EXPERIMENT 1

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CLASS: TE COMPS **BATCH: A**

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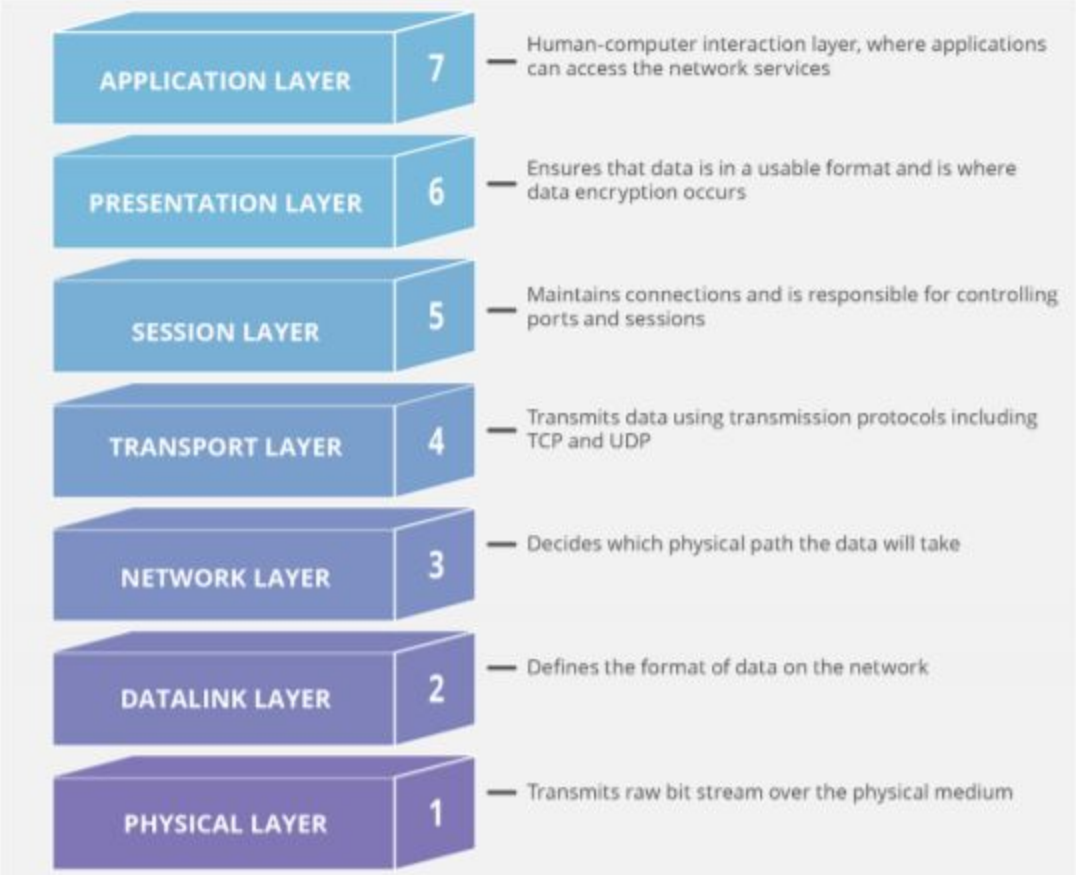
AIM: Study of different types of physical layer wired/wireless connections

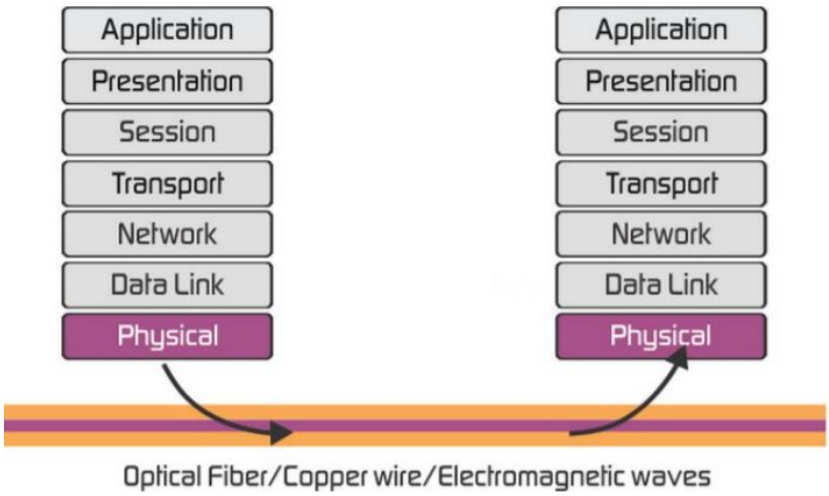
THEORY:

Open Systems Interconnection Model (OSI Model):

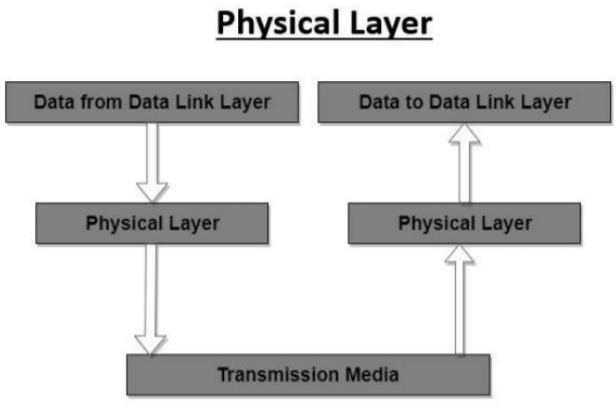
The Open Systems Interconnection model (OSI model) is a **conceptual model** whose goal is the interoperability of diverse communication systems with standard communication protocols. The model partitions a communication system into **abstraction layers**. In this model, each layer serves the layer above it. *(Ref 1)*



Physical Layer:



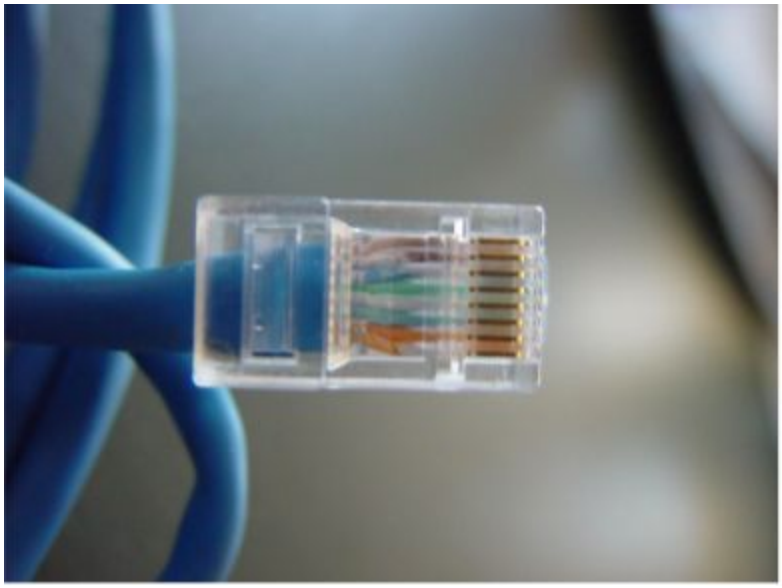
- In the **seven-layer OSI model of computer networking**, the physical layer or layer 1 is the **first and lowest layer**. *(Ref 13)*
- The physical layer consists of the electronic circuit transmission technologies of a network. It is a fundamental layer underlying the higher-level functions in a network and can be implemented through a great number of different hardware technologies with widely varying characteristics.
- The physical layer **defines the means of transmitting raw bits** over a physical data link connecting network nodes. The physical layer provides an electrical, mechanical, and procedural interface to the transmission medium.
- There are two types of network connections in the physical layer:
    - **Wired Connections**
    - **Wireless Connections**



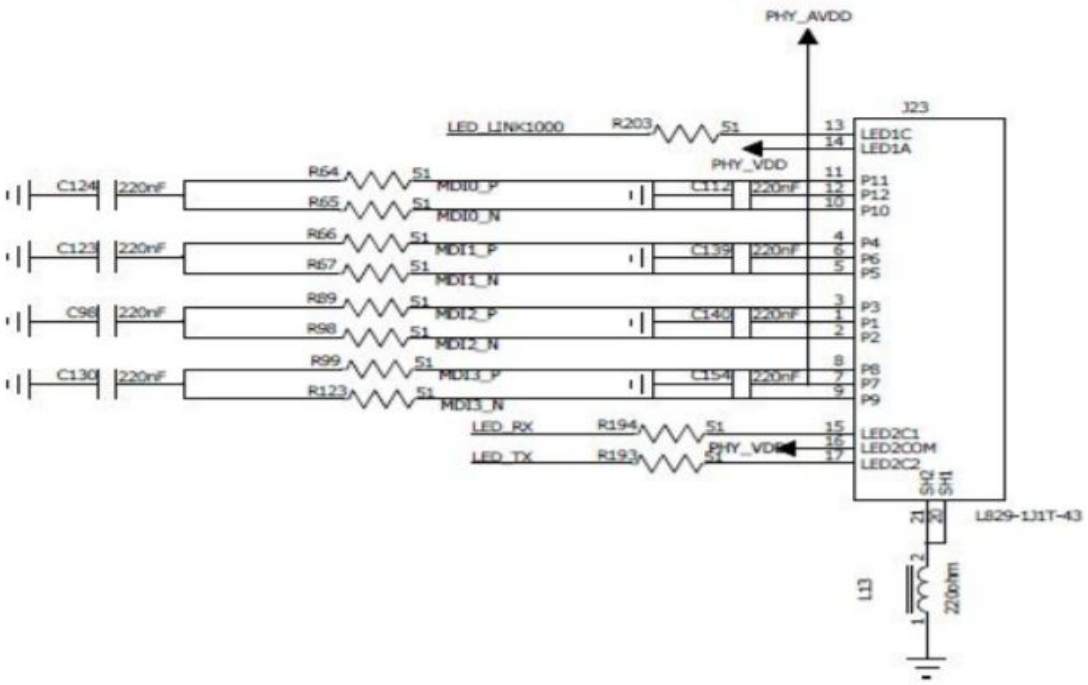
Wired Connections:

Wired connections are by far the most common network connections. The main media in use are coaxial cable, twisted pairs and fibre optics. *(Ref 2)*

Twisted Pair Cable:

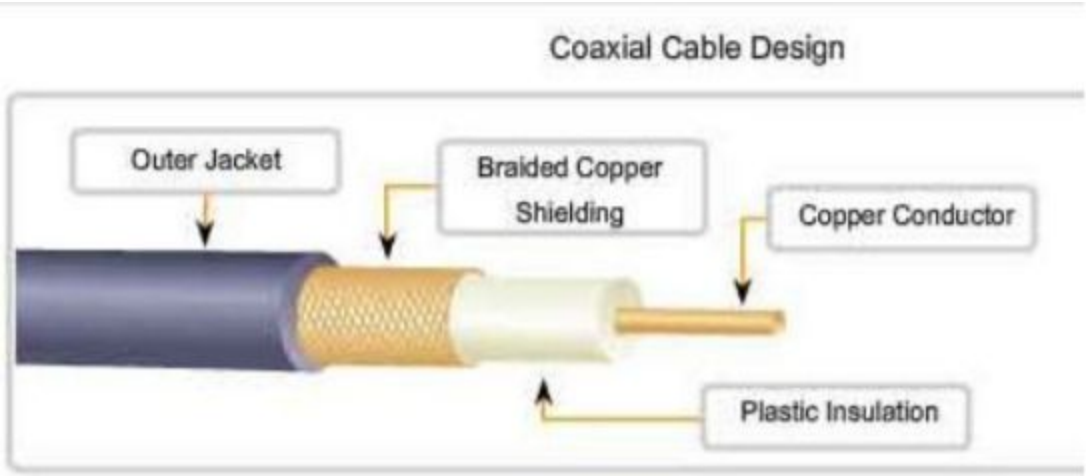


- An **Unshielded Twisted Pair (UTP)** cable is made of two plastic insulated copper wires twisted together to form a single media. Out of these two wires, only one carries the actual signal and another is used for ground reference. The twists between wires are helpful in reducing noise (electromagnetic interference) and crosstalk. The UTP cables are connected by **RJ45 connectors**. In a **Shielded Twisted Pair (STP) cable**, the twisted wire pair is additionally covered in a metal foil which increases the noise resistance.
- UTP is also the most common cable used in computer networking. **Modern Ethernet**, the most common data networking standard, can use UTP cables. Twisted-pair cabling is often used in data networks for **short and medium-length** connections because of its relatively lower costs compared to optical fibre and coaxial cable.



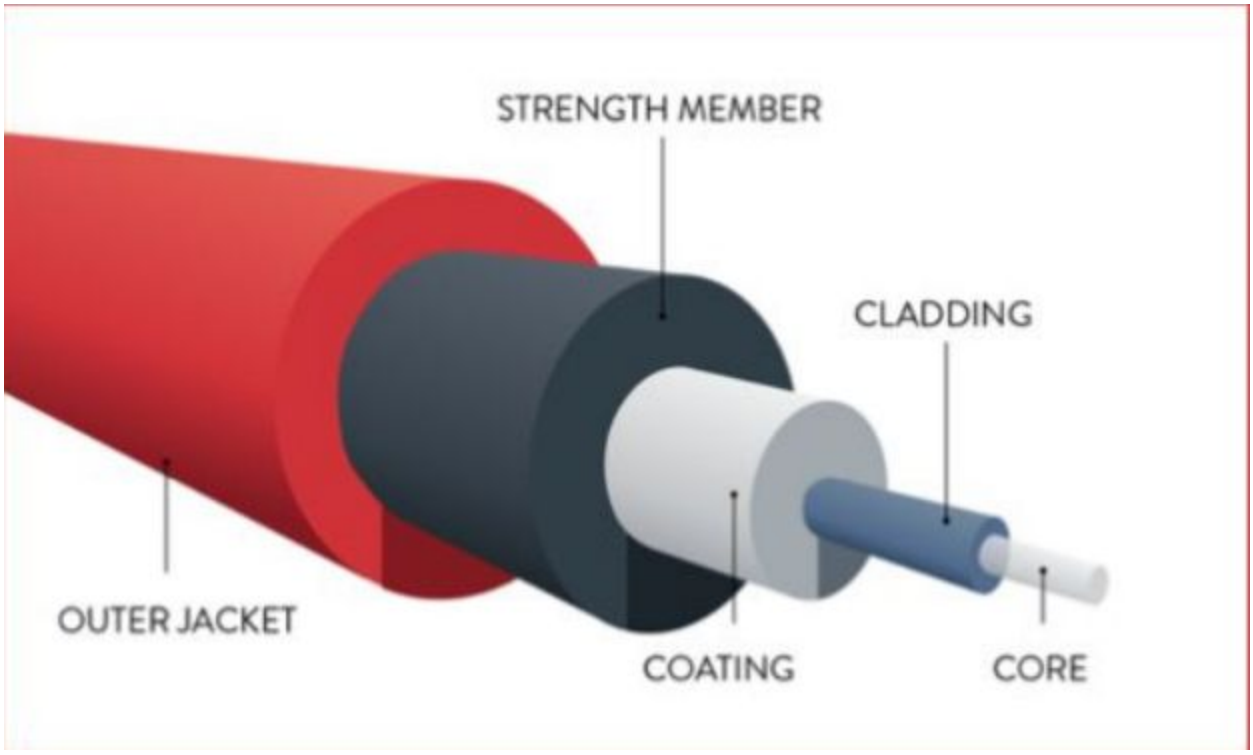
RJ45 connector schematic diagram

Coaxial Cable:



Coaxial cable is a type of transmission line, used to carry **high-frequency electrical signals** with low losses. It is used in such applications as **telephone trunk lines, broadband internet networking cables, high-speed computer data busses, cable television signals**, and connecting radio transmitters and receivers to their antennas. It differs from other shielded cables because the dimensions of the cable and connectors are controlled to give a precise, constant conductor spacing, which is needed for it to function efficiently as a transmission line.

Optical Fibre Cables:



- Fibre-optic cabling uses either **glass or plastic fibres** to guide light impulses from source to destination. The bits are encoded on the fibre as **light impulses**. Optical fibre cabling is capable of **very large raw data bandwidth rates**.
- Because light can only travel in one direction over optical fibre, **two fibres are required** to support **full duplex** operation.
- Optical fibre is used as a medium for telecommunication and computer networking because it is flexible and can be bundled as cables. It is especially advantageous for **long-distance communications** because infrared light propagates through the fibre with much **lower attenuation** compared to electrical cables. This allows long distances to be spanned with few repeaters.
- The per-channel light signals propagating in the fibre have been **modulated** at rates as high as **111 gigabits per second (Gbit/s)** by NTT, although **10 or 40 Gbit/s is typical** in deployed systems.

Ethernet: *(Ref 8,10,11)*

- 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.
- **Ethernet, IEEE 802.3,** is one of the most widely used standards for computer networking and general data communications. It is widely used in all forms of data networking from connecting to home Wi-Fi hubs to business data networks and telecommunications networking. From businesses to gamers, diverse end users depend on the benefits of Ethernet connectivity, which include reliability and security.
- Types of Ethernet:
    - There are several types of Ethernet networks, such as Fast Ethernet, Gigabit Ethernet, and Switch Ethernet.
    - The **Fast Ethernet** is a type of Ethernet network that can transfer data at a rate of 100 Mbps using a twisted-pair cable or a fibre-optic cable.
    - The **Gigabit Ethernet** is a type of Ethernet network capable of transferring data at a rate of 1000 Mbps based on a twisted-pair or fibre optic cable, and it is very popular.
    - Multiple network devices in a LAN require network equipments such as a network switch or hub. When using a network switch, a regular network cable is used instead of a crossover cable.
    - The main function of a network switch is to forward data from one device to another device on the same network. Thus a network switch performs this task efficiently as the data is transferred from one device to another without affecting other devices on the same network. The network switch normally supports

different data transfer rates. The most common data transfer rates include 10 Mbps – 100 Mbps for fast Ethernet, and 1000 Mbps – 10 Gbps for the latest Ethernet.

- **Switch Ethernet** uses a star topology, which is organized around a switch.

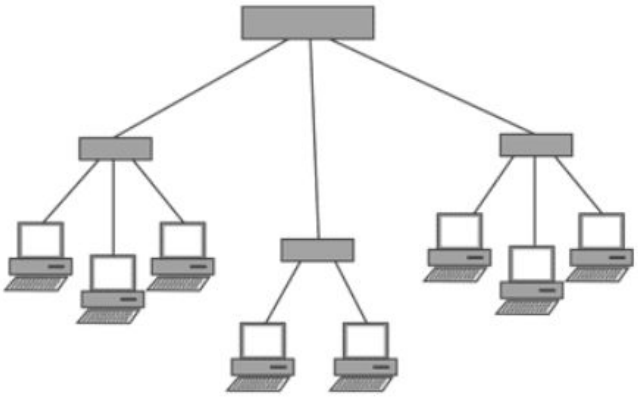
- Ethernet Specifications:
  - Ethernet uses **biphase modulation** to transmit data bits.
  - The original 10BASE5 Ethernet uses **coaxial cable** as a shared medium, while the newer Ethernet variants use **twisted pair** and **fibre optic links** in conjunction with switches. Over the course of its history, Ethernet data transfer rates have been increased from the original **2.94 megabits per second (Mbit/s)** to the latest **400 gigabits per second (Gbit/s).**
  - Other specifications are shown in the figures below.

LAN Technology Specifications

Name	IEEE Standard	Data Rate	Media Type	Maximum Distance
Ethernet	802.3	10 Mbps	10Base-T	100 meters
Fast Ethernet/ 100Base-T	802.3u	100 Mbps	100Base-TX 100Base-FX	100 meters 2000 meters
Gigabit Ethernet/ GigE	802.3z	1000 Mbps	1000Base-T 1000Base-SX 1000Base-LX	100 meters 275/550 meters 550/5000 meters
10 Gigabit Ethernet	IEEE 802.3ae	10 Gbps	10GBase-SR 10GBase-LX4 10GBase-LR/ER 10GBase-SW/LW/EW	300 meters 300m MMF/ 10km SMF 10km/40km 300m/10km/40km

Standard	IEEE 802.3 (1983 onwards)
Physical media	Coaxial cable, twisted pair, optical fiber
Network topology	Point-to-point, star, bus
Major variants	10BASE5, 10BASE2, 10BASE-T, 100BASE-TX, 1000BASE-T, 10GBASE-T
Maximum distance	100 m (328 ft) over twisted pair, up to 100 km over optical fiber
Mode of operation	differential (balanced), optical, single-ended
Maximum bit rate	1 Mbit/s to 400 Gbit/s
Voltage levels	± 2.5 V (over twisted pair)
Common connector types	8P8C, LC, SC, ST

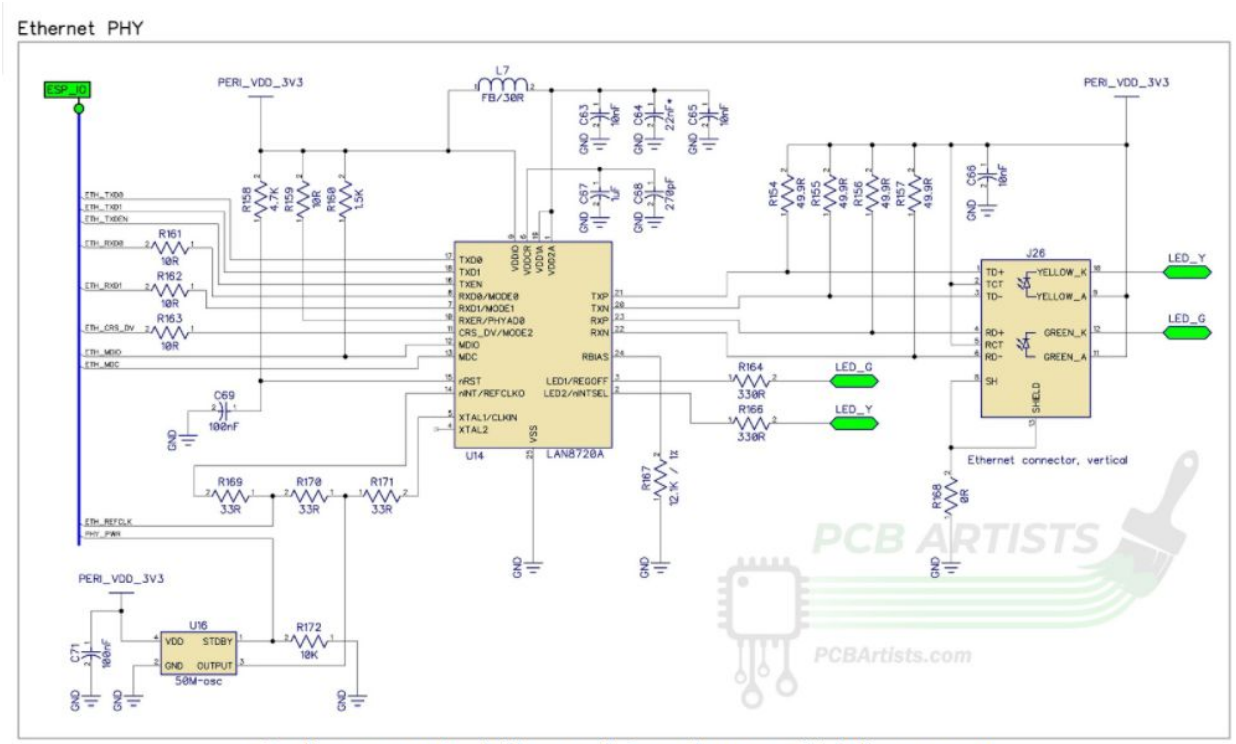
- Ethernet Topologies:
  - There are several network topologies that can be used for Ethernet communications. The actual form used will depend upon the requirements.
  - **Star network:** This type of Ethernet network has been the dominant topology



Star Topology

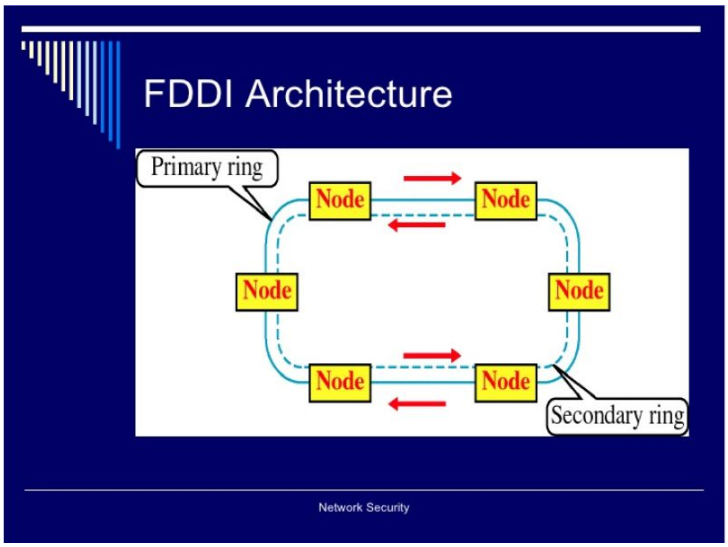
since the early 1990s. It consists of a central network unit, which may be what is termed a multiport repeater or hub, or a network switch.

- All the connections to other nodes radiate out from this and are point to point links. It is this type of network topology that is used and extended. Connections tend to extend out from a central hub using a series of routers or switches to divert the data to the required end node.
- Other topologies include **Point to Point** and **Coaxial Bus**.



Schematic View/Design of Ethernet

<u>Fiber Distributed Data Interface (FDDI):</u> ***(Ref 9)***



- **Fiber Distributed Data Interface** is a standard for data transmission in a local area network. It uses optical fibre as its standard underlying physical medium.
- Fiber Distributed Data Interface (FDDI) is a set of ANSI and ISO standards for transmission of data in **local area network (LAN)** over **fibre optic cables**. It is applicable in large LANs that can extend up to 200 kilometres in diameter.
- FDDI networks are typically used as backbones for **wide-area networks**. An FDDI network contains two **token rings**, The primary ring offers up to 100 Mbps capacity and the secondary ring is for possible backup in case the primary ring fails.
- FDDI has used mainly in mission critical and high traffic networks where large amounts of data flow need to flow quickly and efficiently. FDDI is used anywhere that utilizes a large network in need of high bandwidth.
- 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.
- Infrared light propagates through the fiber with much **lower attenuation** compared to electrical cables. This allows long distances to be spanned with few repeaters. Fiber is also immune to electrical interference; there is no **cross-talk** between signals in different cables and no pickup of environmental **noise**. Non-armored fiber cables do not conduct electricity, which makes fiber a good solution for protecting communications equipment in high voltage environments, such as power generation facilities, or metal communication structures prone to lightning strikes, and also preventing problems with **ground loops**. They can also be used in environments where explosive fumes are present, without danger of **ignition**, and **wiretapping** is more difficult compared to electrical connections
- Different types of cable are used for different applications, for example, l**ong distance telecommunication**, or providing a **high-speed data connection** between different parts of a building. Digital global networks require huge carrying capacity in the main backbones which is currently achieved by fiber optic cables. In September 2012, NTT Japan demonstrated a single fiber cable that was able to transfer **1 petabit per second** (10 15bits/s) over a distance of **50 kilometers**. Modern fiber cables can contain up to a thousand fibers in a single cable, with potential **bandwidth** in the **terabytes per second**. In some cases, only a small fraction of the fibers in a cable may be actually "lit". Companies can lease or sell the unused fiber to other providers who are looking for service in or through an area.

Wireless Connections: *(Ref 3,7)*

- A wireless network uses high-frequency radio waves rather than wires to communicate between nodes.
- Wireless allows for devices to be shared without networking cable which increases mobility but decreases range. There are two main types of wireless networking: **peer to peer or ad-hoc** and **infrastructure**.
- An **ad-hoc or peer-to-peer wireless network** consists of a number of computers each equipped with a wireless networking interface card. Each computer can communicate directly with all of the other wireless-enabled computers.
- An **infrastructure wireless network** consists of an access point or a base station. In this type of network, the access point acts as a hub, providing connectivity for wireless computers.

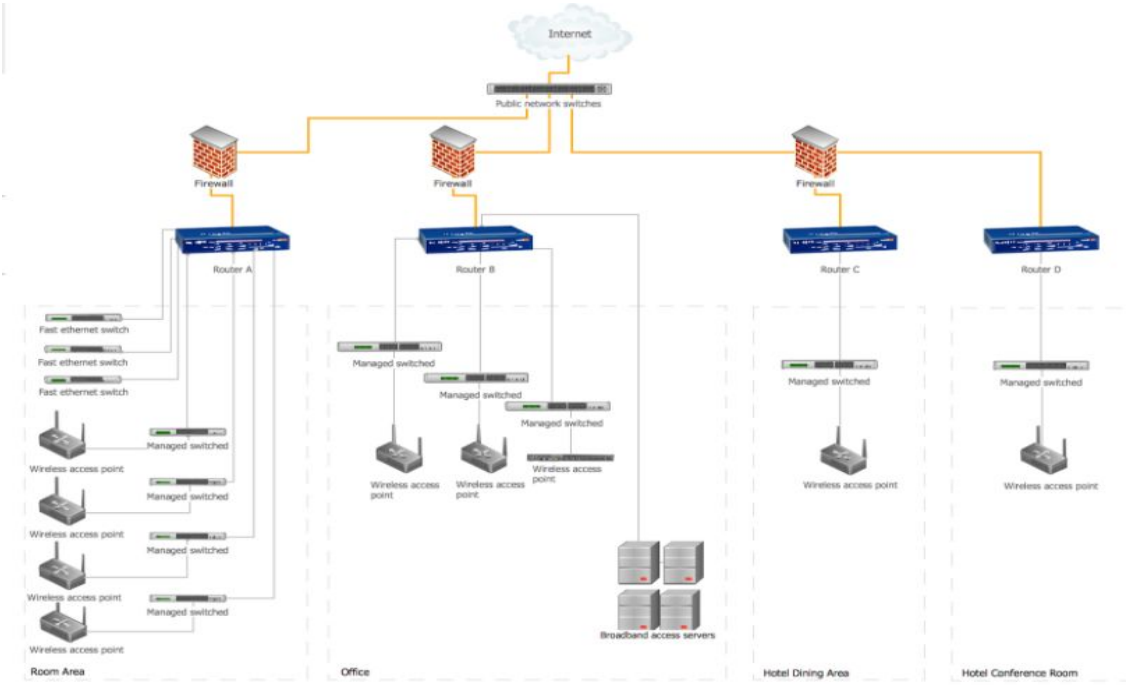
Wi-Fi: *(Ref 5,6,12)*

- **Wi-Fi** is the most popular type of network connection nowadays. Unlike wired connection types, such as Ethernet, it does not require a physical cable to be connected, data is transmitted through wireless signals.
- Wi-Fi is a term for certain types of **wireless local area networks (WLAN)** that use specifications in the 802.11.
- 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)**.
- The 802.11 standard provides several distinct radio frequency ranges for use in **Wi-Fi communications: 900 MHz, 2.4 GHz, 5 GHz, 5.9 GHz, and 60 GHz bands.** An access point (or hotspot) often has a range of about **20 metres indoors** while some modern access points claim up to a **150-metre range outdoors**. Hotspot coverage can be as small as a single room with walls that block radio waves, or as large as many square kilometres using many overlapping access points with roaming permitted between them. Over time the speed and spectral efficiency of Wi-Fi have increased. As of 2019, at close range, some versions of Wi-Fi, running on suitable hardware, can achieve speeds of over **1 Gbit/s**.
- There are several specifications in the 802.11 family −

- 802.11 − This pertains to wireless LANs and provides 1 - or 2-Mbps transmission in the 2.4-GHz band using either frequency-hopping spread spectrum (FHSS) or direct-sequence spread spectrum (DSSS).
- 802.11a − This is an extension to 802.11 that pertains to wireless LANs and goes as fast as 54 Mbps in the 5-GHz band. 802.11a employs the orthogonal frequency division multiplexing (OFDM) encoding scheme as opposed to either FHSS or DSSS.
- 802.11b − The 802.11 high rate WiFi is an extension to 802.11 that pertains to wireless LANs and yields a connection as fast as 11 Mbps transmission (with a fallback to 5.5, 2, and 1 Mbps depending on strength of signal) in the 2.4-GHz band. The 802.11b specification uses only DSSS. Note that 802.11b was actually an amendment to the original 802.11 standard added in 1999 to permit wireless functionality to be analogous to hard-wired Ethernet connections.
- 802.11g − This pertains to wireless LANs and provides 20+ Mbps in the 2.4-GHz band.
- A wireless network uses radio waves, just like cell phones, televisions and radios do. In fact, communication across a wireless network is a lot like two-way radio communication. Here's what happens:
    - A computer's wireless adapter translates data into a radio signal and transmits it using an antenna.
    - A wireless router receives the signal and decodes it. The router sends the information to the Internet using a physical, wired Ethernet connection.
    - The process also works in reverse, with the router receiving information from the Internet, translating it into a radio signal and sending it to the computer's wireless adapter.

- Wi-Fi (Wireless Fidelity) Specifications:

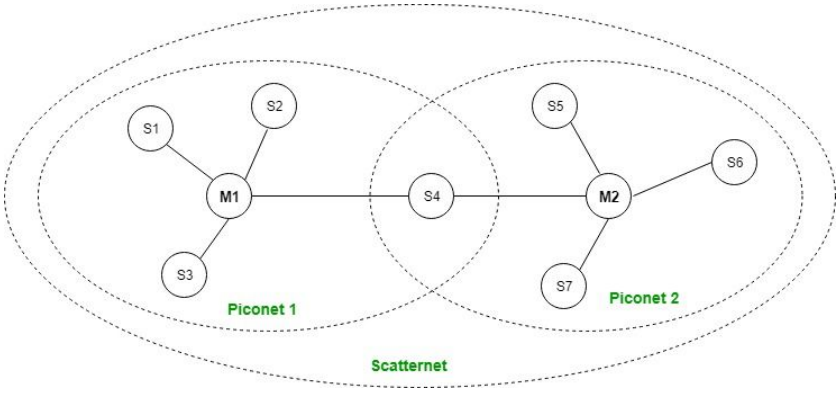
Feature	WiFi (802.11b)	WiFi (802.11a/g)
PrimaryApplication	Wireless LAN	Wireless LAN
Frequency Band	2.4 GHz ISM	2.4 GHz ISM (g) 5 GHz U-NII (a)
Channel Bandwidth	25 MHz	20 MHz
Half/Full Duplex	Half	Half
Radio Technology	Direct Sequence Spread Spectrum	OFDM (64-channels)
Bandwidth	<=0,44 bps/Hz	≤=2.7 bps/Hz
Efficiency		
Modulation	QPSK	BPSK, QPSK, 16-, 64-QAM
FEC	None	Convolutional Code
Encryption	Optional- RC4m (AES in 802.11i)	Optional- RC4(AES in 802.11i)
Mobility	In development	In development
Mesh	Vendor Proprietary	Vendor Proprietary
Access Protocol	CSMA/CA	CSMA/CA



Wireless Access Point Topology

Bluetooth: *(Ref 4,15)*

- 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).**



- Maximum devices that can be connected at the same time are 7. Bluetooth ranges up to 10 meters. It provides data rates up to 1 Mbps or 3 Mbps depending upon the version. The spreading technique which it uses is FHSS (Frequency-hopping spread spectrum). A Bluetooth network is called piconet and a collection of interconnected piconets is called scatternet.
- 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. A manufacturer must meet Bluetooth SIG standards to market it as a Bluetooth device.

Class	Max. permitted power		Typ. range (m)
	(mW)	(dBm)	
1	100	20	~100
1.5 (BT 5 Vol 6 Part A Sect 3)	10	10	~20
2	2.5	4	~10
3	1	0	~1
4	0.5	−3	~0.5

Zigbee: *(Ref 13)*

- **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. Hence, Zigbee is a low-power, low data rate, and close proximity (i.e., personal area) **wireless ad hoc network**.
- 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.
- Zigbee has a defined rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

Cellular Network:

- A cellular network or mobile network is a **radio network** distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell site or base station. In a cellular network, each cell characteristically uses a different set of radio frequencies from all their immediate neighbouring cells to avoid any interference.
- When joined together these cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers (e.g., mobile phones, pagers, etc.) to communicate with each other and with fixed transceivers and telephones anywhere in the network, via **base stations**, even if some of the transceivers are moving through more than one cell during transmission.
- Although originally intended for cell phones, with the development of smartphones, cellular telephone networks routinely carry data in addition to telephone conversations:

  ○ **Global System for Mobile Communications (GSM)**: The GSM network is divided into three major systems: the switching system, the base station system, and the operation and support system. The cell phone connects to the base system station which then connects to the operation and support station; it then connects to the switching station where the call is transferred to where it needs to go. GSM is the most common standard and is used for a majority of cell phones.

  ○ **Personal Communications Service (PCS)**: PCS is a radio band that can be used by mobile phones in North America and South Asia. Sprint happened to be the first service to set up a PCS.

  ○ **D-AMPS**: Digital Advanced Mobile Phone Service, an upgraded version of AMPS, is being phased out due to advancement in technology. The newer GSM networks are replacing the older system.

CONCLUSION:

Through this experiment, I learnt the different types of wireless and wired connections of the physical layer of the OSI Model.

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