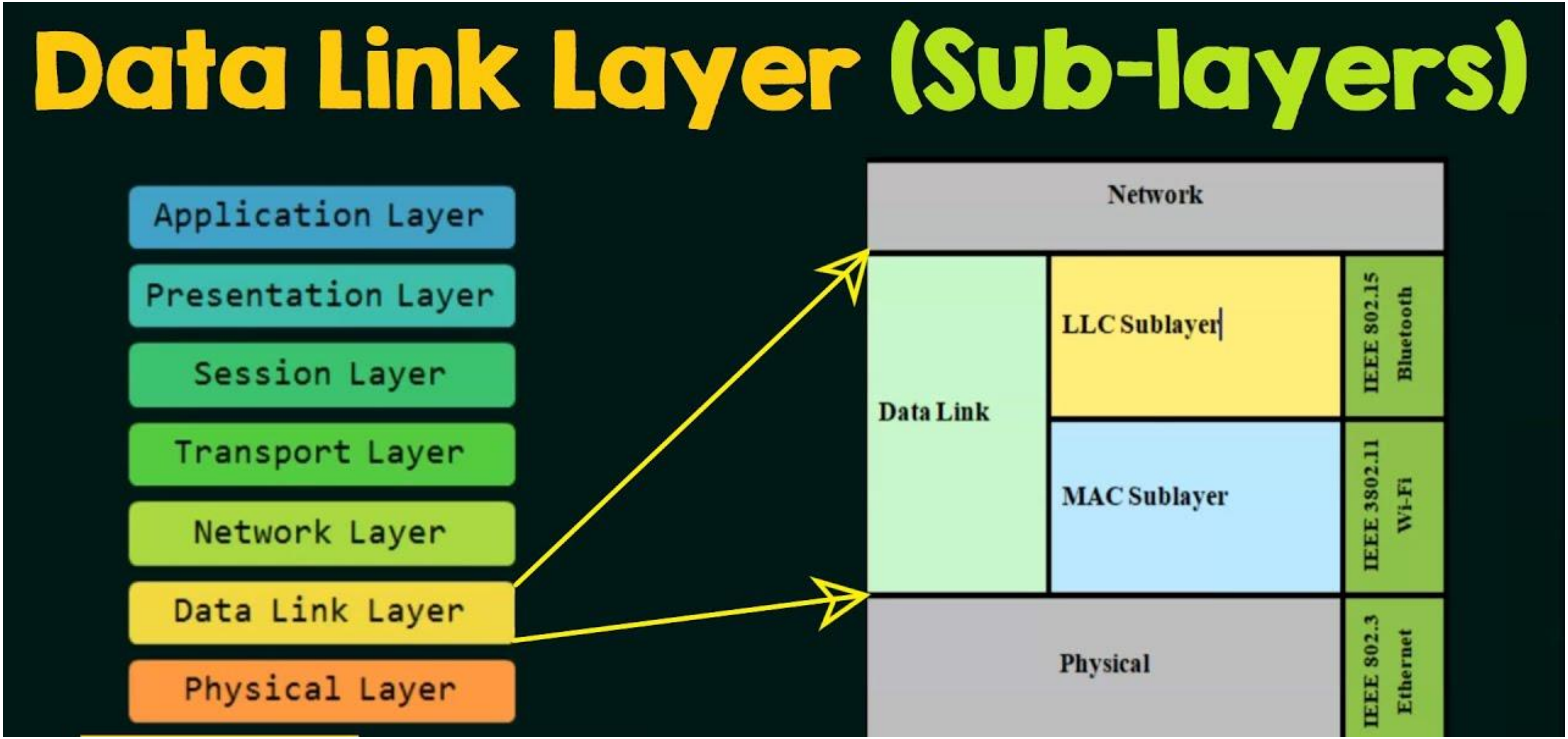
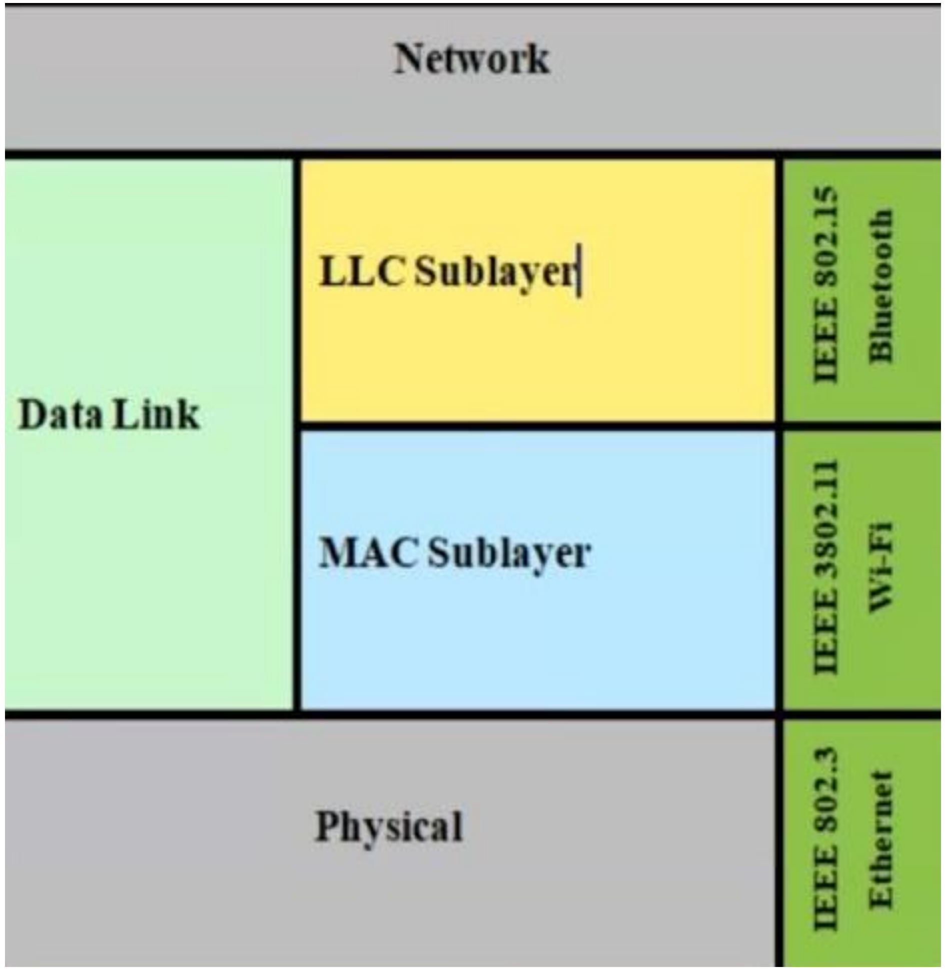
Lec-3.1:Sublayers of Datalink Layer


Data Link Layer (Sub-layers)
Application Layer
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer
Network
Data Link
LLC Sublayer
MAC Sublayer
Physical
IEEE 802.15
Bluetooth
IEEE 3802.11
Wi-Fi
IEEE 802.3
Ethernet

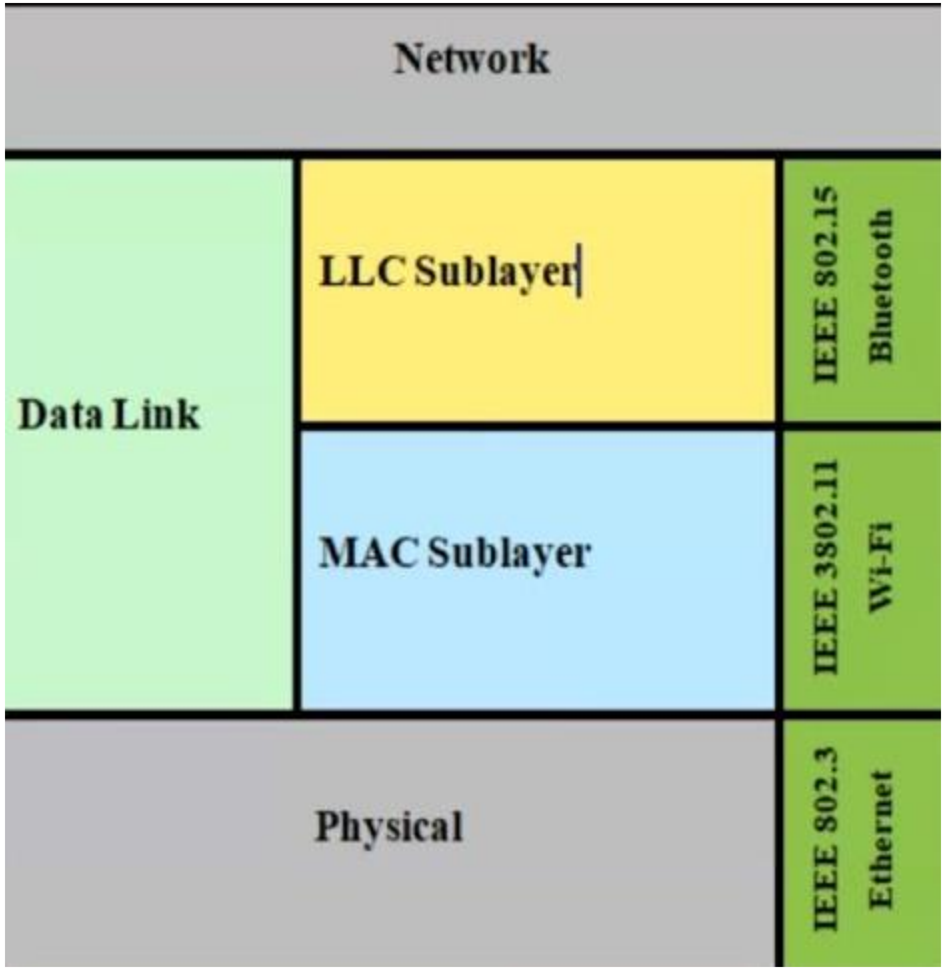
Logical Link Control (LLC) or Data Link Control (DLC)

- Handles communication between upper layer and lower layers
- Specific roles: Takes network protocol data and adds control information to help deliver packets to destination (flow control). Layer deals with the information of network layer.



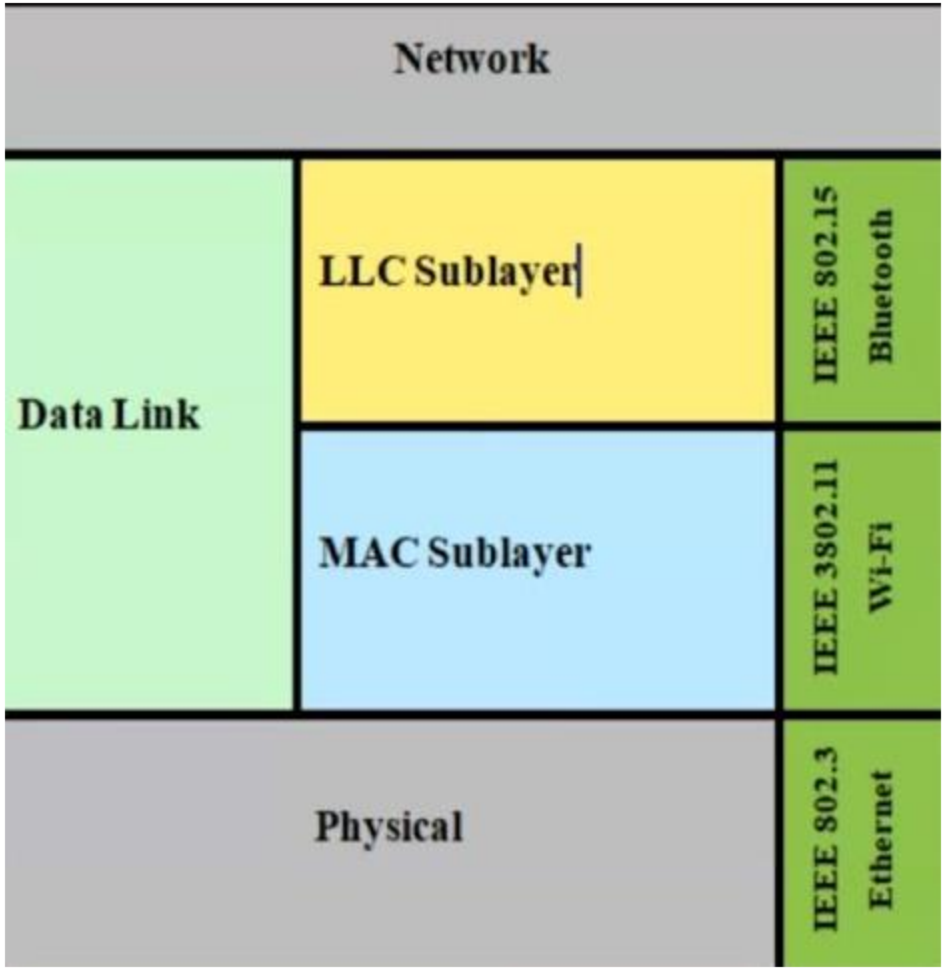
MAC Sublayer

- Constitutes lower sublayer of datalink layer
- Implemented by computer hardware, typically in the computer NIC (MAC address)
- Direct interactivity with physical layer
- Two responsibilities
  - Data Encapsulation: frame assemble before transmission and disassembly upon reception
  - Adds header and trailer information to the network layer PDU
  - Media Access Control
- Three primary functions
  i. Framing
  ii. Physical Addressing
  iii. Error Control



MAC Sublayer

- Upon creation of frame MAC sublayer responsible for placement and removal of frames information on and from media
- Communicates directly to physical layer

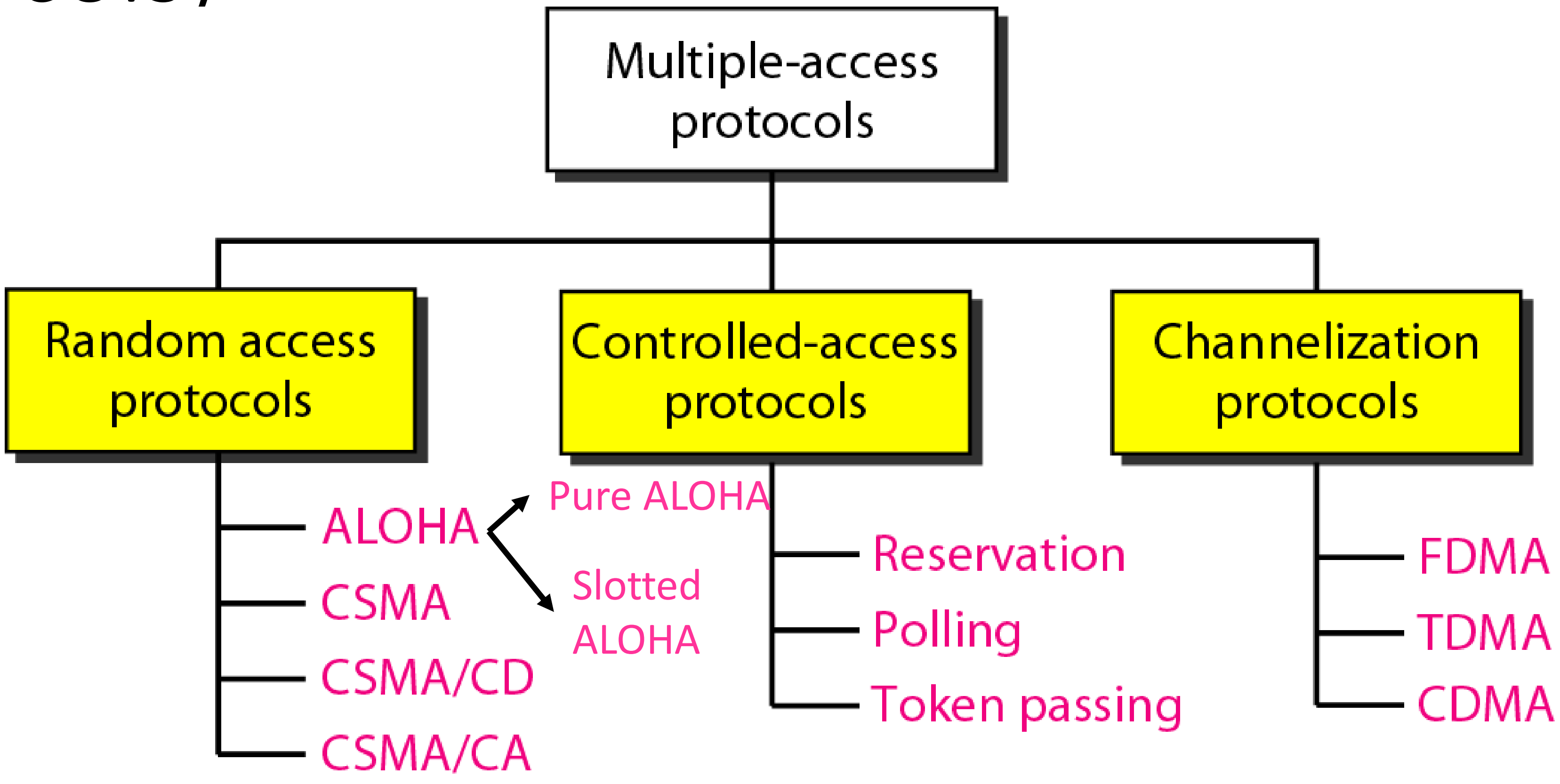


Complete the following task

Service	Sublayer
Flow Control	
Framing	
Physical Addressing	
Error Control	
Access Control	

Service	Sublayer
Flow Control	LLC or DLC
Framing	MAC
Physical Addressing	MAC
Error Control	MAC
Access Control	MAC

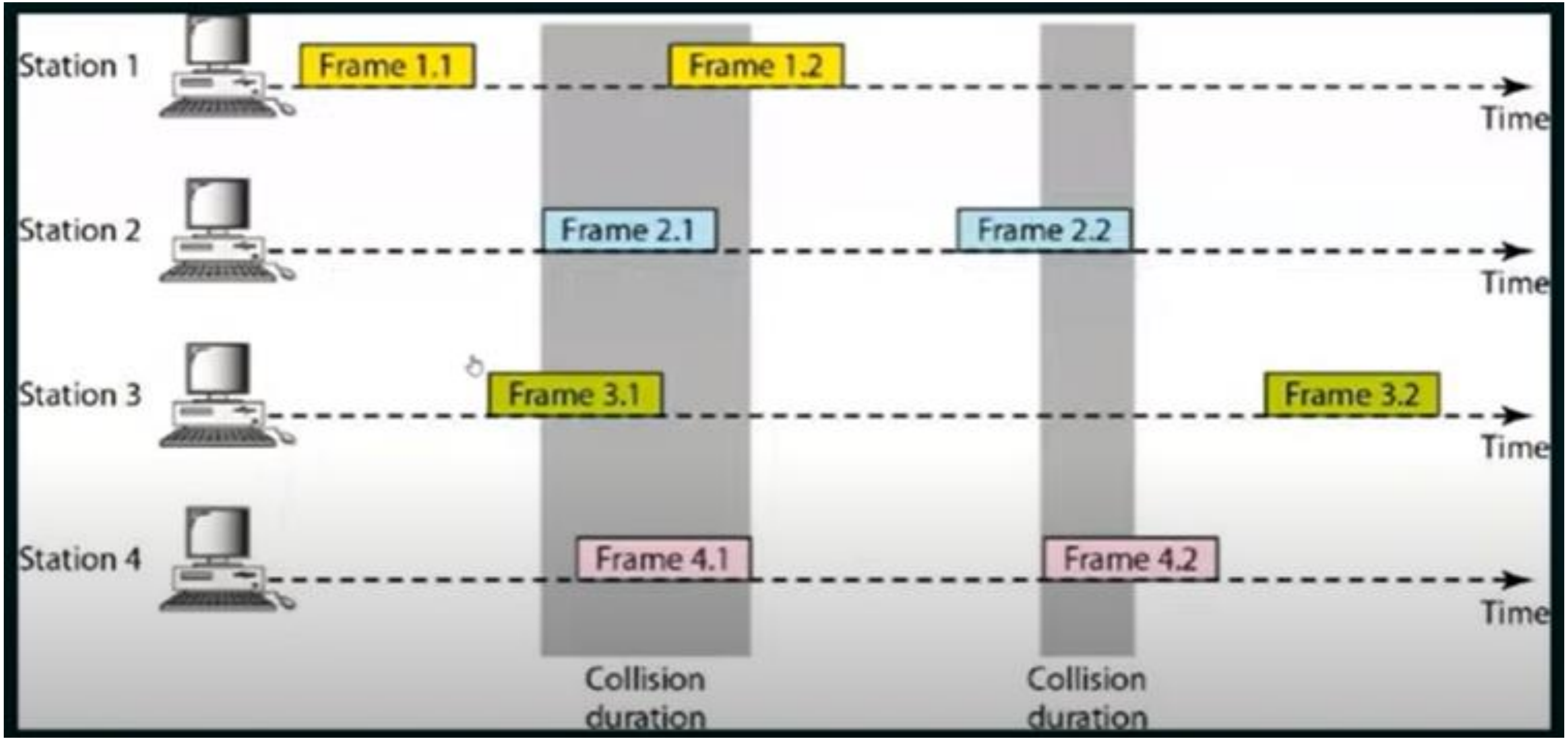
Multiple Access Control Protocol (MAC Protocols)



Pure ALOHA

- Random Access Protocol
- Acknowledgement is there
- LAN based
- Only transmission time
- No propagation time
- Vulnerable time, $V_t = 2*T_t$
- Efficiency, $\eta = G*e^{-2G}$

Pure ALOHA


Station 1
Frame 1.1
Frame 1.2
Time
Station 2
Frame 2.1
Frame 2.2
Time
Station 3
Frame 3.1
Frame 3.2
Time
Station 4
Frame 4.1
Frame 4.2
Time
Collision duration
Collision duration

Pure ALOHA

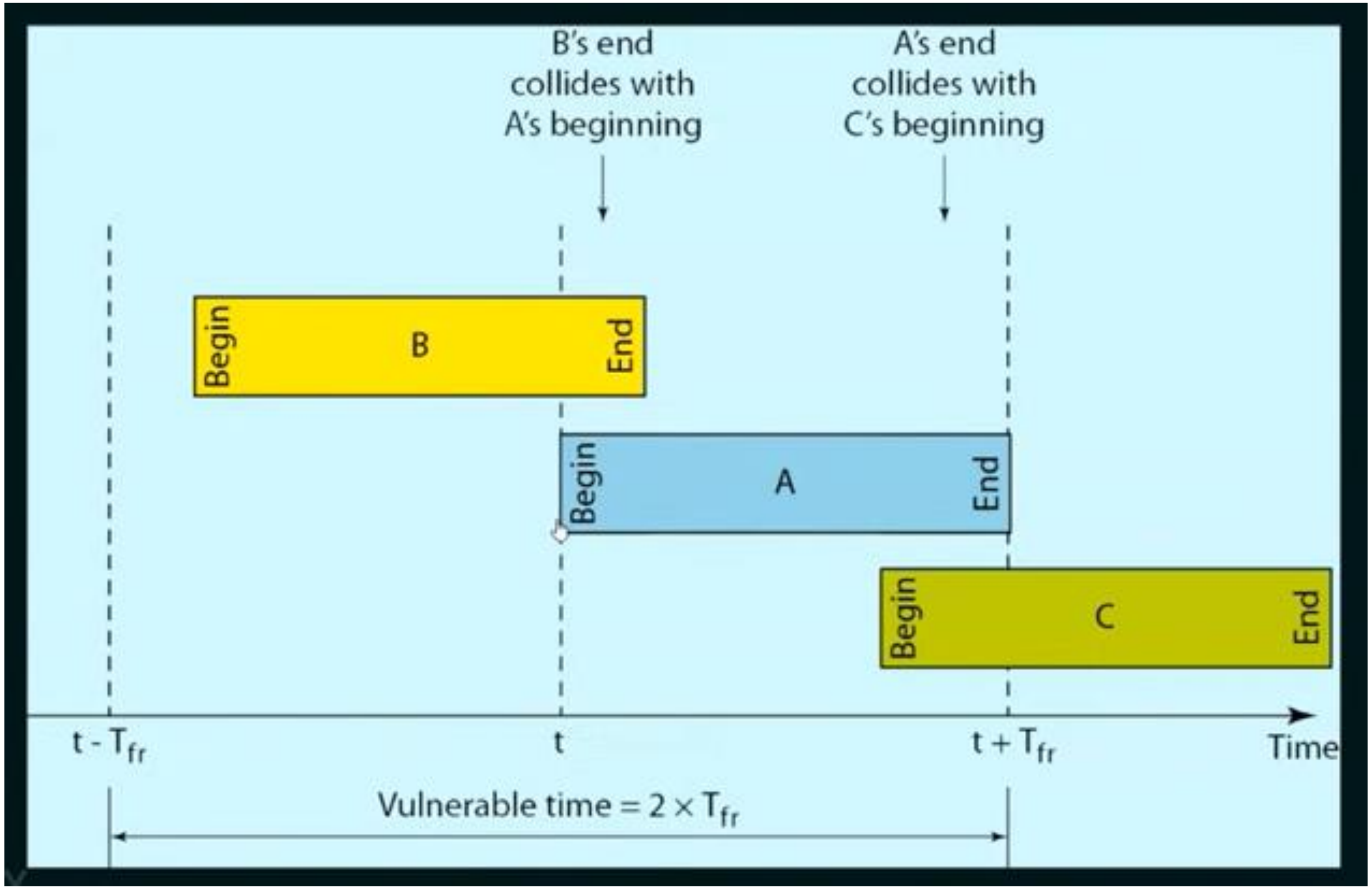
- ★ Pure ALOHA allows stations to transmit whenever they have data to be sent.
- ★ When a station sends data it waits for an acknowledgement.
- ★ If the acknowledgement doesn't come within the allotted time then the station waits for a random amount of time called back-off time (Tb) and re-sends the data.
- ★ Since different stations wait for different amount of time, the probability of further collision decreases.
- ★ The throughput of pure aloha is maximized when frames are of uniform length.

Pure ALOHA

★ Whenever two frames try to occupy the channel at the same time, there will be a collision and both will be garbled.

★ If the first bit of a new frame overlaps with just the last bit of a frame almost finished, both frames will be totally destroyed and both will have to be retransmitted later.

Pure ALOHA



B's end collides with A's beginning
A's end collides with C's beginning
Begin
B
End
Begin
A
End
Begin
C
End
t - T_{fr}
t
t + T_{fr}
Time
Vulnerable time = 2 × T_{fr}

Pure ALOHA

- ★ Whenever two frames try to occupy the channel at the same time, there will be a collision and both will be garbled.
- ★ If the first bit of a new frame overlaps with just the last bit of a frame almost finished, both frames will be totally destroyed and both will have to be retransmitted later.

Vulnerable Time = $2*T_{fr}$

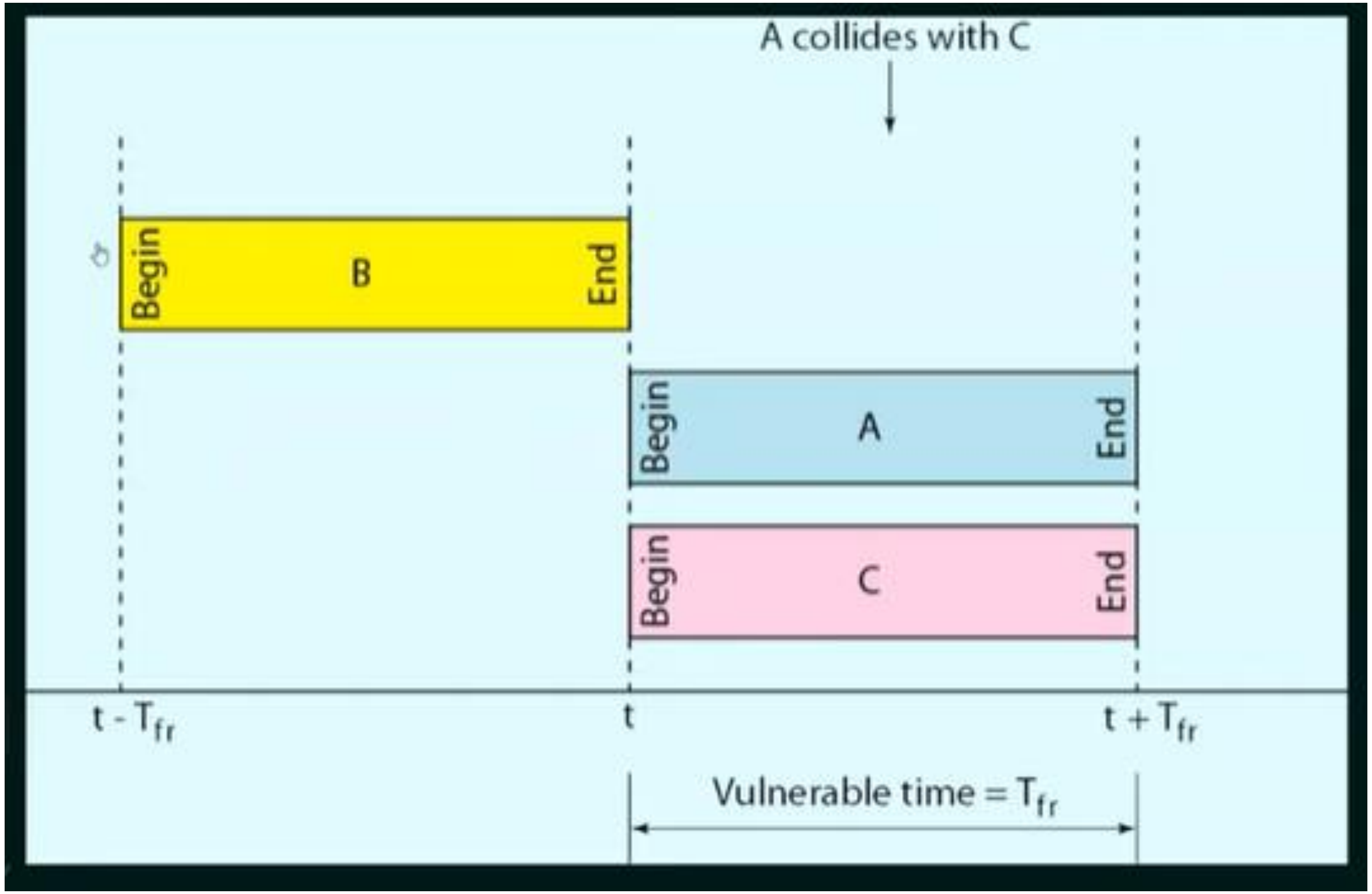
Throughput = $G \times e^{-2G}$; Where G is the number of stations wish to transmit in the same time.

Maximum throughput = 0.184 for G=0.5 (½)

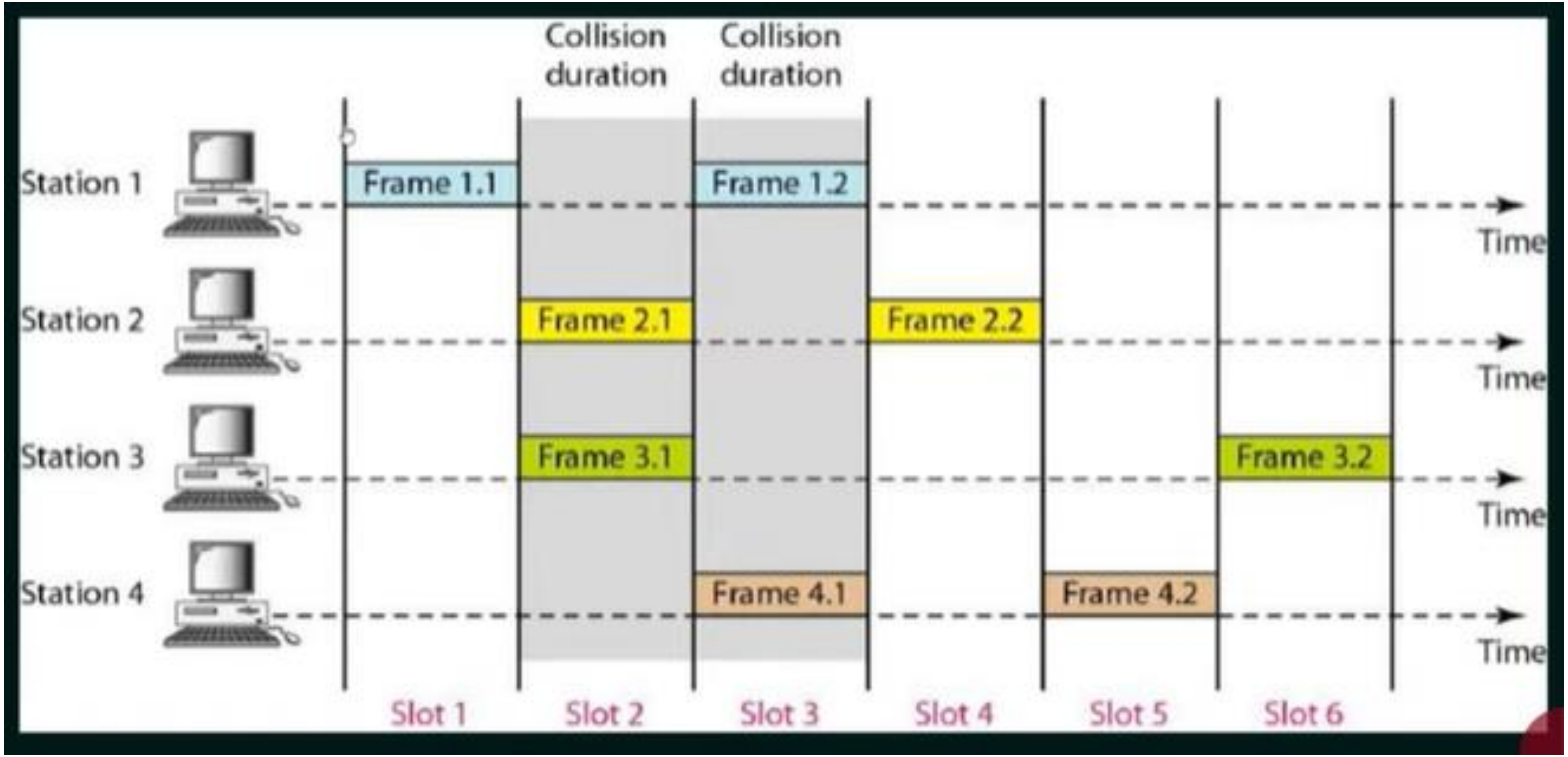
Slotted ALOHA

- ★ It was developed just to improve the efficiency of pure aloha as the chances for collision in pure aloha are high.
- ★ The time of the shared channel is divided into discrete time intervals called slots.
- ★ Sending of data is allowed only at the beginning of these slots.
- ★ If a station misses out the allowed time, it must wait for the next slot. This reduces the probability of collision.

Slotted ALOHA



Slotted ALOHA

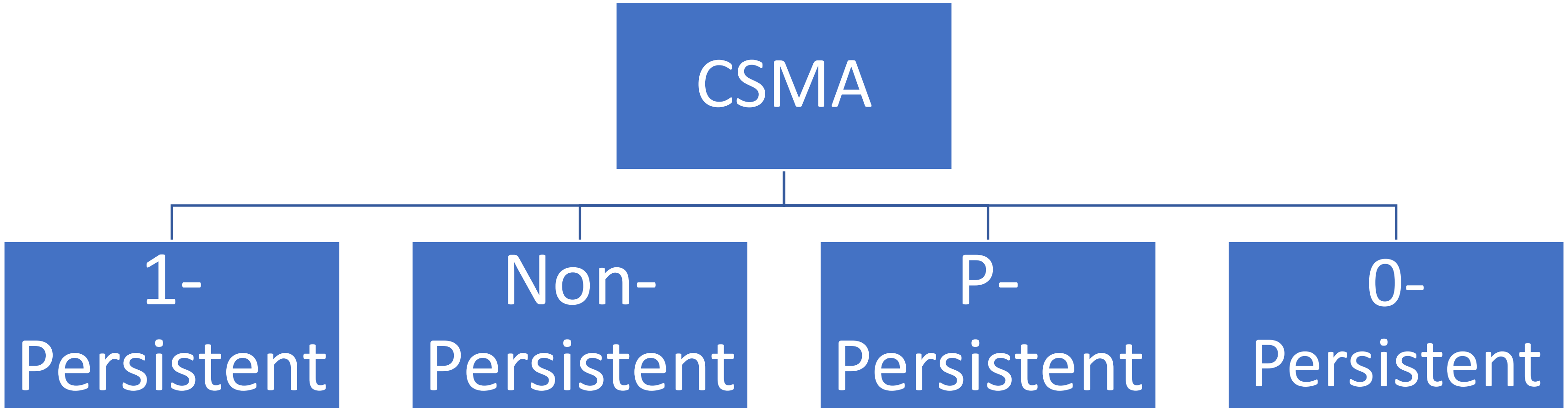


Pure ALOHA vs. Slotted ALOHA

Pure Aloha	Slotted Aloha
Any station can transmit the data at any time.	Any station can transmit the data at the beginning of any time slot.
The time is continuous and not globally synchronized.	The time is discrete and globally synchronized.
Vulnerable time in which collision may occur $= 2 \times T_{Fr}$	Vulnerable time in which collision may occur $= T_{Fr}$
Probability of successful transmission of data packet= $G \times e^{-2G}$	Probability of successful transmission of data packet= $G \times e^{-G}$
Maximum efficiency = 18.4% (Occurs at G = 1/2)	Maximum efficiency = 36.8% (Occurs at G = 1)
Main advantage: Simplicity in implementation.	Main advantage: It reduces the number of collisions to half and doubles the efficiency of pure aloha.

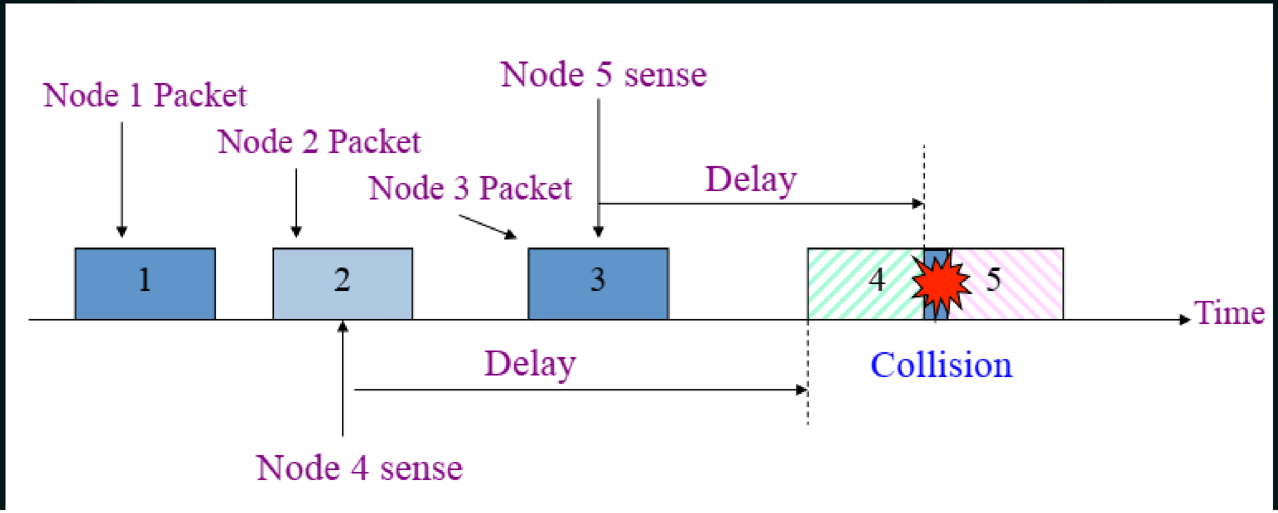
NESO ACADEMY

Carrier Sense Multiple Access (CSMA)



Carrier Sense Multiple Access (CSMA)

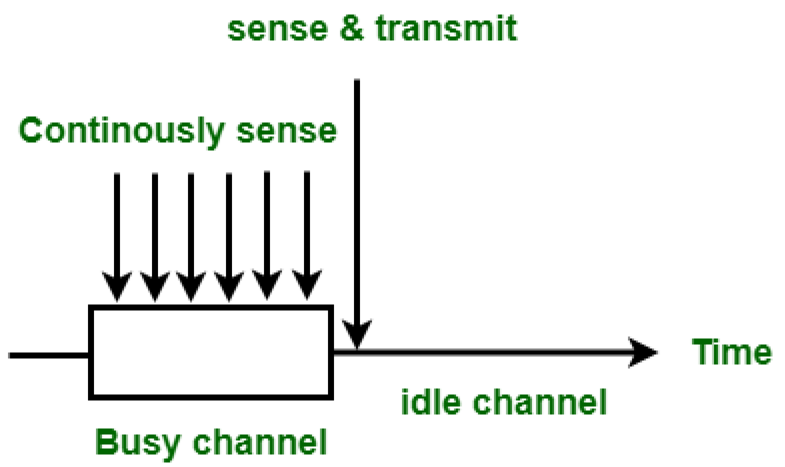
- Carrier Sense Protocol.
- To minimize the chance of collision and, therefore, increase the performance, the CSMA method was developed.
- Principle of CSMA: "sense before transmit" or "listen before talk."

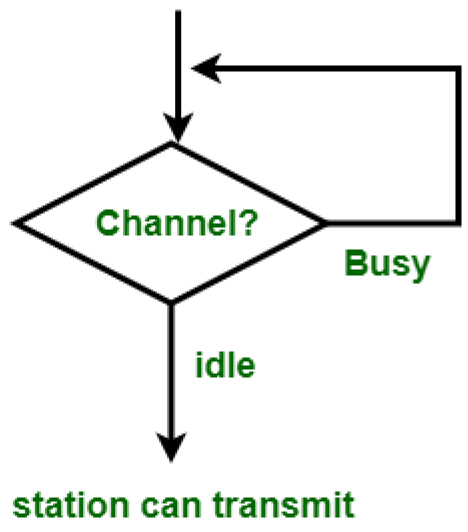


Carrier Sense Multiple Access (CSMA)

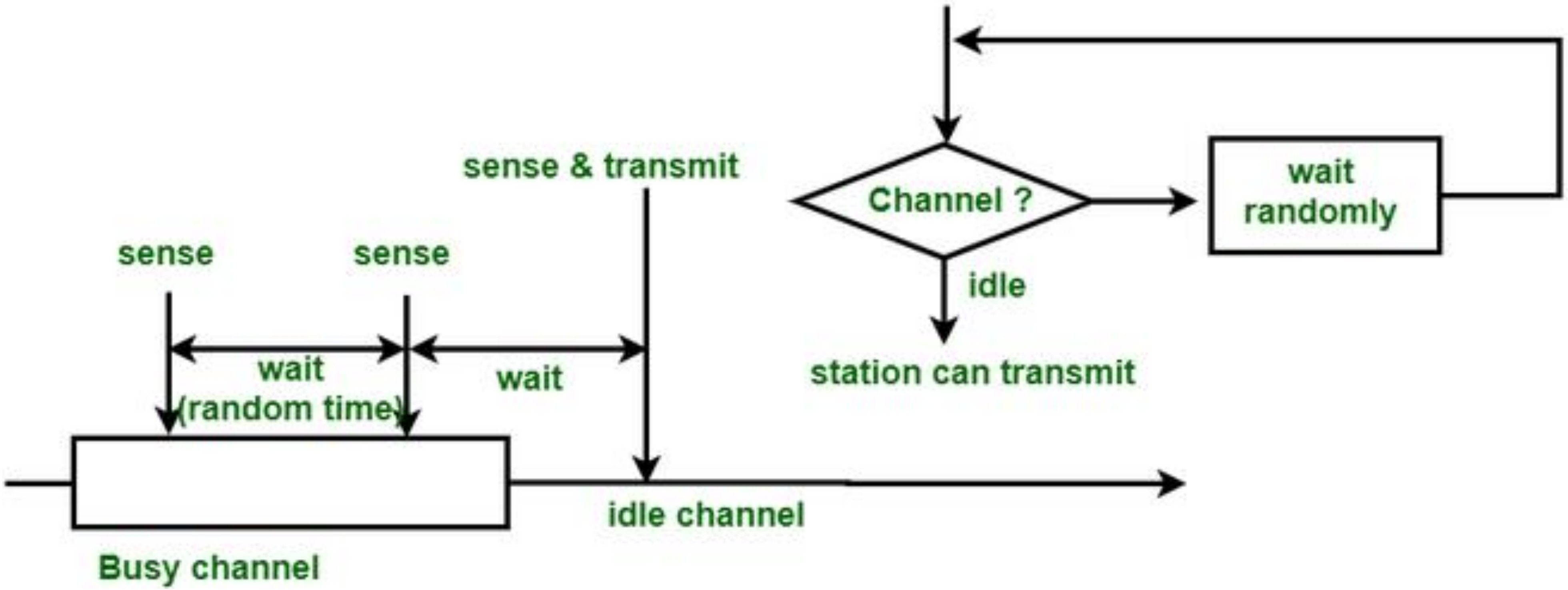
- ★ Carrier Sense Protocol.
- ★ To minimize the chance of collision and, therefore, increase the performance, the CSMA method was developed.
- ★ Principle of CSMA: "sense before transmit" or "listen before talk."
- ★ Carrier busy = Transmission is taking place.
- ★ Carrier idle = No transmission currently taking place.
- ★ 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.

1-Persistent CSMA

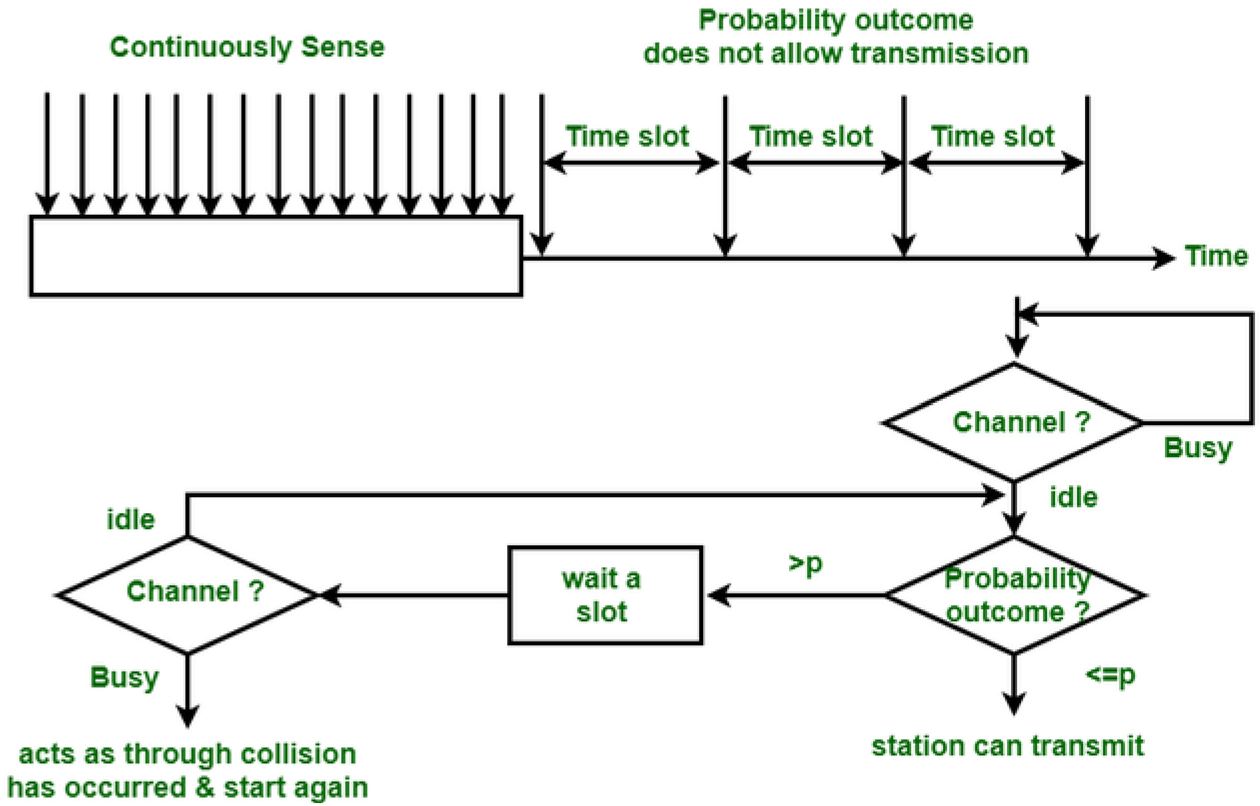




Non-Persistent CSMA

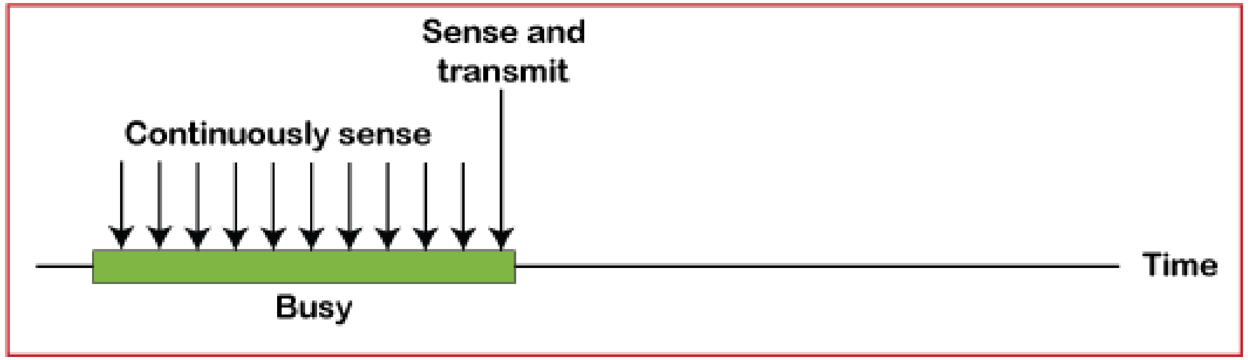


P-Persistent CSMA

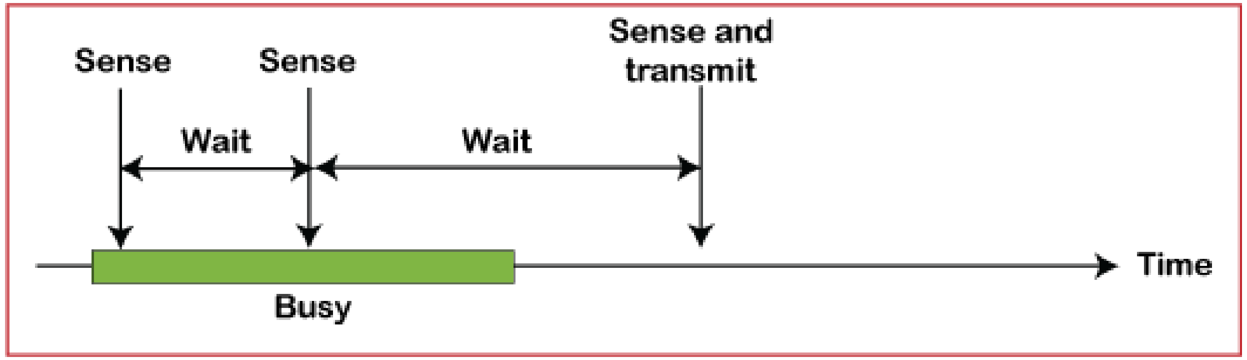


- Each node senses the channel, and if the channel is inactive, it sends a frame with a **P** probability
- If the data is not transmitted, it waits for a (**q = 1-p probability**) random time and resumes the frame with the next time slot

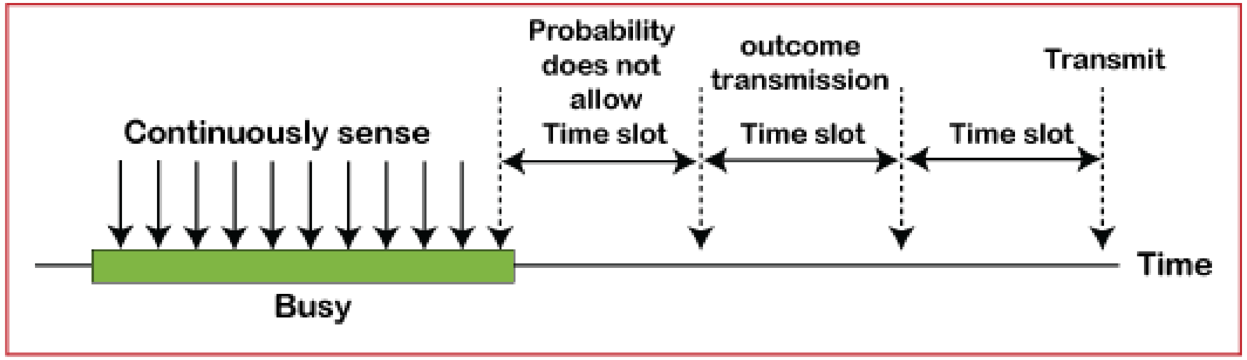
Behavior of Three Persistent Methods



a. 1-persistent



b. Nonpersistent



c. p-persistent

Difference between 1-persistent, P-persistent and Non-persistent CSMA :

Parameter	1-persistent CSMA	p-persistent CSMA	Non-persistent CSMA
Carrier Sense	It sends with the probability of 1 when channel is idle.	It sends with the probability of p when channel is idle.	It send when channel is idle.
Waiting	It continuously senses the channel or carrier.	It waits for the next time slot.	It will wait for the random amount of time to check the carrier.
Chances of Collision	There is highest chances of collision in this.	Less chances as compared to 1-persistence and non-persistence.	Less chances as compared to 1-persistence but more than the p-persistence.
Utilization	It’s utilization is above ALOHA as frames are only sent when the channel is idle.	It’s utilization is depend upon the probability p.	It’s utilization is above 1-persistent as not all the stations constantly check the channel at the same time.
Delay Low Load	It is low as frames are sent when the channel become idle.	It is large when p is small as station will not always send when channel is idle.	It is small as station will send whenever channel is found idle but longer than 1-persistent since it checks for the random time when busy.
Delay High Load	It is high due to collision.	It is large when the probability p of sending is small when channel is idle and channel is rarely idle.	It is longer than 1-persistent as channel is checked randomly when busy.

Modified version of CSMA

1. CSMA/CD
2. CSMA/CA

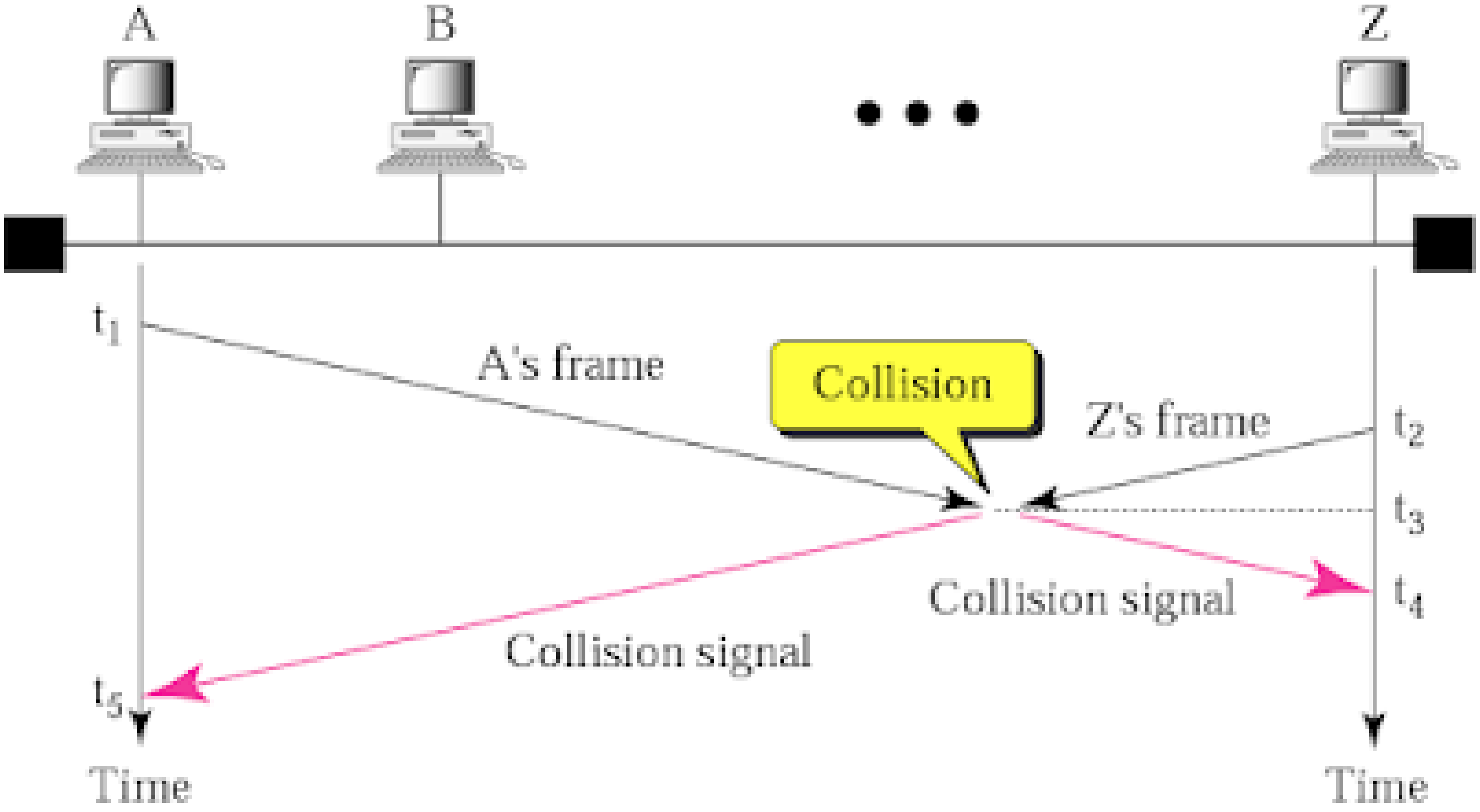
CSMA/CD

i. Every station has an equal right on the medium.

ii. Every station senses the medium before sending a frame and if the medium is idle only then the station sends the frame.

iii. It may happen, that two stations senses the medium at a time and find it idle and send frame. This time a collision will occur. That’s why the protocol forces the stations to sense the medium even after the sending has begun and the stations are able to sense the collision. After sensing the collision the stations send a jam signal which destroys the frames on the line and the stations wait for some random amount of time and re-send their frames avoiding the collision.

CSMA/CD



A
B
Z
t_1
A's frame
Collision
Z's frame
t_2
t_3
t_4
Collision signal
Collision signal
t_5
Time
Time

CSMA/CD

- Procedure
  - Listen to medium and wait until it is free
  - Then start talking, but listen to see if someone else starts talking too
  - If a collision occurs, stop and then start talking after a random back off time
- This scheme is used for hub based Ethernet
- Advantages
  - More efficient than basic CSMA
- Disadvantages
  - Requires ability to detect collisions

CSMA/CD

- In CSMA, if 2 terminals begin sending packet at the sa me time, each will transmit its complete packet (although collision is taking place).
- Wasting medium for an entire packet time.
- CSMA/CD

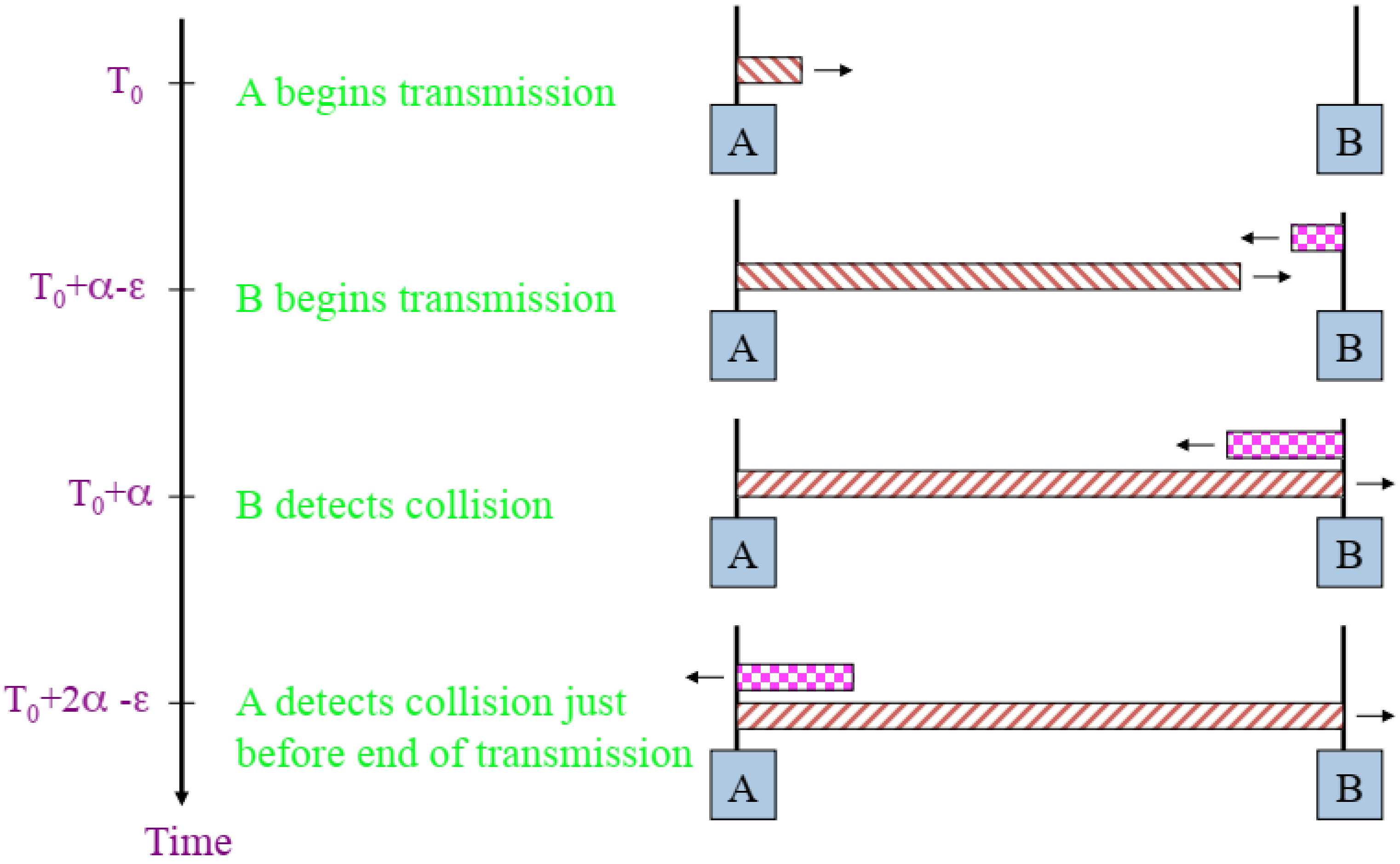
  Step 1: If the medium is idle, transmit

  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

CSMA/CD



Transmission time, $T_t > 2*T_P$
$T_t = L/B$
Transmission time, $L/B \geq 2*T_P$
Message length, $L \geq B*2*T_P$

So, in order to detect a collision, the minimum size of the packet should be $2*Tp*B$

CSMA/CA(WLAN i.e IEEE 802.11 wi-fi)

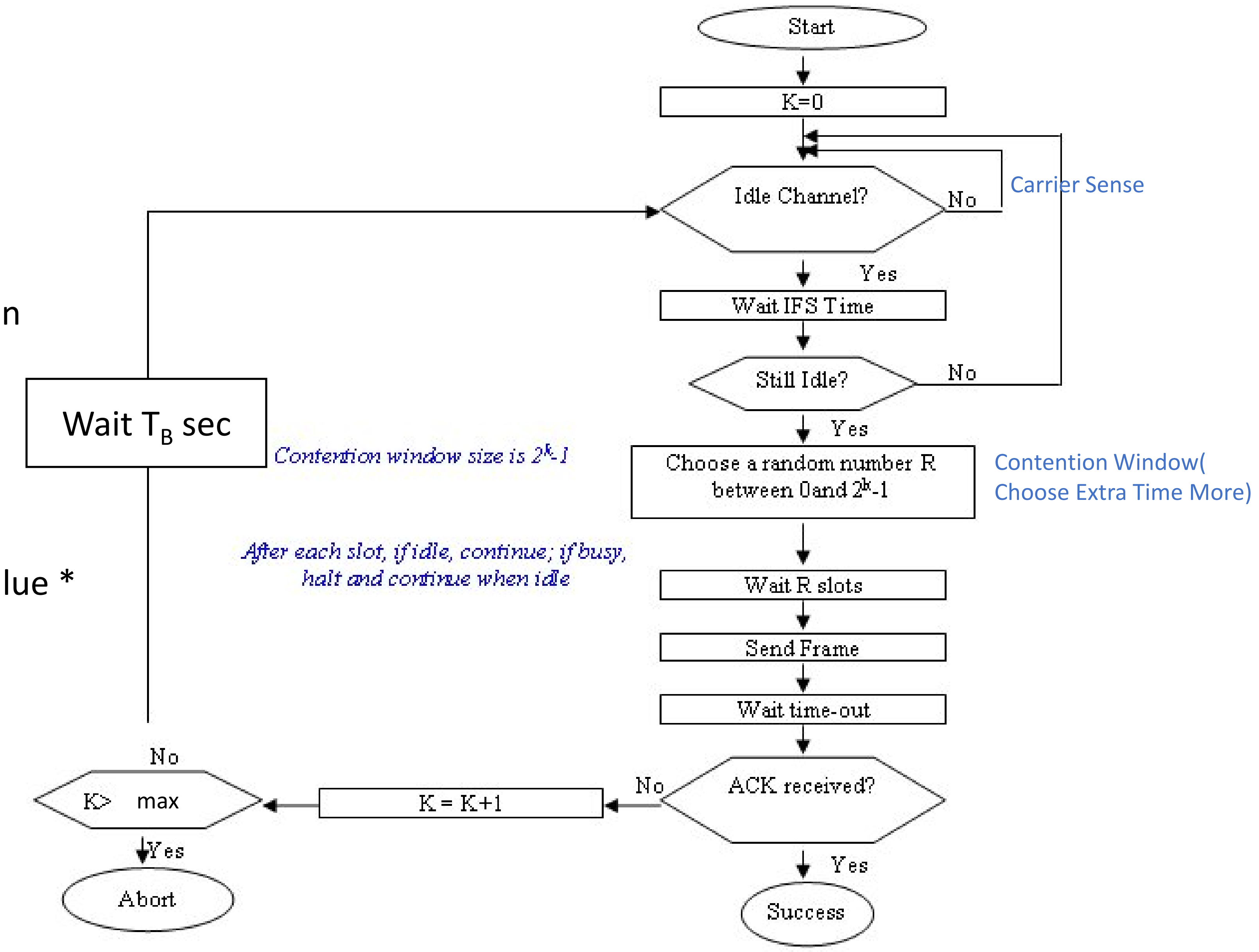
- ★ Carrier-sense multiple access with collision avoidance (CSMA/CA) is a network multiple access method in which carrier sensing is used, but nodes attempt to avoid collisions by beginning transmission only after the channel is sensed to be "idle".
- ★ It is particularly important for wireless networks, where the collision detection of the alternative CSMA/CD is not possible due to wireless transmitters desensing their receivers during packet transmission.
- ★ CSMA/CA is unreliable due to the hidden node problem and exposed terminal problem.
- ★ Solution: RTS/CTS exchange.

CSMA/CA(WLAN i.e IEEE 802.11 wi-fi)

- Procedure
  - Similar to CSMA but instead of sending packets control frames are exchanged
  - RTS = request to send
  - CTS = clear to send
  - DATA = actual packet
  - ACK = acknowledgement

CSMA/CA

- IFS – Interframe Space
- DCF – Distributed Coordination Function
- DIFS
- Collision
- ACK
- K = no. of attempts
- T_B = Backoff Time (Random value * Slot time)
- RTS = Ready to Send
- CTS = Clear To Send



CSMA/CA

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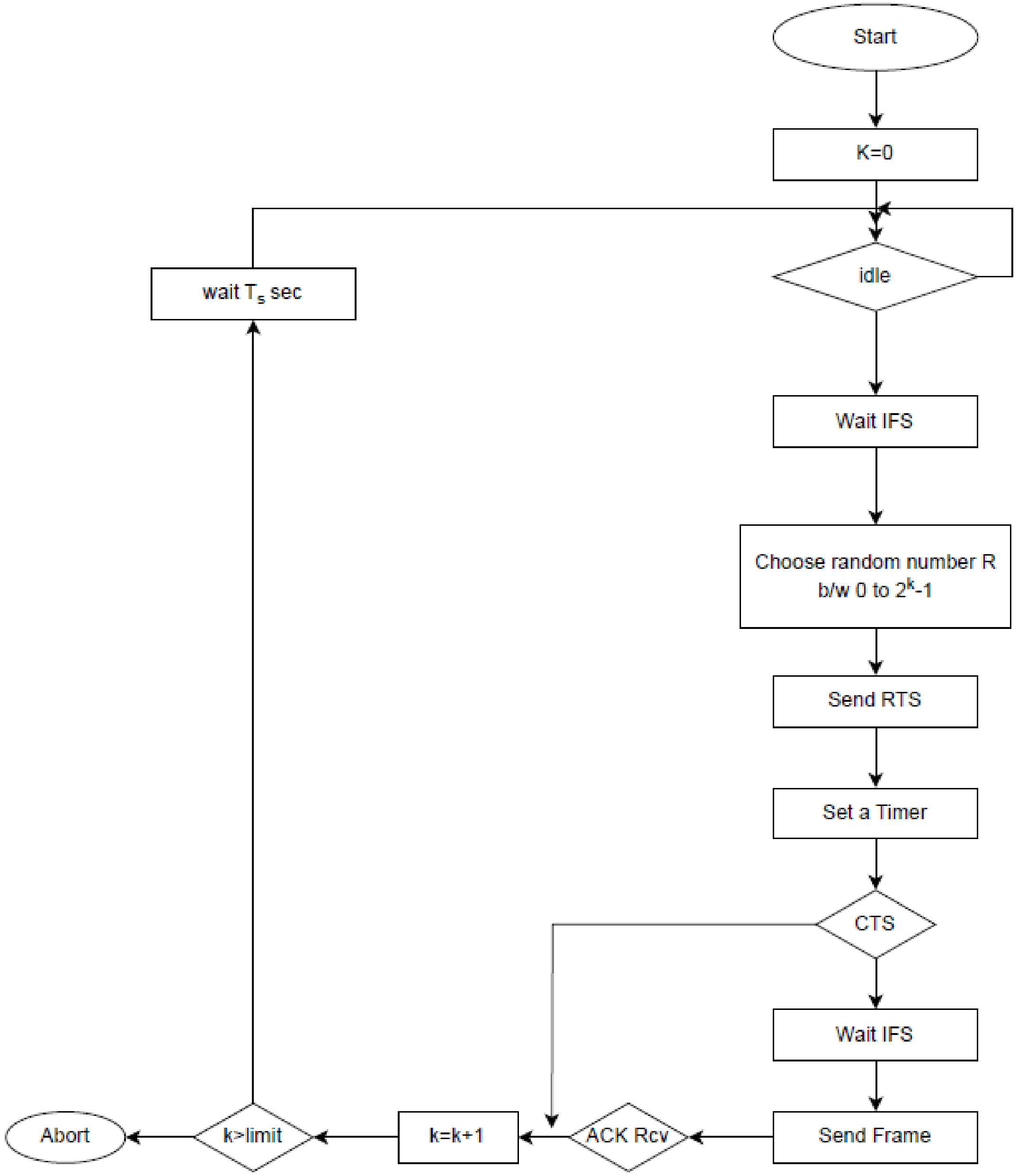
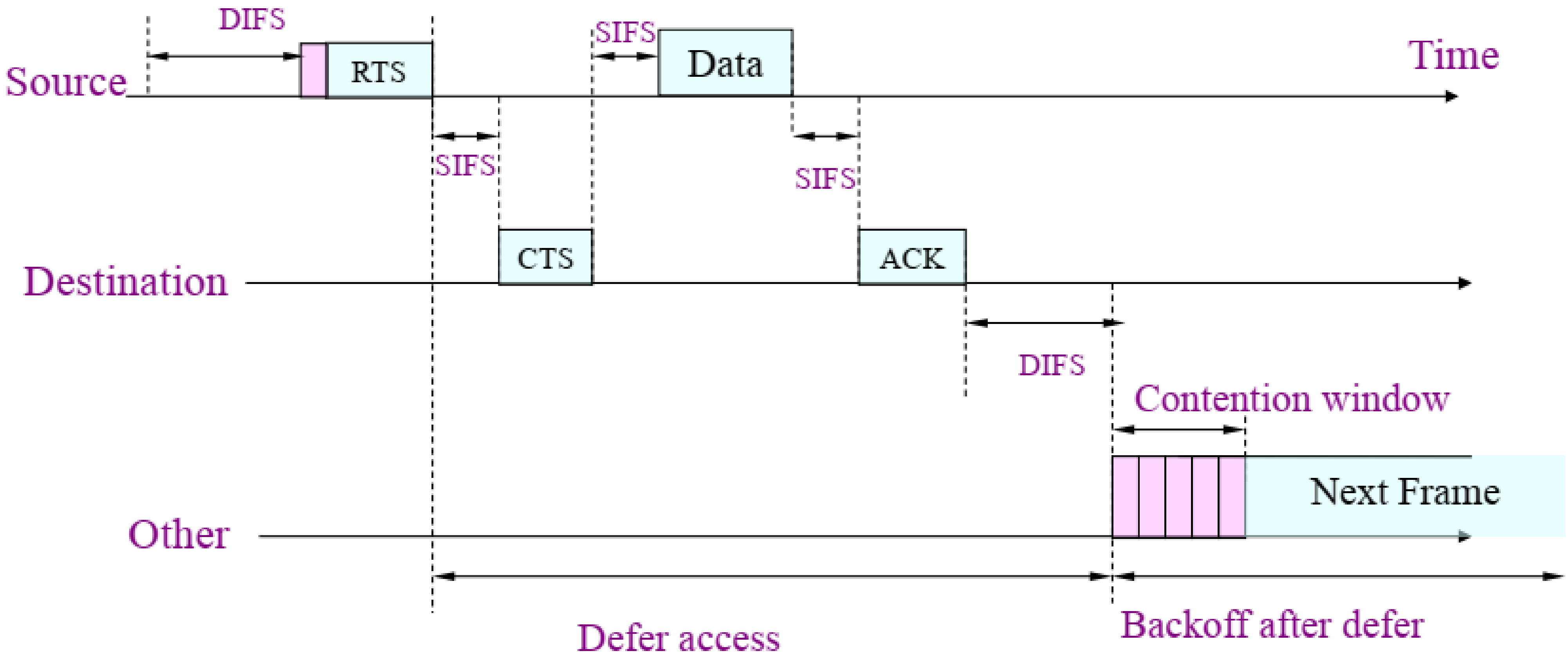


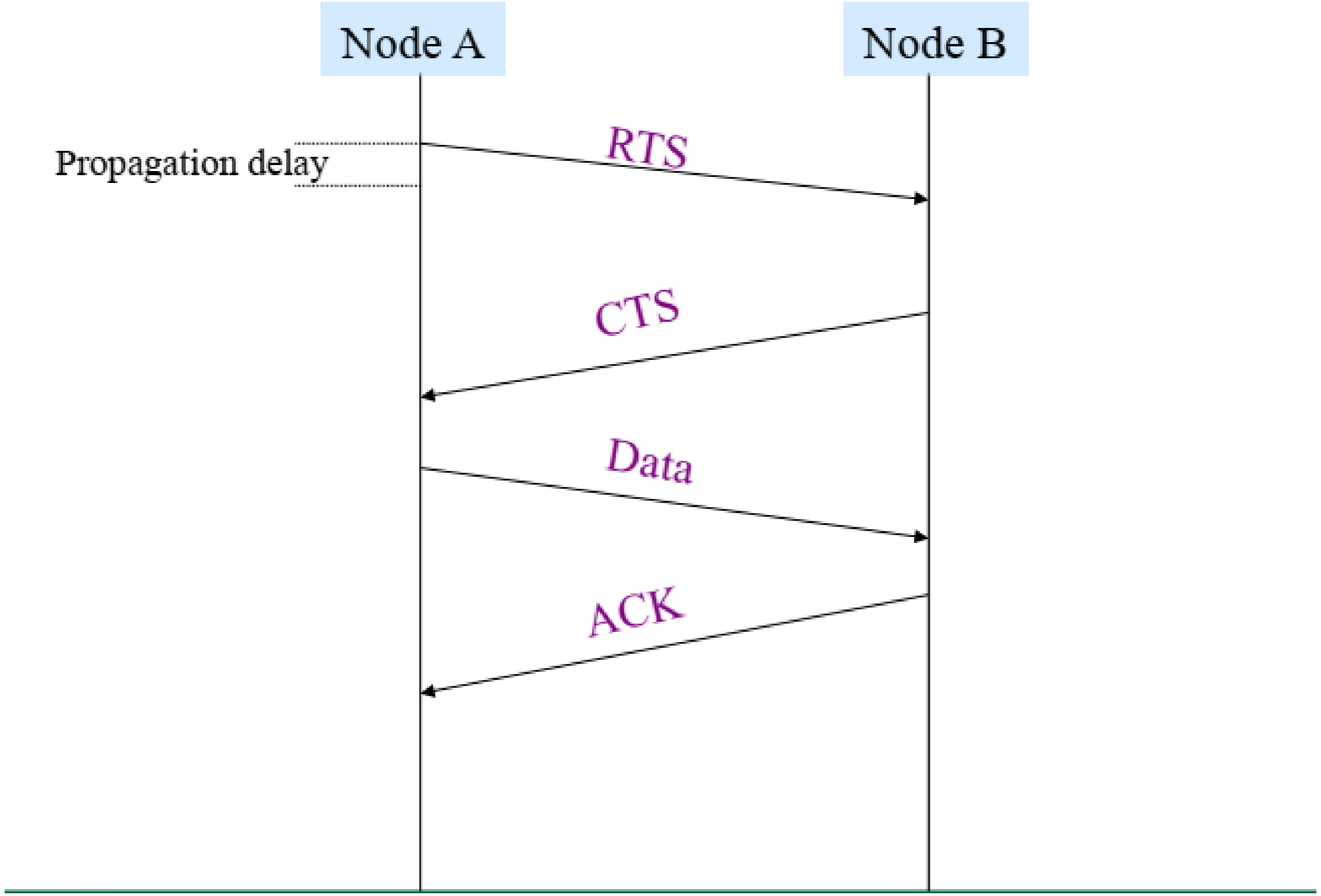
Carrier Sense

Contention Window(Choose Extra Time More)

CSMA/CA with RTS/CTS

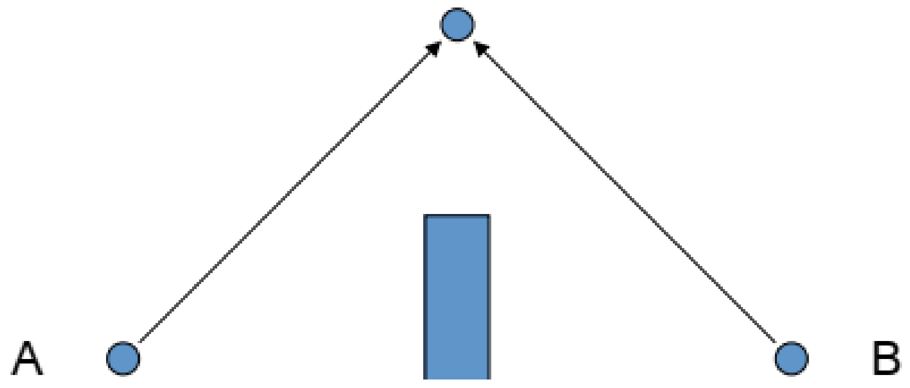


CSMA/CA with RTS/CTS



CSMA/CA(WLAN i.e IEEE 802.11 wi-fi)

- Advantages
  - Small control frames lessen the cost of collisions (when data is large)
  - RTS + CTS provide “virtual” carrier sense which protects against hidden terminal collisions (where A can’t hear B)



CSMA/CA(WLAN i.e IEEE 802.11 wi-fi)

1.Sometime CSMA/CA takes much waiting time as usual to transmit the data packet.
2.It consumes more bandwidth by each station.
3.Its efficiency is less than a CSMA CD.

Differences between ALOHA, CSMA/CD, and CSMA/CA

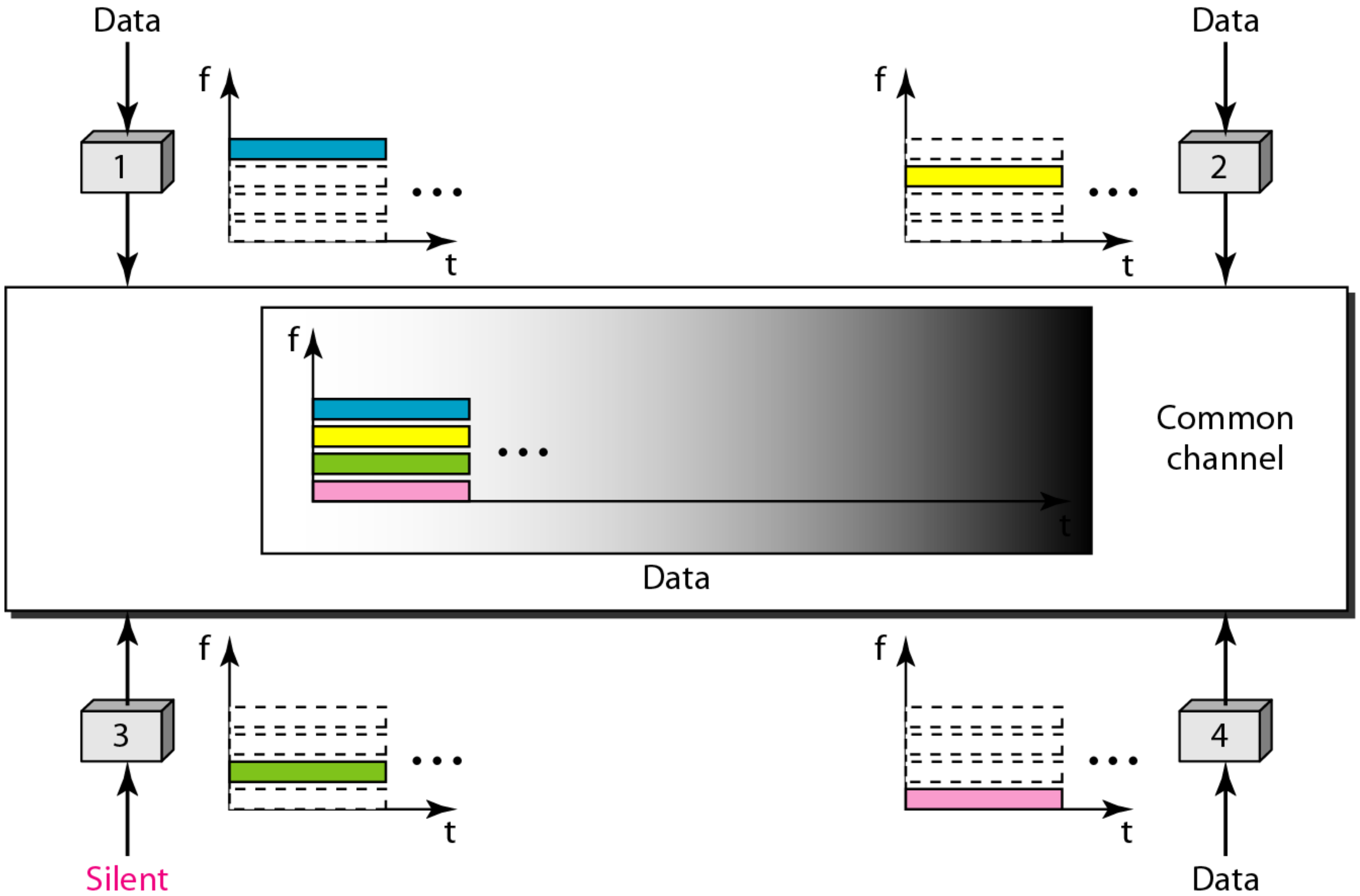
Protocol	Transmission behavior	Collision detection method	Efficiency	Use cases
Pure ALOHA	Sends frames immediately	No collision detection	Low	Low-traffic networks
Slotted ALOHA	Sends frames at specific time slots	No collision detection	Better than pure ALOHA	Low-traffic networks
CSMA/CD	Monitors medium after sending a frame, retransmits if necessary	Collision detection by monitoring transmissions	High	Wired networks with moderate to high traffic
CSMA/CA	Monitors medium while transmitting, adjusts behavior to avoid collisions	Collision avoidance through random backoff time intervals	High	Wireless networks with moderate to high traffic and high error rates

Channelization

- Channelization is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations.

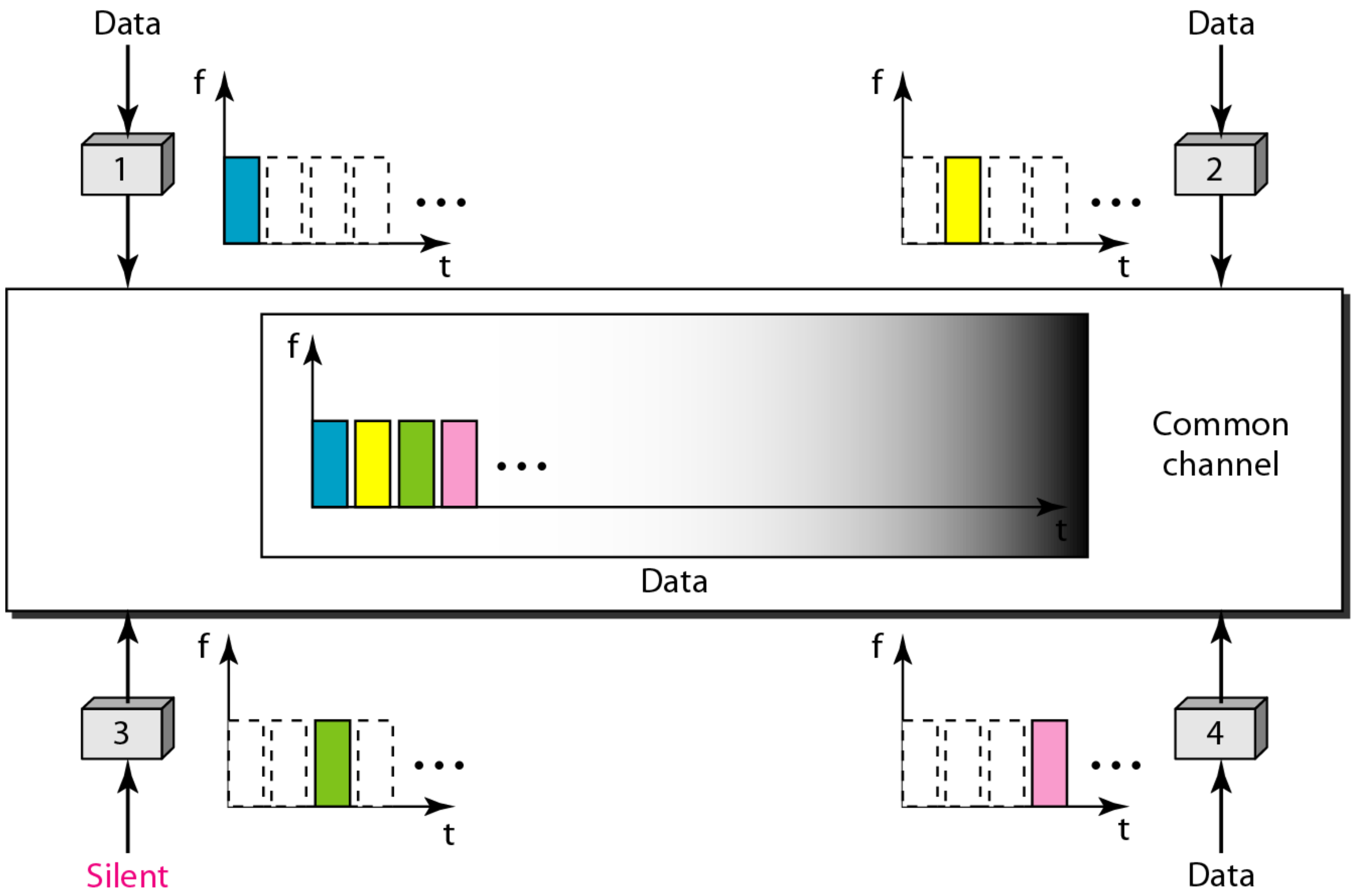
Frequency Division Multiple Access (FDMA)

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



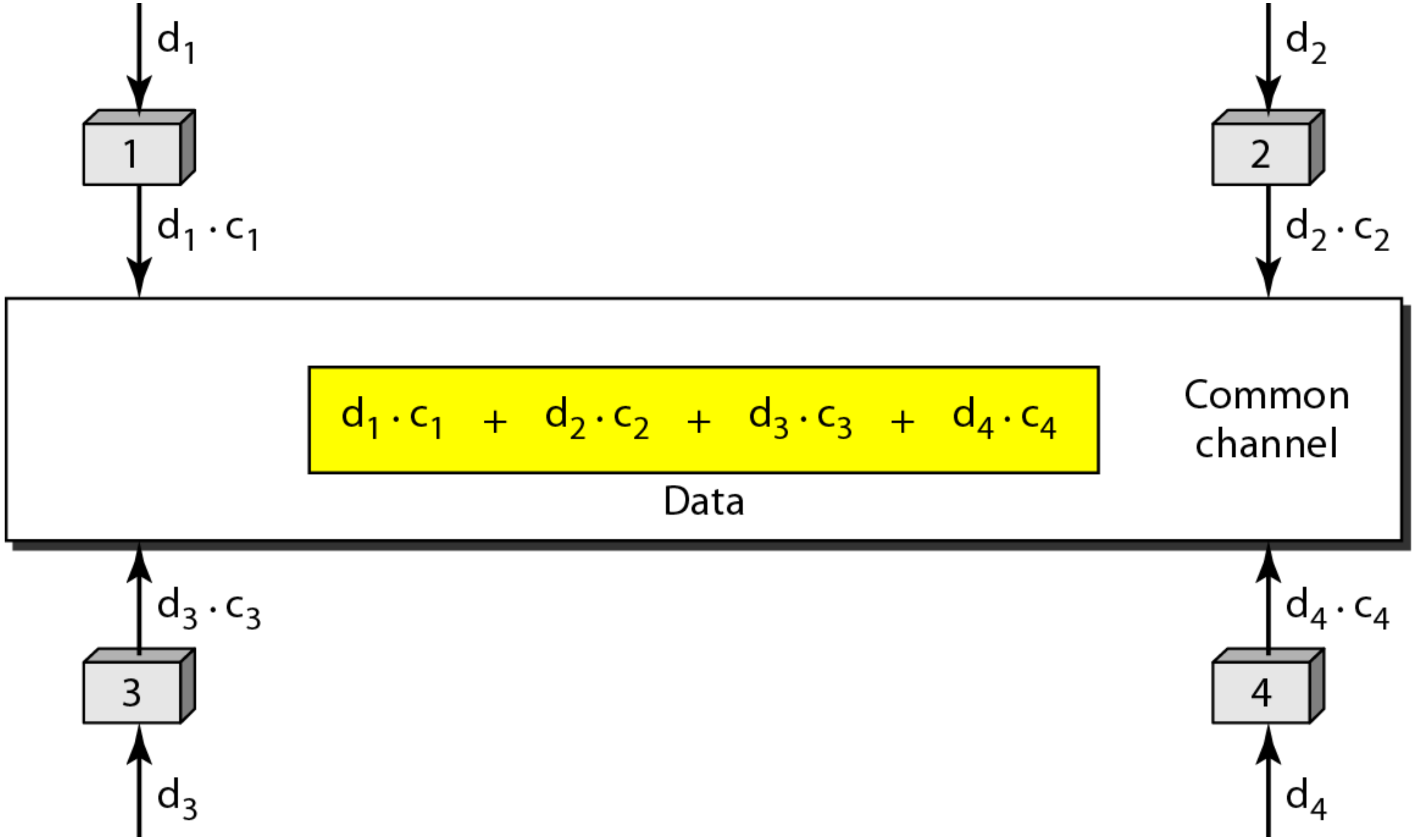
Time Division Multiple Access (TDMA)

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



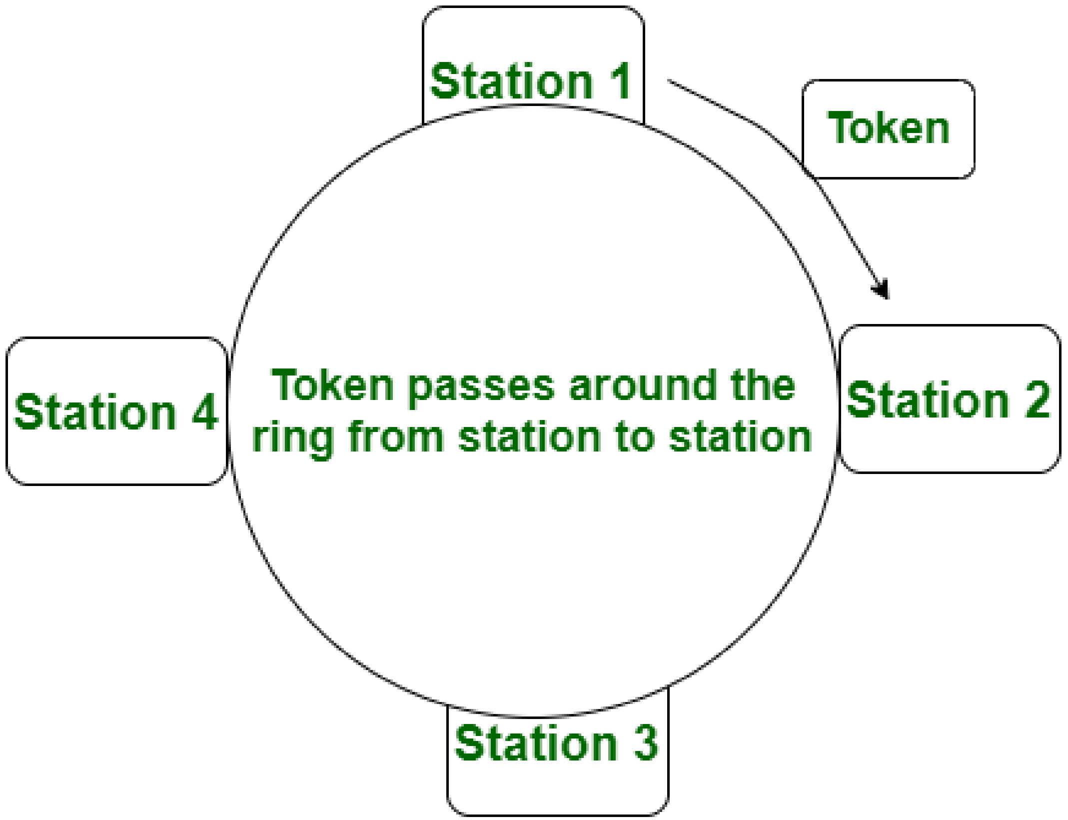
Code Division Multiple Access (CDMA)

In CDMA, one channel carries all transmissions simultaneously.

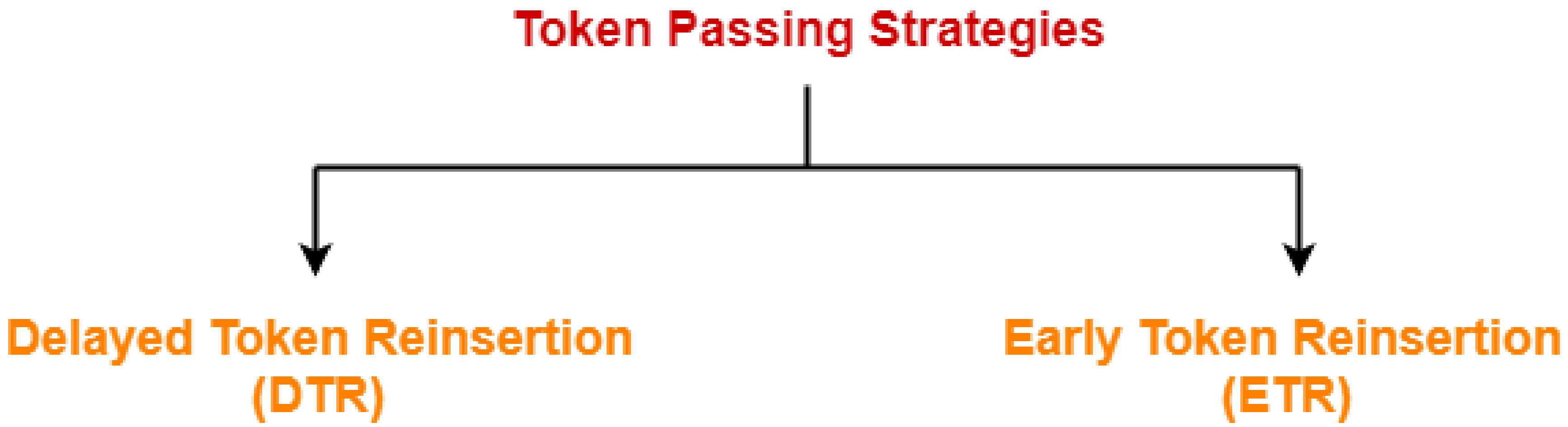


Token Ring (IEEE 802.5)

1) Ring Topology is used
2) Access control method used is token passing
3) Token ring is unidirectional (simplex)
4) Data rate used is 4Mbps & 16Mbps
5) Piggybacking (send ack along with packets) acknowledgement is used
6) Differential Manchester encoding is used
7) Variable size framing



Token Ring (IEEE 802.5)



Token Ring (IEEE 802.5)

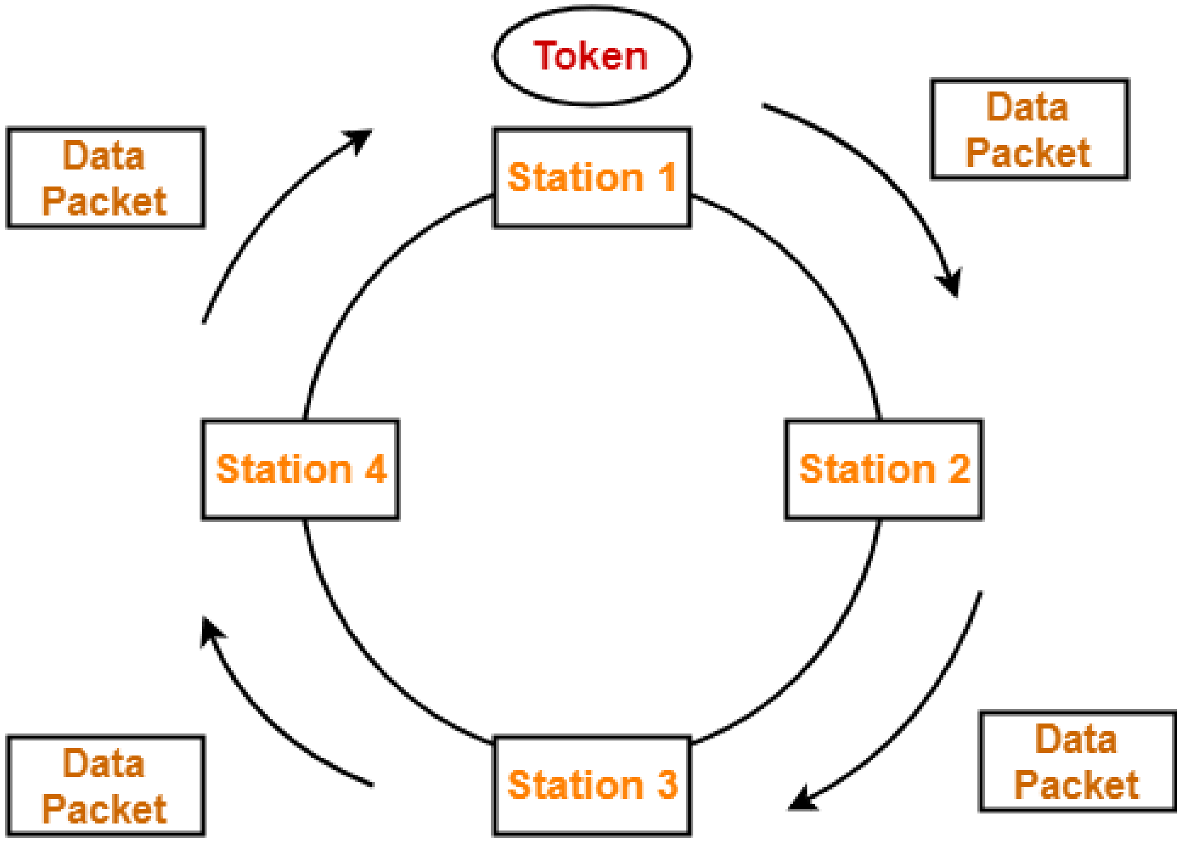
After a station acquires the token,

i. It transmits its data packet.

ii. It holds the token until the data packet reaches back to it.

iii. After data packet reaches to it, it discards its data packet as its journey is completed.

iv. It releases the token.



Delayed Token Reinsertion Token Passing

Token Ring (IEEE 802.5)

- Station releases the token immediately after putting its data packet to be transmitted on the ring.

Step-01: At Station-1:

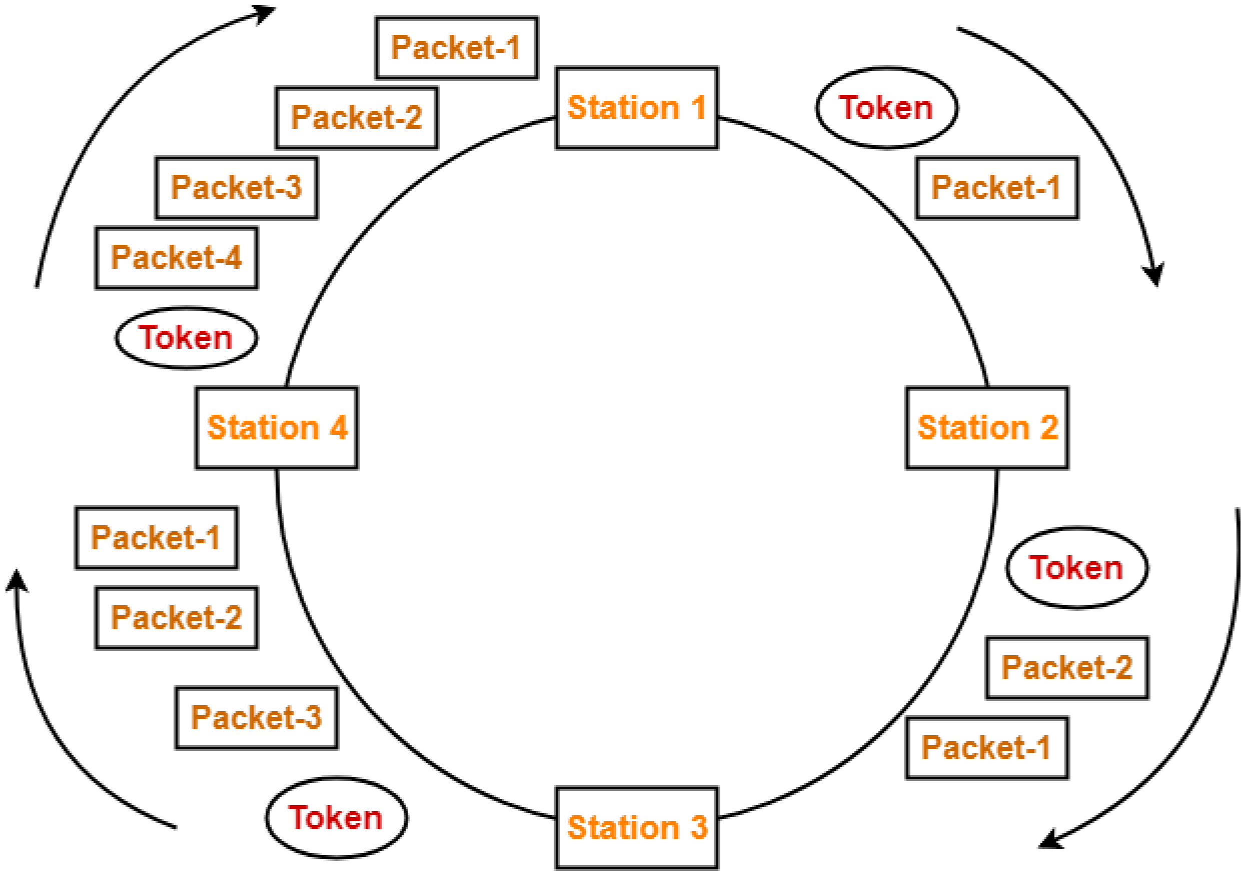
Station-1

- Acquires the token
- Transmits packet-1
- Releases the token

Step-02: At Station-2:

Station-2

- Receives packet-1
- Transmits packet-1
- Acquires the token
- Transmits packet-2
- Releases the token



Early Token Reinsertion

Token Ring (IEEE 802.5)

Step-03: At Station-3:

- Receives packet-1
- Transmits packet-1
- Receives packet-2
- Transmits packet-2
- Acquires the token
- Transmits packet-3
- Releases the token

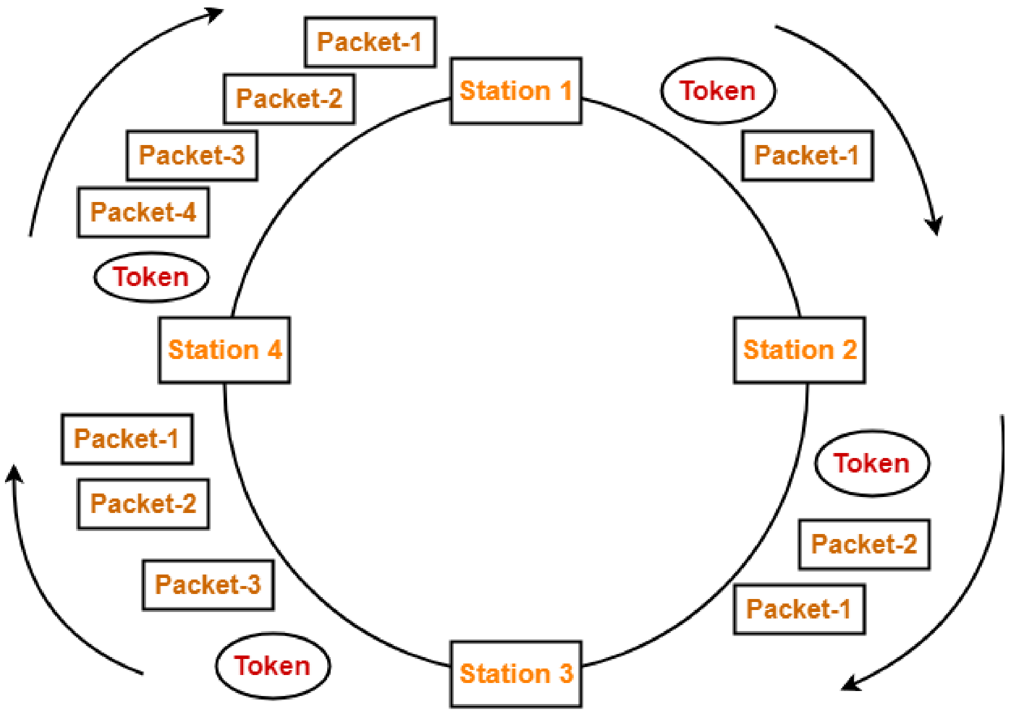
Step-04: At Station-4:

- Receives packet-1
- Transmits packet-1
- Receives packet-2
- Transmits packet-2
- Receives packet-3
- Transmits packet-3
- Acquires the token
- Transmits packet-4
- Releases the token

Step-05: At Station-1:

- Receives packet-1
- Discards packet-1 (as its journey is completed)
- Receives packet-2
- Transmits packet-2
- Receives packet-3
- Transmits packet-3
- Receives packet-4
- Transmits packet-4
- Acquires the token
- Transmits packet-1 (new)
- Releases the token

In this manner, the cycle continues.



Early Token Reinsertion

Token Ring (IEEE 802.5)

Data Frame

SFD	AC	FC	DA	SA	Data	CRC	ED	FS
1	1	1	6	6	>= 0	1	1	1

Token Frame

SFD	AC	ED
1	1	1

i. SFD = Start Frame Delimiter
ii. AC = Access Control
iii. FC = Frame Control
iv. DA = Destination Address
v. SA = Source Address
vi. Data >=0 up to Token Holding Time (TH_t)
vii. CRC = Cyclic Redundancy Check
viii. ED = End Delimiter
ix. FS = Frame Status