

Department of Computer Science

CSE 4820: Wireless and Mobile Security

4. Digital Signal Processing

Dr. Abdullah Aydeger

Location: Harris Inst # 310

Email: aaydeger@fit.edu

Outline

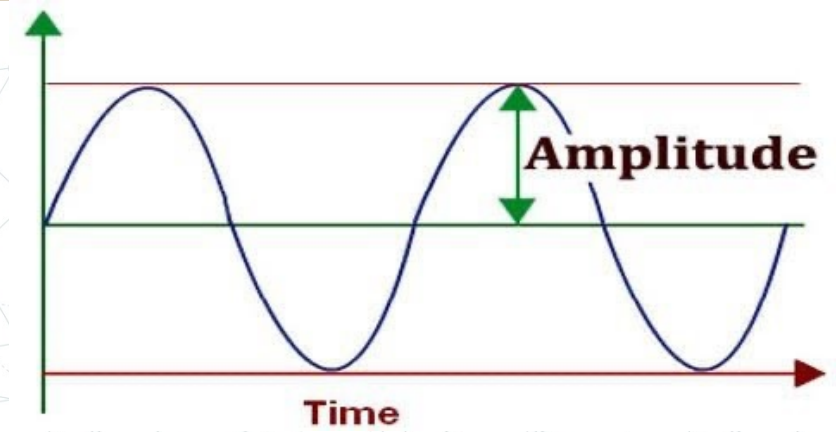
Definitions

Frequency, Amplitude, Wavelength

Modulations

Multiple Access

Amplitude



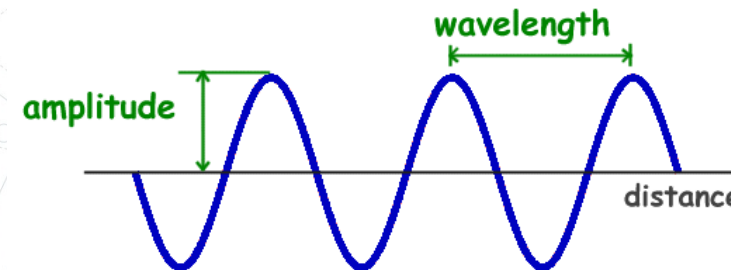
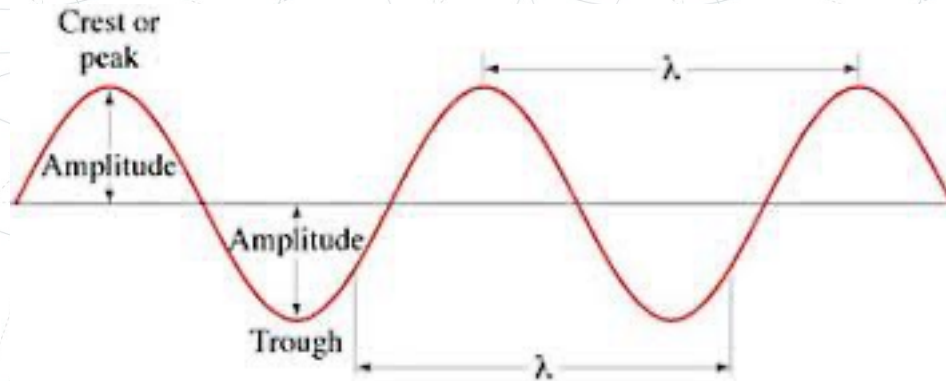
Measure of change of waveform per signal period

The amplitude is a measure of the strength or intensity of the wave

- For example, when looking at a sound wave, the amplitude will measure the loudness of the sound
- The energy of the wave also varies in direct proportion to the amplitude of the wave

Wavelength

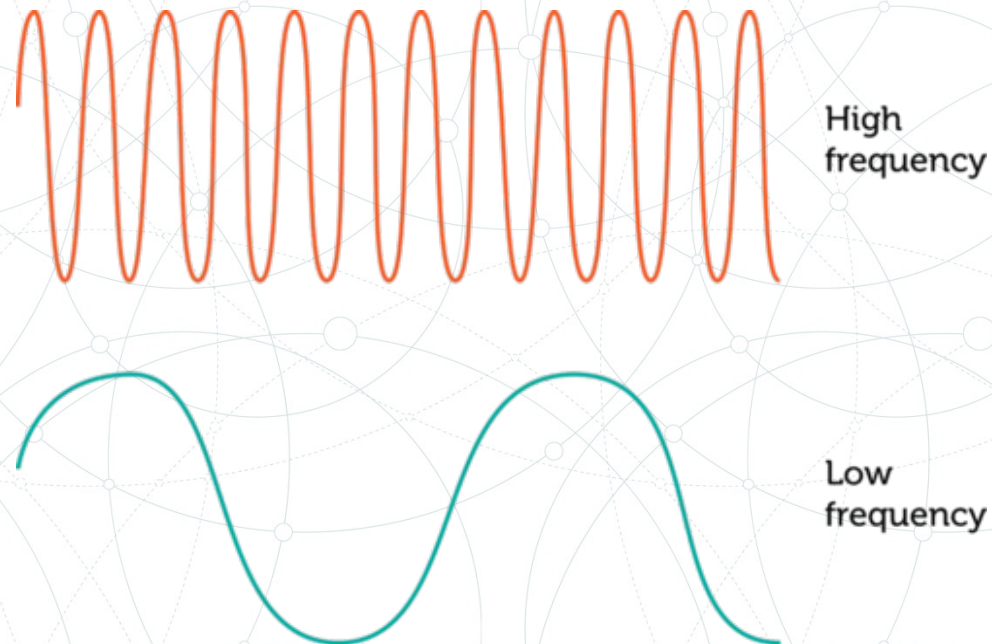
- The wavelength of a wave is the distance between two corresponding points on back-to-back cycles of a wave
- This can be measured between two crests of a wave or two troughs of a wave
- The wavelength is represented in physics by the Greek letter lambda (λ)



Frequency

How often the the waveform repeats per second (measured in hertz)

The unit for wave frequency is the **hertz (Hz)**, where 1 hertz equals 1 wave passing a fixed point in 1 second



Period

- The period of the wave is the time between wave crests
 - Measured in time units such as seconds and represented by the upper case "T"
- The period and frequency are closely related to each other
 - Period equals 1 over the frequency and the frequency is equal to one over the period
 - Reciprocals of each other as shown in the following formulas

$$T = 1/f$$

Velocity

- How fast the disturbance of the wave is moving
 - The speed of mechanical waves depends on the medium that the wave is traveling through
 - For example, sound will travel at a different speed in water than in air
 - The velocity of a wave is usually represented by the letter "v."
 - The velocity can be calculated by multiplying the frequency by the wavelength

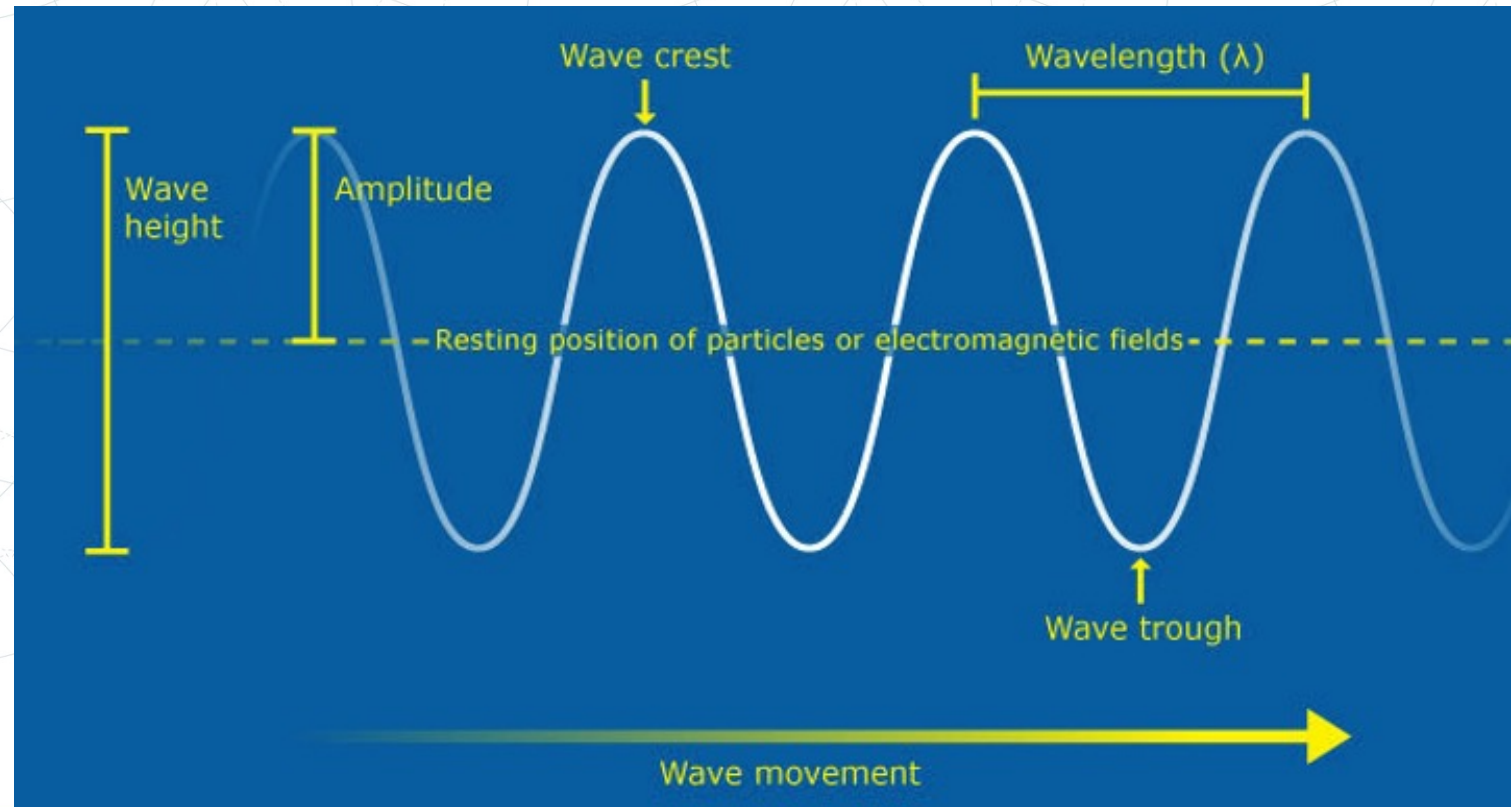
$$v = f * \lambda$$

Sampling Rate

- Average number of samples obtained in 1 second; reduction of continuous signal to discrete signal
- S1 is sampled at $f/2$
S2 is sampled at $f/4$
S2 misses $1/2$ the data

Digital Signal Processing

- DSP: process by which we encode or decode a signal using frequency, sampling, modulation, coding

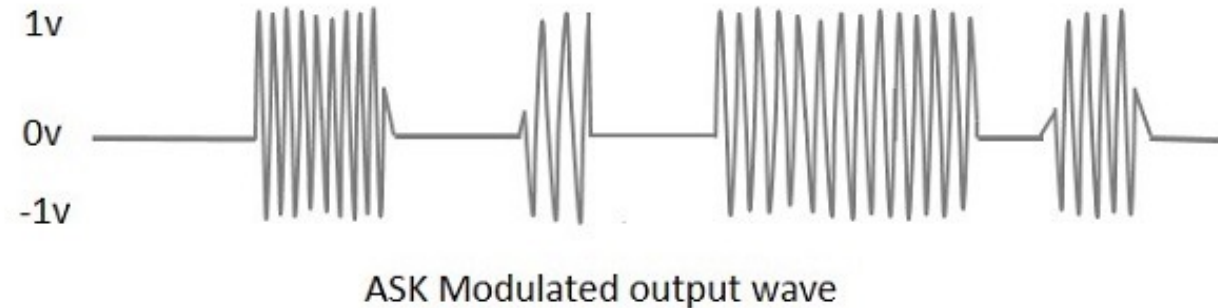
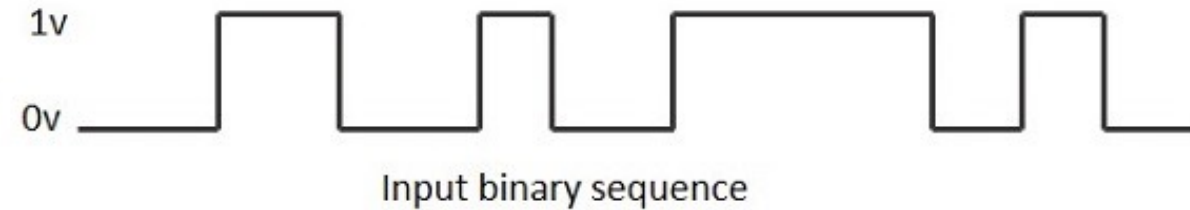


Digital Signal Modulation (Keying)

- Modifying properties of waveform to encode data
- Different potential approaches:
 - Amplitude Shift Keying (ASK)
 - Frequency Shift Keying (FSK)
 - Phase Shift Keying (PSK)
 - Differential BPSK
 - Quadrature Phase Shift Keying

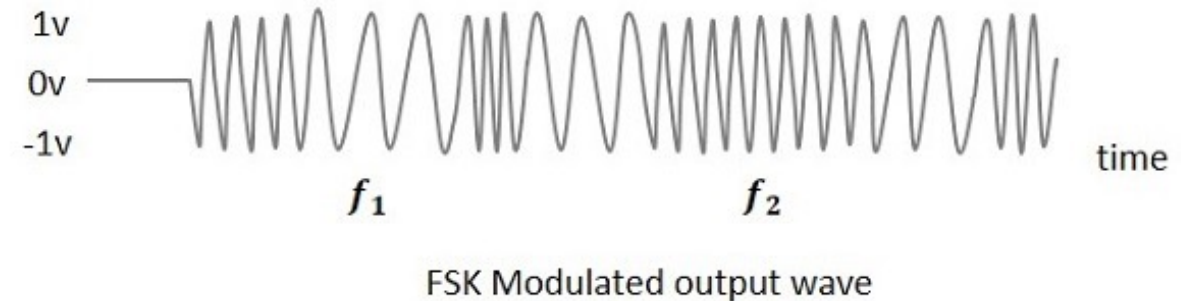
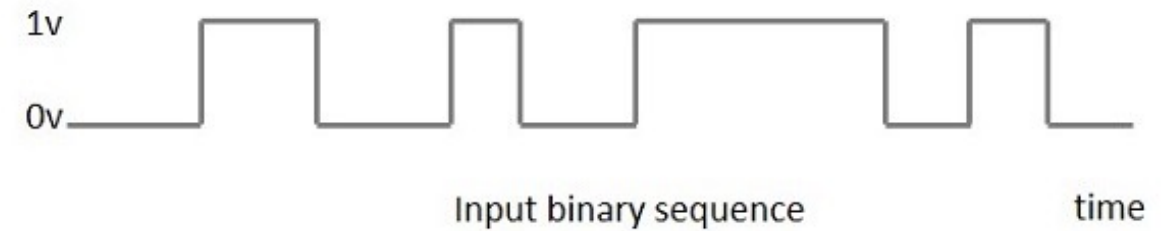
Amplitude Shift Keying (ASK)

- Represents the binary data in the form of variations in the amplitude of a signal
- Any modulated signal has a high frequency carrier
 - The binary signal when ASK modulated, gives a zero value for Low input while it gives the carrier output for High input



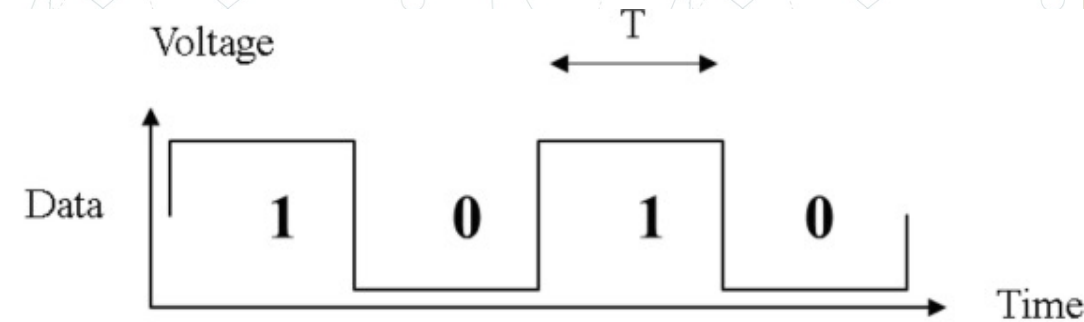
Frequency Shift Keying (FSK)

- The frequency of the carrier signal varies according to the digital signal changes
 - FSK is a scheme of frequency modulation
- The output of a FSK modulated wave is high in frequency for a binary High input and is low in frequency for a binary Low input
 - The binary 1s and 0s are called Mark and Space frequencies

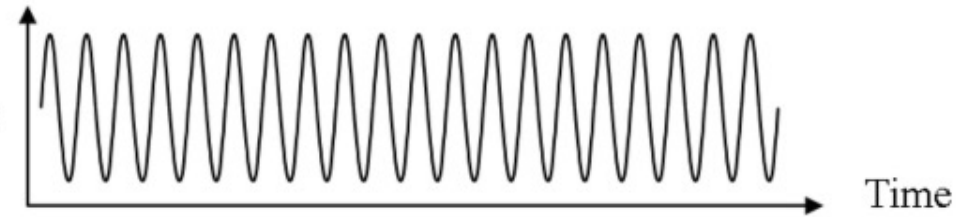


Phase Shift Keying

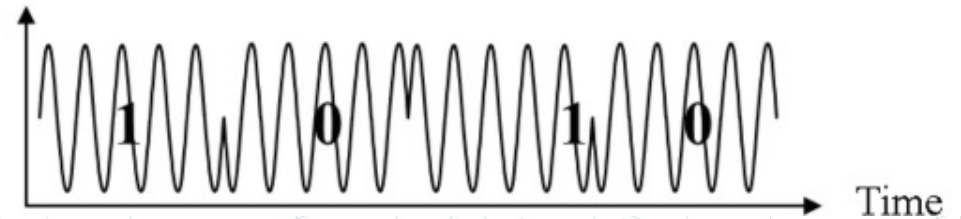
- The phase of the carrier signal is changed by varying the sine and cosine inputs at a particular time
- PSK technique is widely used for wireless LANs, bio-metric, contactless operations, along with RFID and Bluetooth communications



Carrier Frequency
Before Modulation



Carrier Frequency
After Modulation

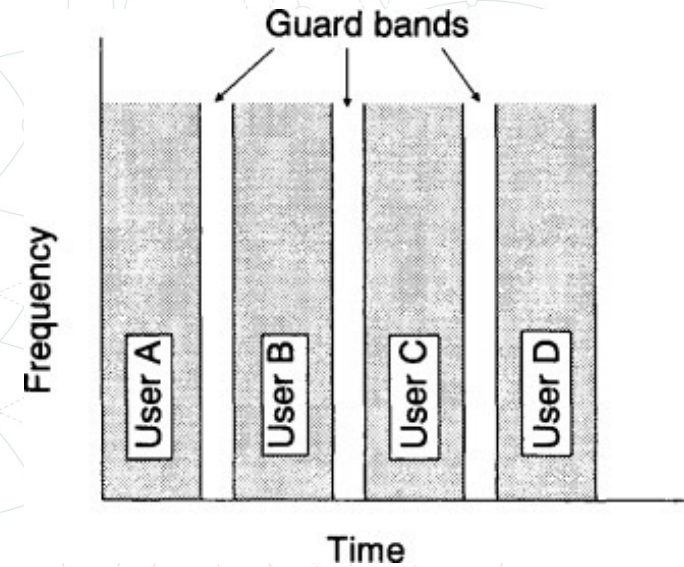


Multiple Access Methods

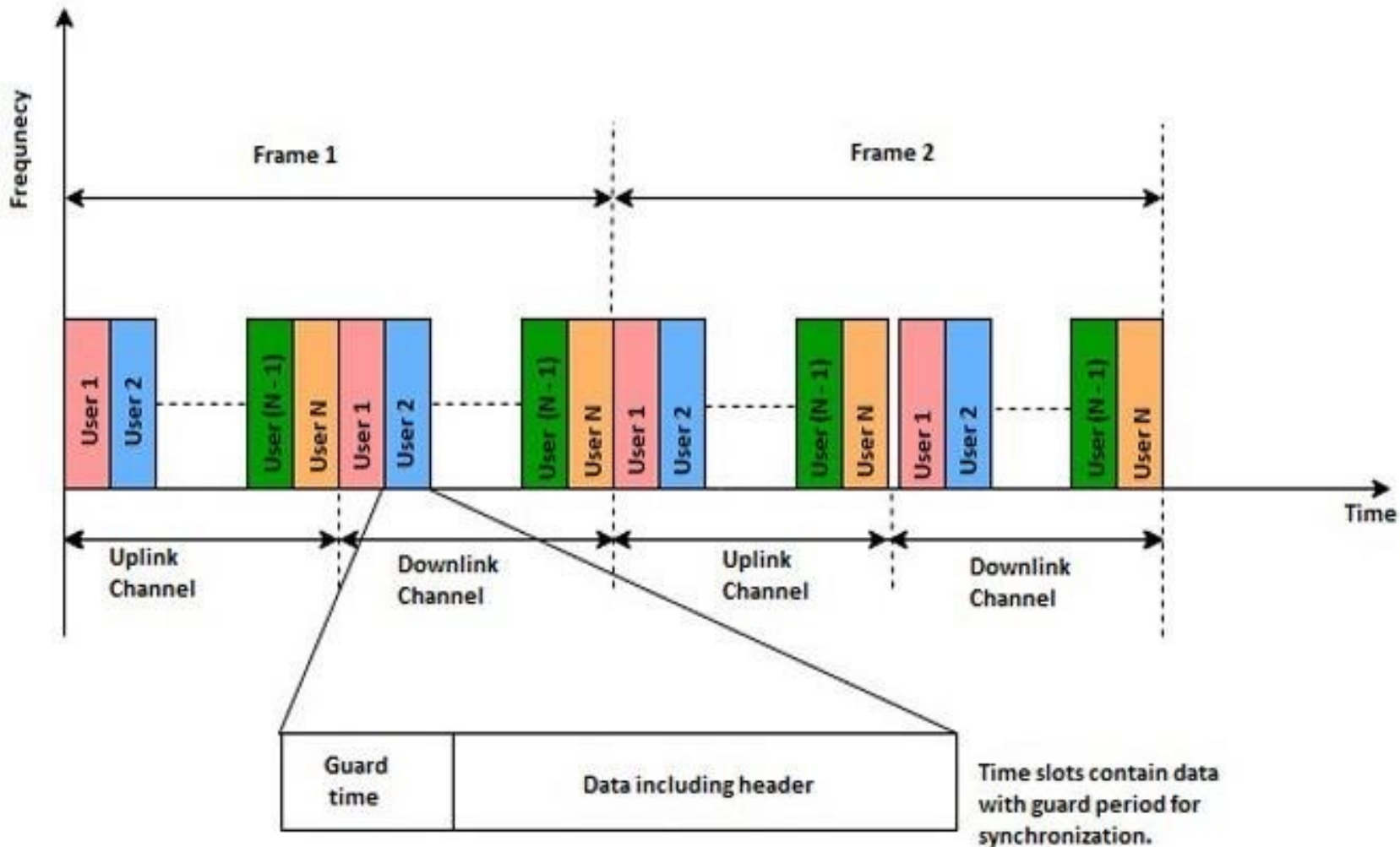
- Time Division Multiple Access
- Frequency Division Multiple Access
- Code Division Multiple Access
- OFDMA

Time Division Multiple Access

- TDMA shares a single carrier frequency with several users
 - Each users makes use of non-overlapping time slots
- Data transmission in TDMA is not continuous, but occurs in bursts
 - Hence handsoff process is simpler
- TDMA uses different time slots for transmission and reception thus duplexers are not required
- TDMA has an advantage that is possible to allocate different numbers of time slots per frame to different users
- Bandwidth can be supplied on demand to different users by concatenating or reassigning time slot based on priority



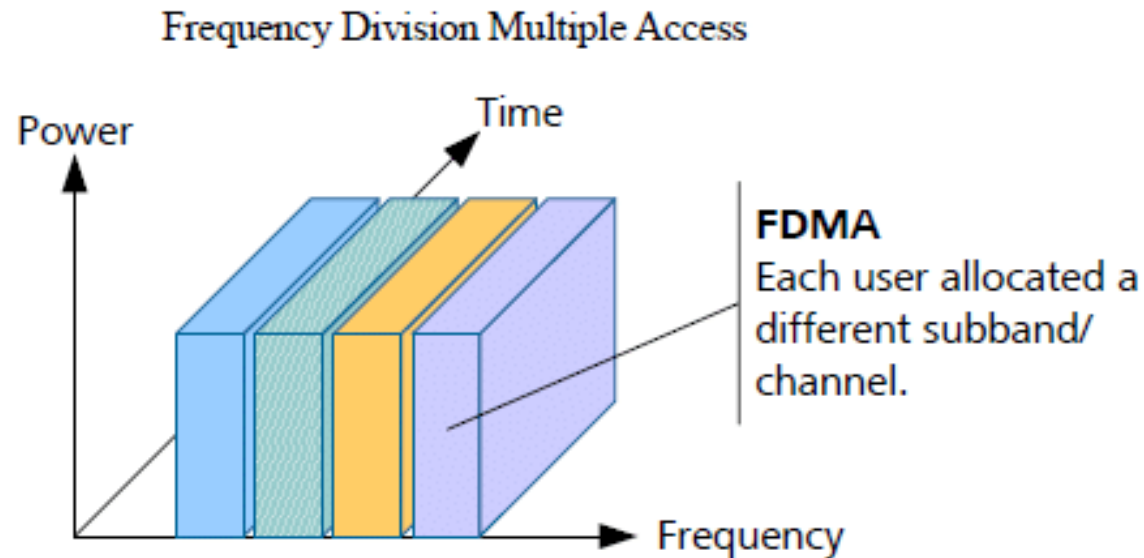
Time Division Multiple Access



- Where continuous transmission is not required, there TDMA is used instead of FDMA

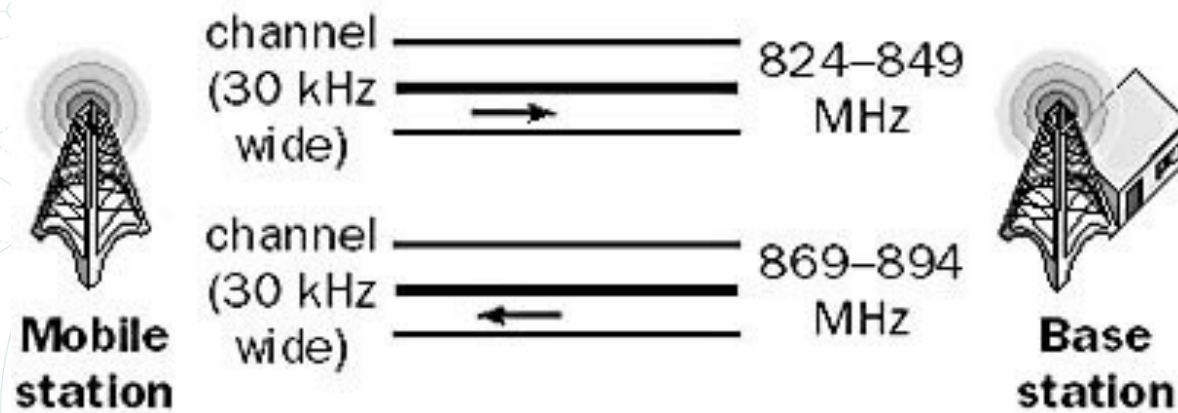
Frequency Division Multiple Access

- FDMA allots a different sub-band of frequency to each different user to access the network
- If FDMA is not in use, the channel is left idle instead of allotting to the other users



Frequency Division Multiple Access

- FDMA is implemented in Narrowband systems
 - It is less complex than TDMA
- The base station BS and mobile station MS, transmit and receive simultaneously and continuously in FDMA



Code Division Multiple Access

- Technique that allows multiple users to simultaneously transmit data signals over a common channel by assigning unique spreading code to each individual user
 - This leads to the increasing of bandwidth used by transmitting stations from a few Hz to a few MHz

Code Division Multiple Access

- CDMA uses the principle of spread spectrum
 - The various signals are modulated after which a single signal is transmitted and is correlated at the receiving end using the spreading function to get the actual data

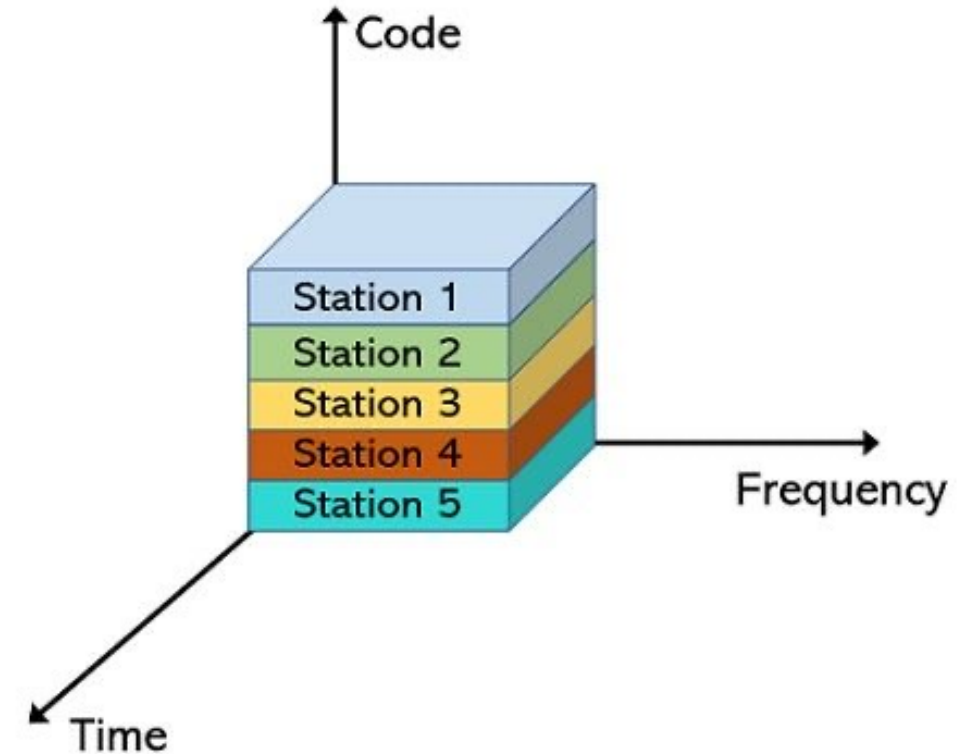


Illustration of CDMA

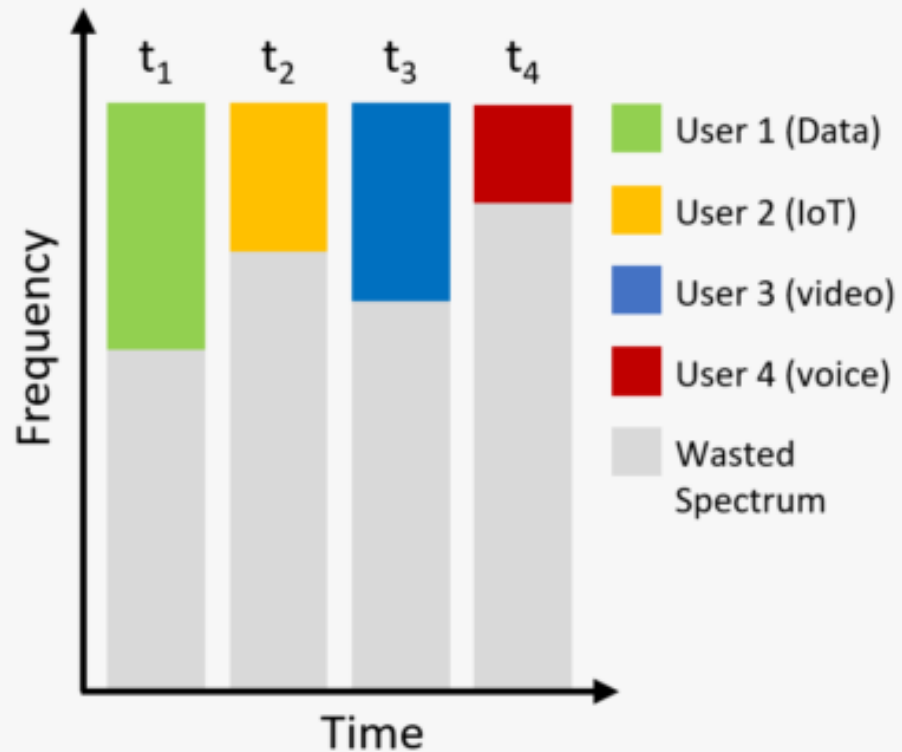
Orthogonal Frequency Division Multiplexing

- Ten 100 kHz channels are better than one 1 MHz Channel
- Frequency band is divided into 256 or more sub-bands
 - Orthogonal -> Peak of one at null of others
- Each carrier is modulated with a BPSK, QPSK, 16-QAM, 64-QAM etc. depending on the noise
- Used in WiFi, LTE, 5G, etc.

OFDM vs OFDMA

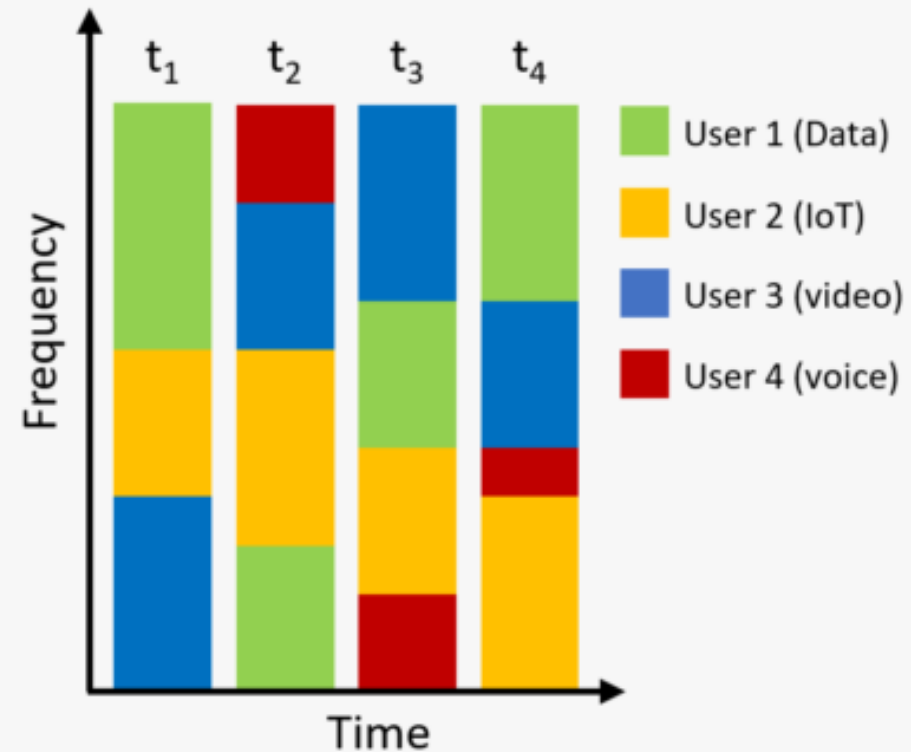
OFDM (Wi-Fi 2-5)

- One user packet per time segment
- Inefficient for small packets
- High voice/video delay



OFDMA (Wi-Fi 6)

- Multiple users packet per time segment
- Highly efficient
- Low voice/video delay



Thank you. Questions?

Dr. Abdullah Aydeger