Multiple Access

- *Propagation Time*
- Propagation time measures the time required for a bit to travel from the source to the destination. The propagation time is calculated by dividing the distance by the propagation speed.
- Propagation time = $\dfrac{\text{Distance}}{\text{Propagation speed}}$

4.2

- Transmission Time
- In data communications we don't send just 1 bit, we send a message. Time taken to put a packet onto link. In other words, it is simply time required to put data bits on the wire/communication medium. It depends on length of packet and bandwidth of network.
- Transmission time = $\dfrac{\text{Message size}}{\text{Bandwidth}}$

- *Queuing Time*
- The third component in latency is the queuing time, the time needed for each intermediate or end device to hold the message before it can be processed.

4.4

- Latency

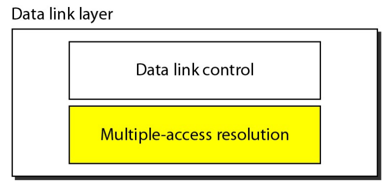
- The latency or delay defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source.

Latency = propagation time +transmission time +queuing time + processing delay

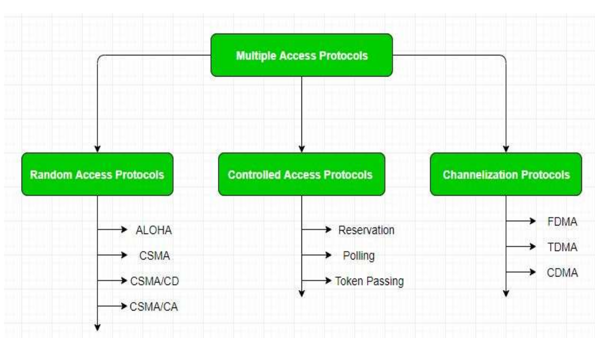
4.5

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

The upper sublayer is responsible for data link control (a mechanism which provides a link with reliable communication), and the lower sublayer is responsible for resolving access to the shared media.



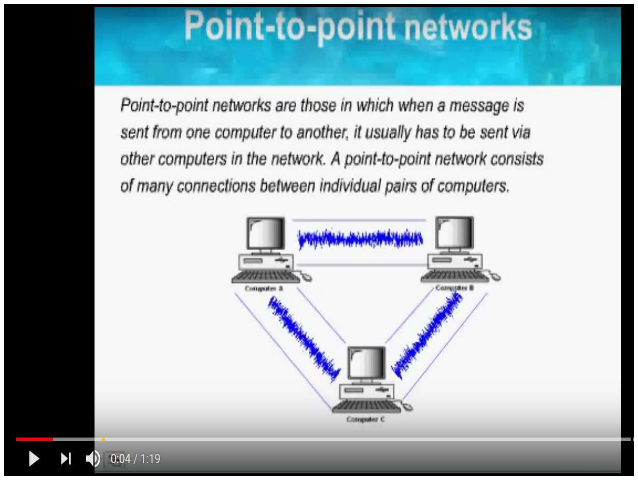
12.6

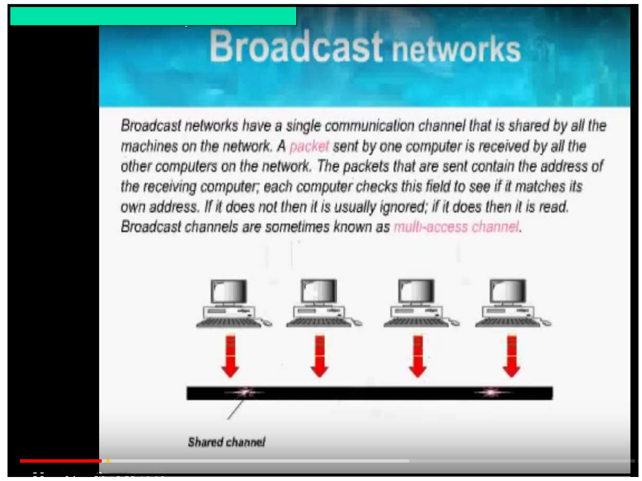


12-1 RANDOM ACCESS

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.
To avoid access conflict or to resolve it when it happens, each station follows a procedure that answers the following questions:
- *When can the station access the medium?*
- *What can the station do if the medium is busy?*
- *How can the station determine the success or failure of the transmission?*
- *What can the station do if there is an access conflict?*

12.8



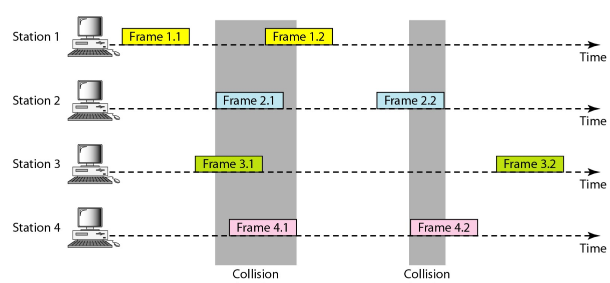


ALOHA

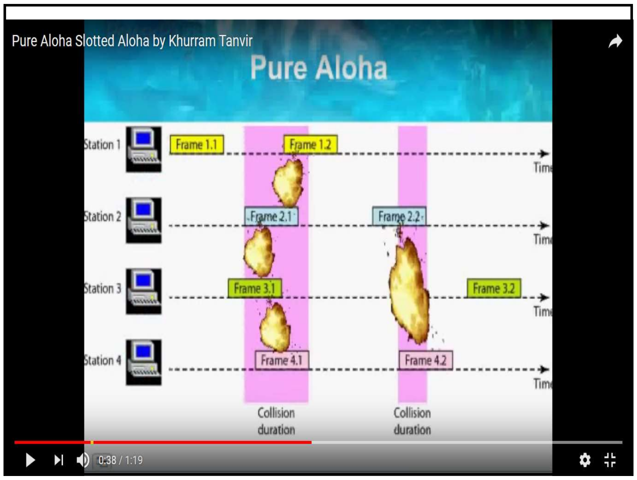
ALOHA, the earliest random access method, was developed at the University of Hawaii in early 1970. It was designed for a radio (wireless) LAN, but it can be used on any shared medium.

12.11

Figure 12.3 ***Frames in a pure ALOHA network***



12.12



Two frames survive: frame 1.1 from station 1 and frame 3.2 from station 3.

The pure ALOHA protocol relies on acknowledgments from the receiver.

If the acknowledgment does not arrive after a time-out period, the station assumes that the frame (or the acknowledgment) has been destroyed and resends the frame.

12.14

A collision involves two or more stations. If all these stations try to resend their frames after the time-out, the frames will collide again

Pure ALOHA dictates that when the time-out period passes, each station waits a random amount of time before resending its frame. The randomness will help avoid more collisions. We call this time the ***back-off time TB.***

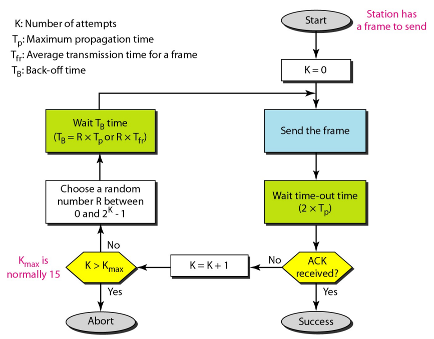
Pure ALOHA has a second method to prevent congesting the channel with retransmitted frames

12.15

After a maximum number of retransmission attempts Kmax' a station must give up and try later

12.16

Figure 12.4 *Procedure for pure ALOHA protocol*



12.17

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 × 10⁸ m/s, we find

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

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.

12.18

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.

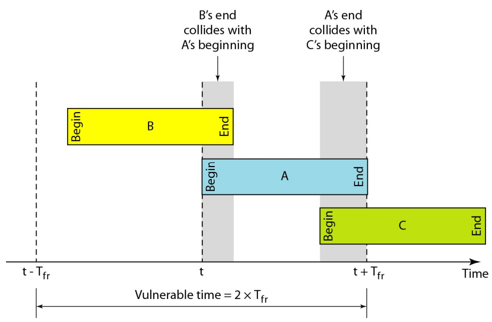
d. We need to mention that if K > 10, it is normally set to 10.

12.19

Vulnerable time
The vulnerable time, in which there is a possibility of collision.

12.20

Figure 12.5 *Vulnerable time for pure ALOHA protocol*



12.21

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.

12.22

Note

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

G transmission-attempts per frame-time.

12.23

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 × 0.135 = 135 frames. Only 135 frames out of 1000 will probably survive.

12.24

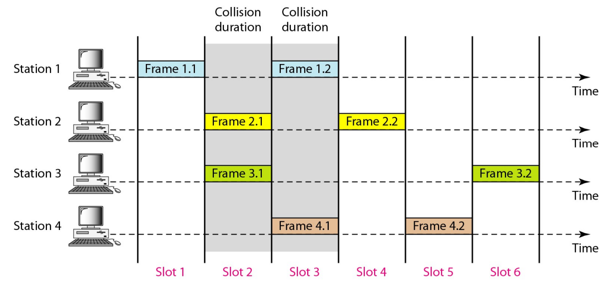
Example 12.3 (continued)

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 $500 \times 0.184 = 92$ and that only 92 frames out of 500 will probably survive. Note that this is the maximum throughput case, percentagewise.*

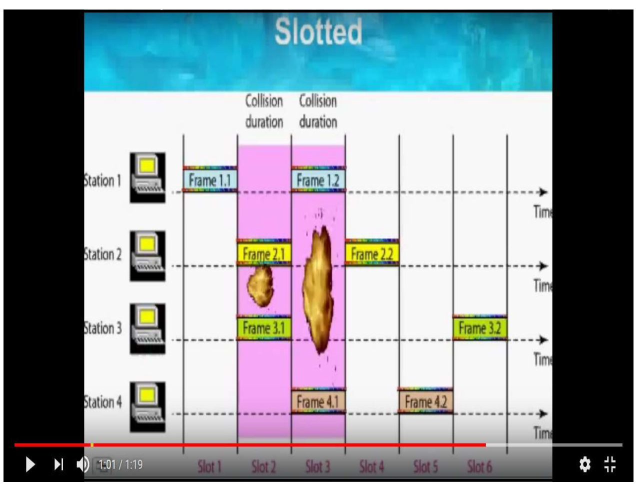
c. *If the system creates 250 frames per second, this is (1/4) frame per millisecond. The load is (1/4). In this case $S = G \times e^{-2G}$ or $S = 0.152$ (15.2 percent). This means that the throughput is $250 \times 0.152 = 38$. Only 38 frames out of 250 will probably survive.*

12.25

Figure 12.6 *Frames in a slotted ALOHA network*



12.26

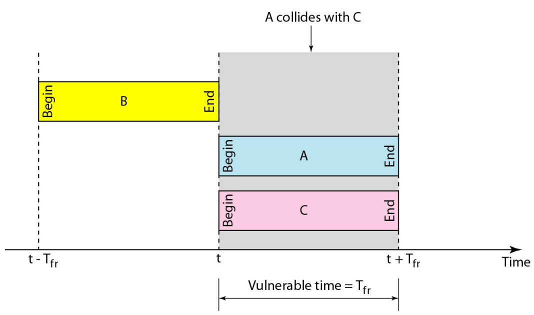


Note

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

12.28

Figure 12.7 *Vulnerable time for slotted ALOHA protocol*



12.29

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 × 0.0368 = 368 frames. Only 386 frames out of 1000 will probably survive.

12.30

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 × 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 × 0.195 = 49. Only 49 frames out of 250 will probably survive.

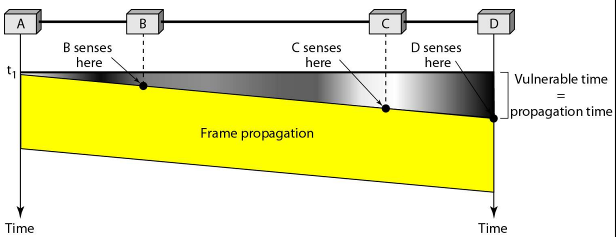
12.31

The chance of collision can be reduced if a station senses the medium before trying to use it.

Carrier sense multiple access (CSMA) requires that each station first listen to the medium before sending. In other words, CSMA is based on the principle "sense before transmit" or "listen before talk."

12.32

Figure 12.9 *Vulnerable time in CSMA*



12.33

What should a station do if the channel is busy?

What should a station do if the channel is idle?

12.34

I-Persistent

The I-persistent method is simple and straightforward. In this method, after the station finds the line idle, it sends its frame immediately This method has the highest chance of collision because---

12.35

Nonpersistent

In the nonpersistent method, a station that has a frame to send senses the line. If the line is idle, it sends immediately. If the line is not idle, it waits a random amount of time and then senses the line again.

12.36

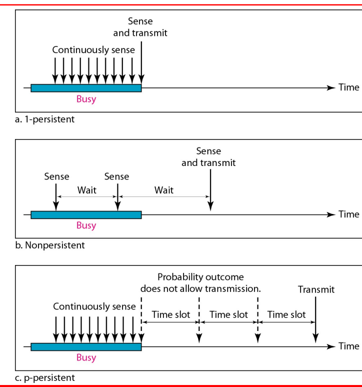
p-persistent

The p-persistent method is used if the channel has time slots with a slot duration equal to or greater than the maximum propagation time. The p-persistent approach combines the advantages of the other two strategies.

1. With probability p, the station sends its frame.
2. With probability q = 1 - p, the station waits for the beginning of the next time slot and checks the line again.

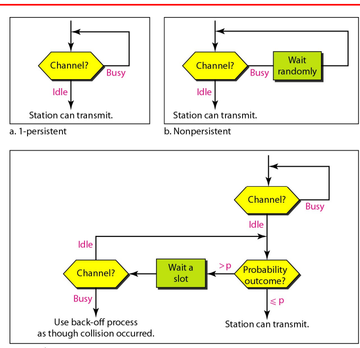
12.37

Figure 12.10 ***Behavior of three persistence methods***



12.38

Figure 12.11 ***Flow diagram for three persistence methods***



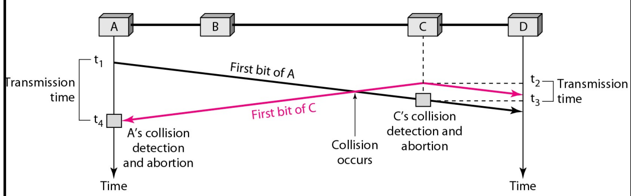
12.39

Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

station monitors the medium after it sends a frame to see if the transmission was successful. If so, the station is finished. If, however, there is a collision, the frame is sent again.

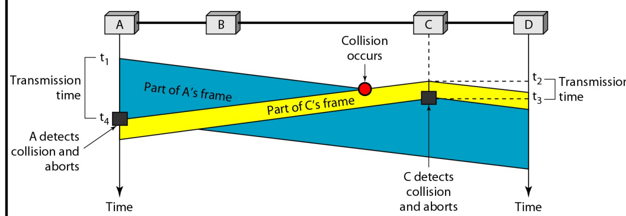
12.40

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



12.41

Figure 12.13 *Collision and abortion in CSMA/CD*



12.42

Minimum Frame Size

For CSMA/CD to work, we need a restriction on the frame size. Before sending the last bit of the frame, the sending station must detect a collision, if any, and abort the transmission.
This is so because the station, once the entire frame is sent, does not keep a copy of the frame

Therefore, the frame transmission time Tfr must be at least two times the maximum propagation time Tp.

12.43

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 $T_{fr} = 2 \times T_p = 51.2\ \mu s$. ***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.***

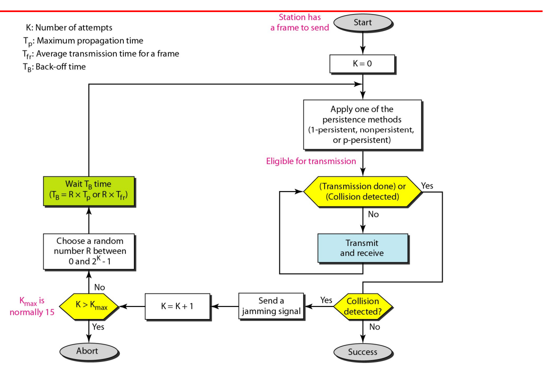
12.44

- Consider a CSMA/CD network that transmits data at a rate of 100 Mbps (10^8 bits per second) over a 1 km (kilometer) cable with no repeaters. If the minimum frame size required for this network is 1250 bytes, what is the signal speed (km/sec) in the cable?

(GATE-2015)

Data should be transmitted at the rate of 100 Mbps.
Transmission Time >= 2*Propagation Time
⇒ 1250*8 / (100 * 10^6) <= 2*length/signal_speed
⇒ => signal_speed <= (2 * 10^3 * 100 * 10^6) / (1250 * 8)
⇒ <= 2 * 10 * (10^3) km/sec <= 20000

Figure 12.14 *Flow diagram for the CSMA/CD*



12.47

CSMA/CD is similar to the one for the ALOHA protocol, but there are differences.

The first difference is the addition of the persistence process.

In ALOHA, we first transmit the entire frame and then wait for an acknowledgment. In CSMA/CD, transmission and collision detection is a continuous process.

The third difference is the sending of a short jamming signal that enforces the collision in case other stations have not yet sensed the collision.

12.48

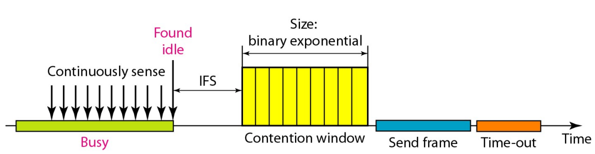
Throughput

I-persistent method the maximum throughput is around 50 percent when G =1. For nonpersistent method, the maximum throughput can go up to 90 percent when G is between 3 and 8.

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

CSMA/CD is not useful for effective collision detection in wireless mode.

Figure 12.16 ***Timing in CSMA/CA***



Interframe Space (IFS)

First, collisions are avoided by deferring transmission even if the channel is found idle. When an idle channel is found, the station does not send immediately

The IFS variable can also be used to prioritize stations or frame types

Contention Window

The contention window is an amount of time divided into slots. A station that is ready to send chooses a random number of slots as its wait time. The number of slots in the window changes according to the binary exponential back-off strategy.

However, if the station finds the channel busy, it does not restart the process; it just stops the timer and restarts it when the channel is sensed as idle. This gives priority to the station with the longest waiting time.

12.53

Acknowledgment

With all these precautions, there still may be a collision resulting in destroyed data. In addition, the data may be corrupted during the transmission. The positive acknowledgment and the time-out timer can help guarantee that the receiver has received the frame.

12.54

Note

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

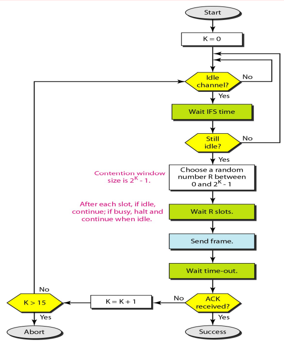
12.55

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.

12.56

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*

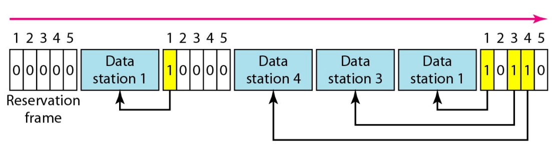


Figure 12.19 *Select and poll functions in polling access method*

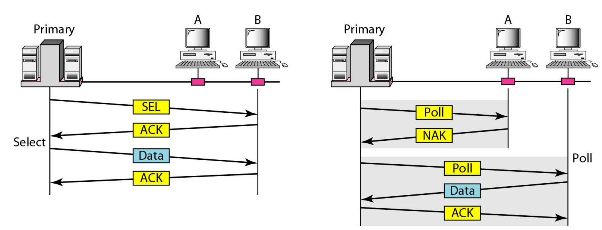
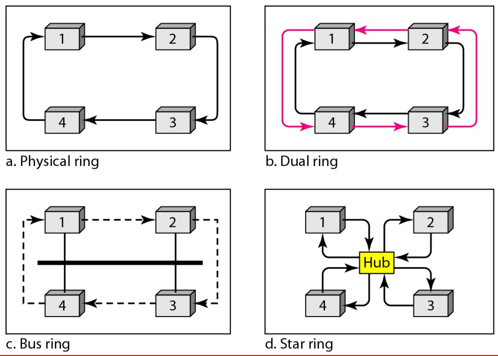


Figure 12.20 *Logical ring and physical topology in token-passing access method*



12.61

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)

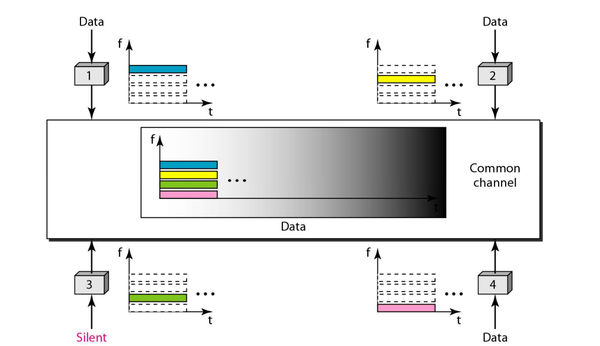
12.62

Note

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

12.63

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



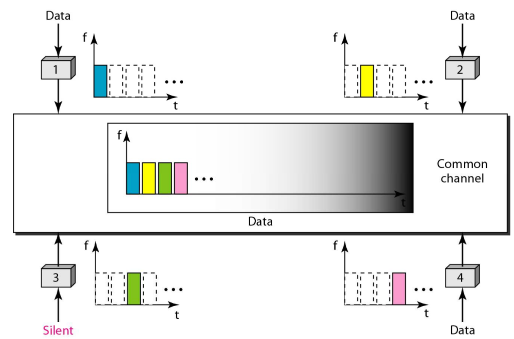
12.64

Note

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

12.65

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



12.66

Note

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

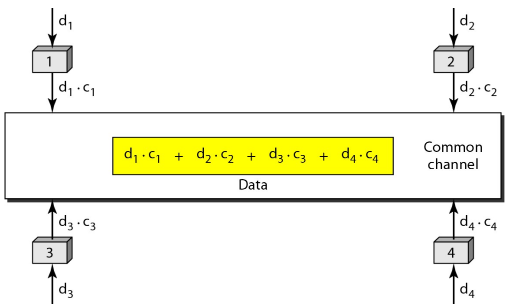
12.67

Note

In CDMA, one channel carries all transmissions simultaneously.

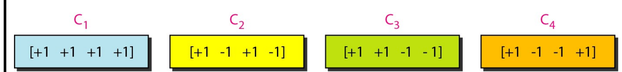
12.68

Figure 12.23 *Simple idea of communication with code*



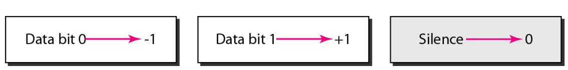
12.69

Figure 12.24 *Chip sequences*



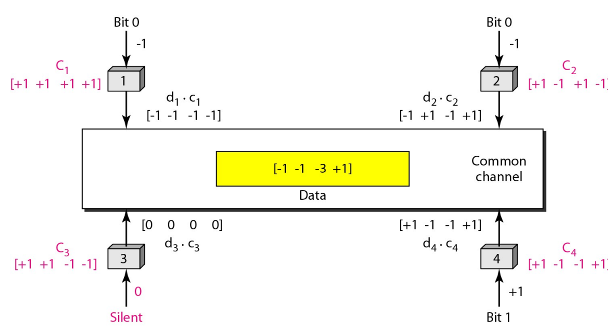
12.70

Figure 12.25 *Data representation in CDMA*



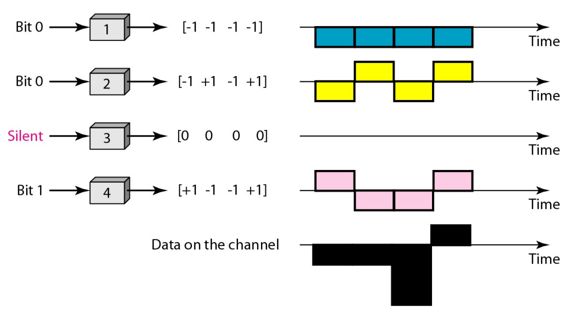
12.71

Figure 12.26 *Sharing channel in CDMA*



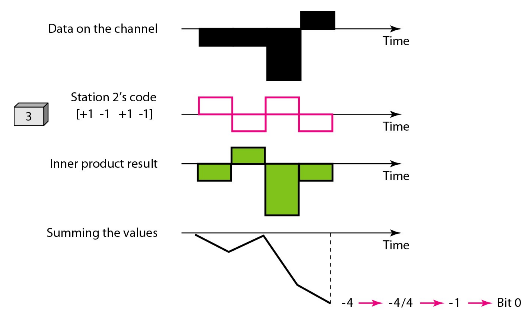
12.72

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



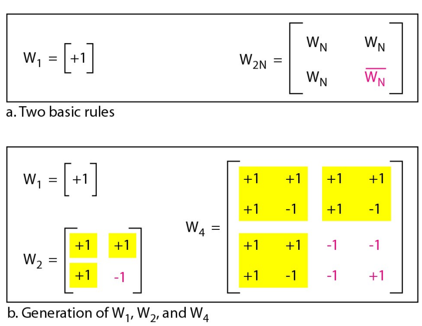
12.73

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



12.74

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



12.75

Note

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

12.76

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.