Module 1

WIRELESS Communication: An Introduction

Learning Objectives

- Introduction to wireless Communication
- Types of Wireless Communications
- Advantages of Wireless Communications
- Challenges for Efficient Wireless Communications
- History of Wireless Communications

1. Introduction

From application of light to generate on/off patterns to highly advance 5G technologies; From the very primitive radio control toys to the highly sophisticated satellites; from 535 kHz AM radio to 2.4 GHz LAN; from very long km waves in submarine communication to ultra wide band short pulses; from global cellular GSM Network to the extremely close body area network, wireless communication has revolutionized the way in which we work, connect or communicate to the world. It has made the world a small close entity and has uncovered concept of pervasive and ubiquitous computing with the ideal of "**ANYWHERE ANYTIME**".

2. Wireless Communication

"***Transmitting or receiving voice & data over a distance without use of electrical conductors or wires***"

When one or all of communicating devices are mobile in nature, it is known as Mobile communications. The distance of communication can be short as few meters in case of Wi-Fi, Bluetooth, TV Remote or it can be significantly long as thousands of kms in case of radio, mobile phones, satellite communications, and High Altitude platforms.

Then how does the communication takes place?

Wireless communications require some form of energy to transmit information. Principle source for wireless communication is the electromagnetic waves.

Electromagnetic waves are movement of massless particles moving in sinusoidal fashion with the speed of light.They are charactrised by different wavelength and frequency.

- **Frequency:** The literal meaning of frequency is rate of change. In context with E.M. waves, frequency means number of cycles/time. Unit of frequency is Hertz.

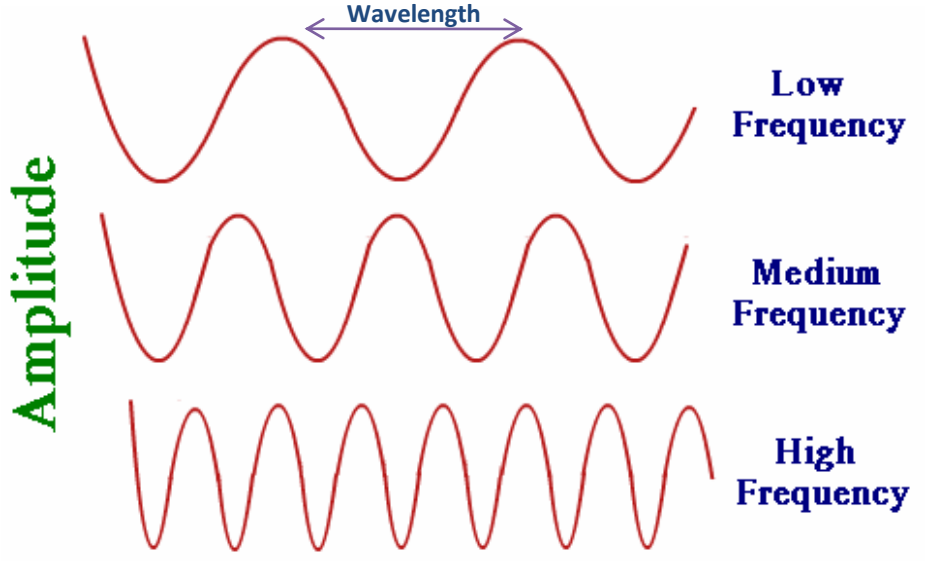

Figure 1: Attributes of E.M. waves

- **Wavelength:** Distance between two peak values of a E.M. wave. Wavelength is inversely proportional to frequency (Fig. 1). Unit is same as of distance.
- **Amplitude:** Strength of E.M. wave. More the amplitude more power an wave as. For ex. For light amplitude specifies brightness of light.

The E.M. waves are arranged according to frequency, wavelength and energy in the form of spectrum known as electromagnetic spectrum. The different bands of E.M. Spectrum range from Gamma rays with highest frequency (order of THz) to radio waves with lowest frequency (of order KHz).

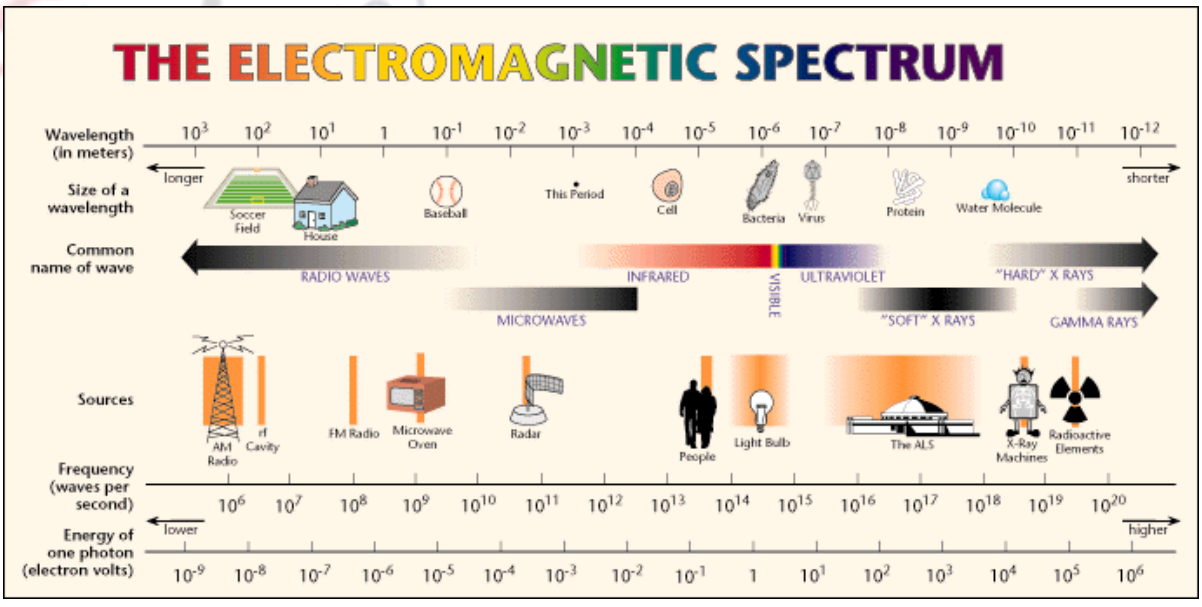

Figure 2: ElectroMagnetic Spectrum

The commonly used bands of electromagnetic spectrum appropriate of wireless communication are:

- Radio waves: Radio, Television, Mobile phones, wireless LAN etc.
  - It can travel through long distances
  - Easily generated
  - Less obstructed by obstacles
  - Can travel along Earth's surface(Ground Waves)
  - Penetrate through layers of atmosphere
  - Can travel across hemisphere of Earth by reflection from ionosphere(Sky Waves/Short Waves)
  - At higher wavelengths, can travel under water, as required in submarine communication
  - Highly licensed
  - Behave differently at different frequency
- Microwaves: Radar, cellular phones
  - Can travel through short distances due to higher frequency
  - Obstructed easily
  - Line-of-sight transmission
- Infrared waves: Remote controllers, Infrared data Association (IrDA)
  - Used for short communication
  - Highly Directional
- Visible: Laser light for wireless Intranet, barcode readers, indoor communication using LEDs
  - Travel in straight line
  - Need Line-of-sight
  - Need to be focused using laser
  - Effected by bad weather

Other forms of energy are :
acoustic used in hydrophones and wireless sensor networks
ultrasonic
electronic where an electron beam is used to transfer the information

3. **Current wireless systems**

Cellular systems based mobile phones (2G……5G)
Cordless Phones
Wireless LAN's

Wimax
GPS
Satellite Systems
Paging
PAN (Bluetooth)
Vehicular adhoc networks
Sensor Networks (RFID)
Body area network
UWB – Ultra wide band radios
Low cost low power Bluetooth and Zigbee

.....and many more to come

4. Advantages of Wireless Communications

- **Freedom from wire**

  When you are not tied, you can fly

  Wireless offers a neat and hassle free environment without worrying about messy yet costly wires, jacks and plugs which makes it easy to establish, use and maintain. Apart from wireless headphones, keyboards, wireless phone chargers, ultra wide band also promises wireless desktops in coming years. Bluetooth technology enabling a sms on mobile phone to be wireless transmitted to a printer have reduced the labor of connecting to jacks, plugs and messy yet costly wires.

- **Mobility**

  The waves supporting wireless communications move freely in air hence do not tie a device to a particular location as done by messy wires and cables. Technologies like Mobile IP and Cellular IP provide undisrupted services to the users on move. Roaming facility initiated by GSM now has been accepted by all standards providing flexibility to stay connected anywhere on globe.

- **Global connectivity**

  Where the wires cannot go, wireless can go

  Wireless communications comes with the tagline "Anywhere anytime". Communications can reach the places which are otherwise infeasible or costly to be connected by wires like rural areas, moving vehicles, hilly regions, underwater submarine. Satellite technologies enables seamless connectivity in remote and inaccessible places like deserts, dense forests, battle fields, calamity affected areas.

For ex: NASA'S FINDER is a handheld device which detects heart beats of humans buried under during Earthquakes. Teleteaching applications, portals for farmers to provide them information regarding crops are many other advantages of global connectivity via wireless communications.

- **Convenience**

Easy is the best

Automatic instant communications without physical setup e.g.: Wi-Fi, Bluetooth. RFID technology enabling automatic toll collections at booth, UPS delivery system which uploads the delivery status real time to the server.

- **Reduced cost**

Since wireless setups do not use elaborate infrastructure, the installation and maintenance cost is less as compared to wired which includes per foot charges of cables and other devices. Time and labor to plan wiring is expensive and further more damage to buried cables requires replacements and replanning hence maintenance is also a costly affair. Conversely, wireless setups if done properly require very less maintenance and that too is easy and cheap.

- **Flexibility**

You can grow only when you are flexible

A wireless setup can easily be scaled by configuring more devices to the existing setup which is otherwise difficult in wired one because of limited number of user supports which are physically connected to the device.

5. Challenges

Ray Davis has truly said "Challenges become obstacles only when you bow to it"

Wireless communications in any form has to undergo and overcome many challenges some of which are listed down**.** There are lot of efforts already made to cope up with these challenges and many more are in pipeline.

- **Efficient Hardware**

The devices used in the wireless communications should be functionally good yet should be small, consume low power and should be low cost hence offering a green wireless communication. With the introduction of 3G and following technologies,

multimedia applications are most sought after which is a most power hungry scenario.

For ex. Power is the most critical resource in Wireless Body area Networks which provide ubiquitous healthcare infrastructure like heart monitoring system etc.

At the equipment level, power saving can be achieved by switching it to sleep mode when not in use and using low power transmitters and receivers as one of the essential hardware requirements for every wireless device. Advances in semiconductor technology and transmissions at high frequencies have resulted in small antenna sizes hence making the devices light weight and energy efficient. Energy efficient signal processing components like CMOS offers an energy efficient, cheap yet slow option than its counterpart ECL which is fast but power hungry.

At operating system level, power can be controlled by use of power aware file systems, graphics drivers and other components. Technologies should be designed in such a way that they extract less of power from the device on which they are installed like Bluetooth, Zigbee the most efficient is Ultra wide band in terms of bandwidth, cost , power , physical size and data rates . Nanotechnology ,a boom in increasing the efficiency of devices by using Magnetic nano particles and metaparticles to reduce size of Antenna, Carbon Nano Tube memory to increase memory, less energy consumption and provide better human interfaces

- **Finite Radio Spectrum**

  Though the recent wireless technologies use license free 2.4 GHz ISM band but radio frequencies used for long distance communications like satellite communication, radios, televisions, mobile phones still rely on licensed frequency spectrum which is limited and regulated by international standards. So it is required to efficiently use the available spectrum without or very less interference allowing more subscribers bases. One approach is Cellular frequency reuse in which the geographical areas are divided into small cells with neighboring cells assigned non-overlapping frequencies. Frequency reuse is supported by assigned same frequency to those cells which are geographically distant from each other. Cognitive radio is emerging as another alternative as it increases the utilization of radio spectrum to support the traffic. Spread Spectrum technologies like Frequency Hopped Spread Spectrum and CDMA allows using entire bandwidth without interference. Cell sizes are getting small to increase the spectral efficiency supported by sectorized antennas.

- **Quality of service**

  As wireless communication is getting more and more ubiquitous, a high quality of service in delivery of voice, video and data is expected. In mobile telephony, QoS is estimated by voice quality, signal strength, low call blocking and dropping, high data rates for multimedia applications, whereas for wireless networks QoS depends on throughput, delay, packet loss-rate, low packet error rate and reliability. Factors effecting QoS are multipath interference, noise, improper handoffs during mobility and many more. The solutions to improve QoS:

  - Signal processing to overcome attenuation
  - Repeaters
  - Wide spread cellular infrastructure
  - MIMO technology
  - OFDM to reduce multipath interference
  - Proper handoff mechanism
  - 3G and 4G technologies(99.999 reliability)
  - Mobile IP
  - Improved TCP algorithms to increase throughput
  - Improved MAC algorithms for carrier sense and collision detection

- **Mobility Management**

  An ideal wireless technology particularly in Mobile computing environment, should maintain uninterrupted connectivity when a mobile device changes location. Proper infrastructure management for installation and maintenance of cells and their networks is essential. Proper Localization techniques and registration methods should be applied to trace and connect the device to the network. GSM uses HLR and VLR databases which maintain information about the location of the devices. Mobility in Internet to support is supported by Mobile IP technology.

- **Multipath Propagation**

  When the signal travels from sender to receiver through the radio channel, it is reflected, refracted, diffracted or scattered by the objects in the environment like buildings, atmosphere etc in mobile telephony and furniture in WLAN. As a result the signal does not follow line-of-sight and follow different propagation paths in the form of multipath components. Each multipath component travel with different amplitude, delay and phase shifts among each other. These components add up constructively or destructively at receiving end affecting total signal amplitude .This effect is called fading. Furthermore each multipath component arrive the receiver as a sequence of pulses with different time, amplitude and phase called Intersymbol interference. MIMO and OFDM are the solution to this affect. OFDM signals can be made orthogonal to each other so that they do not interfere. It is used by 802.11n, Wi-Fi, LTE-advanced, Wimax and many more technologies. MIMO is a technology which uses multiple antennas to setup multiple data streams on the same channel to increase its capacity. It takes advantage of multipath propagation in providing additional capacity to the channel.

- **Security**

  Wireless communications use air as the medium hence are highly susceptible to threats like interception, masquerading, denial-of-service, replay attacks and many more. Though wireless communications in all forms should be performed in a secured way but is more crucial in mobile computing applications in the field of banking, business, governance etc. and is therefore area of special concern. Every technology comes with its own security measure. CDMA itself offers built in security as the reciver has to know the code to decode the data. GSM offers authenticity both at device level and network level. At device level, unique PIN is used to authenticate SIM card. At network level authentication center performs authentication using challenge response technique with the help of secret key on the SIM card. It also same key to encrypt the traffic using algorithm stored on SIM.WLAN offers security through SSID, WEP (Wired equivalent privacy) and authentication servers like radius, Kerberos etc. Digital signatures and certificates are used for verification of records. To maintain anonymity, the data is transmitted using temporary identifiers of the users like TMSI number in GSM. Various Intrusion prevention and detection systems are available for adhoc networks like MANET and VANET.

6. **History of Wireless Communications**

History of wireless communications goes far back in ancient times when light was used to generate on/off patterns in China and smoke signals were used in Greece. The Timeline showing evolution of wireless and mobile communications from its inception by invention of optical telegraph till date.

1794: Claude Chappe invented the optical telegraph using optical telegraph lines. The communication used optical frequencies which could not be focused and was also deviated by rain and fog.

1831: Demonstration of electromagnetic induction by Michael Faraday and Joseph Henry

1864: James C. Maxwell laid foundation for electromagnetic fields with his famous equation

1886: Heinrich Hertz demonstrated the wave character of electrical transmission Nikola Tesla experimented by increasing the distance of electromagnetic transmission

1895: Guglielmo Marconi marked beginning of radio communication. Demonstrated wireless telegraphy

1901: First transatlantic transmission at a distance 3200 kms.

1906: First radio broadcast when Fessenden transmitted voice and music for Christmas.

1907: First commercial transatlantic connections were set up.

1915: First wireless voice transmission was set up between New York and San Francisco.

1920: first commercial radio station started

1920: First commercial radio station started (KDKA from Pittsburgh).

1920: Marconi discovered short waves. They have advantage of being reflected at Ionosphere and hence can be send around the world.

1926: First telephone in a train was available on Berlin Hamburg line with wires parallel to the rail track working as antenna.

1927: First car radio was available

1928: Television broadcasting across Atlantic by John L. Baird

1932: First teleteaching started from CBS Station.

Up until then, all wireless communication used amplitude modulation, which offered relatively poor quality due to interference.

1933: Edwin H. Armstrong invented frequency modulation.

1958: First analog wireless network A-NETZ in Germany using carrier frequency of 160 MHz

1971: ALOHANET developed at University of Hawaii based on packet radio (First wireless lamp).

1972: B-NETZ was followed in Germany

1973: Motorola invented first mobile cellular phone

1979: Northern European countries of Denmark, Finland, Norway, and Sweden agreed upon the nordic mobile telephone (NMT) system which use 450 MHz carrier.

1982: The 'Groupe Special Mobile' was founded which used 900 MHz, allow roaming throughout Europe, was fully digital and offer voice and data service. "GSM was formed"

1983: AMPS, an analog mobile phone system working at 850 MHz started.

1984: Standard CT1 Cordless Telephone for cordless phones formed

1991: ETSI adopted the standard Digital European Cordless Telephone (DECT) for digital cordless telephony which works at a spectrum of 1880-1900 MHz with a range of 100-500 m. It used 120 duplex channels and offered data rate of 1.2 Mbit/sec. Fully digital systems were introduced.

1991: GSM was standardized in a document of more than 5,000. This first version of GSM, now called "Global system for Mobile Communication", works at 900 MHz and uses 124 full-duplex channels.

1996: ETSI standardized the 'High Performance Radio Local Area Network' (HIPERLAN) which operated on 5.2 GHz and offered data rate of 23.5 Mbit/s.

1997: IEEE standard 802.11 was founded and was a strong contender in local area networks. It used 2.4 GHz licensed free band offering data rate of 2 Mbps-10Mbps.

1998: Marked the beginning of mobile communication using satellites with the Iridium system (Iridium, 2002). It consists of 66 satellites in lower earth orbit and uses 1.6 GHz for communication. Marked the beginning of portable mobile satellite phones. Universal Mobile Telecommunication System (UMTS) was standardised. It combined GSM networks technology with CDMS Solution.

1999: ITU standardized IMT-2000 which included family of standards like UMTs, CDMA2000, and DECT.

1999: Bluetooth was commercialized

1999: Wireless Application protocol started.

2000: GPRS offering higher data rates and packet oriented transmissions
3G spectrum started.

2001: Third generation of mobile communication started in Japan with the FOMA service, in Europe with several field trails and in, Korea with cdma2000.IEEE released a new

WLAN standard; 802.11a, operating at 5 GHz and offering gross data rates of 54 Mbit/s.

2002: Digital terrestrial TV started, first UMTS network was launched allowing high-speed applications such as mobile TV and video calling.

2003: EDGE was deployed by AT&T on Singular network in the USA. IEEE 802.11g was added to the 802.11 standard, allowing transmission speeds up to 54 Mb/s. Bluetooth specification 1.2 was released. This new specification includes Adaptive Frequency-hopping (AFH), which reduces RF interference.

2004: Newest version of IEEE 802.16 is added and it completely changes the WiMAX standard. Bluetooth specification 2.0 is released.

2008: 4G launched

2009: The latest in Wi-Fi standards 802.11n approved

2010: IMT-A ratified by ITU and 4G communications deployed all over. First 4G handset is introduced at International CTIA WIRELESS show.

7. Conclusion

In this module we have introduced wireless communication and its types. We have seen advantages and challenges of wireless communication and have browsed through the history since its inception.

"We are living in an era of five point reliability" and a long way to go towards 5G".