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CSCE 5520 - Wireless Networks & Protocols

① Define wireless Communication & explain its importance in today's world. Discuss the advantages and limitations of wireless Communication.

(A) wireless Communication refers to the transmission of data b/w multiple points without the use of physical wires. It relies on various wireless technologies like ratio waves, microwaves & infrared waves through air. wireless is an integral part of The world.

① Mobility & Convienience : wireless Communication empowers users to stay Connected and access information while on the move. Devices like mobiles, tabs & Laptops enable individuals to Communicate & browse the internet.

② Connectivity :- It plays a pivotal role in linking remote and distant regions, and providing internet access to underserved and rural areas.

③ Emergency Services :- wireless Commution is indispensible for emergency services such as police., fire departments and medical personnel. It facilitates swift Communication even in remote or disaster-stricken locations

④ Internet of Things (IOT) :- wireless Communication is essential for IOT devices, which are increasingly prevalent across various sectors, including home automation, health care & agriculture.

Advantages of wireless Communications

① Mobility:- users can move freely while remaining connected, which is very important in fast paced world.

② Scalability:- wireless networks can be easily expanded or modified to accommodate more devices.

③ Rapid Deployment:- wireless networks can be swiftly established in areas where laying cables would be time-consuming.

④ Flexibility:- wireless technology permits adaptable and flexible network configuration

Limitations of wireless Communications:-

① Interference:- wireless signals can be disrupted by interference from other devices, physical obstruction, or environmental factors like adverse weather conditions

② Limited Range:- wireless networks have a restricted range compared to wired connections, which can be challenging in remote areas

③ Reliability:- wireless networks may encounter signal interruptions, affecting communication reliability.

④ Bandwidth Constraints:- The available bandwidth for wireless communications is frequently restricted, potentially resulting in slower data transfer speeds compared to wired connections

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(2) Discuss the principles of signal propagation in wireless communication. Explain the concepts of Line-of-Sight (LOS) & Non-Line-of-Sight (NLOS) and their effects on their signal strength and quality.

(A) Signal propagation in wireless communication is influenced by various principles various principles and factors, including the concepts of Line-of-Sight (LOS) and Non-Line-of-Sight (NLOS). propagation. These concepts have significant impact on signal sig strength an quality.

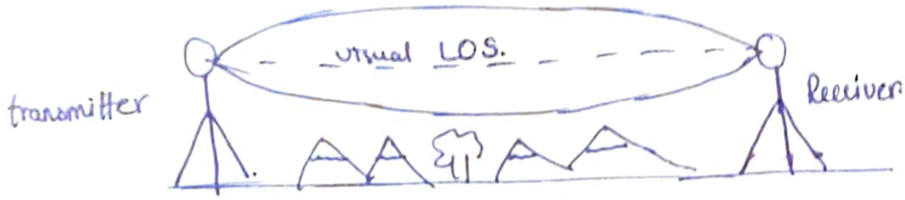
(1) Line-of-Sight Propagation

* LOS propagation occurs when there is an unobstructed direct path b/w the source and destination.
* In this method, the signal travel directly from transmitter to receiver without significant obstacles and/or reflections.

* Characteristics of LOS propagation:-

(1) Signal strength is typically strong in LOS conditions, as there are minimal obstructions to attenuate the signal.

(2) LOS is often preferred for long-range communication, such as satellite communication & point-to-point wireless links



Line-of-Sight.

Non-Line-of-Sight propagation :-

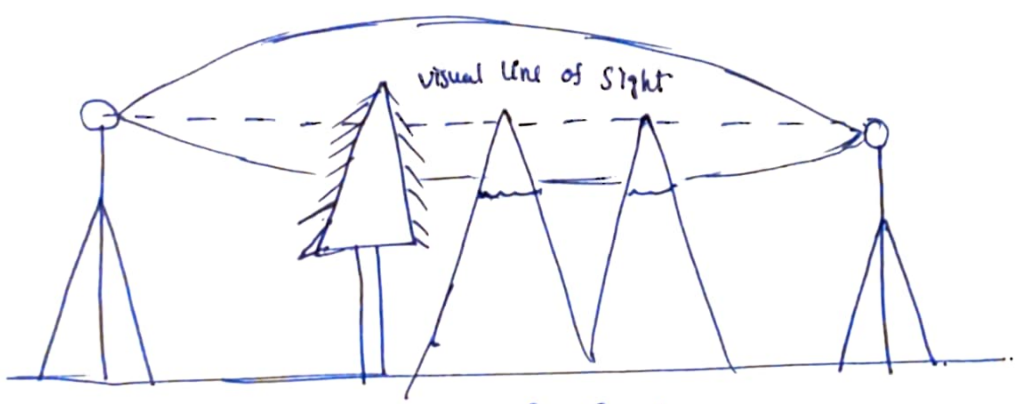
* NLOS propagation is occurred when the signal path b/w the transmitter or the receiver is obstructed by objects, buildings or other obstables

* NLOS Conditions can result in signal scattering, diffraction and reflections leading to multiples signal paths reaching the receiver.

* Characteristics of NLOS propagation.

① Signal strength in NLOS scenarios is often weaker than in LOS Conditions due to signal attenuation. Caused by obstructions.

② NLOS is Common in urban environments, indoor settings, and situations where There are physical obstructions b/w the source & receiver.



Non-Line-of-Sight.

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Impact of Signal Strength & Quality.

① Signal strength:- In general, LOS Conditions yield stronger signal strength because signal travels directly without substantial hindrances.

② Signal Quality: NLOS Conditions typically provide higher signal quality with fewer instances of multipath interferences and these are susceptible to multipath propagation, potentially Causing the decrease in quality due to reflections & phase alterations

③ Delay spread:- NLOS Conditions often result in a more extensive delay spread Characterized by multiple signal paths reaching the receiver with varying delays. This will Cause signal demodulation and affect the data transmission.

③ Explain the Concept of fading in wireless Communication. Discuss the different types of fading, such as path loss, shadowing and multipath fading. provide examples for each type.

④. Signal fading in wireless Communication refers to the fluctuations in in signal strength and quality as it travels from transmitter to the receiver.

Fading occurs due to the altering properties of wireless channel, including factors like signal reflections, diffraction, and interference. that inturn lead to signal detoriation.

① Path loss fading:- This is often called as free-space path loss, results from signal spreading as it travels through the space. This path loss represents a fundamental detoriation in signal strength as the distance b/w transmitter and receiver increases

Eg:- Consider a Wi-Fi Router, As you mover away from it, the strength of the signal goes down. And this represents the reduction in strength as the distance b/w them increases

② Shadowing:- This is also known as log-normal fading, and this arises from substantial obstacles that block or weaken the signal. It leads to gradual, long-term fluctuations in signal strength as the receiver navigates through different environments.

Eg:- When driving through the city with sky scrappers, you may notice fluctuations in mobile signal strength as you move through streets and buildings, This is caused from shadowing by obstructing the signal.

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③ Multipath Fading: This occurs when various copies of the transmitted signal reach the receiver at slightly different times because of reflection, diffraction off objects in the surroundings. These signals combine at the receiving end producing constructive or destructive interferences that result in signal variations.

Eg: In a household with Wi-Fi, experiencing signal dropouts or fluctuations in signal strength while moving around may be attributed to multipath fading. Signals reflecting off walls, furniture, and objects generate multiple routes for the signal to reach your device, leading to interference patterns.

④ Discuss the concept of multiple access in wireless communication. Explain the differences between time-division multiple Access (TDMA), Frequency division multiple Access (FDMA) and Code-division multiple Access. (CDMA).

Ⓐ Multiple Access within the realm of wireless communication compose a fundamental concept that addresses the sharing of available communication resources, including time, frequency or code among multiple devices operating in same area.

Various multiple access techniques have been developed to efficiently manage these shared resources, such as

① Time-Division Multiple Access (TDMA)

* TDMA involves the division of the available time into discrete time slots with each user or device being allocated one or more specific time slots within a fixed time frame.

- Users share the same frequency channel but engage it at distant time intervals

- TDMA necessitates synchronisation among users to ensure that they transmit and receive data at prescribed moments

- TDMA excels at managing intermittent data traffic, as it permits the dynamic allocation of time slots.

Eg:- In TDMA, each cell tower assigns particular time slots to mobile phones within its coverage area., Consequently, phones take turns sending & receiving data during allocated slots.

② Frequency-Division Multiple Access (FDMA)

* FDMA allocates discrete frequency bands to individual user operating within the same geographic area. Each user communicates by transmitting eg and receiving data over dedicated frequencies

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- users share the same time frame but employ diverse frequencies
- In FDMA, the frequency bands allocated to each user remain constant through the communication session.

- FDMA, proves effective for managing applications with constant bit rates but may be less suitable for handling data traffic with surges.

Eg:- In the context of analog radio broadcasting, distinct radio stations utilize dedicated frequency bands to prevent signal interference.

3 Code-Division Multiple Access (CDMA):-

* CDMA designates a unique code to each user. while all users share the same frequency band & time frame, the data of each user is spread across the entire bandwidth through specific assigned code.

- users jointly share both time & frequency resources individually data streams encoded using exclusive spreading codes.

- CDMA extends the signal's bandwidth across a broader frequency range enabling multiple user to concurrently transmit.

- CDMA exhibits robustness against interference and supports concurrent data transmission & reception.

Eg:- In 3G & 4G networks each mobile device is assigned a unique code, as all devices utilize the same frequency. CDMA permits multiple devices to engage in simultaneous communication.

Distinguishing Features :-

* Resource Sharing :- TDMA allocates time, FDMA assigns frequency and CDMA utilizes both time & frequency.

* Synchronization :- TDMA & FDMA often necessitate more stringent synchronization among users, CDMA can accommodate great asynchrony

* Dynamic Allocation :- TDMA excels in the dynamic allocation of time slots based on demand, whereas FDMA & CDMA typically utilize more static resource allocation.

* Illustrations :- TDMA is prevalent in cellular networks, FDMA finds application in radio & TV broadcasting & CDMA is prominent in mobile communication systems such as 3G and 4G

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5) A wireless Communication system operates at a frequency 2.4 GHz and has a bandwidth of 20 MHz. If the Signal-to-noise (SNR) is 25dB, determine the maximum achievable data rate using shannon's equation

A) Bandwidth - 20 MHz.

Signal-to-Noise-(SNR) - 25dB

Signal frequency = 2.4 GHz

Shannon's Equation:-

$$C = B \log_2 (1 + SNR/T)$$

$$B = 20\,MHz = 20 \times 10^6\,Hz.$$

$$SNR(\text{in dB}) = 25\,dB$$

$$SNR_{linear} = 10^{(SNR\,dB/10)}$$

$$= 10^{(25/10)} = 10^{2.5}$$

$$\approx \;\cdot = \; = 316.23$$

$$SNR_{linear} = 316.23$$

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

$$= 20 \times 10^6 \log_2 (1 + 316.23) = 20 \times 10^6 \log_2 317.23$$

$$= 2 \times 10^7 \times \cancel{6.664}\; 8.309$$

$$= \cancel{133} \times 10^6\,bps$$

166.1

$$\boxed{C = 166.1\,Mbps}$$

⑥ A Communication system uses a bandwidth of 4000 Hz and its transmitting a signal with four levels. Determine the maximum achievable data rate using Nyquist's formula.

Ⓐ Given

Bandwidth = 400 Hz

Signal level (M) = 4

Nyquist Limit :-

$$C = 2B \log_2 M$$

$$= 2 \times 4000 \times \log_2 4$$

$$= 2 \times 4000 \times 2 \log_2 2$$

$$= 2 \times 4000 \times 2 \Rightarrow 16000$$

Maximum achievable data rate is 16 Kbps.

⑦ Consider a noiseless channel with a bandwidth of 20 KHz. We need to send 280 Kbps over a channel. How many signal levels are required.

Ⓐ Bandwidth (B) = 20 KHz = 20×10^3 Hz.

Signal strength = 280×10^3 bps

from Nyquist limit $C = 2B \log_2 M$

$$\frac{C}{2B} = \log_2 M \Rightarrow M = 2^{C/2B}$$

$$M = 2^{(280 \times 10^3 / 2 \times 20 \times 10^3)}$$

$$= 2^7$$

$$M = 128$$

∴ The no. of levels required are M = 128

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⑧ A wireless Communication system operates at a frequency of 2.4 GHz and has a transmission power of 20 dBm. The receiver sensitivity is -90 dBm. The path loss exponent for the environment is measured to be 3.5. Calculate the maximum distance b/w the transmitter and receiver that allows successful Communication, assuming free space path loss model.

(A) frequency $(f) = 2.4\ GHz = 2.4 \times 10^9\ Hz$.

transmitted power $(P_t) = 20\ dBm$.

receiver sensitivity $= -90\ dBm$.

The pathloss exponent $= 3.5$

we know, the pathloss formula:

$$P_r = P_t - \text{pathloss}$$

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

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

$$-90 = 20 - 21.98 + 20\log_{10}\left(\frac{3}{24}\right) - 20\log_{10}(d)$$

$$-88.02 = 20(-0.90) - 20\log_{10}(d)$$

$$+20\log_{10} d = +69.95$$

$$\log_{10} d = \frac{69.95}{20} \Rightarrow d = 10^{3.49}$$

$$d = 3147.09\ m \Rightarrow \boxed{d = 3.147\ Km}$$