Multiple Access

Data link layer divided into two functionality-oriented sublayers

Suppose there is no dedicated path to communicate or transfer the data between two devices. In that case, multiple stations access the channel and simultaneously transmits the data over the channel. It may create collision and cross talk. Hence, the multiple access protocol is required to reduce the collision and avoid crosstalk between the channels.

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

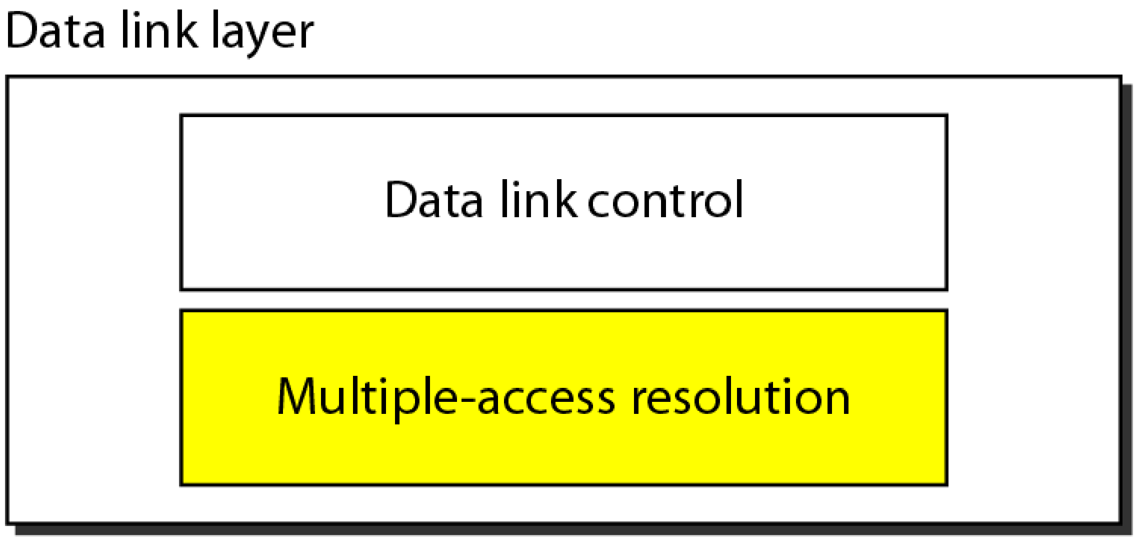
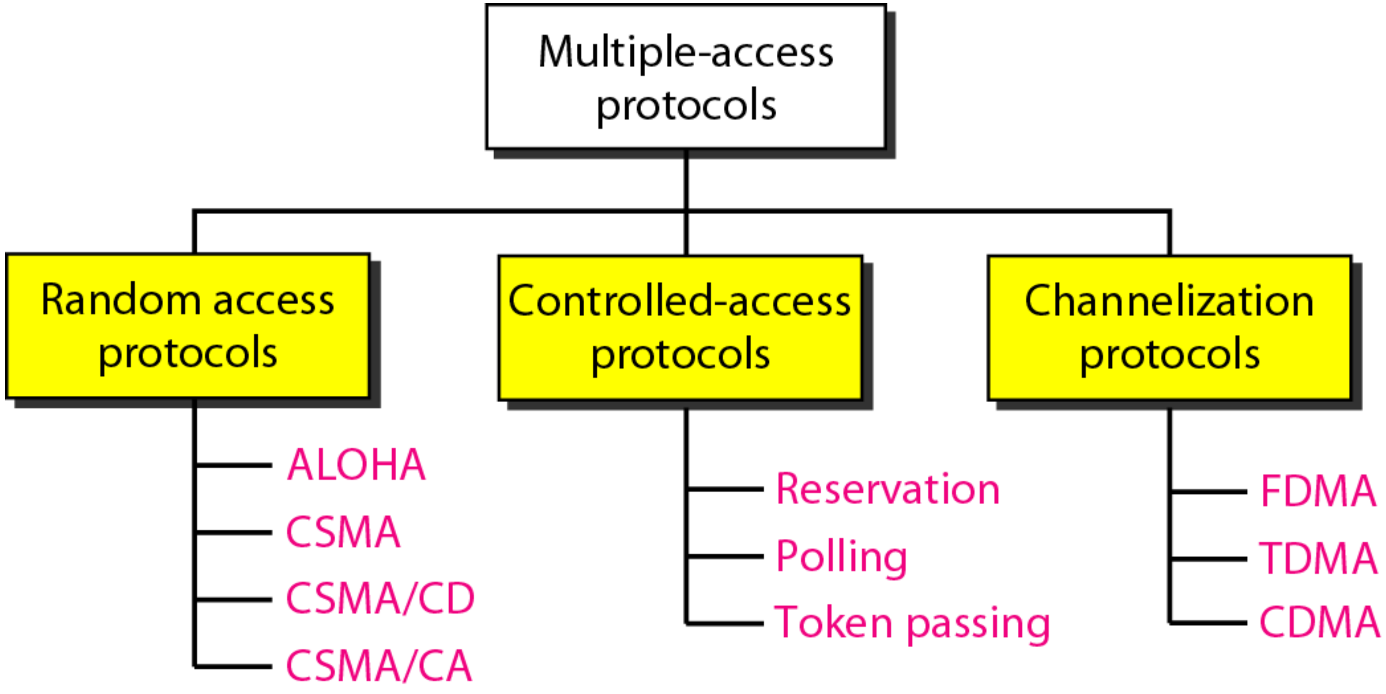


Figure: Taxonomy of multiple-access protocols discussed in this chapter



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.

Each station follows a procedure that answers the following questions:

o When can the station access the medium?

o What can the station do if the medium is busy?

o How can the station determine the success or failure of the transmission?

o What can the station do if there is an access conflict?

ALOHA

There are two different versions of Aloha-

1. Pure Aloha
2. Slotted Aloha

1. Pure Aloha-

- It allows the stations to transmit data at any time whenever they want.
- After transmitting the data packet, station waits for some time.

Then, following 2 cases are possible-

Case-01:

- Transmitting station receives an acknowledgement from the receiving station.
- In this case, transmitting station assumes that the transmission is successful.

Case-02:

- Transmitting station does not receive any acknowledgement within specified time from the receiving station.
- In this case, transmitting station assumes that the transmission is unsuccessful.

Then,

- Transmitting station uses a **Back Off Strategy** and waits for some random amount of time.
- After back off time, it transmits the data packet again.
- It keeps trying until the back off limit is reached after which it aborts the transmission.

Figure Procedure for pure ALOHA protocol

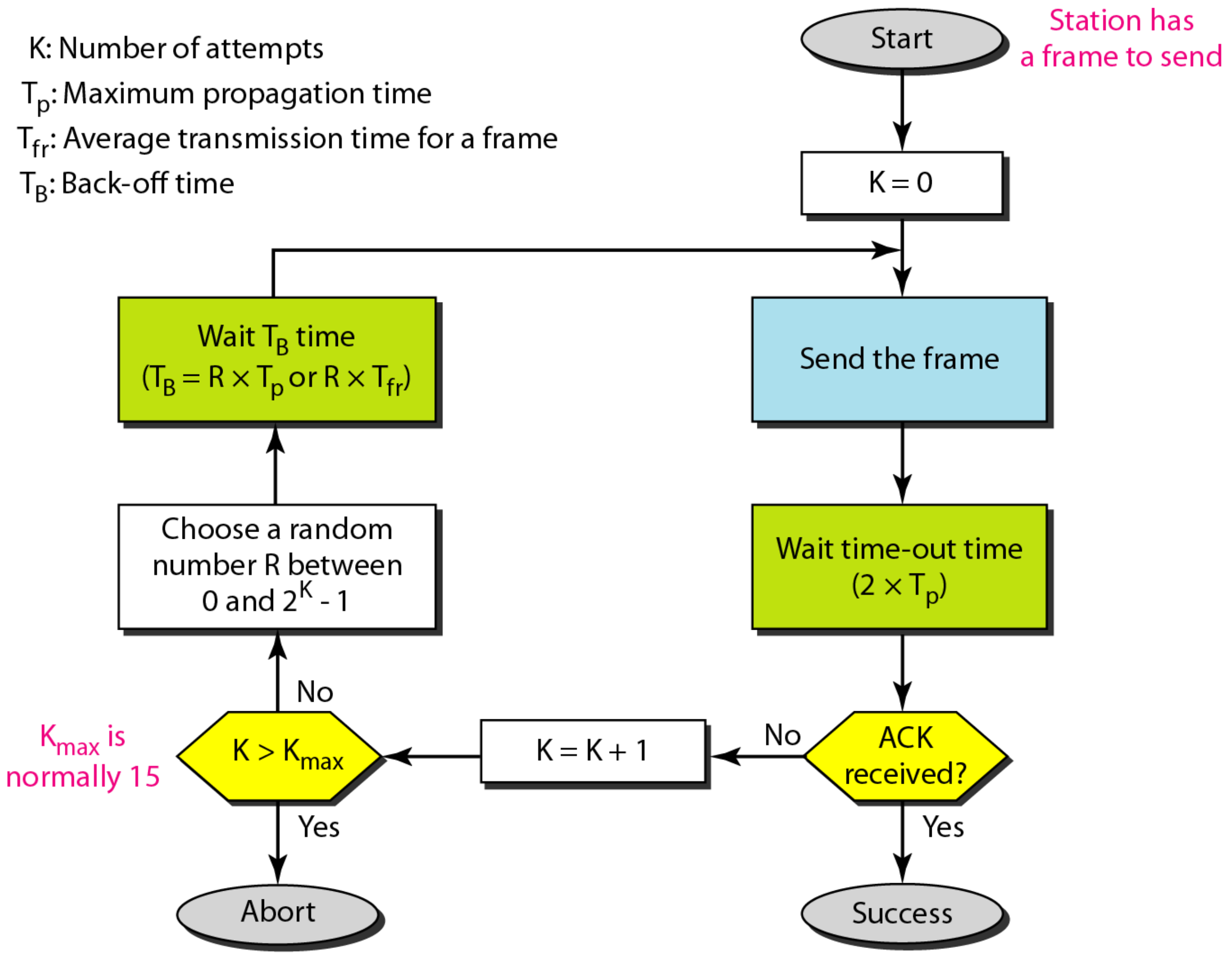
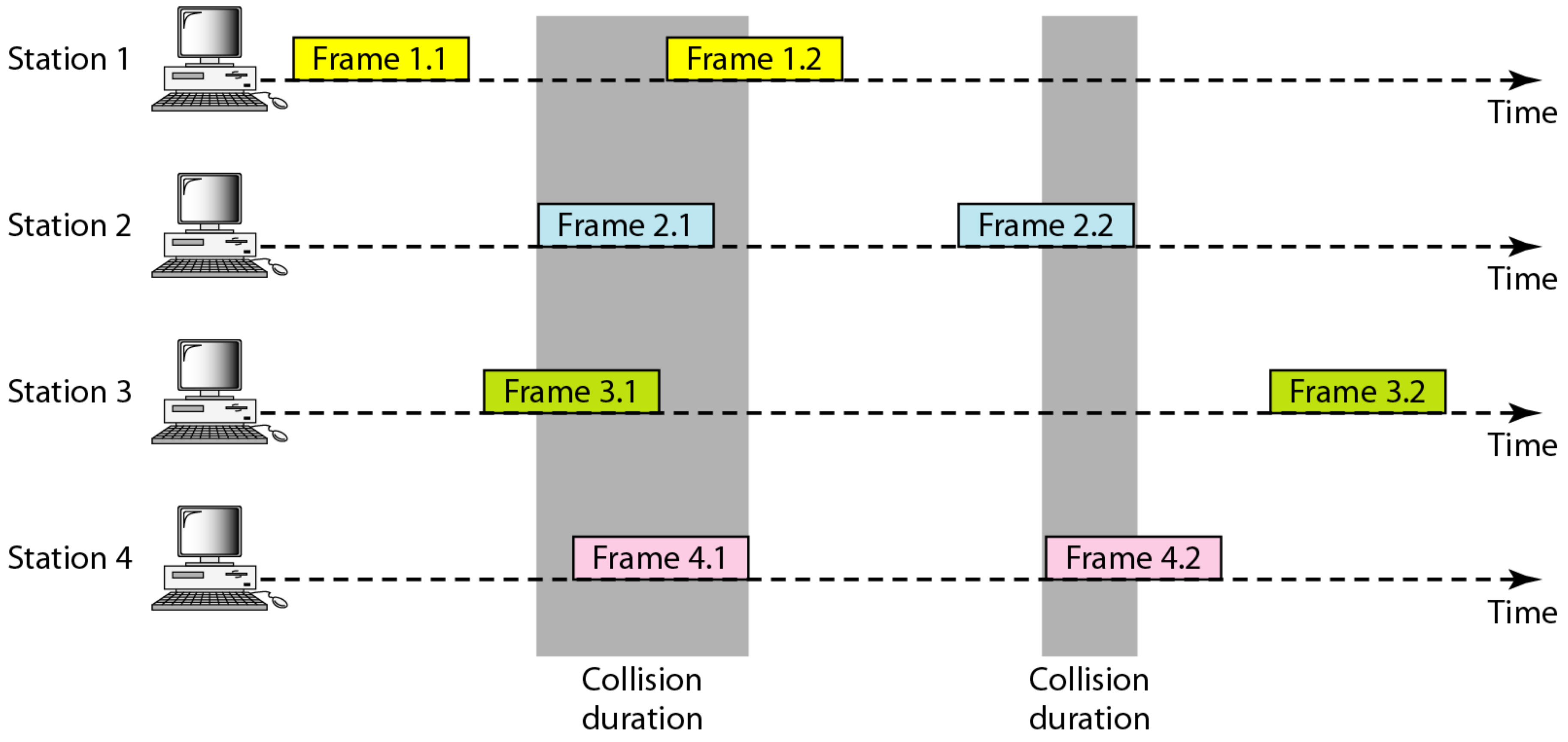


Figure Frames in a pure ALOHA network



Example

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

$$T_p = (600 \times 10^5) / (3 \times 10^8) = 2 \text{ ms.}$$

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 (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.

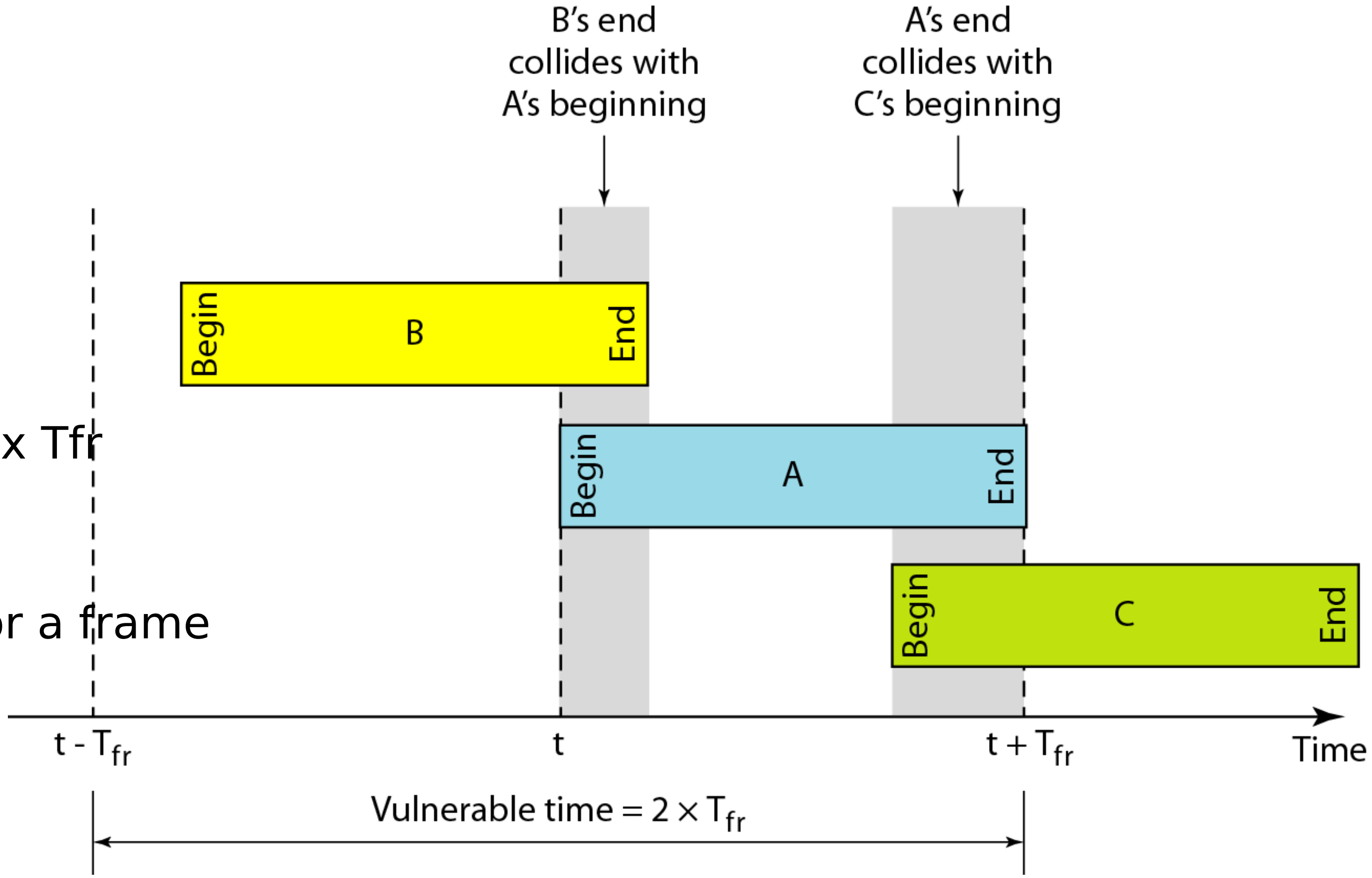
c. For K = 3, the range is {0, 1, 2, 3, 4, 5, 6, 7}. This means that T_B can be 0, 2, 4, . . . , 14 ms, based on the outcome of the random variable.

Figure Vulnerable time for pure ALOHA protocol

The vulnerable time, in which there is a possibility of collision

Pure ALOHA vulnerable time = 2 x Tfr

Tfr: Average transmission time for a frame



Example

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?

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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.

Efficiency-

Efficiency of Pure Aloha (η) = $G \times e^{-2G}$

G the average number of frames generated by the system during one frame transmission time.

Maximum Efficiency-

Maximum Efficiency of Pure Aloha (η) = 18.4%

Note

The throughput for pure ALOHA is

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

The maximum throughput

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

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.

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 (continued)

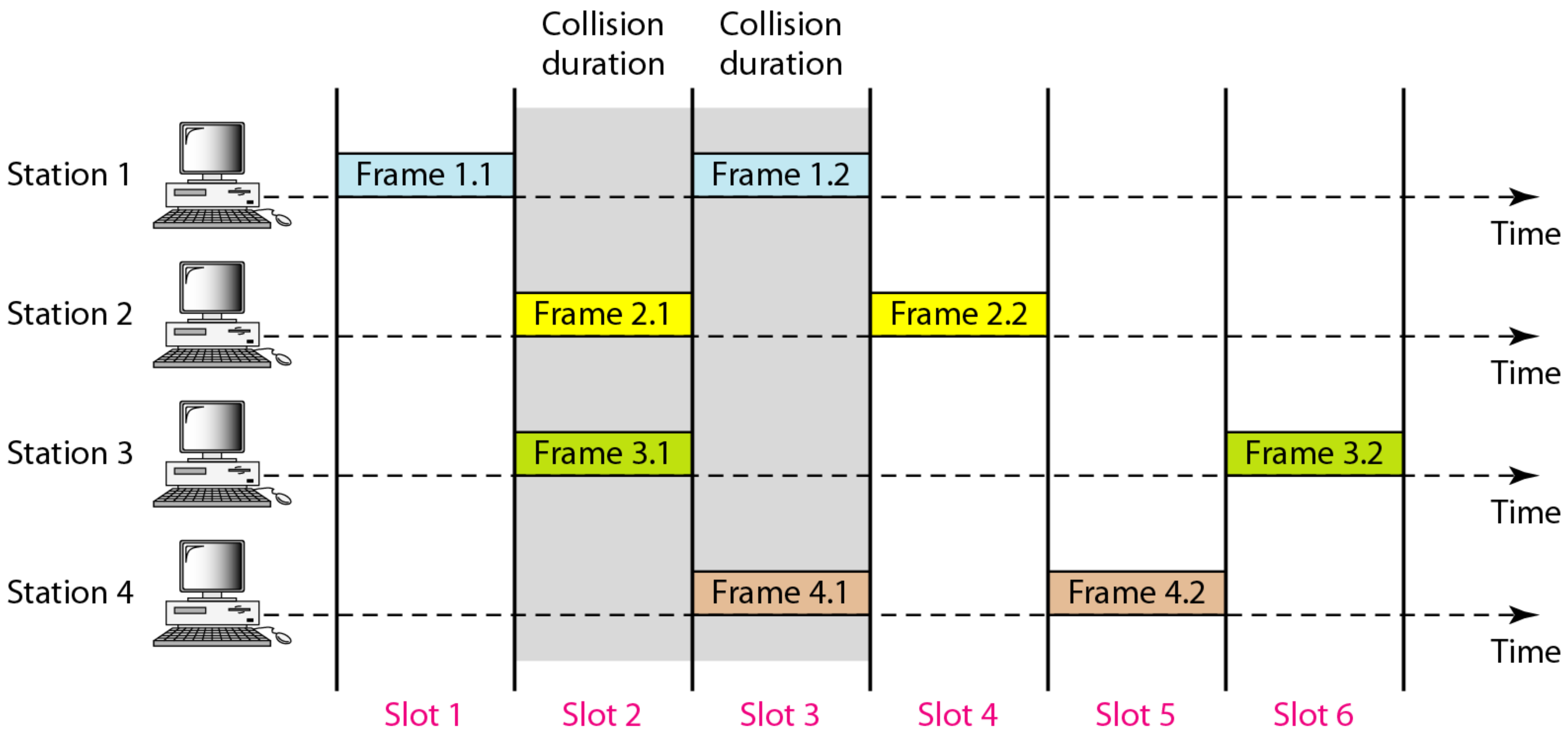
b. If the system creates 500 frames per second, this is (1/2) frame per millisecond. The load is (1/2). In this case $S = G \times e^{-2G}$ or $S = 0.184$ (18.4 percent). This means that the throughput is $500 \times 0.184 = 92$ and that only 92 frames out of 500 will probably survive. Note that this 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.

Slotted Aloha

- Slotted Aloha divides the time of shared channel into discrete intervals called as **time slots**.
- Any station can transmit its data in any time slot.
- The only condition is that station must start its transmission from the beginning of the time slot.
- If the beginning of the slot is missed, then station has to wait until the beginning of the next time slot.
- A collision may occur if two or more stations try to transmit data at the beginning of the same time slot.

Figure Frames in a slotted ALOHA network



Note

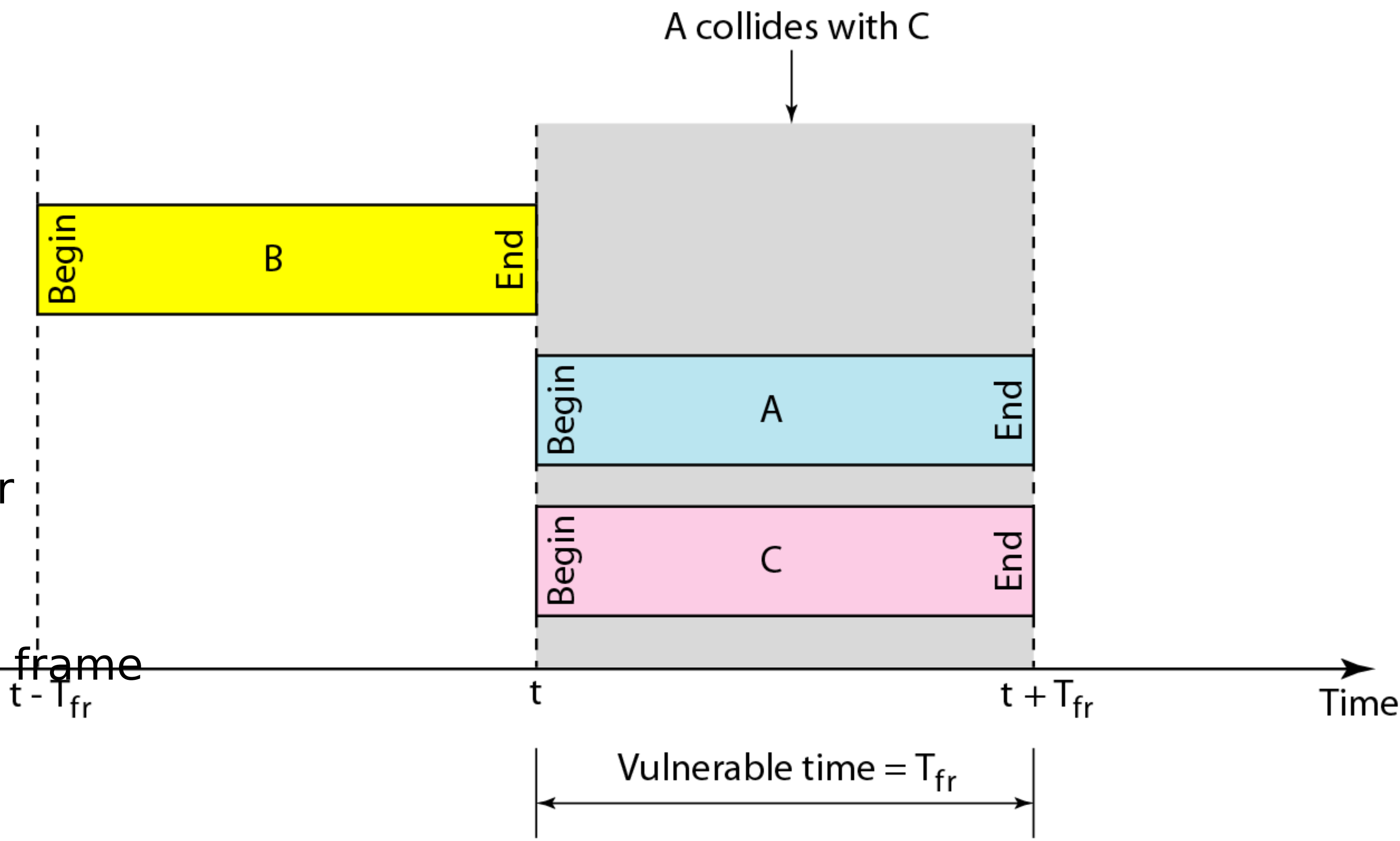
The throughput for slotted ALOHA is

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

The maximum throughput

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

Figure Vulnerable time for slotted ALOHA protocol



The vulnerable time, in which there is a possibility of collision

Slotted ALOHA vulnerable time = Tfr

Tfr: Average transmission time for a frame

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.

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 (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.

Problems

A group of N stations share 100 Kbps slotted ALOHA channel. Each station output a 500 bits frame on an average of 5000 ms even if previous one has not been sent. What is the required value of N?

CSMA

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."

Sensing the Carrier-

- Any station willing to transmit the data senses the carrier.
- If it finds the carrier free, it starts transmitting its data packet otherwise not.

How?

- Each station can sense the carrier only at its point of contact with the carrier.
- It is not possible for any station to sense the entire carrier.
- Thus, there is a huge possibility that a station might sense the carrier free even when it is actually not.

Figure Space/time model of the collision in CSMA

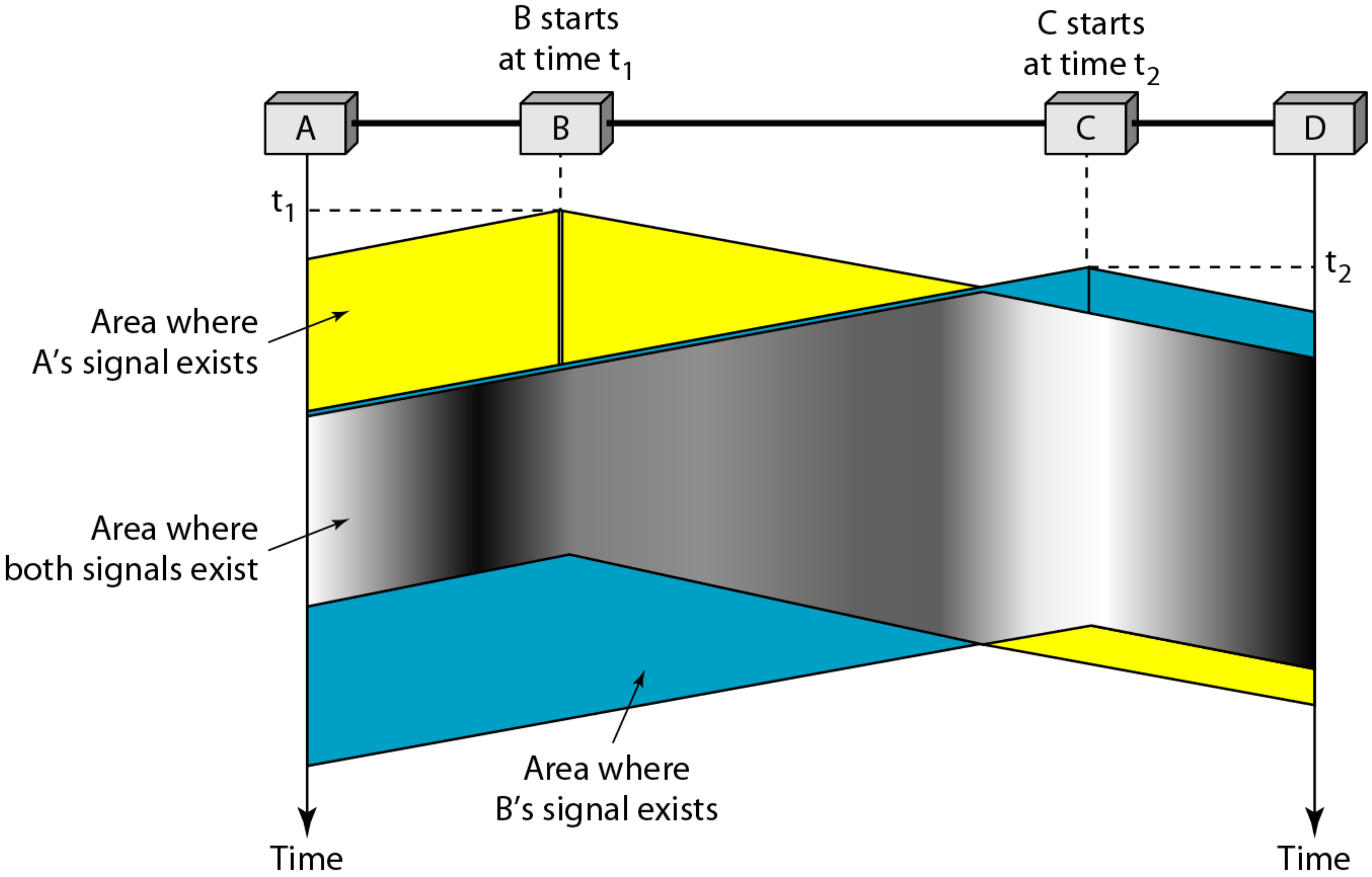


Figure Vulnerable time in CSMA

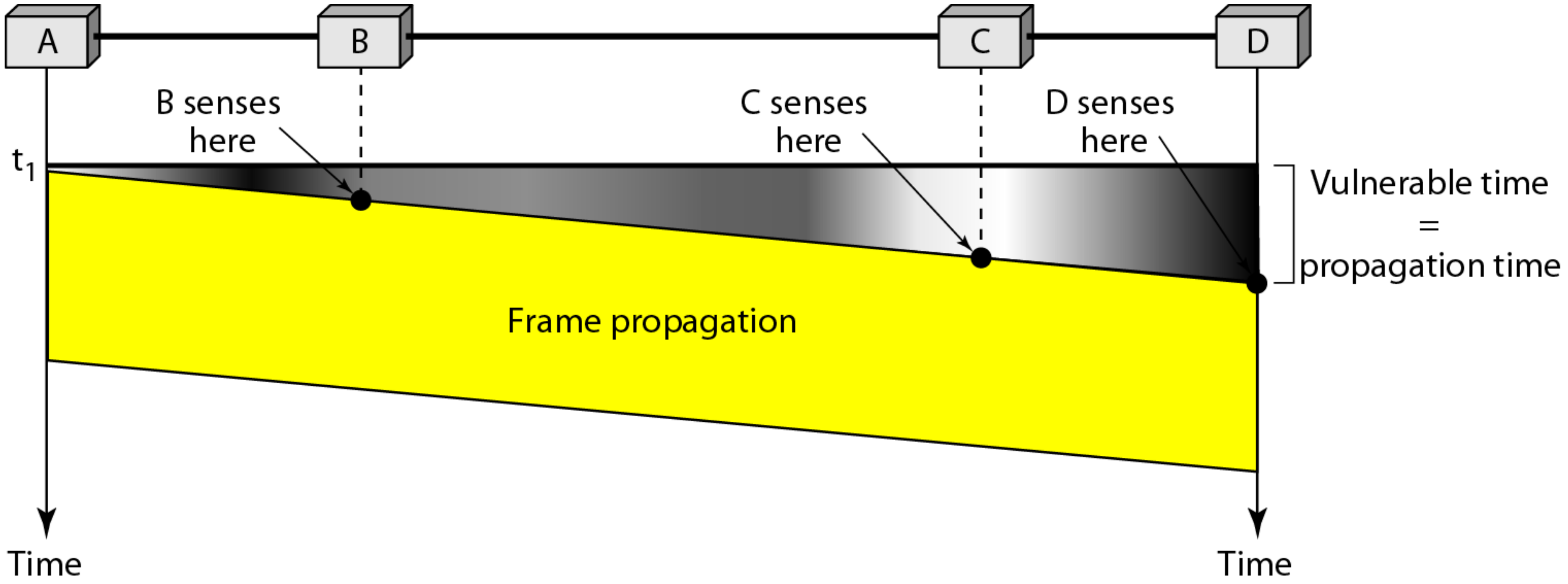


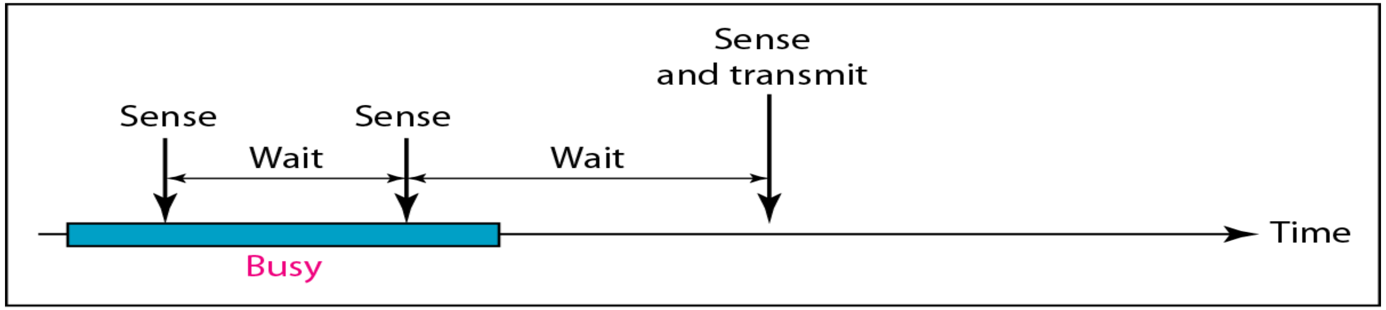
Figure Behavior of three persistence methods

What should a station do if the channel is busy?

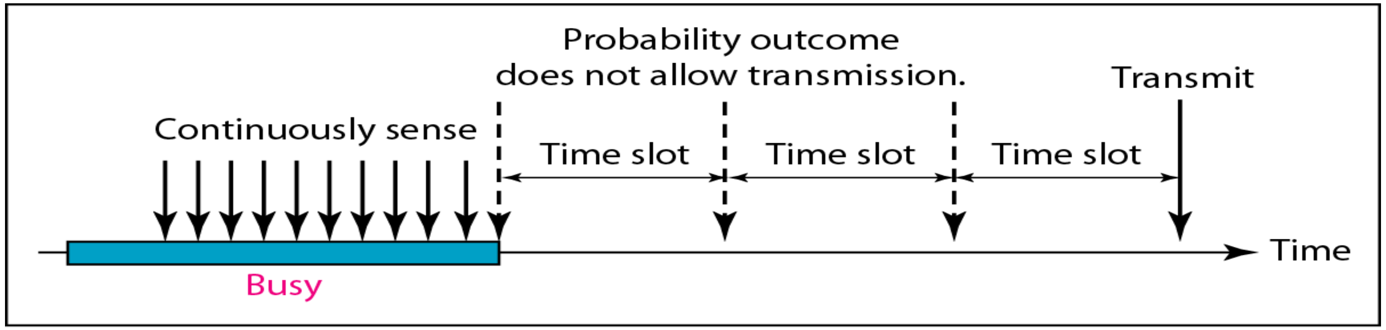
What should a station do if the channel is idle?

Three methods have been devised to answer these questions

a. 1-persistent



b. Nonpersistent



c. p-persistent

I-Persistent

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.

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.

this method reduces the efficiency of the network

p-Persistent

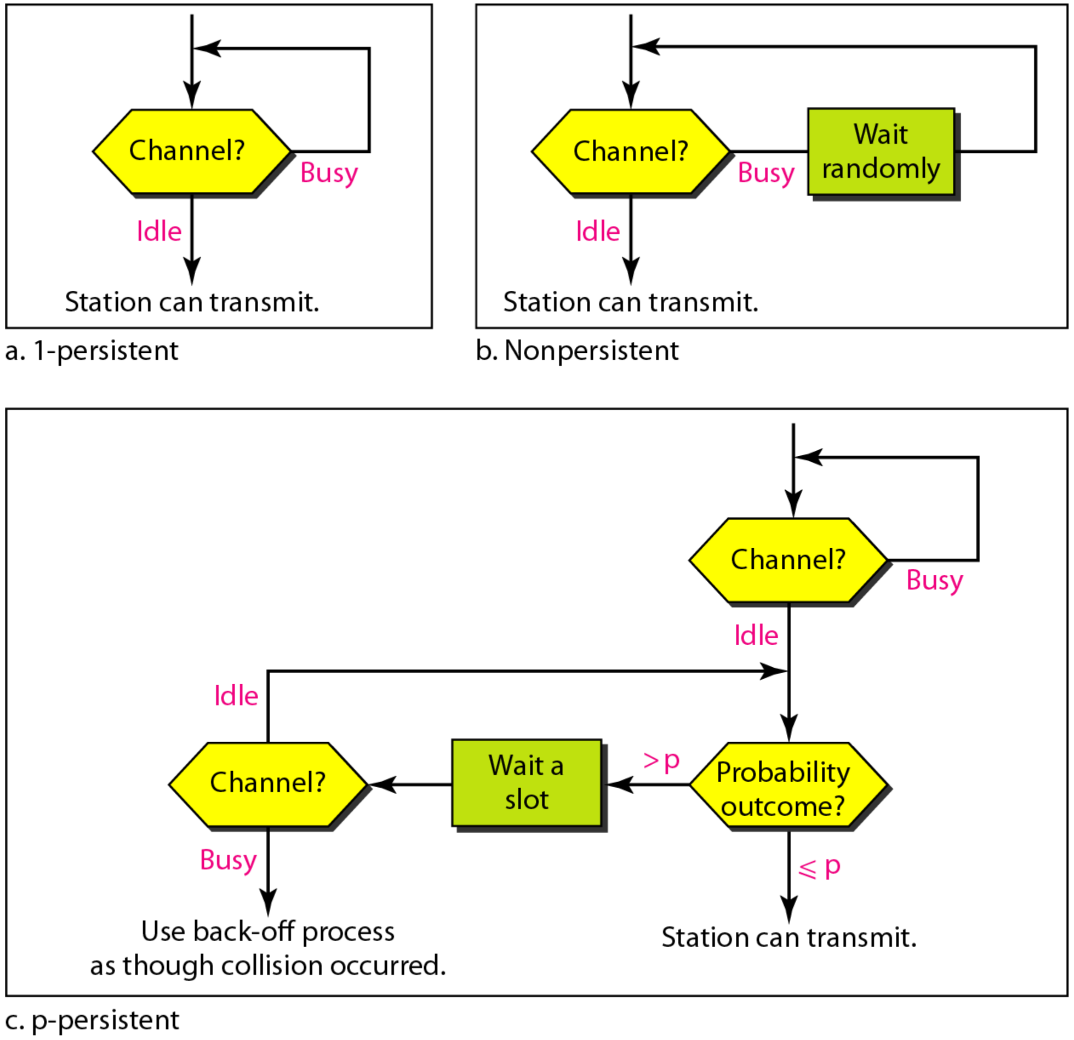
The p-persistent method is used if the channel has time slots with a slot duration equal to or greater than the maximum propagation time.

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 back off procedure.

Figure Flow diagram for three persistence methods



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

The CSMA method does not specify the procedure following a collision. Carrier sense multiple access with collision detection (CSMA/CD) augments the algorithm to handle the collision.

Detecting the Collision-

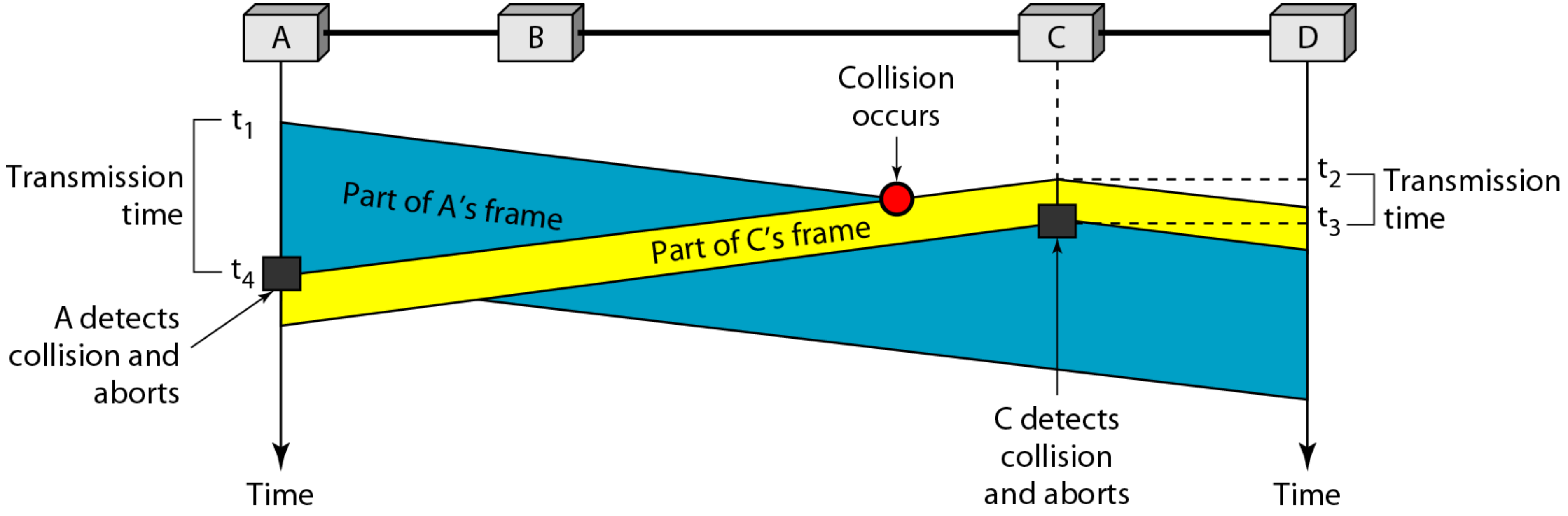
In CSMA / CD,

- It is the responsibility of the transmitting station to detect the collision.
- For detecting the collision, CSMA / CD implements the following condition.
- This condition is followed by each station-
- Transmission delay >= 2 x Propagation delay

According to this condition,

- Each station must transmit the data packet of size whose transmission delay is at least twice its propagation delay.
- If the size of data packet is smaller, then collision detection would not be possible.

Figure Collision and abortion in CSMA/CD



Example

A network using CSMA/CD has a bandwidth of 10 Mbps. If the maximum propagation time is 25.6 μs, what is the minimum size of the frame?

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A network using CSMA/CD has a bandwidth of 10 Mbps. If the maximum propagation time 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.

Problem

A network with CSMA/CD protocol in the MAC layer is running at 1 Gbps over a 1 km cable with no repeaters. The signal speed in the cable is 2 x 10^8 m/sec. The minimum frame size for this network should be

Two cases are possible

Case-01:

If no collided signal comes back during the transmission,

- It indicates that no collision has occurred.
- The data packet is transmitted successfully.

Case-02:

If the collided signal comes back during the transmission,

- It indicates that the collision has occurred.
- The data packet is not transmitted successfully.
- Releasing Jamming signal

Releasing Jam Signal

- Jam signal is a 48 bit signal.
- It is released by the transmitting stations as soon as they detect a collision.
- It alerts the other stations not to transmit their data immediately after the collision.
- Otherwise, there is a possibility of collision again with the same data packet.

Waiting For Back Off Time

- After the collision, the transmitting station waits for some random amount of time called as **back off time**.
- After back off time, it tries transmitting the data packet again.
- If again the collision occurs, then station again waits for some random back off time and then tries again.
- The station keeps trying until the back off time reaches its limit.
- After the limit is reached, station aborts the transmission.

Figure Flow diagram for the CSMA/CD

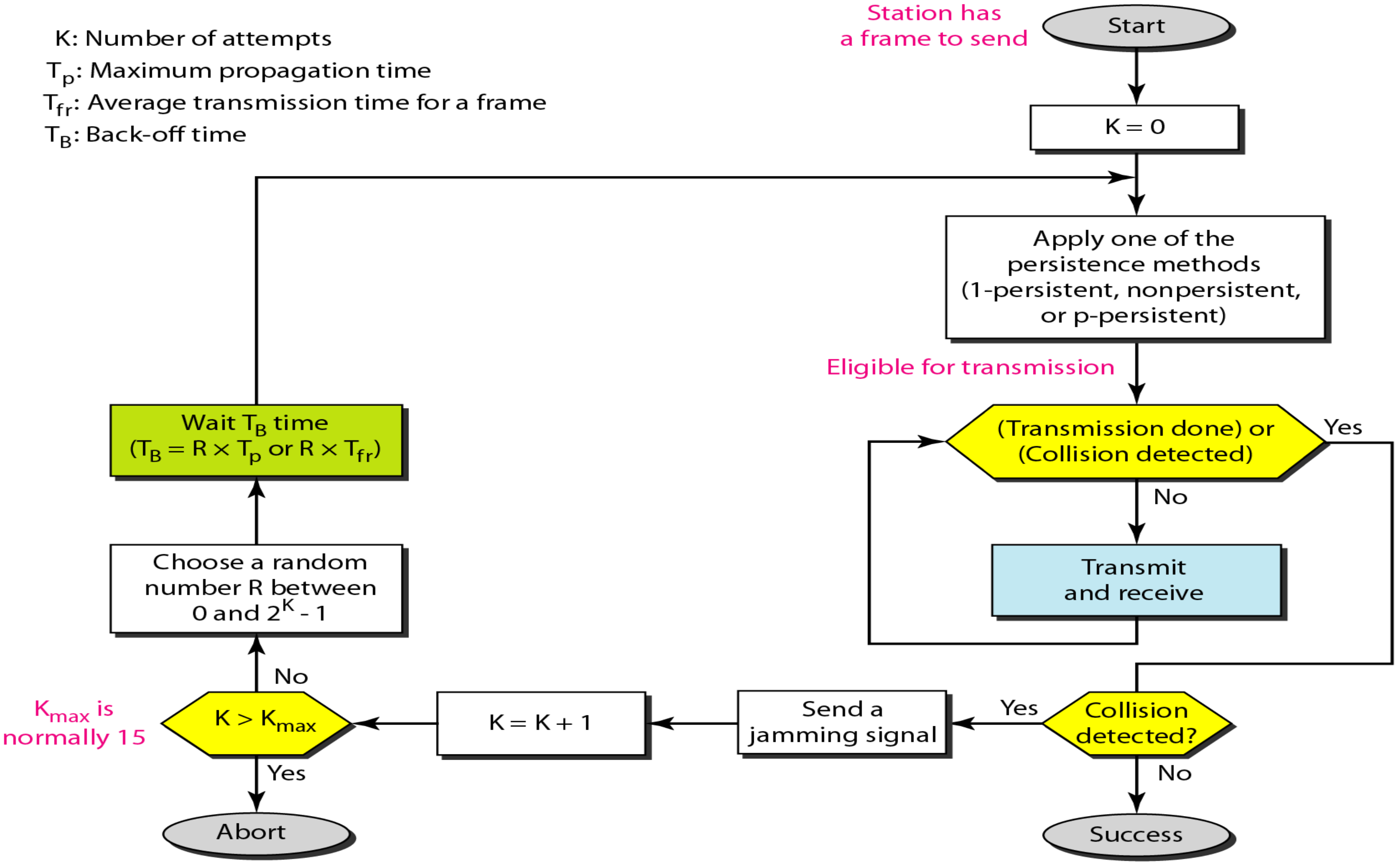
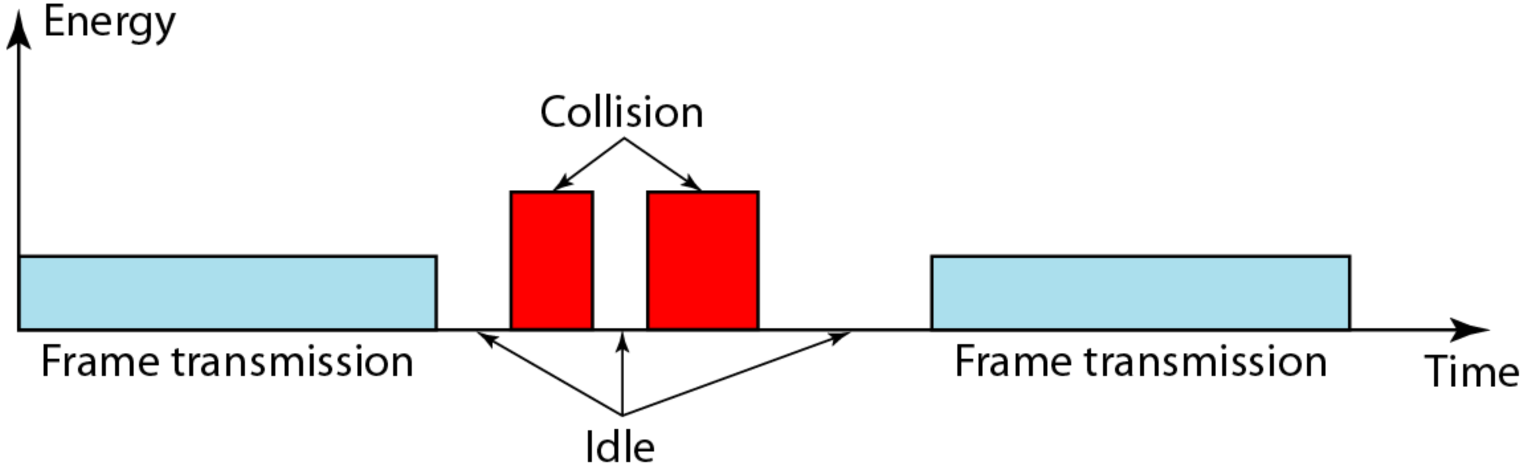


Figure Energy level during transmission, idleness, or collision

At the zero level, the channel is idle.

At the normal level, a station has 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.



Carrier sense multiple access with collision avoidance (CSMA/CA)

In wired networks, if a collision has occurred then the energy of the received signal almost doubles, and the station can sense the possibility of collision.

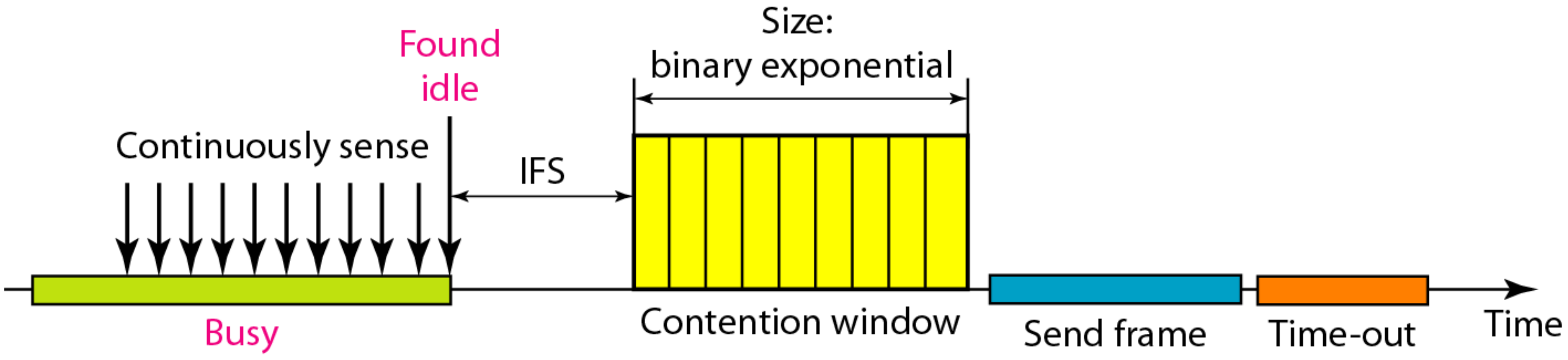
In the case of wireless networks, most of the energy is used for transmission, and the energy of the received signal increases by only 5-10% if a collision occurs. It can't be used by the station to sense collision.

Therefore **CSMA/CA has been specially designed for wireless networks**.

Figure Timing in CSMA/CA

Collisions are avoided through the use of CSMA/CA's three strategies:

1. the interframe space
2. the contention window
3. acknowledgments



Note

In CSMA/CA, the IFS can also be used to define the priority of a station or a frame.

Figure Flow diagram for CSMA/CA