Computer Networks

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Data Link Layer

Access Control

- The first section discusses random-access protocols. Four protocols, ALOHA, CSMA, CSMA/CD, and CSMA/CA, are described in this section. These protocols are mostly used in LANs and WANs.
- The second section discusses controlled-access protocols. Three protocols, reservation, polling, and token-passing, are described in this section. Some of these protocol are used in LANs.
- The third section discusses channelization protocols. Three protocols, FDMA, TDMA, and CDMA are described in this section. These protocols are used in cellular telephony.

Multiple Access Control

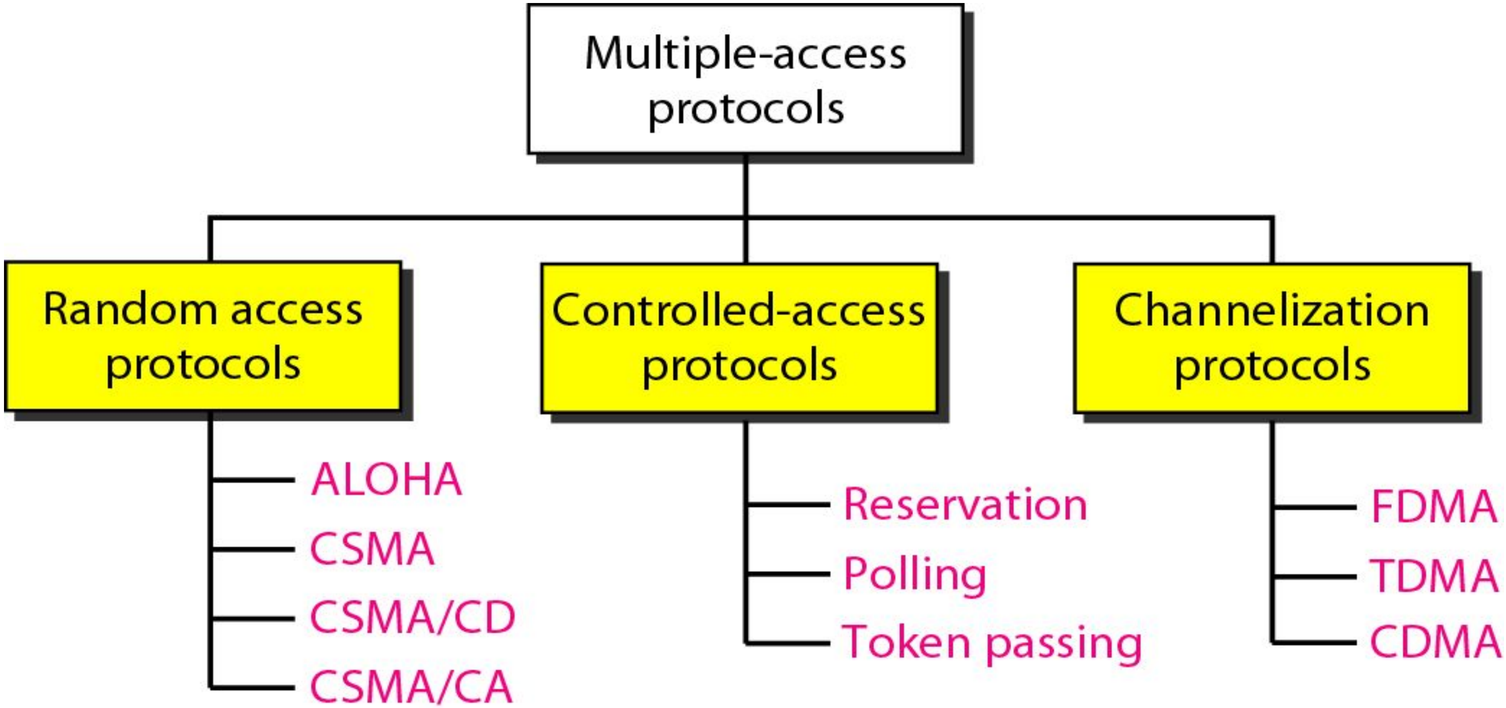


Figure: Multiple-access protocols

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

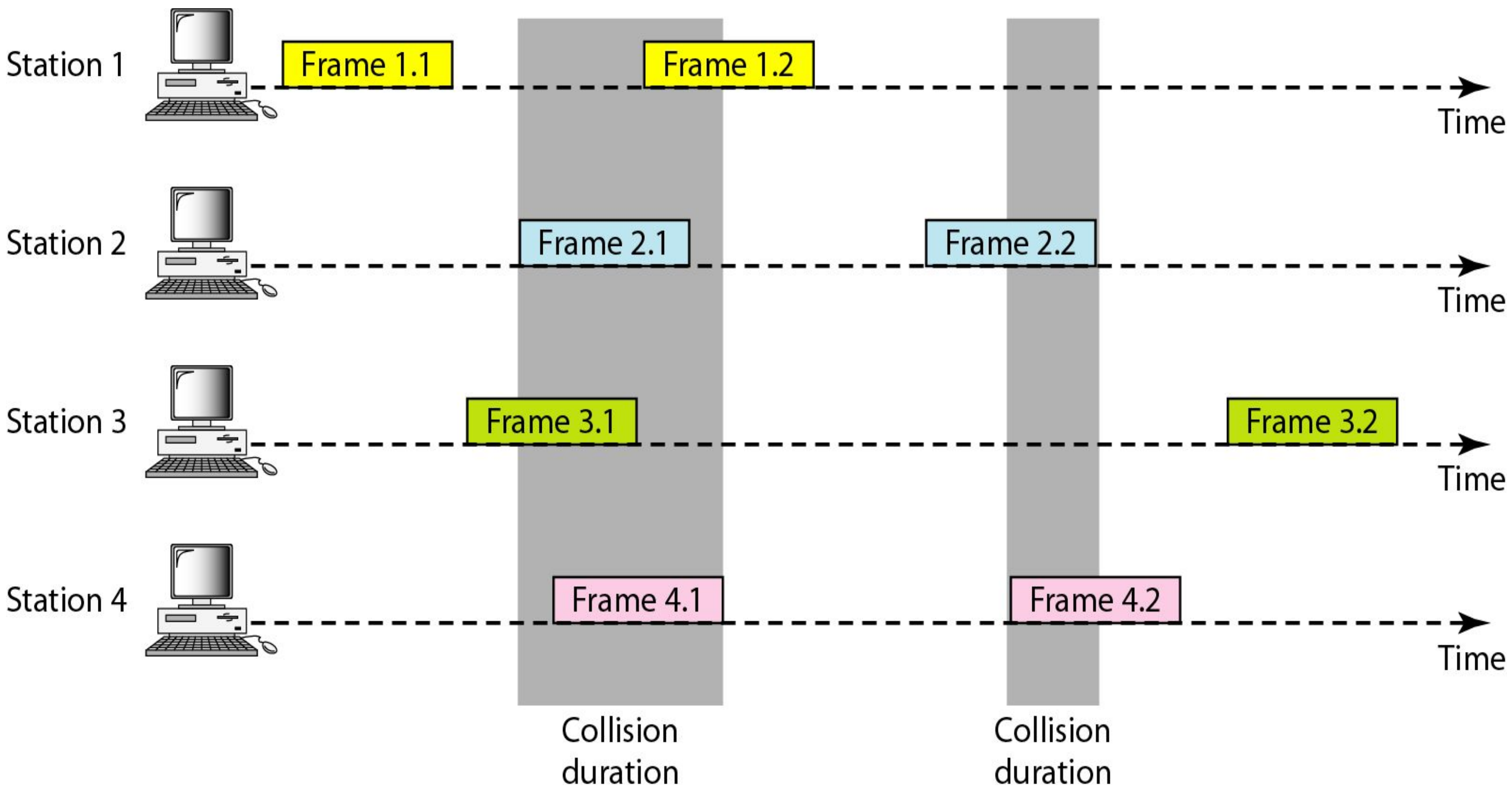
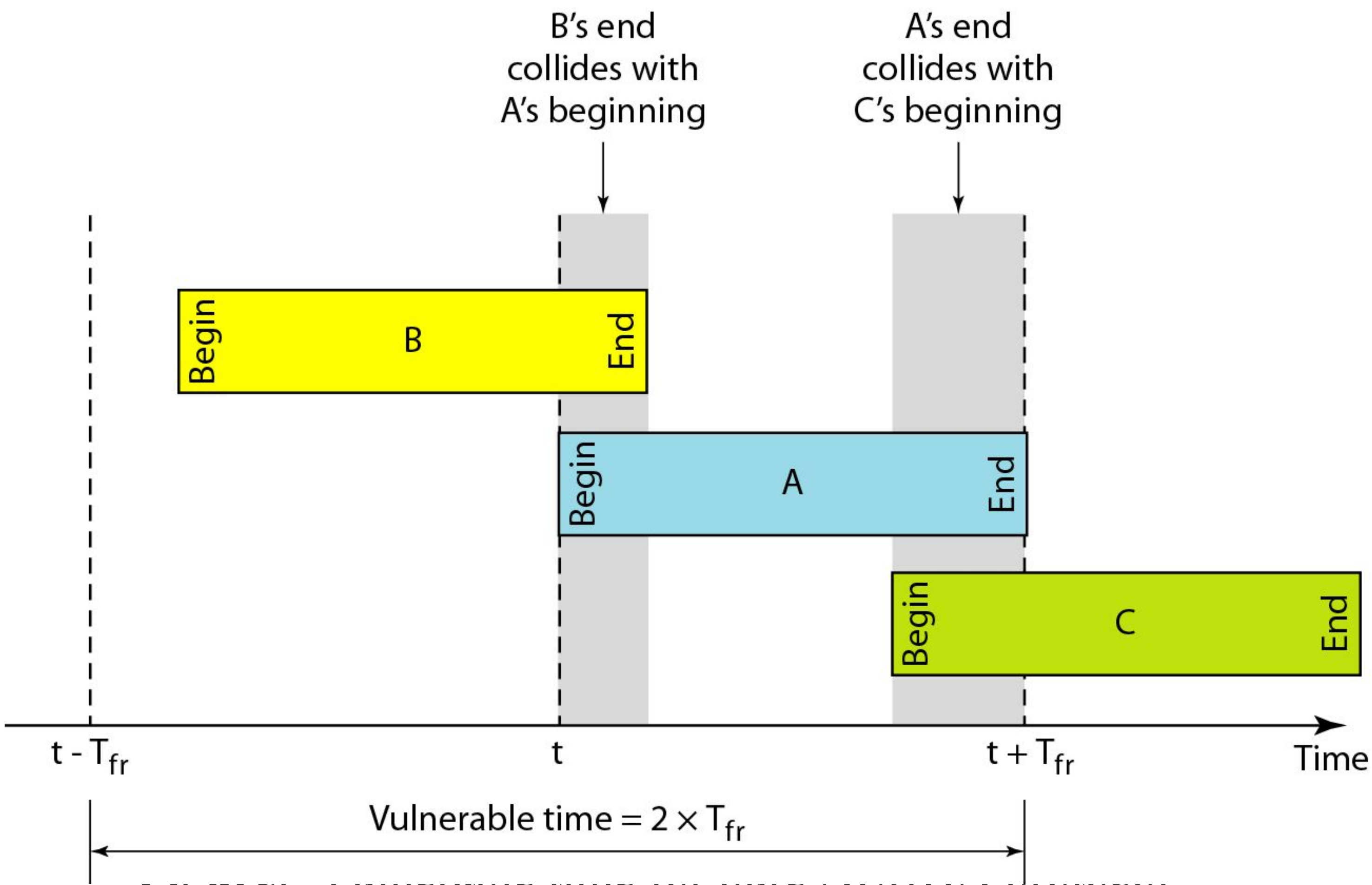


Figure: Frames in a pure ALOHA network

Pure ALOHA protocol



Pure ALOHA

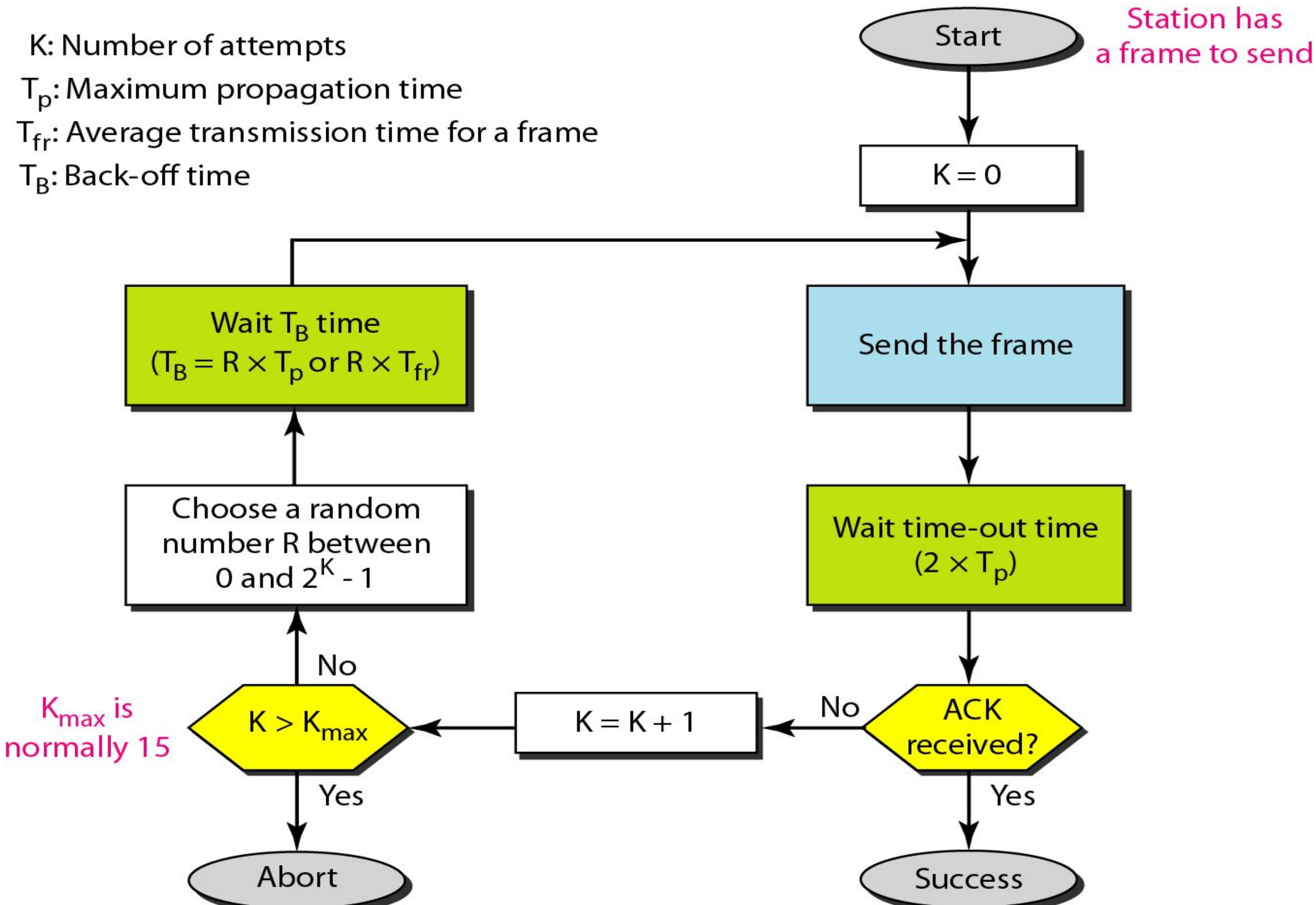


Figure: Procedure for pure ALOHA protocol

Slotted ALOHA

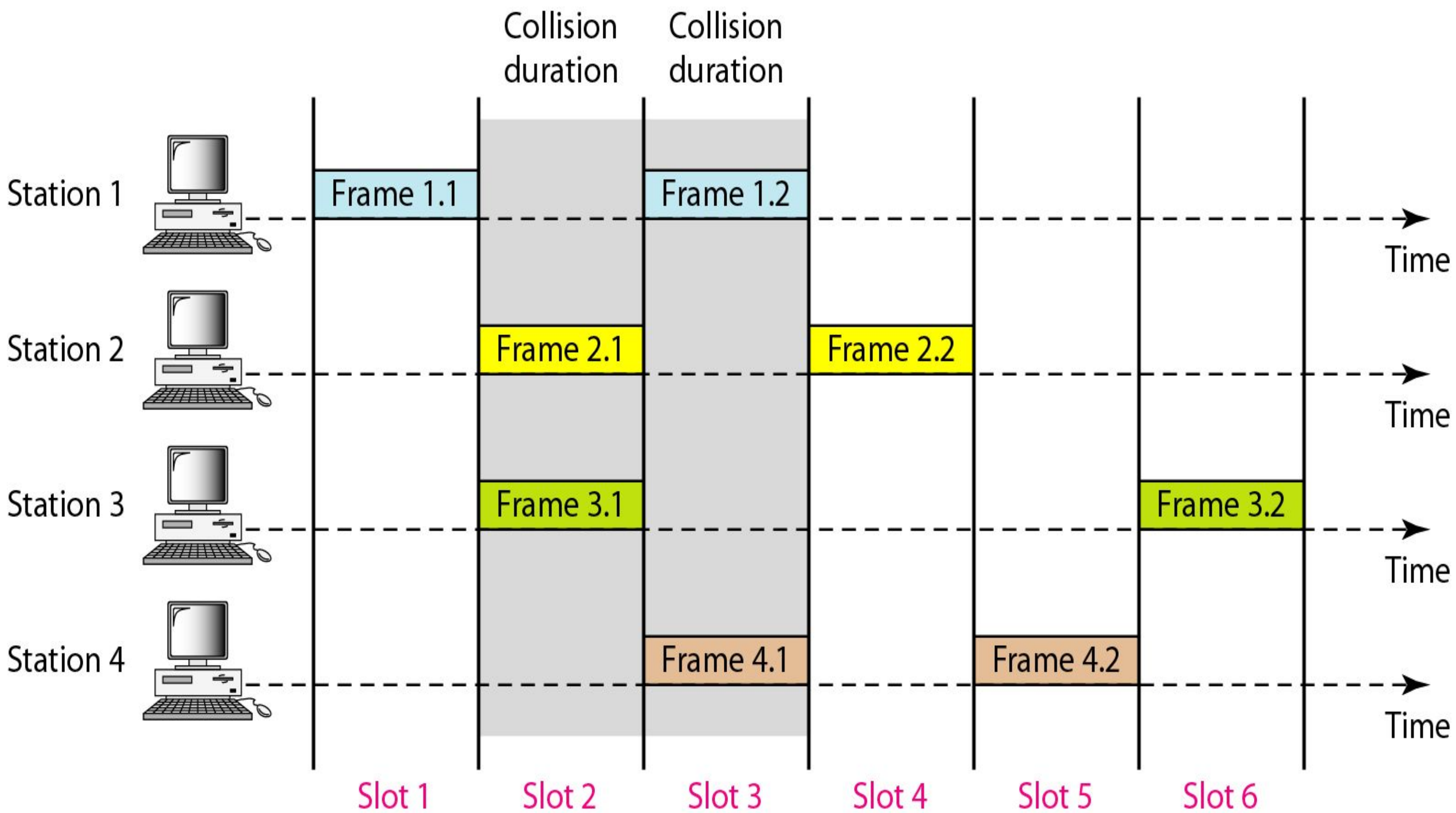


Figure: Frames in a slotted ALOHA network

Slotted ALOHA

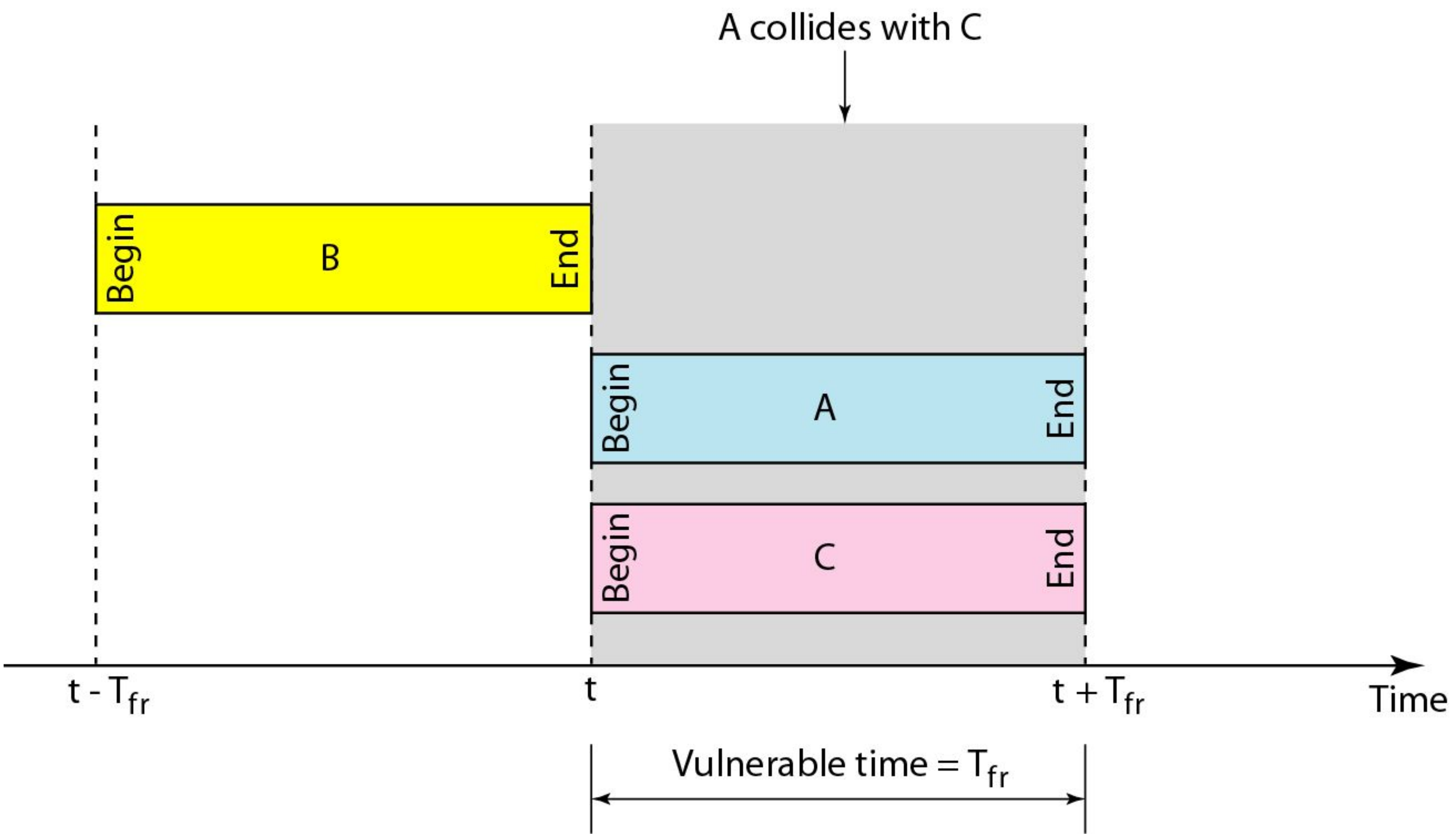


Figure: Vulnerable time for slotted ALOHA protocol

Throughput of pure and slotted ALOHA

- The throughput for pure ALOHA is

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

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

- The throughput for slotted ALOHA is

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

The maximum throughput $S_{max} = 0.368$ when G = 1.

Example 12. 1

The stations on a wireless ALOHA network are a maximum of 600 km apart. Find T_p & T_B for $K = 2$.
Assume that signals propagate at 3×10^8 m/s

If we assume that signals propagate at 3×10^8 m/s, we find $T_p = (600 \times 10^3) / (3 \times 10^8) = 2$ ms.

For $K = 2$, the range of R 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 R.

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 period (1 ms) that this station is sending.

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, or 1 frame per millisecond, then $G = 1$.

In this case $S = G \times e^{-2G} = 0.135$ (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, or 1/2 frames per millisecond, then $G = 1/2$. In this case $S = G \times e^{-2G} = 0.184$ (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, percentage-wise.

c. If the system creates 250 frames per second, or 1/4 frames per millisecond, then $G = 1/4$. In this case $S = G \times e^{-2G} = 0.152$ (15.2 percent). This means that the throughput is $250 \times 0.152 = 38$. Only 38 frames out of 250 will probably survive

Example 12. 4

A slotted ALOHA network transmits 200-bit frames using a shared channel with a 200-kbps bandwidth. Find 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

This situation is similar to the previous exercise except that the network is using slotted ALOHA instead of pure ALOHA. The frame transmission time is 200/200 kbps or 1 ms.

Example 12. 4 (continued)

a) In this case G is 1. So $S = G \times e^{-G} = 0.368$ (36.8 percent). This means that the throughput is $1000 \times 0.0368 = 368$ frames. Only 368 out of 1000 frames will probably survive. Note that this is the maximum throughput case, percentage-wise.

b) Here G is 1/2. In this case $S = G \times e^{-G} = 0.303$ (30.3 percent). This means that the throughput is $500 \times 0.0303 = 151$. Only 151 frames out of 500 will probably survive.

c) Now G is 1/4. In this case $S = G \times e^{-G} = 0.195$ (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 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.
- 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.”

Carrier Sense Multiple Access

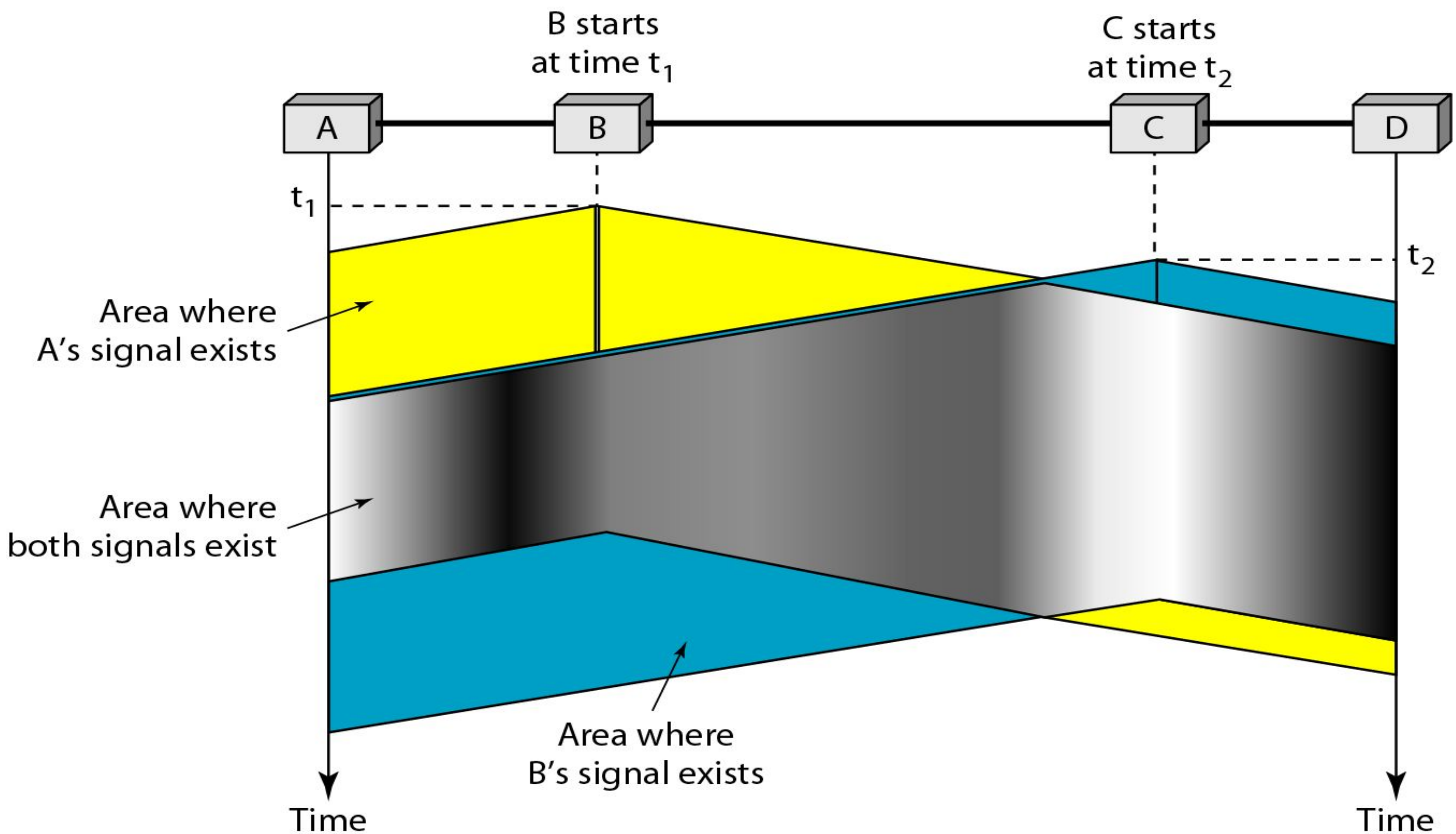


Figure: Space/time model of the collision in CSMA

Carrier Sense Multiple Access

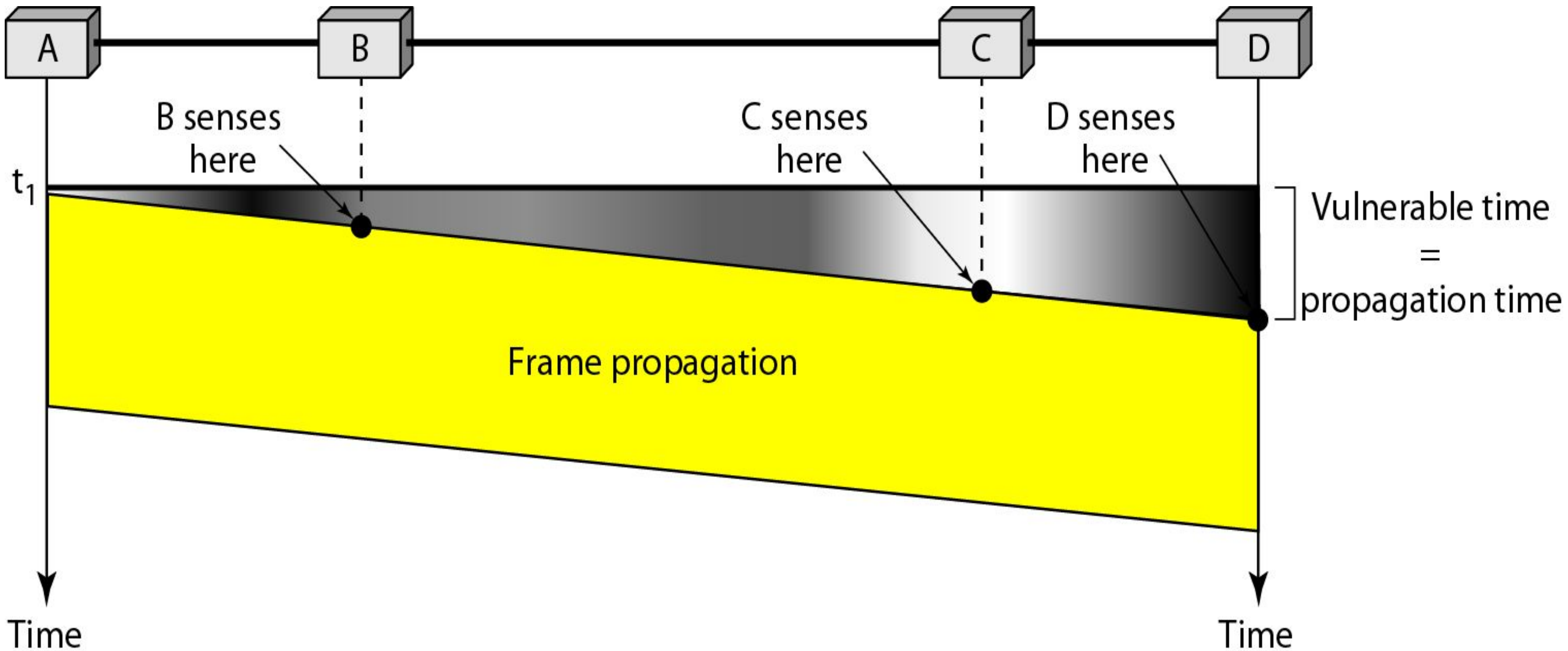


Figure: Vulnerable time in CSMA

Carrier Sense Multiple Access

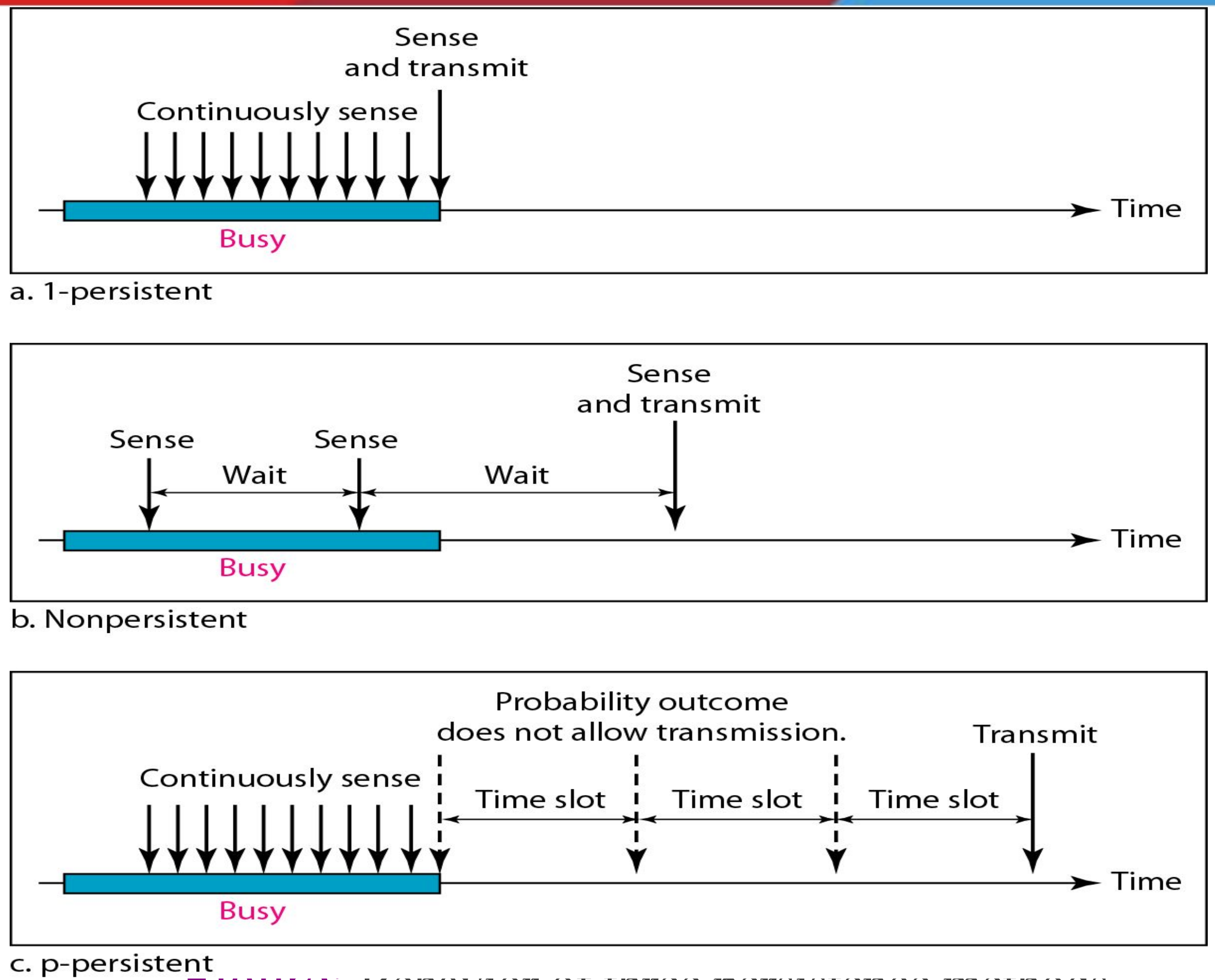
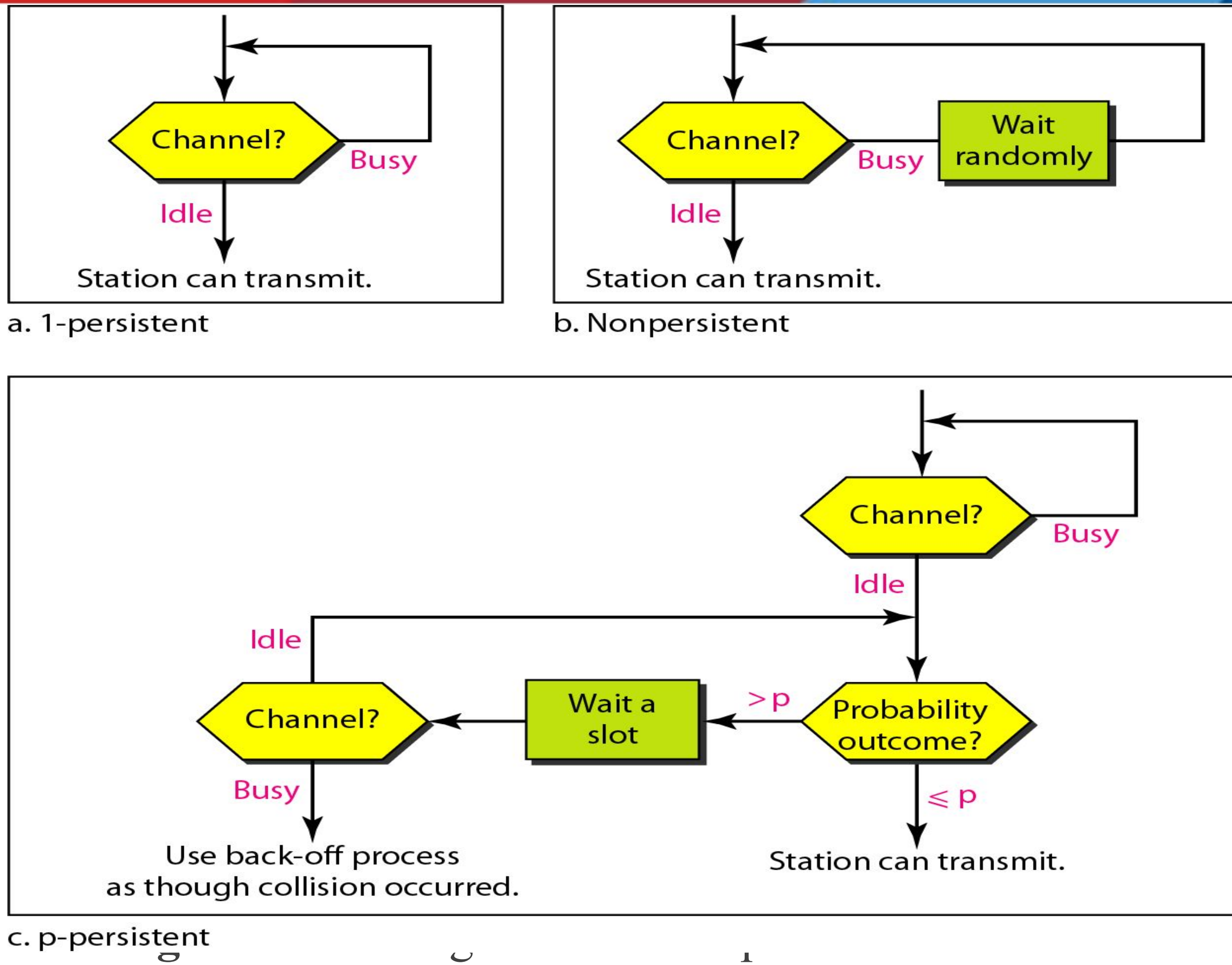


Figure: Behavior of three persistence methods

Carrier Sense Multiple Access



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

- The CSMA method does not specify the procedure following a collision. CSMA/CD gives the algorithm to handle the collision.

- In this method, 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.

Carrier Sense Multiple Access with Collision Detection

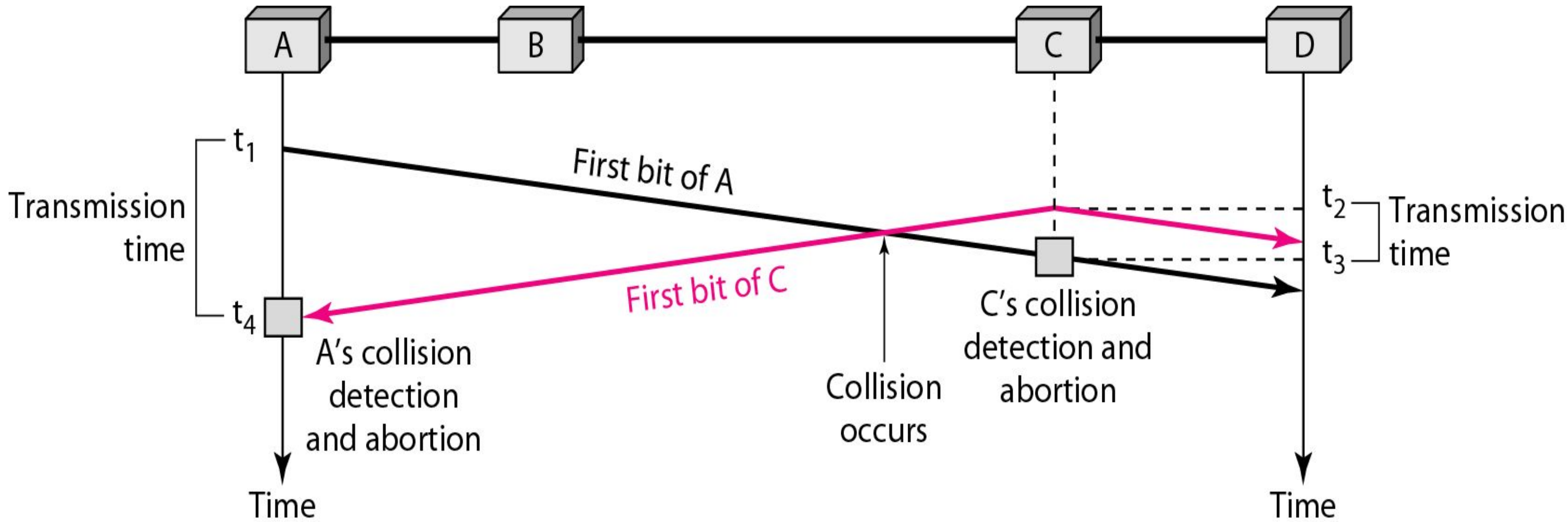


Figure: Collision of the first bit in CSMA/CD

Carrier Sense Multiple Access with Collision Detection

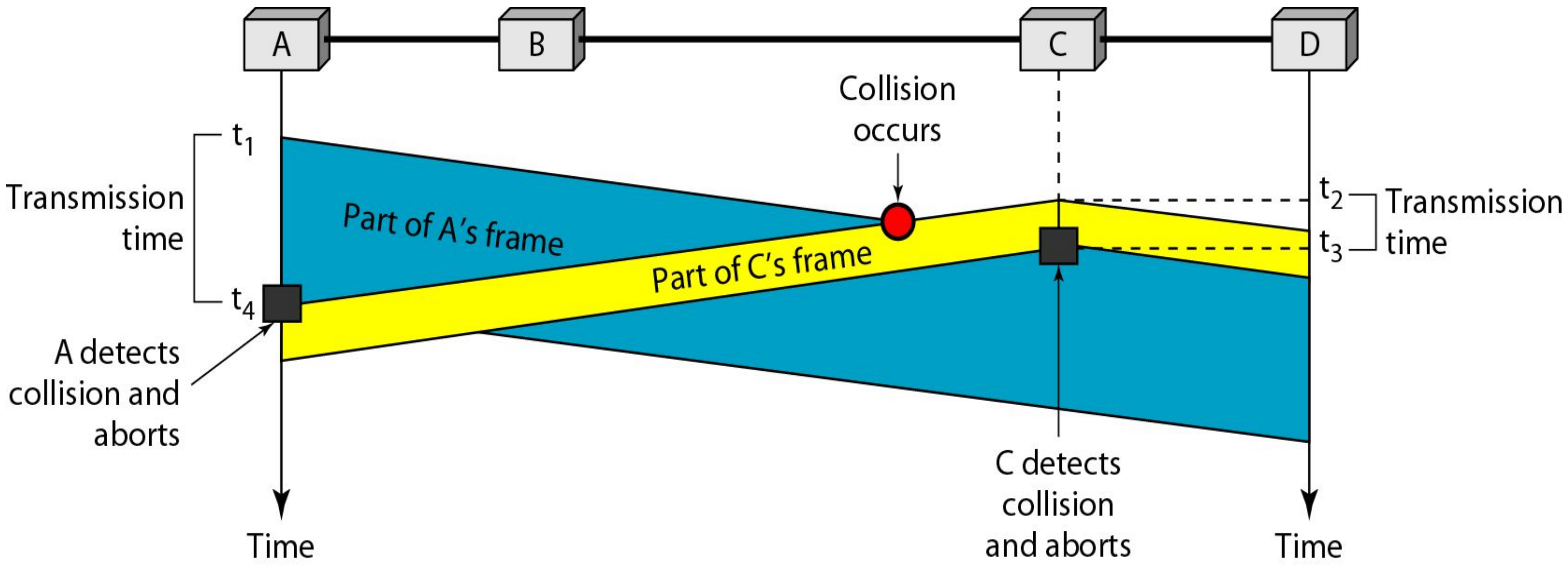


Figure: Collision and abortion in CSMA/CD

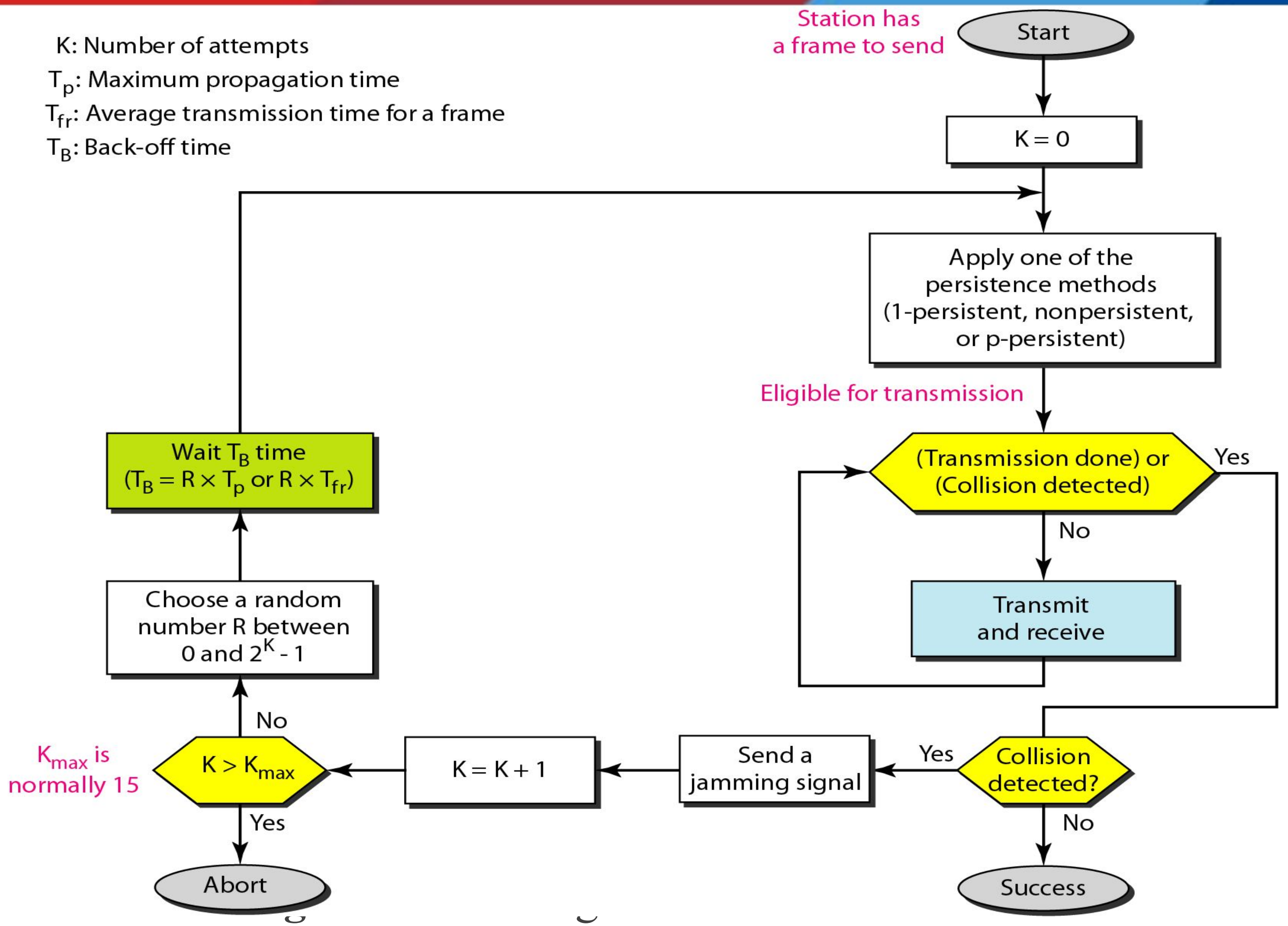
Example 12. 5

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) is 25.6 μs, what is the minimum size of the frame?

Solution

The minimum 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.

Carrier Sense Multiple Access with Collision Detection



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

- Carrier sense multiple access with collision avoidance (CSMA/CA) was invented for wireless networks.

- Collisions are avoided through the use of CSMA/CA’s three strategies:
  - Inter frame space,
  - Contention window, and
  - Acknowledgments

Carrier Sense Multiple Access with Collision Avoidance

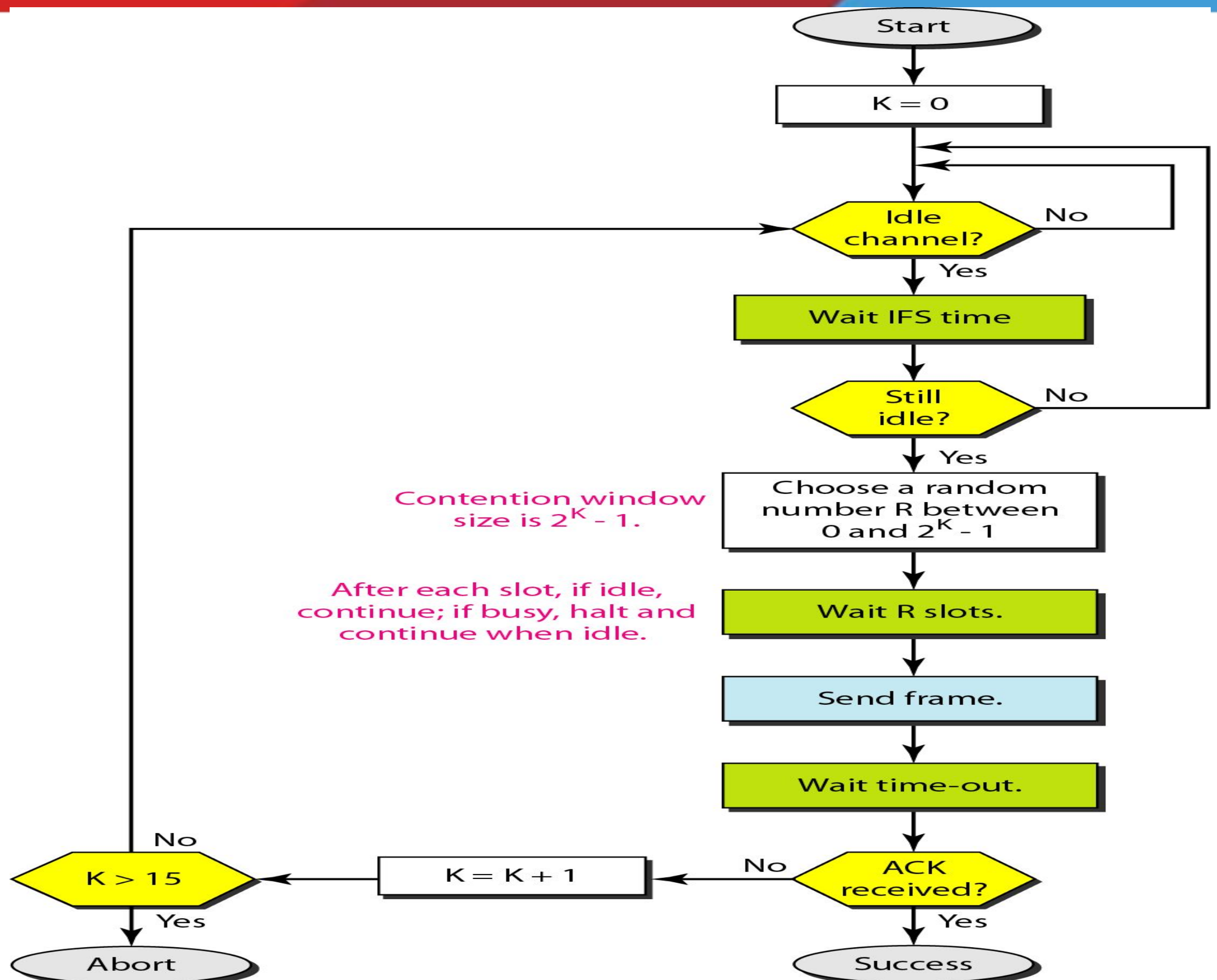


Figure: Flow diagram for CSMA/CA

Carrier Sense Multiple Access with Collision Avoidance

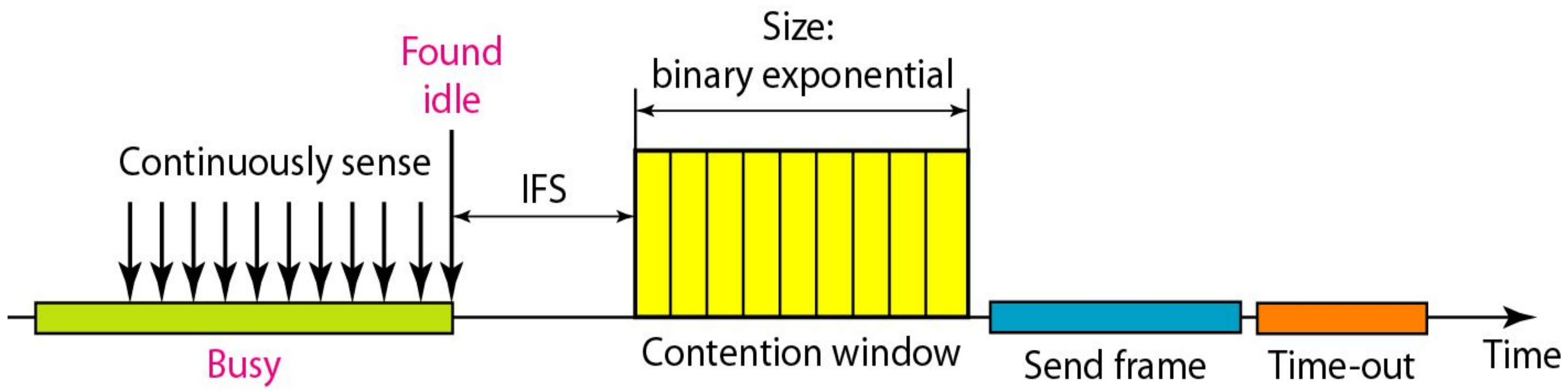


Figure: Timing in CSMA/CA

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

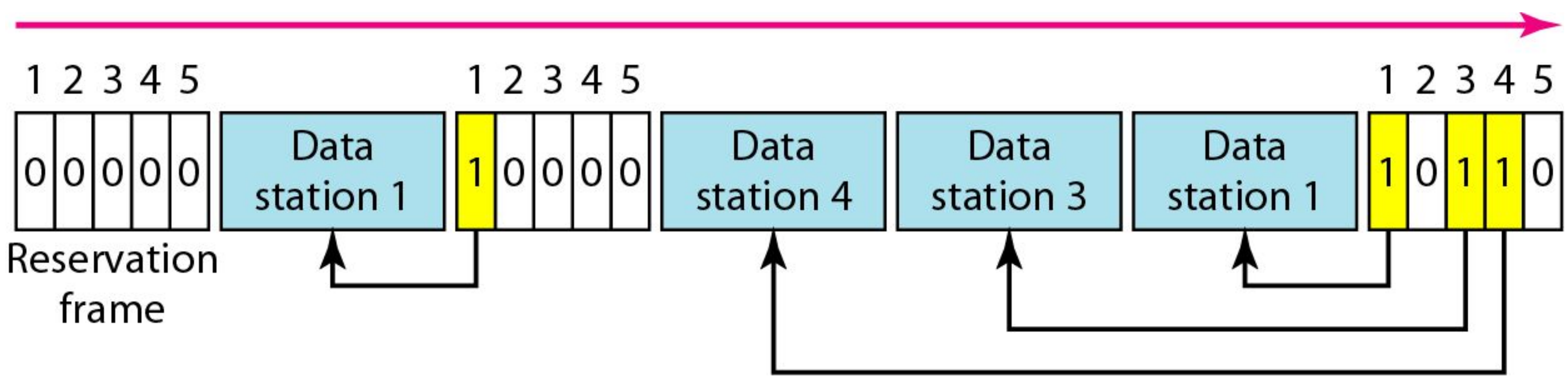


Figure: Reservation access method

Polling

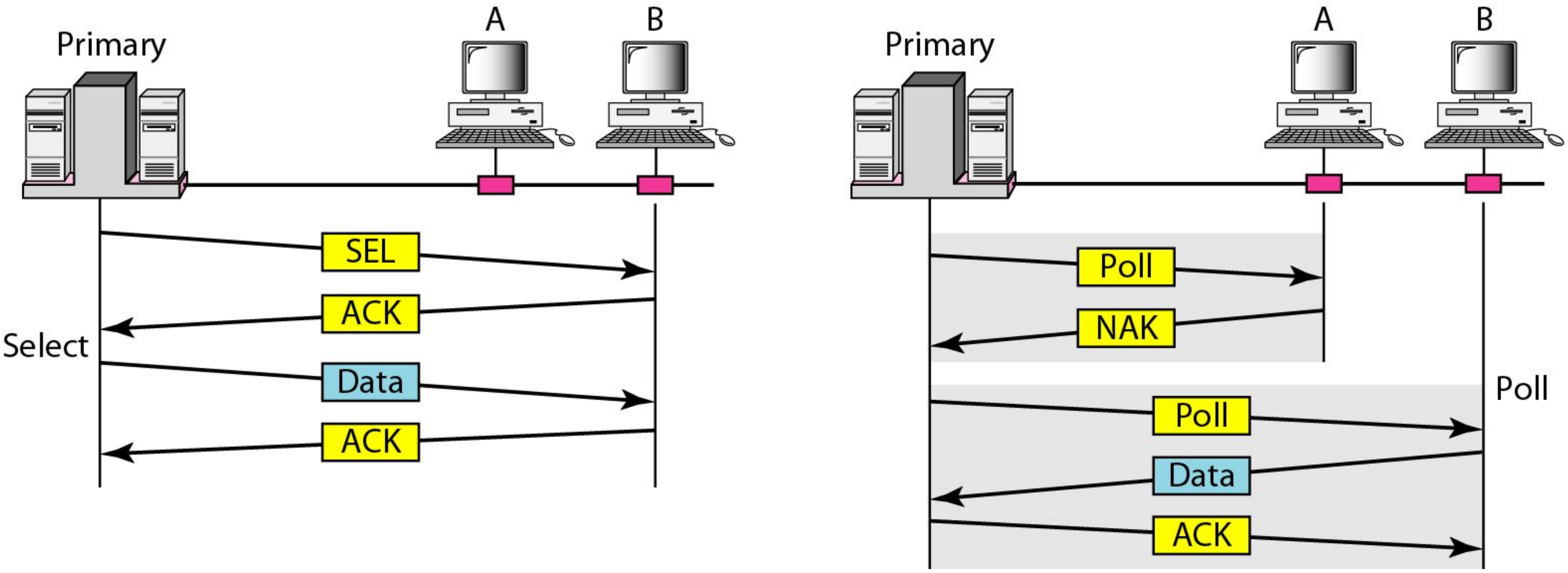


Figure: Select and poll functions in polling access method

Token Passing

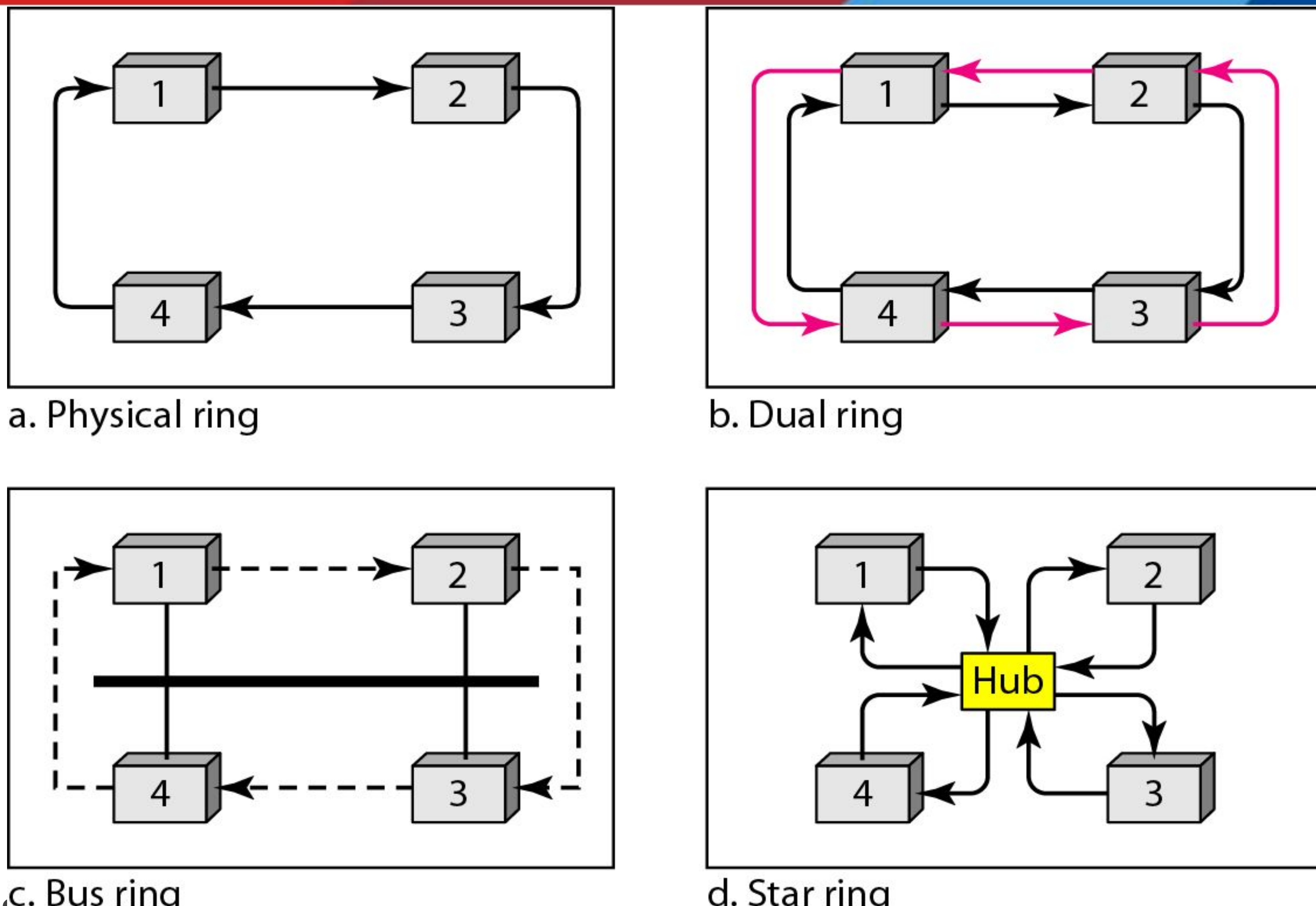


Figure: Logical ring and physical topology in token passing access method

CHANNELIZATION

- It 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)

✔ In FDMA, the available bandwidth of the common channel is divided into bands that are separated by guard bands.

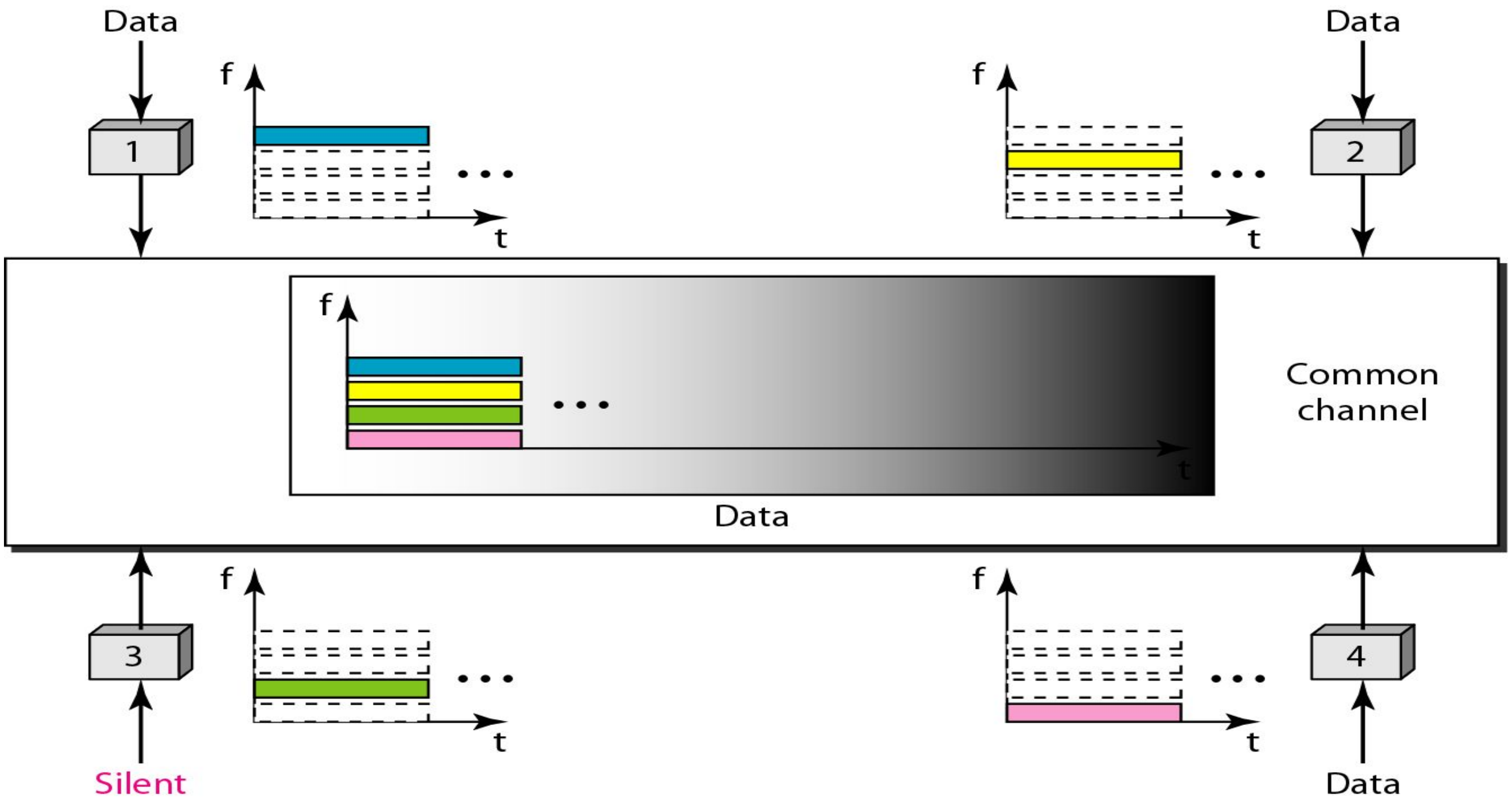


Figure: Frequency-division multiple access (FDMA)

Time-Division Multiple Access (TDMA)

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

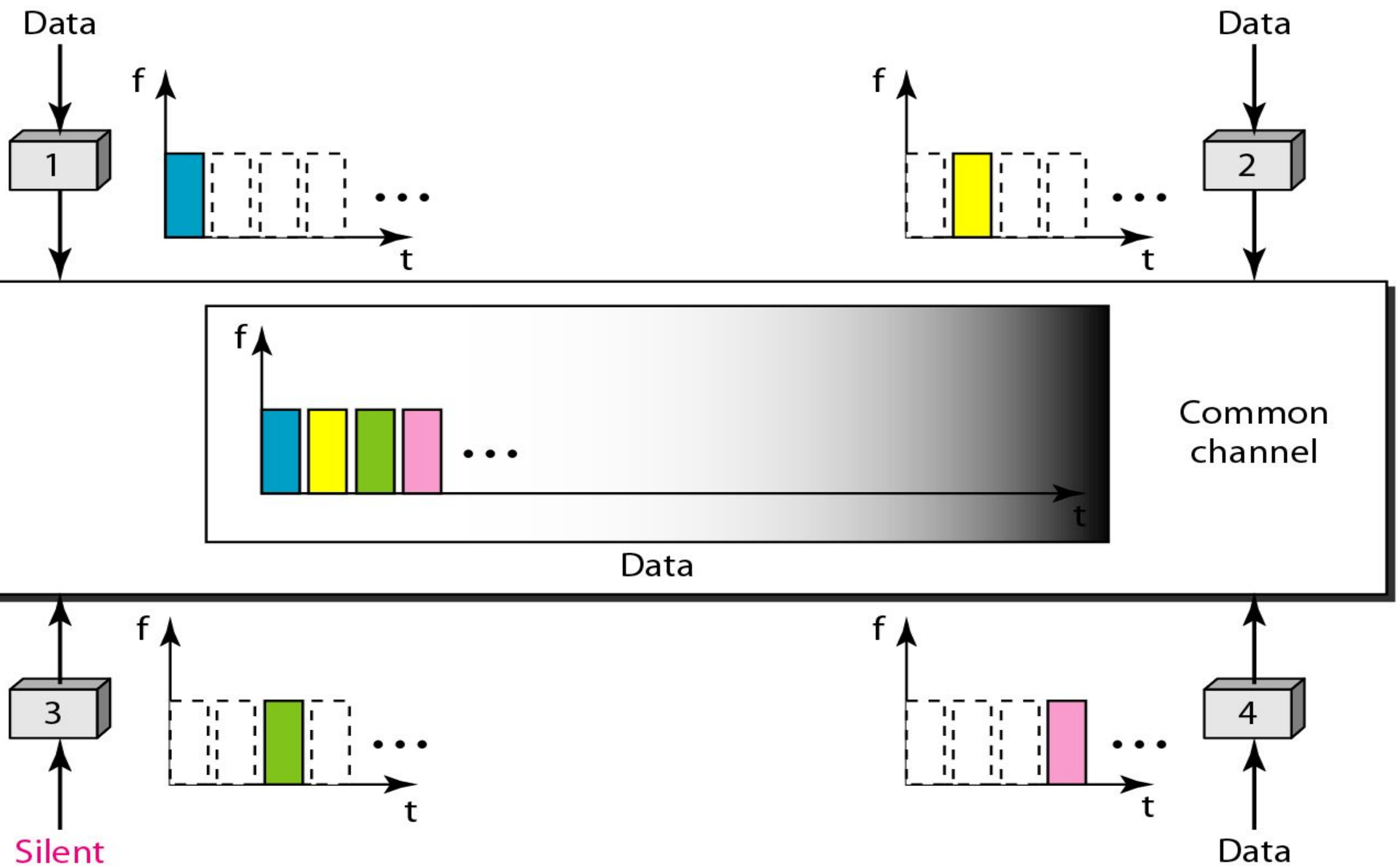


Figure: Time division multiple access (TDMA)

Code-Division Multiple Access (CDMA)

- In CDMA, one channel carries all transmissions simultaneously.

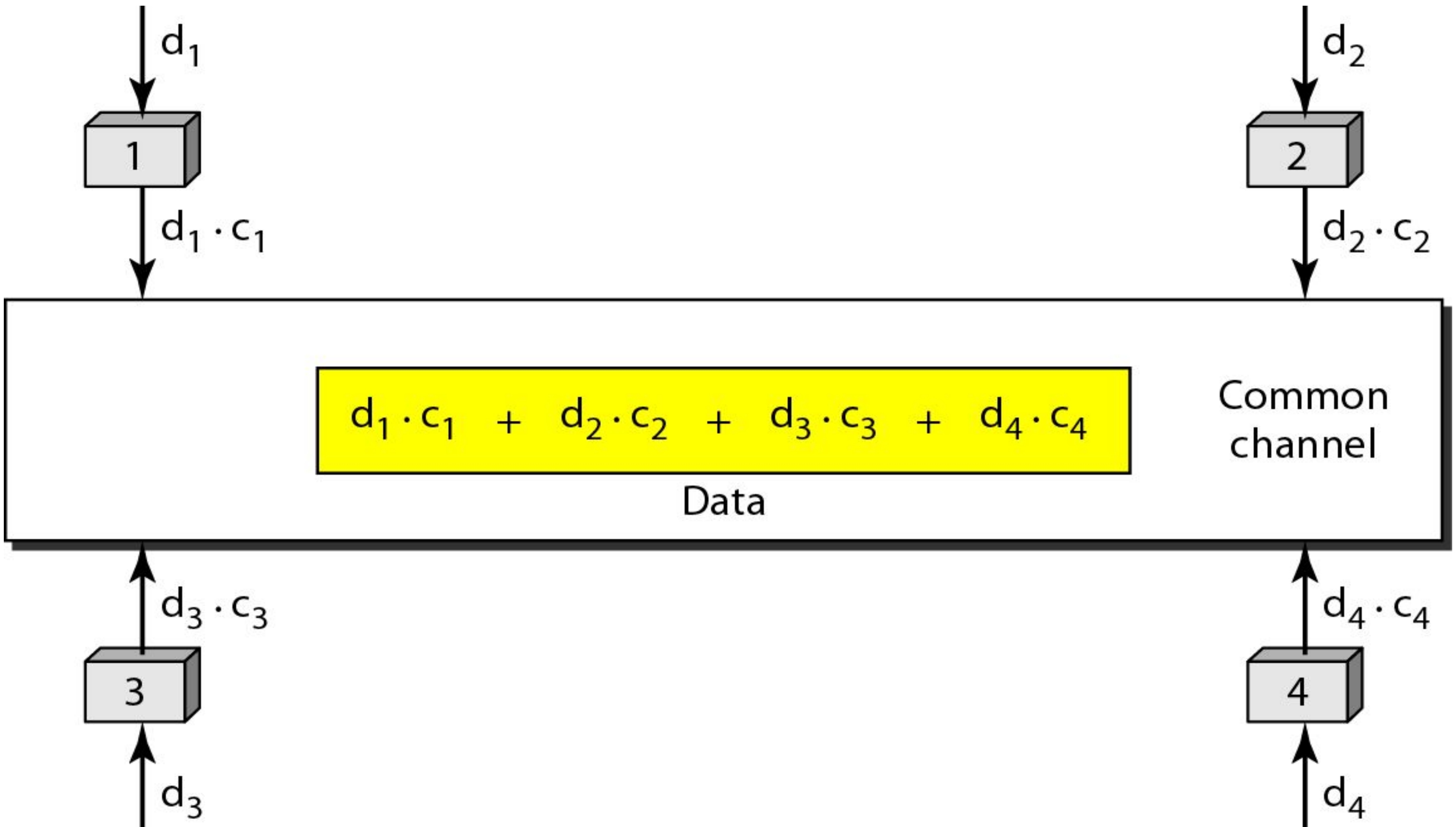


Figure: Simple idea of communication with code