CSCE 5520 (Wireless Network and Protocols)

Homework-1

Malwika. R
(11607929)

1) Wireless Communication:-
It is the transmission of information or data between two or more points without using physical wired connections. It uses electromagnetic waves, such as radio frequency (RF), microwave, infrared (IR), and other wireless technologies to transmit data, voice, video over short or long distances.

Importance of Wireless Communication in Today's World:-

It plays a vital role in today's world and also became an integral part of modern life for several reasons:-

(i) Connectivity:- It enables people and devices to connect accross geographic boundaries. This connectivity extends to remote and underserved areas.

(ii) Efficiency:- It enhances efficiency and productivity in various sectors. In businesses, it enables employees to work remotely, while industries like healthcare benefit from wireless medical devices that monitor patients in real-time.

(iii) Emergency services:- Wireless communication is crucial for emergency services, enabling quick and efficient communication during crises, natural disasters and public safety incidents.

Advantages of wireless Communications:-

(i) Mobility - Users can communicate and access information from virtually anywhere, providing unparalleled convenience.

(ii) Cost Efficiency - Building and maintaing wireless infrastructure can be cost-effective compared to laying physical cables.

(iii) Scalability - wireless networks can be easily expanded or upgraded to accomodate increased demand or new technologies.

(iv) Flexibility - wireless devices and networks are adaptable and can be reconfigured as needed.

Limitations of Wireless Communication:-

(i) Security - Wireless networks are susceptible to security breaches, encryption and security protocols must be implemented to protect data.

(ii) Bandwidth Limitations - wireless networks have limited bandwidth compared to wired connections which results in slower data transfer rates.

while it offers numerous advantages, it also comes with limitations that must be addressed to ensure the reliability and security of wireless devices.

2) Principles of Signal Propagation in Wireless Communication:-

Wireless communication relies on the transmission of electromagnetic waves through the air to carry information.

i) Wavelength and Frequency - The wavelength and frequency of electromagnetic waves determine how they propagate. Lower frequency signals, such as radio waves, can travel longer distances and penetrate obstacles better.

(ii) Line-of-Sight (LOS) - LOS propagation occurs when there ~~it~~ is a direct, unobstructed path between transmitter and receiver.

(iii) Non-Line-of-Sight (NLOS):- NLOS propagation occurs when obstacles, such as buildings, trees or terrain obstruct direct path between the transmitter and receiver.

(iv) Reflection - signals can bounce off surfaces like walls, buildings and the ground, leading to multiple paths for the signal to reach the receiver.

(v) Diffraction - when signals encounter obstacles with sharp edges, such as buildings or mountains, they can diffract around these obstacles enabling them to reach areas that would otherwise be in shadow.

Explanation of Line-of-Sight (LOS) and Non-Line-of-Sight (NLOS) Propagation:-

(i) Line-of-Sight (LOS) Propagation:- In LOS conditions, the transmitter and receiver have an unobstructed, directly by line of sight to each other.

→ LOS propagation is characterized by minimal signal attenuation, resulting in strong signal strength and high-quality communication.

(ii) Non-Line-of-Sight (NLOS) Propagation:-

→ In NLOS conditions, obstacles obstruct the direct path between the transmitter and receiver.

→ NLOS propagation results in signal attenuation, scattering and multipath effects, leading to reduced signal strength and potential signal degradation.

→ NLOS conditions are common in urban environments where buildings, trees, and terrain can block the direct path between devices.

→ Effects on Signal Strength and Quality:-

(i) Signal Strength (Attenuation): In LOS conditions, signal strength is typically high, and attenuation is minimal.

(ii) Signal Quality (Fading and Interference) :- In LOS Conditions, Signal quality is generally excellent, with minimal fading and interference. In NLOS multipath Propagation can cause fading, which results in Signal distortion and reduced quality.

(iii) Data Rate :- LOS Conditions typically support higher data rates because of strong signal and minimal interference.

(iv) Reliability :- LOS Conditions are more reliable for wireless Communication because of the consistent signal strength and quality.

So, the ~~signal~~ ~~of~~ principles of Signal propagation, including LOS and NLOS scenarios, is crucial for designing and optimizing wireless Communication systems. while NLOS Conditions require mitigation techniques to maintain acceptable signal quality and reliability in challenging environments.

3) Fading in Wireless Communications :-

Fading is a Common phenomenon is wireless Communication that results from variations in the received signal strength or quality over time and space. Fading can significantly affect the reliability and performance of wireless systems, including cellular networks and radio communications.

There are different types of Fading such as:-

(i) Path Loss :- It is also known as free-space path loss, occurs as a wireless signal travels through space and spreads out, causing it to weaken with distance. The signal power diminishes in proportion to square of the distance between transmitter and receiver. As a result, the received signal power decreases with increase distance from the transmitter.

Example:- Imagine a Wi-Fi in your home. As you move away from the router, the signal strength decreases due to path loss. This is why you may experience slower internet speeds or dropped connections in areas far from the router.

(ii) Shadowing:- Shadowing, also called log-normal shadowing, is caused by obstructions, buildings or terrain that block or partially block the signal path. Shadowing is often characterized by a log-normal distribution of signal variations which means signal strength follows a statistical pattern.

Example:- When you use your mobile phone in a city, signal strength can vary significantly as you move through areas with tall buildings. This buildings will create shadow signal regions where signals are weak leading to call drops.

(iii) Multipath Fading :- Multipath fading occurs when a wireless signal takes multiple paths to reach the receiver due to reflections, diffractions and scattering off objects in its path. These different signal paths can interfere constructively at the receiver, resulting in signal variations, including deep fades and signal enhancement.

Example :- when you listen to an FM radio station while driving, you may experience signal fading caused by multipath reflections from nearby buildings or hills. As your car moves, the relative phases of the reflected signals change, leading to fading and interference.

Fading in wireless communication refers to the variation in signal strength and quality caused by factors like distance, obstacles and multipath propagation.

4) Multiple Access in Wireless Communications :-
Multiple access is a fundamental concept in wireless communication that allows multiple users or devices to share the same communication medium, such as radio frequency spectrum, in an organised and efficient manner. The choice of multiple access technique depends on factors like the available bandwidth, system requirements, and in interference management.

Differences between TDMA, FDMA and CDMA :-

(i) Allocation Methods :-

→ TDMA allocates time slots to users.
→ FDMA allocates frequency channels to users.
→ CDMA assigns unique codes to users.

(ii) Interference Handling :-

→ TDMA users transmit in seperate time slots, so interference occurs in the time domain.
→ FDMA users transmit in seperate frequency bands, so interference occurs in the frequency domain.
→ CDMA users can transmit simultaneously, but interference is controlled using unique codes and signal processing techniques.

(iii) Bandwidth Efficiency :-

→ TDMA and FDMA may lead to underutilization of bandwidth if users do not fully occupy their allocated slots or channels.

→ CDMA is more bandwidth-efficient as users can transmit concurrently, utilizing the entire bandwidth.

(iv) System Flexibility :-

-> TDMA and FDMA are suited for systems with a fixed number of users and channels.

-> CDMA is more flexible and can accomodate a variable number of users.

Overall, TDMA, FDMA and CDMA are multiple access techniques used in wireless Communication to enable efficient sharing the Communication medium among multiple users.

5) Given a system operates at a frequency of 2.4 GHz

$f = 2.4\,GHz$

and Bandwidth $BW = 20\,MHz$

the Signal-to-noise ratio (SNR) = 25 DB

the maximum achievable data rate = ?

Channel Capacity $C = B \log_2 (1 + SNR)$

$\rightarrow SNR = 25\,dB$

$$10 \log_{10} (S/N) = 25$$

$$\log_{10} (S/N) = 2.5$$

$$S/N = 10^{2.5}$$

$\rightarrow S/N = 316.277$

$\rightarrow C = 20 \times 10^6 \log_2 (1 + 316.277)$

$C = 20 \times 10^6 (8.31)$

$C = 16.62 \times 10^7$ bps

$C = 166.2$ Mbps.

$\therefore$ The maximum achievable data rate is 166.2 Mbps.

6) Nyquist's Bitrate = maximum bit rate for noiseless channel

$$= 2 \times \text{Bandwidth} \times \log_2(m)$$

Given, Bandwidth = 4000 Hz

$m = 4$

maximum Data rate $= 2 \times 4000 \times \log_2(4)$

$= 16000$ bps

Maximum achievable data rate is 16000 bps.

7) Given the Band width $B \cdot W = 20 KHz$ (noiseless channel)

need to send 280 Kbps to Channel

$$280 \text{ Kbps} = C$$

$$m = ?$$

now, $C = 2 B \log_2 m$

$$28\cancel{0} \times 1\cancel{0}^3 = 2(2\cancel{0} \times \cancel{10^3}) \log_2 m$$

$$7 = \log_2 m$$

$$m = 2^7$$

$$\therefore m = 128$$

To achieve a data rate of 280 Kbps over a noiseless channel with a bandwidth of 20KHZ, 128 Signal levels are required.

8) In data Base, we have

$$Pr(dBM) = Pt(dBM) - 21.98 + 20\log_{10}(\lambda) - 20\log_{10}(d)$$

Pah loss $= Lp = Pt - Pr = 21.98 - 2\log_{10}(\lambda) + 20\log_{10}(d)$

$$\lambda = C/F$$

Given, $f = 2.4\ GHz$

transmission power $= 20\ dBm \Rightarrow Pt$

receiver sensitivity $= 90\ dBm \Rightarrow Pr$

path loss Component $= 3.5$

distance between T & R $\Rightarrow d = ?$

now, substitute all values in above formula

$$Pr = Pt = 21.98 + 20\log_{10}(\lambda) - 20\log_{10}(d)$$

$$-90 = 20 - 21.98 + 20\log_{10}\left(\frac{3\times10^8}{2.4\times10^9}\right) - 20\log_{10}(d)$$

$$20\log_{10}(d) = 20 - 21.98 + 90 - 18.06$$

$$20\log_{10}(d) = 69.96 \Rightarrow \log_{10}(d) = 3.498$$

$$d = 10^{3.498} \Rightarrow d = 3147.74$$

Hence the maximum distance between transmitter and receiver that allows successful Communication $d = 3147.74\ m$