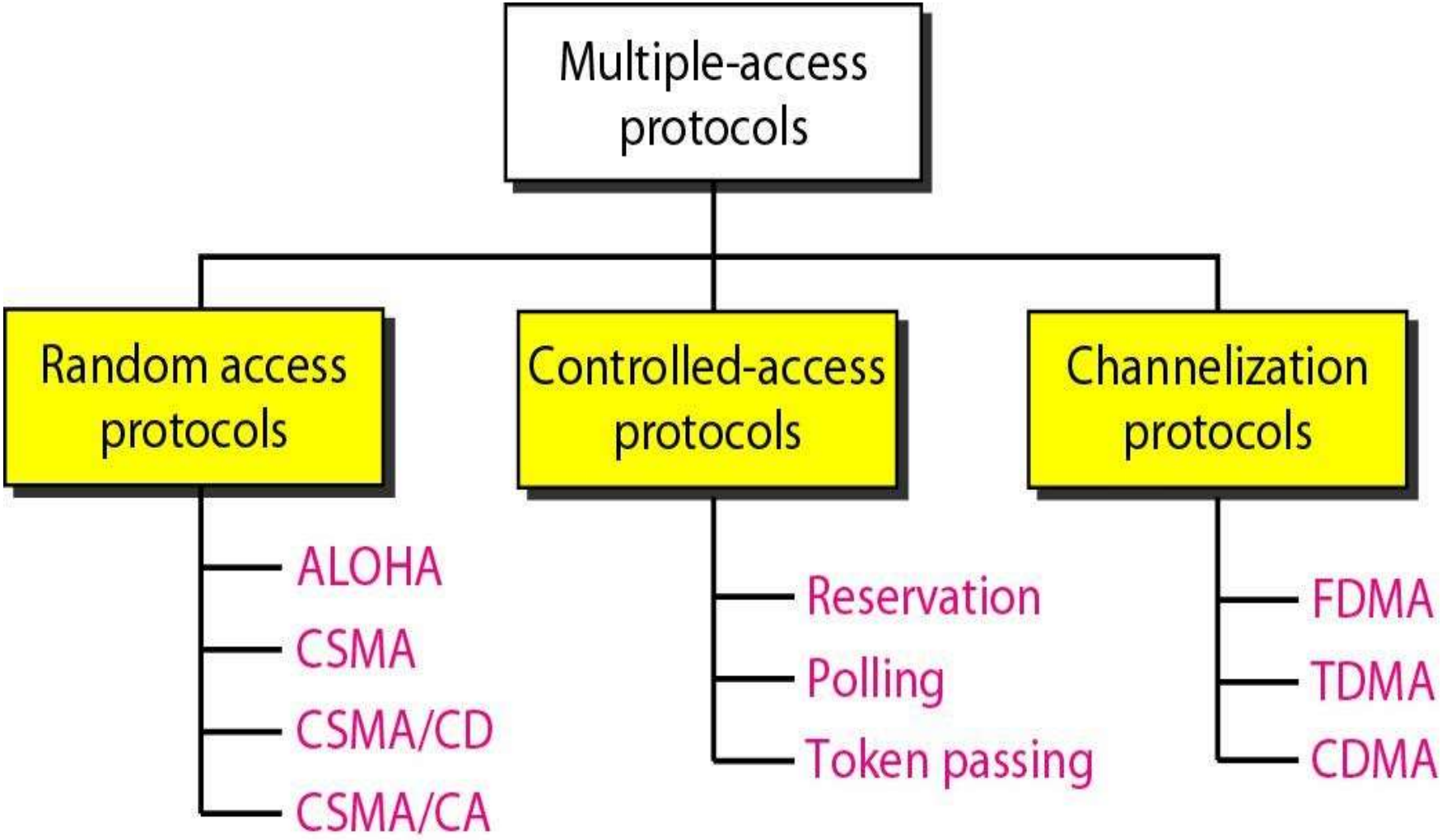
UNIT – III: Media Access Control: Random Access: ALOHA, Carrier sense multiple access (CSMA), CSMA with Collision Detection, CSMA with Collision Avoidance, **Controlled Access:** Reservation, Polling, Token Passing, **Channelization:** frequency division multiple Access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA).

Wired LANs: Ethernet, Ethernet Protocol, Standard Ethernet, Fast Ethernet(100 Mbps), Gigabit Ethernet, 10 Gigabit Ethernet.

Multiple Access Protocols



- **Random Access Protocols:**

  In this, all stations have same superiority that is no station has more priority than another station. Any station can send data depending on medium's state(idle or busy).
- **Controlled Access Protocols:**
  In this, the data is sent by that station which is approved by all other stations.
- **Channelization Protocols:**
  In this, the available bandwidth of the link is shared in time, frequency and code to multiple stations to access channel simultaneously

Random Access Protocols

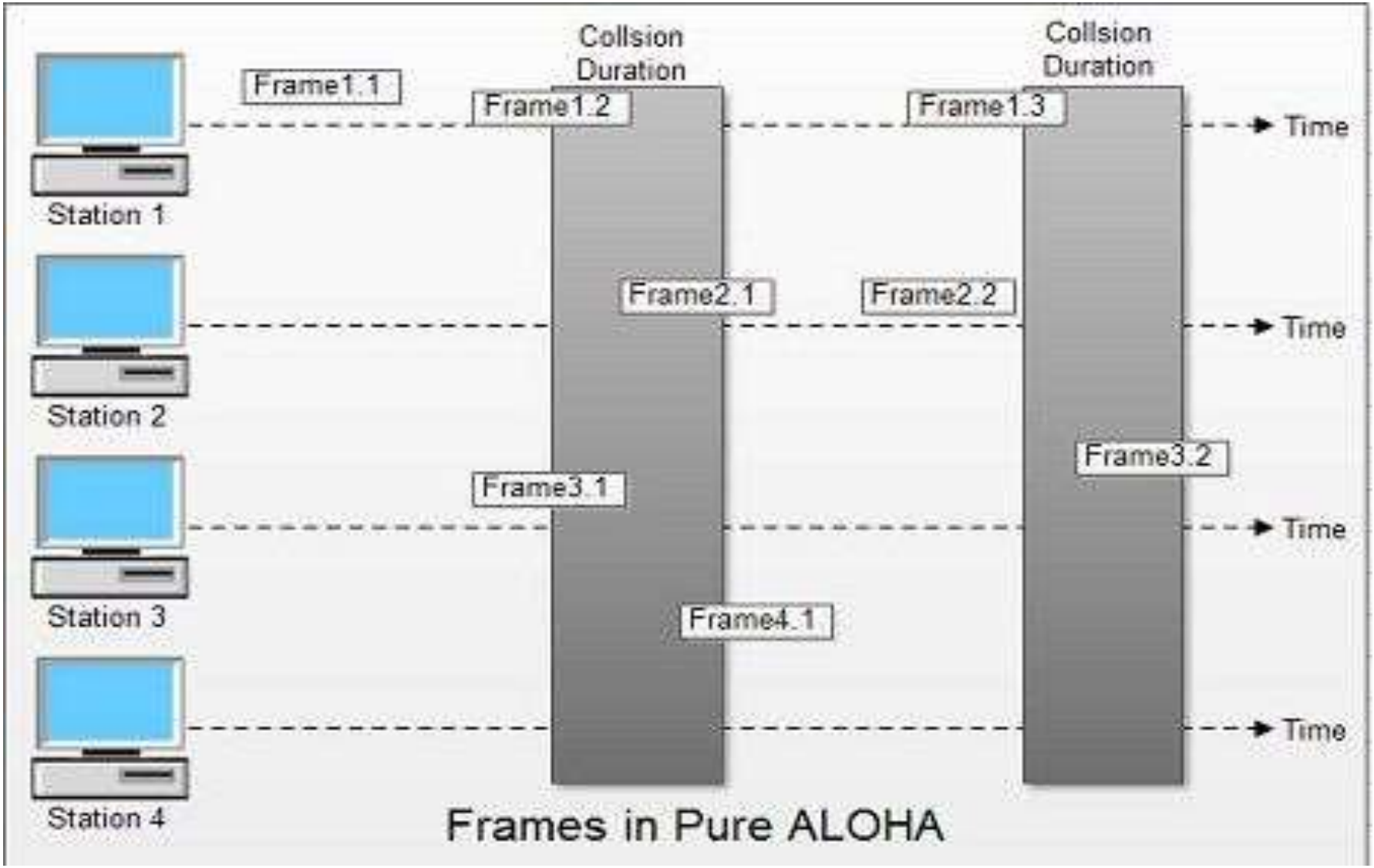
- **ALOHA:**
- It was designed for wireless LAN but is also applicable for shared medium.
- In this, multiple stations can transmit data at the same time and can hence lead to collision and data being garbled.
- They are two versions of ALOHA protocols: **pure** and **slotted**.
- **Pure ALOHA:**
- When 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

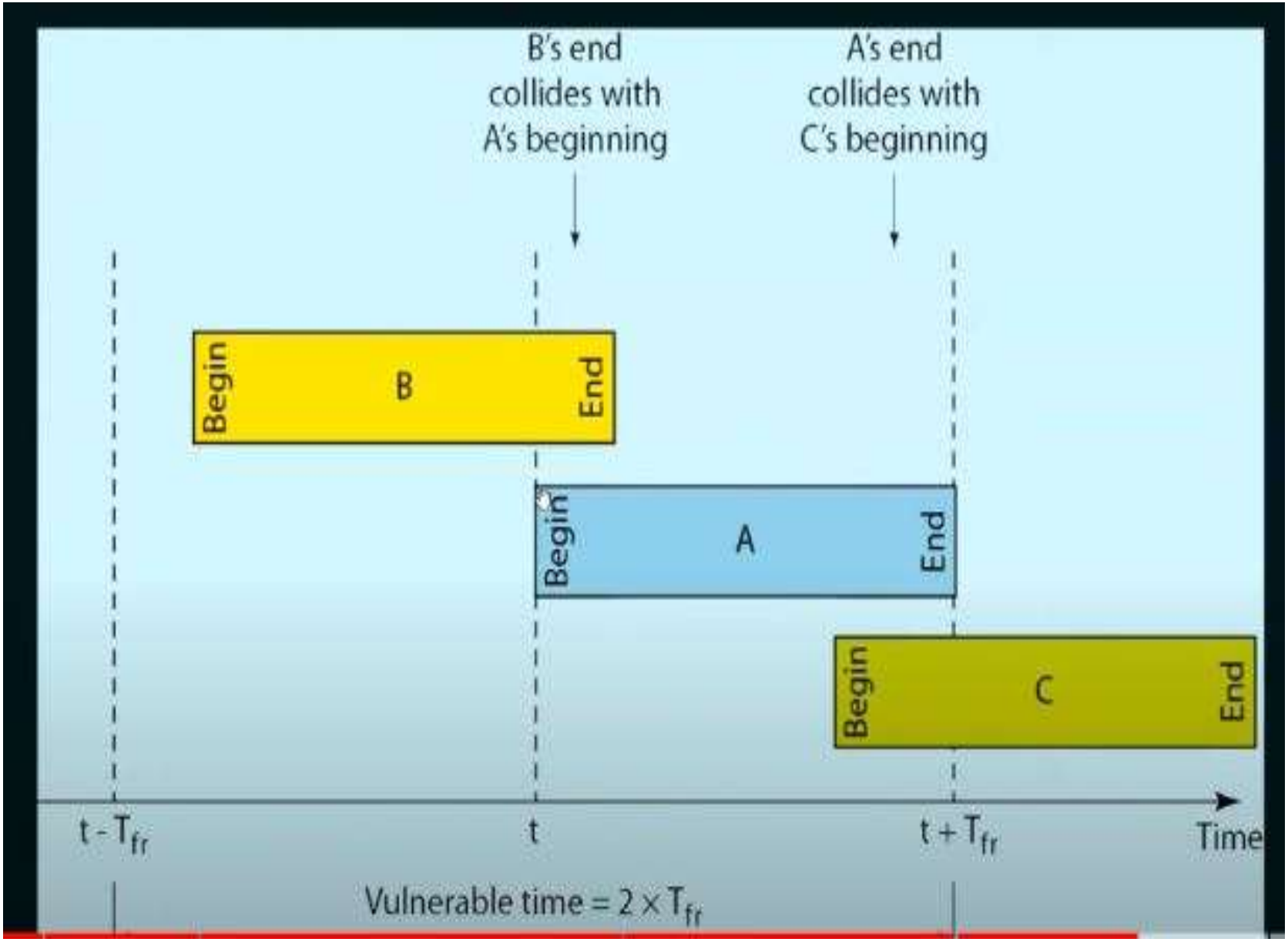
- **Vulnerable Time:**
- The vulnerable time is the period during which a transmitted frame is susceptible to collisions. For Pure ALOHA, this period is twice the frame transmission time (2Tt).

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


Collsion Duration
Collsion Duration
Frame1.1
Frame1.2
Frame1.3
Time
Station 1
Frame2.1
Frame2.2
Time
Station 2
Frame3.2
Frame3.1
Time
Station 3
Frame4.1
Time
Station 4
Frames in 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 - Tfr
t
t + Tfr
Time
Vulnerable time = 2 × Tfr

- ★ 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

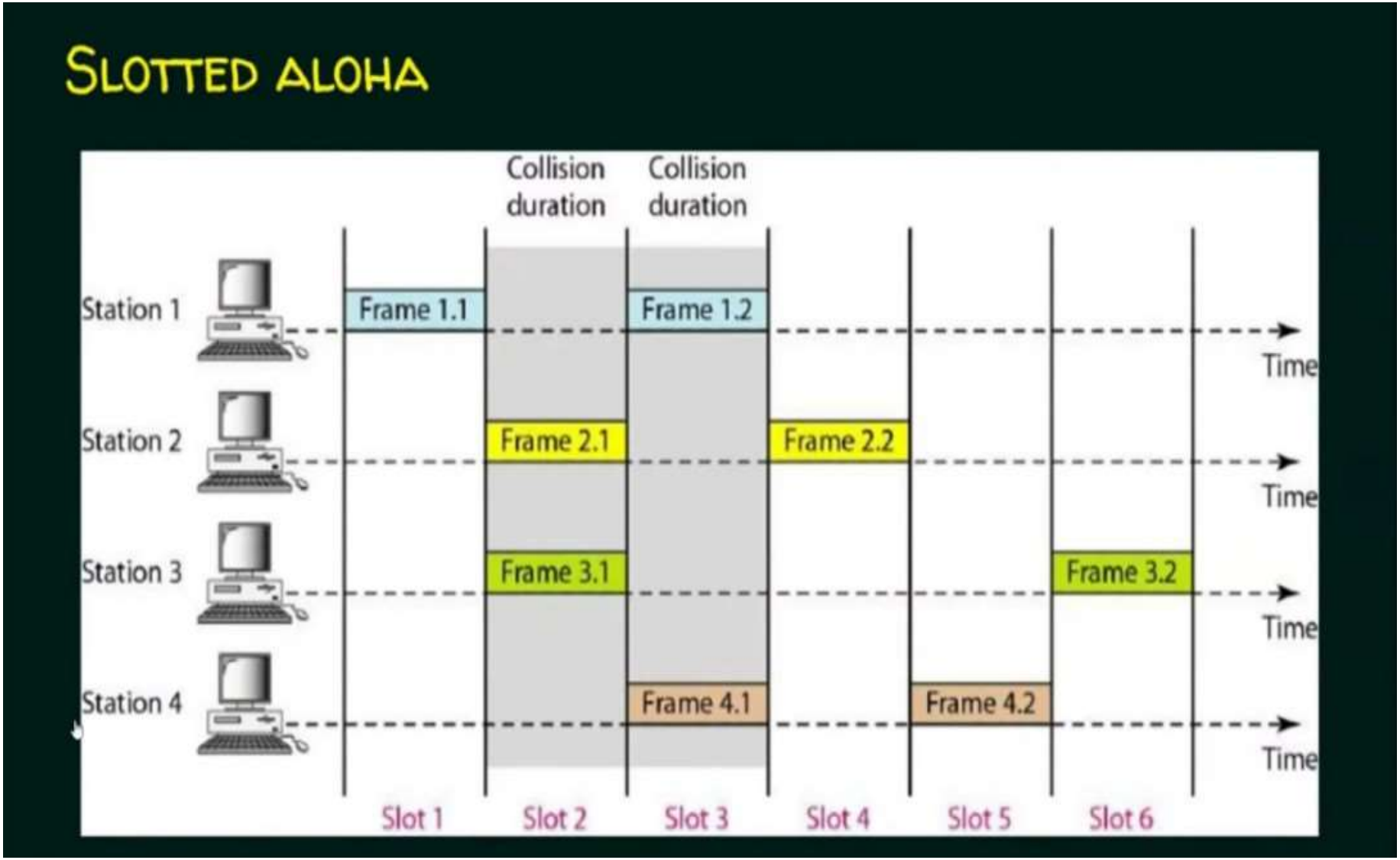
- It was developed just to improve the efficiency of pure aloha as the chances for collision in pure aloha are high.
- We divide time into slots and sending of data is allowed only at the beginning of these slots.
- If a station misses out the allowed time, it must wait for the next slot
- In this, The time is discrete and globally synchronized.
- In Slotted Aloha, Probability of successful transmission of data packet= $G \times e^{-G}$
- Slotted aloha reduces the number of collisions to half and doubles the efficiency of pure aloha

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.

NESO ACADEMY

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

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.

Non-Persistent CSMA

- In this method of CSMA, if the station finds the channel busy, then it will wait for a random amount of time before sensing the channel again.
- If the station wants to transmit the data then first of all it will sense the medium.
- If the medium is idle then the station will immediately send the data.
- Otherwise, if the medium is busy then the station waits for a random amount of time and then again senses the channel after waiting for a random amount of time.
- In Non-persistent there is less chance of collision in comparison to the 1-persistent method as this station will not continuously sense the channel but since the channel after waiting for a random amount of time.

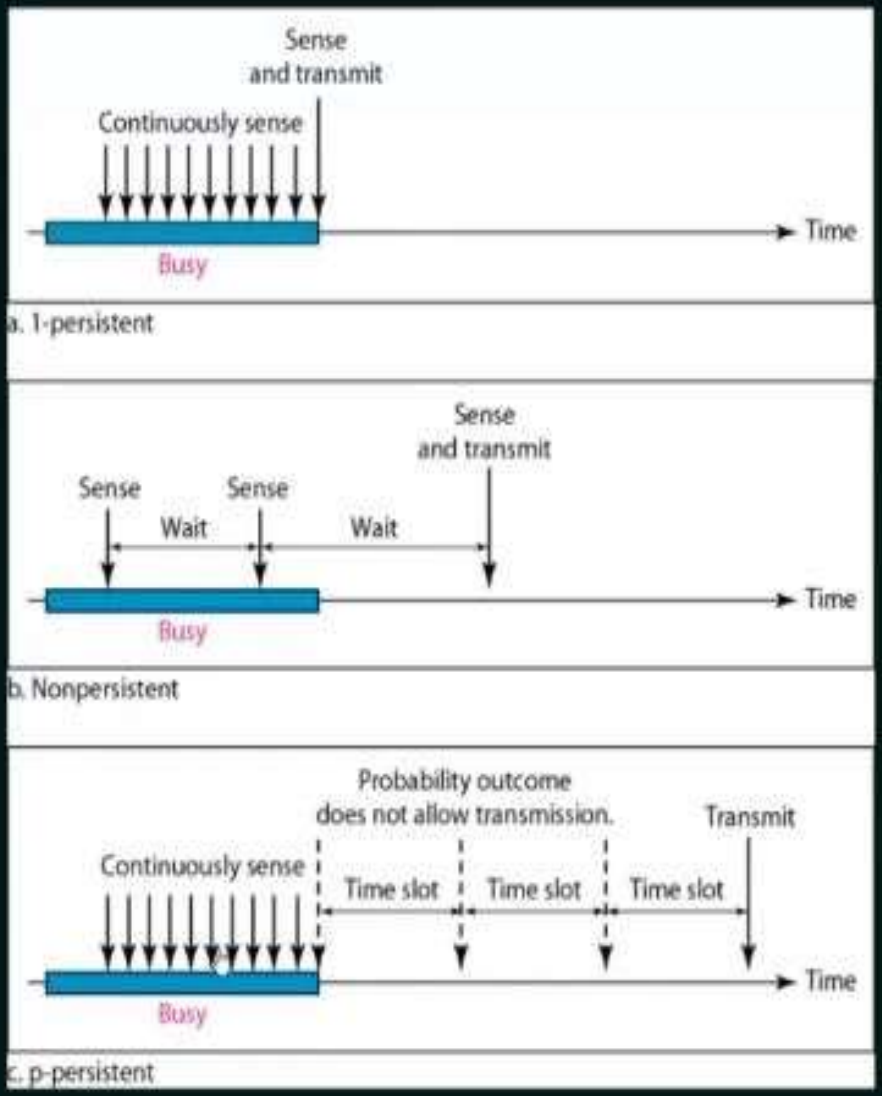
P – Persistent CSMA

- The P-persistent method of CSMA is used when the channel is divided into multiple time slots and the duration of time slots is greater than or equal to the maximum propagation time.
- This method is designed as a combination of the advantages of 1-Persistent and Non-Persistent CSMA.
- The p-persistent method of CSMA reduces the chance of collision in the network and there is an increment in the efficiency of the network.
- When any station wants to transmit the data firstly it will sense the channel, If the channel is busy then the station continuously senses the channel until the channel becomes idle.

If the channel is idle then the station does the following steps.

- The station transmits its data frame in the network by p probability.
- The station waits for the start of the next time slot with probability q=1-p and after waiting again senses the channel.
- If the channel is again idle, then it again performs step 1. If the channel is busy, then it thinks that there is a collision in the network and now this station will follow the back-off procedure.

Behaviour of three persistent methods



ESO ACADEMY

- **O- Persistent:** In O-persistent CSMA, each node is assigned a transmission order by a supervisory node. When the channel is idle, nodes wait for their designated time slot before transmitting, rather than immediately sending. This ensures a structured transmission order and minimizes collisions.

Key aspects of O-persistent CSMA:

- **Supervisory Node:**

  A supervisory node assigns a transmission order to each node in the network.

- **Idle Channel Behavior:**

  When the channel is idle, nodes wait for their assigned time slot before transmitting.

- **Orderly Transmission:**

  This method ensures a defined order for data transmission, with nodes transmitting in their assigned sequence when the channel is free.

- **Collision Avoidance:**

  By assigning transmission orders and having nodes wait their turn, O-persistent CSMA reduces the likelihood of collisions compared to methods where multiple nodes might transmit simultaneously.

CSMA with Collision Detection

- Carrier Sense Multiple Access with Collision Detection (CSMA/CD) is a media access control (MAC) protocol used in wired local area networks (LANs), notably in early Ethernet technology.
- CSMA/CD improves upon basic CSMA by actively detecting and reacting to collisions, thus minimizing the time wasted on corrupted transmissions and enhancing the overall efficiency of the network under moderate loads. However, in modern full-duplex Ethernet networks, where separate channels exist for sending and receiving, CSMA/CD is largely obsolete as collisions are inherently avoided.

The fundamental principle of CSMA/CD involves three main phases:

- **Carrier Sensing:**

  Before transmitting data, a station "listens" to the shared communication channel (the "carrier") to determine if it is currently in use by another station. If the channel is busy, the station defers its transmission and waits until the channel becomes idle. This "carrier sense" mechanism helps to reduce the likelihood of collisions.

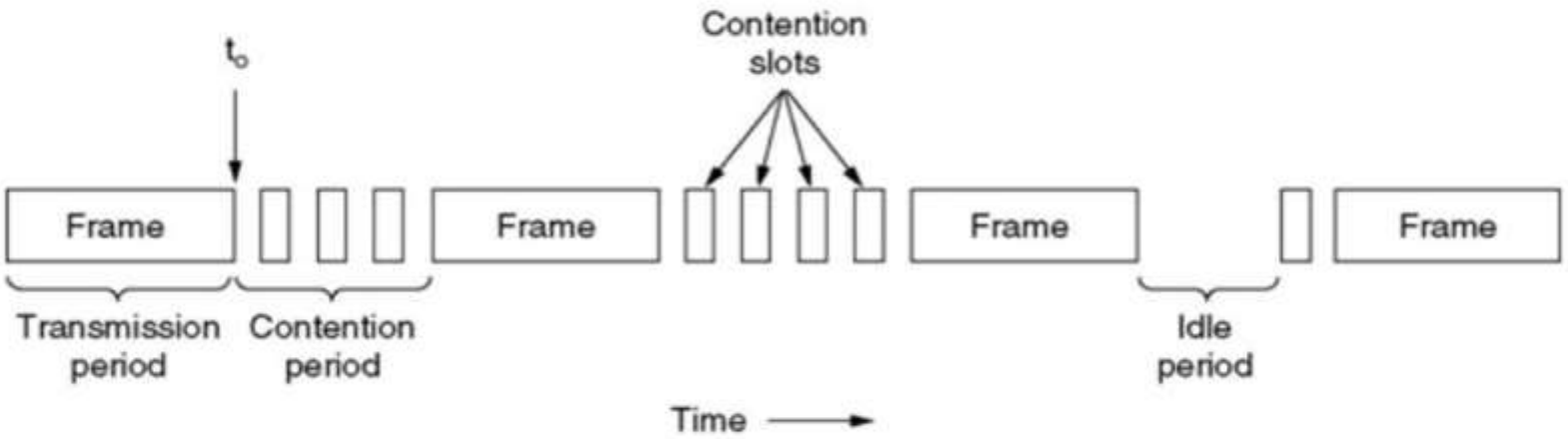
- **Transmission and Collision Detection:**

  If the channel is detected as idle, the station begins transmitting its data frame. Crucially, while transmitting, the station simultaneously monitors the channel for the presence of other transmissions. This is the "collision detection" aspect. If the station detects a signal that indicates another station is transmitting at the same time, a collision has occurred.

- **Collision Handling and Retransmission:**

  Upon detecting a collision, the transmitting station immediately stops its transmission and sends a "jam signal" to ensure all other stations on the network are aware of the collision. After sending the jam signal, the station enters a "back-off" period, waiting a random amount of time before attempting to retransmit the data frame. This random back-off time helps to prevent the same stations from colliding repeatedly. If multiple retransmission attempts fail, the transmission may be abandoned.

CSMA with Collision Detection



CSMA/CD can be in one of three states: contention, transmission, or idle.

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.

CSMA with Collision Avoidance

- In contrast to CSMA/CD (Carrier Sense Multiple Access/Collision Detection) that deals with collisions after their occurrence, CSMA/CA prevents collisions prior to their occurrence.

The algorithm of CSMA/CA is:

- When a frame is ready, the transmitting station checks whether the channel is idle or busy.
- If the channel is busy, the station waits until the channel becomes idle.
- If the channel is idle, the station waits for an Inter-frame gap (IFG) amount of time and then sends the frame.
- After sending the frame, it sets a timer.
- The station then waits for acknowledgement from the receiver. If it receives the acknowledgement before expiry of timer, it marks a successful transmission.
- Otherwise, it waits for a back-off time period and restarts the algorithm.

Advantage of CSMA CA

- When the size of data packets is large, the chances of collision in CSMA CA is less.
- It controls the data packets and sends the data when the receiver wants to send them.
- It is used to prevent collision rather than collision detection on the shared channel.
- CSMA CA avoids wasted transmission of data over the channel.
- It is best suited for wireless transmission in a network.
- It avoids unnecessary data traffic on the network with the help of the RTS/ CTS extension.

The disadvantage of CSMA CA

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

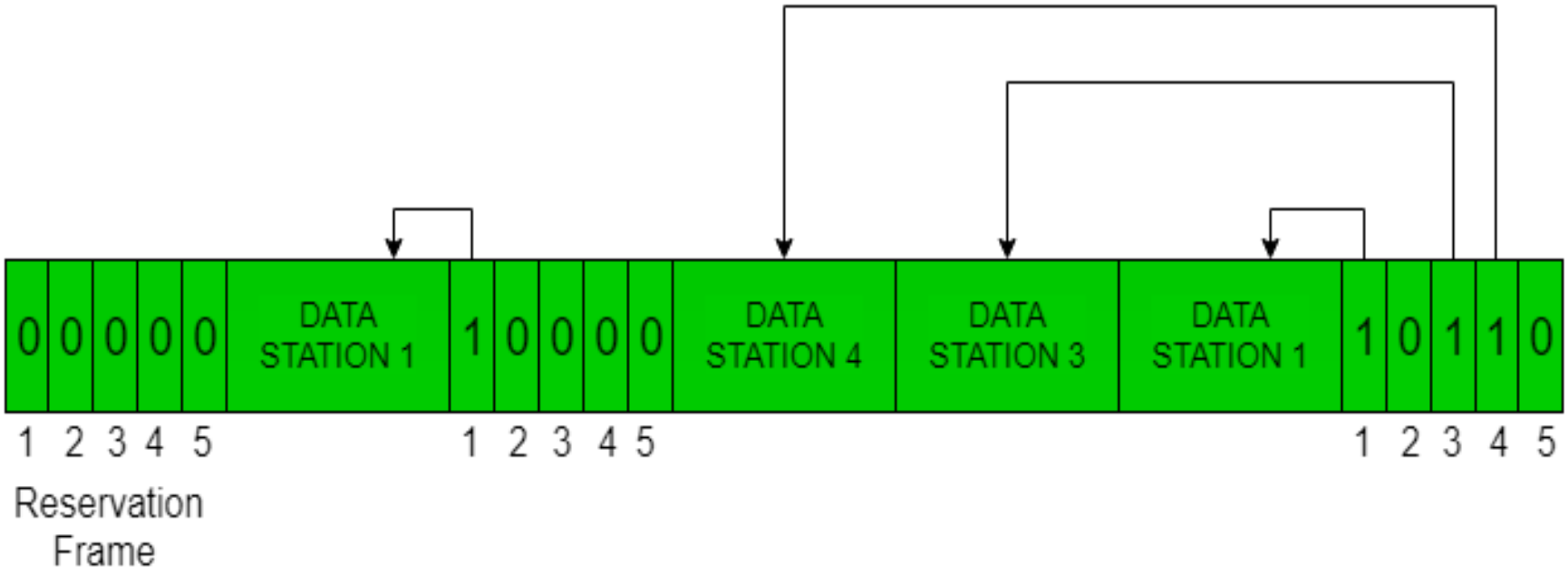
Controlled Access Protocols

- Controlled Access Protocols (CAPs) in computer networks control how data packets are sent over a common communication medium. These protocols ensure that data is transmitted efficiently, without collisions. the stations seek data from one another to find which station has the right to send. It allows only one node to send at a time, to avoid the collision of messages on a shared medium. The three controlled-access methods are:
  - Reservation
  - Polling
  - Token Passing

1. Reservation

- In the reservation method, a station needs to make a reservation before sending data.
- The timeline has two kinds of periods:
  - Reservation interval of fixed time length
  - Data transmission period of variable frames.
- If there are M stations, the reservation interval is divided into M slots, and each station has one slot.
- Suppose if station 1 has a frame to send, it transmits 1 bit during the slot 1. No other station is allowed to transmit during this slot.
- In general, i th station may announce that it has a frame to send by inserting a 1 bit into i th slot. After all N slots have been checked, each station knows which stations wish to transmit.
- The stations which have reserved their slots, transfer their frames in that order.
- After data transmission period, next reservation interval begins.
- Since everyone agrees on who goes next, there will never be any collisions.

- The following figure shows a situation with five stations and a five-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.



Advantages of Reservation

- The main advantage of reservation is *high rates and low rates of data accessing* time of the respective channel can be predicated easily. Here time and rates are fixed.
- Priorities can be set to provide speedier access from secondary.
- Reservation-based access methods can reduce contention for network resources, as access to the network is pre-allocated based on reservation requests. This can improve network efficiency and reduce packet loss.

Disadvantages of Reservation

- Highly trust on controlled *dependability.*
- *Decrease in capacity* and channel data rate under light loads; increase in turn-around time.

2. Polling

- In computer networks, polling is a process where a master device (primary station) repeatedly asks (polls) other devices (secondary stations) if they have data to transmit or if they are ready to receive data. This controlled access method ensures that only one device can transmit at a time, preventing collisions and managing network traffic.

How Polling Works:

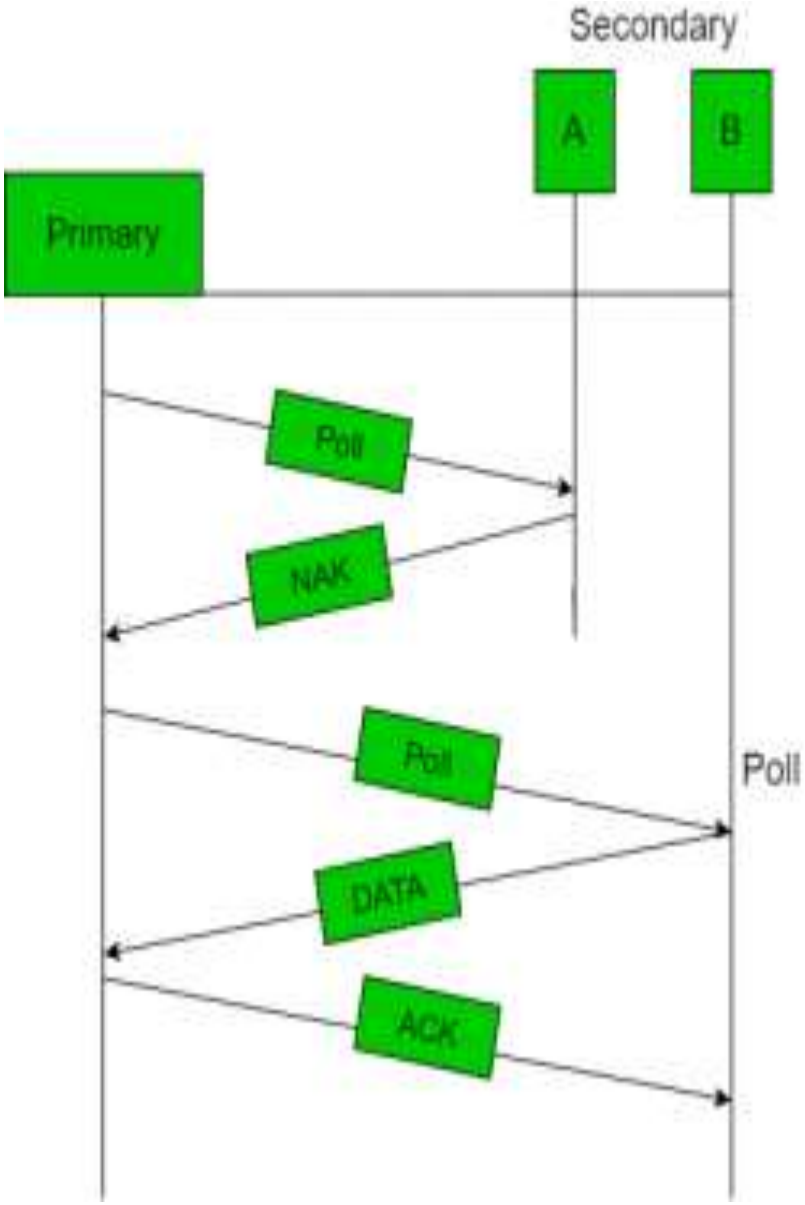
1. Designated Master:

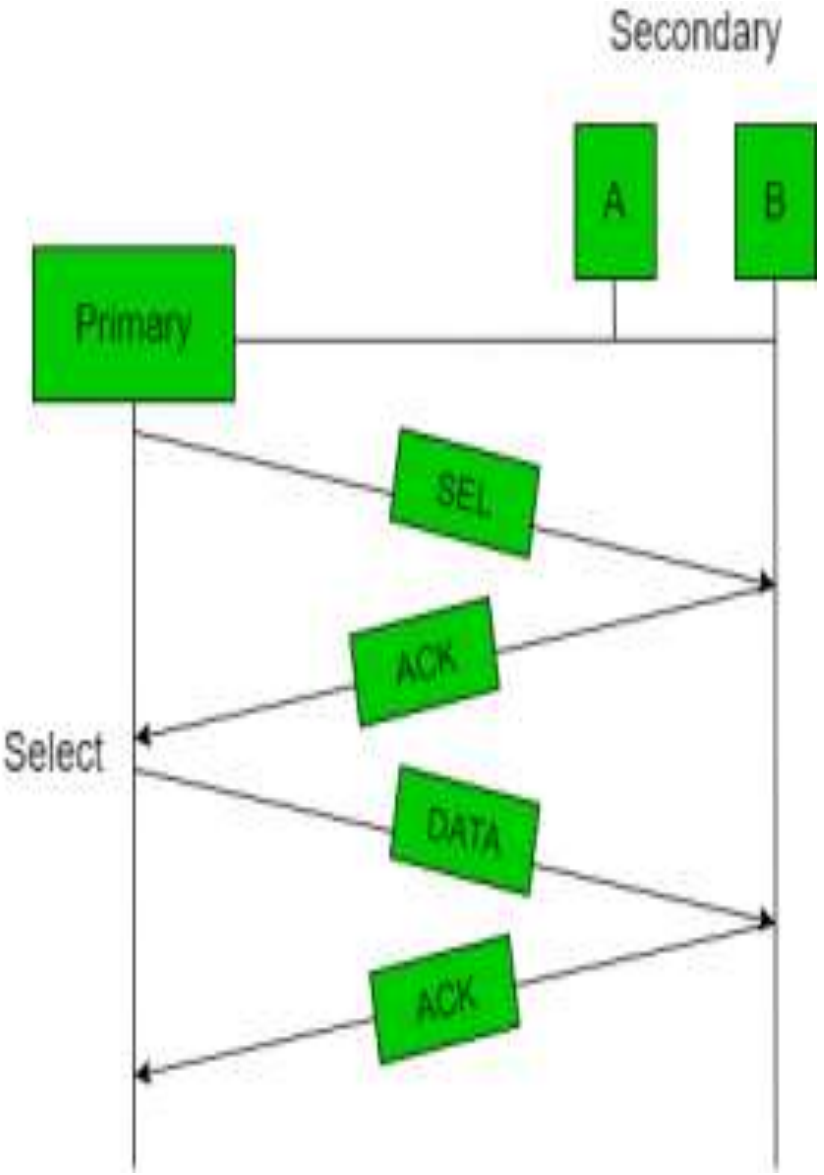
- One device on the network is designated as the primary (or master) station, while the others are secondary stations.

2. Polling Cycle:

- The primary station initiates a polling cycle, sequentially querying each secondary station.

3. **Request and Response:**
- The primary station sends a "poll" message to each secondary station, asking if they have data to send.
4. **Data Transmission:**
- If a secondary station has data to transmit, it responds with the data. If not, it sends a negative acknowledgment (NAK).
5. **Controlled Access:**
- The primary station manages the channel, allowing only one secondary station to transmit at a time, based on its polling responses.
6. **Select Function:**
- When the primary station wants to send data, it uses a "select" function to inform the intended recipient secondary station to prepare for receiving the data.


Secondary
A
B
Primary
Poll
NAK
Poll
Poll
DATA
ACK


Secondary
A
B
Primary
SEL
ACK
Select
DATA
ACK

Advantages of Polling

- The maximum and minimum access time and data rates on the channel are fixed predictable.
- It has maximum *efficiency.*
- It has maximum *bandwidth.*
- No slot is wasted in polling.
- There is assignment of priority to ensure faster access from some secondary.

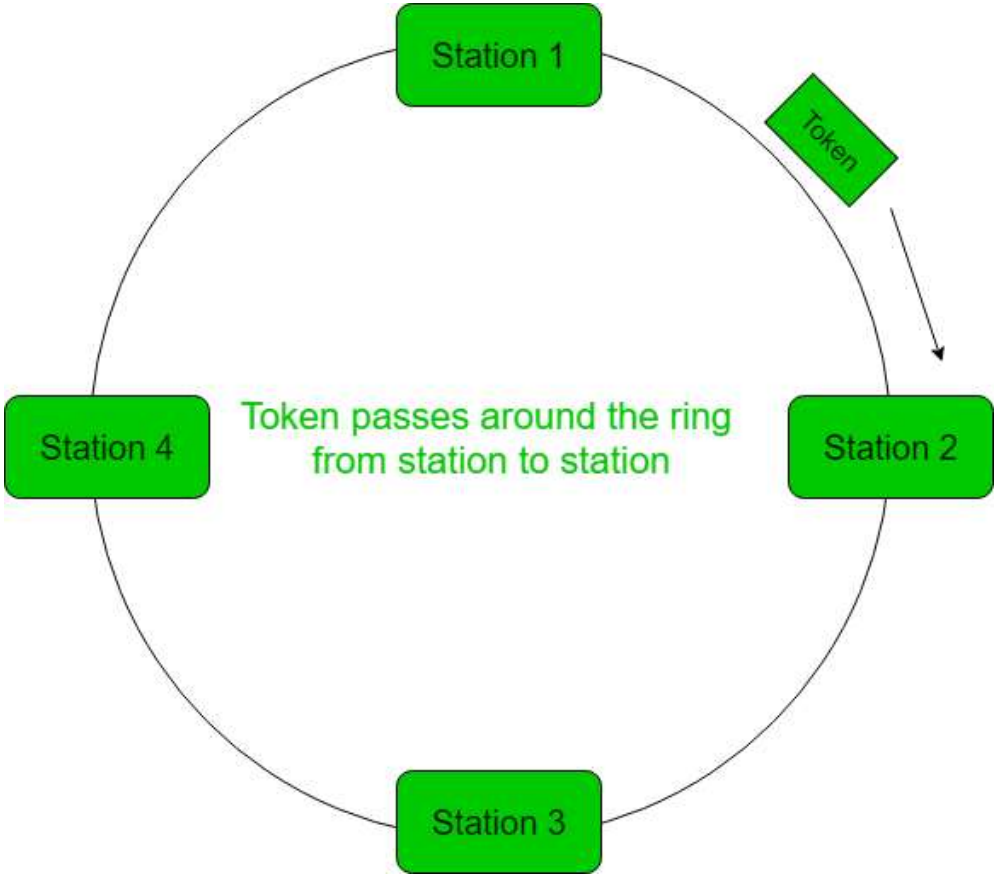
Disadvantages of Polling

- It consume *more time.*
- Since every station has an equal chance of winning in every round, link sharing is *biased.*
- Only some station might run out of data to send.
- An increase in the turnaround time leads to a drop in the data rates of the channel under low loads.

3. Token Passing

- In token passing scheme, the stations are connected logically to each other in form of ring and access to stations is governed by tokens.
- A token is a special bit pattern or a small message, which circulate from one station to the next in some predefined order.
- In Token ring, token is passed from one station to another adjacent station in the ring.
- In this case, token represents permission to send. If a station has a frame queued for transmission when it receives the token, it can send that frame before it passes the token to the next station. If it has no queued frame, it passes the token simply.
- After sending a frame, each station must wait for all N stations (including itself) to send the token to their neighbours and the other N - 1 stations to send a frame, if they have one.

- There exists problems like duplication of token or token is lost or insertion of new station, removal of a station, which need be tackled for correct and reliable operation of this scheme.

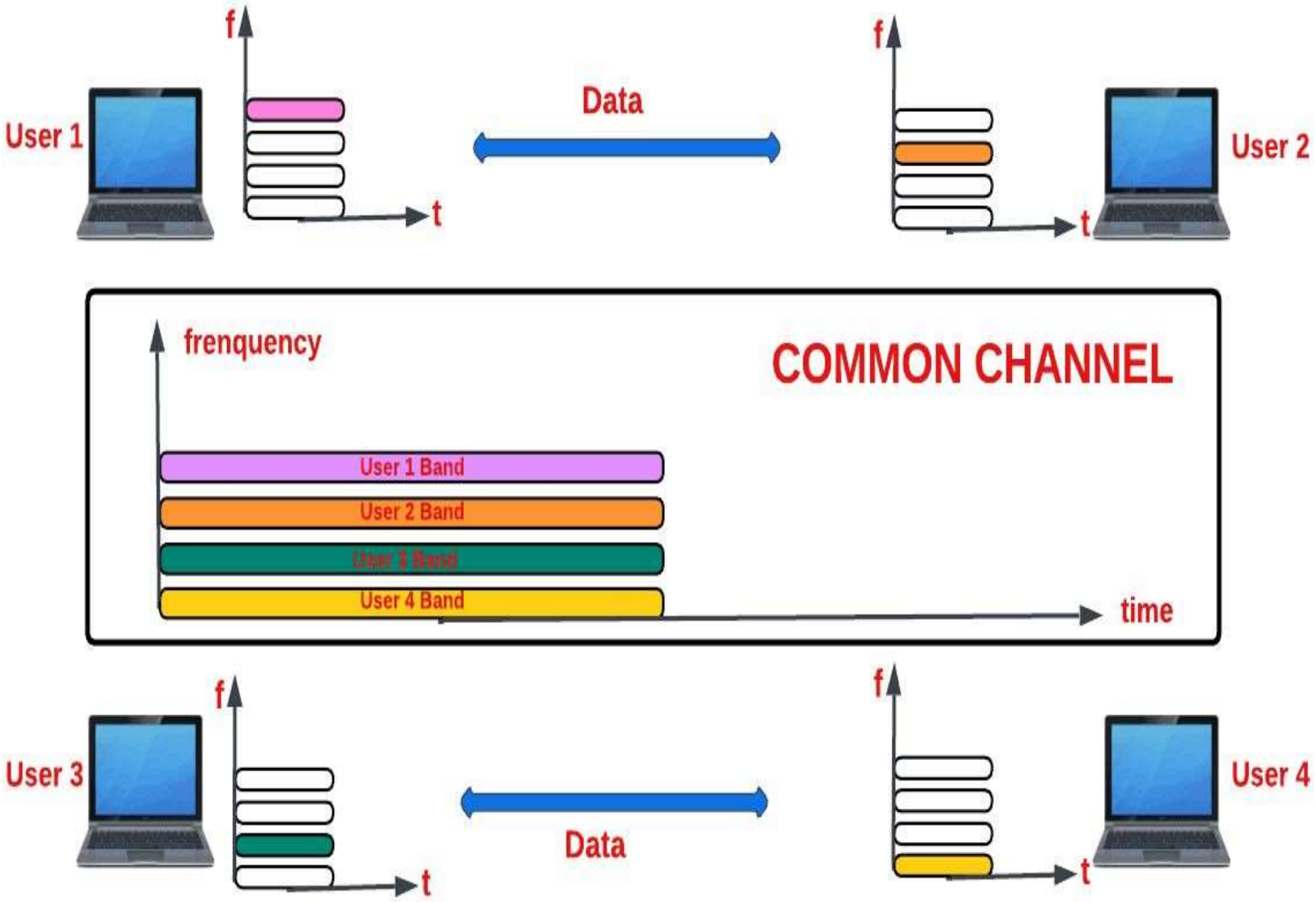


Channelization

- Channels are communication resources we assign to a user to establish communication with other users in the network. These resources include frequency, time, code, space, bandwidth, and so on. We name each channelization protocol based on the kind of channel resources we employ for channelization. These protocols are:
- Frequency division multiple access (FDMA)
- Time division multiple access (TDMA)
- Code division multiple access (CDMA)

Frequency Division Multiple Access (FDMA) Protocol

- We design the FDMA protocol by utilizing the channel resource of frequency. By dividing the channel's bandwidth into non-overlapping frequency bands or slices, we allocate each user a distinct band for exclusive transmission and reception. This enables the concurrent operation of multiple users within a single communication channel. To mitigate interference and crosstalk during data transmission, we equip each user with a customized band pass filter complemented by a small guard band.


User 1
f
t
Data
f
t
User 2
frenquency
COMMON CHANNEL
User 1 Band
User 2 Band
User 3 Band
User 4 Band
time
User 3
f
t
Data
f
t
User 4

Advantages of FDMA Protocols

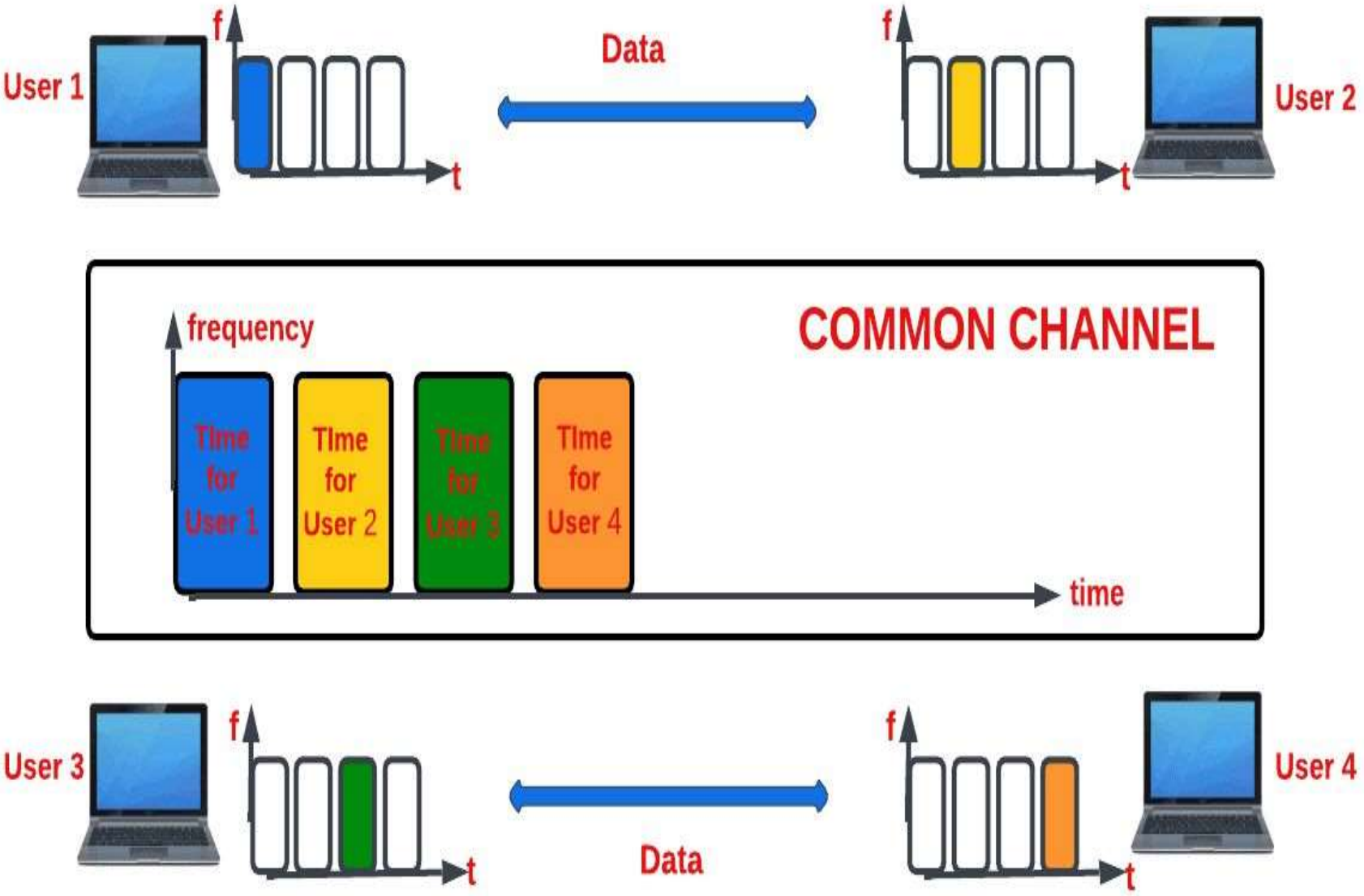
- Some notable merits which FDMA protocols offer us are:
- enable simultaneous transmission through the same frequency channel, with each user operating at a single frequency
- using frequency as the channel resource eliminates timing-related issues often encountered in TDMA protocols
- FDMA effectively resolves the near-far problem inherent in CDMA protocols by implementing bandpass filtering
- as we assign users frequency slots, this allows for distinct transmission and reception at different frequencies

Disadvantages of FDMA Protocols

- the design of high-performing hardware filters proves to be a challenging task
- despite the inclusion of guard bands, FDMA remains susceptible to crosstalk, potentially leading to interference and transmission disruptions

Time Division Multiple Access (TDMA) Protocol

- Time serves as the channel resource for this protocol. **Using the TDMA protocol, we divide each user's signal into a different time slot and assign each time slot to a different user**. This technique enables numerous users to share and use the same frequency channel. The global system of mobile communication (GSM) system, a 2G cellular system, is one significant application where we have used the TDMA protocol.
- Synchronizing the various users of the channel is one of the biggest challenges we face when utilizing the TDMA protocol. To achieve synchronization, we ensure each user knows their respective slots' start and endpoints.


User 1
f
t
Data
f
t
User 2
COMMON CHANNEL
frequency
TIme for User 1
TIme for User 2
TIme for User 3
TIme for User 4
time
User 3
f
t
Data
f
t
User 4

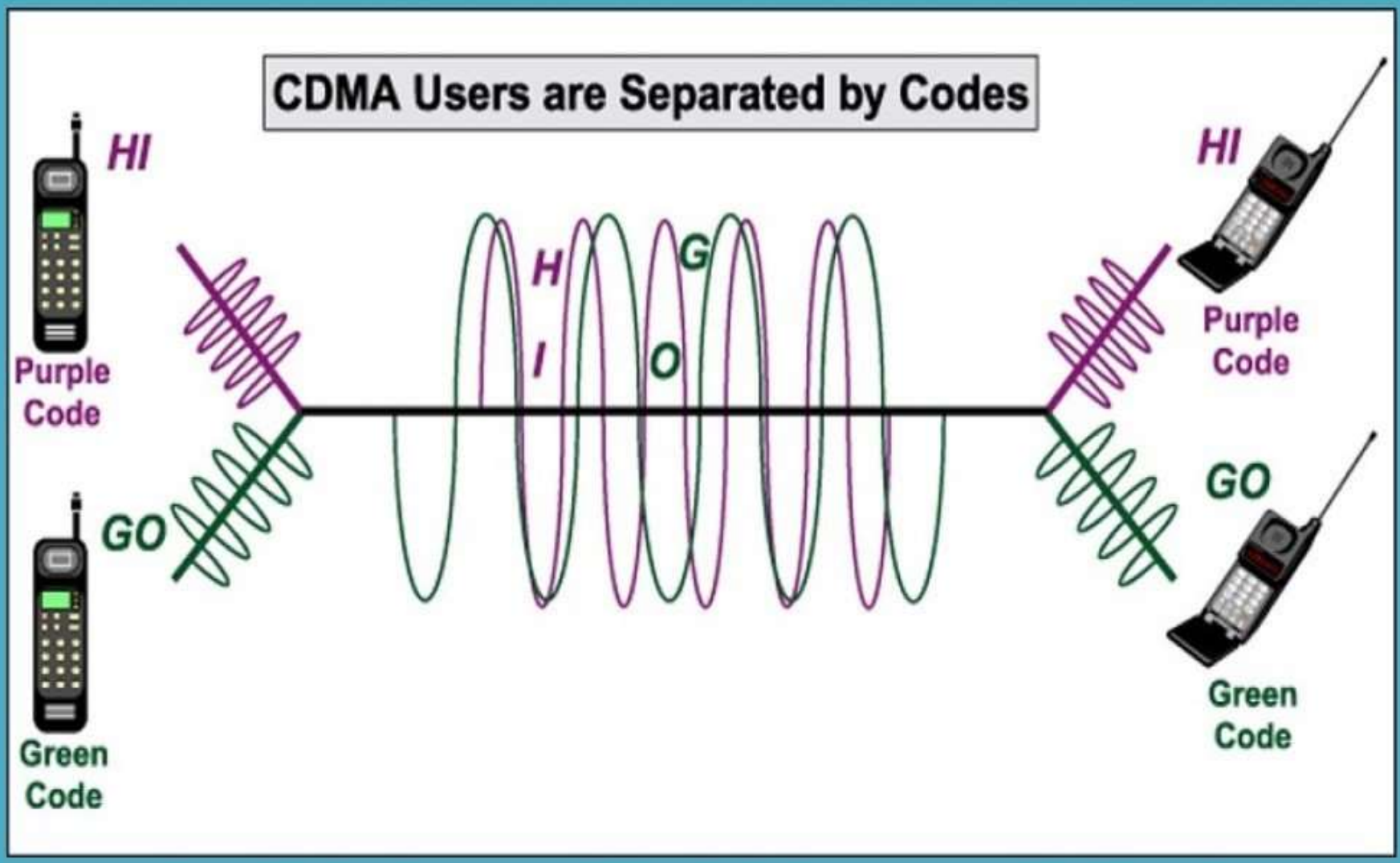
Another significant drawback we encounter when utilizing TDMA systems is the potential for causing interference at a frequency that closely adjoins another user's active time slot. This interference manifests as the buzzing sound we occasionally hear when a TDMA phone is near a radio or speakers.

Just like in the FDMA protocol, there are two methods we use to administer time slots to users:

- Fixed time division multiple access (F-TDMA)
- Dynamic time division multiple access (D-TDMA)
- While we use F-TDMA for fixed allocation of time slots to users, we use D-TDMA to assign time slots to users based on the traffic demand of the channel.

Code Division Multiple Access (CDMA) Protocol

- The channel resource for this protocol is code. CDMA, which stands for Code Division Multiple Access, is a digital wireless communication technology that enables multiple users to share the same frequency channel simultaneously. It uses unique codes to differentiate users, allowing them to transmit data concurrently without interfering with each other. This technology is crucial in mobile communication systems, including 2G and 3G networks. .


CDMA Users are Separated by Codes
HI
Purple
Code
GO
Green
Code
H
I
G
O
HI
Purple
Code
GO
Green
Code

Key Concepts:

- **Spread Spectrum:** CDMA employs a spread spectrum technique, where the data signal is spread across a wider frequency band than necessary.
- **Unique Codes:** Each user is assigned a unique code (spreading code) that is used to modulate their data.
- **Simultaneous Transmission:** Multiple users can transmit data at the same time on the same frequency channel because their signals are differentiated by their unique codes.
- **Code Separation at the Receiver:** At the receiver, the unique code is used to separate and recover the desired signal from the combined signal.

- The beauty of this protocol is that we don’t share the frequency as we do in FDMA, and neither do we share time as we do in TDMA. In CDMA, we employ both time and frequency for users to send their data over the entire bandwidth of the channel with a unique spreading code allotted to the user. Only receivers having this unique code can receive the sent messages.