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DCCN Experiment -1

Aim:

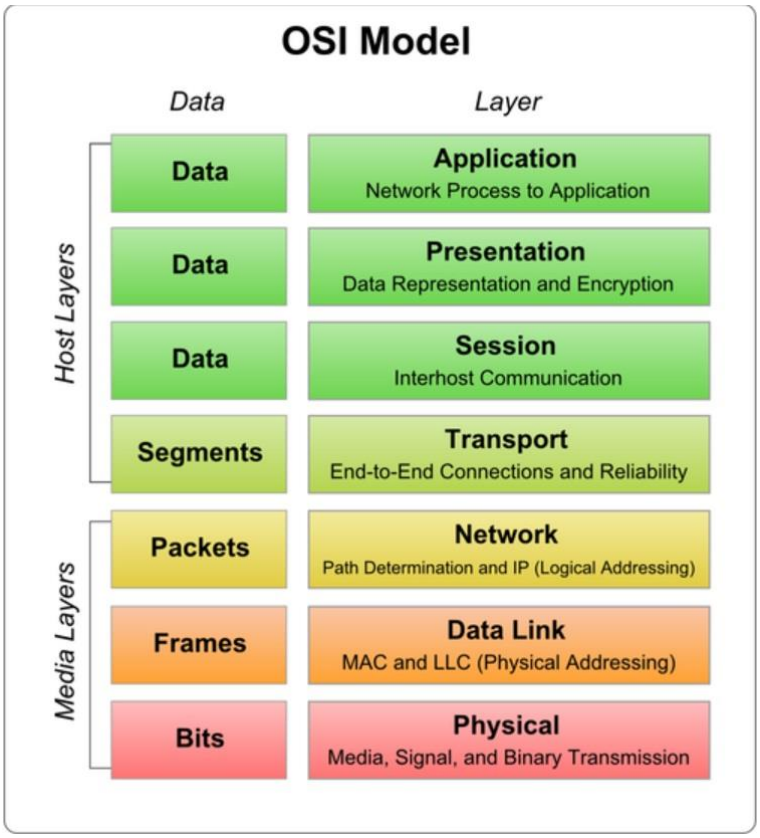
To study different types of physical layer wired and wireless connections.

Theory:

OSI Model (Ref no. 1)

The Open Systems Interconnection (OSI) model defines a networking framework to implement protocols in layers, with control passed from one layer to the next. It is primarily used today as a teaching tool. It conceptually divides computer network architecture into 7 layers in a logical progression.

The lower layers deal with electrical signals, chunks of binary data, and routing of these data across networks. Higher levels cover network requests and responses, representation of data, and network protocols, as seen from a user's point of view.



Wired Connections (Ref no. 4)

Twisted Pair Cable (Ref no. 5)

It consists of 2 separately insulated conductor wires wound about each other. Generally, several such pairs are bundled together in a protective sheath. They are the most widely used Transmission Media. Twisted Pair is of two types:

1. **Unshielded Twisted Pair (UTP):**

   This type of cable has the ability to block interference and does not depend on a physical shield for this purpose. It is used for telephonic applications.

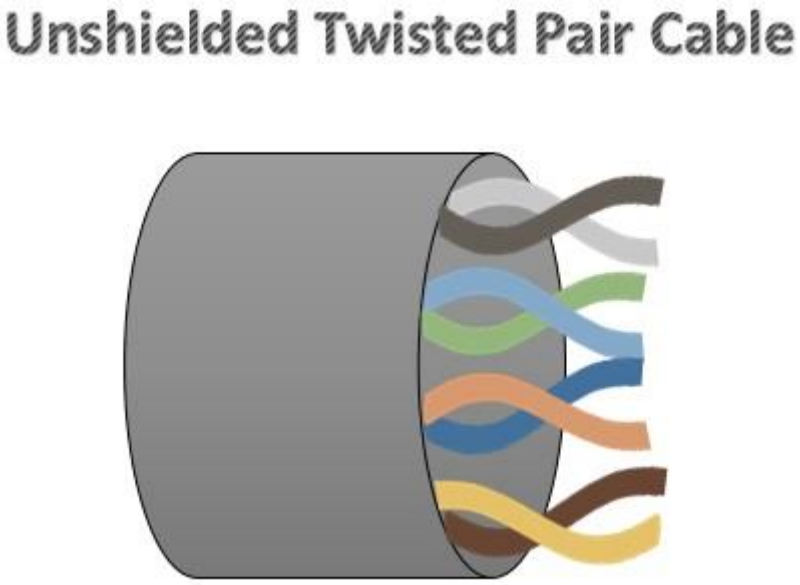
   Specifications:

Range	**100 Hz – 5 Mhz**
Cable Length	**100 m**
Data Transfer Rate	**Max 1000 Mbps**

   Uses:

   They are typically used in computer networking such as Ethernet for short-to-medium distances because of their relatively cheap price compared to optical fiber and coaxial cables.

   Schematic View:



Advantages:

- Least expensive
- Easy to install
- High speed capacity
- Susceptible to external interference
- Lower capacity and performance in comparison to STP
- Short distance transmission due to attenuation

2. **Shielded Twisted Pair (STP):**

This type of cable consists of a special jacket to block external interference. It is used in fast-data-rate Ethernet and in voice and data channels of telephone lines.

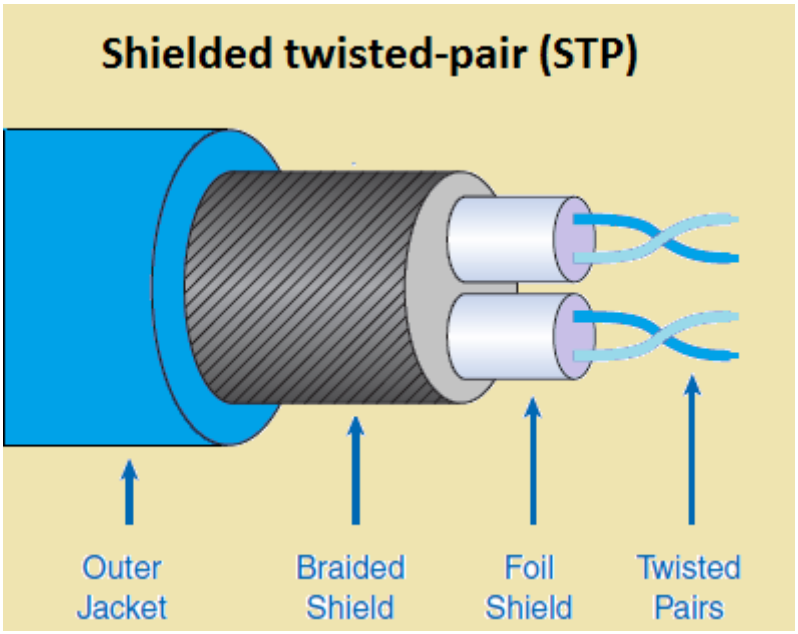
Specifications:

Range	**100 Hz – 5 Mhz**
Cable Length	**100 m**
Data Transfer Rate	**Max 500 Mbps**

Uses:

STP cables are often used in Ethernet networks, particularly fast-data-rate Ethernets.

Schematic View:



Advantages:

- Better performance at a higher data rate in comparison to UTP
- Eliminates crosstalk
- Comparatively faster
- Comparatively difficult to install and manufacture
- More expensive
- Bulky

Coaxial Cable (Ref no. 6)

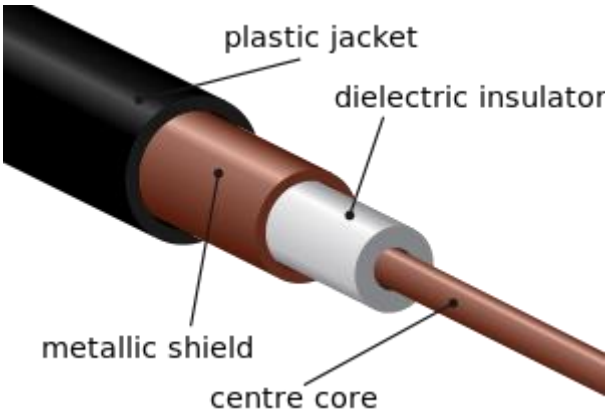
It has an outer plastic covering containing 2 parallel conductors each having a separate insulated protection cover. Coaxial cable transmits information in two modes: Baseband mode(dedicated cable bandwidth) and Broadband mode(cable bandwidth is split into separate ranges). Cable TVs and analog television networks widely use Coaxial cables.

Specifications:

Uses:

The coaxial cable is primarily used for audio and visual purposes. Modern homes are typically equipped with at least one coaxial cable outlet in each room. This is because cable companies primarily use coaxial cables to bring cable television to their customers. Coaxial cables can be connected from the wall outlet directly to the customer's television or cable box. A second use for coaxial cables is connecting VCRs to a television. A final use of the coaxial cable is attaching a personal antenna to a television set or digital converter box.

Schematic View:



Advantages:

- High Bandwidth
- Better noise Immunity
- Easy to install and expand
- Inexpensive

Disadvantages:

- Single cable failure can disrupt the entire network

Optical Fibre Cable (Ref no. 7)

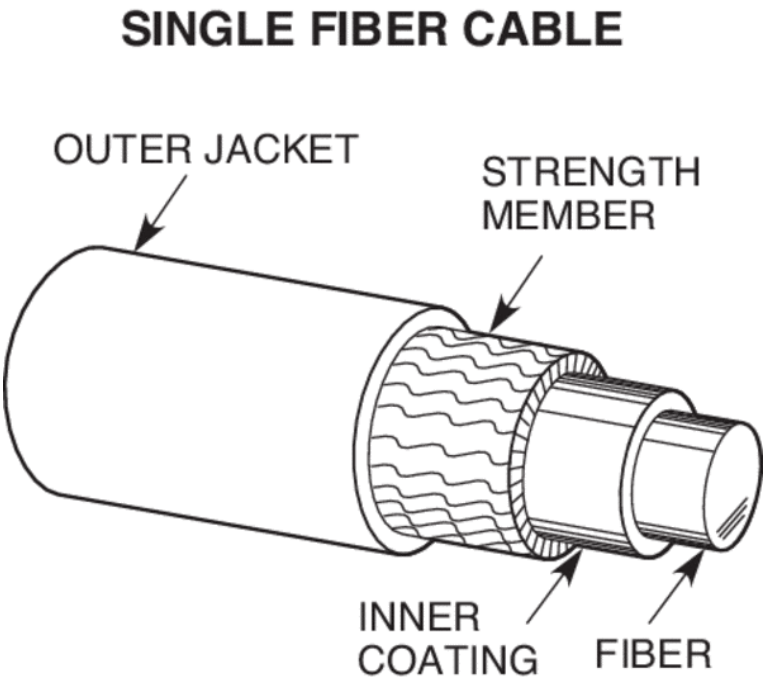
It uses the concept of reflection of light through a core made up of glass or plastic. The core is surrounded by a less dense glass or plastic covering called the cladding. It is used for transmission of large volumes of data.

The cable can be unidirectional or bidirectional. The WDM (Wavelength Division Multiplexer) supports two modes, namely unidirectional and bidirectional mode.

Uses:

- **Medical**
  Used as Light guides, imaging tools and also as lasers for surgeries
- **Defense/Government**
  Used as hydrophones for seismic and SONAR uses, as wiring in aircraft, submarines and other vehicles and also for field networking
- **Data Storage**
  Used for Data transmission
- **Telecommunications**
  Fiber is laid and used for transmitting and receiving purposes
- **Networking**
  Used to connect Users and servers in a variety of Network settings and help increase the speed and accuracy of data transmission
- **Industrial/Commercial**
  Used for imaging in hard to reach areas, as wiring where EMI is an issue, as sensory devices to make temperature, pressure and other measurements, and as wiring in automobiles and in industrial settings
- **Broadcast/CATV**
  Broadcast/cable companies are using fiber optic cables for wiring CATV, HDTV, internet, video on-demand and other applications.

Schematic View:



Advantages:

- Increased capacity and bandwidth
- Light weight
- Less signal attenuation
- Immunity to electromagnetic interference
- Resistance to corrosive materials

Disadvantages:

- Difficult to install and maintain
- High cost
- Fragile

Some Technologies used in wired media:

1)Universal Serial Bus (Ref no.8)

Universal Serial Bus (**USB**) is an industry standard that establishes specifications for cables and connectors and protocols for connection, communication and power supply (interfacing) between computers, peripherals and other computers. A broad variety of USB hardware exists, including several different connectors, of which USB-C is the most recent.

Released in 1996, the USB standard is currently maintained by the USB Implementers Forum (USB- IF). There have been four generations of USB specifications: USB 1.x, USB 2.0, USB 3.x and USB4.

Specifications:

- **Range:**

  - The USB 1.1 standard specifies that a standard cable can have a maximum length of 5 meters (16 ft 5 in) with devices operating at full speed (12 Mbit/s), and a maximum length of 3 meters (9 ft 10 in) with devices operating at low speed (1.5 Mbit/s).
  - USB 2.0 provides for a maximum cable length of 5 meters (16 ft 5 in) for devices running at high speed (480 Mbit/s).
  - The USB 3.0 standard does not directly specify a maximum cable length, requiring only that all cables meet an electrical specification: for copper cabling with AWG 26 wires, the maximum practical length is 3 meters (9 ft 10 in).

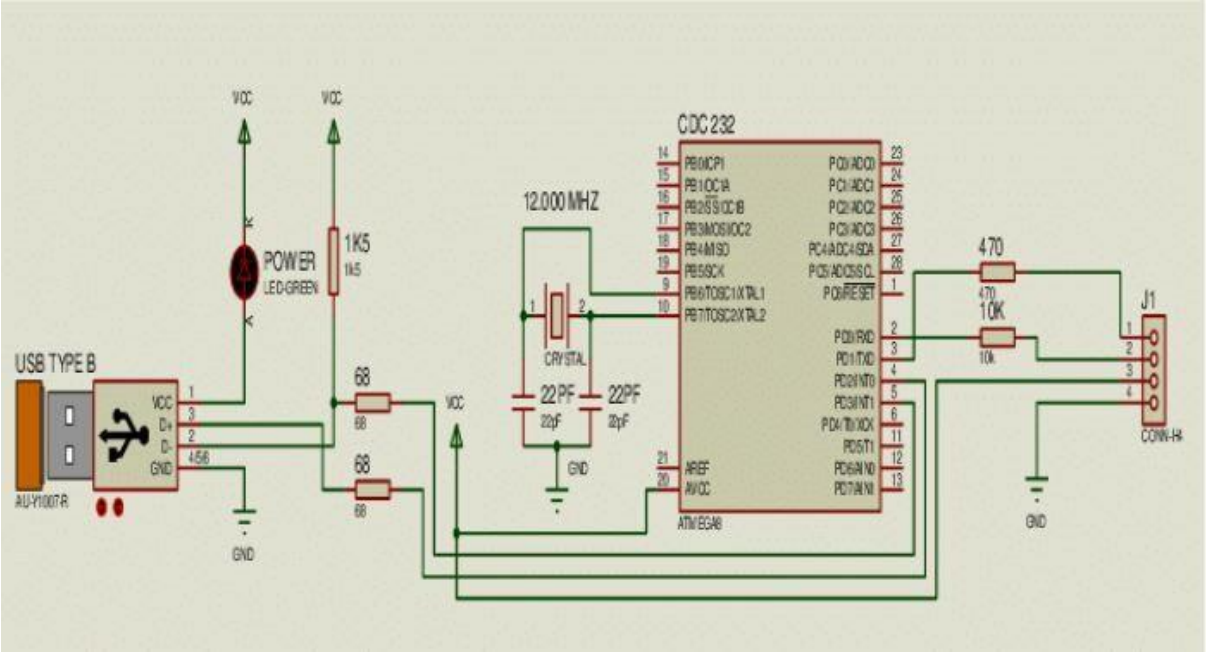
● ***Modulation:***

- At the input, the device communicates via MIDI and USB protocols. At the output is tension. Its value is managing by pulse-width modulation.
- Pulse-width modulation (PWM) is used for controlling the amplitude of digital signals in order to control devices and applications requiring power or electricity. It essentially controls the amount of power, from the perspective of the voltage component, that is given to a device by cycling the on-and-off phases of a digital signal quickly and varying the width of the "on" phase or duty cycle.

Maximum transfer rates for each USB version: (Ref no.9)

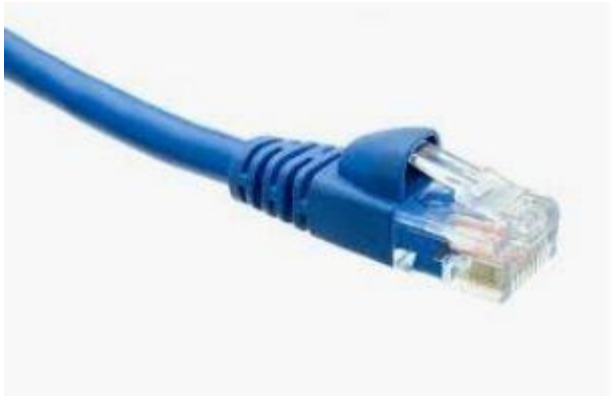
USB VERSION	RELEASE DATE	NAME	TRANSFER RATES
USB 1.0	January 1996	Full speed	12 Mbps
USB 1.1	August 1998	Full speed	12 Mbps
USB 2.0	April 2000	High Speed	480 Mbps
USB 3.0	November 2008	SuperSpeed	5 Gbps
USB 3.1	July 2013	SuperSpeed+	10 Gbps
USB 3.2	September 2017	SuperSpeed+	20 Gbps

Schematic View:



2)Ethernet (Ref no.10)

Ethernet is the traditional technology for connecting devices in a wired local area network (LAN) or wide area network (WAN), enabling them to communicate with each other via a protocol -- a set of rules or common network language. Ethernet describes how network devices can format and transmit data so other devices on the same local or campus area network segment can recognize, receive and process the information. An Ethernet cable is the physical, encased wiring over which the data travels.



Connected devices accessing a geographically localized network with a cable -- that is, with a wired rather than wireless connection -- likely use Ethernet. From businesses to gamers, diverse end users depend on the benefits of Ethernet connectivity, which include reliability and security.

Specifications:

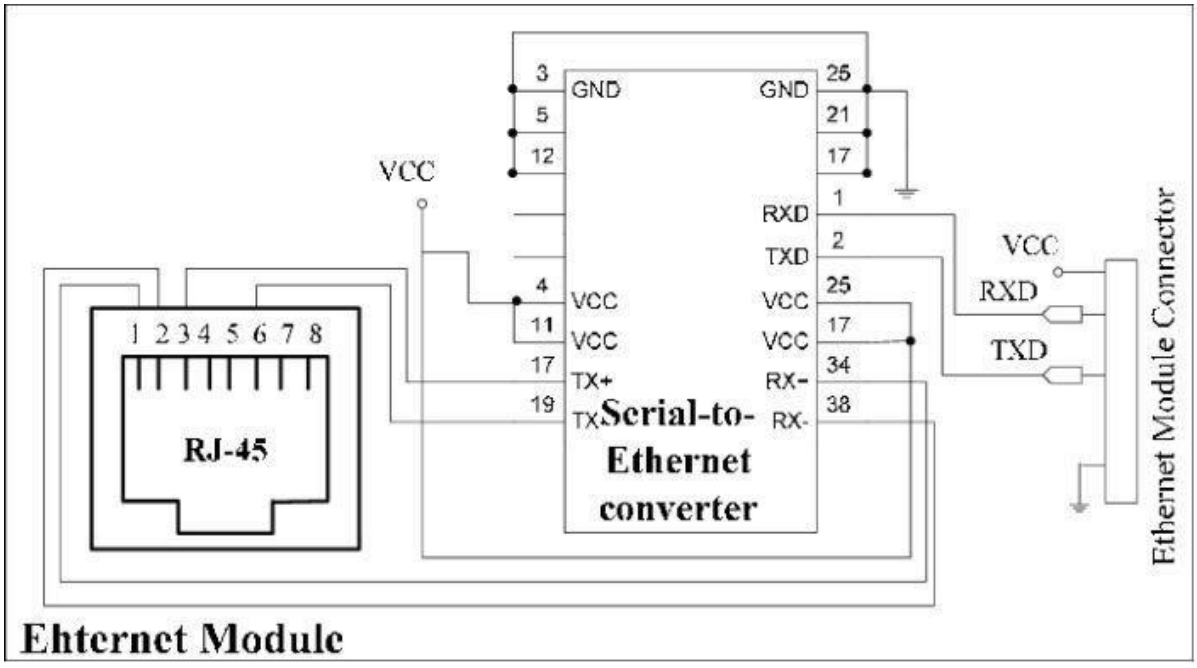
● ***Range***

Over deployed multi-mode cabling ethernet supports ranges of between 240 m and 300 m with 400/500 MHz·km modal bandwidth. It also supports 10 km over single-mode fiber.

● ***Modulation***

Ethernet uses biphase modulation to transmit data bits, this is accomplished by using a Manchester encoded bit-stream. Ethernet does not use IQ modulation because it is not bandwidth limited by the FCC.

Schematic View:



Wireless Connections

Radiowaves (Ref no. 18)

These are easy to generate and can penetrate through buildings. The sending and receiving antennas need not be aligned. Frequency Range: 3KHz – 1GHz. Further categorized as (i) Terrestrial and (ii) Satellite.

Uses:

AM and FM radios and cordless phones use radiowaves for transmission.

Microwaves (Ref no. 17)

It is a line of sight transmission i.e. the sending and receiving antennas need to be properly aligned with each other. The distance covered by the signal is directly proportional to the height of the antenna.

Specifications:

Frequency Range: 1GHz – 300GHz.

Uses:

- Satellites in geostationary orbit are useful for communications since a microwave antenna can be aimed at them without having to know their exact location. Wireless LAN protocols make use of microwaves. If you've ever used Bluetooth or the WiFi then you have had experience with one of the uses of microwaves.
- A lot of tasks of modern living can now be done over the internet, and there's a microwave to thank for that. Without it, buying groceries, paying bills, and booking movie tickets through smartphones and laptops won't be possible.
- Satellites in geostationary orbit are useful for communications since a microwave antenna can be aimed at them without having to know their exact location.
- Major broadcast television networks have also made use of geostationary satellites to distribute programming to local affiliates. Such satellites are also used by cable TV networks.

Bluetooth (Ref no. 11)

Bluetooth is a wireless technology standard used for exchanging data between fixed and mobile devices over short distances using short-wavelength UHF radio waves in the industrial, scientific and medical radio bands, from 2.402 GHz to 2.480 GHz, and building personal area networks (PANs).

The IEEE standardized Bluetooth as IEEE 802.15.1, but no longer maintains the standard. The Bluetooth SIG oversees development of the specification, manages the qualification program, and protects the trademarks.

Specifications:

Bluetooth operates at frequencies between 2.402 and 2.480 **GHz**, or 2.400 and 2.4835 **GHz** including guard bands 2 MHz wide at the bottom end and 3.5 MHz wide at the top. This is in the globally unlicensed (but not unregulated) industrial, scientific and medical (ISM) 2.4 **GHz** short-**range** radio frequency band.

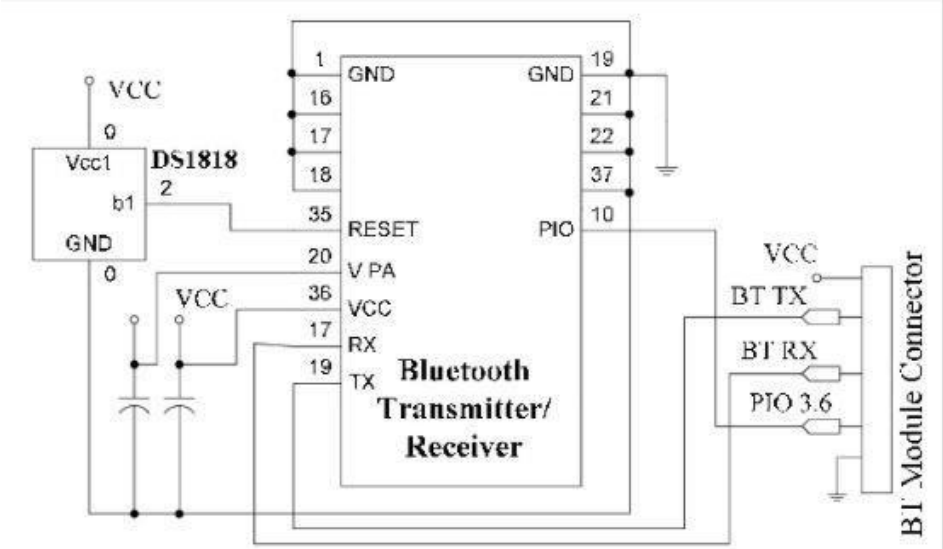
Physical range: Typically less than 10 m (33 ft)

Modulation (Ref no. 11)

The enhanced data rate capability for Bluetooth modulation is implemented as an additional capability so that the system remains backwards compatible.

The Bluetooth modulation schemes and the general format do not lend themselves to carrying higher data rates. For Bluetooth 3, the higher data rates are not achieved by changing the format of the Bluetooth modulation, but by working cooperatively with an IEEE 802.11g physical layer. In this way data rates of up to around 25 Mbps can be achieved.

Schematic View:



Bluetooth Module

Near Field Communication (NFC) (Ref no. 13)

Near-field communication transmits data through electromagnetic radio fields to enable two devices to communicate with each other.

Specifications:

Range

NFC is a set of short-range wireless technologies, typically requiring a separation of 10 cm or less. **NFC** operates at 13.56 MHz on ISO/IEC 18000-3 air interface and at rates ranging from 106 kbit/s to 424 kbit/s.They can be custom-encoded by their manufacturers or **NFC** Forum **specifications**.

Modulation

NFC employs two different coding systems on the RF signal to transfer data. In most cases a level of 10% **modulation** is used, with a Manchester coding format. However for an active device transmitting data at 106 kbps, a modified Miller coding scheme is used with 100% **modulation**.

Uses:

Near-field communication (NFC) is a short-range wireless technology that makes your smartphone, tablet, wearables, payment cards, and other devices even smarter. With NFC, you can transfer information between devices quickly and easily with a single touch—whether paying bills, exchanging business cards, downloading coupons, or sharing a research paper.

Wireless Fidelity (WiFi) (Ref no. 14)

Wi-Fi is a family of wireless network protocols, based on the IEEE 802.11 family of standards, which are commonly used for local area networking of devices and Internet access. Wi-Fi uses multiple parts of the IEEE 802 protocol family and is designed to interwork seamlessly with its wired sibling Ethernet. Compatible devices can network through wireless access points to each other as well as to wired devices and the Internet.

Wi-Fi stations communicate by sending each other data packets: blocks of data individually sent and delivered over radio. As with all radio, this is done by the modulating and demodulation of carrier waves. Different versions of Wi-Fi use different techniques, 802.11b uses DSSS on a single carrier, whereas 802.11a, Wi-Fi 4, 5 and 6 use multiple carriers on slightly different frequencies within the channel (OFDM).

Specifications:

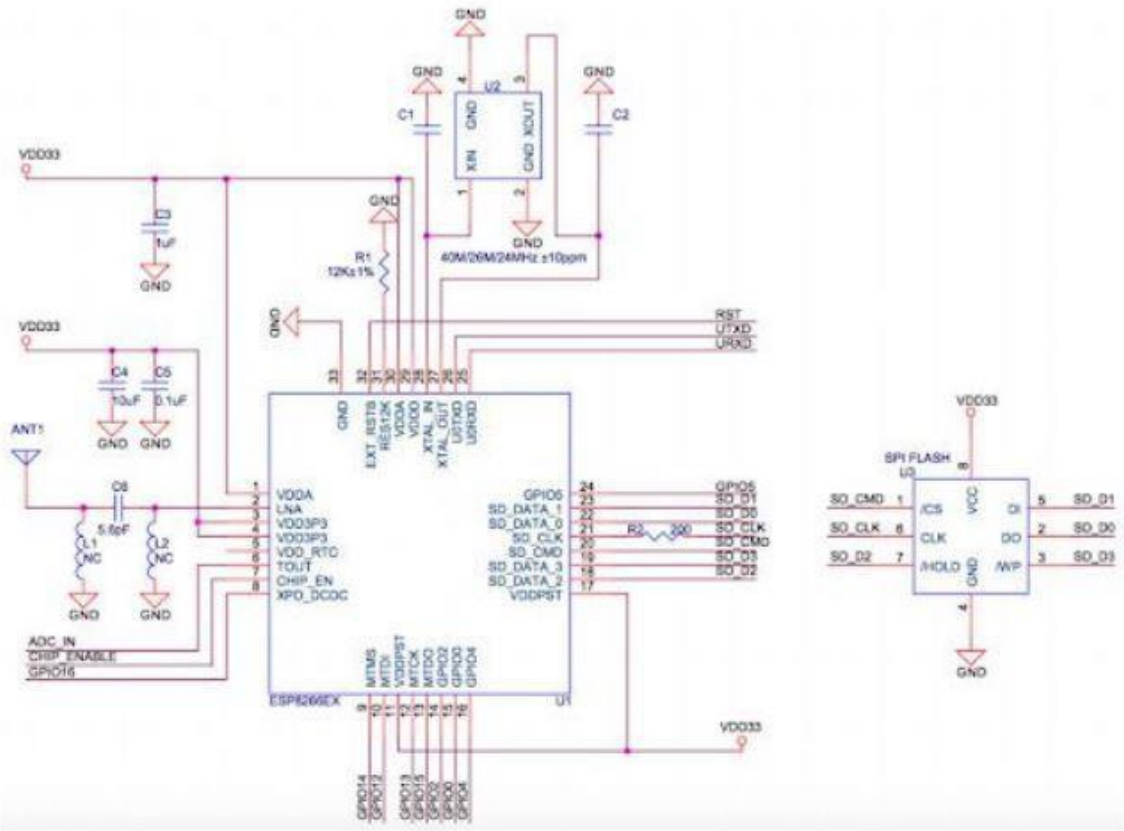
Range

- A wireless network's range can vary wildly depending on the type of network. A standard home network using one wireless router can serve a single-family dwelling, but often not much more.
- Business networks with grids of access points can serve large office buildings, and wireless hotspots spanning several square miles have been built in some cities.
- Wi-Fi can be used on several types of devices like personal computers, video game console, smart phones, digital camera, tablet computers etc. You can use Wi-Fi to create a hotspot within the **range** of 20 meters (66 feet).

Modulation

WiFi systems use two primary radio transmission techniques.

Schematic View:



Schematic View ESP8266 - WiFi Module

ESP8266 has powerful on-board processing and storage capabilities that allow it to be integrated with the sensors and other application-specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, and the entire solution, including the front-end module, is designed to occupy minimal PCB area. ESP8266 Serial Wifi Wireless Transceiver Module is suitable for Uno, Mega 2560, and Nano.

WiMax (Ref no. 19)

WiMAX (**Worldwide Interoperability for Microwave Access**) is a family of wireless broadband communication standards based on the IEEE 802.16 set of standards, which provide multiple physical layer (PHY) and Media Access Control (MAC) options.

Specifications

WiMAX supports **ATM, IPv4, IPv6, Ethernet, and VLAN services**. So, it can provide a rich choice of service possibilities to voice and data network service providers. In addition, WiMAX provides an ideal wireless backhaul technology to connect **802.11 wireless LANs** and **commercial hotspots** with the Internet.

Range:

The IEEE 802.16 standard addresses frequencies from 10GHz to 66GHz. The 802.16a specification, which is an extension of IEEE802.16, covers bands in the 2GHz-to-11GHz range.

Scalability

Unlike WiFi, WiMAX's range is typically measured in miles rather than feet. The main distinction of the difference between the two standards means that WiFi is focused on a local-area networking (LAN) technology and that WiMAX is a **MAN technology.**

The WiMAX can be used on a variety of wireless broadband connections and solutions:

- "Last Mile" Broadband Access Solution—Metropolitan-Area Networks (MAN) connections to home and business office, especially in those areas that were not served by cable or DSL or in areas where the local telephone company may need a long time to deploy broadband service. The WiMAX-based wireless solution makes it possible for the service provider to scale-up or scale-down service levels in short times with the client request.

- Backhaul networks for cellular base stations, bypassing the Public Switched Telephone Network (PSTN); the cellular service providers can look to wireless backhaul as a more cost-effective alternative. The robust WiMAX technology makes it a nice choice for backhaul for enterprises such as hotspots as well as point-to-point backhaul solutions.
- Backhaul enterprise connections to the Internet for WiFi hotspots. It will allow users to connect to a wireless Internet service provider even when they roam outside their home or business office.
- A variety of new business services by wireless Internet service provider.

Zigbee (Ref no. 20)

Zigbee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection.

Scalability:

The technology defined by the Zigbee specification is intended to be simpler and less expensive than other **wireless personal area networks (WPANs)**, such as Bluetooth or more general wireless networking such as Wi-Fi.

Specifications:

Operating Range	35 feet
Max No. of Devices	65000
Data rate	40-250 kbps
Frequency	915 MHz/2.4 GHz
Network type	Mesh

Uses:

Applications include wireless light switches, home energy monitors, traffic management systems, and other consumer and industrial equipment that requires short-range low-rate wireless data transfer.

5G Technology (Ref no. 16)

5G, which stands for "fifth generation," is an upcoming standard for mobile telecommunications service that promises to be significantly faster than today's 4G technology. 5G works a bit differently. This upgraded mobile network uses a combination of frequencies from multiple bands to maximize throughput. In addition to traditional macro cell towers, 5G will also use a large number of much smaller micro cells for new millimeter wave spectrum bands to create a blanket of ultrahigh-speed network coverage.

Specifications:

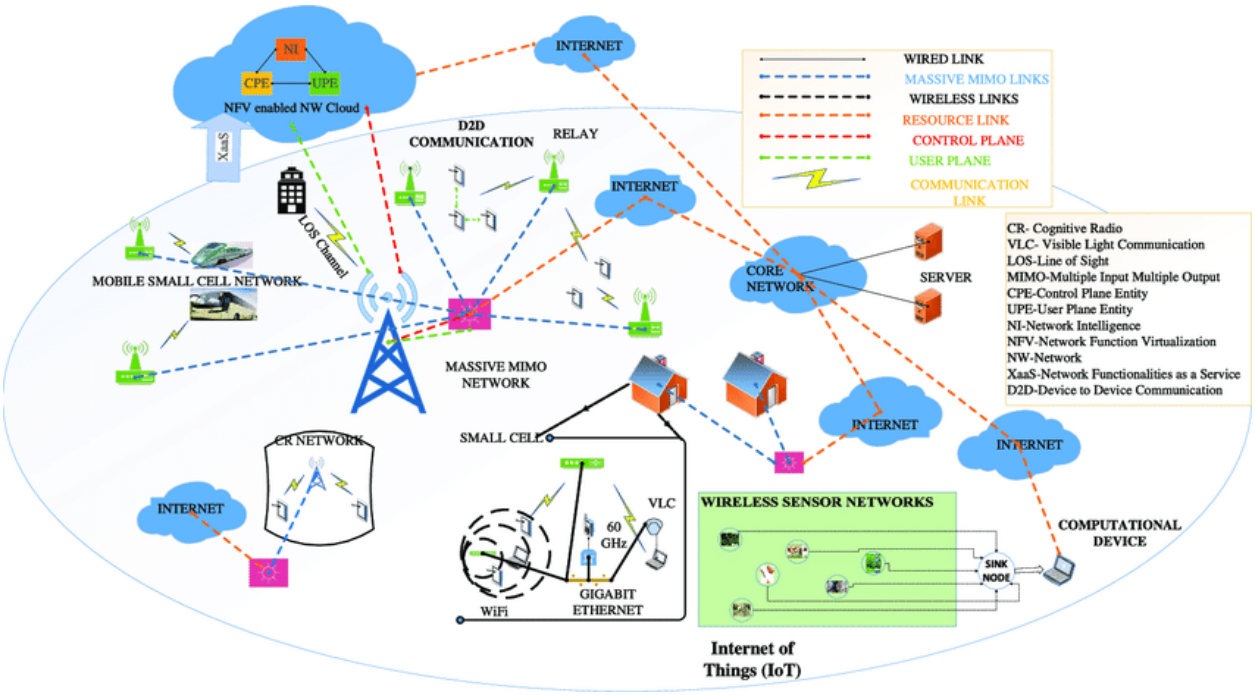
- **Peak data rate:** 5G will offer significantly faster data speeds. Peak data rates can hit 20Gbps downlink and 10Gbps uplink per mobile base station. Mind you, that's not the speed you'd experience with 5G (unless you have a dedicated connection) — it's the speed shared by all users on the cell.
- **Real-world speeds:** While the peak data rates for 5G sound pretty impressive, actual speeds won't be the same. The spec calls for user download speeds of 100Mbps and upload speeds of 50Mbps.
- **Latency:** Latency, the time it takes data to travel from one point to another, should be at 4 milliseconds in ideal circumstances, and at 1 millisecond for use cases that demand the utmost speed. Think remote surgeries, for instance.
- **Efficiency:** Radio interfaces should be energy efficient when in use, and drop into low-energy mode when not in use. Ideally, a radio should be able to switch into a low-energy state within 10 milliseconds when no longer in use.
- **Spectral efficiency:** Spectral efficiency is "the optimized use of spectrum or bandwidth so that the maximum amount of data can be transmitted with the fewest transmission errors." 5G should have a slightly improved spectral efficiency over LTE, coming in at 30bits/Hz downlink, and 15 bits/Hz uplink.

Advantages:

- With predicted 5G speed of up to 10 Gbps, new networks will be up to 100x faster than their predecessors.
- For industrial, agricultural, and commercial use cases, the biggest benefits of 5G are its high capacity and minimal lag.
- With up to 5x the bandwidth available with 4G, 5G will give rise to new methods of production and distribution.
- Early tests also show that 5G may cut network latency in half.

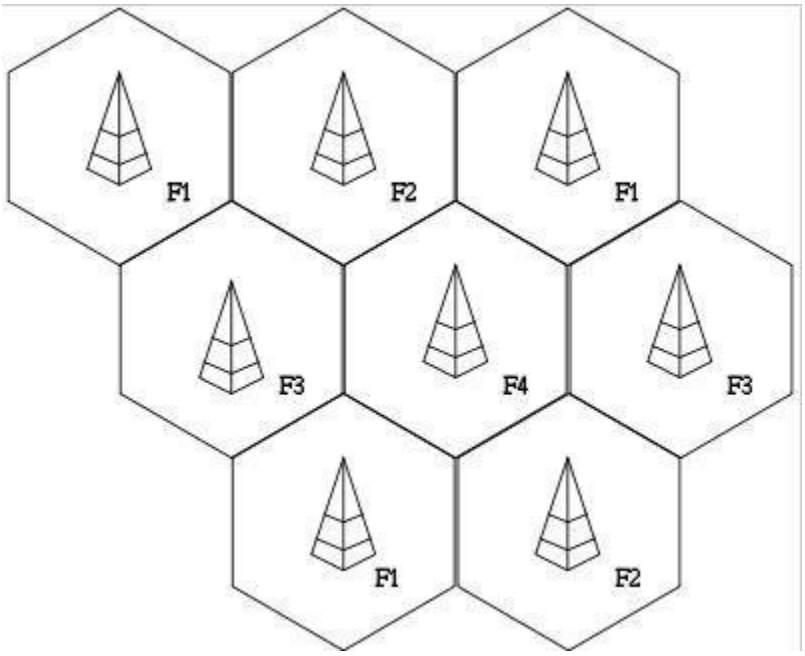
Uses:

It will allow users to browse the internet, upload or download videos, and use data-intensive apps or features such as virtual reality much more quickly and smoothly than is possible now.



Cellular Network (Ref no.21)

A cellular network or mobile network is a communication network where the last link is wireless. The network is distributed over land areas called "cells", each served by at least one fixed- location transceiver, but more normally, three cell sites or base transceiver stations.



Cellular networks offer a number of desirable features:

- More capacity than a single large transmitter, since the same frequency can be used for multiple links as long as they are in different cells
- Mobile devices use less power than with a single transmitter or satellite since the cell towers are closer
- Larger coverage area than a single terrestrial transmitter, since additional cell towers can be added indefinitely and are not limited by the horizon

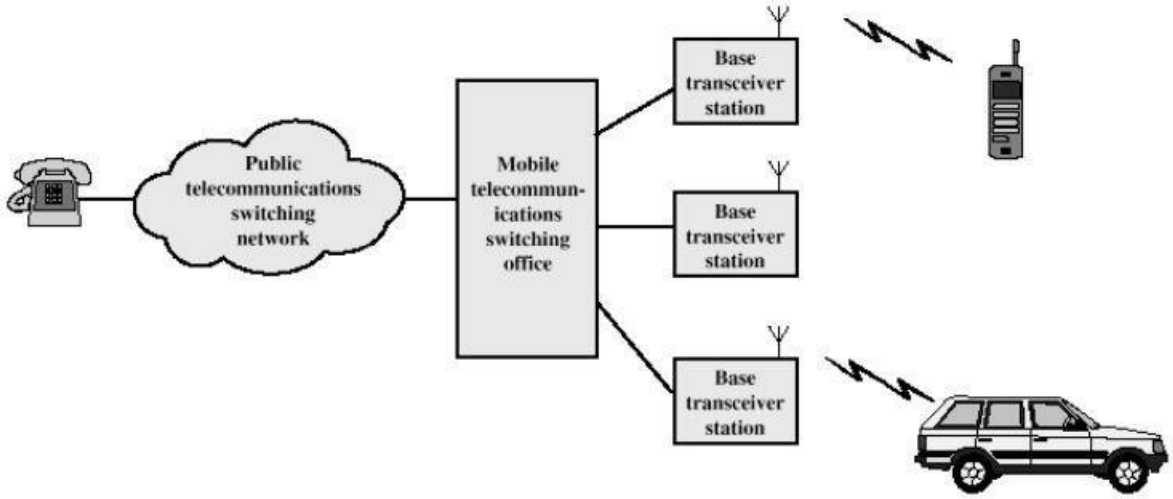
Specifications:

Range

- A cellular network is used by the mobile phone operator to achieve both coverage and capacity for their subscribers. Large geographic areas are split into smaller cells to avoid line- of-sight signal loss and to support a large number of active phones in that area
- In cities, each cell site may have a range of up to approximately 1⁄2 mile (0.80

km), while in rural areas, the range could be as much as 5 miles (8.0 km). It is possible that in clear open areas, a user may receive signals from a cell site 25 miles (40 km) away.

Cellular System Overview:



- Base Station (BS) – includes an antenna, a controller, and a number of receivers
- Mobile telecommunications switching office(MTSO) – connects calls between mobile units
- Two types of channels available between mobile unit and BS
- Control channels – used to exchange information having to do with setting up and maintaining calls
- Traffic channels – carry voice or data connection between users

Starlink Project (Ref no. 15)

Owned by billionaire entrepreneur Elon Musk and operated through his commercial aerospace company SpaceX.

And back down on Earth, the Starlink broadband router (technically a satellite dish) has now been approved by US regulators for consumer use, marking a significant step forward in connecting our homes to the upper atmosphere.

Starlink instead transmits data through lasers, which are lightspeed, so it's more-or-less on a par with fibre-optic broadband in terms of how fast the connection is.

Specifications:

Starlink once said that in perfect conditions — which would be periods of low consumer demand while there are lots of nearby orbiting satellites — it could reach speeds up to 100Mbps download and 40Mbps upload. A recent test with the US Air Force even saw it hit ultrafast speeds of 600Mbps.

Uses:

The project aims to beam strong broadband connections across the globe using a network of thousands of satellites.

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17) https://en.wikipedia.org/wiki/Microwave_transmission
18) https://www.britannica.com/technology/radio-technology/Development-of-radio-technology
19) https://www.wi-fiplanet.com/wimax-broadband-wireless-access/
20) https://www.tomsguide.com/us/smart-home-wireless-network-primer,news-21085.html

Conclusion:

I studied in great detail different types of wired and wireless connections. I gained an in-depth understanding of different IEEE standards used in networking.