- *UNIT – III:* Media Access Control: Random Access: ALOHA, Carrier sense multiple access (CSMA), CSMA with Collision Detection, CSMA with Collision Avoidance, Controlled Access: Reservation, Polling, Token Passing, Channelization: frequency division multiple Access(FDMA), time division multiple access(TDMA), code division multiple access(CDMA). ,
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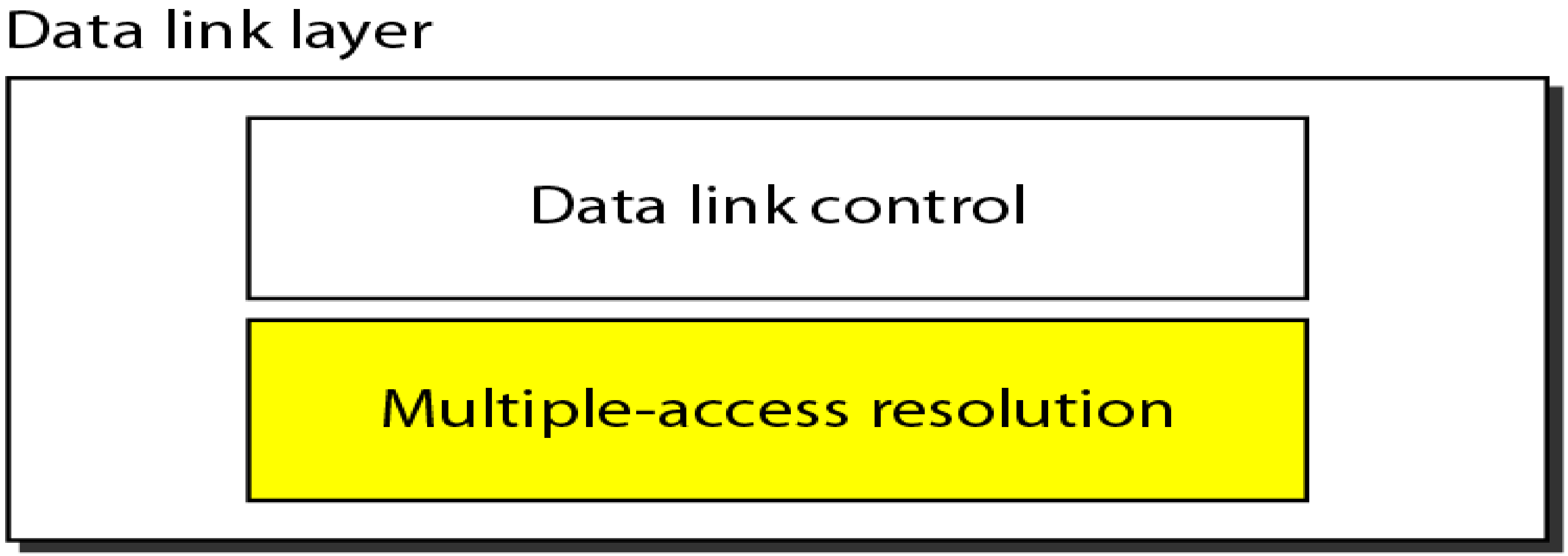
- Data link layer is sub divided into 2 sublayers.
- -1. Data Link Control
- 2. MAC (Medium Access Control) sublayer



- Data Link Control is responsible for flow and error control. MAC sub layer is responsible for resolving the access to shared media.
- When two or more nodes transmit at the same time using a shared single media, their frames will collide and the link bandwidth is wasted during collision.
- The solution is we need a protocol to determine who goes next on a shared media. 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).
- MAC is important in LAN which use a multi access channel as the basis for communication

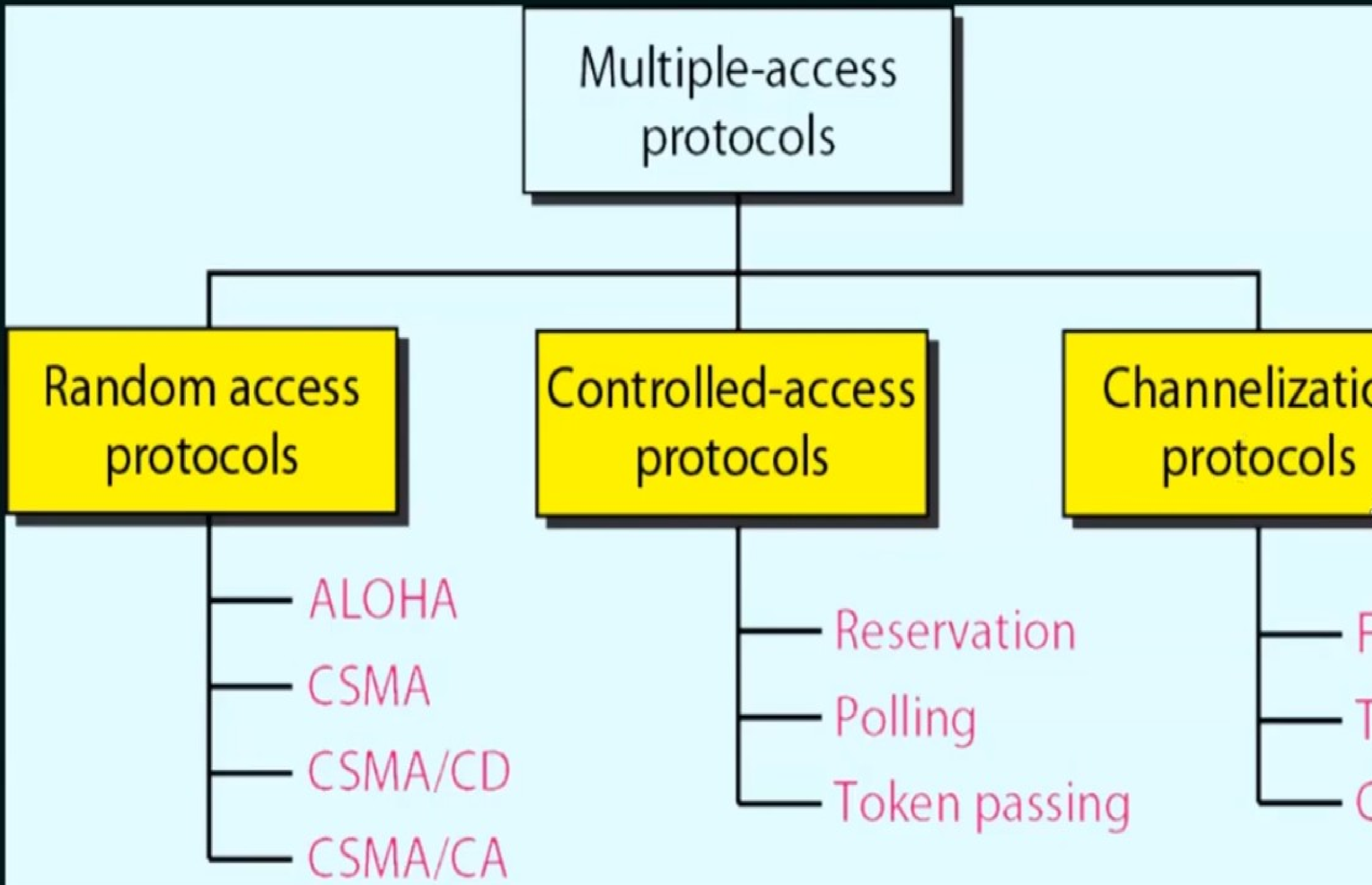
- **Carrier Sense or No Carrier Sense:**
- With the carrier sense assumption, stations can identify if the channel is in use before trying to use it.
- No station will attempt to use the channel while it is sensed as busy.
- If there is no carrier sense, stations cannot sense the channel before trying to use it.
- They will transmit then. Only later they can determine whether the transmission was successful.

WHY MULTIPLE ACCESS PROTOCOLS?

If there is a dedicated link between the sender and the receiver then data link control layer is sufficient, however if there is no dedicated link present then multiple stations can access the channel simultaneously.

Hence multiple access protocols are required to decrease collision and avoid crosstalk.

MULTIPLE ACCESS PROTOCOLS



RANDOM ACCESS PROTOCOLS

- ★ In this, all stations have same superiority that is no station has more priorit than another station. Any station can send data depending on medium' state(idle or busy).
- ★ In a Random access method, each station has the right to the mediu without being controlled by any other station.
- ★ If more than one station tries to send, there is an access conflict (COLLISION and the frames will be either destroyed or modified.

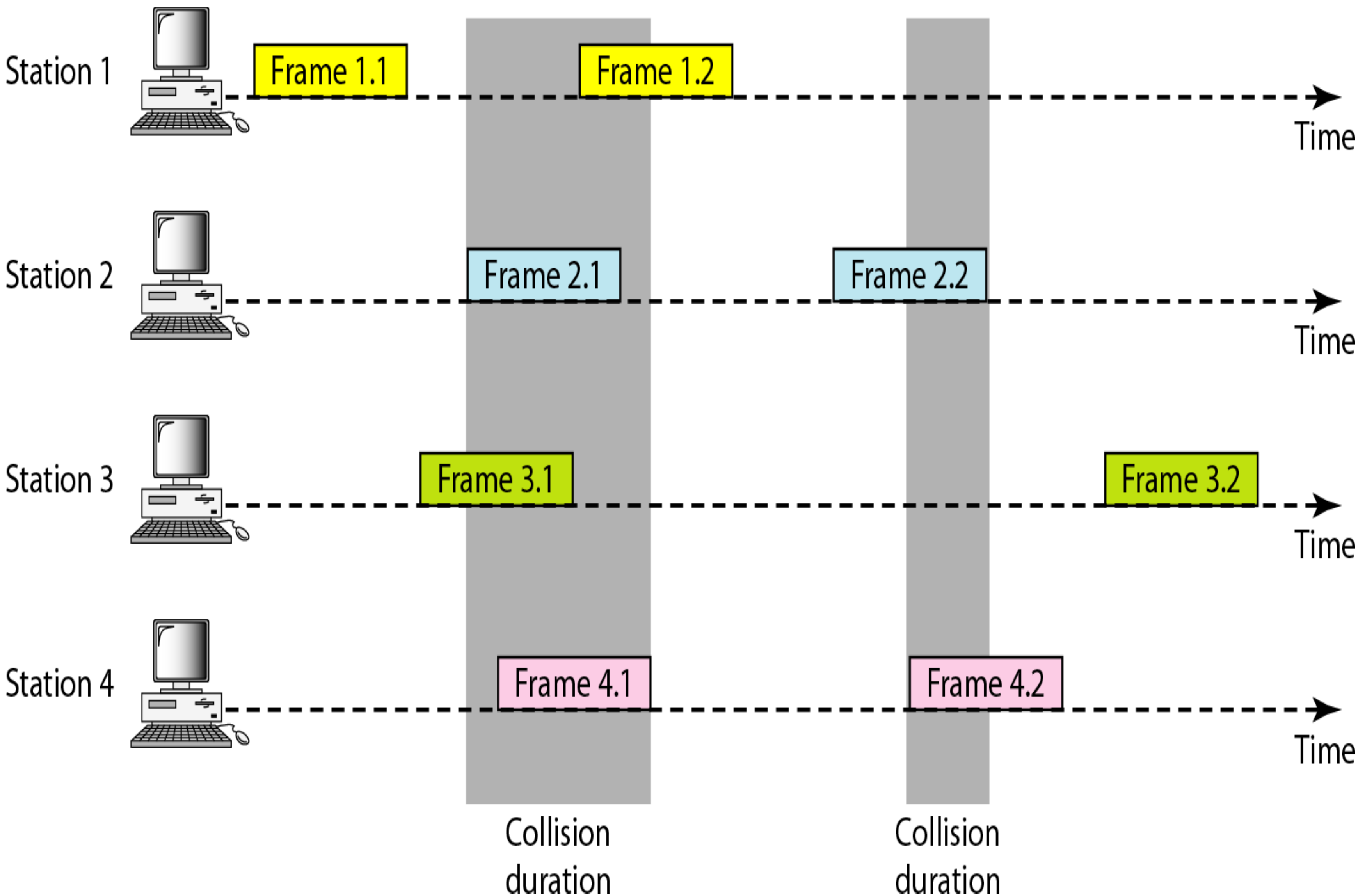
Random Access Protocols

ALOHA

- ALOHA is the random access method.
- It was developed at the University of Hawaii in early 1970.
- It was designed for radio (Wireless) LAN, but it can be used for any shared medium.
- There are two versions of ALOHA
  - Pure ALOHA
  - Slotted ALOHA
- **Pure ALOHA**
- The original ALOHA protocol is called pure ALOHA. The idea is that each station sends a frame whenever it has a frame to send.
- However, since there is only one channel to share, there is the possibility of collision between frames from different stations. The following figure shows an example of frame collisions in pure ALOHA

COLLISION

Frames in a pure ALOHA network

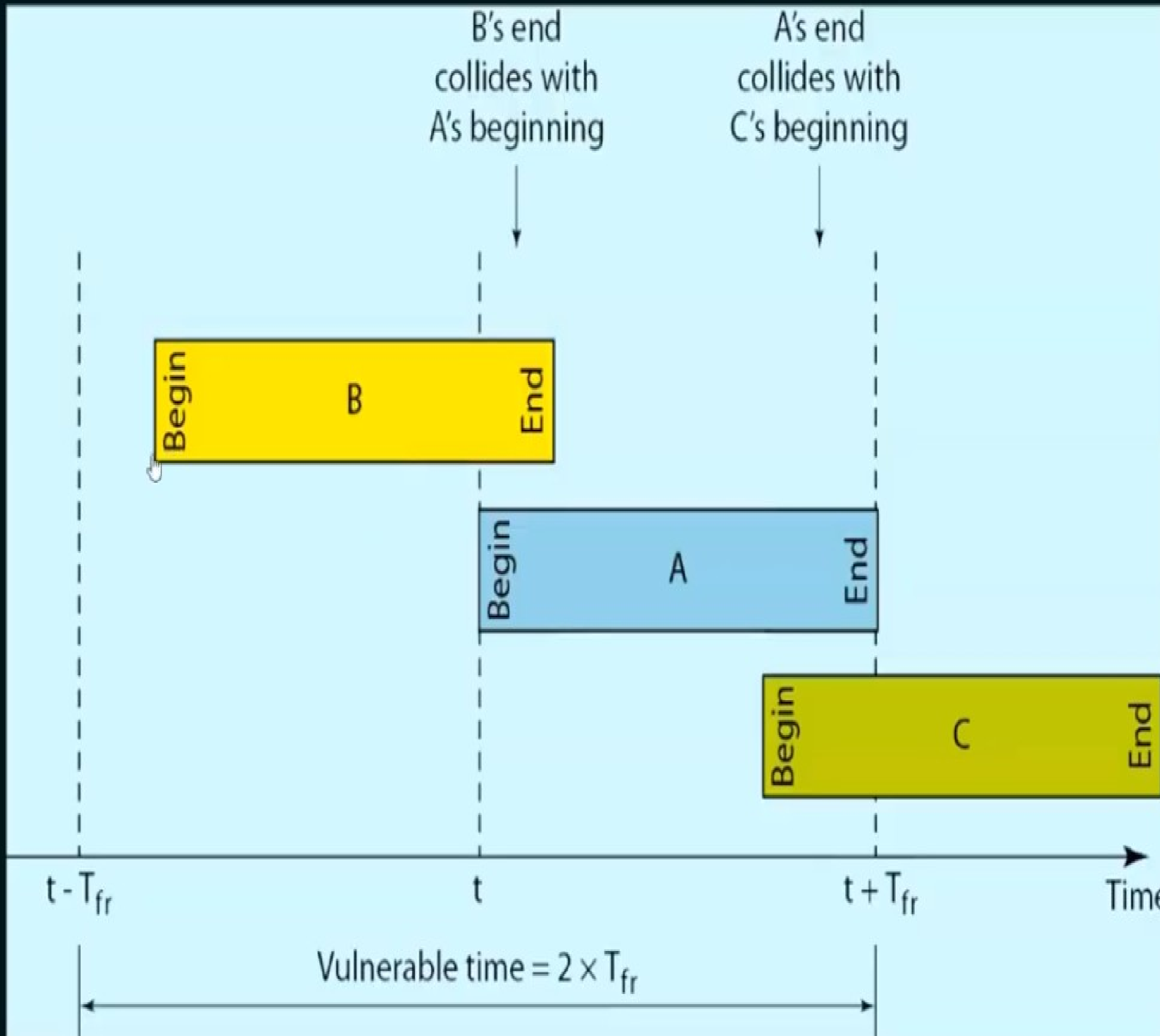


PURE ALOHA

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

- To avoid more collisions after timeout, each station waits for a random amount of time before resending the frame. This time is called as back-off time (TB)

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 = $2 * T_{fr}$

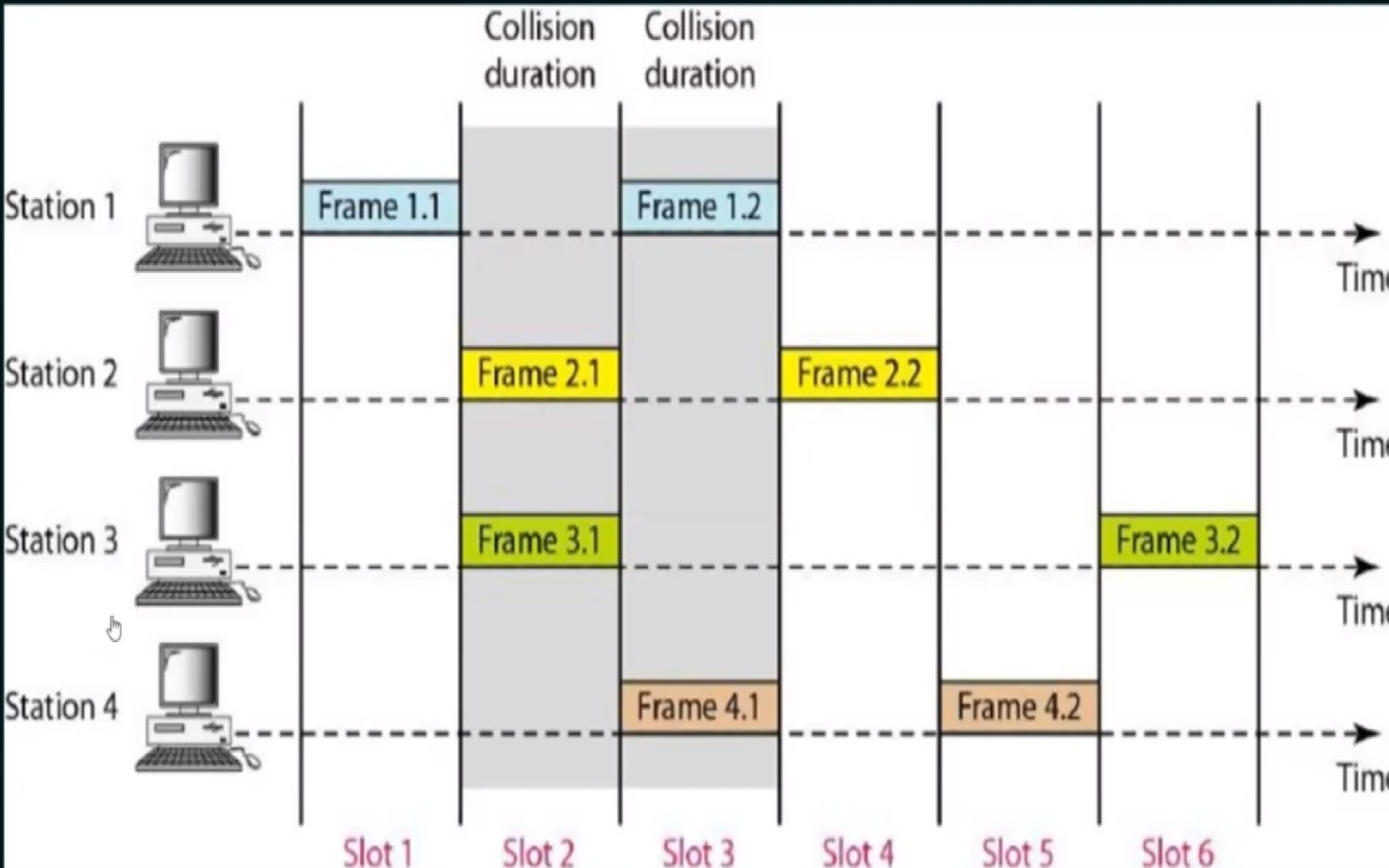
Throughput = $G \times e^{-2G}$; Where G is the number of stations wish to transmit in the same time.

Maximum throughput = 0.184 for G=0.5 (½)

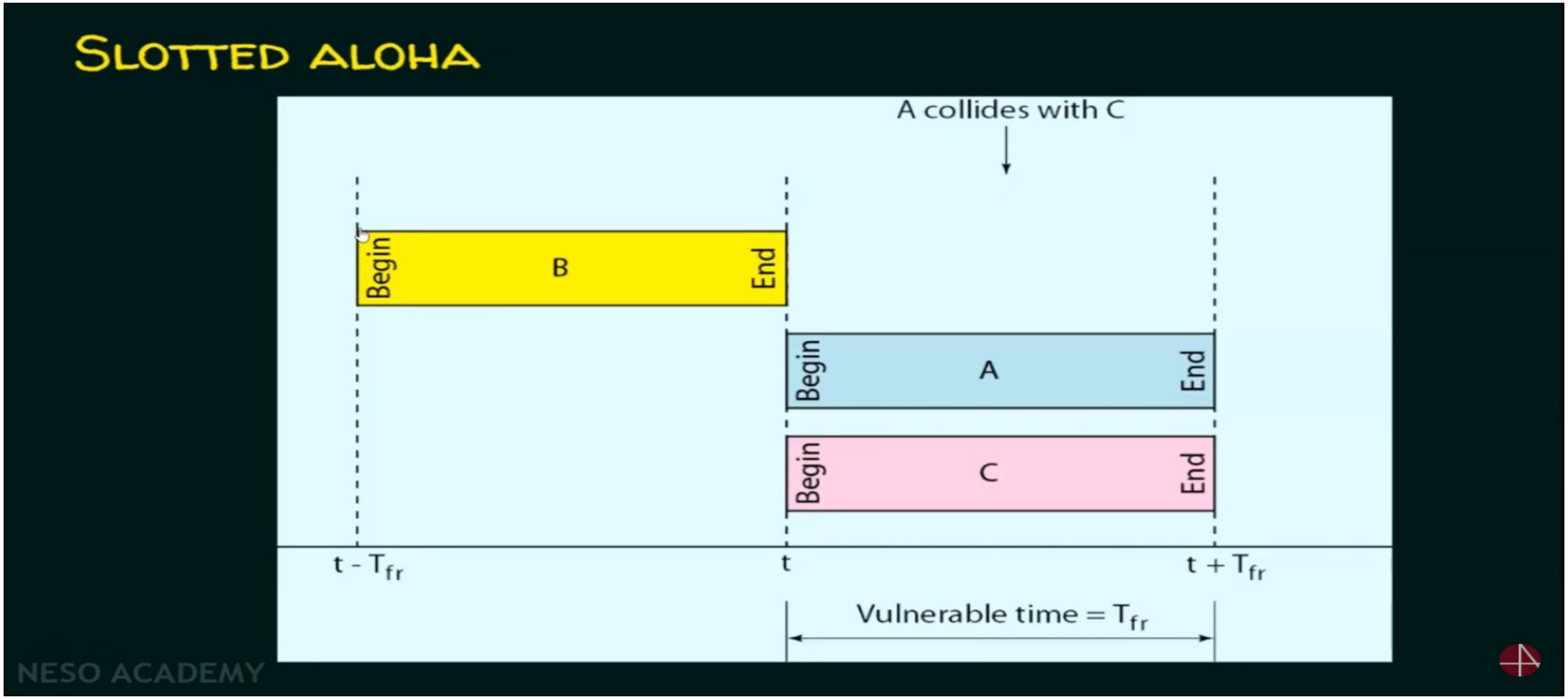
Slotted aloha

- ★ It was developed just to improve the efficiency of pure aloha as th
chances for collision in pure aloha are high.
- ★ The time of the shared channel is divided into discrete time interval
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 slo
This reduces the probability of collision.

Slotted aloha



- The a station is allowed to send only at the beginning of the synchronized time slot, if a station misses this moment, it must wait until the beginning of the next time slot. There is still possibility of collision if two stations try to send at the beginning of the same time slot. The **vulnerable time** is reduced to one-half that of pure ALOHA i.e Tfr.



SLOTTED ALOHA

Vulnerable Time = Frame Transmission Time.

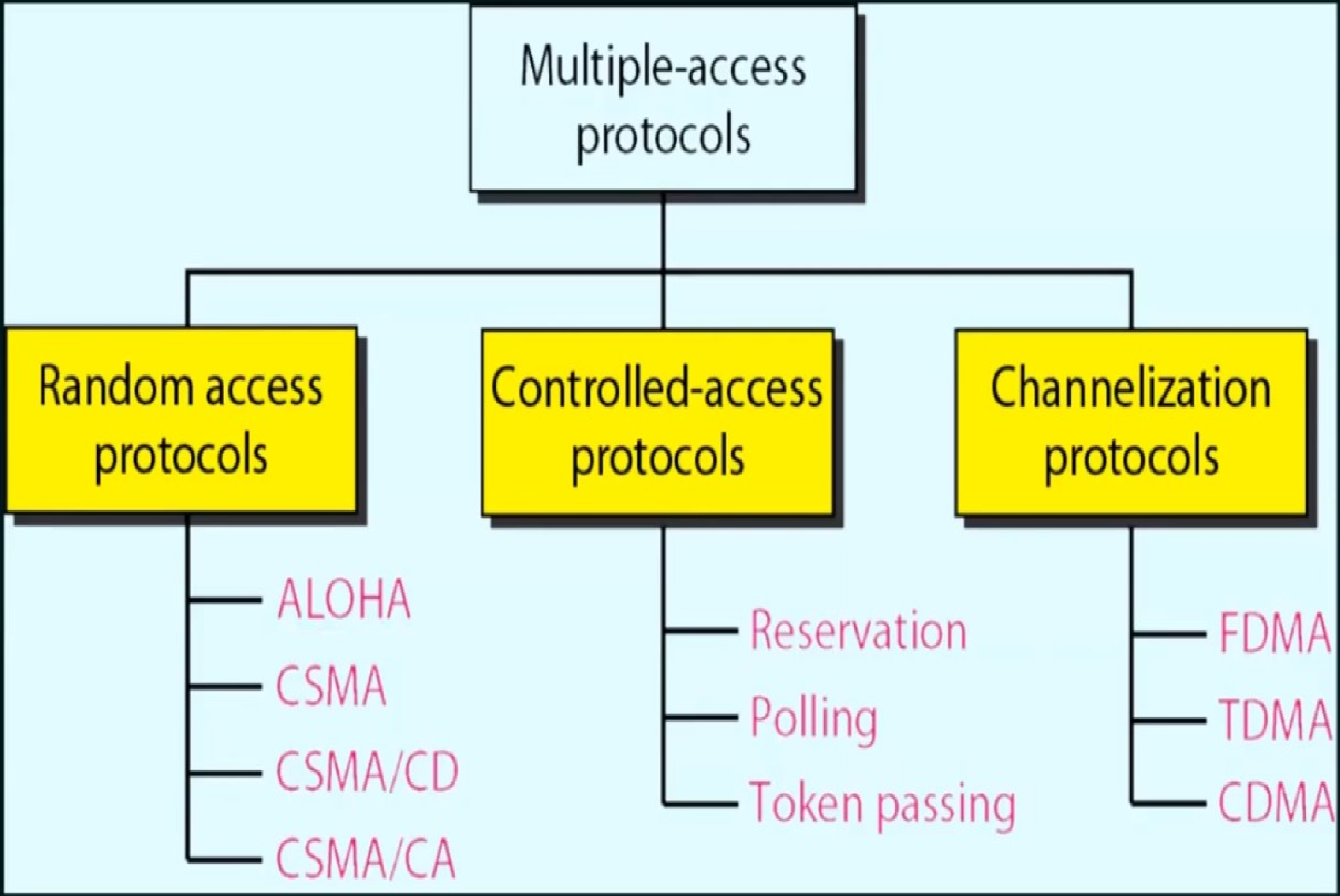
Throughput = $G \times e^{-G}$; Where G is the number of stations wish to transmit in the same time.

Maximum throughput = 0.368 for G=1.

Pure aloha vs Slotted aloha

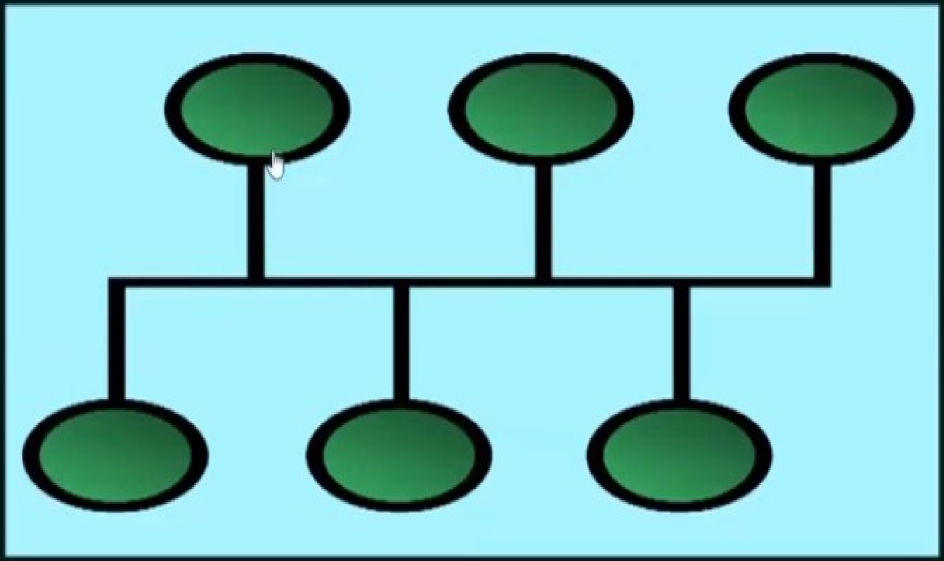
Pure Aloha	Slotted Aloha
Any station can transmit the data at any time.	Any station can transmit the data at the beginning of any time slot.
The time is continuous and not globally synchronized.	The time is discrete and globally synchronized.
Vulnerable time in which collision may occur $= 2 \times T_{Fr}$	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.

MULTIPLE ACCESS PROTOCOLS



CSMA PROTOCOL

- ★ 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."



CSMA PROTOCOL

- ★ 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.

TYPES OF CSMA

1. 1-Persistent CSMA

2. P-Persistent CSMA

3. Non-Persistent CSMA

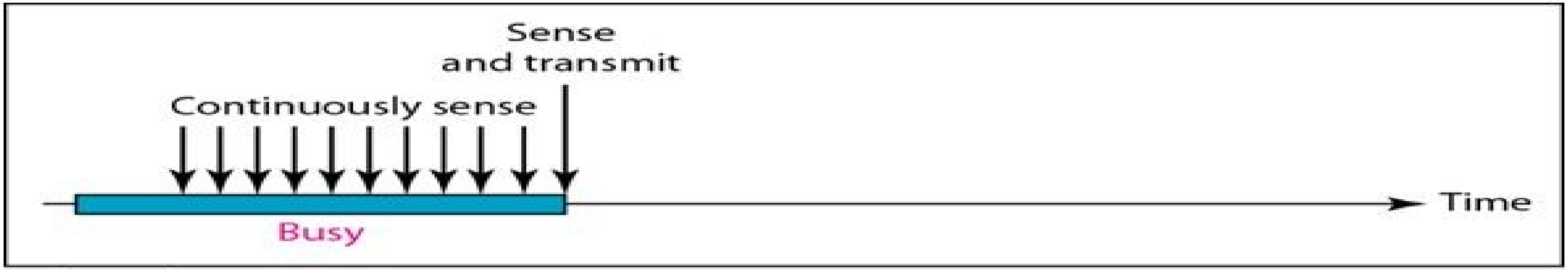
4. O-Persistent CSMA

CSMA/CD (CSMA with Collision Detection)

CSMA/CA (CSMA with Collision Avoidance)

1-Persistent CSMA

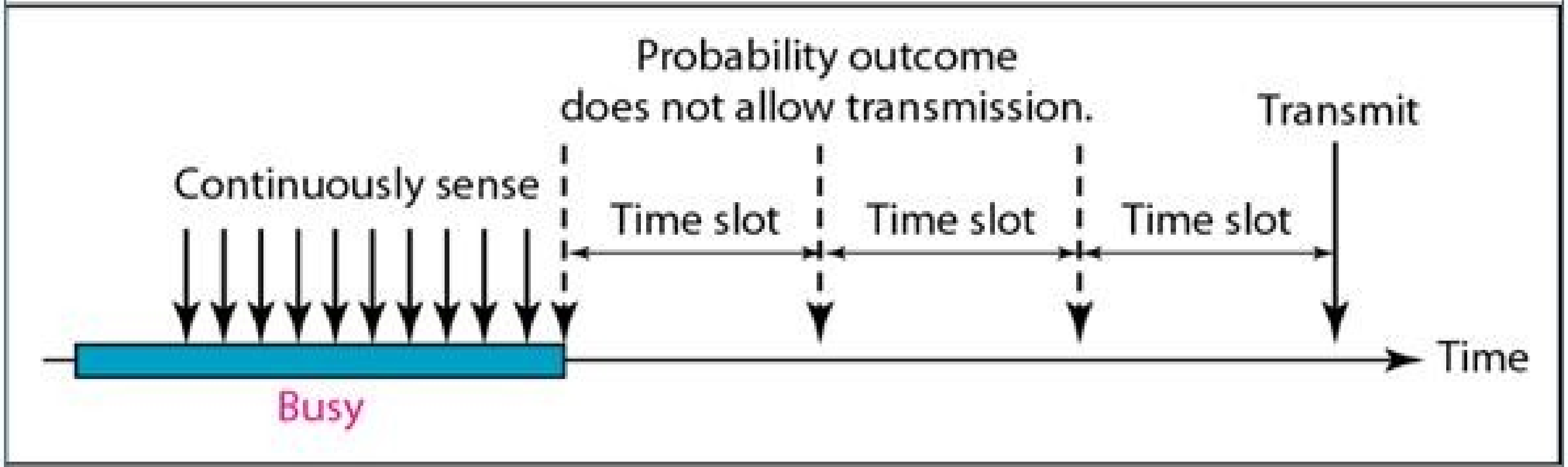
- Before sending the data, the station first listens to the channel to see if anyone else is transmitting the data at that moment.
- If the channel is idle, the station transmits a frame.
- If busy, then it senses the transmission medium continuously until it becomes idle.
- Since the station transmits the frame with the probability of 1 when the carrier or channel is idle, this scheme of CSMA is called as 1-Persistent CSMA.
- The propagation delay has an important effect on the performance of the protocol.



a. 1-persistent

P-Persistent CSMA

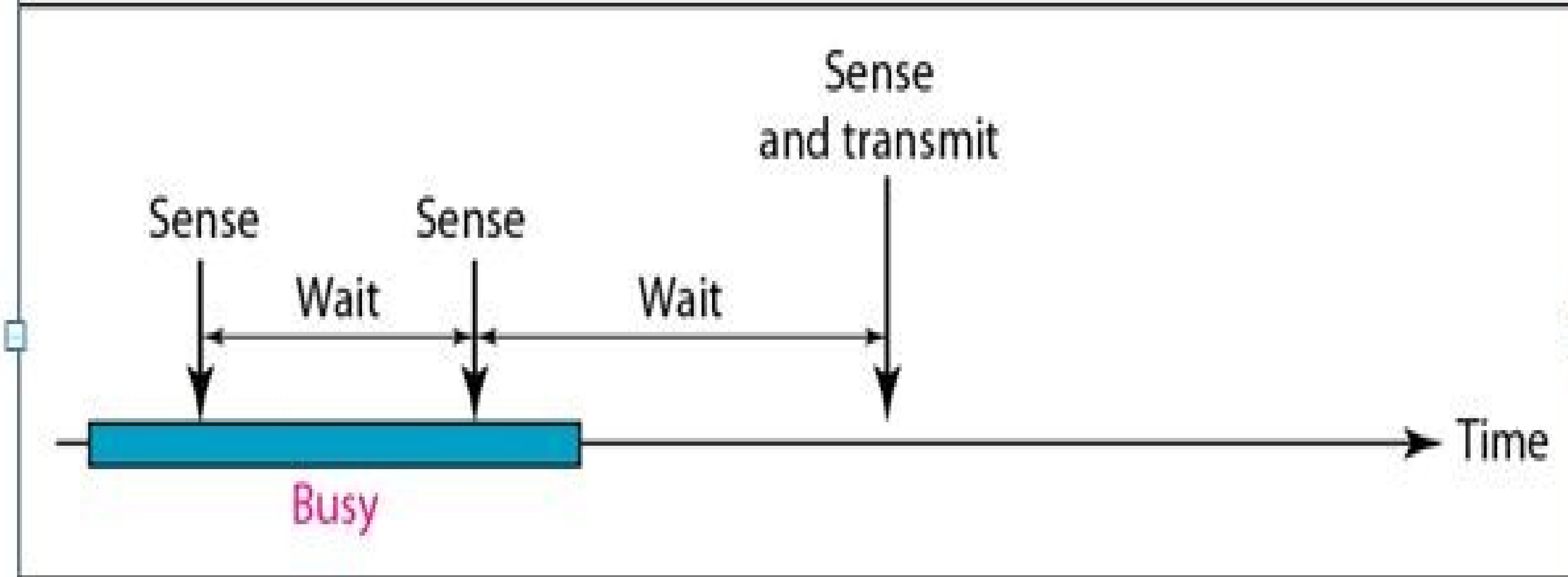
- ★ It applies to slotted channels.
- ★ When a station becomes ready to send, it senses the channel.
- ★ If it is idle, it transmits with a probability P.
- ★ With a probability Q=1-P, it defers until the next slot.
- ★ If that slot is also idle, it either transmits or defers again, with probabilities P and Q.
- ★ This process is repeated until either the frame has been transmitted or another station has begun transmitting.
- ★ In the latter case, the unlucky station acts as if there had been a collision (i.e., it waits a random time and starts again).
- ★ If the station initially senses the channel busy, it waits until the next slot and applies the above algorithm.



c. p-persistent

NON-PERSISTENT CSMA

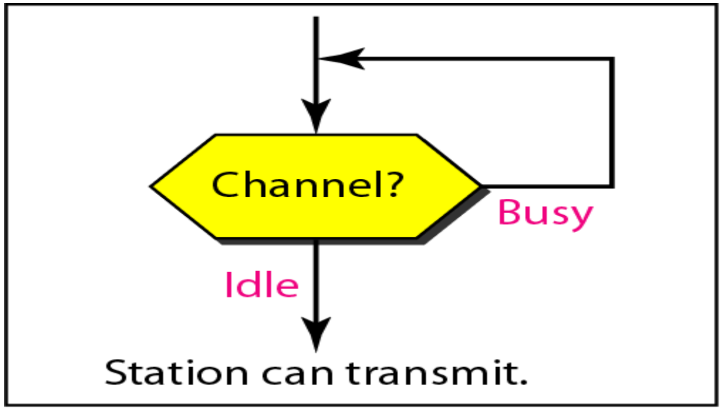
- ★ Before sending, a station senses the channel. If no one else is sending, the station begins doing so itself.
- ★ However, if the channel is already in use, the station does not continually sense it for the purpose of seizing it immediately upon detecting the end of the previous transmission.
- ★ Instead, it waits a random period of time and then repeats the algorithm. Consequently, this algorithm leads to better channel utilization but longer delays than 1-persistent CSMA.



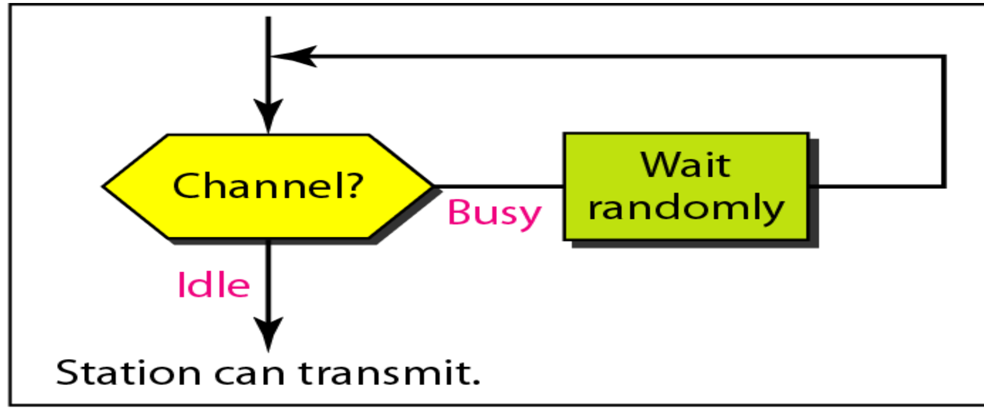
b. Nonpersistent

O-Persistent CSMA

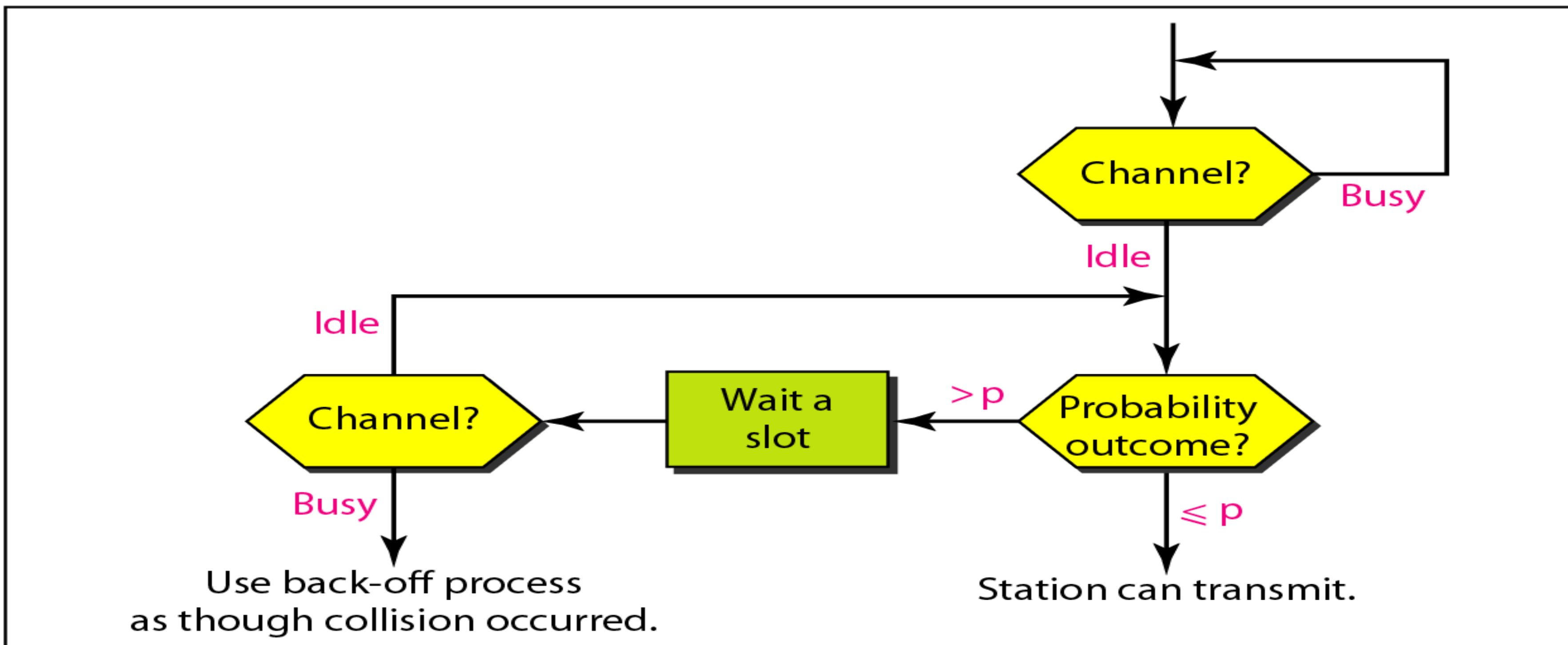
★ Each node is assigned a transmission order by a supervisory node.



a. 1-persistent



b. Nonpersistent



c. p-persistent

The **Carrier Sense Multiple Access/ Collision Detection**

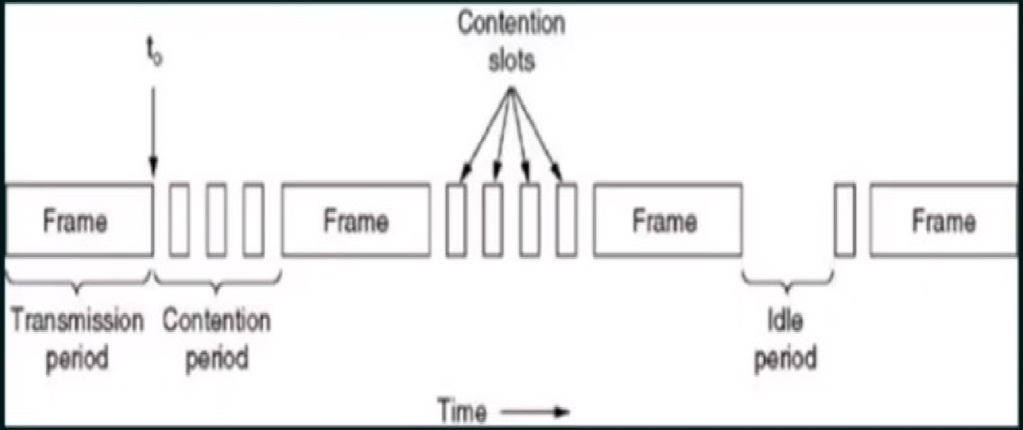
- **This** protocol is used to detect a collision in the media access control (**MAC**) layer. Once the collision was detected, the CSMA CD immediately stopped the transmission by sending the signal so that the sender does not waste all the time to send the data packet. Suppose a collision is detected from each station while broadcasting the packets. In that case, the CSMA CD immediately sends a jam signal to stop transmission and waits for a random time context before transmitting another data packet. If the channel is found free, it immediately sends the data and returns it

CSMA/CD

- If two stations sense the channel to be idle and begin transmitting simultaneously, they will both detect the collision almost immediately.
- Rather than finish transmitting their frames, which are irretrievably garbled anyway, they should abruptly stop transmitting as soon as the collision is detected.
- Quickly terminating damaged frames saves time and bandwidth.
- This protocol, known as CSMA/CD (CSMA with Collision Detection) is widely used on LANs in the MAC sublayer.
- Access method used by Ethernet: CSMA/CD.

CSMA/CD

- ★ At the point marked t_0, a station has finished transmitting its frame.
- ★ Any other station having a frame to send may now attempt to do so. If two or more stations decide to transmit simultaneously, there will be a collision.



CSMA/CD

- ★ At the point marked t_0, a station has finished transmitting its frame.
- ★ Any other station having a frame to send may now attempt to do so. If two or more stations decide to transmit simultaneously, there will be a collision.
- ★ Collisions can be detected by looking at the power or pulse width of the received signal and comparing it to the transmitted signal.
- ★ After a station detects a collision, it aborts its transmission, waits a random period of time, and then tries again, assuming that no other station has started transmitting in the meantime.
- ★ Therefore, model for CSMA/CD will consist of alternating contention and transmission periods, with idle periods occurring when all stations are quiet.

- **Advantages of CSMA CD:**
- It is used for collision detection on a shared channel within a very short time.
- CSMA CD is better than CSMA for collision detection.
- CSMA CD is used to avoid any form of waste transmission.
- When necessary, it is used to use or share the same amount of bandwidth at each station.
- It has lower CSMA CD overhead as compared to the CSMA CA.
- **Disadvantage of CSMA CD**
- It is not suitable for long-distance networks because as the distance increases, CSMA CD' efficiency decreases.
- It can detect collision only up to 2500 meters, and beyond this range, it cannot detect collisions.
- When multiple devices are added to a CSMA CD, collision detection performance is reduced.

S. No	CSMA CD	CSMA CA
1.	It is the type of CSMA to detect the collision on a shared channel.	It is the type of CSMA to avoid collision on a shared channel.
2.	It is the collision detection protocol.	It is the collision avoidance protocol.
3.	It is used in 802.3 Ethernet network cable.	It is used in the 802.11 Ethernet network.
4.	It works in wired networks.	It works in wireless networks.
5.	It is effective after collision detection on a network.	It is effective before collision detection on a network.
6.	Whenever a data packet conflicts in a shared channel, it resends the data frame.	Whereas the CSMA CA waits until the channel is busy and does not recover after a collision.
7.	It minimizes the recovery time.	It minimizes the risk of collision.
8.	The efficiency of CSMA CD is high as compared to CSMA.	The efficiency of CSMA CA is similar to CSMA.
9.	It is more popular than the CSMA CA protocol.	It is less popular than CSMA C

Carrier Sense Multiple Access Collision Avoidance

- CSMA/CA
- It means that it is a network protocol that uses to avoid a collision rather than allowing it to occur, and it does not deal with the recovery of packets after a collision. It is similar to the CSMA CD protocol that operates in the media access control layer. In CSMA CA, whenever a station sends a data frame to a channel, it checks whether it is in use. If the shared channel is busy, the station waits until the channel enters idle mode. Hence, we can say that it reduces the chances of collisions and makes better use of the medium to send data packets more efficiently.

CSMA/CA

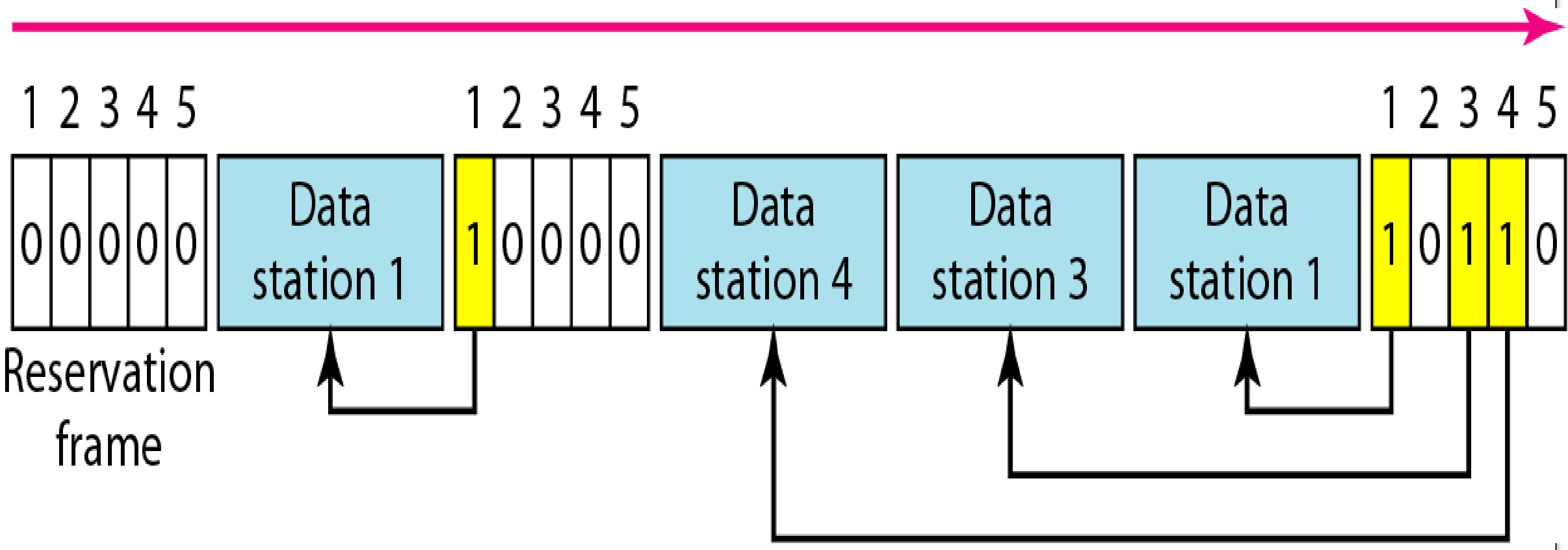
- Carrier-sense multiple access with collision avoidance (CSMA/CA) is a network multiple access method in which carrier sensing is used, but nodes attempt to avoid collisions by beginning transmission only after the channel is sensed to be "idle".
- It is particularly important for wireless networks, 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.

CSMA/CA

★ The Access method used by IEEE 802.11 Wi-Fi is CSMA/CA.

Reservation

- A station need to make a reservation before sending data.
- In each interval, a reservation frame precedes the data frames ser
  that interval.
- If there are N stations in the system, there are exactly N reservat
  minislots in the reservation frame.
- Each minislot belongs to a station.
- When a station needs to send a data frame, it makes a reservatio
  its own minislot.
- The stations that have made reservations can send their data fram
  after the reservation frame.



1 2 3 4 5
0 0 0 0 0
Reservation frame
Data station 1
1 2 3 4 5
1 0 0 0 0
Data station 4
Data station 3
Data station 1
1 2 3 4 5
1 0 1 1 0

- When a station needs to send a data frame, it makes a reservation in its own mini slot. The stations that have made reservations can send their data frames after the reservation frame.
- The following Figure shows a situation with five stations and a five-mini slot reservation frame. In the first interval, only stations 1, 3, and 4 have made reservations. In the second interval, only station 1 has made a reservation.

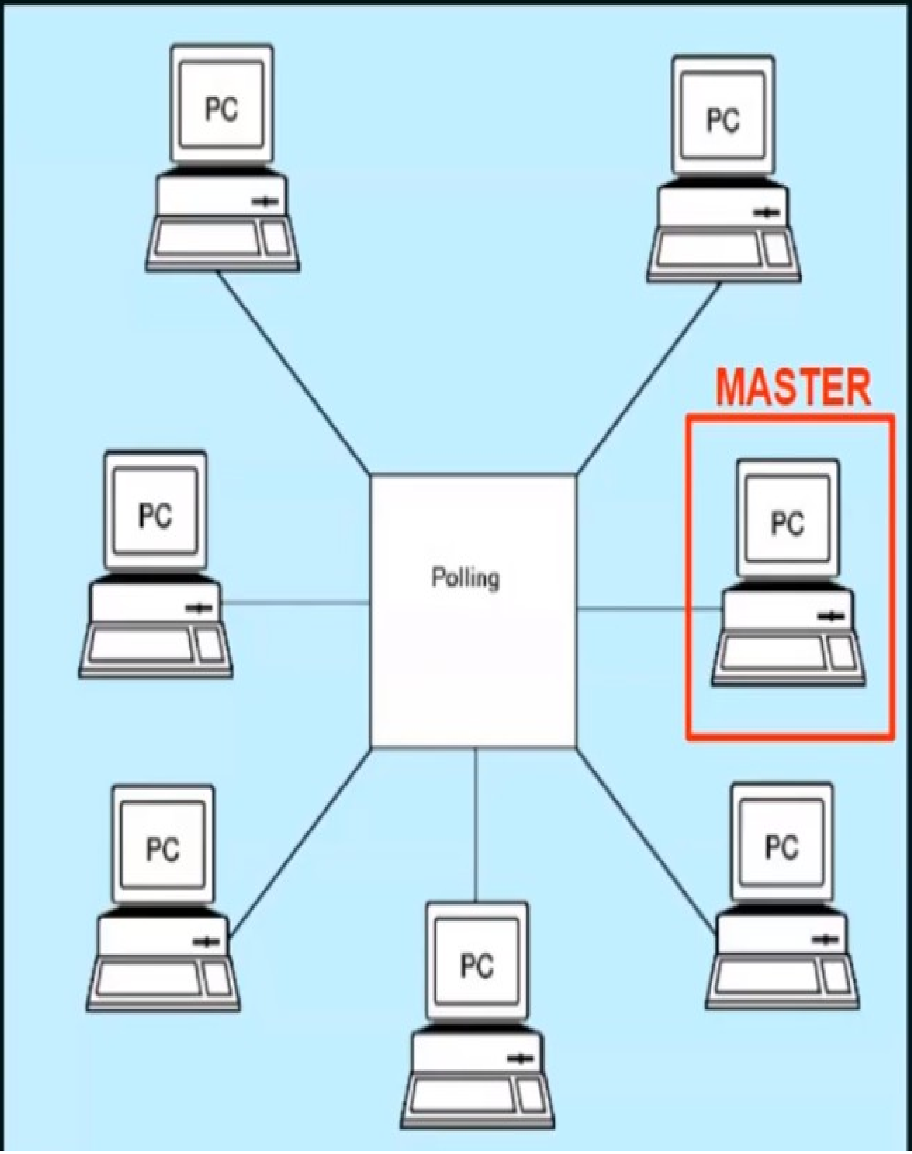
Polling

- The polling protocol requires one of the nodes to be designated as a Master node (Primary station).
- The master node polls each of the nodes in a round-robin fashion.
- In particular, the master node first sends a message to node 1, saying that it (node 1) can transmit up to some maximum number of frames.
- After node 1 transmits some frames, the master node tells node 2 it (node 2) can transmit up to the maximum number of frames.
- The master node can determine when a node has finished sending its frames by observing the lack of a signal on the channel.

Polling

- ★ The procedure continues in this manner, with the master node polling each of the nodes in a cyclic manner.
- ★ The polling protocol eliminates the collision.
- ★ This allows polling to achieve a much higher efficiency.
- ★ The first drawback is that the protocol introduces a polling delay—the amount of time required to notify a node that it can transmit.
- ★ The second drawback, which is potentially more serious, is that if the master node fails, the entire channel becomes inoperative.

Polling



Polling – Functions

- **Poll function :** If the primary wants to receive data, it asks the secondaries if they have anything to send.
- **Select function :** If the primary wants to send data, it tells the secondary to get ready to receive.

Efficiency of Polling

Let T_{poll} be the time for polling and T_t be the time required for transmission of data. Then,

$$Efficiency = \frac{T_t}{T_t + T_{poll}}$$

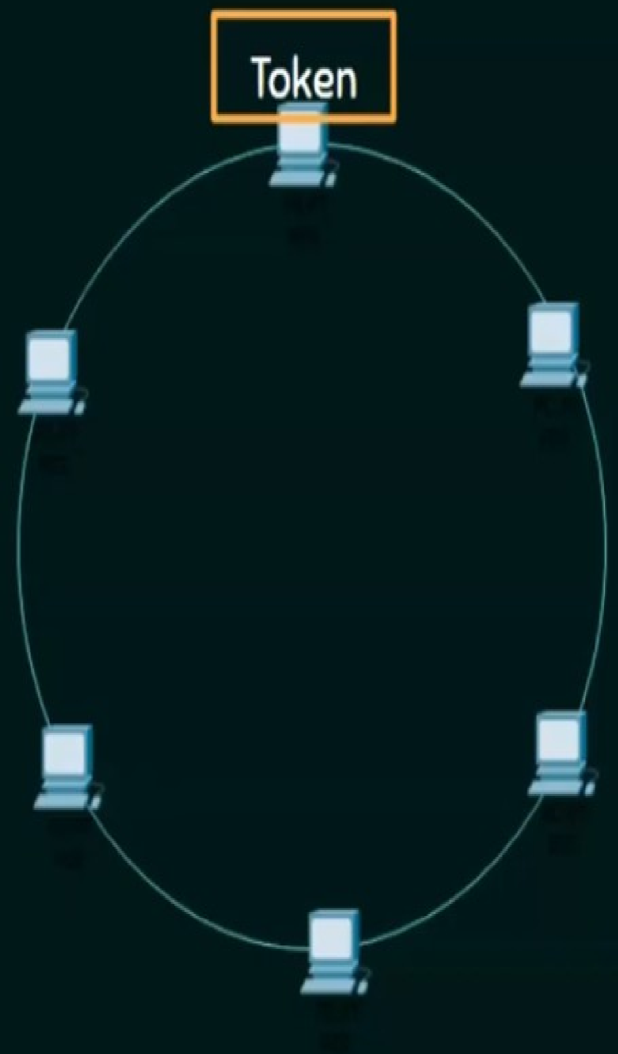
Token passing

- A station is authorized to send data when it receives a special frame called a token.
- Here there is no master node.
- A small, special-purpose frame known as a token is exchanged among the nodes in some fixed order.
- When a node receives a token, it holds onto the token only if it has some frames to transmit; otherwise, it immediately forwards the token to the next node.

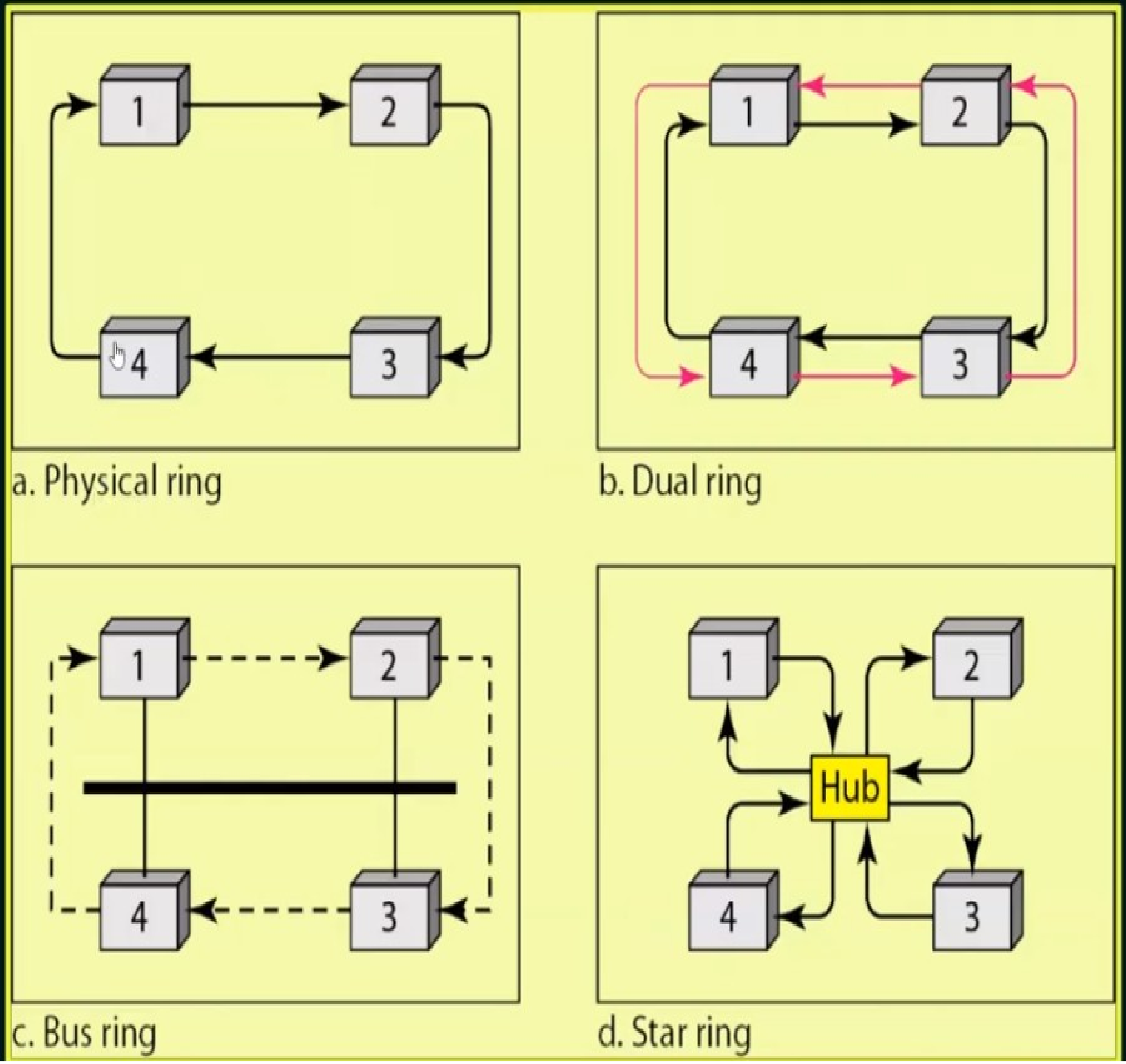
Token passing

- If a node does have frames to transmit when it receives the token, it sends up to a maximum number of frames and then forwards the token to the next node.
- Token passing is decentralized and highly efficient. But it has problems as well.
- For example, the failure of one node can crash the entire channel. Or if a node accidentally neglects to release the token, then some recovery procedure must be invoked to get the token back in circulation.

Token Passing



Token passing



PERFORMANCE OF TOKEN PASSING

$$S = \frac{1}{1 + a/N} \quad ; \text{for } a < 1$$

$$S = \frac{1}{a(1 + 1/N)} \quad ; \text{for } a > 1$$

$$a = \frac{T_p}{T_t}$$

S = Throughput

N = number of stations

T_p = Propagation delay

T_t = Transmission delay

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.

MULTIPLEXING

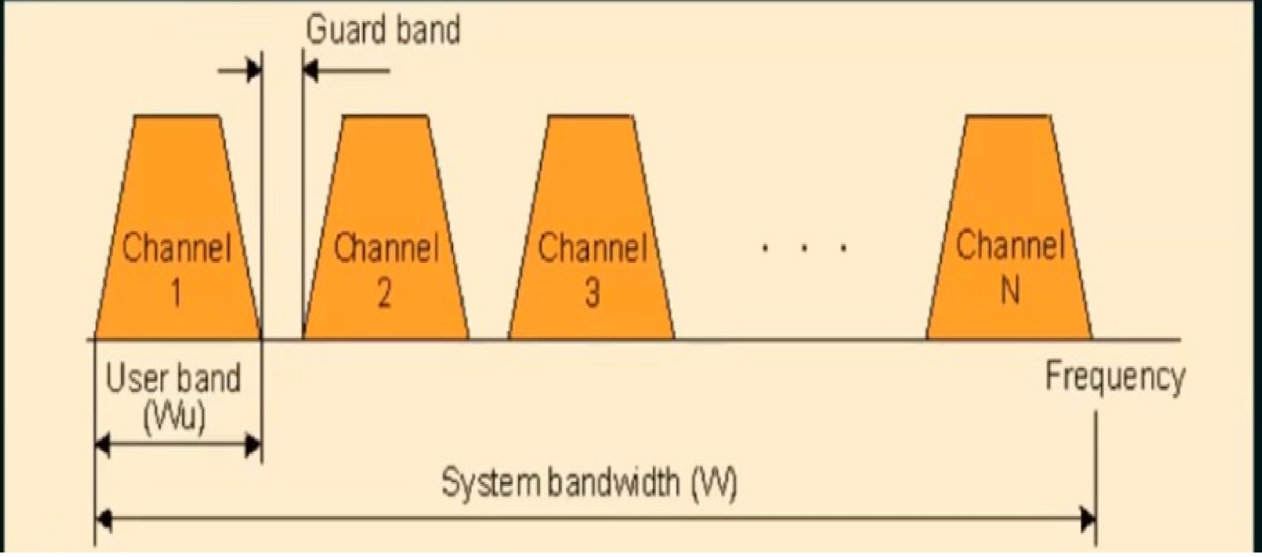
- Multiplexing in computer networking means multiple signals are combined together thus travel simultaneously in a shared medium.
- Multiplexing = Sharing the bandwidth.

Various multiple access methods

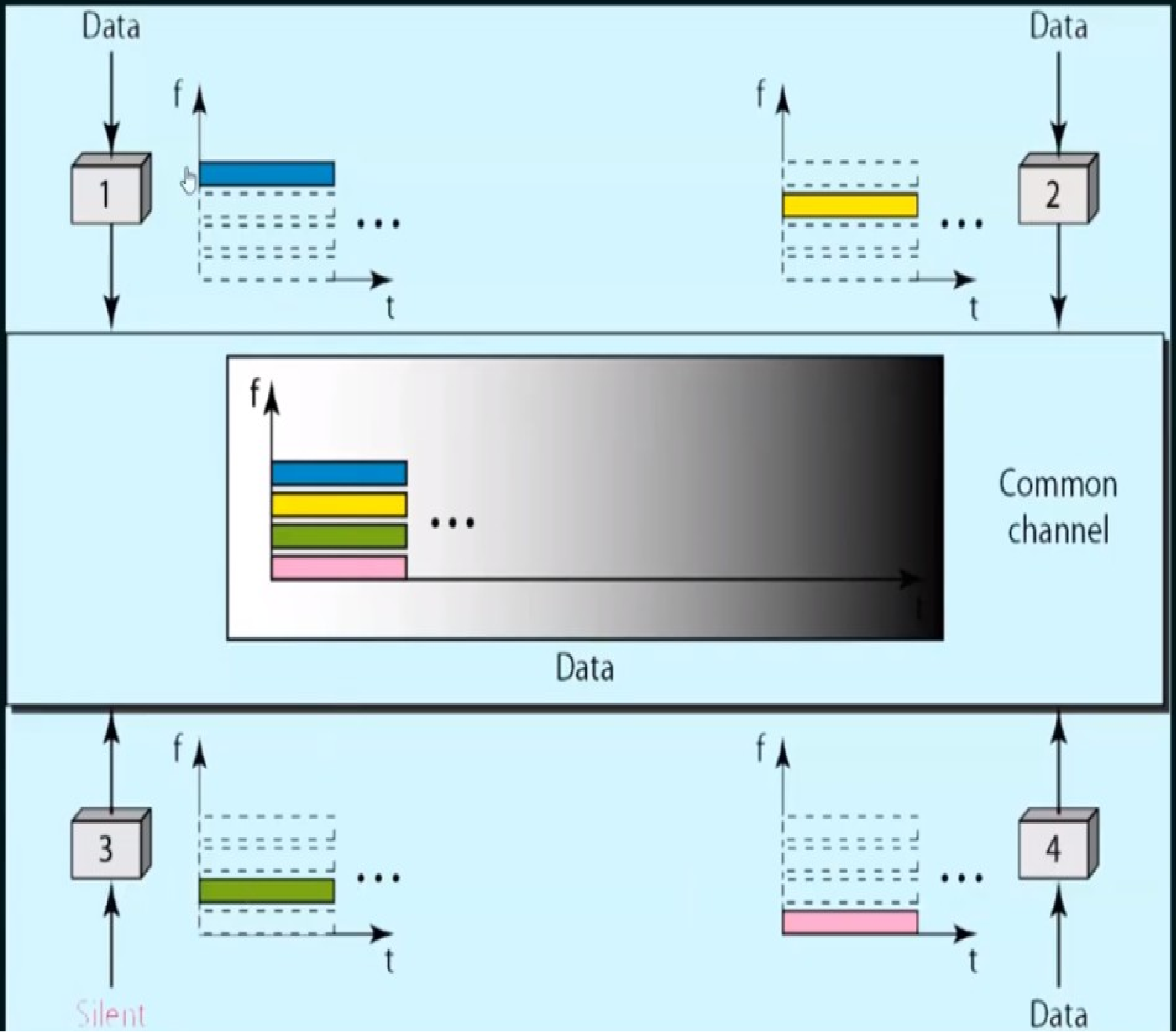
- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)

FDMA

- In FDMA, the available bandwidth of the common channel is divided into bands that are separated by guard bands.
- The available bandwidth is shared by all stations.
- The FDMA is a data link layer protocol that uses FDM at the physical layer.



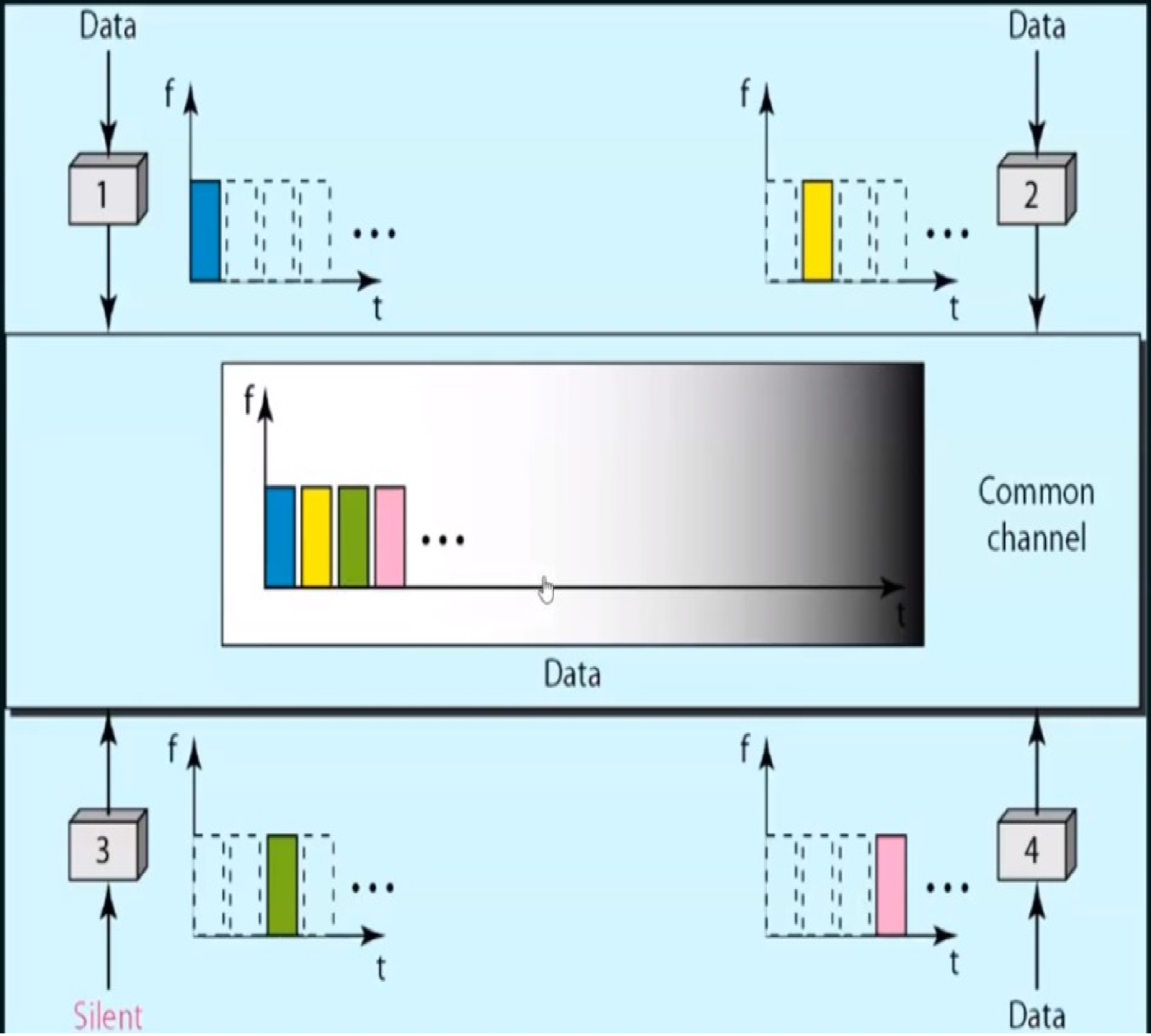
FDMA



TDMA

- ★ In TDMA, the bandwidth is just one channel that is time shared between different stations.
- ★ The entire bandwidth is just one channel.
- ★ Stations share the capacity of the channel in time.

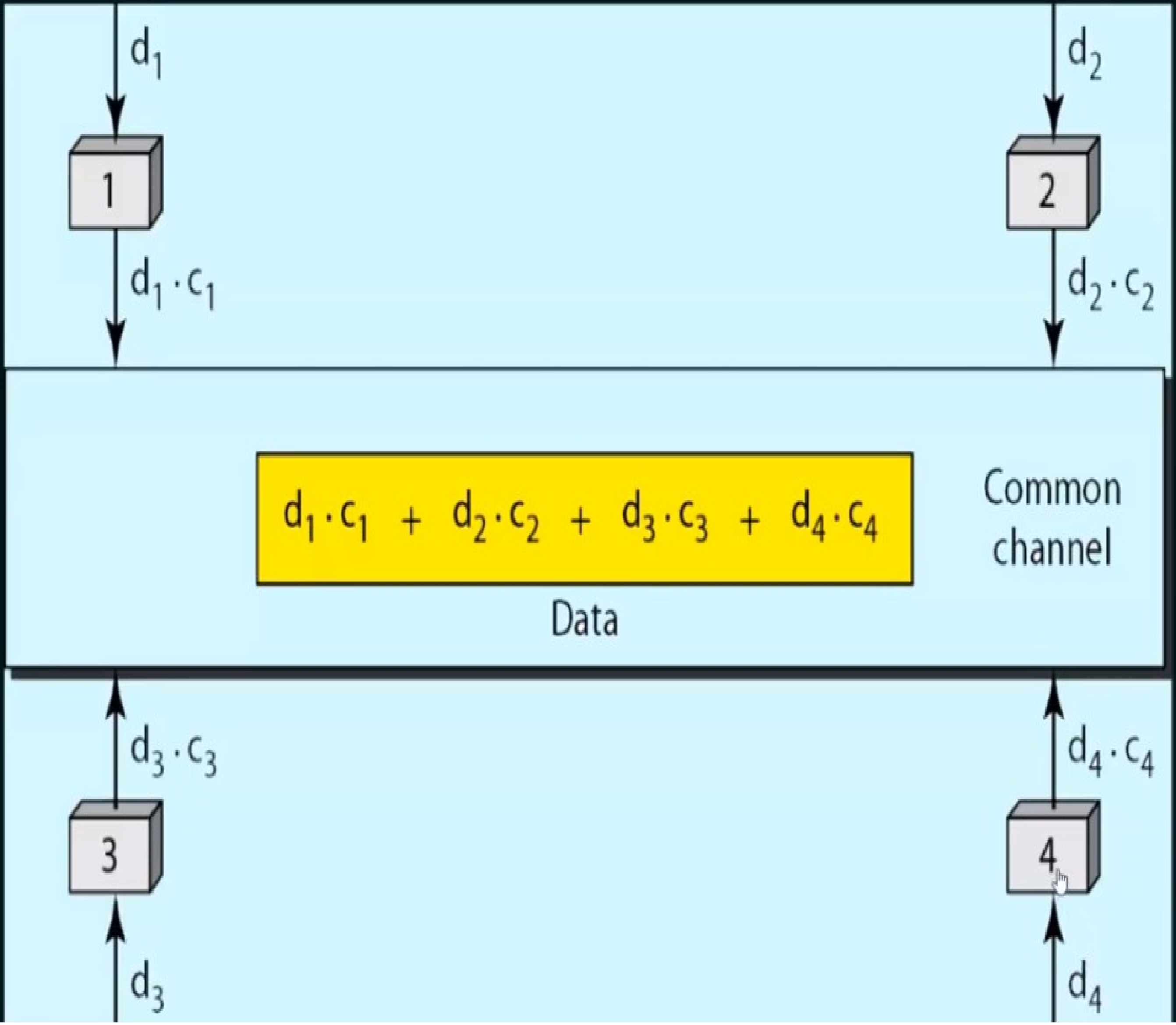
TDMA



CDMA

- In CDMA, one channel carries all transmissions simultaneously.
- CDMA differs from FDMA because only one channel occupies the entire bandwidth of the link.
- It differs from TDMA because all stations can send data simultaneously; there is no time sharing.

CDMA



d_1
1
$d_1 \cdot c_1$
d_2
2
$d_2 \cdot c_2$
$d_1 \cdot c_1 + d_2 \cdot c_2 + d_3 \cdot c_3 + d_4 \cdot c_4$
Data
Common channel
$d_3 \cdot c_3$
3
d_3
$d_4 \cdot c_4$
4
d_4