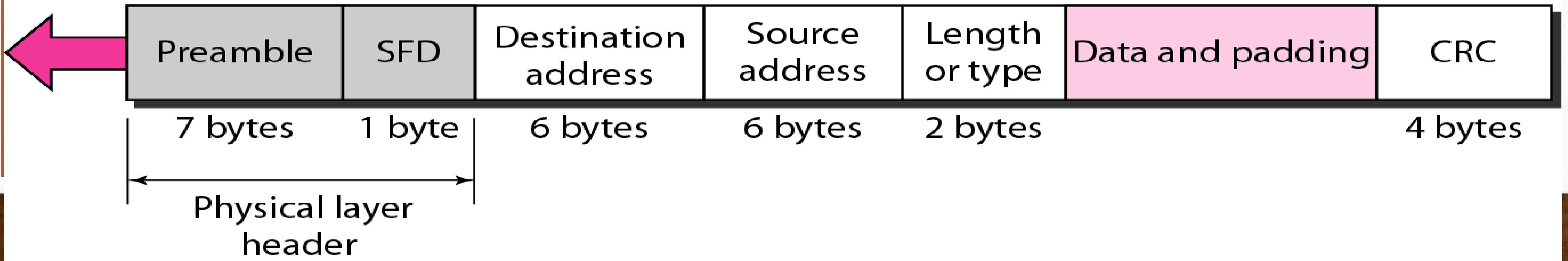
Frame Format

- The Ethernet frame contains seven fields: preamble, SFD, DA, SA, length or type of protocol data unit (PDU), upper-layer data, and the CRC. Ethernet does not provide any mechanism for acknowledging received frames, making it what is known as an unreliable medium. Acknowledgments must be implemented at the higher layers. The format of the MAC frame is shown in Figure .

Figure *802.3 MAC frame*

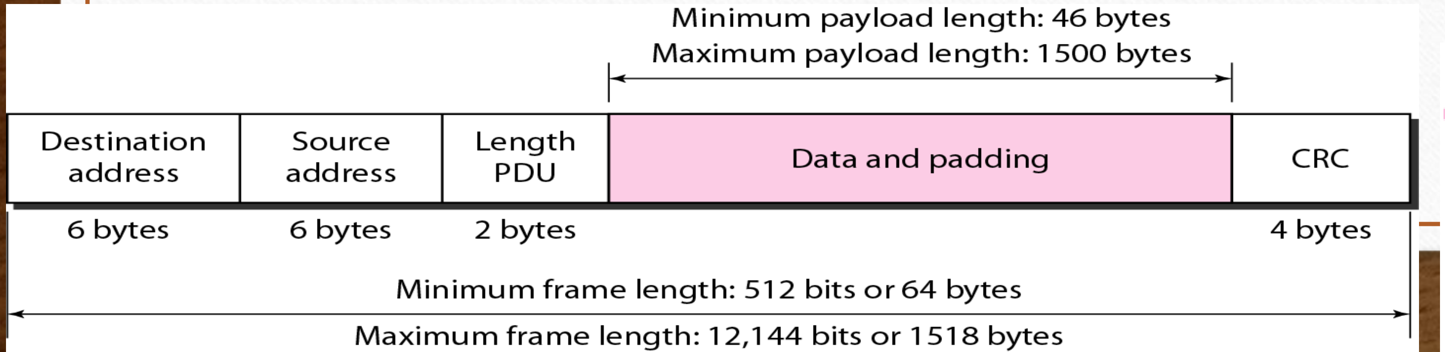
Preamble: 56 bits of alternating 1s and 0s.

SFD: Start frame delimiter, flag (10101011)



- **Preamble.** The first field of the 802.3 frame contains 7 bytes (56 bits) of alternating Os and 1s that alerts the receiving system to the coming frame and enables it to synchronize its input timing. 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. The preamble is actually added at the physical layer and is not (formally)part of the frame.
- **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. The last 2 bits is 11 and alerts the receiver that the next field is the destination address.
- **Destination address (DA).** The DA field is 6 bytes and contains the physical address of the destination station or stations to receive the packet.
- **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. The IEEE standard used it as the length field to define the number of bytes in the data field. Both uses are common today.
- **Data.** This field carries data encapsulated from the upper-layer protocols. It is a minimum of 46 and a maximum of 1500 bytes, as we will see later.
- **CRC.** The last field contains error detection information, in this case a CRC-32

- ***Frame Length***
- Ethernet has imposed restrictions on both the minimum and maximum lengths of a frame, as shown in Figure . The minimum length restriction is required for the correct operation of *CSMAlCD* 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. If we count 18 bytes of header and trailer (6 bytes of source address, 6 bytes of destination address, 2 bytes of length or type, and 4 bytes of CRC), then the minimum length of data from the upper layer is 64 - 18 = 46 bytes. If the upper-layer packet is less than 46 bytes, padding is added to make up the difference.
- The standard defines the maximum length of a frame (without preamble and SFD field) as 1518 bytes. If we subtract the 18 bytes of header and trailer, the maximum length of the payload is 1500 bytes. The maximum length restriction has two historical reasons. First, memory was very expensive when Ethernet was designed: a maximum length restriction helped to reduce the size of the buffer. Second, the maximum length restriction prevents one station from monopolizing the shared medium, blocking other stations that have data to send.
- ***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 6-byte physical address. As shown in Figure, the Ethernet address is 6 bytes (48 bits), normally written in hexadecimal notation, with a colon between the bytes.

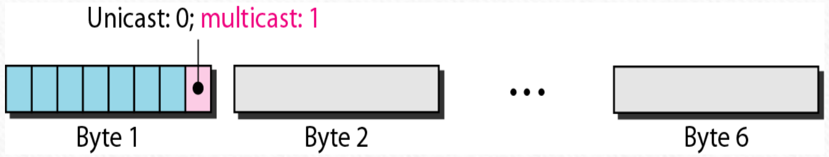


- **Unicast, Multicast, and Broadcast Addresses** A source address is always a unicast address-the frame comes from only one station. The destination address, however, can be unicast, multicast, or broadcast. Figure shows how to distinguish a unicast address from a multicast address. If the least significant bit of the first byte in a destination address is 0, the address is unicast; otherwise, it is multicast.
- **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 Is.
- ***Access Method:*** *CSMA/CD*- Standard Ethernet uses I-persistent CSMA/CD .
- **Slot Time** In an Ethernet network, the round-trip time required for a frame to travel from one end of a maximum-length network to the other plus the time needed to send the jam sequence is called the slot time.
- ***Eg***: Define the type of the following destination addresses: a. 4A:30:10:21:1O: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.



Physical Layer

- The Standard Ethernet defines several physical layer implementations; four of the most common, are shown in Figure
- ***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, thereceived signal is interpreted as Manchester and decoded into data. Manchester encoding is self-synchronous, providing a transition at each bit interval.Figure shows the encoding scheme for Standard Ethernet.

Fig *Categories of Standard Ethernet*

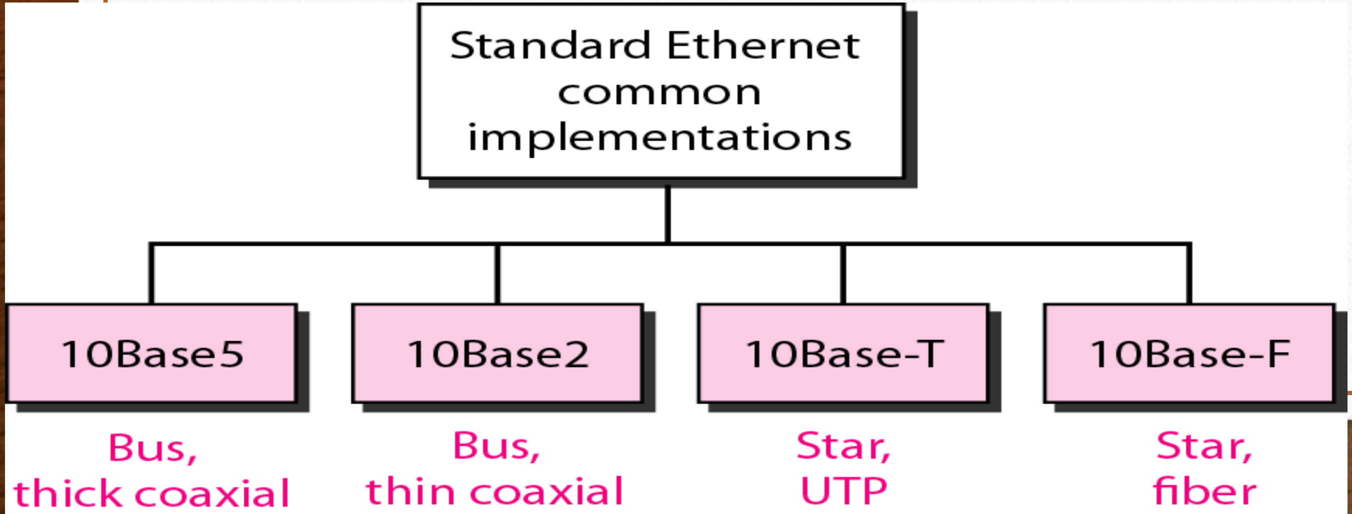
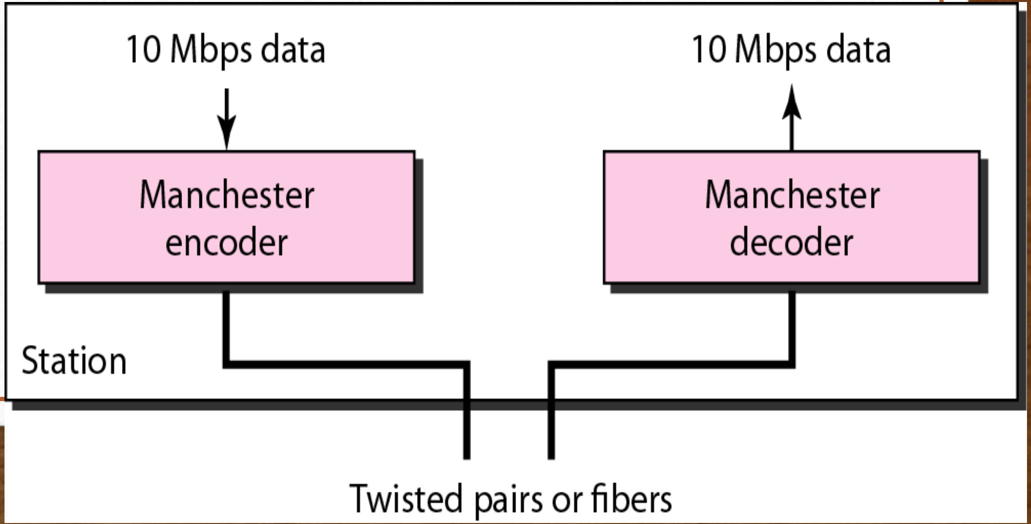


Fig *Encoding in a Standard Ethernet implementation*

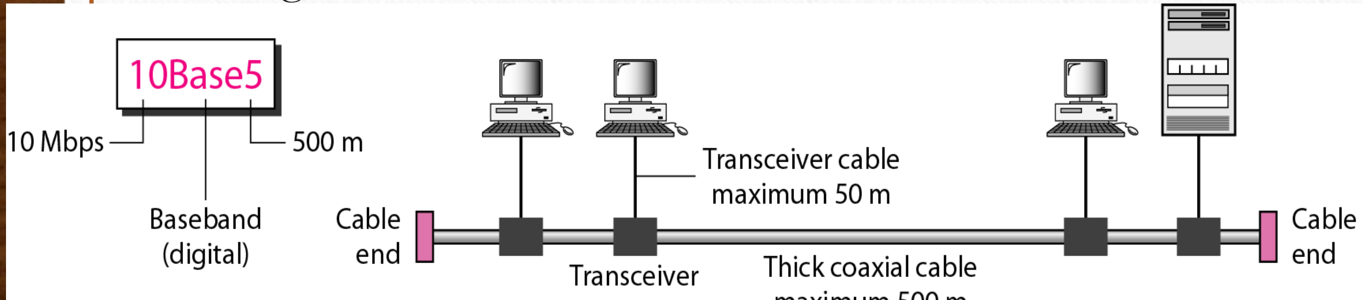


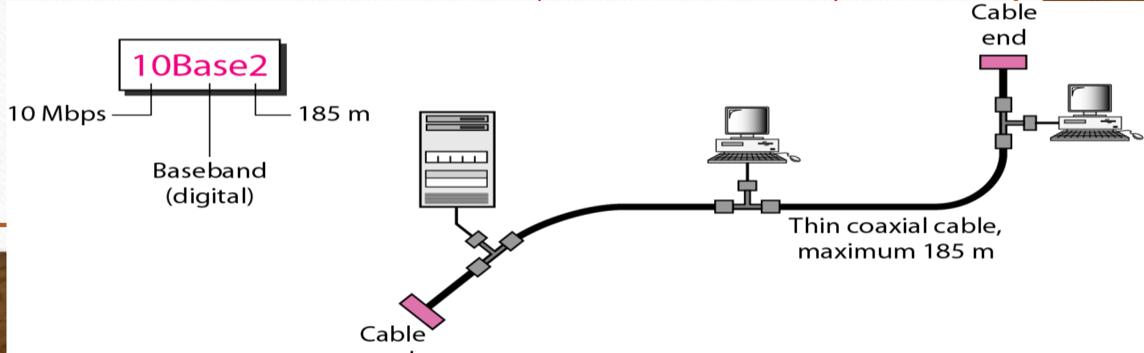
lOBase5: Thick Ethernet

- The first implementation is called **10BaseS, thick Ethernet, or Thicknet.** The nickname derives from the size of the cable, which is roughly the size of a garden hose and too stiff to bend with your hands. lOBase5 was the first Ethernet specification to use a bus topology with an external **transceiver** (transmitter/receiver) connected via a tap to a thick coaxial cable. Figure shows a schematic diagram of a lOBase5 implementation.The transceiver is responsible for transmitting, receiving, and detecting collisions. The transceiver is connected to the station via a transceiver cable that provides separate paths for sending and receiving. This means that collision can only happen in the coaxial cable. The maximum length of the coaxial cable must not exceed *500* m, otherwise, there is excessive degradation of the signal. If a length of more than *500* m is needed, up to five segments, each a maximum of 5OO-meter, can be connected using repeaters.

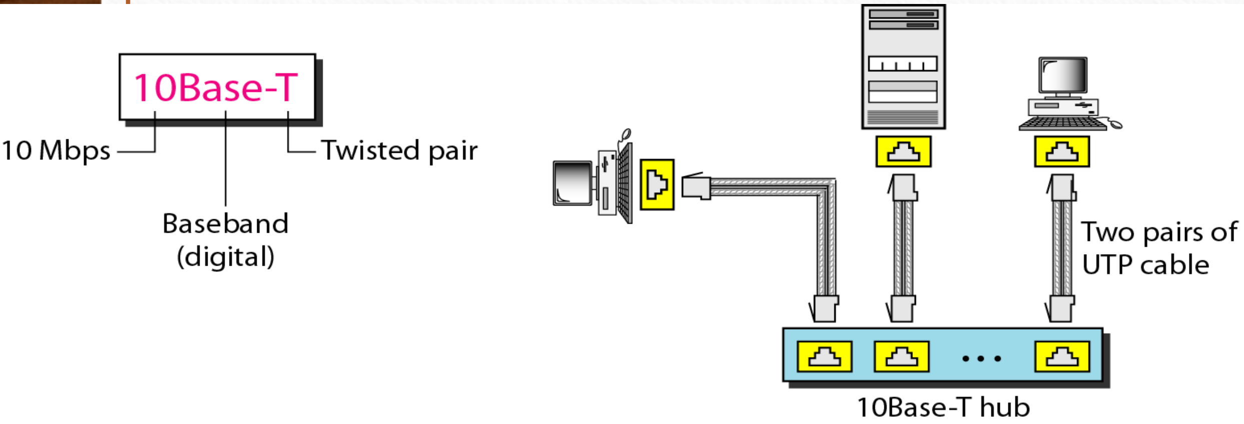
10Base2: Thin Ethernet

- The second implementation is called lOBase2, **thin** Ethernet, or Cheapernet. 10 Base2 also uses a bus topology, but the cable is much thinner and more flexible. The cable can be bent to pass very close to the stations. In this case, the transceiver is normally part of the network interface card (NIC), which is installed inside the station. Figure shows the schematic diagram of a 10 Base2 implementation.Note that the collision here occurs in the thin coaxial cable. This implementation is more cost effective than 10BaseS because thin coaxial cable is less expensive than thick coaxial and the tee connections are much cheaper than taps. Installation is simpler because the thin coaxial cable is very flexible. However, the length of each segment cannot exceed *185* m (close to 200 m) due to the high level of attenuation in thin coaxial cable.





- ***lOBase-T: Twisted-Pair Ethernet***
- The third implementation is called 10 Base-T or twisted-pair Ethernet. 1OBase-T uses a physical star topology. The stations are connected to a hub via two pairs of twisted cable, as shown in Figure Note that two pairs of twisted cable create two paths (one for sending and one for receiving) between the station and the hub. Any collision here happens in the hub. Compared to lOBase5 or lOBase2, we can see that the hub actually replaces the coaxial. cable as far as a collision is concerned. The maximum length of the twisted cable here is defined as 100 m, to minimize the effect of attenuation in the twisted cable.
- ***lOBase-F: Fiber Ethernet***
- Although there are several types of optical fiber lO-Mbps Ethernet, the most common is called 10Base-F. lOBase-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 Figure



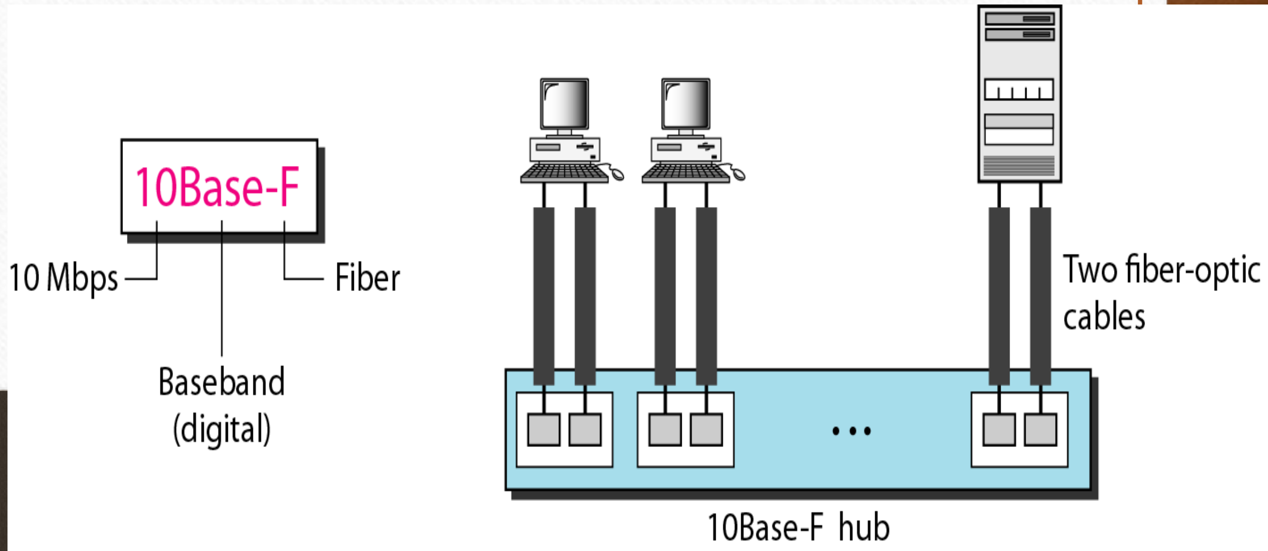


Table *Summary of Standard Ethernet implementations*

Characteristics	*10Base5*	*10Base2*	*10Base-T*	*10Base-F*
Media	Thick coaxial cable	Thin coaxial cable	2 UTP	2 Fiber
Maximum length	500 m	185 m	100 m	2000 m
Line encoding	Manchester	Manchester	Manchester	Manchester

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.
- Bluetooth technology has several applications. Peripheral devices such as a wireless mouse or keyboard can communicate with the computer through this technology. Monitoring devices can communicate with sensor devices in a small health care center. Home security devices can use this technology to connect different sensors to the main security controller. Conference attendees can synchronize their laptop computers at a conference.
- Bluetooth was originally started as a project by the Ericsson Company. It is named for Harald Blaatand, the king of Denmark (940-981) who united Denmark and Norway. *Blaatand* translates to *Bluetooth* in English. 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.

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. 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 shows a piconet.
- Although a piconet can have a maximum of seven secondaries, an additional eight secondaries can be in the *parked state*. A secondary in a parked state is synchronized with the primary, but cannot take part in communication until it is moved from the parked state. Because only eight stations can be active in a piconet, activating a station from the parked state means that an active station must go to the parked state.

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. Fig illustrates a scatternet.

Bluetooth Devices

- A Bluetooth device has a built-in short-range radio transmitter. The current data rate is 1 Mbps with a 2.4-GHz bandwidth. This means that there is a possibility of interference between the IEEE 802.11b wireless LANs and Bluetooth LANs.

Bluetooth Layers

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

Fig ***Piconet***

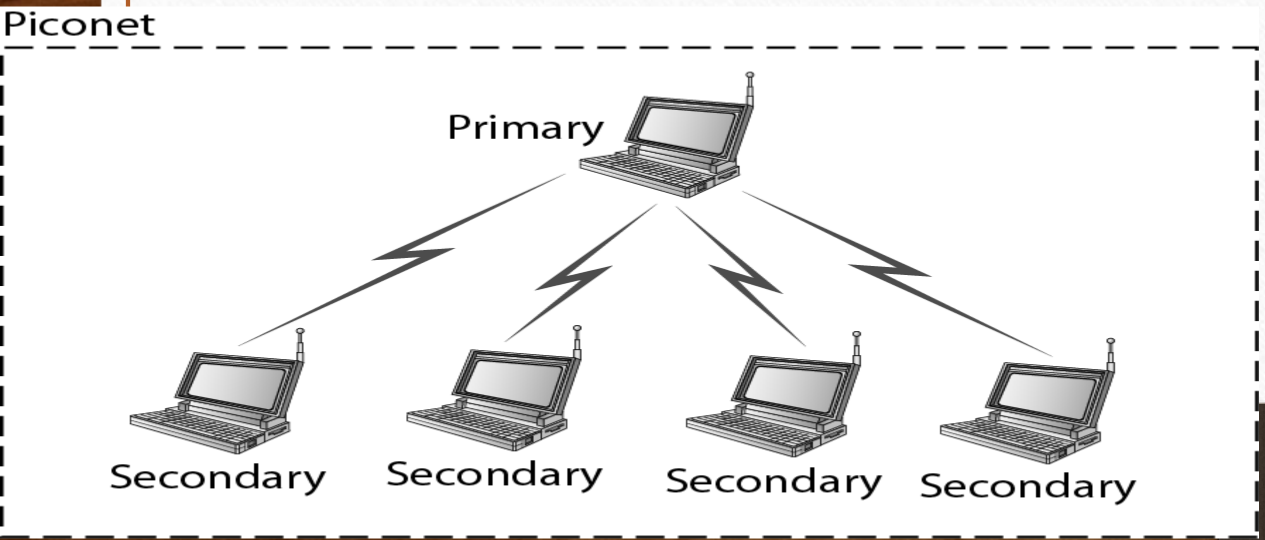
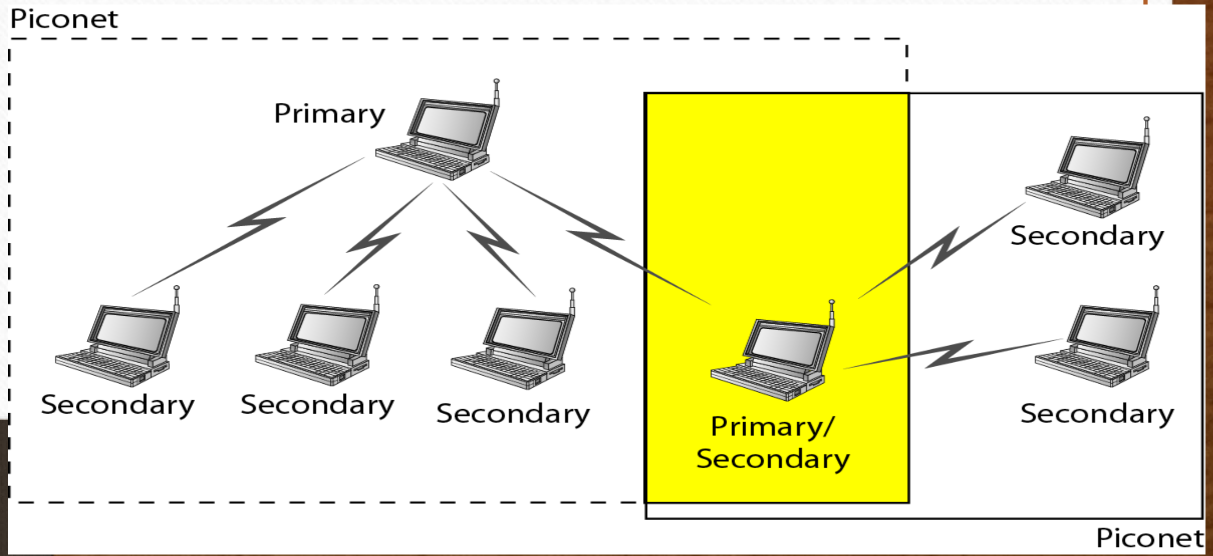


Fig ***Scatternet***

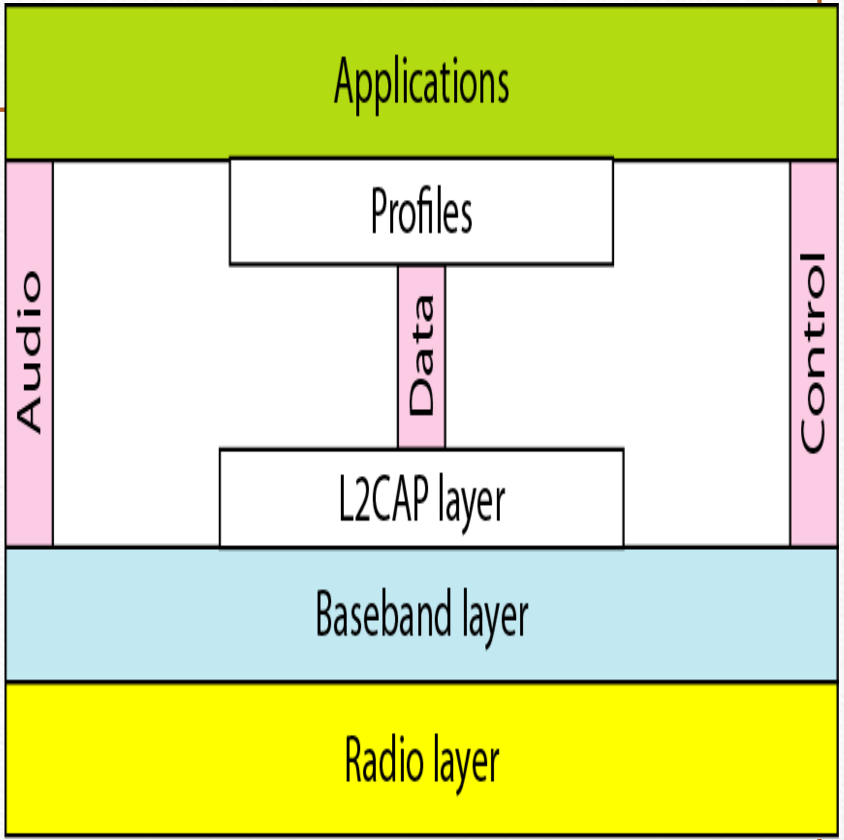


Radio Layer

- The radio layer is roughly equivalent to the physical layer of the Internet model. Bluetooth devices are low-power and have a range of 10 m.
- ***Band***-Bluetooth uses a 2.4-GHz ISM band divided into 79 channels of 1 MHz each.
- ***FHSS***- Bluetooth uses the frequency-hopping spread spectrum (FHSS) method in the physical layer to avoid interference from other devices or other networks. Bluetooth hops 1600 times per second, which means that each device changes its modulation frequency 1600 times per second. A device uses a frequency for only 625 μs (1/1600 s) before it hops to another frequency; the dwell time is 625 μs
- ***Modulation***-To transform bits to a signal, Bluetooth uses a sophisticated version of FSK, called GFSK (FSK with Gaussian bandwidth filtering; GFSK has a can'ier frequency. Bit 1 is represented by a frequency deviation above the carrier; bit 0 is represented by a frequency deviation below the carrier.

Baseband Layer

- The baseband layer is roughly equivalent to the MAC sublayer in LANs. The access method is TDMA .The primary and secondary communicate with each other using time slots. The length of a time slot is exactly the same as the dwell time, 625 μs . This means that during the time that one frequency is used, a sender sends a frame to a secondary, or a secondary sends a frame to the primary. Note that the communication is only between the primary and a secondary; secondaries cannot communicate directly with one another.



- ***TDMA***- Bluetooth uses a form of TDMA that is called TDD-TDMA (time division duplex TDMA). TDD-TDMA is a kind of half-duplex communication in which the secondary and receiver send and receive data, but not at the same time (half duplex); however, the communication for each direction uses different hops. This is similar to walkie-talkies using different carrier frequencies.
- **Single-Secondary Communication** If the piconet has only one secondary, the TDMA operation is very simple. The time is divided into slots of 625 μs . The primary uses even numbered slots (0, 2, 4, ...); the secondary uses odd-numbered slots (1, 3, 5, ...). TDD-TDMA allows the primary and the secondary to communicate in half-duplex mode. In slot 0, the primary sends, and the secondary receives; in slot 1, the secondary sends, and the primary receives. The cycle is repeated. Figure shows the concept.

Fig ***Single-secondary communication***

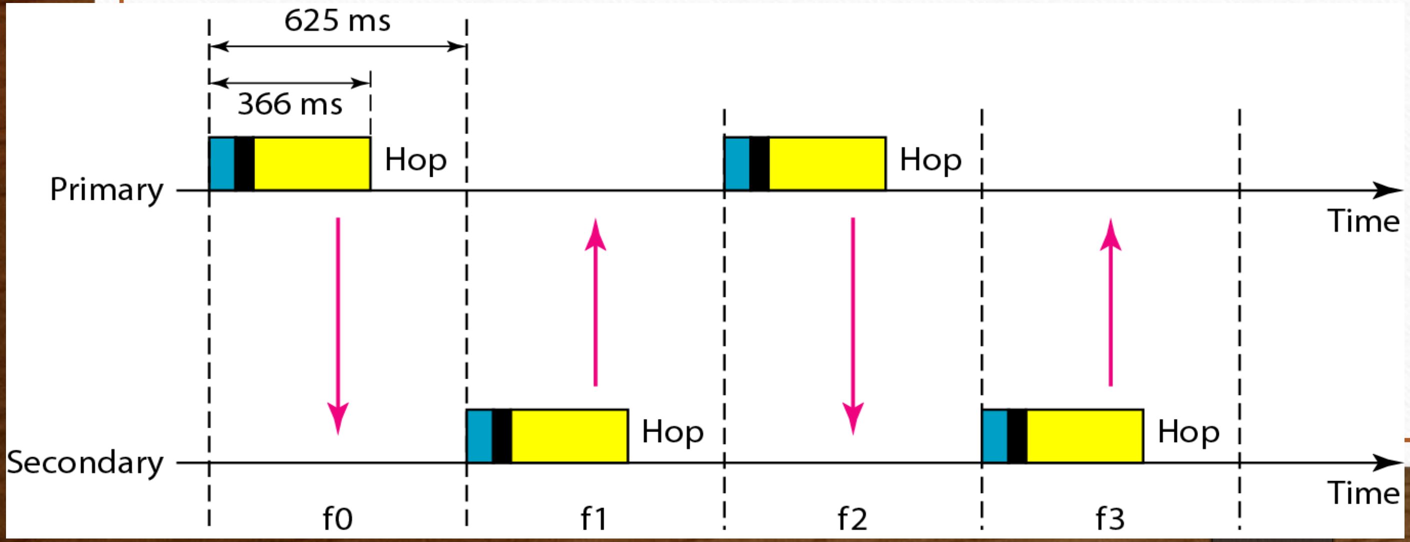
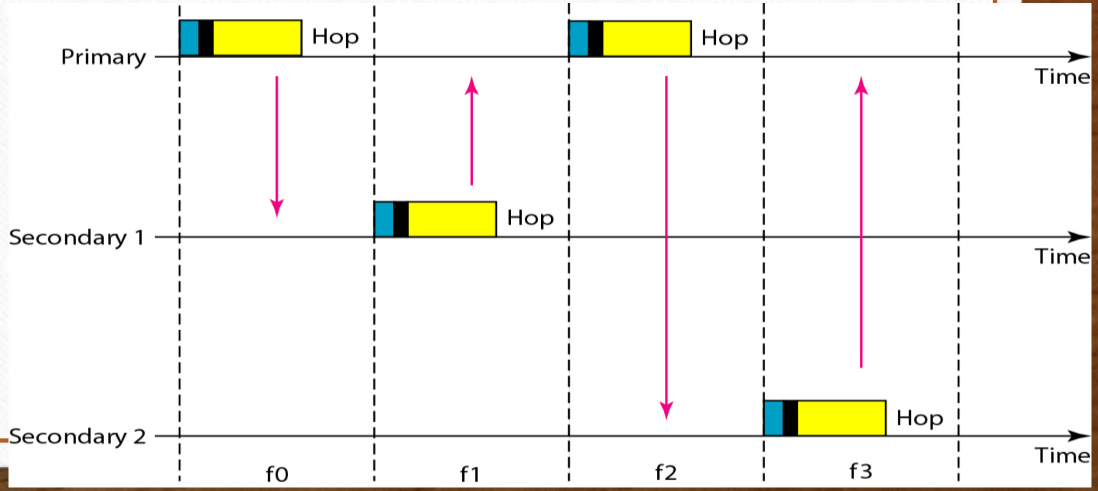


Fig ***Multiple-secondary communication***



- **Multiple-Secondary Communication** The process is a little more involved if there is more than one secondary in the piconet. Again, the primary uses the even-numbered slots, but a secondary sends in the next odd-numbered slot if the packet in the previous slot was addressed to it. All secondaries listen on even-numbered slots, but only one secondary sends in any odd-numbered slot. Figure shows a scenario. Let us elaborate on the figure.

1. In slot 0, the primary sends a frame to secondary 1.
2. In slot 1, only secondary I sends a frame to the primary because the previous frame was addressed to secondary 1; other secondaries are silent.
3. In slot 2, the primary sends a frame to secondary 2.
4. In slot 3, only secondary 2 sends a frame to the primary because the previous frame was addressed to secondary 2; other secondaries are silent.
5. The cycle continues.

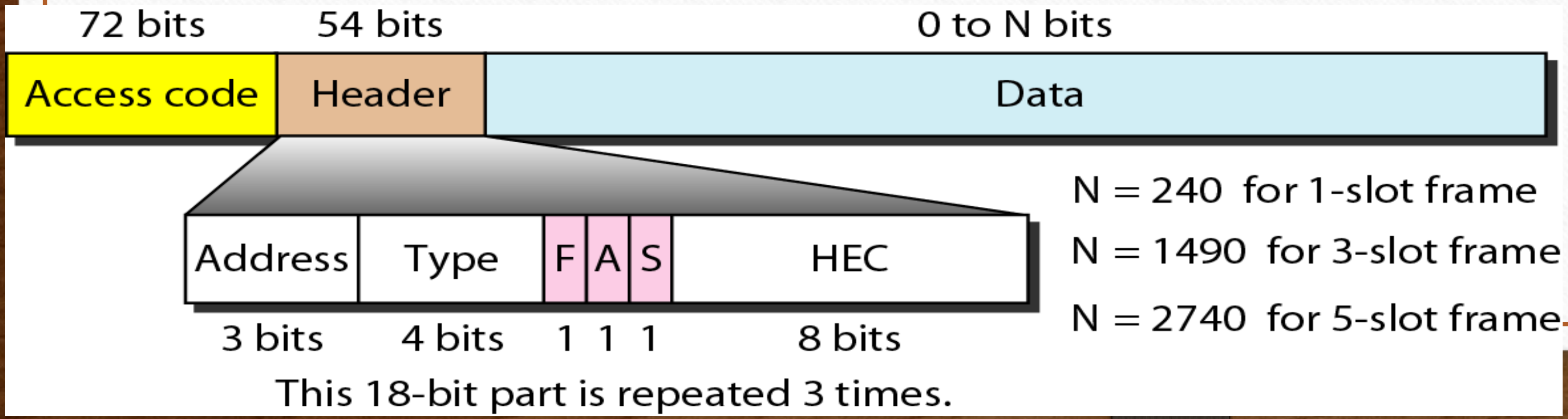
We can say that this access method is similar to a poll/select operation with reservations. When the primary selects a secondary, it also polls it. The next time slot is reserved for the polled station to send its frame. If the polled secondary has no frame to send, the channel is silent.

- ***Physical Links***
- Two types of links can be created between a primary and a secondary: SCQ links and ACL links.
- **SCO** A synchronous connection-oriented (SCO) link is used when avoiding latency (delay in data delivery) is more important than integrity (error-free delivery). In an SCO link, a physical link is created between the primary and a secondary by reserving specific slots at regular intervals. The basic unit of connection is two slots, one for each direction. If a packet is damaged, it is never retransmitted. SCO is used for real-time audio where avoiding delay is all-important. A secondary can create up to three SCO links with the primary, sending digitized audio (PCM) at 64 kbps in each link.
- **ACL** An asynchronous connectionless link (ACL) is used when data integrity is more important than avoiding latency. In this type of link, if a payload encapsulated in the frame is corrupted, it is retransmitted. A secondary returns an ACL frame in the available odd-numbered slot if and only if the previous slot has been addressed to it. ACL can use one, three, or more slots and can achieve a maximum data rate of 721 kbps.

Frame Format

- A frame in the baseband layer can be one of three types: one-slot, three-slot, or five-slot. A slot, as we said before, is 625 μs . However, in a one-slot frame exchange, 259 μs is needed for hopping and control mechanisms. This means that a one-slot frame can last only 625 - 259, or 366 μs . With a 1-MHz bandwidth and 1 bit/Hz, the size of a one-slot frame is 366 bits. A three-slot frame occupies three slots. However, since 259 μs is used for hopping, the length of the frame is 3 x 625 - 259 = 1616 μs or 1616 bits. A device that uses a three-slot frame remains at the same hop (at the same carrier frequency) for three slots.
- Even though only one hop number is used, three hop numbers are consumed. That means the hop number for each frame is equal to the first slot of the frame. A five-slot frame also uses 259 bits for hopping, which means that the length of the frame is 5 x 625 - 259 =2866 bits.
- Figure 14.24 shows the format of the three frame types.
- The following describes each field:
- o **Access code**. This 72-bit field normally contains synchronization bits and the identifier of the primary to distinguish the frame of one piconet from another.

- **Header.** This 54-bit field is a repeated I8-bit pattern. Each pattern has the following subfields:
- 1. **Address**.- The 3-bit address subfield can define up to seven secondary's (l to 7). If the address is zero, it is used for broadcast communication from the primary to all secondary's.
- 2. **Type**. The 4-bit type subfield defines the type of data coming from the upper layers. We discuss these types later.
- 3. **F-** This 1-bit subfield is for flow control. When set (I), it indicates that the device is unable to receive more frames (buffer full).
- 4. **A-** ~~This 1-bit subfield is for acknowledgment. Bluetooth uses Stop-and-Wait ARQ; 1 bit is sufficient for acknowledgment.~~
- 5. **S-** This 1-bit subfield holds a sequence number. Bluetooth uses Stop-and-Wait ARQ; 1 bit is sufficient for sequence numbering.
- 6. **HEC**. The 8-bit header error correction subfield is a checksum to detect errors in each 18-bit header section. The header has three identical 18-bit sections. The receiver compares these three sections, bit by bit. If each of the corresponding bits is the same, the bit is accepted; if not, the majority opinion rules. This is a form of forward error correction (for the header only). This double error control is needed because the nature of the communication, via air, is very noisy. Note that there is no retransmission in this sublayer.
- o **Payload**. This subfield can be 0 to 2740 bits long. It contains data or control information corning from the upper layers.



L2CAP

- The Logical Link Control and Adaptation Protocol, or L2CAP (L2 here means LL), is roughly equivalent to the LLC sublayer in LANs. It is used for data exchange on an ACL link; SCQ channels do not use L2CAP. The I6-bit length field defines the size of the data, in bytes, coming from the upper layers. Data can be up to 65,535 bytes. The channel ID (CID) defines a unique identifier for the virtual channel created at this level (see below).The L2CAP has specific duties: multiplexing, segmentation and reassembly, quality of service (QoS), and group management.
- ***Multiplexing***- The L2CAP can do multiplexing. At the sender site, it accepts data from one of the upper-layer protocols, frames them, and delivers them to the baseband layer. At the receiver site, it accepts a frame from the baseband layer, extracts the data, and delivers them to the appropriate protocol layer. It creates a kind of virtual channel that we will discuss in later chapters on higher-level protocols.
- ***Segmentation and Reassembly-*** The maximum size of the payload field in the baseband layer is 2774 bits, or 343 bytes. This includes 4 bytes to define the packet and packet length. Therefore, the size of the packet that can arrive from an upper layer can only be 339 bytes. However, application layers sometimes need to send a data packet that can be up to 65,535 bytes (an Internet packet, for example). The L2CAP divides these large packets into segments and adds extra information to define the location of the segments in the original packet. The L2CAP segments the packet at the source and reassembles them at the destination.
- ***QoS-*** Bluetooth allows the stations to define a quality-of-service level. if no quality-of-service level is defined, Bluetooth defaults to what is called *best-effort* service; it will do its best under the circumstances.
- ***Group Management-*** Another functionality of L2CAP is to allow devices to create a type of logical addressing between themselves. This is similar to multicasting. For Eg, two or three secondary devices can be part of a multicast group to receive data from the primary.

Other Upper Layers

- Bluetooth defines several protocols for the upper layers that use the services of L2CAP; these protocols are specific for each purpose.

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 tum, 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
- 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 it may create interference for the users located near the cell boundaries. However, the set of frequencies available is limited, and frequencies need to be reused. 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. Figure shows two of them.
- 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 shows, in a pattern with reuse factor 4, only one cell separates the cells using the same set of frequencies. In the pattern with reuse factor 7, two cells separate there using cells.

Fig *Cellular system*

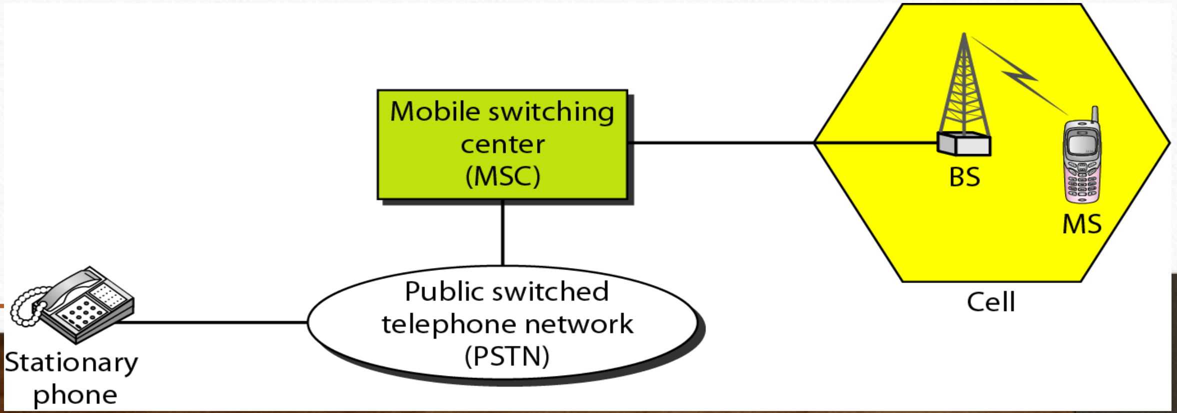
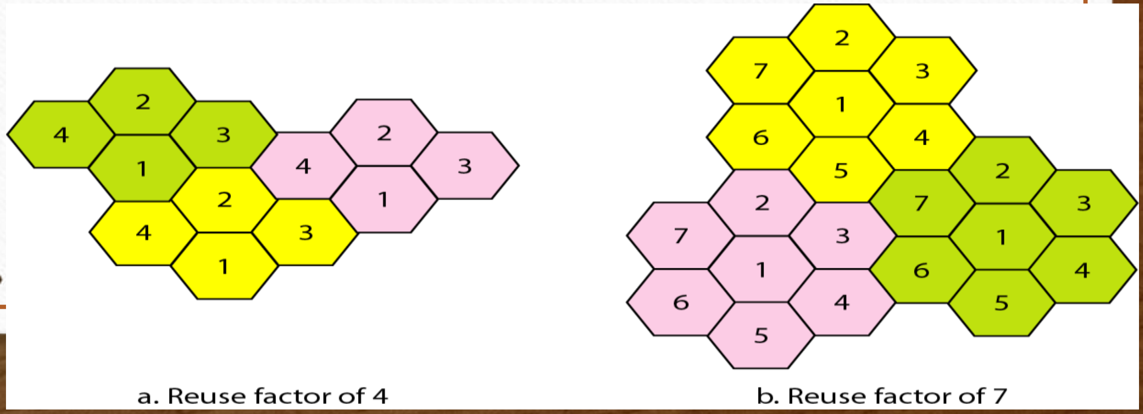


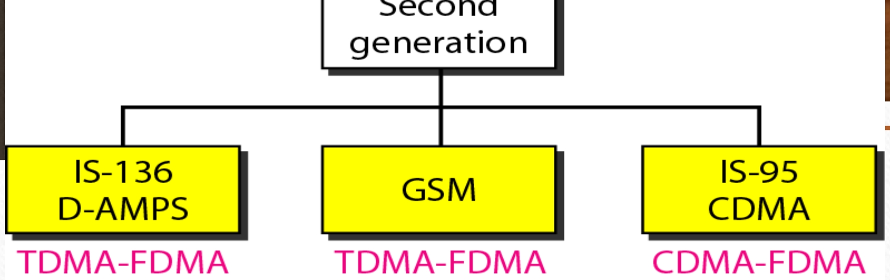
Fig *Frequency reuse patterns*



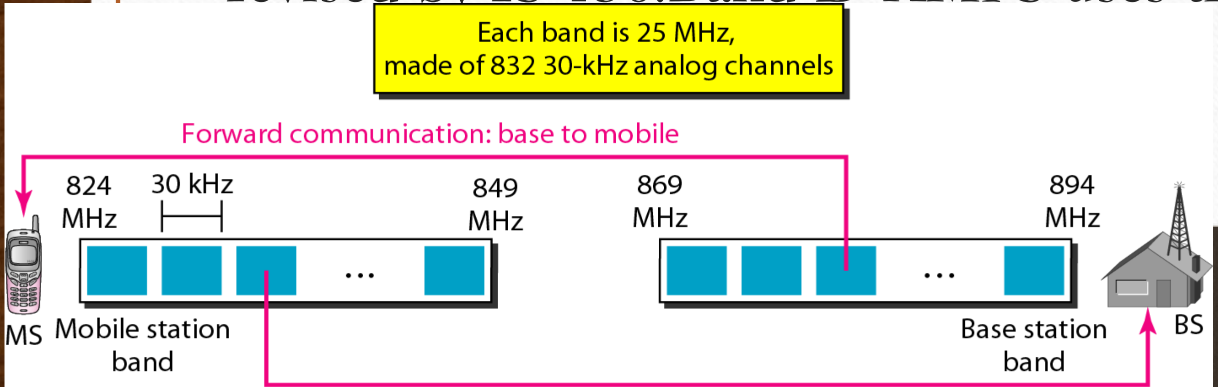
- **Transmitting-** To place a call from a mobile station, the caller enters a code of 7 or 10 digits (a phone number) and presses the send button. The mobile station then scans the band, seeking a setup channel with a strong signal, and sends the data (phone number) to the closest base station using 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. At this point, the MSC assigns an unused voice channel to the call, and a connection is established. The mobile station automatically adjusts its tuning to the new channel, and communication can begin.
- **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 (hands the signal off from the old channel to a new one).
- **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 before communication can be established with the new one. This may create a rough transition.
- **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.

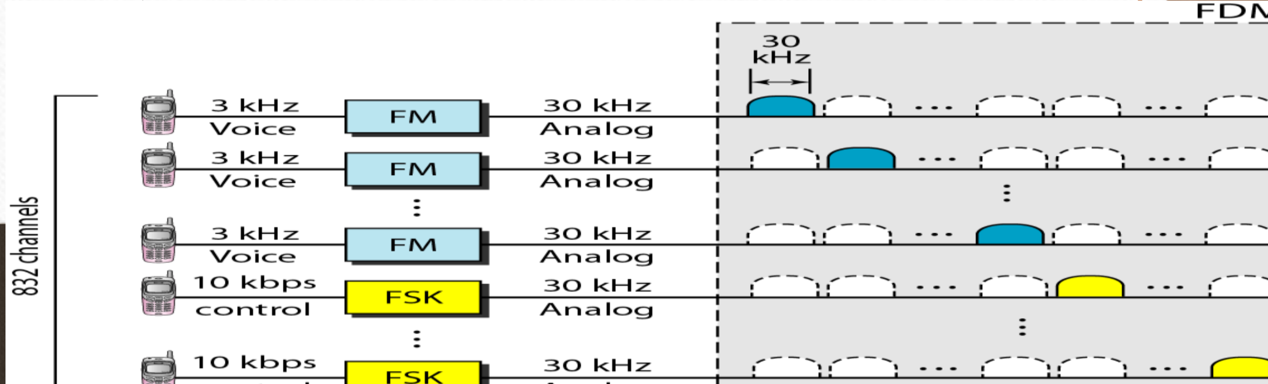
First Generation

- Cellular telephony is now in its second generation with the third on the horizon. The first generation was designed for voice communication using analog signals. We discuss one first-generation mobile system used in North America, AMPS.
- ***AMPS*** Advanced **Mobile Phone** System (AMPS) is one of the leading analog cellular systems in North America. It uses FDMA to separate channels in a link. Bands AMPS operates in the ISM 800-MHz band. The system uses two separate analog channels, one for forward (base station to mobile station) communication and one for reverse (mobile station to base station) communication. The band between 824 and 849 MHz carries reverse communication; the band between 869 and 894 MHz carries forward communication. Each band is divided into 832 channels. However, two providers can share an area, which means 416 channels in each cell for each provider. Out of these 416, 21 channels are used for control, which leaves 395 channels. AMPS has a frequency reuse factor of 7; this means only one-seventh of these 395 traffic channels are actually available in a cell. Transmission AMPS uses FM and FSK for modulation. Figure 16.4 shows the transmission in the reverse direction. Voice channels are modulated using FM, and control channels use FSK to create 30-kHz analog signals. AMPS uses FDMA to divide each 25-MHz band into 3D-kHz channels.



- **Second Generation**
- To provide higher-quality (less noise-prone) mobile voice communications, the second generation of the cellular phone network was developed. While the first generation was designed for analog voice communication, the second generation was mainly designed for digitized voice. Three major systems evolved in the second generation, as shown in Figure 16.5.
- *D-AMPS* The product of the evolution of the analog AMPS into a digital system is digital AMPS(D-AMPS). D-AMPS was designed to be backward-compatible with AMPS. This means that in a cell, one telephone can use AMPS and another D-AMPS. D-AMPS was first defined by IS-54 (Interim Standard 54) and later revised by IS-136.Band D-AMPS uses the same bands and channels as AMPS.





GSM

- The Global System for Mobile Communication (GSM) is a European standard that was developed to provide a common second-generation technology for all Europe. The aim was to replace a number of incompatible first-generation technologies.
- Bands GSM uses two bands for duplex communication. Each band is 25 MHz in width, shifted toward 900 MHz, as shown in Figure 16.7. Each band is divided into 124 channels of 200 kHz separated by guard bands.

IS-95

- One of the dominant second-generation standards in North America is Interim Standard 95 (IS-95). It is based on CDMA and DSSS. Bands and Channels IS-95 uses two bands for duplex communication. The bands can be the traditional ISM 800-MHz band or the ISM 1900-MHz band. Each band is divided into 20 channels of 1.228 MHz separated by guard bands.

Third Generation

- The third generation of cellular telephony refers to a combination of technologies that provide a variety of services. Ideally, when it matures, the third generation can provide both digital data and voice communication. Using a small portable device, a person should be able to talk to anyone else in the world with a voice quality similar to that of the existing fixed telephone network. A person can download and watch a movie, can download and listen to music, can surf the Internet or play games, can have a video conference, and can do much more. One of the interesting characteristics of a third generation system is that the portable device is always connected; you do not need todial a number to connect to the Internet.
- The third-generation concept started in 1992, when ITU issued a blueprint called the Internet Mobile Communication 2000 (IMT-2000). The blueprint defines some criteria for third-generation technology as outlined below:
- o Voice quality comparable to that of the existing public telephone network.
- o Data rate of 144 kbps for access in a moving vehicle (car), 384 kbps for access as
- the user walks (pedestrians), and 2 Mbps for the stationary user (office or home).
- o Support for packet-switched and circuit-switched data services.
- o A band of 2 GHz.
- o Bandwidths of 2 MHz.
- o Interface to the Internet.

- ***IMT-2000 Radio Interface***
- Figure 16.12 shows the radio interfaces (wireless standards) adopted by 1MT-2000. All five are developed from second-generation technologies. The first two evolve from COMA technology. The third evolves from a combination of COMA and TOMA. The fourth evolves from TOMA, and the last evolves from both FOMA and TOMA.
- IMT-DS This approach uses a version of COMA called wideband COMA or W-COMA. W-COMA uses a 5-MHz bandwidth. It was developed in Europe, and it is compatible with the COMA used in IS-95. IMT-MC This approach was developed in North America and is known as COMA 2000. It is an evolution of COMA technology used in IS-95 channels. It combines the new wideband (I5-MHz) spread spectrum with the narrowband (l.25-MHz) COMA of
- **IS-95.** It is backward-compatible with IS-95. It allows communication on multiple 1.25-MHz channels (l, 3, 6, 9, 12 times), up to 15 MHz. The use of the wider channels allows it to reach the 2-Mbps data rate defined for the third generation.
- **IMT-TC** This standard uses a combination of W-COMA and TDMA. The standard tries to reach the IMT-2000 goals by adding TOMA multiplexing to W-COMA.
- **IMT-SC** This standard only uses TOMA.
- **IMT-FT** This standard uses a combination of FDMA and TOMA.