Chapter 12

Multiple Access

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

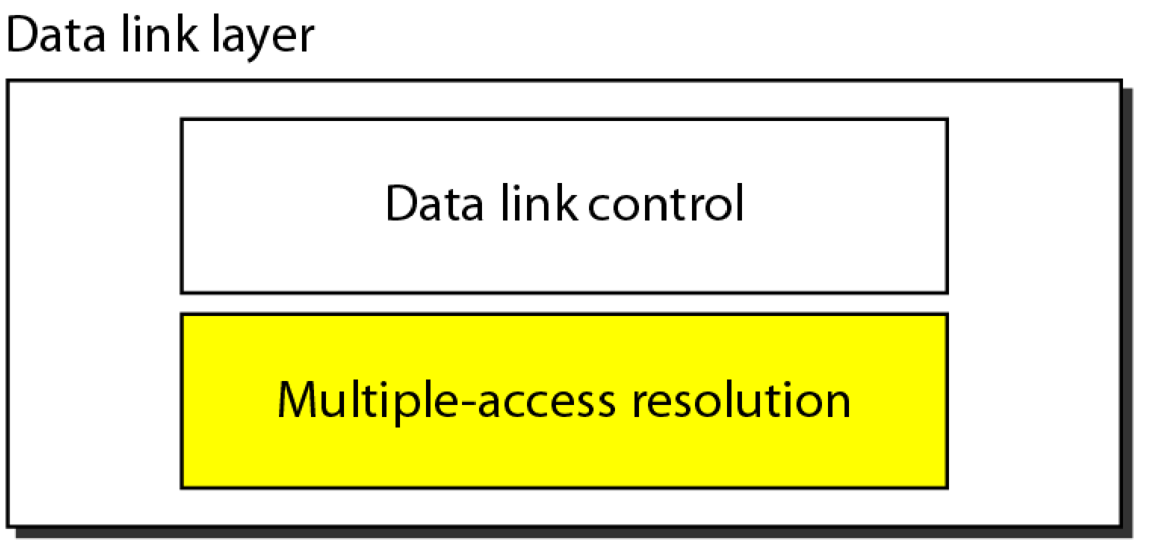
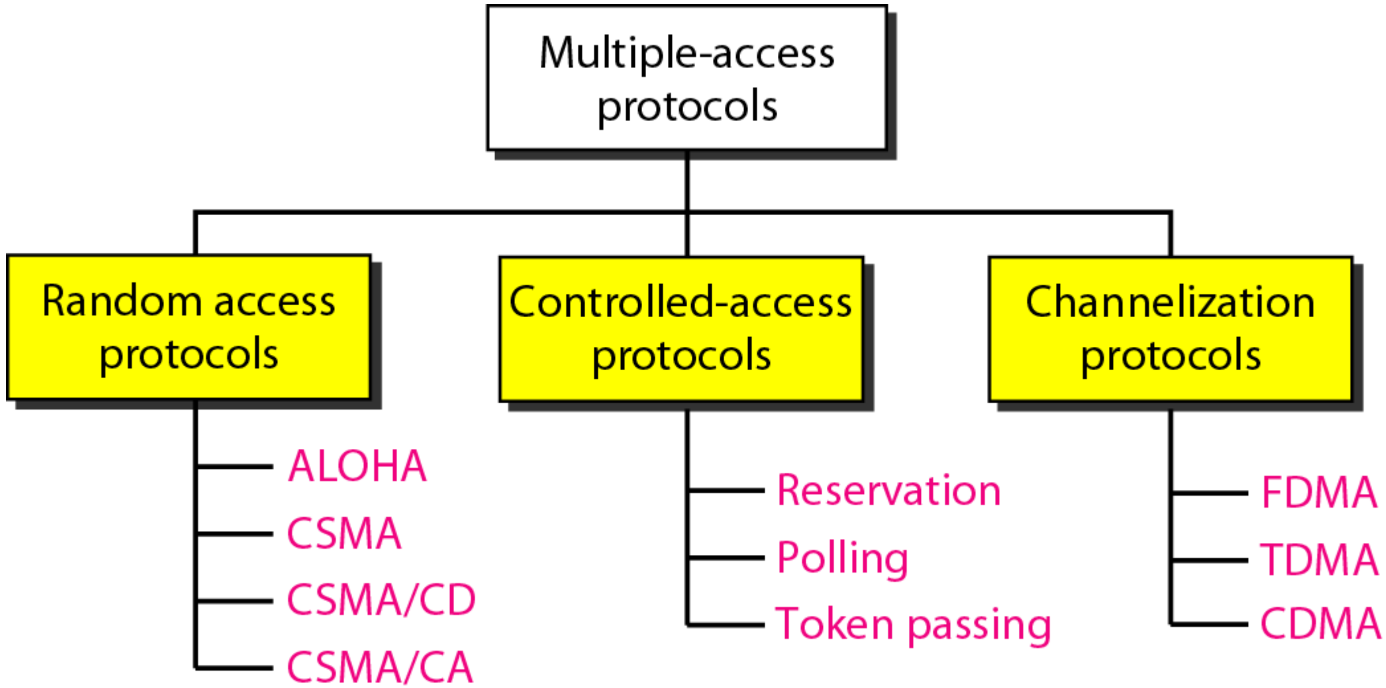


Figure 12.2 *Taxonomy of multiple-access protocols discussed in this chapter*

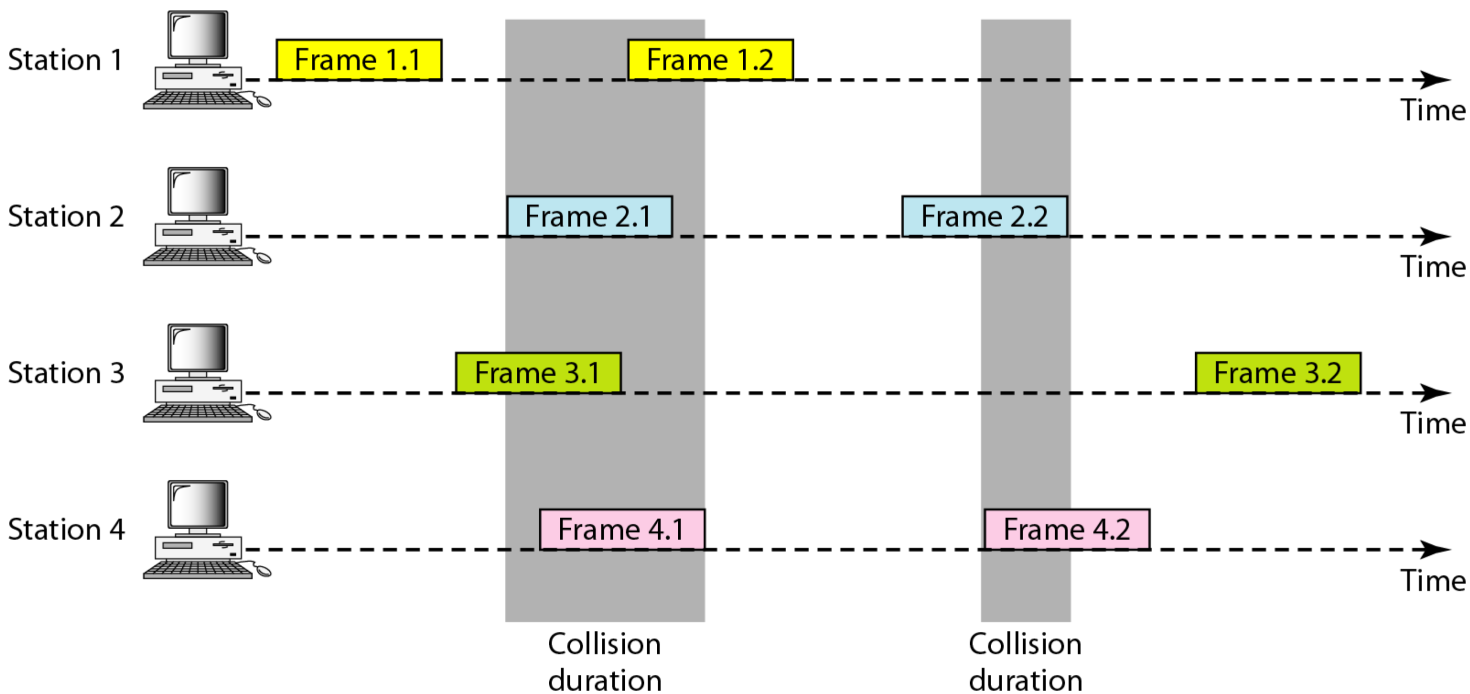


ALOHA: Pure, Slotted ALOHA, CSMA, CSMA/CD

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.

Figure 12.3 *Frames in a pure ALOHA network*



- ✓ Sender expects an **acknowledgement**.
- ✓ If **time-out** indicates frame or ack lost (**collision** is the cause)

- ✓ If collision takes place, each station waits a random amount of time: ***backoff time.***
- ✓ After K_{max} retransmission attempts give up, try later

Figure 12.4 *Procedure for pure ALOHA protocol*

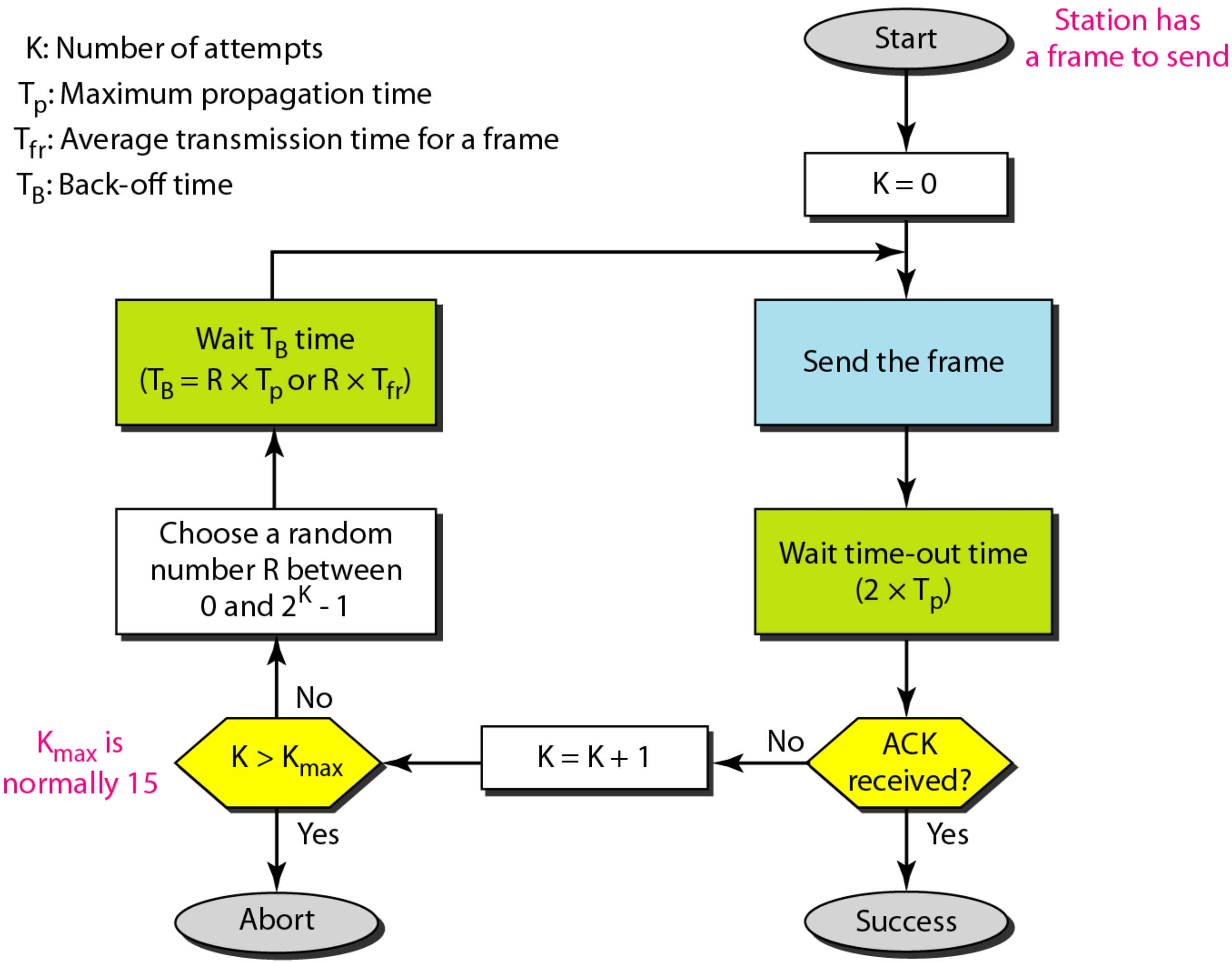
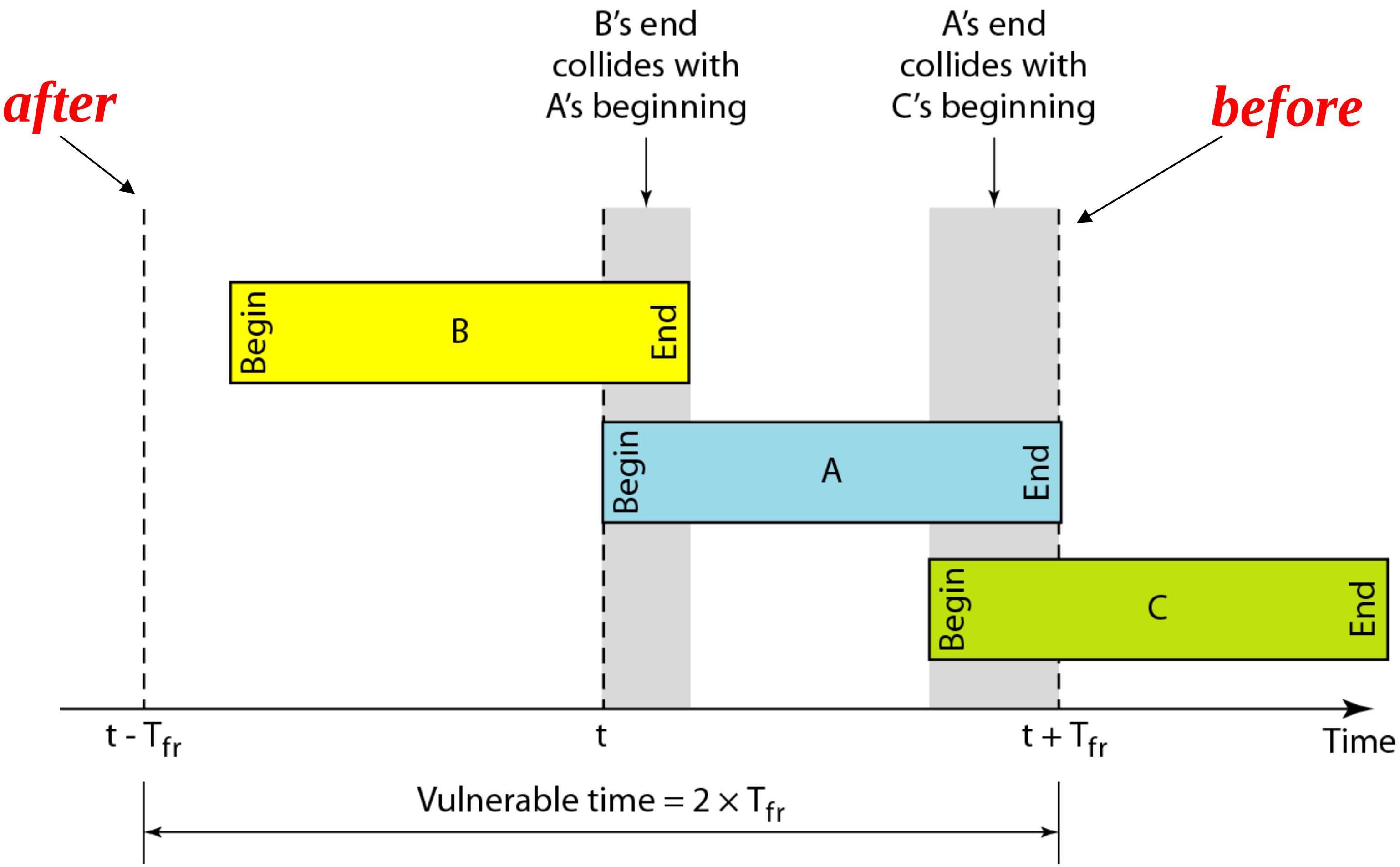


Figure 12.5 *Vulnerable time for pure ALOHA protocol*



✓ Each frame takes T_{fr} seconds to send

Example 12.2

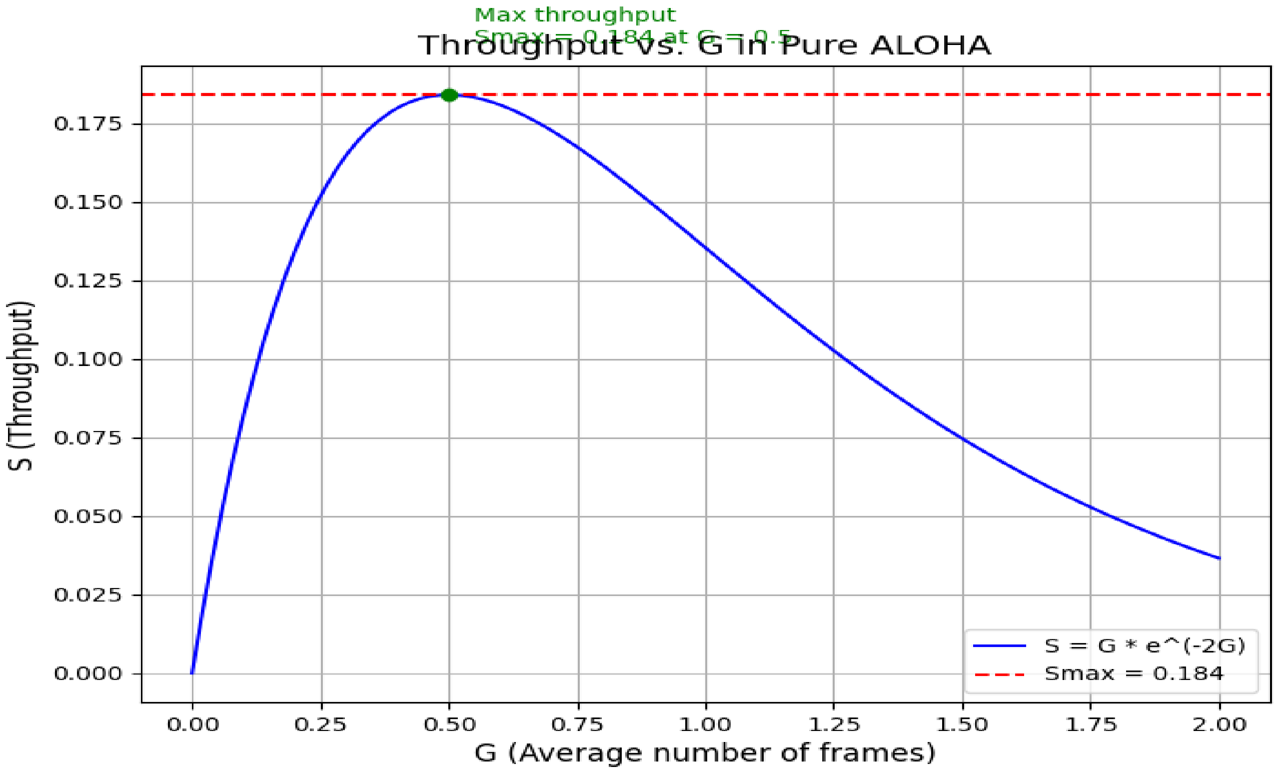
A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the requirement to make this frame collision-free?

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

The maximum throughput $S_{max} = 0.184$ when G= (1/2).



The total system load is G, meaning that, on average, G frames are generated per frame time.

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.

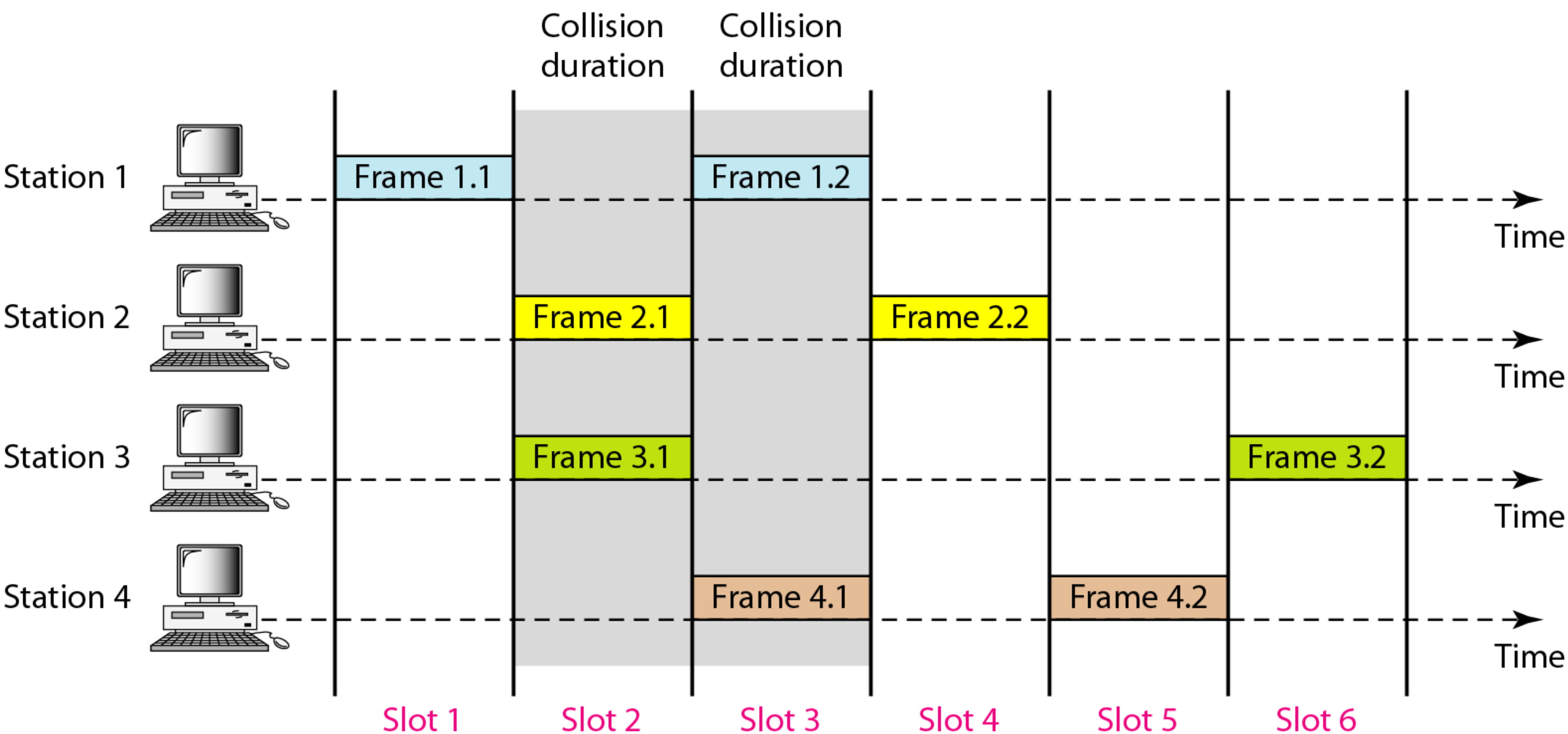
a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case $S = G \times e^{-2G}$ or $S = 0.135$ (13.5 percent). This means that the throughput is $1000 \times 0.135 = 135$ frames. Only 135 frames out of 1000 will probably survive.

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.*

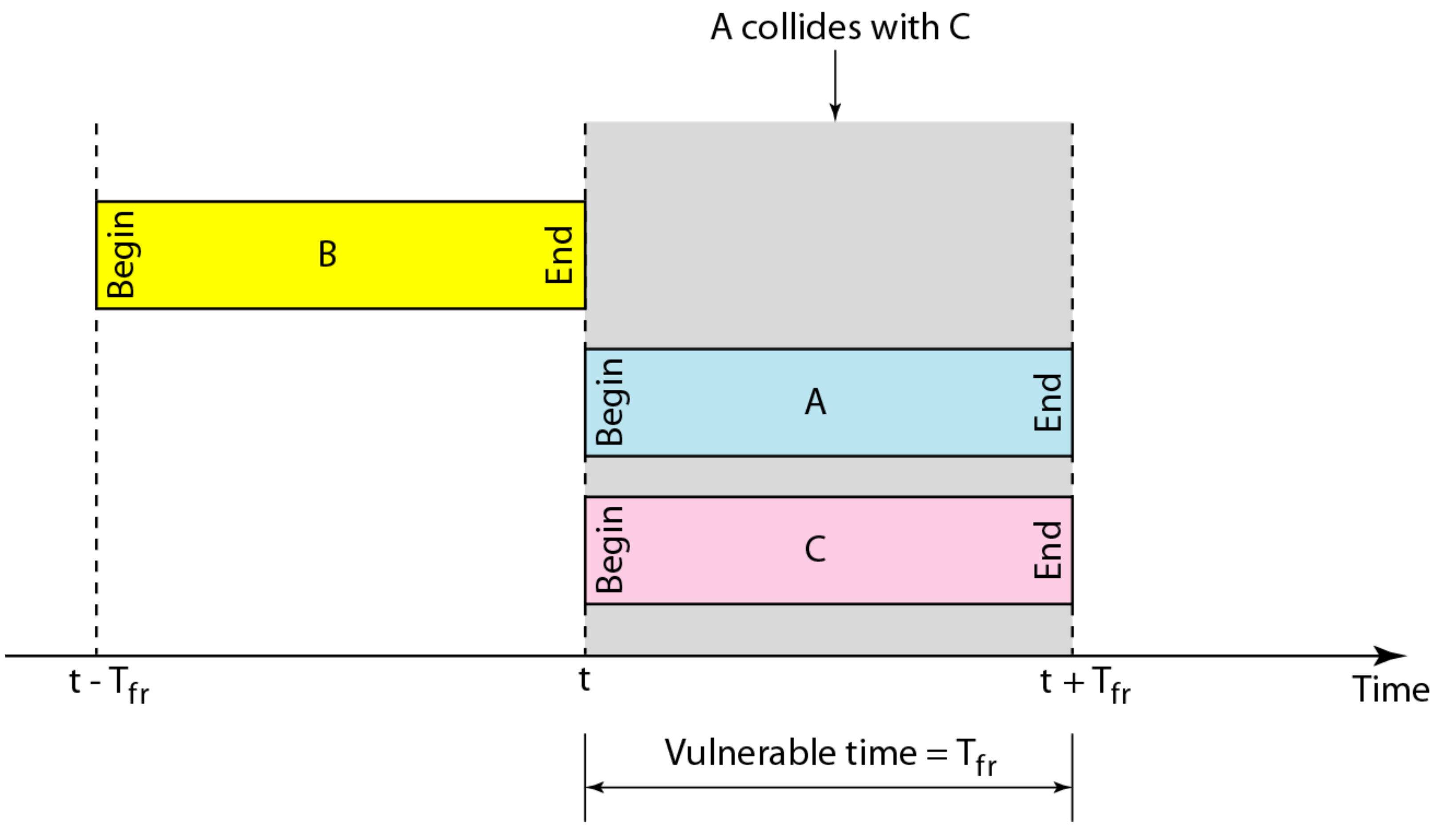
Figure 12.6 *Frames in a slotted ALOHA network*



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*

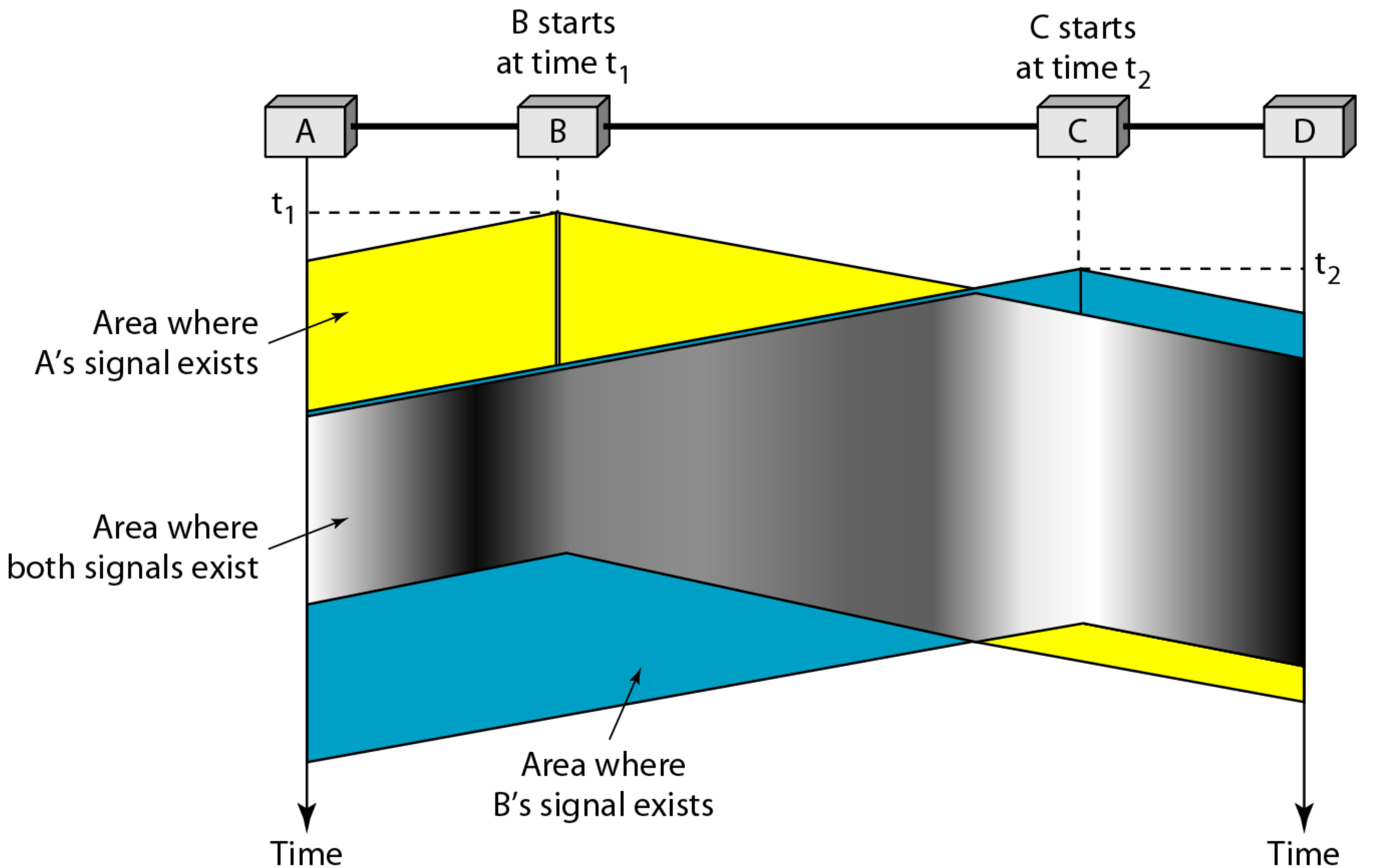


Figure 12.9 *Vulnerable time in CSMA*

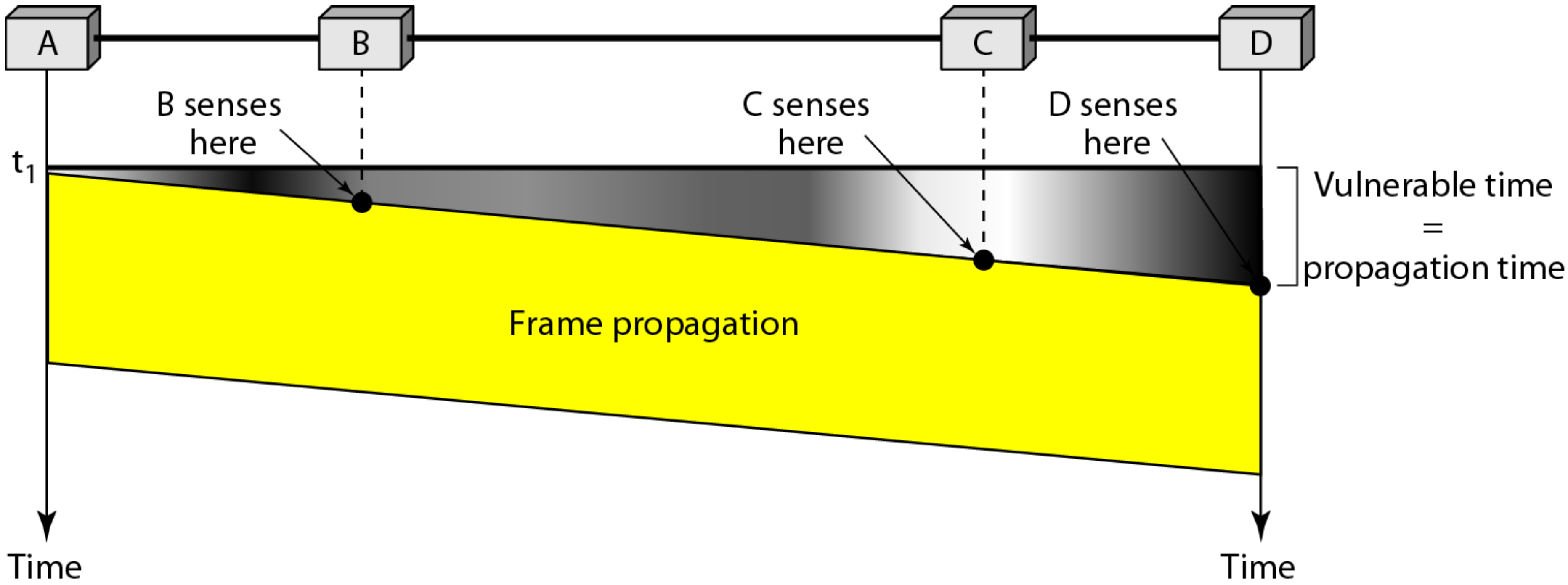


Figure 12.10 *Behavior of three persistence methods*

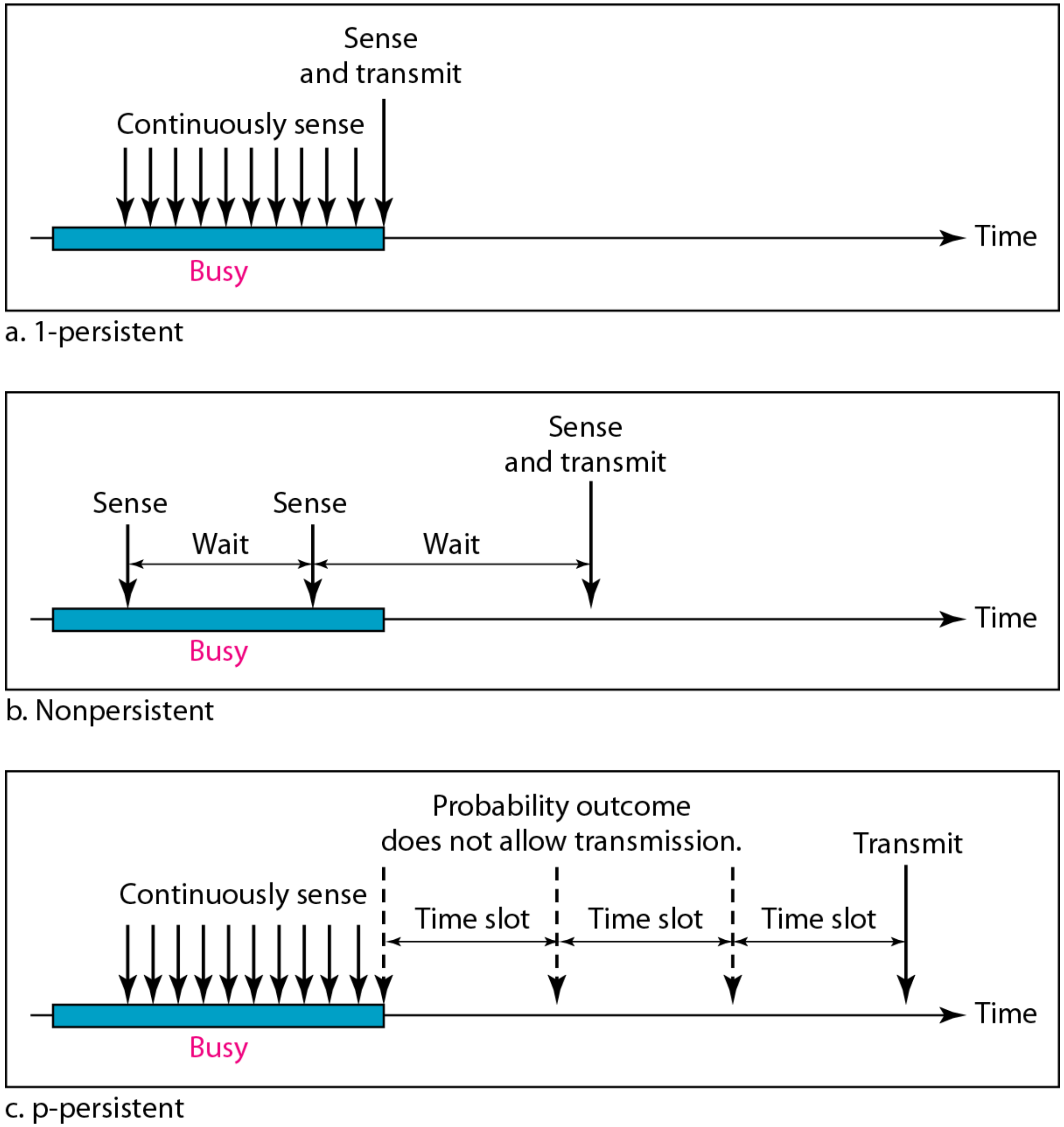


Figure 12.11 *Flow diagram for three persistence methods*

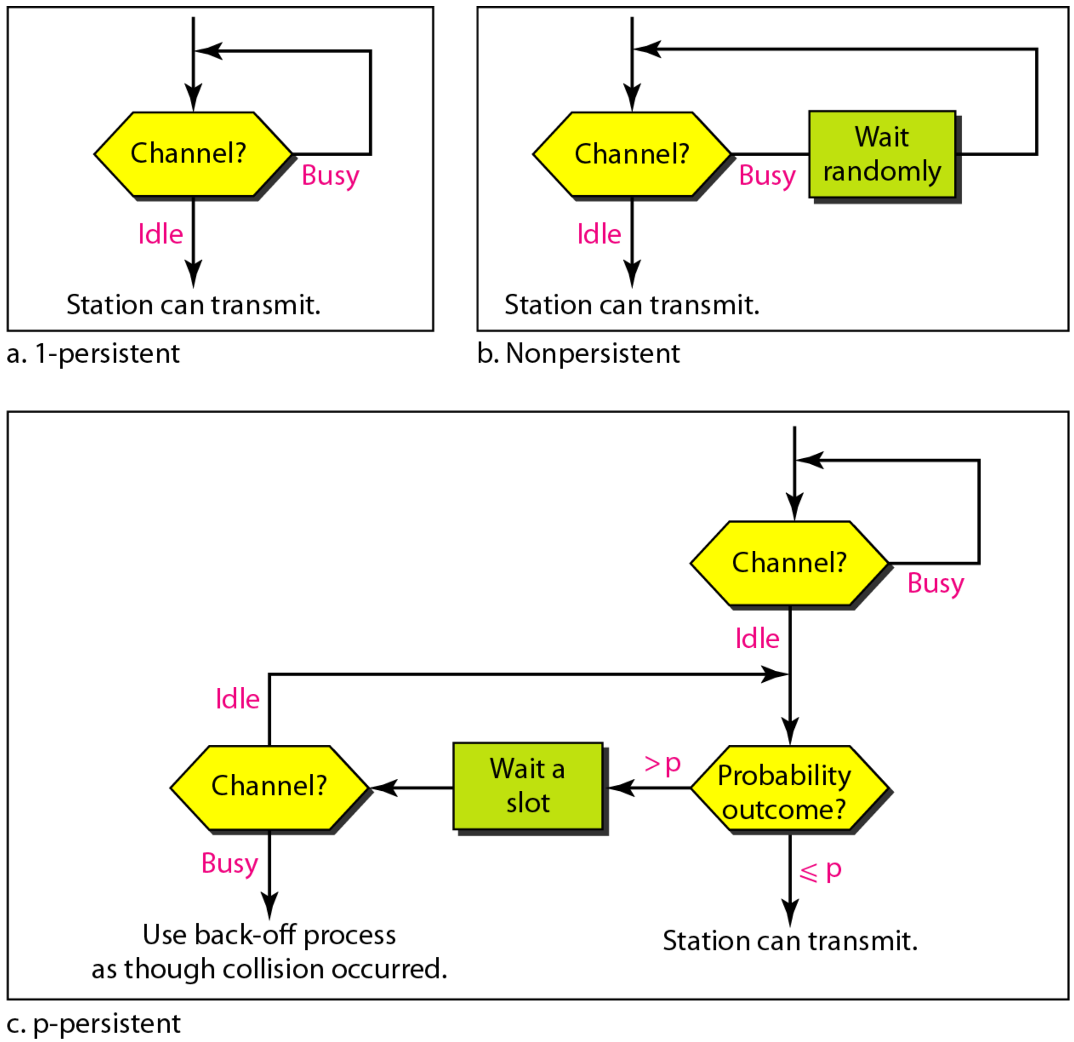


Figure 12.12 *Collision of the first bit in CSMA/CD*

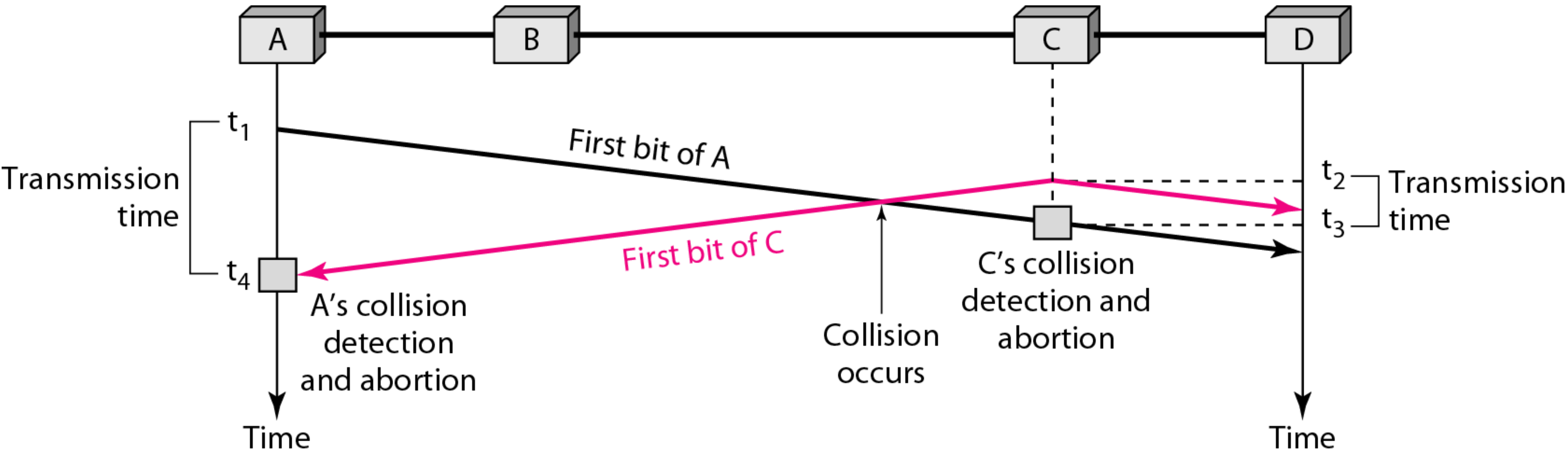
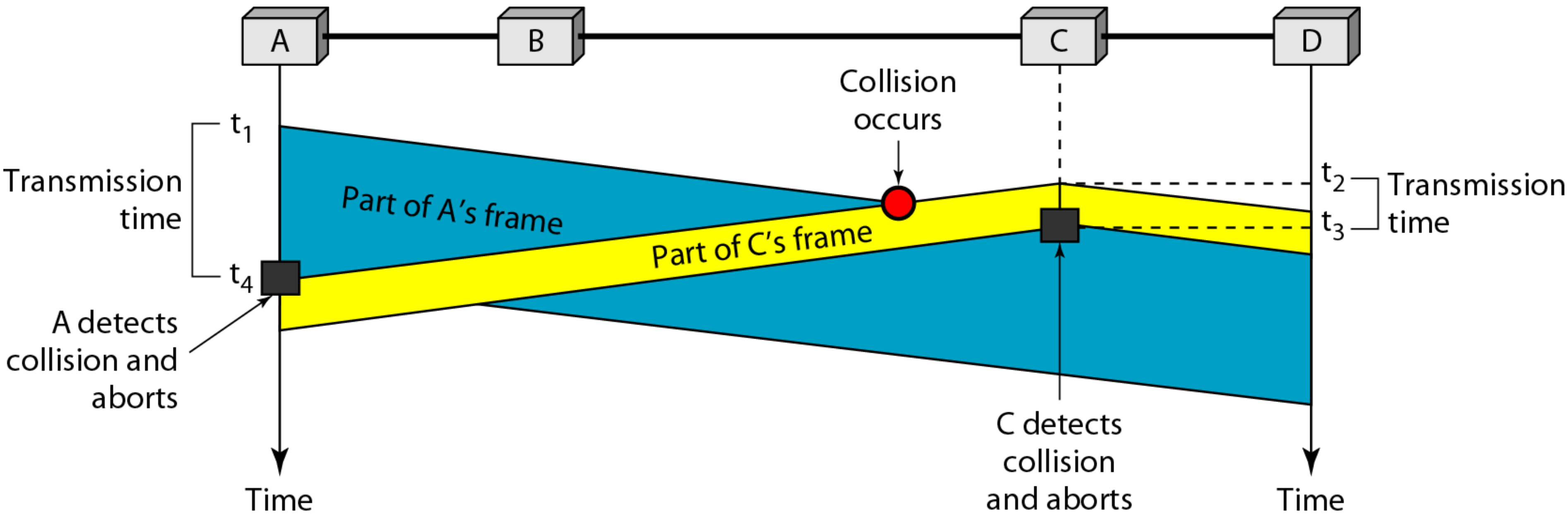


Figure 12.13 *Collision and abortion in CSMA/CD*



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

Figure 12.14 *Flow diagram for the CSMA/CD*

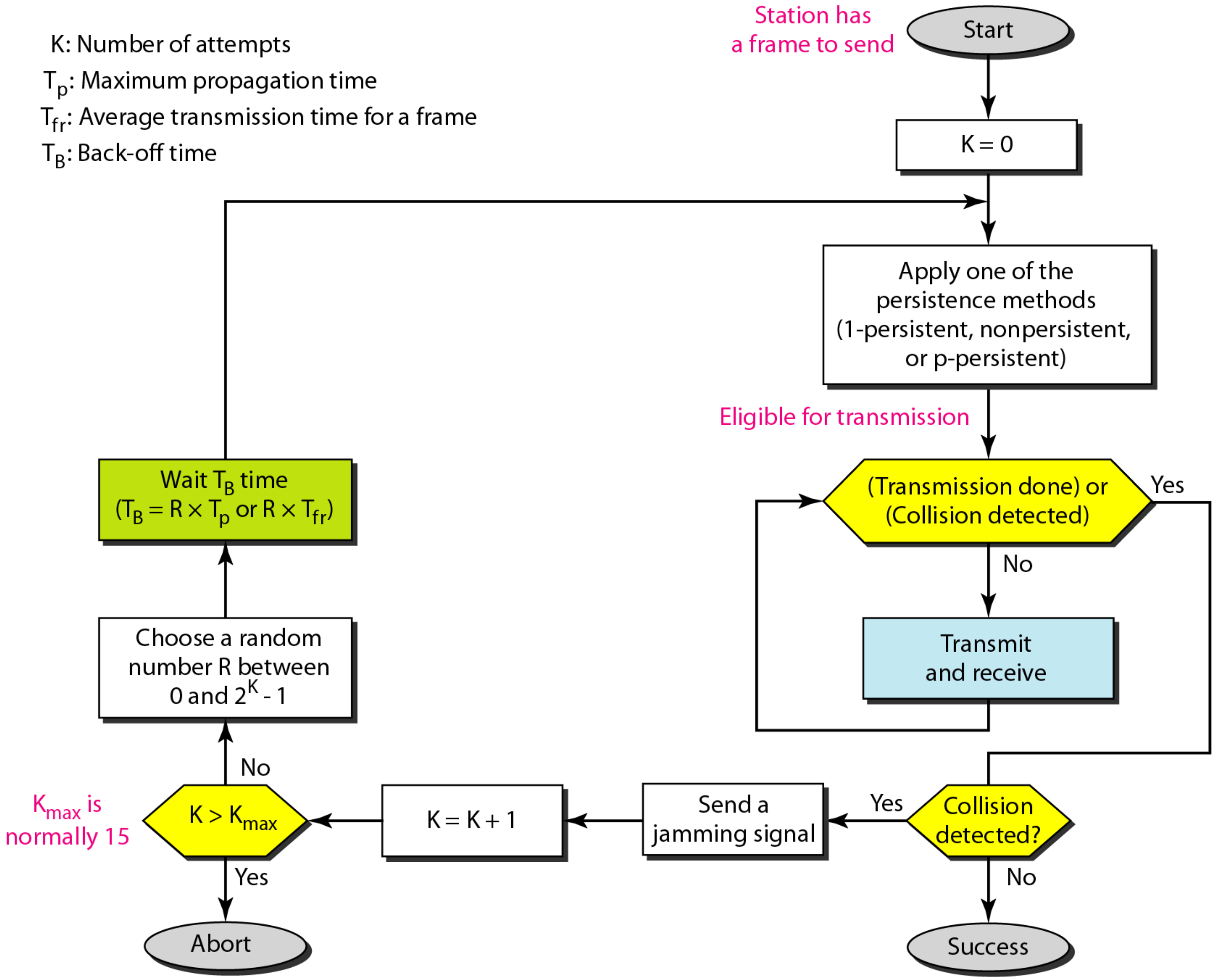
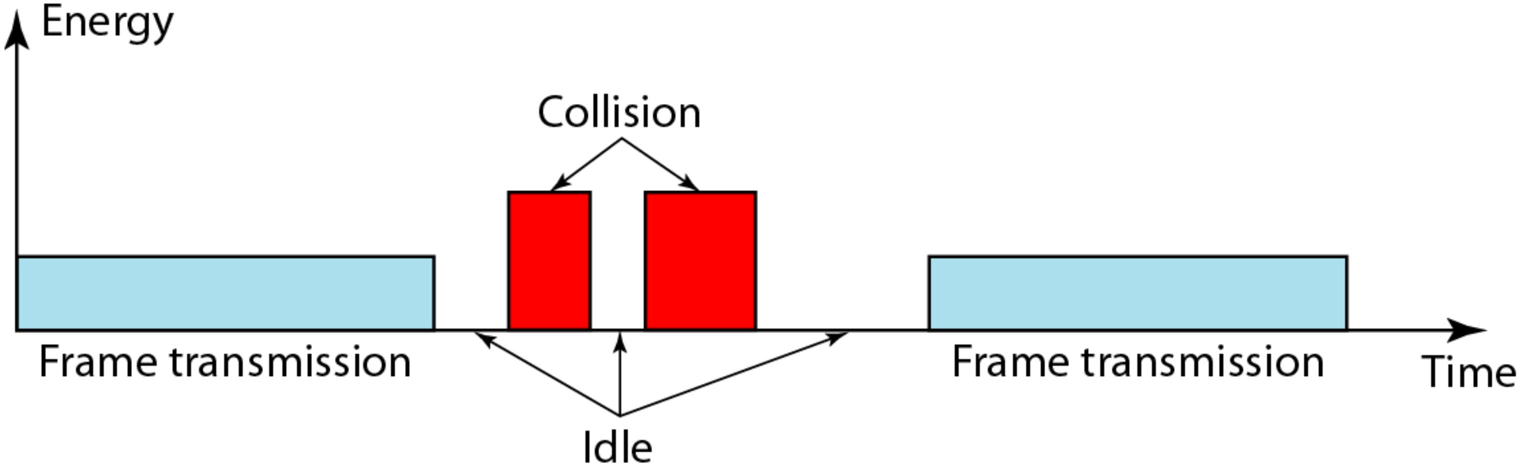


Figure 12.15 *Energy level during transmission, idleness, or collision*



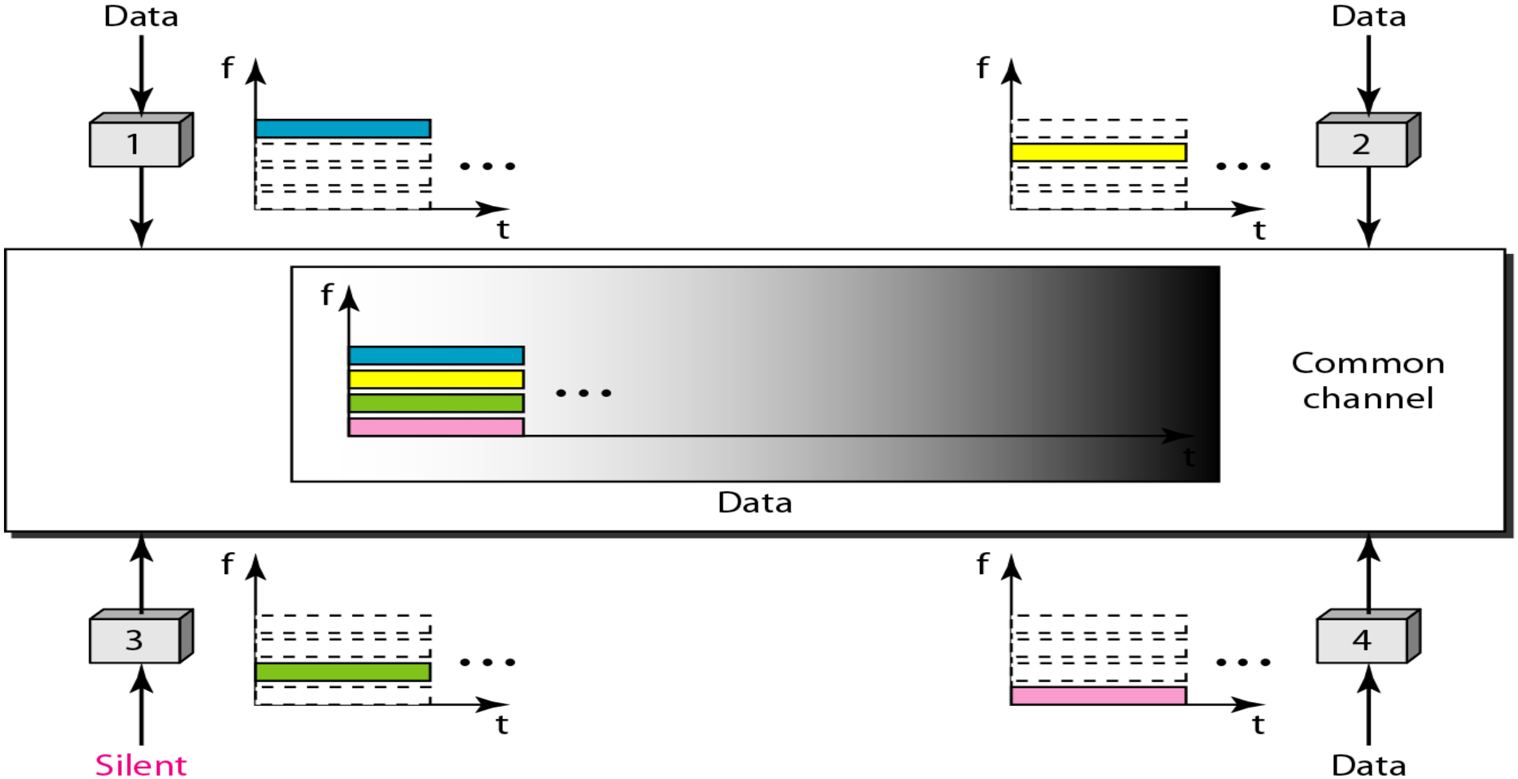
12-3 CHANNELIZATION

- Channelization is a multiple-access method in which the available bandwidth of a link is shared between different stations as:
  - in time,
  - frequency, or
  - through code,.
- 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)*

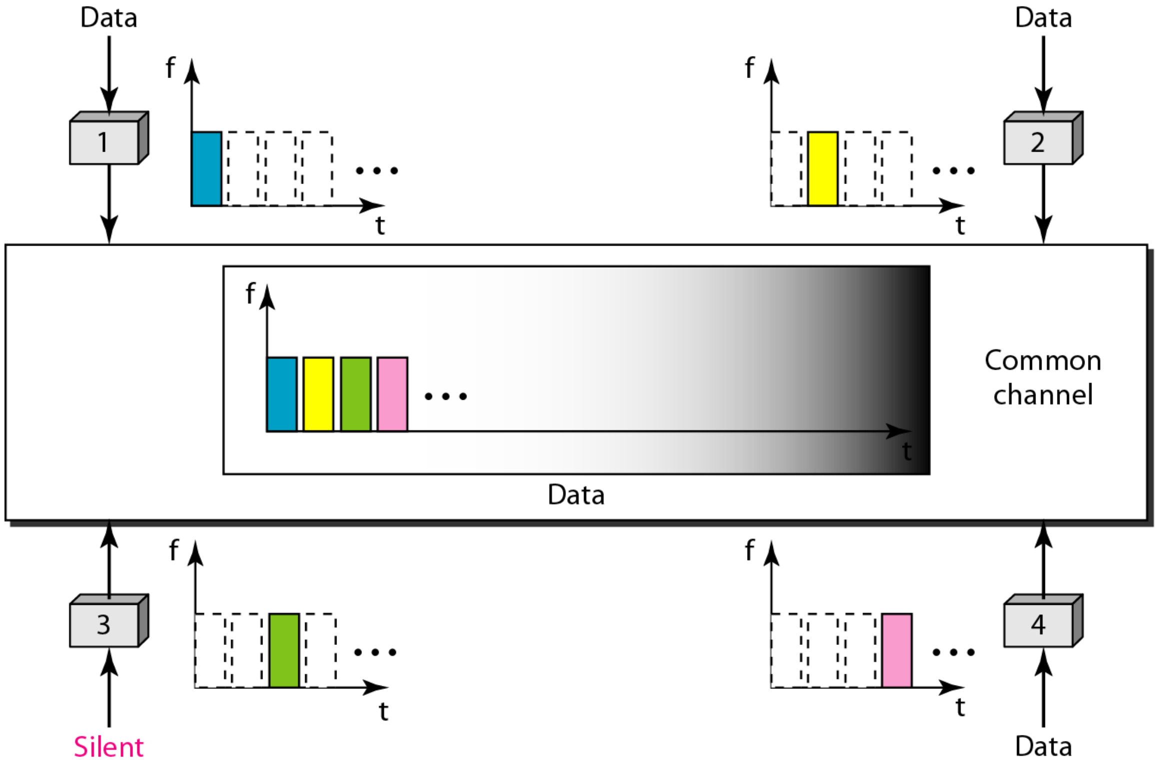


- ✓ Each station uses a **bandpass filter** to confine the transmitter frequencies.
- ✓ To **prevent interferences**, the allocated bands are **separated** by small ***guard bands***.

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)*



Synchronization

- ✓ Stations needs to know the beginning of its slot and slot location.
- ✓ **Propagation delays** when stations are spread over a large area.
- ✓ To compensate for the delays, we can insert ***guard times***

Preamble

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*

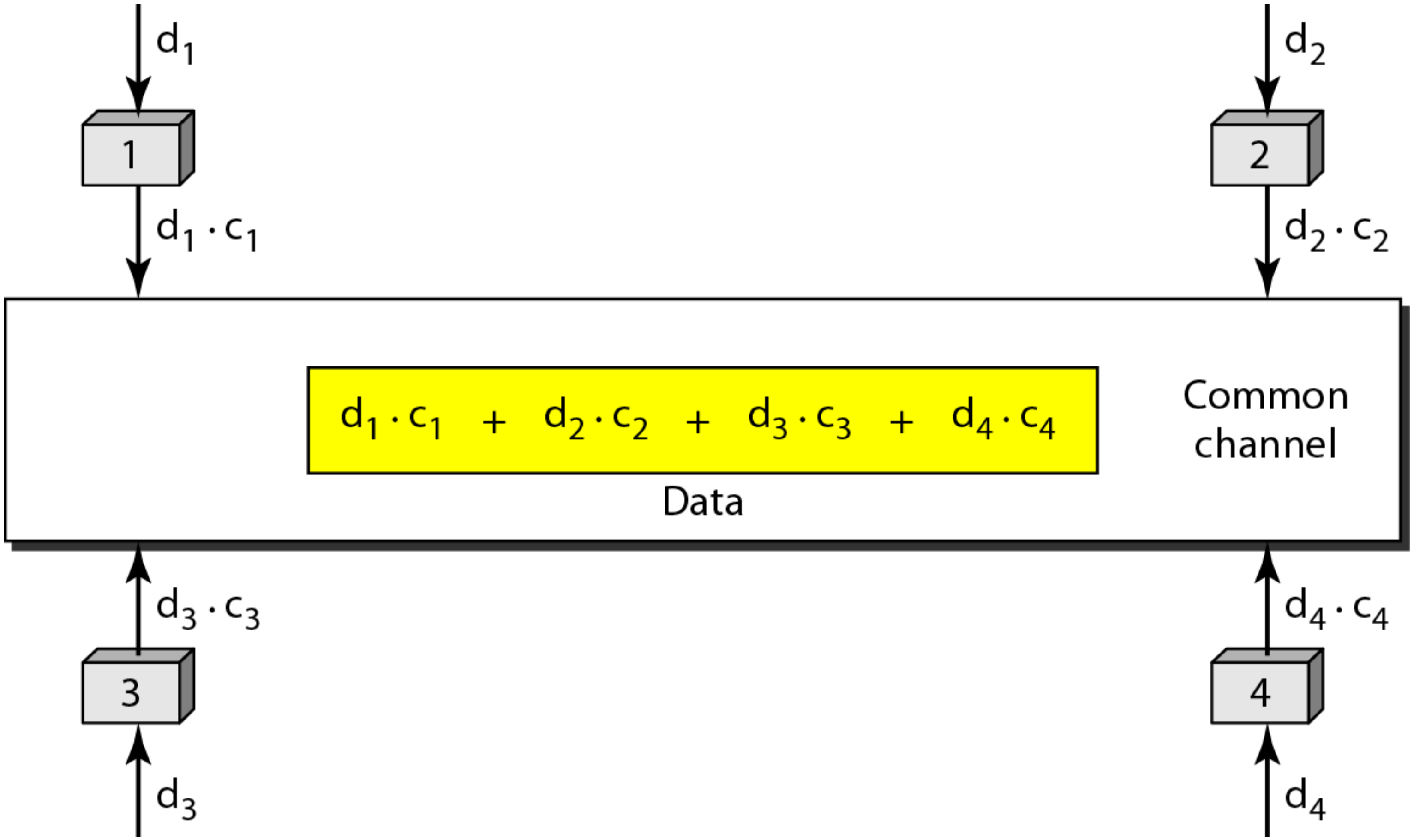


Figure 12.23 ***Simple idea of communication with code***

Properties for the assigned codes:

1) If we **multiply each code by another**, we **get O.**
2) If we **multiply each code by itself**, we get **4** (the number of stations).

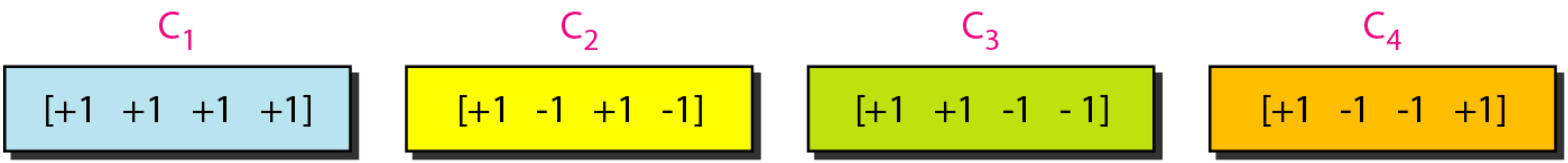


Figure 12.24 ***Chip sequences***

$$
\begin{aligned}
C1 \text{ x } C2 &= (+1 \text{ x } +1) + (+1 \text{ x } -1) + (+1 \text{ x } +1) + (+1 \text{ x } -1) \\
&= 1 + -1 + 1 -1 \\
&= 0
\end{aligned}
$$

Figure 12.24 ***Chip sequences***

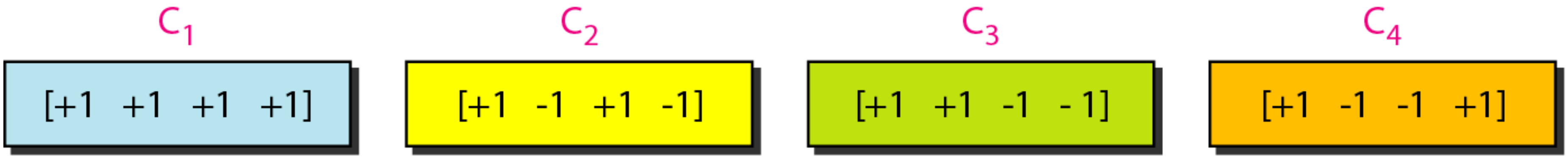


Figure 12.25 *Data representation in CDMA*

Figure 12.26 *Sharing channel in CDMA*

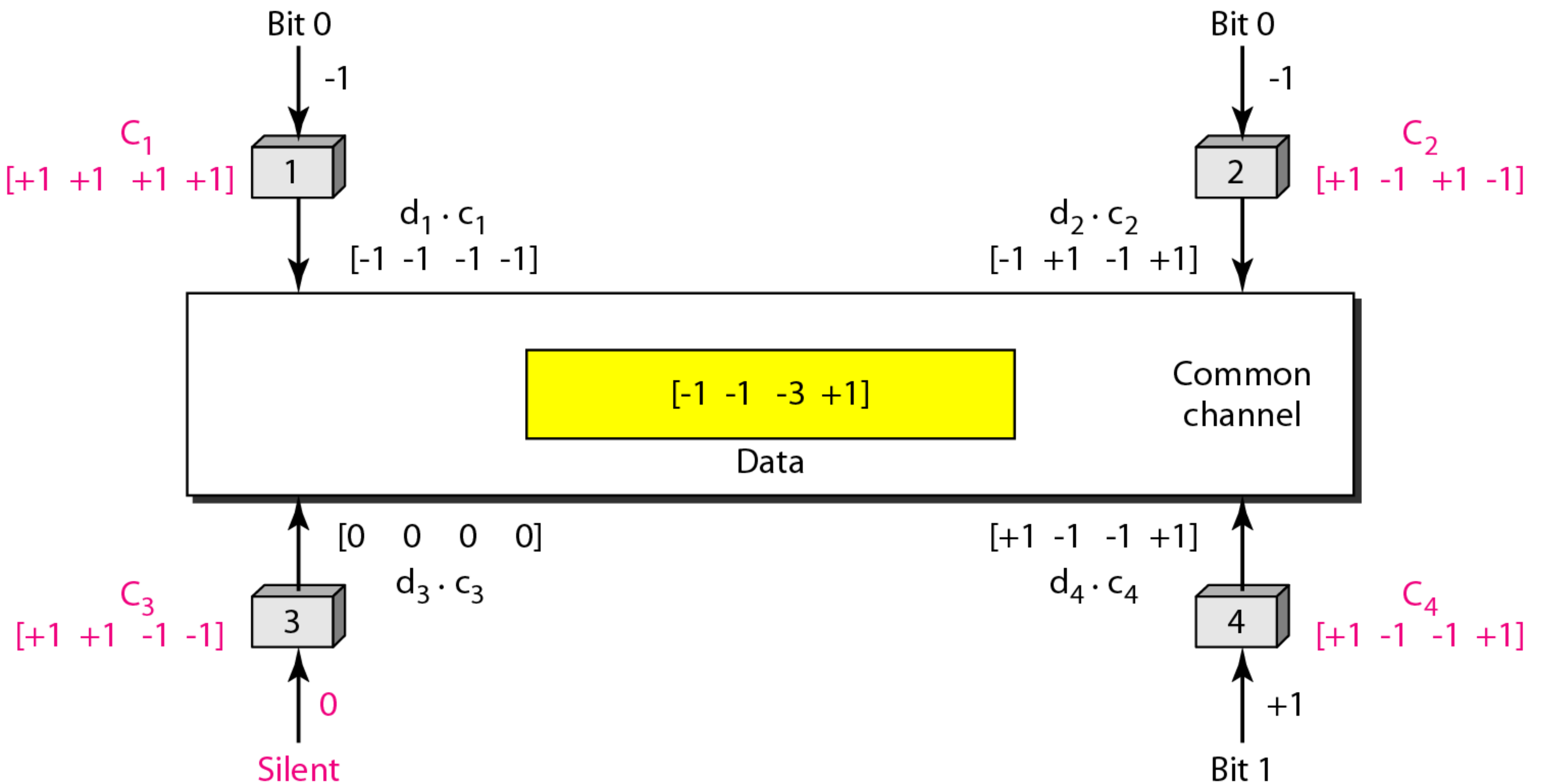


Figure 12.27 Digital signal created by four stations in CDMA

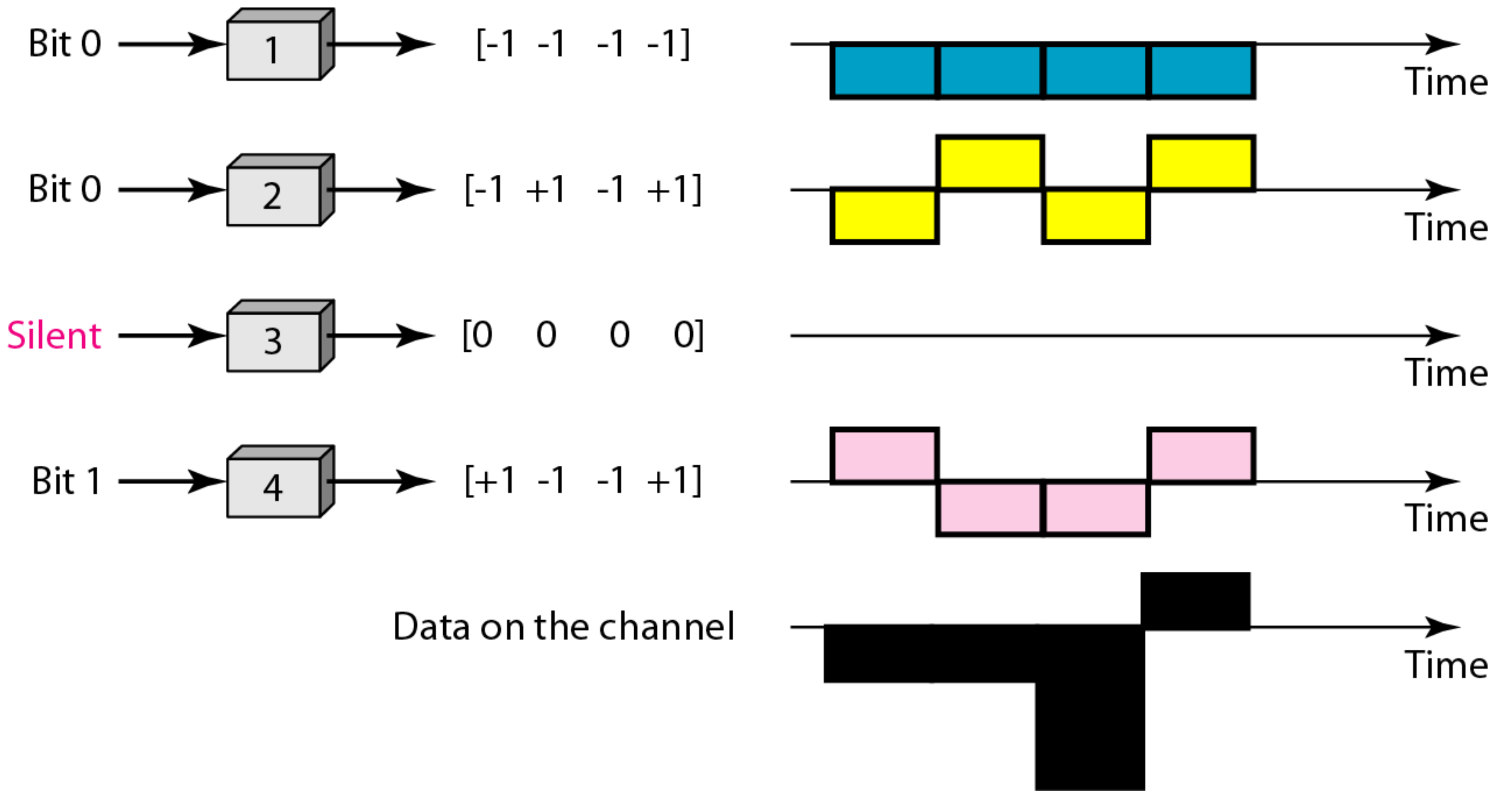


Figure 12.28 *Decoding of the composite signal for one in CDMA*

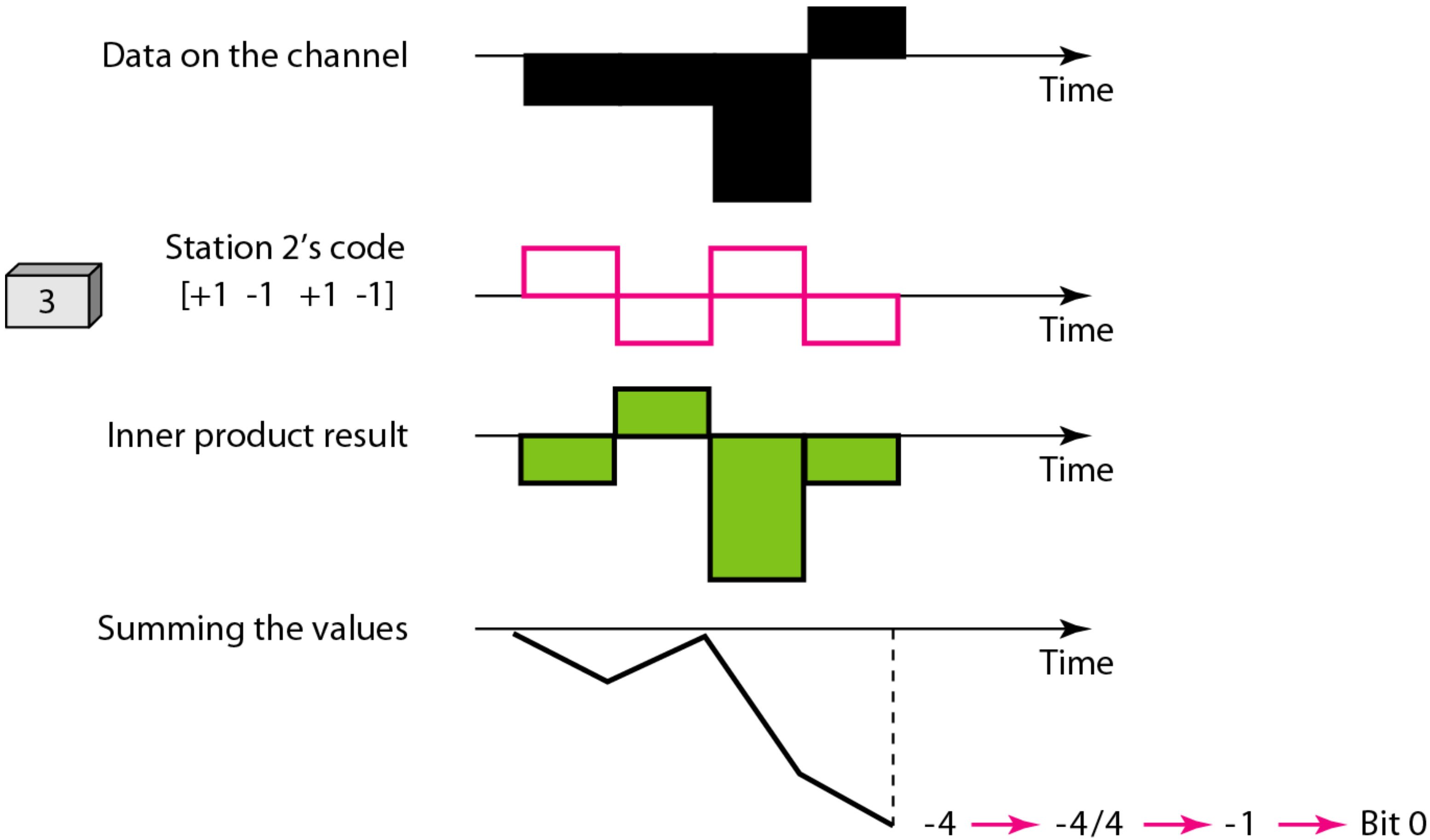


Figure 12.29 General rule and examples of creating Walsh tables

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

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

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

$$\begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

+1	+1	+1	+1	+1	+1	+1	+1
+1	-1	+1	-1	+1	-1	+1	-1
+1	+1	-1	-1	+1	+1	-1	-1
+1	-1	-1	+1	+1	-1	-1	+1
+1	+1	+1	+1	-1	-1	-1	-1
+1	-1	+1	-1	-1	+1	-1	+1
+1	+1	-1	-1	-1	-1	+1	+1
+1	-1	-1	+1	-1	+1	+1	-1

Generation of W_8

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 .