Data Communications and Networking Fourth Edition

Forouzan

# Chapter 12

# Multiple Access

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

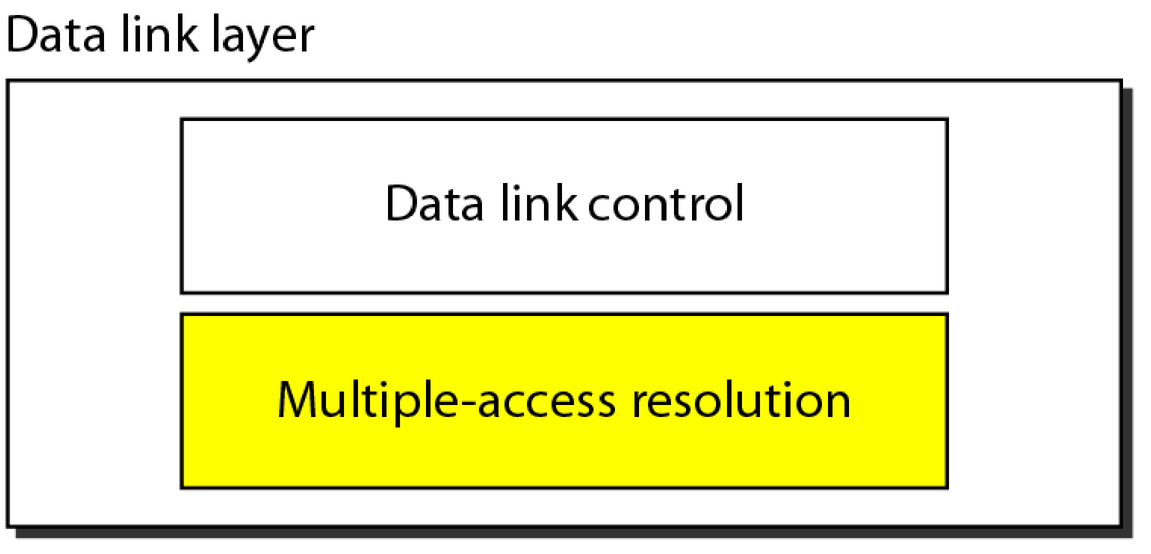
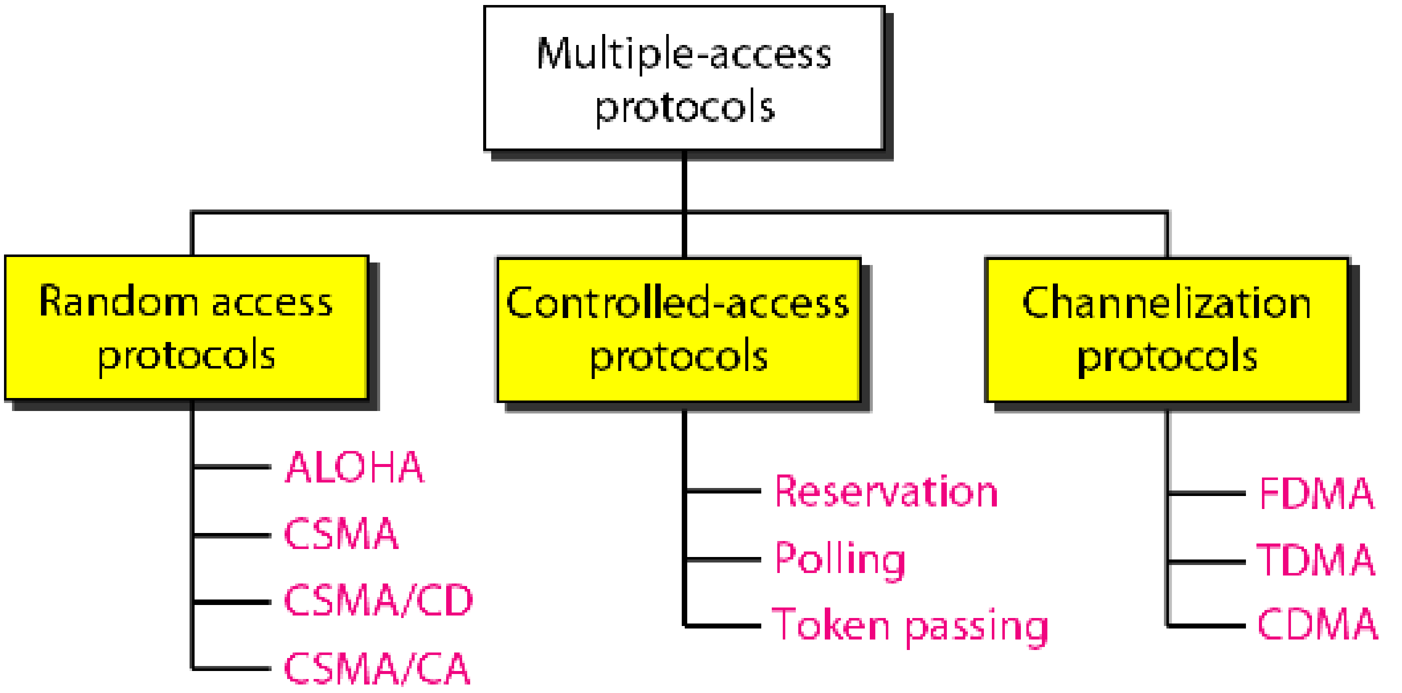


**Figure 12.2** ***Taxonomy of multiple-access protocols discussed in this chapter***



## 12-1 RANDOM ACCESS

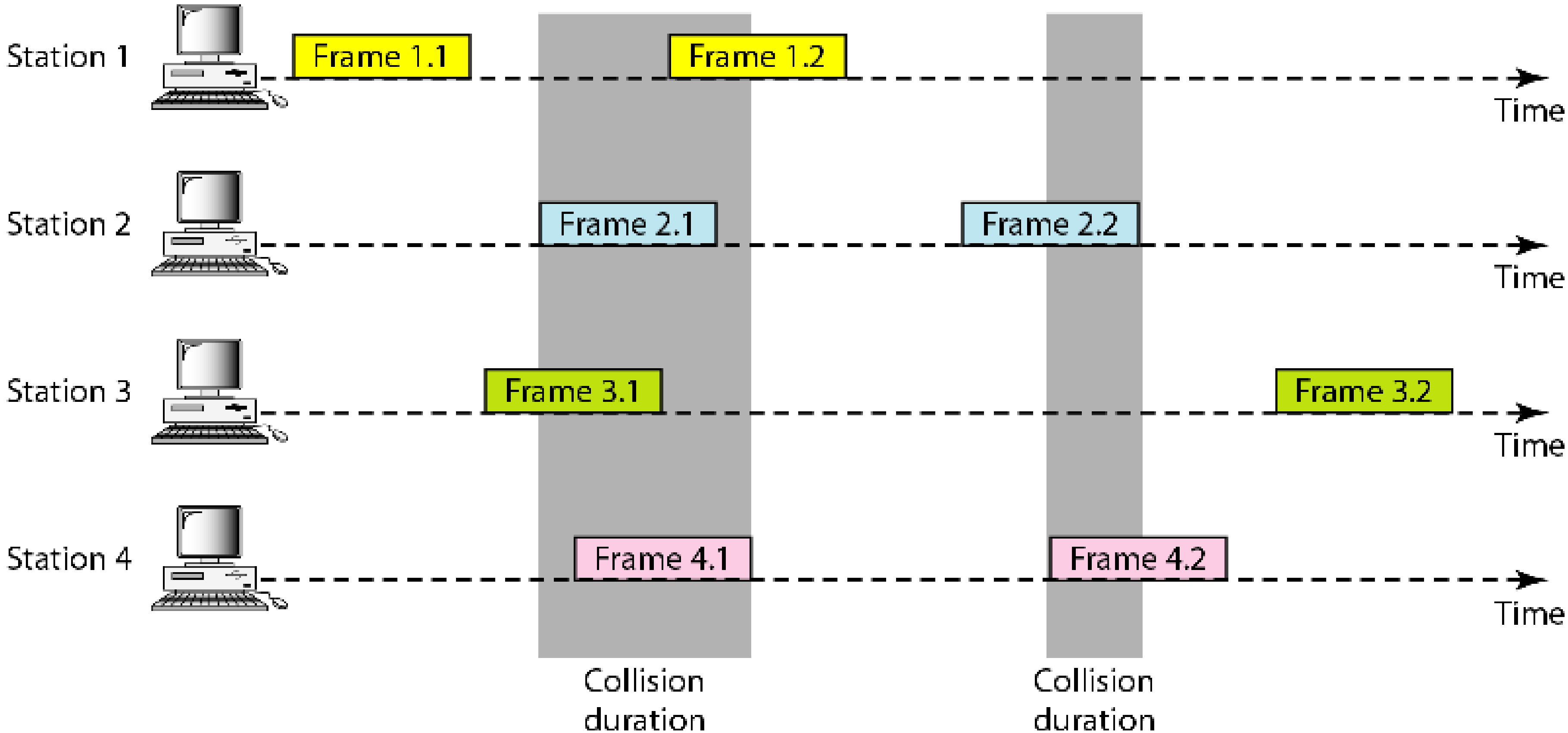
***In random access or contention methods, no station is superior to another station and none is assigned the control over another.***

***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.***

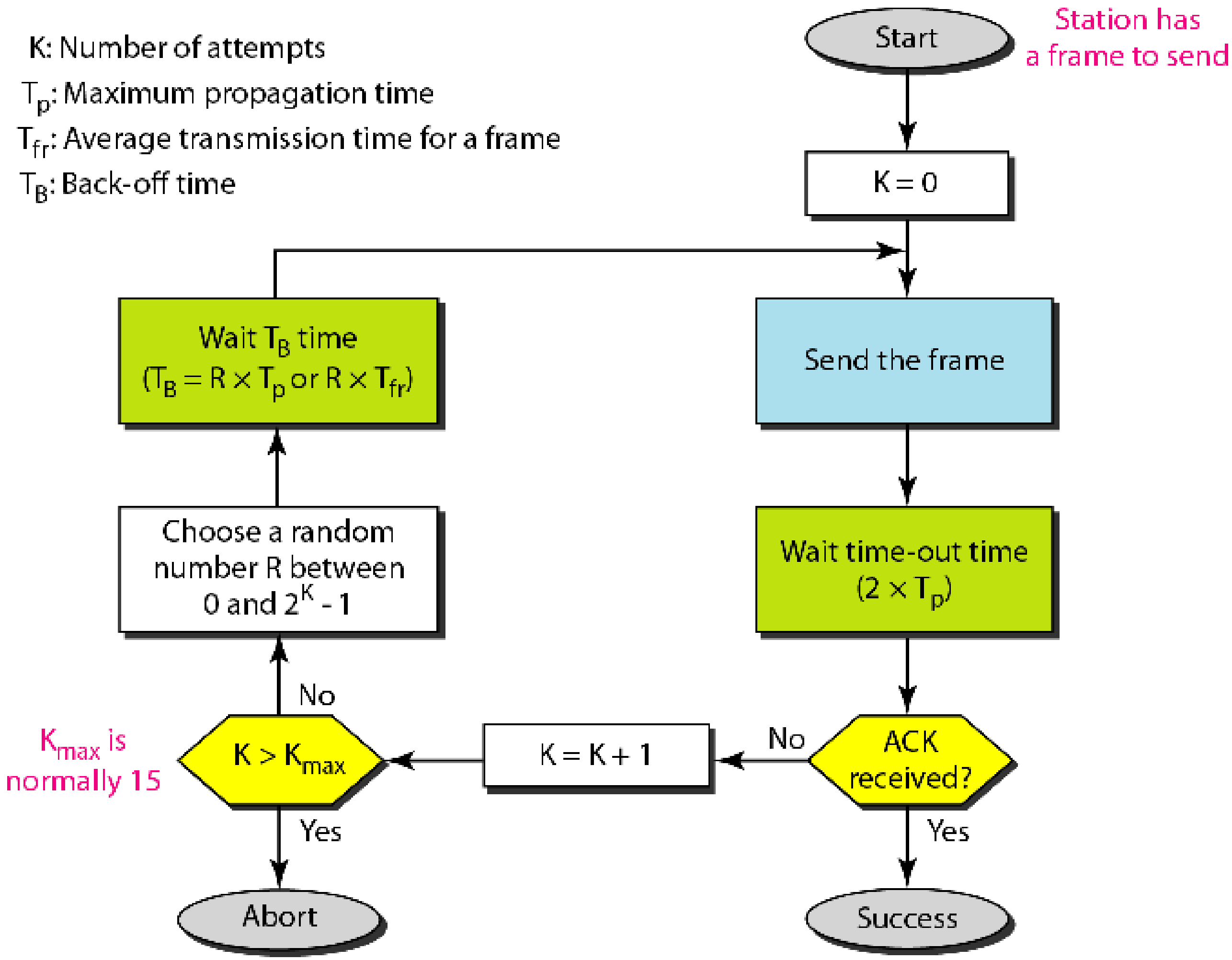
***Topics discussed in this section:***

**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 $3 \times 10^8$ 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 ($0 \times 2$) or 2 ms***

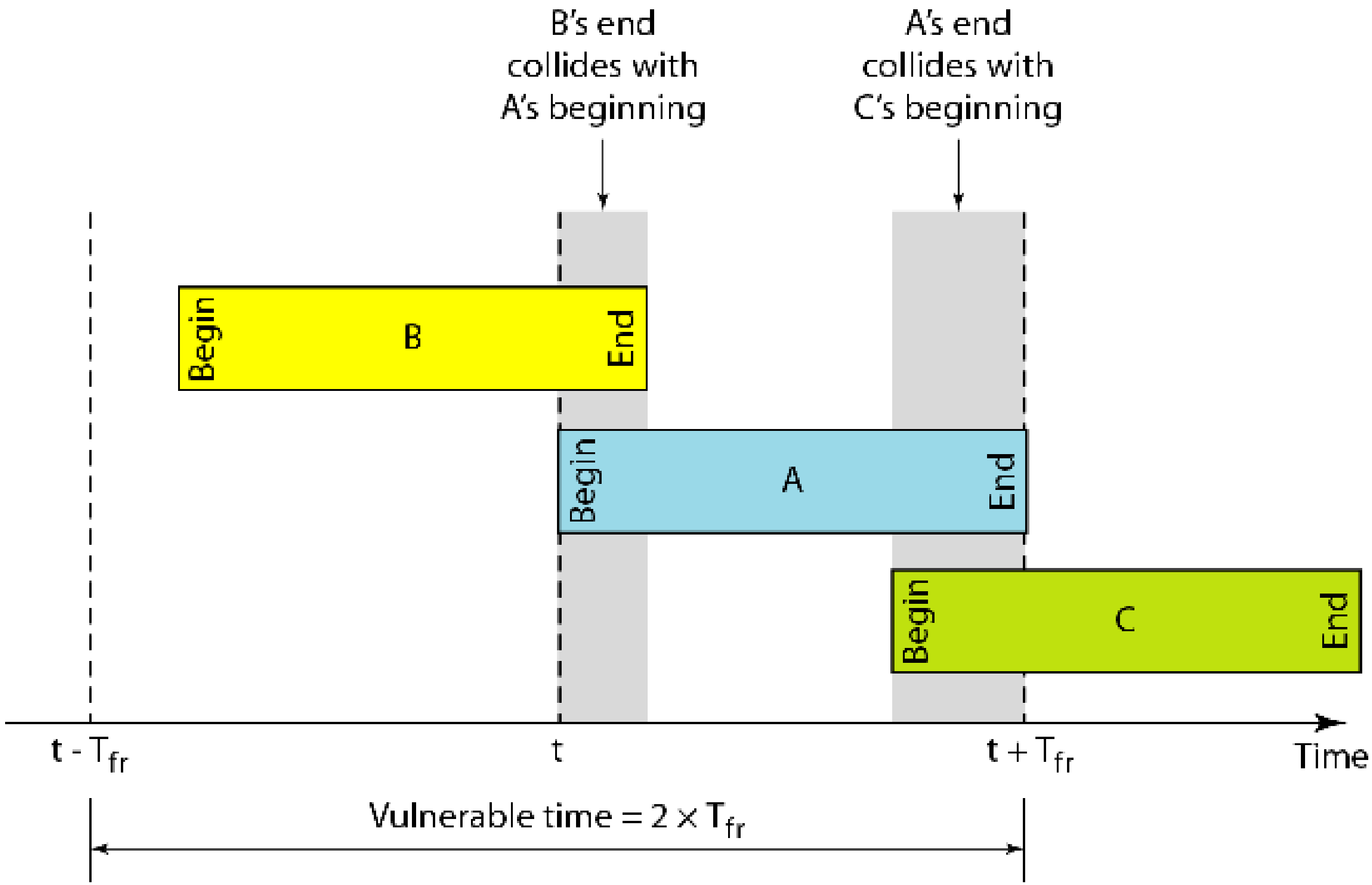
# Example 12.1 (continued)

**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*

## 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.***

The throughput for pure ALOHA is

$$S = G \times e^{-2G}$$

Where G is frames per milli sec called load.

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

## Solution

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

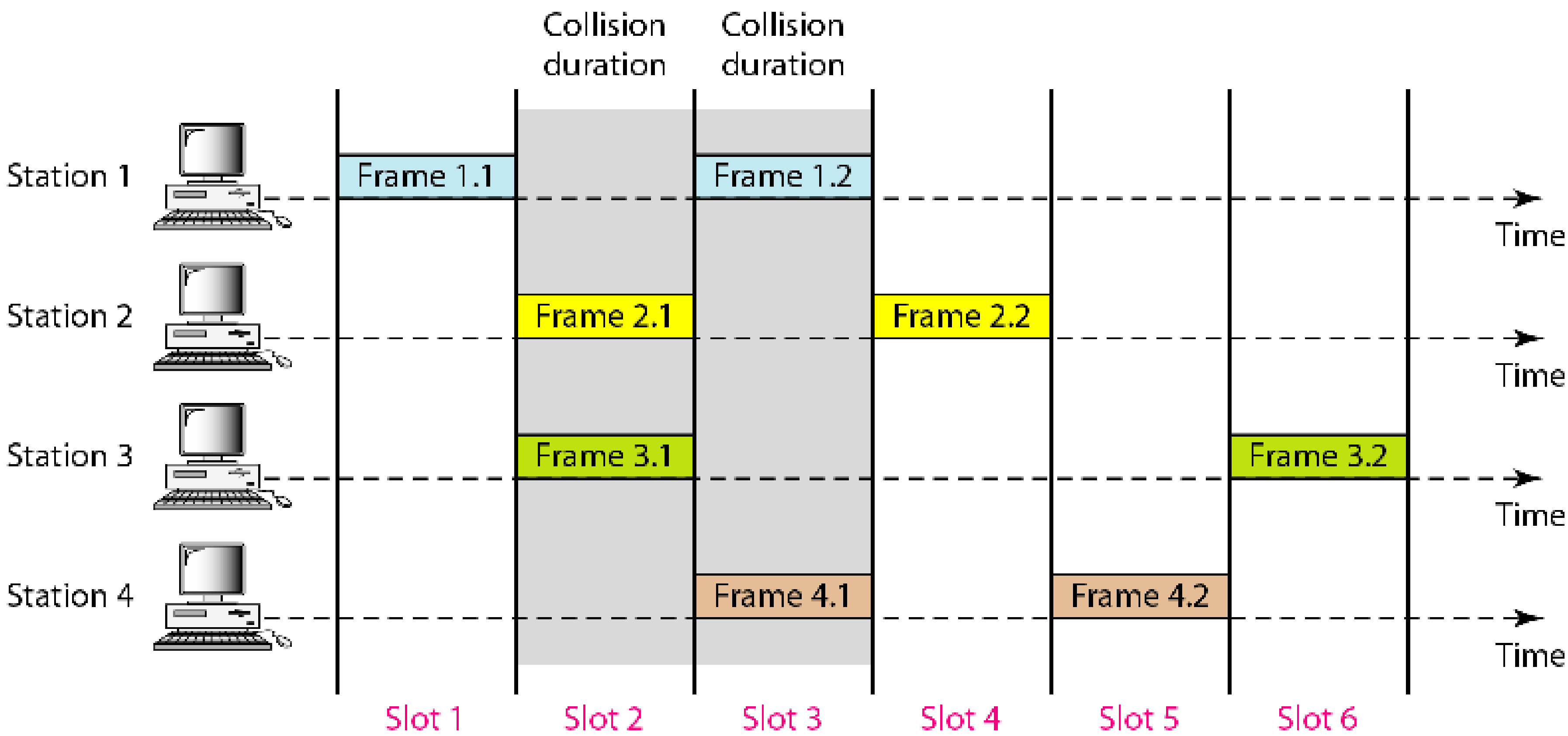
a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case $S = G \times e^{-2G}$ or $S = 0.135$ (13.5 percent). This means

## 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,

## Figure 12.6 *Frames in a slotted ALOHA network*



***Note***

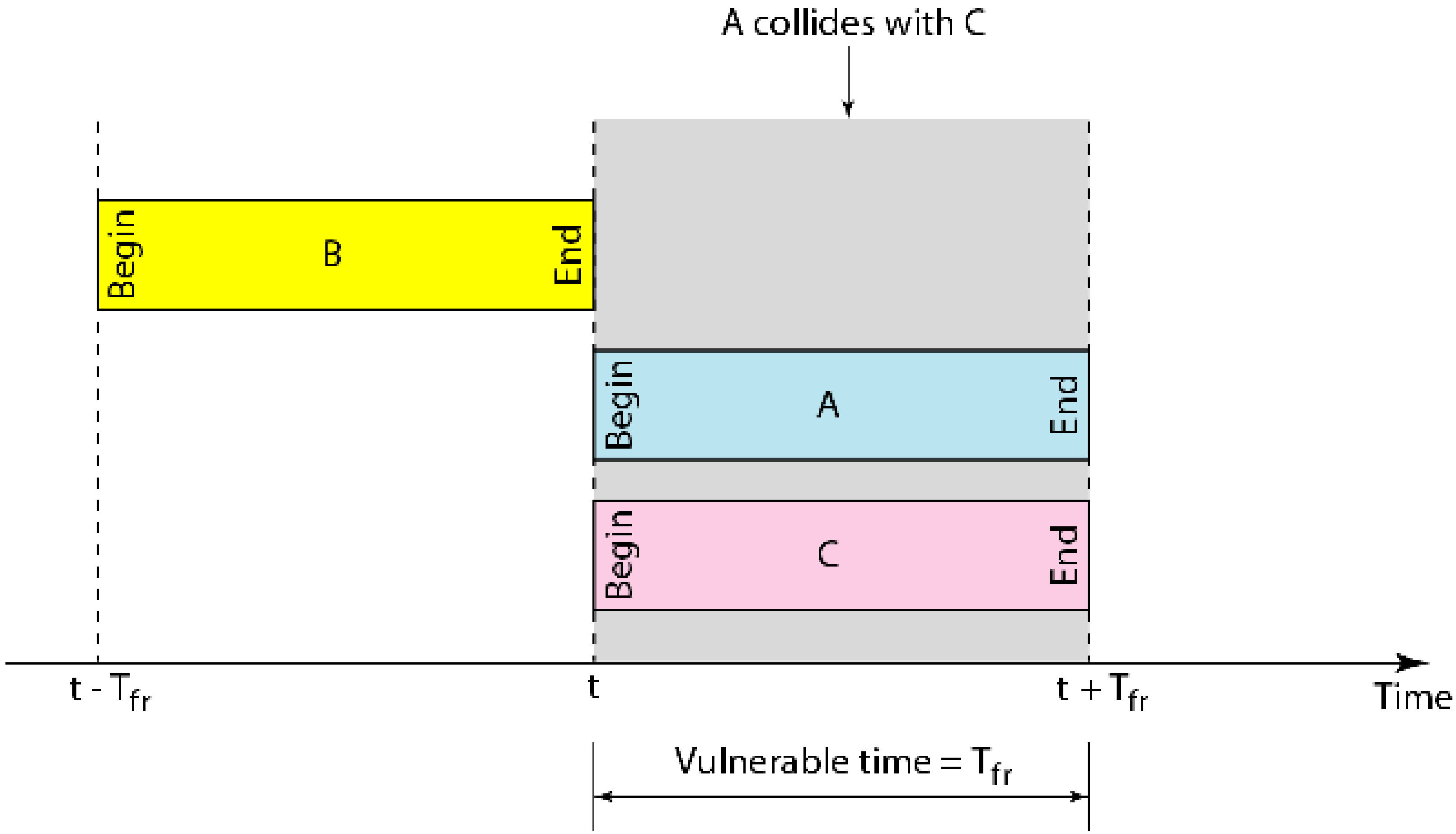
**The throughput for slotted ALOHA is**

**$S = G \times e^{-G}$ .**

**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*

## 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*

# 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*

# CSMA basic notion

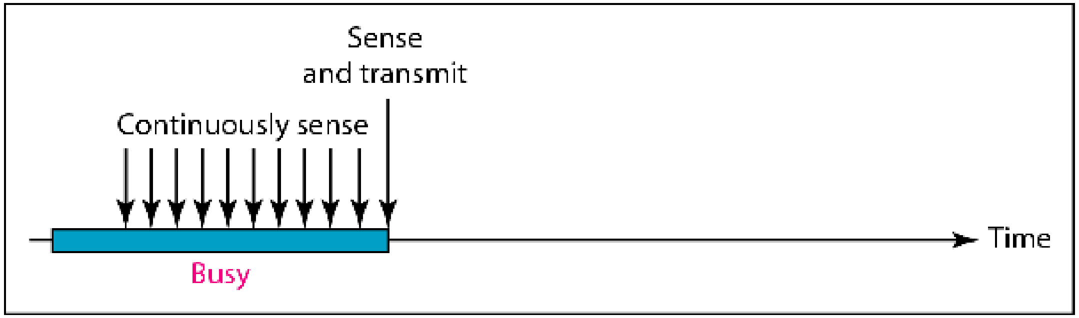
- From previous examples, it is clear that in ALOHA and slotted ALOHA, there are significant chances of Collison.
- Thus, the CSMA method is invented in which the channel is sensed before transmission.

- CSMA is based on the principle "sense before transmit" or "listen before talk."
- CSMA can reduce the possibility of collision, but it cannot eliminate it because of propagation delay.
- when a station sends a frame, it still takes time (although very short) for the first bit to reach every station and for every station to sense it.
- In other words, a station may sense the medium and find it idle, only because the first bit sent by another station has not yet been received
- The vulnerable time for CSMA is the propagation time (Tp)

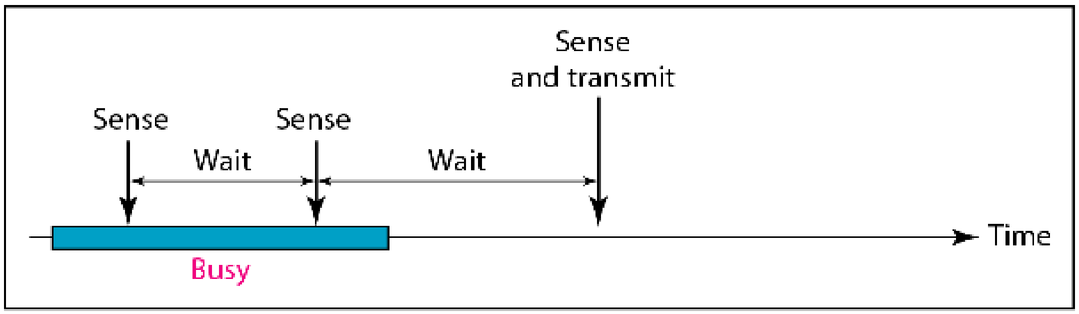
# *Persistence Methods*

- What should a station do if the channel is busy?
- What should a station do if the channel is idle?
- Three methods have been devised to answer these questions:

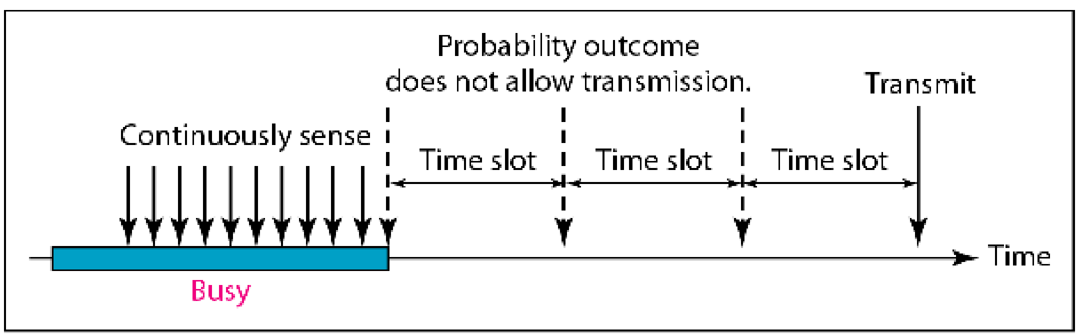
# Figure 12.10 *Behavior of three persistence methods*




a. 1-persistent

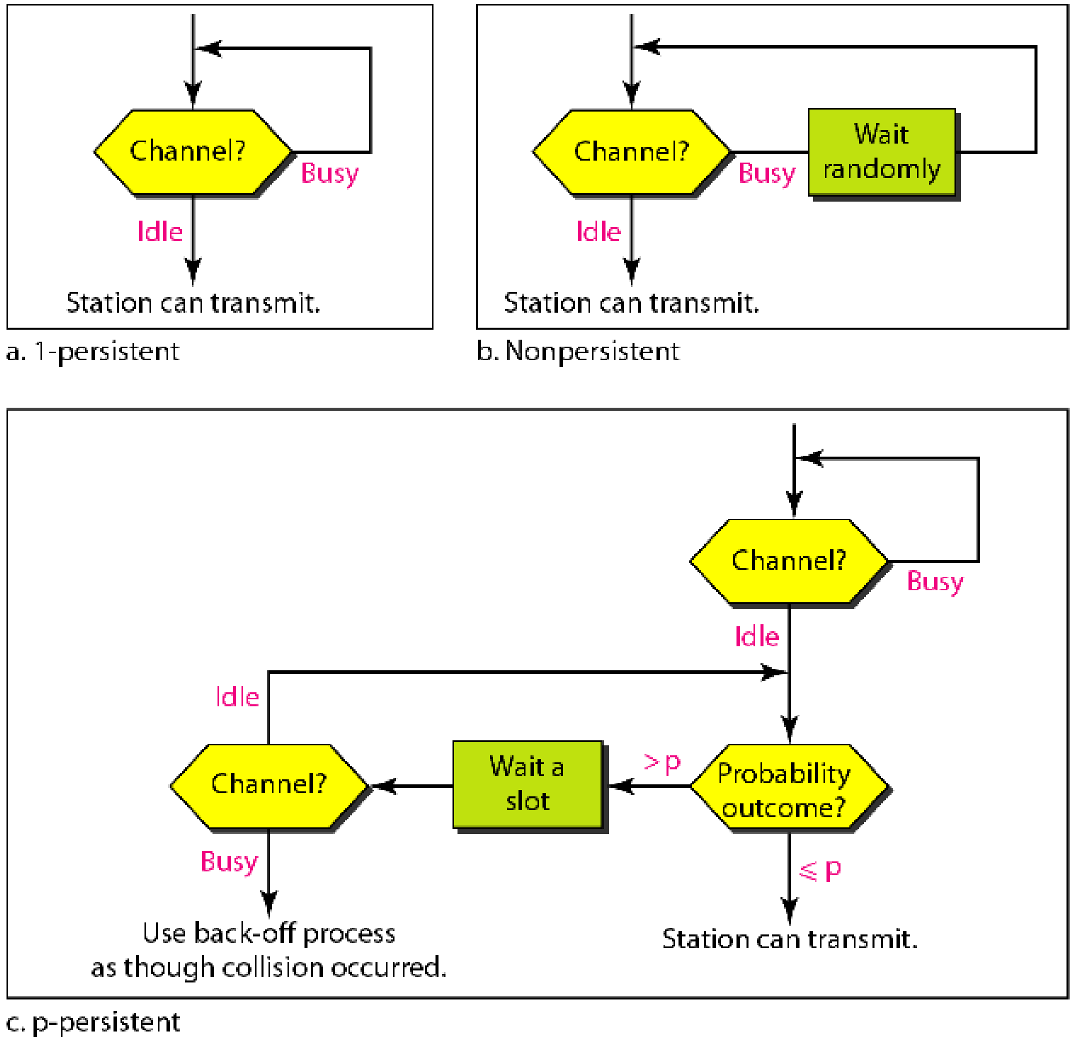



b. Nonpersistent

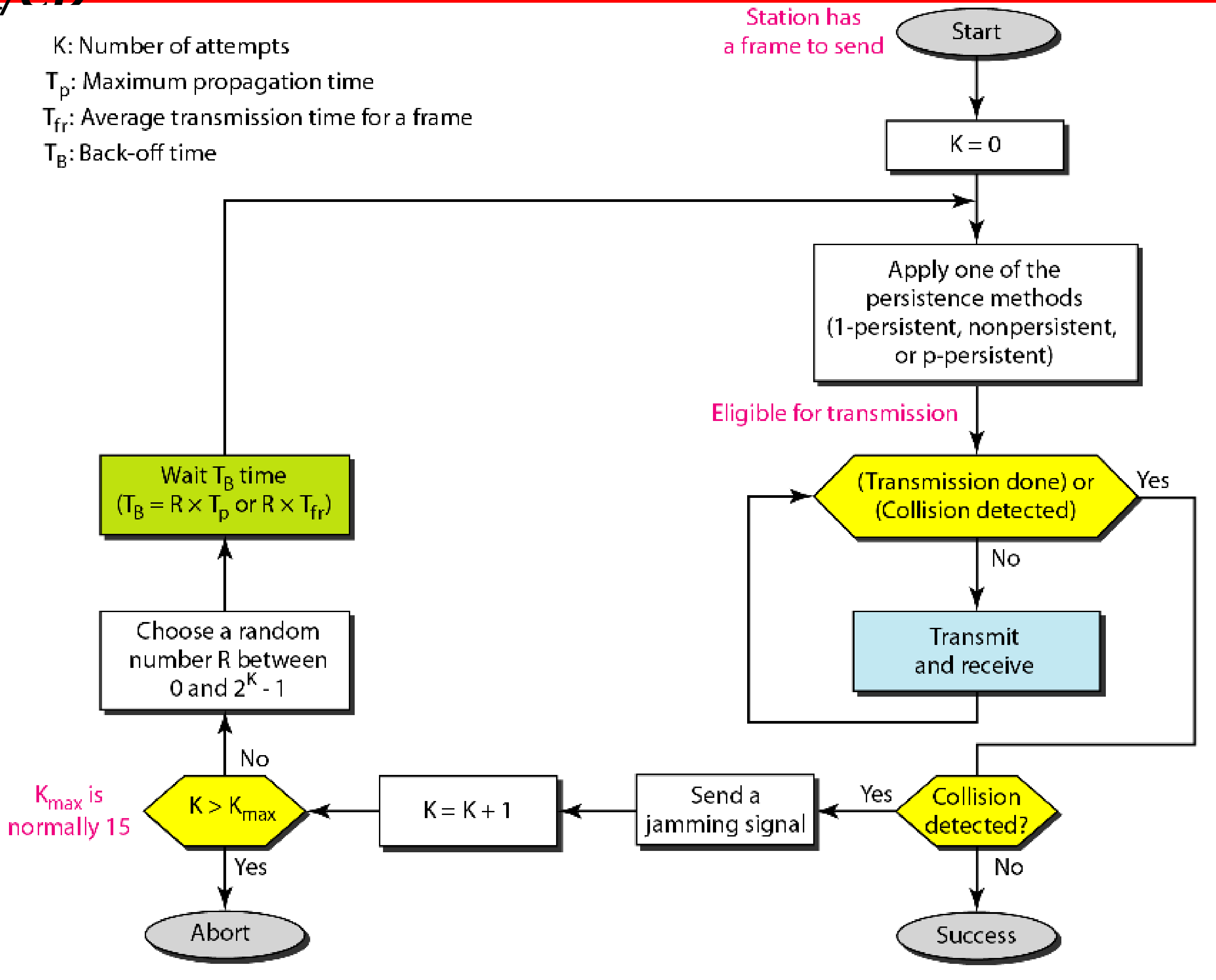



c. p-persistent

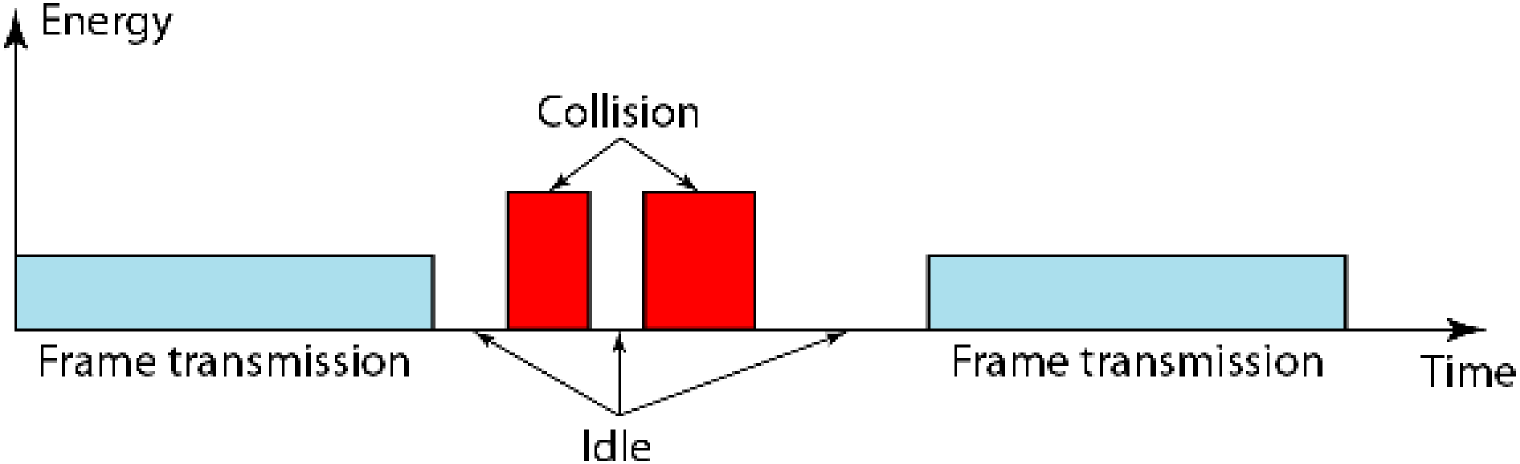
# Figure 12.11 *Flow diagram for three persistence methods*



## **Figure 12.14** *Flow diagram for the CSMA/CD*

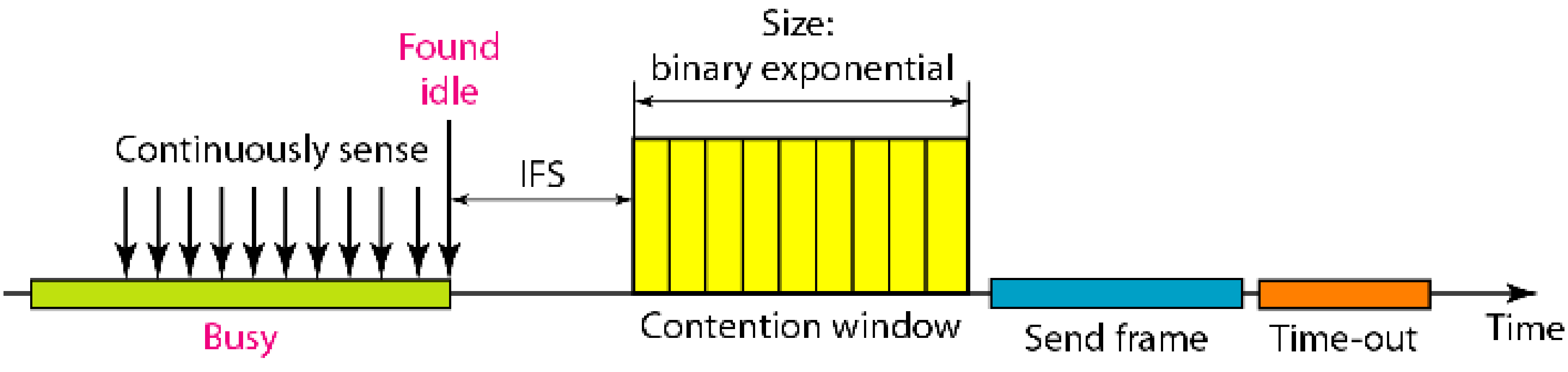


## Figure 12.15 *Energy level during transmission, idleness, or collision*



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

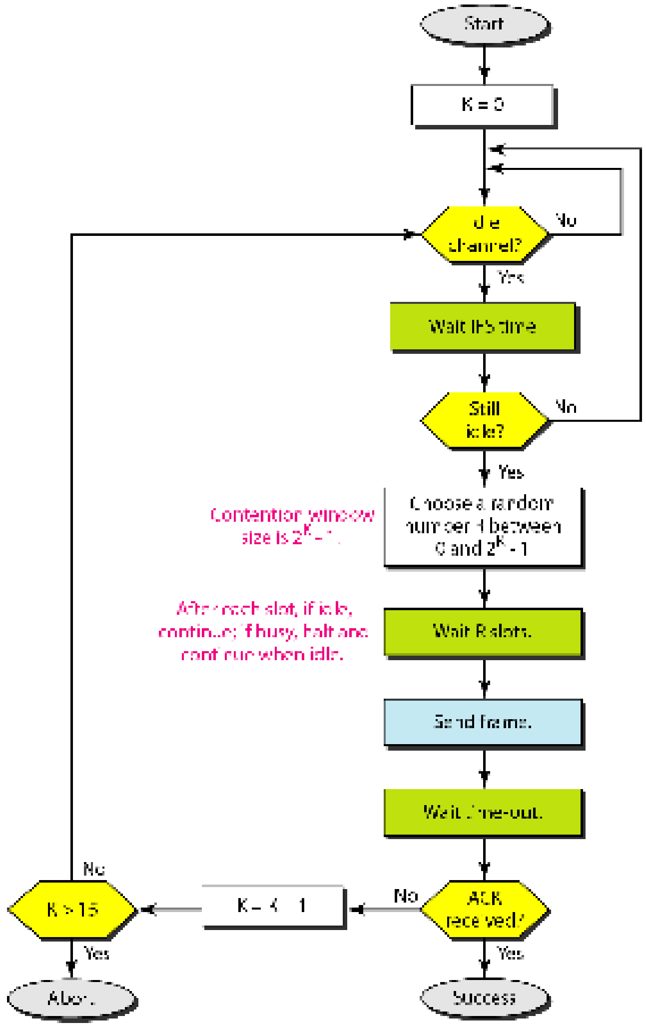
- IFS: inter frame space



***Note***

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

# Figure 12.17 *Flow diagram for CSMA/CA*



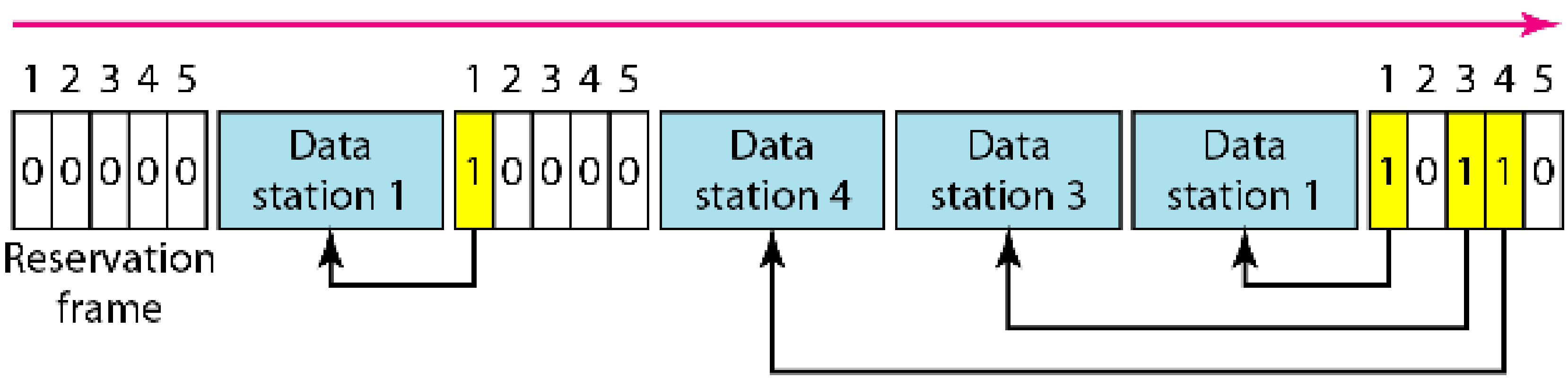
# 12-2 CONTROLLED ACCESS/ Collision Free

***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.***

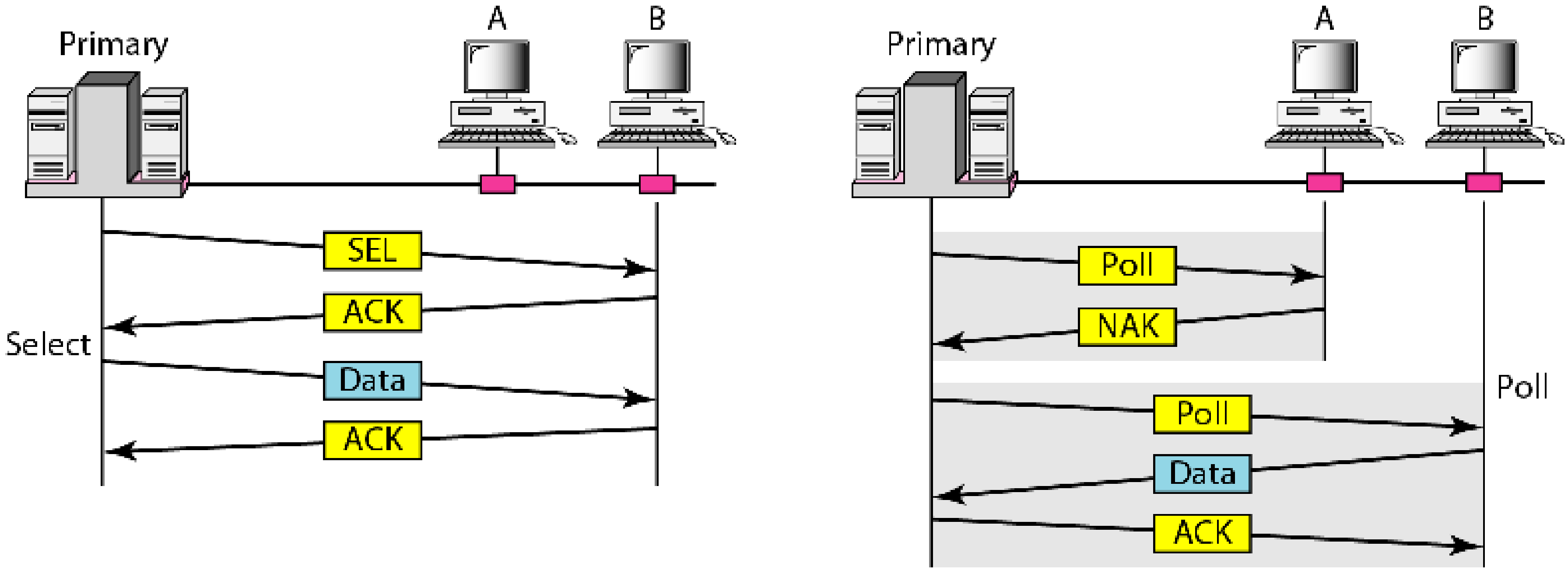
***Topics discussed in this section:***

**Reservation**
**Polling**
**Token Passing**

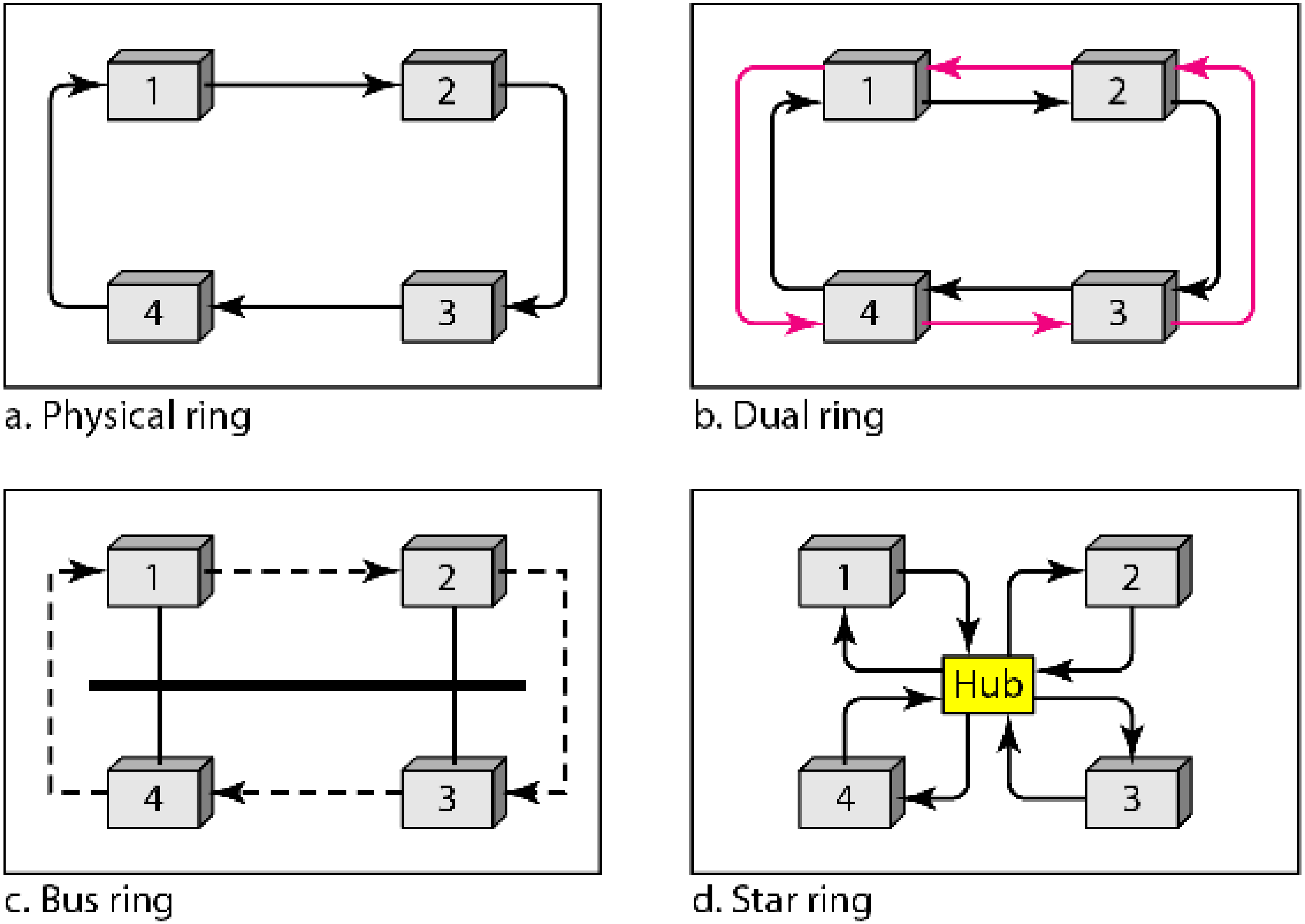
## Figure 12.18 *Reservation access method*



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



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



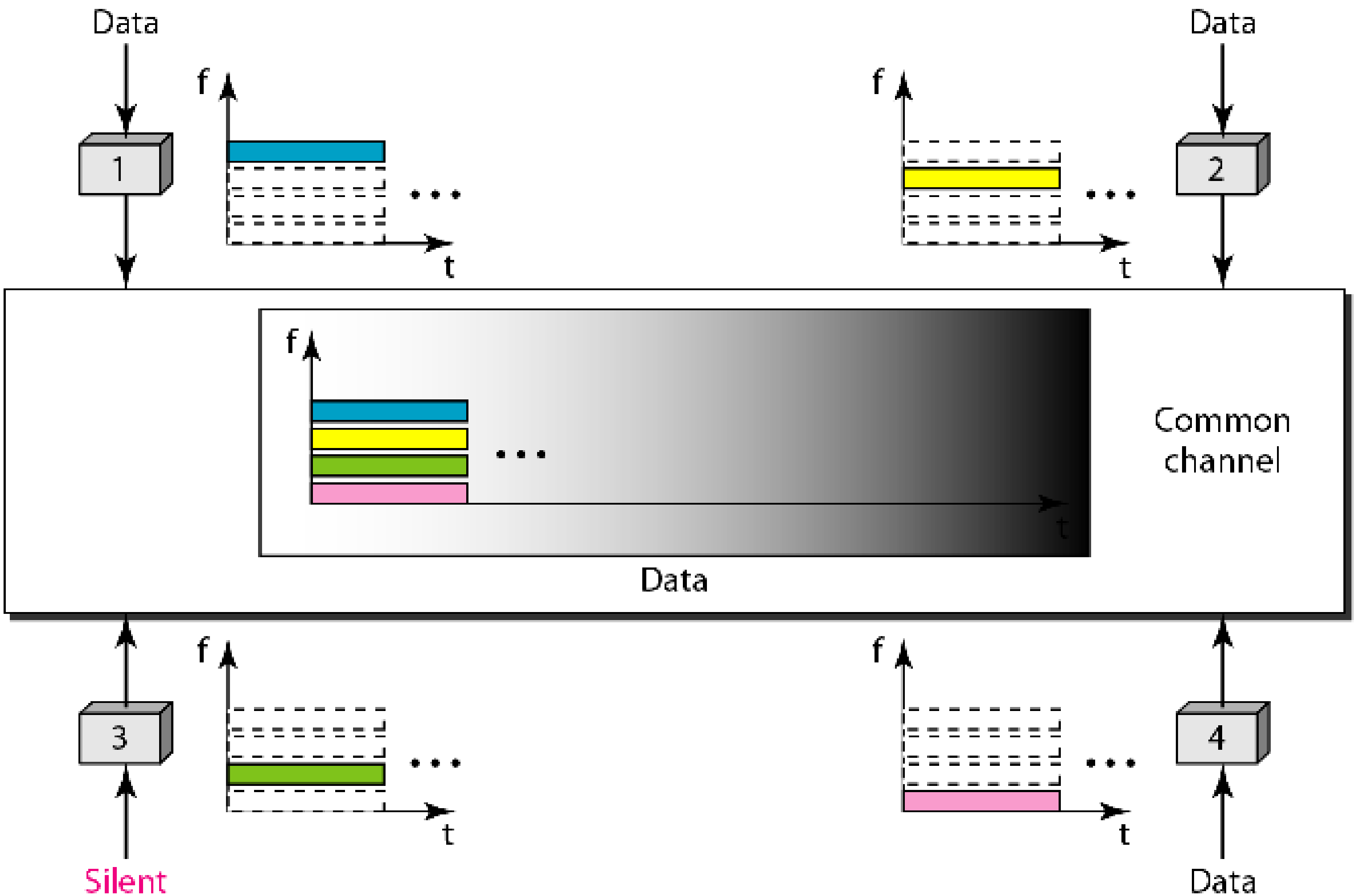
# 12-3 CHANNELIZATION

***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)**

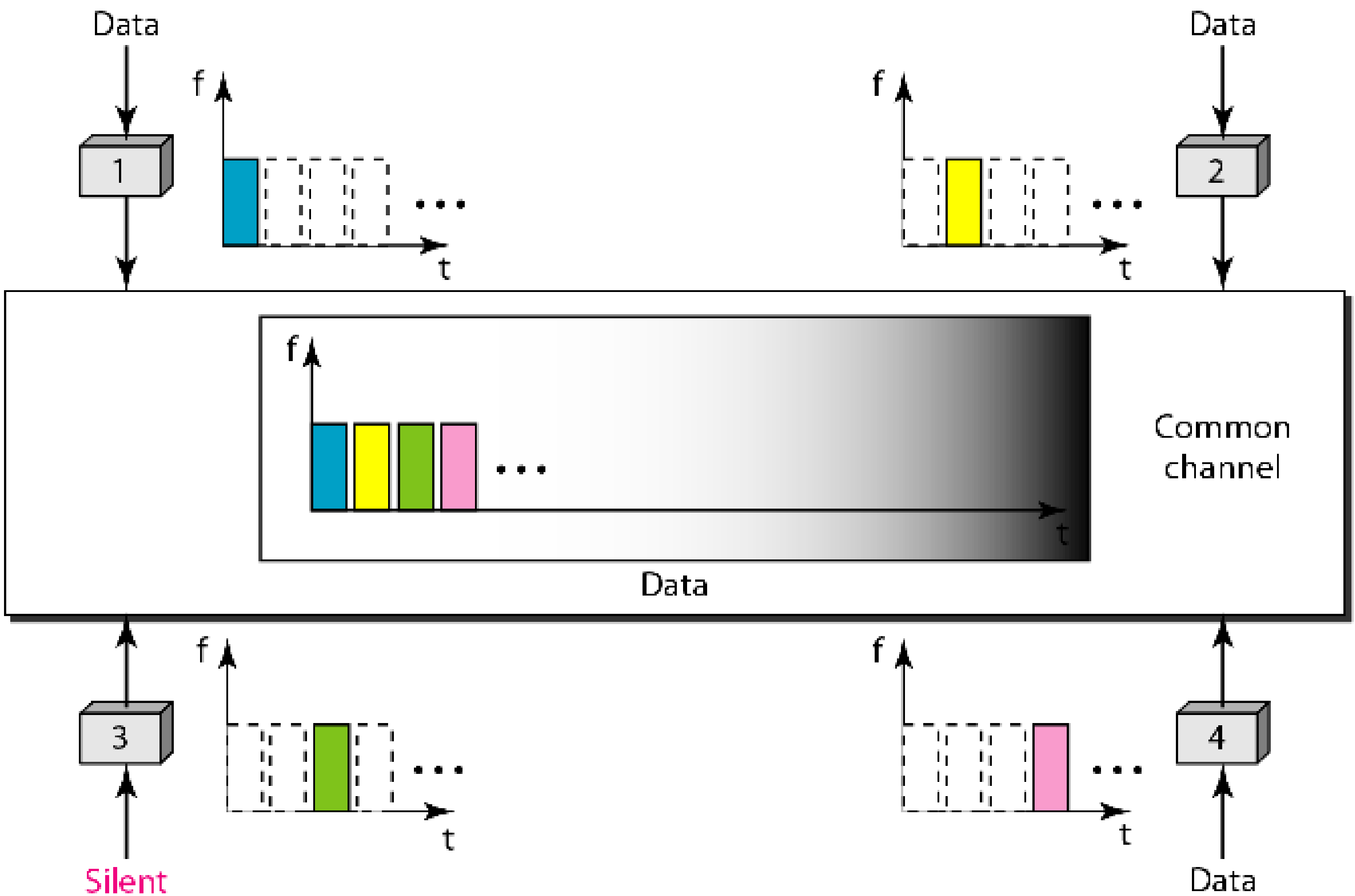
## Figure 12.21 *Frequency-division multiple access (FDMA)*



*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)*



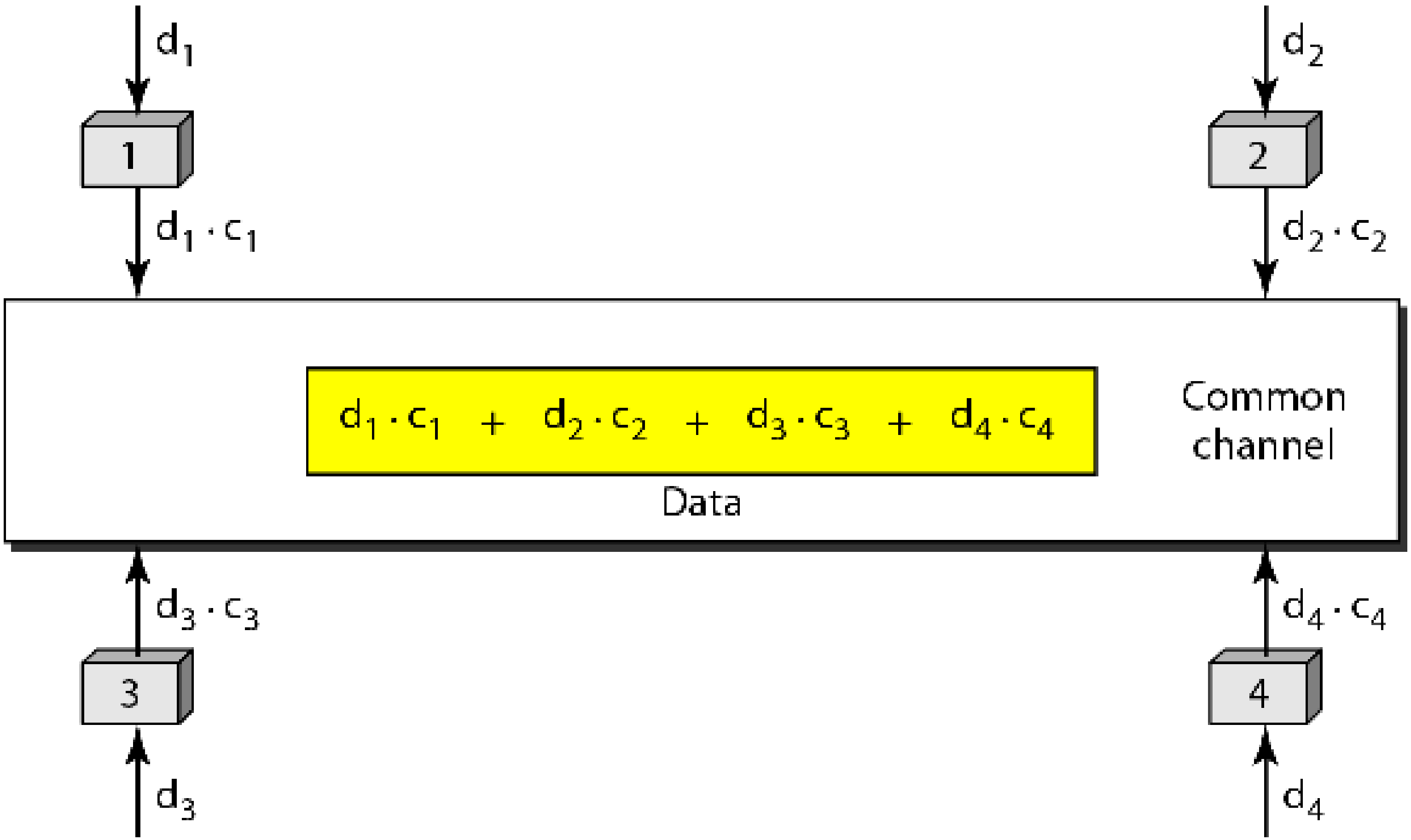
***Note***

**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*

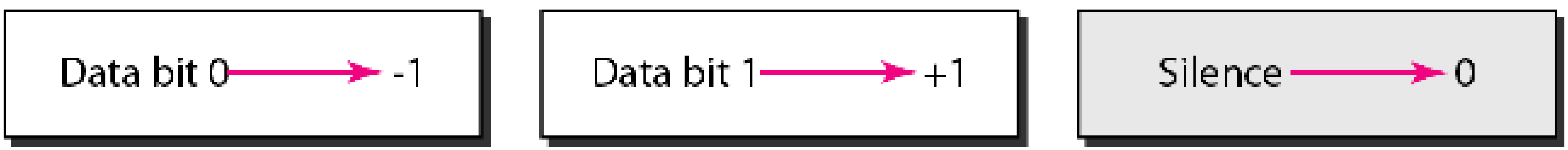
$C_1$: [+1 +1 +1 +1]

$C_2$: [+1 -1 +1 -1]

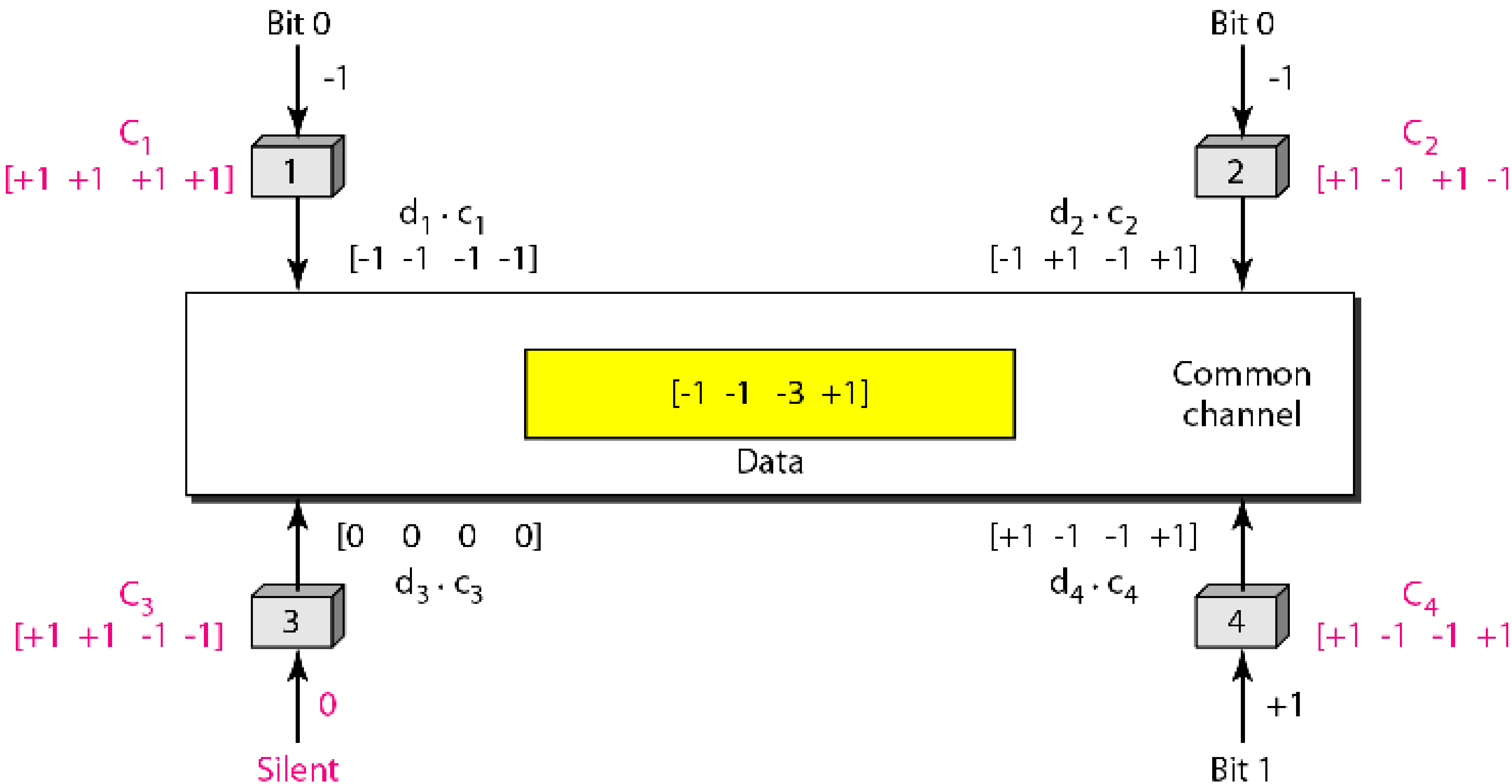
$C_3$: [+1 +1 -1 -1]

$C_4$: [+1 -1 -1 +1]

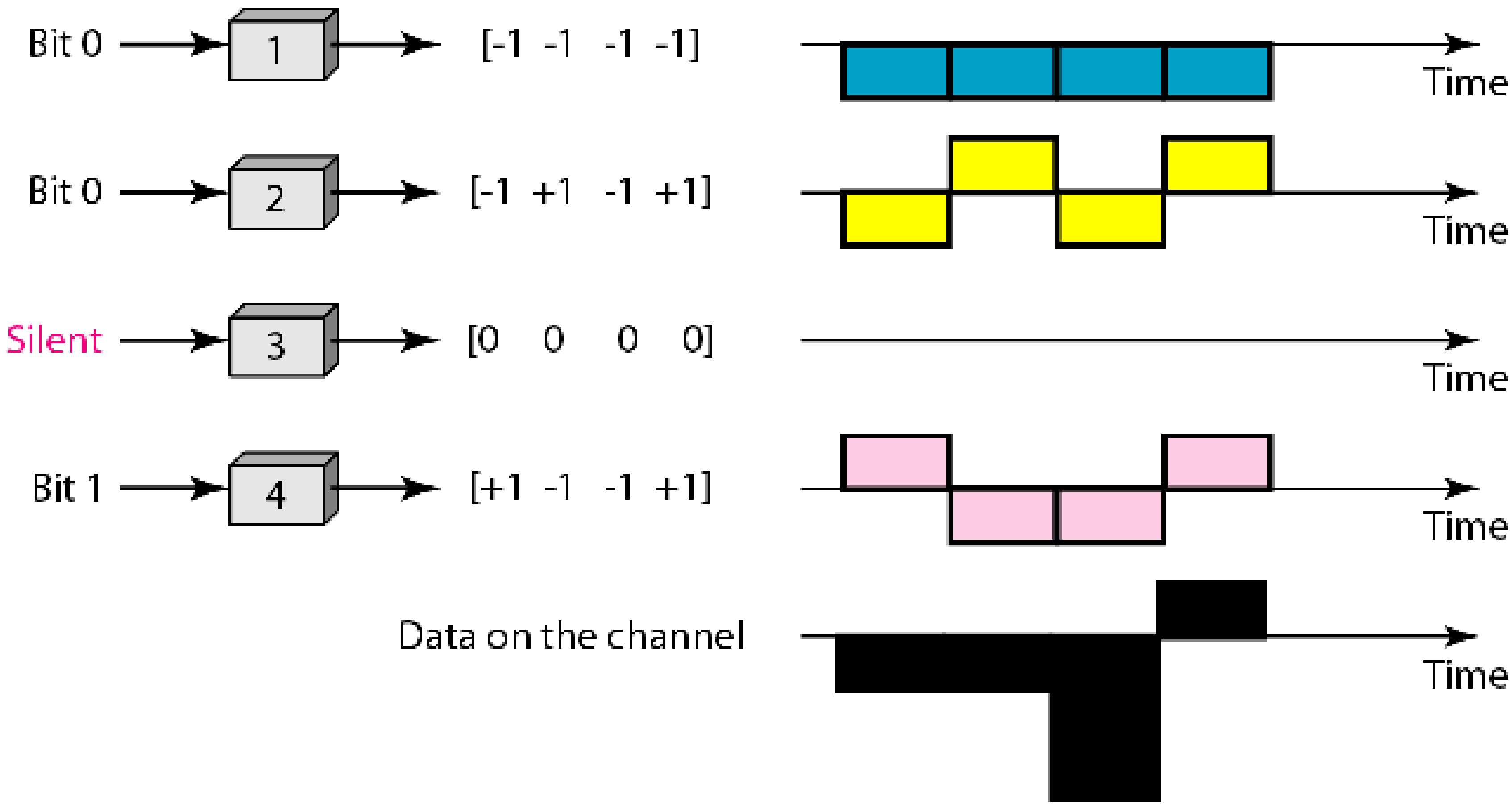
## Figure 12.25 *Data representation in CDMA*



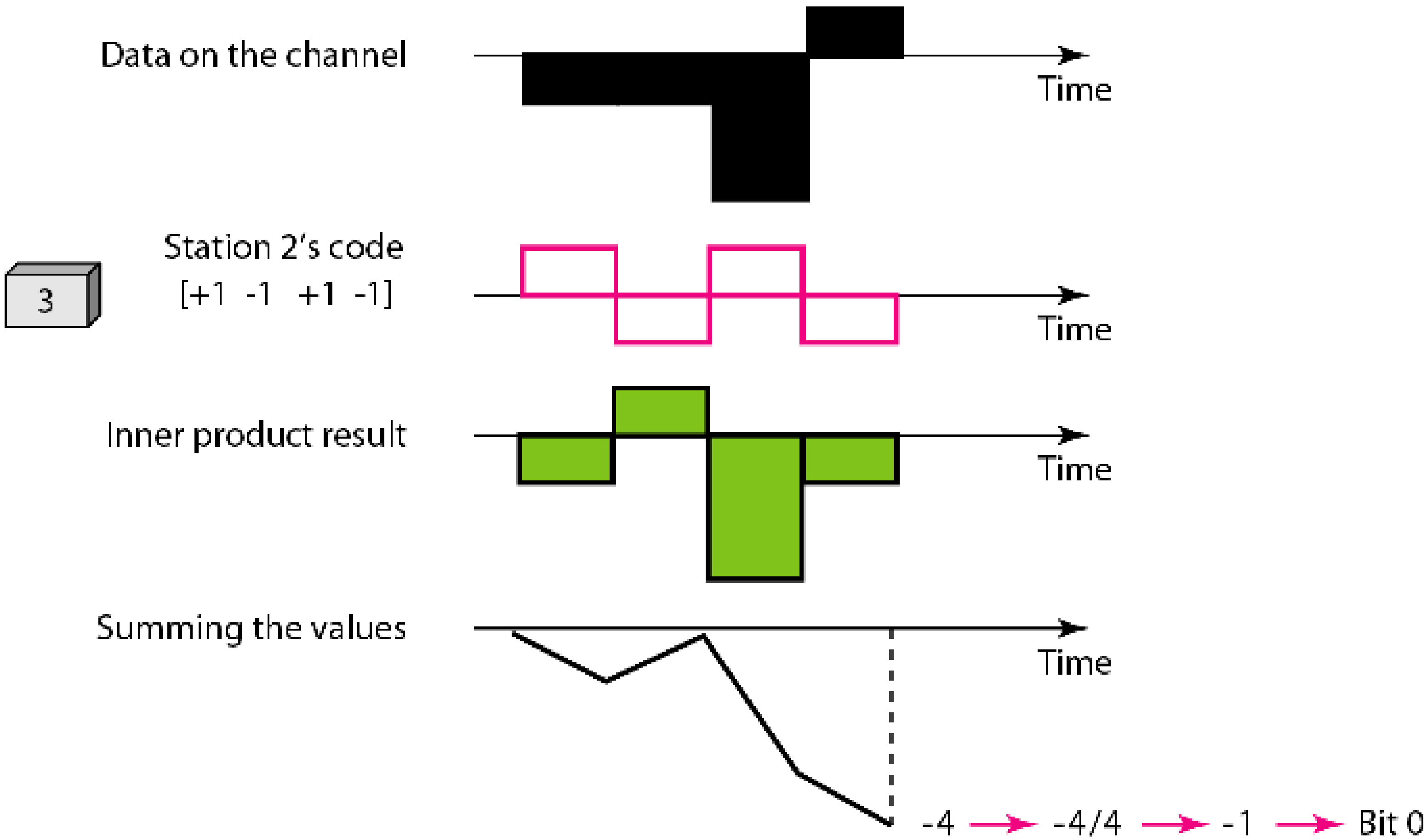
## Figure 12.26 *Sharing channel in CDMA*



## 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 $d_1$.***