5G Cellular Network Scenario
01/12/24

PROBLEM STATEMENT
A wireless service provider is rolling out 5G services and wants their field service technicians to have a better understanding of how voice, video and data signals are transmitted across their networks. Better understanding allows technicians to troubleshoot and maintain their networks. Specifically, they aim to address issues related to wavelength and frequency quality based on distance and obstacles.

SCENARIO DESCRIPTION AND SPECIFIC EXAMPLE
To enhance the proficiency of field service technicians in managing the deployment and maintenance of 5G networks, an understanding of key transmission factors is crucial. Wavelength and frequency, integral components of 5G technology, play a pivotal role in signal propagation. Technicians should grasp the inverse relationship between wavelength and frequency, recognizing that higher frequencies, such as mmWave, exhibit shorter wavelengths and are more susceptible to obstacles. Troubleshooting and maintenance involve measuring signal strength, analyzing obstacles, and implementing strategies for signal optimization. Continuous education on evolving technologies ensures technicians remain adept in troubleshooting and maintaining 5G networks, ensuring robust voice, video, and data services for end-users.

SOME DEFINITIONS

Bandwidth is how much information you receive every second.

Throughput is how much information actually gets delivered in a certain amount of time.

Network Speed is how fast that information is received or downloaded.

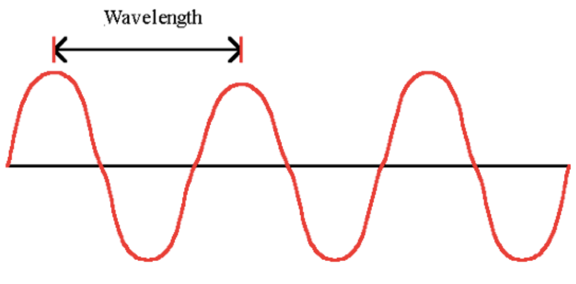
Latency is sometimes referred to as delay or ping rate. It's the lag you experience while waiting for something to load. If bandwidth is the amount of information sent per second, latency is the amount of time it takes that information to get from its source to you.

Packet loss occurs when one or more packets of data travelling across a computer network fail to reach their destination. Packet loss is either caused by errors in data transmission, typically across wireless networks, or network congestion. Packet loss is measured as a percentage of packets lost with respect to packets transmitted successfully.

So if bandwidth is the max amount of data, throughput is how much of that data makes it to its destination – taking latency, network speed, packet loss and other factors into account. For this scenario we will focus on network speed, considering wavelength and frequency.

Wavelength

Cellular signals are electromagnetic radiation and sinusoidal in nature.
Wavelength, represented by the Greek letter lambda (λ), is a distance measurement usually expressed in meters. Wavelength is defined as the distance in meters of one sinusoidal cycle as illustrated in the figure below.



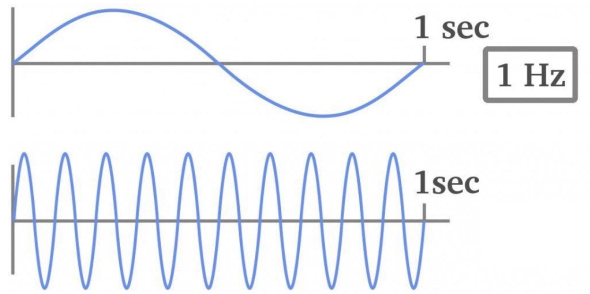
Frequency

Frequency is the number of occurrences of a repeating event per unit of time.
Higher frequency signals have the capacity to transmit larger amounts of information when compared to lower frequencies.

CELLULAR NETWORK SPECTRUM

The radio spectrum encompasses frequencies ranging from 3 kilohertz (kHz) to 300 gigahertz (GHz). Throughout the evolution of cellular networks, different generations have operated at varying frequency bands. Early networks like 1G utilized frequencies around 850 MHz and 1900 MHz. As technology advanced, 2G and 3G networks incorporated additional bands, particularly around 2100 MHz. The advent of 4G LTE saw operations at diverse frequency bands such as 600 MHz, 700 MHz, 1.7/2.1 GHz, 2.3 GHz, and 2.5 GHz. As an example, Verizon's 5G Ultra Wideband network represents one of the latest, utilizing spectrum bands at 28 GHz and 39 GHz. This spectrum diversity allows for improved capacity, speed, and overall performance in wireless communication networks.

Frequency Calculation Example



In the first example one sine wave cycle is completed in 1 second – this is referred to as the period and abbreviated T. To calculate the frequency (f) in cycles per second or Hertz (Hz) calculate the reciprocal the period in seconds (s).

So for the first example T = 1 second and

$$f = 1/T = 1 / 1 \text{ s} = 1 \text{ Hz}$$

Class Exercise: Find the frequency of the second example in Hz.

Wavelength and Frequency Are Related

As an example, consider a WiFi signal at 2.4 Giga Hertz (GHz) – what is the wavelength?

$1Hz = 1 \text{ cycle per second}$

All electromagnaetic radiation travels at the speed of light, abbreviated "c".

$Speed\ of\ Light = c = 300{,}000{,}000 \text{ meters per second} = 3\times10^8\ m/s$

Our frequency (f) in this example is $2.4\ GHz = 2.4\times10^9\ Hz$

Calculating Wavelength in meters:

$\lambda = cf = (3\times10^8\ m/s)/(2.4\times10^9\ Hz) = .125m = 12.5cm$

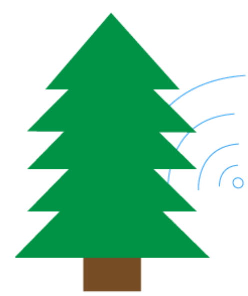
12.5 cm is approximately 4.92 inches and...... that's your wavelength.

Wavelength and frequency are inversely related in the context of electromagnetic waves, including those used in wireless communications. As the frequency of a wave increases, its wavelength decreases, and vice versa. This inverse relationship is pivotal in understanding the characteristics of electromagnetic waves, including those utilized in wireless communication systems. In practical terms, it influences signal propagation, penetration through obstacles, and the overall performance of wireless networks. Engineers and technicians leverage this knowledge to optimize the balance between signal range, data transmission speed, and coverage when developing and deploying wireless communication technologies.

Class Exercises

1. Verizon's 5G Ultra Wideband network uses 28 GHz and 39 GHz mmWave spectrum bands. Calculate the wavelength for each of these frequencies.
2. Verizon's 4G network uses about 700 MHz-2500 MHz frequency to transfer information. What is the wavelength for a 2500 MHz 4G signal?
3. Compare your answers from 1 and 2.
   - Which has the longer wavelength, 4G or 5G?
   - Which signal will travel farther? Why?

WAVELENGTH AND FREQUENCY IN WIRELESS COMMUNICATIONS



Wavelength plays a crucial role in shaping the characteristics of wireless communications. The frequency of a signal, and by extension its wavelength, directly influences how well it propagates through space and interacts with its environment. Higher frequencies, corresponding to shorter wavelengths, enable the transmission of more information but come with the drawback of increased signal loss and attenuation, limiting their effective range. On the other hand, lower frequencies, with longer wavelengths, exhibit better penetration through obstacles like walls and trees, making them more suitable for extended-range communication and coverage in complex environments. The interplay between these factors necessitates a careful consideration of frequency bands in designing wireless networks, balancing the need for data transmission speed with the requirement for reliable and widespread coverage. The ongoing advancements in wireless technologies, such as the deployment of 5G networks using higher frequencies like millimeter waves, highlight the ongoing effort to optimize these trade-offs for enhanced performance in diverse communication environments.

Additional Class Exercises

1. Cellular service providers (Verizon, AT&T, etc) are offering 5G services using sub-6GHz bands that cover wider areas. They are also planning to launch or have already launched mmWave service in select urban locations. Do some research on the web to determine:
   a. Which carriers are currently offering sub-6GHz band service in your region?
   b. Which carriers are currently offering mmWave service in your region?

2. Research 5G phones currently being sold that will work with your current carrier 5G service offerings. Describe the phone you would select and why.

3. Fixed Wireless Access (FWA) is a broadband solution that leverages wireless communication to provide high-speed internet connectivity to fixed locations, such as homes and businesses. This technology offers a flexible and cost-effective alternative to traditional wired solutions, especially in areas where laying physical cables is challenging or economically impractical. FWA establishes a wireless link between a base station or access point and a customer location. One of the key advantages of FWA is its ability to address the last-mile connectivity challenge, delivering high-speed internet access comparable to wired broadband. This makes FWA particularly valuable in rural and underserved areas, helping bridge the digital divide by providing reliable connectivity. List and describe three advantages and three disadvantages of fixed 5G service for your home.