Module 5

Wired LANs, Wireless LANs, Connecting Devices

13-1 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 is a way of specifying functions of the physical layer and the data link layer of major LAN protocols.

Topics discussed in this section:

Data Link Layer
Physical Layer

Figure 13.1 *IEEE standard for LANs*

- The IEEE has subdivided the data link layer into 2 sub layers-LLC (Logical Link Control) and MAC (Media Access Control).
- IEEE has also created several physical layer standards for different LAN protocols.

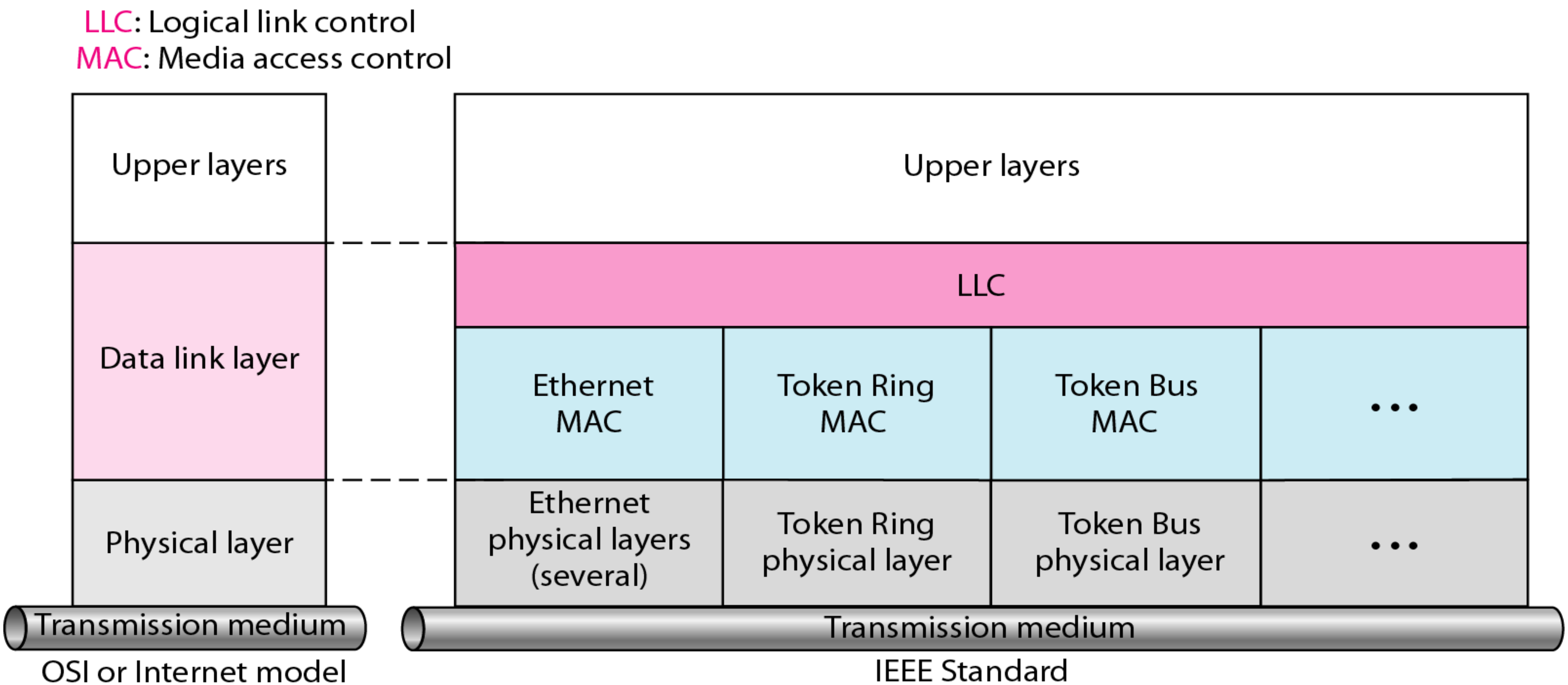
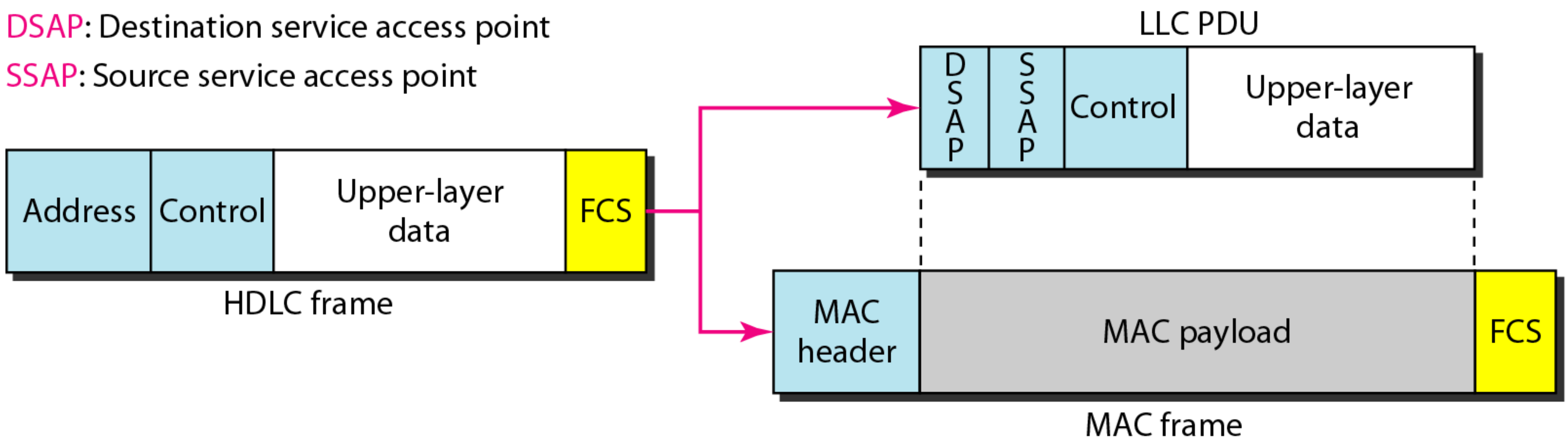


Figure 13.2 *HDLC frame compared with LLC and MAC frames*



Logical Link Control (LLC)

- The data link control handle framing, flow control and error control
- In IEEE project 802, flow control, error control and part of framing duties are collected into one sub layer called logic link control (LLC).
- Framing is handled in both LLC sublayer and MAC sublayer.
- The LLC provides a single link layer control protocol for all IEEE LANs. This means LLC protocol can provide interconnectivity between different LAN because it makes the MAC sublayer transparent.

Media Access Control (MAC)

- IEEE Project 802 has created a sub layer called media access control that defines the specific access method for each LAN.
- It defines CSMA/CD as the media access method for Ethernet LANs and defines token passing method for Token Ring, and Token Bus LANs
- A part of framing function is also handled by MAC sublayer.

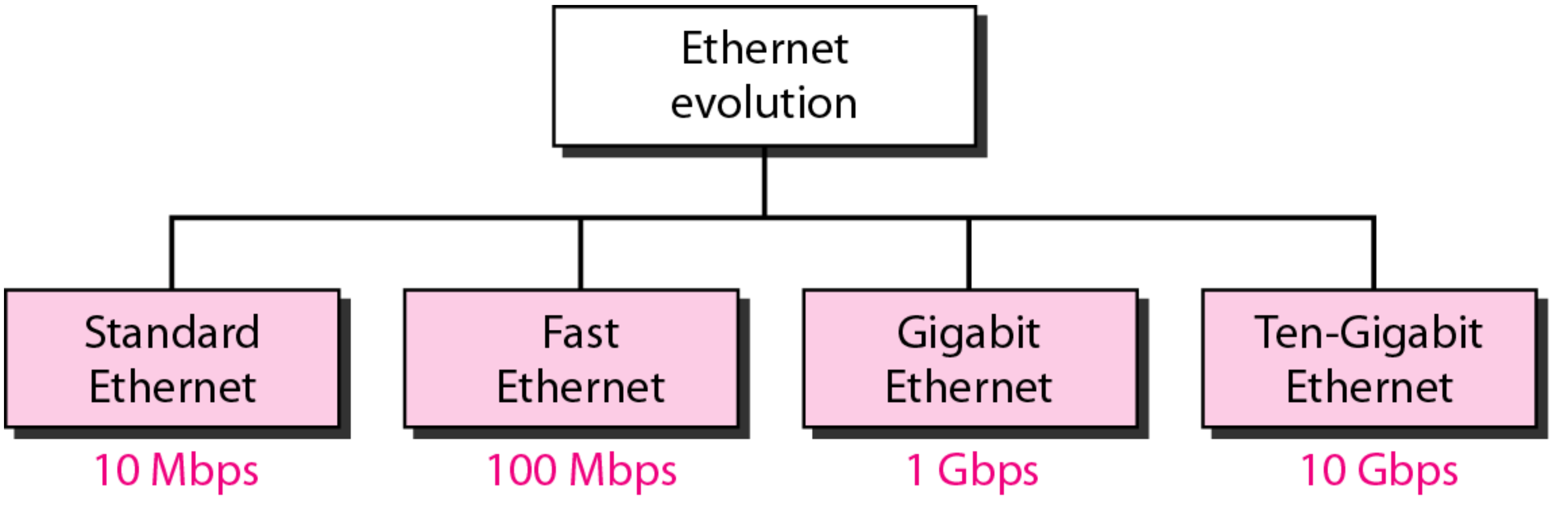
13-2 STANDARD ETHERNET

The original Ethernet was created in 1976 at Xerox's Palo Alto Research Center (PARC).

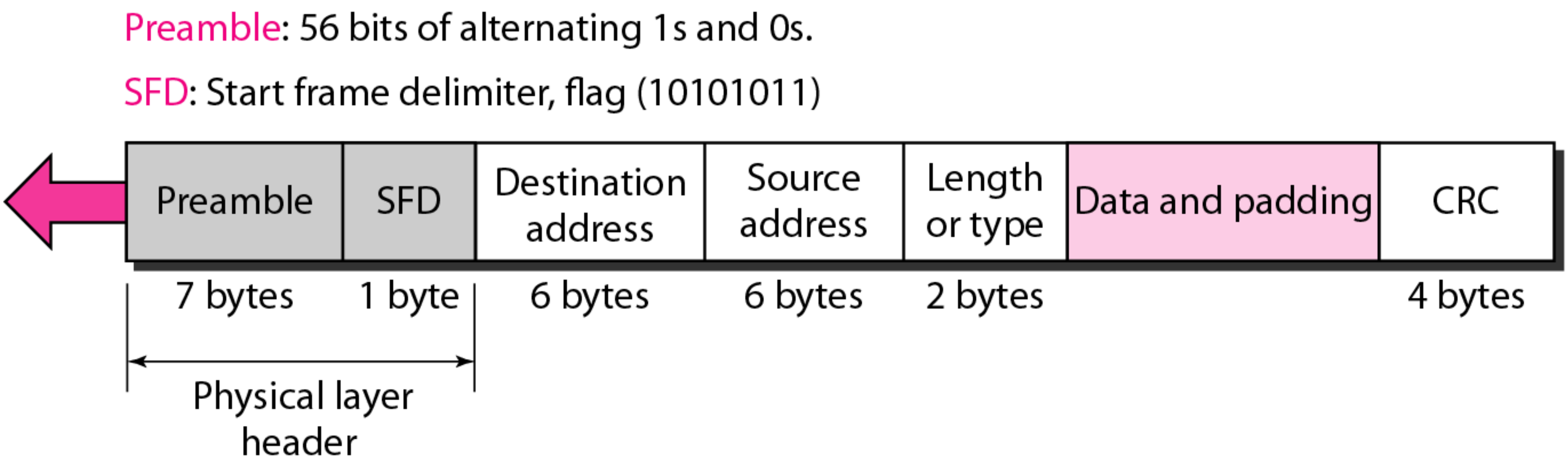
Topics discussed in this section:

Frame Format
Addressing
Physical Layer Implementation

Figure 13.3 *Ethernet evolution through four generations*



Frame Format : Figure 13.4 *802.3 MAC frame*



Frame Format

Preamble:

- This field contain 7 bytes(56 bits) of alternating 0s and s that alert the receiving system to the coming frame and enable it to synchronize its clock if its out of synchronization.
- The pattern provides only an alert and a timing pulse. The preamble is actually added at the physical layer and is not (formally) a part of frame

Start Frame Delimiter (SFD):

- This field is 1 byte (10101011) signals the beginning of the frame.
- This field is actually a flag that defines the beginning of the frame.
- SFD field added in the physical layer

Frame Format

Destination Address (DA):

- This field is six byte (48 bits) and contains the link layer address of the destination station or station to receive the packet.
- When the receiver sees its own link layer address, or a multicast address for a group that the receiver is a member of, or a broadcast address, it decapsulates the data from the frame and passes the data to the upper layer protocol defined by the value of the type field.

Source Address (SA):

- 6 byte address and contain link layer address of the sender of the packet.
- Unicast addresses are used.

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. It is used for multiplexing and demultiplexing.

Frame Format

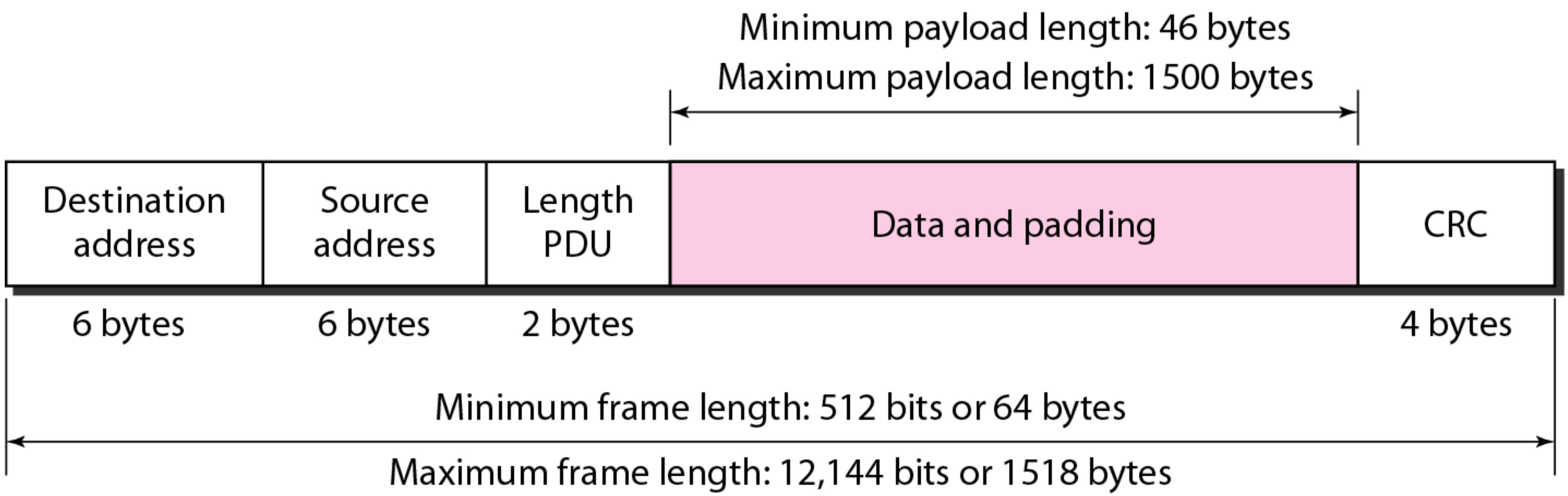
Data:

- This field carries data encapsulated from the upper layer protocols. It is 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 than46 bytes, it need to be padded with extra 0's.
- A padded data frame is delivered to the upper layer protocol as it is (without removing padding), which means that it is the responsibility of the upper layer to remove or add the padding.

CRC:

- The last field contain error detection information 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 discard the frame.

Figure 13.5 *Minimum and maximum lengths*



Note

Frame length:

Minimum: 64 bytes (512 bits)

Maximum: 1518 bytes (12,144 bits)

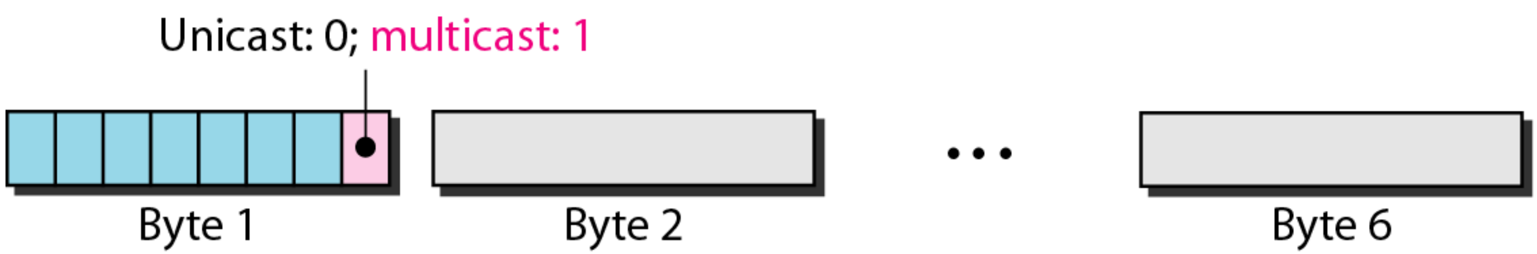
Addressing:

Figure 13.6 *Example of an Ethernet address in hexadecimal notation*

- Each station on Ethernet network has its own NIC (Network Interface Card). It provide the station with a 6 byte physical address.
- Ethernet is a 6 byte written in hexadecimal notation with a colon between the bytes.

Figure 13.7 *Unicast and multicast addresses*

- A source address is always a unicast address i.e., frame comes from only one station.
- Destination address can be unicast, multicast or broadcast.
- The LSB of the 1st byte define the type of address. If it is 0, address is unicast, otherwise it is multicast.
- Broadcast is a special case of multicast addresses, the recipient are all stations on the LAN.
- A broadcast destination address in which forty eight bits are 1s; i.e., all bits are 1s.



Note

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

Note

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

Example 13.1

Define the type of the following destination addresses:

a. 4A:30:10:21:10:1A ***b. 47:20:1B:2E:08:EE***

c. FF:FF:FF:FF:FF:FF

Solution

To find the type of the address, we need to look at the second hexadecimal digit from the left. If it is even, the address is unicast. If it is odd, the address is multicast. If all digits are F's, the address is broadcast. Therefore, we have the following:

a. This is a unicast address because A in binary is 1010.

b. This is a multicast address because 7 in binary is 0111.

c. This is a broadcast address because all digits are F's.

Example 13.2

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

Solution

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

← 11100010 00000100 11011000 01110100 00010000 01110111

Figure 13.8 *Categories of Standard Ethernet*

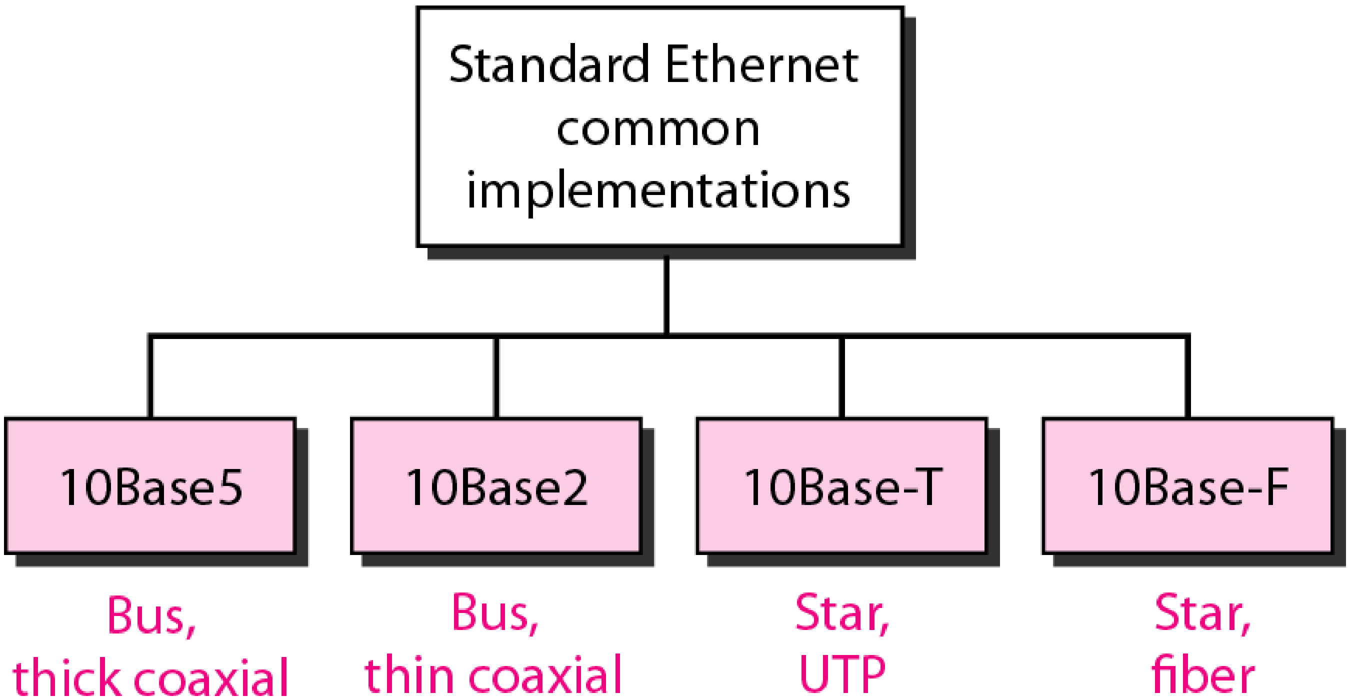


Figure 13.9 *Encoding in a Standard Ethernet implementation*

- Uses digital signaling (base band) at 10Mbps.
- At sender data are converted to digital signal using Manchester scheme and at the receiver received signal is interpreted as Manchester and decoded data

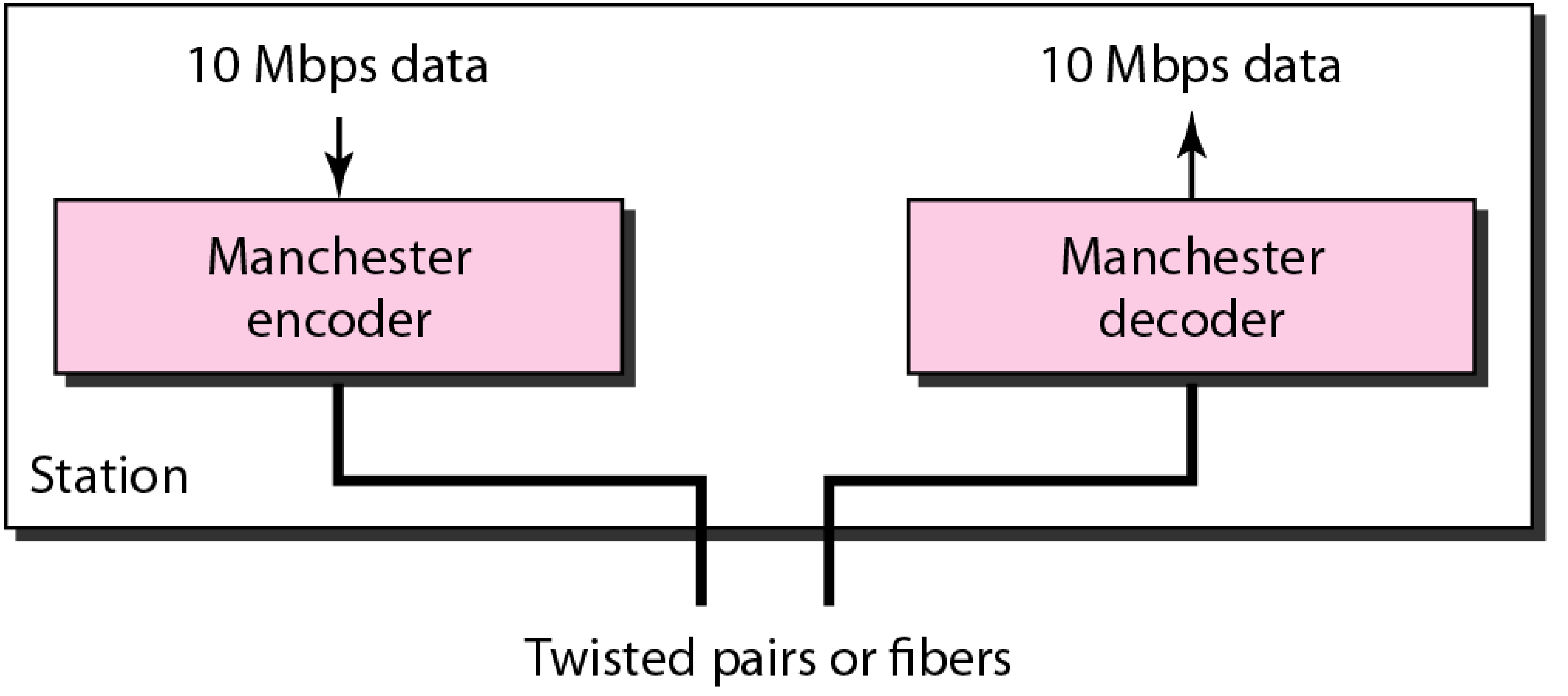


Figure 13.10 *10Base5 (Thick Ethernet/Thicknet) implementation*

- First Ethernet implementation.
- Uses bus topology with an external transceiver connected via thick coaxial cable.
- Maximum length of the cable is 500m, otherwise excessive degradation of signal.

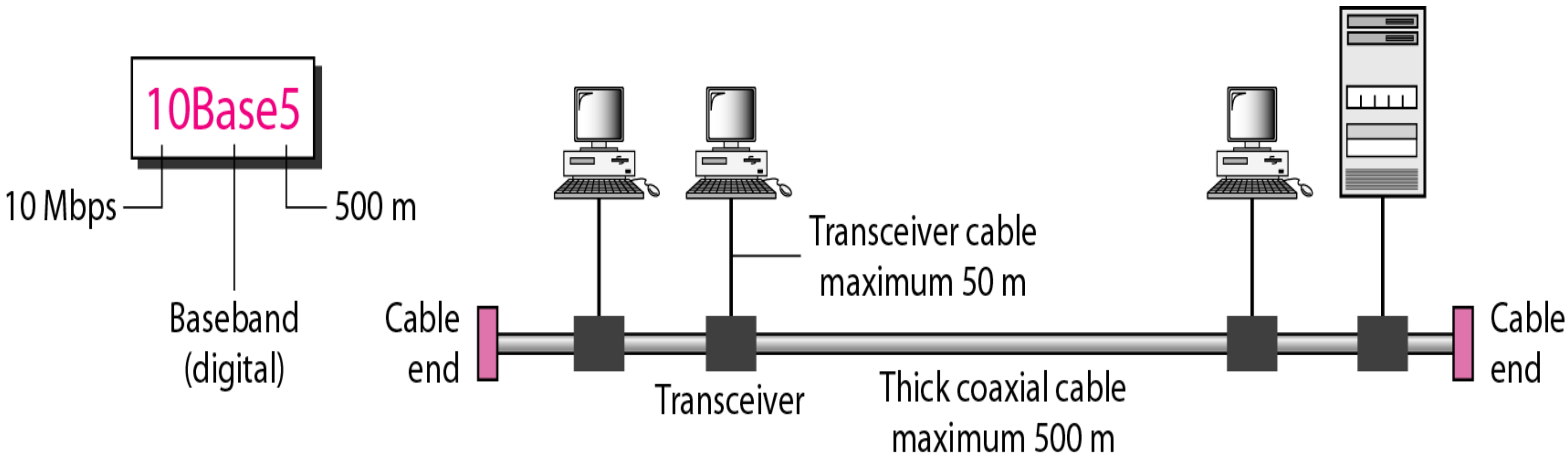


Figure 13.11 *10Base2 (thin Ethernet/Cheapernet) implementation*

- Uses bus topology but cables are much thinner and more flexible.
- Cables can be bend, normally a part of NIC installed inside station.
- Implementation is more cost effective than 10Base5.
- Less expensive and tee connection are cheaper than taps
- Installation is simple because the coaxial cables are very flexible.
- However the length of the cable is 185m, due to high level of attenuation in this coaxial.

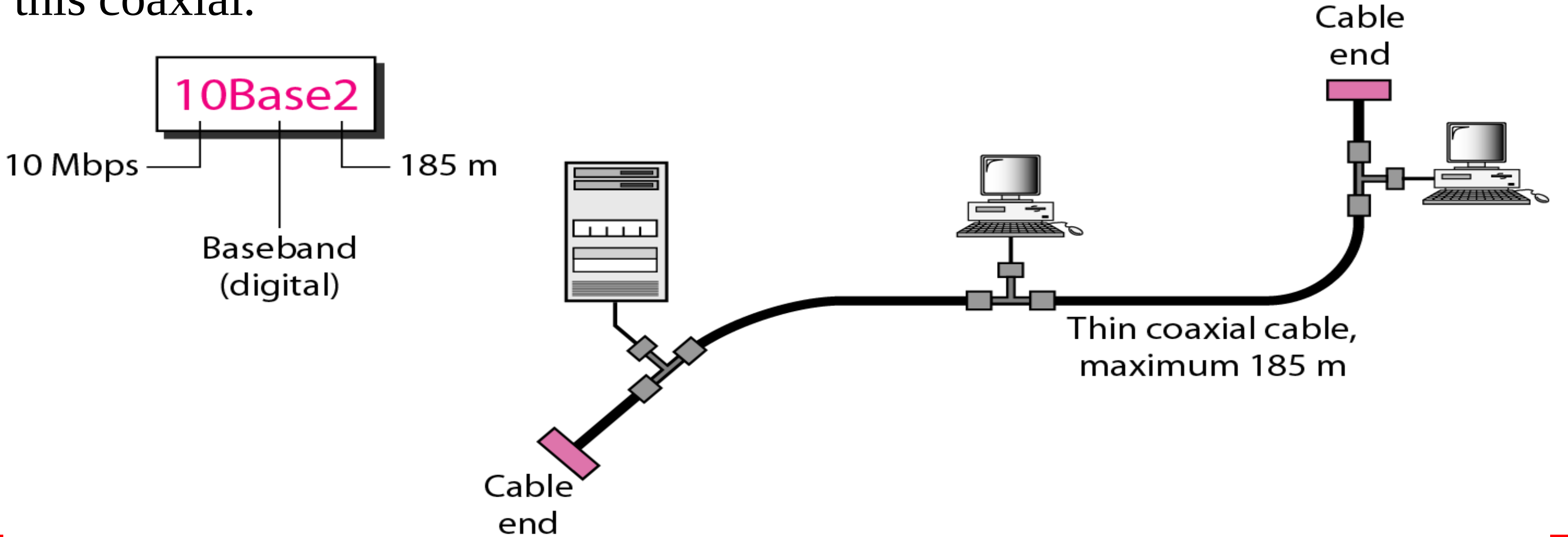
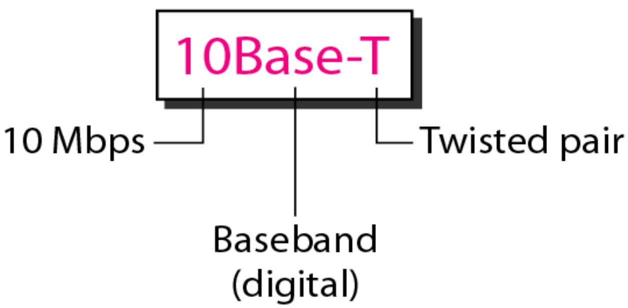


Figure 13.12 ***10Base-T implementation***

- Uses star topology. The stations are connected to a hub via 2 pairs of twisted cable.
- Two pairs of twisted cable creates two path (one for sending and one for receiving) between stations and hubs.
- Any collision here in Hub.
- Compared to 10Base2 and 10Base5, hub replaces coaxial as far as collision concerned.
- Maximum length of the cable is defined as 100m to minimize the effect of attenuation twisted cable.



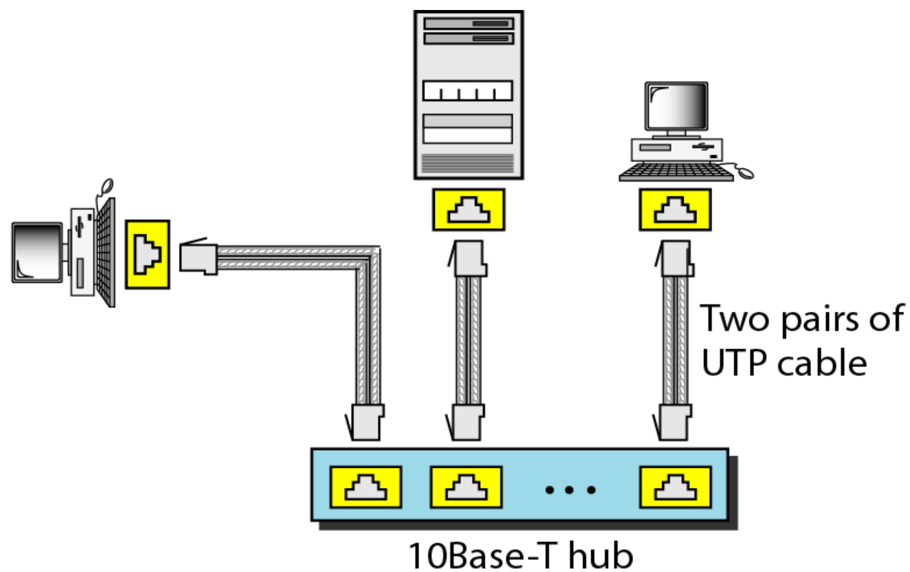


Figure 13.13 *10Base-F implementation*

- Uses star topology to connect stations to a hub.
- Stations are connected to the hub using 2 fiber optic cables.
- The maximum length it can obtained is 2000m.

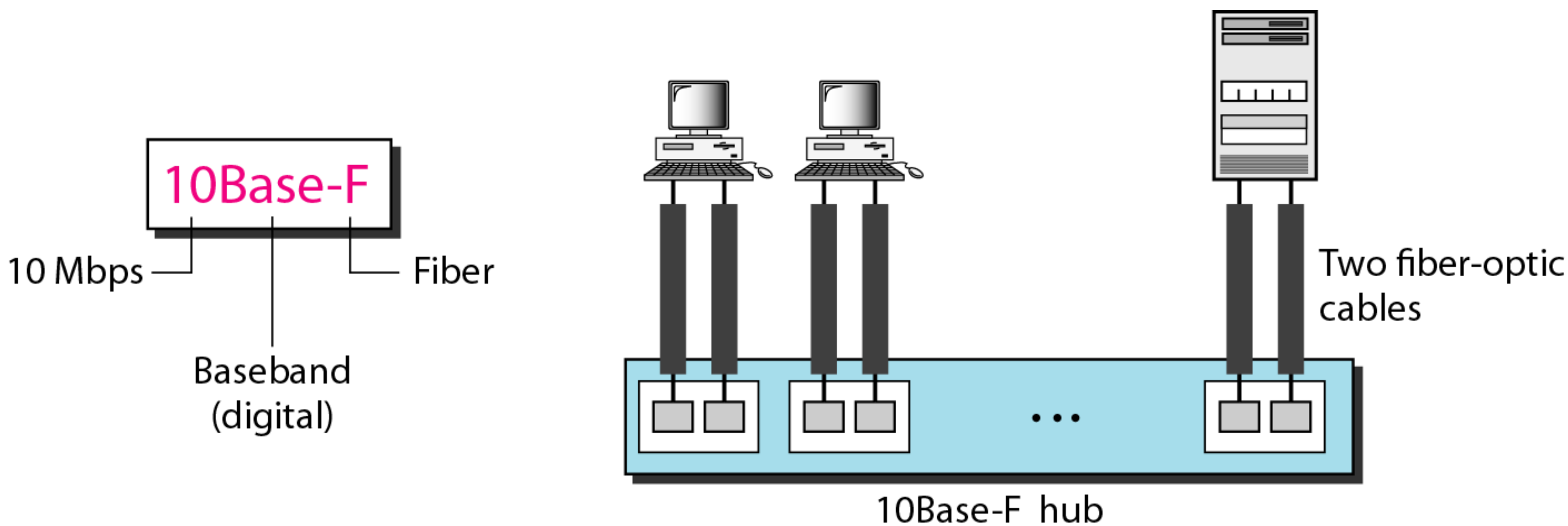


Table 13.1 *Summary of Standard Ethernet implementations*

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

14-1 IEEE 802.11

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

Topics discussed in this section:

Architecture
MAC Sublayer
Physical Layer

Note

A BSS without an AP is called an ad-hoc network; a BSS with an AP is called an infrastructure network.

Figure 14.1 *Basic service sets (BSSs)*

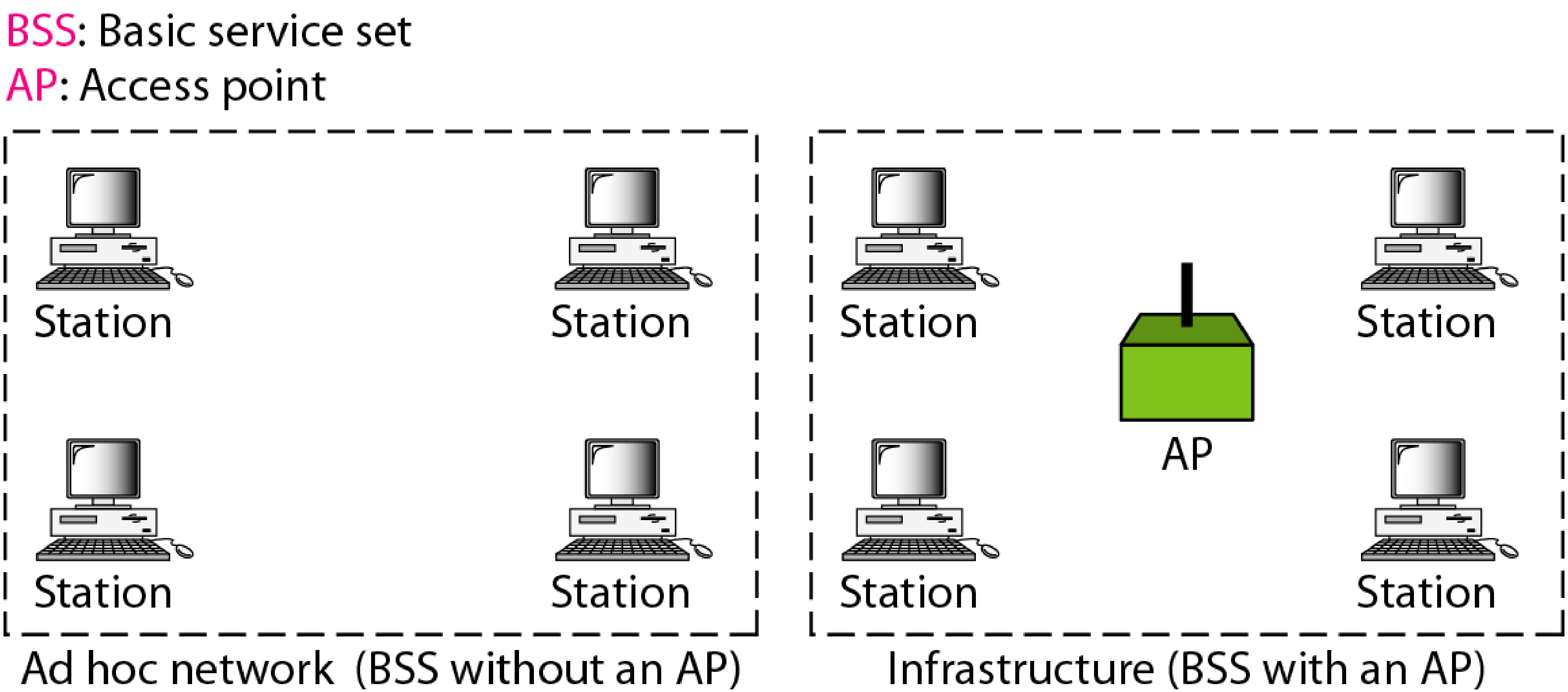
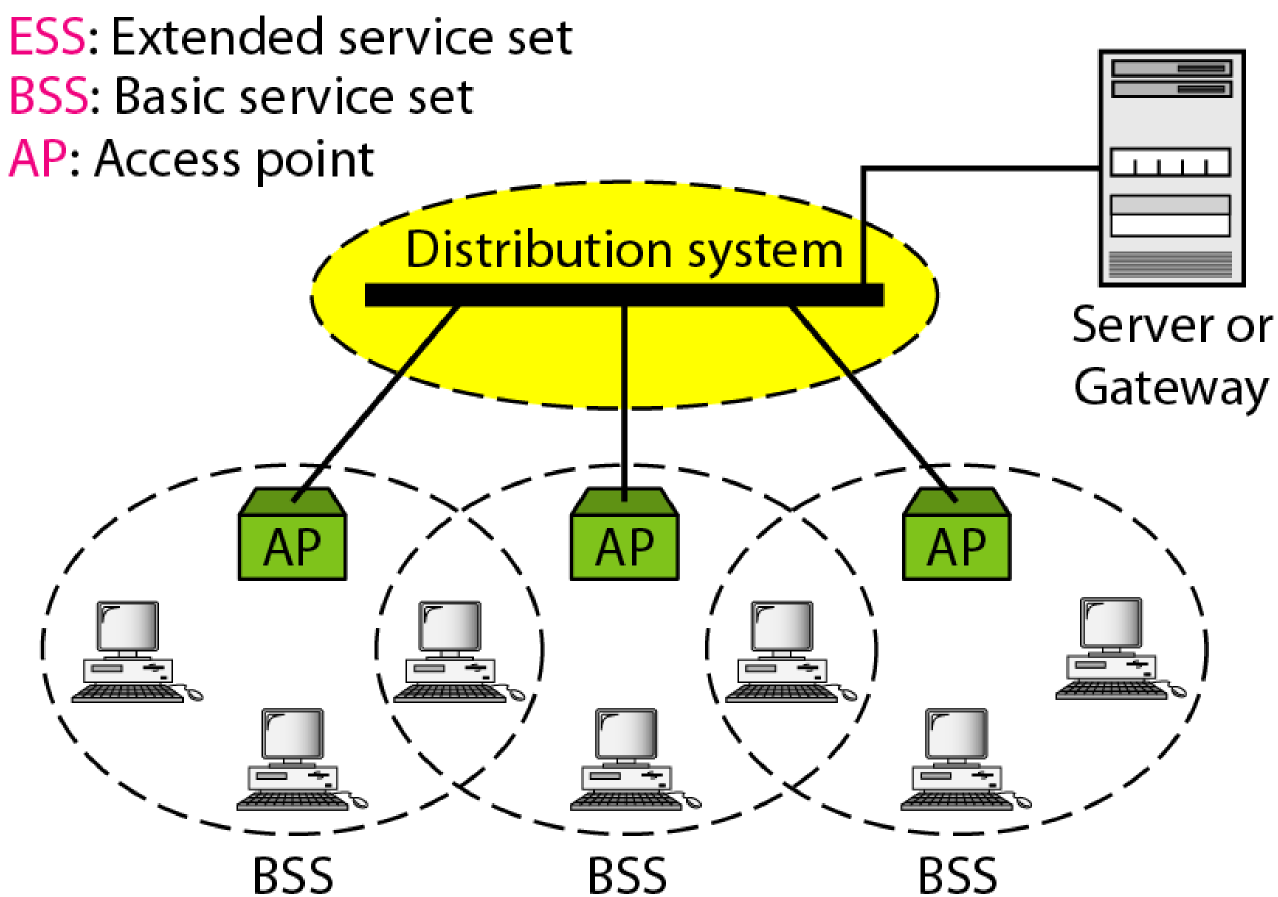


Figure 14.2 *Extended service sets (ESSs)*



Station Types

- **There are 3 types of stations based on their mobility in WLAN.**

1. **No- Transition mobility**

   A station with no transition mobility is either stationary or moving only inside a BSS.

2. **BSS Transition mobility**

   A station with BSS- transition mobility can move from one BSS to another, but the movement is confined inside one ESS.

3. **ESS- Transition mobility**

   A station with ESS transition mobility can move from one ESS to another.

Figure 14.3 *MAC layers in IEEE 802.11 standard*

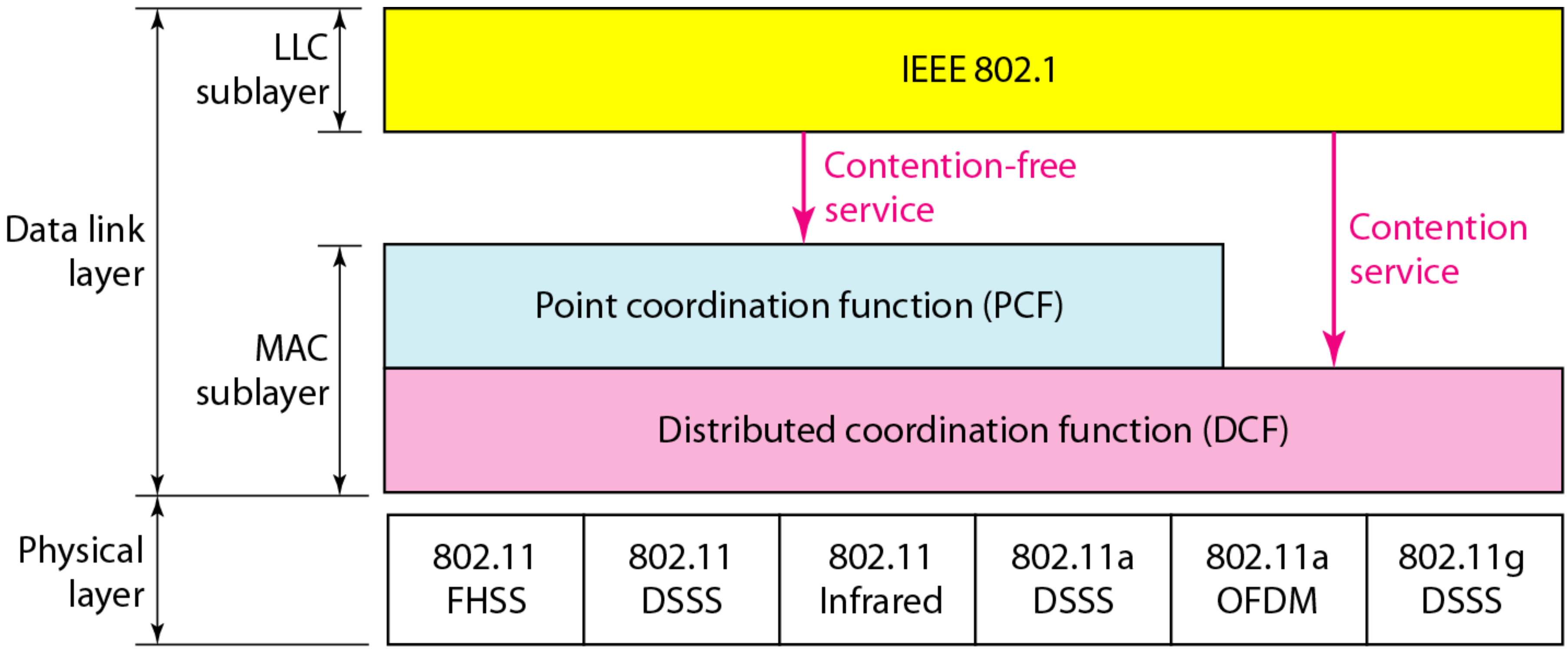
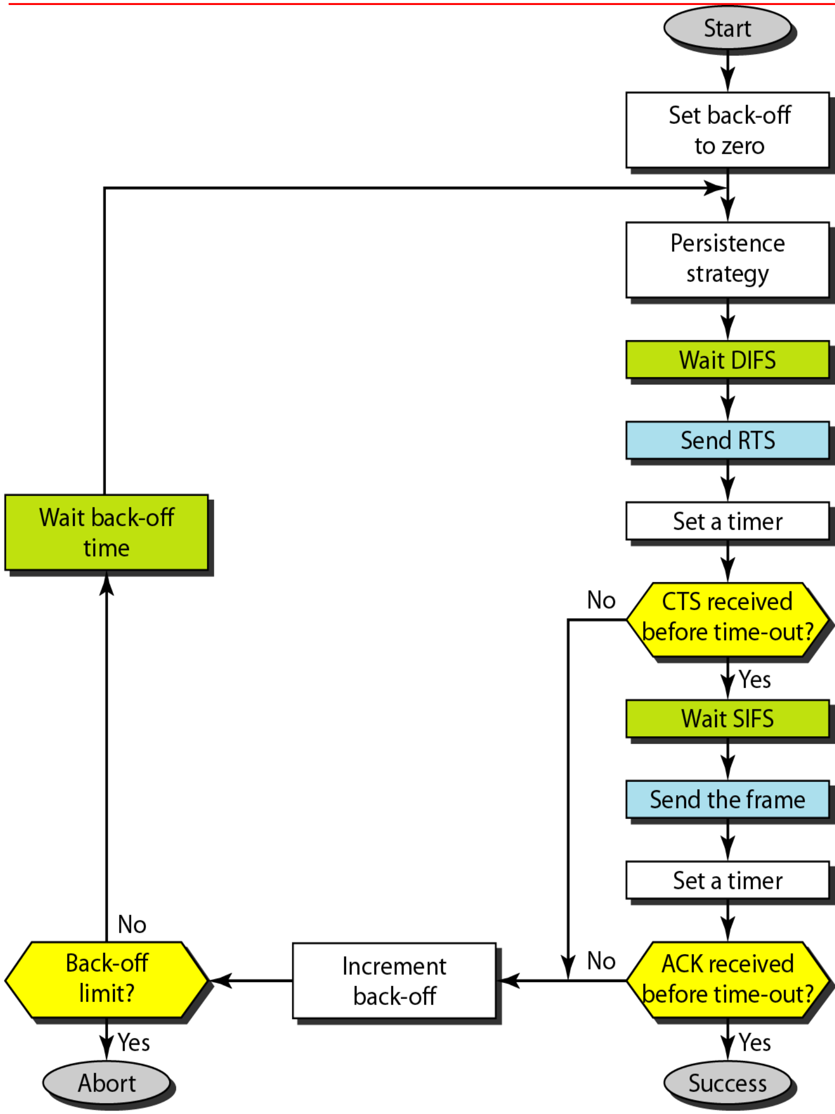


Figure 14.4 *CSMA/CA flowchart*



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

Network Allocation Vector (NAV)

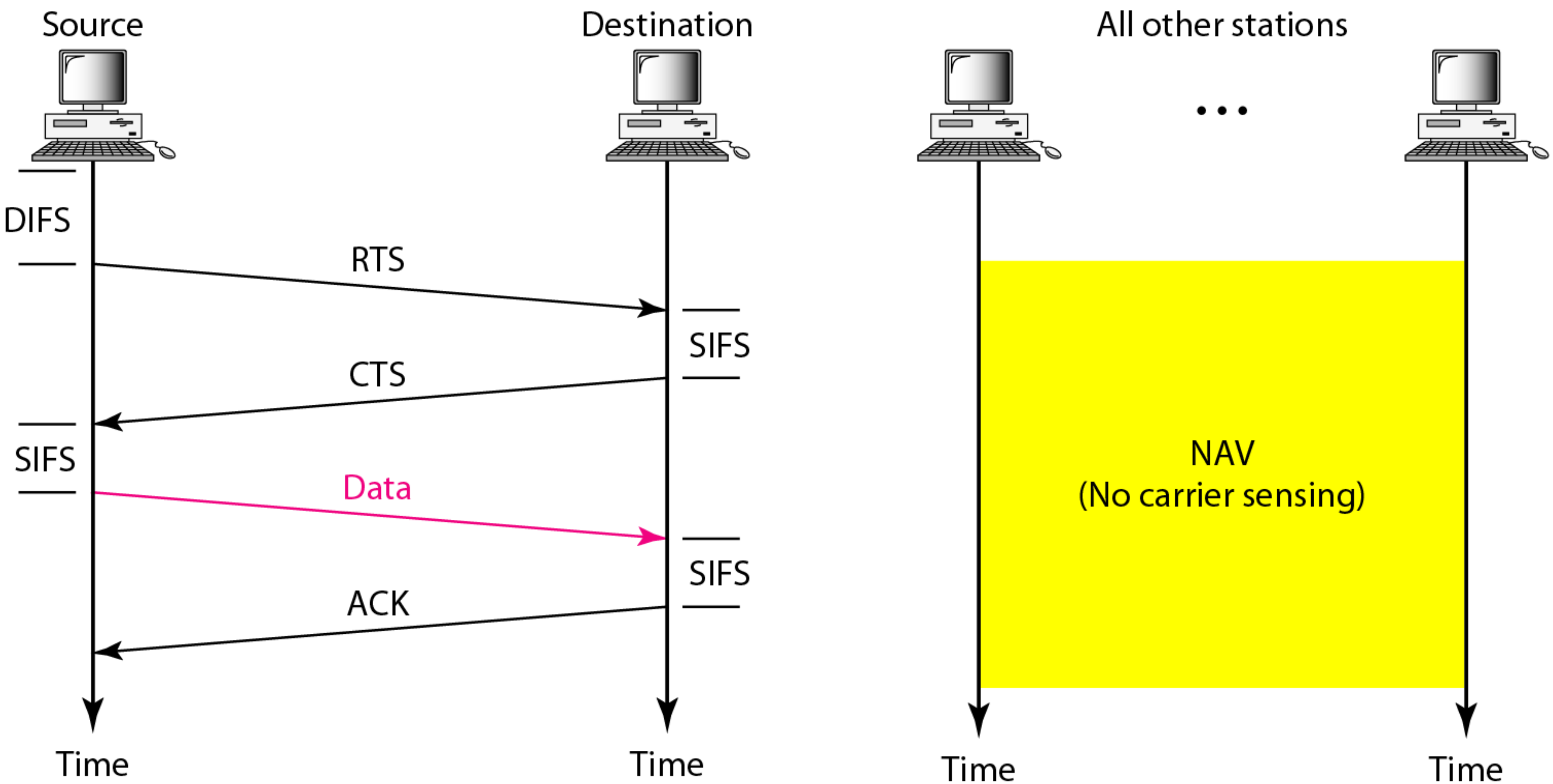
How do other stations defer sending their data if one station acquires access?

KEY is feature called NAV

For collision avoidance,

- When one station sends an RTS frame, it includes the duration of time, it needs to occupy the channel. The other stations start a timer called Network allocation vector (NAV).
- In otherwords, each station, before sensing the physical medium to see if it is idle, first check NAV to see, if it has expired.

Figure 14.5 *CSMA/CA and NAV*



Collision During Handshaking

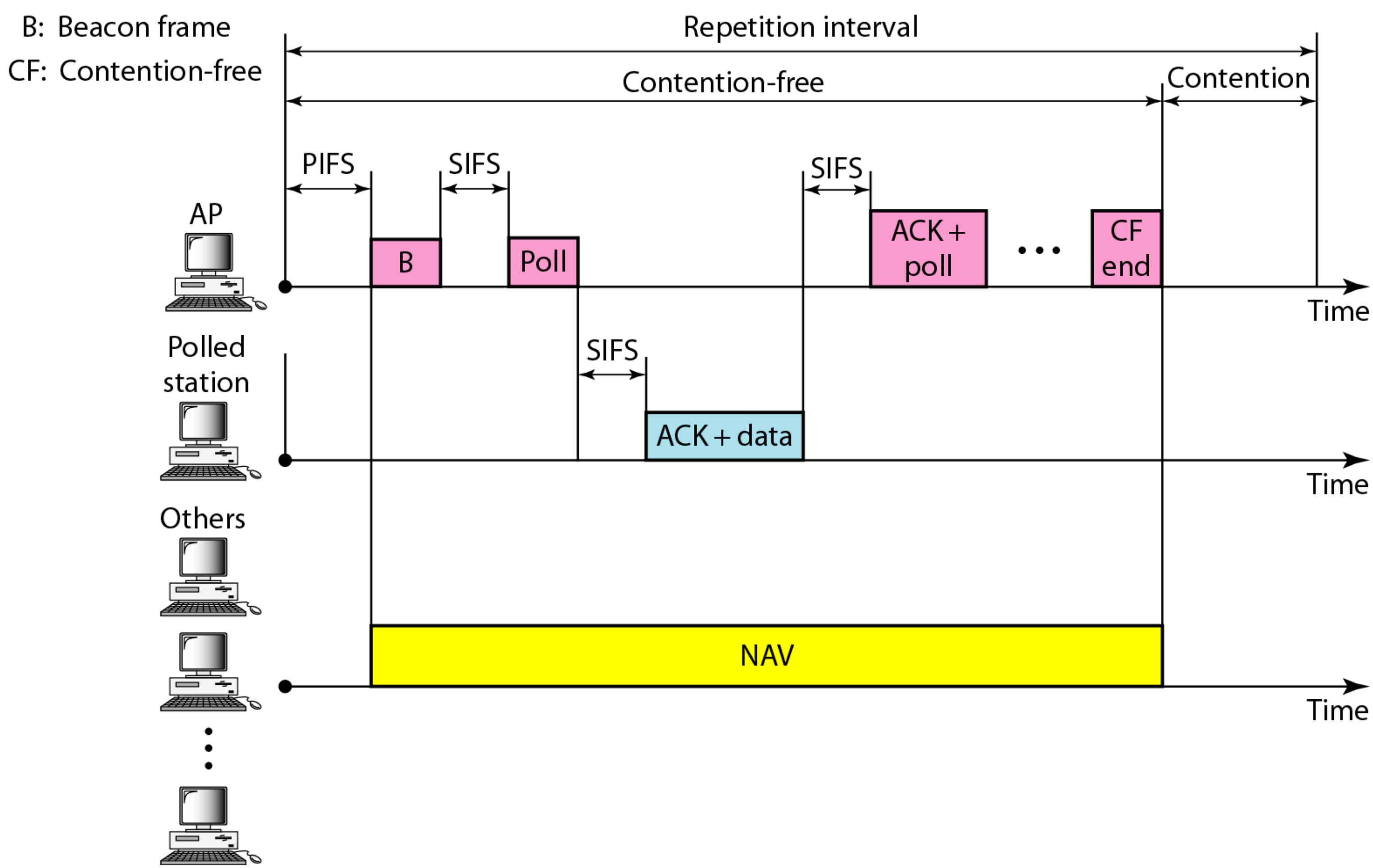
What happens if there is collision during the time when RTS or CTS control frames are in transition; often called handshaking period?

- Two or more station may try to send RTS frame at same time. These control frames may collide.
- There is no collision detection, the sender assume s there have been a collision , if has not received the CTS frame from the receiver
- **The back-off strategy is employed** and the sender tries again.

Point Coordination Function (PCF)

- Optional access method in an infrastructure network (not adhoc network).
- Implemented on top of the DCF and is used mostly for time sensitive transmission.
- PCF has a centralized, contention free polling method. The AP performs polling for stations. The station that are polled one after another, sending any data they have to the AP.
- Uses PIFS(PCF IFS) when issuing polls. Point coordinator polls in Round robin to stations configured for polling.
- If a station wants to use only DCF and the AP wants to use PCF, then AP has priority.

Figure 14.6 *Example of repetition interval*



Point Coordination Function (PCF)

- Due to the priority of PCF over DCF, the stations that uses only DCF may not gain access to the medium. To prevent this, **a repetition interval** has been designed to cover both contention free (PCF) and contention based (DCF) traffic.
- Repetition interval, which is repeated continuously, start with a special frame, called a **beacon frame.**
- When the stations hear the beacon frame, they start their NAV for their duration of contention free period of the repetition interval.
- During the repetition interval, the point controller (PC) can send poll frame, receive data, send ACK and receive ACK or uses piggybacking.
- At the end of contention-free period, PC sends a CF (contenton-free) end frame to all contention based stations to use the medium.

MAC layer- 3 values for IFS

- Use three values for IFS

1. SIFS (short IFS):
   - Shortest IFS
   - For all immediate response actions.

2. PIFS (point coordination function IFS):
   - Midlength IFS
   - Used by the centralized controller in PCF scheme when issuing polls.

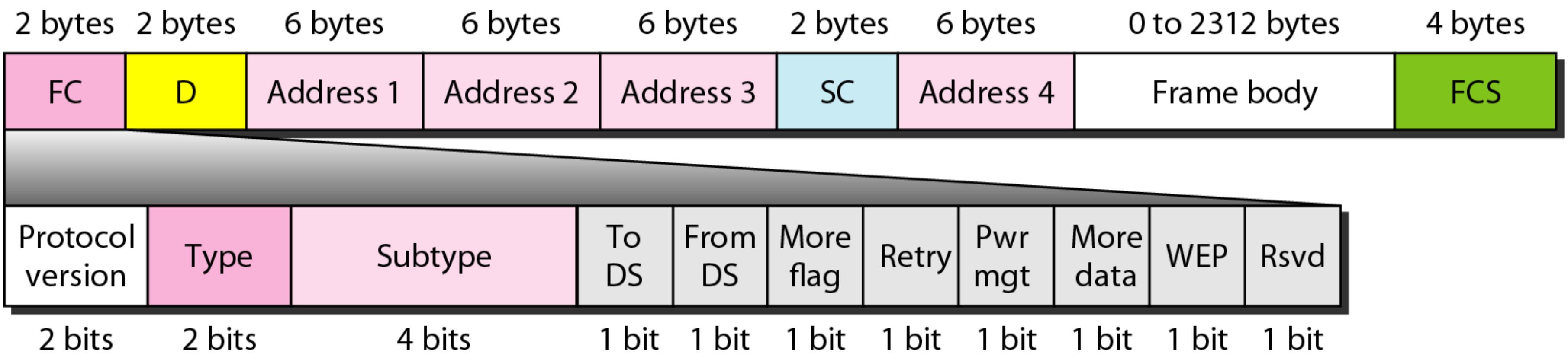
3. DIFS (distributed coordination function IFS):
   - Longest IFS
   - Used as minimum delay for asynchronous frames contending for access

Fragmentation

- Wireless environment is noisy.
- Corrupt frames has to be retransmitted.
- It recommends fragmentation- Division of a large frame into smaller ones.
- It is more efficient to resend a small frame than a large one

Figure 14.7 *Frame format*

MAC layer frame consist of 9 fields



- **Frame control (FC):** Defines the type of frame and some control information.
- **Duration (D):** To set the duration of the transmission that is used to set the value of NAV.
- **Addresses:** Four address field , each 6 byte long. The field depends on the value of the To DS and From DS subfields.
- **Sequence control (SC):** Sequence number of the frame to be used in flow control.
- **Frame body:** It can be between 0 and 2312 bytes , contains information based on the type and subtype defined in FC field.
- **FCS:** 4 bytes long and contain CRC-32 errpr detection sequence

Table 14.1 *Subfields in FC field*

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 14.2)
To DS	Defined later
From DS	Defined later
More flag	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

Frame Types

1. **Management Frames: Used for initial communication between stations and access points.**
2. **Control Frames: Used for accessing channel and acknowledging frames.**

Figure 14.8 ***Control frames***

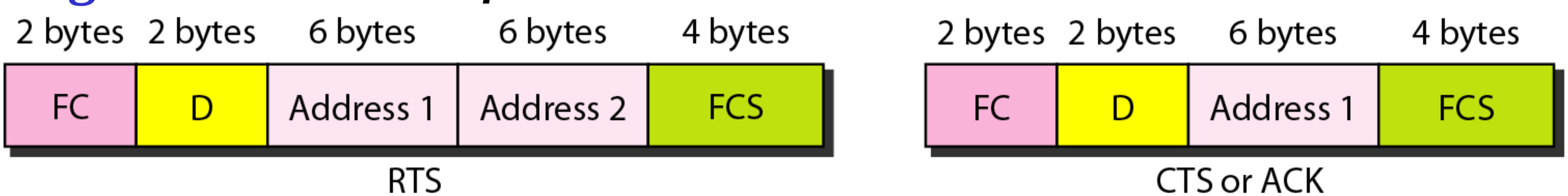


Table 14.2 ***Values of subfields in control frames***

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

3. Data Frames: Used for carrying data and control information

Addressing Mechanisms

IEEE 802.11 addressing mechanism specifies 4 cases, defined by the **value of two flags in FC field , To DS and From DS.** Each flag can be either **0 or 1**, resulting in 4 different situations**.**

Table 14.3 *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

Address 1 is always address of next device.
Address 2 is always the address of previous device.
Address 3 is the address of final station, if it is not defined by Address 1.
Address 4 is the address of source station, if it is not same as Address 2.

Addressing Mechanism

Case 1: ***To DS=0* and *From DS=0***

- Frame is not going to a distribution system (To DS=0) and not coming from a distribution system (From DS=0)
- Frame is going from one station in a BSS to another without passing through the distribution system.
- The ACK frame should be sent to the original sender.

Case 2: ***To DS=0* and *From DS=1***

- Frame is coming from a distribution system (From DS=1).
- The frame is coming from an AP and going to a station.
- The ACK should be sent to AP.
- Address 3 contains the original sender of the frame from another BSS.

Case 3: ***To DS=1* and *From DS=0***

- Frame is going to a distribution system (To DS=1).
- The ACK sent to the original station
- Address 3 contain final destination of the frame in another BSS.

Case 4: ***To DS=1* and *From DS=1***

- Frame is going from one AP to another AP in wireless distribution system.
- We need 4 addresses to define original sender, the final destination, and 2 intermediate APs

Figure 14.9 *Addressing mechanisms*

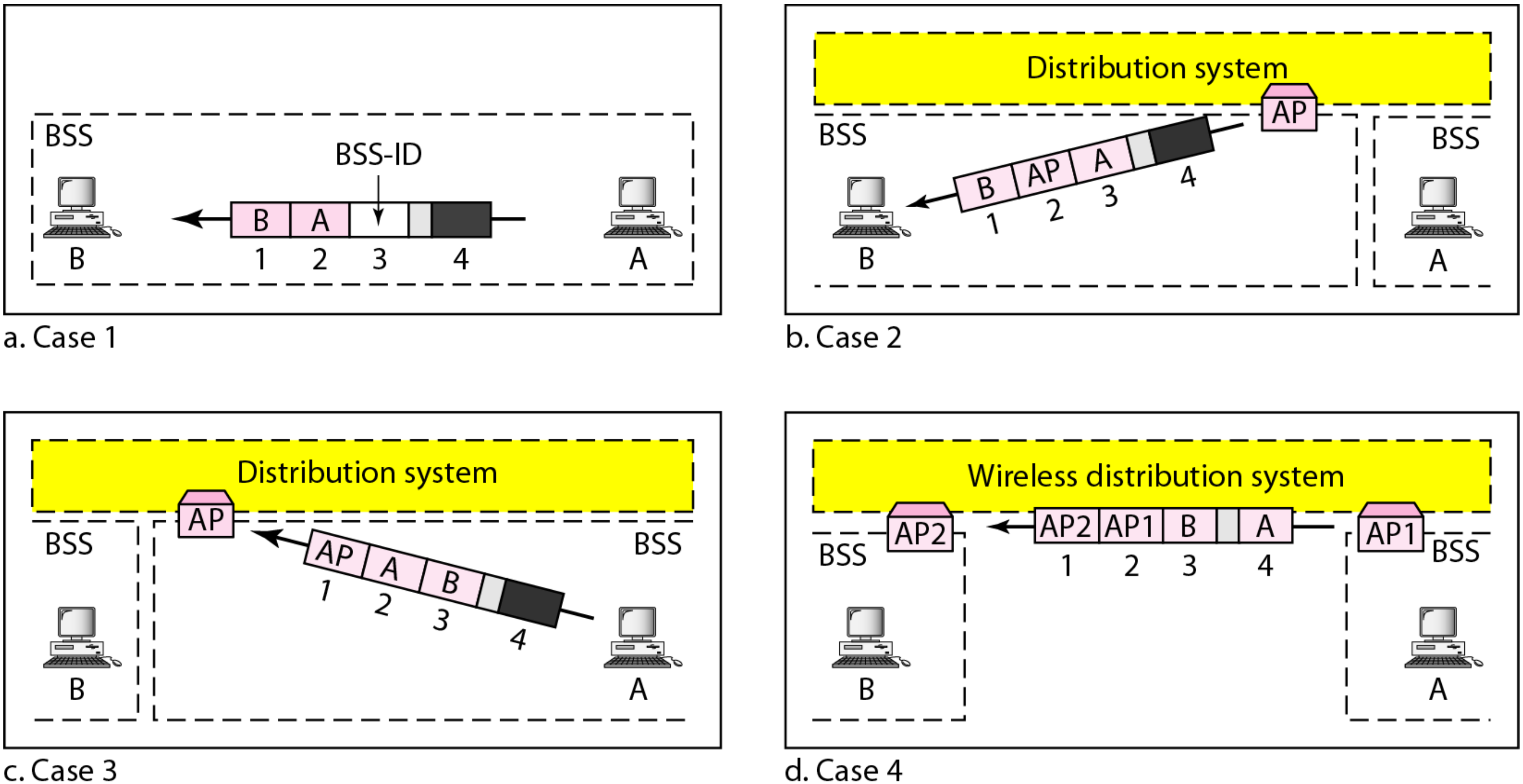
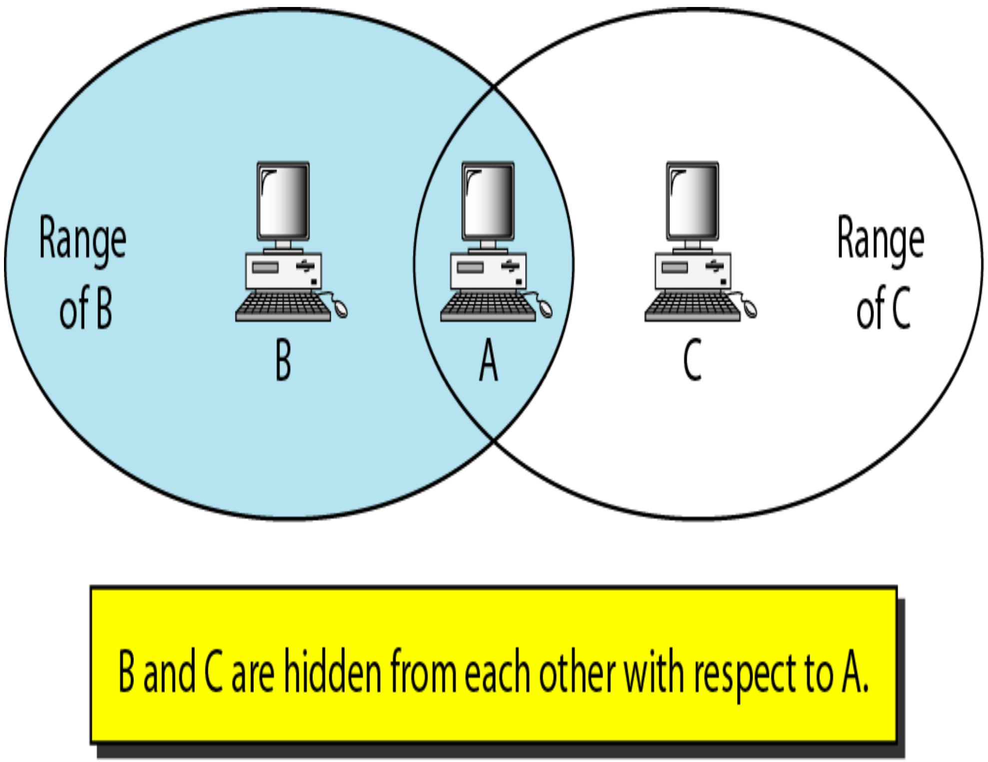


Figure 14.10 *Hidden station problem*



Assume Station B is sending data to Station A. In the middle of this transmission, Station C also send data to Station A.
Station C is out of B's range and the transmission of B cant reach C. Therefore Station C think, medium is free.

Collision happened at Station A, because Station A is receiving data from both Station B and Station c

Note

The CTS frame in CSMA/CA handshake can prevent collision from a hidden station.

Figure 14.11 *Use of handshaking to prevent hidden station problem*

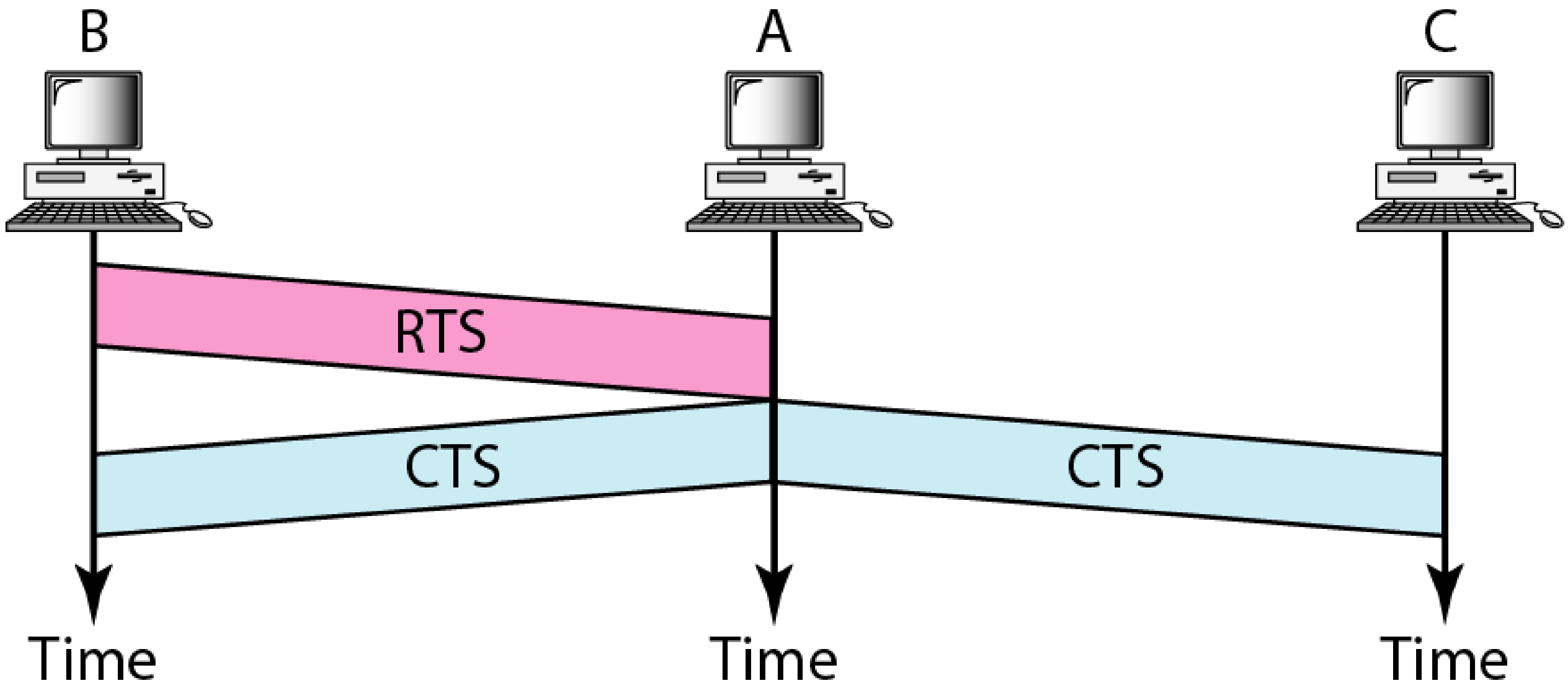
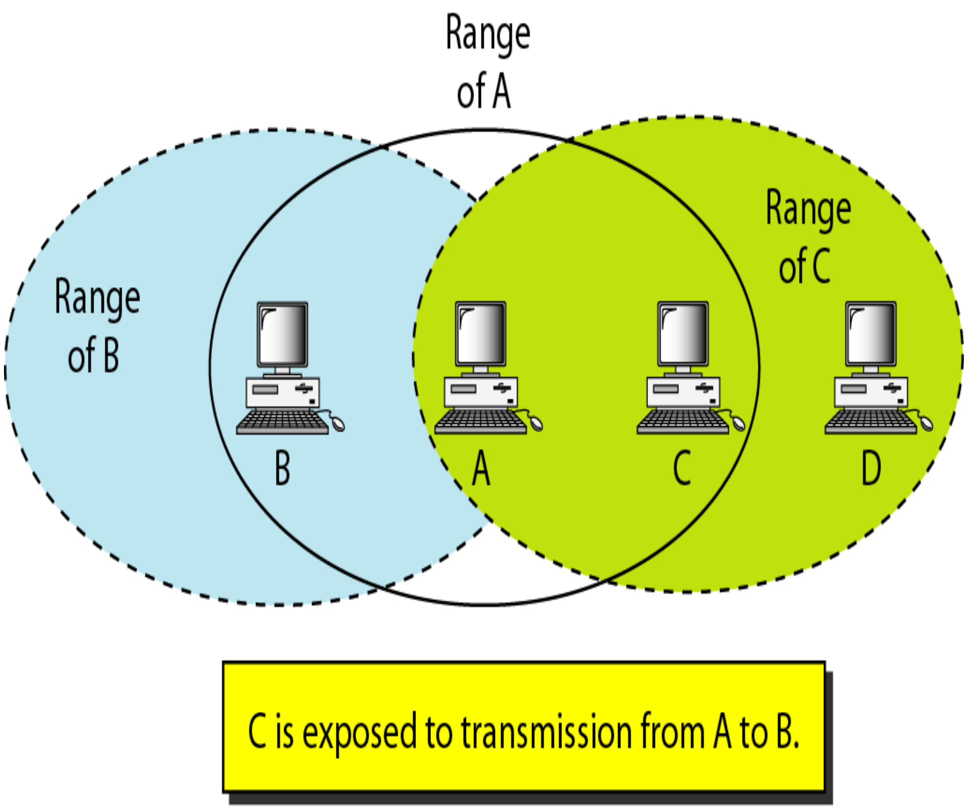


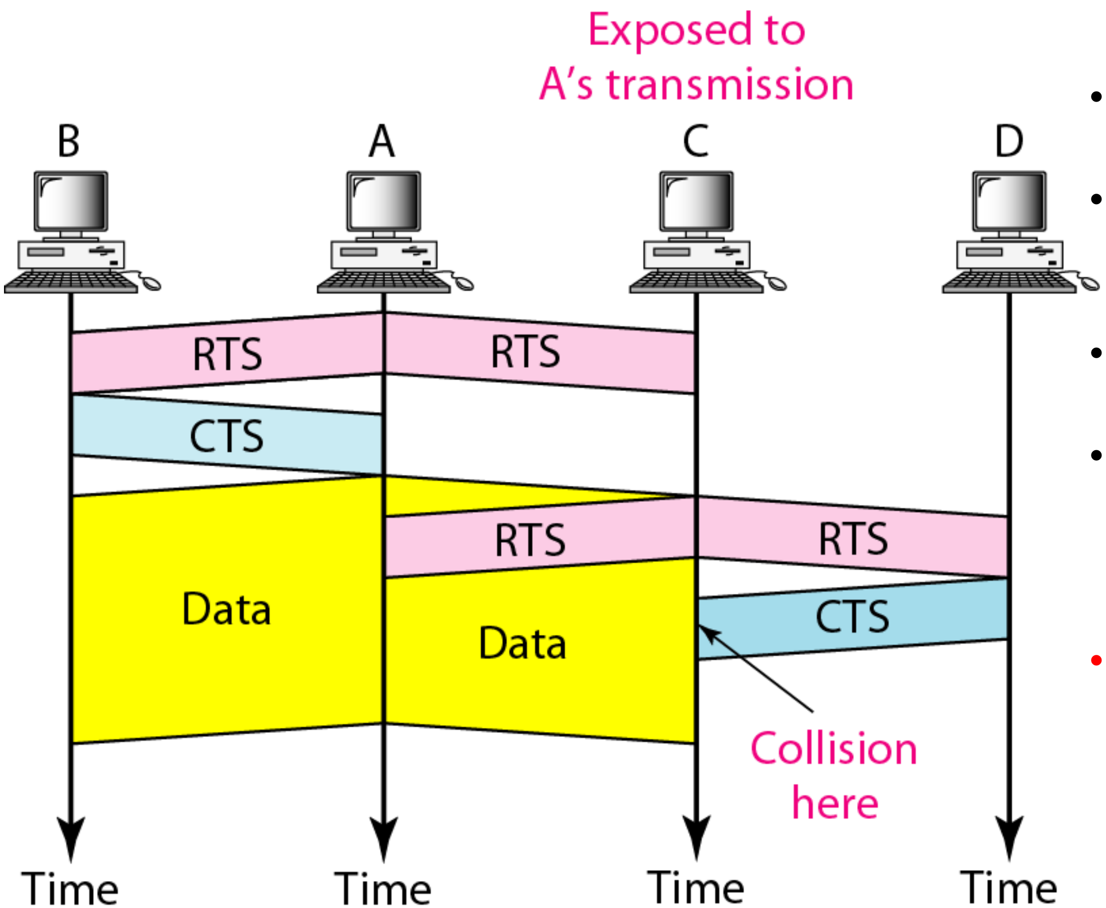
Figure 14.12 *Exposed station problem*



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 Station A. It hears what A is sending and thus refrains from sending.

Handshaking message RTS and CTS cant help this case.

Figure 14.13 *Use of handshaking in exposed station problem*



- **Station C hears RTS from A, but does not hear CTS from B.**
- **Station C, after hearing RTS from A , can wait for a time so that CTS from B reaches A.**
- **It then send an RTS to D to show that it need to communicate with D.**
- **Both B and A hear this RTS, But Station A is in sending state , not receiving state**

- **Problem is here: When Station A has started sending its data, Station C cannot hear CTS from Station D because of collision; It cant send its data to D. It remains exposed until A finishes sending its data.**

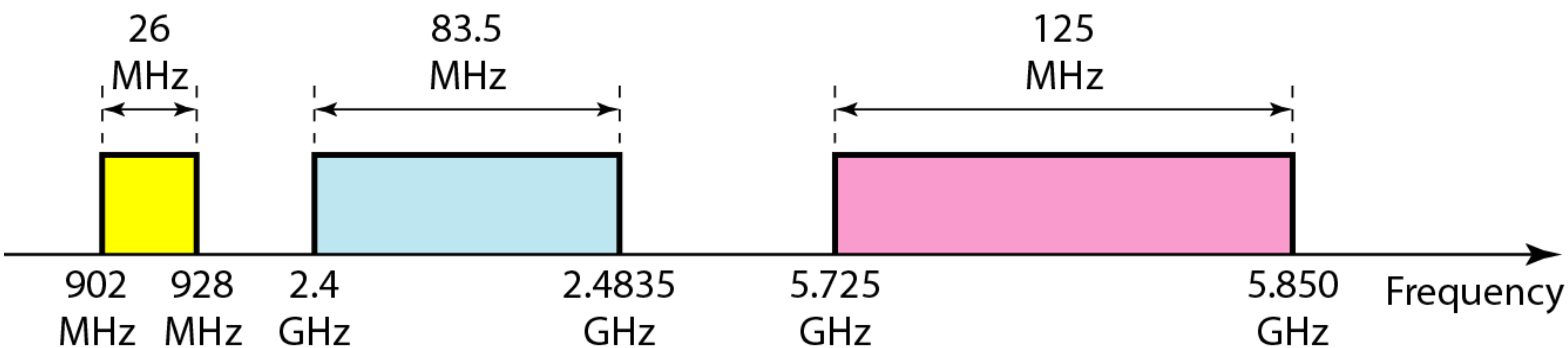
Physical Layer

Table 14.4 ***Physical layers and six specification***

IEEE	*Technique*	*Band*	*Modulation*	*Rate (Mbps)*
802.11	FHSS	2.4 GHz	FSK	1 and 2
	DSSS	2.4 GHz	PSK	1 and 2
		Infrared	PPM	1 and 2
802.11a	OFDM	5.725 GHz	PSK or QAM	6 to 54
802.11b	DSSS	2.4 GHz	PSK	5.5 and 11
802.11g	OFDM	2.4 GHz	Different	22 and 54

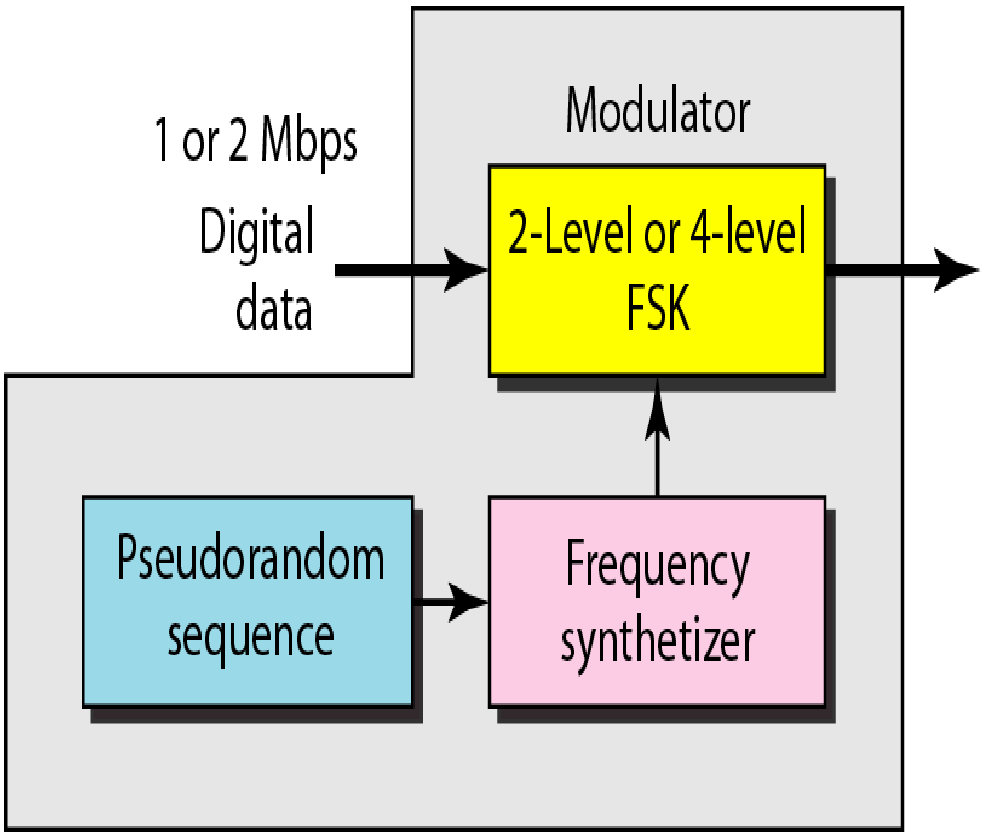
All implementation except infrared operate in the industrial, scientific and medical (ISM) bands.

Figure 14.14 ***Industrial, scientific, and medical (ISM) band***



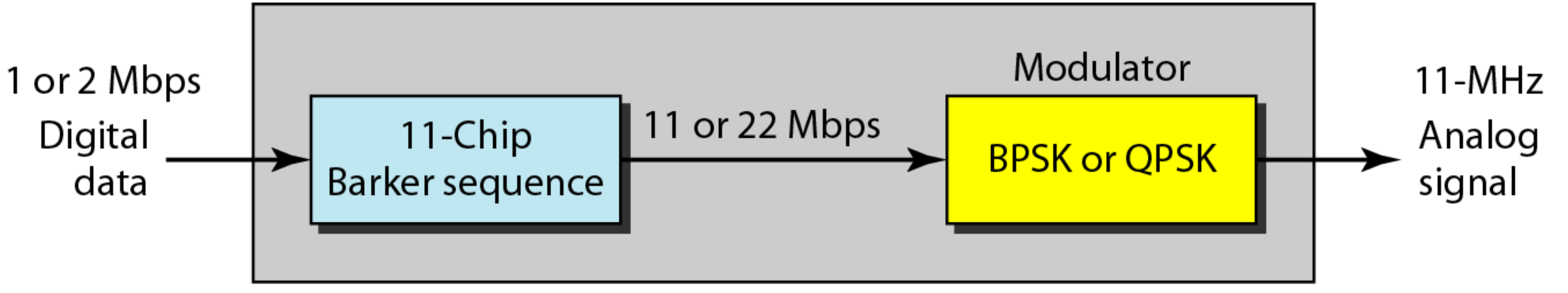
ISM bands defines 3 unlicensed bands in 3 ranges 902-928 MHz, 2400-4.835 GHz and 5.725-5.850 GHz.

Figure 14.15 *Physical layer of IEEE 802.11 FHSS (Frequency hopping spread spectrum)*



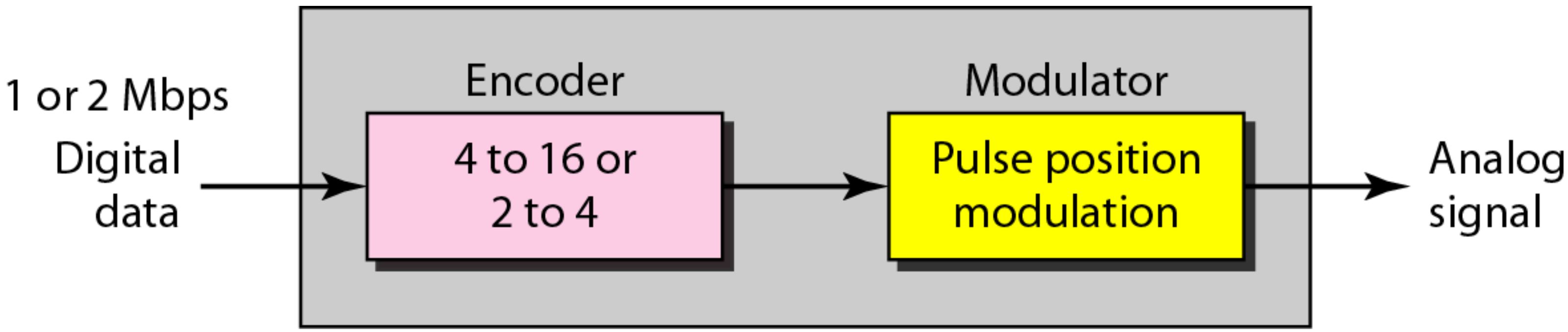
- **FHSS** uses 2.4 GHz ISM band.
- Band is divided inti 79 subbands of 1 MHz.
- A pseudorandom generator selects the hopping sequence.
- Modulation technique is 2-level or 4-level FSK with 1 or2 bits/baud, which results in a data rate of 1 or 2 Mbps.

Figure 14.16 *Physical layer of IEEE 802.11 DSSS (Direct sequence spread spectrum)*



- **Uses 2.4 GHz ISM band.**
- **Modulation Technique is PSK at 1 Mbaud/s.**
- **System allow 1 or 2 bits/baud, which results in a data rate of 1 or 2 Mbps.**

Figure 14.17 *Physical layer of IEEE 802.11 infrared*

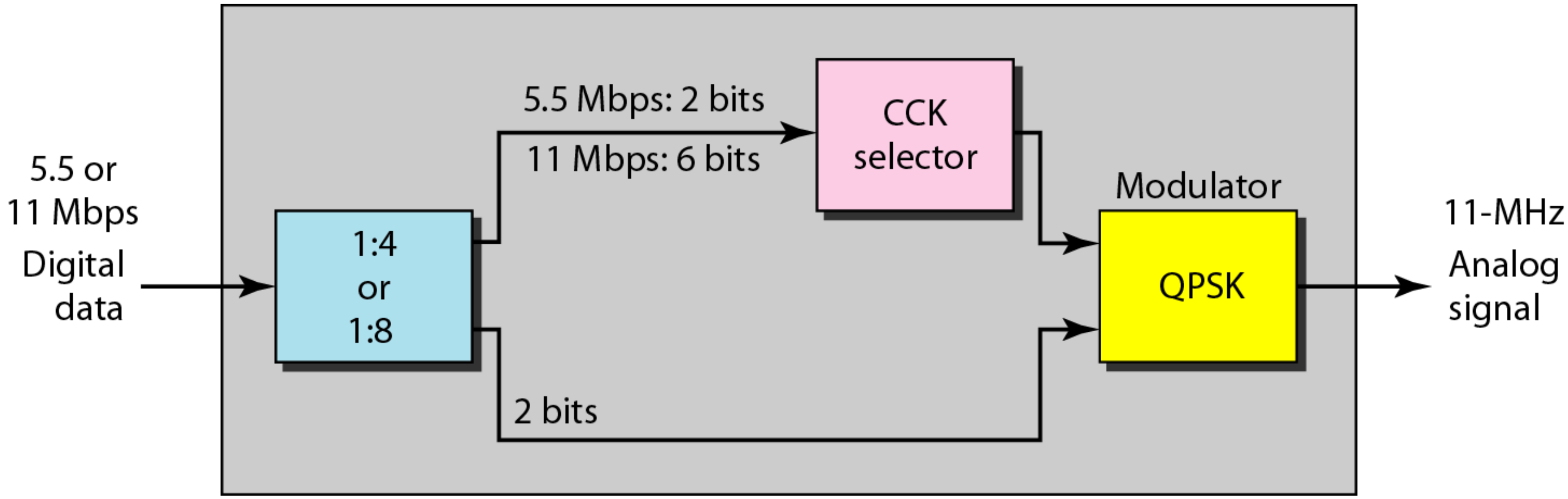


- Infrared uses infrared light in the range of 800 to 950 nm.
- Modulation technique is **pulse position modulation**.
- For 1 Mbps data rate, a 4 bit sequence is first mapped into 16 bit sequence in which only one bit is set to 1 and the rest are set to 0.
- For 2 Mbps data rate, a 2 bit sequence is first mapped into 4-bit sequence in which only one bit is set to 1 and the rest are set to 0.
- The mapped sequence are then converted to optical signals; the presence of light specifies 1 , the absence specifies 0.

IEEE 802.11a or OFDM (Orthogonal Frequency-Division Multiplexing)

- Uses **5-GHz ISM band**.
- OFDM is similar to FDM with one major difference, where all subbands are used by one source at a given time.
- The band is divided into 52 subbands, with 48 subbands for sending 48 groups of bits at a time and 4 subbands for control information.
- Dividing bands into subbands **diminishes the effect of interference.**
- If subbands are used randomly, security can also be increased.
- Modulation techniques are **PSK and QAM**
- Data rates are **18Mbps (PSK) and 54Mbps (QAM).**

Figure 14.18 *Physical layer of IEEE 802.11b DSSS (High rate direct sequence spread spectrum)*



- HR-DSSS uses 2.4 GHZ ISM band.
- Encoding method is called complementary code keying (CCK).
- CCK encodes 4 or 8 bits to one CCK symbol.
- HR-DSSS defines 4 data rates:1,2,5.5 and 11 Mbps
- The first two uses the same modulation technique as DSSS(i.e; PSK).
- The 5.5Mbps uses BPSK and transmit at 1.375Mbps with 4 bit CCK encoding.
- 11 Mbps uses QPSK and transmit 1.375 Mbps with 8 bit CCK encoding.

IEEE 802.11g

- Modulation technique is **OFDM.**
- OFDM using **2.4 GHz ISM** band.
- It defines forward error correction.
- The modulation technique **achieves 22 or 54 Mbps data rate.**

14-2 BLUETOOTH (IEEE 802.15)

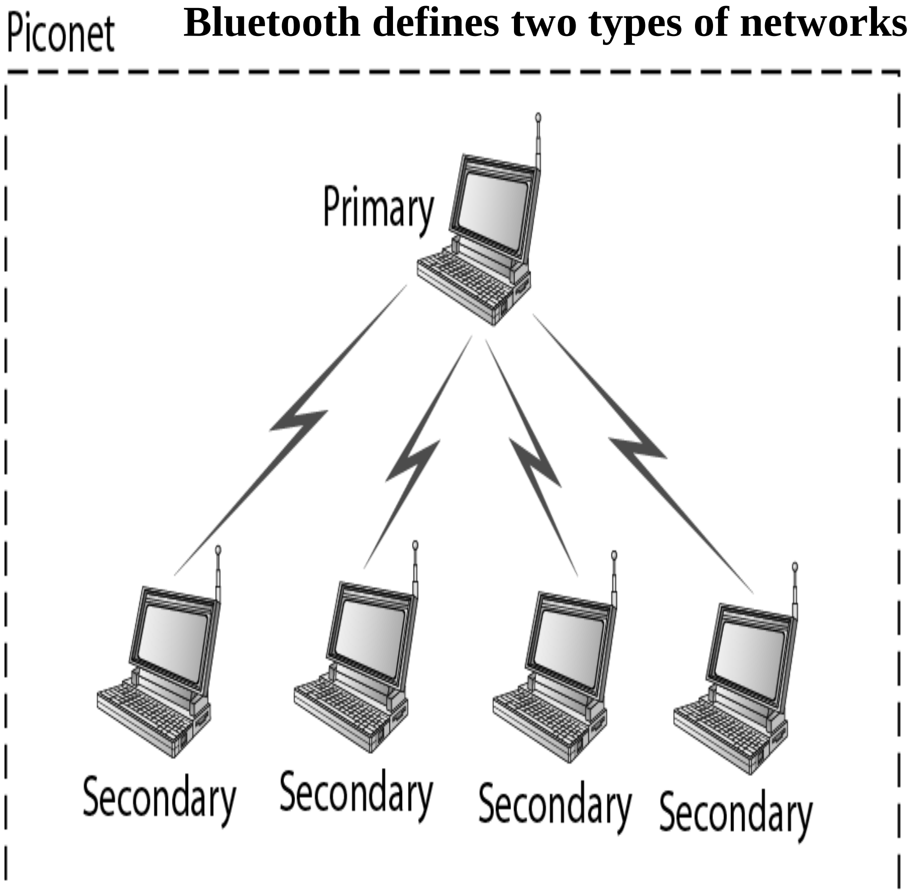
***Bluetooth* is a wireless LAN technology designed to connect devices of different functions such as telephones, notebooks, computers, cameras, printers, coffee makers, and so on. A Bluetooth LAN is an adhoc network, which means that the network is formed spontaneously.**

The standard defines a personal area network (PAN) operable with in 10 km.

Topics discussed in this section:

Architecture
Bluetooth Layers
Baseband Layer
L2CAP

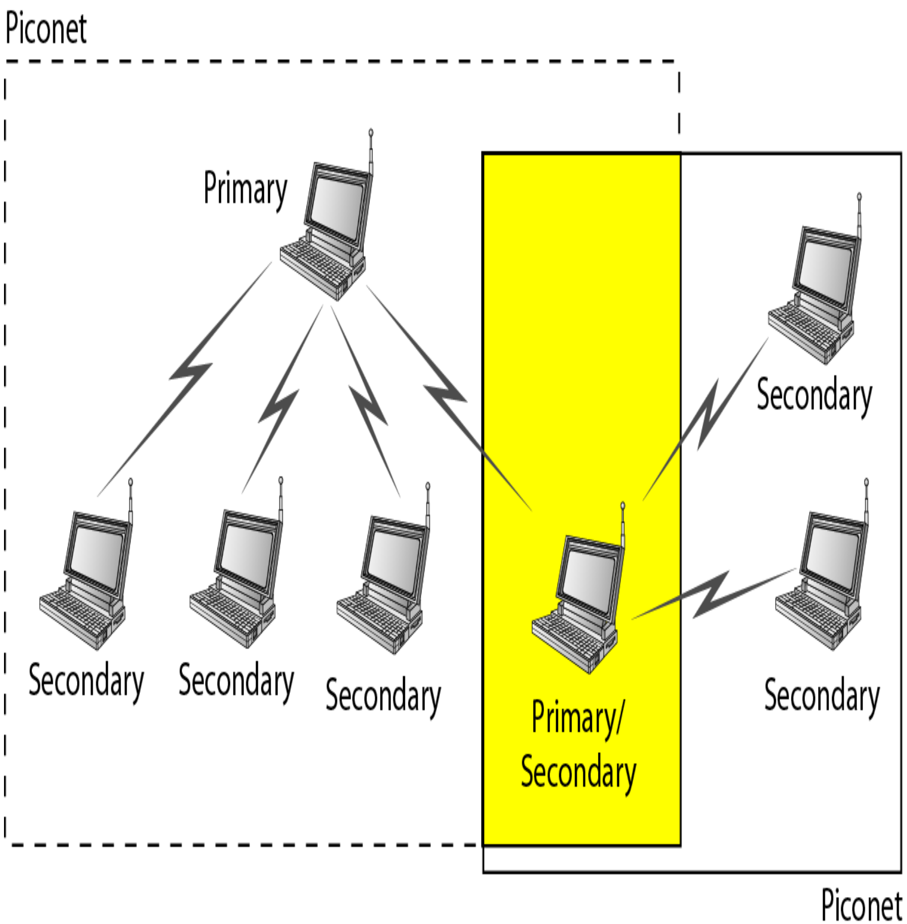
Figure 14.19 *Piconet*



Bluetooth defines two types of networks: piconet and scatternet.

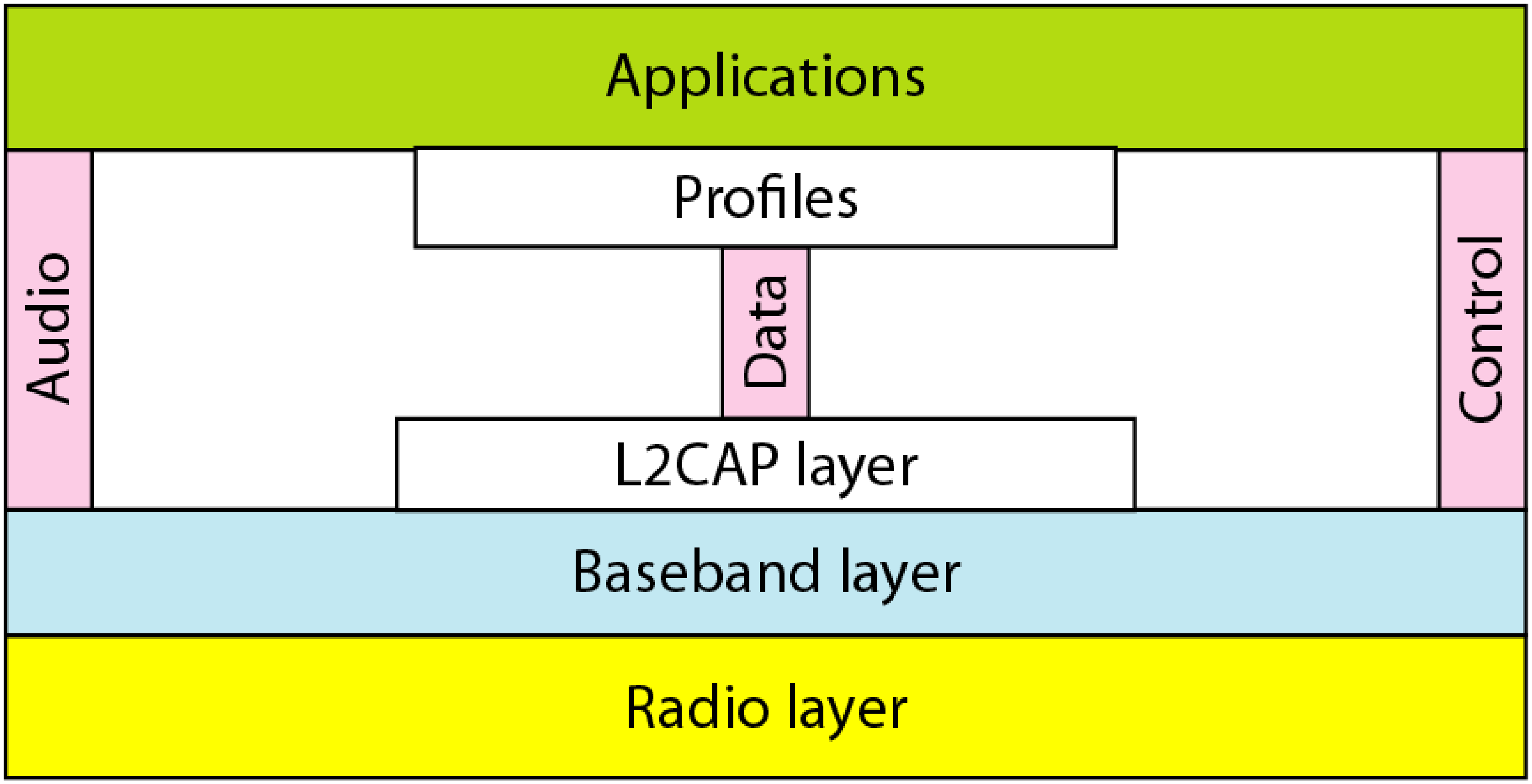
- **A Bluetooth network is called a piconet, or a small net.**
- **A piconet can have up to 8 stations, one of which is primary and the rest are called secondaries.**
- **All the secondary stations synchronize their clocks and hopping sequence with the primary.**
- **Piconet can have only one primary station and maximum of 7 secondaries.**
- **The communication between the primary and secondary can be one to one or one to many.**
- **Additional eight secondaries can be in the parked state**
- **Only 8 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**

Figure 14.20 *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 message from the primary in the first piconet (as a secondary) and acting as primary , deliver them to secondaries in the second piconet.
- A station can be member of two piconets is shown in Figure 14.20.

Figure 14.21 *Bluetooth layers*



Radio Layer

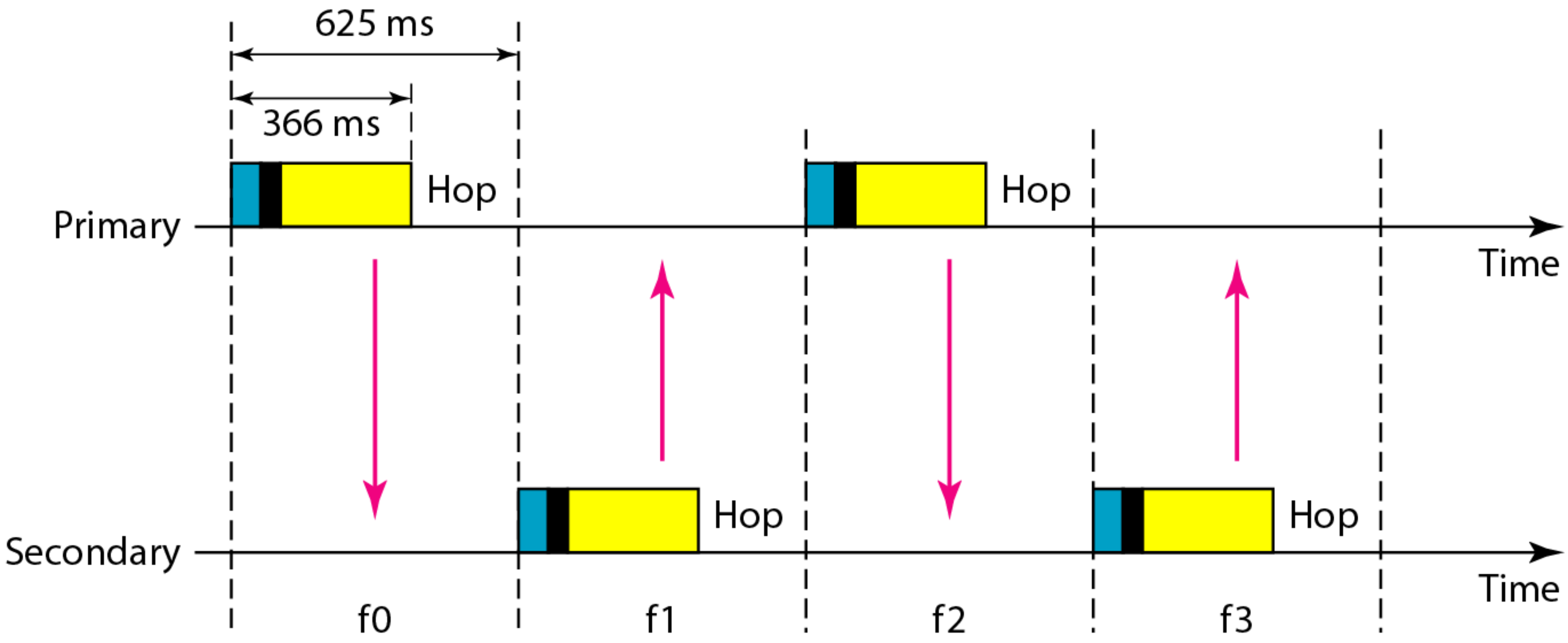
- The radio layer is equivalent to the **physical layer of the Internet model**.
- Bluetooth devices are **low power and have a range of 10m**.
- **Band:** Uses **2.4 GHz ISM** band divided into 79 channels of 1 MHz each.
- **FHSS:** Uses frequency- hopping spread spectrum method in physical layer to avoid interference from other devices or other network.
    - 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 625μs (1/1600 s) before it hops to another frequency; ie, dwell time is 625μs.
- **Modulation:** To transform bits into signals.
    - Uses sophisticated version of FSK, called GFSK(Gaussian bandwidth filtering)
    - The frequencies in mega hertz are defined as

$$f_c=2402+n,\ n=0,1,2\ldots78$$

Baseband Layer

- The bandwidth layer is equivalent to **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.
- Bluetooth uses a form of TDMA is called **TDD-TDMA (Time Division Duplex TDMA)**
- TDD-TDMA is a kind of half –duplex communication in which secondary and receiver send and receive data , but not at the same time.
- **Single secondary Communication:**
  - If the piconet has only one secondary, the TDMA operation very simple.
  - The time is divided into slots of 625 μs.
  - The primary uses even time slots (0,2,4…) and the secondary uses (1,3,5…).
  - TDD-TDMA allows the primary and secondary to communicate in half duplex mode.
  - In slot 0, the primary sends and secondary receives; in slot 1, the secondary sends and the primary receives. The cycle is repeated.

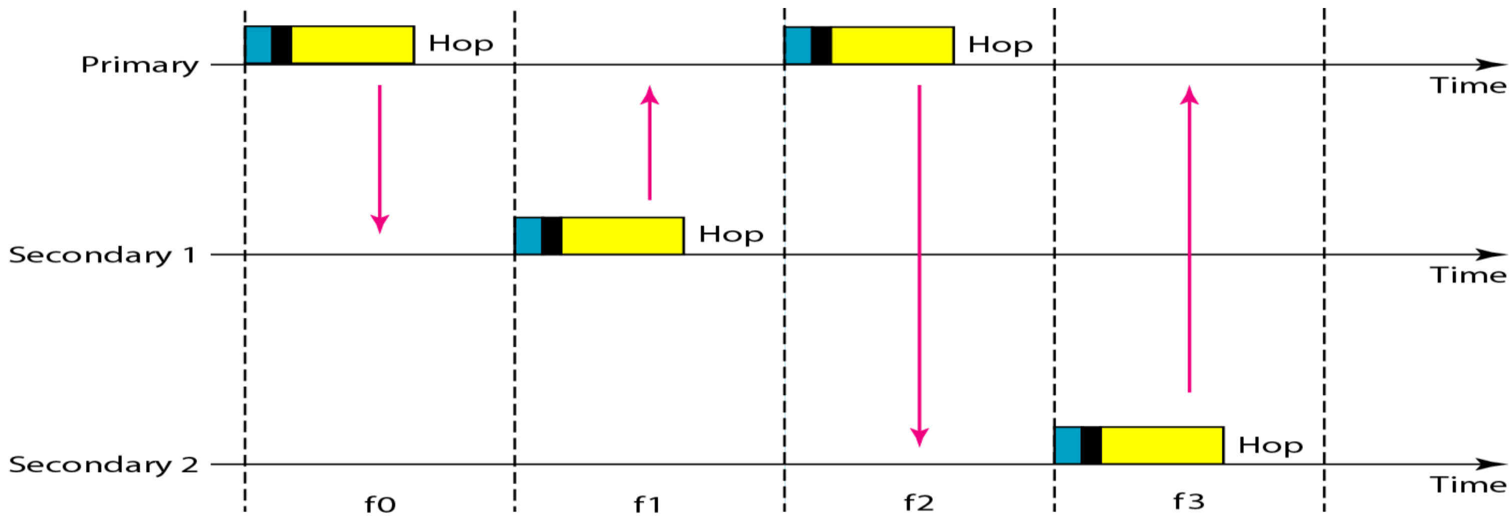
Figure 14.22 *Single-secondary communication*



Multiple-secondary communication

- Multi- secondary communication happened when there is more than one secondary in the piconet.
- Primary uses even numbered slots, but the secondary sends in the next odd-numbered slot if the packet in the previous slot was addressed to it.
- All secondaries are listen on even numbered slots, but only one secondary sends in any odd numbered slot.
- 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.

Figure 14.23 *Multiple-secondary communication*



1. **In slot 0, the primary sends a frame to secondary 1.**
2. **In slot 1, only secondary 1 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.**

Physical Links

Two type of link can be created between a primary and a secondary: SCO links and ACL links

1. **SCO (Synchronous Connection-Oriented) link:**
    1. Used when avoiding latency (delay in data delivery) is more important than integrity (error free delivery).
    2. In an SCO link, a physical link is created between the primary and a secondary by reserving specific slots at regular interval.
    3. The basic unit of connection is two slot, one for each direction. If a packet is damaged, it **never retransmitted**.
    4. SCO is used **for real time audio** where **avoiding delay is all-important**.
    5. A secondary can create up to **3 SCO links** with the primary, sending digitized audio (PCM) at 64kbps in each link.

2. **ACL (Asynchronous connectionless) link:**
    1. Used when **data integrity is more important** than avoiding latency.
    2. If the payload encapsulated in the frame is corrupted, it **is retransmitted**.
    3. A secondary returns an ACL frame in the available odd-numbered slot if and only if the previous slot has been addressed to it.
    4. ACL can use one, three or more slots and can achieve **a maximum data rate of 72kbps**.

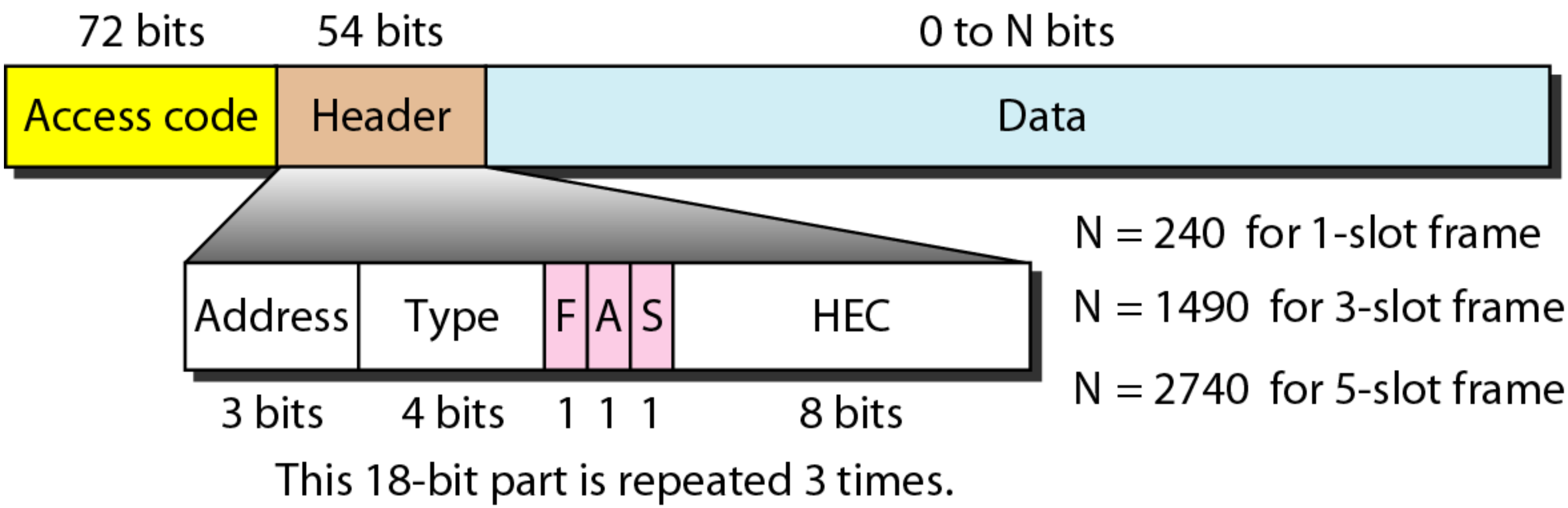
Frame format types

- **Access code:** 72 bit field contains synchronization bits and the identifier of the primary to distinguish the frame of one piconet from another.
- **Header:** 54 bit field is a repeated 18 bit pattern.

  - ***Address:*** 3 bit address define upto 7 secondaries (1 to 7). If the address is zero, it is used for broadcast communication from primary to all secondaries.
  - ***Type:*** 4 bit type subfield defines the type of data coming from upper layer.
  - ***F:*** 1-bit subfield is for flow control. When set (1), it indicates that the device is unable to receive more frame(buffer is full)
  - ***A:*** 1 bit subfield is used for acknowledgment. Bluetooth uses stop and wait protocol.
  - ***S:*** 1 bit subfield hold a sequence number.
  - ***HEC:*** 8 bit header error correction

- **Payloads:** This subfield can be 0 to 2740 bits long. It contain data and control information from upper layer.

Figure 14.24 *Frame format types*



L2CAP (Logical Link Control And Adaptation protocols

- **It is equivalent to the LLC sublayer in LANs**
- **It is used for data exchange on an ACL link.**
- **SCO channels do not use L2CAP.**
- **16 bit length field defines the size of data, in bytes, coming from upper layers.**
- **Data can be upto 65,535 bytes.**
- **Channel ID(CID) defines a unique identifier for the virtual channel**
- **Has specific duties: multiplexing, segmentation, reassembly, QoS, and group management.**
- **Maximum Size of payload field is 2774 bits (343 bytes) where 4 bytes to define packet and packet length.**
- **Size of packet that can arrive from an upper layer can only be 339 bytes**

15-1 CONNECTING DEVICES

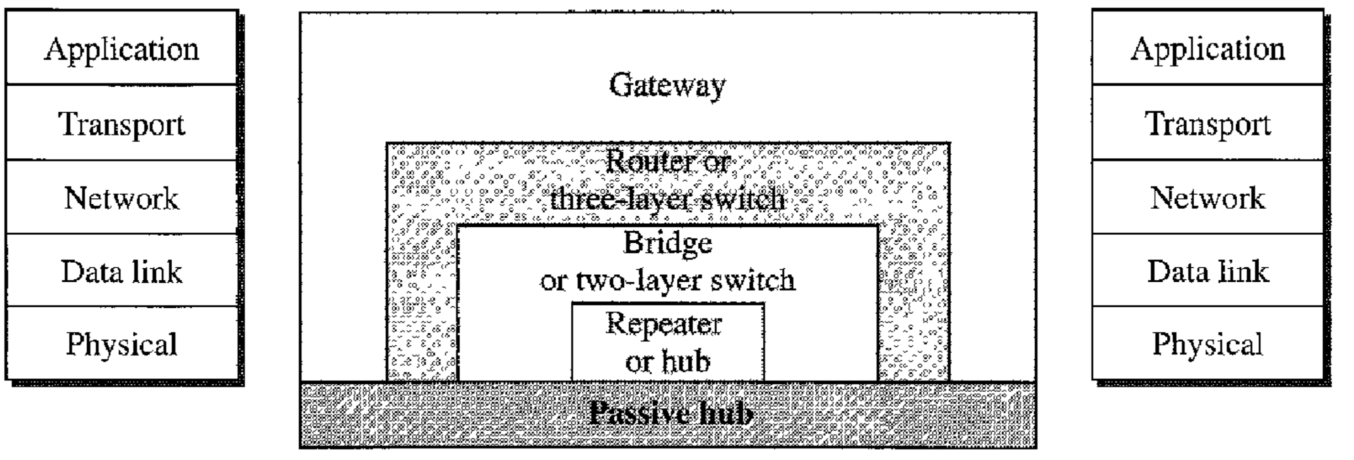
***Connecting Devices** are used to connect LANs or segments of LANs. Connecting devices can operate in different layers of the Internet model.*

Topics discussed in this section:

Passive Hubs
Repeaters
Active Hub
Bridges
Two-Layer Switches
Three-Layer Switches
Gateways

Figure 15.1 ***Five different categories of Connecting Devices based on the layer in which they operate in a network***

Figure 15.1 *Five categories of connecting devices*



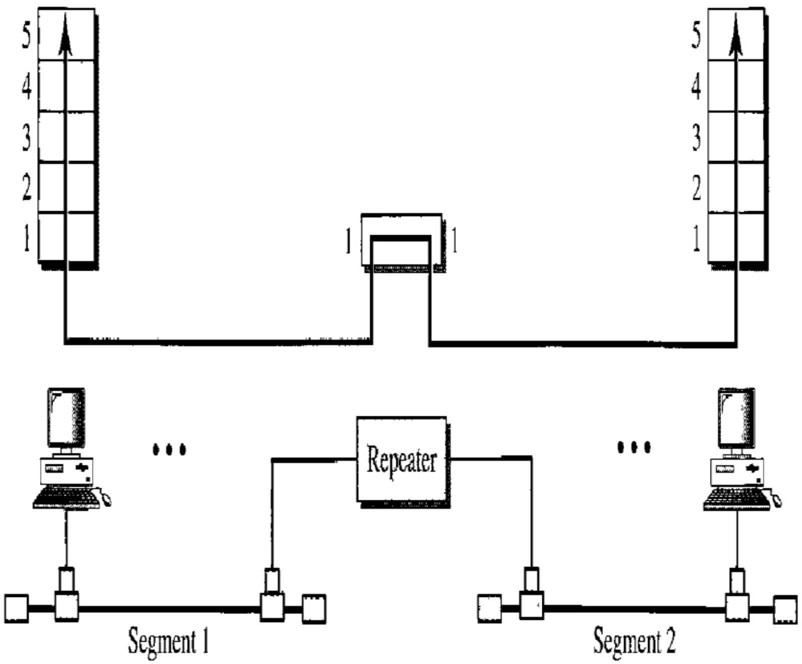
- **Connecting devices operate below the physical layer such as passive hub.**
- **Connecting devices operate at physical layer such as repeater, an active hub.**
- **Connecting devices operate at the physical layer and data link layers such a bridge, a two layer switch.**
- **Connecting devices operate at the physical layer, data link layers and network layers such as router, three layer switch.**
- **Connecting devices operate at all five layers such as gateways.**

Passive Hubs

- A Passive hub is a connector.
- It connects the wires coming from different branches.
- In a star topology Ethernet LAN, a passive hub is a point where the signals coming from different stations collide; A hub is a collision point.
- It is a part of the media.
- Location in the Internet model is below the physical layer.

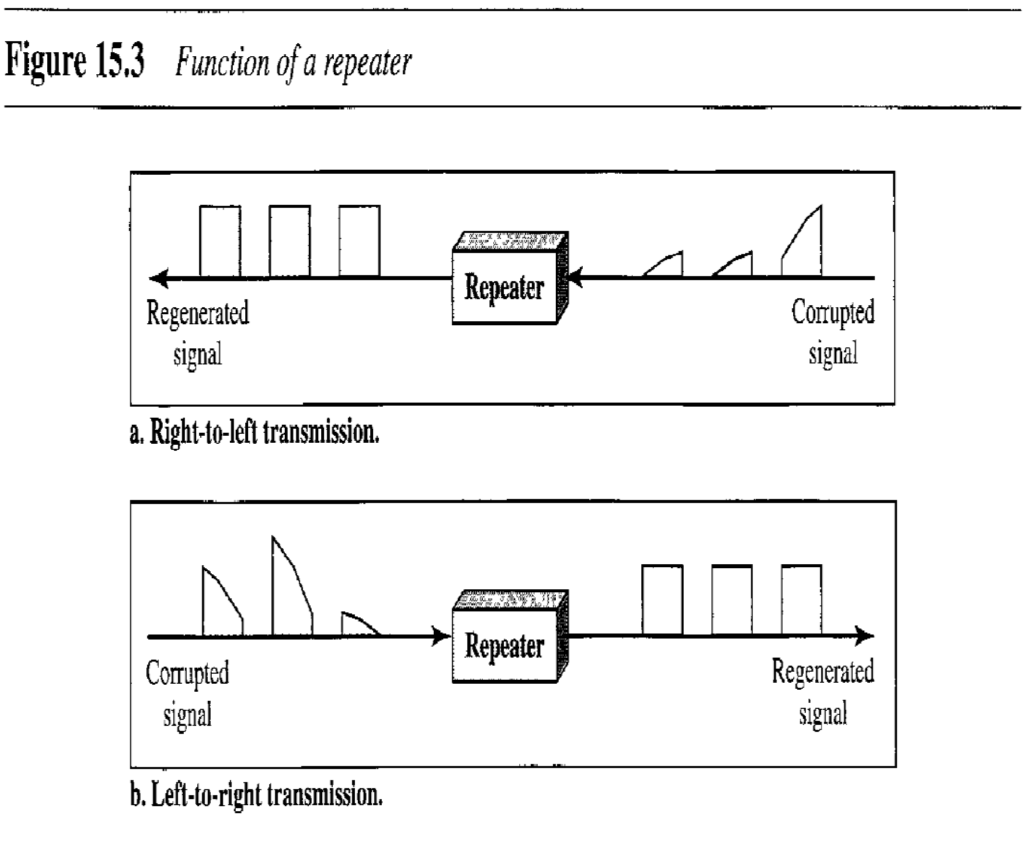
Repeaters

Figure 15.2 *A repeater connecting two segments of a LAN*



- A repeater is a device which operates only in the physical layer
- A repeater receives the signal and, before it becomes too weak or corrupted, regenerates the original bit pattern. The repeater sends the refreshed signal.
- A repeater can extend the physical length of the LAN as shown in Figure 15.2
- A repeater connects segments of a LAN.
- A repeater forwards every frame; it has no filtering capacity.
- A repeater is a regenerator , not amplifier. When it receives a weakened or corrupted signal, it creates a copy, bit for bit , at original strength.

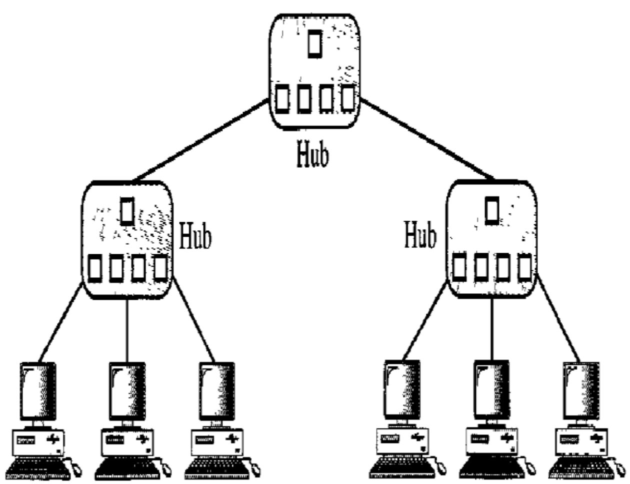
Figure 15.3 *Function of a Repeater*



- **The location of the repeater on a link is vital.**
- **A repeater must be placed so that a signal reaches it before any noise changes the meaning of any bits.**
- **A little noise can alter the precision of bit's voltage without destroying its identity which is shown in Figure 15.3.**
- **If the corrupted bit travels much farther , accumulated noise can change its meaning completely. At that point the original voltage is not recoverable and needs to be corrected.**
- **A repeater placed on the line before the legibility of the signal becomes lost and can read the signal well to determine the intended voltage and replicate them to their original form**

Active Hubs

Figure 15.4 *A hierarchy of hubs*

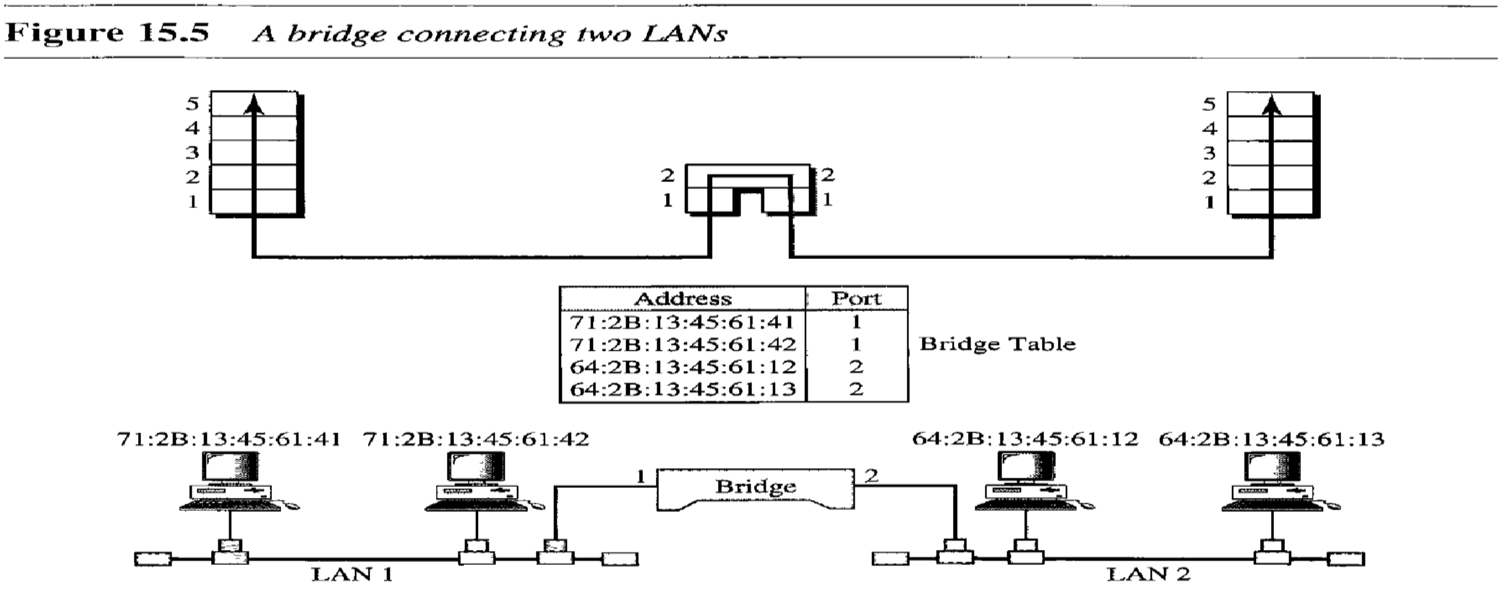


- **An Active Hub is a multiport repeater.**
- **It is used to create connections between stations in a physical star topology.**
- **Eg: 10 Base T**
- **Hub can also be used to create multiple level of hierarchy as shown in Figure 15.4.**
- **The length limitation of 10BaseT can be removed by using hierarchy of hubs.**

Bridges

- A bridge operates in both **physical layer and data link layer**.
- As a **physical device**, it **regenerates the signal** it receives.
- As the **data link layer device** , bridge can **check the physical MAC addresses** (Source and Destination) contained in the frame.
- A bridge has a **filtering capability**. It can check the destination address of a frame and decide if the frame should be forwarded or dropped.
- If the frame is to be forwarded, the decision must specify the port.
- A bridge has a **table that maps addresses to port**.
- It is used in filtering decision.

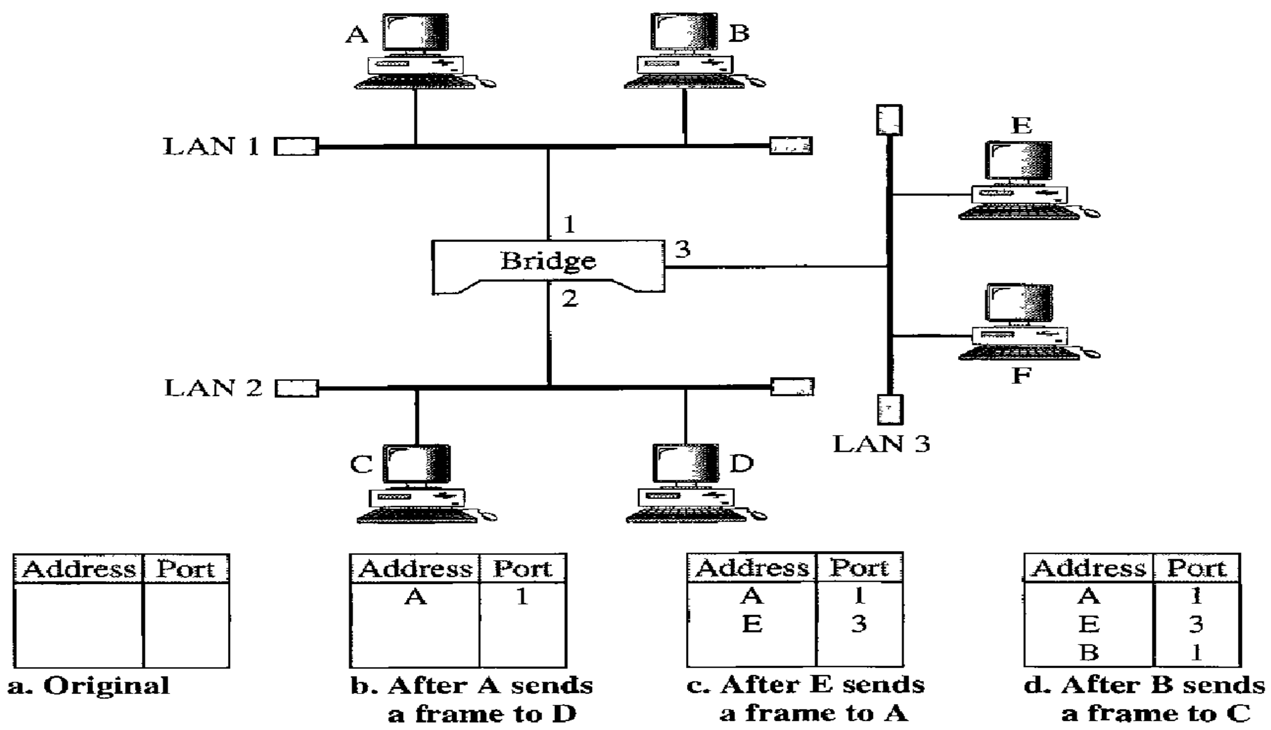
Figure 15.5 *A Bridge connecting two LANs*



- **Case 1: If a frame destined for station 71:2B13:45:61:42 arrives at port 1, the bridge consults its table to find departing port and found it is port 1. So there is no need of forwarding, ad the frame is dropped.**
- **Case 2: If a frame destined for station 71:2B13:45:61:41 arrives at port 2, the departing port is port 1 and the frame is forwarded.**
- **In the first case , LAN 2 remains free for traffic, but in the second case, both LAN have traffic.**
- **A bridge doesnot change the physical MAC address in a frame.**

Figure 15.6 *A learning Bridge and the process of learning*

Figure 15.6 *A learning bridge and the process of learning*

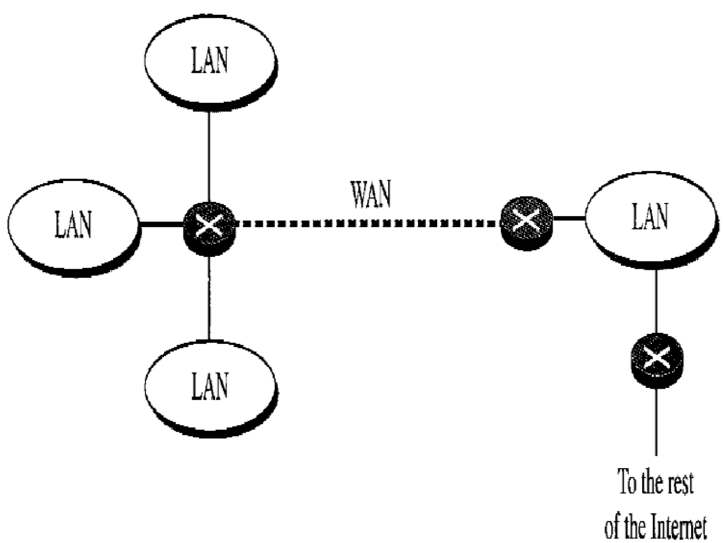


Two-Layer Switches

- A two-layer switch performs at physical and data link layers.
- A two- layer switch is a bridge, a bridge with many ports and a design that allows better performance.
- A bridge with many ports may be able to allocate a unique port for each station, with each station on its own independent entity. So there wont be o collision or competing traffic.
- A two layer switch makes filtering decision based on MAC address of the frame it received.
- Two layer switches also called cut- through switches, have designed to forward the frame as soon as they check the MAC addresses in the header of the frame.

Routers

Figure 15.11 *Routers connecting independent LANs and WANs*



- A router is three layer device that routes packets based on their **logical addresses** (host –to- host addressing)
- A router connects LANs and WANs in the Internet and has **routing table** that is used for making decision about the route.
- The routing tables **are dynamic** and updated using routing protocols

Three-Layer Switches

- A three layer switch is a router, but **faster and more sophisticated**.
- The switching fabric in a three layer switch **allows faster table look up and forwarding**

Gateway

- A gateway is a computer that operates in all 5 layers or 7 layers of OSI model.
- A gateway takes an application message , read it and interpret it. This means that it can be used as connecting device between two internetworks that us different models
- Eg: A network designed to use OSI model can be connected to another network using the Internet model