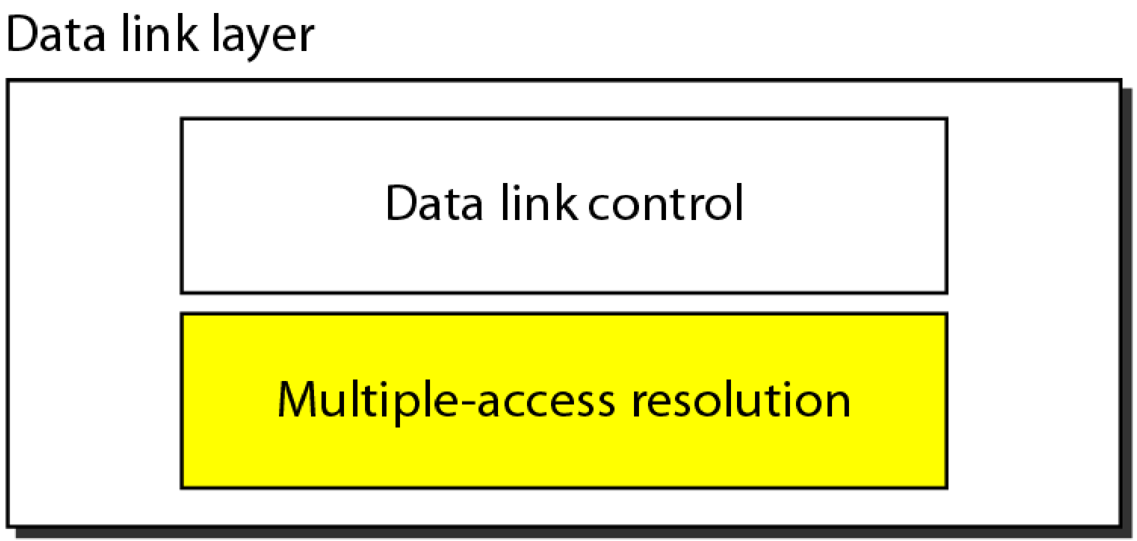
Multiple Access

- ***The two main functions of the data link layer are data link control and media access control.***

- ***The first, data link control, deals with the design and procedures for communication between two adjacent nodes: node-to-node communication.***

- ***The second function of the data link layer is media access control, or how to share the link.***

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



- ***Consider the data link layer as two sublayers.***

- ***The upper sublayer is responsible for data link control, and the lower sublayer is responsible for resolving access to the shared media.***

- ***If the channel is dedicated, we do not need the lower sublayer.***

- ***When nodes or stations are connected and use a common link, called a multipoint or broadcast link, we need a multiple-access protocol to coordinate access to the link.***

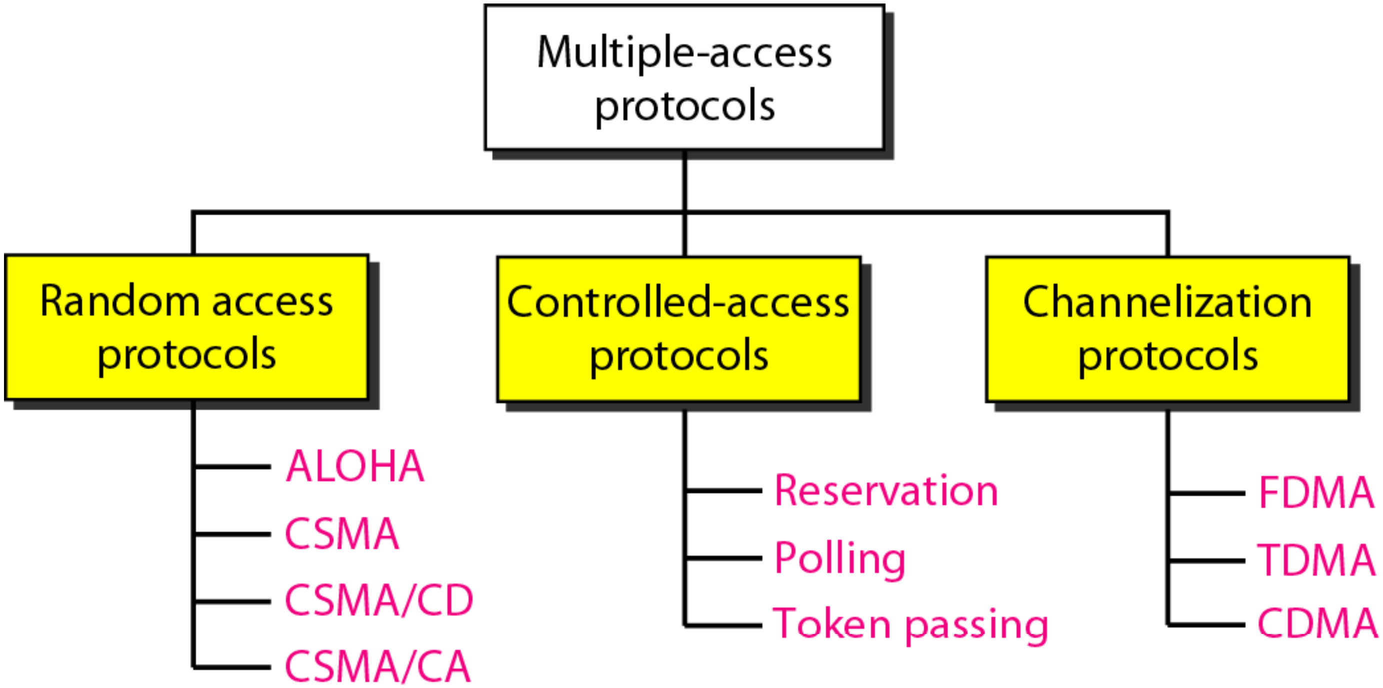
- ***The problem of controlling the access to the medium is similar to the rules of speaking in an assembly.***

- ***Two people do not speak at the same time, do not interrupt each other, do not monopolize the discussion, and so on.***

- ***The situation is similar for multipoint networks.***

- ***Many formal protocols have been devised to handle access to a shared link. We categorize them into three groups.***

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

12-1 RANDOM ACCESS

Two features give this method its name.

First, there is no scheduled time for a station to transmit. Transmission is random among the stations. That is why these methods are called random access.

Second, no rules specify which station should send next. Stations compete with one another to access the medium. That is why these methods are also called contention methods.

In a random access method, each station has the right to the medium without being controlled by any other station.

However, if more than one station tries to send, there is an access conflict-collision-and the frames will be either destroyed or modified.

The random access methods have evolved from a very interesting protocol known as ALOHA, which used a very simple procedure called Multiple Access (MA).

The method was improved with the addition of a procedure that forces the station to sense the medium before transmitting. This was called Carrier Sense Multiple Access.

This method later evolved into two parallel methods: Carrier Sense Multiple Access with Collision Detection (CSMAlCD) and Carrier Sense Multiple Access With Collision Avoidance (CSMA/CA).

CSMA/CD tells the station what to do when a collision is detected.

CSMA/CA tries to avoid the collision.

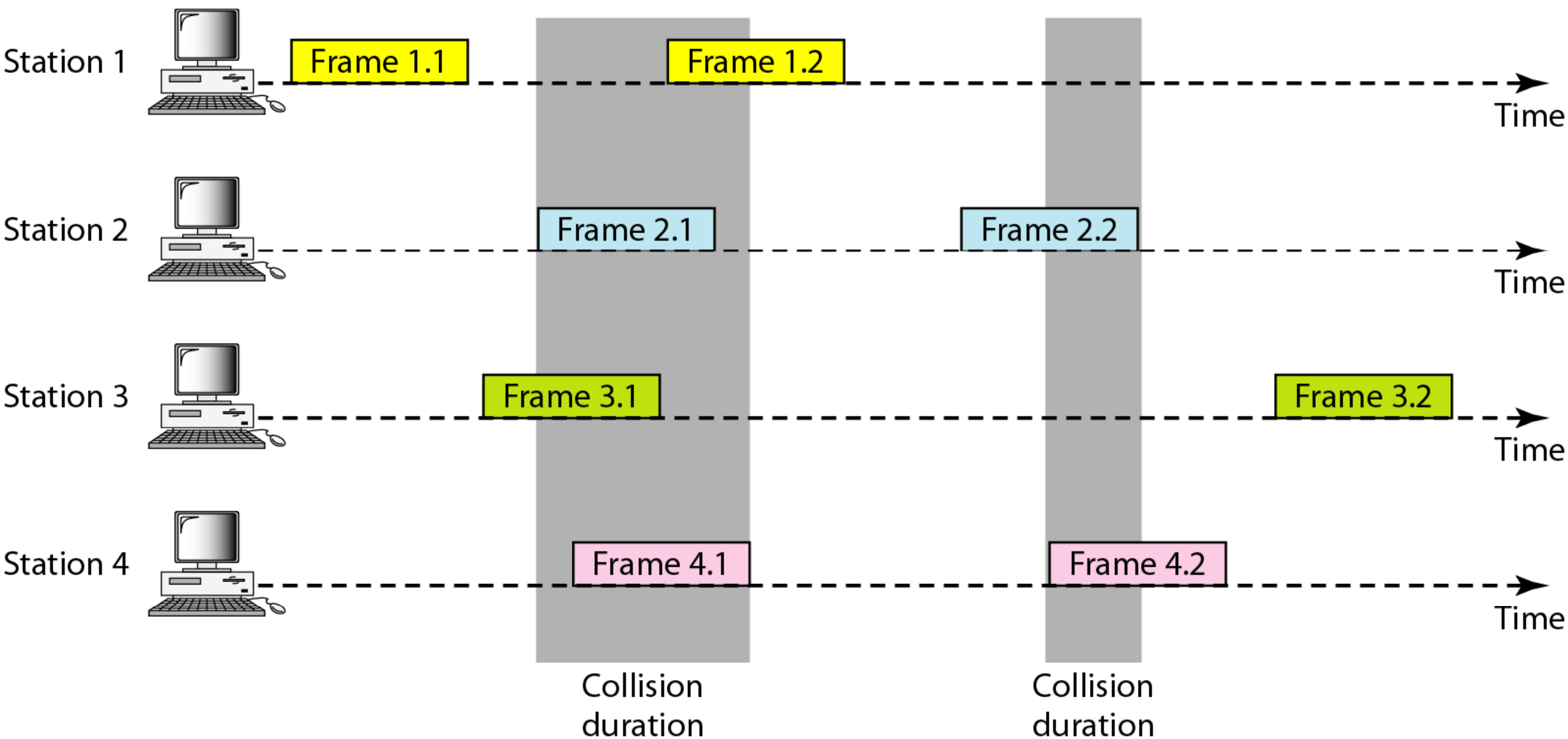
Pure ALOHA

The original ALOHA protocol is called pure ALOHA. This is a simple, but elegant protocol.

The idea is that each station sends a frame whenever it has a frame to send.

However, since there is only one channel to share, there is the possibility of collision between frames from different stations.

Figure 12.3 *Frames in a pure ALOHA network*



There are four stations that contend with one another for access to the shared channel.

The figure shows that each station sends two frames; there are a total of eight frames on the shared medium.

Some of these frames collide because multiple frames are in contention for the shared channel.

It is obvious that we need to resend the frames that have been destroyed during transmission.

The pure ALOHA protocol relies on acknowledgments from the receiver.

When a station sends a frame, it expects the receiver to send an acknowledgment.

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.

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 T_B.

Carrier Sense Multiple Access (CSMA)

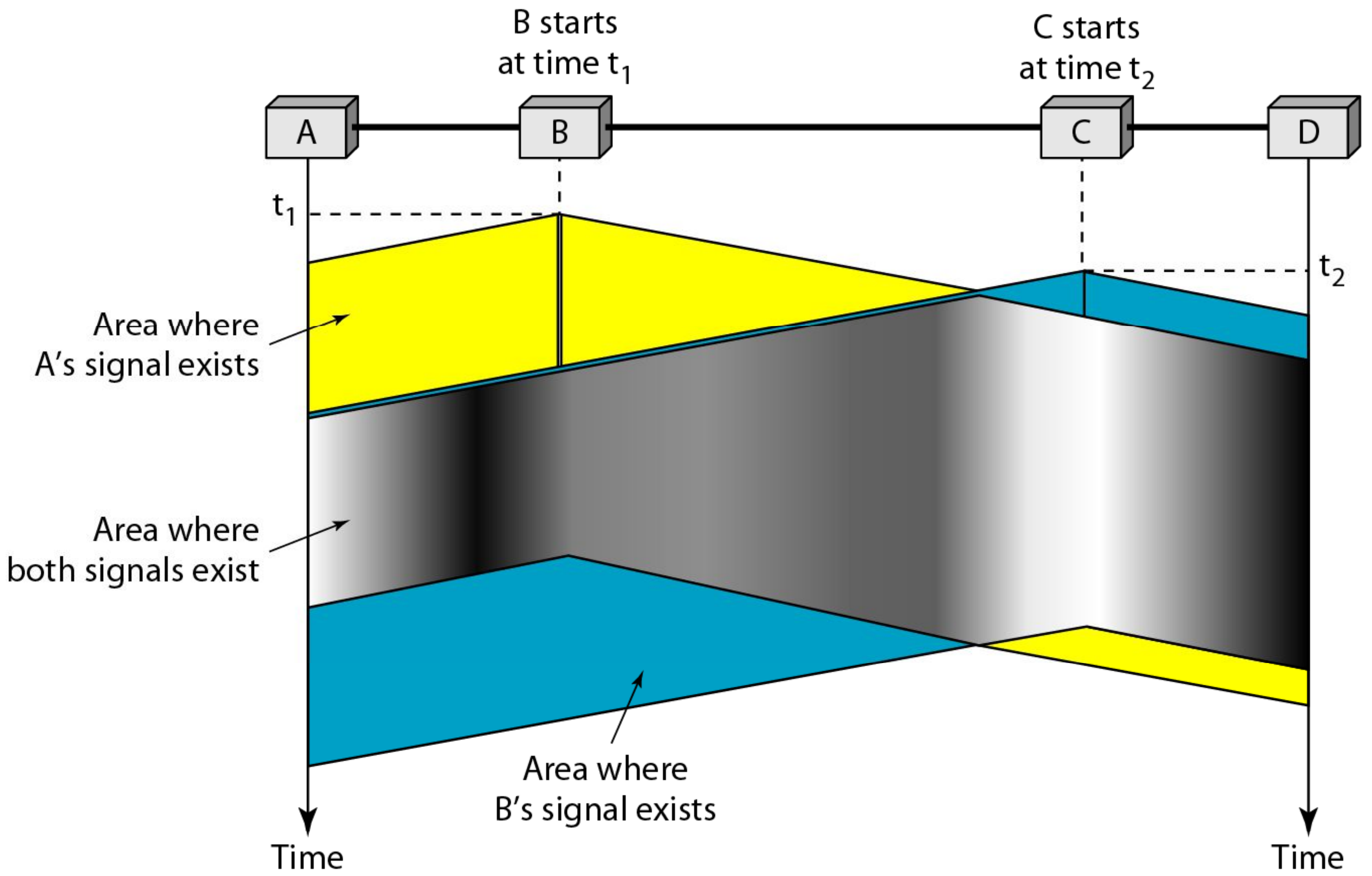
To minimize the chance of collision and, therefore, increase the performance, the CSMA method was developed.

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 (or check the state of the medium) before sending.

In other words, CSMA is based on the principle "sense before transmit" or "listen before talk."

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



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:

- ***Persistent method***
- ***Nonpersistent method***
- ***p-persistent method.***

Persistent

The 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 two or more stations may find the line idle and send their frames immediately.

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.

The nonpersistent approach reduces the chance of collision because it is unlikely that two or more stations will wait the same amount of time and retry to send simultaneously.

However, this method reduces the efficiency of the network because the medium remains idle when there may be stations with frames to send.

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.

It reduces the chance of collision and improves efficiency.

Figure 12.10 *Behavior of three persistence methods*

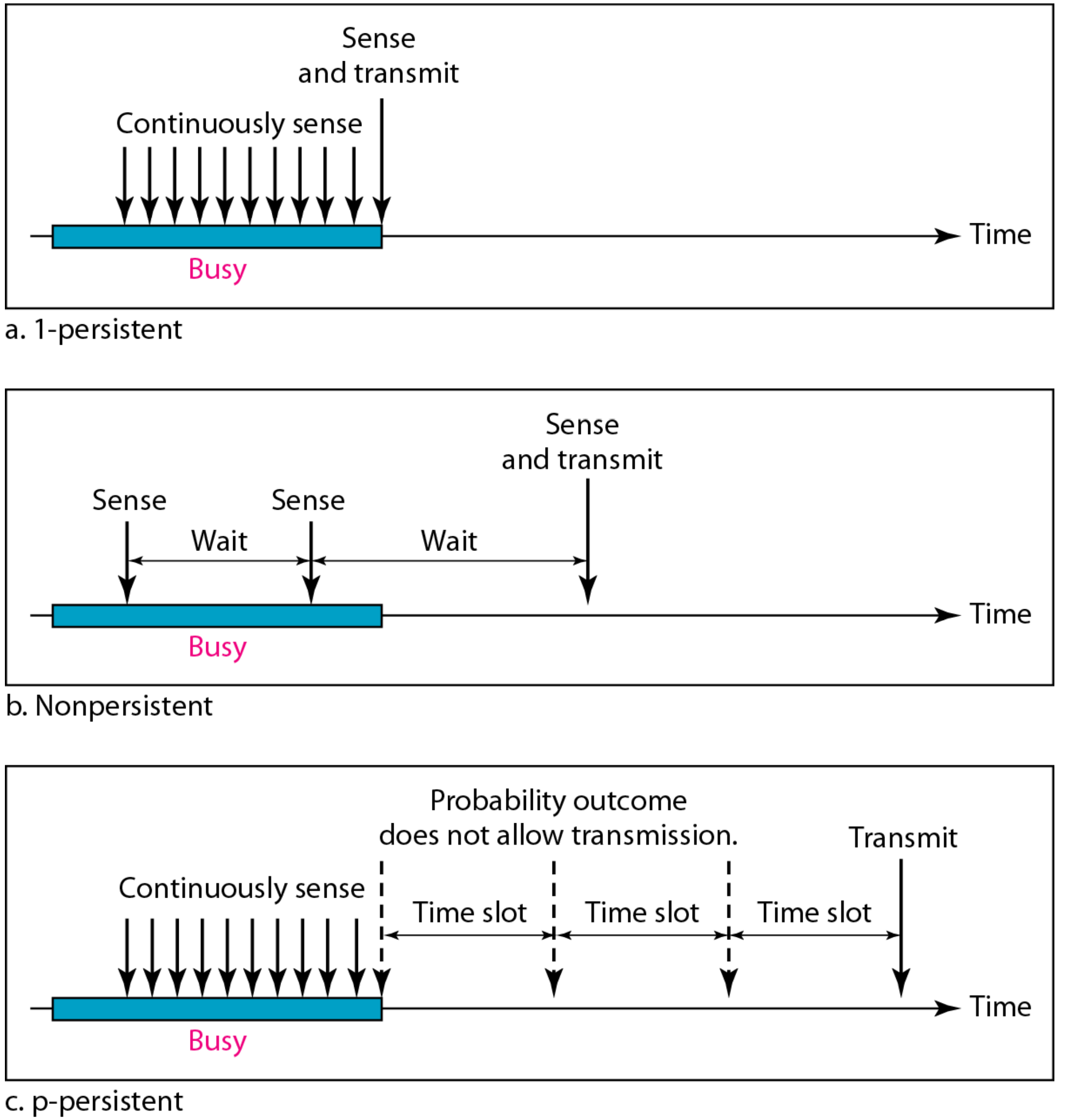


Figure 12.11 *Flow diagram for three persistence methods*

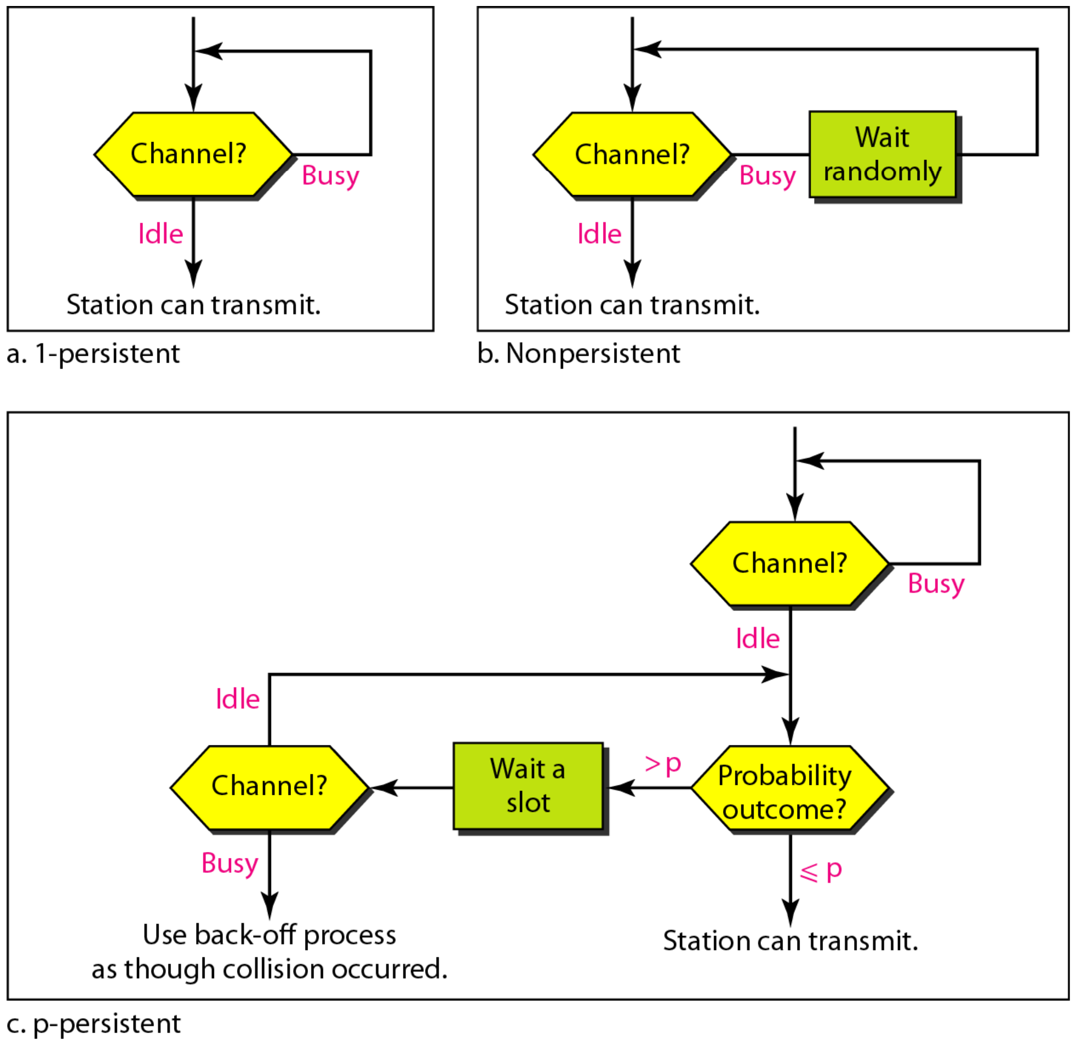


Figure 12.12 *Collision of the first bit in CSMA/CD*

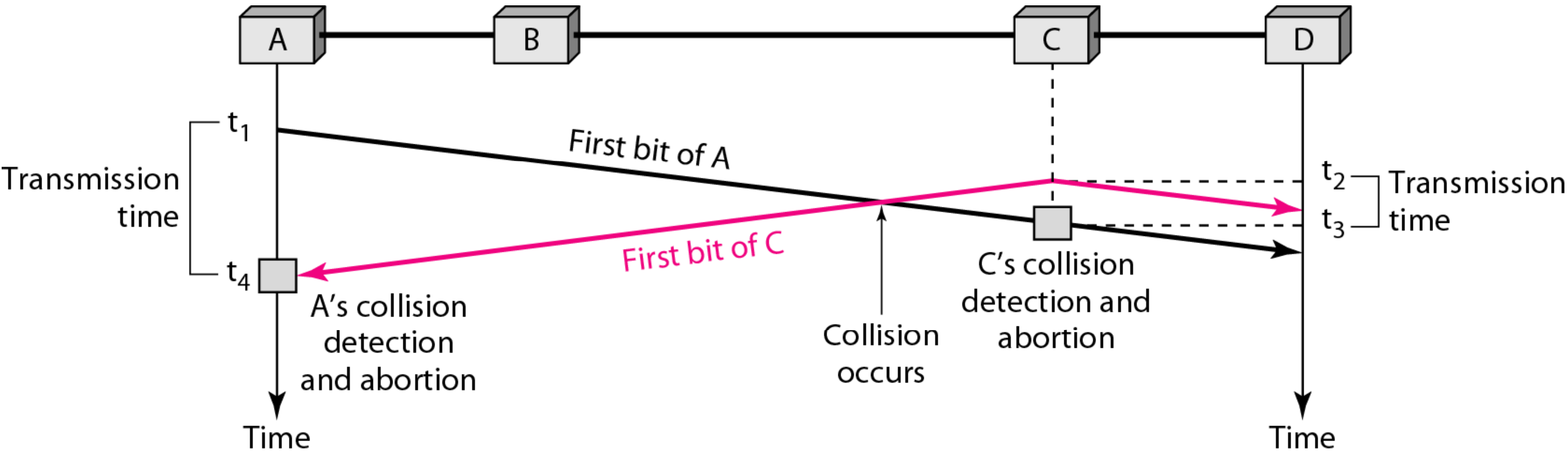


Figure 12.13 *Collision and abortion in CSMA/CD*

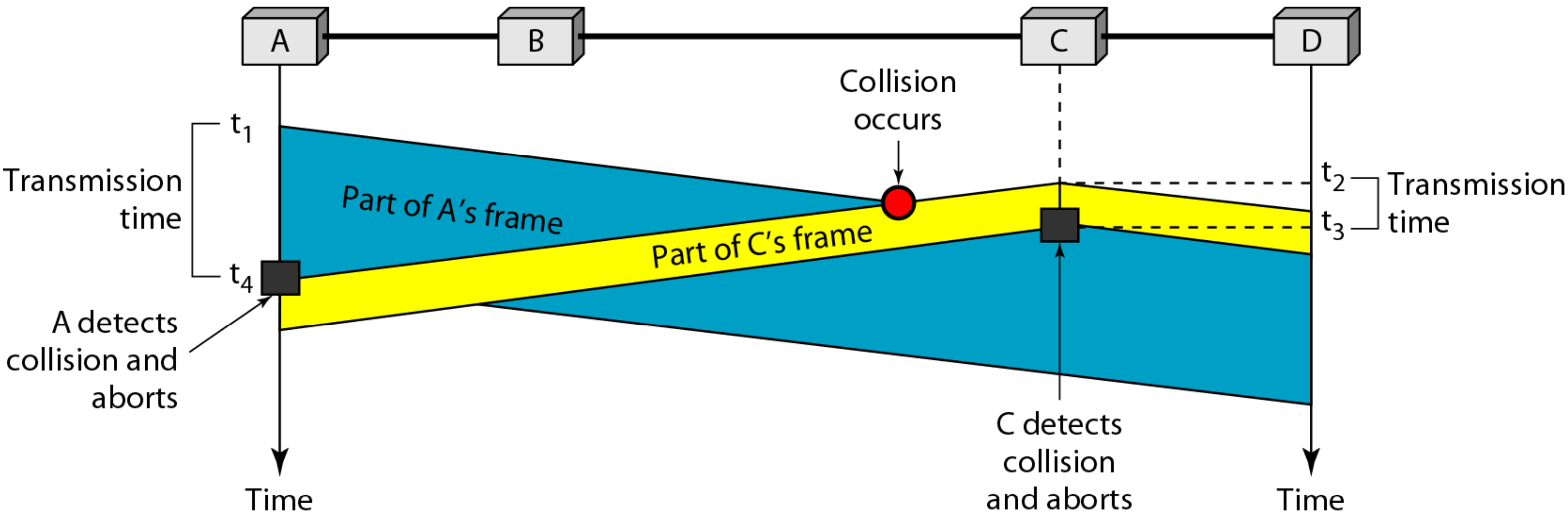


Figure 12.15 *Energy level during transmission, idleness, or collision*

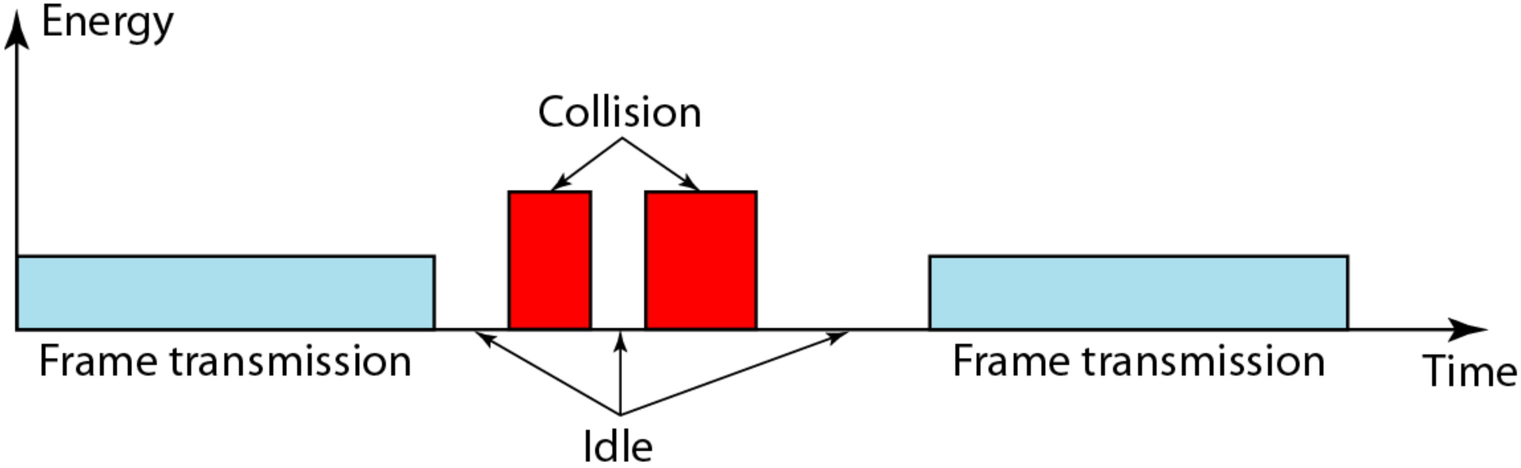
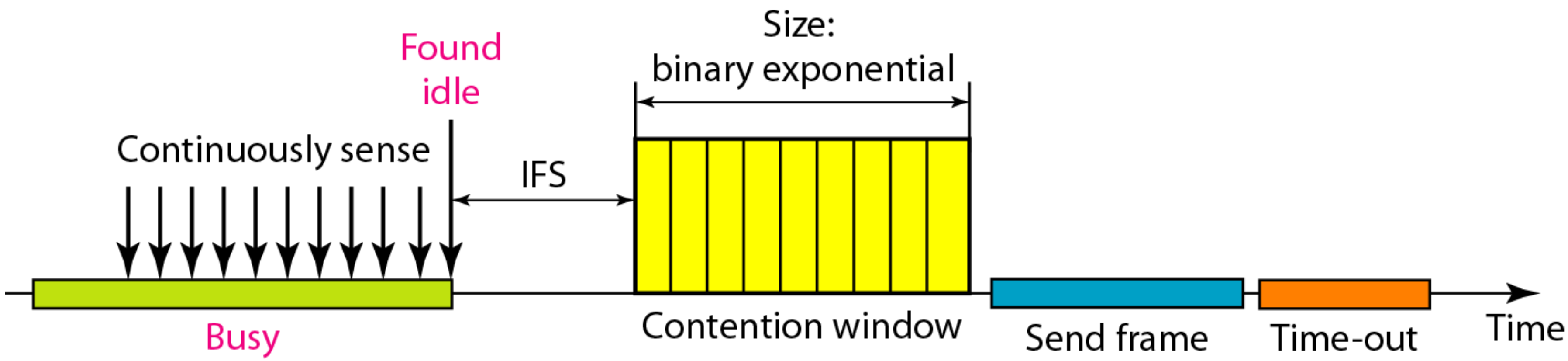


Figure 12.16 *Timing in CSMA/CA*



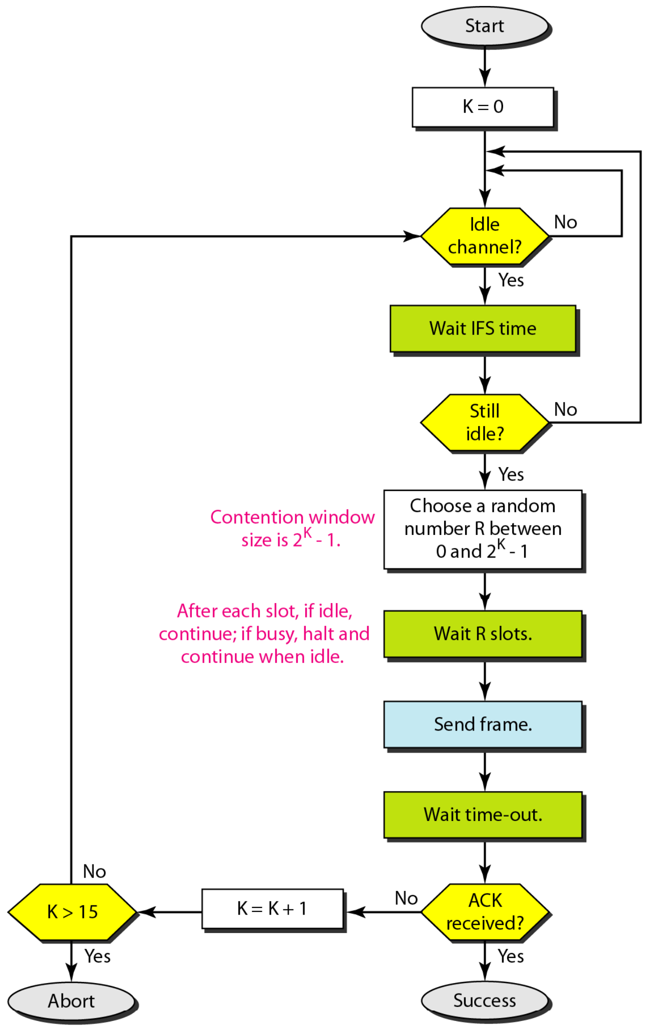
Note

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

Reservation

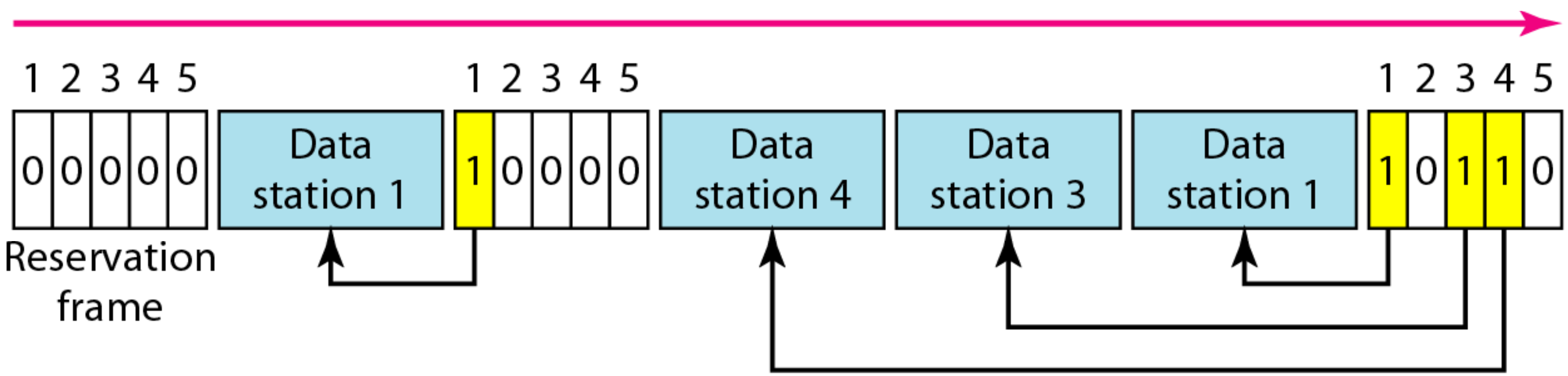
In the reservation method, a station needs to make a reservation before sending data.

Time is divided into intervals.

In each interval, a reservation frame precedes the data frames sent in that interval.

Figure 12.18 *Reservation access method*

Figure shows a situation with five stations and a five-mini slot reservation frame. In the first interval, only stations 1, 3, and 4 have made reservations. In the second interval, only station 1 has made a reservation.



Polling

Polling works with topologies in which one device is designated as a primary station and the other devices are secondary stations.

All data exchanges must be made through the primary device even when the ultimate destination is a secondary device.

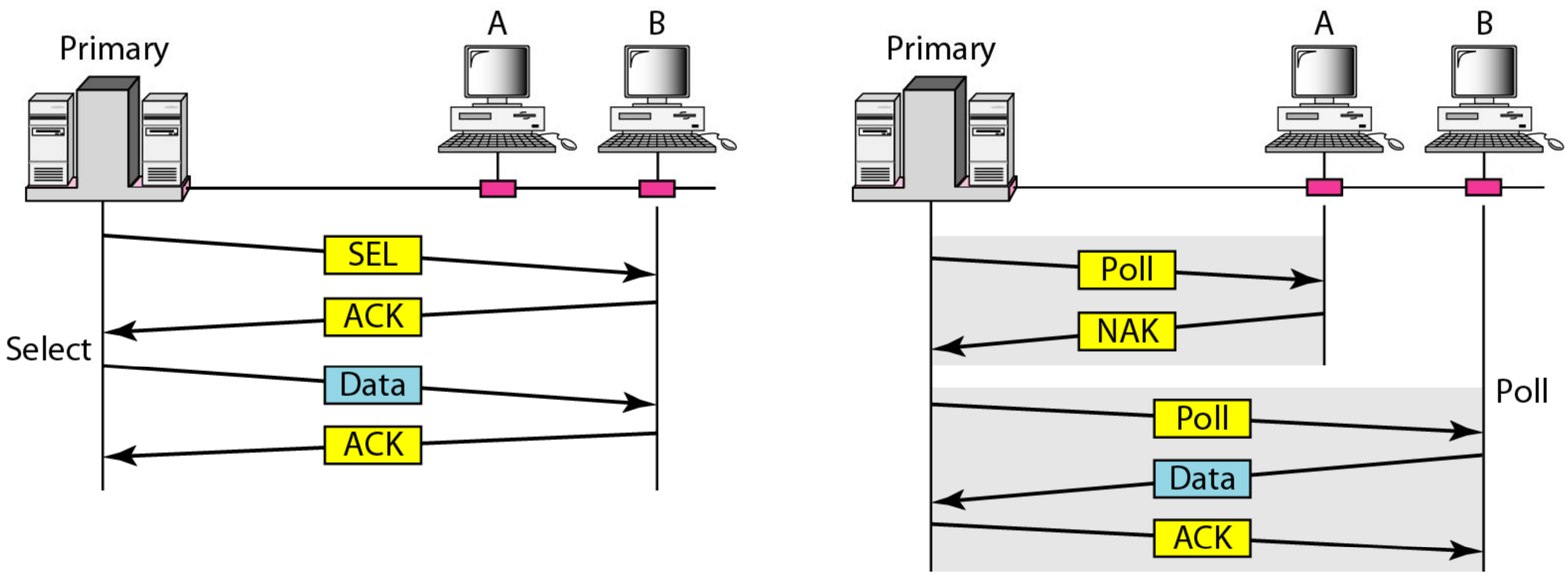
The primary device controls the link; the secondary devices follow its instructions.

It is up to the primary device to determine which device is allowed to use the channel at a given time.

If the primary wants to receive data, it asks the secondary's if they have anything to send; this is called poll function.

If the primary wants to send data, it tells the secondary to get ready to receive; this is called select function.

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



Token Passing

- ***In the token-passing method, the stations in a network are organized in a logical ring.***

- ***In other words, for each station, there is a predecessor and a successor.***

- ***The predecessor is the station which is logically before the station in the ring;***

- ***The successor is the station which is after the station in the ring.***
-
- ***The current station is the one that is accessing the channel now.***

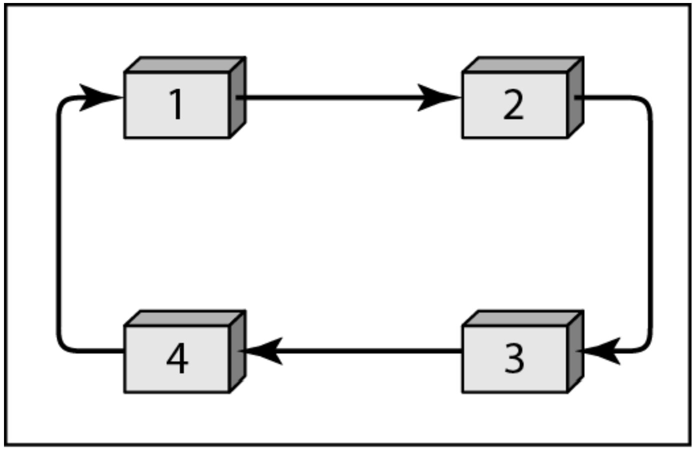
In this method, a special packet called a token circulates through the ring.

When a station has some data to send, it waits until it receives the token from its predecessor.

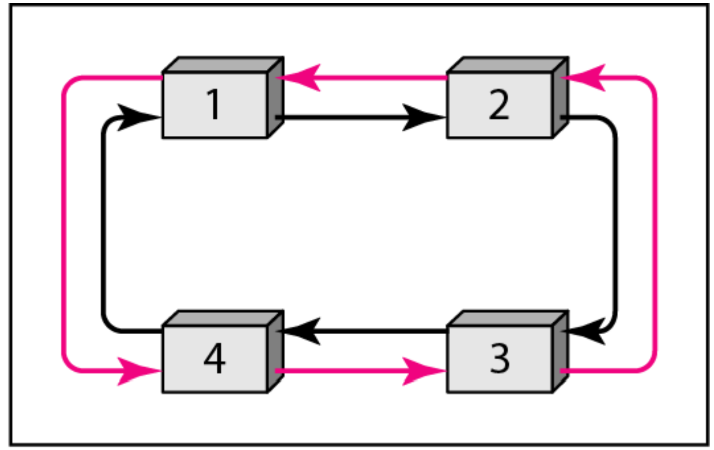
It then holds the token and sends its data.

When the station has no more data to send, it releases the token, passing it to the next logical station in the ring.

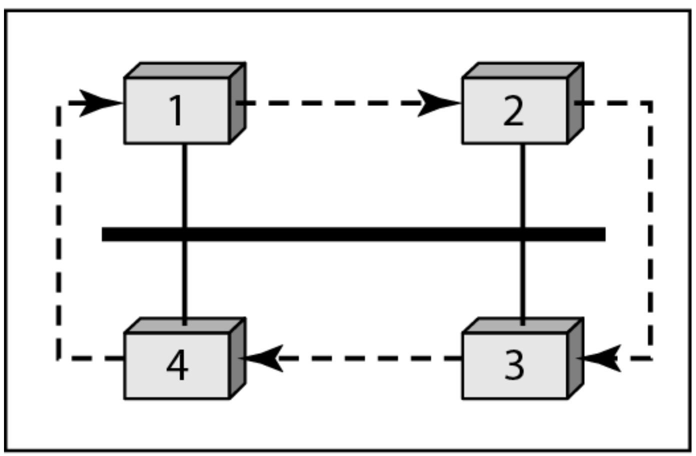
Figure 12.20 *Logical ring and physical topology in token-passing access method*



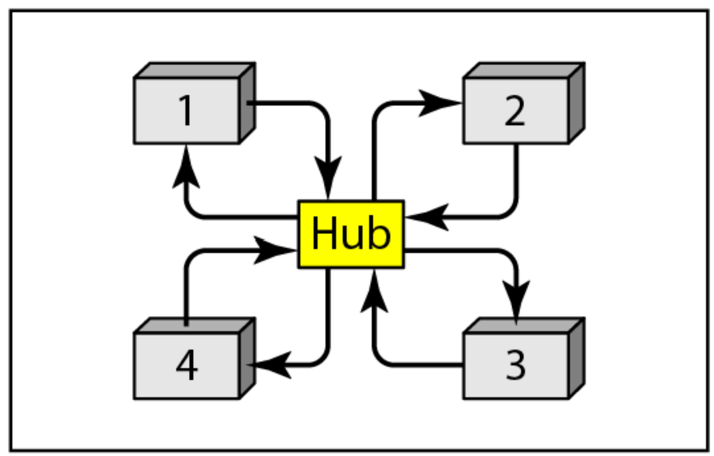
a. Physical ring



b. Dual ring



c. Bus ring



d. Star ring

physical ring topology

In the physical ring topology, when a station sends the token to its successor, the token cannot be seen by other stations; the successor is the next one in line.

This means that the token does not have to have the address of the next successor.

The problem with this topology is that if one of the links-the medium between two adjacent stations fails, the whole system fails.

The dual ring topology uses a second (auxiliary) ring which operates in the reverse direction compared with the main ring.

The second ring is for emergencies only (such as a spare tire for a car).

If one of the links in the main ring fails, the system automatically combines the two rings to form a temporary ring.

After the failed link is restored, the auxiliary ring becomes idle again.

Note that for this topology to work, each station needs to have two transmitter ports and two receiver ports.

In the bus ring topology, also called a token bus, the stations are connected to a single cable called a bus.

They, however, make a logical ring, because each station knows
the address of its successor (and also predecessor for token management purposes).

When a station has finished sending its data, it releases the token and inserts the address of its successor in the token.

Only the station with the address matching the destination address of the token gets the token to access the shared media.

In a star ring topology, the physical topology is a star. There is a hub, however, that acts as the connector.

The wiring inside the hub makes the ring; the stations are connected to this ring through the two wire connections.

This topology makes the network less prone to failure because if a link goes down, it will be bypassed by the hub and the rest of the stations can operate.

Also adding and removing stations from the ring is easier.

This topology is still used in the Token Ring LAN designed by IBM.

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)

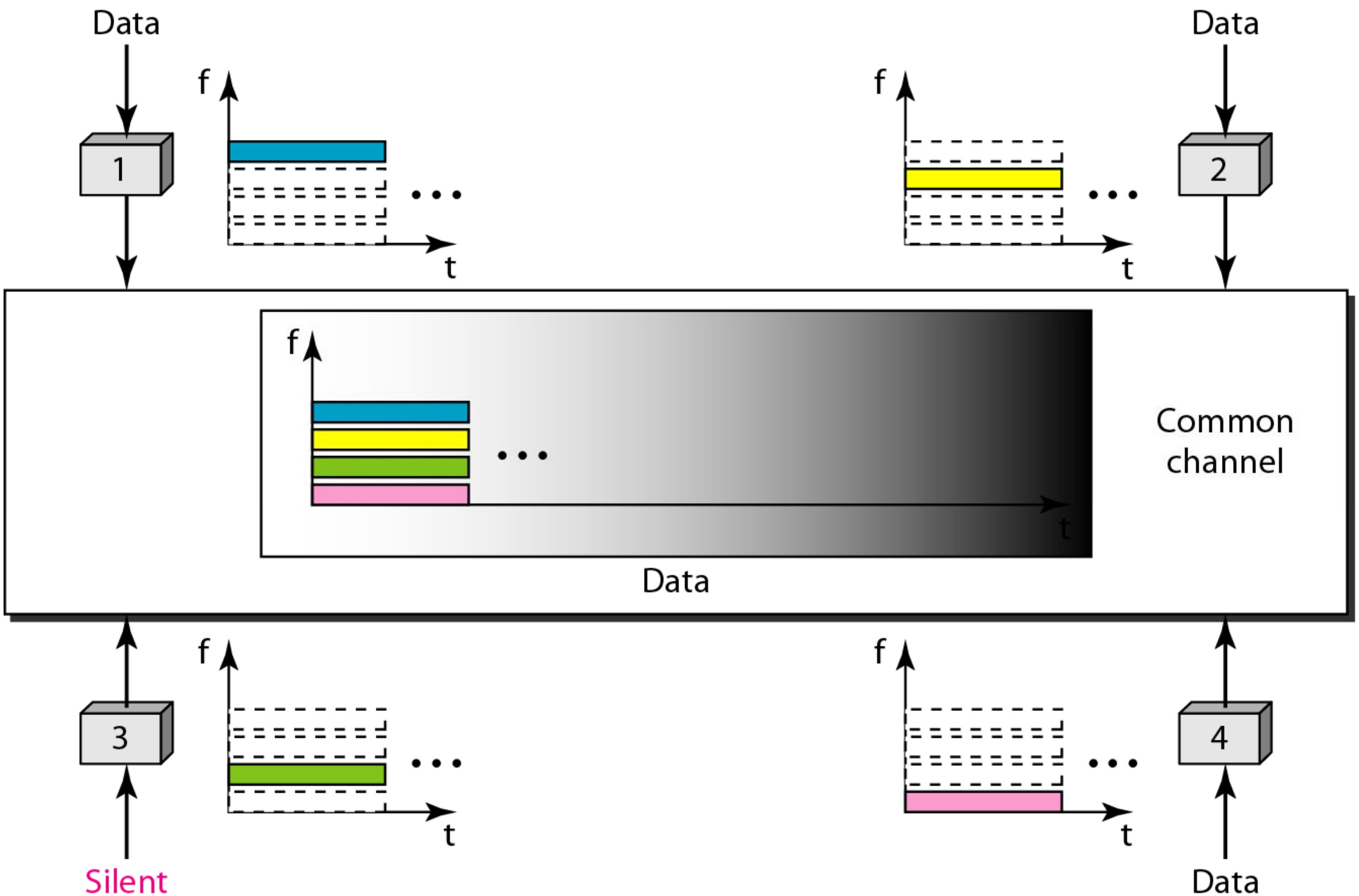
In frequency-division multiple access (FDMA), the available bandwidth is divided into frequency bands.

Each station is allocated a band to send its data. In other words, each band is reserved for a specific station, and it belongs to the station all the time.

Each station also uses a band pass filter to confine the transmitter frequencies.

To prevent station interferences, the allocated bands are separated from one another by small guard bands.

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.

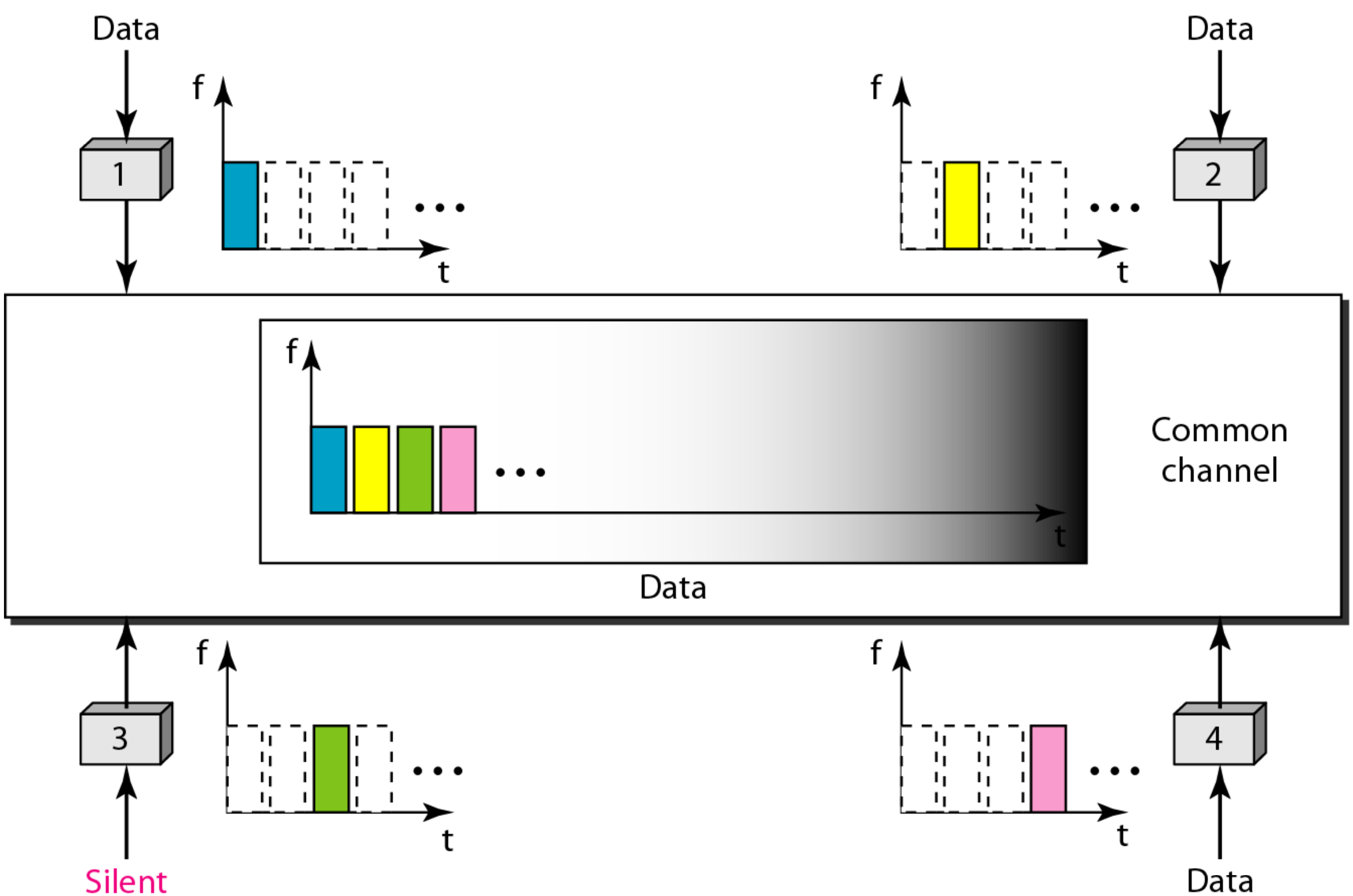
Time-Division Multiple Access (TDMA)

In time-division multiple access (TDMA), the stations share the bandwidth of the channel in time.

Each station is allocated a time slot during which it can send data.

Each station transmits its data in is assigned time slot.

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*

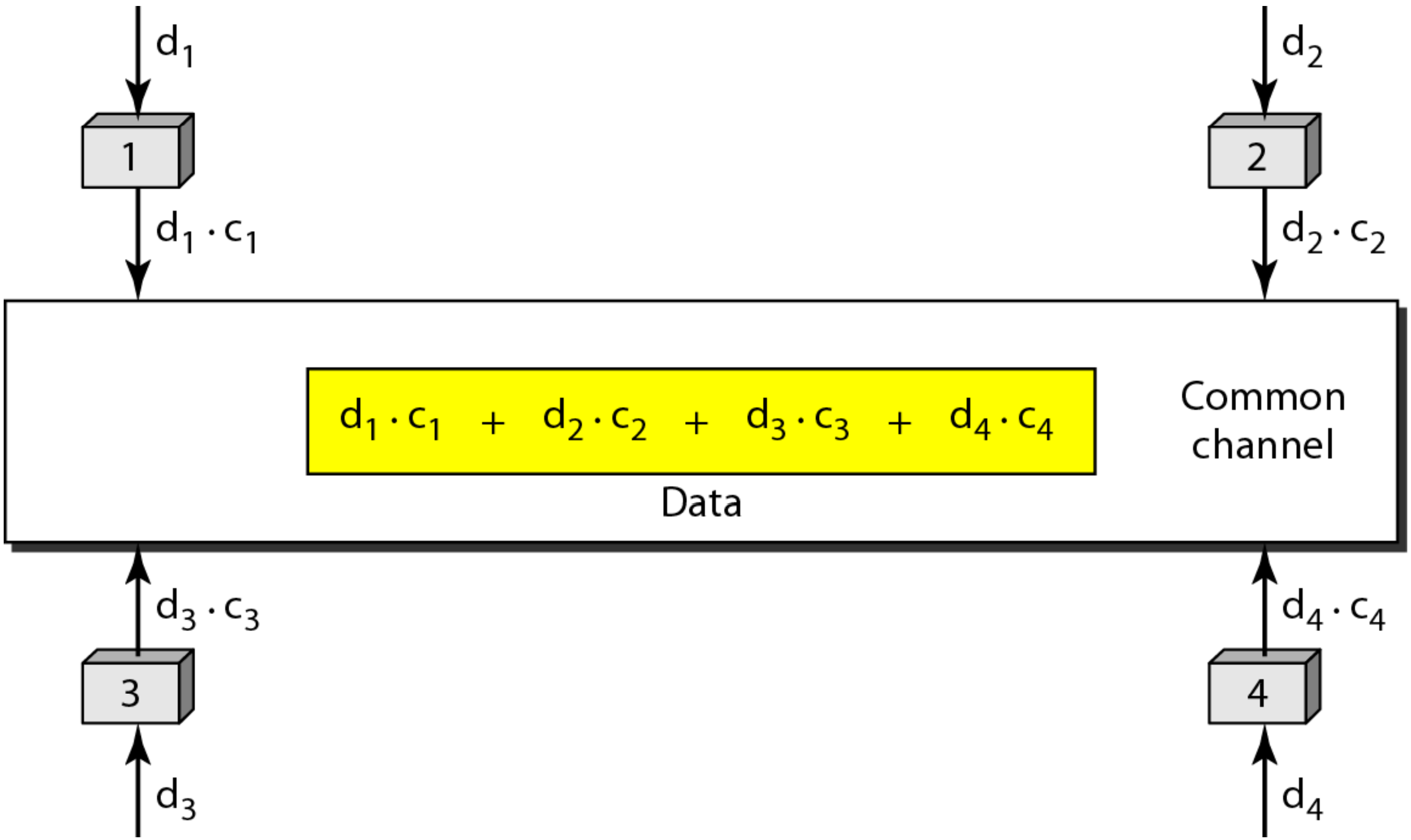


Figure 12.24 *Chip sequences*

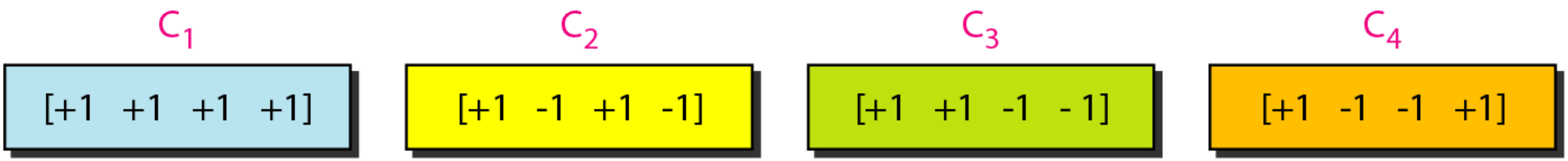


Figure 12.25 *Data representation in CDMA*

Figure 12.26 *Sharing channel in CDMA*

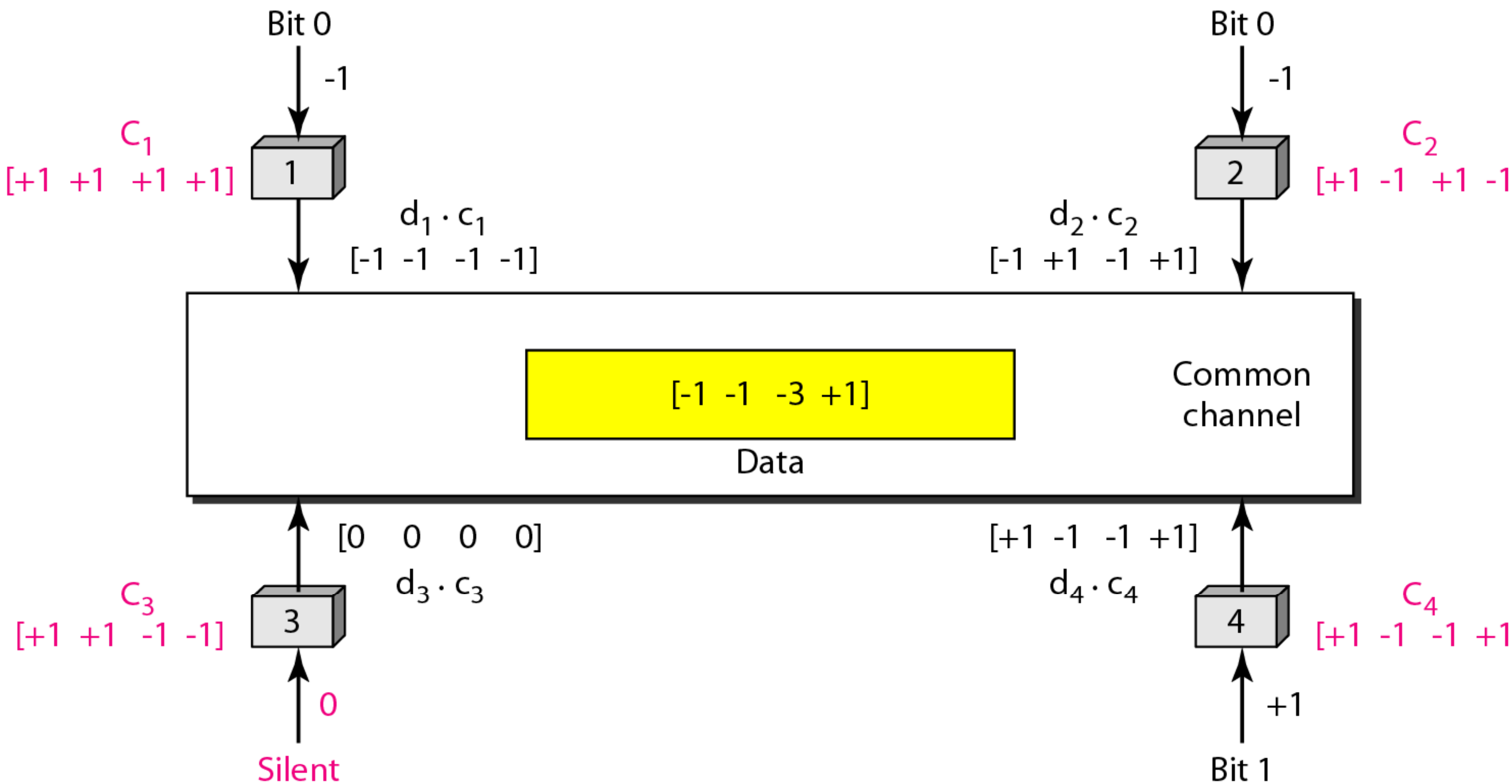


Figure 12.27 *Digital signal created by four stations in CDMA*

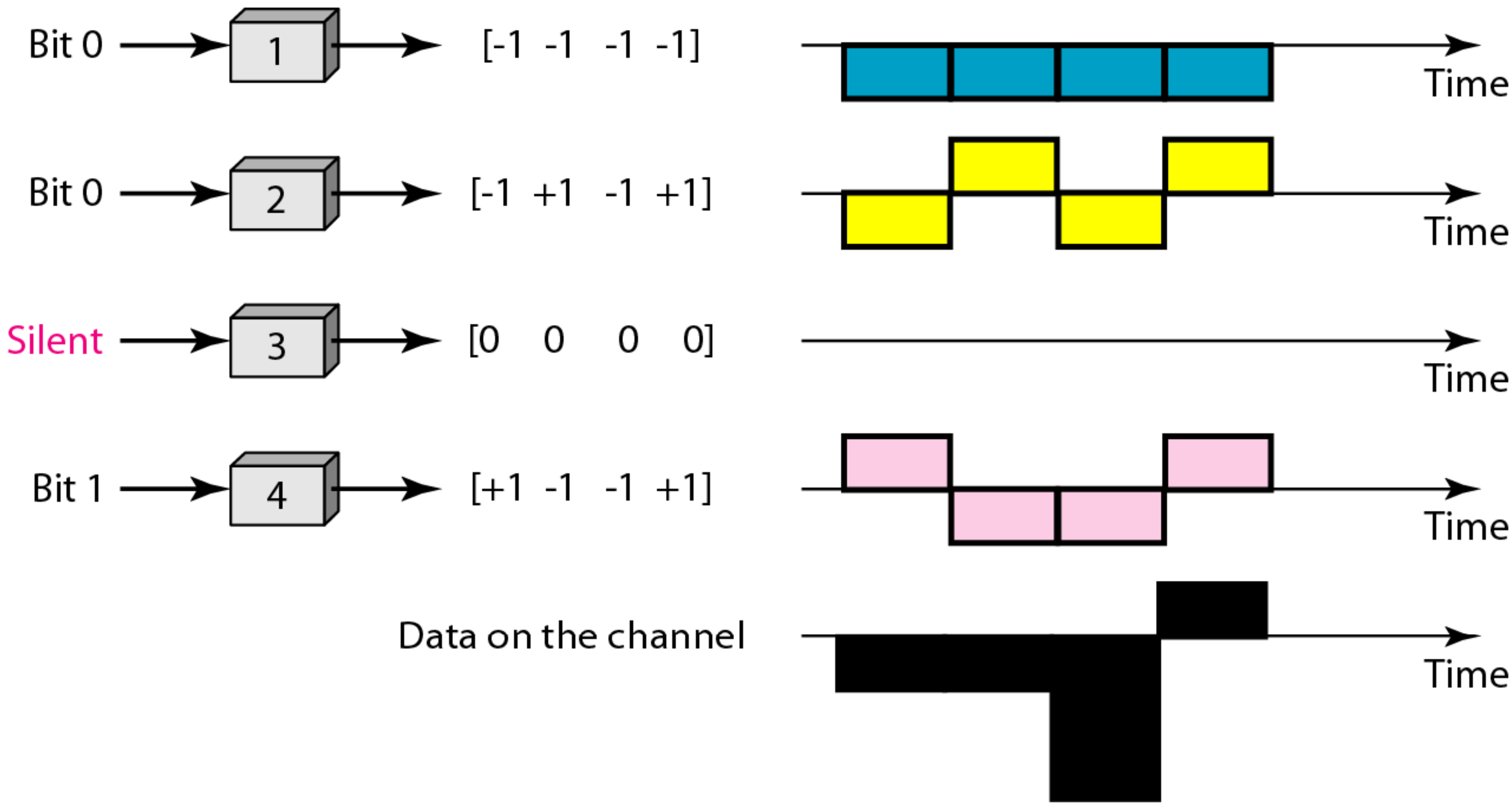


Figure 12.28 *Decoding of the composite signal for one in CDMA*

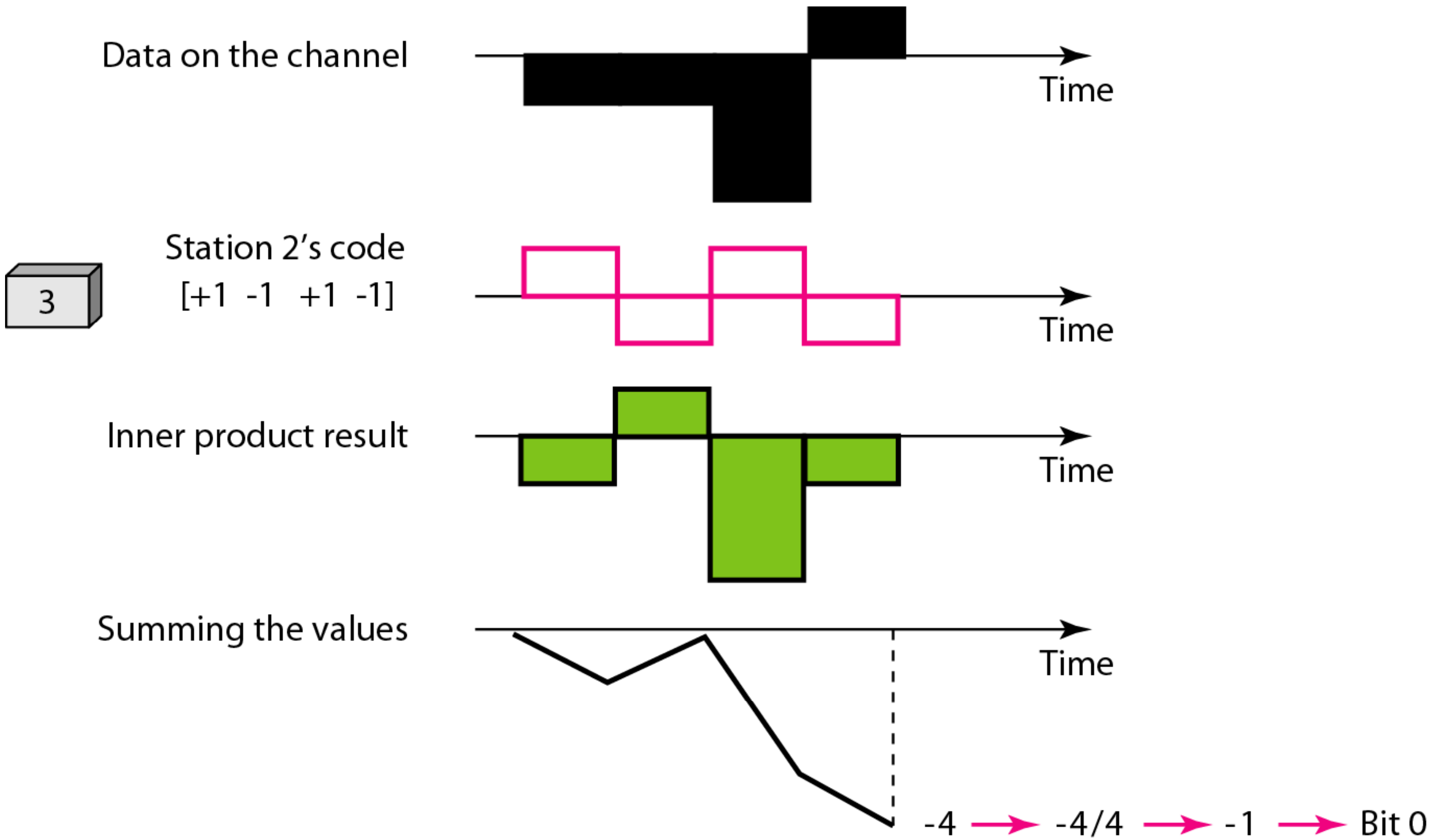


Figure 12.29 *General rule and examples of creating Walsh tables*

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

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.