CAP275: Data Communication and Networking
Data Link Layer-Multiple Access Control

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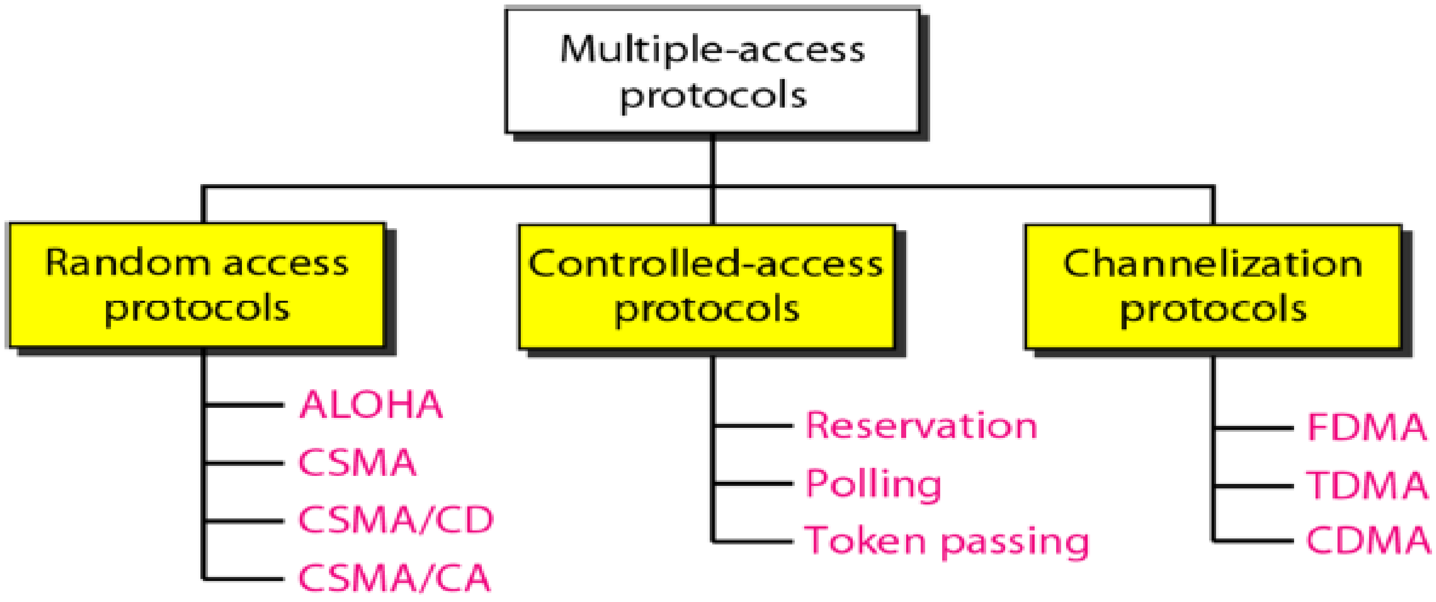
Multiple Access Control

- These protocols are called Medium or Multiple Access Control (MAC) Protocols belong to a sublayer of the data link layer called MAC (Medium Access Control)
- 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.



RANDOM ACCESS

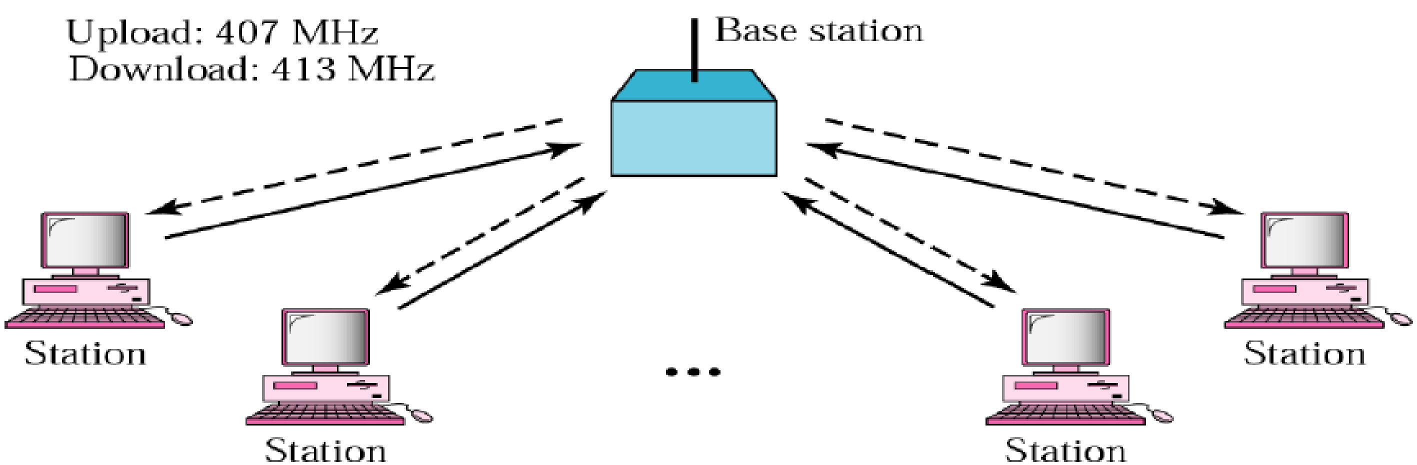
- In random access or contention methods, no station is superior to another station and none is assigned the control over another.
- No station permits, or does not permit, another station to send. At each instance, a station that has data to send uses a procedure defined by the protocol to make a decision on whether or not to send.
- If more than one station tries to send, there is an access conflict i.e. COLLISION, the frames will be either destroyed or modified.
- To avoid access conflict, each station follows a procedure.
  - When can the station access the medium ?
  - What can the station do if the medium is busy ?
  - How can the station determine the success or failure of the transmission?
  - What can the station do if there is an access conflict ?

Random Access Control Protocols

- **ALOHA**
- **Carrier Sense Multiple Access (CSMA)**
  - **Carrier Sense Multiple Access with Collision Detection (CSMA/CD)**
  - **Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)**

ALOHA

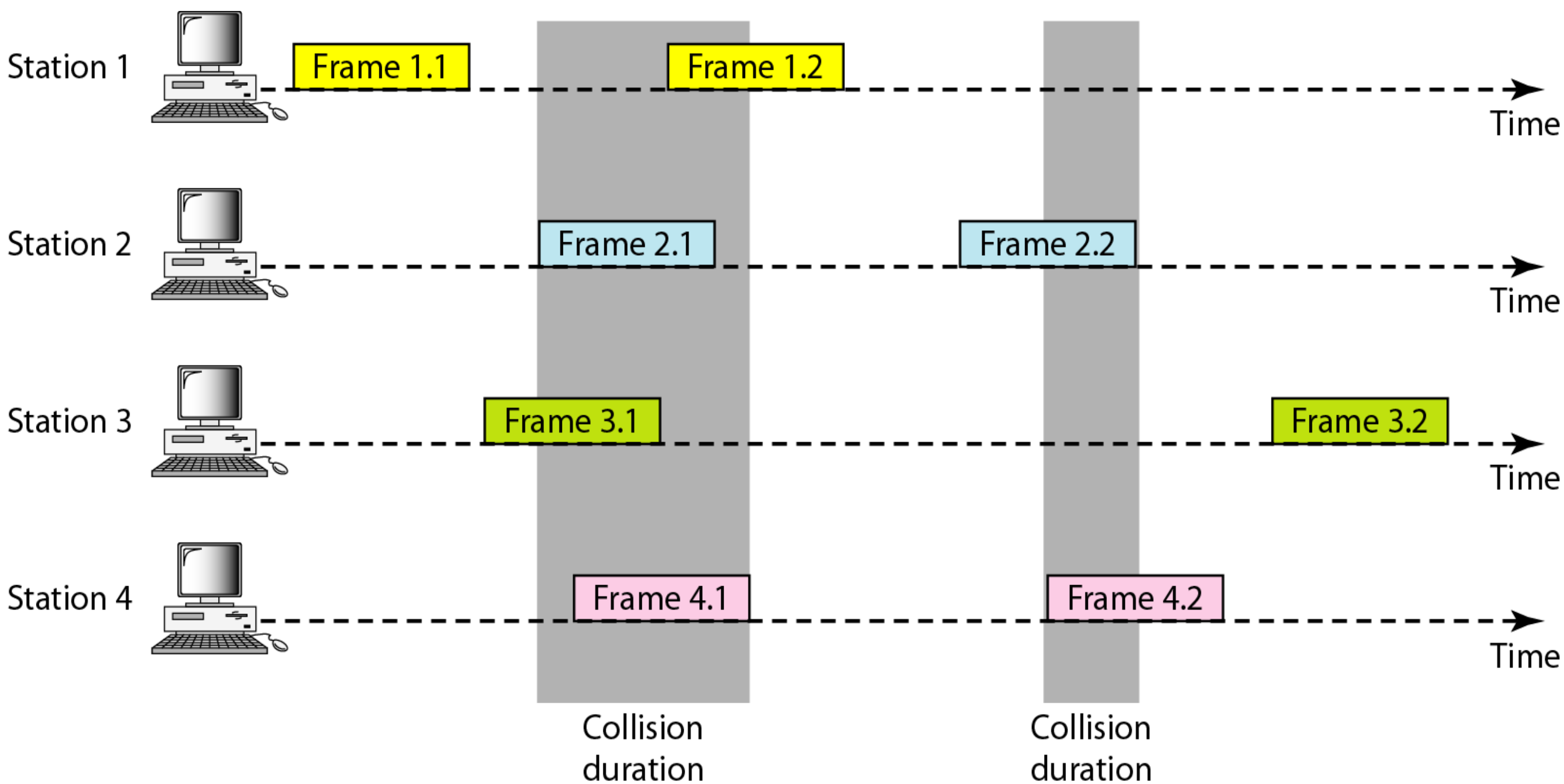
- A very interesting protocol known as ALOHA, which used a very simple procedure called multiple access (MA), the earliest random-access method, was developed at the Univ. of Hawaii in the early 1970s.
  - Base station is central controller
  - Base station acts as a hop
  - Potential collisions, all incoming data is @ 407 MHz



- The original ALOHA protocol is a simple, but elegant protocol. The idea is that each station sends a frame whenever it has a frame to send. Figure shows an example of frame collisions
- ALOHA was designed for a radio (wireless) LAN, but it can be used on any shared medium.
- It is obvious that there are potential collisions in this arrangement.
- The medium is shared between the stations. When a station sends data, another station may attempt to do so at the same time.
- The data from the two stations collide and become garbled.
- The ALOHA is categorized into two:
  - Pure ALOHA Protocol
  - Slotted ALOHA Protocol

Pure ALOHA Protocol

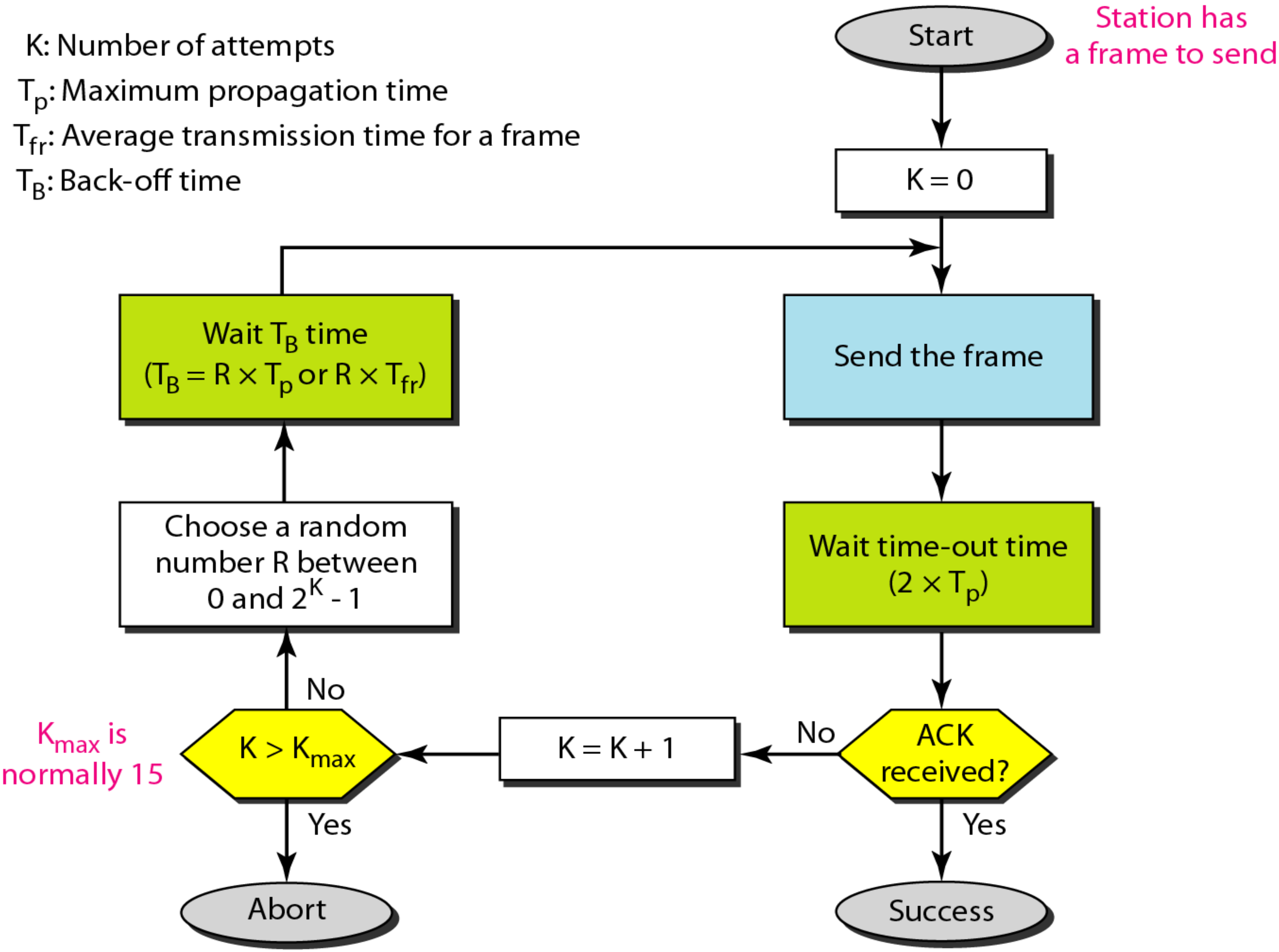
- In Pure ALOHA. Some of these frames collide because multiple frames are in contention for the shared channel.
  1. Each station sends a frame whenever is has a frame to send
  2. One channel to share, possibility of collision between frames from different stations



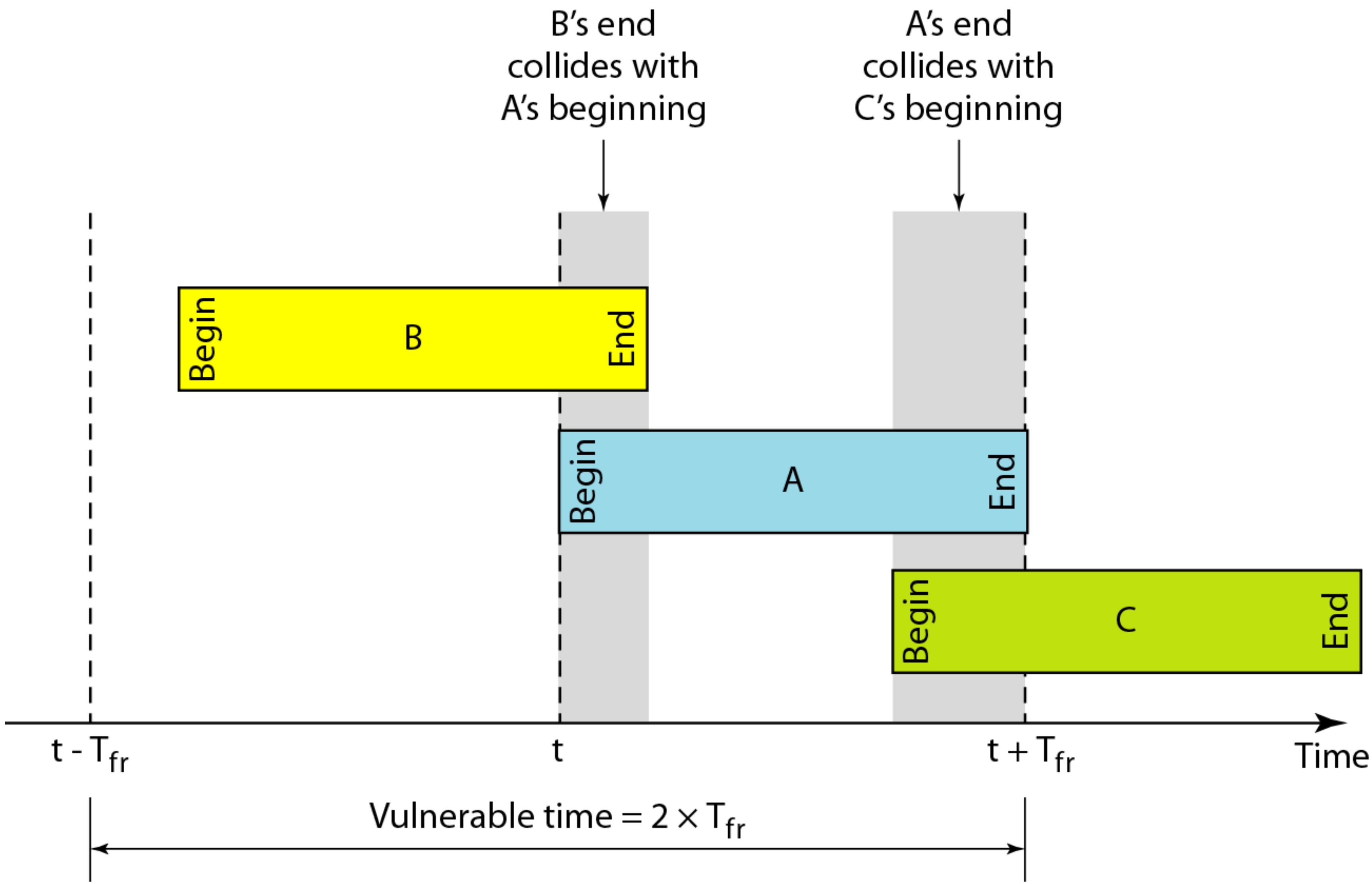
ALOHA Protocol Rule

- After sending the frame, the station waits for an acknowledgment. If it does not receive an acknowledgement during the 2 times the maximum propagation delay between the two widely separated stations ($2 \times T_P$), it assumes that the frame is lost; it tries sending again after a random amount of time ($T_B = R \times T_P$, or $R \times T_{fr}$).
  - T_p (Maximum propagation time)= distance / propagation speed
  - T_B (Back off time) : common formula is binary exponential back-off
  - R is random number chosen between 0 to 2k - 1
  - K is the number of attempted unsuccessful transmissions
  - T_{fr} (the average time required to send out a frame)

Procedure for pure ALOHA protocol

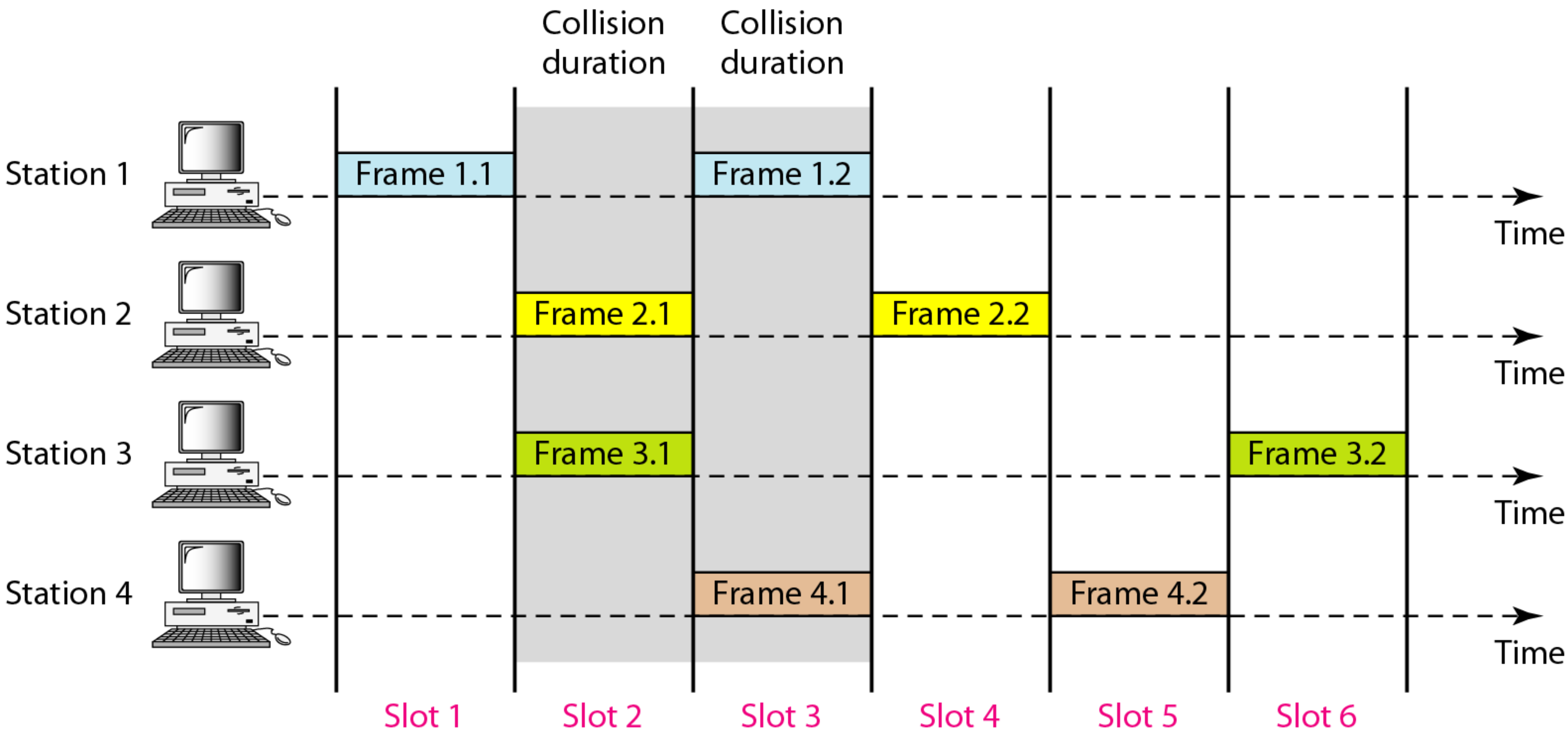


Vulnerable time for pure ALOHA protocol



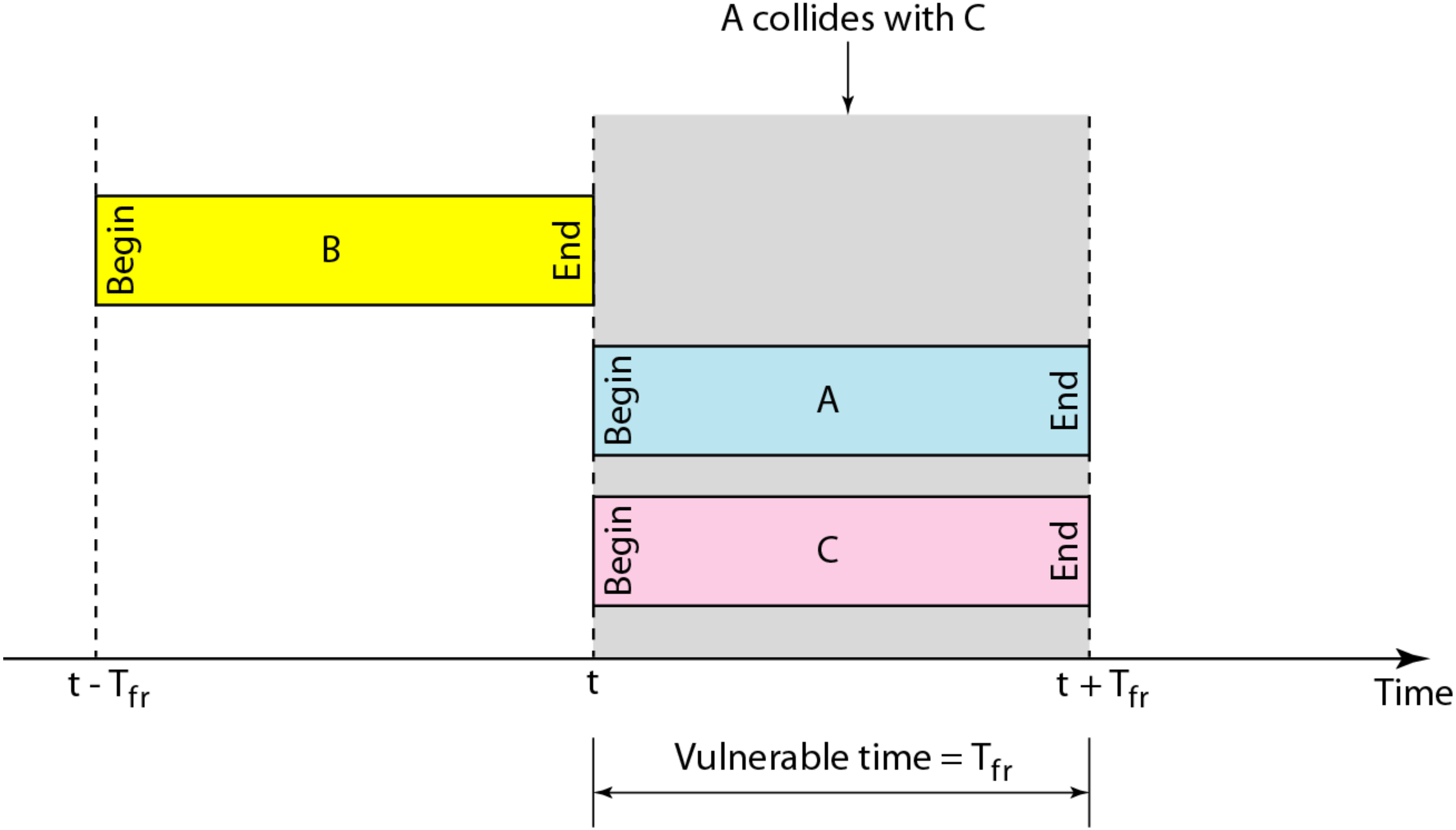
Slotted ALOHA Protocol

- In slotted ALOHA the time is divided into slots of T_{fr} and force the station to send only at the beginning of the time slot.



Vulnerable time for slotted ALOHA protocol

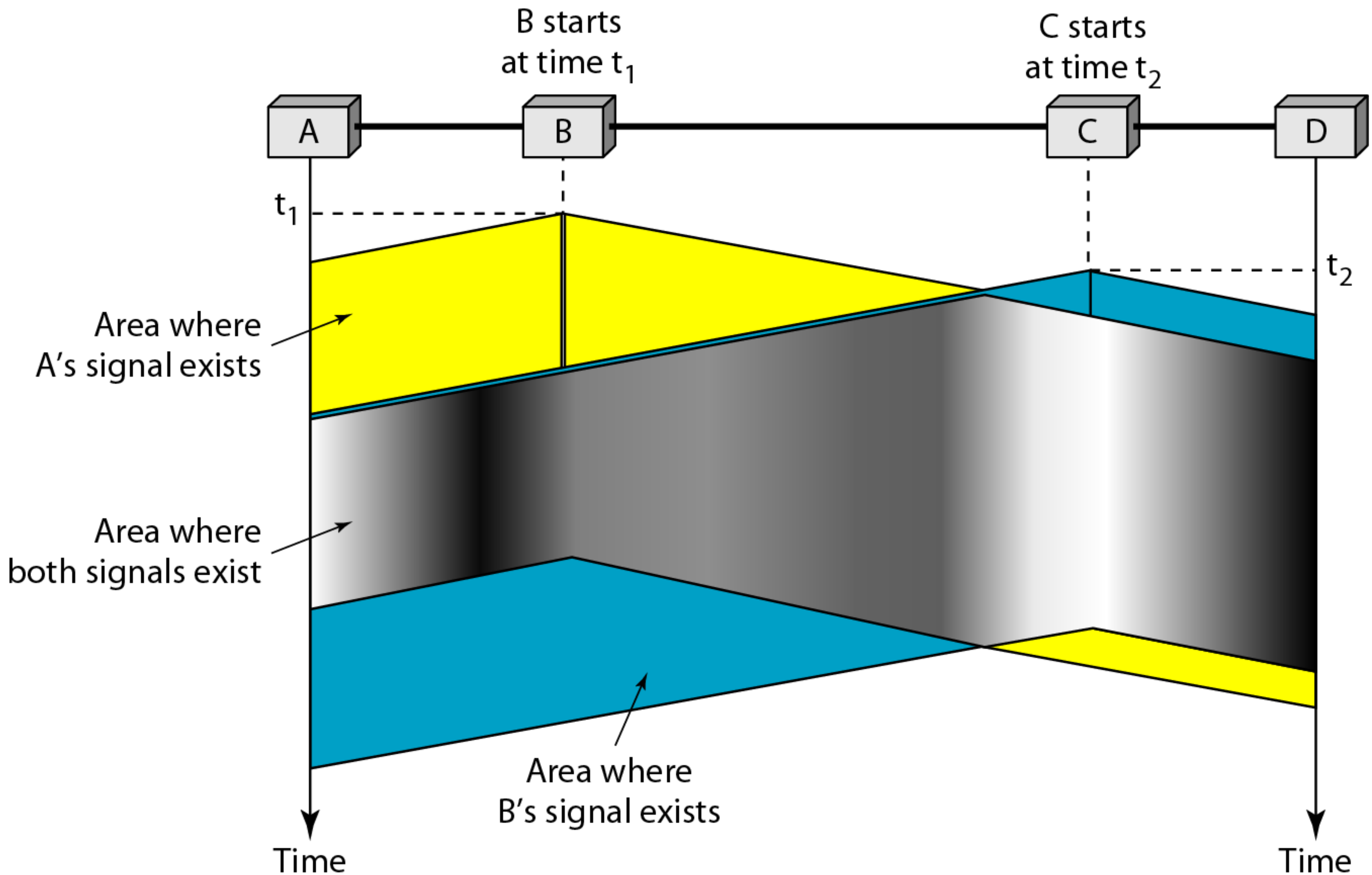
Slotted ALOHA vulnerable time = T_{fr}



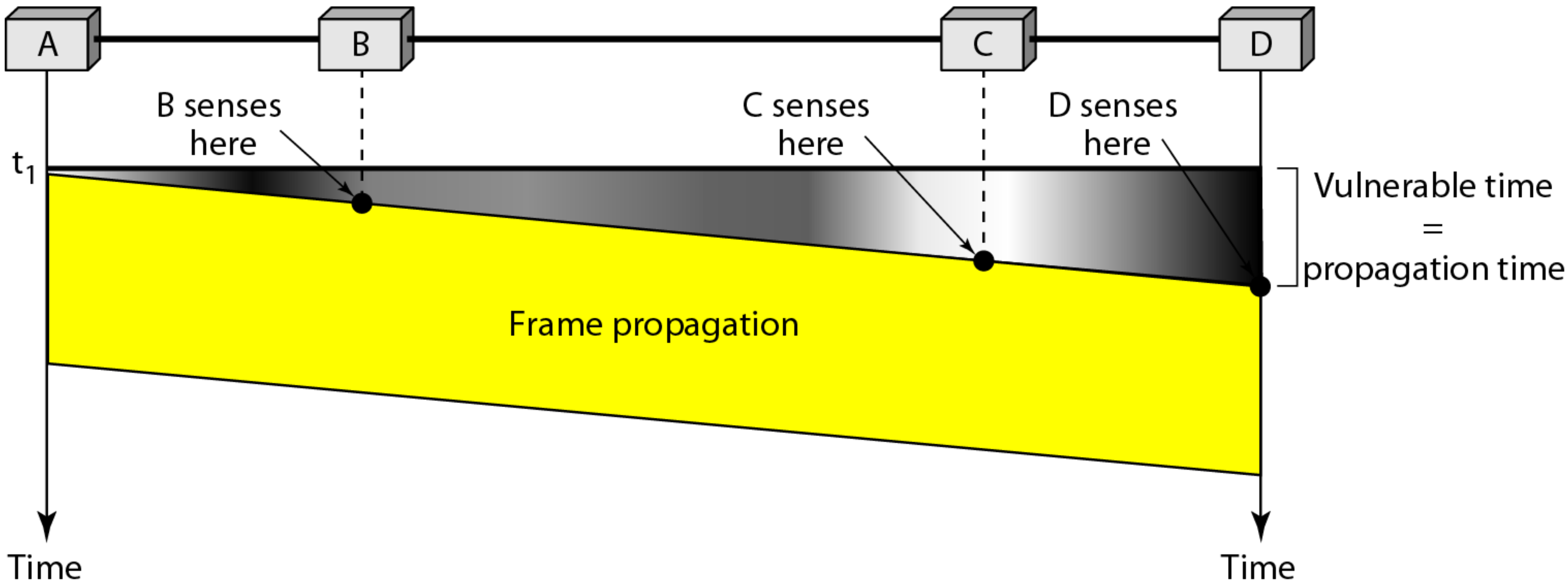
Carrier Sense Multiple Access (CSMA)

- 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.
- CSMA requires that each station first listen to the medium (or check the state of the medium) before sending. it is based on the principle "sense before transmit“.
- CSMA can reduce the possibility of collision, but it cannot eliminate it.
- The possibility of collision still exists because of propagation delay; a station may sense the medium and find it idle, only because the first bit sent by another station has not yet been received.

Space/time model of the collision in CSMA



Vulnerable time in CSMA



Types of CSMA methods

- Different CSMA methods that determine:
  - What a station should do when the medium is idle?
  - What a station should do when the medium is busy?
- Three persistence strategies have been devised to answer these questions:
  - **1-persistent method:** after the station finds the line idle, it sends its frame immediately (with probability 1)
  - **Non-persistent 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.
  - ***p*-persistent method:** After the station finds the line idle, with probability p, the station sends its frames with probability q=1-p, the station waits for the beginning of the next time slot and checks the line again.

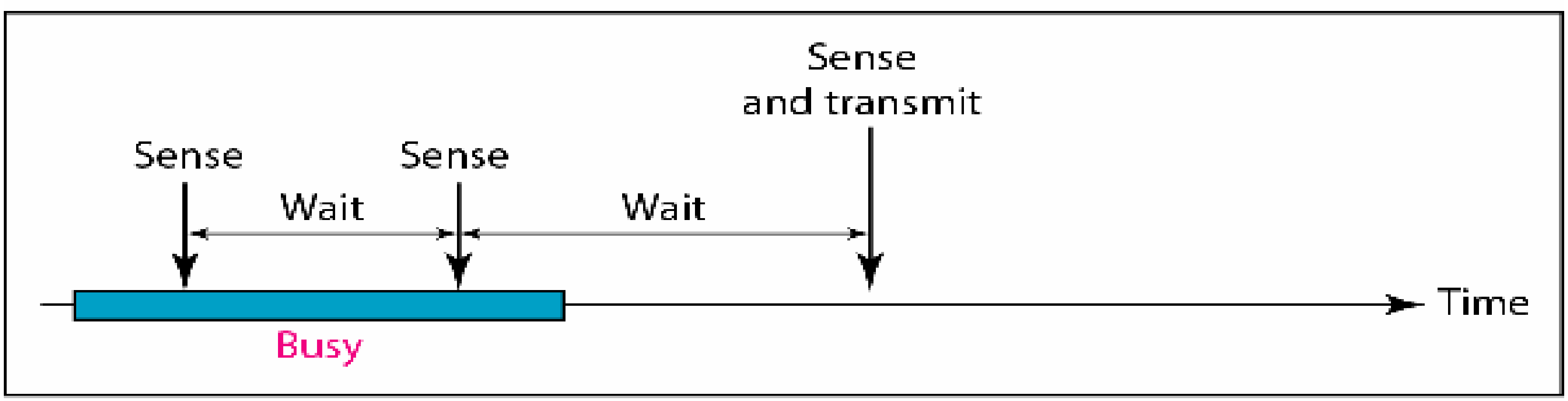
1-Persistent Method

- To avoid idle channel time, 1-persistent protocol used. Station wishing to transmit listens to the medium:
  - If medium idle, transmit immediately;
  - If medium busy, continuously listen until medium becomes idle; then transmit immediately with probability 1
- Performance
  - 1-persistent stations are selfish
  - If two or more stations becomes ready at the same time, collision guaranteed

a. 1-persistent

Non-Persistent Method

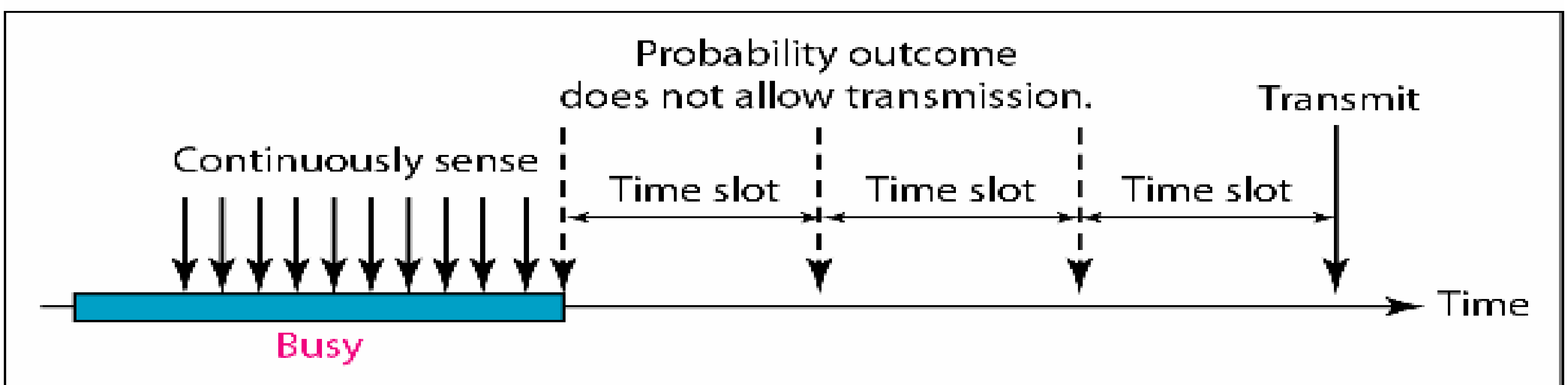
- A station with frames to be sent, should sense the medium
  - If medium is idle, **transmit**; otherwise, go to 2
  - If medium is busy, (**backoff**) wait a ***random* amount of time** and repeat **1**
- Non-persistent Stations are **deferential (respect others)**
- Performance:
  - Random delays reduces probability of collisions because two stations with data to be transmitted will wait for different amount of times.
  - Bandwidth is **wasted** if waiting time (backoff) is large because medium will remain idle following end of transmission even if one or more stations have frames to send



b. Nonpersistent

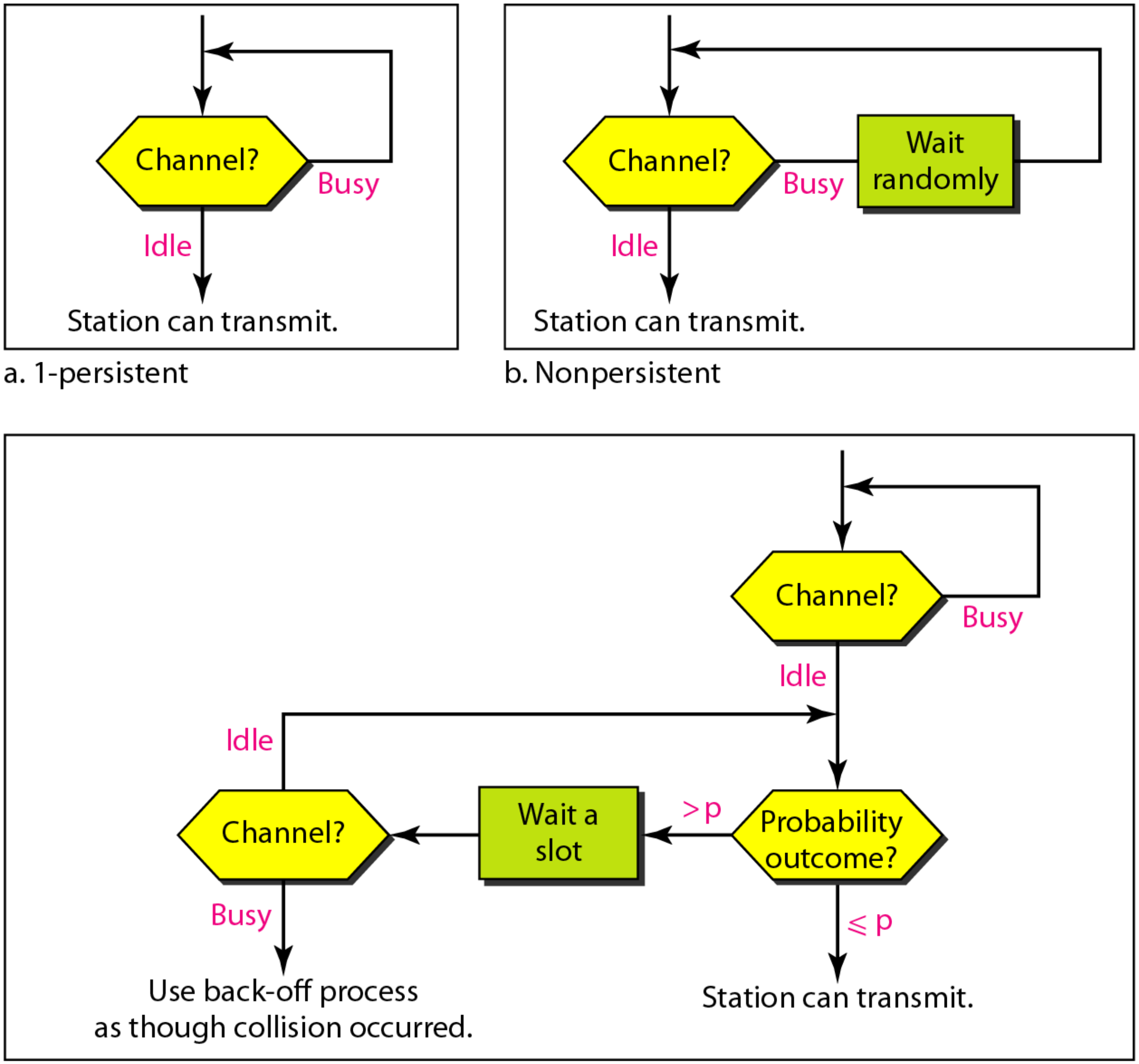
p-Persistent Method

- Time is divided to slots where each Time unit (slot) typically equals **maximum propagation delay**
- Station wishing to transmit listens to the medium:
  - If medium idle,
    - transmit with probability (**p**), OR
    - wait **one time unit (slot)** with probability (**1 – p**), then repeat 1.
  - If medium busy, **continuously listen until idle** and repeat step **1**
- Performance
  - Reduces the possibility of collisions like **nonpersistent**
  - Reduces channel idle time like **1-persistent**



c. p-persistent

Flow diagram for three persistence methods



a. 1-persistent

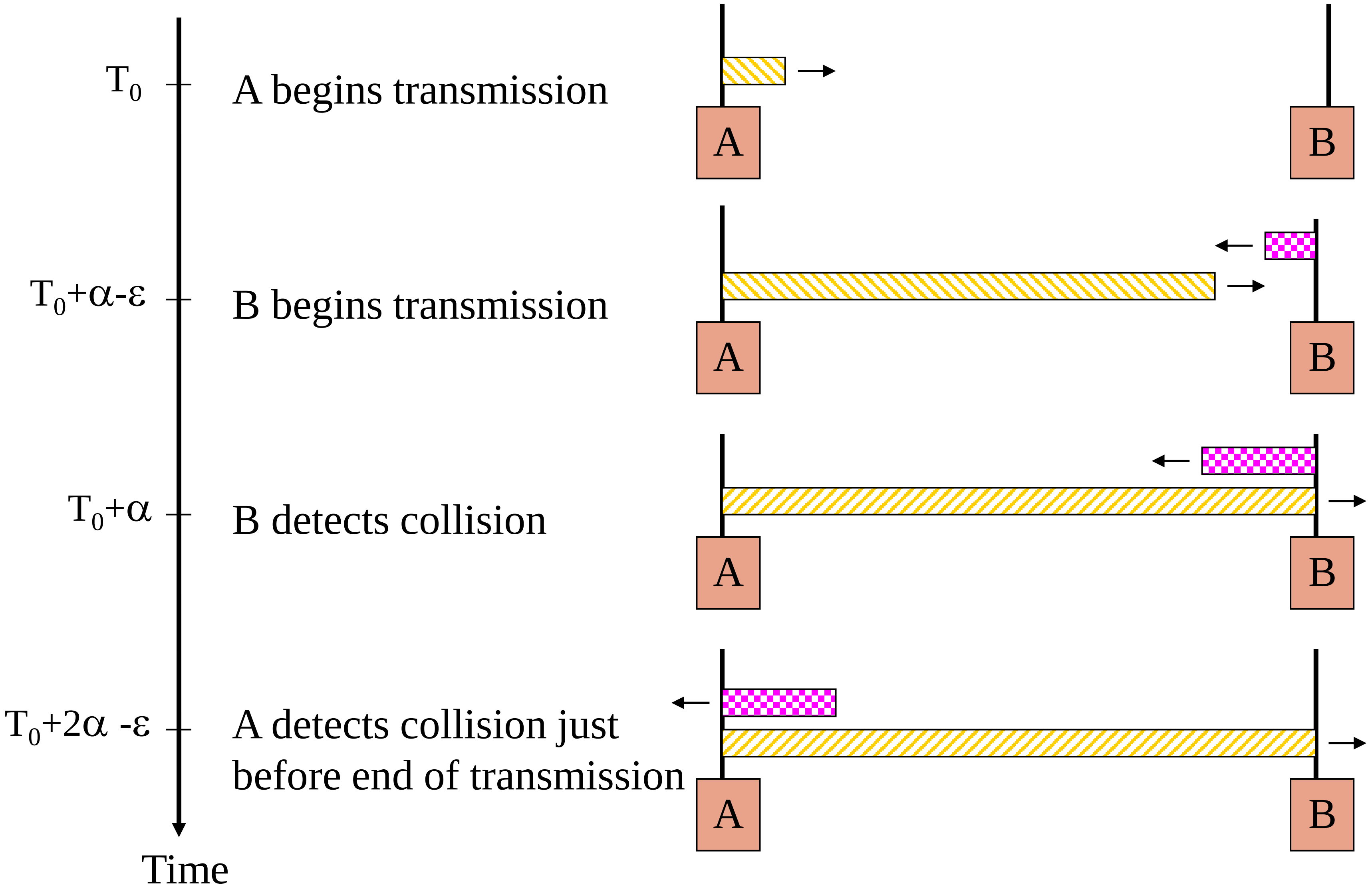
b. Nonpersistent

c. p-persistent

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

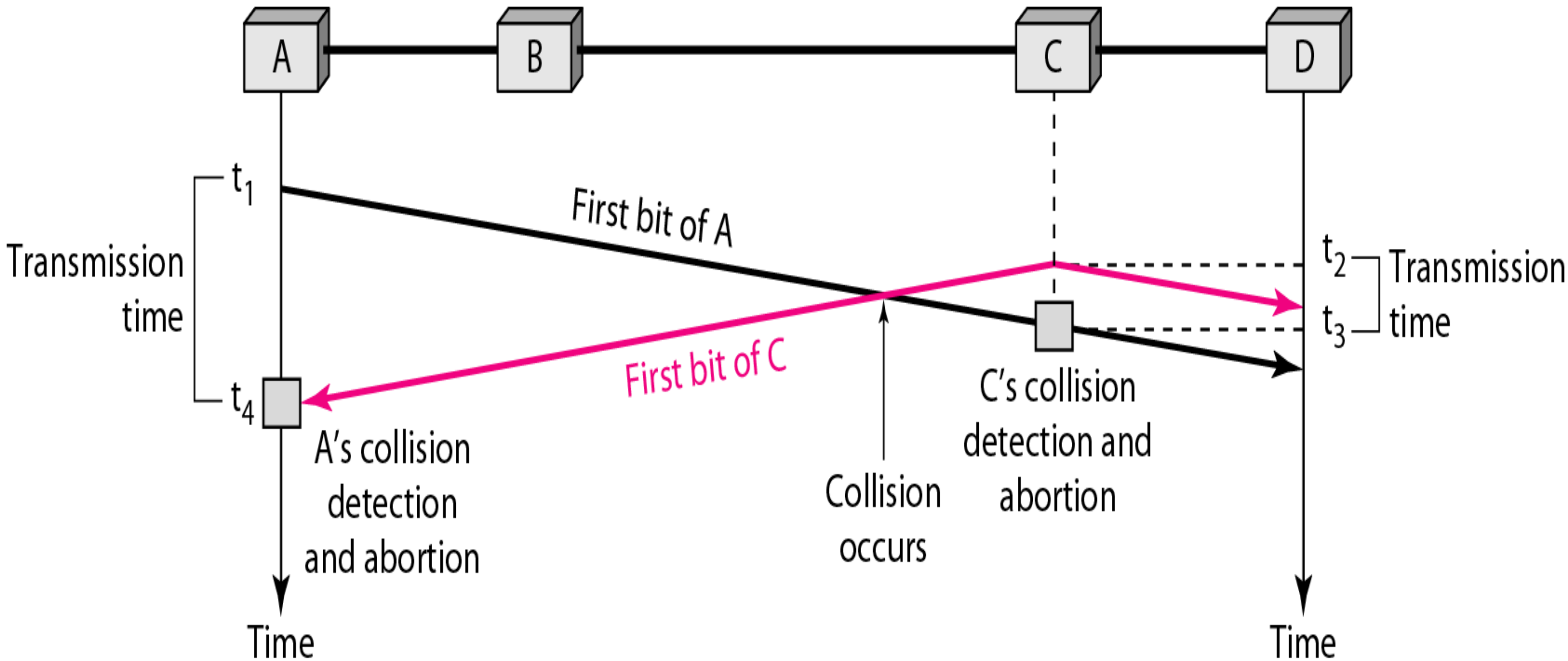
- In this method, a station monitors the medium after it sends a frame to see if the transmission was successful. If so, the station is finished. If, however, there is a collision, the frame is sent again.
- In CSMA/CD, if 2 terminals begin sending packet at the same time, each will transmit its complete packet (although collision is taking place). Therefore wasting medium for an entire packet time.
- CSMA/CD performs the following steps

Step 1:	If the medium is idle, transmit
Step 2:	If the medium is busy, continue to listen until the channel is idle then transmit
Step 3:	If a collision is detected during transmission, cease transmitting
Step 4:	Wait a random amount of time and repeats the same algorithm

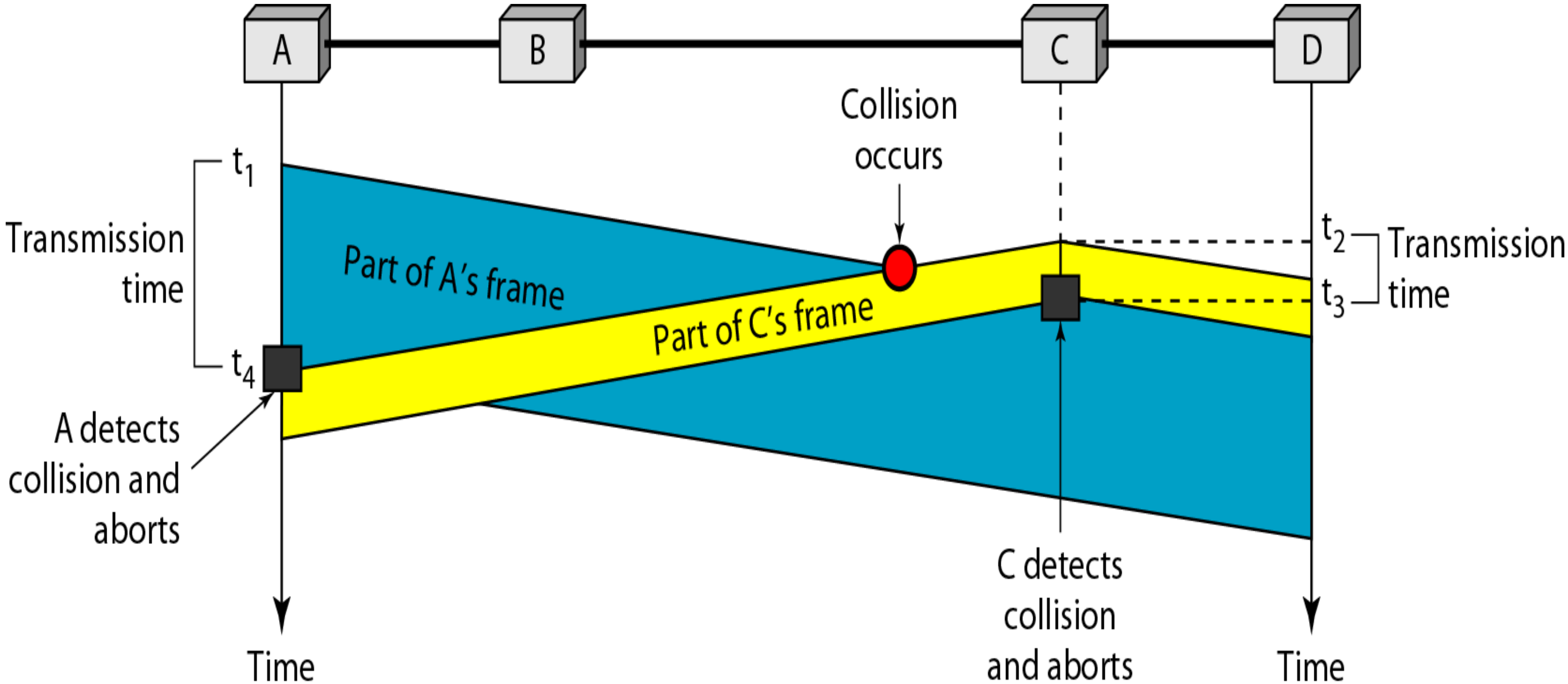


(α is the propagation time)

Collision of the first bit in CSMA/CD

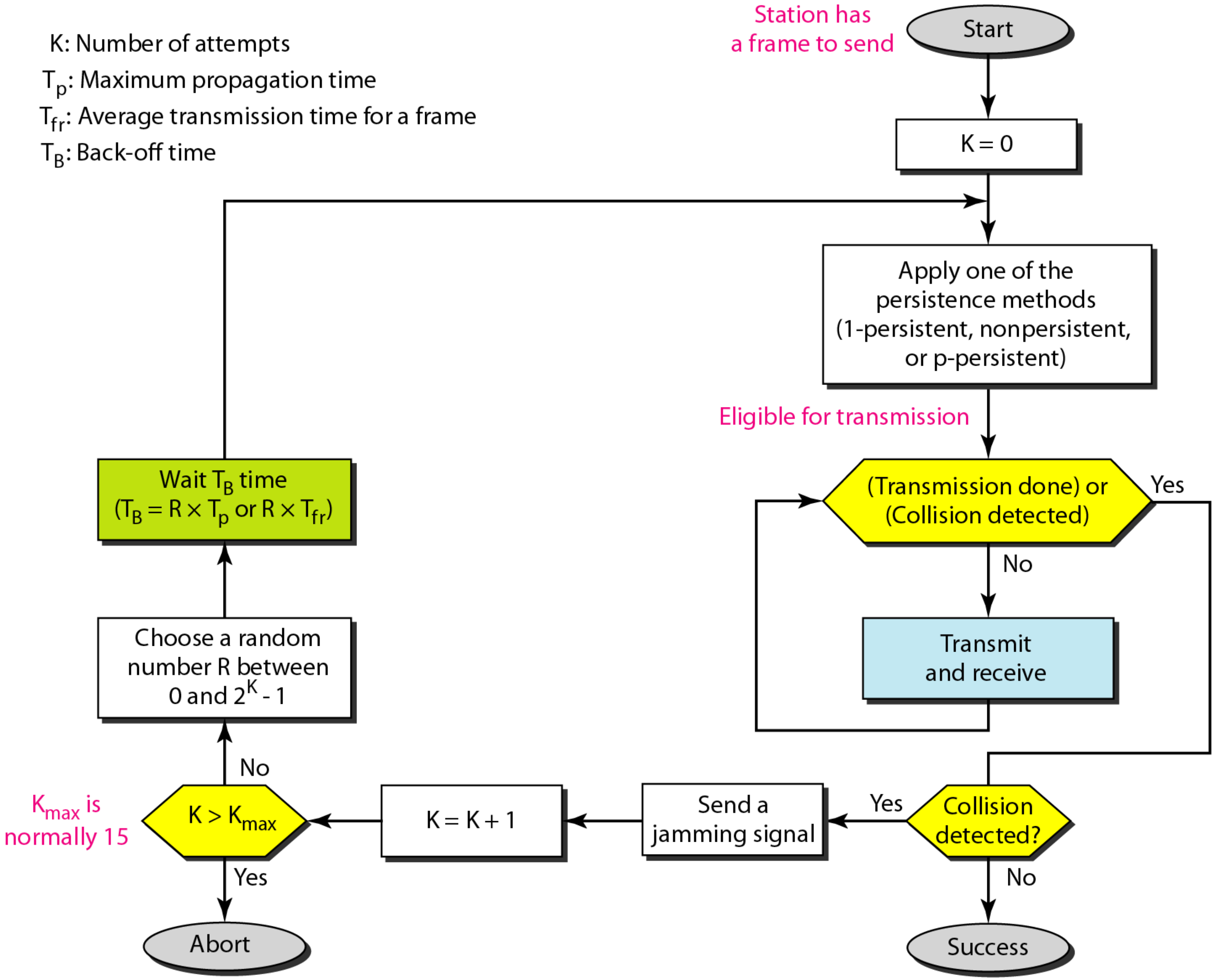


Collision and abortion in CSMA/CD



- For CSMA/CD to work, we need a restriction on the frame size.
- The frame transmission time T_{fr} must be at least two times the maximum propagation time T_p .

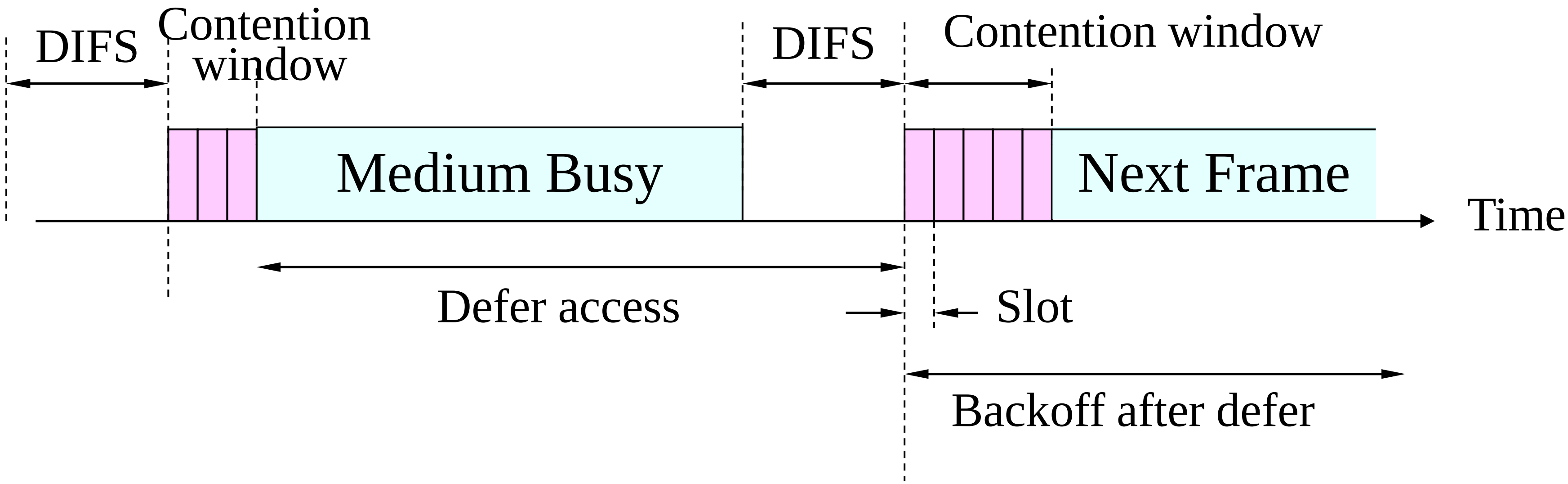
Flow diagram for the CSMA/CD



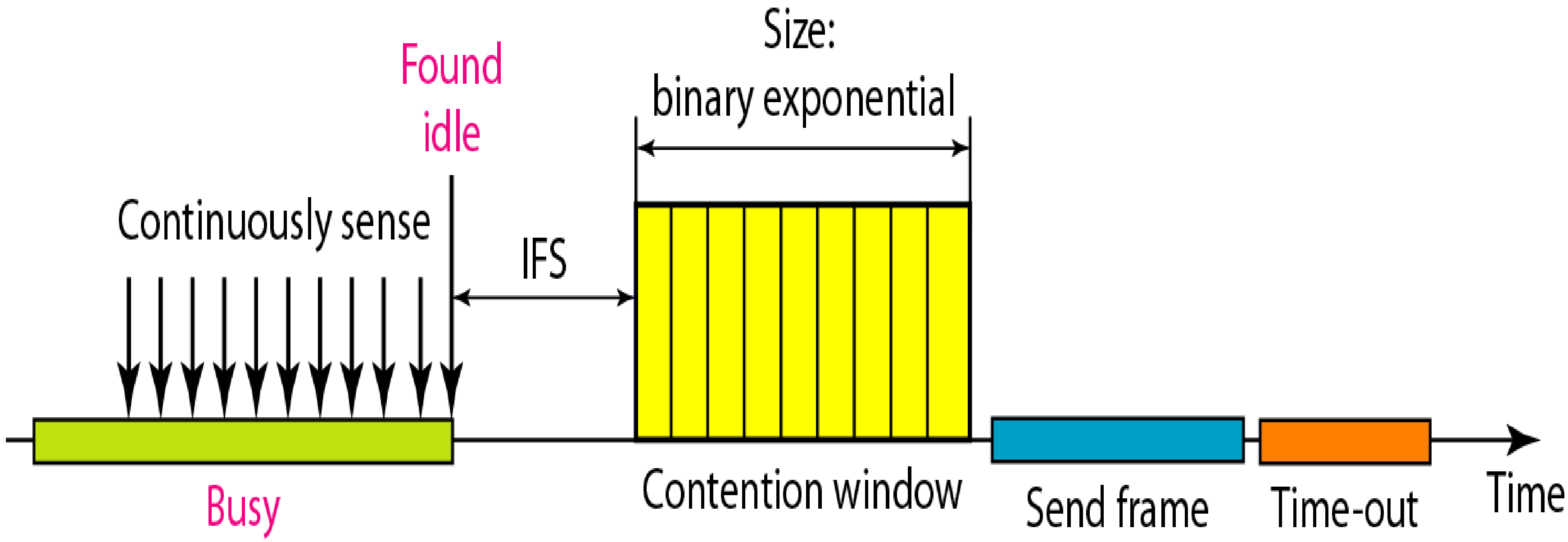
Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

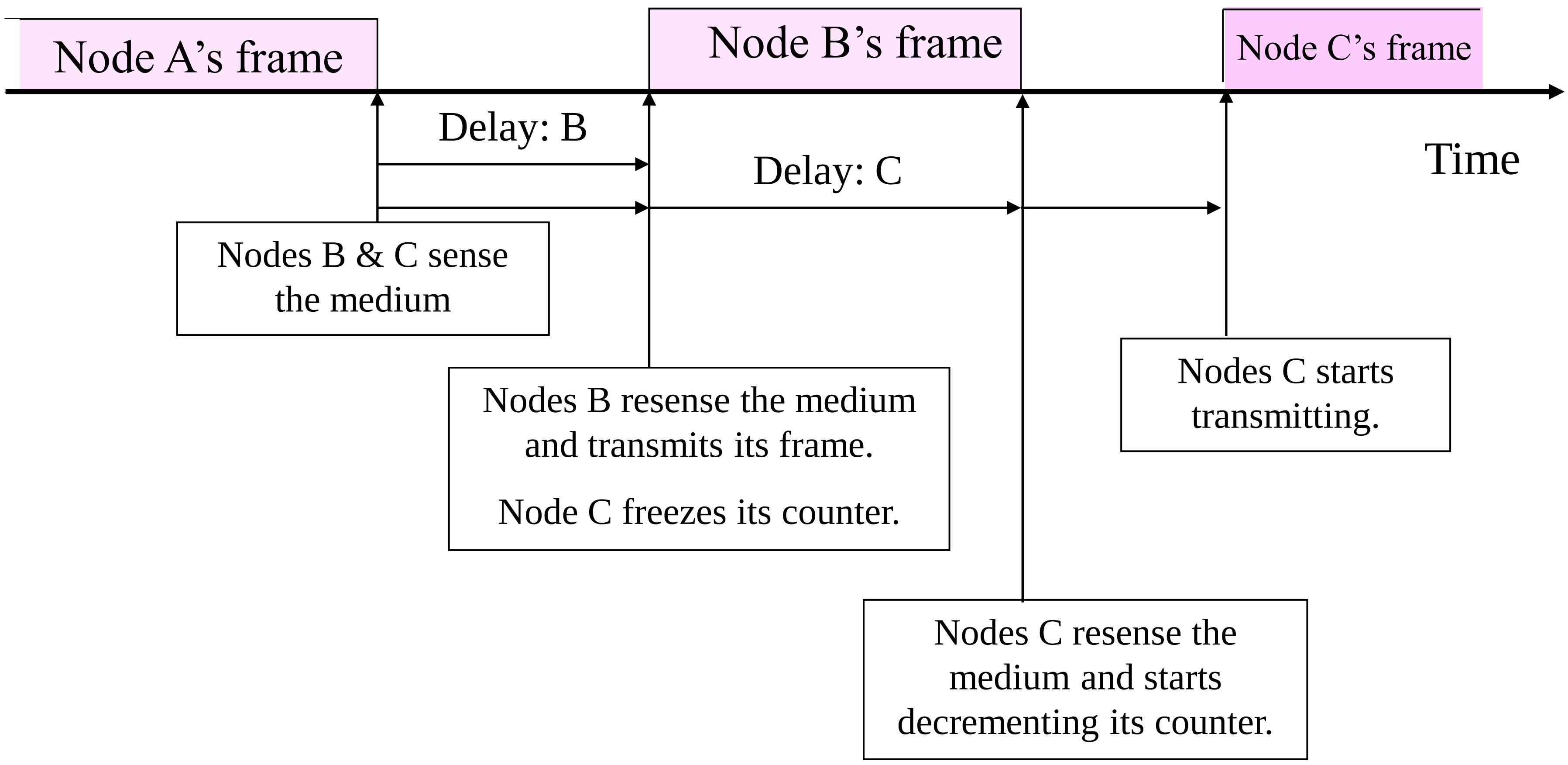
- Collisions are avoided through the use of CSMA/CA's three strategies: the interframe space, the contention window, and acknowledgments.
  - **Interframe Space:** Collisions are avoided by deferring transmission even if the channel is found idle. When an idle channel is found, the station does not send immediately. It waits for a period of time called the interframe space or IFS.
  - **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.
  - **Acknowledgment:** 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 acknowledgment and the time-out timer can help guarantee that the receiver has received the frame.

- All terminals listen to the same medium as CSMA/CD.
- Terminal ready to transmit senses the medium.
- If medium is busy it waits until the end of current transmission.
- It again waits for an additional predetermined time period DIFS (Distributed inter frame Space). when the counter reaches to zero.
- Then picks up a random number of slots (the initial value of backoff counter) within a contention window to wait before transmitting its frame.
- If there are transmissions by other terminals during this time period (backoff time), the terminal freezes its counter.
- It resumes count down after other terminals finish transmission + DIFS. The terminal can start its transmission when the counter reaches to zero.

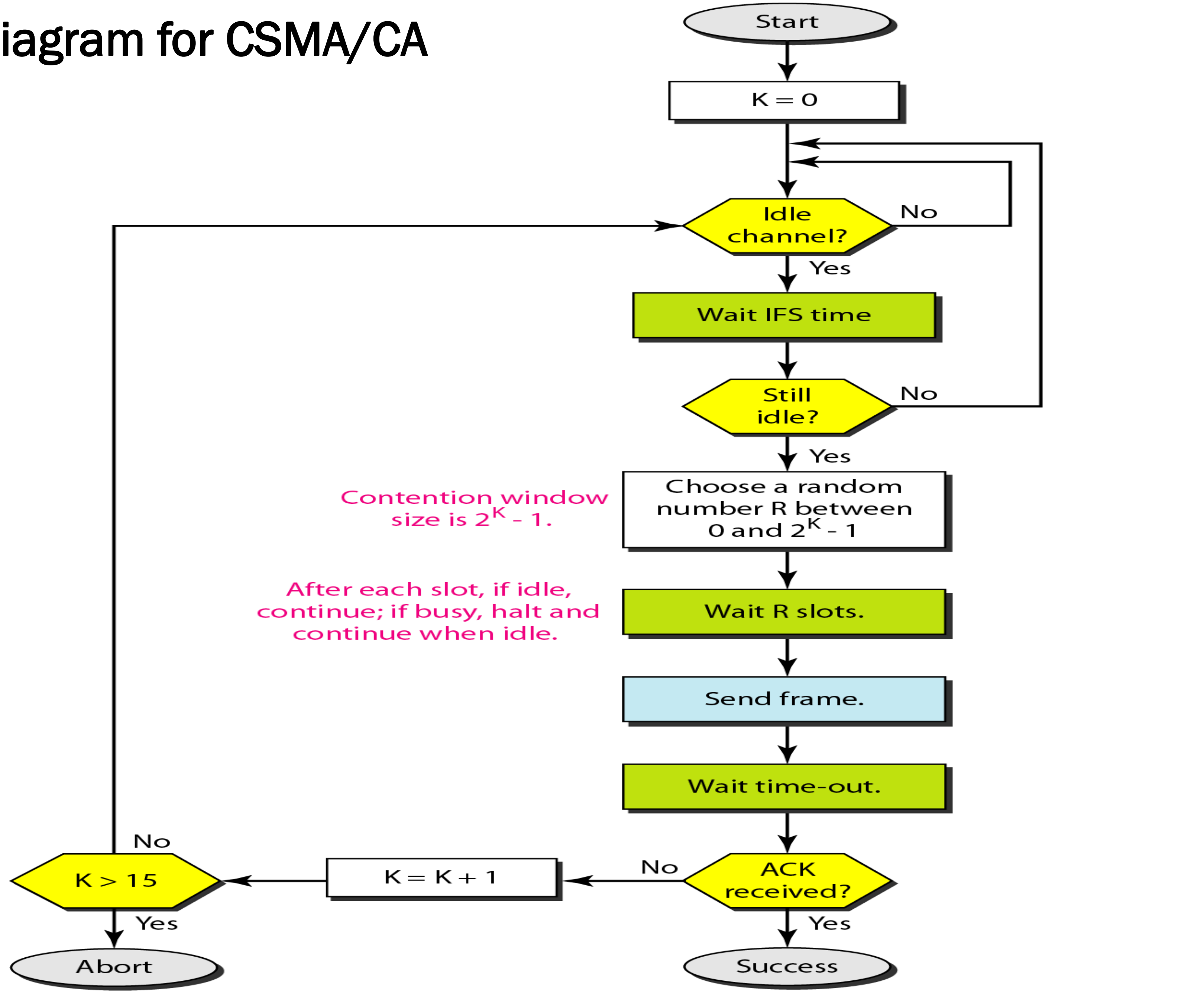


DIFS – Distributed Inter Frame Spacing



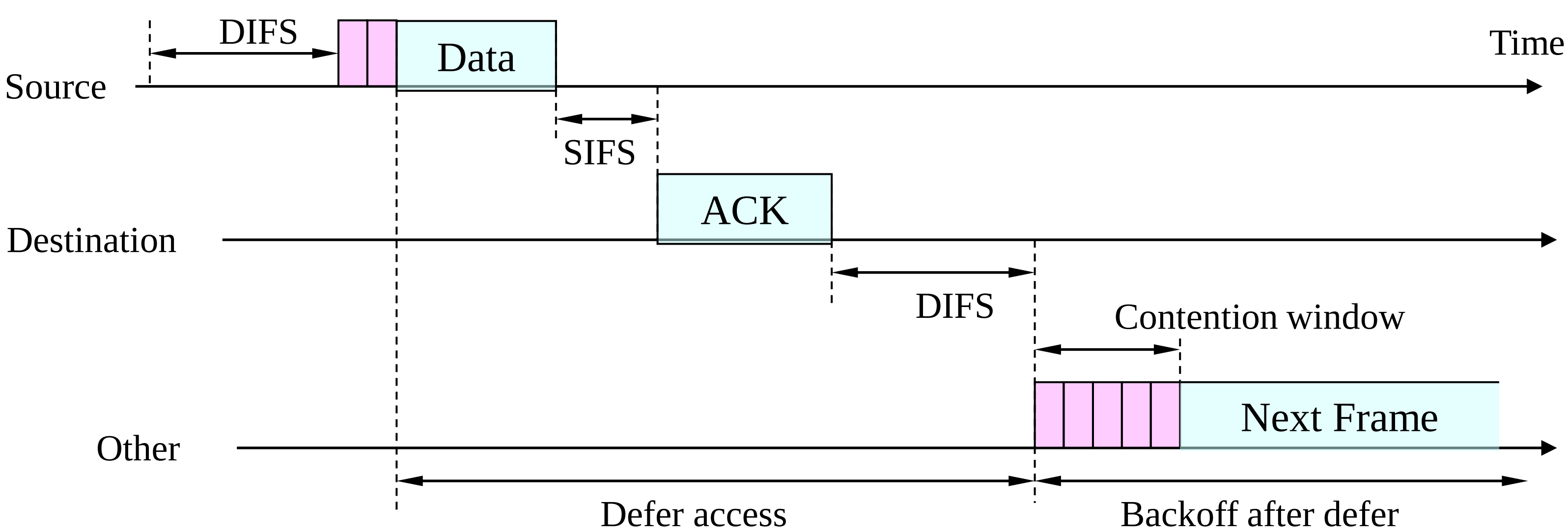

Node A’s frame
Node B’s frame
Node C’s frame
Delay: B
Delay: C
Time
Nodes B & C sense the medium
Nodes B resense the medium and transmits its frame.
Node C freezes its counter.
Nodes C starts transmitting.
Nodes C resense the medium and starts decrementing its counter.

Flow diagram for CSMA/CA



CSMA/CA with ACK

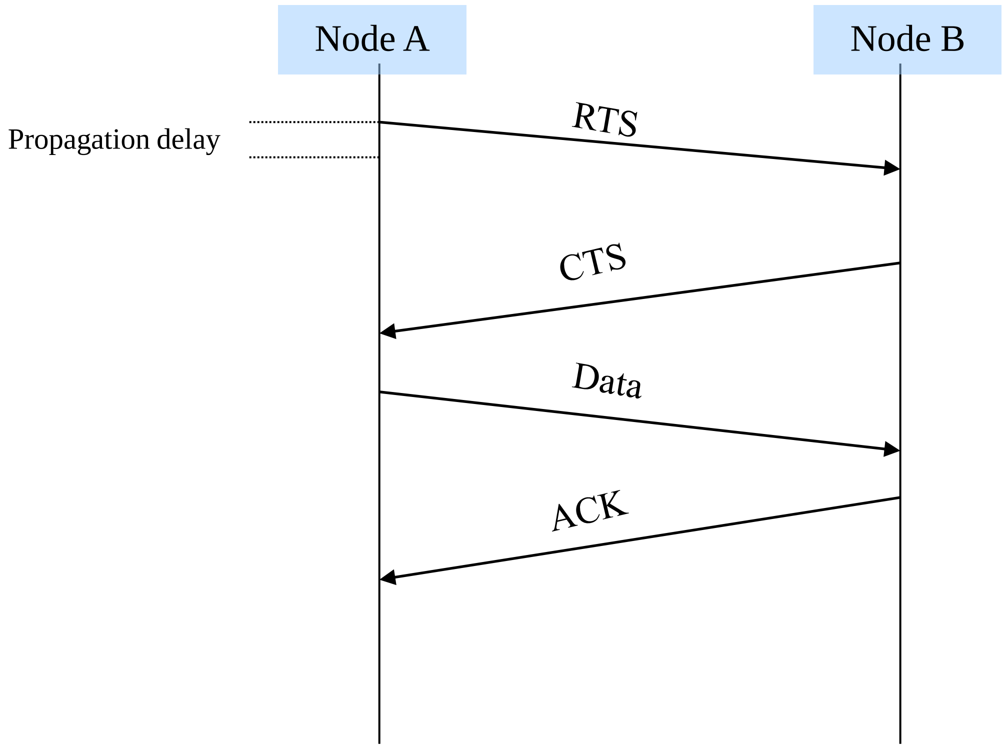
- Immediate Acknowledgements from receiver upon reception of data frame without any need for sensing the medium.
- ACK frame transmitted after time interval SIFS (*Short Inter-Frame Space*) (*SIFS* < *DIFS*)
- Receiver transmits ACK without sensing the medium.
- If ACK is lost, retransmission done.



SIFS – Short Inter Frame Spacing

CSMA/CA with RTS/CTS

- Transmitter sends an RTS (request to send) after medium has been idle for time interval more than DIFS.
- Receiver responds with CTS (clear to send) after medium has been idle for SIFS.
- Then Data is exchanged.
- RTS/CTS is used for reserving channel for data transmission so that the collision can only occur in control message.

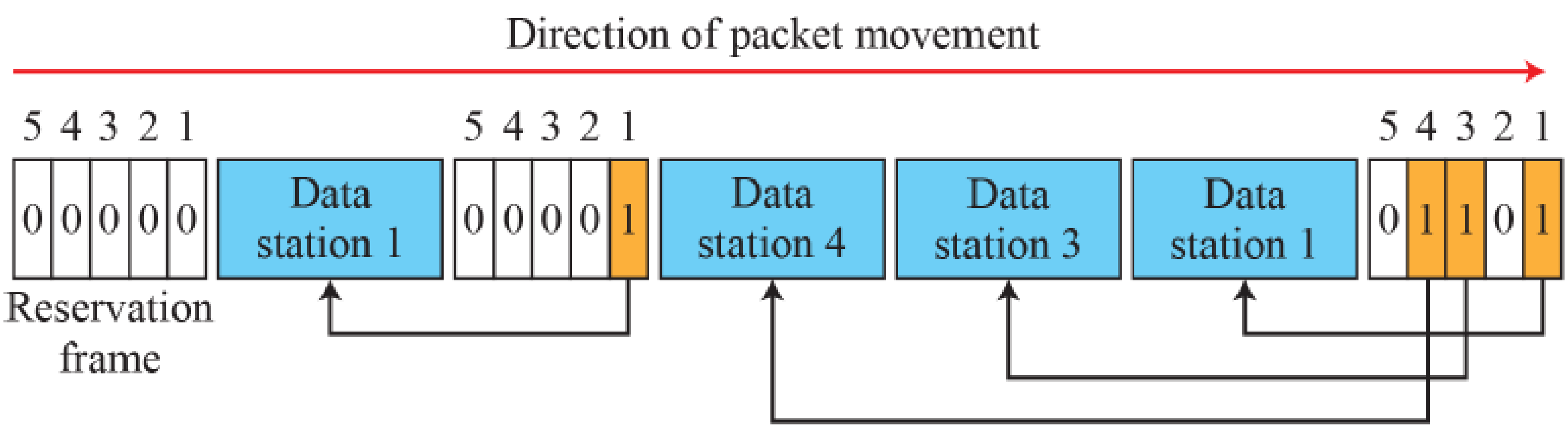


Controlled Access

- 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.
- There are three controlled-access methods:
  - Reservation
  - Polling
  - Token Passing

Reservation Access

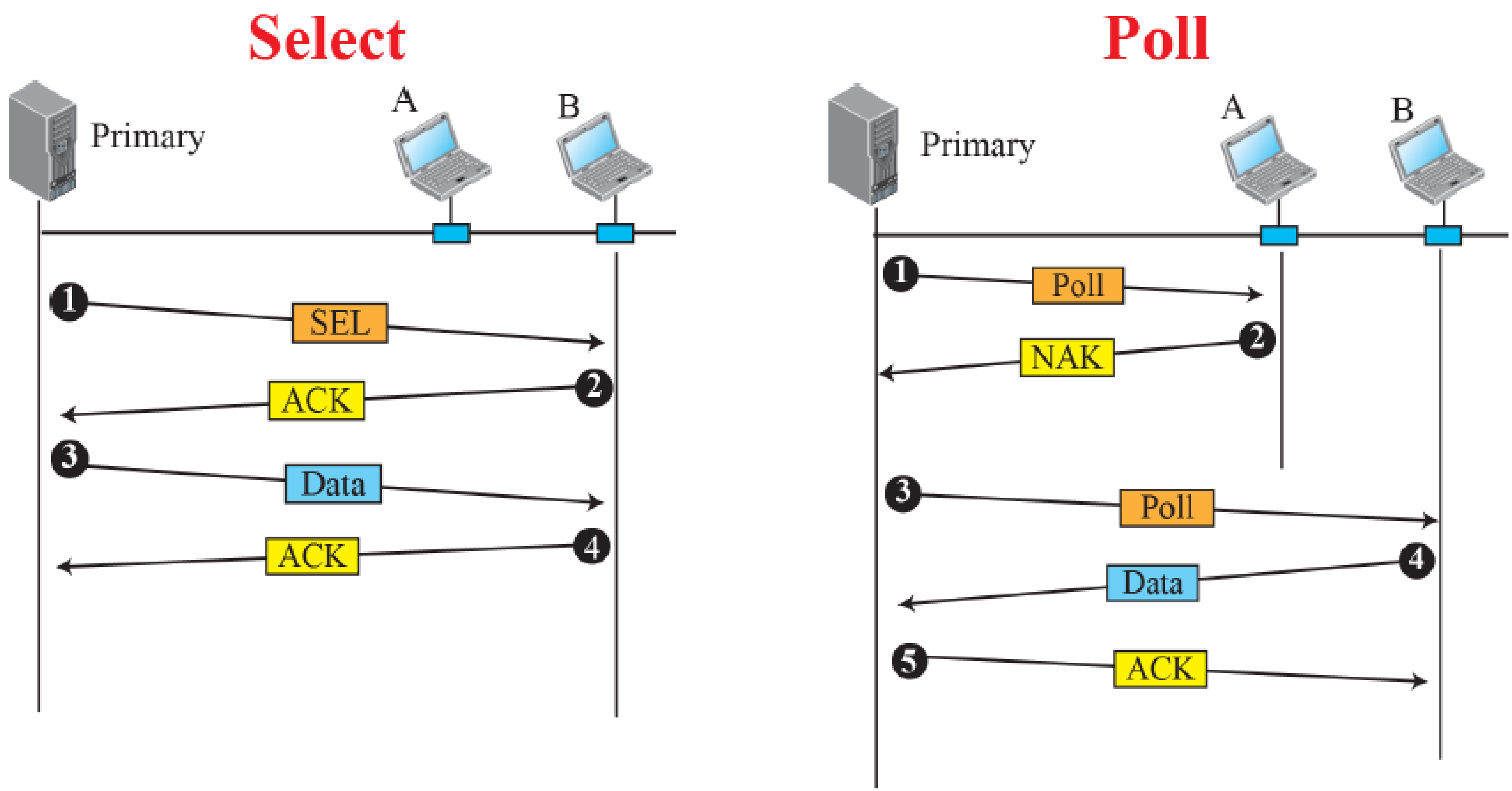
- A station needs to make a reservation before sending data.
- Time is divided into intervals.
- In each interval, a reservation frame precedes the data frames sent in that interval.



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.

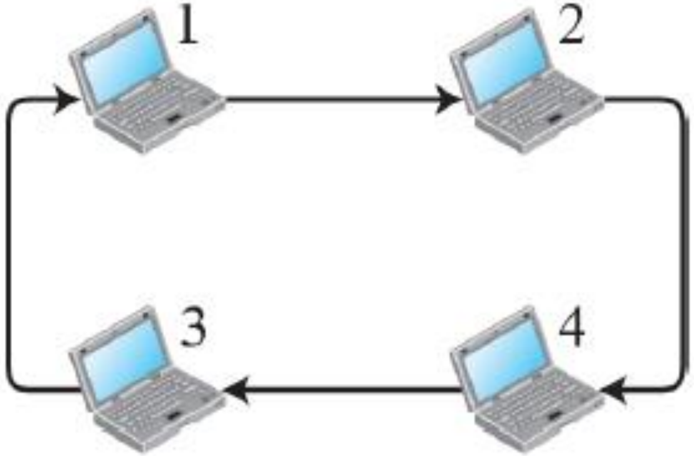
Select and Poll functions in Polling-Access method



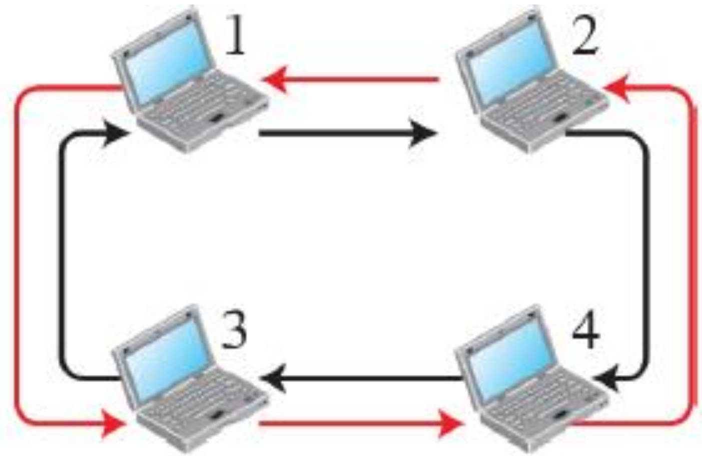
Token Passing

- 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.

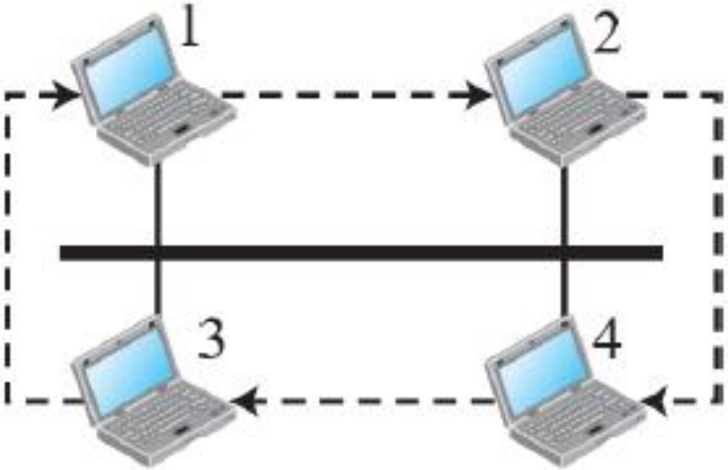
Logical Ring and Physical Topology in Token-Passing Access method



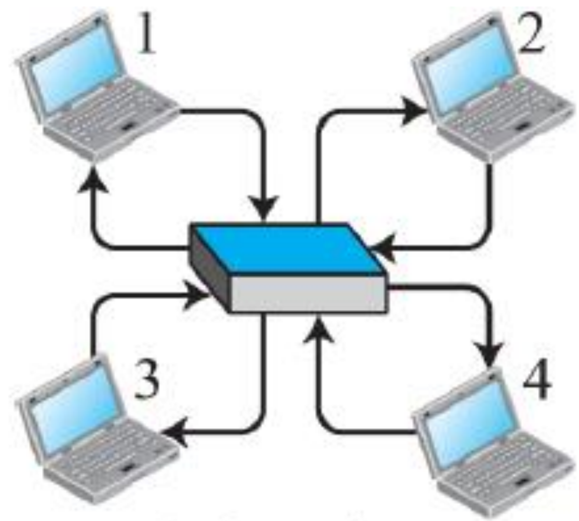
a. Physical ring



b. Dual ring



c. Bus ring



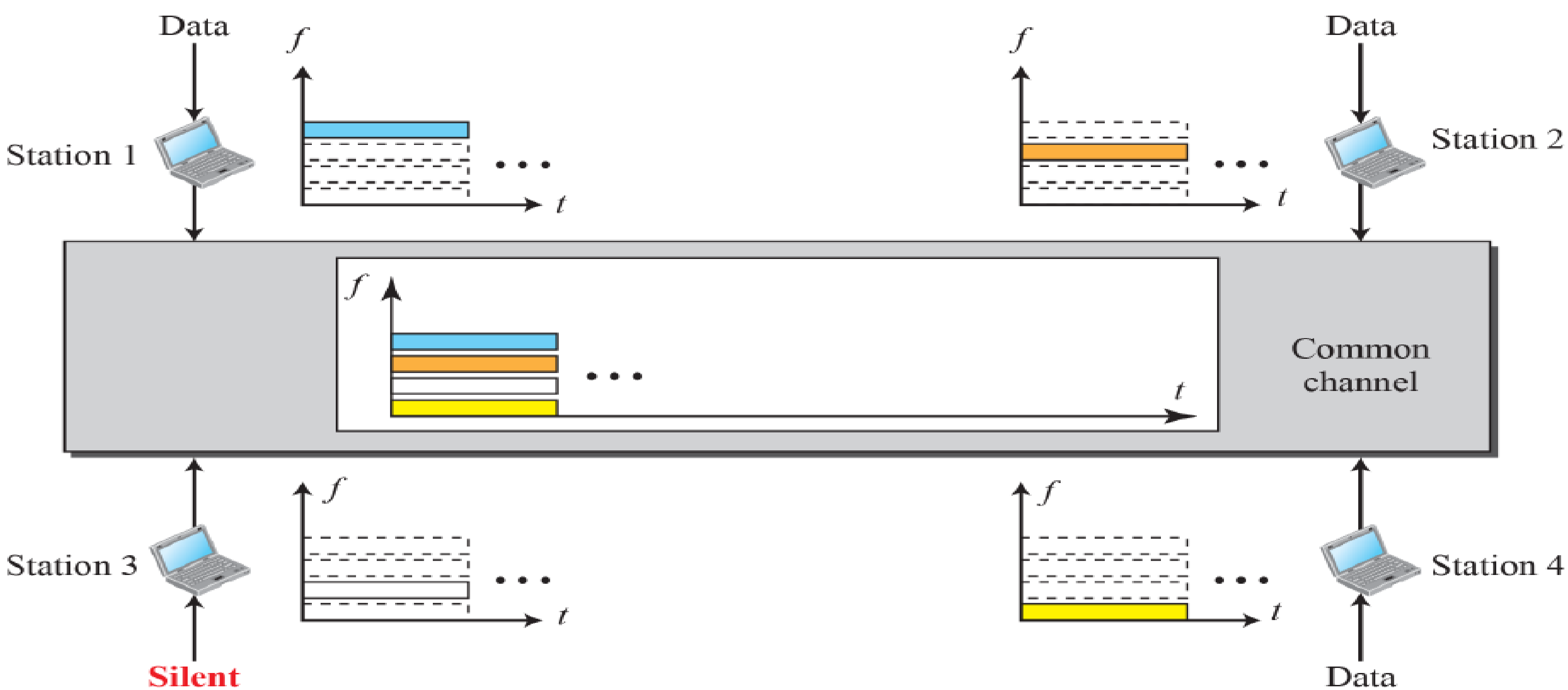
d. Star ring

CHANNELIZATION

- Channelization (or channel partition, as it is sometimes called) is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, among different stations.
- Three protocols are used in this method:
  - FDMA
  - TDMA
  - CDMA.

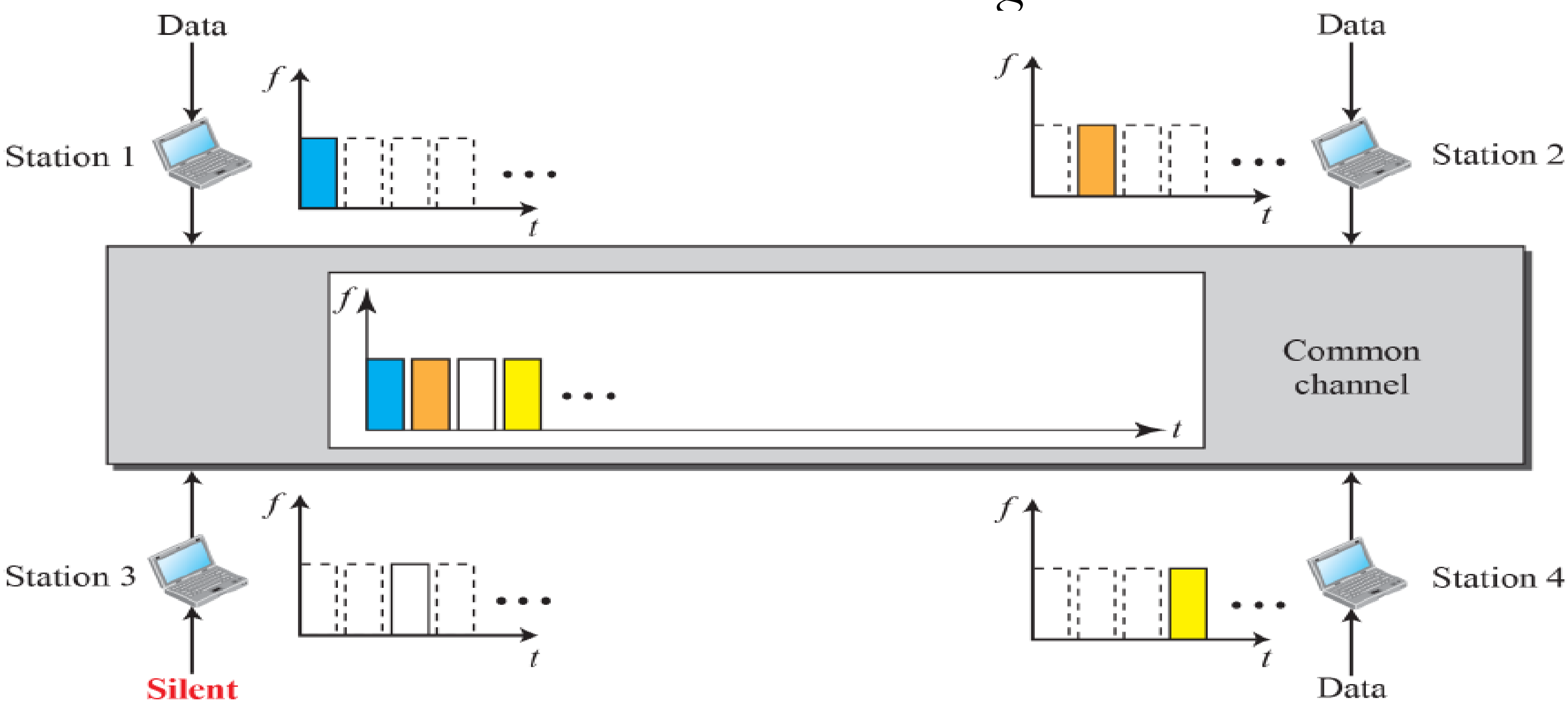
Frequency-Division Multiple Access (FDMA)

- 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



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 its assigned time slot



Code Division Multiple Access (CDMA)

- CDMA differs from FDMA in that only one channel occupies the entire bandwidth of the link
- It differs from TDMA in that all stations can send data simultaneously; there is no timesharing