

MOBILE COMPUTING

CHAPTER – TWO

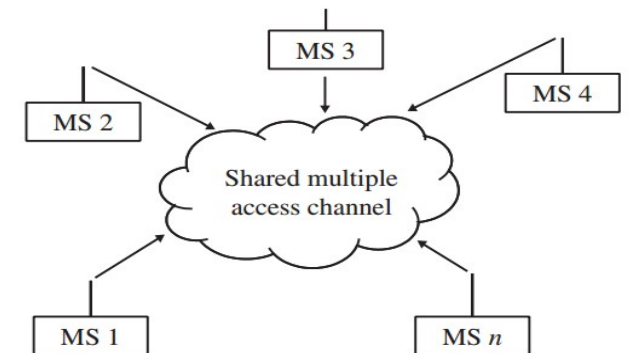
Medium Access Control

Objective

- ▶ By the end of this lecturer, you should be able to:
 - ✓ Understand the concept of mobility medium access
 - ✓ Understand the functions of SDMA, FDMA, TDMA and CDMA
 - ✓ Understand the difference between various medium access type.

Introduction

- ▶ A telecommunications network has finite resources (bandwidth).
- ▶ More than one user will access such limited bandwidth.
 - ✓ Everyone can use services.
 - ✓ No single user spends all available resources.
- ▶ Wireless **is a shared medium and** wireless device must compete for a medium
- ▶ If more than one node transmit at a time on the control channel to BS, a collision occurs
- ▶ How to determine which node can transmit to B
- ▶ These issues could be solved by multiple access



Medium Access Control (MAC) Protocols

- ▶ MAC is responsible for managing **how multiple devices access and share a common communication medium**, such as a wireless channel or a wired network
- ▶ The MAC layer ensures **efficient** and **fair** utilization of the available resources while **minimizing collisions** and **interference** between devices.

Medium Access Control (MAC) Protocols

► Importance of MAC in Mobile Computing

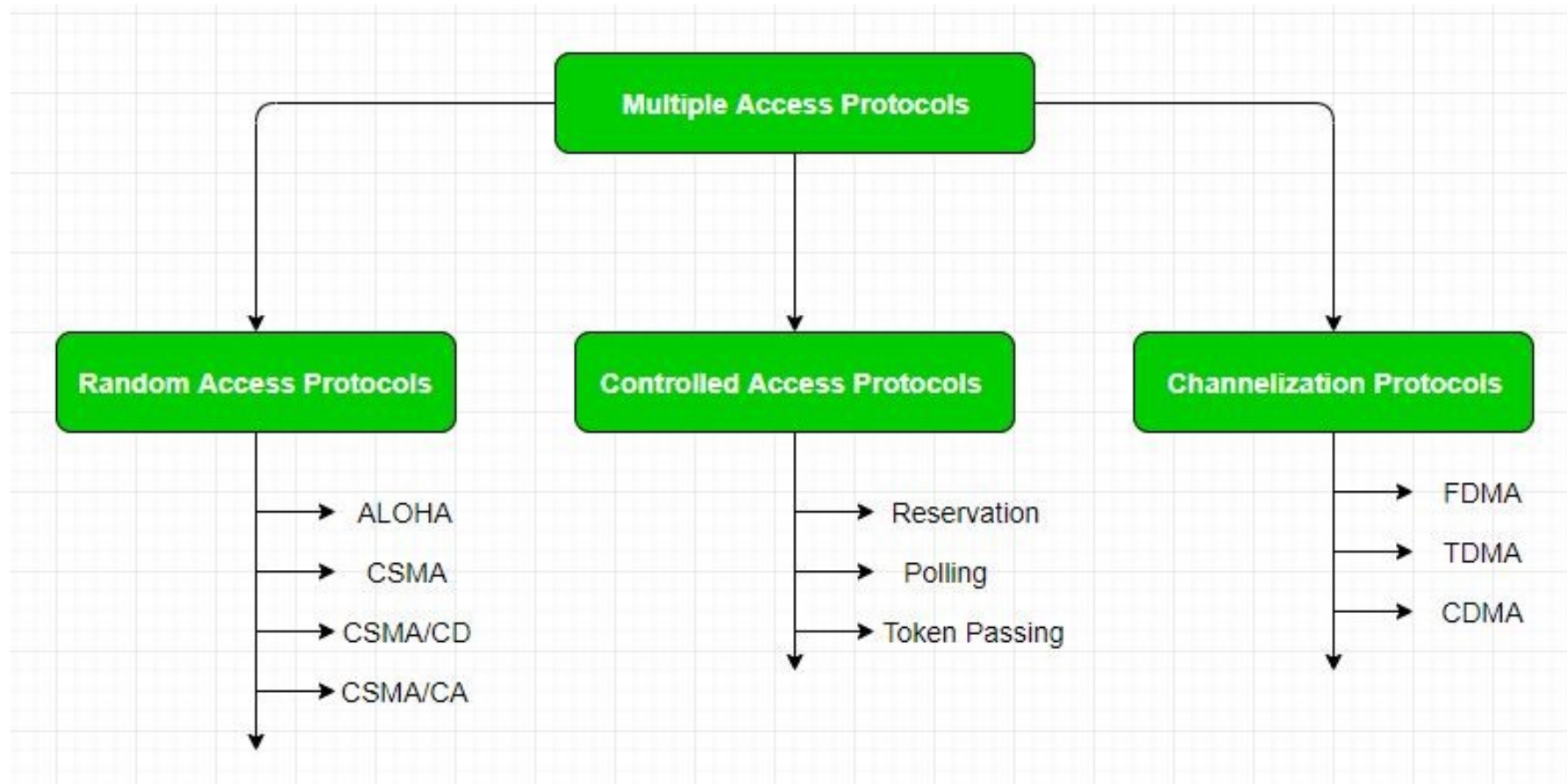
- ✓ In mobile computing, where devices are often wireless and communicate through shared airwaves, proper medium access control is essential:
 - to prevent data collisions,
 - manage interference, and
 - ensure that all devices get a fair opportunity to transmit their data.

Multiplexing vs MAC Protocol

- ▶ Multiplexing is the process to combine multiple signal for transmit it over a single channel or media.
- ▶ Generally multiplexing combines several low-speed signals for transmission over a single high speed connection
- ▶ MAC protocols ensure that devices can transmit their data efficiently and fairly while avoiding data collisions.

MAC Techniques

- Several MAC protocols and techniques have been developed to address the challenges of medium access in mobile computing:



Random Access Protocols

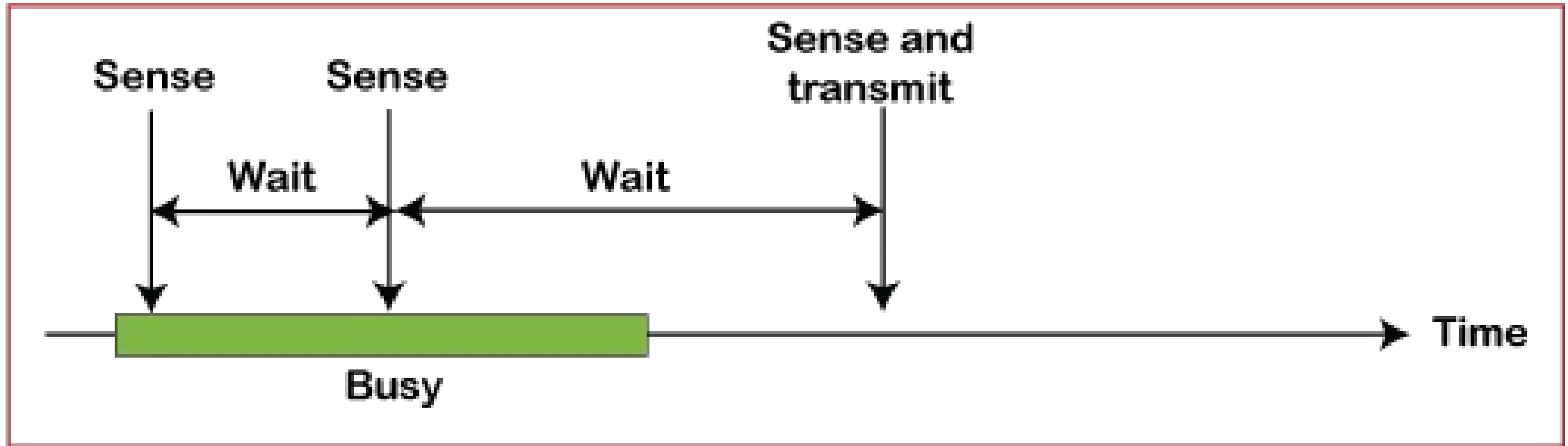
- ▶ Can also called **contention** based protocol
- ▶ It assigns **uniform priority** to all connected nodes.
- ▶ Any node can send data if the transmission channel is **idle**.
- ▶ No fixed **time** or fixed **sequence** is given for data transmission.
- ▶ However, if more than one station sends the data over a channel, there may be a **collision** or data **conflict**.
- ▶ Due to the collision, the data frame packets may be **lost** or changed.
- ▶ The Random access protocols are further subdivided as: **CMSA, CMSA/CD, CMSA/CA**

Random Access Protocols - Cont...

A. CSMA (Carrier Sense Multiple Access)

- ▶ It sense the traffic on a channel (**idle or busy**) before transmitting the data.
- ▶ It means that if the channel is **idle**, the station **can send** data to the channel.
- ▶ Otherwise, it must **wait** until the channel becomes idle.
- ▶ A station Listens to the channel before transmitting (**sense b4 transmit/
listen b4 talk-LBT protocol**) a packet (avoid avoidable collisions)

Random Access Protocols - Cont...

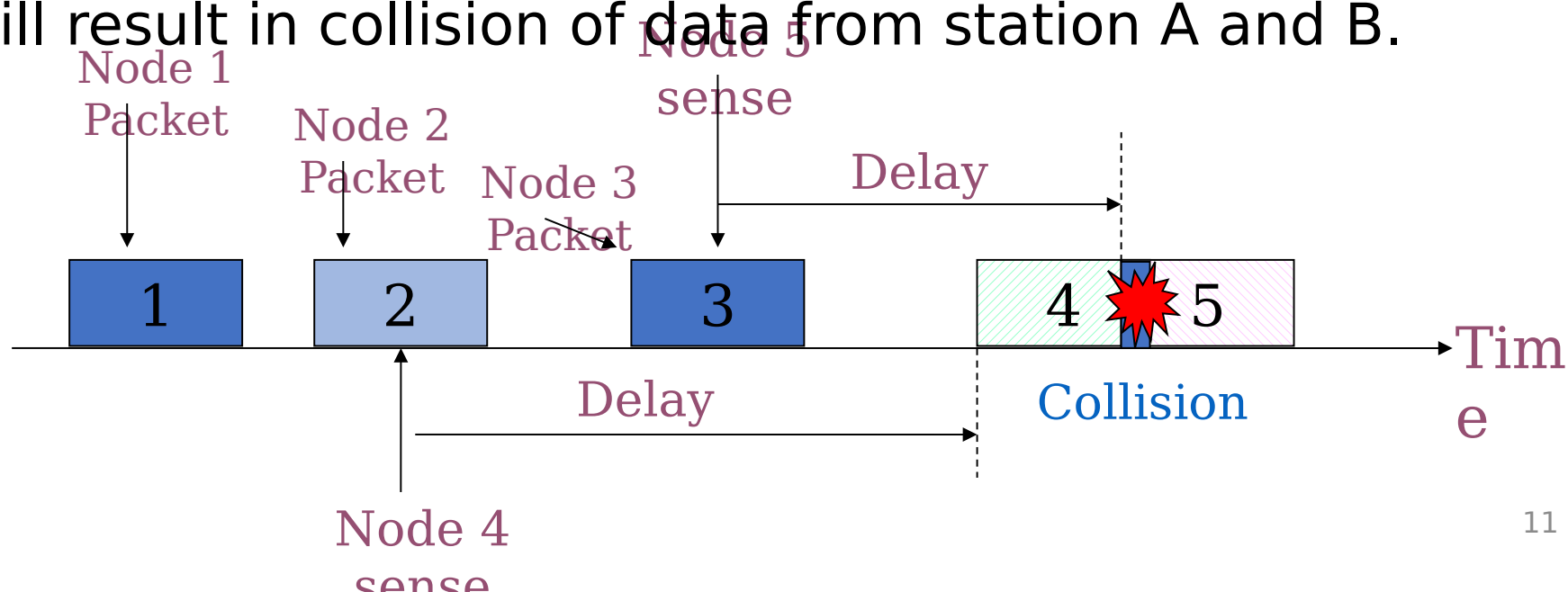


- However there is still chance of collision in CSMA due to propagation delay.

Random Access Protocols - Cont...

Collision Mechanism in CSMA

- By the time the first bit of data is transmitted (delayed due to propagation delay) from station A, if station B requests to send data and senses the medium it will also find it idle and will also send data.
- This will result in collision of data from station A and B.



Random Access Protocols - Cont...

B. CSMA/CD (CSMA with Collision Detection)

- ✓ Step 1: It first **senses** the shared channel, if the medium is **idle**, it **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

Random Access Protocols - Cont...

C. CSMA/CA (CSMA with collision Avoidance)

- ▶ In contrast to CSMA/CD that deals with collisions after their occurrence, CSMA/CA prevents collisions prior to their occurrence.
- ▶ 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.

Random Access Protocols - Summary

- ▶ CSMA (Carrier Sense Multiple Access)
 - ✓ Improvement: Start transmission only if no transmission is ongoing
- ▶ CSMA/CD (CSMA with Collision Detection)
 - ✓ Improvement: Stop ongoing transmission if a collision is detected
- ▶ CSMA/CA (CSMA with Collision Avoidance)
 - ✓ Improvement: Wait a random time and try again when carrier is quiet. If still quiet, then transmit

Channelization Protocols

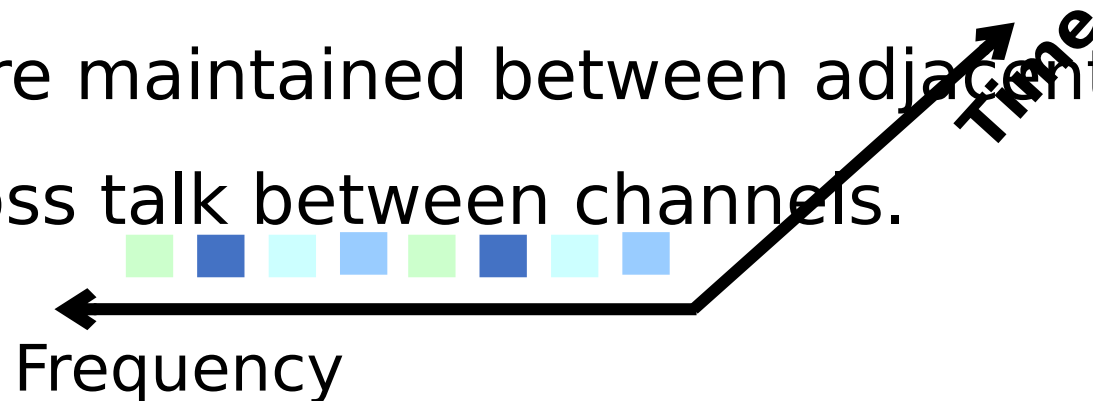
- ▶ It is conflict/collision free access protocols
- ▶ It allows the total usable bandwidth in a shared channel to be shared across multiple stations based on their time, distance and codes.
- ▶ three channelization protocols: FDMA, TDMA, and CDMA
- ▶ Orthogonal frequency division multiplexing (**OFDM**) and space division multiple access (**SDMA**) have **recently been introduced**.

1. Frequency Division Multiple Access (FDMA)

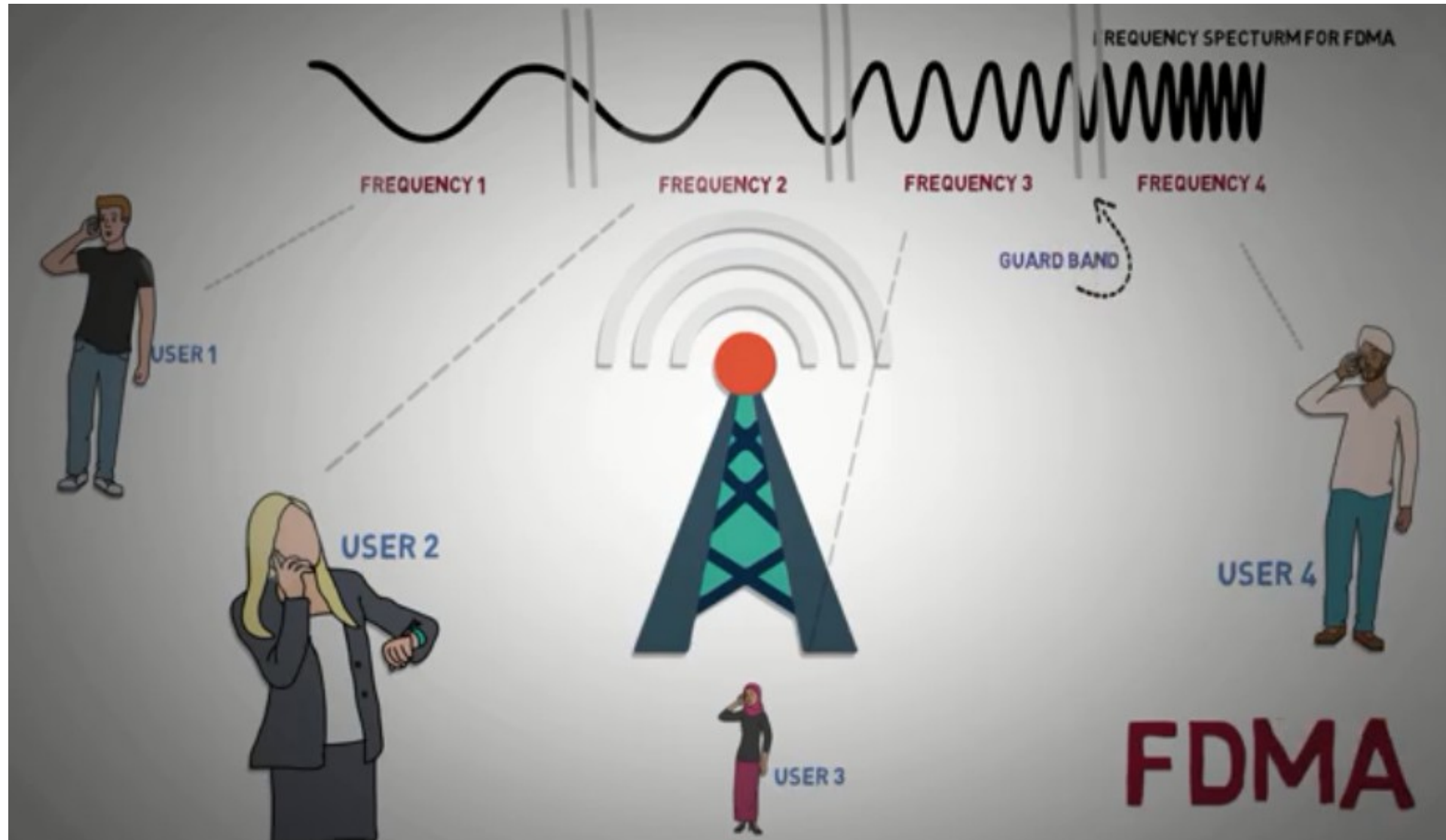
- ▶ Used to divide the available bandwidth into **non-overlapping frequency bands or channels**.
- ▶ Each frequency band is allocated to a specific user or device so that each user can send data through a **different frequency**.
- ▶ Best suited to **analog** mobile radio.
- ▶ Used in 1G cellular system(AMPS)

Frequency Division Multiple Access (FDMA) – Cont...

- ▶ FDMA assigns individual channels to individual users.
- ▶ These channels are assigned on demand to users who request service.
- ▶ During the period of the call, no other user can share the same channel.
- ▶ Guard bands are maintained between adjacent signal spectra to minimize cross talk between channels.



1. Frequency Division Multiple Access (FDMA) – Cont...



The Features of FDMA

- ▶ An idle FDMA channel cannot be used by another user.
- ▶ FDMA is usually implemented in narrowband systems(30khz).
- ▶ Continuous transmission
- ▶ Low overhead
- ▶ FDMA is not vulnerable to the timing problems that TDMA has
- ▶ Tight filtering is required which increases the cost of both mobile terminal and a base station.
- ▶ Due to the frequency filtering, FDMA is not sensitive to near- far problem

FDMA Pros and Cons

► Advantage:

- ✓ **Non-Overlap**: channels do not overlap, ensuring that there is **no interference** between users on different channels.
- ✓ **Parallel Communication**: multiple devices can communicate **simultaneously**, leading to **efficient** use of the spectrum.
- ✓ **Analog Compatibility**: it is well-suited for analog communication systems, such as traditional **radio** and **television** broadcasting.
- ✓ **Reliability**: it provides reliable communication because devices don't compete for the same frequency channel.

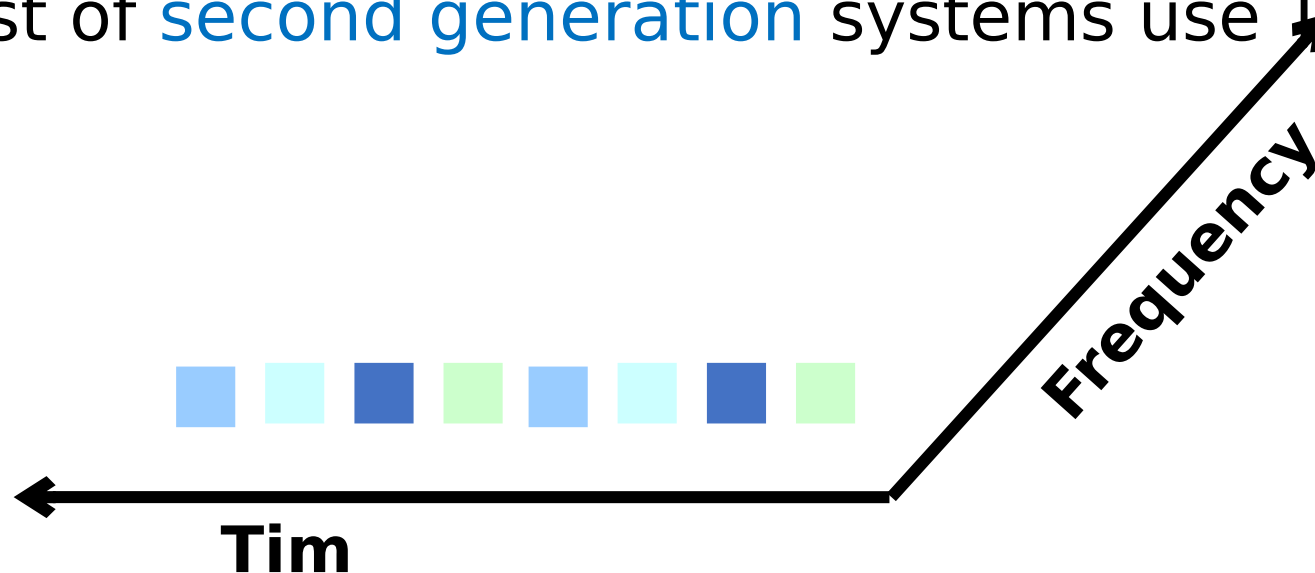
FDMA Pros and Cons - Cont...

► Disadvantage

- ✓ Frequencies are allocated **permanently** and hence spectrum will be **wasted** when station are not transmitting and receiving
- ✓ It uses **Guard band** to prevent interference: **wastage**
- ✓ Requires right **RF filtering** to minimize adjacent channel interference
- ✓ Flow rate (Data rate) are fixed: not used for burst data

2. Time Division Multiple Access (TDMA)

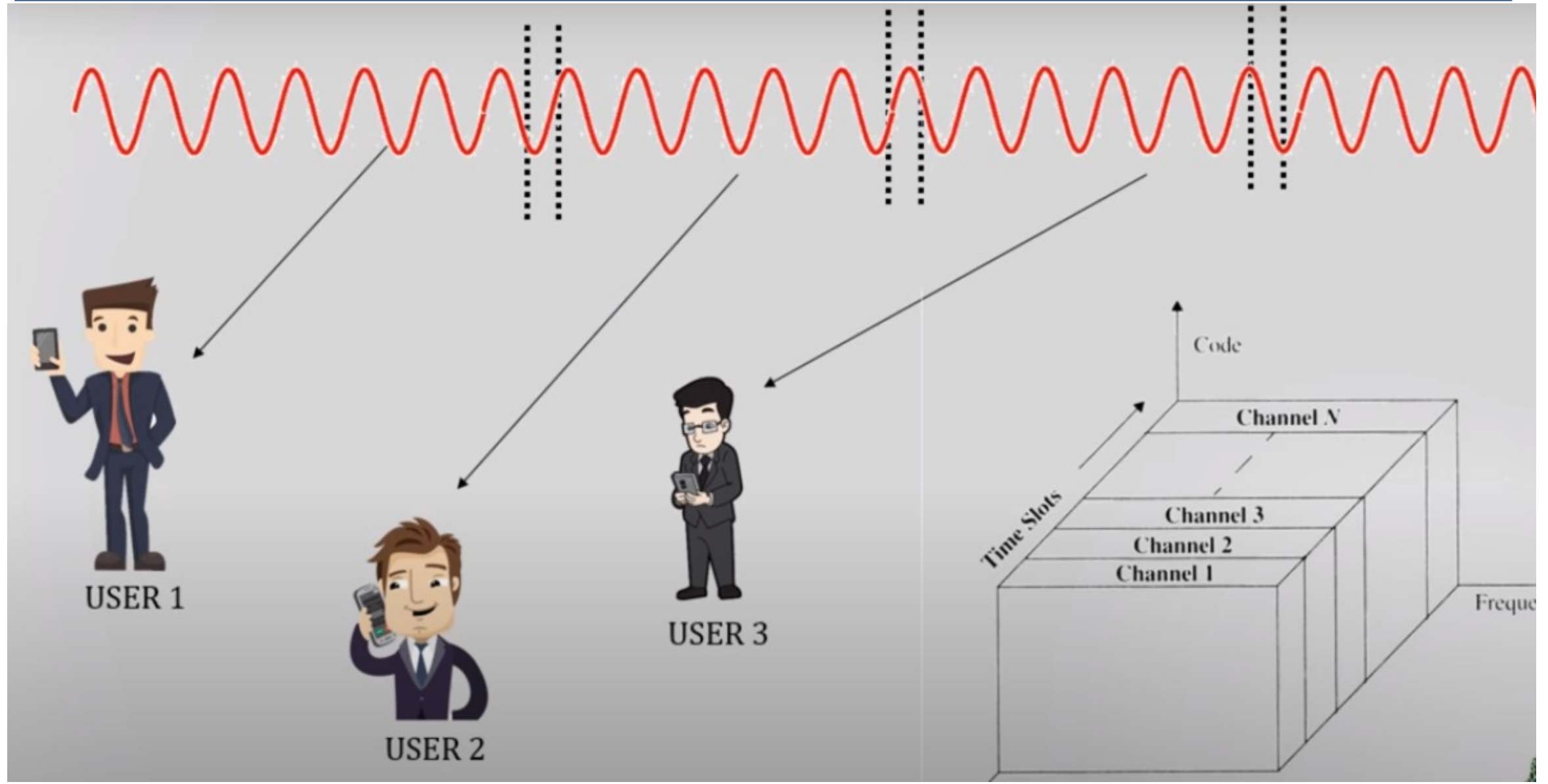
- ▶ TDMA systems divide the radio spectrum **into time slots**, and in each slot only one user is allowed to either transmit or receive.
- ▶ TDMA systems transmit data in a **buffer-and burst** method, thus the transmission for any user is **non continuous**.
- ▶ Most of **second generation** systems use TDMA



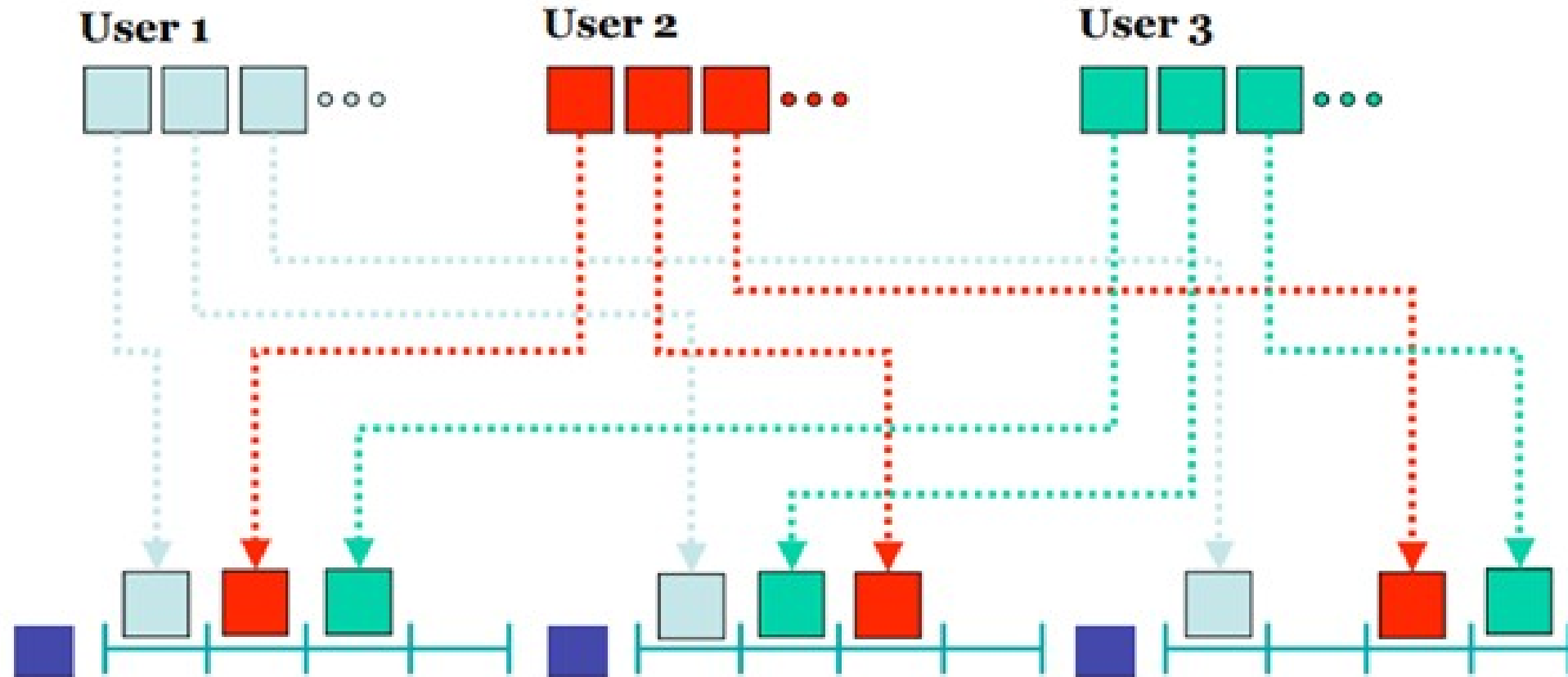
Time Division Multiple Access (TDMA)

- ▶ The individual mobile stations are **cyclically** assigned a frequency for exclusive use only for the **duration of a time slot**.
- ▶ Each device connected to the network is assigned one or more specific time slots by central controller or base station.
- ▶ Devices **do not compete** for access to the medium simultaneously, reducing the chances of collisions and data loss.
- ▶ The **guard time** between the slots is required.
- ▶ The TDMA technique is used in **digital mobile radio** systems.

Time Division Multiple Access (TDMA)



TDMA Frame Structure



TDMA: Frame Structure

TDMA: Frame Format

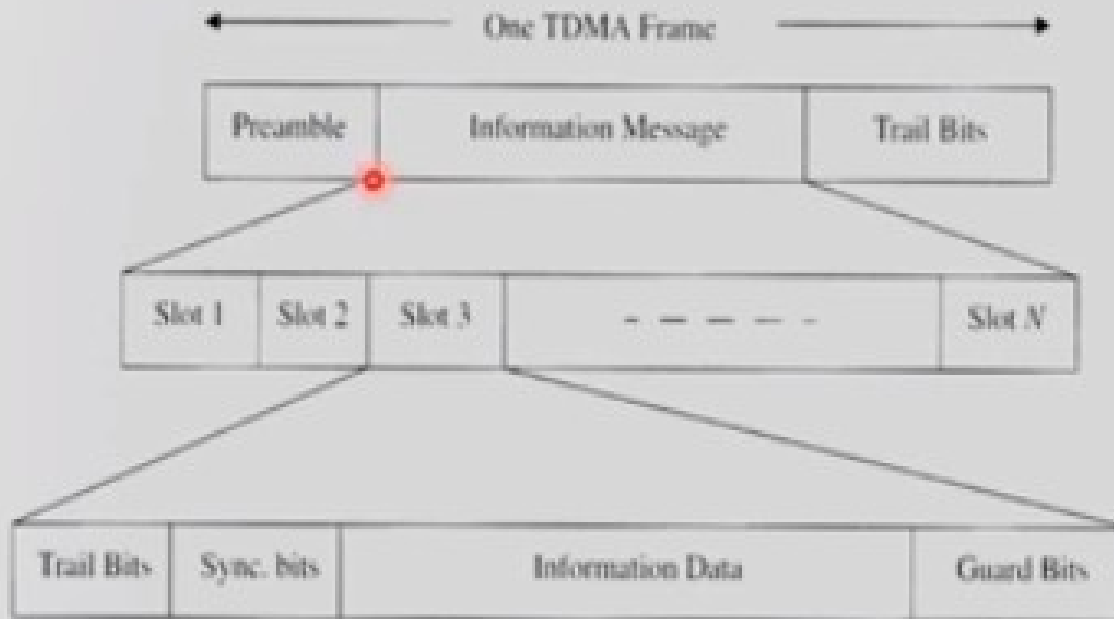


Figure 9.4 TDMA frame structure. The frame is cyclically repeated over time.

✓ Preamble:

- ✓ Consists of Address and Synchronisation bits which is used by base stations subscribers to identify each others.

✓ Information Message:

- ✓ Contains multiple slots of user information
- ✓ Each slot will have
 - ✓ Trail Bits
 - ✓ Sync Bits
 - ✓ Information
 - ✓ Guard Bits

✓ Trail Bits

Advantages of TDMA

- ▶ **Efficiency**: TDMA efficiently utilizes available bandwidth by ensuring that devices transmit sequentially in their assigned time slots.
- ▶ **Fairness**: All devices are guaranteed access to the medium, ensuring fairness in data transmission
- ▶ **Reduced Collisions**: Since each device has exclusive access to the medium during its time slot, collisions are minimized.
- ▶ It is the most **cost effective** technology to convert an analogue system to digital.

Disadvantages of TDMA

► **Synchronization Requirements:**

- ✓ TDMA systems require precise synchronization between devices to ensure that they transmit and receive data in the correct time slots.

► **Variable Traffic:**

- ✓ In scenarios where the traffic load varies significantly, some time slots may be underutilized, leading to potential inefficiency.

► **Complex Management:**

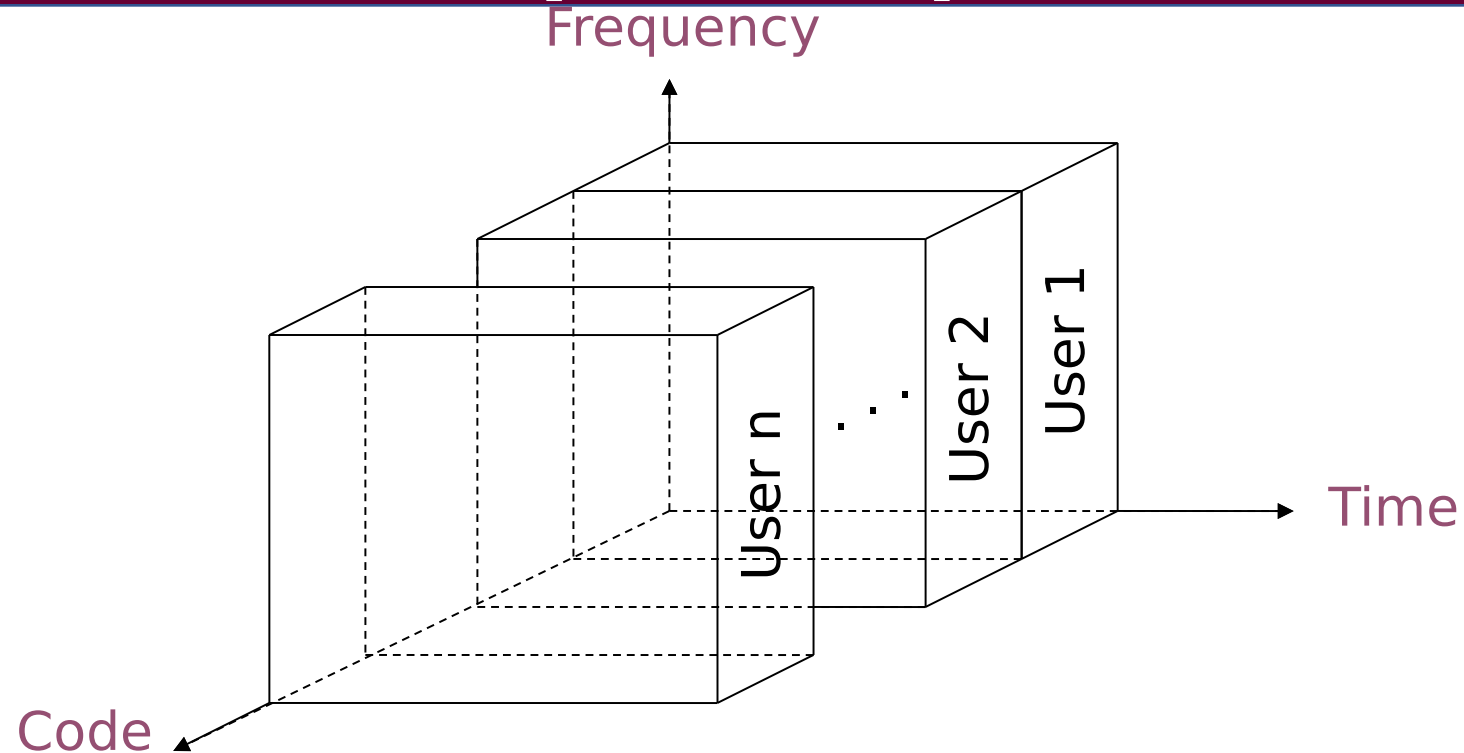
Code Division Multiple Access (CDMA)

- ▶ CDMA allows multiple devices to share the **same frequency band simultaneously** by assigning a **unique code** to each device.
- ▶ This coding scheme enables multiple users to transmit and receive data **concurrently without interfering** with each other.
- ▶ These codes are orthogonal, meaning they have minimal interference with one another.
- ▶ When a device wants to transmit data, it modulates its data signal with its unique spreading code.

CDMA Analogy

- ▶ In a large room with many people, two people can talk privately in English if nobody else understands English.
- ▶ Another two people can talk in Amharic if they are the only ones who understand Amharic, and so on.
- ✓ the common **channel**, the space of the room in this case, can easily allow communication between several couples, but in different **languages (codes)**

Code Division Multiple Access (CDMA)



- ▶ Users share bandwidth by using code sequences that are orthogonal to each other
- ▶ Some second generation systems use CDMA
- ▶ Most of third generation systems use CDMA

Pros and cons of CDMA

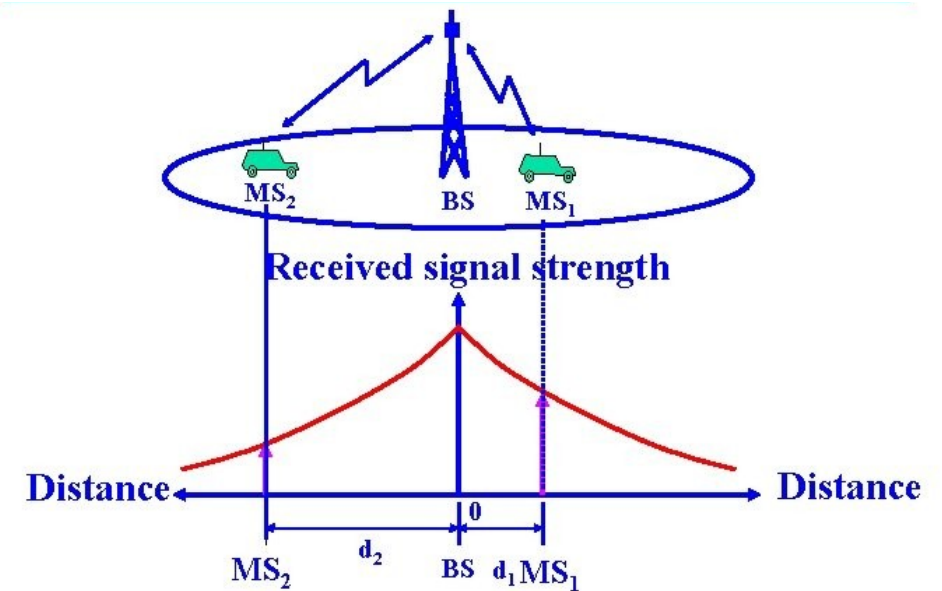
► Advantages

- ✓ **Efficient Spectrum Usage:** CDMA efficiently utilizes the available frequency spectrum as multiple users can share the same frequency band simultaneously.
- ✓ **Privacy and Security:** CDMA offers a level of privacy and security as each user's signal is uniquely encoded, making it difficult for unauthorized users to intercept or eavesdrop.
- ✓ The CDMA does not require any **synchronization**.
- ✓ Due to codeword allocated to each user, **interference is reduced**.
- ✓ **Soft handover** is possible so that minimizes the chance of call drop and disconnections

Pros and cons of CDMA

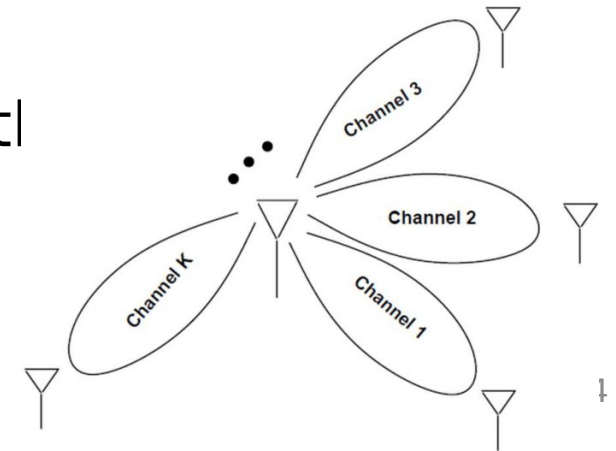
► Disadvantages

- ✓ The system is more complicated.
- ✓ Near far problem arises which needs close control of transmitted power of MS
- ✓ As the number of users increases, the overall quality of services decreases.
- ✓ Loss of code orthogonality – self jamming problem arise



Space Division Multiple Access (SDMA)

- ▶ SDMA focuses on using multiple antennas to create separate spatial channels for simultaneous communication.
- ▶ Both the transmitter and receiver are equipped with multiple antennas.
- ▶ These antennas are used to create multiple spatial channels for communication.
- ▶ All users can communicate at the same time using the same frequency.
- ▶ SDMA is completely free from interference.



Space Division Multiple Access (SDMA)

- ▶ A single satellite can communicate with more satellites receivers of the same frequency.
- ▶ A typical application involves assigning an optimal base station to a mobile phone user.
- ▶ A mobile phone may receive several base stations with different quality.

Comparison of FDMA, TDMA, CDMA, SDMA

Technique	FDMA	TDMA	CDMA	SDMA
Concept	Divide the frequency band into disjoint subbands	Divide the time into non-overlapping time slots	Spread the signal with orthogonal codes	Divide the space into sectors
Active terminals	All terminals active on their specified frequencies	Terminals are active in their specified slot on same frequency	All terminals active on same frequency	Number of terminals per beam depends on FDMA/TDMA/CDMA
Signal separation	Filtering in frequency	Synchronization in time	Code separation	Spatial separation using smart antennas
Handoff	Hard handoff	Hard handoff	Soft handoff	Hard and soft handoffs
Advantages	Simple and robust	Flexible	Flexible	Very simple, increases system capacity
Disadvantages	Inflexible, available frequencies are fixed, requires guard bands	Requires guard space, synchronization problem	Complex receivers, requires power control to avoid near-far problem	Inflexible, requires network monitoring to avoid intracell handoffs
Current applications	Radio, TV, and analog cellular	GSM and PDC	2.5G and 3G	Satellite systems, others being explored

Exercises

1. Why did the 2G cellular systems shift from analog FDMA to digital TDMA and CDMA?
2. What are the advantages of the CDMA access techniques?
3. Explain the difference between carrier-sending mechanisms in the wired and wireless channels