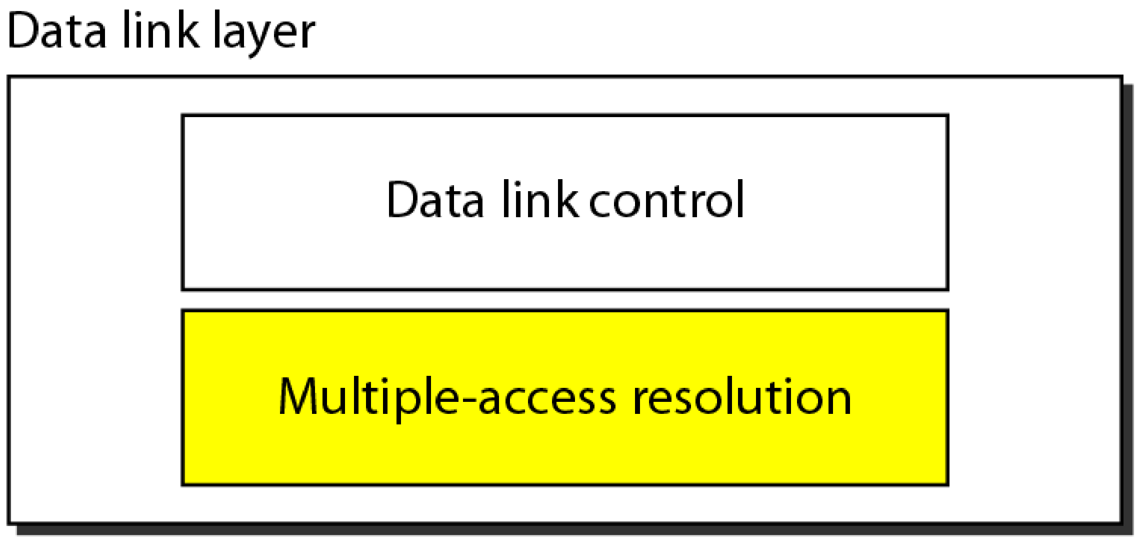
Lecture 5

Multiple Access

(Chapter 12 of "Data Communications and Networking" [B. A. Forouzan])

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



In the previous lecture "Data Link Control", we assume the for each data or ACK transmission, target transceivers have obtained the opportunity to access the channel. But in a shared medium, how to get the opportunity of channel access?

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. (an example in our daily life: an intersection with 4-way stop signs)

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*

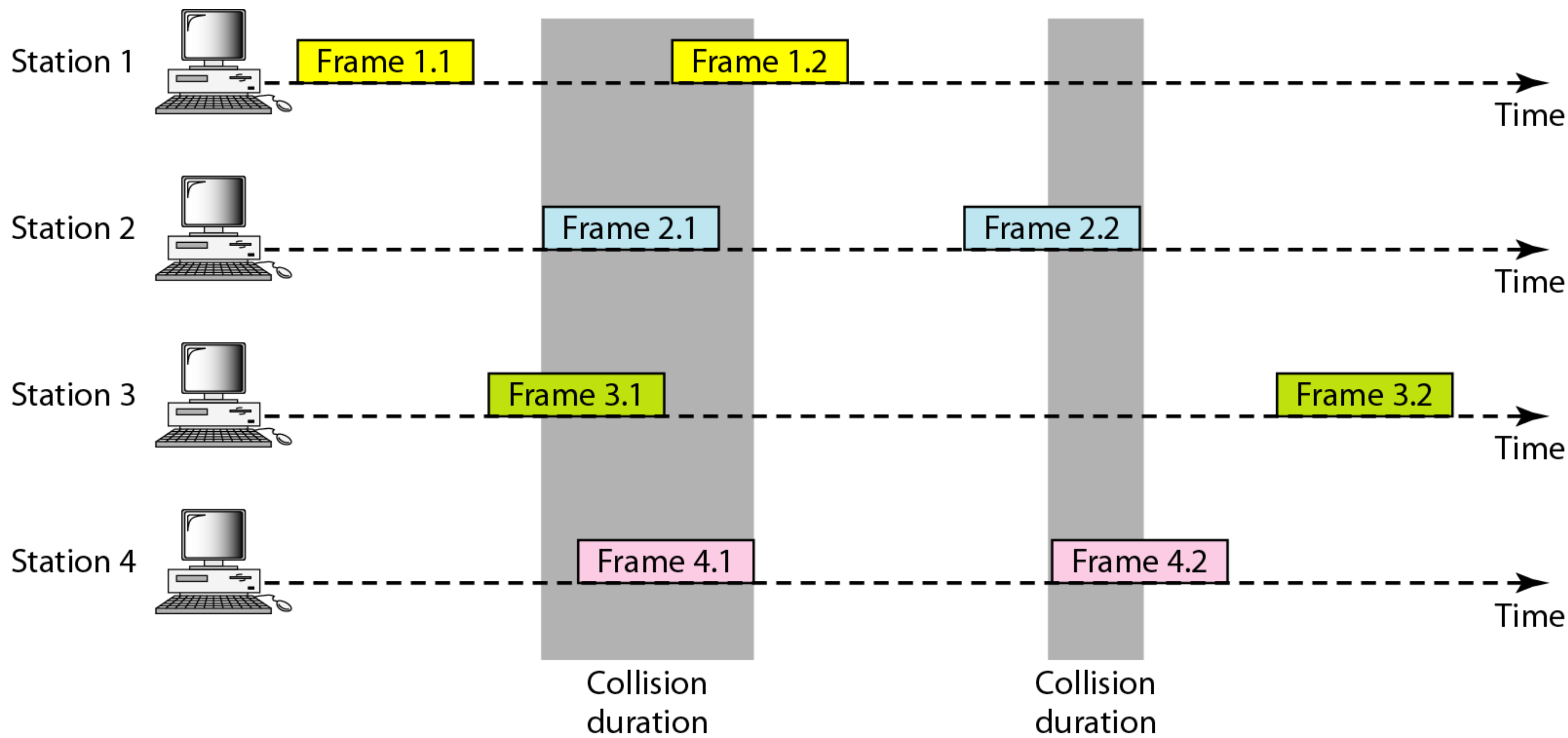
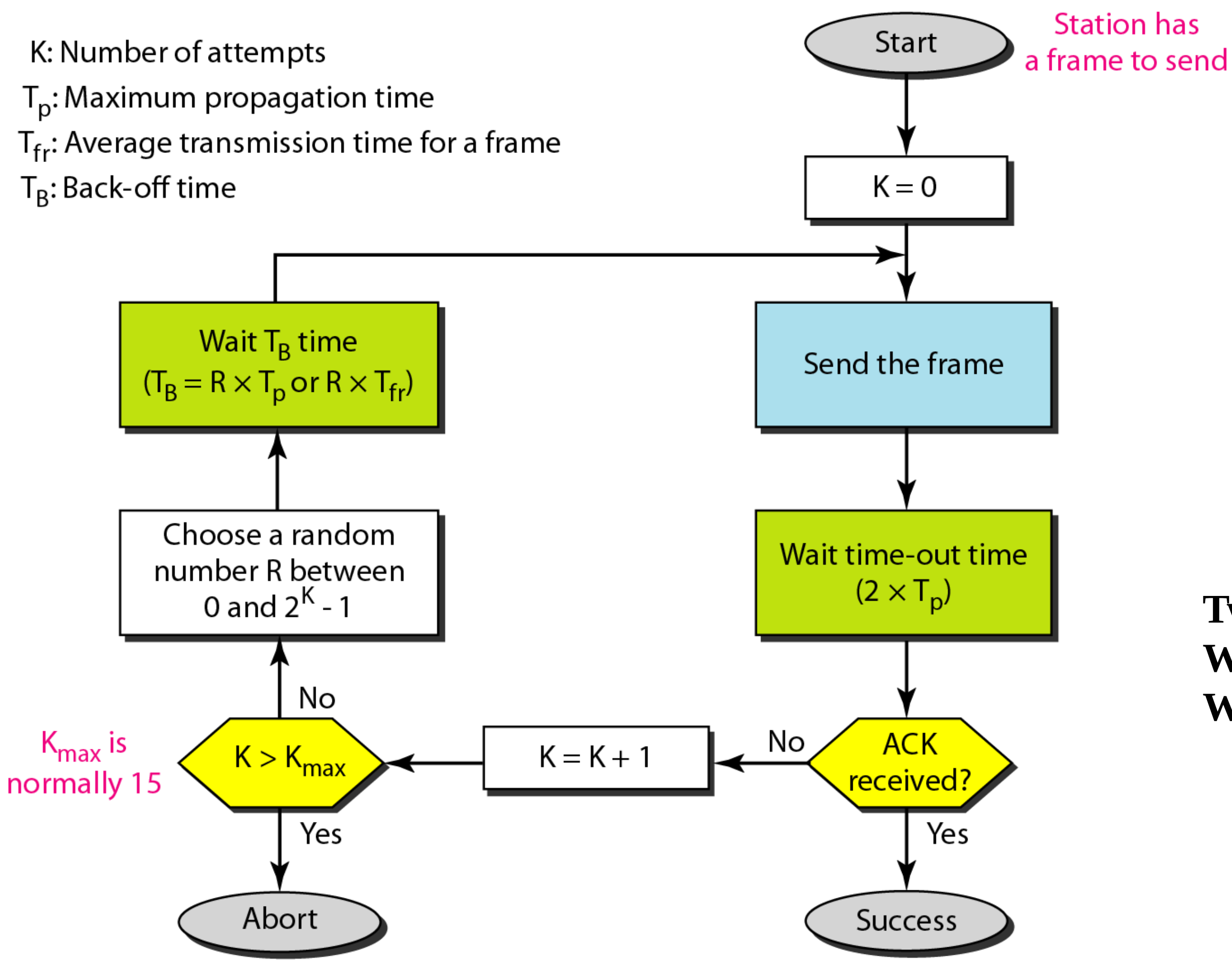


Figure 12.4 *Procedure for pure ALOHA protocol*



Two issues:
When to access the channel?
What if an access fails?

Example 12.1

The stations on a wireless ALOHA network are a maximum of 600 km apart. If we assume that signals propagate at 3×10^8 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 (0×2) or 2 ms (1×2), based on the outcome of the random variable.

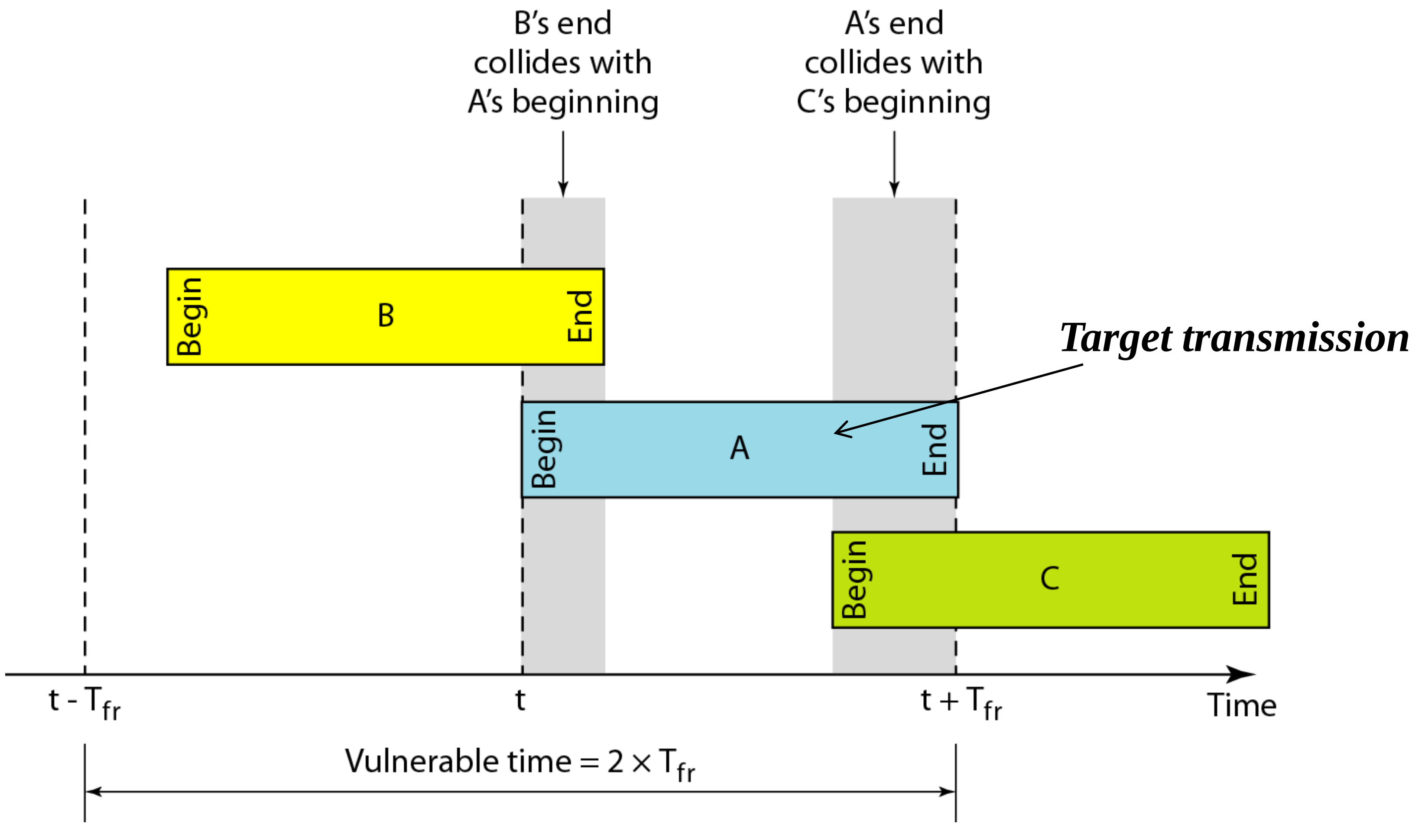
Example 12.1 (continued)

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 normally set to 10. (in other words, the range is {0,1,2,…,1023})***

Figure 12.5 *Vulnerable time for pure ALOHA protocol*



Vulnerable time of a target transmission: a period in which a transmission request to any other station will make the target transmission vulnerable

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: average # of frames generated by the system during one frame transmission time
S: average # of successful frames during one frame transmission 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.

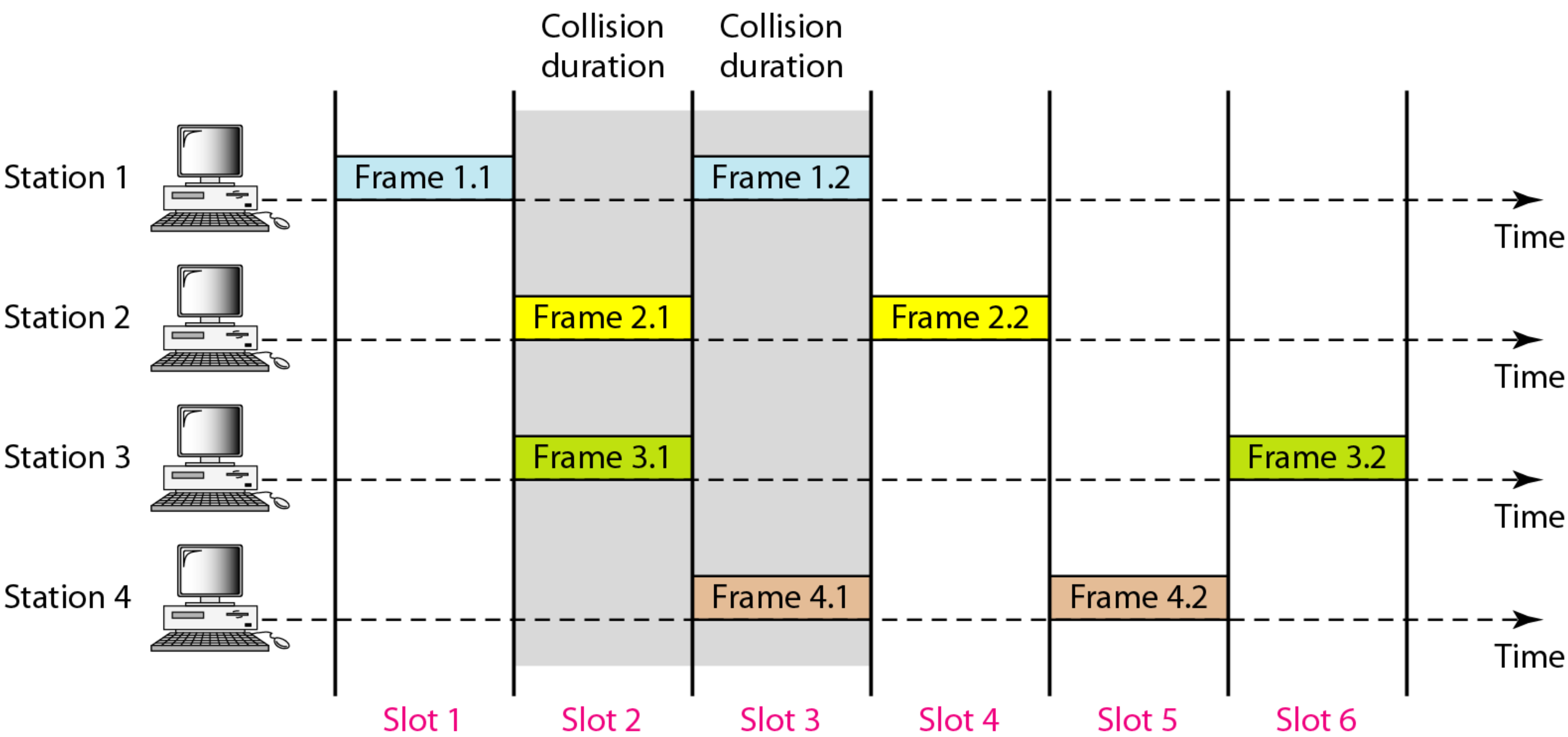
a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case $S = G \times e^{-2G}$ ***or*** $S = 0.135$***. In a second, there are 135 successful frames. This means that 13.5% of the generated frames will probably survive.***

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*** $S = 0.184$***. In a second, there are 184 successful frames. This means that 36.8% of the generated frames 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 $S = G \times e^{-2G}$ ***or*** $S = 0.152$***. In a second, there are 152 successful frames. This means that 60.8% of the generated frames will probably survive.***

# of frames generated/second	G (# of frames generated per T_{fr})	S (# of successful frames per T_{fr})	# of successful frames/second	Successful prob.
1000	1	0.135	135	13.5%
500	0.5	0.184	184	36.8%
250	0.25	0.152	152	60.8%

Figure 12.6 *Frames in a slotted ALOHA network*

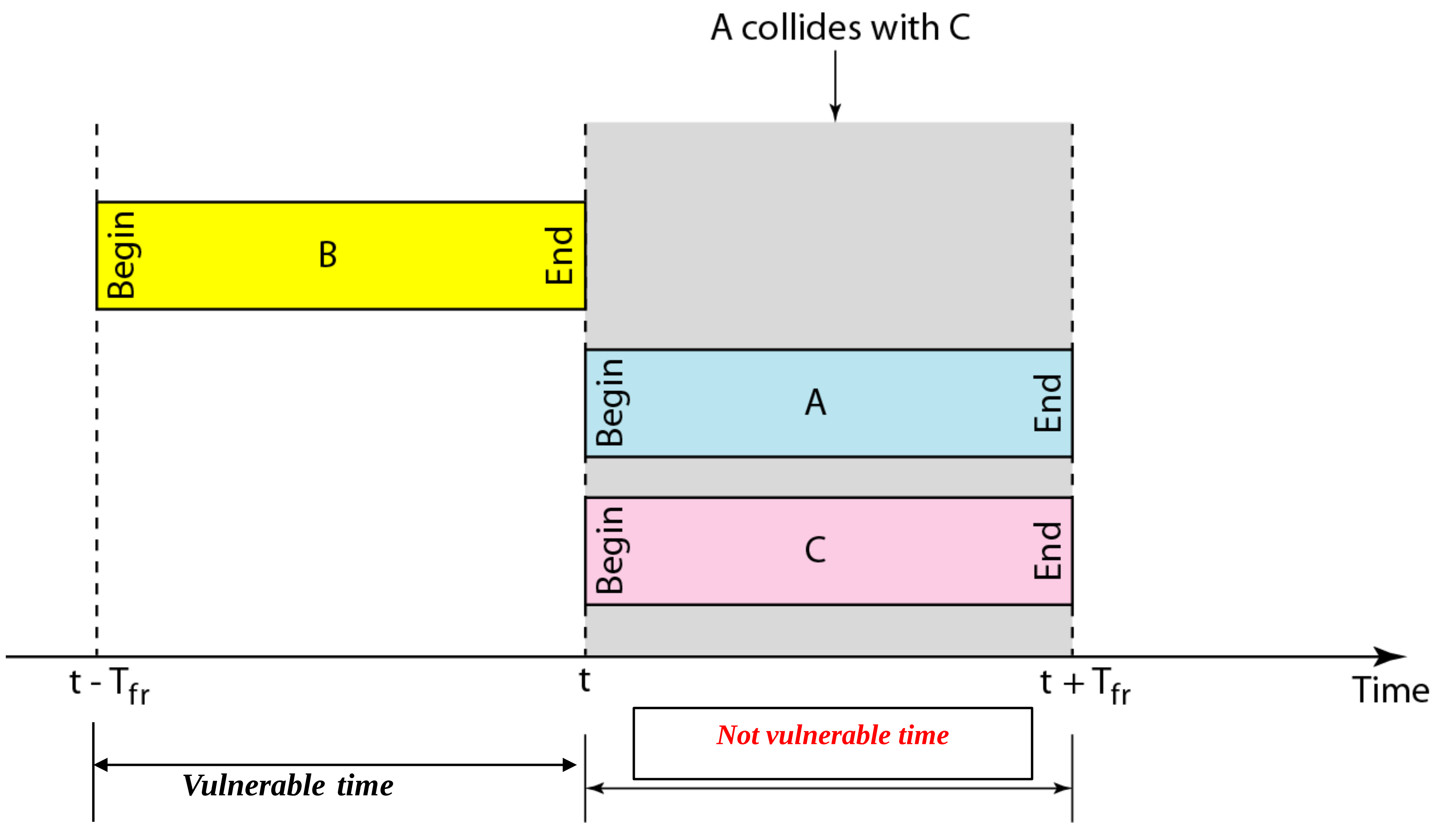


Note

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.

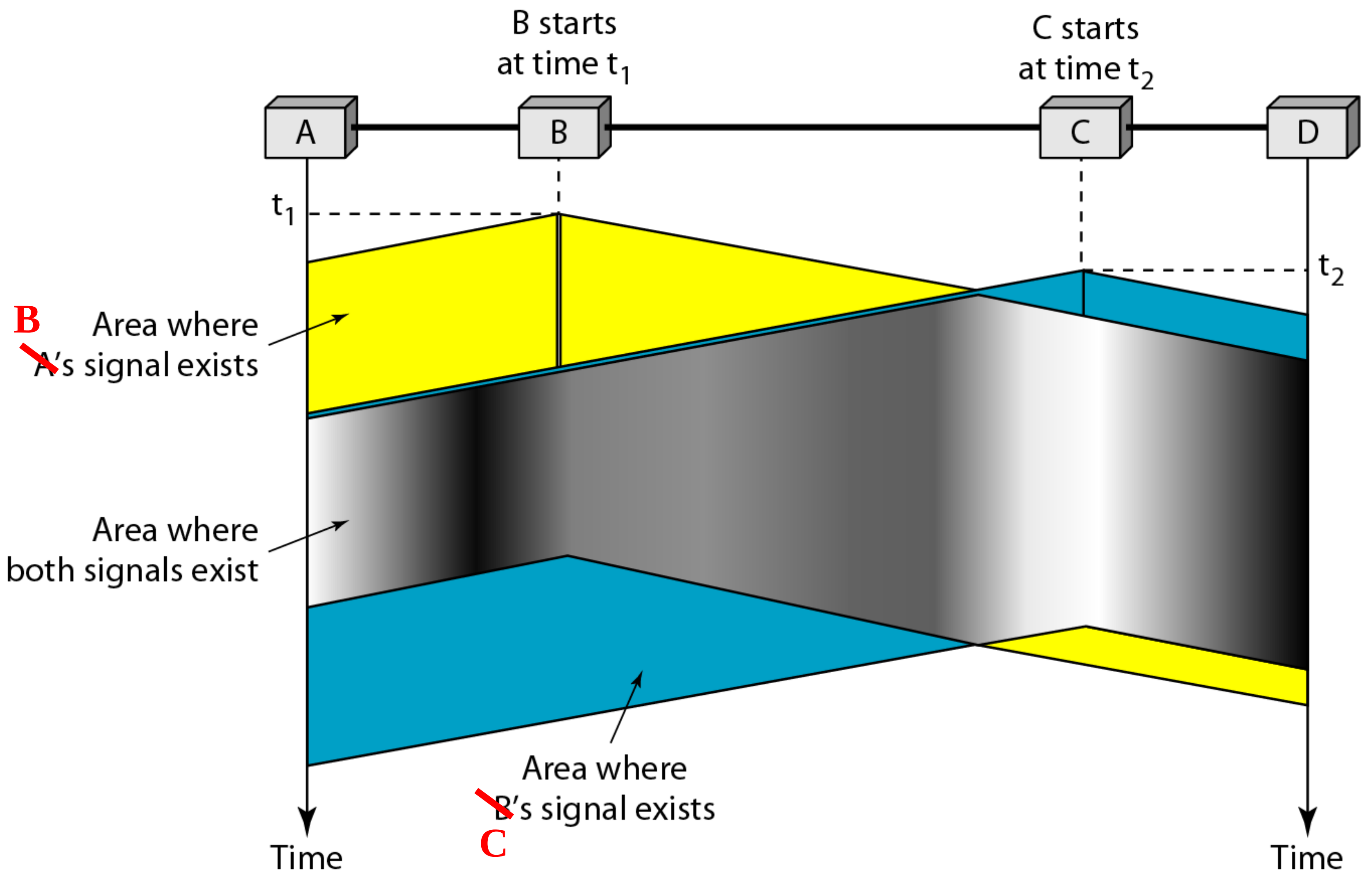
a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case $S = G \times e^{-G}$ or $S = 0.368$. In a second, there are 368 successful frames. This means that 36.8% of the generated frames will probably survive.

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. In a second, there are 303 successful frames. This means that 60.6% of the generated frames 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. In a second, there are 195 successful frames. This means that 78% of the generated frames will probably survive.*

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



Each station listens to the medium before sending. "listen before talk"
Reduce the probability of collisions, but cannot eliminate them.

Figure 12.9 *Vulnerable time in CSMA*

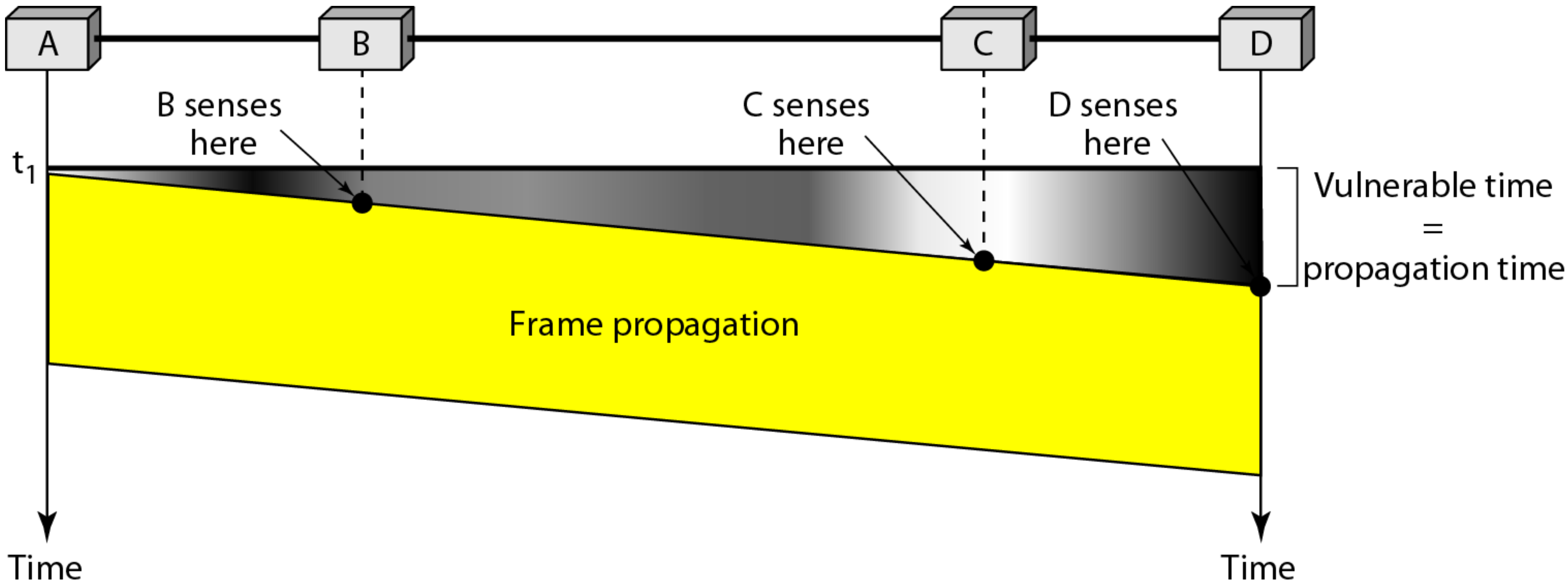
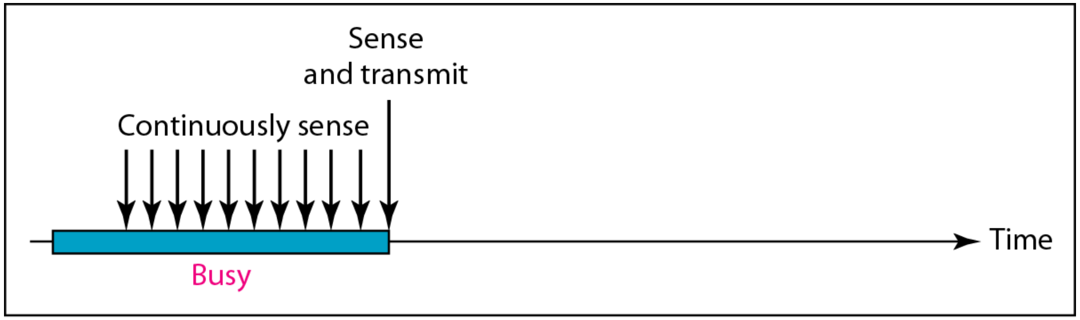
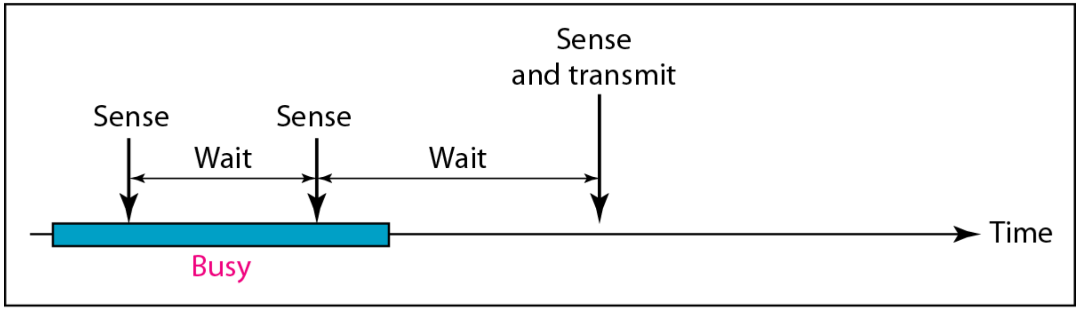


Figure 12.10 *Behavior of three persistence methods*



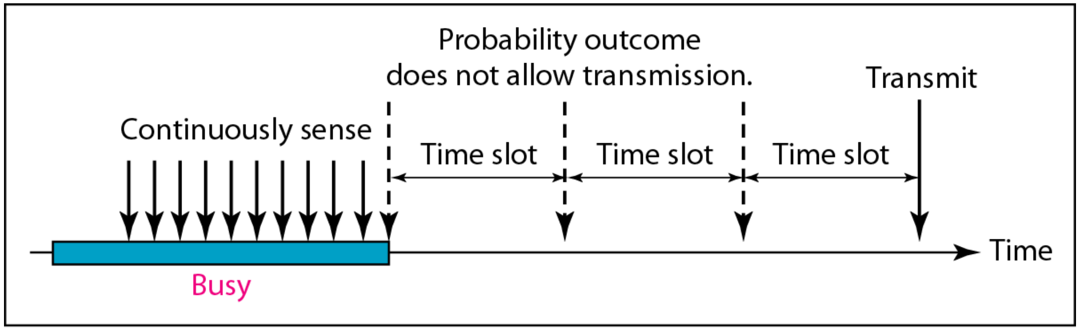
a. 1-persistent

Highest chance of collision.
Ethernet (CSMA/CD) uses this method.
Ethernet can detect collision. If a collision is detected, transmission is aborted. So impact of collisions is not high.



b. Nonpersistent

Wait a random amount of time until channel is idle.
Reduce the chance of collision.
Reduce efficiency.



c. p-persistent

Sense until channel is idle.

At the beginning of each time slot, send with probability p.

Slot duration is more than propagation delay, and is much less than transmission time.

A persistence method decides: if the channel is sensed busy, when to try again?

Figure 12.11 *Flow diagram for three persistence methods*

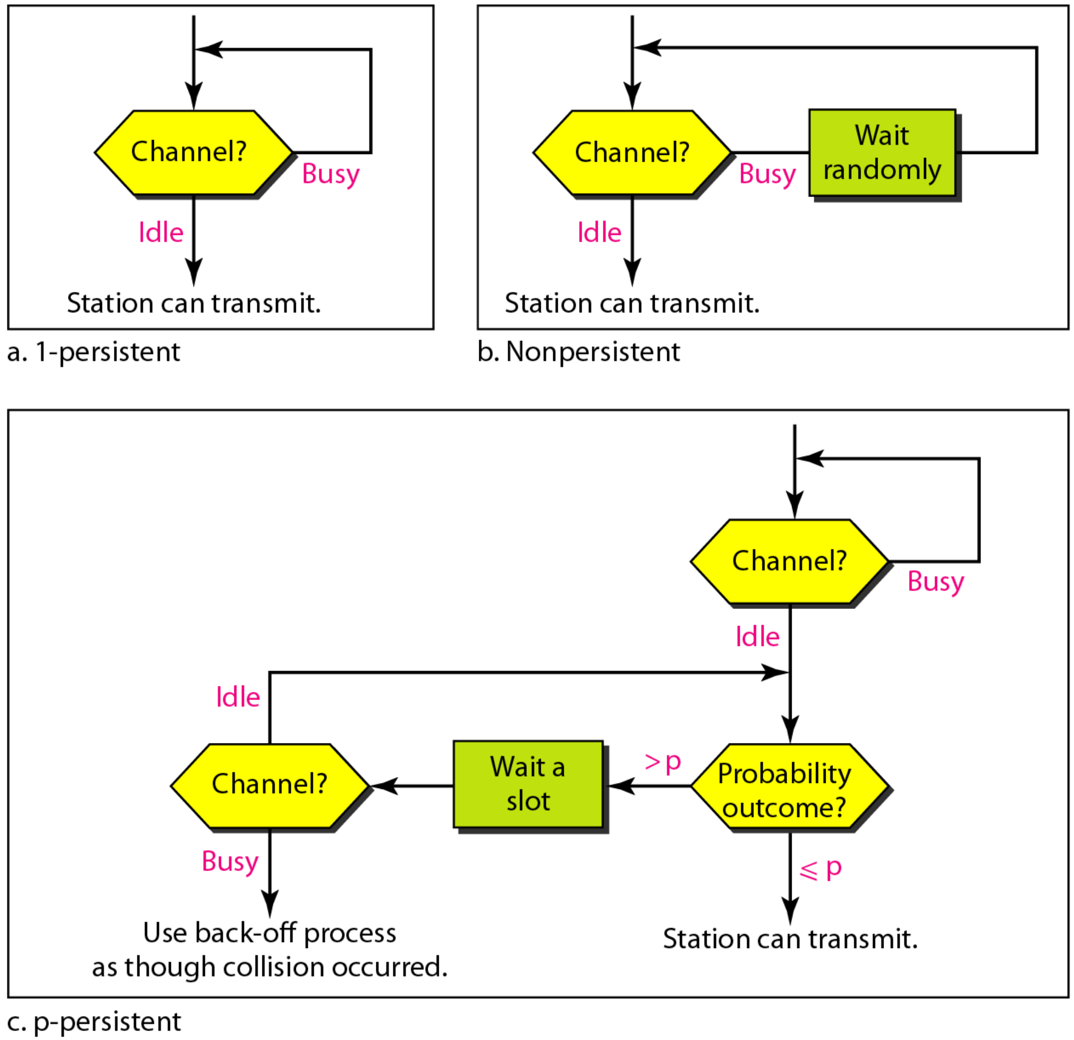
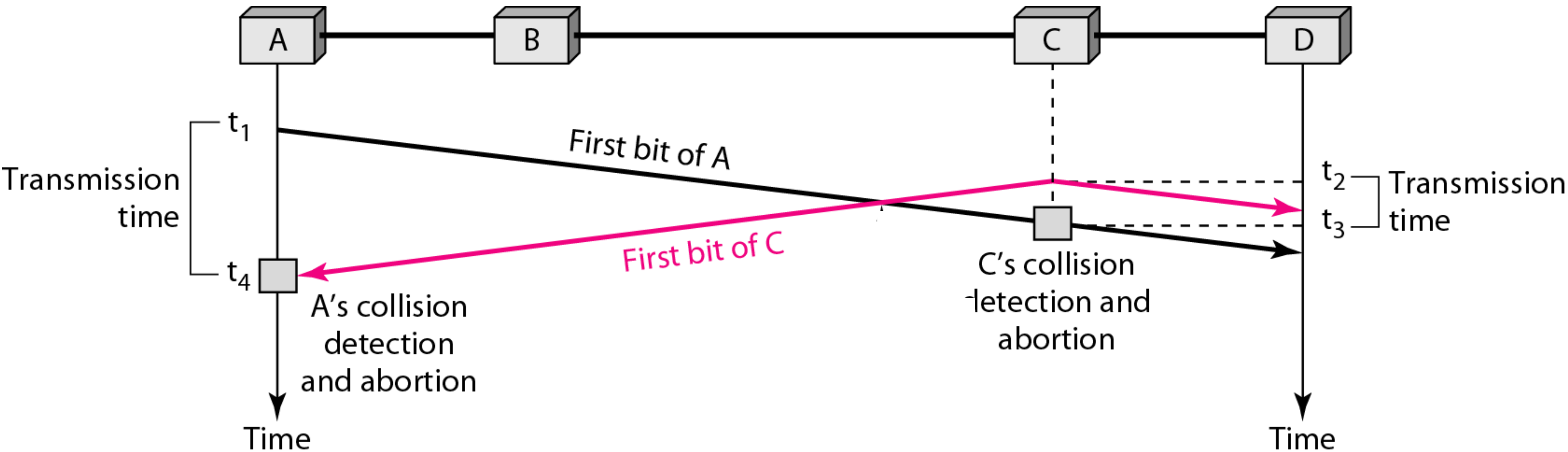
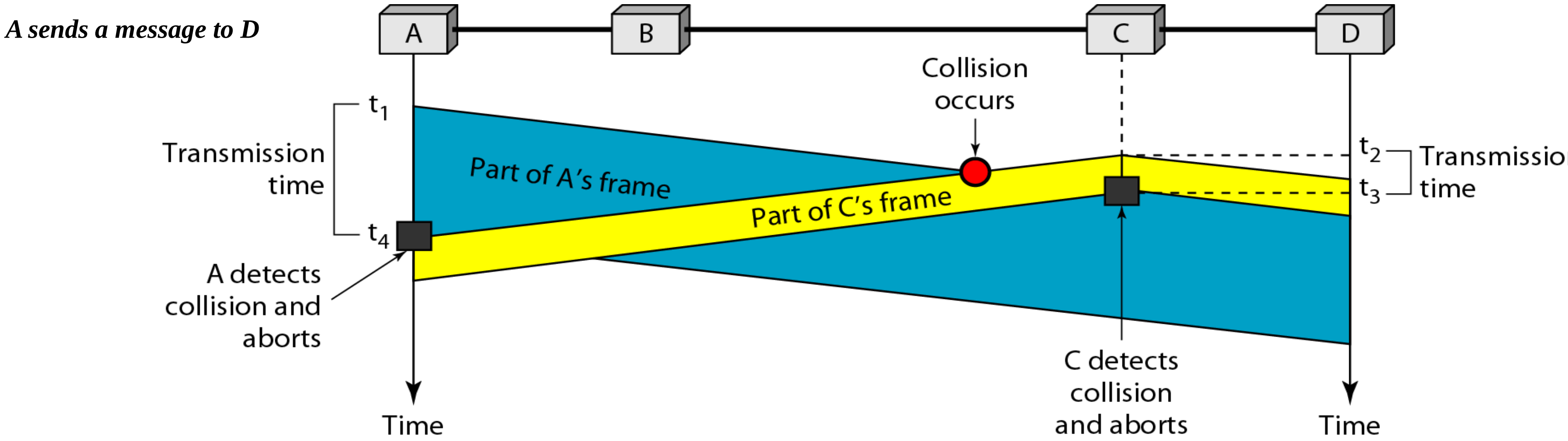


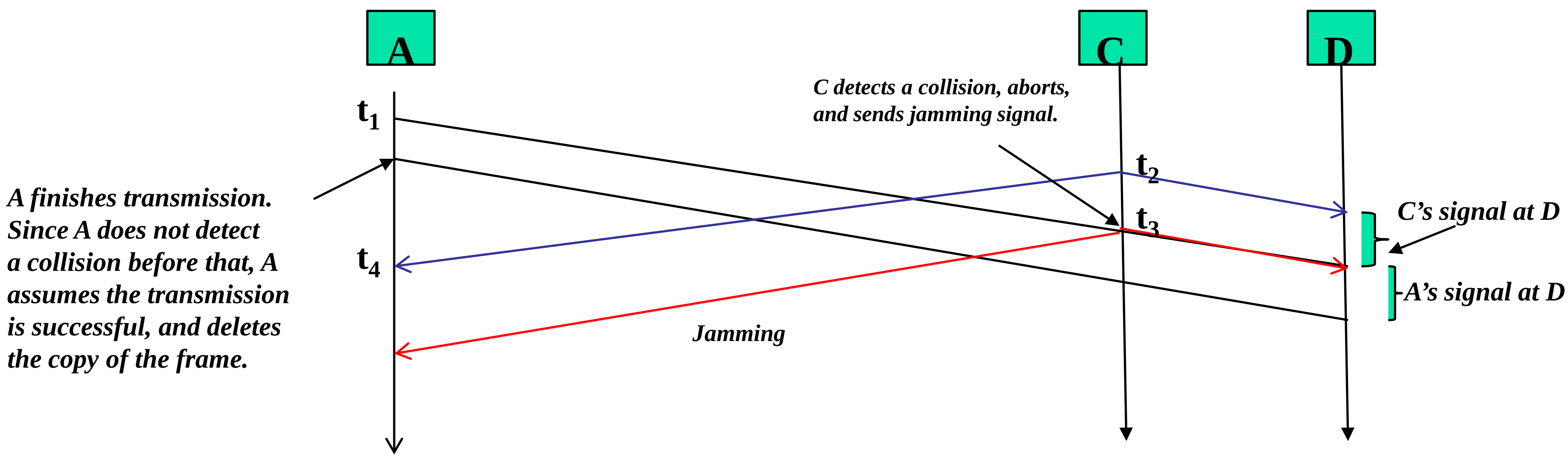
Figure 12.12 *Collision of the first bit in CSMA/CD*



CSMA does not specify the procedure following a collision, which is addressed in CSMA/CD

Figure 12.13 *Collision and abortion in CSMA/CD*





Frame transmission time must be more than twice the maximum propagation time• This is because once the entire frame is sent, the sender does not keep a copy of the frame.

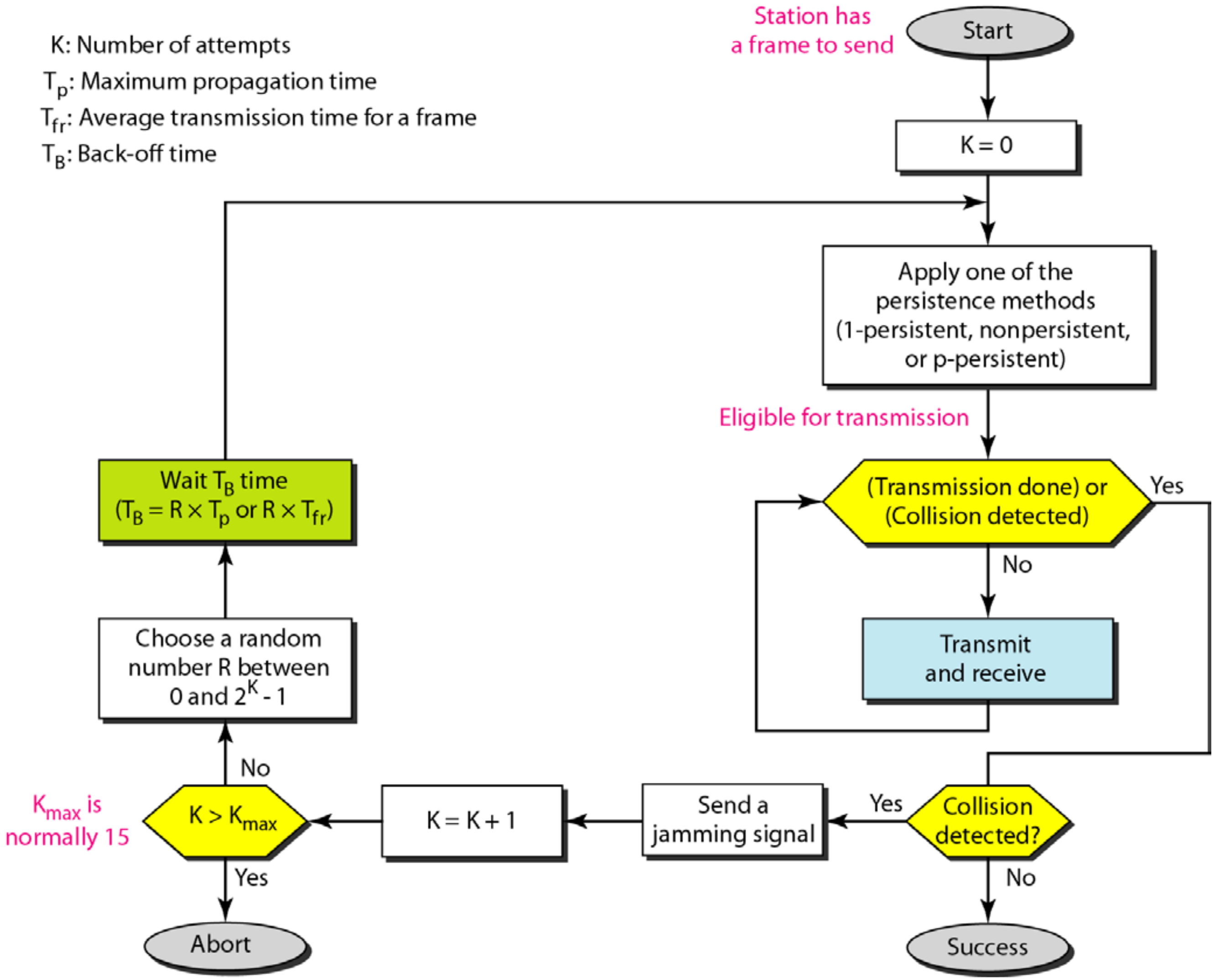
Example 12.5

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



ALOHA: first send entire frame, then wait for ACK

CSMA/CD: send and detect simultaneously. No ACK is needed.

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

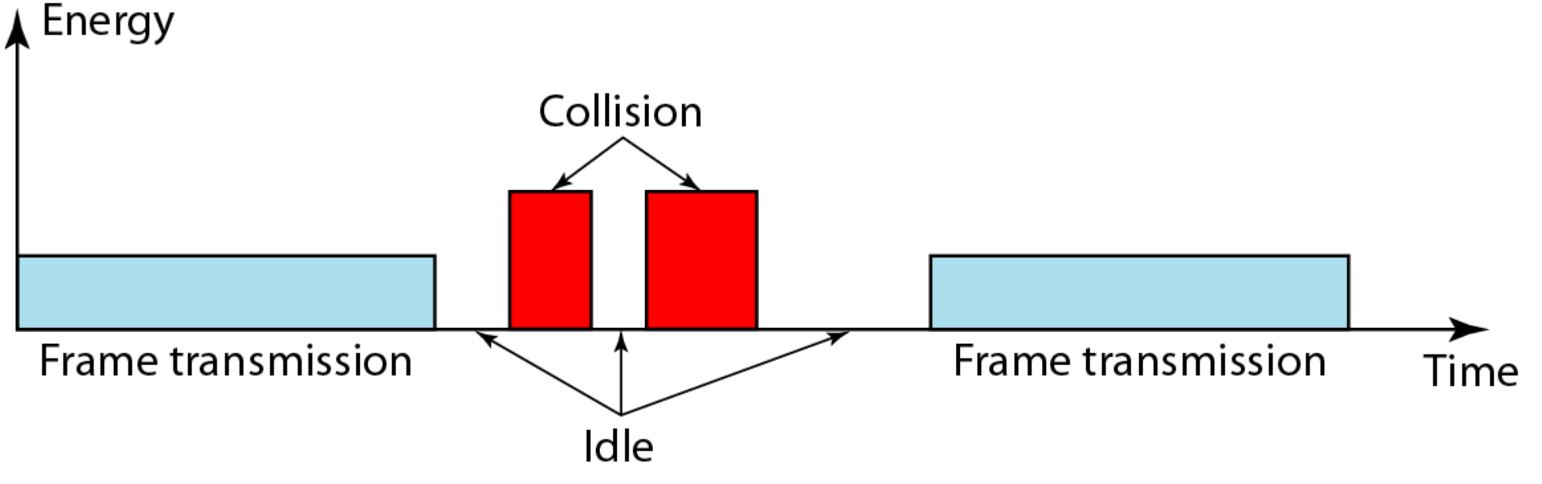
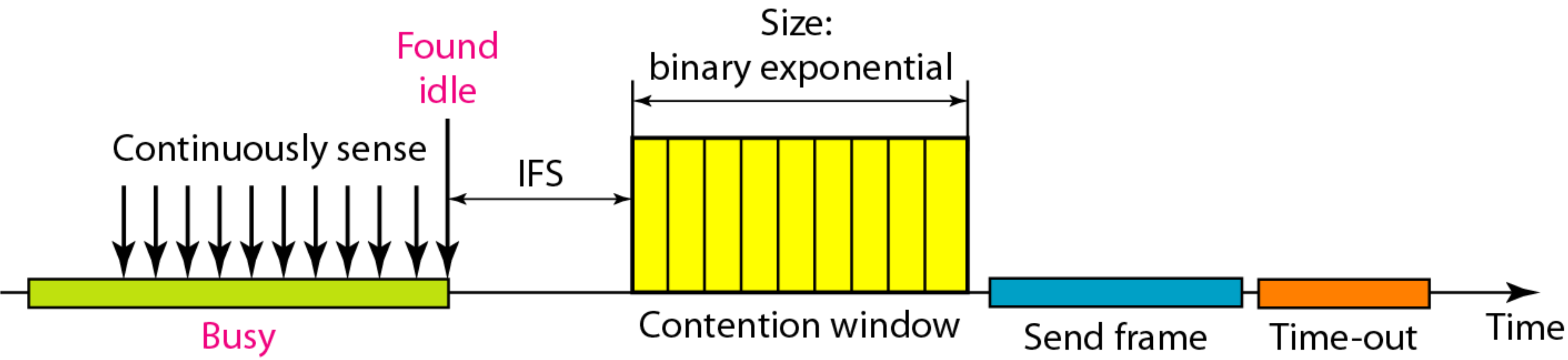


Figure 12.16 *Timing in CSMA/CA*



CSMA/CD: a collision will almost double the energy level.
This applies in wired networks.
However, in wireless networks, the case is different: Hard to send and monitor at the same time over the same frequency band.

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*

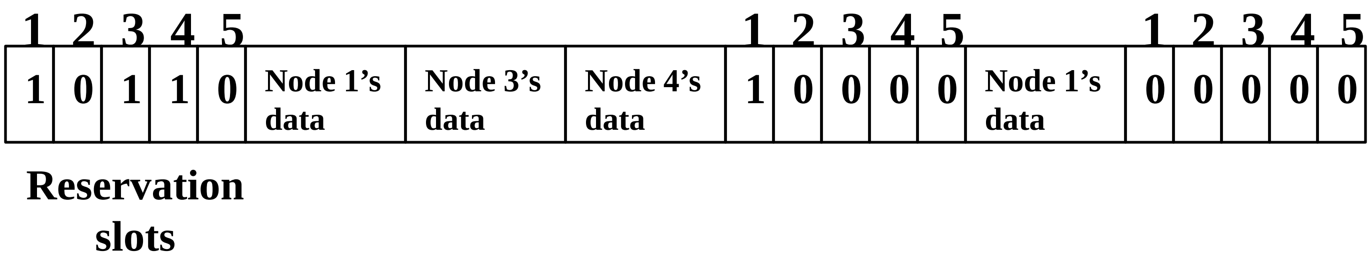


Figure 12.19 *Select and poll functions in polling access method*

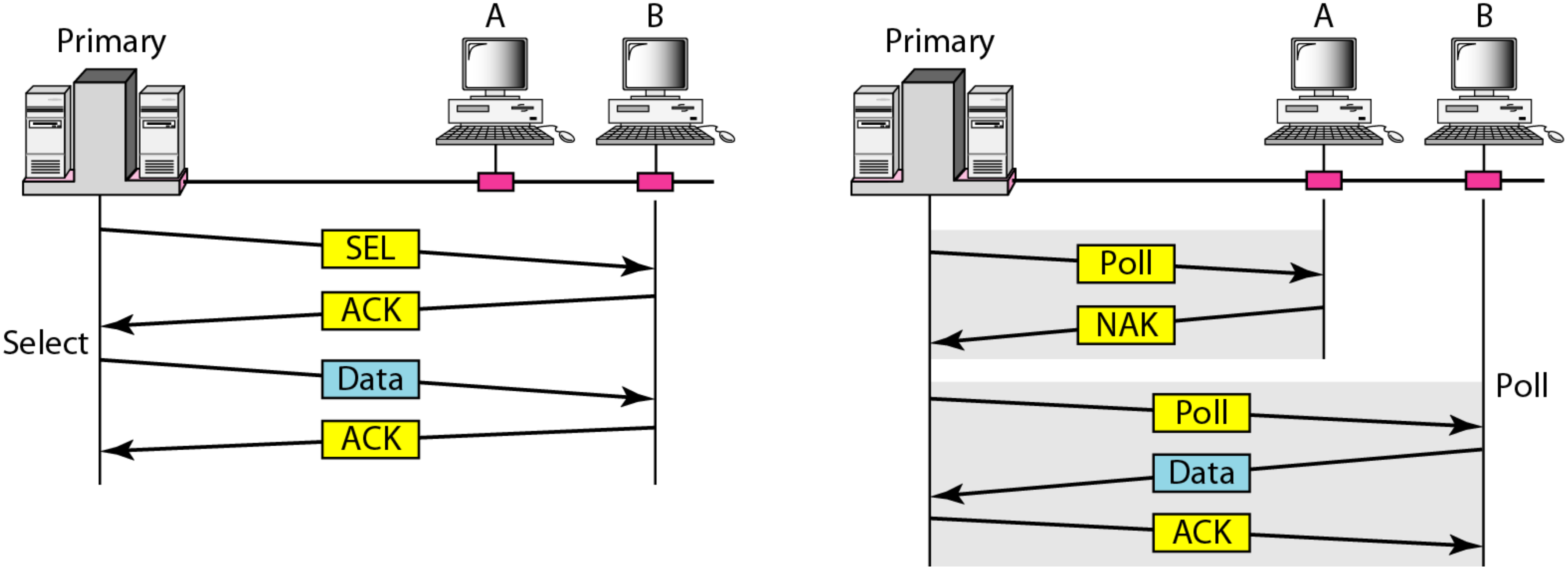
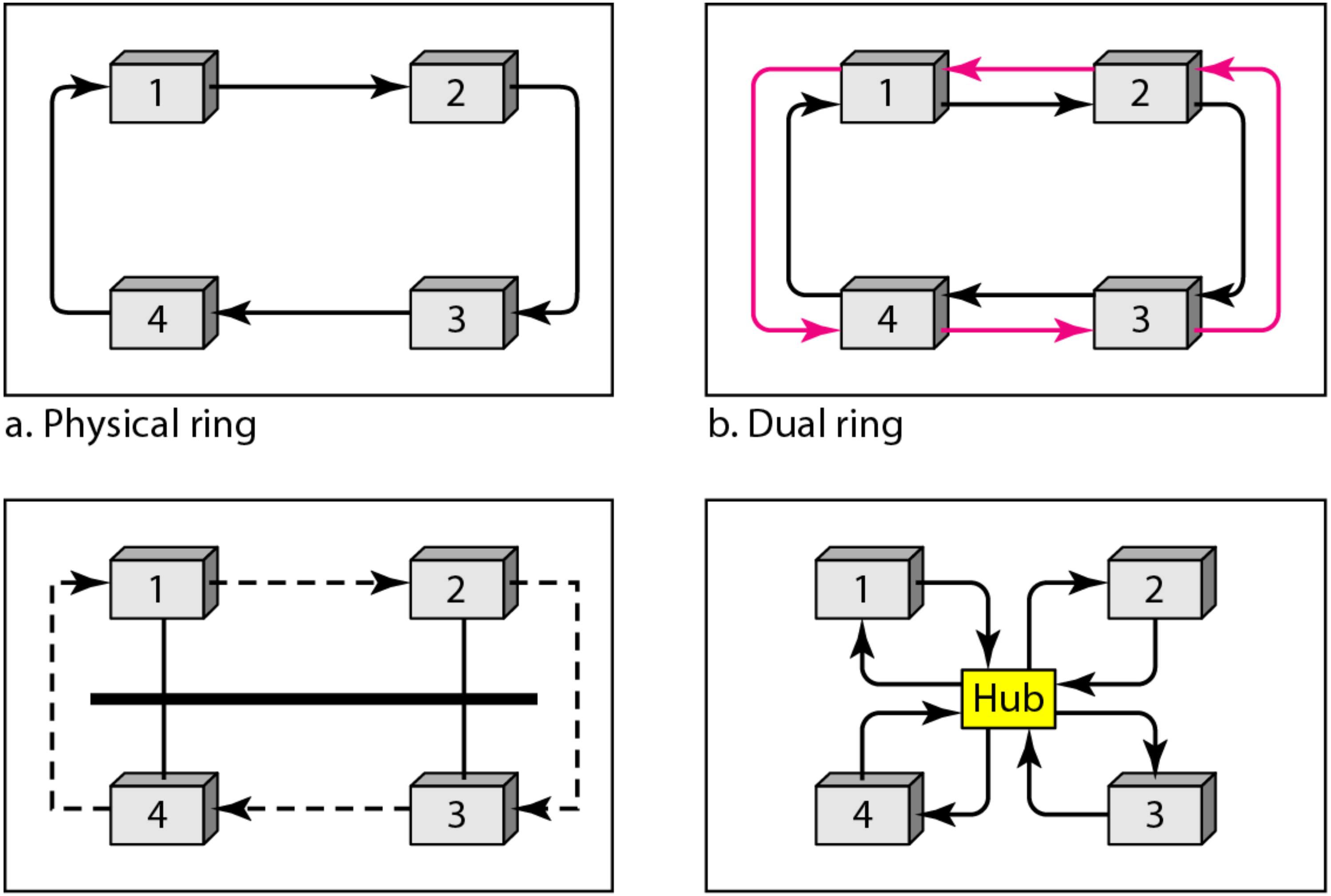


Figure 12.20 *Logical ring and physical topology in token-passing access method*



a. Physical ring
b. Dual ring
c. Bus ring
d. Star ring

If a link fails, it will be bypassed by the hub