Chapter 12

Multiple Access

Figure 12.1 *Data link layer divided into two functionality-oriented sublayers*

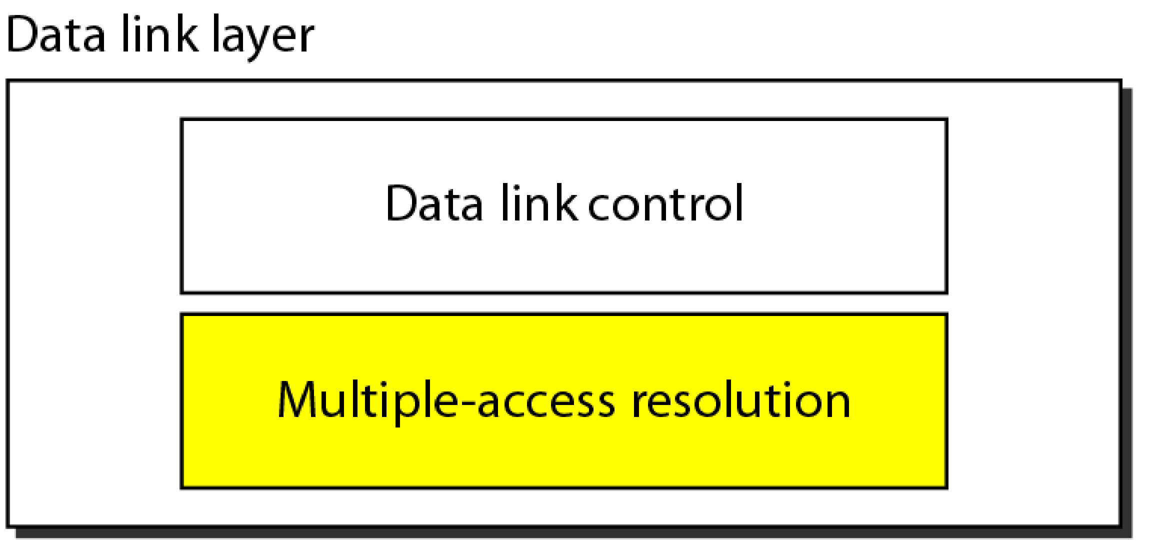
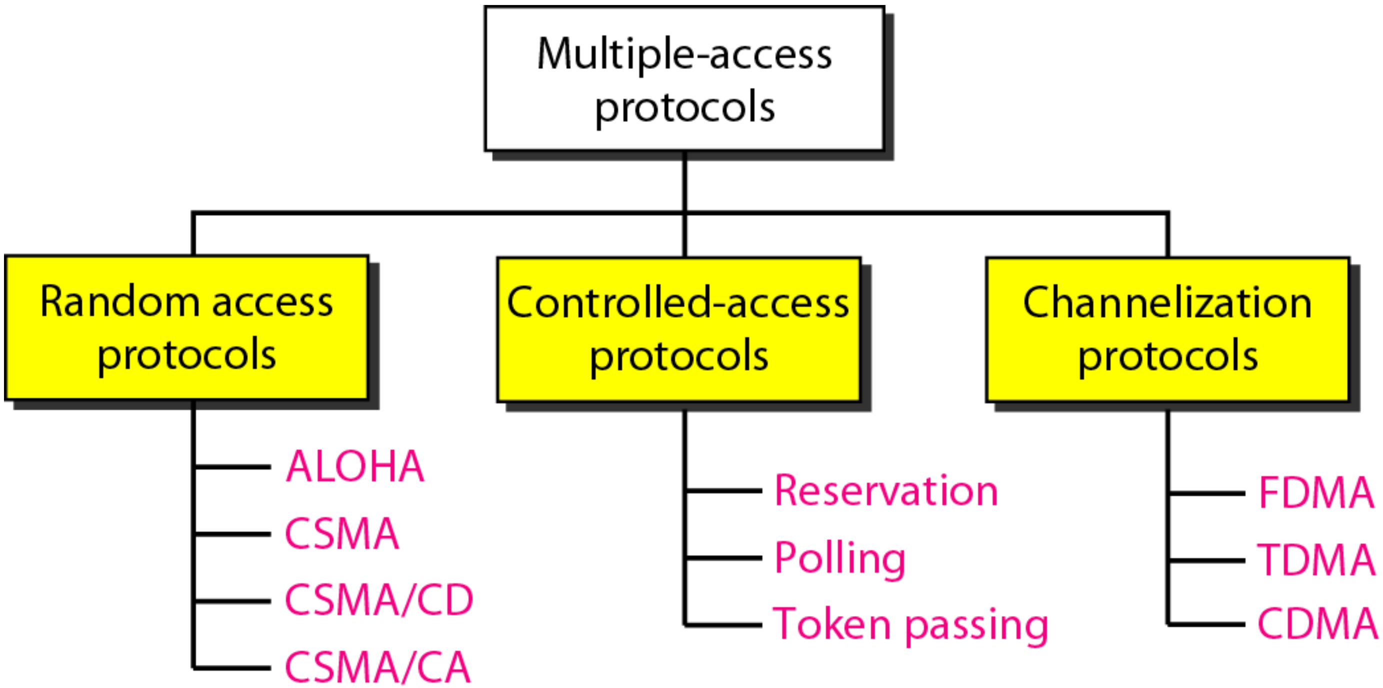


Figure 12.2 *Taxonomy of multiple-access protocols discussed in this chapter*



12-1 RANDOM ACCESS

In random access or contention methods, no station is superior to another station and none is assigned the control over another. No station permits, or does not permit, another station to send. At each instance, a station that has data to send uses a procedure defined by the protocol to make a decision on whether or not to send.

Topics discussed in this section:

ALOHA
Carrier Sense Multiple Access
Carrier Sense Multiple Access with Collision Detection
Carrier Sense Multiple Access with Collision Avoidance

Figure 12.3 *Frames in a pure ALOHA network*

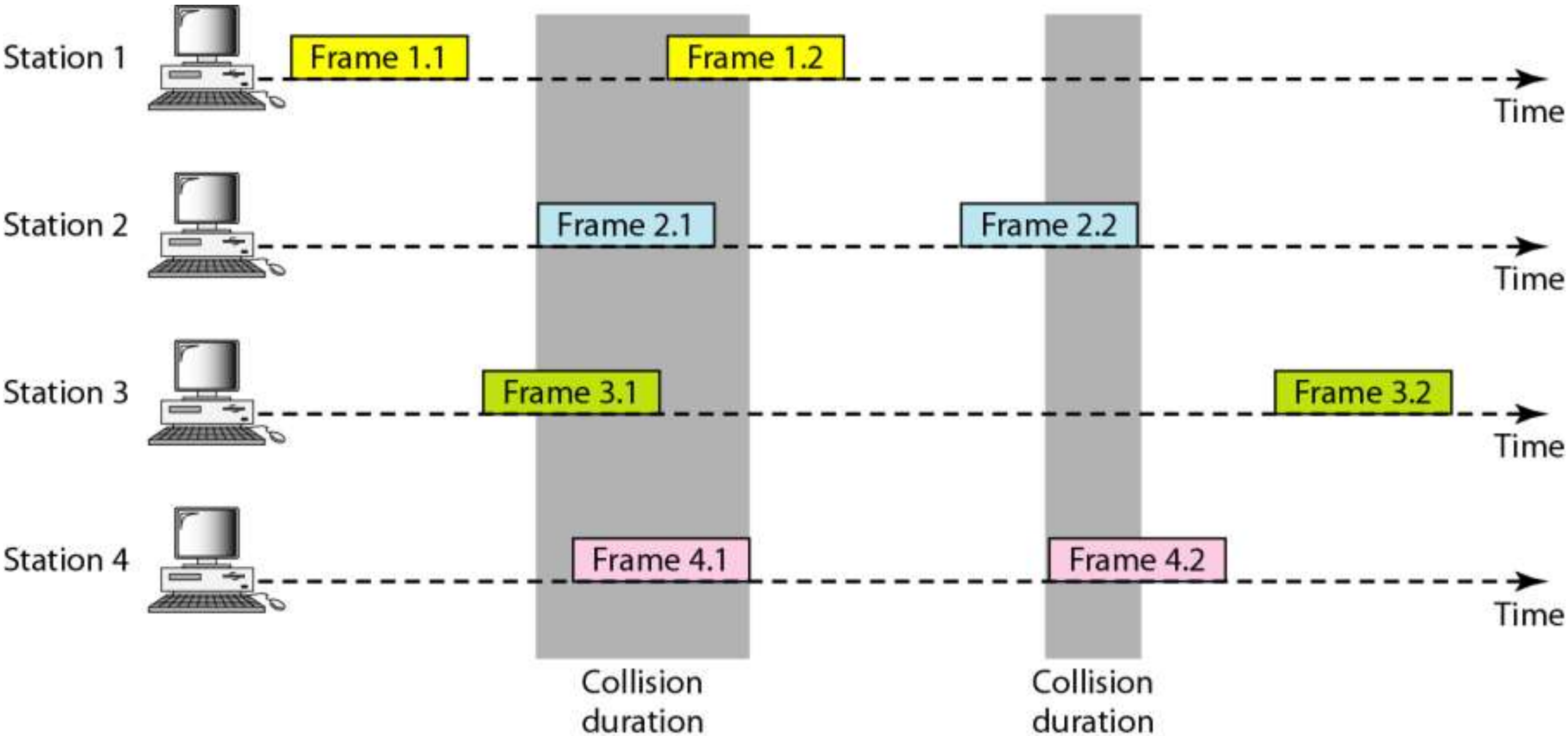
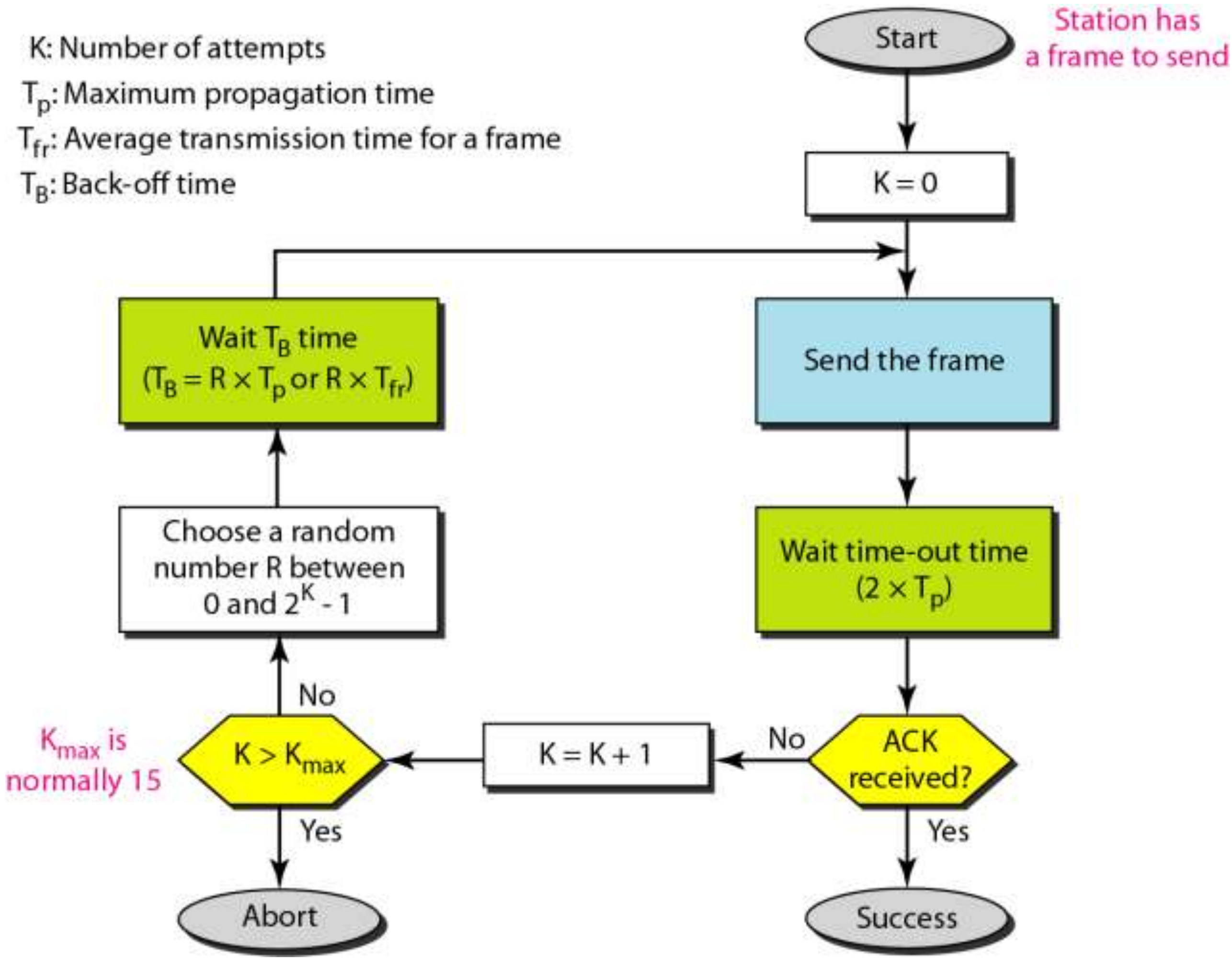


Figure 12.4 *Procedure for pure ALOHA protocol*



Example 12.1

The stations on a wireless ALOHA network are a maximum of 600 km apart. If we assume that signals propagate at 3×10^8 m/s, we find

$$T_p = (600 \times 10^5) / (3 \times 10^8) = 2 \text{ ms.}$$

Now we can find the value of T_B for different values of K .

a. For K = 1, the range is {0, 1}. The station needs to generate a random number with a value of 0 or 1. This means that T_B is either 0 ms (0 × 2) or 2 ms (1 × 2), based on the outcome of the random variable.

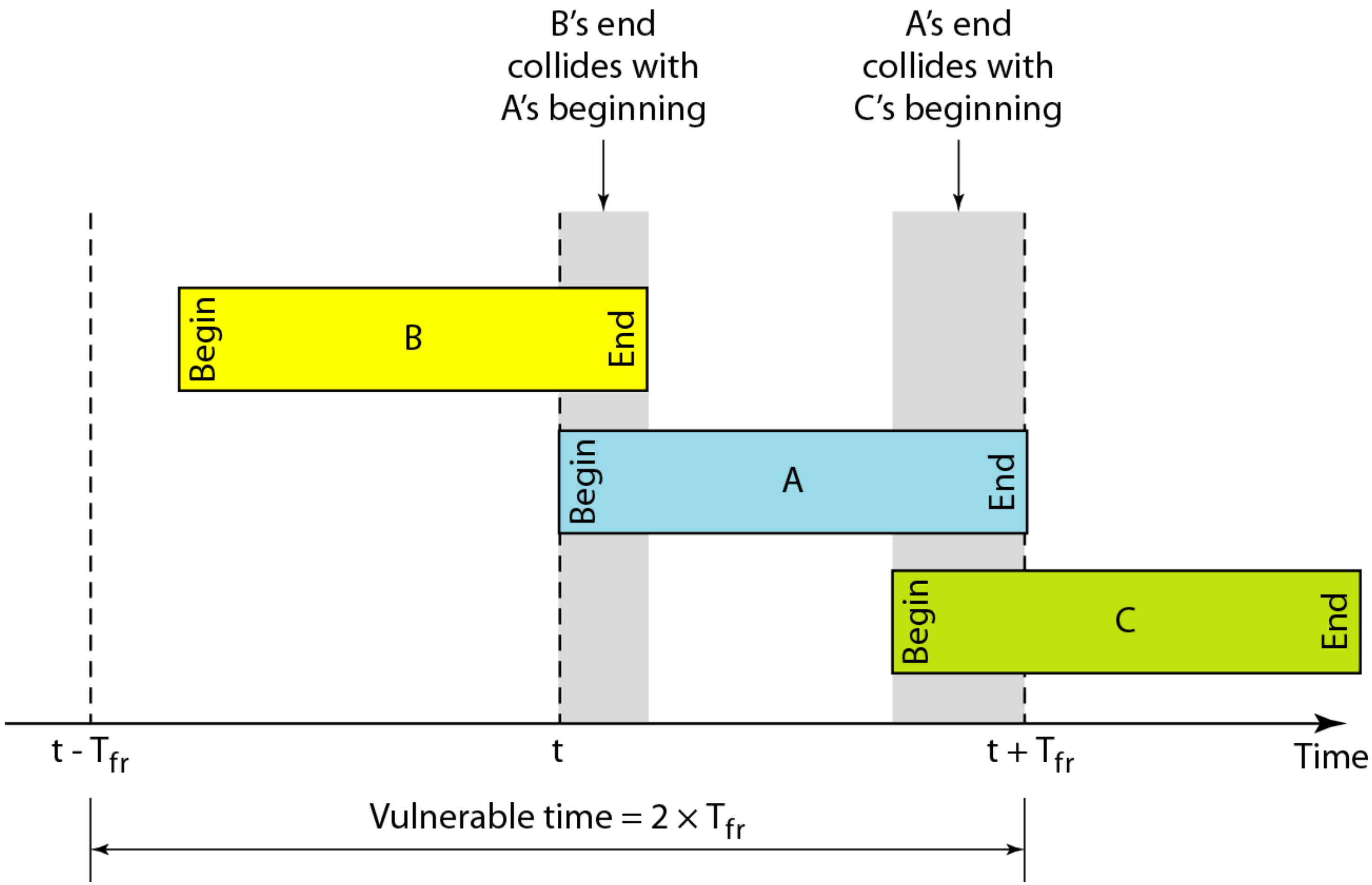
Example 12.1 (continued)

***b.** For K = 2, the range is {0, 1, 2, 3}. This means that T_B can be 0, 2, 4, or 6 ms, based on the outcome of the random variable.*

***c.** For K = 3, the range is {0, 1, 2, 3, 4, 5, 6, 7}. This means that T_B can be 0, 2, 4, . . . , 14 ms, based on the outcome of the random variable.*

***d.** We need to mention that if K > 10, it is normally set to 10.*

Figure 12.5 *Vulnerable time for pure ALOHA protocol*



Example 12.2

A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the requirement to make this frame collision-free?

Solution

Average frame transmission time T_{fr} is 200 bits/200 kbps or 1 ms. The vulnerable time is 2 × 1 ms = 2 ms. This means no station should send later than 1 ms before this station starts transmission and no station should start sending during the one 1-ms period that this station is sending.

Note

The throughput for pure ALOHA is
$S = G \times e^{-2G}$.
The maximum throughput
$S_{max} = 0.184$ when G= (1/2).

Example 12.3

A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the throughput if the system (all stations together) produces
a. 1000 frames per second ***b. 500 frames per second***
c. 250 frames per second.

Solution

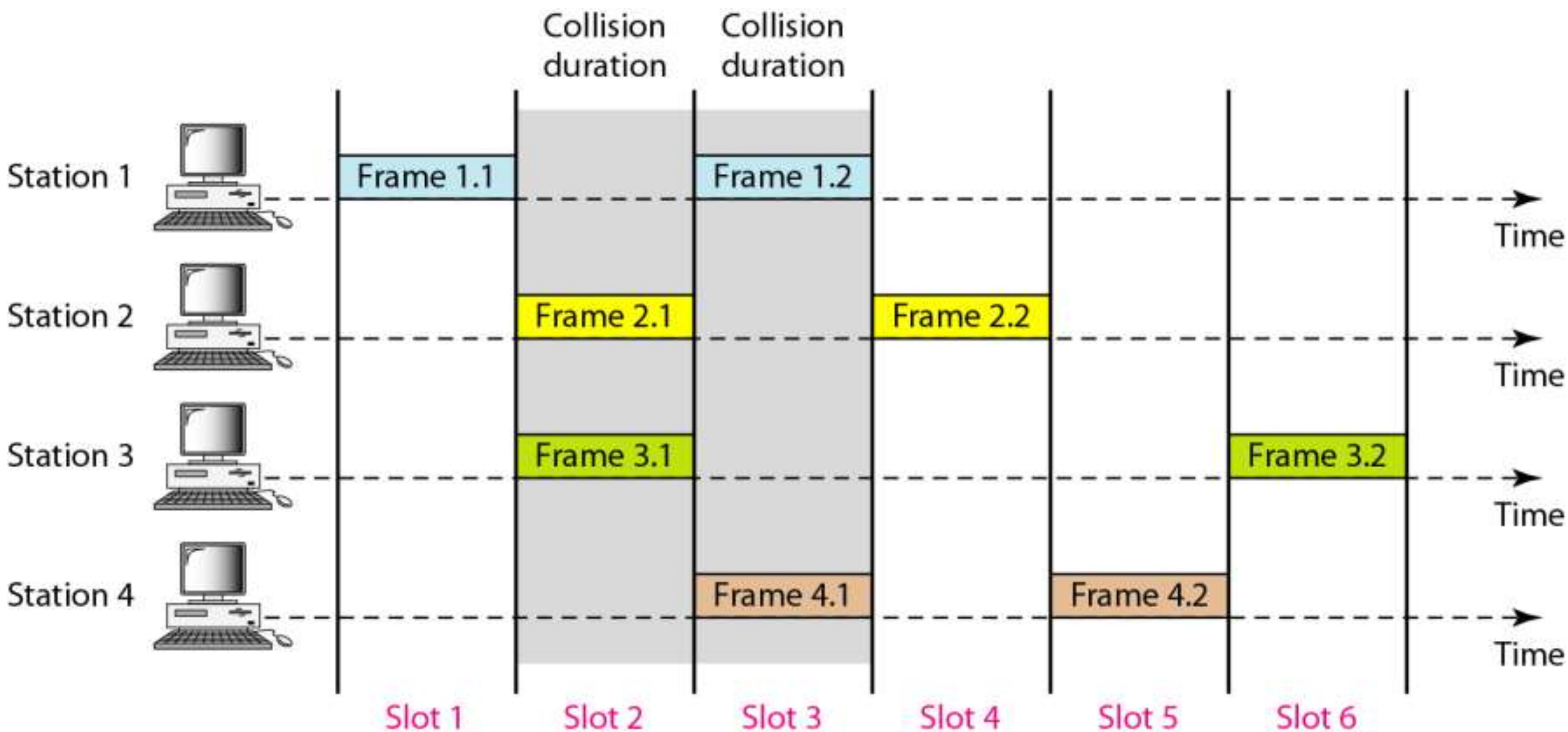
The frame transmission time is 200/200 kbps or 1 ms.
a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case $S = G \times e^{-2G}$ or $S = 0.135$ (13.5 percent). This means that the throughput is $1000 \times 0.135 = 135$ frames. Only 135 frames out of 1000 will probably survive.

Example 12.3 (continued)

b. ***If the system creates 500 frames per second, this is (1/2) frame per millisecond. The load is (1/2). In this case*** $S = G \times e^{-2G}$ ***or*** $S = 0.184$ ***(18.4 percent). This means that the throughput is 500 × 0.184 = 92 and that only 92 frames out of 500 will probably survive. Note that this is the maximum throughput case, percentagewise.***

c. ***If the system creates 250 frames per second, this is (1/4) frame per millisecond. The load is (1/4). In this case*** $S = G \times e^{-2G}$ ***or*** $S = 0.152$ ***(15.2 percent). This means that the throughput is 250 × 0.152 = 38. Only 38 frames out of 250 will probably survive.***

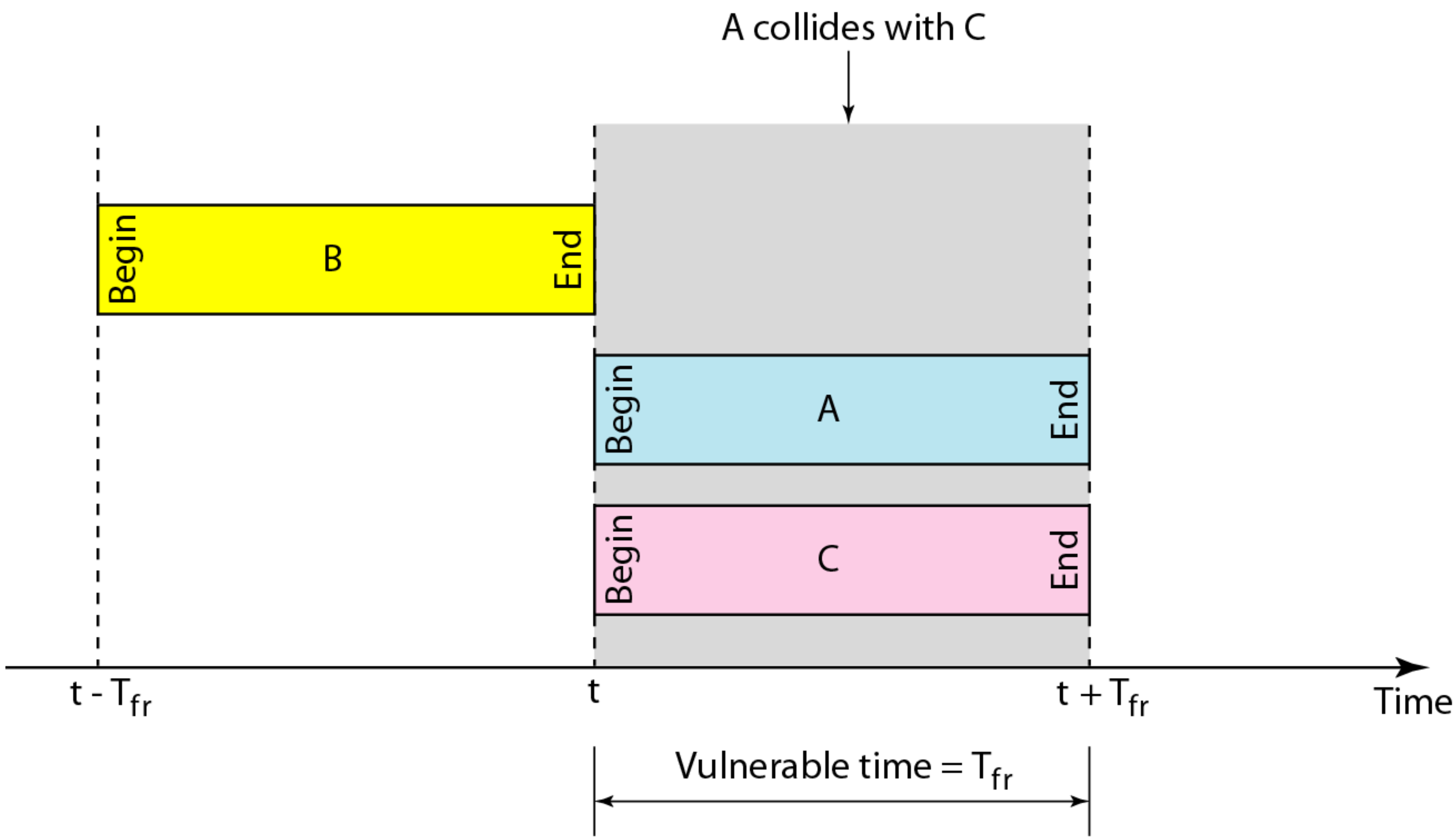
Figure 12.6 *Frames in a slotted ALOHA network*



Note

The throughput for slotted ALOHA is
$S = G \times e^{-G}$.
The maximum throughput
$S_{max} = 0.368$ when G = 1.

Figure 12.7 *Vulnerable time for slotted ALOHA protocol*



Example 12.4

A slotted ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the throughput if the system (all stations together) produces
a. 1000 frames per second b. 500 frames per second
c. 250 frames per second.

Solution

The frame transmission time is 200/200 kbps or 1 ms.

a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case $S = G \times e^{-G}$ or $S = 0.368$ (36.8 percent). This means that the throughput is $1000 \times 0.0368 = 368$ frames. Only 386 frames out of 1000 will probably survive.

Example 12.4 (continued)

b. If the system creates 500 frames per second, this is (1/2) frame per millisecond. The load is (1/2). In this case $S = G \times e^{-G}$ or $S = 0.303$ (30.3 percent). This means that the throughput is $500 \times 0.0303 = 151$. Only 151 frames out of 500 will probably survive.

c. If the system creates 250 frames per second, this is (1/4) frame per millisecond. The load is (1/4). In this case $S = G \times e^{-G}$ or $S = 0.195$ (19.5 percent). This means that the throughput is $250 \times 0.195 = 49$. Only 49 frames out of 250 will probably survive.

Figure 12.8 *Space/time model of the collision in CSMA*

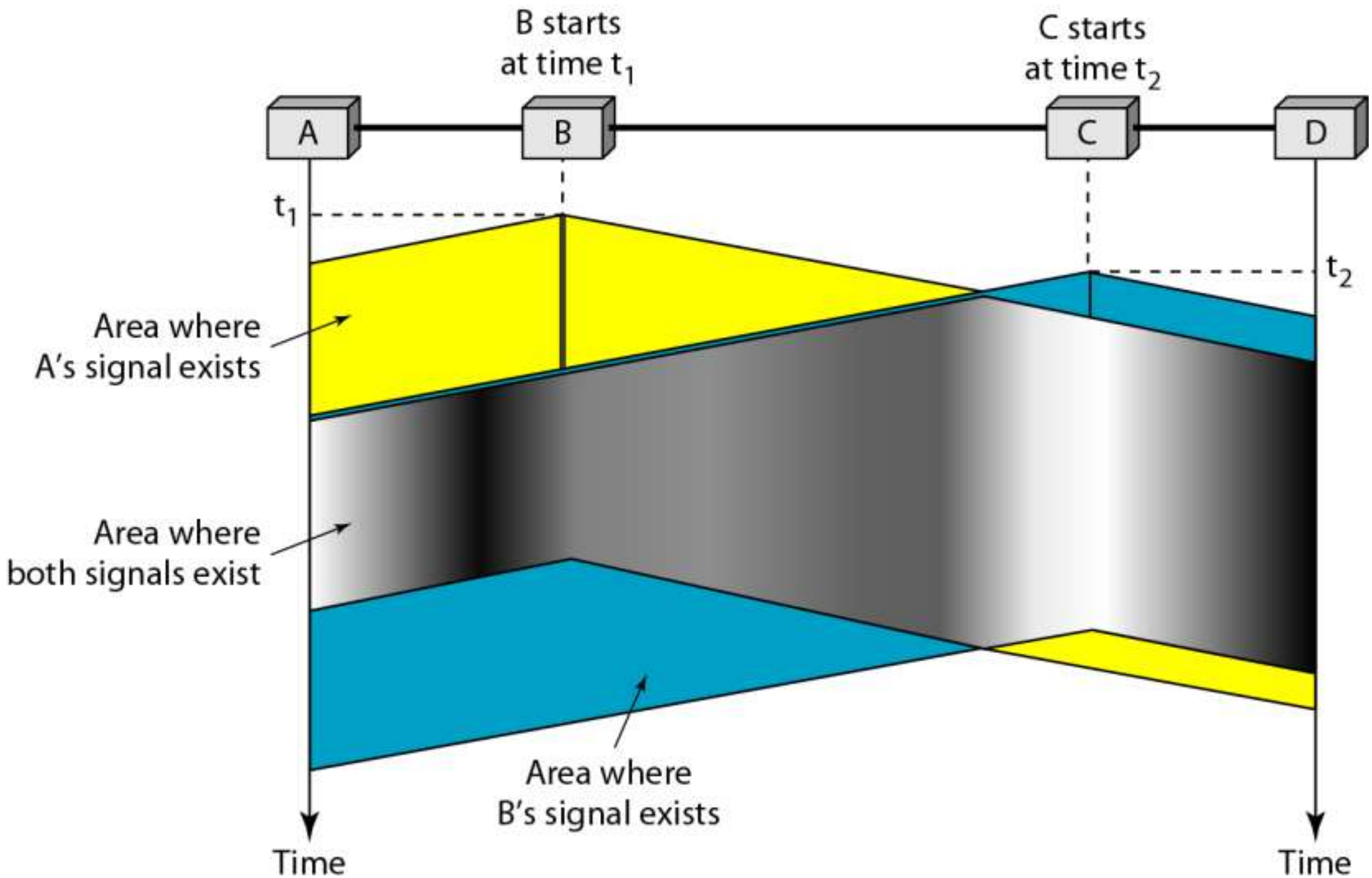


Figure 12.9 *Vulnerable time in CSMA*

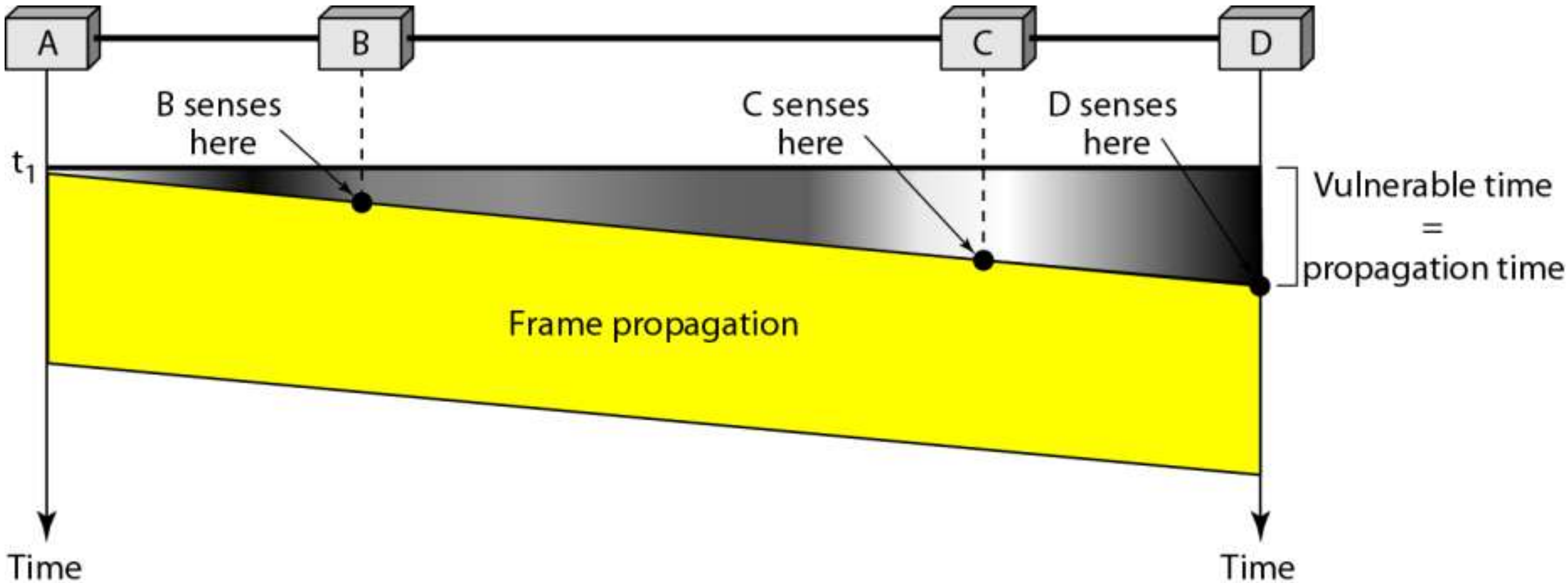
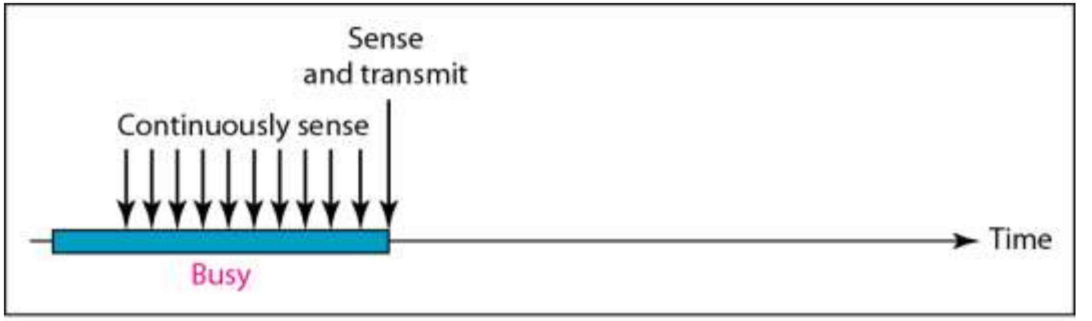
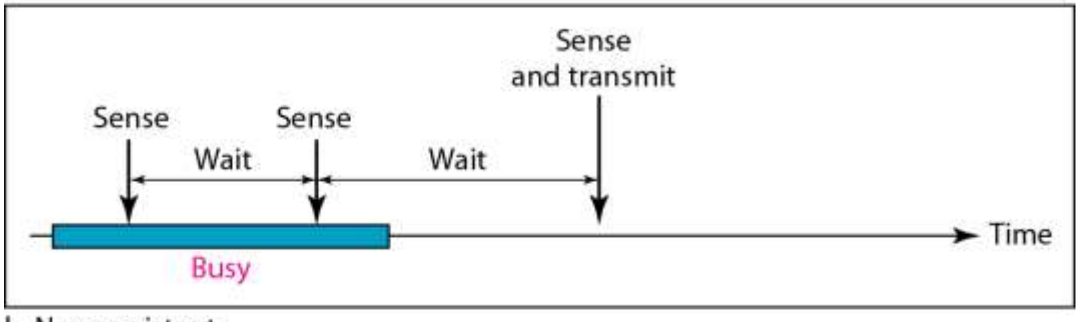


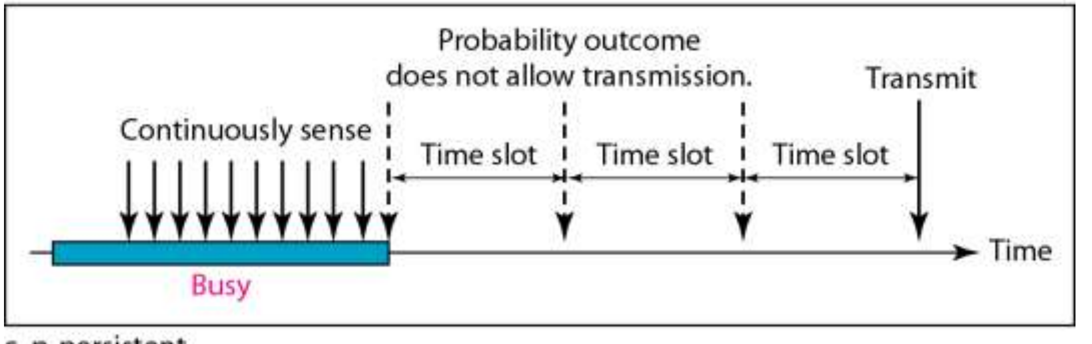
Figure 12.10 *Behavior of three persistence methods*



a. 1-persistent



b. Nonpersistent



c. p-persistent

Figure 12.11 *Flow diagram for three persistence methods*

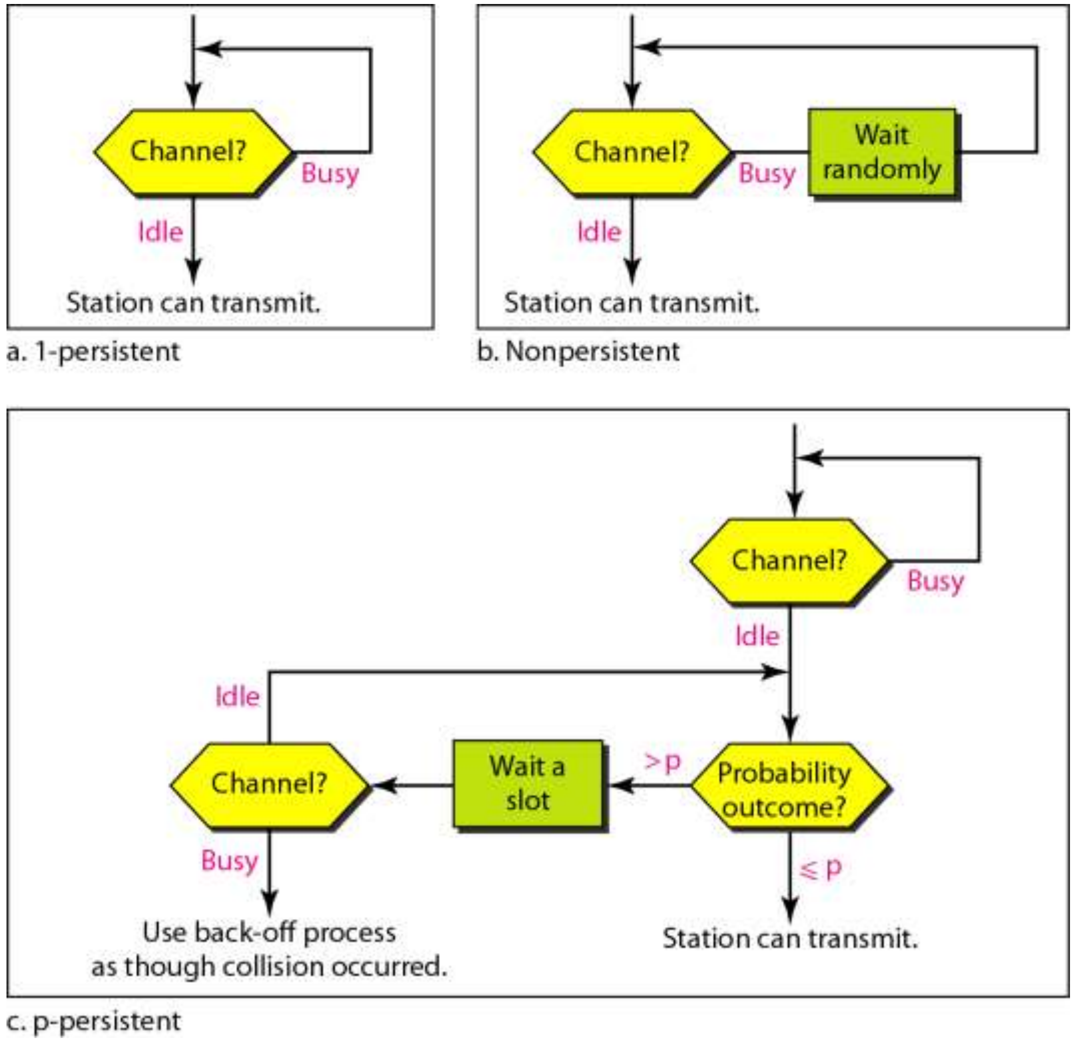


Figure 12.12 *Collision of the first bit in CSMA/CD*

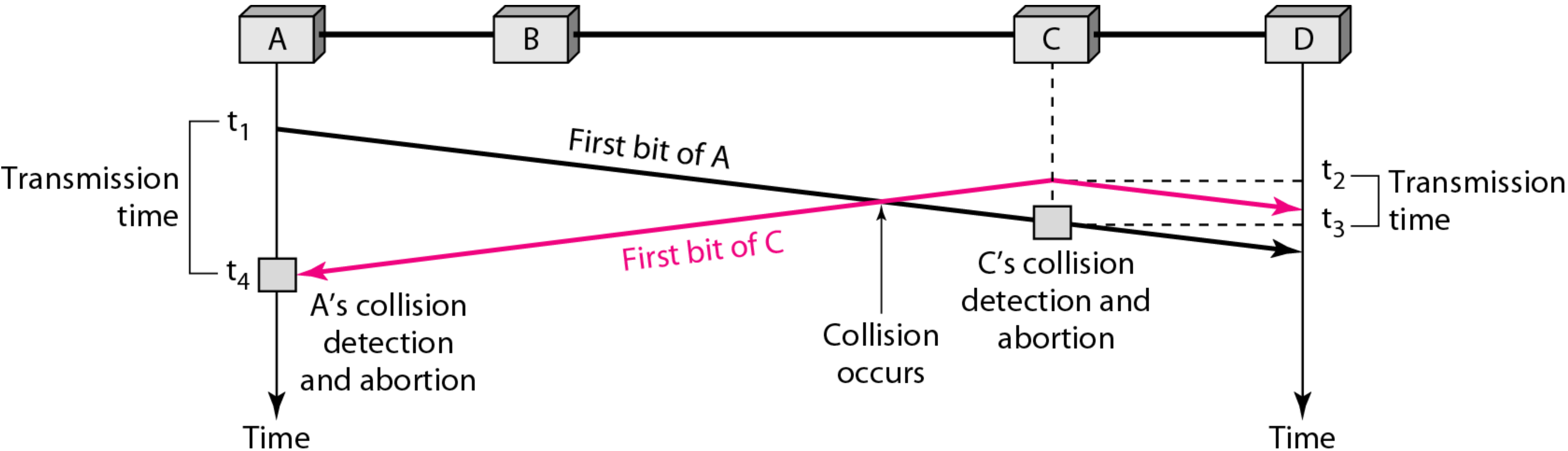
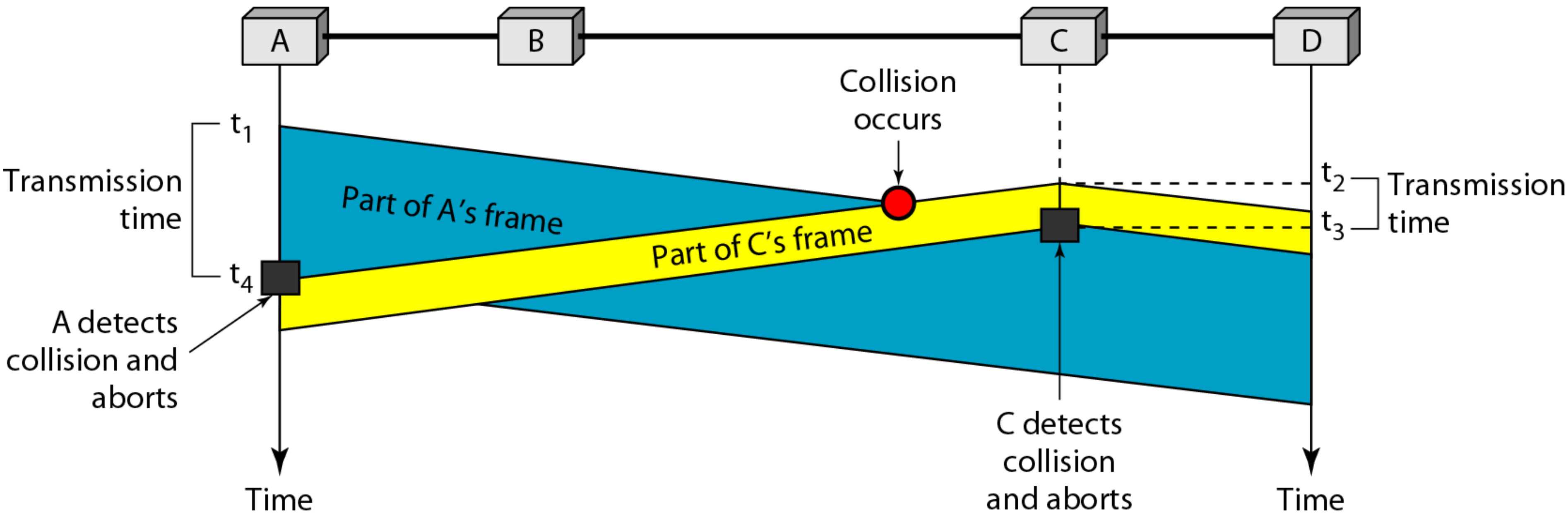


Figure 12.13 ***Collision and abortion in CSMA/CD***



Example 12.5

A network using CSMA/CD has a bandwidth of 10 Mbps. If the maximum propagation time (including the delays in the devices and ignoring the time needed to send a jamming signal, as we see later) is 25.6 μs, what is the minimum size of the frame?

Solution

The frame transmission time is $T_{fr} = 2 \times T_p = 51.2$ μs. This means, in the worst case, a station needs to transmit for a period of 51.2 μs to detect the collision. The minimum size of the frame is 10 Mbps × 51.2 μs = 512 bits or 64 bytes. This is actually the minimum size of the frame for Standard Ethernet.

Figure 12.14 *Flow diagram for the CSMA/CD*

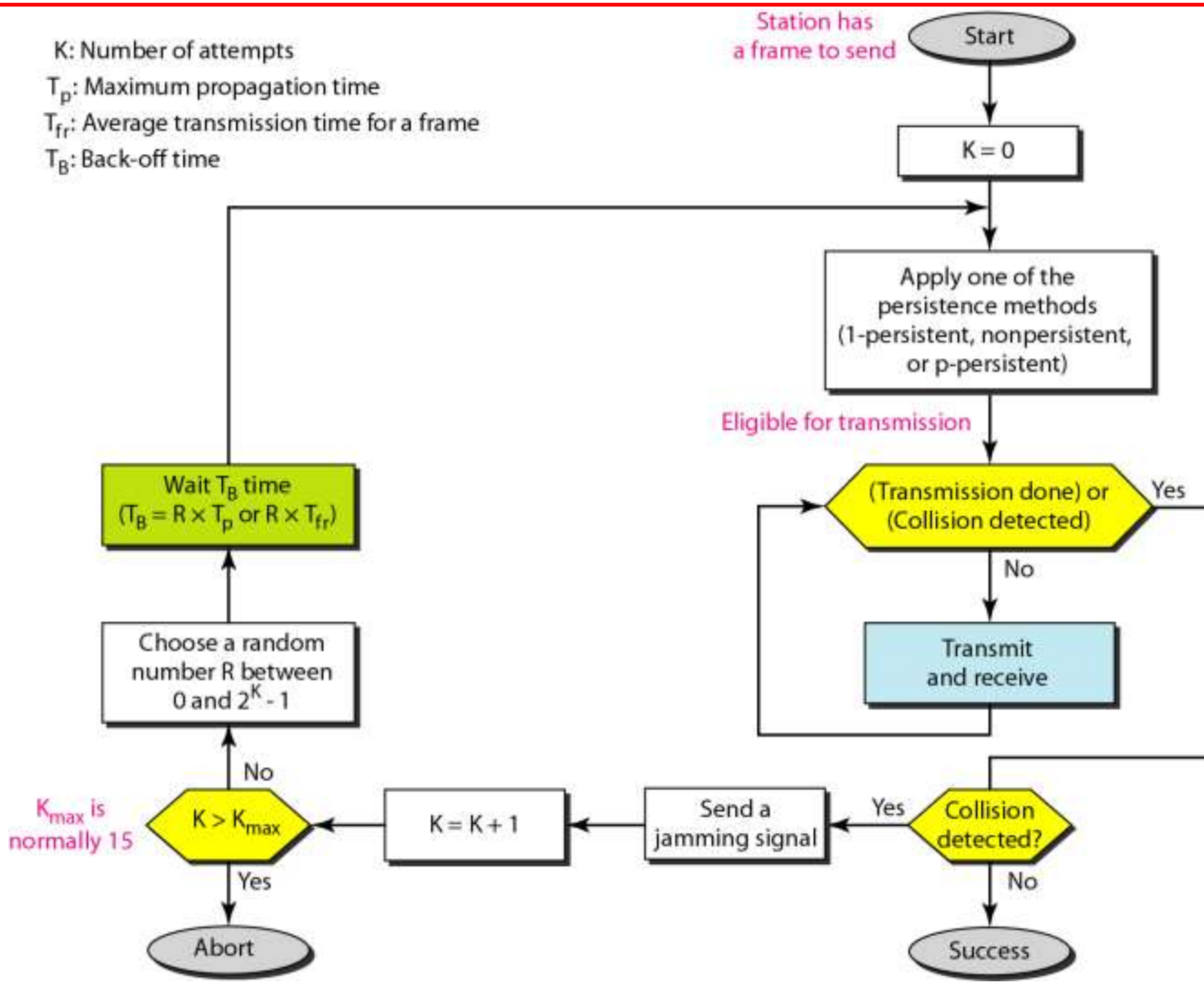


Figure 12.15 *Energy level during transmission, idleness, or collision*

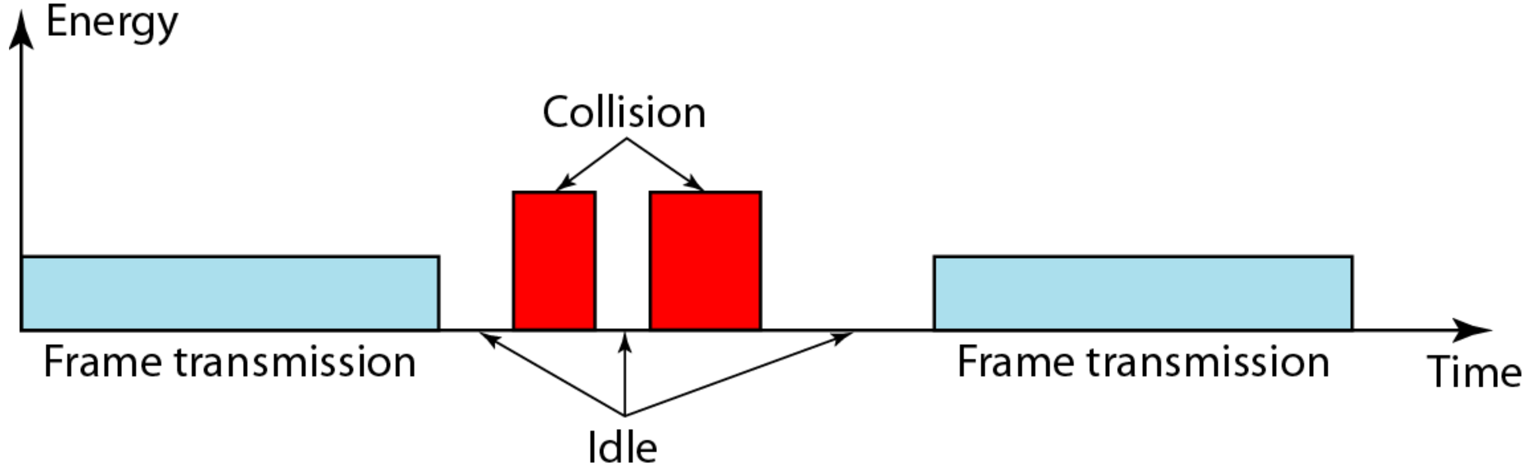
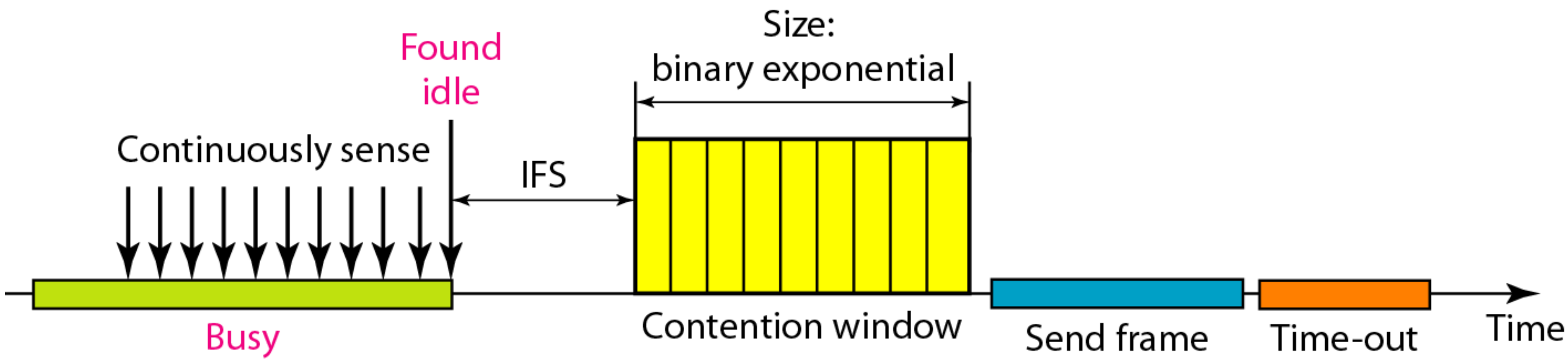


Figure 12.16 *Timing in CSMA/CA*



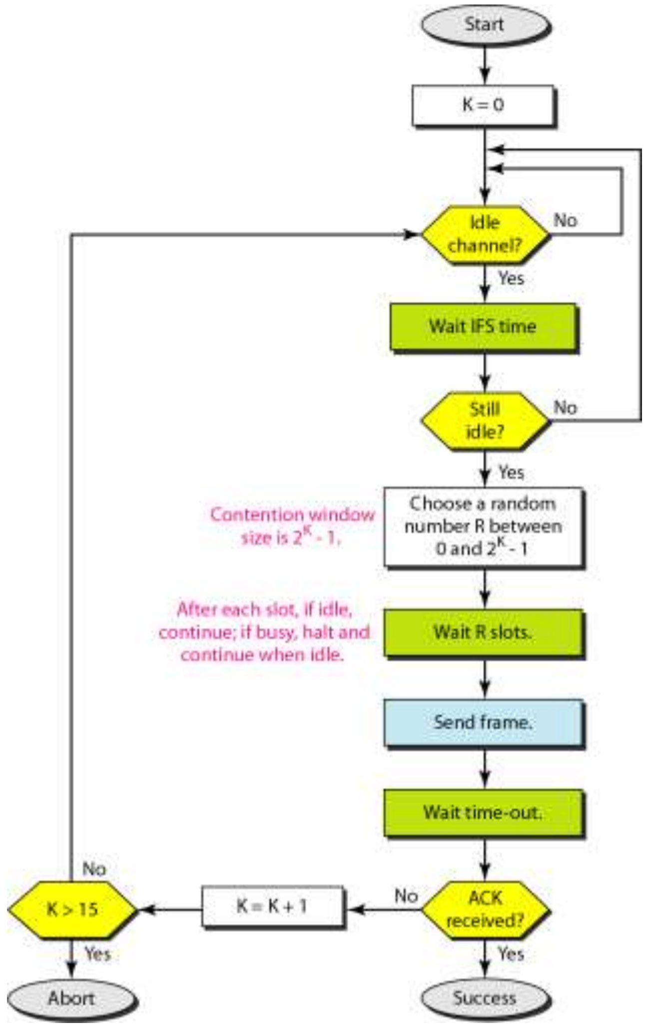
Note

In CSMA/CA, the IFS can also be used to define the priority of a station or a frame.

Note

In CSMA/CA, if the station finds the channel busy, it does not restart the timer of the contention window;
it stops the timer and restarts it when the channel becomes idle.

Figure 12.17 *Flow diagram for CSMA/CA*



12-2 CONTROLLED ACCESS

In controlled access, the stations consult one another to find which station has the right to send. A station cannot send unless it has been authorized by other stations. We discuss three popular controlled-access methods.

Topics discussed in this section:

Reservation
Polling
Token Passing

Figure 12.18 *Reservation access method*

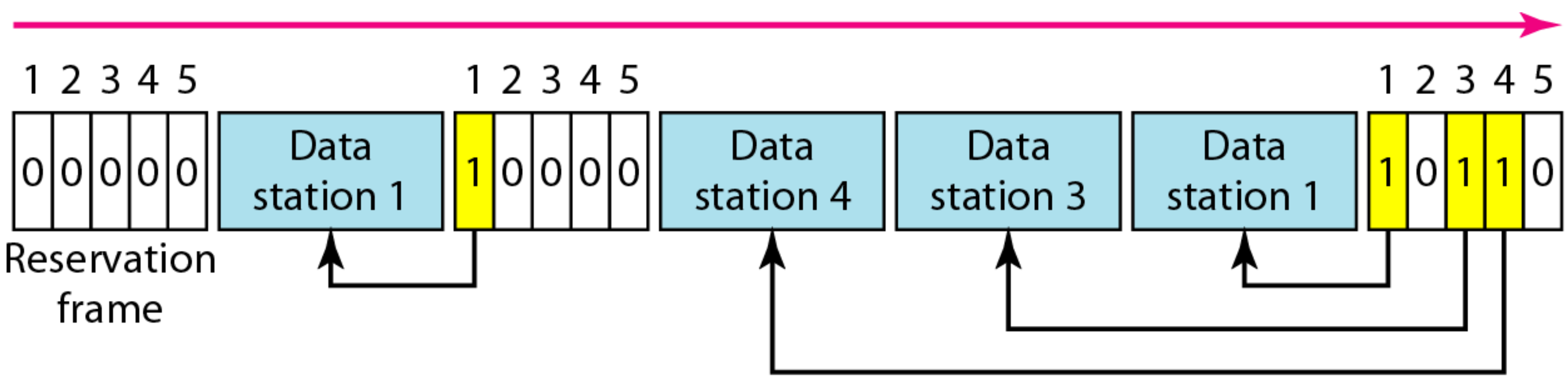


Figure 12.19 *Select and poll functions in polling access method*

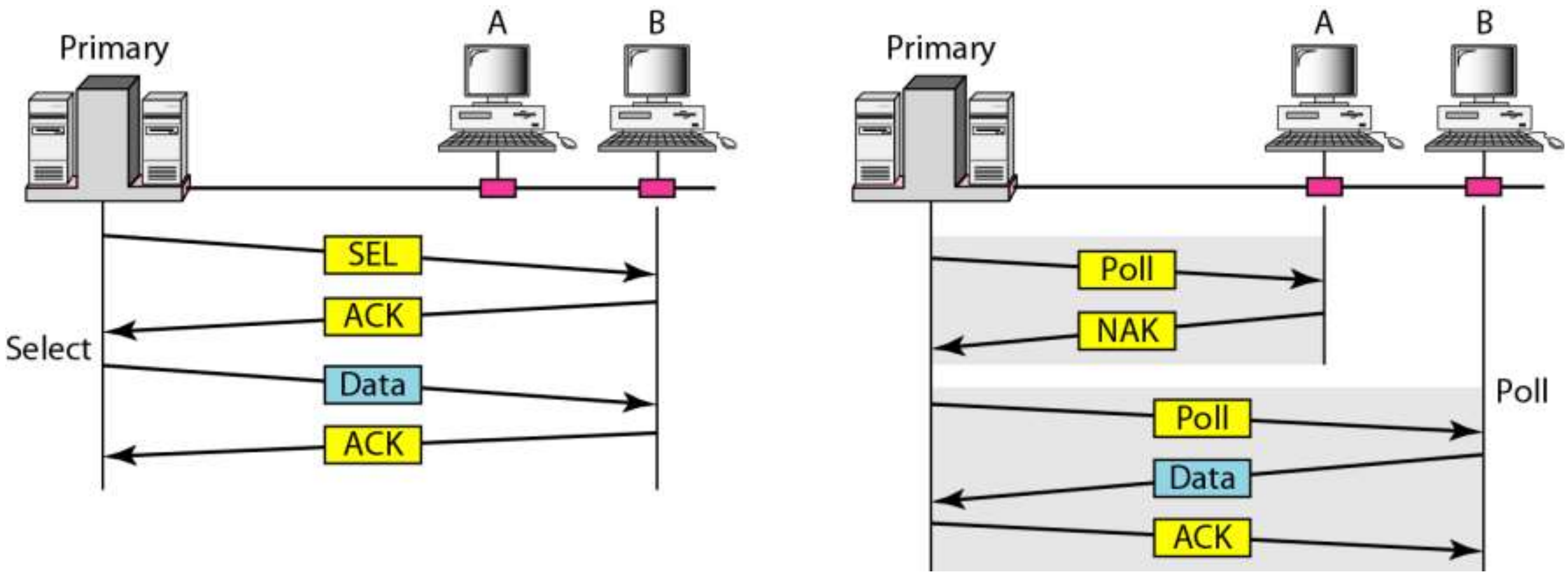
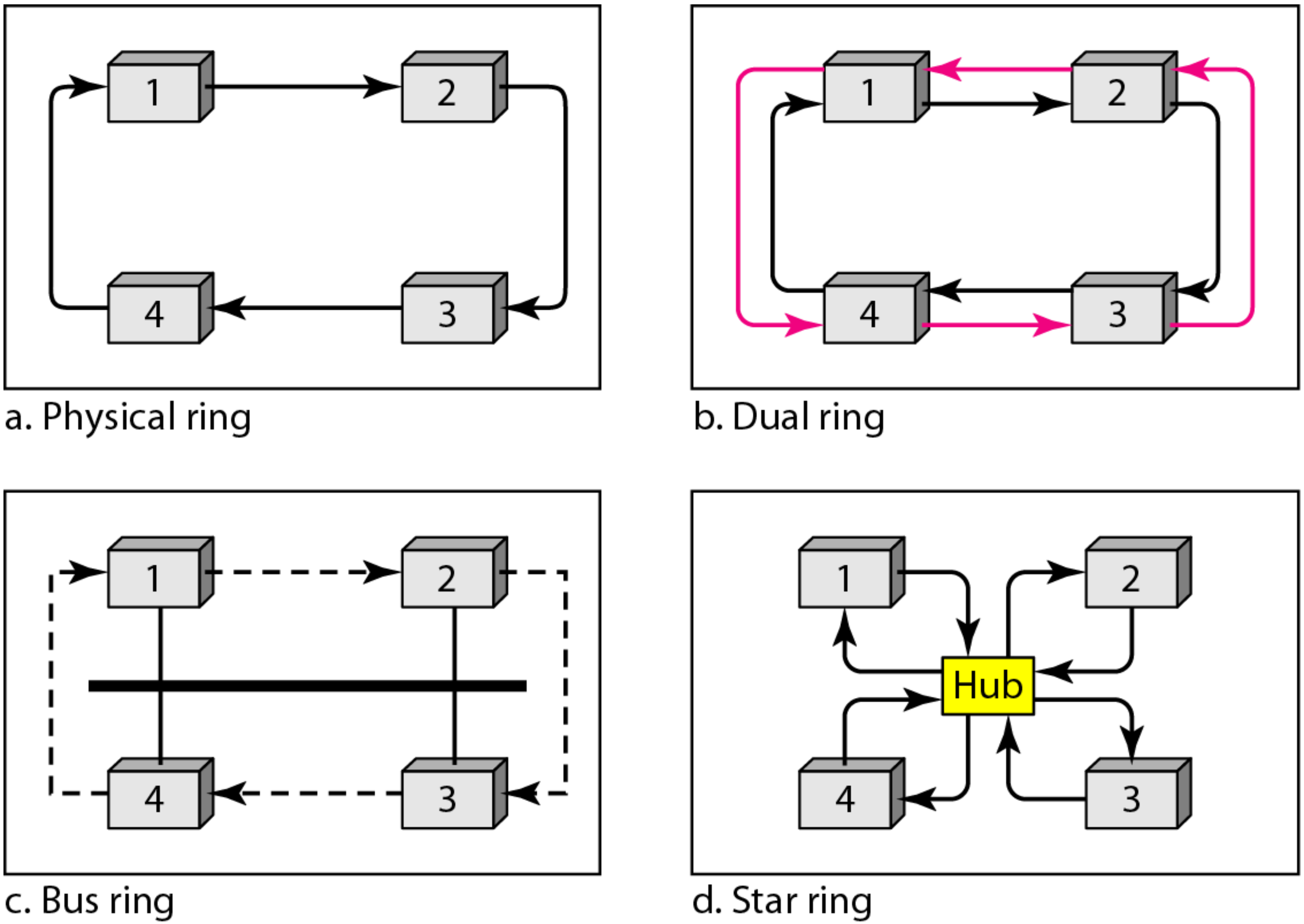


Figure 12.20 *Logical ring and physical topology in token-passing access method*



12-3 CHANNELIZATION

***Channelization* is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations. In this section, we discuss three channelization protocols.**

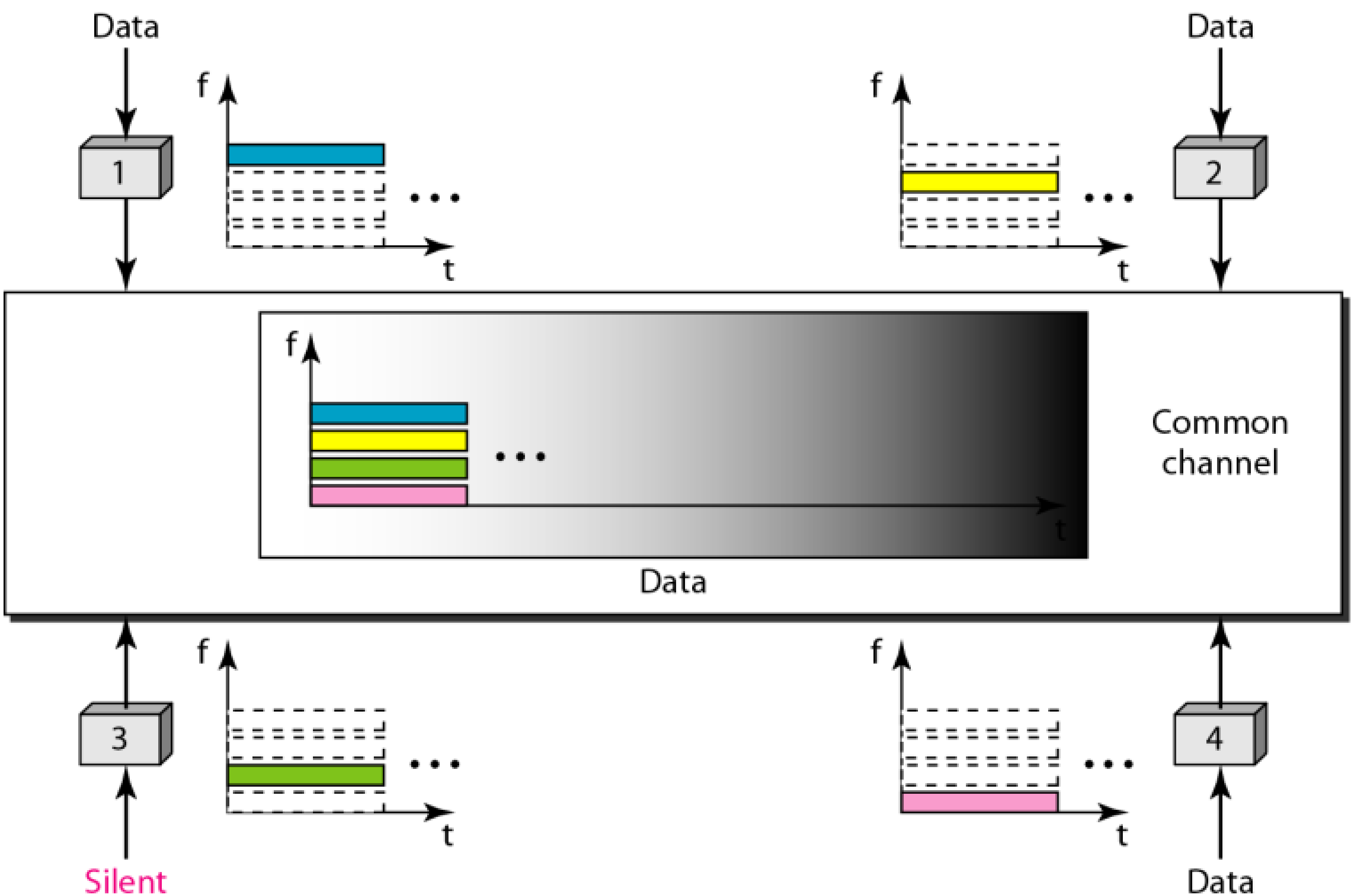
Topics discussed in this section:

Frequency-Division Multiple Access (FDMA)
Time-Division Multiple Access (TDMA)
Code-Division Multiple Access (CDMA)

Note

We see the application of all these methods in Chapter 16 when we discuss cellular phone systems.

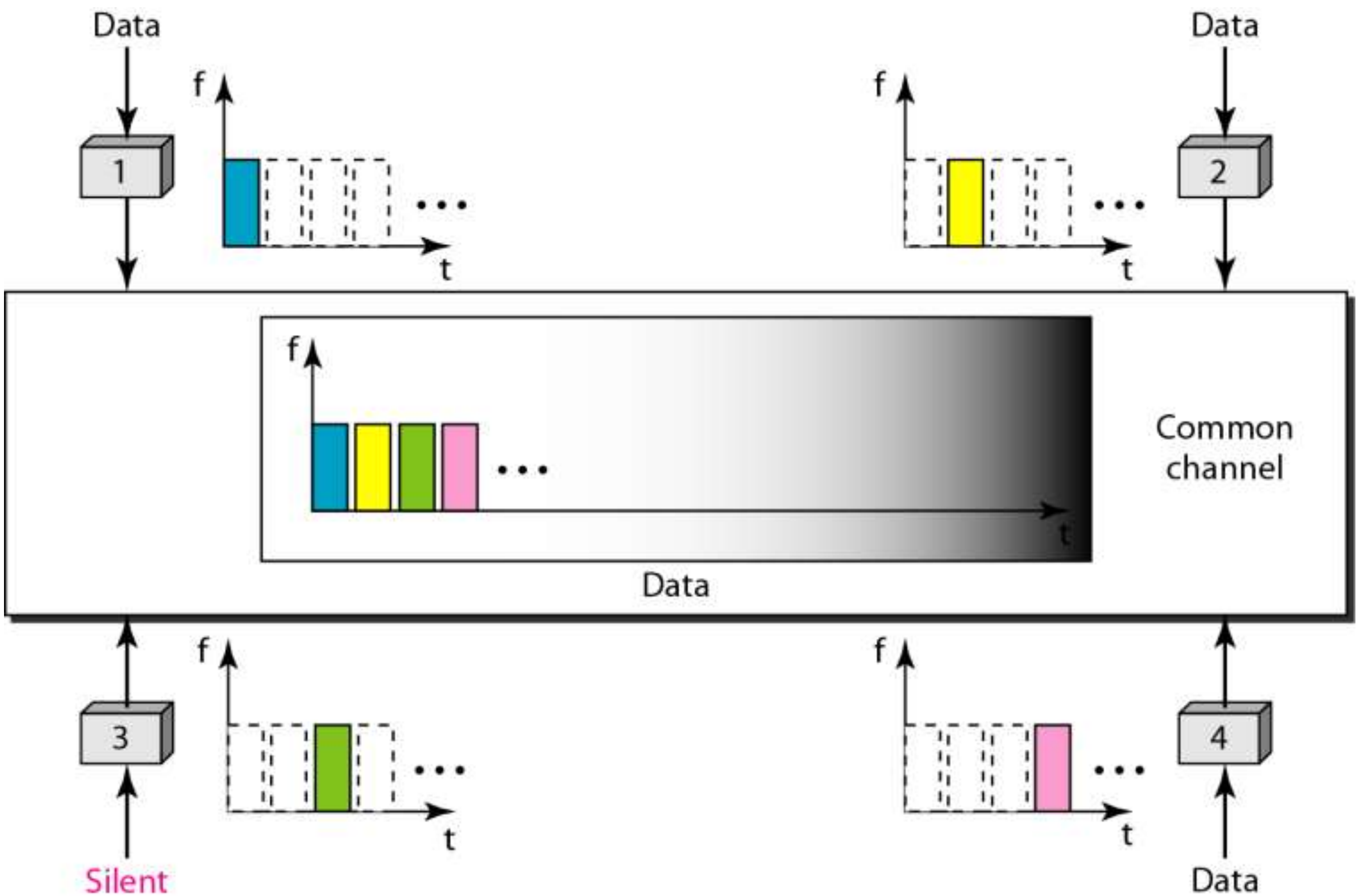
Figure 12.21 *Frequency-division multiple access (FDMA)*



Note

In FDMA, the available bandwidth of the common channel is divided into bands that are separated by guard bands.

Figure 12.22 *Time-division multiple access (TDMA)*



Note

In TDMA, the bandwidth is just one channel that is timeshared between different stations.

Note

In CDMA, one channel carries all transmissions simultaneously.

Figure 12.23 *Simple idea of communication with code*

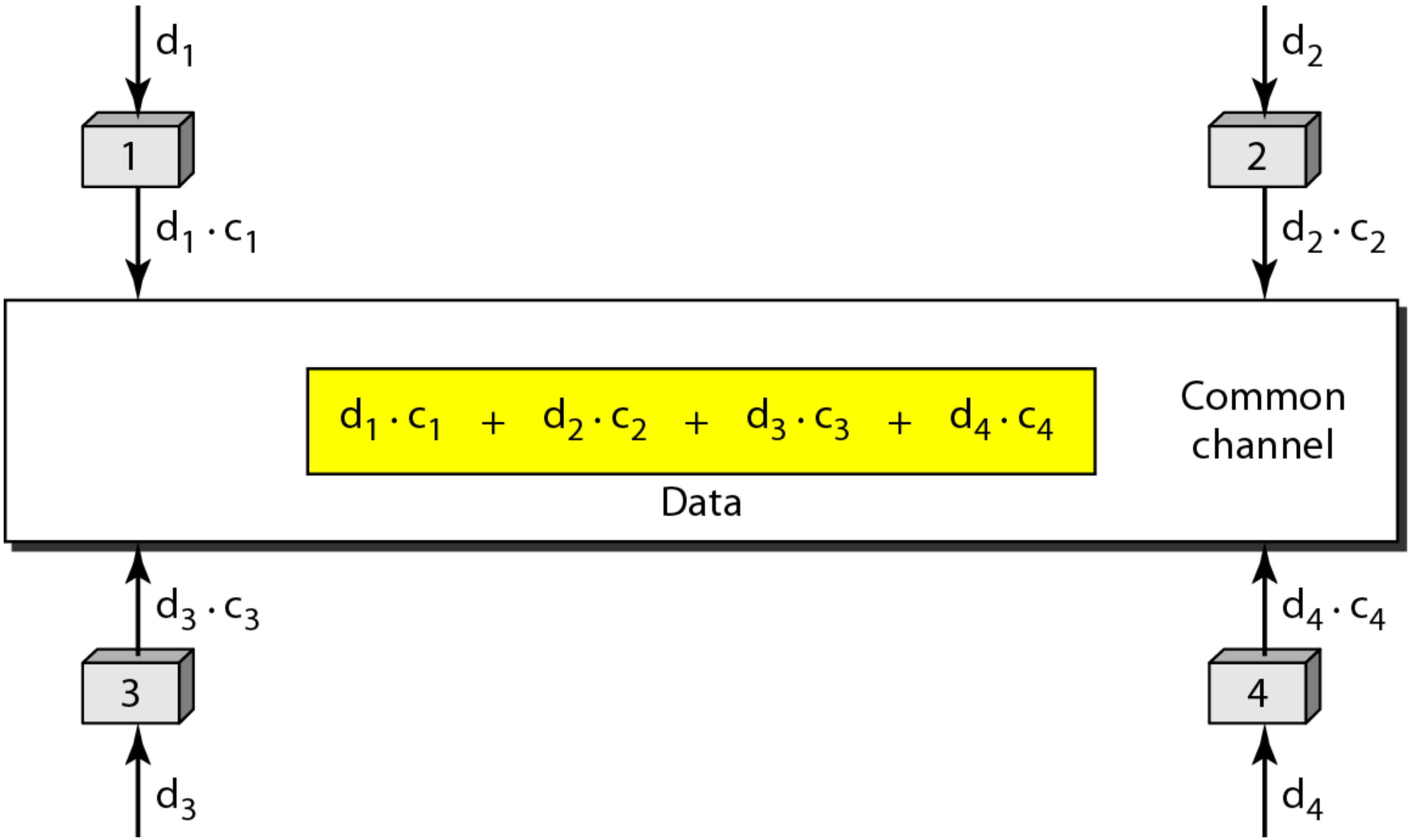


Figure 12.24 *Chip sequences*

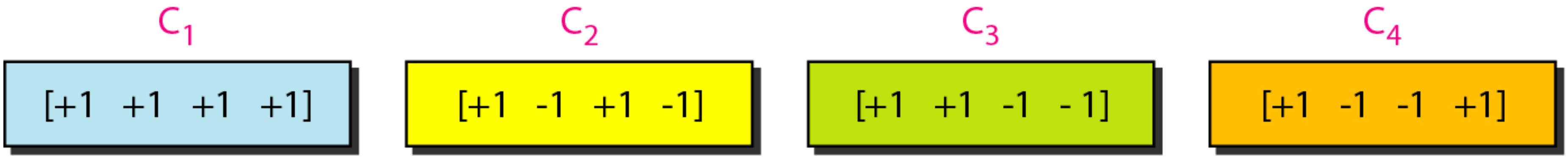


Figure 12.25 *Data representation in CDMA*

Figure 12.26 *Sharing channel in CDMA*

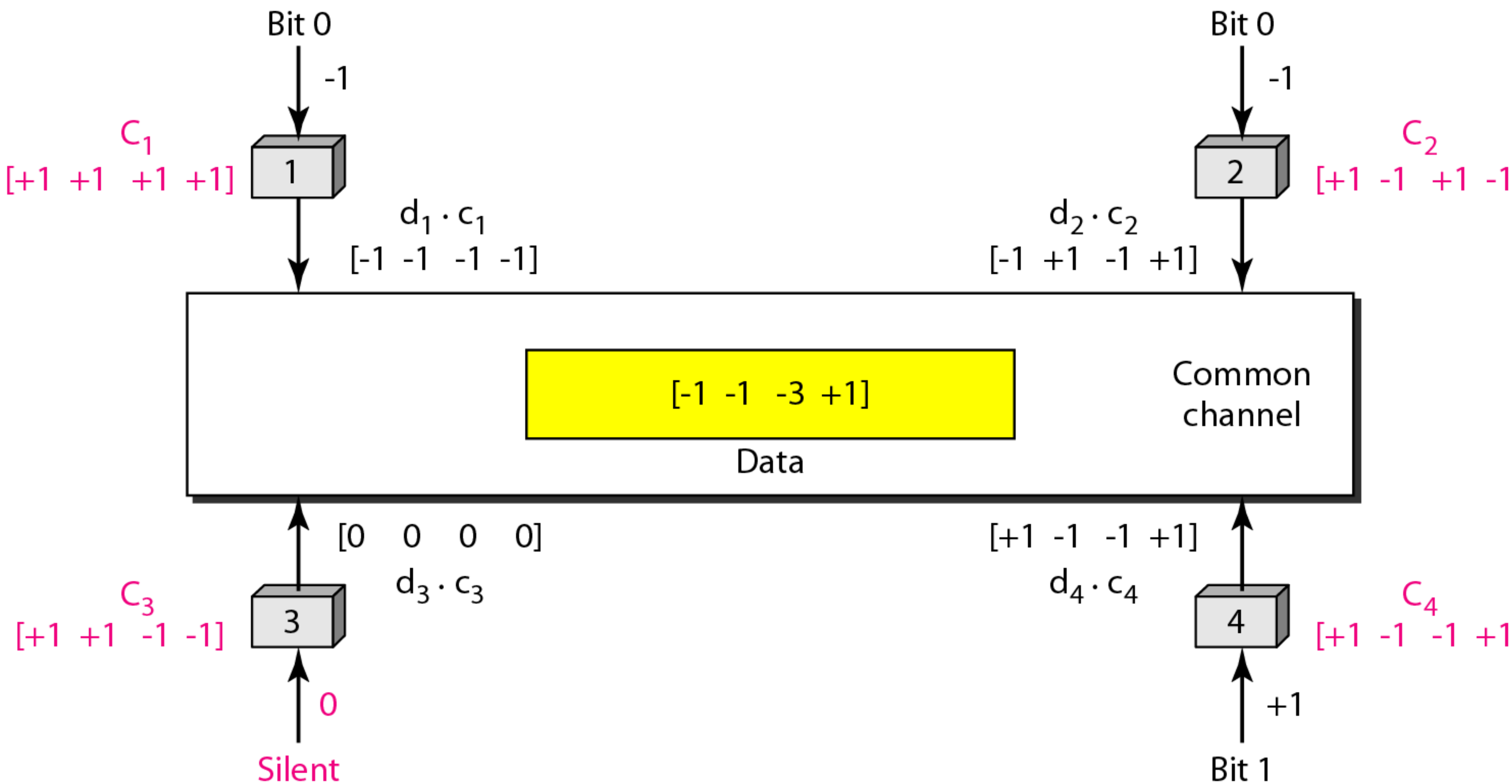


Figure 12.27 ***Digital signal created by four stations in CDMA***

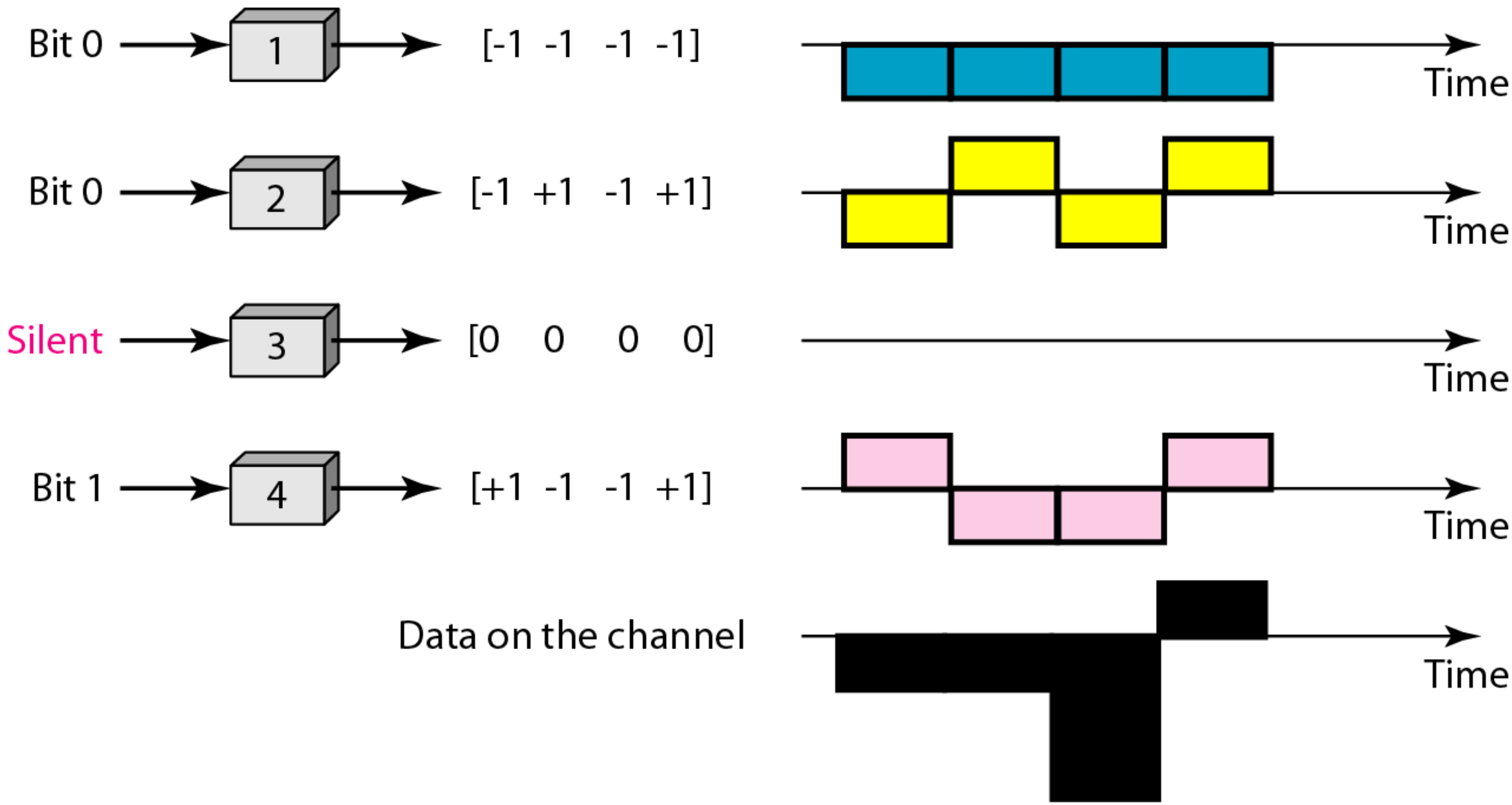


Figure 12.28 *Decoding of the composite signal for one in CDMA*

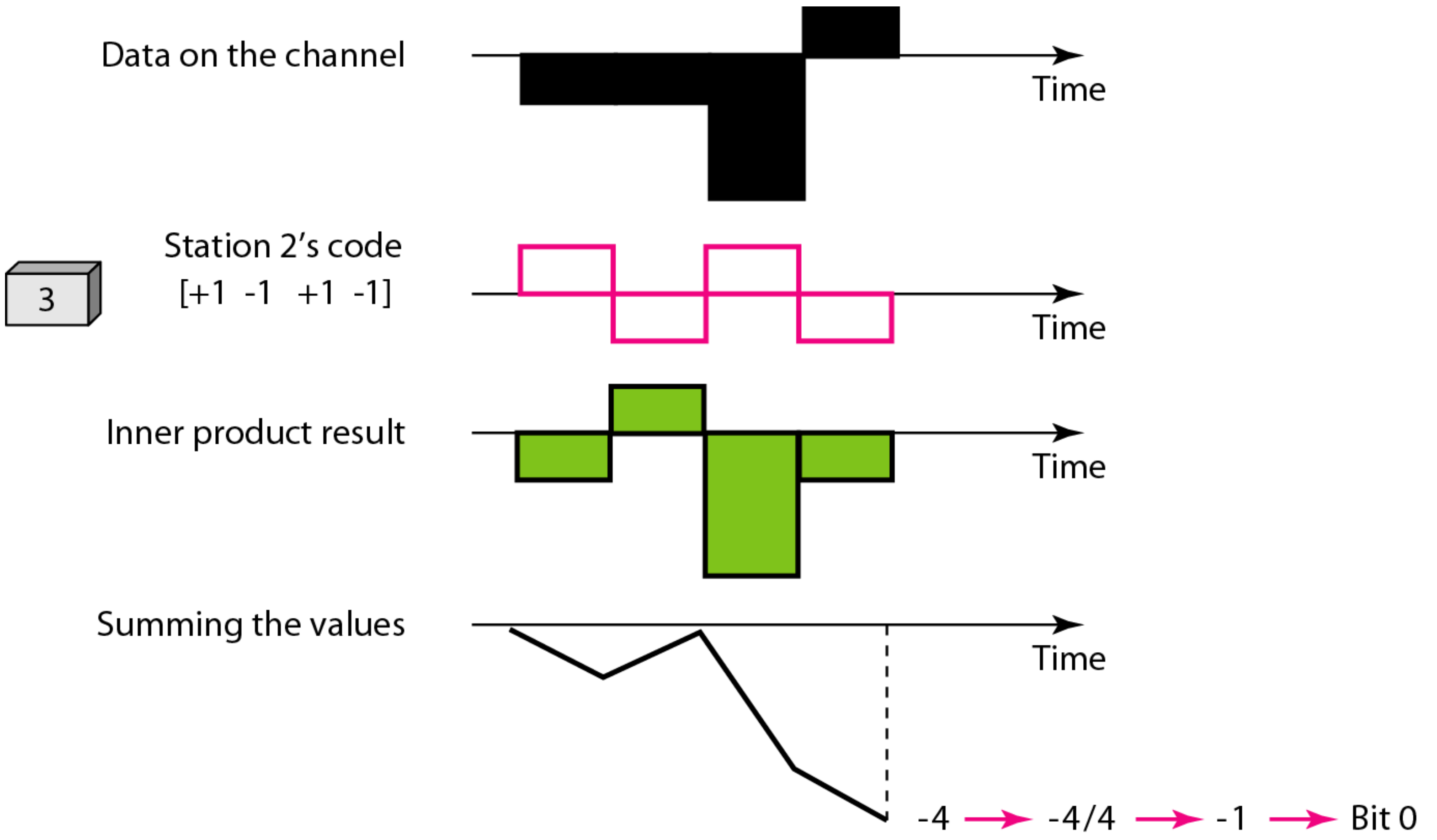


Figure 12.29 *General rule and examples of creating Walsh tables*

$$W_1 = \begin{bmatrix} +1 \end{bmatrix} \qquad W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

a. Two basic rules

$$W_1 = \begin{bmatrix} +1 \end{bmatrix}$$

$$W_2 = \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix} \qquad W_4 = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \end{bmatrix}$$

b. Generation of W_1, W_2, and W_4

Note

The number of sequences in a Walsh table needs to be $N = 2^m$.

Example 12.6

Find the chips for a network with
a. Two stations ***b. Four stations***

Solution

We can use the rows of W_2 and W_4 in Figure 12.29:

a. For a two-station network, we have

[+1 +1] and [+1 −1].

b. For a four-station network we have

[+1 +1 +1 +1], [+1 −1 +1 −1],
[+1 +1 −1 −1], *and* [+1 −1 −1 +1].

Example 12.7

What is the number of sequences if we have 90 stations in our network?

Solution

The number of sequences needs to be 2^m. We need to choose $m = 7$ and $N = 2^7$ or 128. We can then use 90 of the sequences as the chips.

Example 12.8

Prove that a receiving station can get the data sent by a specific sender if it multiplies the entire data on the channel by the sender's chip code and then divides it by the number of stations.

Solution

Let us prove this for the first station, using our previous four-station example. We can say that the data on the channel

$$D = (d_1 \cdot c_1 + d_2 \cdot c_2 + d_3 \cdot c_3 + d_4 \cdot c_4).$$

The receiver which wants to get the data sent by station 1 multiplies these data by c_1.

Example 12.8 (continued)

$$
\begin{aligned}
D \cdot c_1 &= (d_1 \cdot c_1 + d_2 \cdot c_2 + d_3 \cdot c_3 + d_4 \cdot c_4) \cdot c_1 \\
&= d_1 \cdot c_1 \cdot c_1 + d_2 \cdot c_2 \cdot c_1 + d_3 \cdot c_3 \cdot c_1 + d_4 \cdot c_4 \cdot c_1 \\
&= d_1 \times N + d_2 \times 0 + d_3 \times 0 + d_4 \times 0 \\
&= d_1 \times N
\end{aligned}
$$

When we divide the result by N, we get d_1.

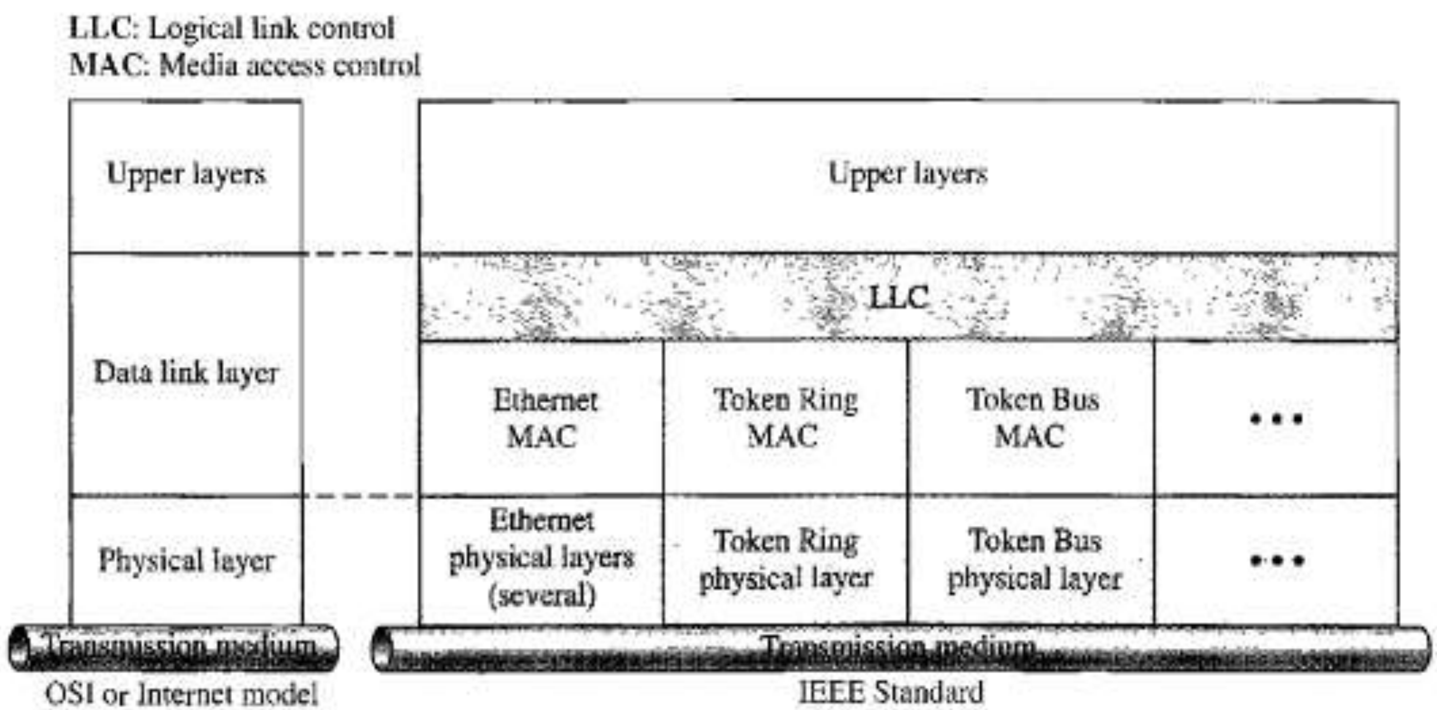
Wired LANs and wireless LANs

content

- Wired LANs: Types and frame format
- Wireless LANs: Types and frame format

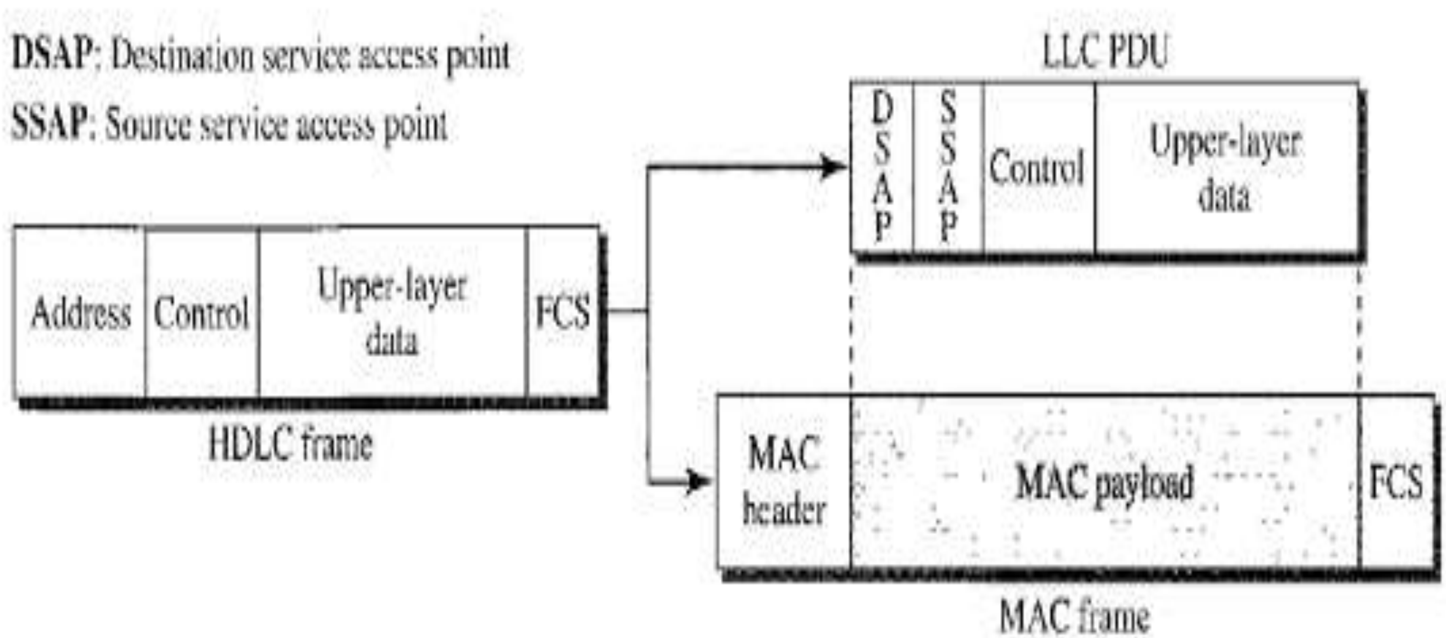
IEEE STANDARDS

Figure 13.1 *IEEE standard for LANs*



LLC and MAC frames

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



STANDARD ETHERNET

Figure 13.3 *Ethernet evolution through four generations*

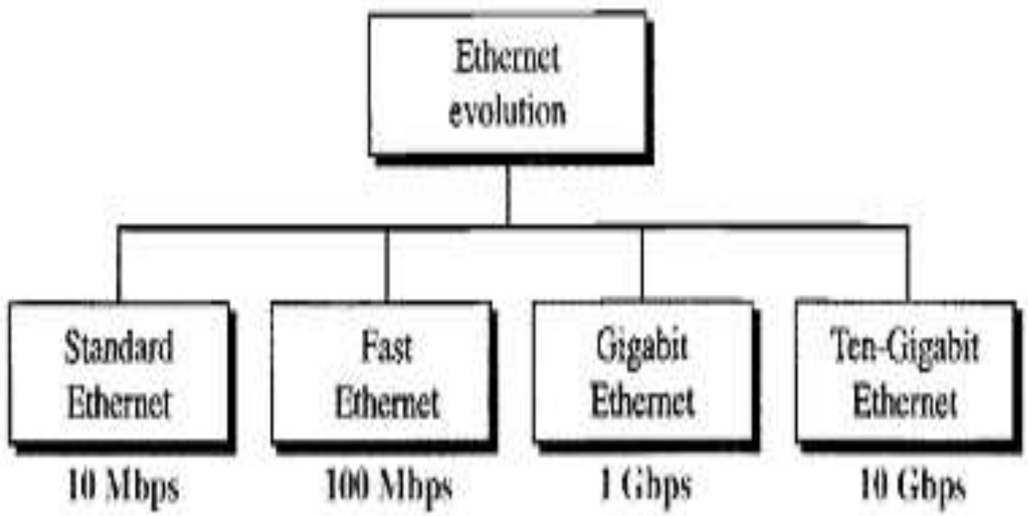
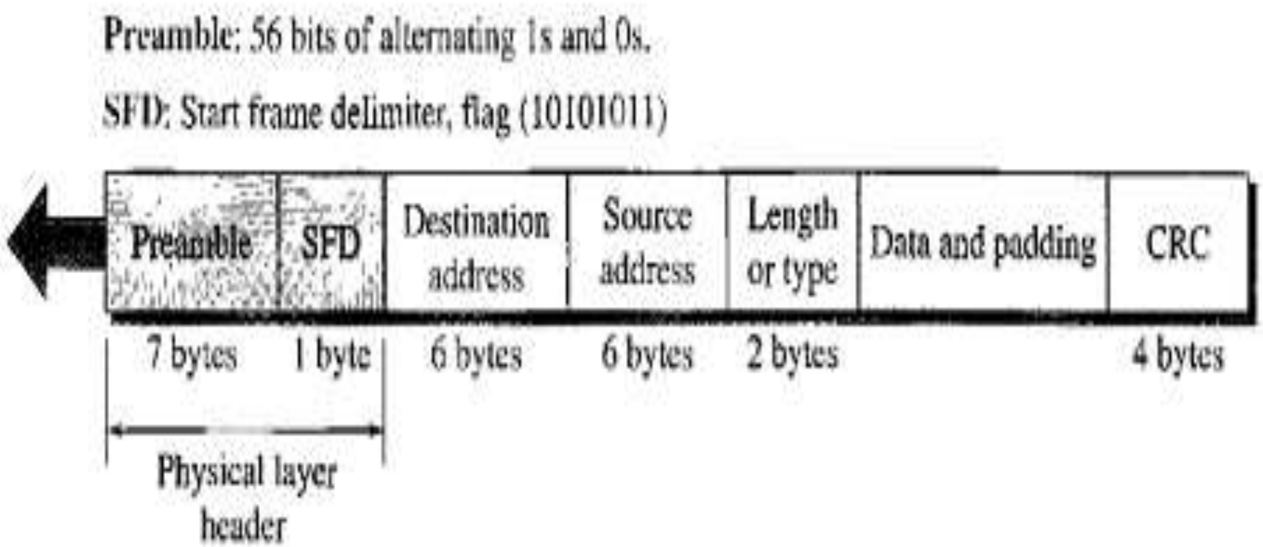


Figure 13.4 *802.3 MAC frame*



ADDRESSING

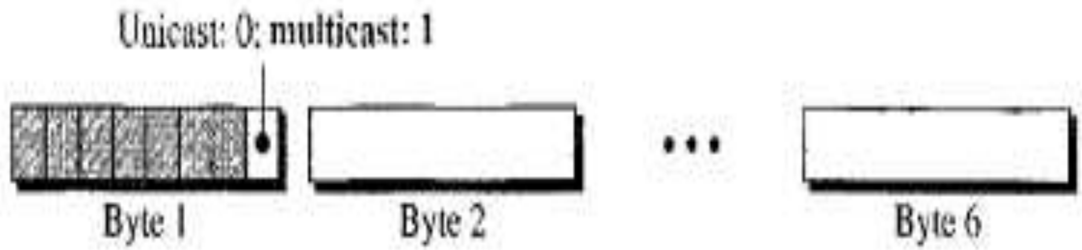
- Figure 13.6 *Example of an Ethernet address in hexadecimal notation*

  06:01 :02:01:2C:4B

- 6 bytes = 12 hex digits = 48 bits

UNICAST AND MULTICAST ADDRESSES

Figure 13.7 *Unicast and multicast addresses*



**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.**

Categories of Standard Ethernet

Figure 13.8 *Categories of Standard Ethernet*

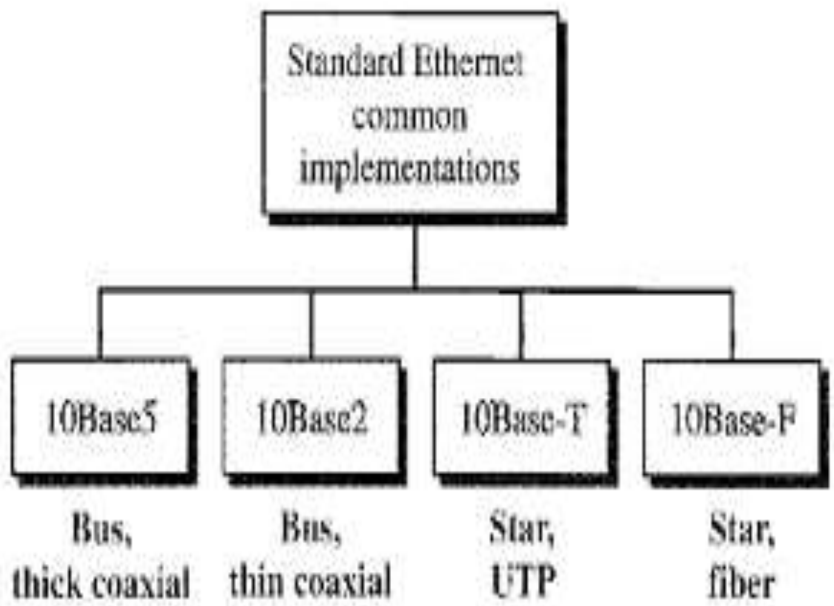
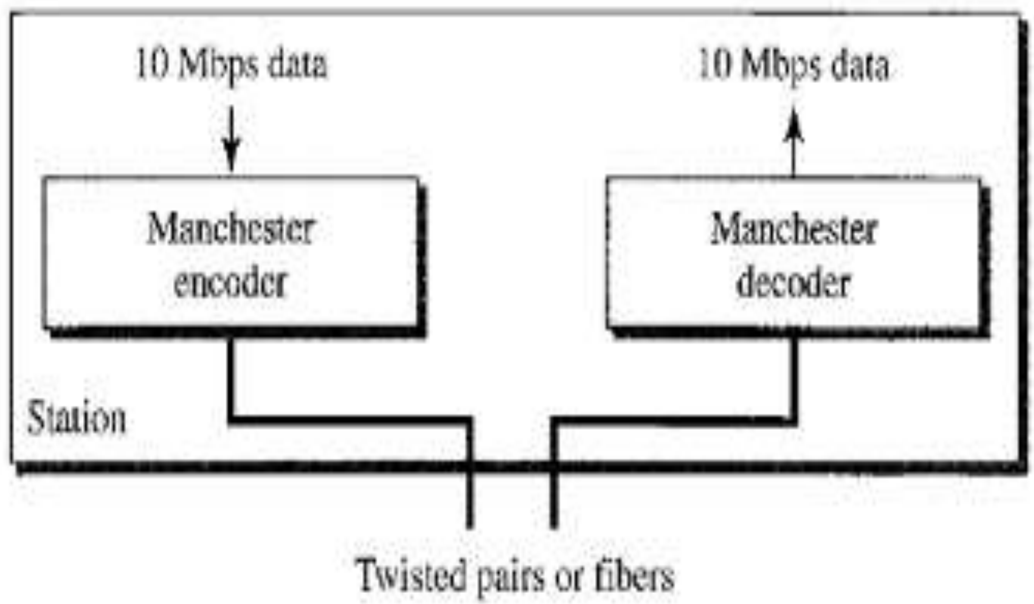
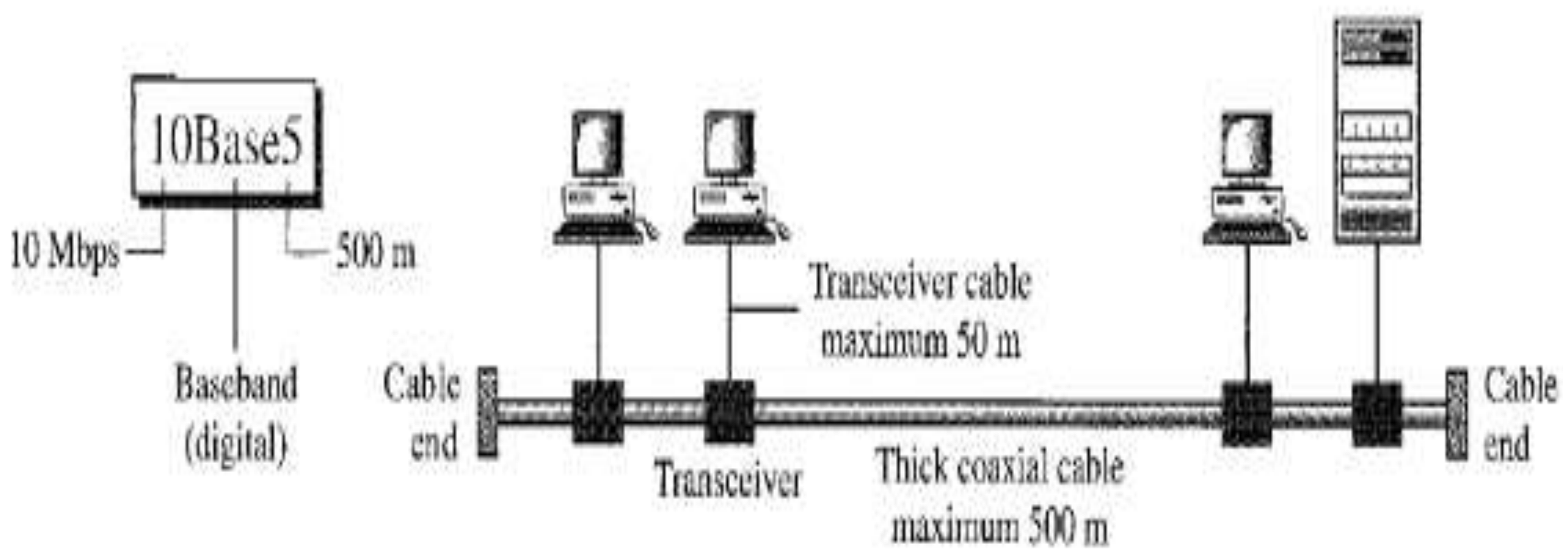


Figure 13.9 *Encoding in a Standard Ethernet implementation*



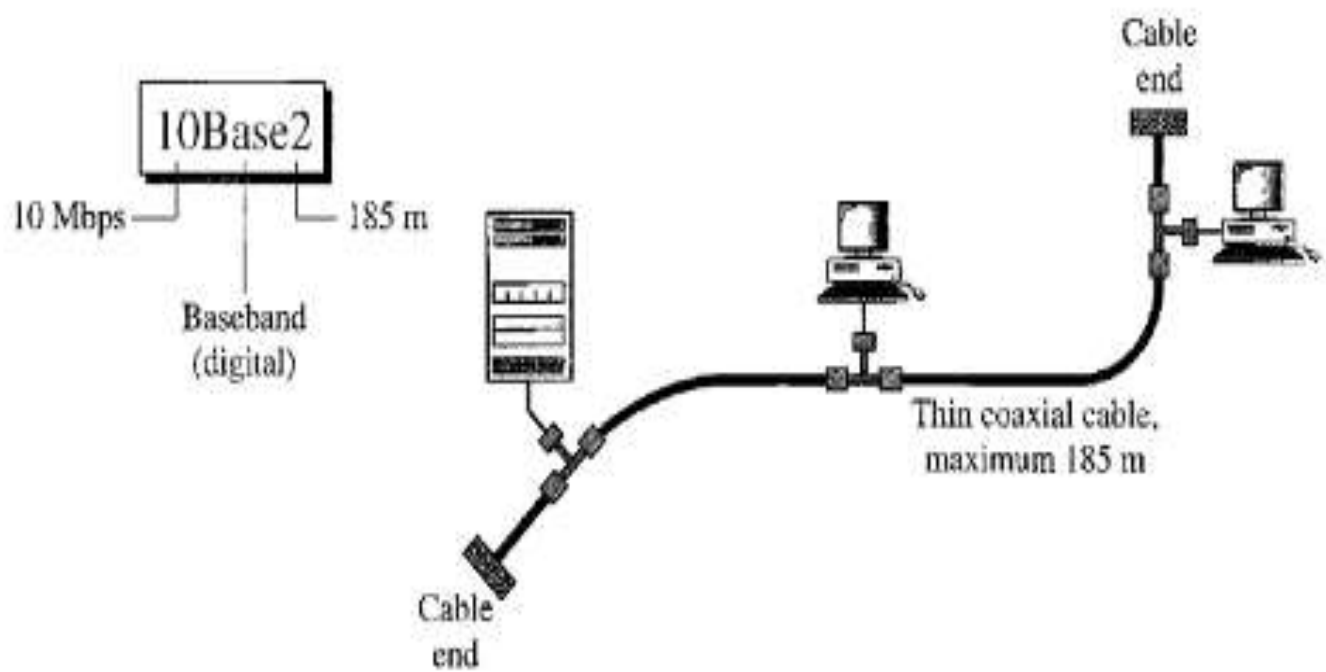
10 Base 5 implementation

Figure 13.10 *10Base5 implementation*



10 Base 2 implementation

Figure 13.11 *10Base2 implementation*



10 Base-T implementation

Figure 13.12 *10Base-T implementation*

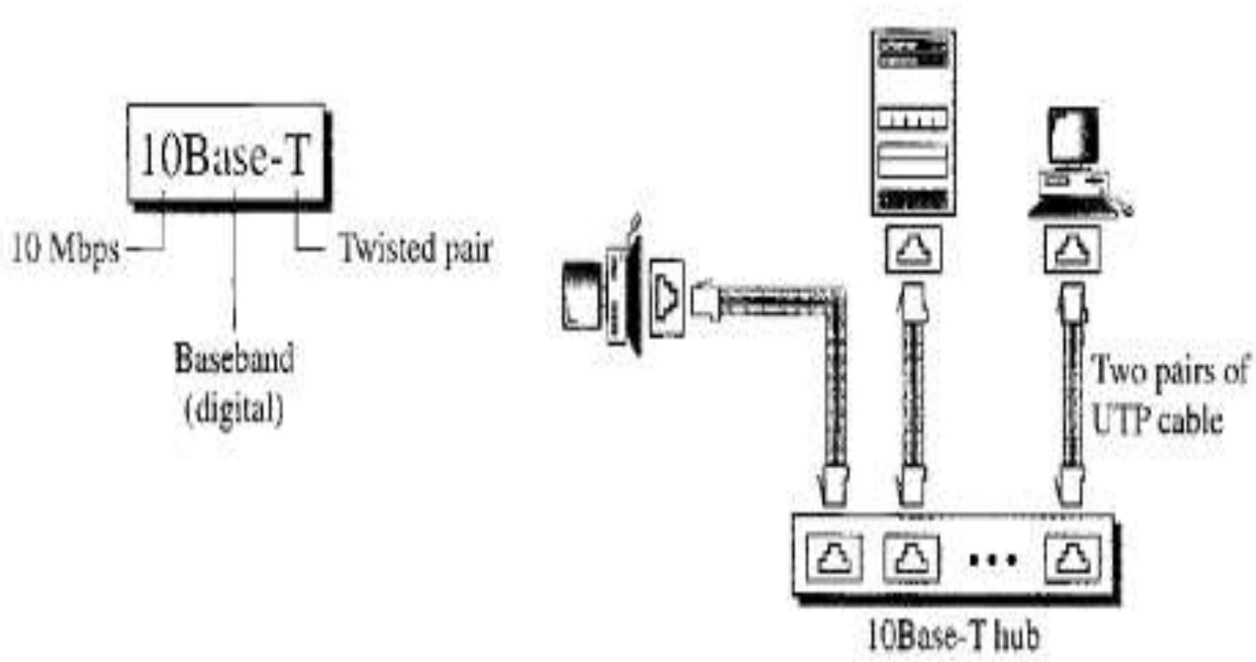
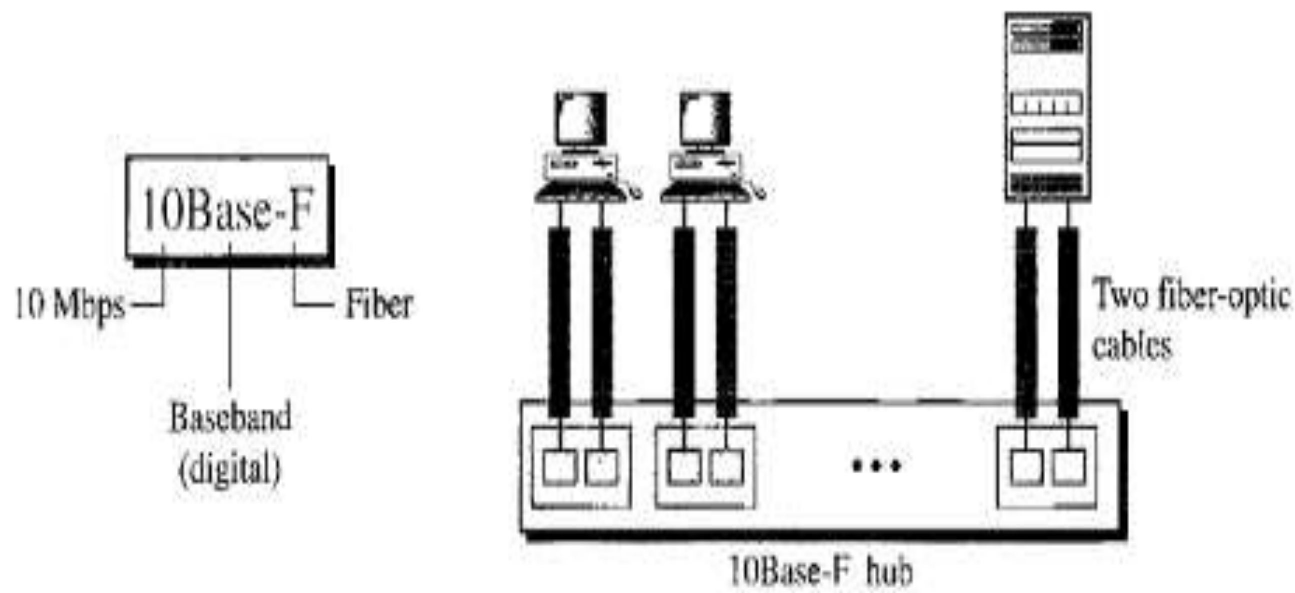


Figure 13.13 *10Base-F implementation*



CHANGES IN THE STANDARD

- Bridged Ethernet
- Switched Ethernet
- Full duplex Ethernet

Bridged Ethernet

Figure 13.14 *Sharing bandwidth*

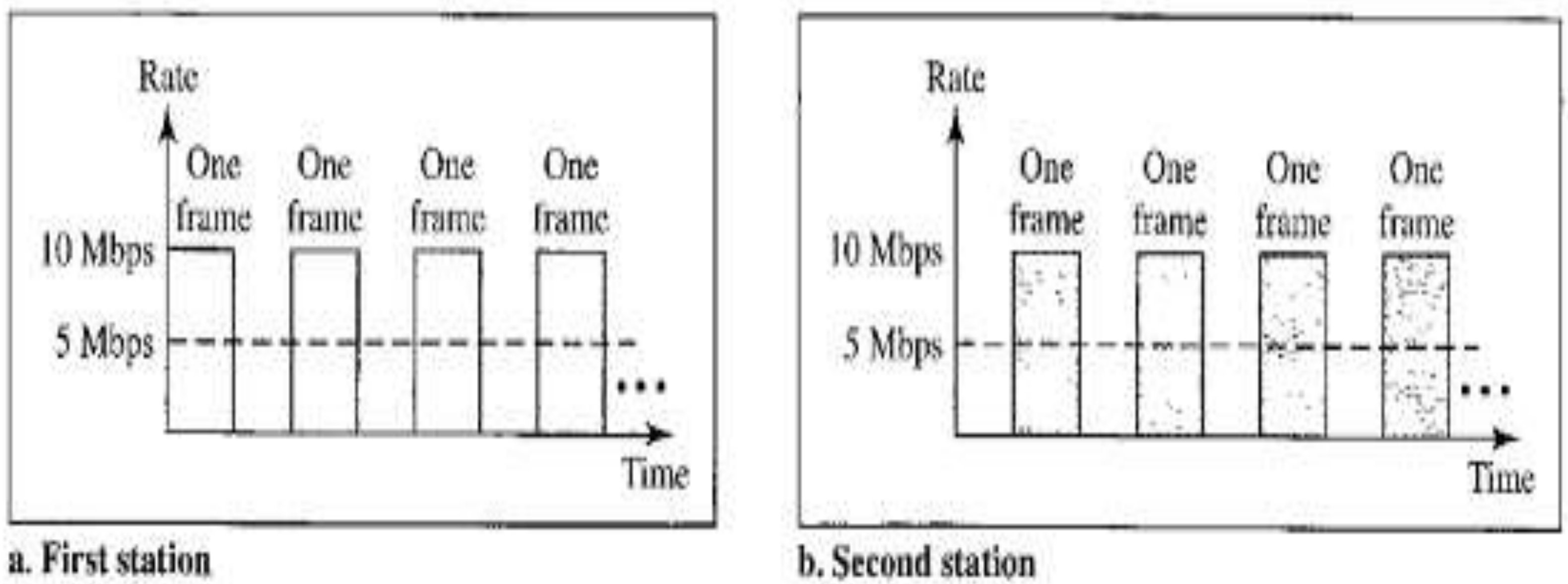
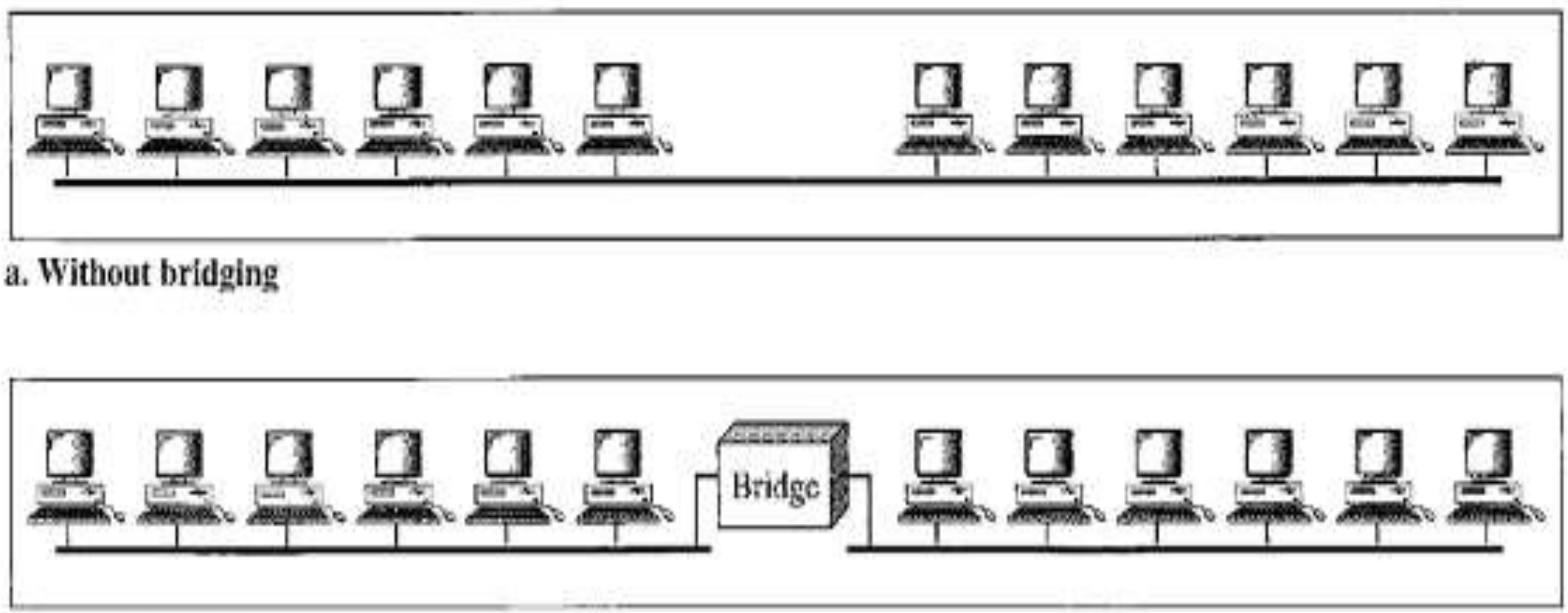


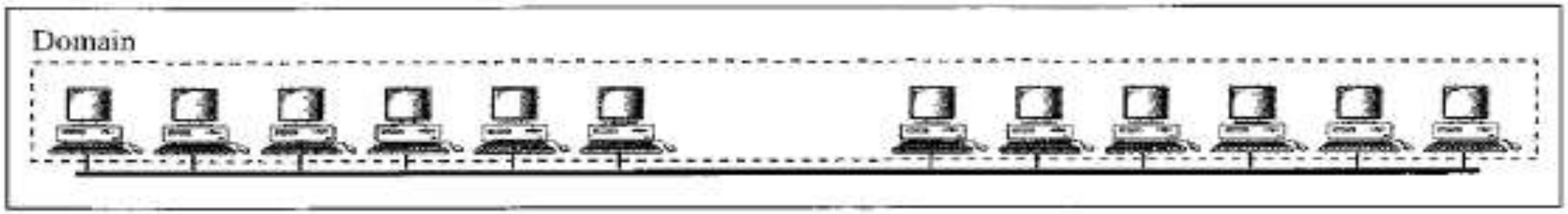
Figure 13.15 *A network with and without a bridge*



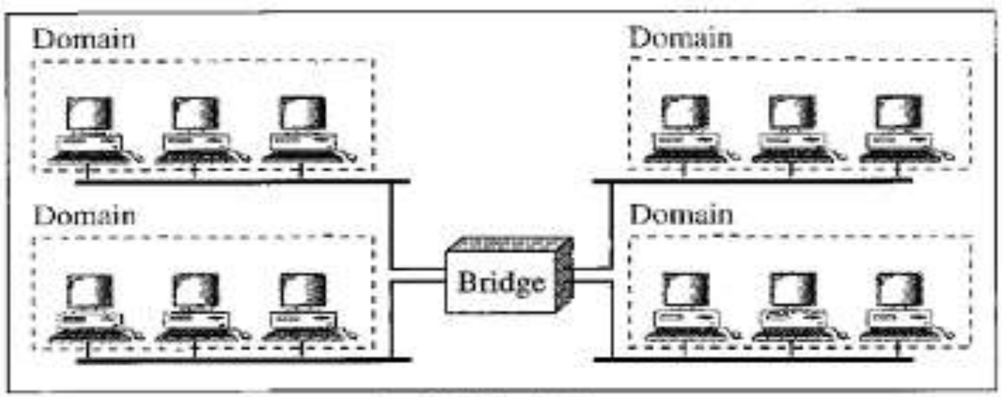
a. Without bridging

b. With bridging

Figure 13.16 *Collision domains in an unbridged network and a bridged network*



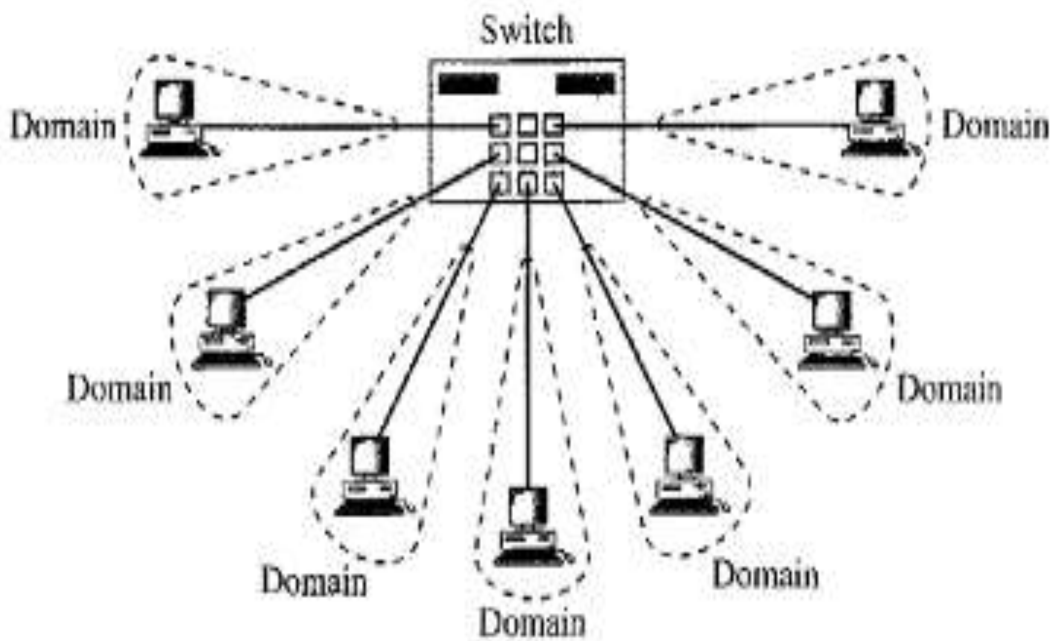
a. Without bridging



b. With bridging

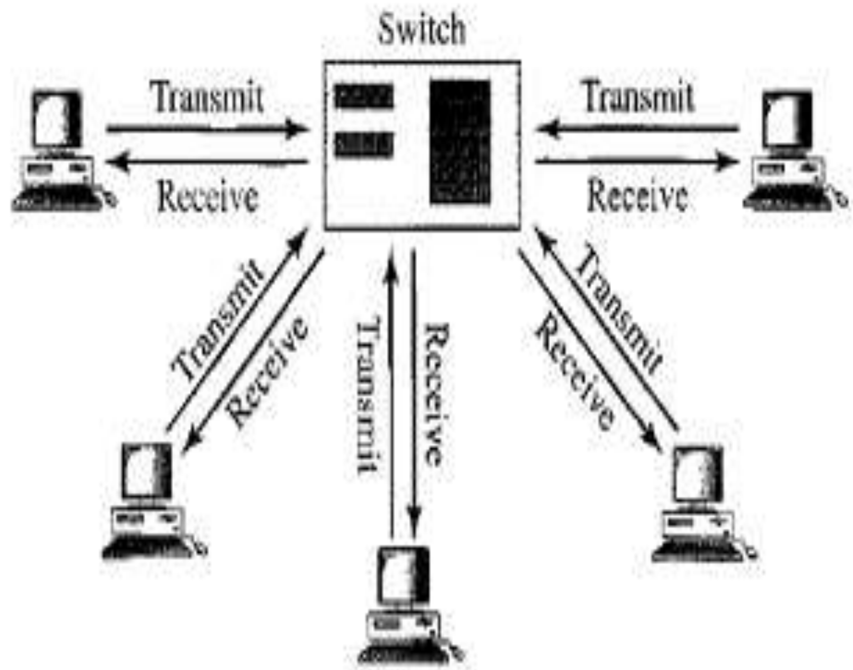
Switched Ethernet

Figure 13.17 *Switched Ethernet*



Full-duplex switched Ethernet

Figure 13.18 *Full-duplex switched Ethernet*



FAST ETHERNET

- Upgrade the data rate to 100 Mbps.
- Make it compatible with Standard Ethernet.
- Keep the same 48-bit address.
- Keep the same frame format.
- Keep the same minimum and maximum frame lengths.

MAC Sublayer

- The access method is the same *(CSMAlCD)* for the half-duplex approach; for fullduplex Fast Ethernet, there is no need for *CSMAlCD.*

Autonegotiation

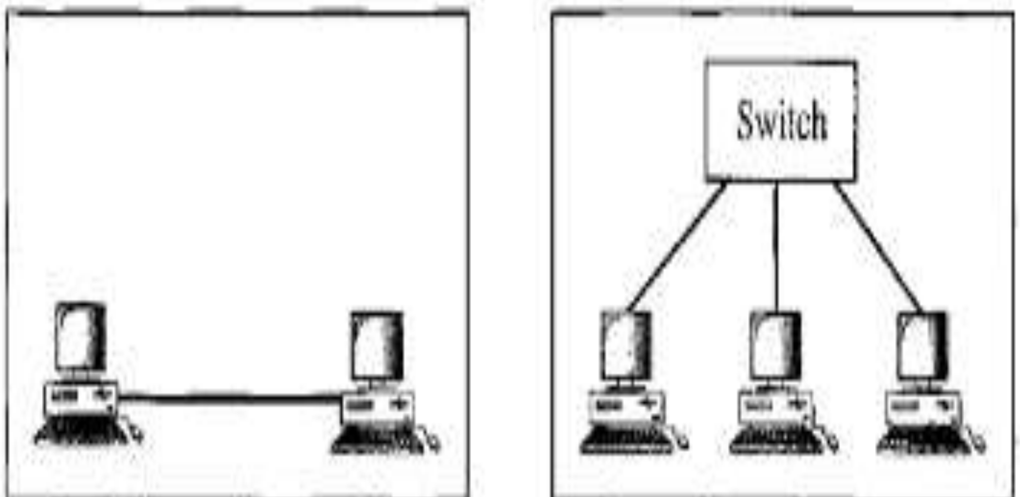
- It allows a station or a hub a range of capabilities.Autonegotiation allows two devices to negotiate the mode or data rate of operation.

Functions

- To allow incompatible devices to connect to one another. For example, a device with a maximum capacity of 10 Mbps can communicate with a device with a 100 Mbps capacity (but can work at a lower rate).
- To allow one device to have multiple capabilities.
- To allow a station to check a hub's capabilities.

Physical Layer

Figure 13.19 *Fast Ethernet topology*

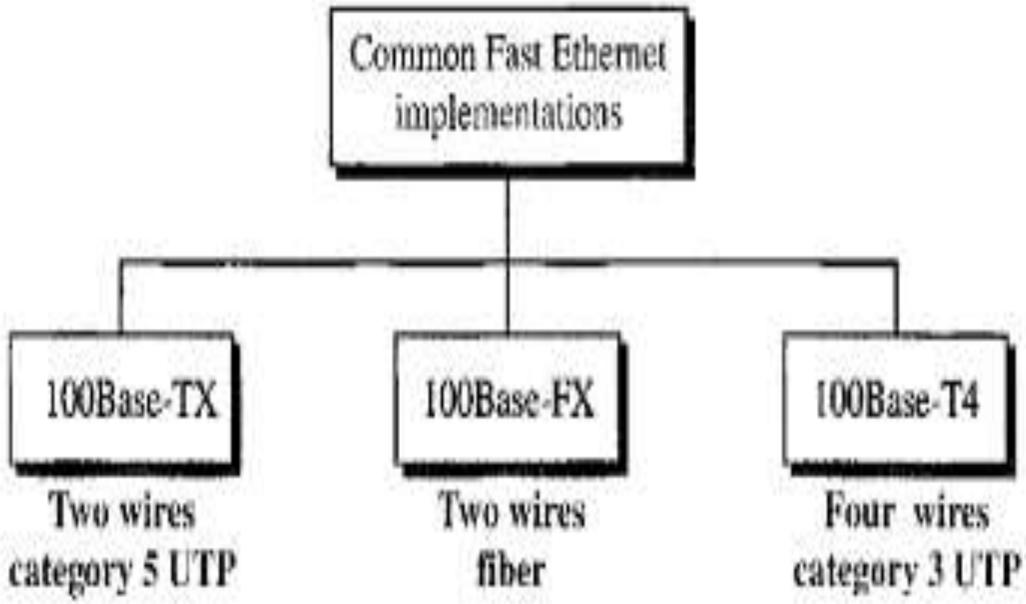


a. Point-to-point

b. Star

Fast Ethernet Implementation

Figure 13.20 *Fast Ethernet implementations*



Comparison of Fat Ethernet

Table 13.2 *Summary of Fast Ethernet implementations*

Characteristics	*100Base-TX*	*100Base-FX*	*100Base-T4*
Media	Cat 5 UTP or STP	Fiber	Cat 4 UTP
Number of wires	2	2	4
Maximum length	100 m	100 m	100 m
Block encoding	4B/5B	4B/5B	
Line encoding	MLT-3	NRZ-I	8B/6T

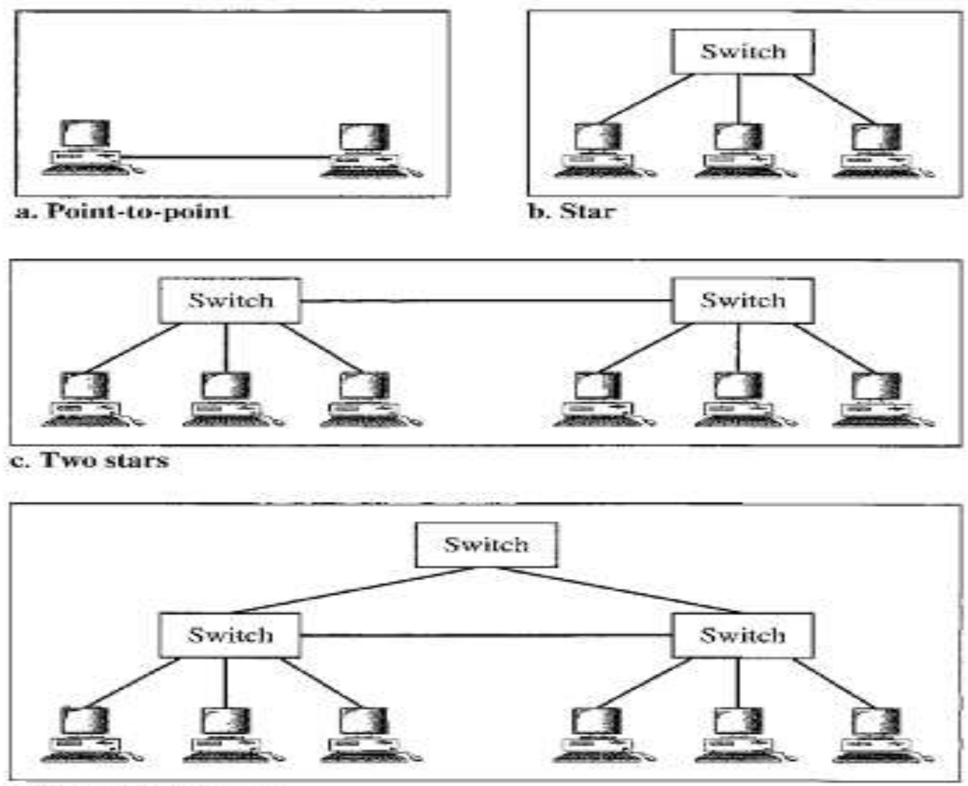
GIGABIT ETHERNET

- The need for an even higher data rate resulted in the design of the Gigabit Ethernet protocol (1000 Mbps). The IEEE committee calls the Standard 802.3z. The goals of the Gigabit Ethernet design can be summarized as follows:

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

Topologies

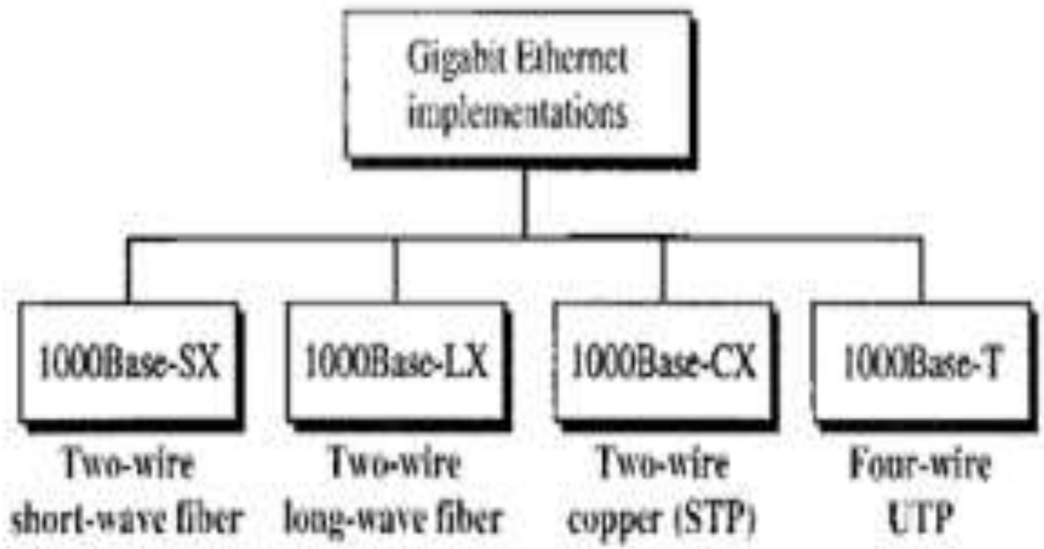
Figure 13.22 *Topologies of Gigabit Ethernet*



a. Point-to-point
b. Star
c. Two stars
d. Hierarchy of stars

Implementation

Figure 13.23 *Gigabit Ethernet implementations*



Comparision

Table 13.3 *Summary of Gigabit Ethernet implementations*

Characteristics	*1000Base-SX*	*1000Base-LX*	*1000Base-CX*	*1000Base-T*
Media	Fiber short-wave	Fiber long-wave	STP	Cat 5 UTP
Number of wires	2	2	2	4
Maximum length	550 m	5000 m	25 m	100 m
Block encoding	8B/10B	8B/10B	8B/10B	
Line encoding	NRZ	NRZ	NRZ	4D-PAM5

Ten-Gigabit Ethernet

- Ten-Gigabit Ethernet
- The IEEE committee created Ten-Gigabit Ethernet and called it Standard 802.3ae. The goals of the Ten-Gigabit Ethernet design can be summarized as follows:
-
- 1. Upgrade the data rate to 10 Gbps.
- 2. Make it compatible with Standard, Fast, and Gigabit Ethernet.
- 3. Use the same 48-bit address.
- 4. Use the same frame format.
- *5.* Keep the same minimum and maximum frame lengths.
- 6. Allow the interconnection of existing LANs into a metropolitan area network (MAN)or a wide area network (WAN).
- 7. Make Ethernet compatible with technologies such as Frame Relay and ATM

comparision

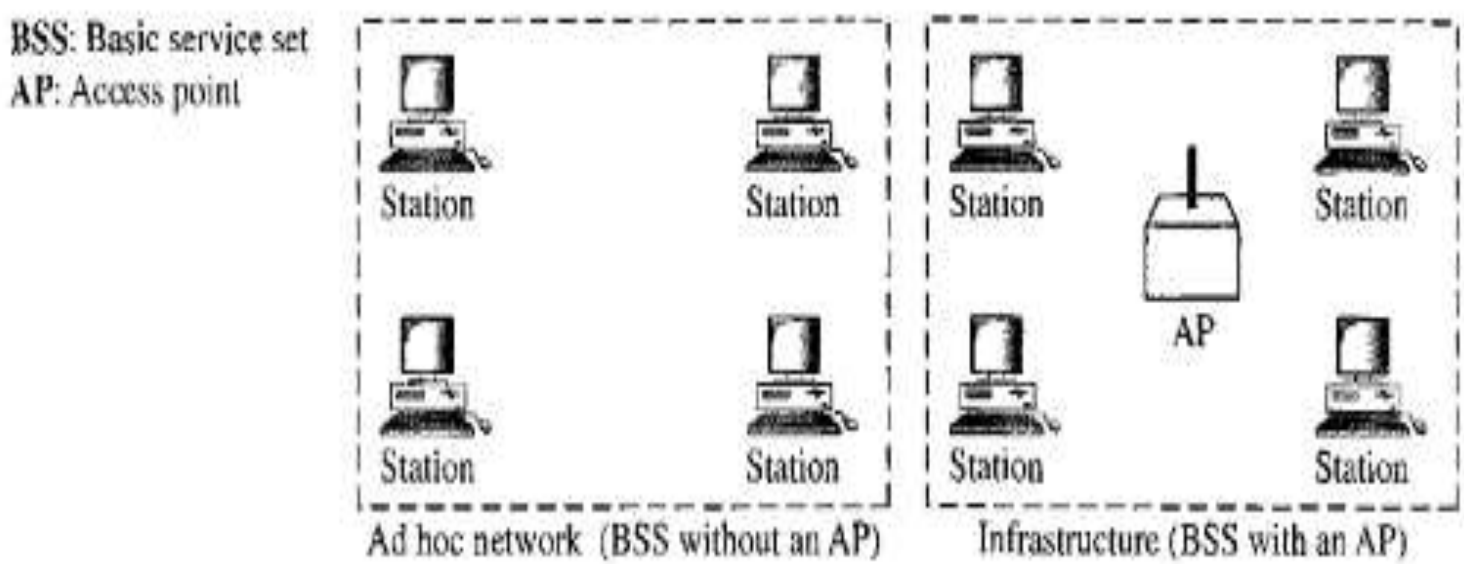
Table 13.4 *Summary of Ten-Gigabit Ethernet implementations*

Characteristics	*10GBase-S*	*10GBase-L*	*10GBase-E*
Media	Short-wave 850-nm multimode	Long-wave 1310-nm single mode	Extended 1550-mm single mode
Maximum length	300 m	10 km	40 km

WIRELESS LANS

IEEE 802.11

Figure 14.1 *Basic service sets (BSSs)*



ESSs

Figure 14.2 *Extended service sets (ESSs)*

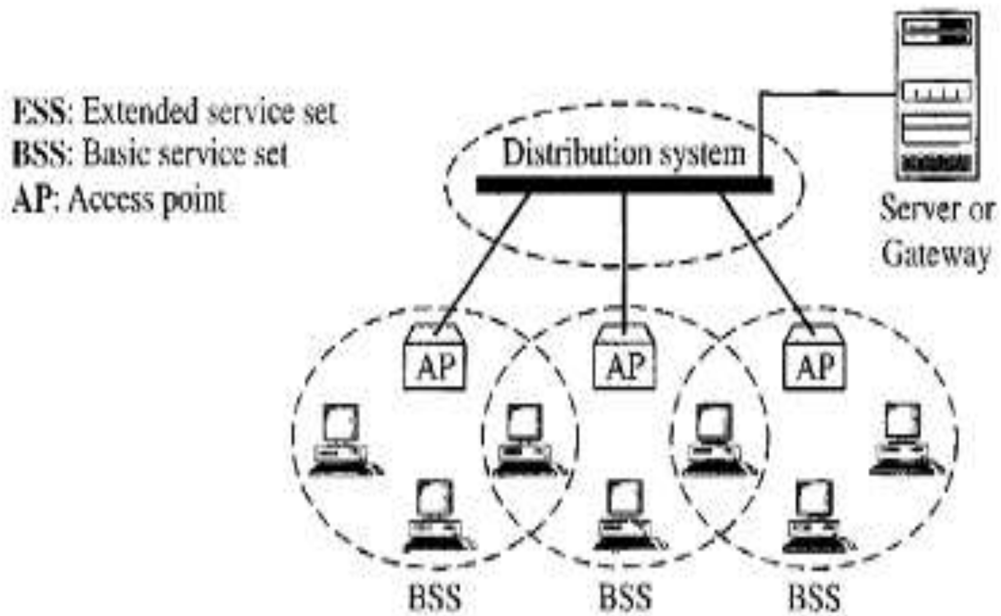
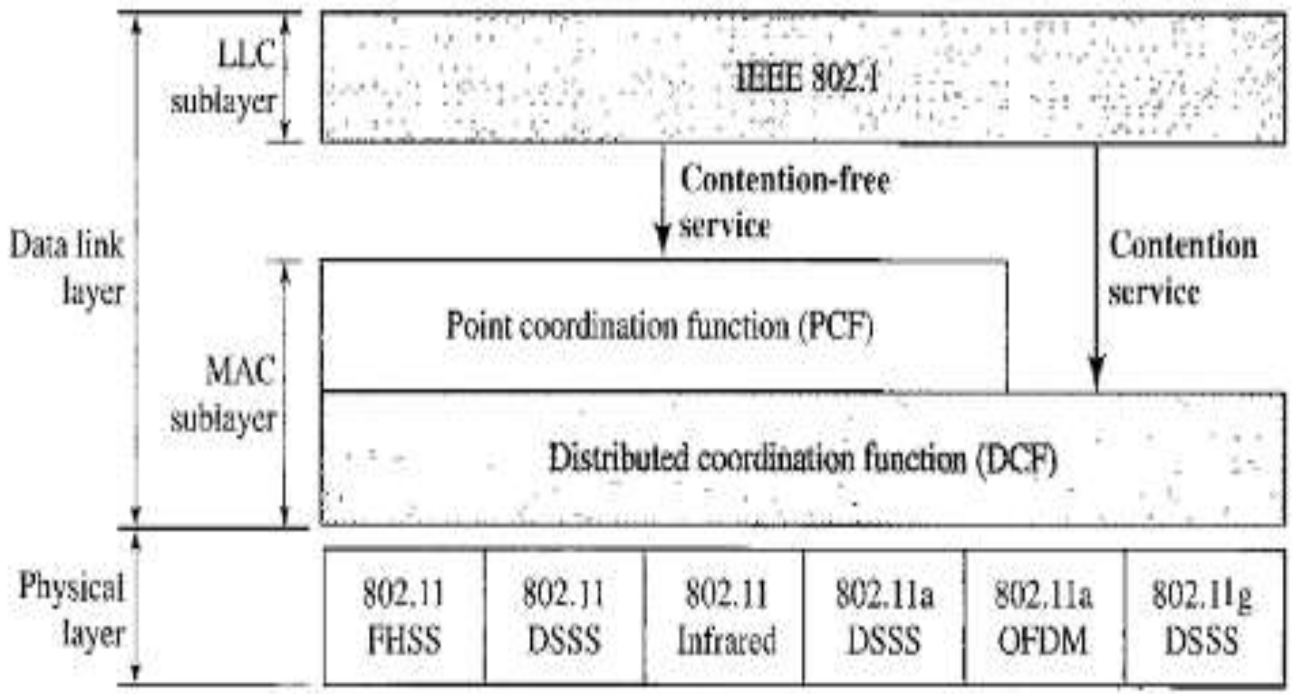


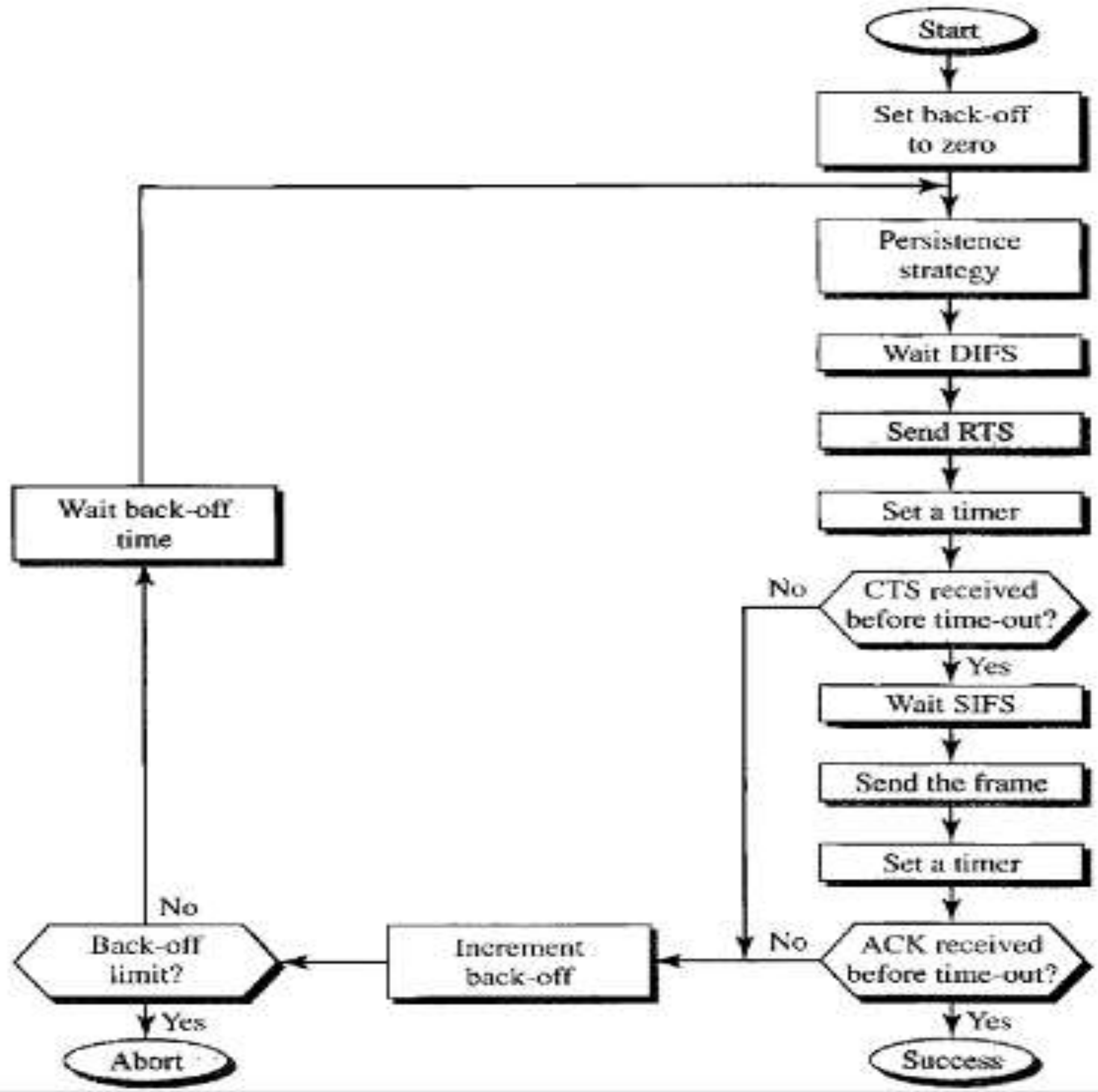
Figure 14.3 *MAC layers in IEEE 802.11 standard*



Physical layer

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	OPDM	5.725 GHz	PSKorQAM	6 to 54
802.11b	DSSS	2.4 GHz	PSK	5.5 and 11
S02.1Ig	OFDM	2.4 GHz	Different	22 and 54

Distributed Coordination Function



Point Coordination Function (PCF)

- Polling method

BLUETOOTH

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

Figure 14.19 *Piconet*

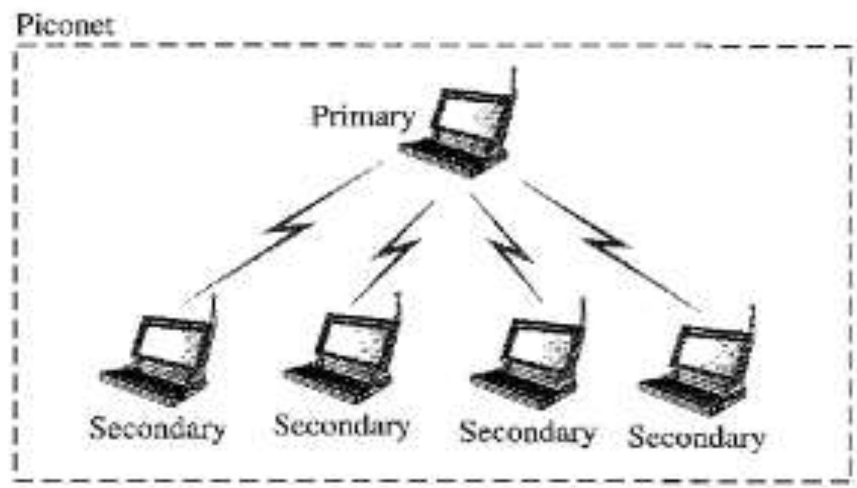
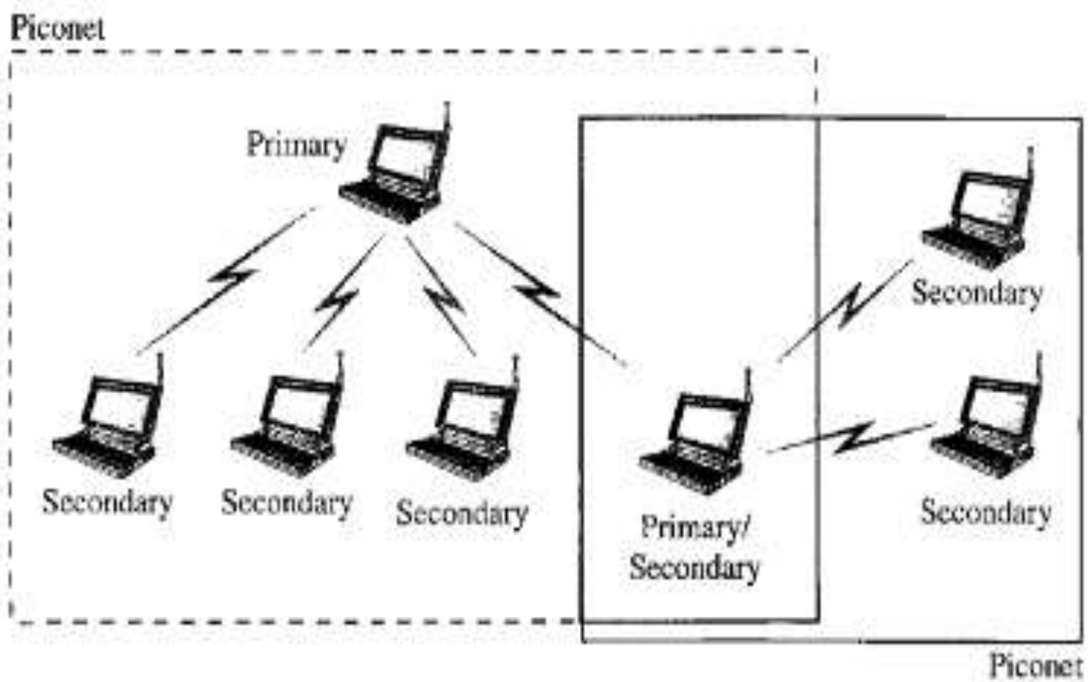


Figure 14.20 *Scatternet*



BLUETOOTH LAYERS

Figure 14.21 *Bluetooth layers*