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Subject : DCCN

EXPERIMENT NO. 1

Aim: To study different types of physical layer wired/wireless connections

Theory:

Physical layer in the OSI model plays the role of interacting with actual hardware and signalling mechanism. Physical layer is the only layer of OSI network model which actually deals with the physical connectivity of two different stations. This layer defines the hardware equipment, cabling, wiring, frequencies, pulses used to represent binary signals etc.

The media over which the information between two computer systems is sent, called transmission media. Transmission media comes in two forms.

- **Wired / Guided Media**

  All communication wired /cables are guided media, such as UTP, coaxial cables, and fibre Optics. In this media, the sender and receiver are directly connected and the information is sent (guided) through it.

- **Wireless / Unguided Media**

  Wireless or open-air space is said to be unguided media, because there is no connectivity between the sender and receiver. Information is spread over the air, and anyone including the actual recipient may collect the information.

Wired Media :

1) Fiber optic cable

A **fiber-optic cable**, also known as an **optical-fiber cable**, is an assembly similar to an electrical cable, but containing one or more optical fibers that are used to carry light. The optical fiber elements are typically individually coated with plastic layers and contained in a protective tube suitable for the environment where the cable will be deployed.

Specifications:

- Propagation speed and delay:

  Optical cables transfer data at the speed of light in glass. The round-trip delay time for 1000 km is around 11 milliseconds.

- Reliability and quality

  Optical fibers are very strong, but the strength is drastically reduced by unavoidable microscopic surface flaws inherent in the manufacturing process. The initial fiber strength, as well as its change with time, must be considered relative to the stress imposed on the fiber during handling, cabling, and installation for a given set of environmental conditions.

- Range

  Typical transmission speed and distance limits are 100 Mbit/s for distances up to 2 km (100BASE-FX), 1 Gbit/s up to 1000 m, and 10 Gbit/s up to 550 m.

- Losses

  Signal loss in optic fiber is measured in decibels (dB). A loss of 3 dB across a link means the light at the far end is only half the intensity of the light that was sent into the fiber. A 6 dB loss means only one quarter of the light made it through the fiber. Once too much light has been lost, the signal is too weak to recover and the link becomes unreliable and eventually ceases to function entirely. The exact point at which this happens depends on the transmitter power and the sensitivity of the receiver.[1]

Applicability

Optical fiber is used by many telecommunications companies to transmit telephone signals, Internet communication and cable television signals. It is also used in a multitude of other industries, including medical, defence/government, for data storage, and industrial/commercial. In addition to serving the purposes of telecommunications, it is used as light guides, for imaging tools, lasers, hydrophones for seismic waves, SONAR, and as sensors to measure pressure and temperature.

Due to much lower attenuation and interference, optical fiber has large advantages over existing copper wire in long-distance, high-demand applications. However, infrastructure development within cities was relatively difficult and time-consuming, and fiber-optic systems were complex and expensive to install and operate. Due to these difficulties, fiber-optic communication systems have primarily been installed in long-distance applications, where they can be used to their full transmission capacity, offsetting the increased cost. The prices of fiber-optic communications have dropped considerably since 2000. [2]

Schematic view

Fiber Optics is the communications medium that works by sending optical signals down hair-thin strands of extremely pure glass or plastic fiber. The light is "guided" down the center of the fiber called the "core". The core is surrounded by a optical material called the "cladding" that traps the light in the core using an optical technique called "total internal reflection." The fiber itself is coated by a "buffer" as it is made to protect the fiber from moisture and physical damage. The buffer is what one strips off the fiber for termination or splicing.

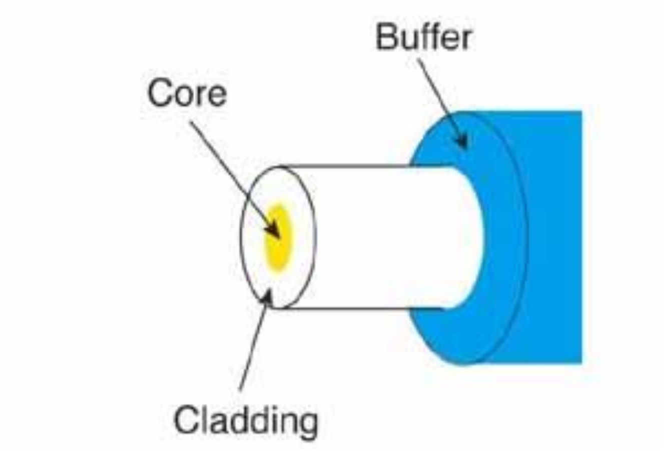

Fig. 1.1 : Fibre optic cable

The optical fiber cable has 2 types : Multimode & Singlemode

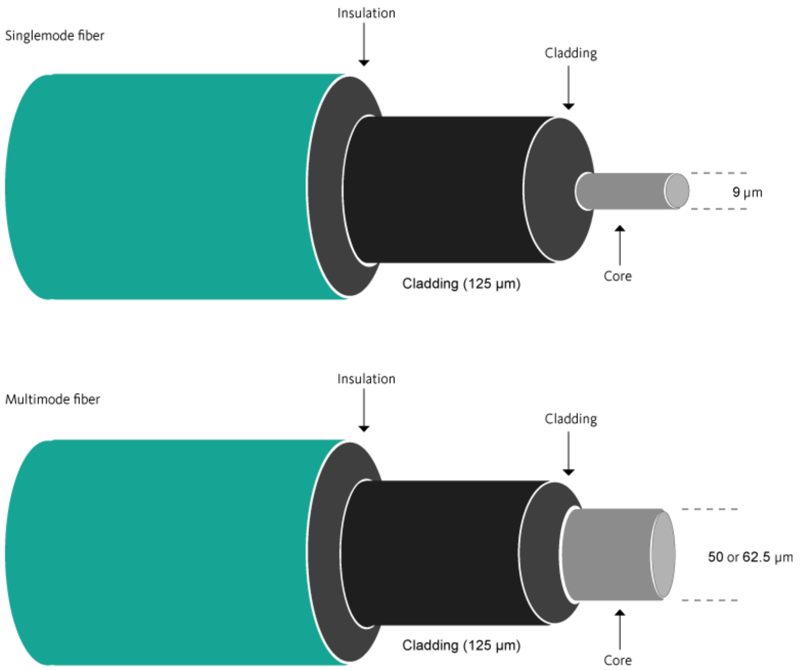

Fig. 1.2 : Types of fibre optic cable

Single-mode fiber optic cable

This excels at long-distance communication. Single-mode cable is designed to carry a single signal source with low transmission loss over great distances. It is frequently used for communication systems due to the clarity it provides. This type of fiber optic cable has the smallest core and the thickest sheathing.

Multimode cables

These cables are designed to carry multiple signals, however, this capacity comes with a loss of range. Multimode cables come in two primary varieties. What are the different types of multimode fiber optic cables? Your choices are step index or graded index cables. [3][4]

2) Coaxial cables

Coaxial cable, or **coax** is a type of electrical cable consisting of an inner conductor surrounded by a concentric conducting shield, with the two separated by a dielectric (insulating material); many coaxial cables also have a protective outer sheath or jacket. The term "coaxial" refers to the inner conductor and the outer shield sharing a geometric axis.

Specifications:

- Range

Coaxial cable supports 10 to 100 Mbps and is relatively inexpensive, although it is more costly than UTP on a per-unit length. However, coaxial cable can be cheaper for a physical bus topology because less cable will be needed. Coaxial cable can be cabled over longer distances than twisted-pair cable. For example, Ethernet can run approximately 100 meters (328 feet) using twisted-pair cabling. Using coaxial cable increases this distance to 500m (1640.4 feet).

- Loss / Attenuation specification

Another major performance parameter for coax is the loss or attenuation. There is always a reduction in signal as the signal moves through a feeder. This arises from a number of factors and is present on all cables. It is also proportional to the length. [5][6]

Applicability

For LANs, coaxial cable offers several advantages. It can be run with fewer boosts from repeaters for longer distances between network nodes than either STP or UTP cable. Repeaters regenerate the signals in a network so that they can cover greater distances. Coaxial cable is less expensive than fiber-optic cable, and the technology is well known; it has been used for many years for all types of data communication.[5]

Schematic view:

Coaxial cable conducts electrical signal using an inner conductor (usually a solid copper, stranded copper or copper plated steel wire) surrounded by an insulating layer and all enclosed by a shield, typically one to four layers of woven metallic braid and metallic tape. The cable is protected by an outer insulating jacket. Normally, the outside of the shield is kept at ground potential and a signal carrying voltage is applied to the center conductor. [5]

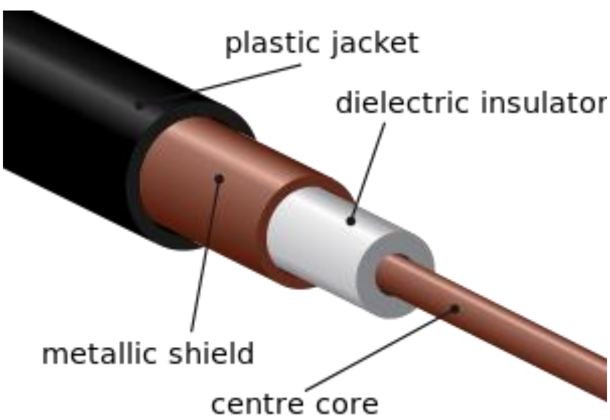

Fig. 2.1: Coaxial cable

Fig. 2.2: Coaxial cable with BNC connectors

3) Unshielded Twisted Pair cables

UTP stands for Unshielded Twisted Pair cable. UTP cable is a 100 ohm copper cable that consists of 2 to 1800 unshielded twisted pairs surrounded by an outer jacket. They have no metallic shield. This makes the cable small in diameter but unprotected against electrical interference. The twist helps to improve its immunity to electrical noise and EMI. [11]

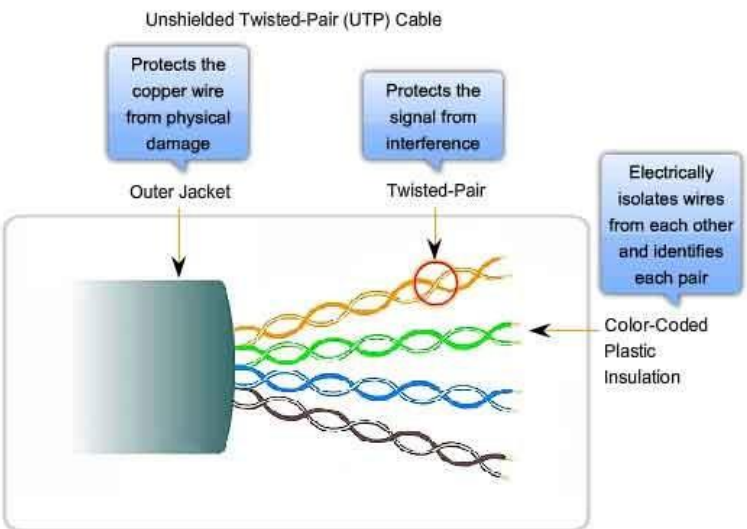

Fig 3.1 Unshielded Twisted Pair cable

For horizontal cables, the number of pairs is typically 4 pair as shown below.

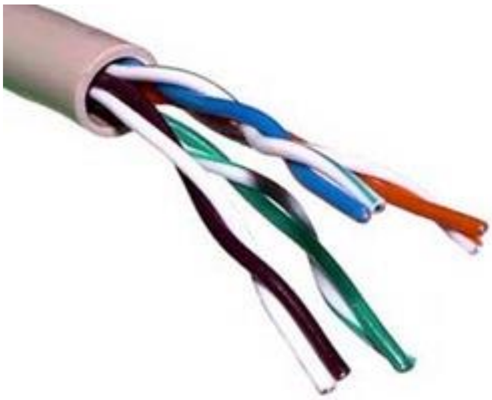

Fig : 3.2 4 paired UTP

For backbone cables, the number of pairs will typically be some increment of 25, because multi-pair UTP cables are constructed in 25-pair binder group. A sample backbone UTP cable is shown below.

Fig 3.3 : Multi pair UTP

Applications

UTP cables are mostly used for LAN networks. They can be used for voice, low-speed data, high-speed data, audio and paging systems, and building automation and control systems. UTP cable can be used in both the horizontal and backbone cabling subsystems.

UTP Color Codes

UTP Horizontal Cable Color Code

Horizontal UTP cable is four-pair construction by industry cabling standard. Each pair has two conductors. One wire of the pair is assigned the pair color with a white stripe and the other wire is assigned the color white with the pair color stripe. The table below lists the pair and color code for a four-pair horizontal UTP cable.

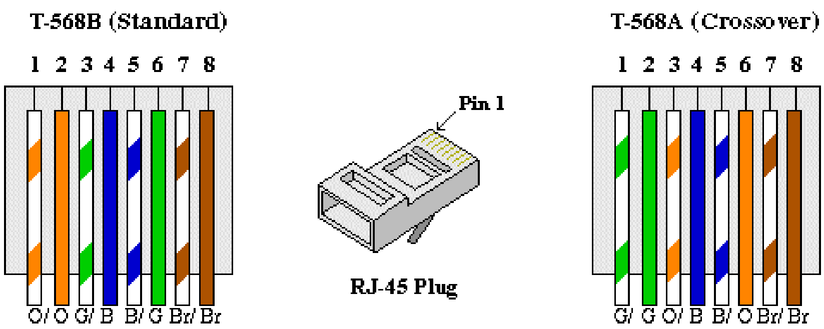

Fig 3.4 : UTP Colour codes

4) Ethernet cables

An Ethernet cable is a common type of network cable used with wired networks. Ethernet cables connect devices such as PCs, routers, and switches within a local area network. These physical cables are limited by length and durability. If a network cable is too long or of poor quality, it won't carry a good network signal. These limits are one reason there are different types of Ethernet cables that are optimized to perform certain tasks in specific situations.

Types of Ethernet Cables

Ethernet cables support one or more industry standards including Category 5 and Category 6. Most technicians refer to these standards as CAT5 and CAT6, respectively. Because of this, many online stores that sell network cables use this abbreviated language as well.

Ethernet cables are manufactured in two basic forms:

- Solid Ethernet cables offer slightly better performance and improved protection against electrical interference. They're also commonly used on business networks, wiring inside office walls, or under lab floors to fixed locations.
- Stranded Ethernet cables are less prone to physical cracks and breaks, making them more suitable for travelers or in-home network setups.

Limitations of Ethernet Cables

A single Ethernet cable has a maximum distance capacity, meaning the cable has an upper limit as to how long it can be before there is a signal loss (called attenuation). This problem results because the electrical resistance of a long cable affects performance.

Both ends of the cable should be close enough to each other to receive signals quickly, and far enough away from outside electrical interference to avoid interruptions. However, this precaution doesn't limit the size of a network, because hardware like routers or hubs can join multiple Ethernet cables together on the same network. This distance between the two devices is called the network diameter.

The maximum length of a CAT5 cable, before attenuation occurs, is 100m (328ft). CAT6 can go up to 700 feet. Ethernet cables can be longer but may suffer from signal loss, especially if they pass near large electrical appliances.

Different types of RJ-45 connectors serve different purposes. One type, designed for use with stranded cables, is incompatible with solid cables. Other types of RJ-45 connectors may work with both stranded and solid cables. [10]

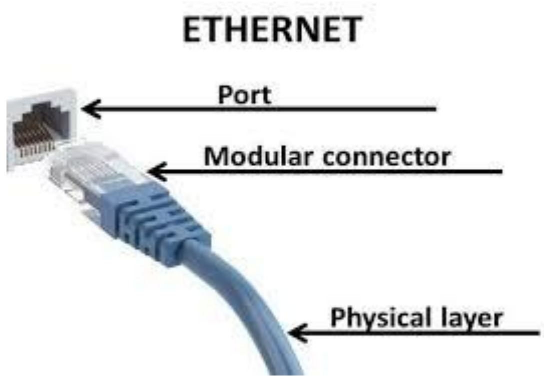

Fig. 4.1 – Ethernet cable

Cat5 or Cat6 Ethernet cable. Which one is better?

The type of cable you choose depends on how frequently you use the internet in your business. If you want faster internet speeds, Cat6 is a good choice. It reduces something called “crosstalk” — signal transfers that disrupt your communication channels.

If you are happy with your current internet speeds, however, Cat5 might be all you need. Besides, Cat5 cables tend to be cheaper than Cat6.

More and more companies are using the cloud nowadays, too. If you have moved your server to the cloud — or are thinking about doing so in the future — a Cat5 is probably adequate. This type of cable is reliable, easy to use and does everything you need it to. If you’re looking for a cable that optimizes performance, though, Cat6 might be right for you.

Typically, Cat6 cables tend to be thicker than Cat5 cables. This might be something to think about if you lack space in your office. [9]

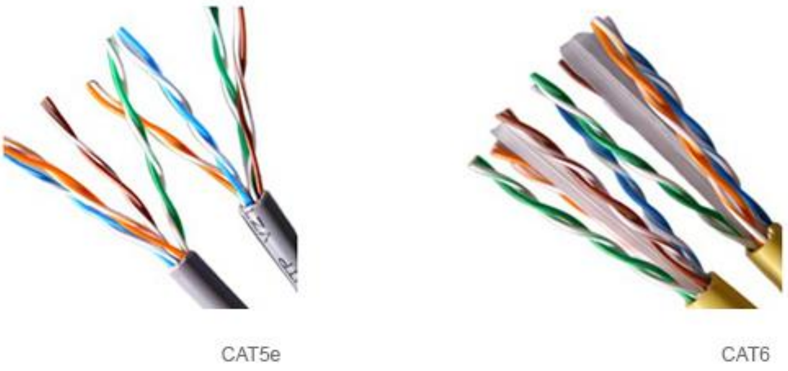

Fig 4.2 : Cat5 vs Cat6

Wireless Media:

The different types of wireless communication mainly include, IR wireless communication, satellite communication, broadcast radio, Microwave radio, Bluetooth, etc.

1) Cellular

A cellular network uses encrypted radio links, modulated to allow many users to communicate across the single frequency band. As the individual handsets lack significant broadcasting power, the system depends on a network of cellular towers which are capable of triangulating the source of any signal and handing reception duties off to the most suitable antenna.

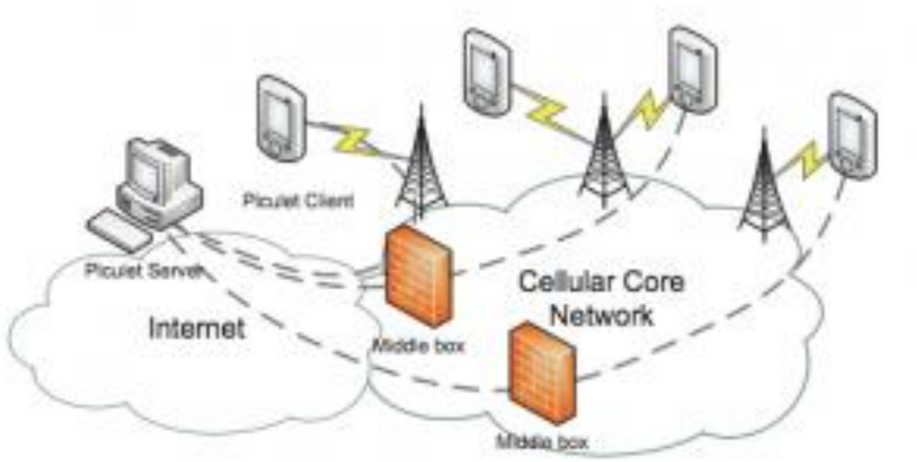

Fig: 1.1 Cellular Network

The data transmission over cellular networks is possible with modern 4G systems capable of speeds reaching that of wired DSL. Cellular companies charge their customers by a minute of their voice and by the kilobytes for data. [7]

Features of Cellular Systems

Wireless Cellular Systems solves the problem of spectral congestion and increases user capacity. The features of cellular systems are as follows −

- Offer very high capacity in a limited spectrum.
- Reuse of radio channel in different cells.
- Enable a fixed number of channels to serve an arbitrarily large number of users by reusing the channel throughout the coverage region.

- Communication is always between mobile and base station (not directly between mobiles).
- Each cellular base station is allocated a group of radio channels within a small geographic area called a cell.
- Neighbouring cells are assigned different channel groups.
- By limiting the coverage area to within the boundary of the cell, the channel groups may be reused to cover different cells.
- Keep interference levels within tolerable limits.
- Frequency reuse or frequency planning.
- Organization of Wireless Cellular Network.

Cellular network is organized into multiple low power transmitters each 100w or less. [14]

- Multihop cellular network

2) General Packet Radio Service (GPRS)

It is a packet oriented mobile data standard on the 2G and 3G cellular communication network's global system for mobile communications (GSM). GPRS was established by European Telecommunications Standards Institute (ETSI) in response to the earlier CDPD and i-mode packet-switched cellular technologies. It is now maintained by the 3rd Generation Partnership Project (3GPP).

GPRS is typically sold according to the total volume of data transferred during the billing cycle, in contrast with circuit switched data, which is usually billed per minute of connection time, or sometimes by one-third minute increments. Usage above the GPRS bundled data cap may be charged per MB of data, speed limited, or disallowed.

GPRS is a best-effort service, implying variable throughput and latency that depend on the number of other users sharing the service concurrently, as opposed to circuit switching, where a certain quality of service (QoS) is guaranteed during the connection. In 2G systems, GPRS provides data rates of 56–114 kbit/sec. 2G cellular technology combined with GPRS is sometimes described as *2.5G*, that is, a technology between the second (2G) and third (3G) generations of mobile telephony. It provides moderate-speed data transfer, by using unused time division multiple access (TDMA) channels in, for example, the GSM system. GPRS is integrated into GSM Release 97 and newer releases.

GPRS supports the following protocols:

- Internet Protocol (IP). In practice, built-in mobile browsers use IPv4 before Ipv6 is widespread.
- Point-to-Point Protocol (PPP) is typically not supported by mobile phone operators but if a cellular phone is used as a modem for a connected computer, PPP may be used to tunnel IP to the phone. This allows an IP address to be dynamically assigned (using IPCP rather than DHCP) to the mobile equipment.
- X.25 connections are typically used for applications like wireless payment terminals, although it has been removed from the standard. X.25 can still be supported over PPP, or even over IP, but this requires either a network-based router to perform encapsulation or software built into the end-device/terminal; e.g., user equipment (UE).

When TCP/IP is used, each phone can have one or more IP addresses allocated. GPRS will store and forward the IP packets to the phone even during handover. The TCP restores any packets lost (e.g. due to a radio noise induced pause). [15]

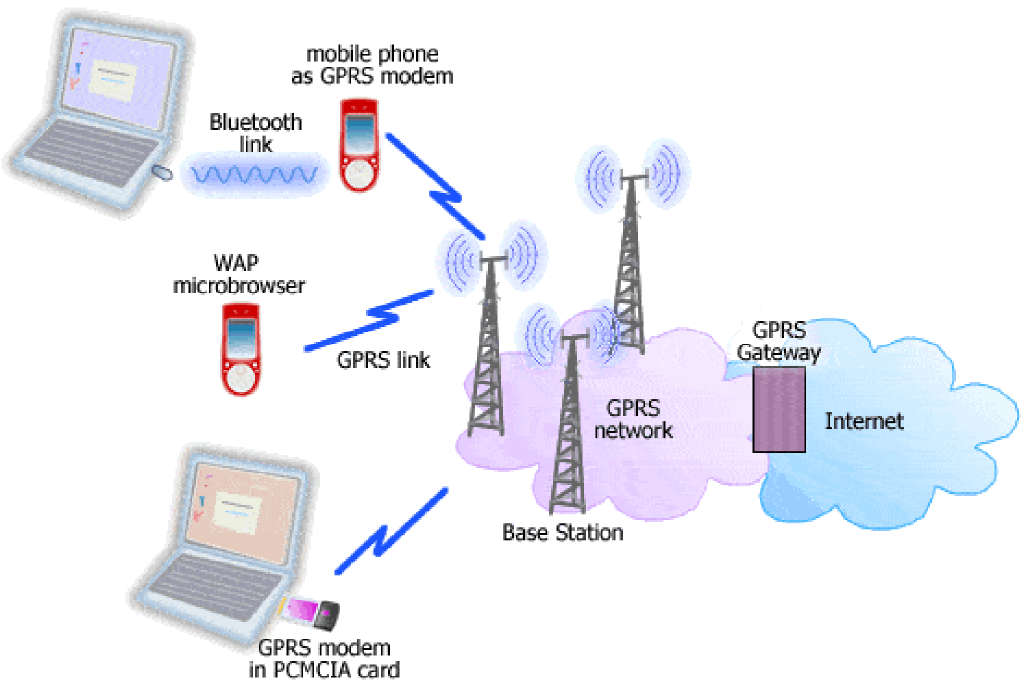

Fig: 2.1 : GPRS Architecture

Benefits of GPRS

- Higher Data Rate

GPRS benefits the users in many ways, one of which is higher data rates in turn of shorter access times. In the typical GSM mobile, setup alone is a lengthy process and equally, rates for data permission are restrained to 9.6 kbit/s. The session establishment time offered while GPRS is in practice is lower than one second and ISDN-line data rates are up to many 10 kbit/s.

- Easy Billing

GPRS packet transmission offers a more user-friendly billing than that offered by circuit switched services. In circuit switched services, billing is based on the duration of the connection. This is unsuitable for applications with bursty traffic. The user must pay for the entire airtime, even for idle periods when no packets are sent (e.g., when the user reads a Web page). [16]

3) 4G network

4G is the fourth generation of broadband cellular network technology, succeeding 3G. A 4G system must provide capabilities defined by ITU in IMT Advanced. Potential and current applications include amended mobile web access, IP telephony, gaming services, high-definition mobile TV, video conferencing, and 3D television.

The first-release Long Term Evolution (LTE) standard was commercially deployed in Oslo, Norway, and Stockholm, Sweden in 1998, and has since been deployed throughout most parts of the world. It has, however, been debated whether first-release versions should be considered 4G LTE. [17]

Data speeds of LTE :

Peak Download100 Mbit/s

Peak Upload50 Mbit/s

4) 5G networks

5G networks are digital cellular networks, in which the service area covered by providers is divided into small geographical areas called *cells*. Analog signals representing sounds and images are digitized in the telephone, converted by an analog-to-digital converter and transmitted as a stream of bits. All the 5G wireless devices in a cell communicate by radio waves with a local antenna array and low power automated transceiver (transmitter and receiver) in the cell, over frequency channels assigned by the transceiver from a pool of frequencies that are reused in other cells. The local antennas are connected with the telephone network and the Internet by a high-bandwidth optical fiber or wireless backhaul connection. As in other cell networks, a mobile device crossing from one cell to another is automatically "handed off" seamlessly to the new cell. 5G can support up to a million devices per square kilometer, while 4G supports only up to 100,000 devices per square kilometer. The new 5G wireless devices also have 4G LTE capability, as the new networks use 4G for initially establishing the connection with the cell, as well as in locations where 5G access is not available. [13]

<u>Speed</u>

5G speeds will range from ~50 Mbit/s to over a gigabit/s. The fastest 5G is known as mmWave. As of July 3, 2019, mmWave had a top speed of 1.8 Gbit/s on AT&T's 5G network.

How 5G works:

5G is a new digital system for transforming bytes - data units - over air. It uses a 5G New Radio interface, along with other new technologies, that utilises much higher radio frequencies (28 ghz compared to 700 mhz - 2500 mhz for 4G) to transfer exponentially more data over the air for faster speeds, reduced congestion and lower latency, which is the delay before a transfer of data begins following an instruction.

This new interface, which uses millimetre wave spectrum, enables more devices to be used within the same geographic area; 4G can support about 4,000 devices per square kilometre, whereas 5G will support around one million. This means more Netflix streaming, voice calls and You Tube carried, without interruption, over the limited air space. 5G also uses a new digital technology called Massive MIMO, which stands for multiple input multiple output, that uses multiple targeted beams to spotlight and follow users around a cell site, improving coverage, speed and capacity. Current network technologies operate like floodlights, illuminating an area but with lots of wastage of the light/signal. Part of the roll-out of 5G involves installing Massive MIMO and 5G New Radio to all mobile network base stations on top of the existing 4G infrastructure. [12]

	3G	4G	5G
Deployment	2004-05	2006-10	2020
Bandwidth	2mbps	200mbps	>1gbps
Latency	100-500 milliseconds	20-30 milliseconds	<10 milliseconds
Average Speed	144 kbps	25 mbps	200-400 mbps

Fig: 4.1 3G vs 4G vs 5G

5) WiMAX

WiMAX is one of the hottest broadband wireless technologies around today. WiMAX systems are expected to deliver broadband access services to residential and enterprise customers in an economical way.

Loosely, WiMax is a standardized wireless version of Ethernet intended primarily as an alternative to wire technologies (such as Cable Modems, DSL and T1/E1 links) to provide broadband access to customer premises.

More strictly, WiMAX is an industry trade organization formed by leading communications, component, and equipment companies to promote and certify compatibility.

WiMAX would operate similar to WiFi, but at higher speeds over greater distances and for a greater number of users. WiMAX has the ability to provide service even in areas that are difficult for wired infrastructure to reach and the ability to overcome the physical limitations of traditional wired infrastructure.

Wifi vs WiMax [18]

- IEEE Standards

Wi-Fi is based on IEEE 802.11 standard whereas WiMAX is based on IEEE 802.16. However, both are IEEE standards

- Range

Wi-Fi typically provides local network access for a few hundred feet with the speed of up to 54 Mbps, a single WiMAX antenna is expected to have a range of up to 40 miles with the speed of 70 Mbps or more. As such, WiMAX can bring the underlying Internet connection needed to service local Wi-Fi networks.

- Scalability

Wi-Fi is intended for LAN applications, users scale from one to tens with one subscriber for each CPE device. Fixed channel sizes (20MHz).

WiMAX is designed to efficiently support from one to hundreds of Consumer premises equipments (CPE)s, with unlimited subscribers behind each CPE. Flexible channel sizes from 1.5MHz to 20MHz.

- Bit rate

Wi-Fi works at 2.7 bps/Hz and can peak up to 54 Mbps in 20 MHz channel.

WiMAX works at 5 bps/Hz and can peak up to 100 Mbps in a 20 MHz channel.

- Quality of Service

Wi-Fi does not guarantee any QoS but WiMax will provide your several level of QoS.

As such, WiMAX can bring the underlying Internet connection needed to service local Wi-Fi networks. Wi-Fi does not provide ubiquitous broadband while WiMAX does.

IEEE Standards

The WiMAX umbrella currently includes 802.16-2004 and 802.16e. 802.16-2004 utilizes OFDM to serve multiple users in a time division fashion in a sort of a round-robin technique, but done extremely quickly so that users have the perception that they are always transmitting/receiving. 802.16e utilizes OFDMA and can serve multiple users simultaneously by allocating sets of *tones* to each user.

	802.16	802.16a	802.16e
Spectrum	10 – 66 GHz	2 – 11 GHz	<6 GHz
Configuration	Line of Sight	Non- Line of Sight	Non- Line of Sight
Bit Rate	32 to 134 Mbps (28 MHz Channel)	≤ 70 or 100 Mbps (20 MHz Channel)	Up to 15 Mbps
Modulation	QPSK, 16-QAM, 64-QAM	256 Sub-Carrier OFDM using QPSK, 16-QAM, 64-QAM, 256-QAM	Same as 802.16a
Mobility	Fixed	Fixed	≤75 MPH
Channel Bandwidth	20, 25, 28 MHz	Selectable 1.25 to 20 MHz	5 MHz (Planned)
Typical Cell Radius	1-3 miles	3-5 miles	1-3 miles
Completed	Dec, 2001	Jan, 2003	2nd Half of 2005

Fig 5.1 IEEE Standards supported by WiMax

6) Satellite Communication

Satellite communication is one type of self contained wireless communication technology, it is widely spread all over the world to allow users to stay connected almost anywhere on the earth. When the signal (a beam of modulated microwave) is sent near the satellite then, satellite amplifies the signal and sent it back to the antenna receiver which is located on the surface of the earth. Satellite communication contains two main components like the space segment and the ground segment. The ground segment consists of fixed or mobile transmission, reception and ancillary equipment and the space segment, which mainly is the satellite itself. [8]

Fig 6.1 : Satellite Communication

7) Radio

Radio communication was one of the first wireless technology developed and it is still in use. The portable multi-channel radios allow the user to communicate over short distances whereas citizen band and maritime radios provide communication services over long distances for truckers and sailors.

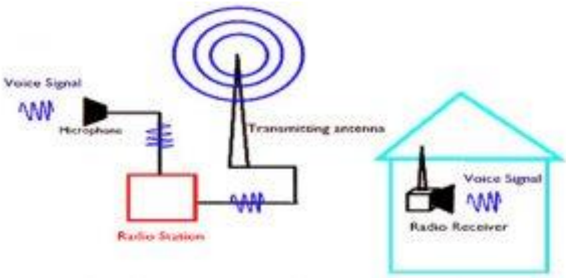

Fig : 7.1 Radio communication overview

Mostly radio broadcasts sound through the air as radio waves. Radio has a transmitter which transmits the data in the form of radio signals to the receiver antenna.

To broadcast common programming stations are associated with the radio networks. The broadcast happens either in simulcast or syndication or both the forms. Radio broadcasting may be done via cable FM, and satellites over long distances at up to two megabits/Sec. [7]

8) Zigbee [19]

Zigbee is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless IoT networks. The Zigbee standard operates on the IEEE 802.15.4 physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.

The 802.15.4 specification upon which the Zigbee stack operates gained ratification by the Institute of Electrical and Electronics Engineers (IEEE) in 2003. The specification is a packet-based radio protocol intended for low-cost, battery-operated devices. The protocol allows devices to communicate in a variety of network topologies and can have battery life lasting several years.

The Zigbee 3.0 Protocol

The Zigbee protocol has been created and ratified by member companies of the Zigbee Alliance.Over 300 leading semiconductor manufacturers, technology firms, OEMs and service companies comprise the Zigbee Alliance membership. The Zigbee protocol was designed to provide an easy-to-use wireless data solution characterized by secure, reliable wireless network architectures.

Zigbee protocol features include:

- Support for multiple network topologies such as point-to-point, point-to-multipoint and mesh networks
- Low duty cycle – provides long battery life
- Low latency
- Direct Sequence Spread Spectrum (DSSS)
- Up to 65,000 nodes per network
- 128-bit AES encryption for secure data connections
- Collision avoidance, retries and acknowledgements

Zigbee Applications

Zigbee enables broad-based deployment of wireless networks with low-cost, low-power solutions. It provides the ability to run for years on inexpensive batteries for a host of monitoring and control applications. Smart energy/smart grid, AMR (Automatic Meter Reading), lighting controls, building automation systems, tank monitoring, HVAC control, medical devices and fleet applications are just some of the many spaces where Zigbee technology is making significant advancements.

Mesh Networks

A key component of the Zigbee protocol is the ability to support mesh networking. In a mesh network, nodes are interconnected with other nodes so that multiple pathways connect each node.

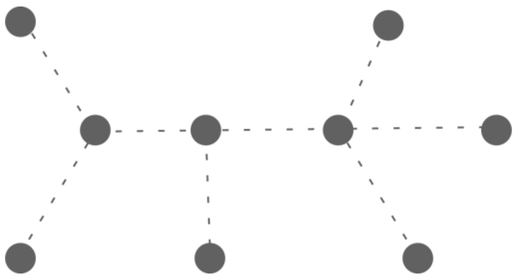

Fig: 8.1 : Mesh topology

Connections between nodes are dynamically updated and optimized through sophisticated, built-in mesh routing table.

Mesh networks are decentralized in nature; each node is capable of self-discovery on the network. Also, as nodes leave the network, the mesh topology allows the nodes to reconfigure routing paths based on the new network structure. The characteristics of mesh topology and ad-hoc routing provide greater stability in changing conditions or failure at single nodes.

Conclusion :

Thus, in this experiment, I have understood the working of physical layer of the OSI model and the different types of transmission media that can be used for communication at that level.

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