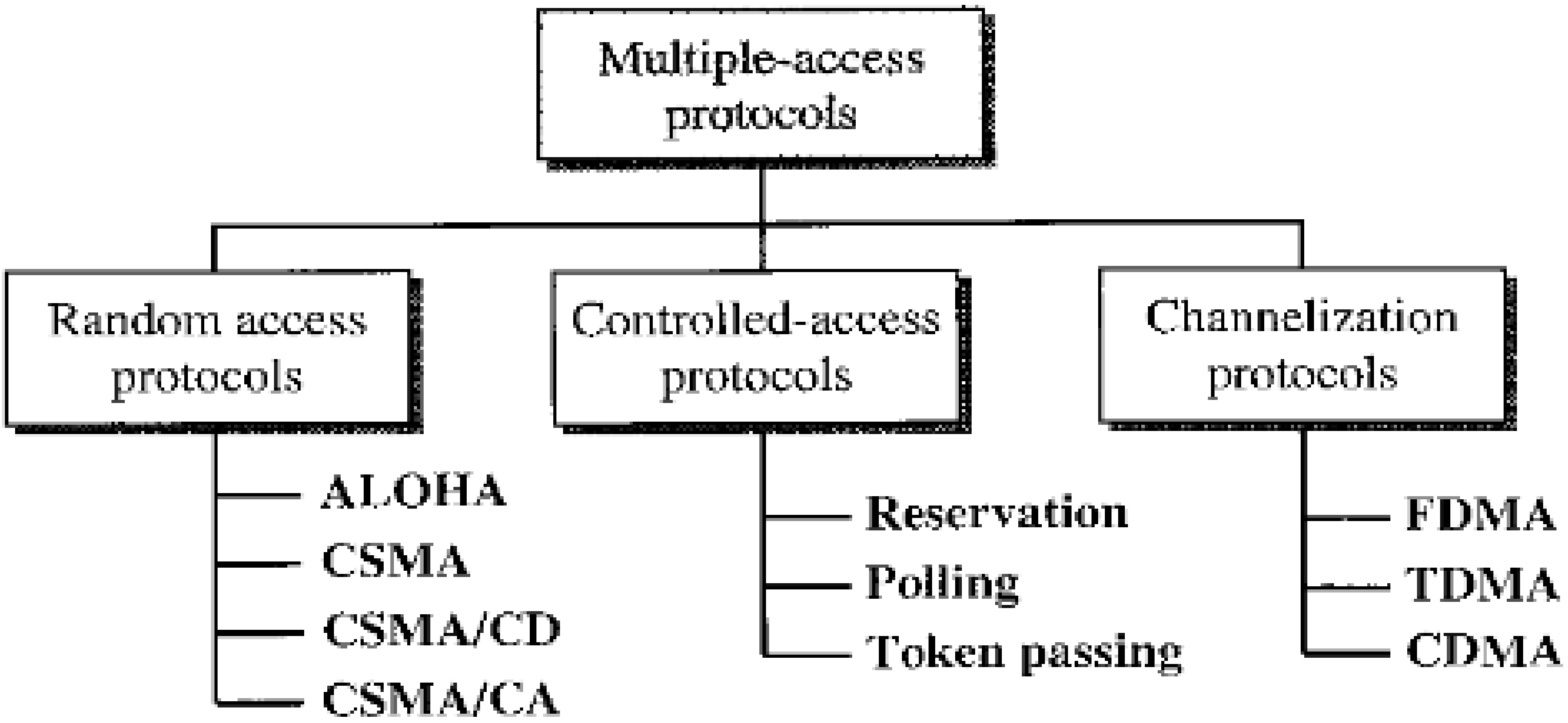
# Chapter 12

# Multiple Access

- We can consider the data link layer as two sublayers: data link control and media access
- When stations are connected and use a common link, we need a multiple-access protocol to coordinate access to the link

# Multiple Access



# Random Access

- Aka contention methods
- No station is superior to another station and none is assigned the control over another
- Each station that has data to send uses a procedure defined by the protocol to make a decision on whether or not to send
- Decision depends on the state of the medium
- No scheduled time for a station to transmit
- No rules specify which station should send next

# Random Access

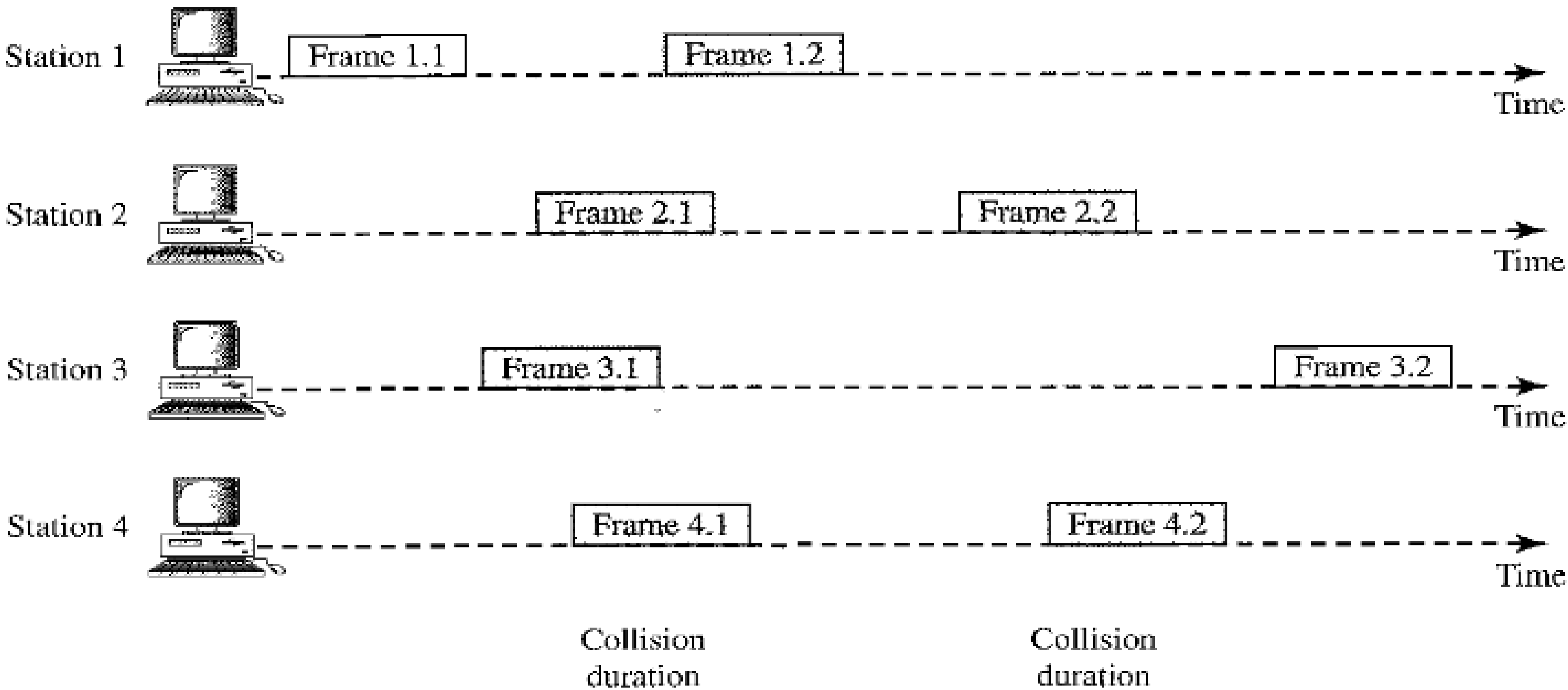
- If more than one station tries to send, there is an access conflict, called collision
  - When can the station access the medium?
  - What can the station do if the medium is busy?
  - How can the station determine the success or failure of the transmission?
  - What can the station do if there is an access conflict?

# ALOHA

- Earliest random access method
- Developed at the University of Hawaii, 1970's
- Designed for radio LAN
- Medium(wireless) is shared between stations, collisions may happen

# Pure ALOHA

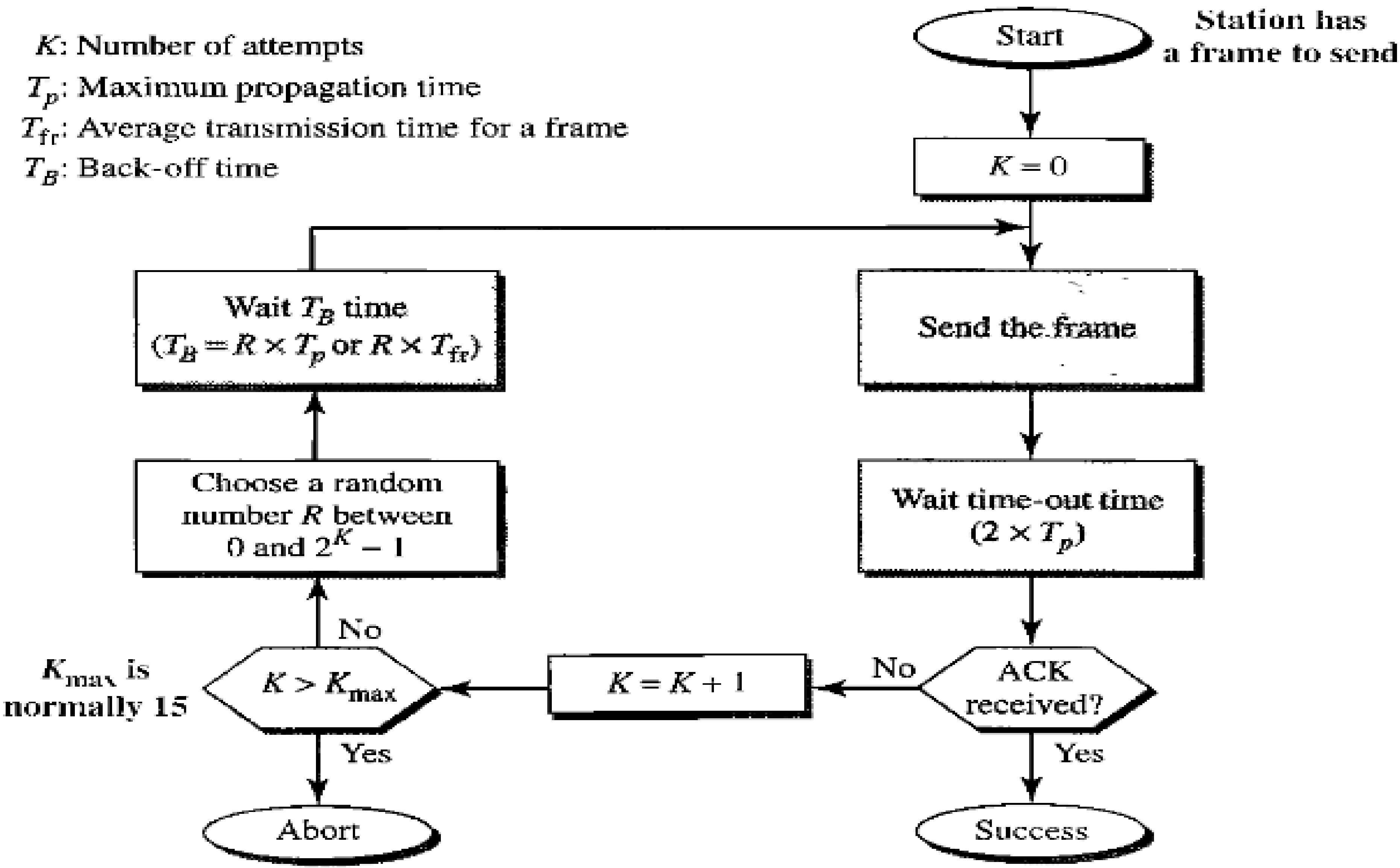
- Send whenever there is a frame to send



# Pure ALOHA

- Relies on ACKs
- When a the time-out period passes, each stations waits a random amount of time before resending its frame – back-off time, $T_b$
- After a maximum number of retransmission attempts $K_{max}$, a station must give up and try later
- Binary exponential back-off: multiplier in the range 0 to $2^k-1$ is randomly chosen and multiplied by propagation time, $T_p$

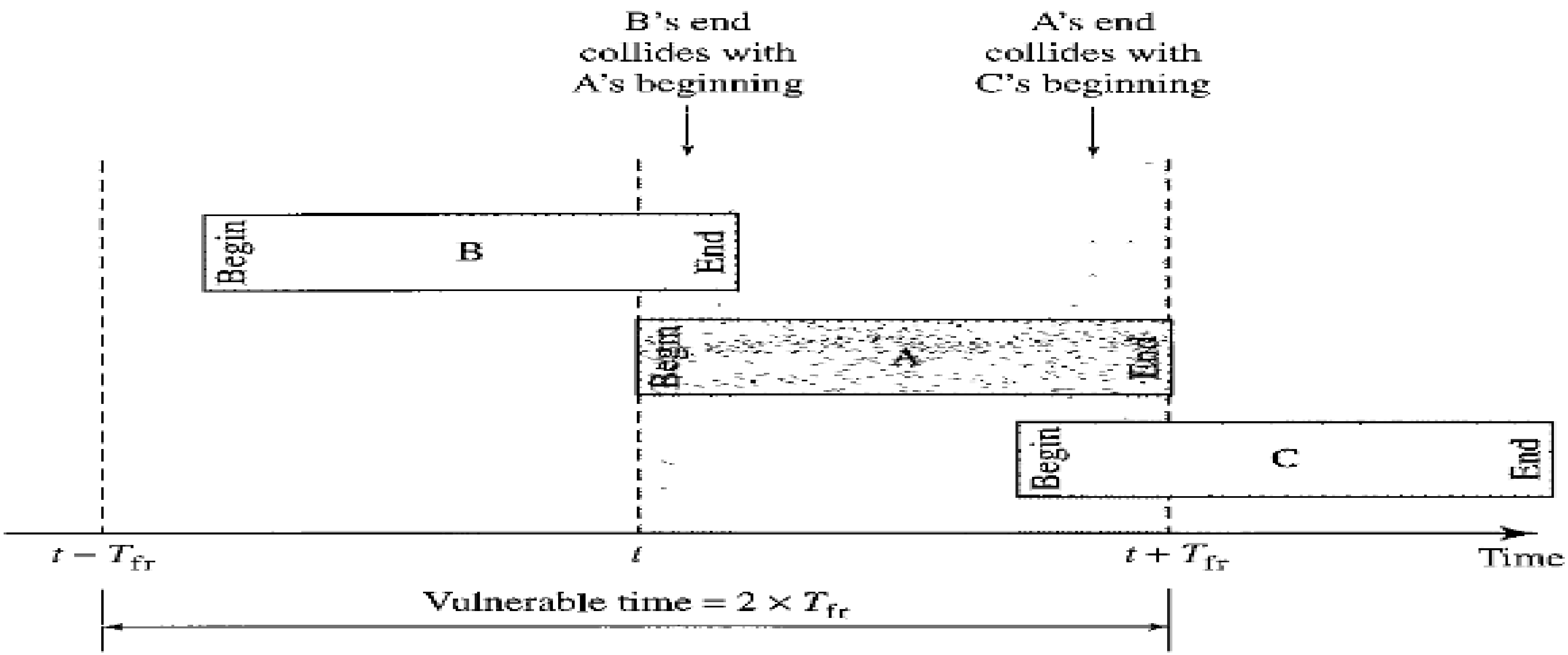
# Pure ALOHA



K: Number of attempts
T_p: Maximum propagation time
T_fr: Average transmission time for a frame
T_B: Back-off time
Start
Station has a frame to send
K = 0
Send the frame
Wait time-out time (2 × T_p)
ACK received?
No
Yes
Success
K = K + 1
K > K_max
K_max is normally 15
Yes
Abort
No
Choose a random number R between 0 and 2^K − 1
Wait T_B time (T_B = R × T_p or R × T_fr)

# Pure ALOHA

- Vulnerable time – time that a possibility of a collision might occur; 2 x $T_{fr}$



# Pure ALOHA

- Given an ALOHA network that transmits 200-bit frames of a shared channel of 200 kbps. What is the requirement to make this frame collision free?
  - $T_{fr}$ = 200 bits/200 kbps = 1 ms
  - Vulnerable time is 2 x 1 ms = 2 ms
  - No station should send later than 1 ms before this station starts transmission and no station should start sending during the 1-ms period that this station is sending

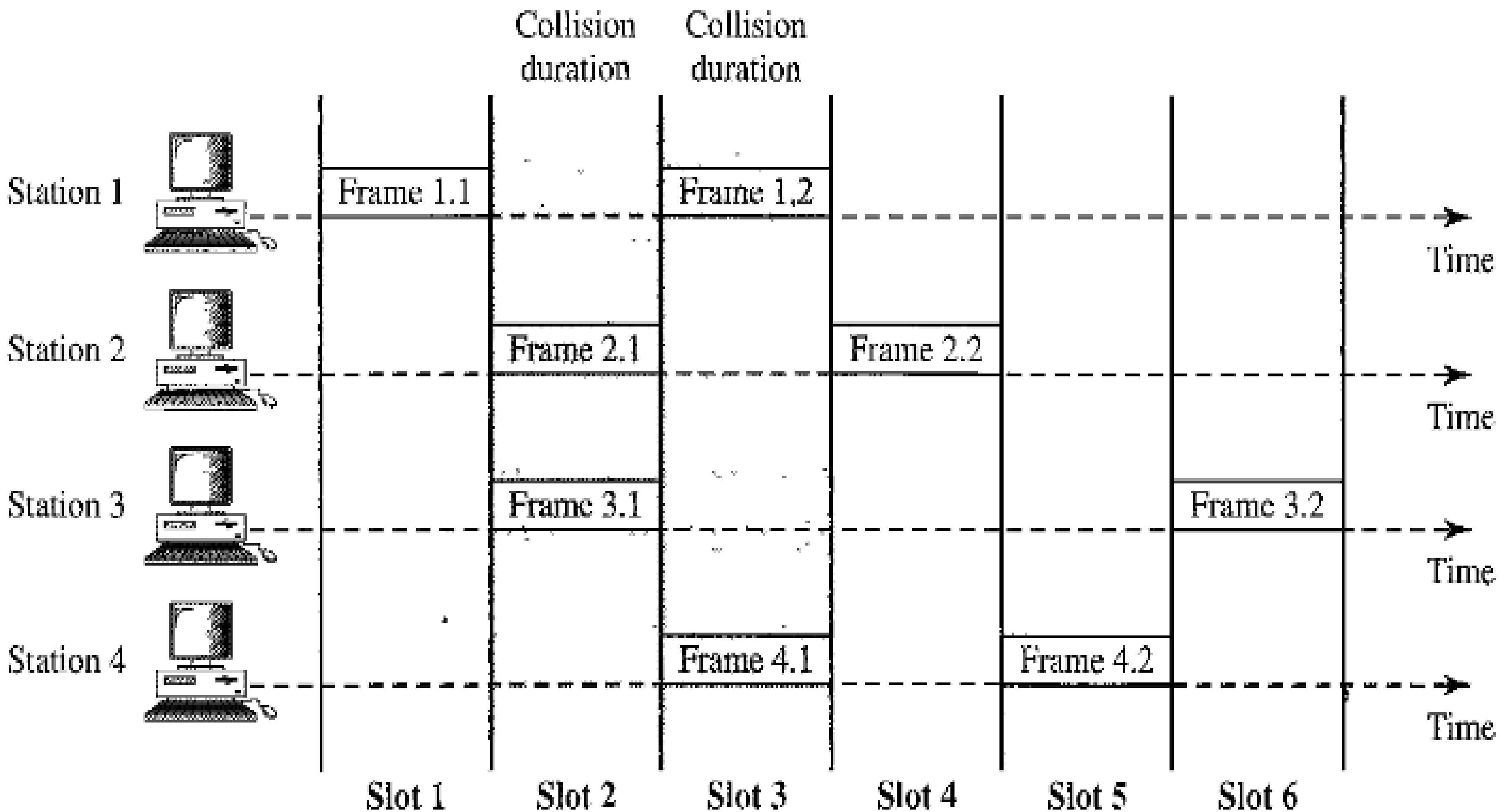
# Pure ALOHA

- Throughput: $S = G \times e^{-2G}$
- G is the average number of frames generated by the system during one frame transmission time
- $S_{max} = 0.184$, for G=1/2
- 18.4% of frames generated at one-half frame transmission time will reach their destination successfully

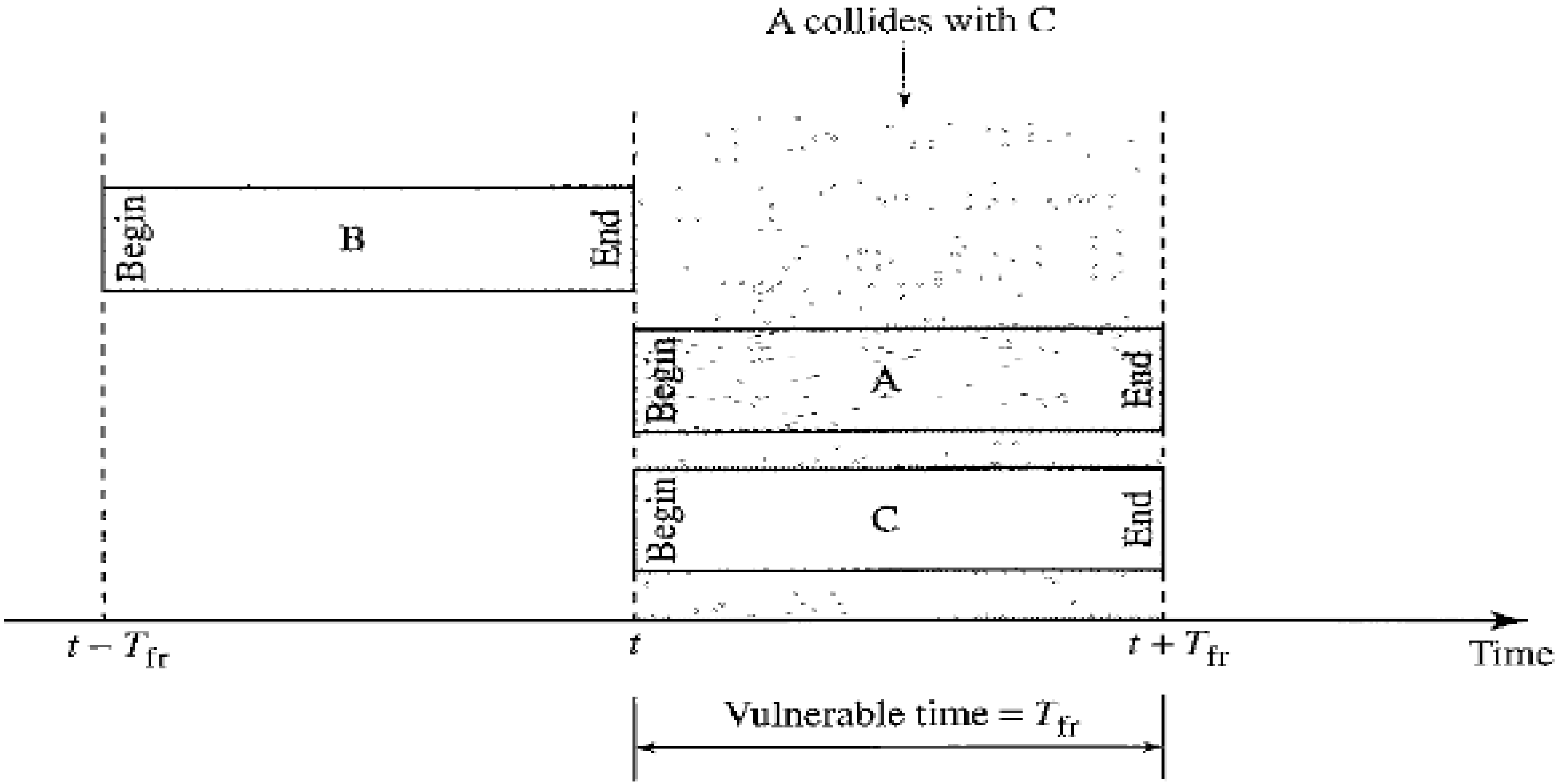
# Slotted ALOHA

- Improves the efficiency of Pure ALOHA
- Divide the time into slots of Tfr and force the station to send only at the beginning of the time slot
- Vulnerable time is $T_{fr}$
- Throughput $S = G \times e^{-G}$
- $S_{max} = 0.368$, when G=1

# Slotted ALOHA



# Slotted ALOHA

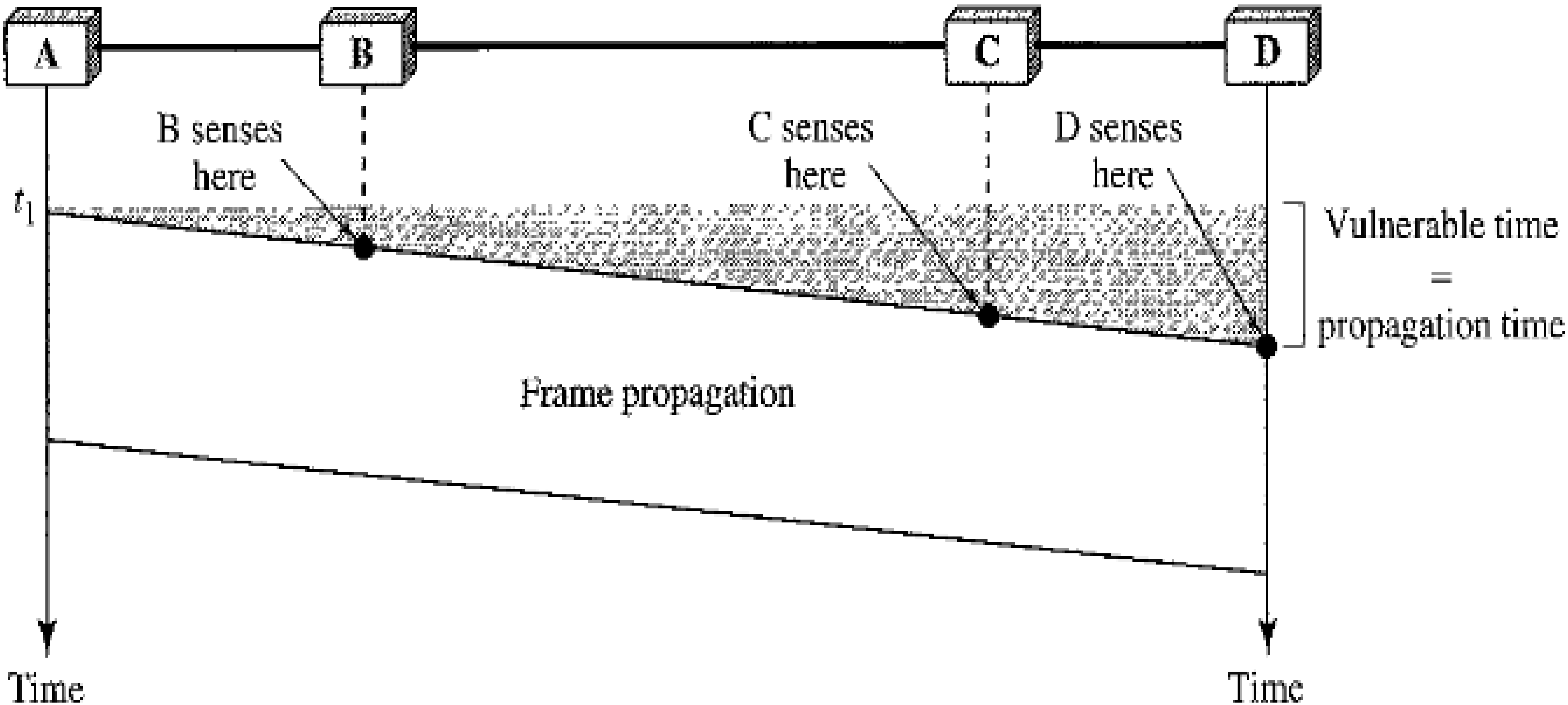


# CSMA

- Carrier Sense Multiple Access
- The chance of collision can be reduced if a station senses the medium before trying to use it
- Each station first listens to the medium(check the state of the medium) before sending
- “sense before transmit”, “listen before talk”
- Can reduce possibility of collision but cannot eliminate it; because of propagation delay

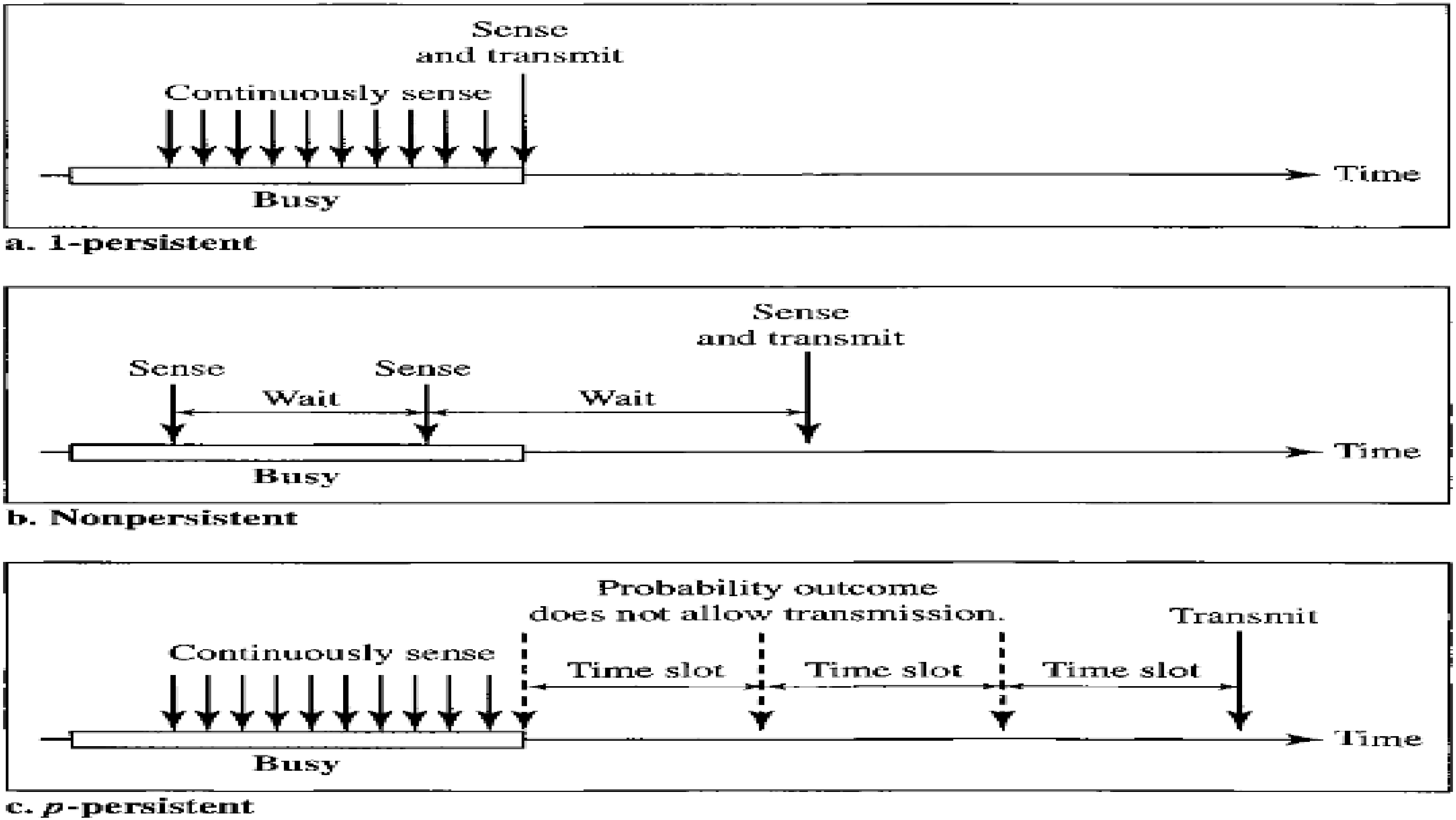
# CSMA

- Vulnerable time is the propagation time $T_n$

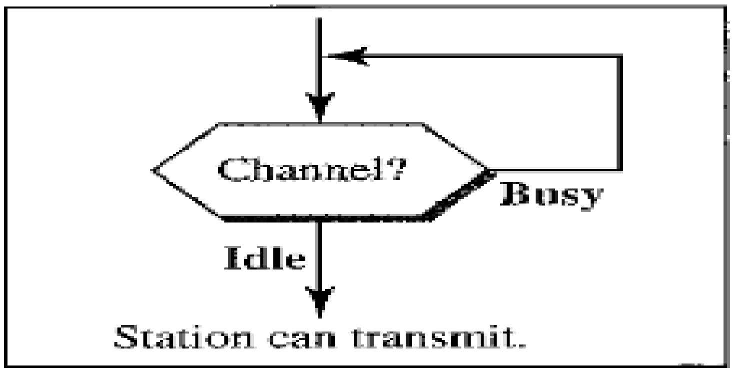


# CSMA – Persistence Methods

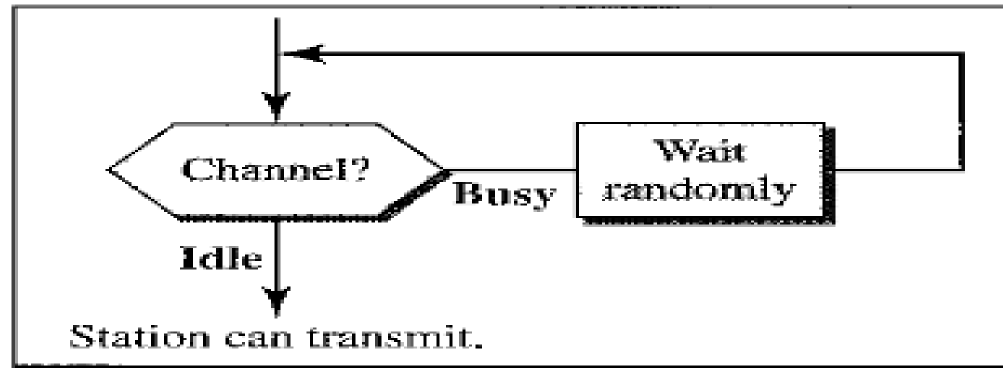
- What to do if channel is busy?



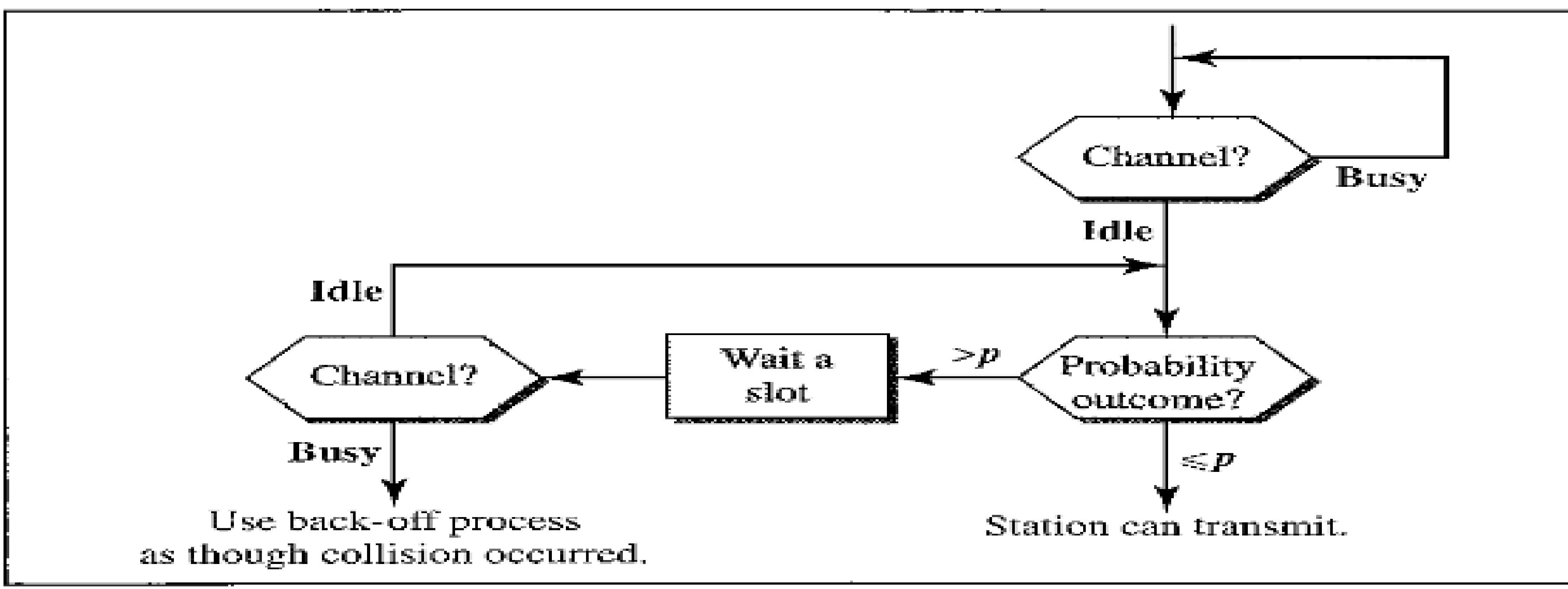
# CSMA – Persistence Methods



a. 1-persistent



b. Nonpersistent

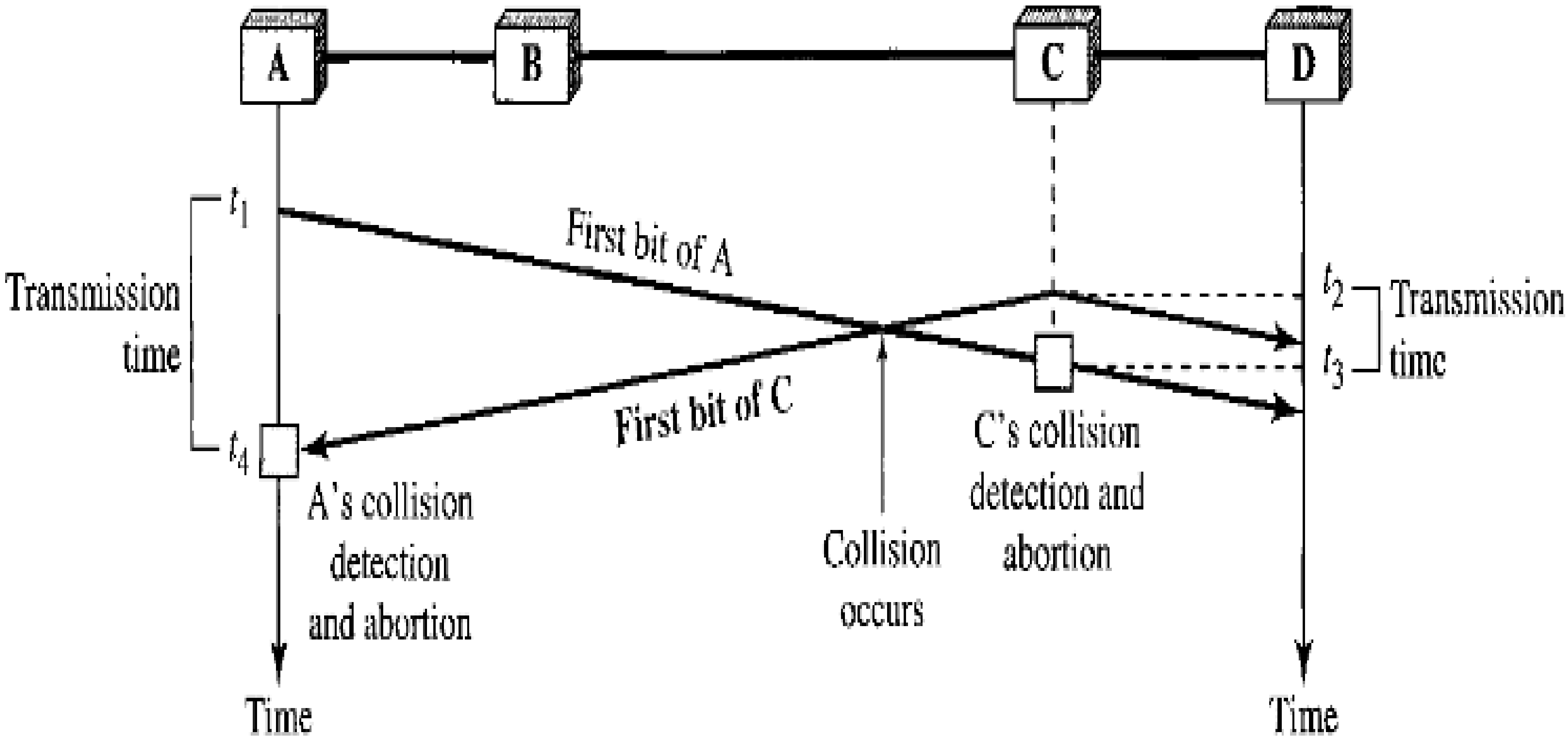


c. *p*-persistent

# CSMA/CD

- Carrier Sense Multiple Access with Collision Detection
- A station monitors the medium after it sends a frame if the transmission was successfull

# CSMA/CD

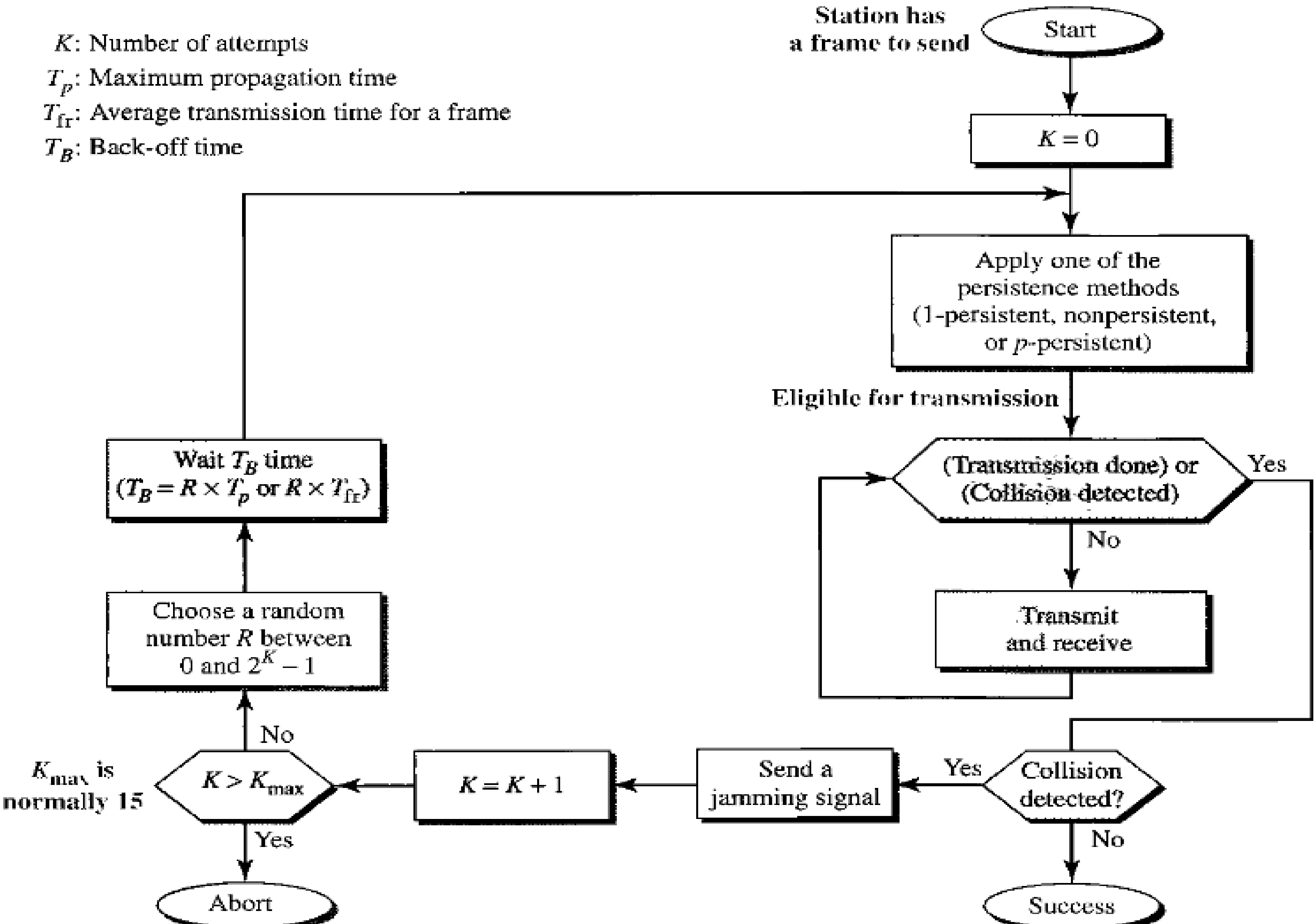

A
B
C
D
$t_1$
Transmission time
$t_4$
First bit of A
First bit of C
$t_2$
$t_3$
Transmission time
A's collision detection and abortion
Collision occurs
C's collision detection and abortion
Time
Time

# CSMA/CD

- Minimum Frame Size
- Before sending the last bit of the frame, sending station must detect a collision
- $T_{fr} = 2 \times T_p$

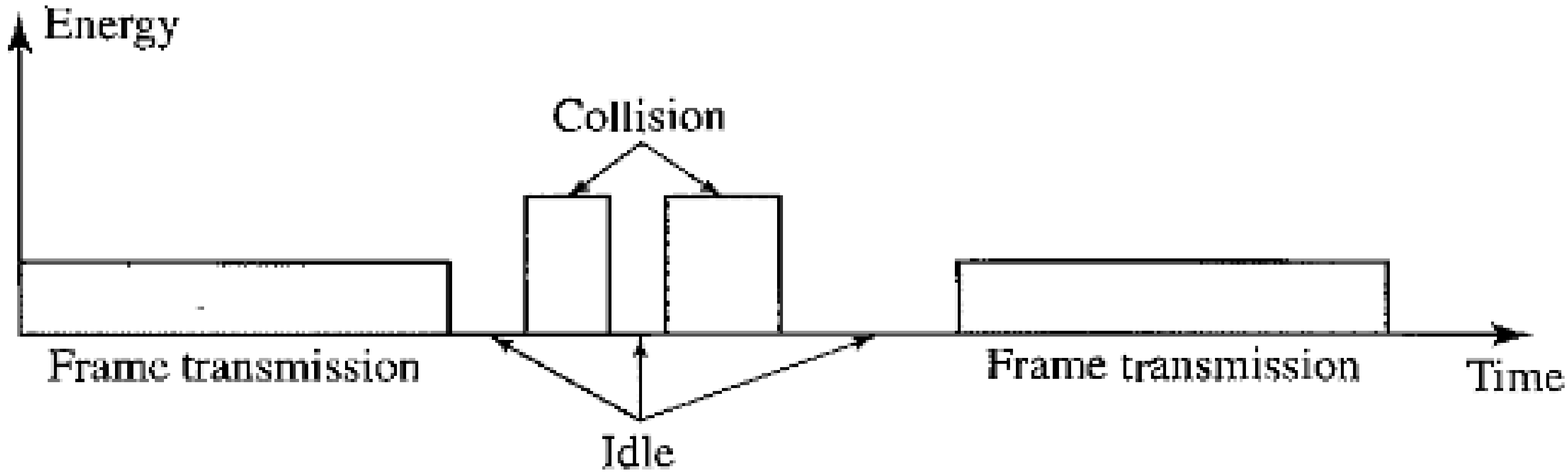
# CSMA/CD

- Given a network with a bandwidth of 10 Mbps. If the max propagation time is 25.6 micro seconds, what is the minimum size of the frame?
  - $T_{fr} = 2 \times T_p$ = 51.2 micro seconds
  - Frame size = 10 Mbps x 51.2 micro seconds = 512 bits or 64 bytes (Ethernet)


K: Number of attempts
T_p: Maximum propagation time
T_fr: Average transmission time for a frame
T_B: Back-off time
Station has a frame to send
Start
K = 0
Apply one of the persistence methods (1-persistent, nonpersistent, or p-persistent)
Eligible for transmission
(Transmission done) or (Collision detected)
Yes
No
Transmit and receive
Collision detected?
Yes
No
Success
Send a jamming signal
K = K + 1
K > K_max
K_max is normally 15
Yes
Abort
No
Choose a random number R between 0 and 2^K − 1
Wait T_B time (T_B = R × T_p or R × T_fr)

# CSMA/CD

- Energy level of the channel: zero (idle), normal(successful), abnormal(collision)



# CSMA/CD

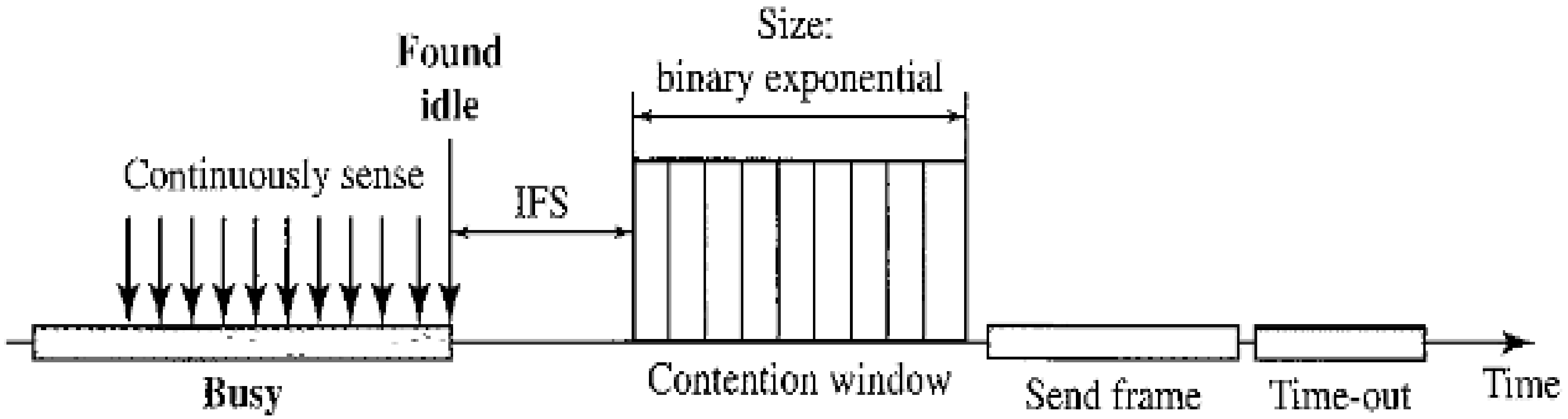
- Throughput greater than pure and slotted ALOHA
- $S_{max}$ depends on G and persistence method used
- For 1-persistent method, 50% when G=1
- For nonpersistent method, 90%, 3 < G < 8

# CSMA/CA

- Carrier Sense Multiple Access with Collision Avoidance
- A station needs to be able to receive while transmitting to detect collision
- No collision: station receives it own signal
- Collision: station receives it own signal and the signal transmitted by a second station
- In wireless, collisions must be avoided because it is difficult to detect
- Strategies: Interframe space, collision window, ACKs

# CSMA/CA

- Timing

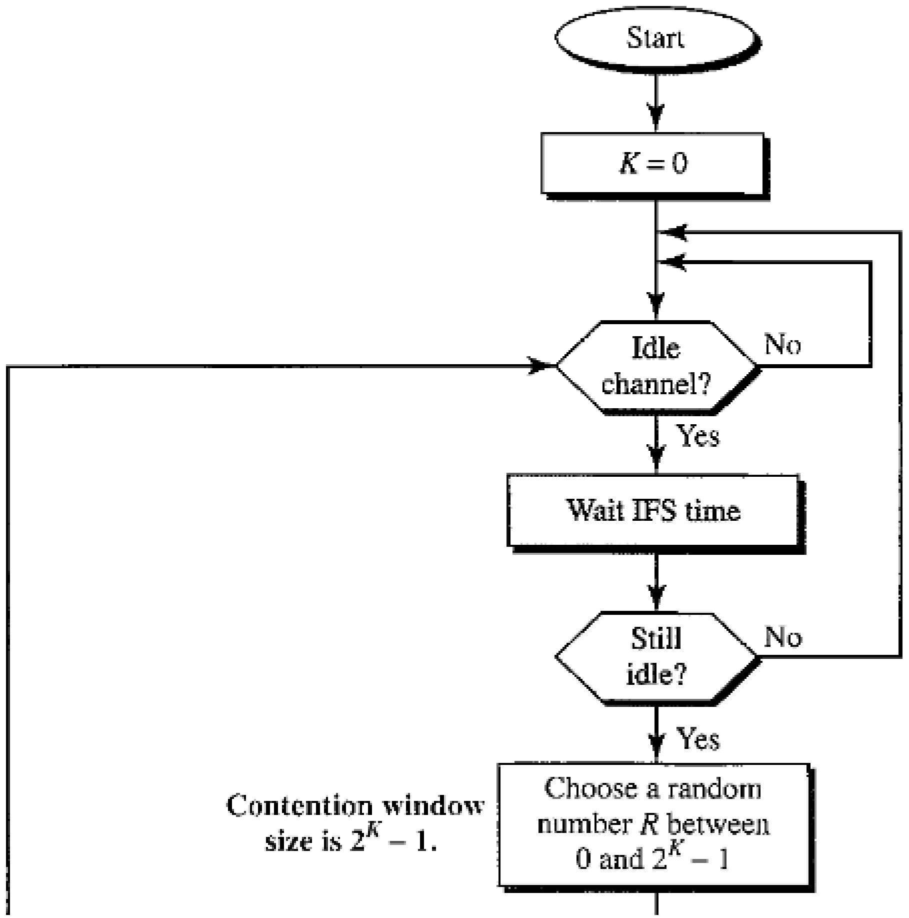


# CSMA/CA

- Interframe Space (IFS)
  - Defer transmission even if channel is idle
  - Can be used to define the priority of a station
- Contention Window
  - An amount of time divided into slots
  - Station must sense the channel after each time slot
  - Does not restart the process if channel is busy
- Acknowledgments – guarantees receipt of frame

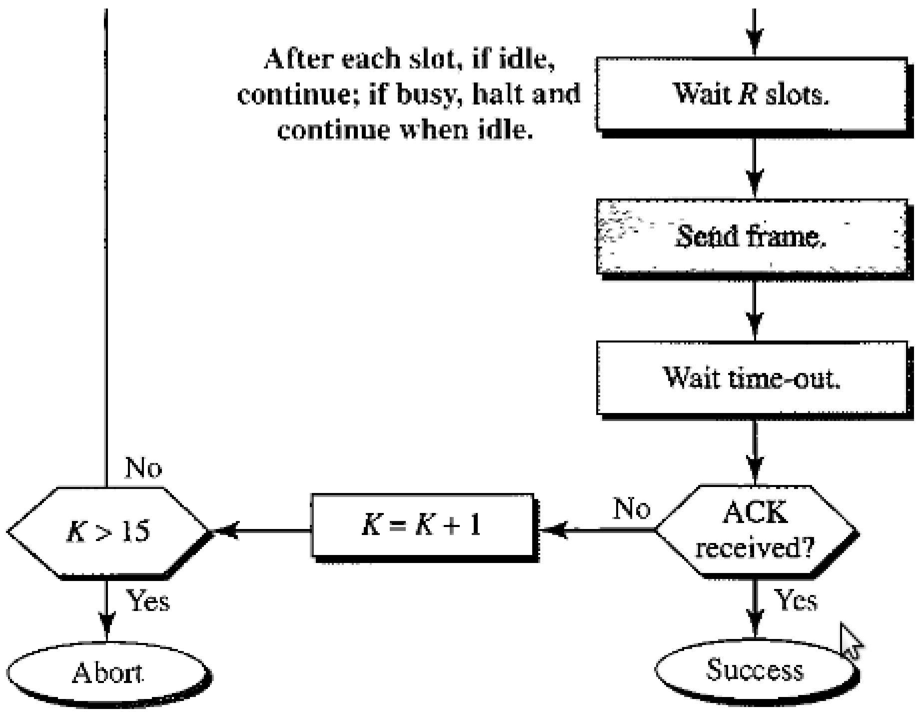
# CSMA/CA

- Flow


Start
$K = 0$
Idle channel?
No
Yes
Wait IFS time
Still idle?
No
Yes
Contention window size is $2^K - 1$.
Choose a random number $R$ between 0 and $2^K - 1$

# CSMA/CA

- Flow

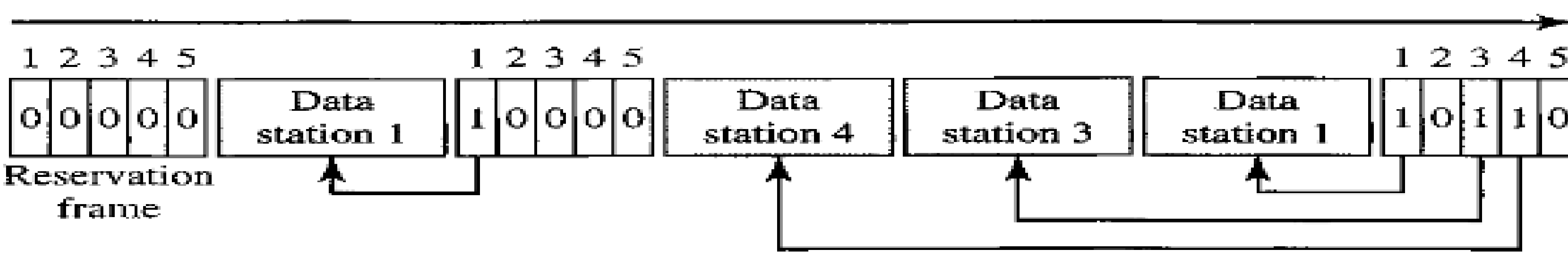

After each slot, if idle, continue; if busy, halt and continue when idle.
Wait R slots.
Send frame.
Wait time-out.
ACK received?
No
Yes
Success
K = K + 1
K > 15
No
Yes
Abort

# Controlled Access

- 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
- Methods: Reservation, Polling, Token Passing

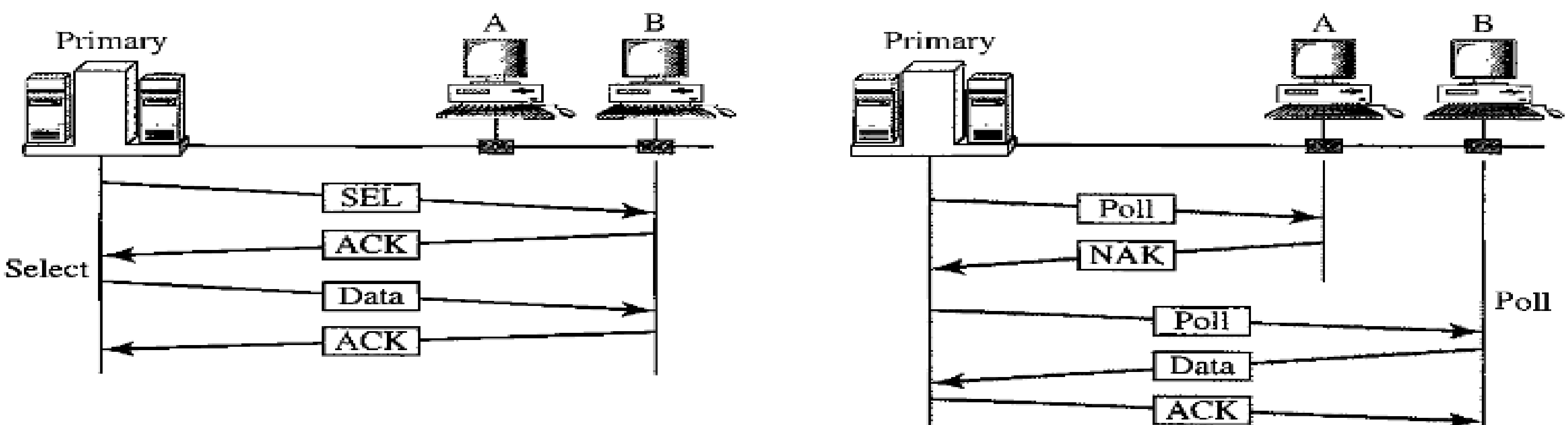
# Reservation

- Station must make a reservation before sending data
- Time is divided into intervals, at each interval, a reservation frame precedes the data frame
- N stations, N minislots in the reservation frame
- Station that have made reservations can send data frames after reservation frame



# Polling

- Designated primary and secondary stations
- Data exchanges must be made through the primary device even when destination is a secondary
- Primary station controls the link



# Polling

- Select
  - Used whenever primary has something to send
  - Must check if the receiver is ready receive
  - A SEL frame is send first, and station waits for ACK
- Poll
  - Used by primary to solicit transmissions from secondary devices
  - Must poll all stations

# Token Passing

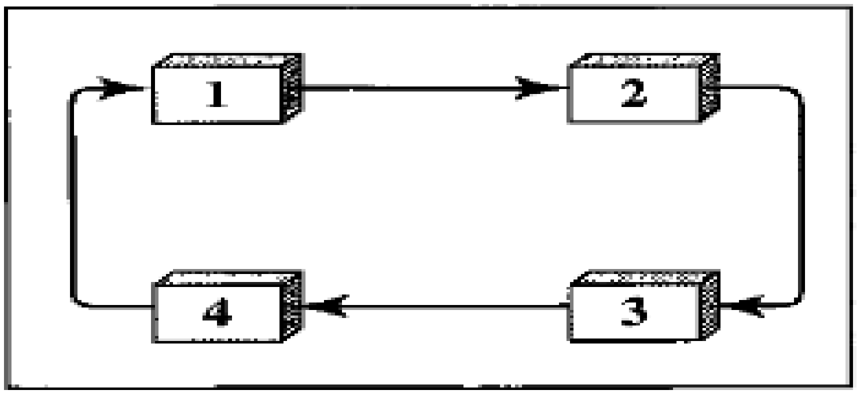
- Stations in a network is organized in a logical ring
- For each station, there is a predecessor and a successor
- Current station has access to channel, right to access has been passed from predecessor, will be passed to the successor
- A special frame, token frame, circulates around the ring
- Token frame gives right access to a station

# Token Passing

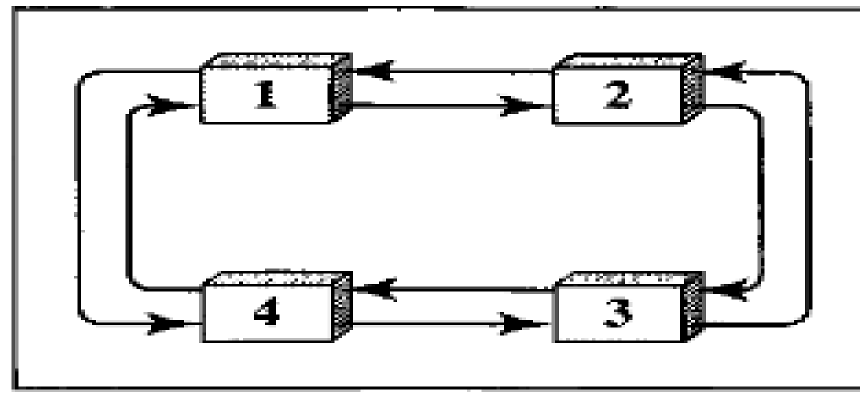
- Token Management
  - Stations must be limited in the time they can have possession of the token
  - Token must be monitored to ensure it has not been lost or destroyed
  - Assign priorities to stations
  - Low-priority stations must release the token to high priority stations

# Token Passing

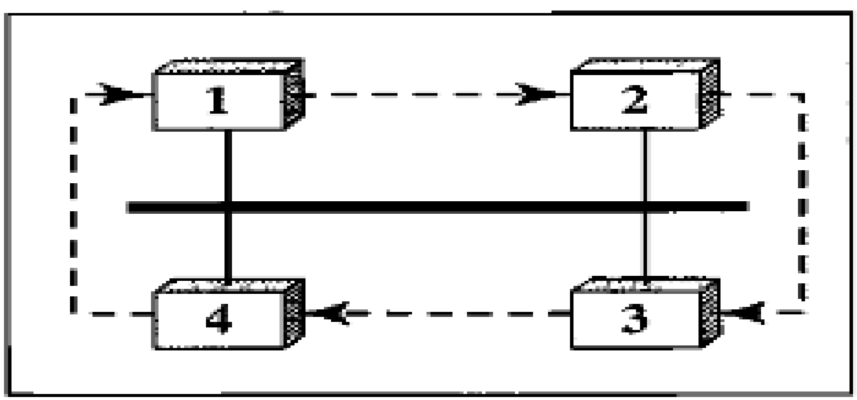
- Logical Ring



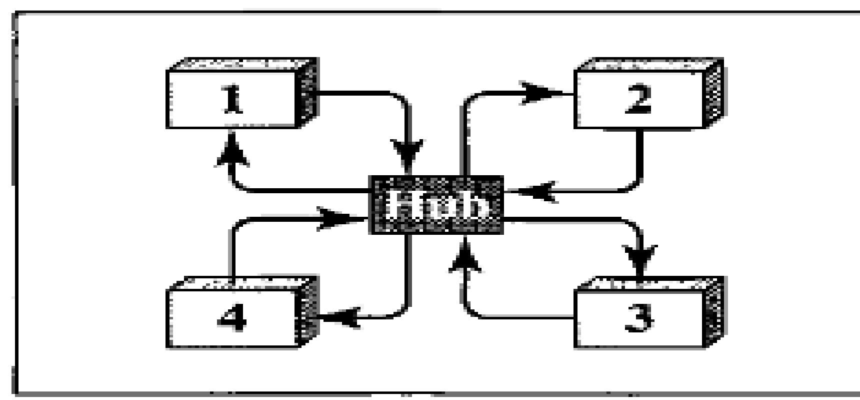

a. Physical ring




b. Dual ring




c. Bus ring



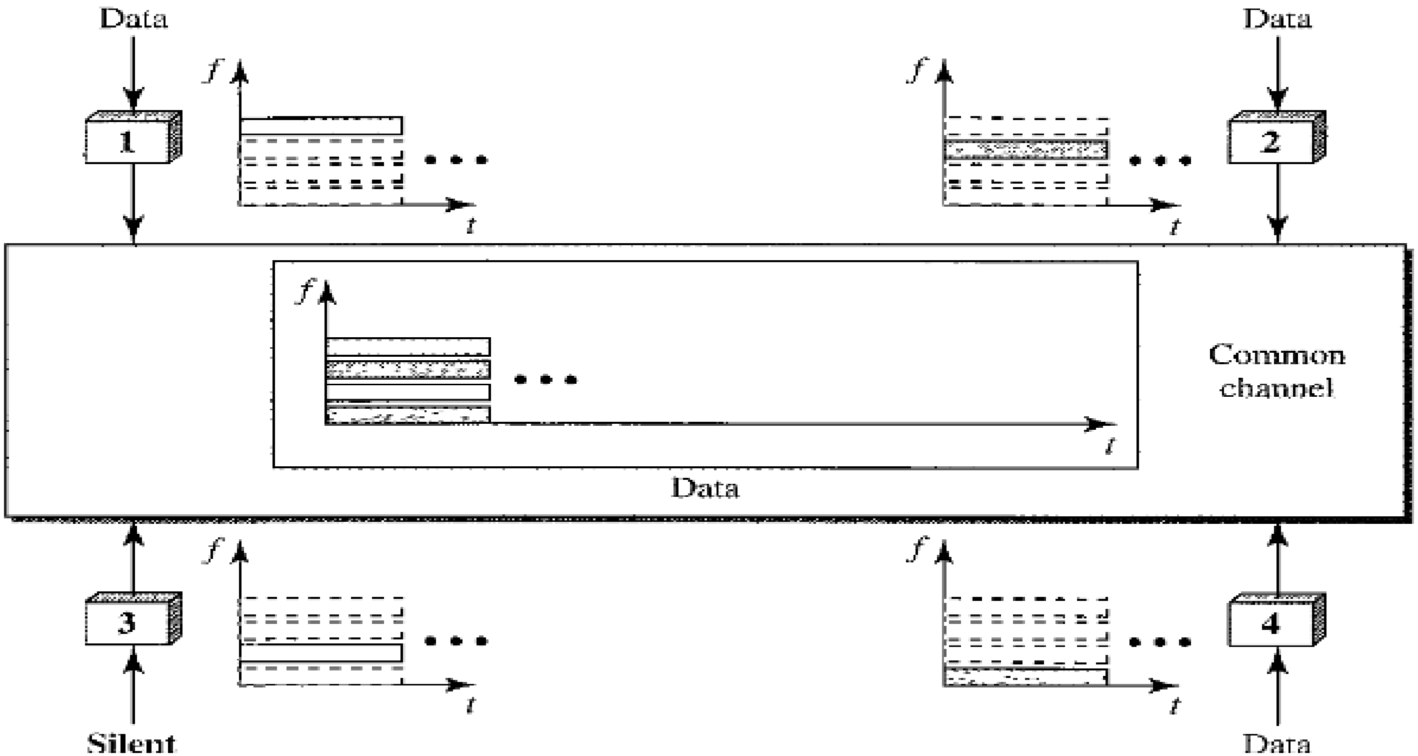

d. Star ring

# Channelization

- Multiple-access method in which available bandwidth of a link is shared in time, frequency, or code
- Protocols: FDMA, TDMA, CDMA

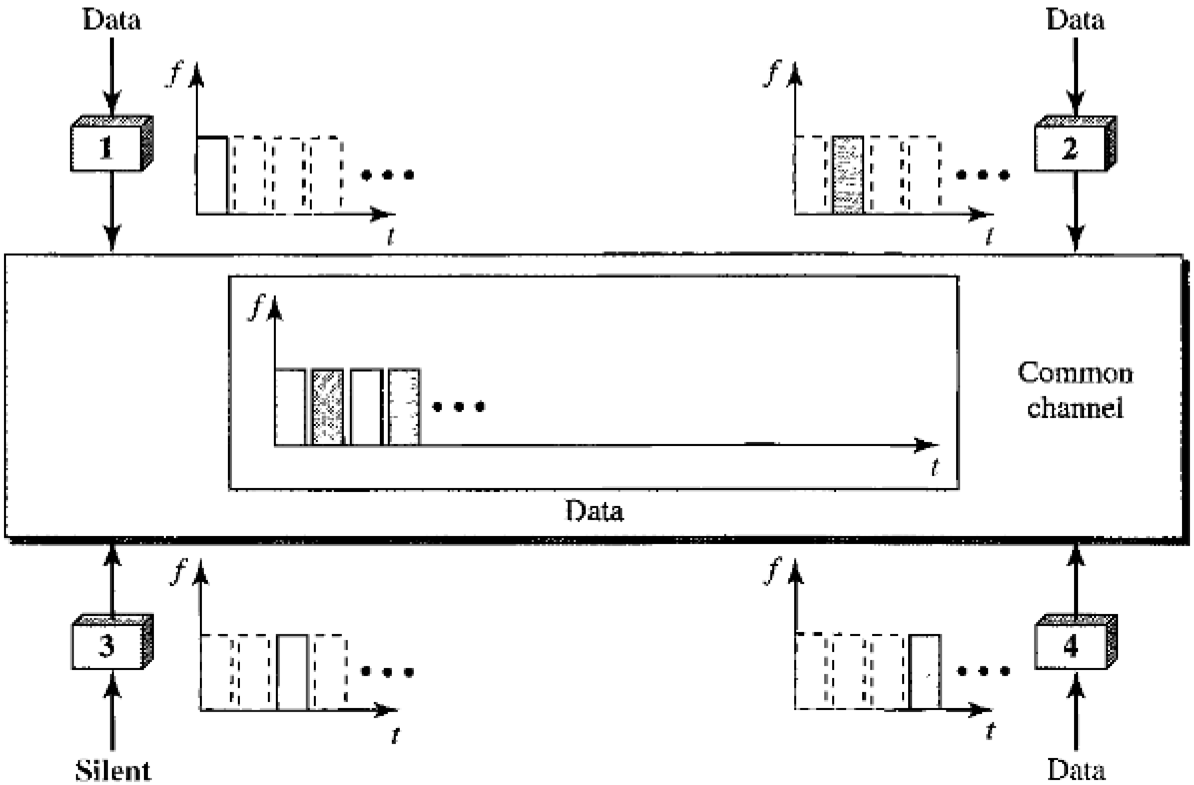
# FDMA

- Frequency-Division Multiple Access
- Available bandwidth is divided into bands separated by guard bands



# TDMA

- Time-Division Multiple Access
- Share the bandwidth of the channel in time
- Sync problem present



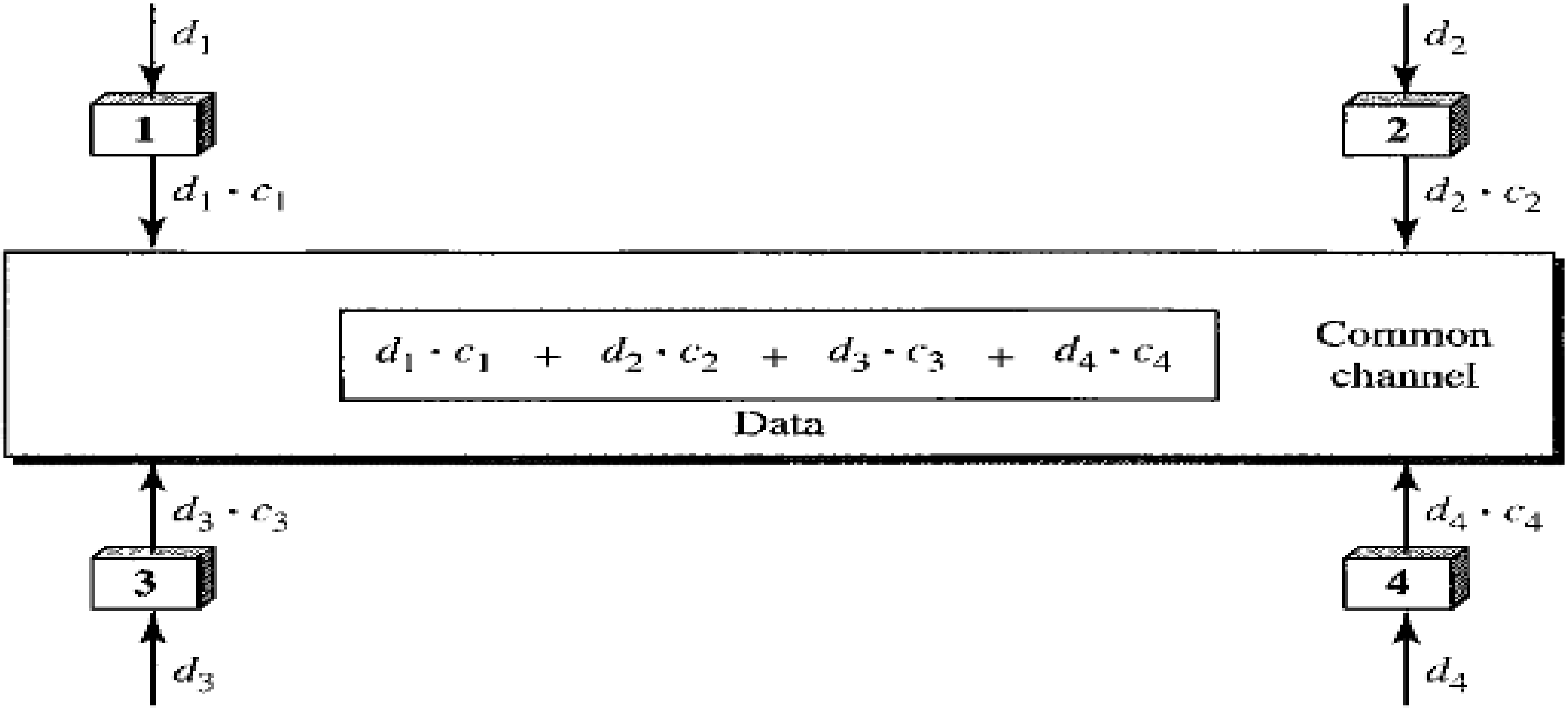
# CDMA

- Code-Division Multiple Access
- One channel carries all transmissions simultaneously
- Communication with different codes

# CDMA

- Assume we have four stations 1,2,3,4
- Data from station 1 are $d_1$, from station 2 are $d_2$, etc
- Code assigned to station 1 is $c_1$, to the second is $c_2$
- Assume the code has the ff. properties
  - If we multiply each code by another we get 0
  - If we multiply each code by itself we get 4 (number of stations)

# CDMA




$$\begin{aligned}\text{data} &= (d_1 \cdot c_1 + d_2 \cdot c_2 + d_3 \cdot c_3 + d_4 \cdot c_4) \cdot c_1 \\ &= d_1 \cdot c_1 \cdot c_1 + d_2 \cdot c_2 \cdot c_1 + d_3 \cdot c_3 \cdot c_1 + d_4 \cdot c_4 \cdot c_1 = 4 \times d_1\end{aligned}$$

Enjoy! :)