CS321: Computer Networks

Media Access Control (MAC)

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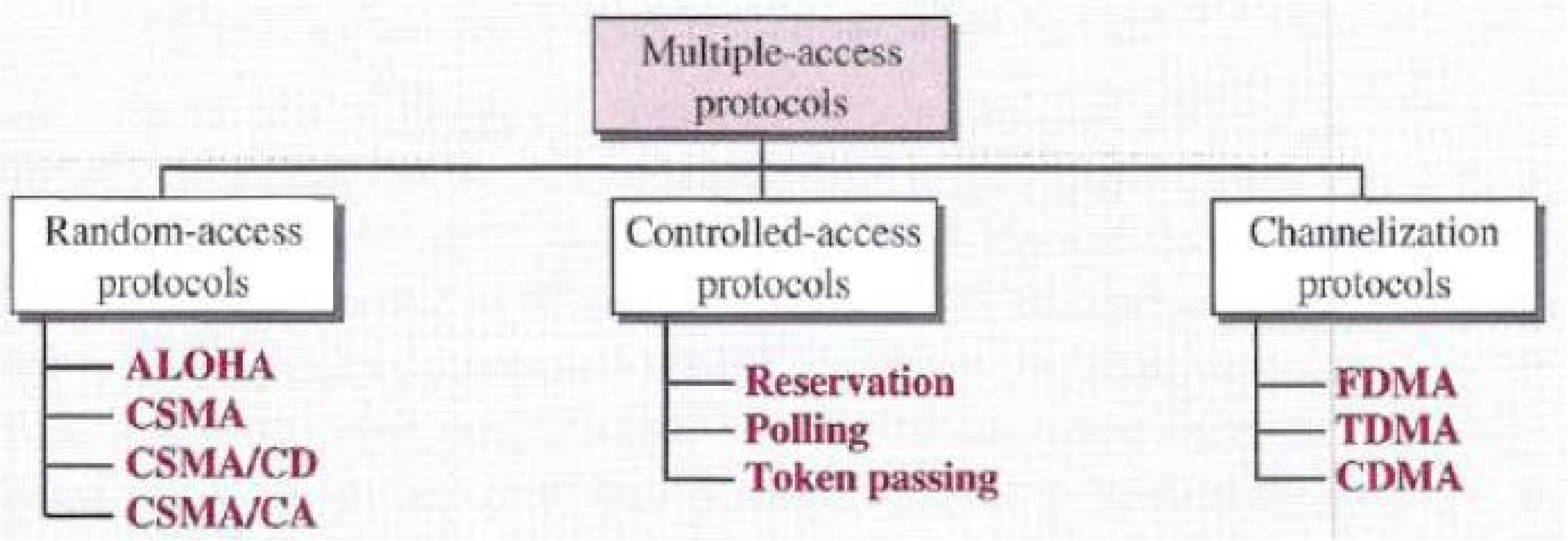
Introduction to MAC

- Two types of network links:
  - point-to-point links
    - protocol => PPP, HDLC
  - broadcast links
    - protocol => multiple access protocols

- Handles the problem of controlling the access to the medium which is shared among nodes
  - Who
  - When
  - How

Multiple Access Protocols



- Random Access
  - No station is superior to another station
  - None is assigned control over another
  - No scheduled time for transmission
  - Station compete with one another to access the medium

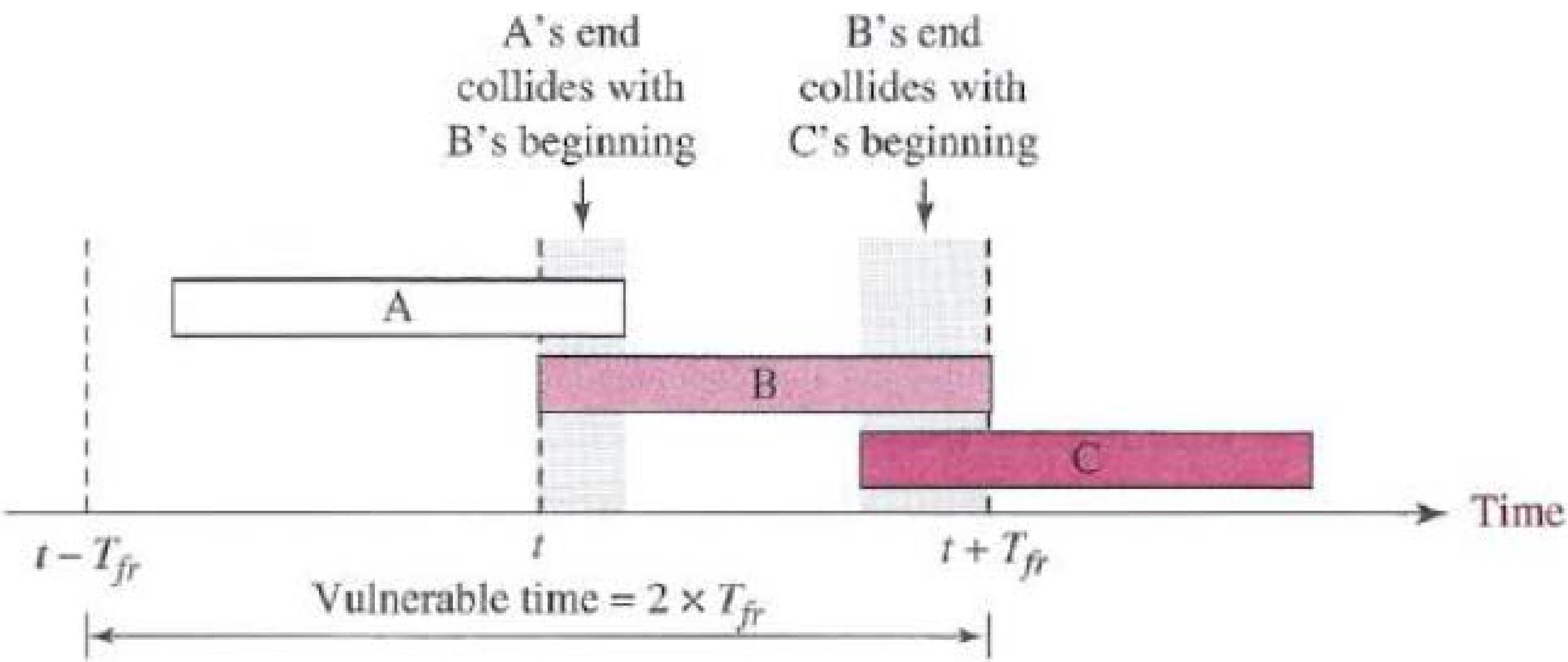
Pure ALOHA

- Developed in early 1970 at University of Hawaii
- Principle:
  - each station sends a frame whenever it has a frame to send
  - relies on acknowledgments from the receiver
  - if time-out occurs, then wait for random backoff time before retransmission
  - after a maximum number of retransmission, a station must give up and try later

  - Time-out := maximum round-trip time
  - Backoff time := random value generated by backoff algorithm (e.g. binary exponential backoff)

Problem in Pure ALOHA

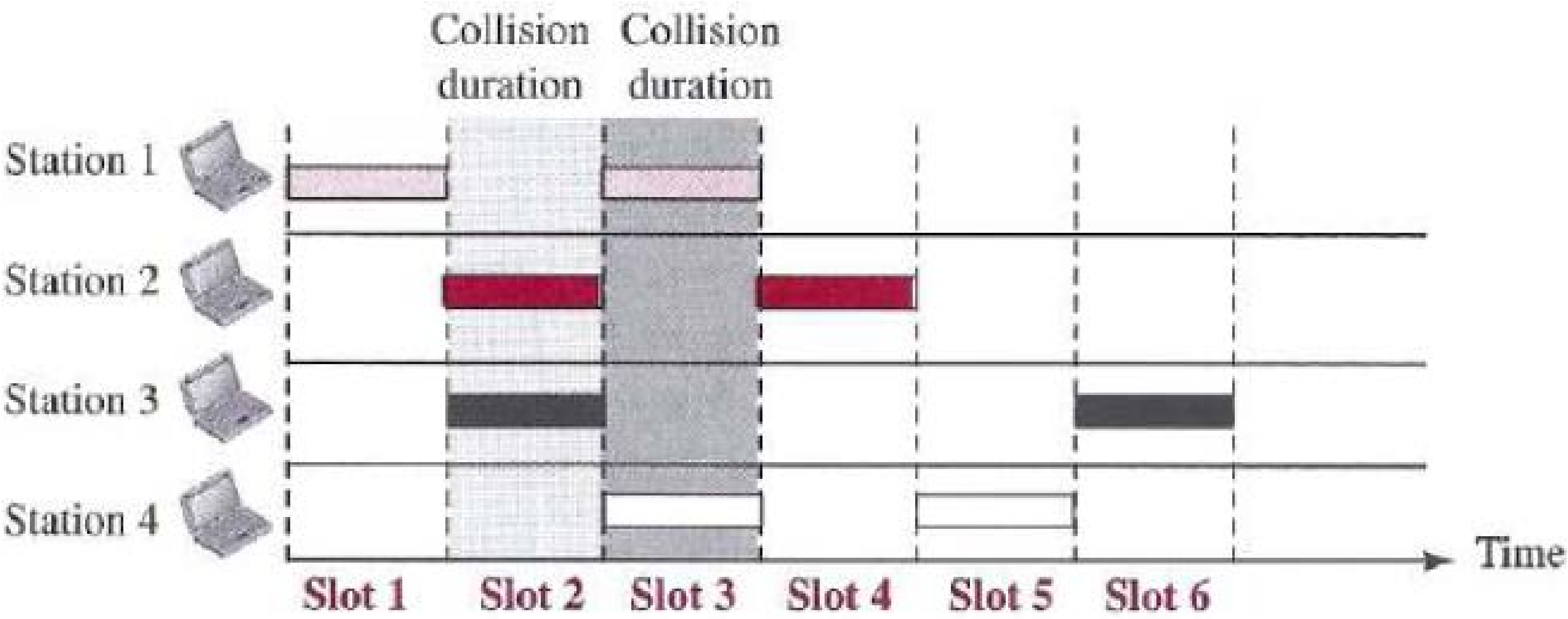
- Frame Collision



- vulnerable time: the length of time in which there is a possibility of collision.

Slotted ALOHA

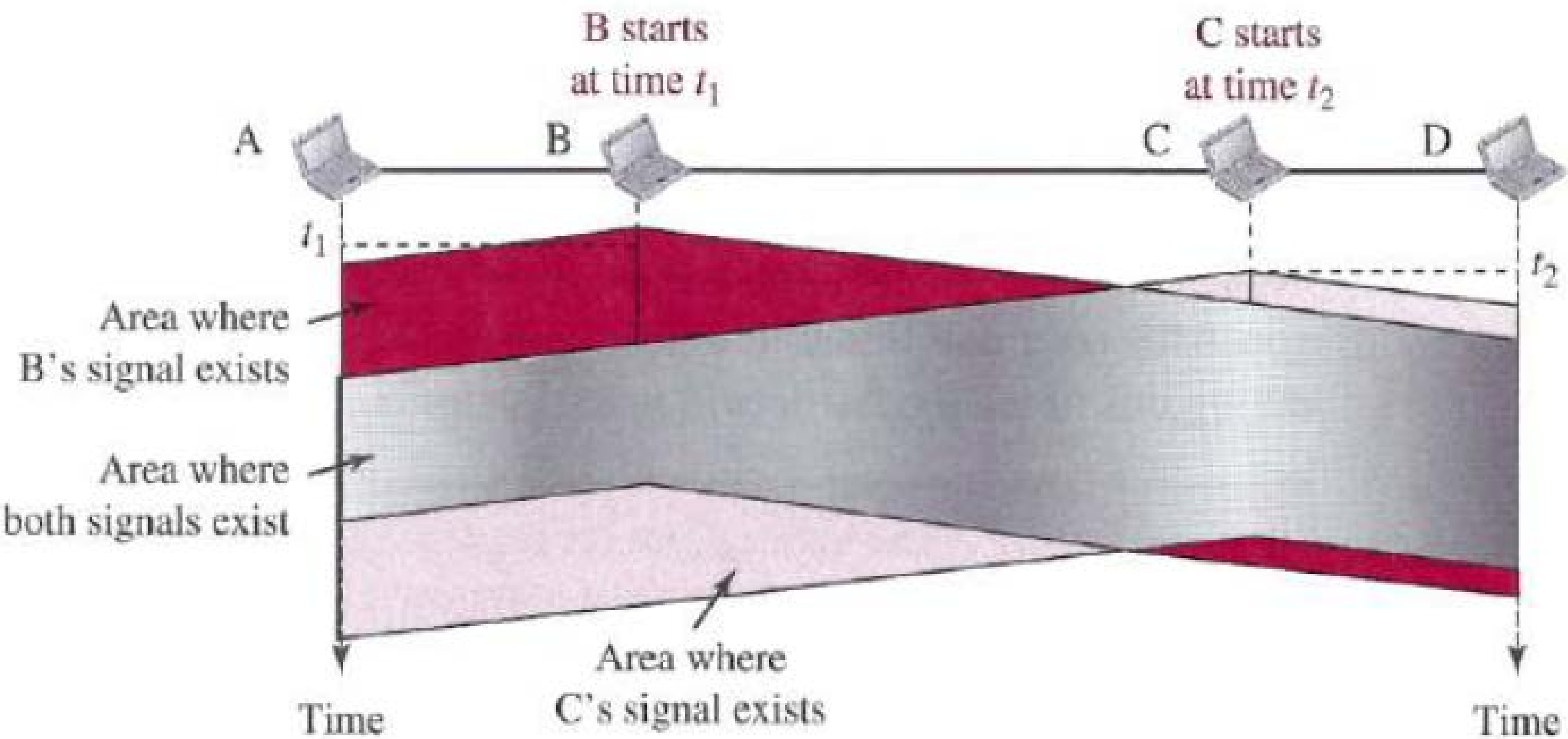
- we divide the time into slots of T_{fr} seconds and force the station to send only at the beginning of the time slot



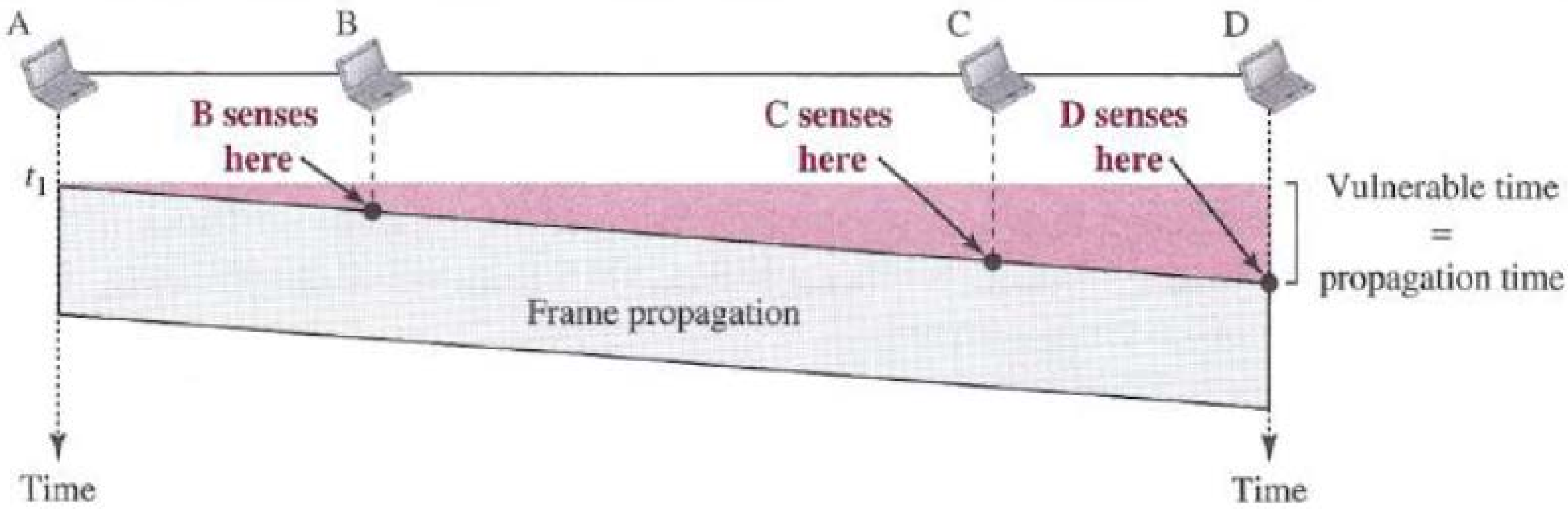
- Vulnerable time= T_{fr}

Carrier Sense Multiple Access

- Sense the medium before trying to use it
- “sense before transmit” or “listen before talk”



CSMA vulnerable time

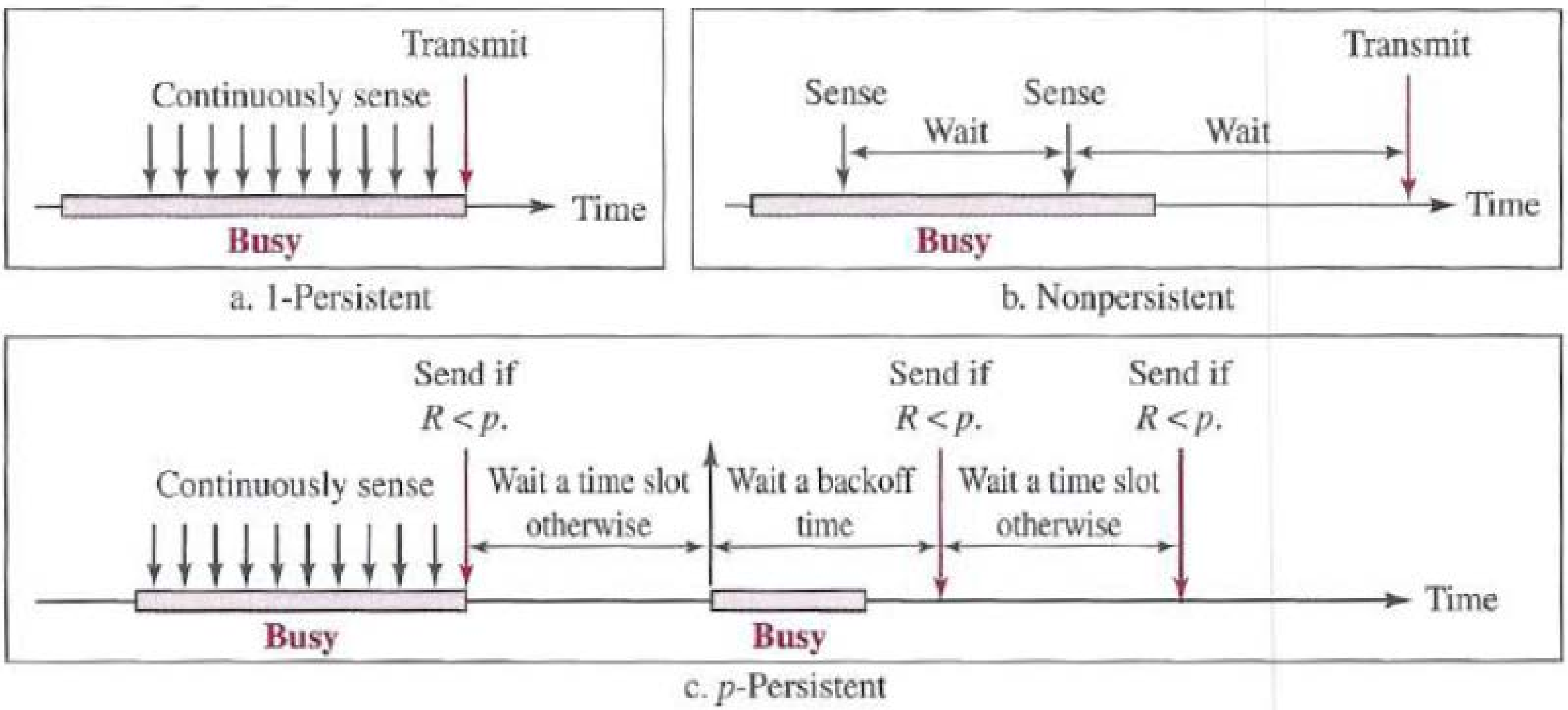


- What should a station do if channel is busy/idle?
  - 1-persistent
  - Non-persistent
  - p-persistent

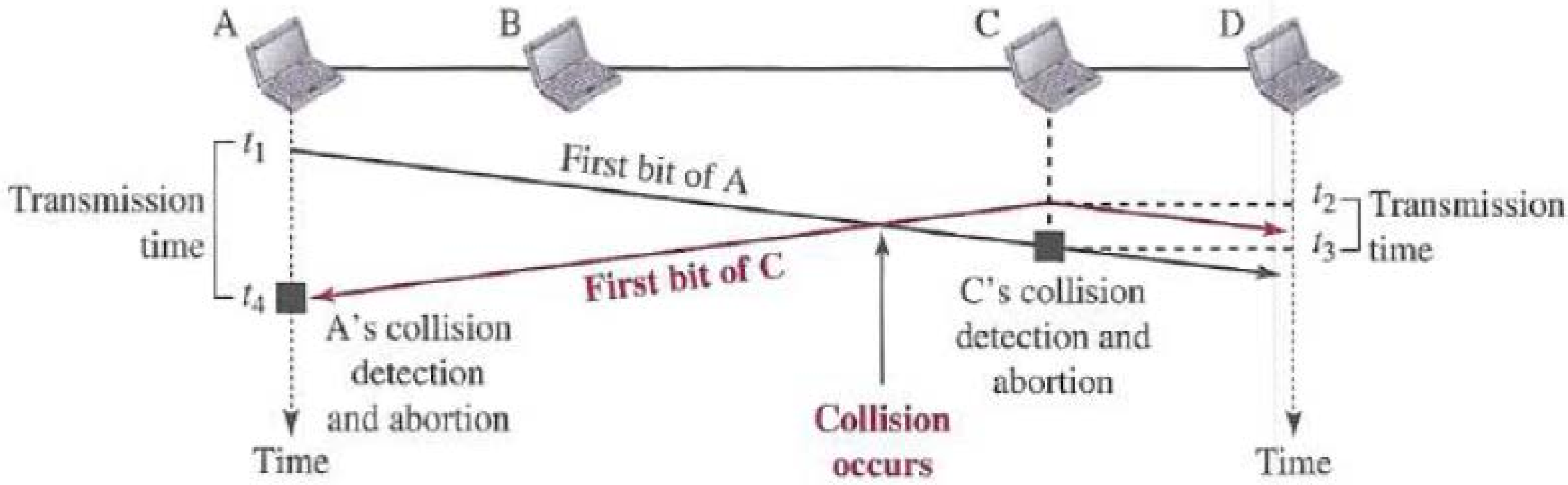
Persistent Methods

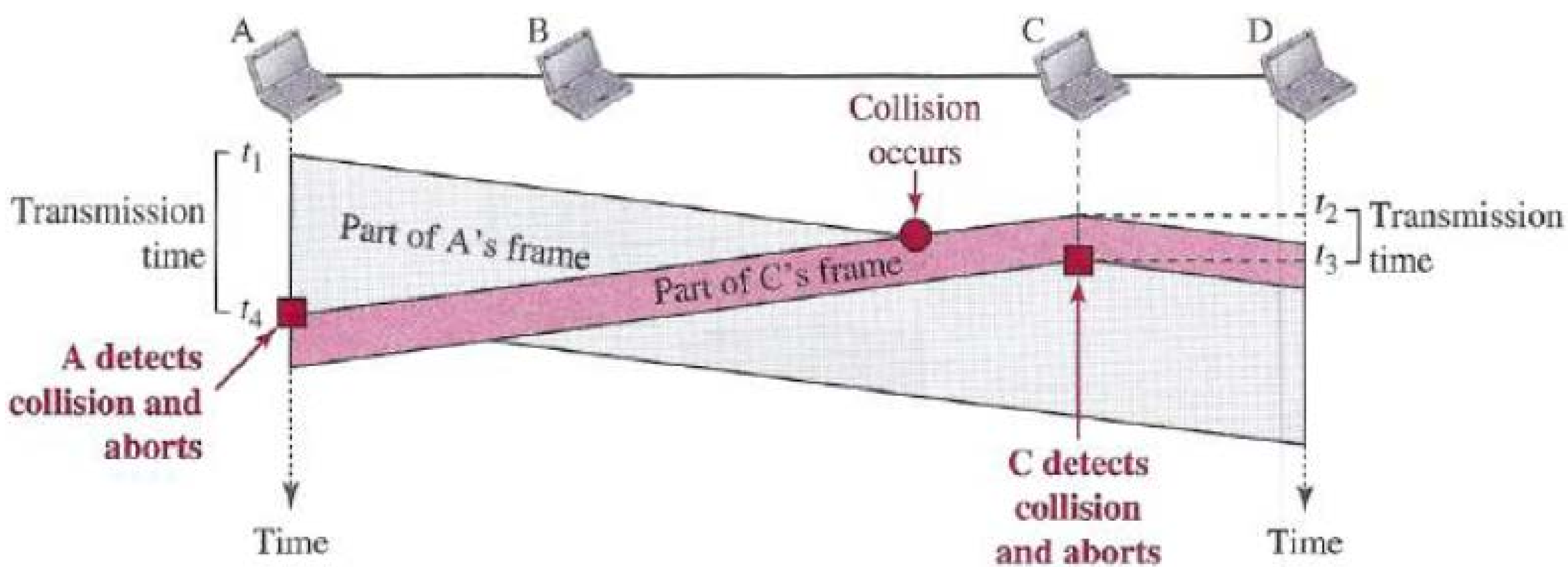
- 1-persistent
  - Continuously sense the channel
  - if idle, transmit frame (with probability 1)
- Non-persistent
  - Sense the channel
  - If idle, transmit frame (with probability 1)
  - If busy, wait a random amount of time and then sense the channel again
- *p*-persistent
  - Non-persistent , but transmit frame (with probability *p*)

Cont…

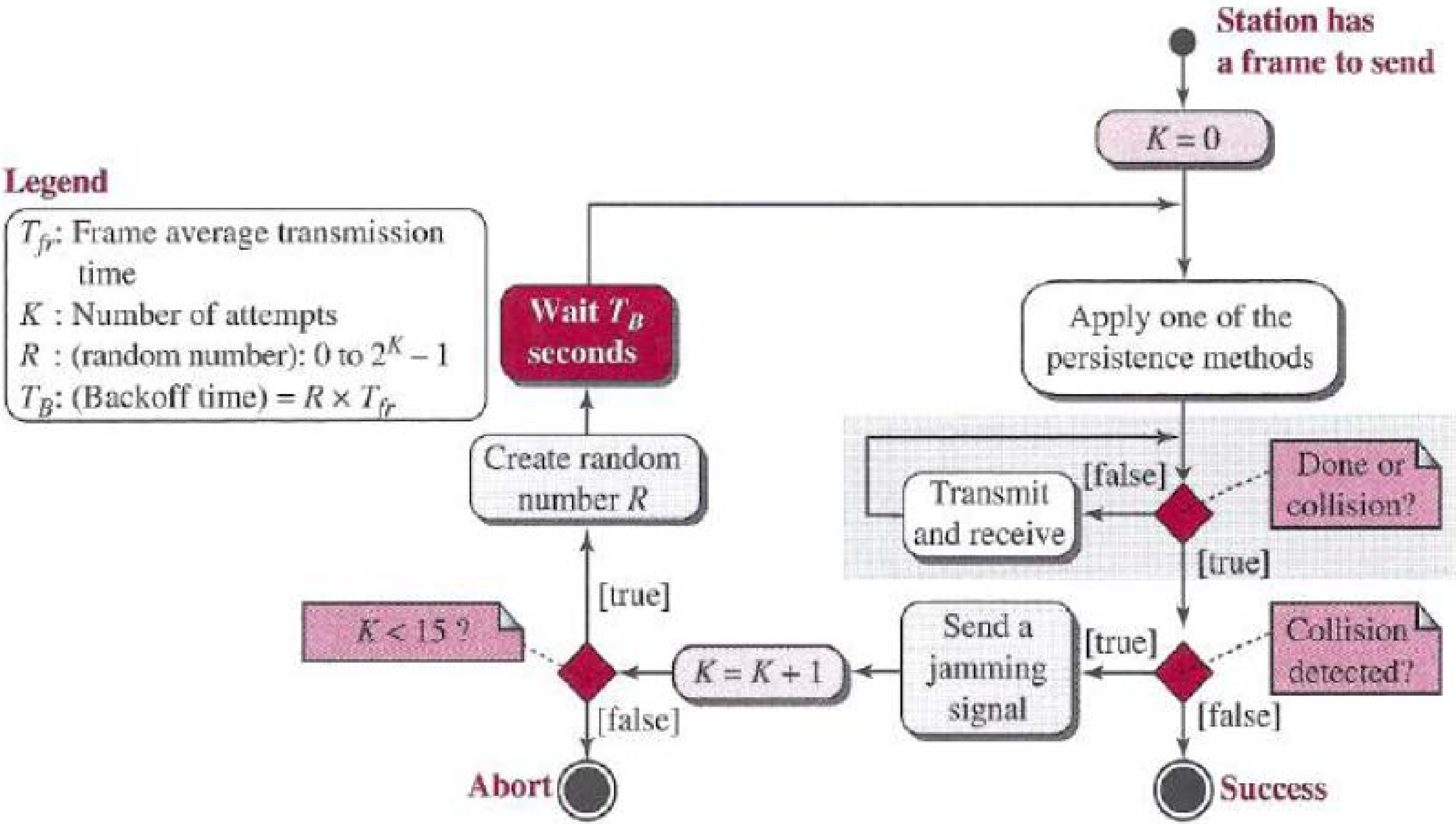

Transmit
Continuously sense
Time
Busy
a. 1-Persistent
Sense
Wait
Sense
Wait
Transmit
Time
Busy
b. Nonpersistent
Send if
$R < p$.
Continuously sense
Wait a time slot
otherwise
Wait a backoff
time
Send if
$R < p$.
Wait a time slot
otherwise
Send if
$R < p$.
Time
Busy
Busy
c. p-Persistent

CSMA/CD (Collision Detection)





Cont…


Station has
a frame to send
K = 0
Legend
T_{fr}: Frame average transmission time
K : Number of attempts
R : (random number): 0 to $2^K - 1$
T_B: (Backoff time) = $R \times T_{fr}$
Wait T_B seconds
Apply one of the persistence methods
Create random number R
[false]
Transmit and receive
Done or collision?
[true]
[true]
$K < 15$?
Send a jamming signal
[true]
Collision detected?
$K = K + 1$
[false]
[false]
Abort
Success

Cont…

- Points to remember:
  - Use of the persistence process
  - The station transmits and receives continuously and simultaneously (using two different ports or a bidirectional port)
  - We constantly monitor in order to detect one of two conditions: either transmission is finished or a collision is detected
  - sending of a short jamming signal to make sure that all other stations become aware of the collision
  - Use of random backoff mechanism
  - Use of retransmission limit

Jamming Signal in CSMA/CD

- Did a collision occur? If so, go to collision detected procedure.
  - In that procedure, continue transmission (**with a jam signal** instead of frame header/data/CRC) until minimum packet time is reached to ensure that all receivers detect the collision.
  - The **jam signal** is a signal that carries a 32-bit binary pattern
  - The maximum jam-time:
    - The maximum allowed diameter of an Ethernet is limited to 232 bits. This makes a round-trip-time of 464 bits. As the slot time in Ethernet is 512 bits, the difference between slot time and round-trip-time is 48 bits (6 bytes), which is the maximum "jam-time".

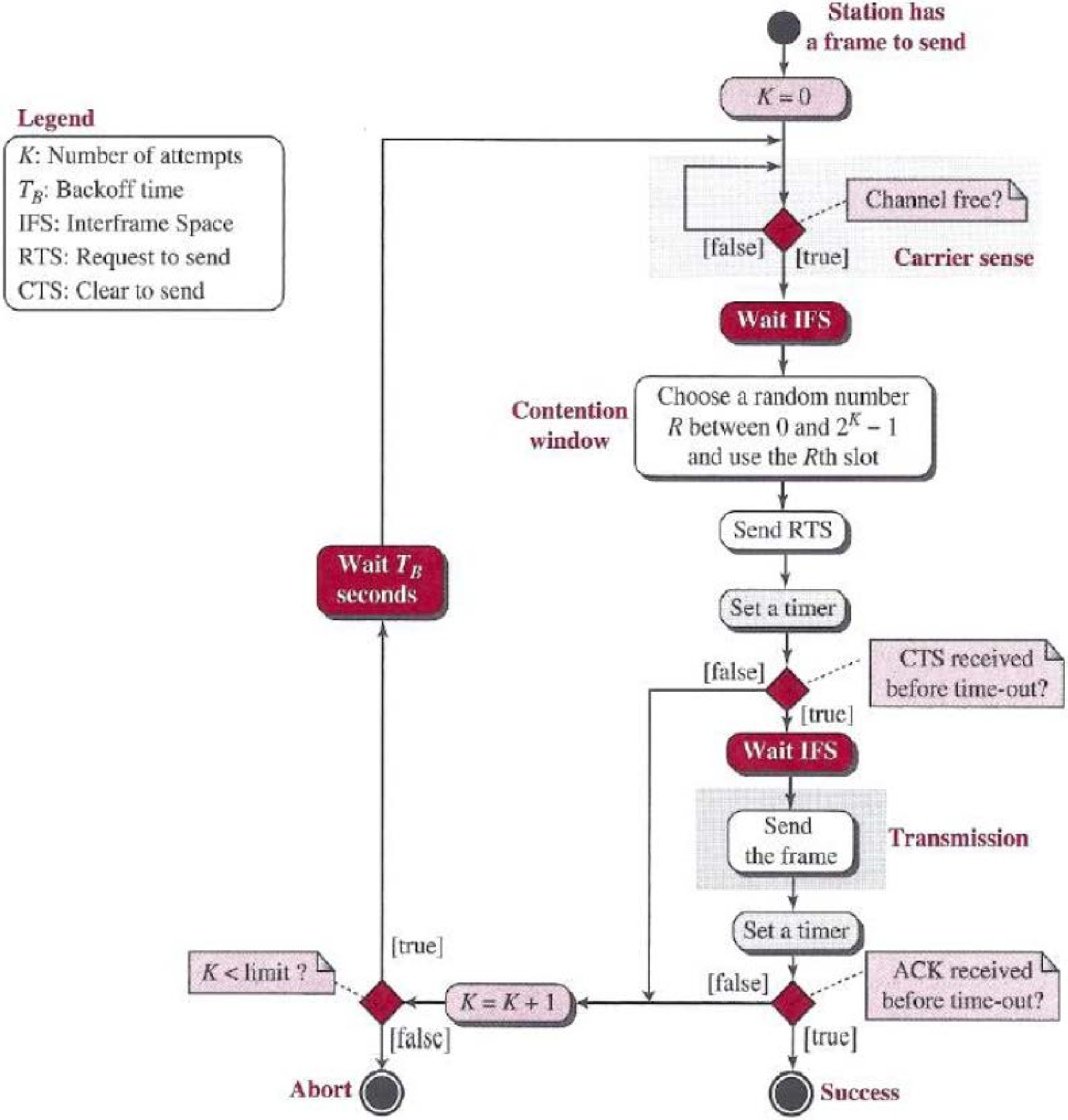
CSMA/CA (Collision Avoidance)

- CSMA/CD is not useful in wireless networks
- So, CSMA/CA was invented
- Why??
  - In wireless, send power (generally around 100mw) and receive sensitivity (commonly around 0.01 to 0.0001mw)
  - The sending would cover up any possible chance of receiving a foreign signal, no chance of "Collision Detection“
  - So, wireless transceivers can't send and receive on the same channel at the same time
  - But, in wired networks (like Ethernet) the voltage is around 1 to 2.5v; sending and receiving are roughly same voltage
  - Let, sending a 2.5v signal, and someone else collides with a 2.5v signal; so receive signal would be around 5v.

Cont…

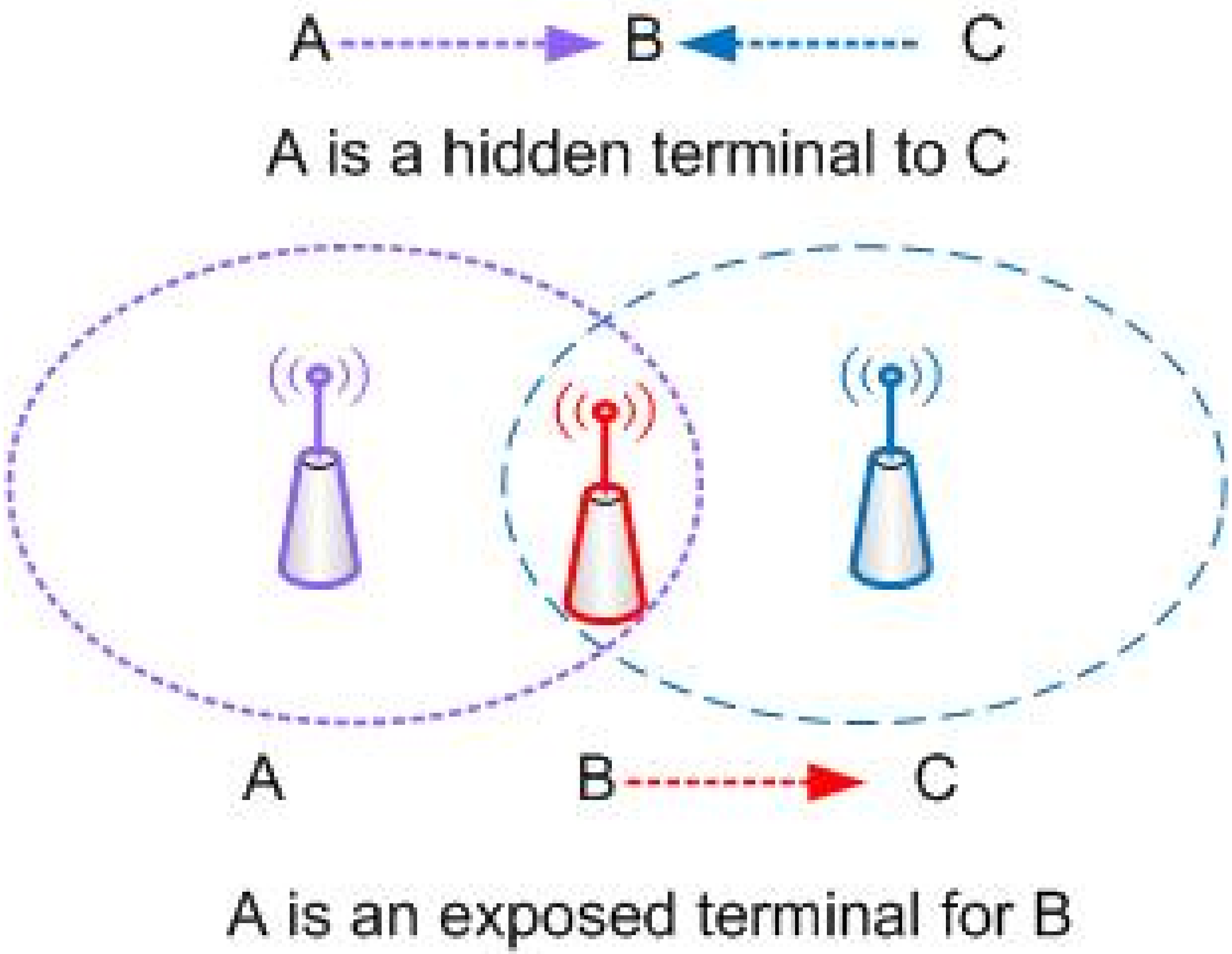
- Common features:
  - Channel sensing; Retransmission; Backoff
- Important modifications:
  - Inter-Frame Space (IFS): used instead of persistent method
  - Contention window (CW) and Binary exponential backoff (BEB) : time is treated in slots
  - Acknowledgement / Timeout : no collision detection
  - Basic / RTS-CTS mode of transmission
  - Use of Network Allocation Vector (NAV)

Cont…

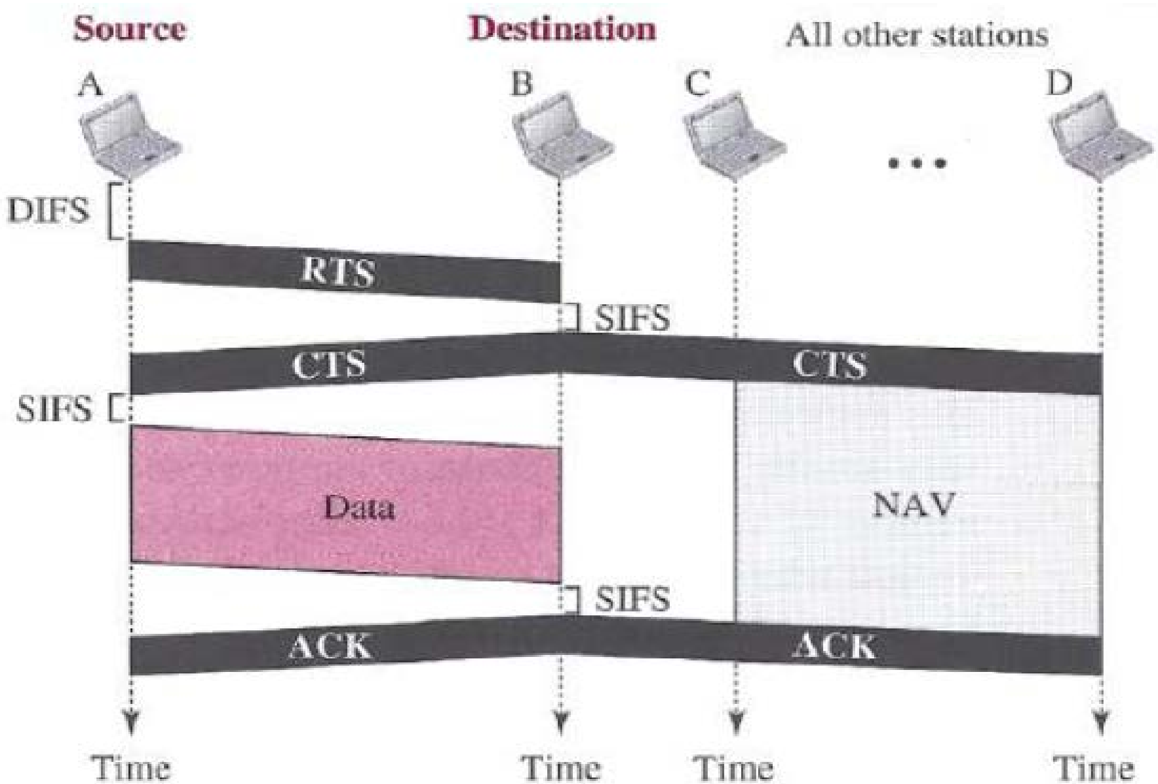


Legend
K: Number of attempts
T_B: Backoff time
IFS: Interframe Space
RTS: Request to send
CTS: Clear to send
Station has a frame to send
K = 0
Channel free?
[false]
[true]
Carrier sense
Wait IFS
Contention window
Choose a random number R between 0 and $2^K - 1$ and use the Rth slot
Send RTS
Set a timer
CTS received before time-out?
[false]
[true]
Wait IFS
Send the frame
Transmission
Set a timer
ACK received before time-out?
[false]
[true]
Success
K = K + 1
K < limit ?
[true]
[false]
Abort
Wait T_B seconds

HT/ET Problem



RTS/CTS-based Approach



RTS: Request-to-send
CTS: Clear-to-send
ACK: Acknowledgement

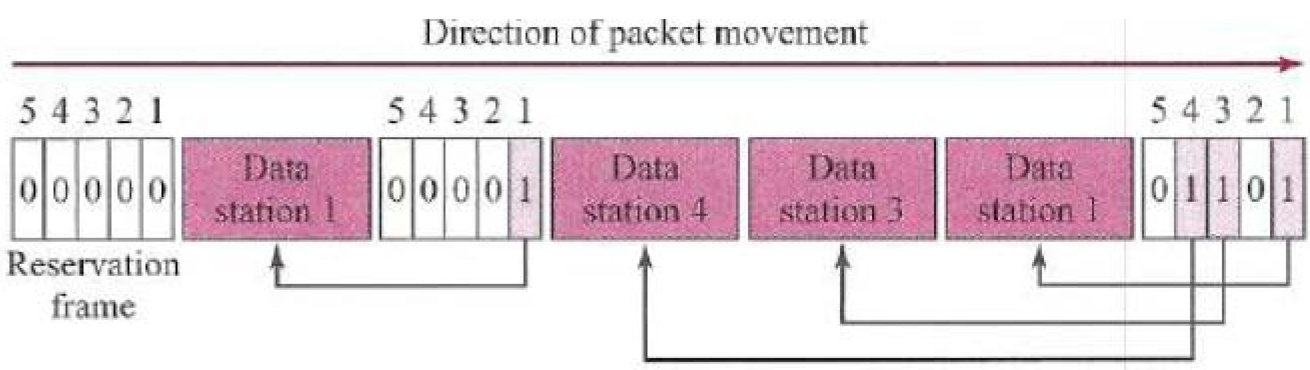
NAV: how much time must pass before these stations are allowed to check the channel for idleness.

DIFS: DCF Inter-frame Space = SIFS + 2*slot time

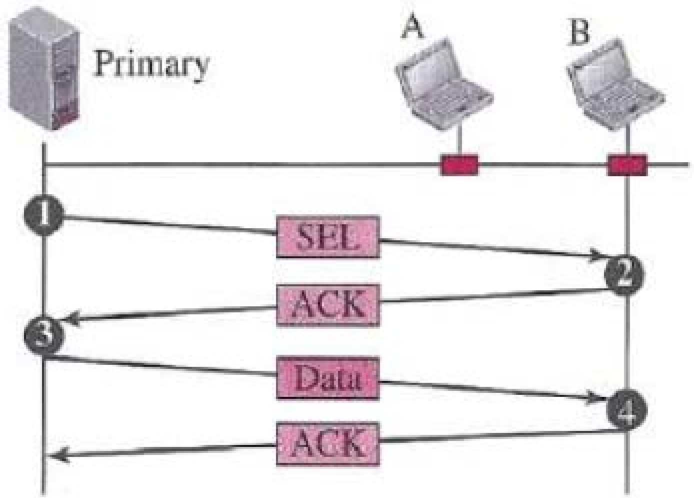
SIFS: Short Inter-frame Space

Controlled Access

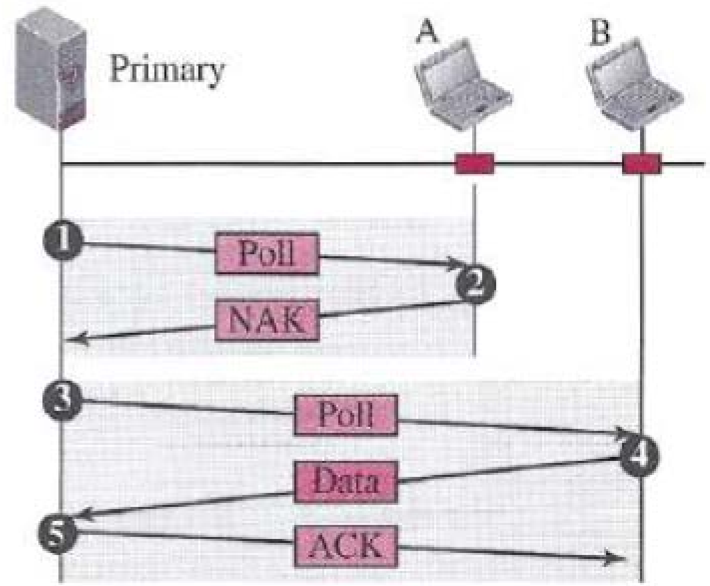
- Basic Idea: the stations consult one another before transmission
- Approaches:
  - Reservation
  - Polling
  - Token Passing



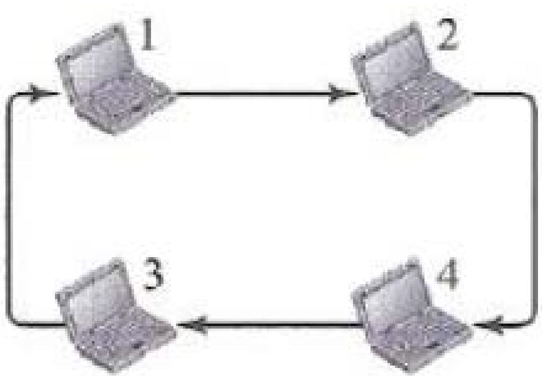
Cont…



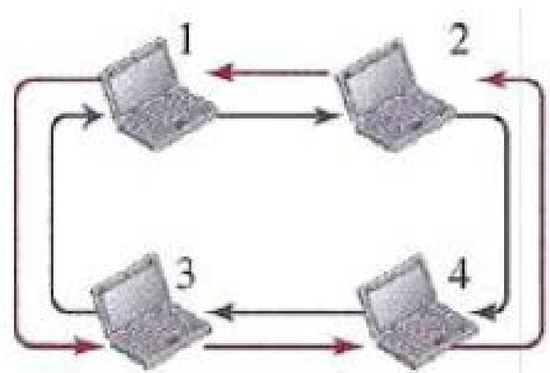
Select



Poll



a. Physical ring



b. Dual ring

Channelization Approach

- Basic idea: the available bandwidth of a link is shared in time, frequency, or through code, among different stations.

- Protocols:
  - FDMA (frequency-division multiple access)
  - TDMA (time-division multiple access)
  - CDMA (code-division multiple access)

Basic Idea of CDMA

- Let 4 stations: 1,2,3,4
- Their data frames: d_1, d_2, d_3, d_4
- Assigned codes: c_1, c_2, c_3, c_4
  - Property-1: $c_i \,.\, c_k$ => 0
  - Property-2: $c_i \,.\, c_i$ => 4 (number of station)
- Channel carrying:
  - $(d_1.c_1)+(d_2.c_2)+(d_3.c_3)+(d_4.c_4)$
- Let station 1 & 3 are talking,
- station1 wants data from station3
- Station1 do:

  $(d1.c1)+(d2.c2)+(d3.c3)+(d4.c4).c_3 = 4.d_3$

Chip Sequences & Operations

C_1	C_2	C_3	C_4
[+1 +1 +1 +1]	[+1 −1 +1 −1]	[+1 +1 −1 −1]	[+1 −1 −1 +1]

- Multiply by number: $2 \bullet [+1\ +1\ -1\ -1] = [+2\ +2\ -2\ -2]$
- Inner product: $[+1\ +1\ -1\ -1] \bullet [+1\ +1\ -1\ -1] = 1 + 1 + 1 + 1 = 4$

  $[+1\ +1\ -1\ -1] \bullet [+1\ +1\ +1\ +1] = 1 + 1 - 1 - 1 = 0$
- Addition: $[+1\ +1\ -1\ -1] + [+1\ +1\ +1\ +1] = [+2\ +2\ 0\ 0]$
- Encoding Rules:

  0 => -1; 1=> 1; silence => 0

Example

- wants to send:
  - Station1: 0; Station2: 0; Station3: silent; Station4: 1
- Encoded to: [-1, -1, 0, 1]
- Transmitted:

  [-1.(+1 +1 +1 +1)] + [-1.(+1 -1 +1 -1)] + [0.(+1 +1 -1 -1)] +[+1 .(+1 -1 -1 +1)]

  =[-1 -1 -1 -1] + [-1 +1 -1 +1] + [0 0 0 0] + [+1 -1 -1 +1]

  =[-1 -1 -3 1]
- Let station4 wants to listen station2
  - Station4 do: [-1 -1 -3 +1].[+1 -1 +1 -1] = -4
  - Receive: -4/4 = -1 → bit 0

Walsh Table

$$W_1 = \begin{bmatrix} +1 \end{bmatrix} \quad W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

a. Two basic rules

$$W_2 = \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix} \quad W_4 = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \end{bmatrix}$$

b. Generation of W_2 and W_4

Thanks!