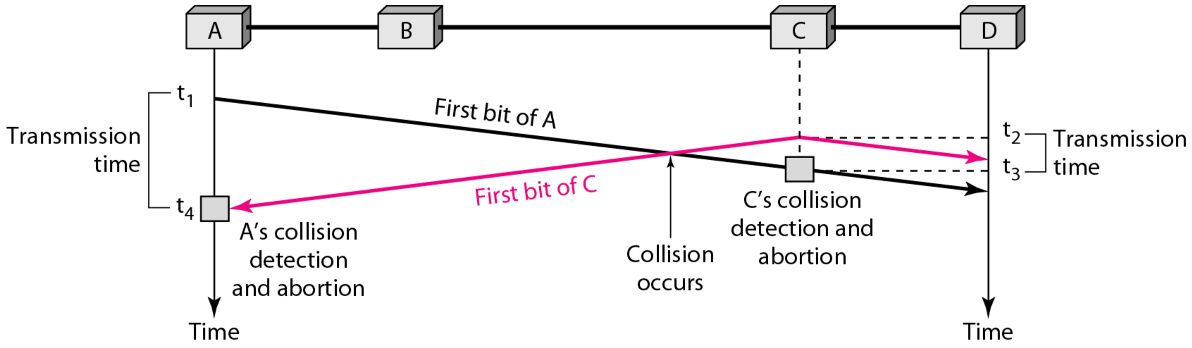
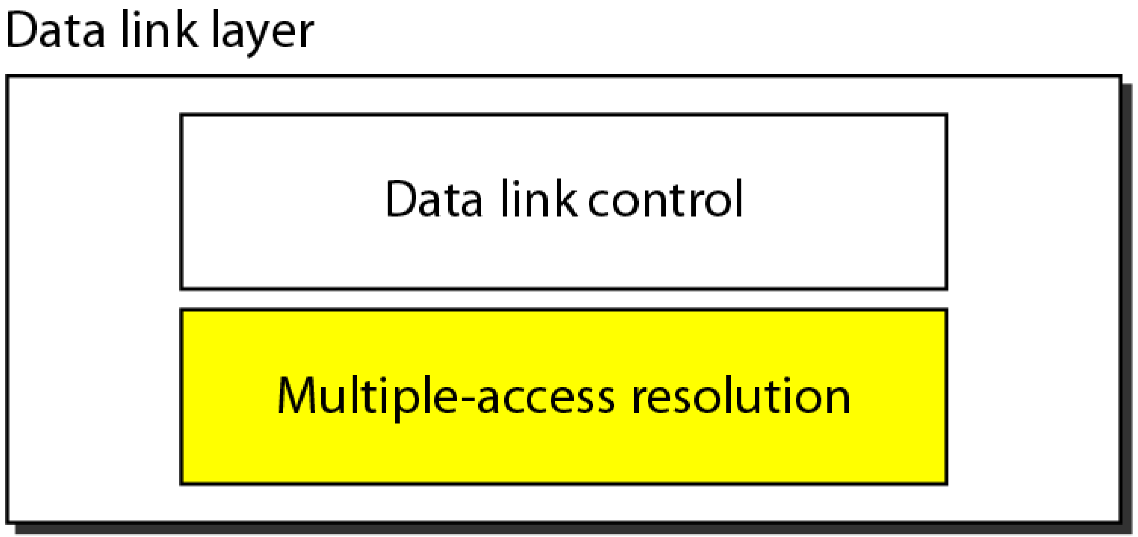


Data link Layer MAC

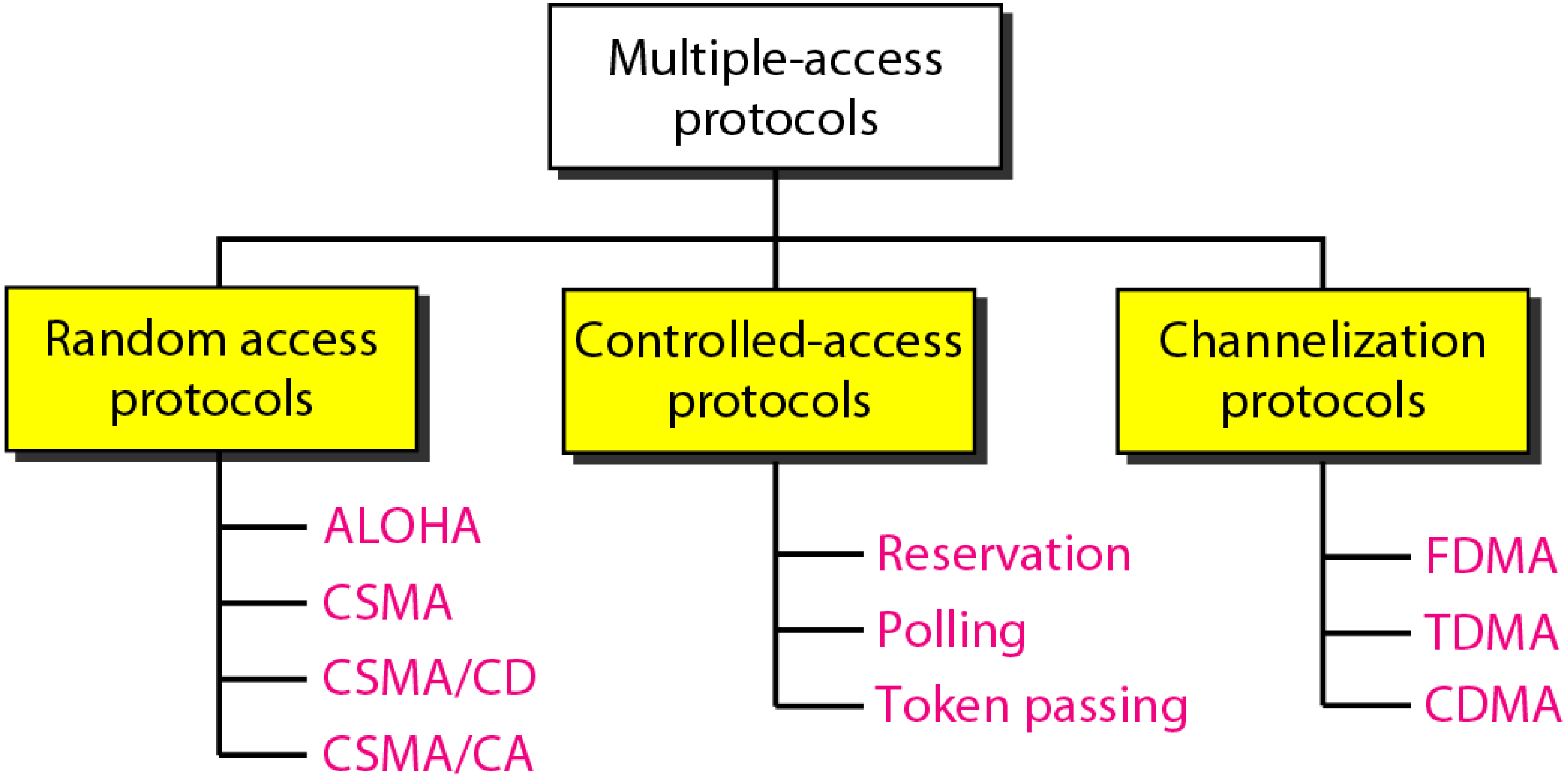
Data Link Layer



Multiple Access Protocols

- 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.
- The procedures guarantee that the right to speak is upheld and ensure that two people do not speak at the same time, do not interrupt each other, do not monopolize.

Taxonomy Multiple Access Protocols

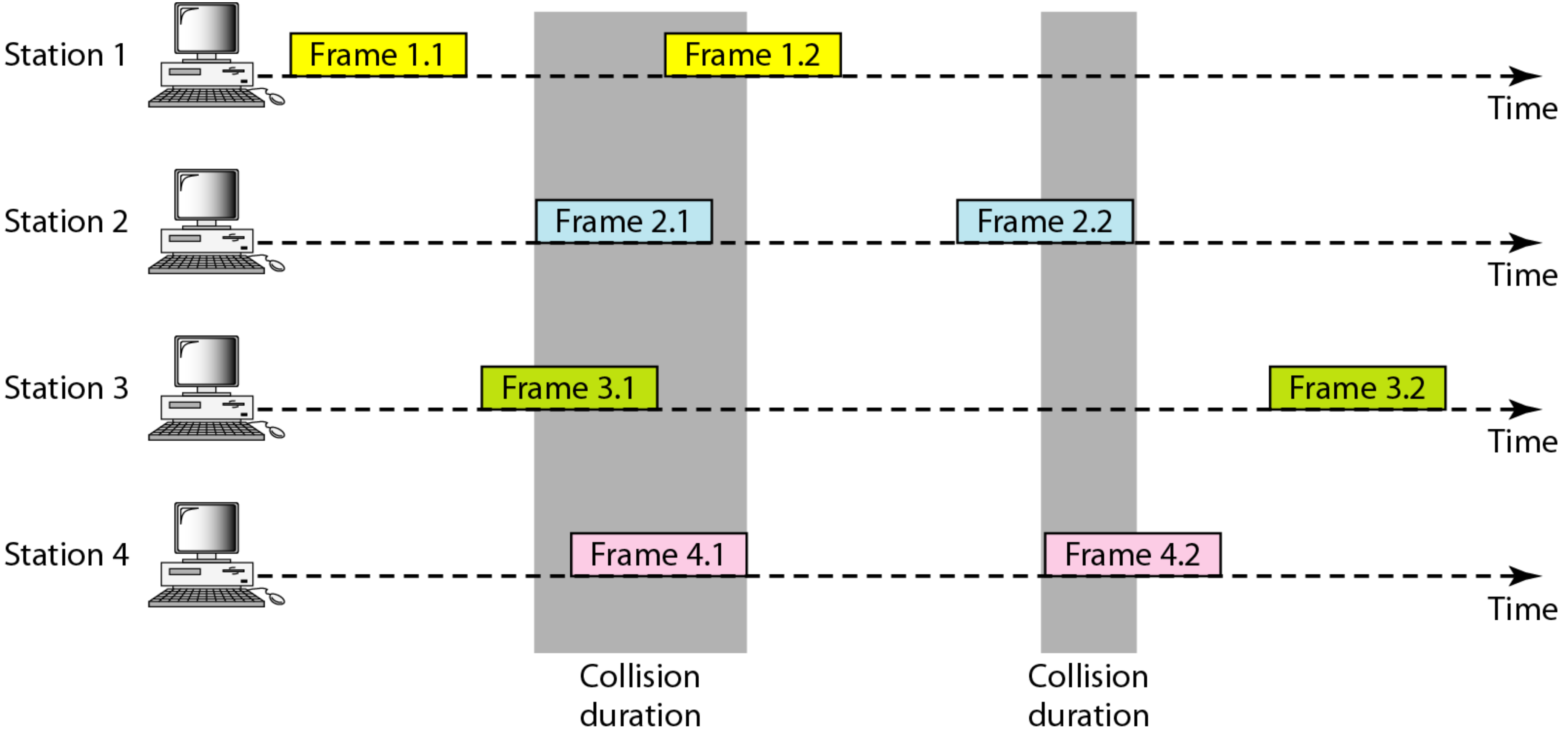


Random Access Protocol

- 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.

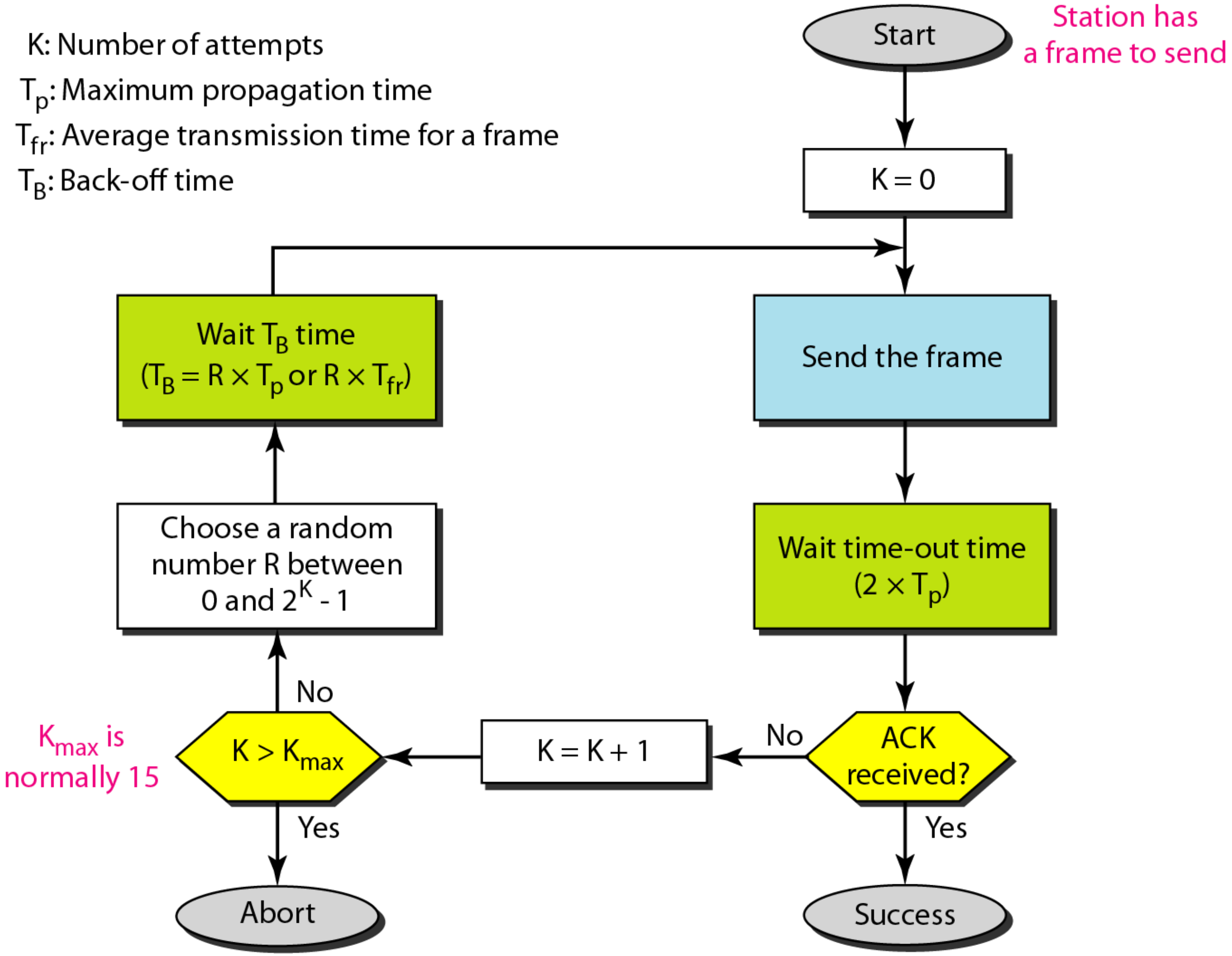
ALOHA
Carrier Sense Multiple Access
Carrier Sense Multiple Access with Collision Detection
Carrier Sense Multiple Access with Collision Avoidance

Pure ALOHA

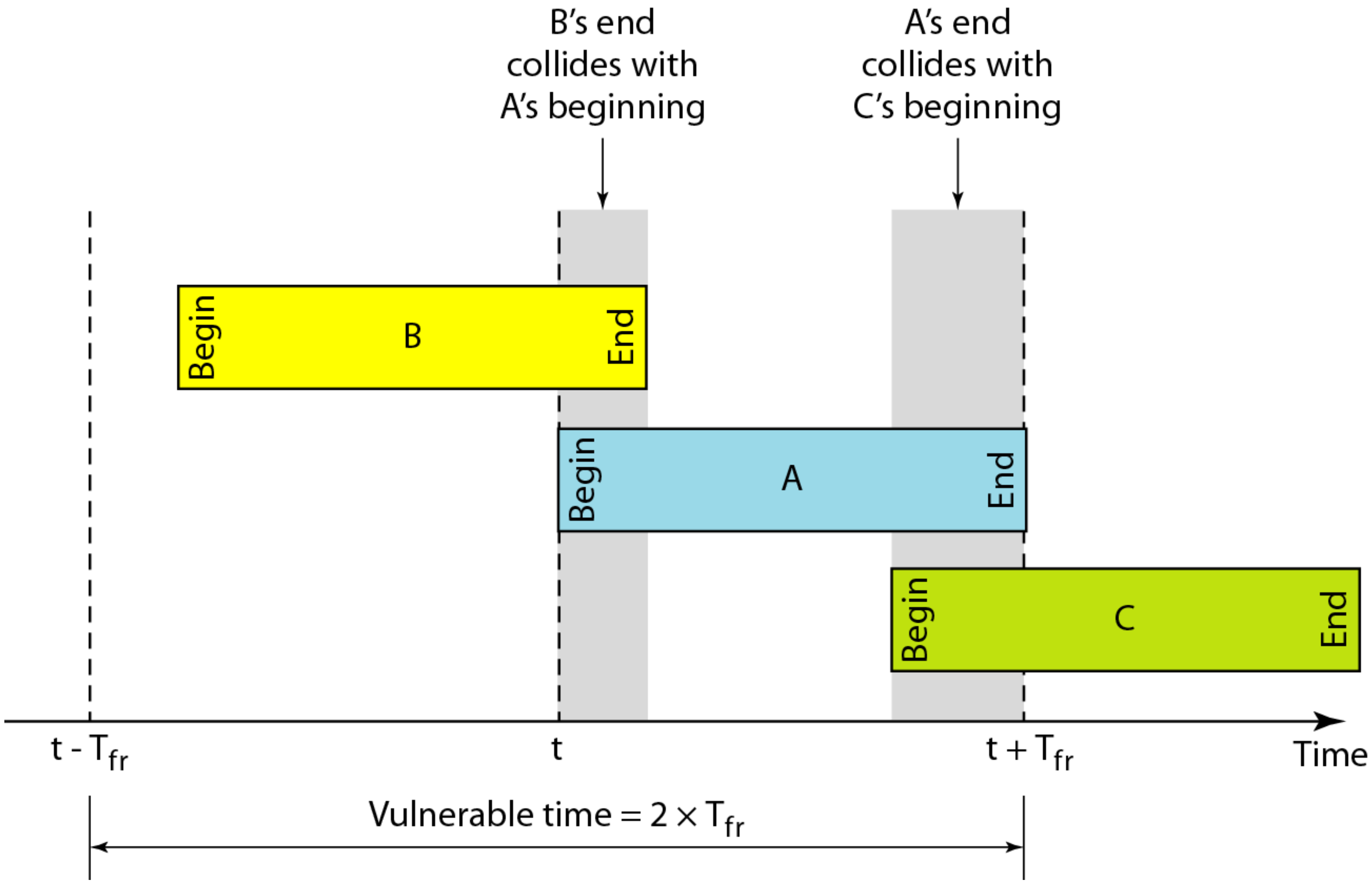


Station 1
Station 2
Station 3
Station 4
Frame 1.1
Frame 1.2
Frame 2.1
Frame 2.2
Frame 3.1
Frame 3.2
Frame 4.1
Frame 4.2
Time
Time
Time
Time
Collision duration
Collision duration

Procedure for pure ALOHA protocol



Vulnerable time for pure ALOHA protocol



Example

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.

Example

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.

Note

The throughput for pure ALOHA is

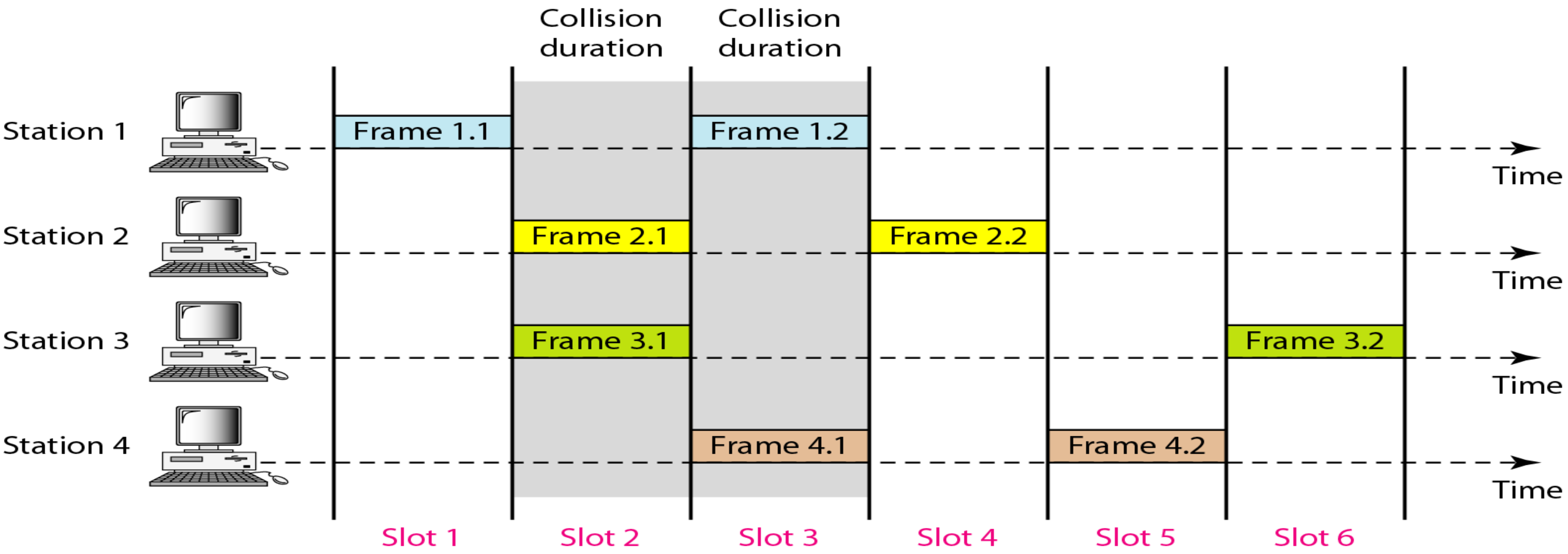
$S = G \times e^{-2G}$.

The maximum throughput

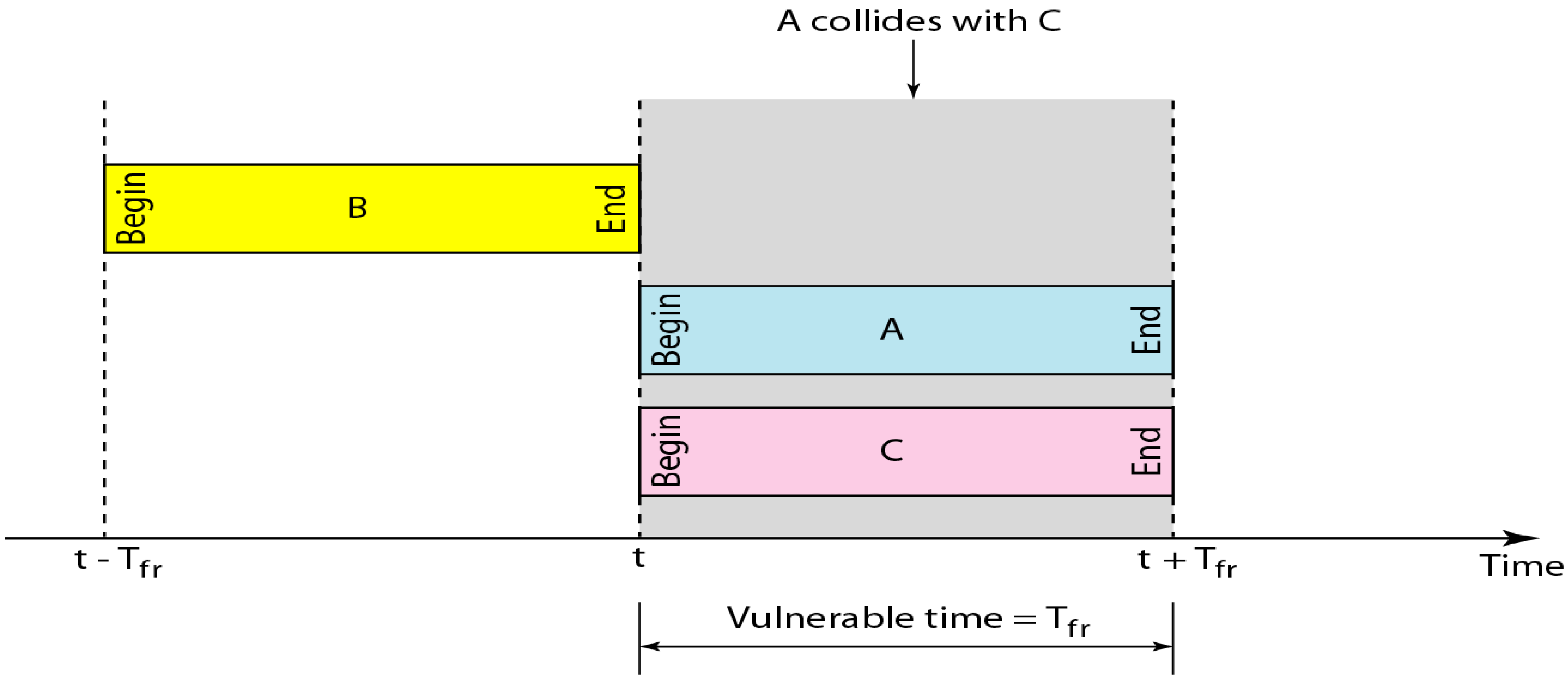
$S_{max} = 0.184$ when G= (1/2).

In Pure Aloha G = 0.5
G = No of Stations

Slotted ALOHA network



Vulnerable time for slotted ALOHA protocol



Note

The throughput for slotted ALOHA is

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

The maximum throughput

$S_{max} = 0.368$ when G = 1.

In Slotted Aloha G = 1

G = No of Stations

Example

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)

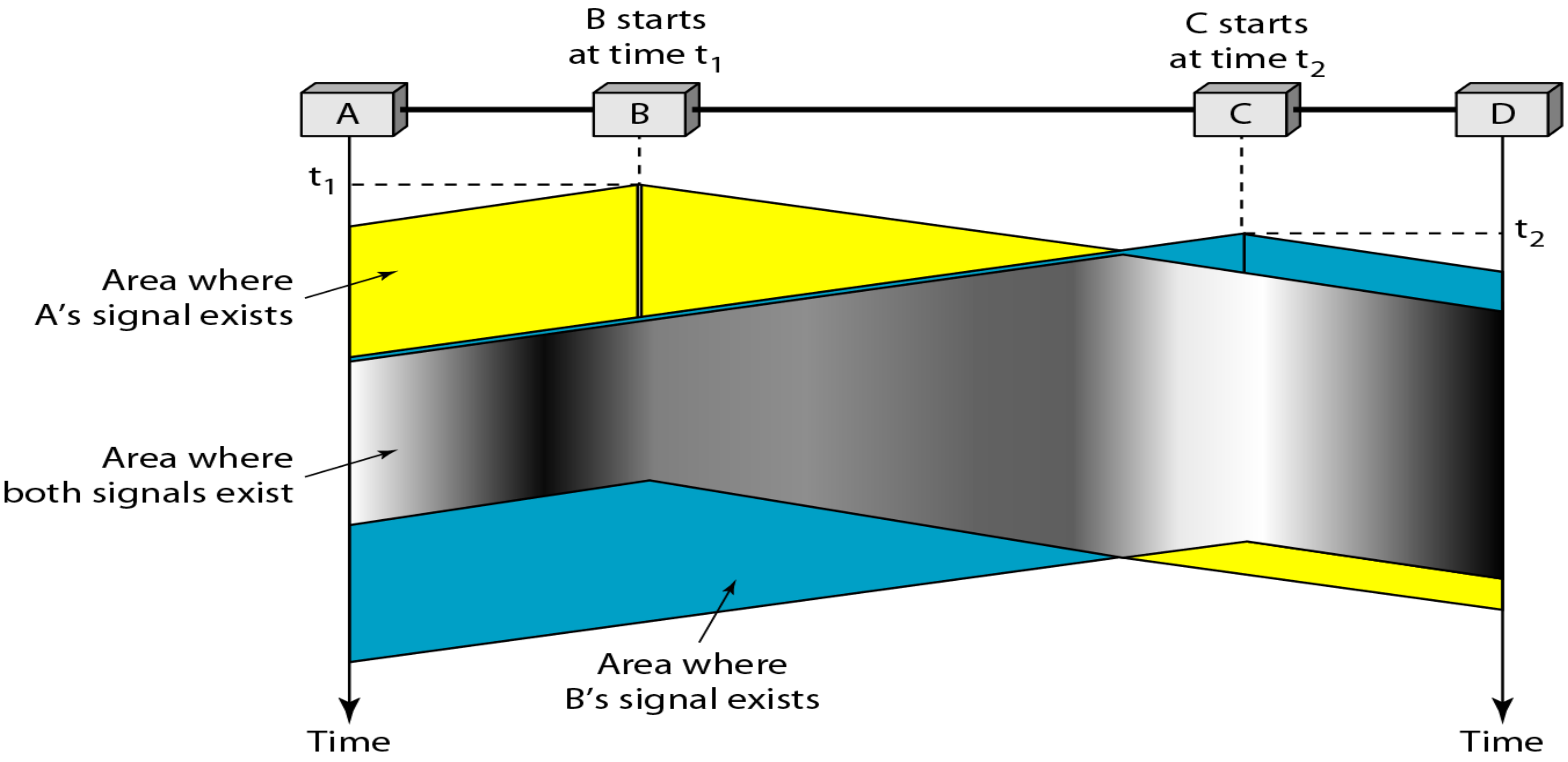
b. If the system creates 500 frames per second, this is (1/2) frame per millisecond.
The load is (1/2). In this case $S = G \times e^{-G}$ or $S = 0.303$ (30.3 percent).
This means that the throughput is $500 \times 0.0303 = 151$.
Only 151 frames out of 500 will probably survive.

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.

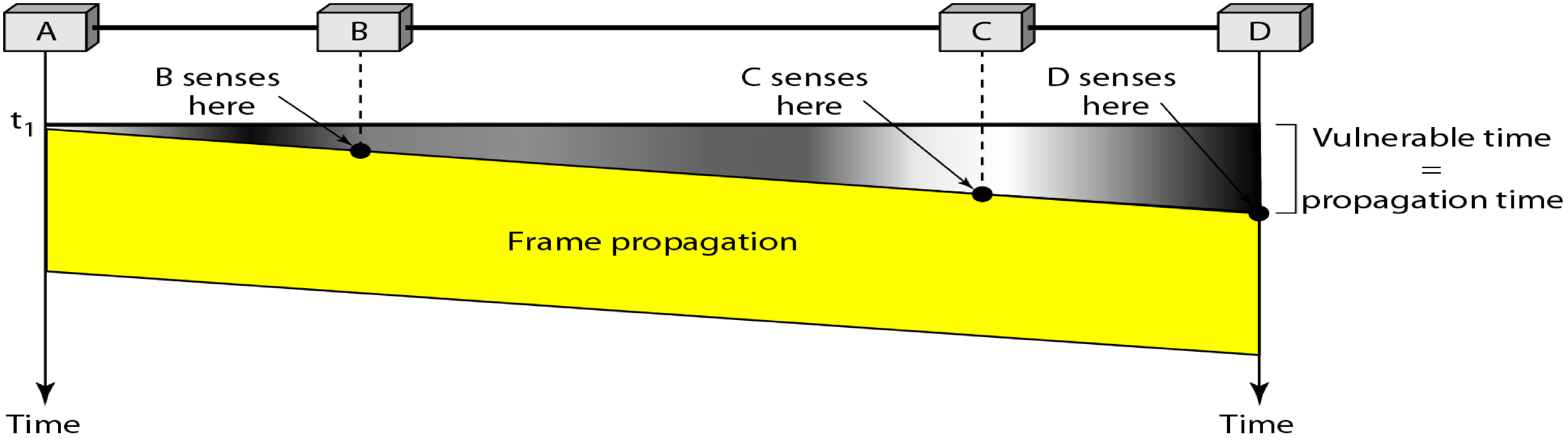
Carrier Sense Multiple Access (CSMA)

- 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.“
- CSMA can reduce the possibility of collision, but it cannot eliminate it

Space/time model of the collision in CSMA



Vulnerable time in CSMA



CSMA

- 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:

- 1-persistent method,
- nonpersistent method
- p-persistent method.

CSMA – Persistent Methods

1-Persistent

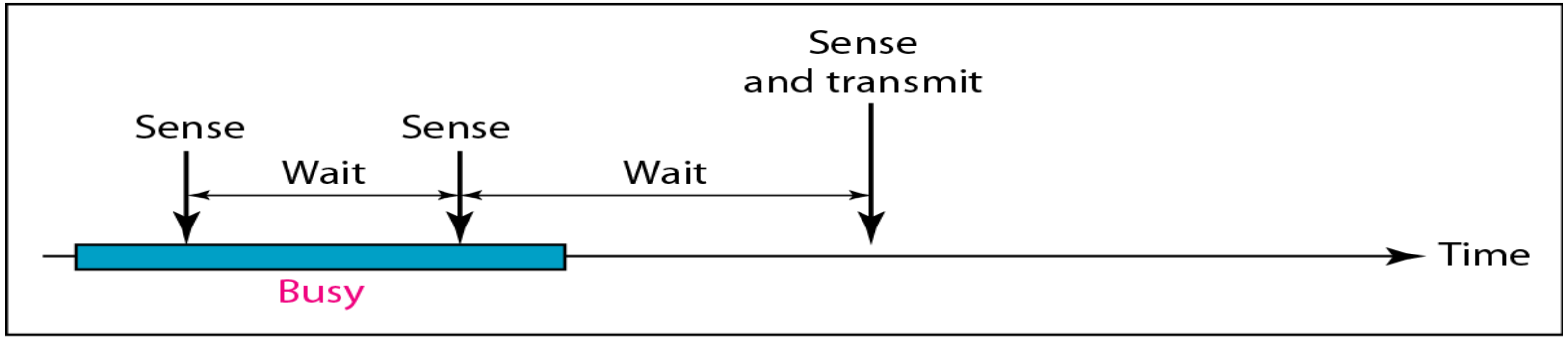
- The 1-persistent method is simple and straightforward.
- In this method, after the station finds the line idle, it sends its frame immediately (with probability 1).
- This method has the highest chance of collision because two or more stations may find the line idle and send their frames immediately.

a. 1-persistent

CSMA – Persistent Methods

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



b. Nonpersistent

CSMA – Persistent Methods

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.
- In this method, after the station finds the line idle it follows these steps:

1. With probability p, the station sends its frame.

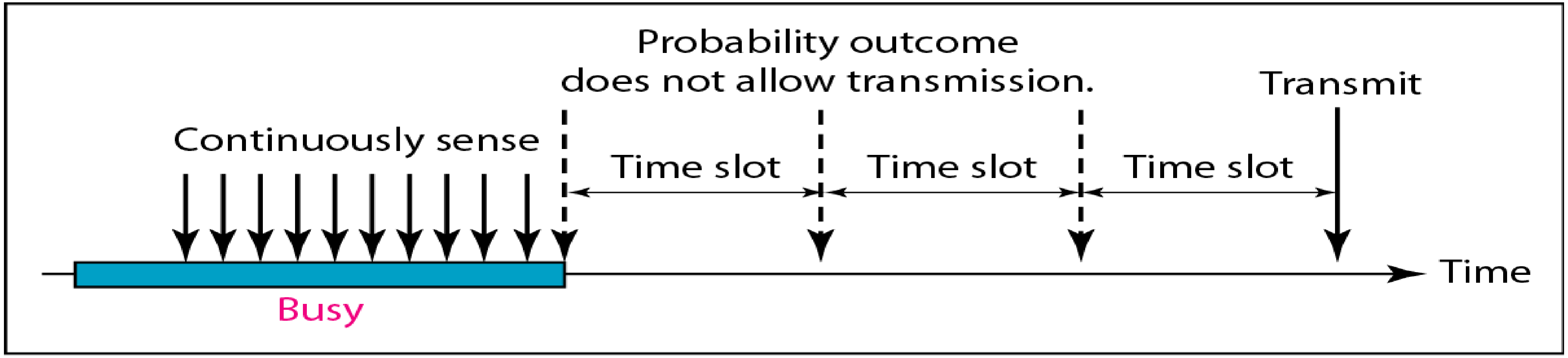
2. With probability q = 1 - p, the station waits for the beginning of the next time slot and checks the line again.

   a. If the line is idle, it goes to step 1.

   b. If the line is busy, it acts as though a collision has occurred and uses the backoff procedure.

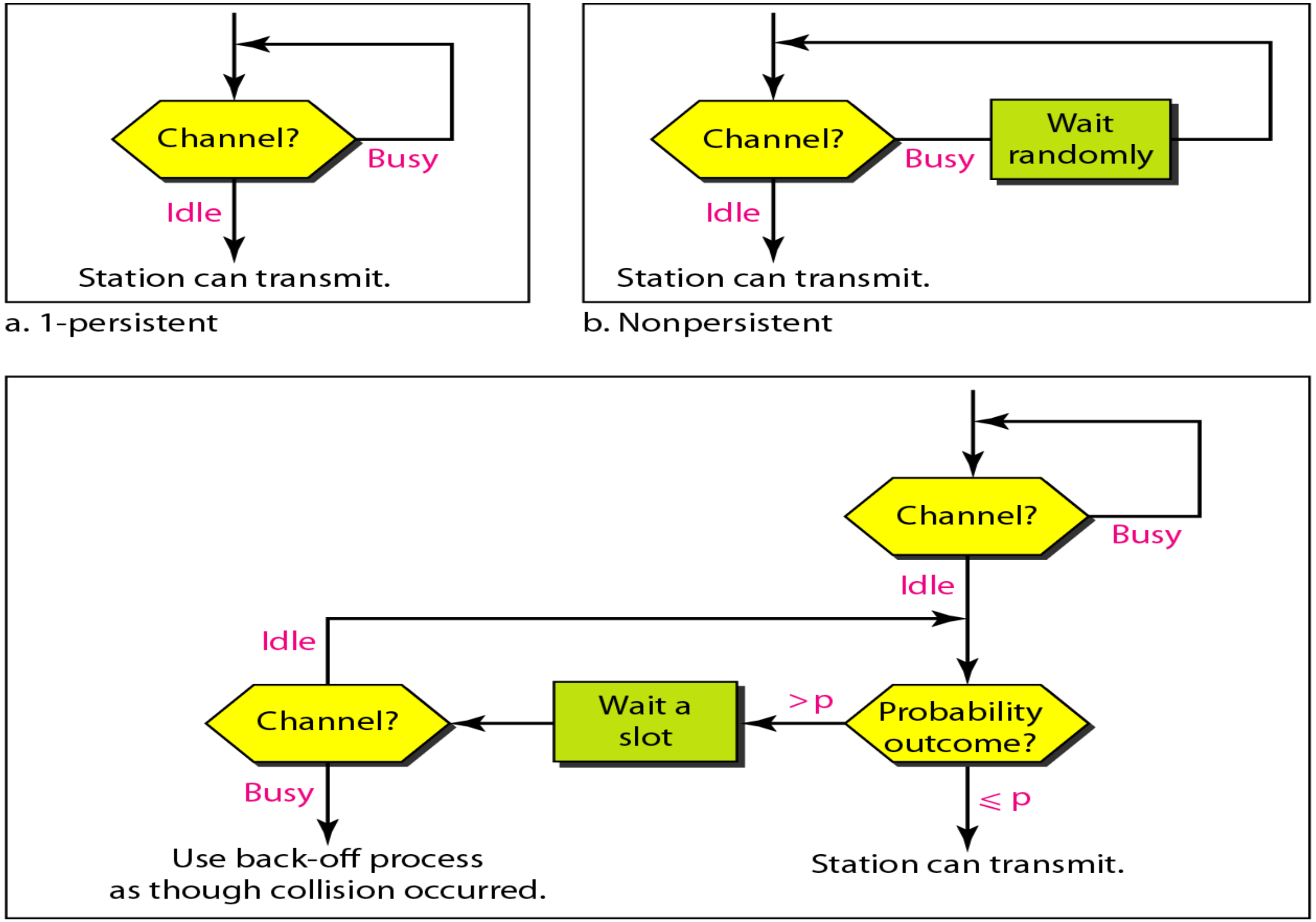
CSMA – Persistent Methods

p-Persistent



c. p-persistent

Flow diagram for three persistence methods



a. 1-persistent

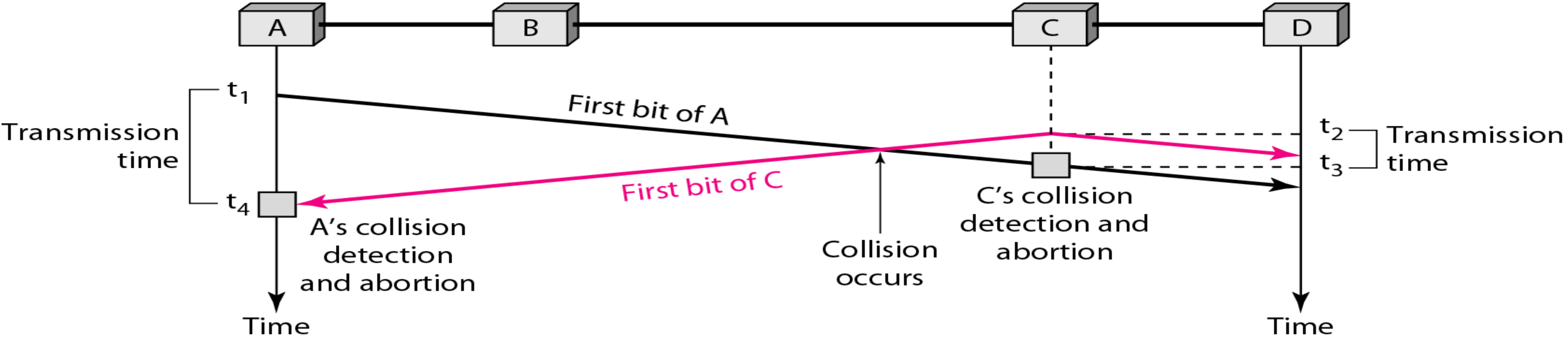
b. Nonpersistent

c. p-persistent

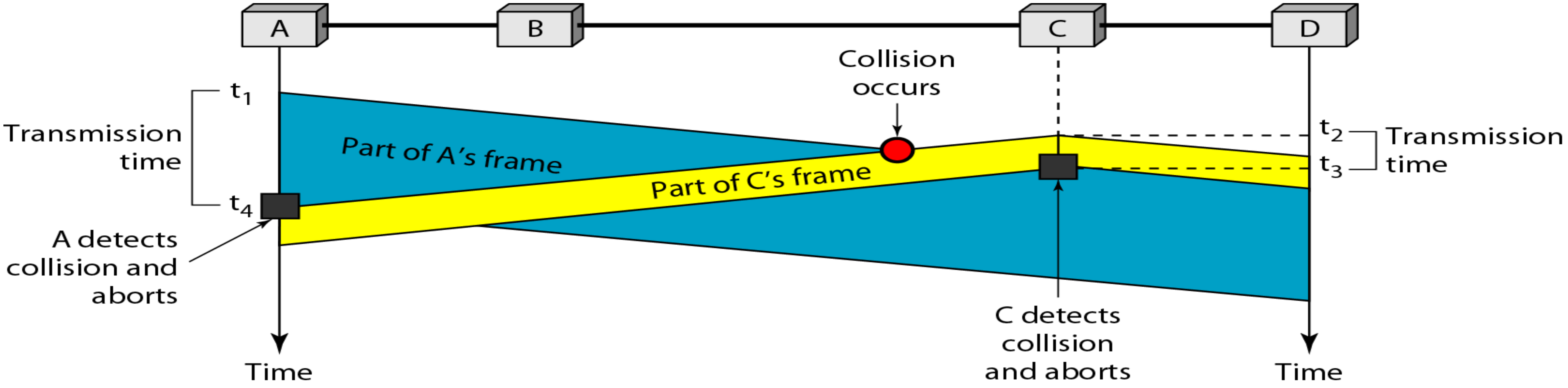
Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

- The CSMA method does not specify the procedure following a collision.
- A 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.

Collision of the first bit in CSMA/CD



Collision and abortion in CSMA/CD



Minimum frame size in CSMA/CD

- 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 and does not monitor the line for collision detection.
- Therefore, the frame transmission time Tfr must be at least two times the maximum propagation time Tp.
- Best-case scenario : -
- Average –case scenario:- Tfr >= Tp
- worst-case scenario : - If the two stations involved in a collision are the maximum distance apart, the signal from the first takes time Tp to reach the second, and the effect of the collision takes another time Tp to reach the first. So the requirement is that the first station must still be transmitting after 2Tp .

Example 12.5

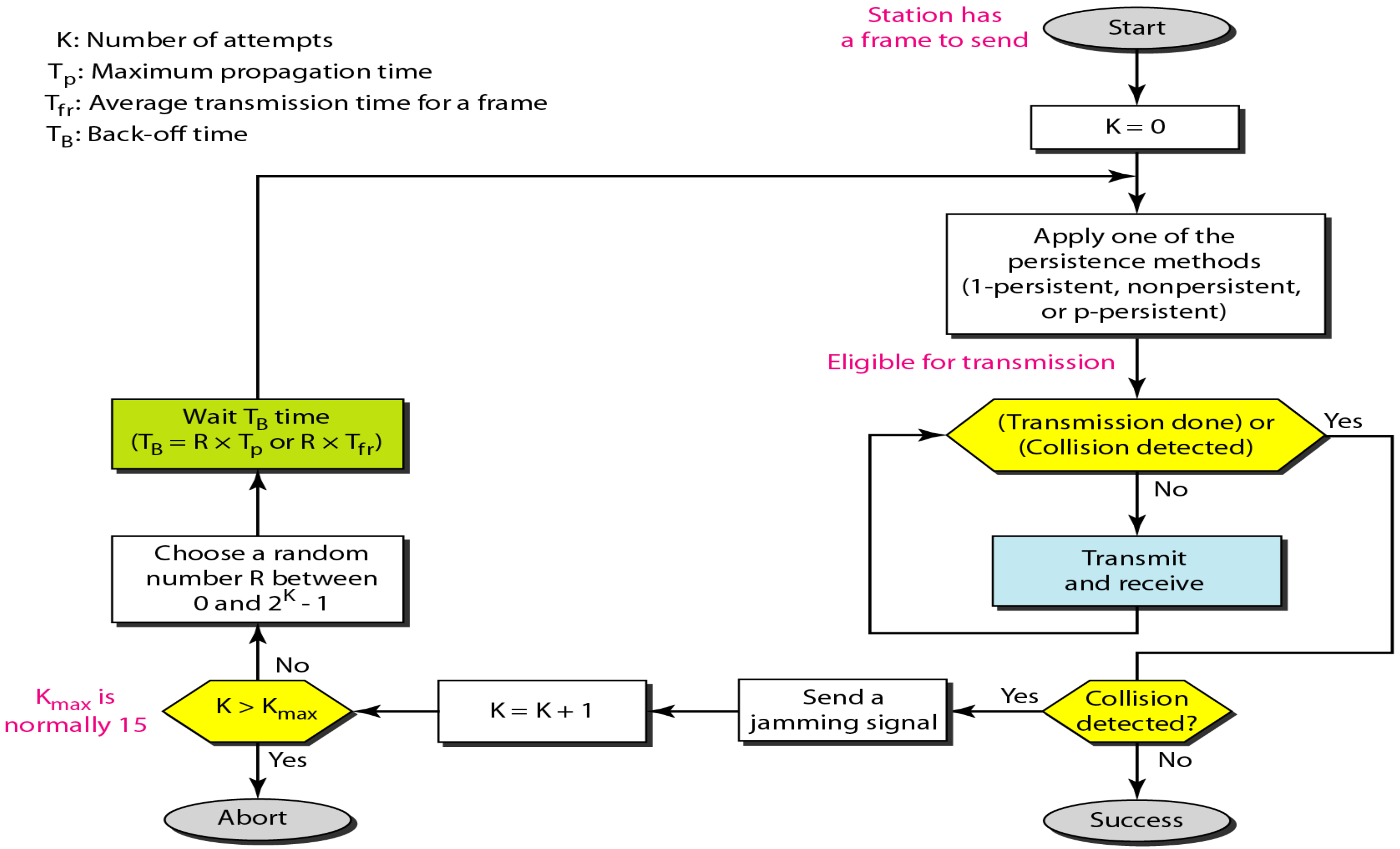
A network using CSMA/CD has a bandwidth of 10 Mbps. If the maximum propagation time (including the delays in the devices and ignoring the time needed to send a jamming signal, as we see later) is 25.6 μs, what is the minimum size of the frame?

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 × 51.2 μs = 512 bits or 64 bytes. This is actually the minimum size of the frame for Standard Ethernet.

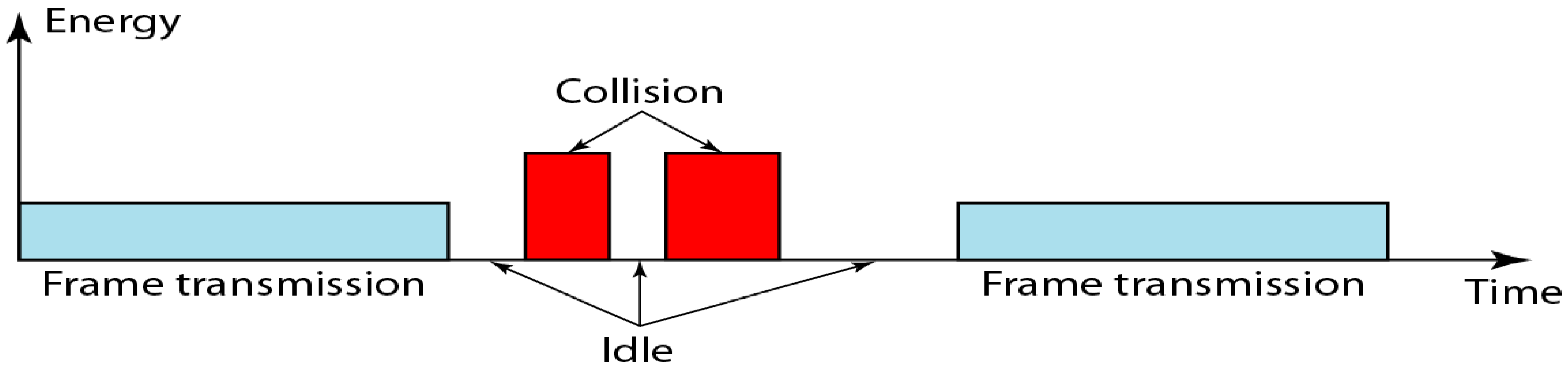
Ttf = 2 * Tp
L/B = 2* Tp
L = 2 * Tp * B

Flow diagram for the CSMA/CD



Energy level during transmission, idleness, or collision

- level of energy in a channel can have three values: zero, normal, and abnormal.
- At the normal level, successfully captured the channel and is sending its frame.
- At the abnormal level, there is a collision and the level of the energy is twice the normal level. A station that has a frame to send or is sending a frame needs to monitor the energy level to determine if the channel is idle, busy, or in collision mode



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

- The basic idea behind CSMA/CD is that a station needs to be able to receive while transmitting to detect a collision.
- When there is no collision, the station receives one signal: its own signal. When there is a collision, the station receives two signals: its own signal and the signal transmitted by a second station.
- To distinguish between these two cases, the received signals in these two cases must be significantly different.
- In other words, the signal from the second station needs to add a significant amount of energy to the one created by the first station.
- In a wired network, the received signal has almost the same energy as the sent sig-nal because either the length of the cable is short or there are repeaters that amplify the energy between the sender and the receiver.
- This means that in a collision, the detected energy almost doubles.

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

- in a wireless network, much of the sent energy is lost in transmission. The received signal has very little energy.
- collision may add only 5 to 10 percent additional energy.
- This is not useful for effective collision detection.
- We need to avoid collisions on wireless networks because they cannot be detected.
- Carrier sense multiple access with collision avoidance(CSMA/CA) was invented for this network.
- Collisions are avoided through the use of CSMAICA's three strategies:
    - Interframe space(IFS),
    - Contention window
    - Acknowledgments

Carrier Sense Multiple Access with Collision Avoidance (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. It waits for a period of time called the interframe space or IFS.
- The distant station's signal has not yet reached this station.
- The IFS time allows the front of the transmitted signal by the distant station to reach this station.
- If after the IFS time the channel is still idle, the station can send, but it still needs to wait a time equal to the contention time

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

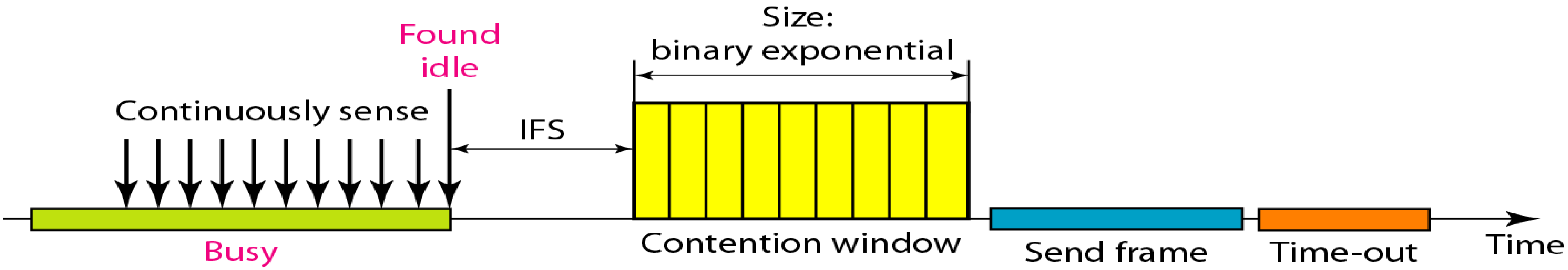
Contention Window

- 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.
- One interesting point about the contention window is that the station needs to sense the channel after each time slot. 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.

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

Acknowledgement

- 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 acknowl-edgment and the time-out timer can help guarantee that the receiver has received the frame.



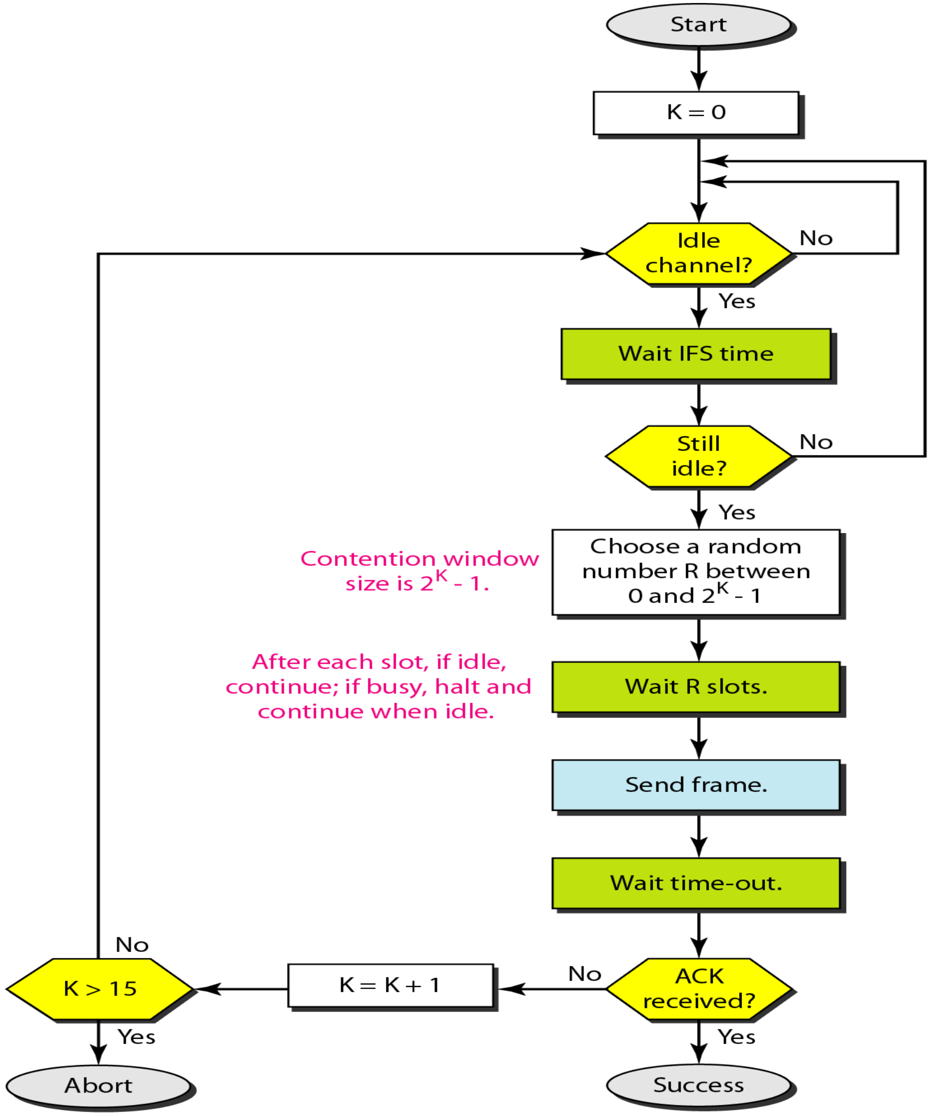
Note

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.

Flow diagram for CSMA/CA



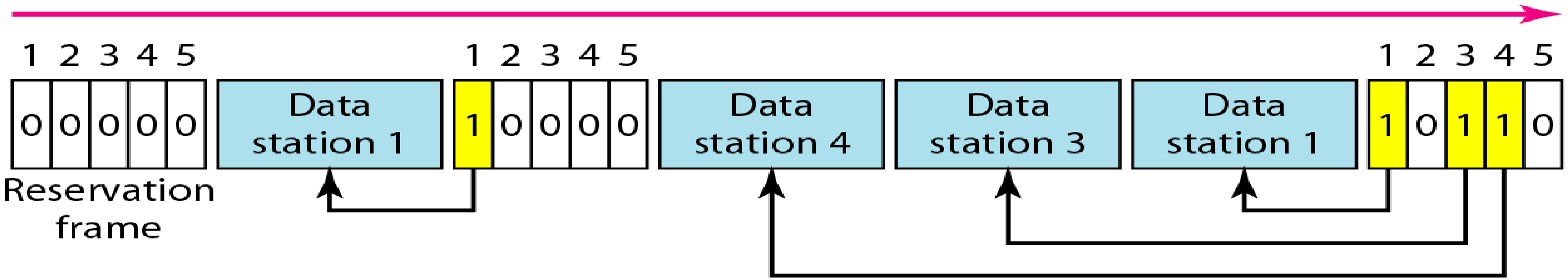
CONTROLLED ACCESS

- 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.

Reservation
Polling
Token Passing

Reservation access 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.
- If there are N stations in the system, there are exactly N reservation minislots in the reservation frame.
- Each minislot belongs to a station. When a station needs to send a data frame, it makes a reservation in its own minislot.

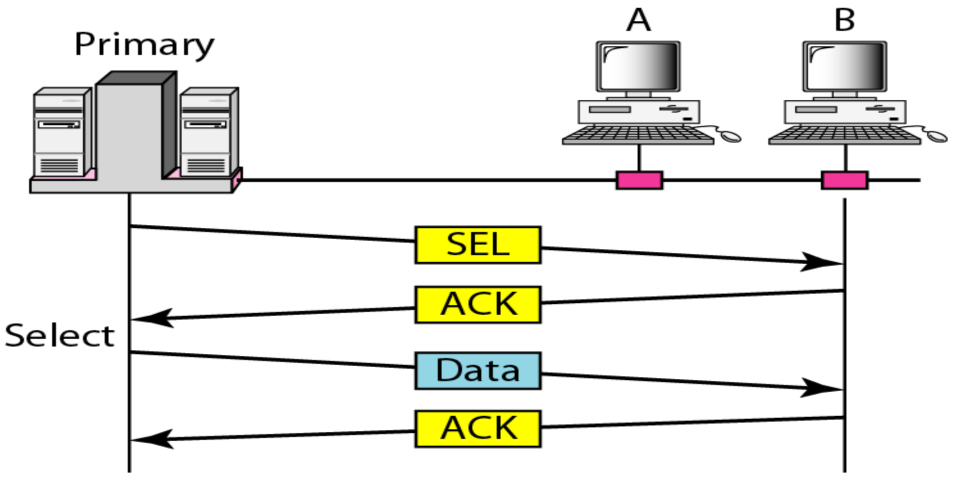


Polling

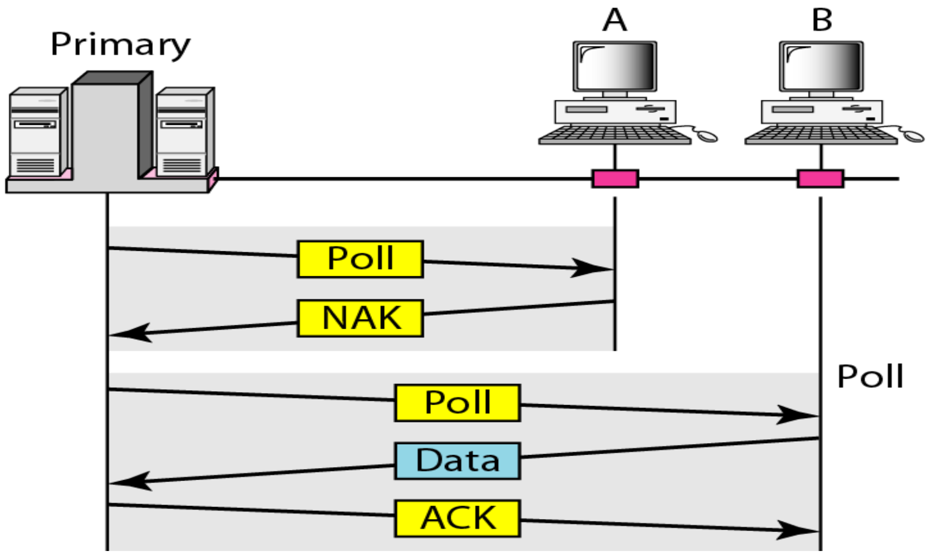
- Polling works with topologies in which one device is designated as a primary station and the other devices are secondary stations.
- All data exchanges must be made through the primary device even when the ultimate destination is a secondary device.
- The primary device controls the link; the secondary 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.
- The primary device, therefore, is always the initiator of a session
- There are two functions : Select and POLL

Polling

- Select : Primary want to send data
- POLL : primary want to receive data



Select

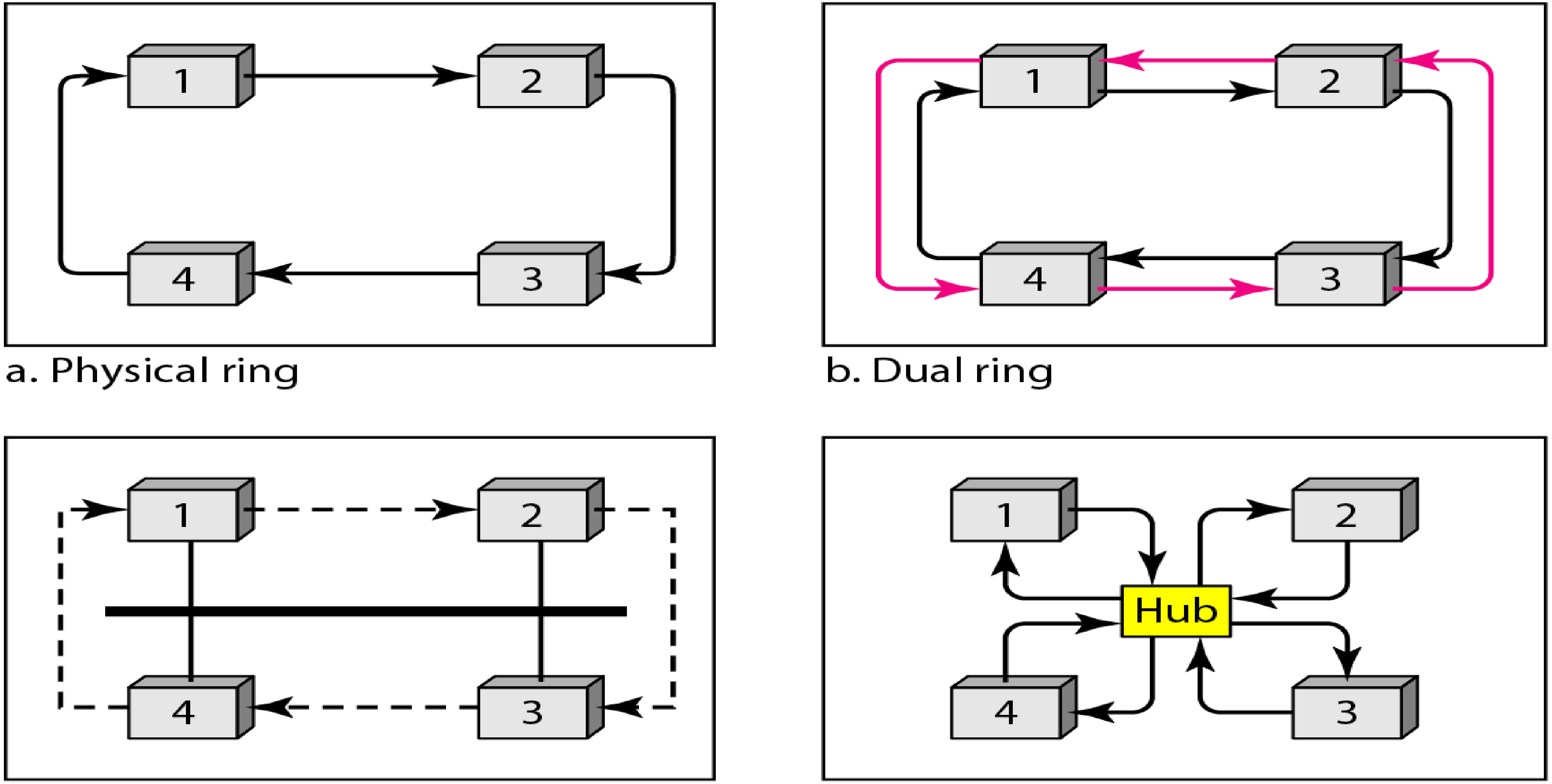


Poll

Token-passing access method

- The stations in a network are organized in a logical ring.
- each station, there is a predecessor and a successor.
- The current station is the one that is accessing the channel now. The right to this access has been passed from the predecessor to the cur-rent station.
- The right will be passed to the successor when the current station has no more data to send.
- Token management is needed for this access method.

Token-passing access method



a. Physical ring

b. Dual ring

c. Bus ring

d. Star ring

CHANNELIZATION

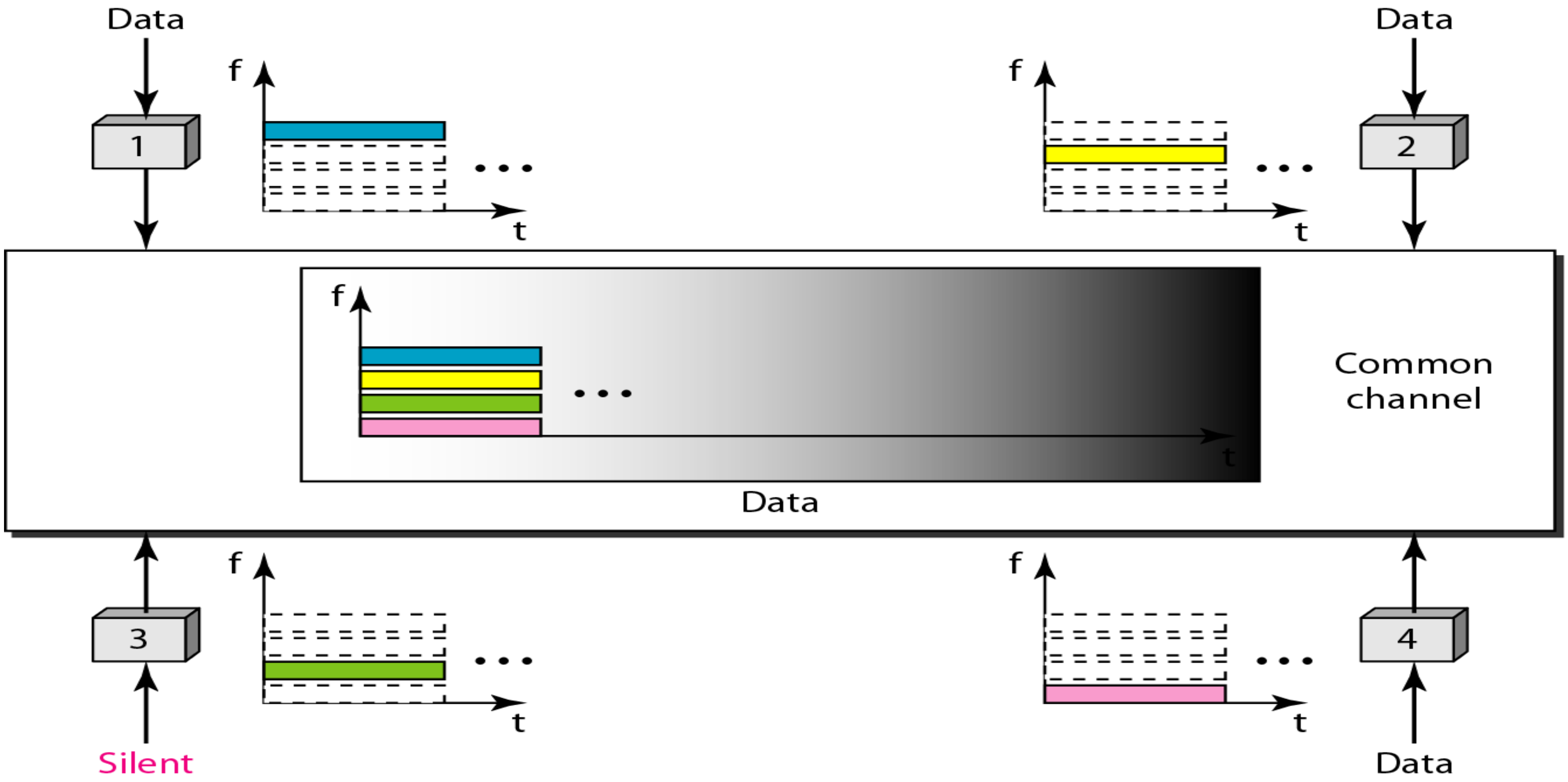
- Channelization is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations. In this section, we discuss three channelization protocols.

Frequency-Division Multiple Access (FDMA)
Time-Division Multiple Access (TDMA)
Code-Division Multiple Access (CDMA)

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 pre-vent station interferences, the allocated bands are separated from one another by small guard bands.

Frequency-division multiple access (FDMA)



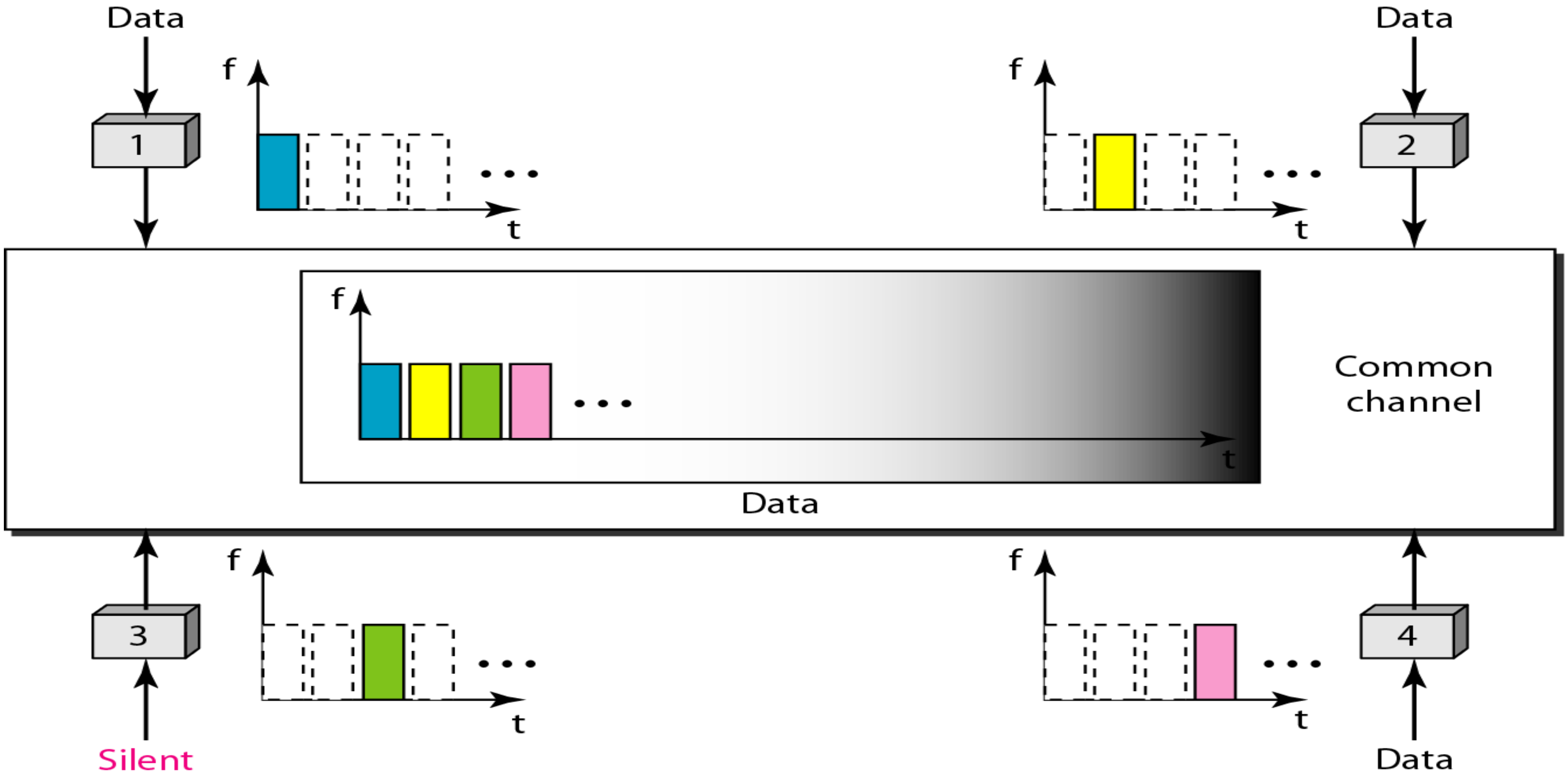
Note

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.

Time-division multiple access (TDMA)



Note

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

Code-Division multiple access (CDMA)

- In CDMA, one channel carries all transmissions simultaneously.
- CDMA simply means communication with different codes.
- For example,
- In a large room with many people, two people can talk in English if nobody else understands English. Another two people can talk in Chinese if they are the only ones who understand Chinese, and so on.
- In other words, the common channel, the space of the room in this case, can easily allow communication between several couples, but in different languages (codes).

Note

In CDMA, one channel carries all transmissions simultaneously.

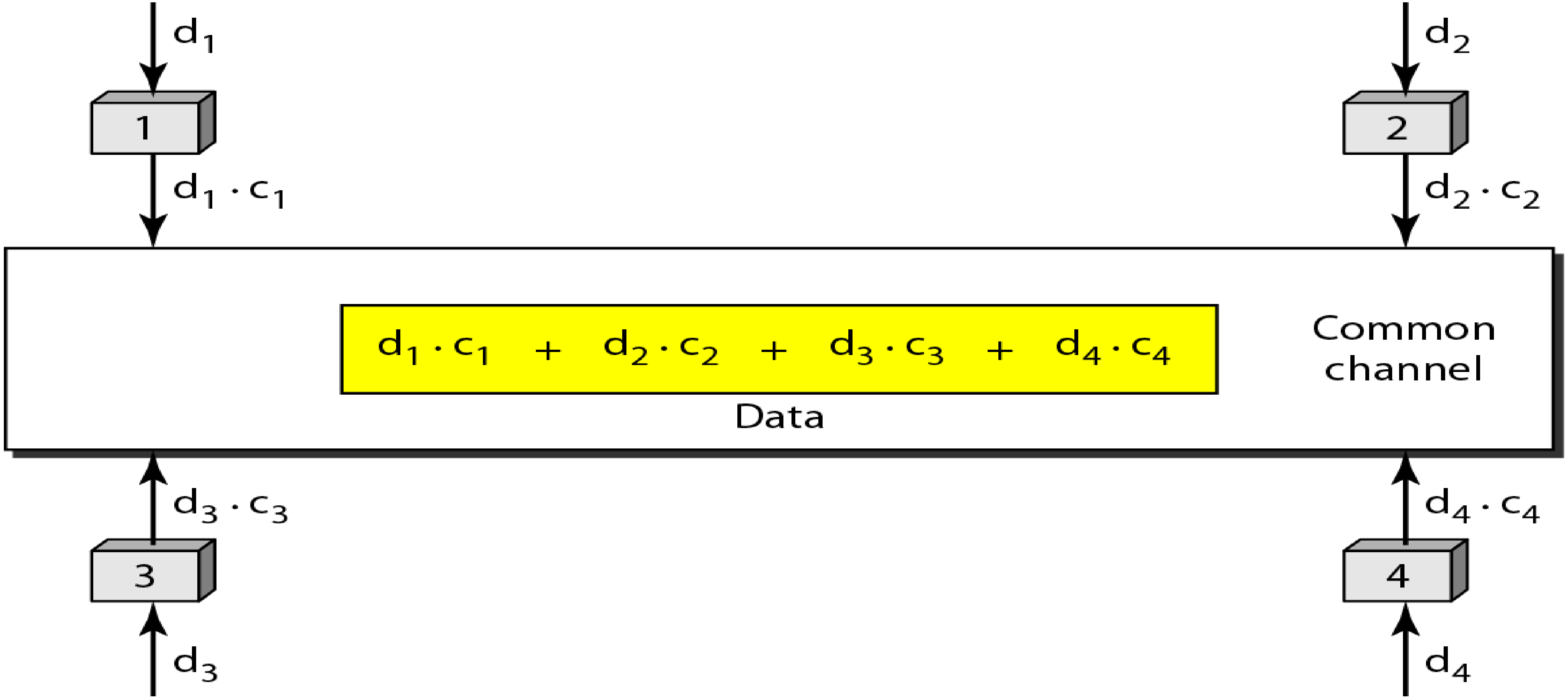
Code-Division multiple access (CDMA)

- Let us assume we have four stations **1, 2, 3,** and **4** connected to the same channel.
- The data from station **1** are ***d1*** , from station **2** are ***d2****,* and so on.
- The code assigned to the first station is **c1**, to the second is ***c2****,* and so on.
- We assume that the assigned codes have two properties.

  1. If we multiply each code by another, we get **0**.
  2. If we multiply each code by itself, we get **4** (the number of stations).

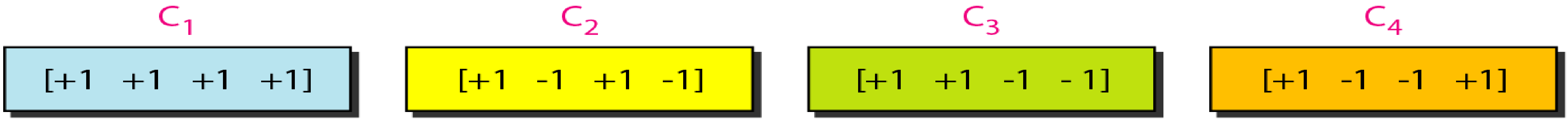
- If station 2 want to hear what station 1 is saying. It multiples the data on channel by c1
  - Data = 4d1

Simple idea of communication with code

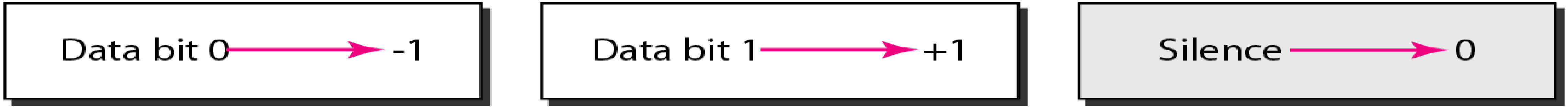


CDMA - Chip sequences

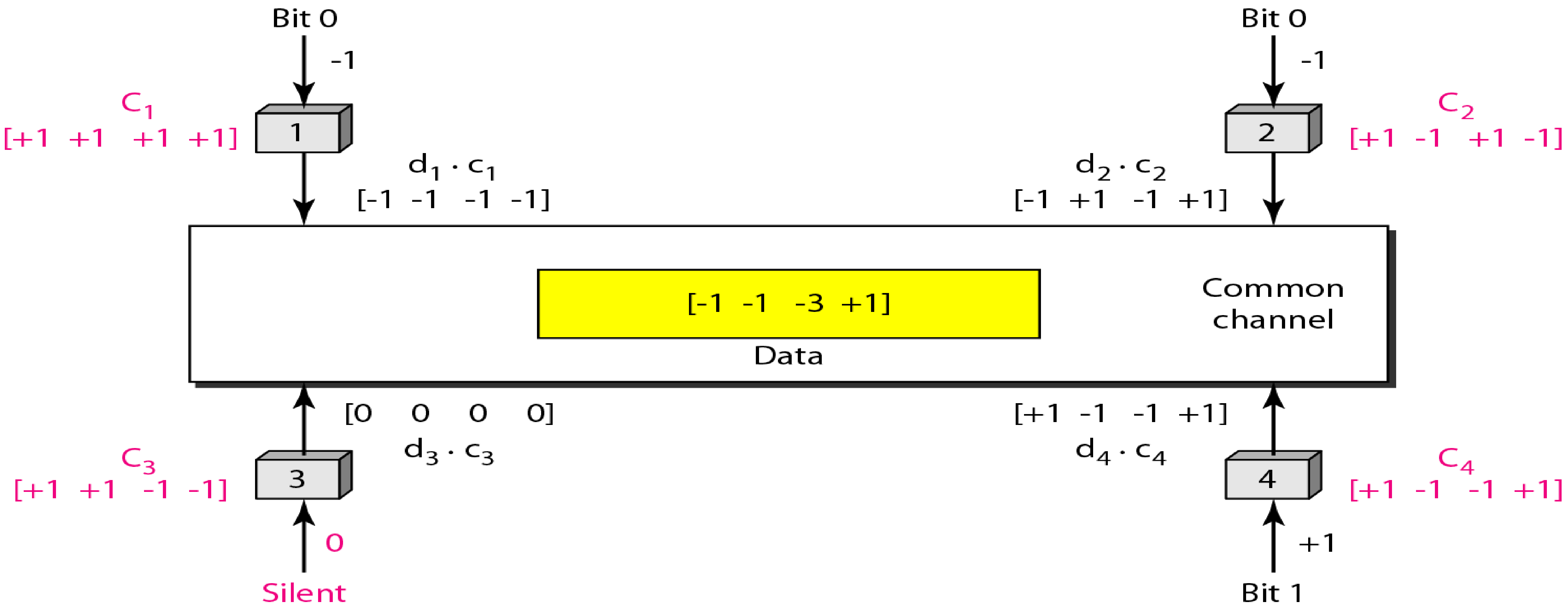
- CDMA is based on coding theory. Each station is assigned a code, which is a sequence of numbers called chips



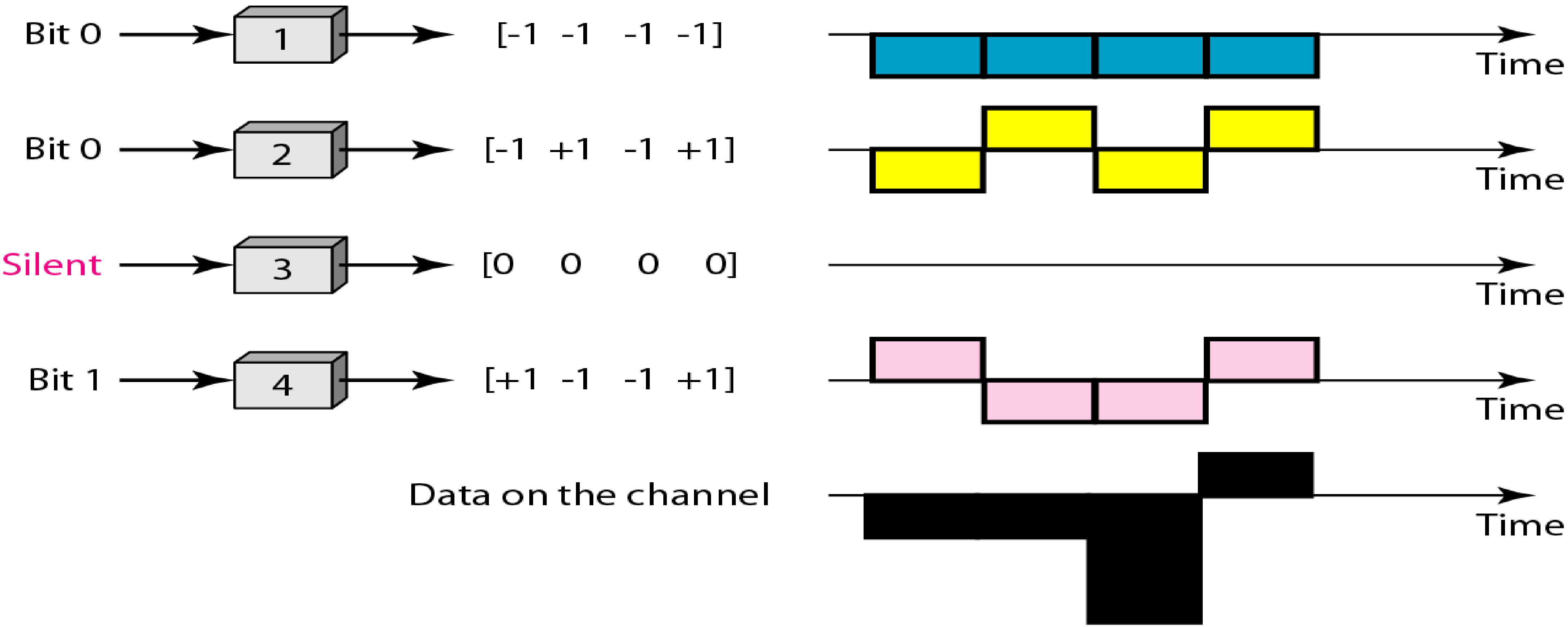
Data representation in CDMA



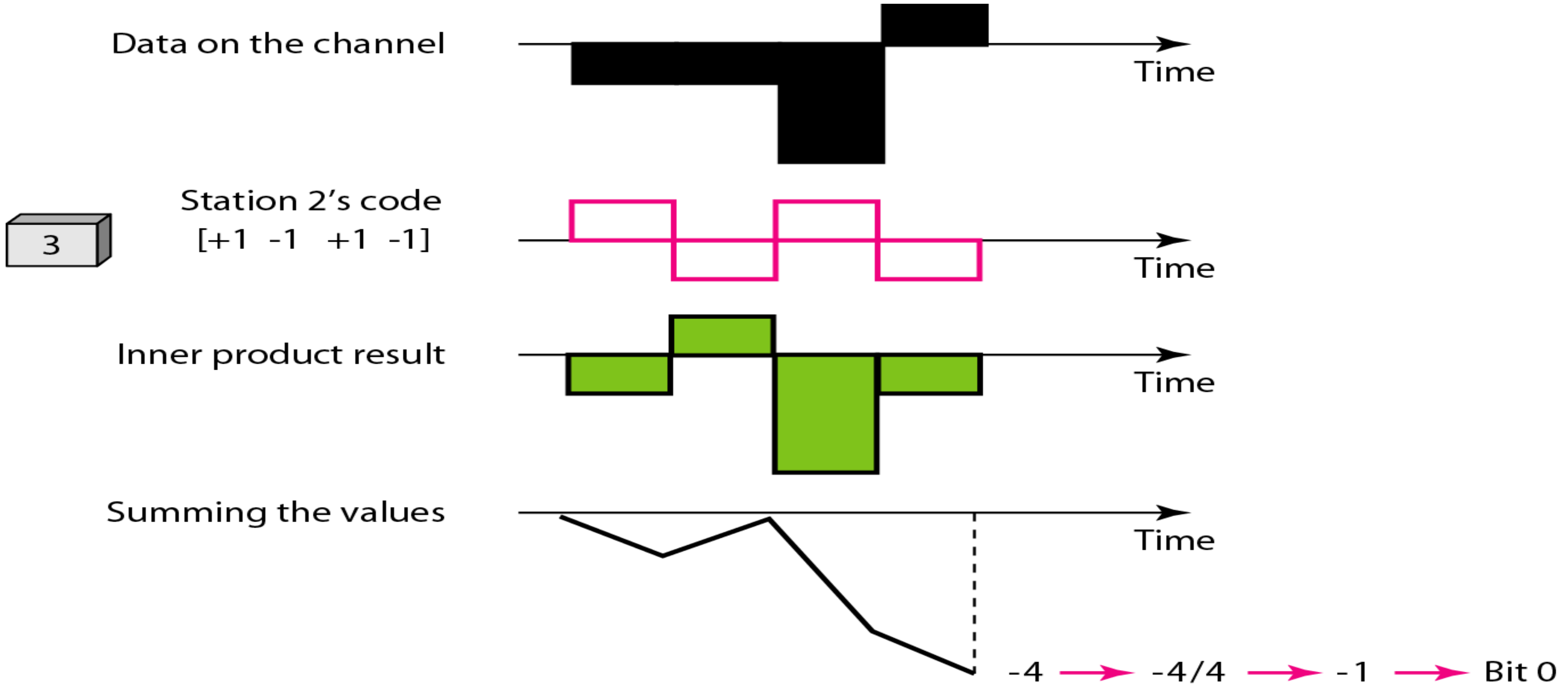
Sharing channel in CDMA



Digital signal created by four stations in CDMA



Decoding of the composite signal for one in CDMA



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

GUNI Limitless Learning

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 W2 and W4

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

$$D = (d1 \cdot c1 + d2 \cdot c2 + d3 \cdot c3 + d4 \cdot c4).$$

The receiver which wants to get the data sent by station 1 multiplies these data by c1.

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 d1 .