Chapter 11: Multiple Access

Sunghyun Cho
School of Computer Science
Hanyang University
chopro@hanyang.ac.kr

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

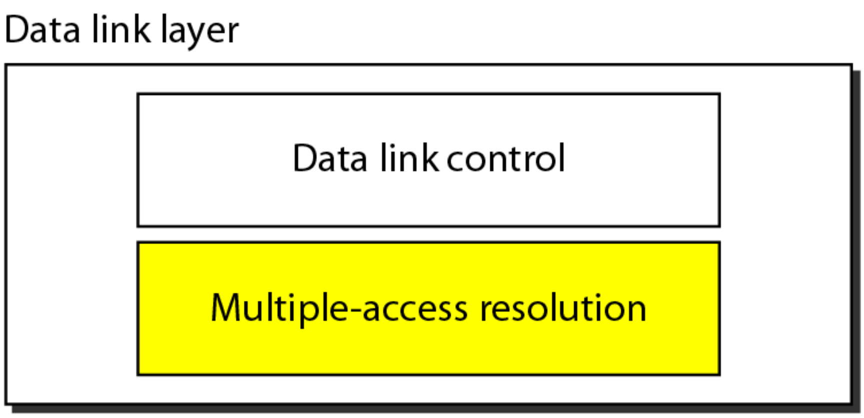
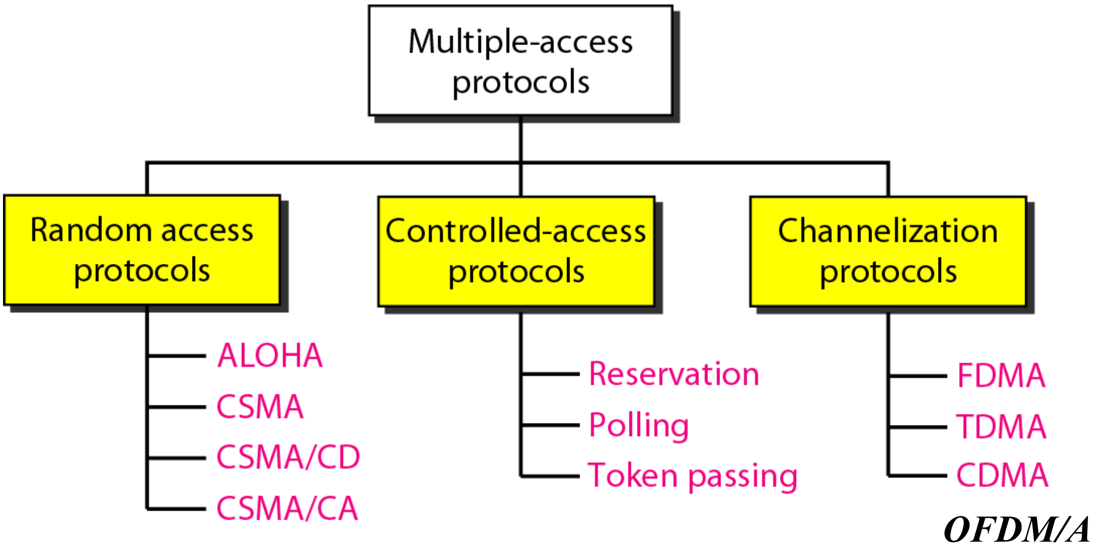


Figure 12.2 *Taxonomy of multiple-access protocols discussed in this chapter*



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*

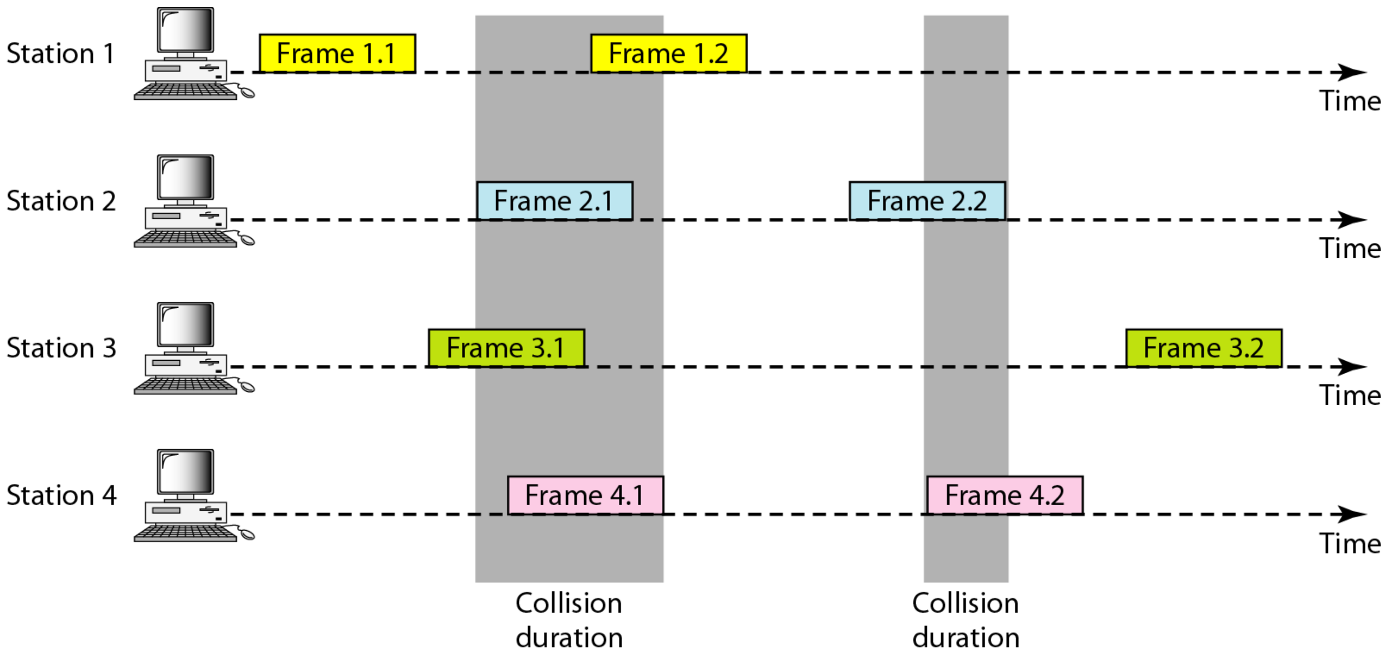


Figure 12.4 *Procedure for pure ALOHA protocol*

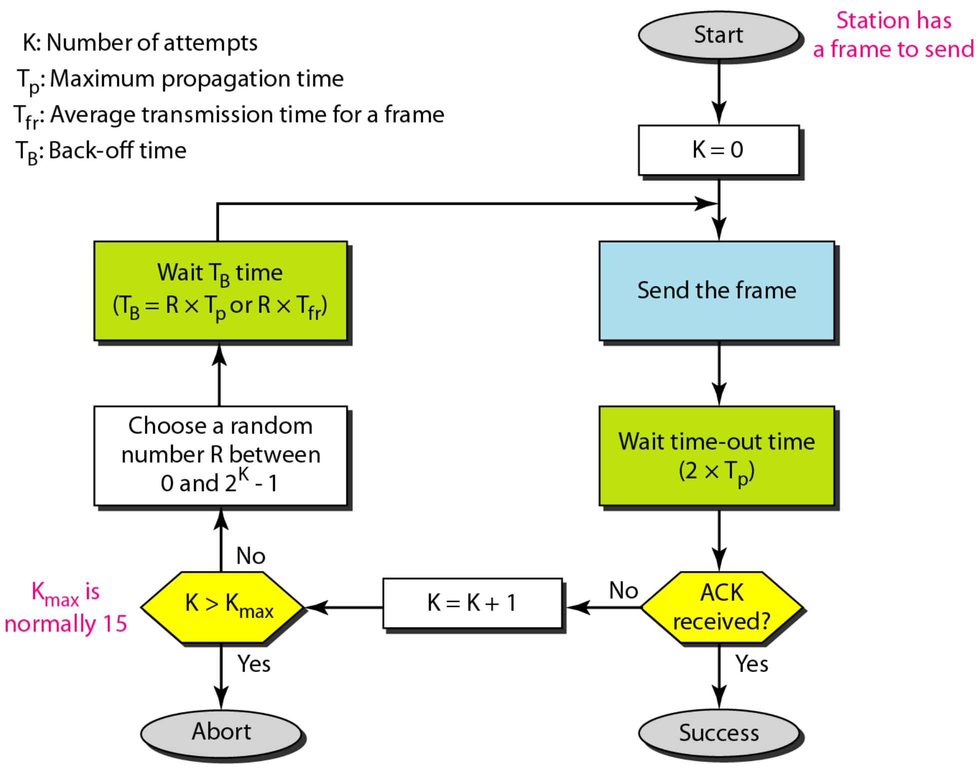
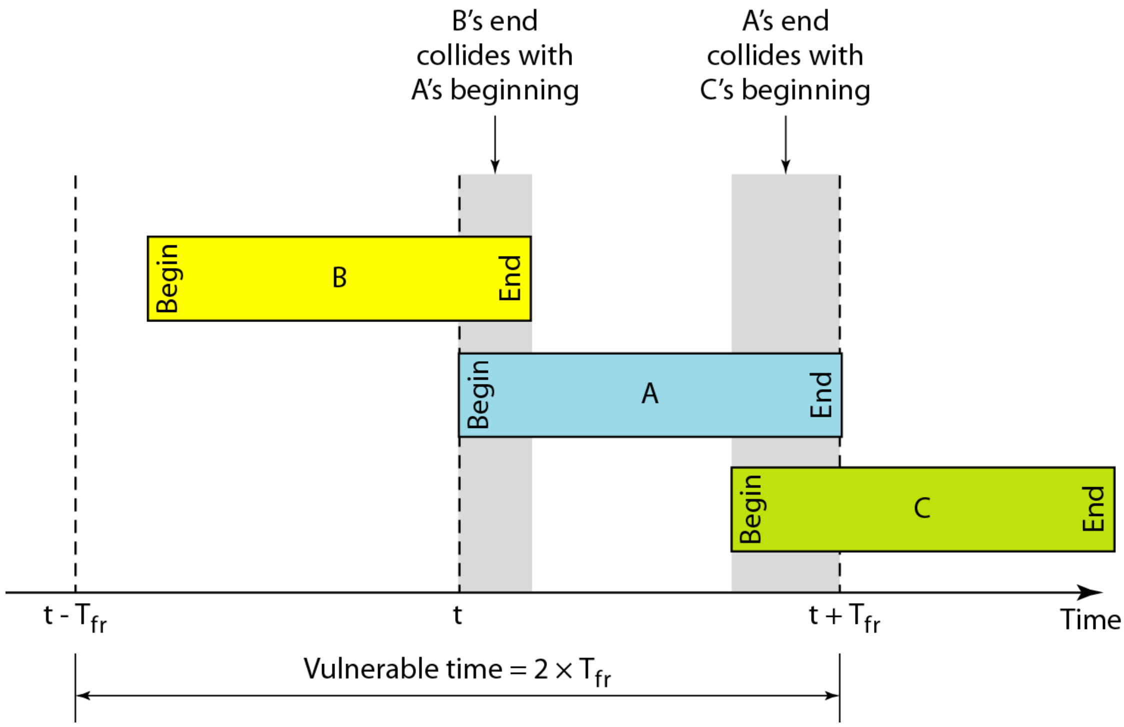


Figure 12.5 *Vulnerable time for pure ALOHA protocol*



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 $G = (1/2)$.

G = the average number of frames generated by the system during one frame transmission time

Poisson distribution: $f(n, \lambda) = \frac{\lambda^n e^{-\lambda}}{n!}$ (λ: 사건이 일어날 기대값, n: 사건이 일어날 횟수)

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.

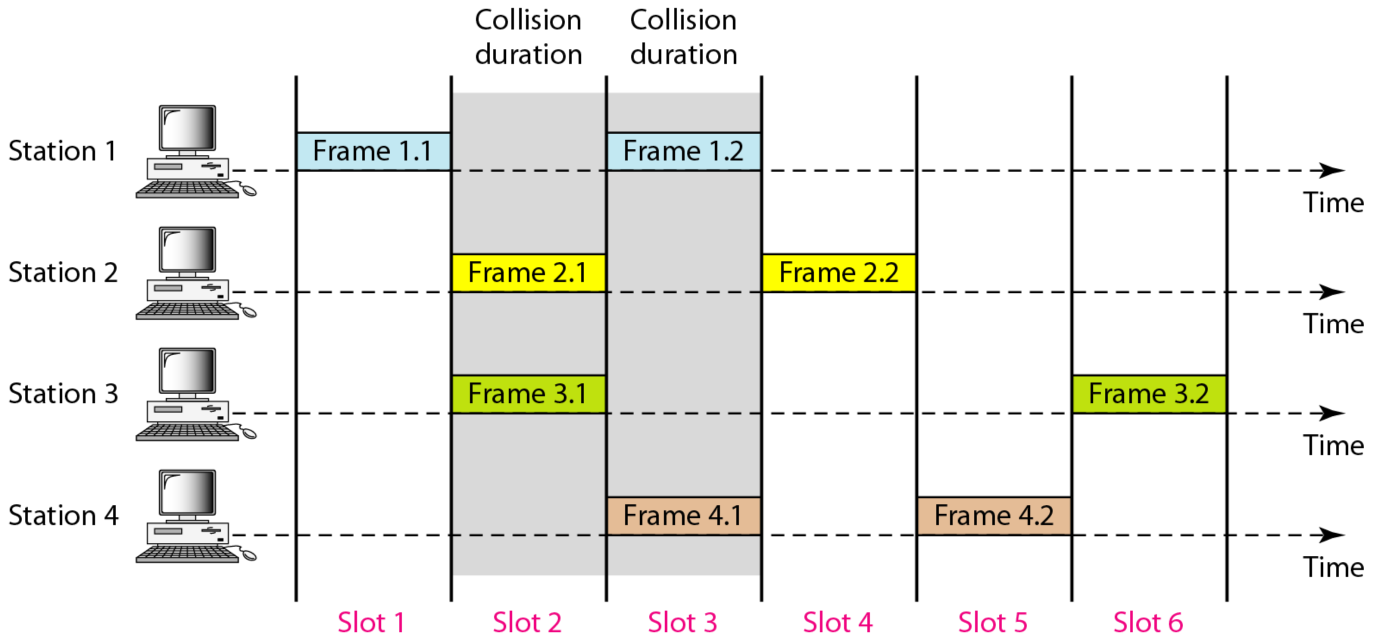
a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case $S = G \times e^{-2G}$ or $S = 0.135$ (13.5 percent). This means that the throughput is $1000 \times 0.135 = 135$ frames. Only 135 frames out of 1000 will probably survive.

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 $500 \times 0.184 = 92$ 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.***

Figure 12.6 *Frames in a slotted ALOHA network*

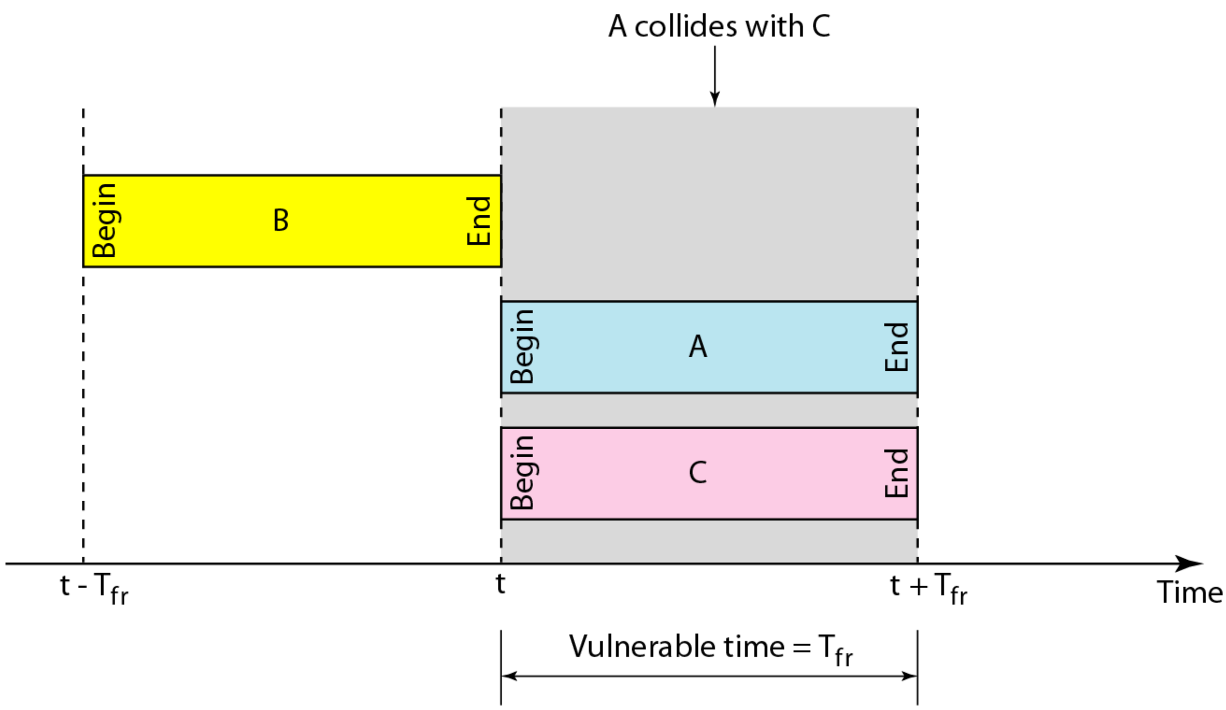


Note

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*

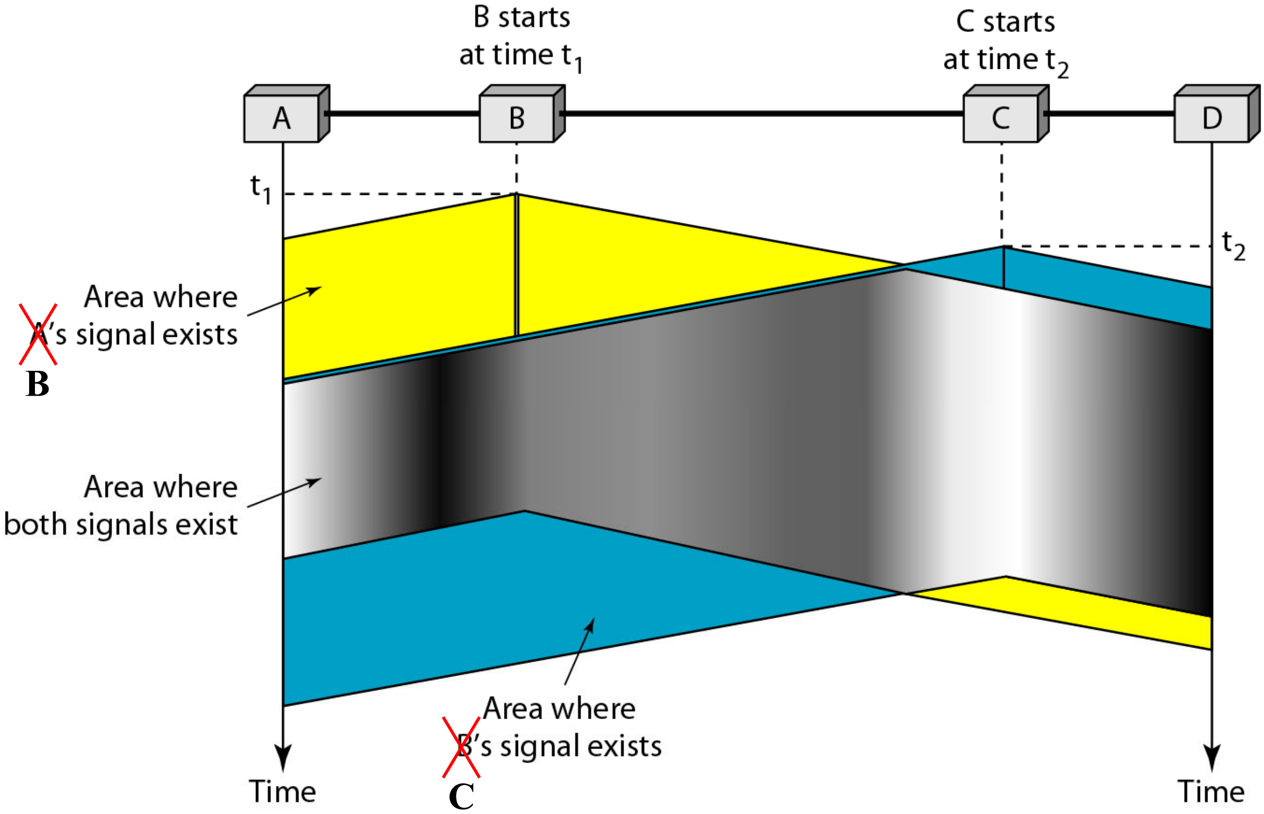


Figure 12.9 *Vulnerable time in CSMA*

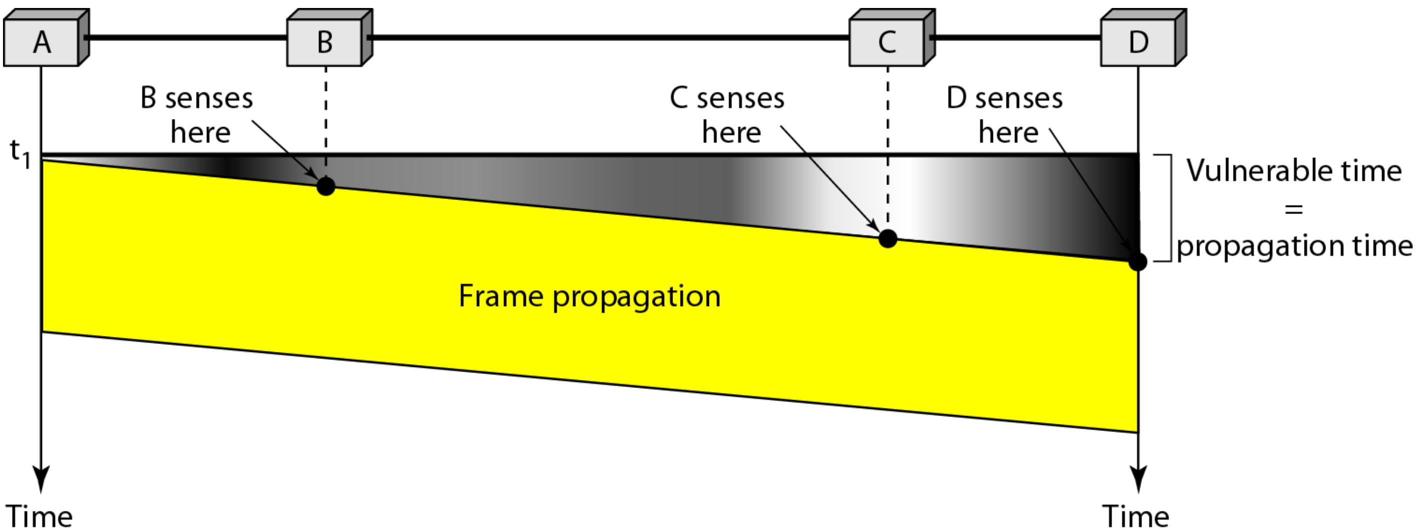


Figure 12.10 *Behavior of three persistence methods*

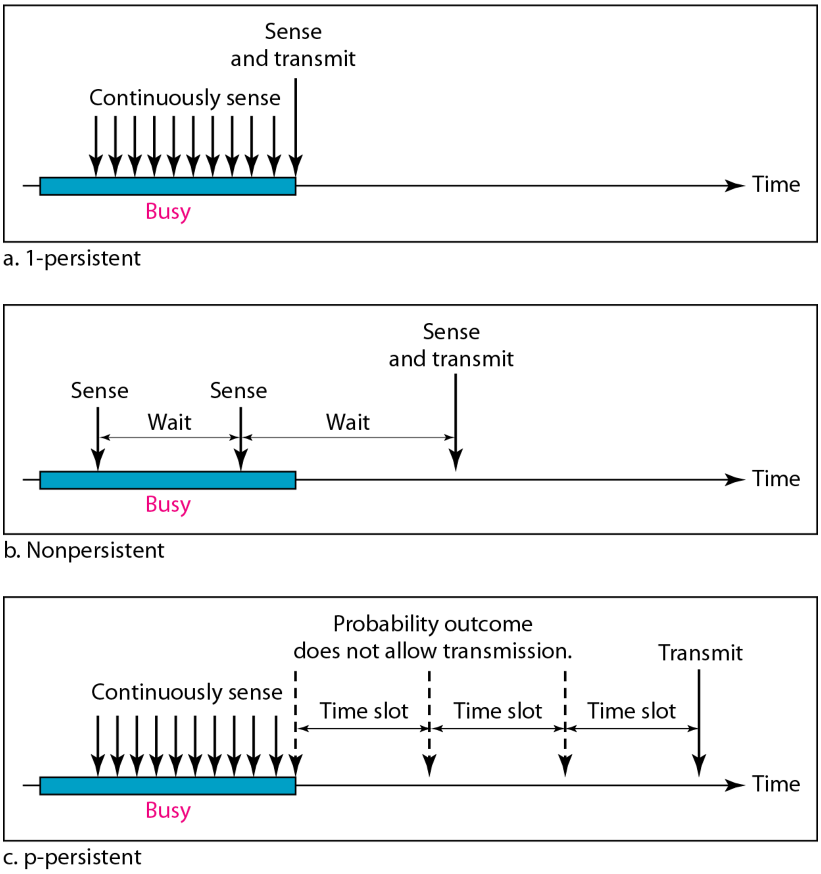


Figure 12.11 *Flow diagram for three persistence methods*

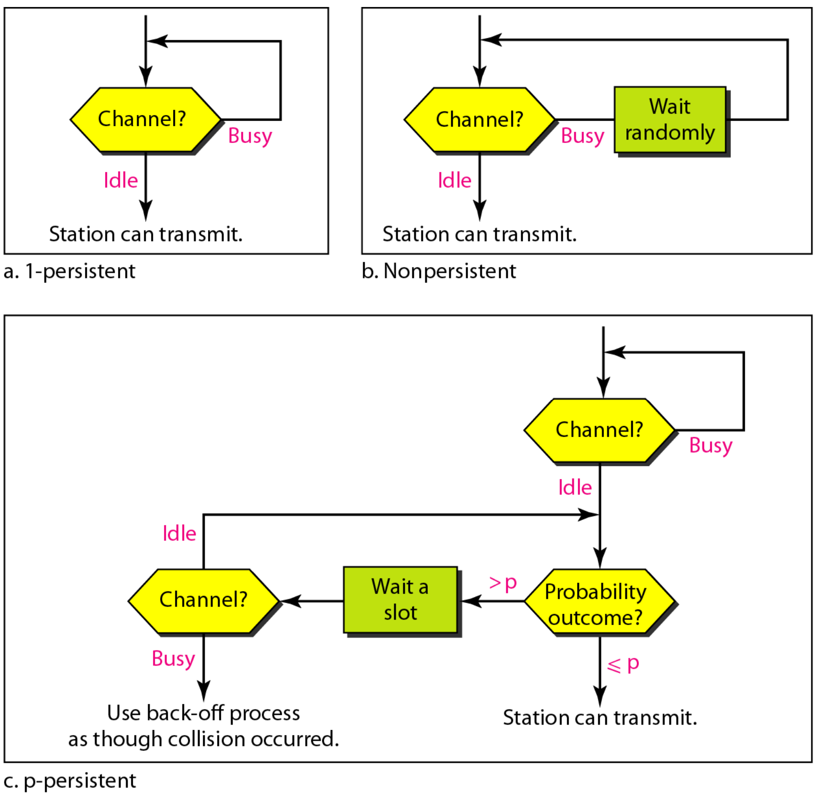


Figure 12.12 *Collision of the first bit in CSMA/CD*

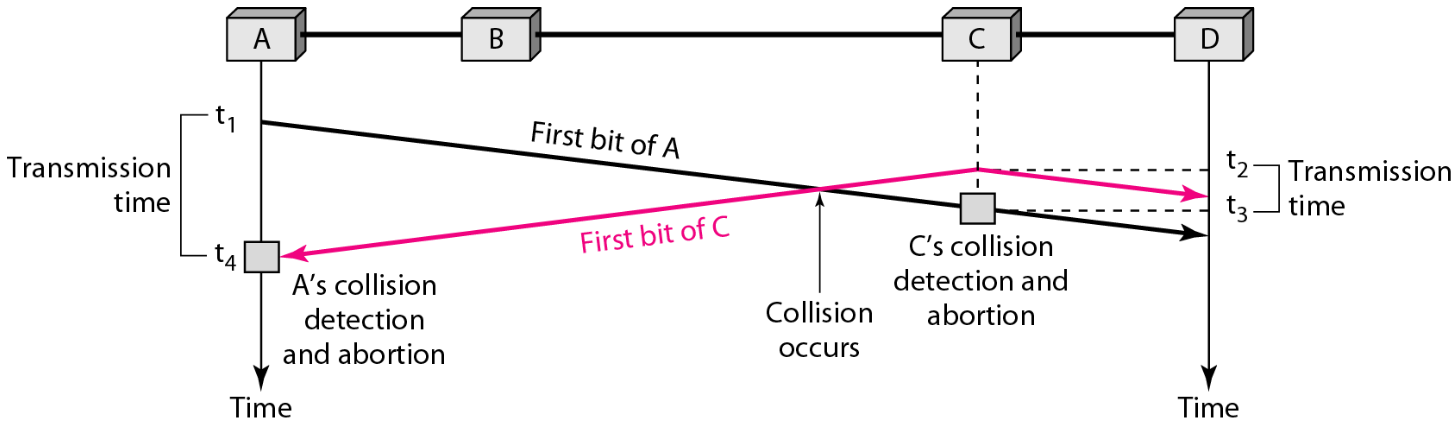
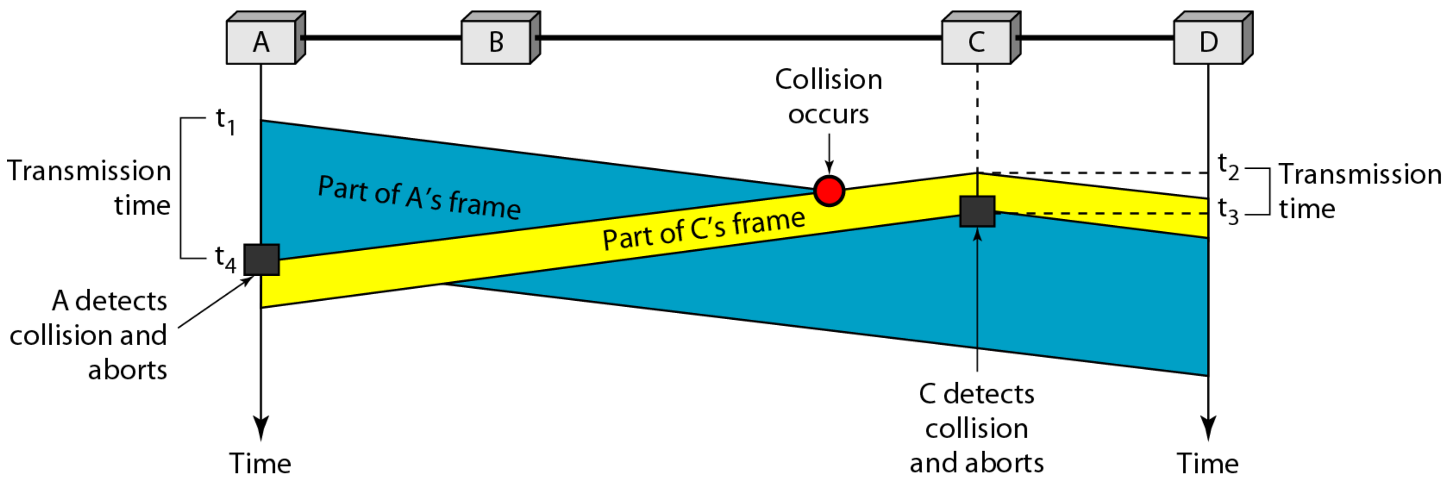


Figure 12.13 *Collision and abortion in CSMA/CD*



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 $\times$ 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*

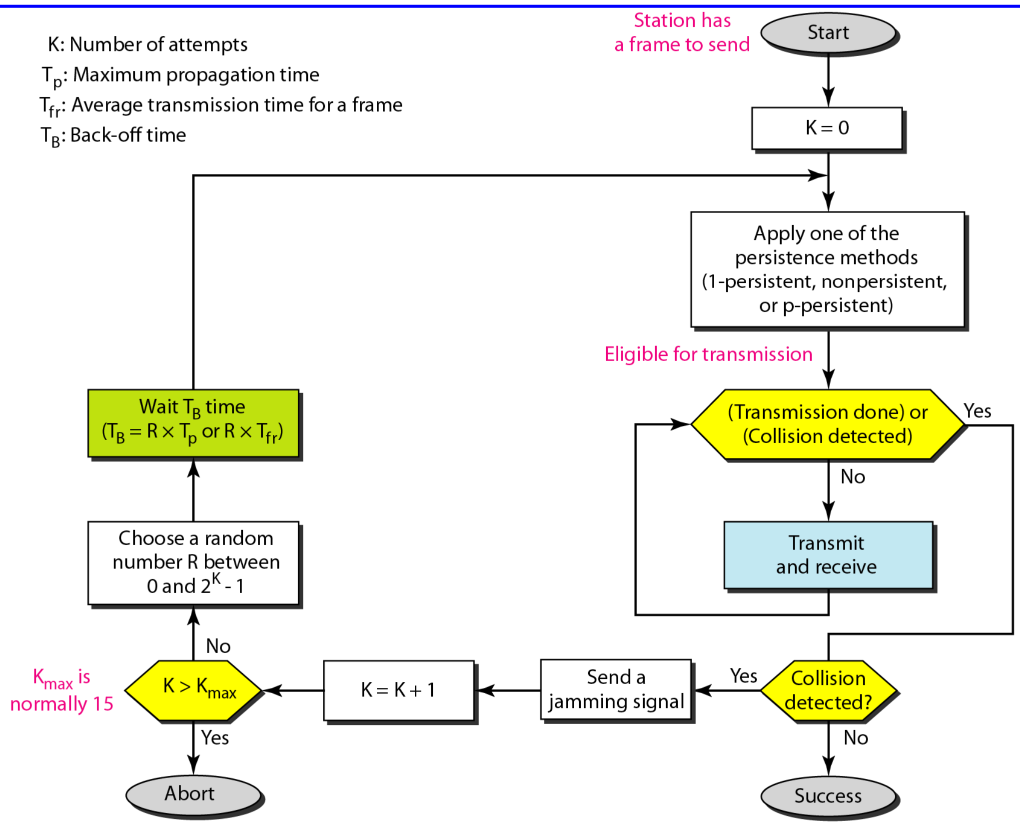


Figure 12.15 *Energy level during transmission, idleness, or collision*

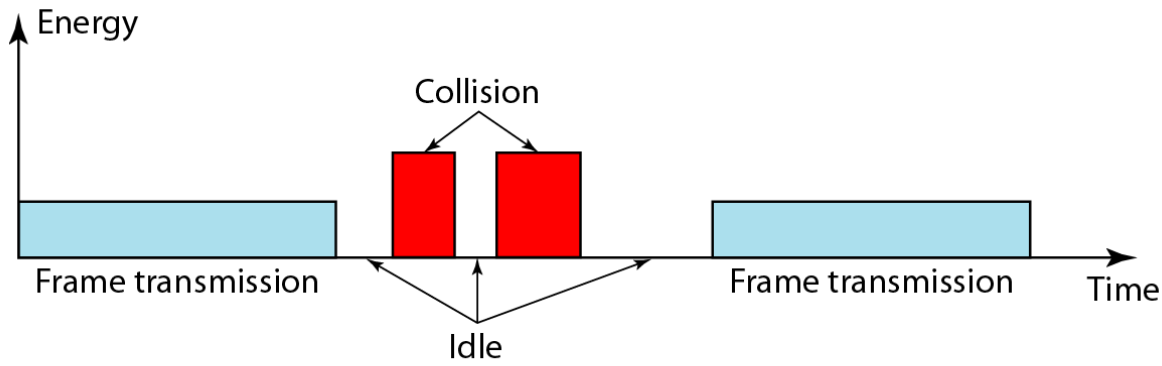
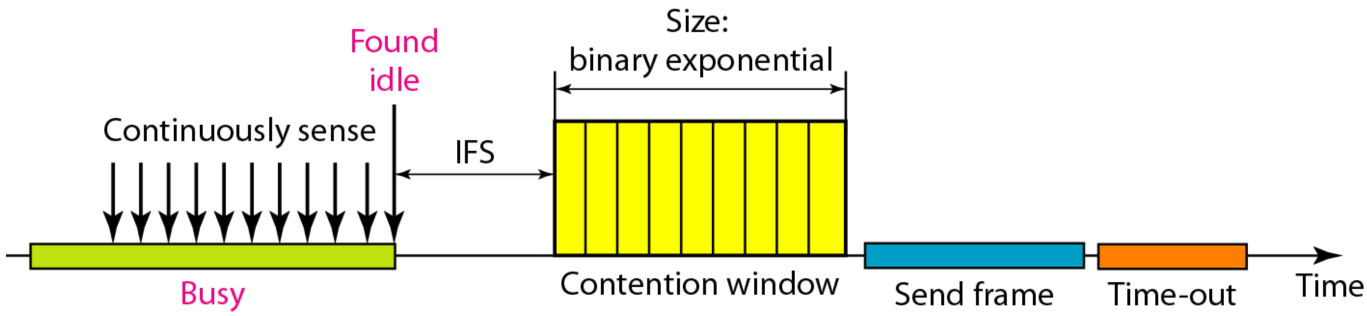


Figure 12.16 *Timing in CSMA/CA*



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*

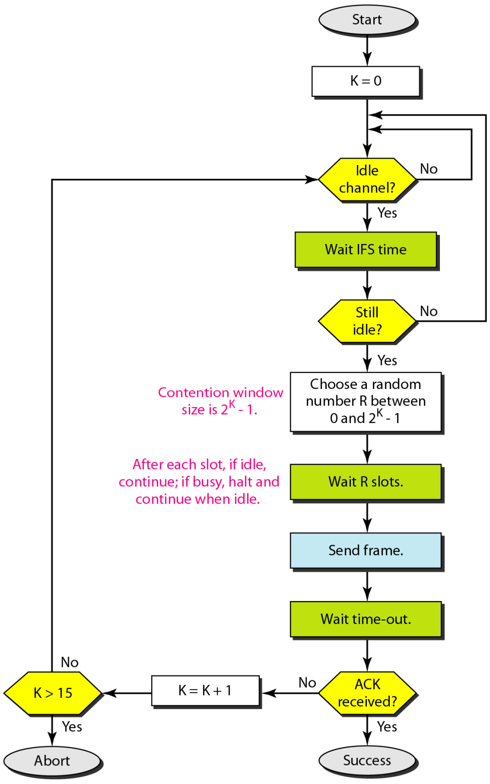
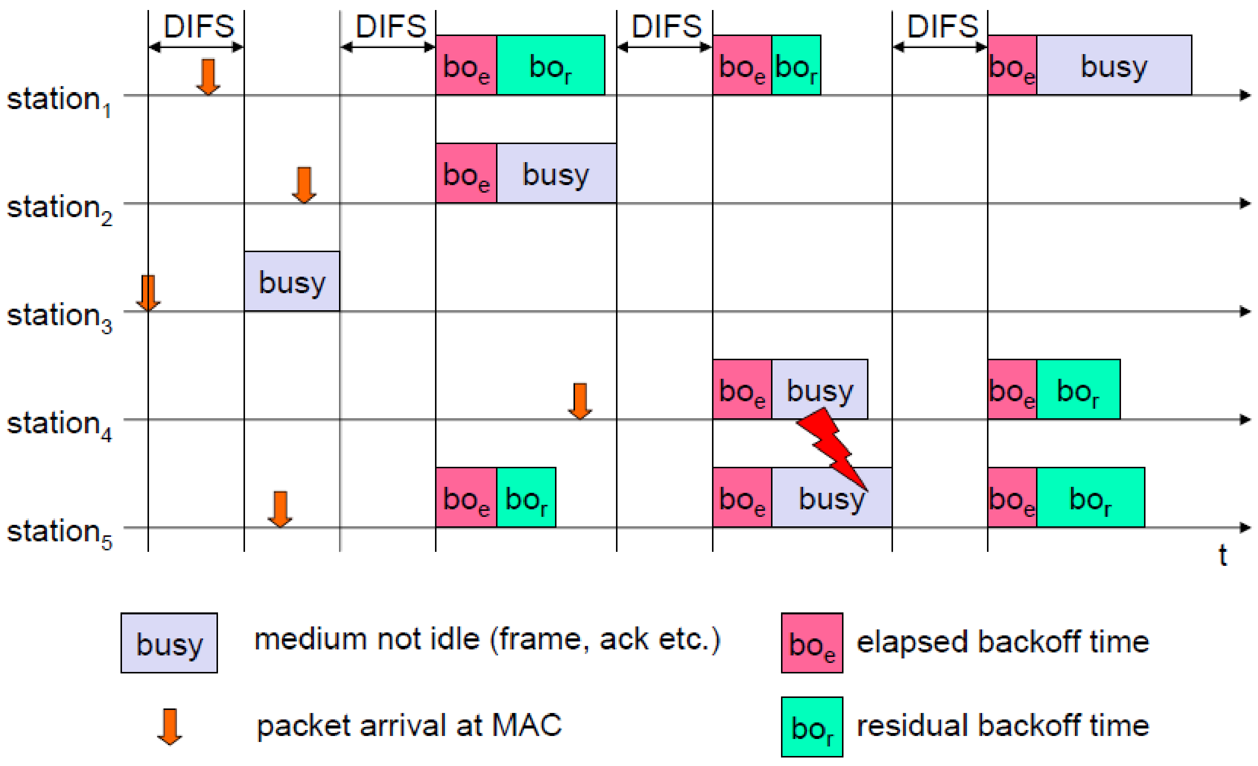


Figure. *802.11 Competing Stations*



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*

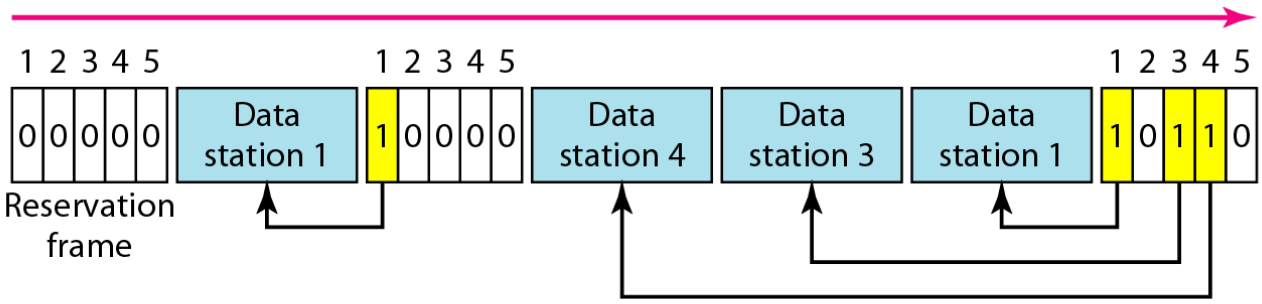


Figure 12.19 *Select and poll functions in polling access method*

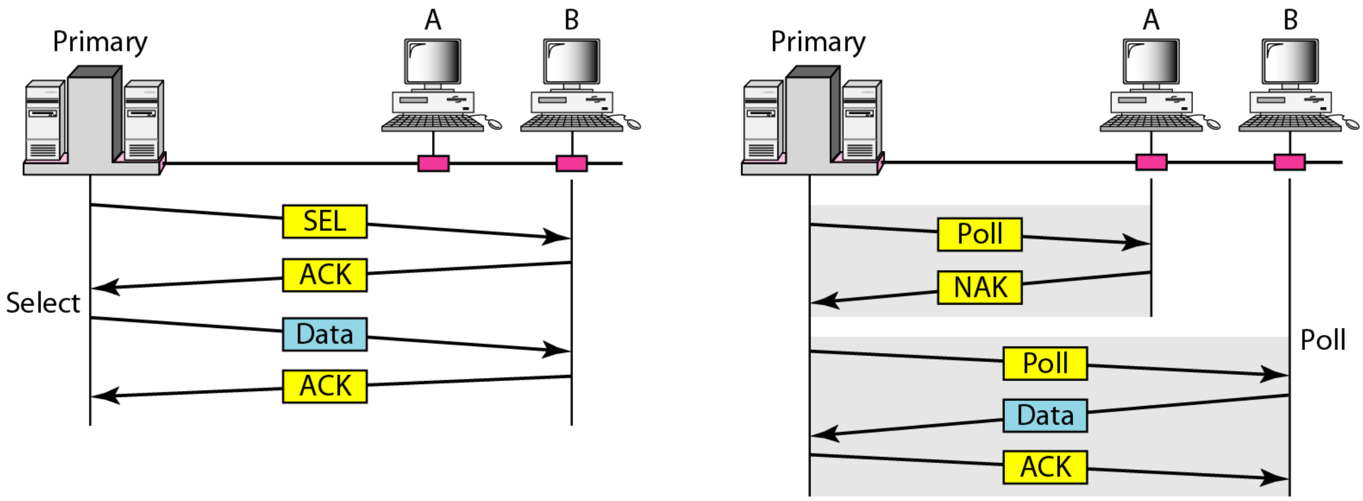
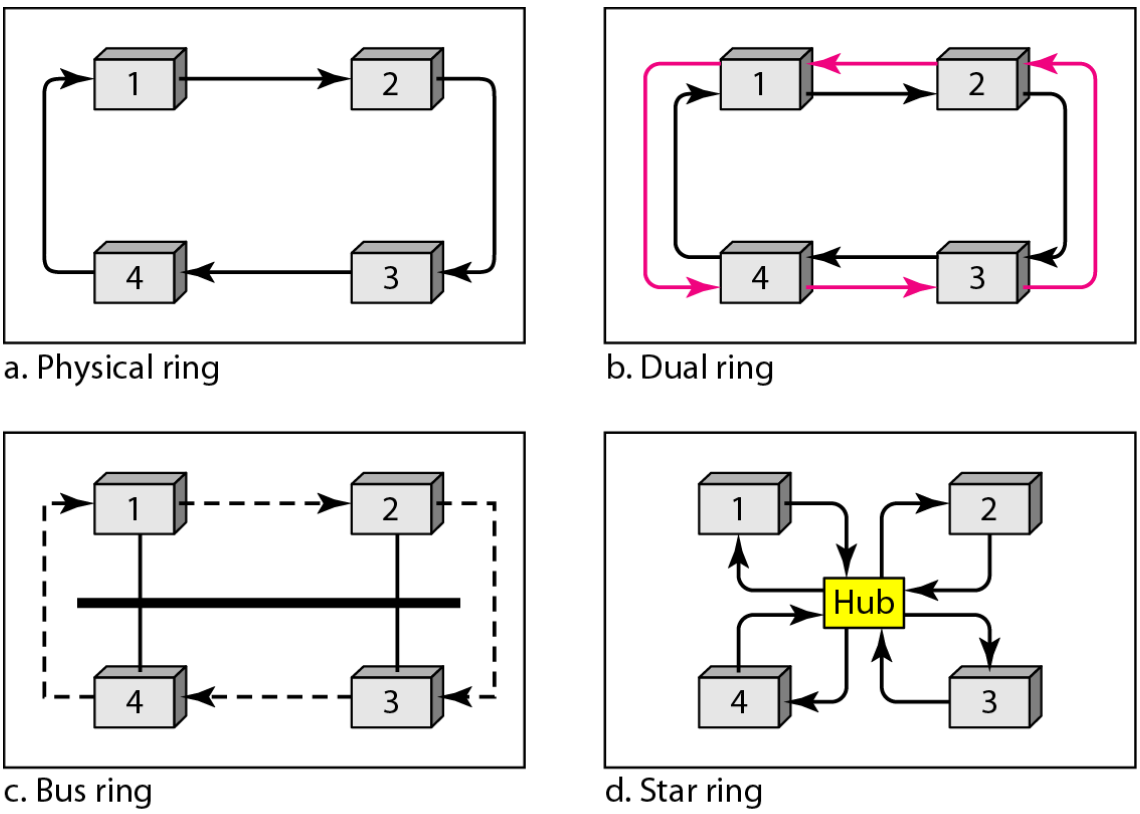


Figure 12.20 *Logical ring and physical topology in token-passing access method*



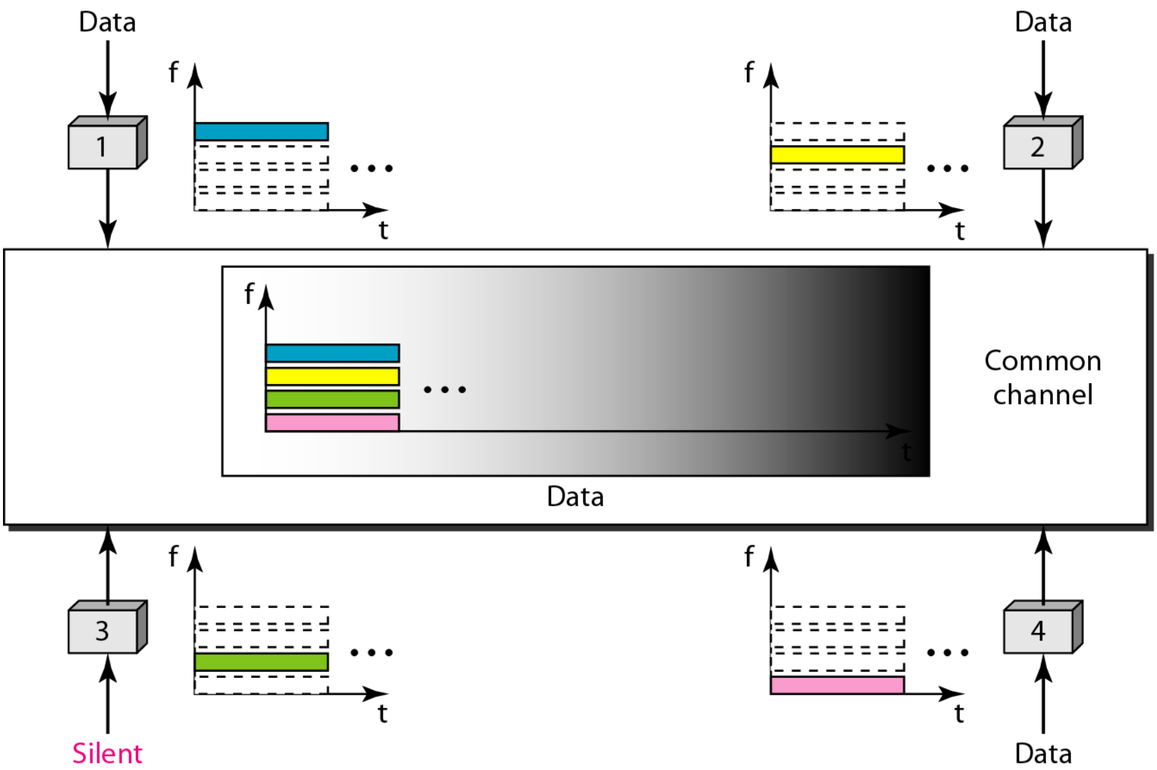
12-3 CHANNELIZATION

***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)

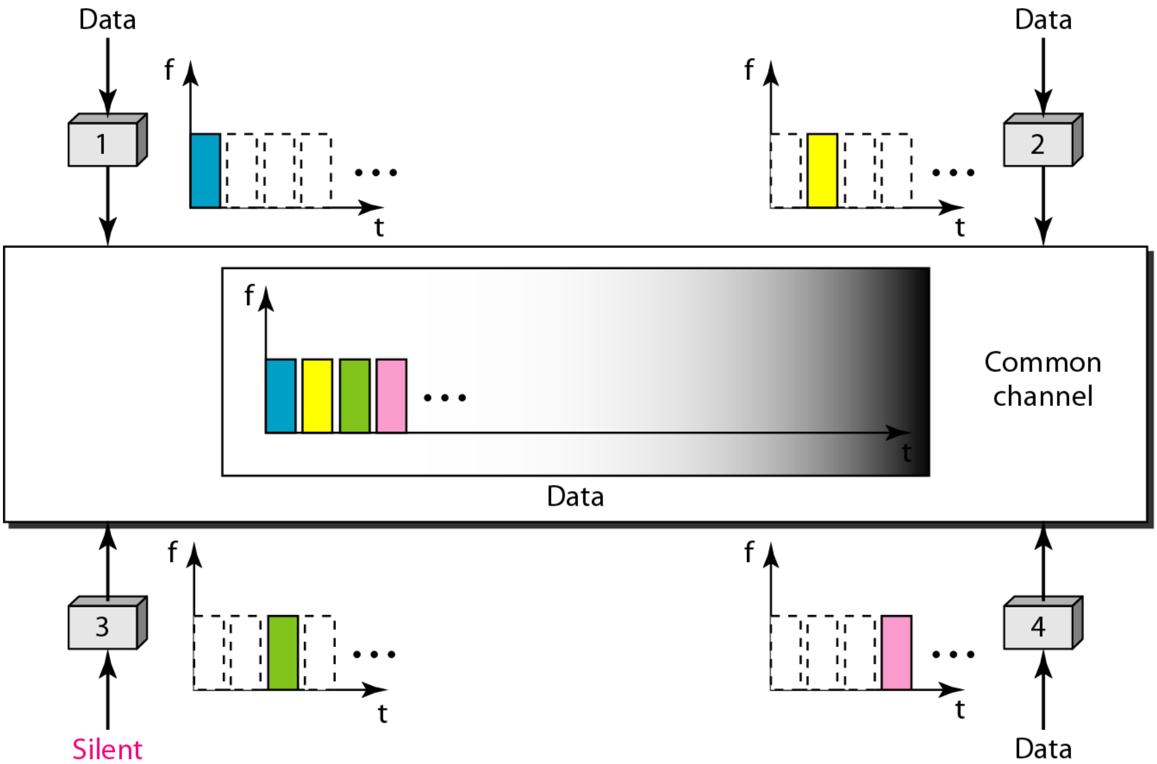
Figure 12.21 *Frequency-division multiple access (FDMA)*



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*

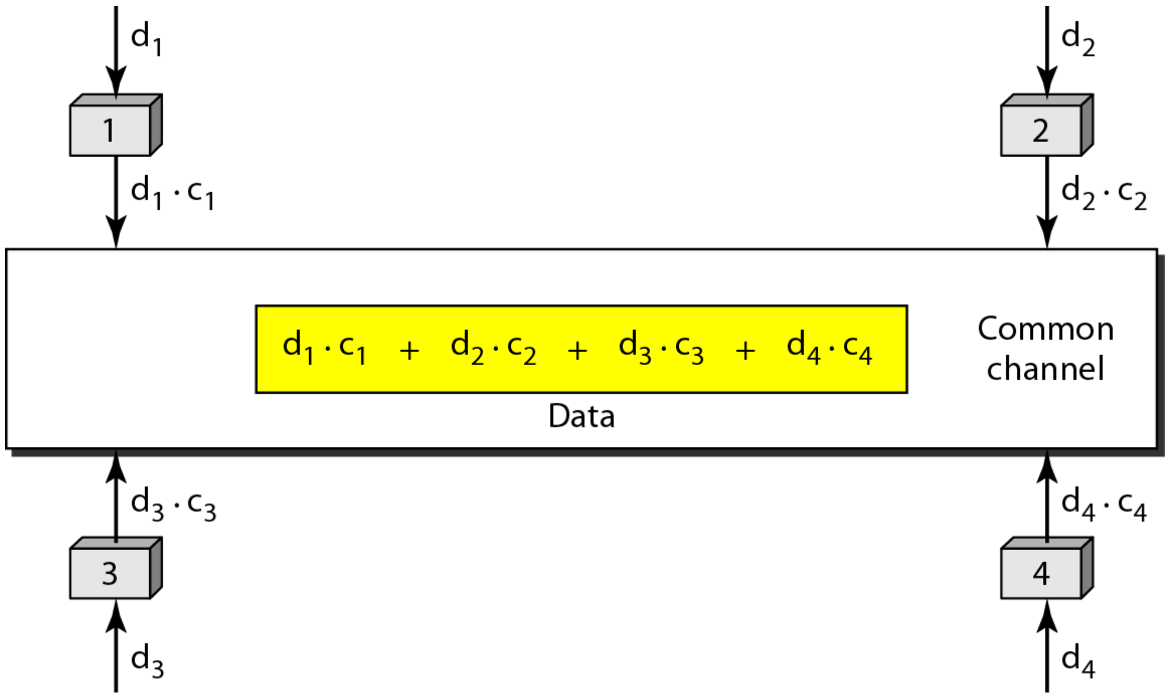


Figure 12.24 *Chip sequences*

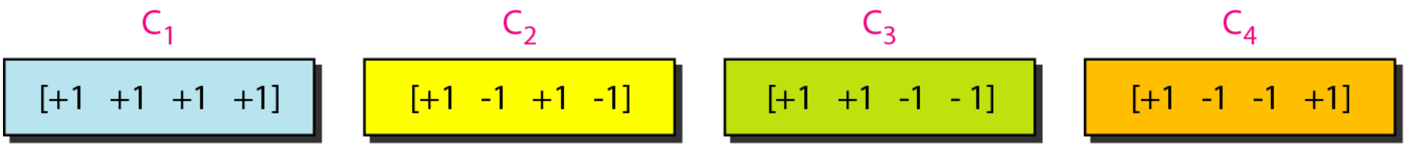


Figure 12.25 *Data representation in CDMA*

Figure 12.26 *Sharing channel in CDMA*

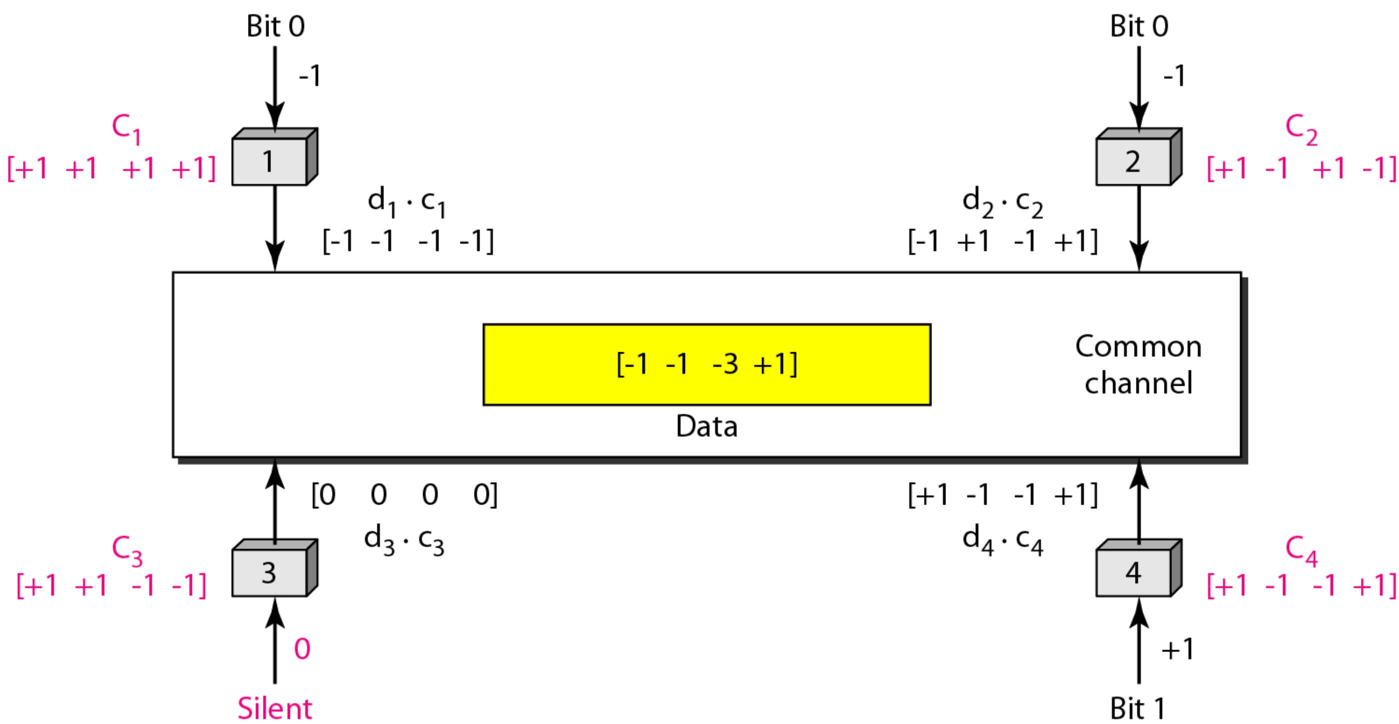


Figure 12.27 *Digital signal created by four stations in CDMA*

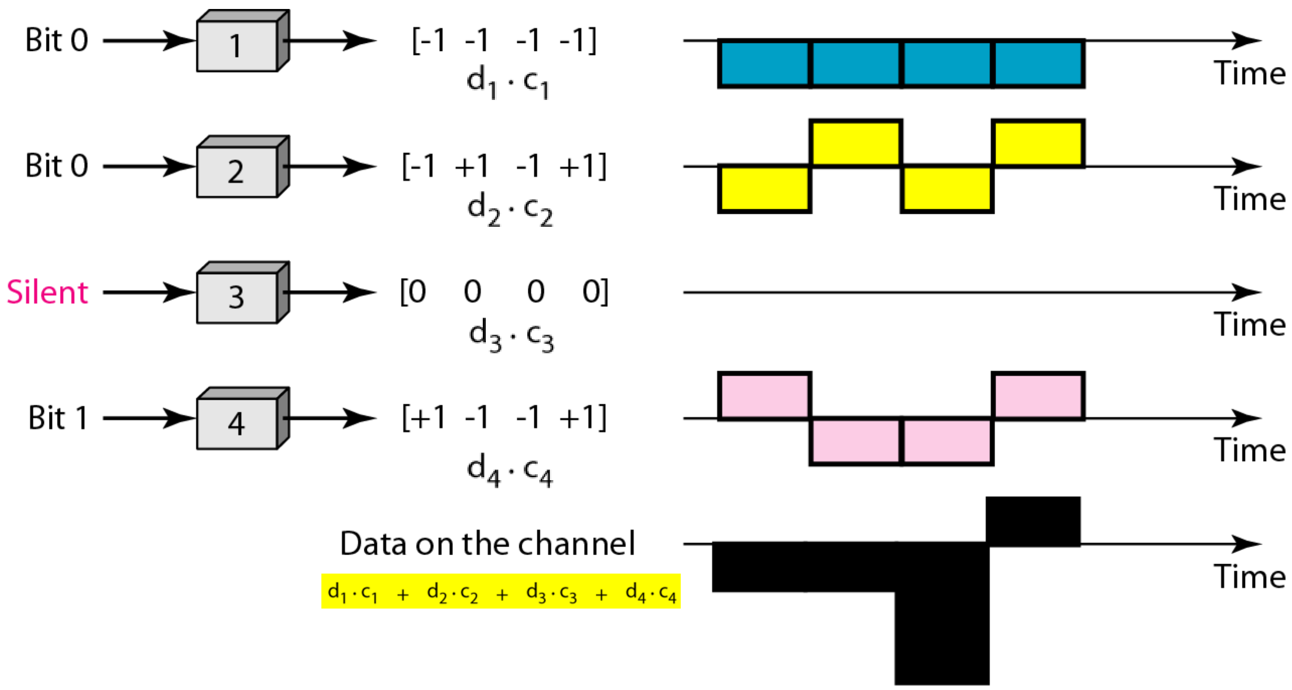


Figure 12.28 *Decoding of the composite signal for one in CDMA*

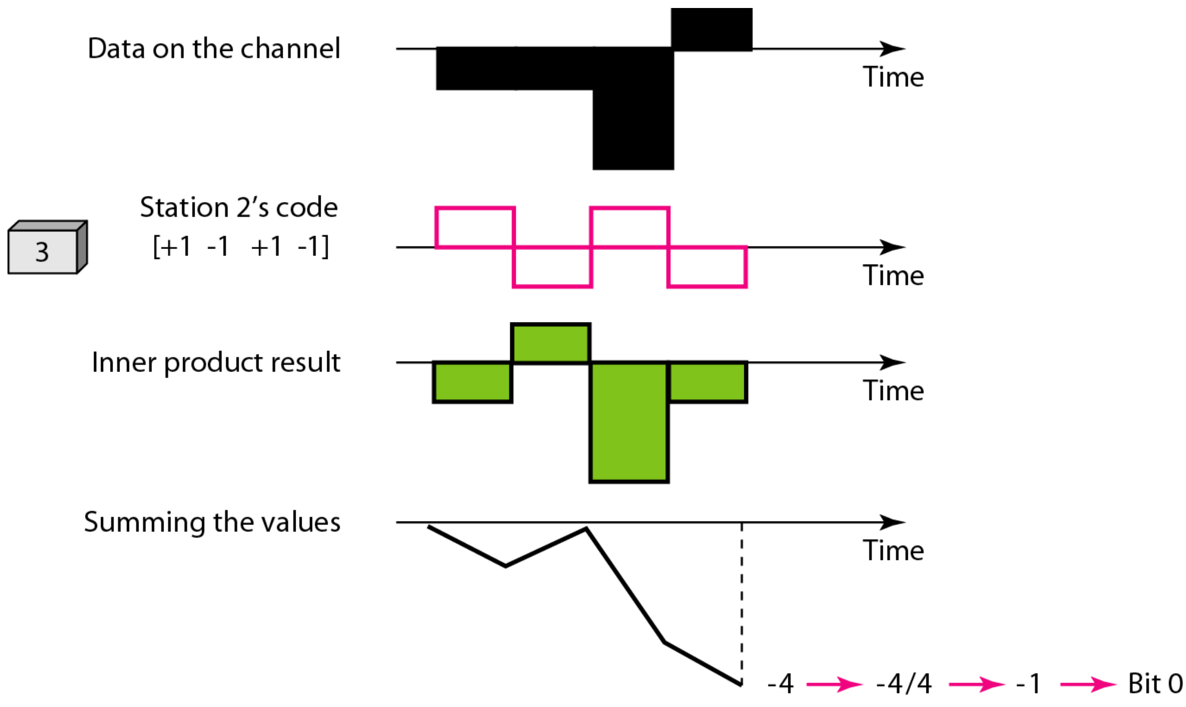


Figure. *Orthogonal Frequency Division Multiple Access (OFDMA)*

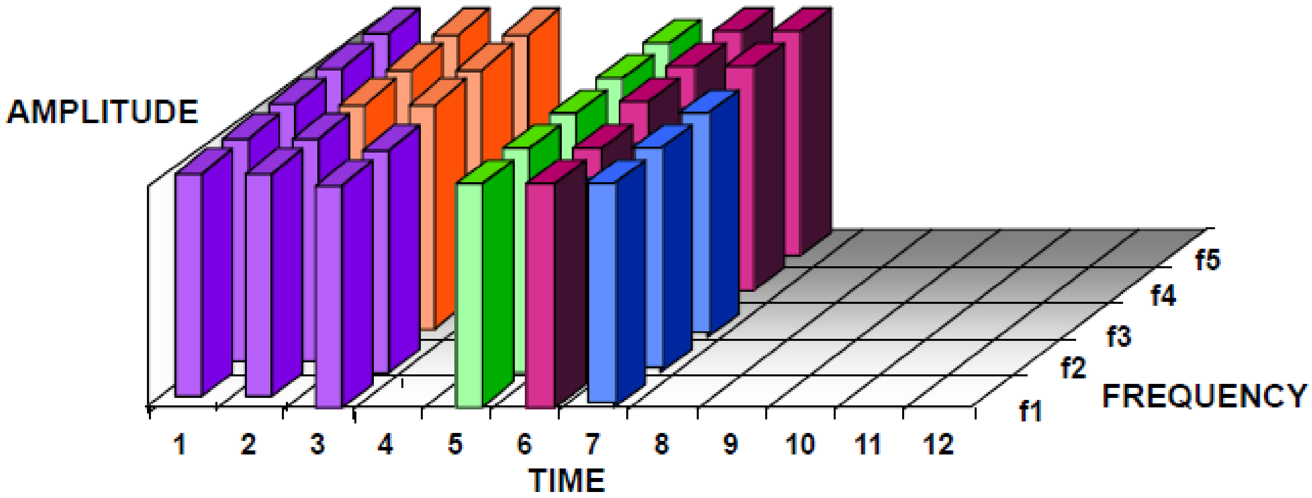


Figure. *Difference between multiple access mechanisms*

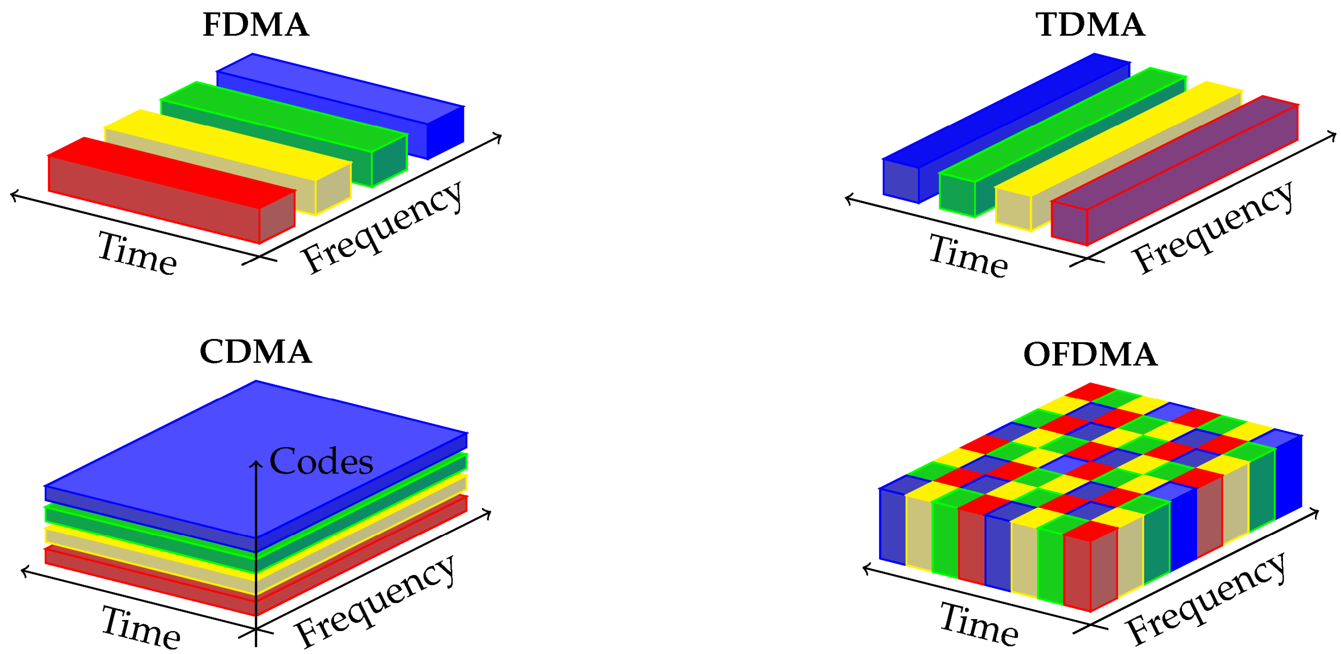
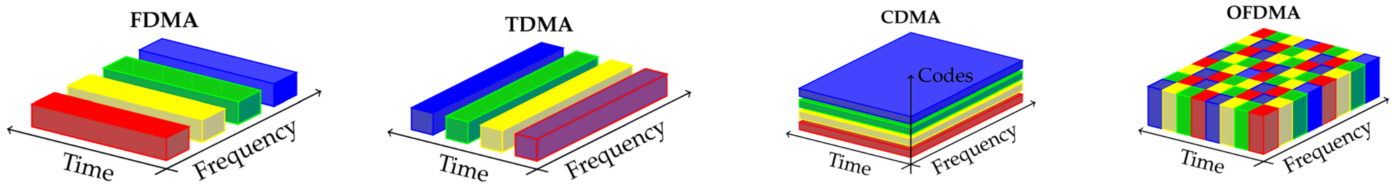


Figure. *Difference between multiple access mechanisms*



간단함(쉬움) **구현 복잡도** 복잡함(어려움)

비교적 작다(속도가 느리다) **전송 용량** 비교적 크다(속도가 빠르다)

Figure. *Non-Orthogonal Multiple Access (NOMA)*

SIC : Successive Interference Cancellation