Cellular Concepts and Frequency Planning

Topics

- Communication Technique- Duplexing
- Multiple Access Techniques
- Mobile radio propagation

Terminology

- **Mobile**: A radio terminal attached to a high speed mobile platform (e.g: cell phone in a fast moving vehicle)
- **Portable**: A radio terminal that can be hand held and used by someone at walking speed (e.g: cordless telephone)
- **Mobile Station (MS)**: A mobile/ portable user
- **Base station (BS)**: Fixed antenna units where the subscriber communicates. Connected to power and backbone network.

Terminology

- **Cells**: The area of coverage is divided into cells. Each cells has a base station
- **Control Channel**: Radio channel used for transmission of call setup, call request and call initiation
- **Forward channel (downlink)**: Radio channel used for transmission of information *from the base station to the mobile*.
- **Reverse channel (uplink)**: Radio channel used for transmission of information *from the mobile to the base station.*

Terminology

- **Full duplex**: Simultaneous two way communication. Transmission and reception on two different channels
- **Handoff**: The process of transferring the mobile station from one channel/ base station to another
- **Page**: A brief message that broadcast over the entire service area by many base stations at the same time.
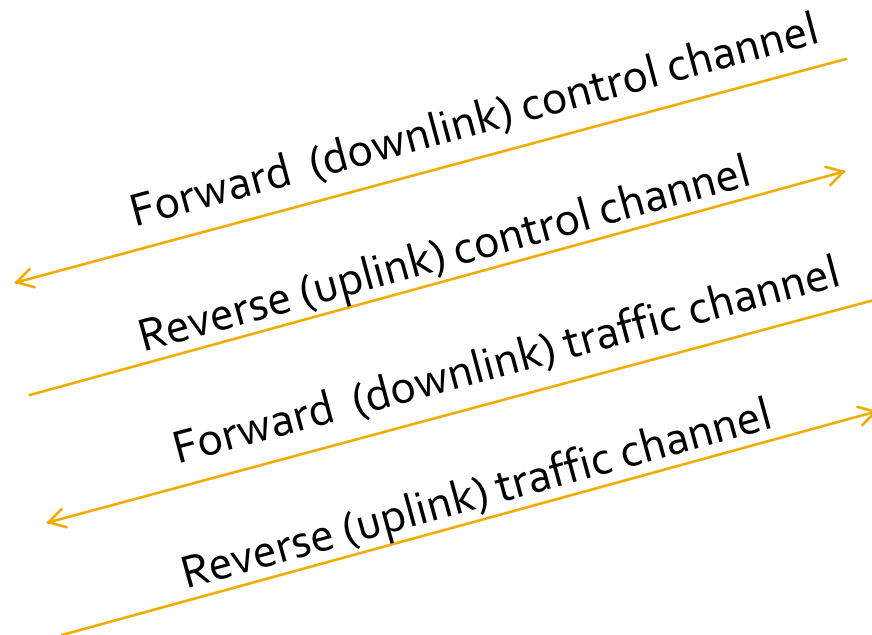
Uplink and Downlink

Uplink/reverse link

Mobile Station(MS)

Downlink/forward link

eNode B/Base Station (BS)
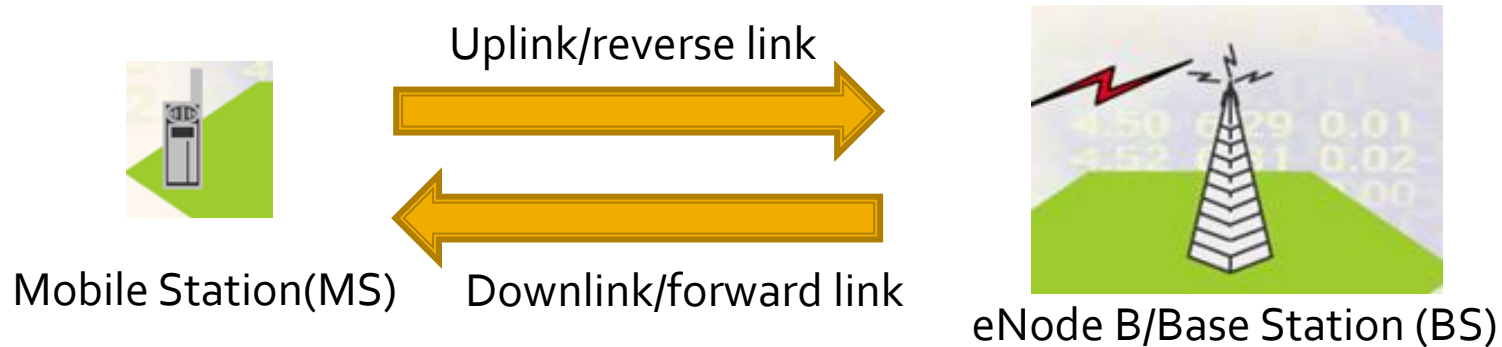
- Uplink/reverse– Transmission from MS to BS
- Downlink/forward – Transmission from BS to MS

Control and Traffic channels

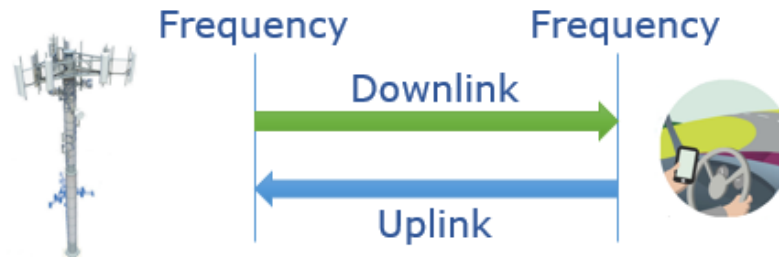- Control: setting up call
- Traffic: sending data

Forward (downlink) control channel

Reverse (uplink) control channel

Forward (downlink) traffic channel

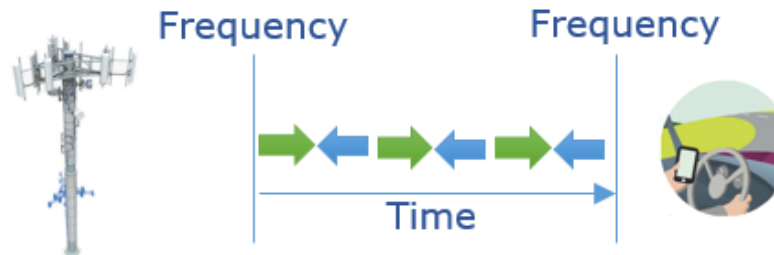Reverse (uplink) traffic channel

Base Station

Duplexing Methods: TDD vs FDD

FDD vs TDD

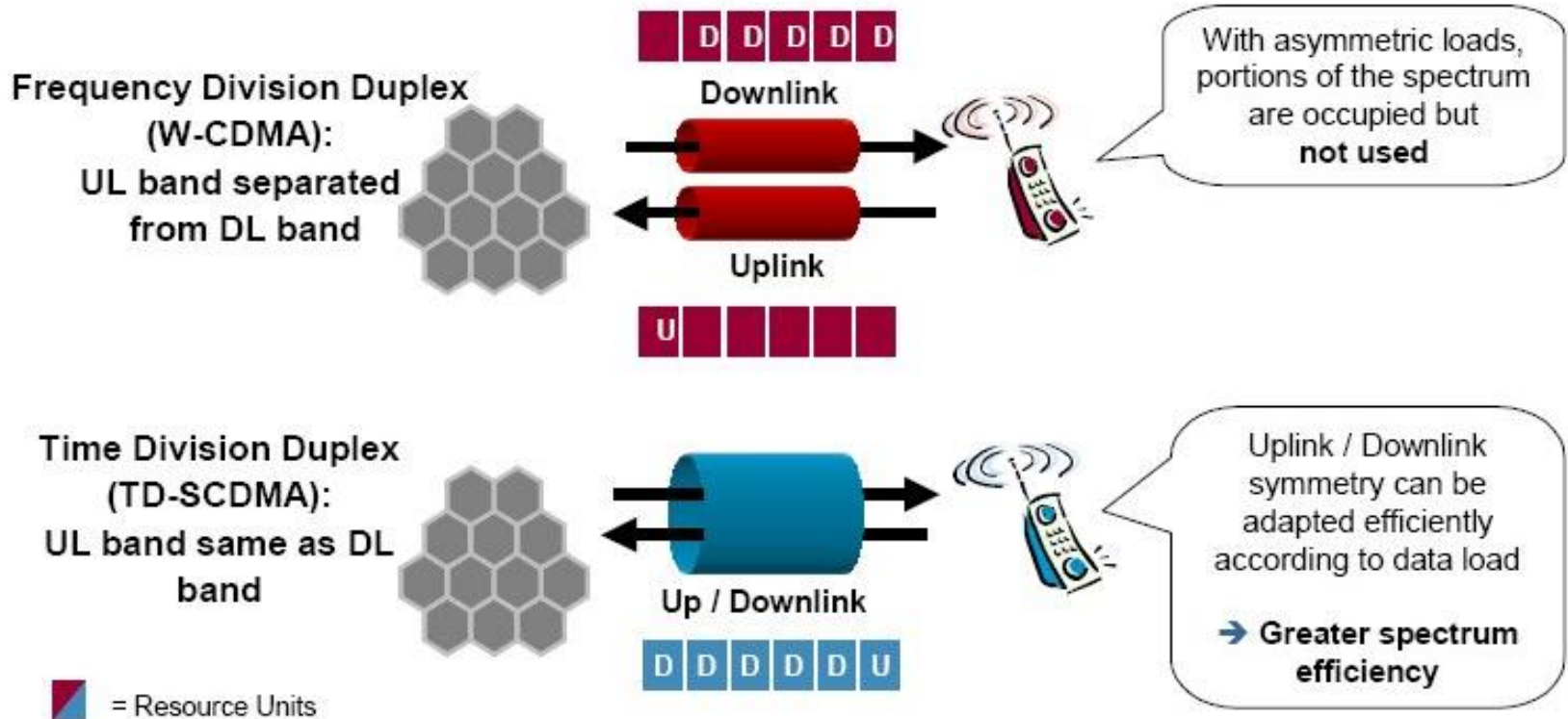FDD (Frequency Division Duplex) : Uplink and Downlink use different frequency

TDD (Time Division Duplex) : Uplink and Downlink use different slots in time, but both operates in the same frequency.
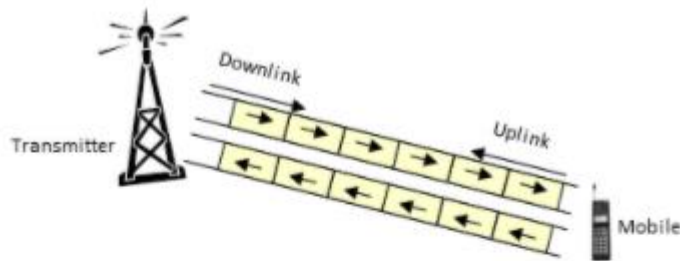
Duplexing Methods: TDD vs FDD

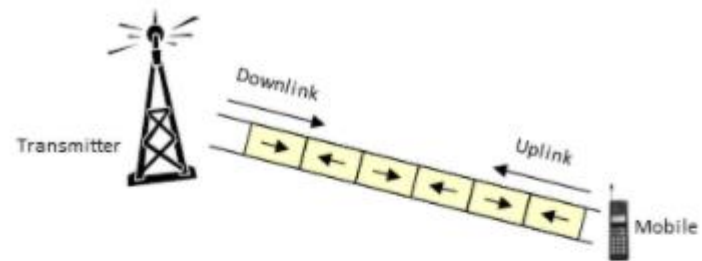Communication methods between Transmitter and Receiver

Duplexing Methods: TDD vs FDD

Frequency Division Duplex (FDD)

- ❏ Simpler to implement
- ❏ Simultaneous downlink and uplink transmission
- ❏ No need for synchronisation hence simpler implementation
- ❏ Needs paired spectrum
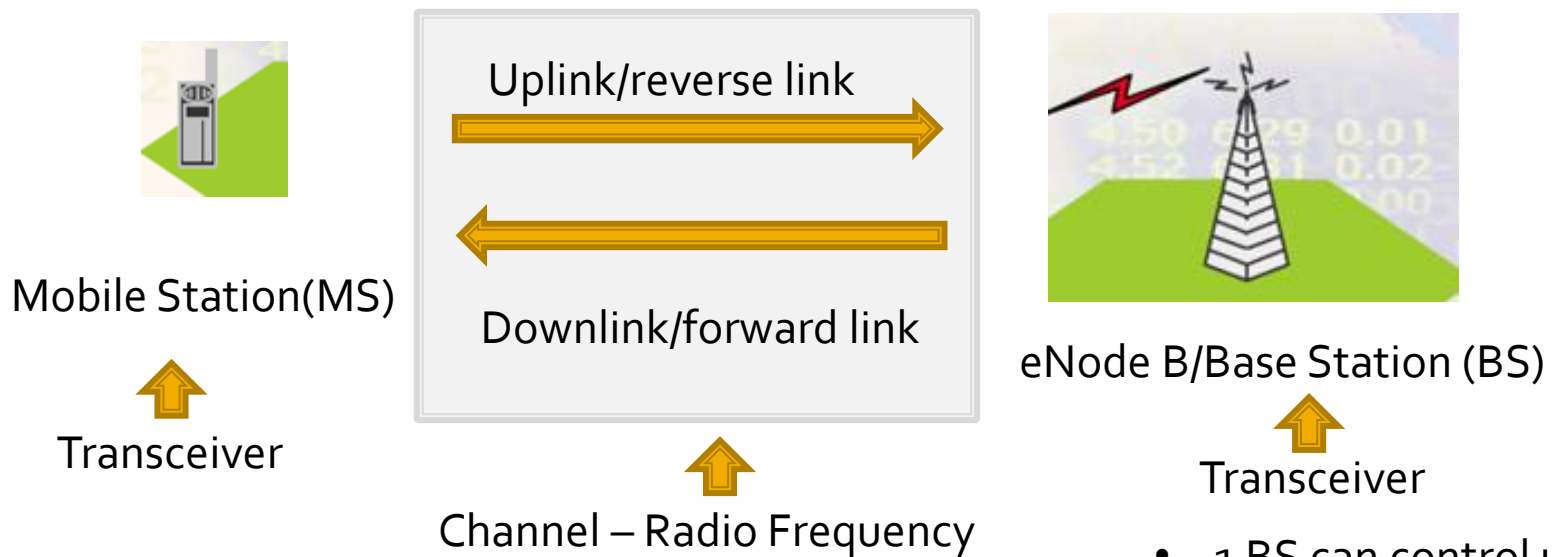- ❏ UL/DL ratio is fixed.

Time Division Duplex (TDD)

- ❏ Implementation is complex
- ❏ Only uplink (UL) or downlink (DL) at any time
- ❏ Need for synchronisation within the whole network
- ❏ No need for paired spectrum
- ❏ Number of UL/DL ratio is changeable

TDD vs FDD

From the video answer the following questions about TDD and FDD

- Definition of Duplexing and types
- How it is implemented in LTE
- List FIVE decision factors to use FDD or TDD
- Compare FDD and TDD based on decision factors
- Which countries implement TDD?

Cellular Concept

Uplink/reverse link

Downlink/forward link

Mobile Station(MS)

Transceiver

eNode B/Base Station (BS)

Transceiver

Channel – Radio Frequency

	Uplink	Downlink
MS	Transmitter	Receiver
BS	Receiver	Transmitter

- 1 BS can control up to several no. of MS at the same time based on BS spec
- Multiple access technique to allow users send data at the same time
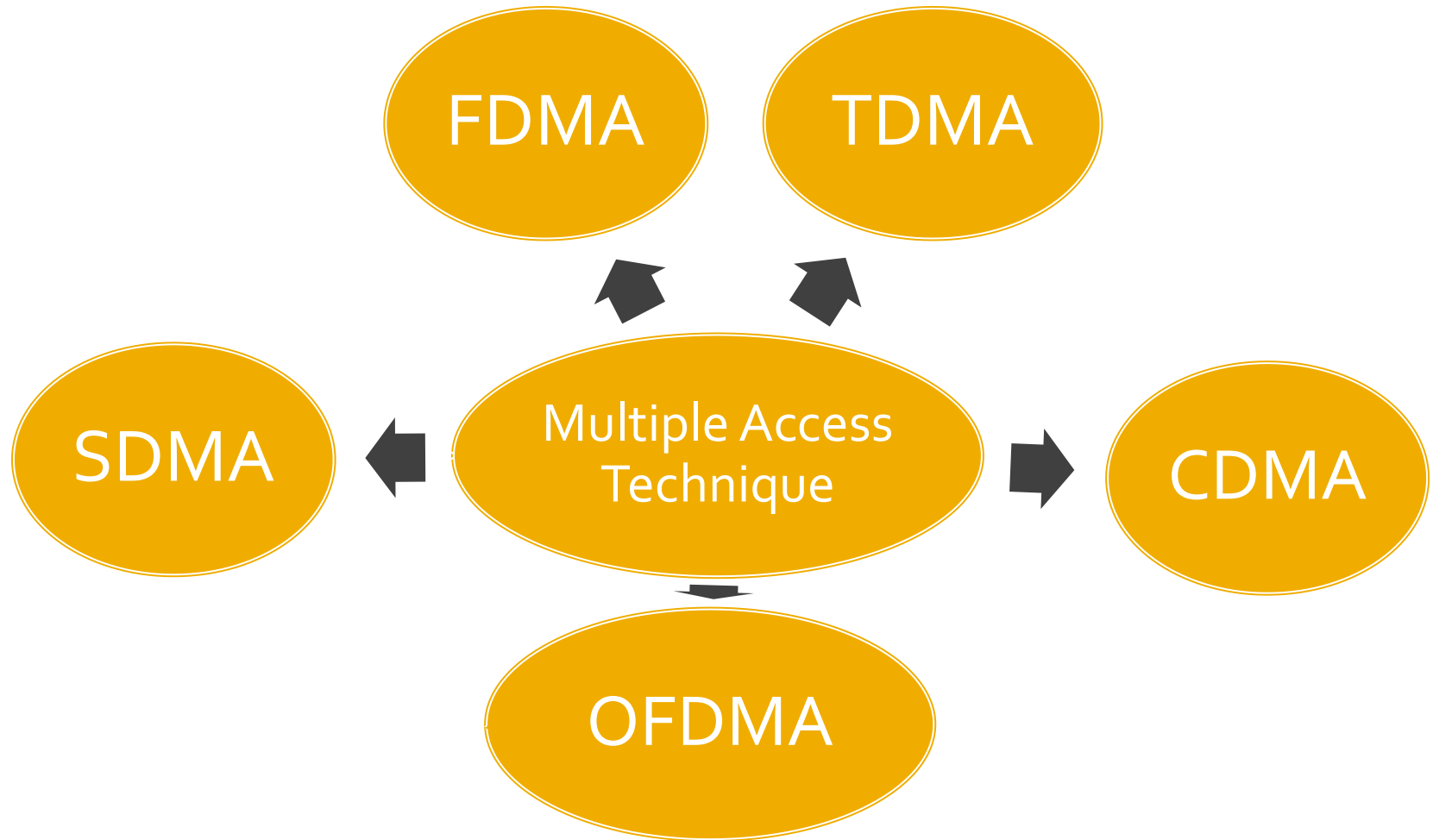
Multiple Access: Basic Concepts

- To allow multiple users to share a fair amount of finite radio spectrum
- Sharing of spectrum is required to achieve high capacity by simultaneously allocating the bandwidth
- Constraint!
 - There should not be severe performance degradation

Multiplexing

- **Multiplexing describes how several users can share a medium with minimum or no interference**
  - Example: lanes in a highway
  - Cars in different lanes (space division multiplexing)
  - Cars in a line but at different times (time division multiplexing)
- Multiplexing in **4 dimensions**
  - **space (s)**
  - **time (t)**
  - **frequency (f)**
  - **code (c)**
- Important: guard spaces needed!
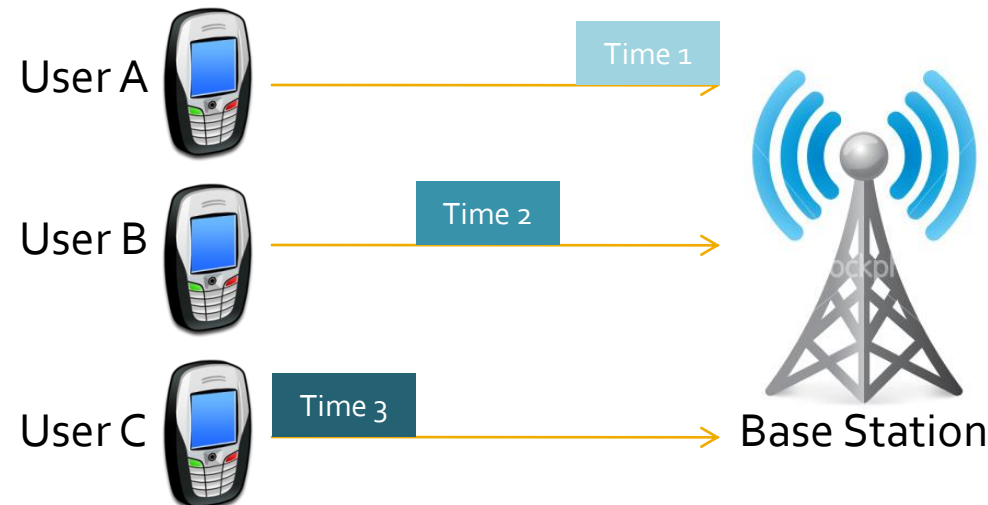
Multiple Access

Time Division Multiple Access (TDMA)

frequency

TDMA

time

User A — Time 1
User B — Time 2
User C — Time 3

Base Station
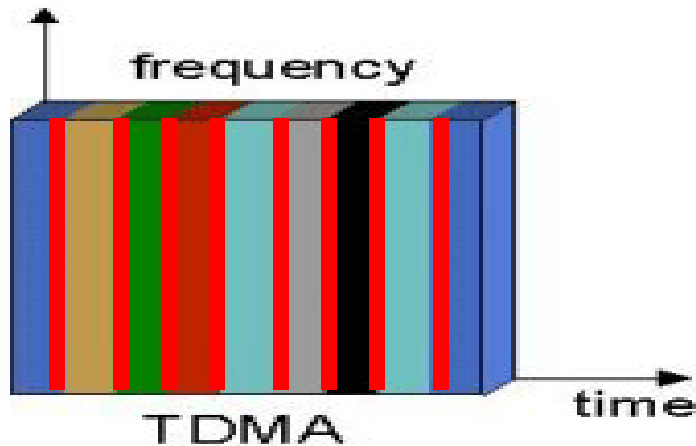
- Each user uses the whole bandwidth.
- Allocated different time to transmit (time slots)
- Needs Time Guard Band
  - What determines the duration of Time Guard Band in general?
  - A: depends on the allowable time jitter in the system.
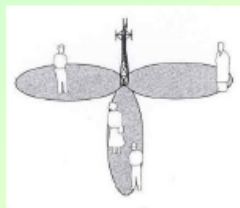
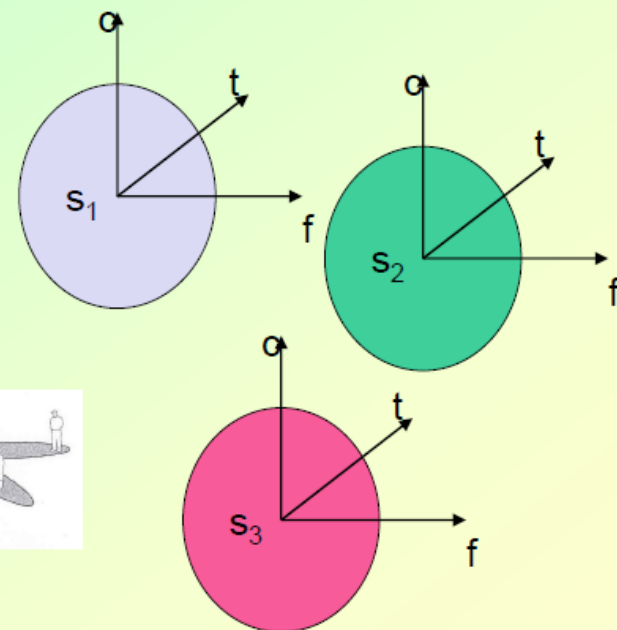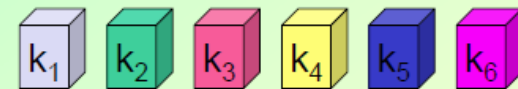# Frequency Division Multiple Access (FDMA)
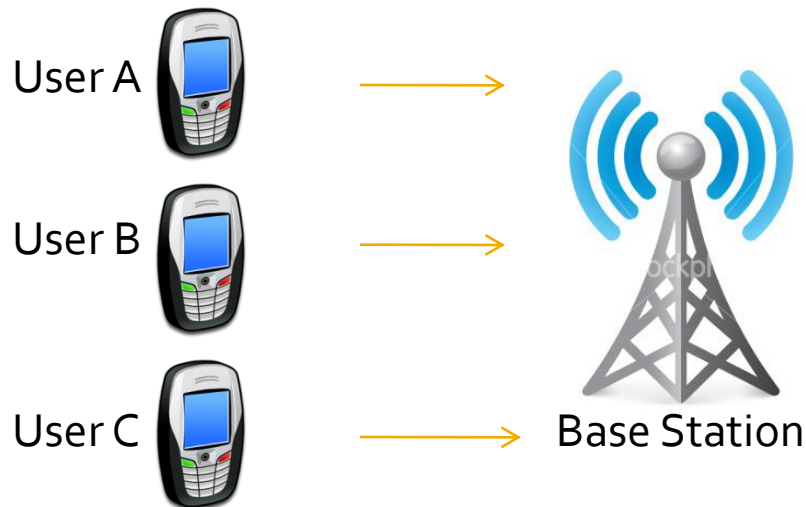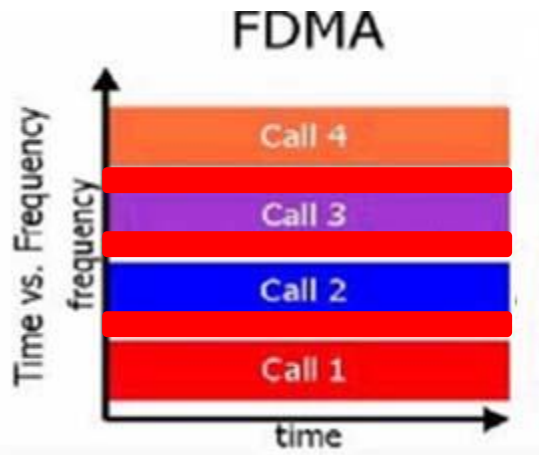
- Each user is allocated different (personal) frequency
- In need of a Guard Band
  - narrow frequency range
  - to separate two wider frequency ranges
  - ensure that multiple users can transmit simultaneously without interfering each other

Space Division Multiple Access (SDMA)

- The spatial dimension is used for multiplexing
- Data stream are transmitted over, non-overlapping transmission channels
- Uses spot beam antennas
- Base station tracks user when moving
- Cover areas with same frequency as TDMA, CDMA, and FDMA
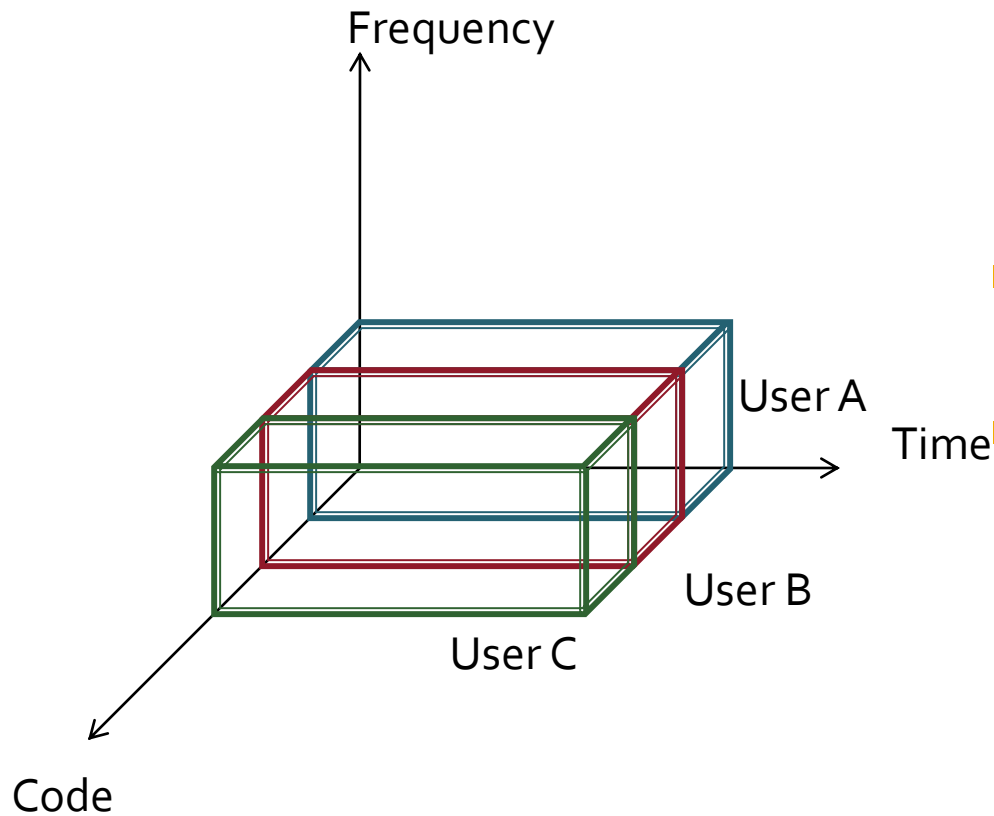- Can be achieved using:
    - Beam forming
    - Sectorization

- But, needs perfect adaptive antenna system: infinitely large antenna needed
- Compromise needed

channels k_i

k_1 k_2 k_3 k_4 k_5 k_6

s_1

s_2

s_3

Code Division Multiple Access (CDMA)

- Each user are allowed to use the whole frequency and the at any time by using different codes.
- BS understands all the codes.
- How the user knows which code to use to decode the messages?
  - A: using control channel

CDMA

- The user's signal is spread by an unique sequence
- All user share the same bandwidth with different sequences
- A communication is identify by the sequence
- Sender and receiver know the sequence in advance
- Other ongoing communication appears to be noise
- Power control needed to avoid near far effect
- Soft capacity limit
- Multi-path is reduced due to spreading sequence
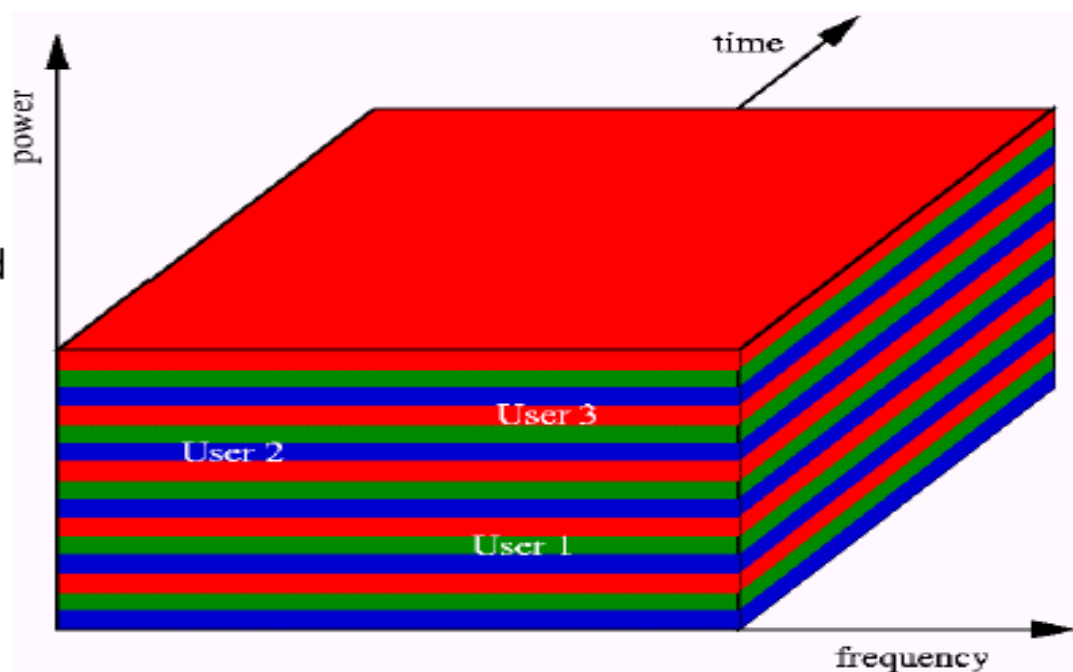
CDMA

- CDMA is a system based on spread-spectrum technology.
- Spread-spectrum – transmission technique wherein data occupy a larger bandwidth than necessary.
- There are two basic types of implementation methodologies:
  - Direct Sequence (DS)
  - Frequency Hoping (FH)

OFDM Basic Concept

- OFDM is a special case of *Frequency Division Multiplexing* (FDM)
- For FDM
  - No special relationship between the carrier frequencies
  - Guard bands have to be inserted to avoid *Adjacent Channel Interference* (ACI)

- For OFDM
  - Strict relation between carriers: $f_k = k \cdot \Delta f$ where $\Delta f = 1/T_U$ (T_U - symbol period)
  - Carriers are orthogonal to each other and can be packed tight

- OFDMA - When multiple users share spectrum using OFDM
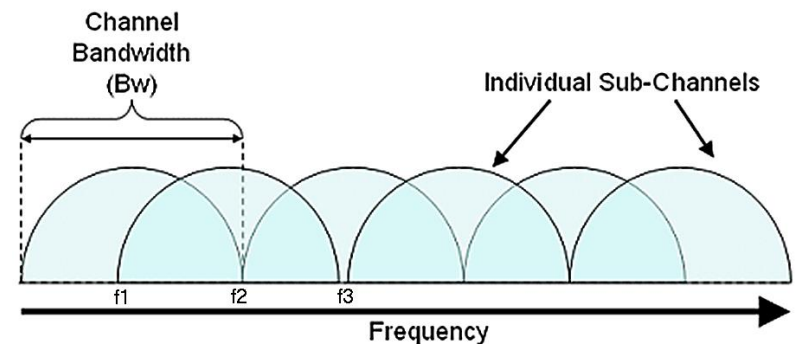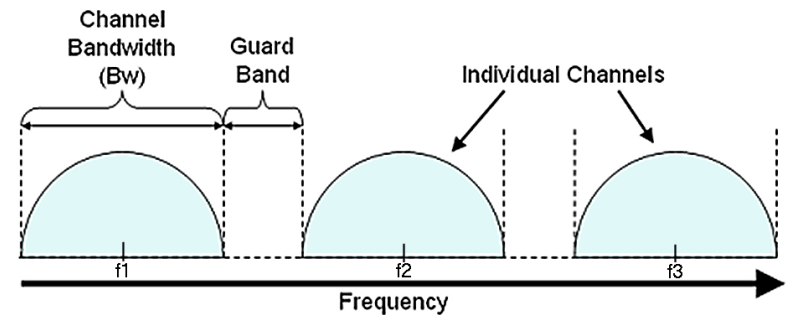
Multiple Access Summary

- From the video answer the following questions about Multiple Access Techniques

  - Definition of multiplexing and multiple access
  - List multiple access with its related mobile generation
  - Explain how spreading is implemented in CDMA
  - How the W-CDMA improve previous generation
  - Why OFDMA is selected to be the next generation multiple access techniques