Experiment 1

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Aim:

To study different types of physical layer wired/wireless connections

Theory:

In the seven-layer OSI model of computer networking, the physical layer or layer 1 is the first and lowest layer. It defines the means of transmitting raw bits over a physical data link connecting network nodes. It provides an electrical, mechanical, and procedural interface to the transmission medium. The shapes and properties of the electrical connectors, the frequencies to broadcast on, the line code to use and similar low-level parameters, are specified by the physical layer.

Physical layer elements are broadly classified into two categories: wired and wireless.

Wired connections:

1. USB cable

   USB stands for Universal Serial Bus. It is an industry standard that establishes specifications for cables and connectors. USB cables have plugs, and the corresponding receptacles are on the computers or electronic devices. In common practice, the A end is usually the standard format, and the B side varies over standard, mini, and micro.

   - Specifications

     Physical Design:

     - Based on the physical design of the USB plugs and ports, the three different types are USB A, USB B, and USB C. [1] [2]
     - Based on the functionality of USB connectors, there are three generations of USB cable. The specifications are broken down according to functionality:

     Data transfer rates: [3]

     - USB 1.0 (Low-Speed): 1.5Mbps
     - USB 2.0 (Hi-Speed): 480 Mbps
     - USB 3.0 (SuperSpeed): 10Gbps

Range: [4]

- USB 1: 3 meters (9 feet 10 inches)
- USB 2: 5 meters (16 feet 5 inches)
- USB 3: 3 meters (9 feet 10 inches)

Compatibility:

- USB 2 cables are backwards compatible with USB 1 cables; hence they work fine with any USB 1 devices. However, the transfer rates will be limited to the low speeds of USB 1
- USB 3 cables are backwards compatible with USB 1 and USB 2 cables; hence they work fine with any USB 1 or USB 2 devices. However, the transfer rates will be limited to the low speeds of USB 1 or high speeds of USB 2, whichever they are used with

Power Output: [5]

- USB 1: 2.5V, 500mA
- USB 2: 2.5V, 1.8A
- USB 3: 5V, 1.8A

Modulation:

All functional treatment for needs device control by the help of pulse-width modulation. Currently, due to precise keeping of necessary norms for all suitable kinds of universal serial bus device, a Universal serial bus digital binary values control pulse width modulation utility Device Firmware compatible with most of operating systems is being developed.

- Scalability

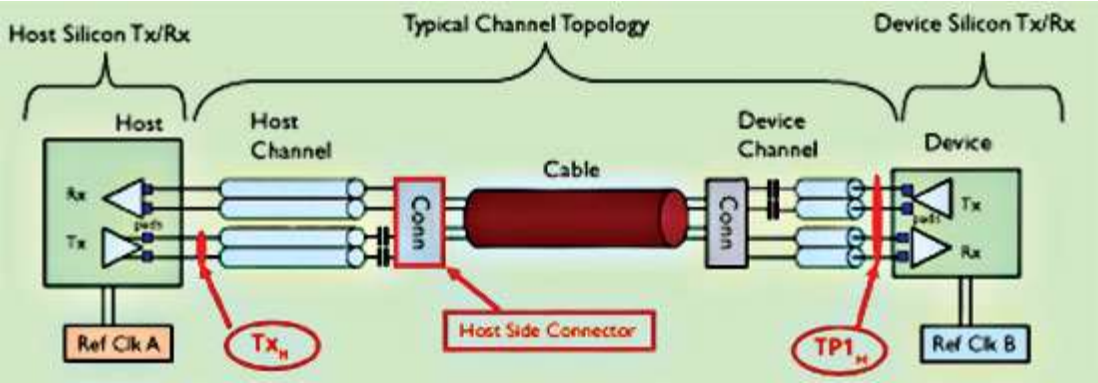
  The USB is controlled by a host; there can be multiple peripherals but only one host per bus. The host can be taken as master and peripheral as slaves, whereby the former is responsible for managing the connection, transactions, and scheduling bandwidth. The USB system uses tiered start topology. It consists of 7-bit addressing; this means it can support up to 127 devices at once. [7]

  As mentioned above, the length of USB cables ranges from 3 to 5 meters. However, using active (repeater) cables can extend the range of use. The maximum recommended lengths of USB repeater cables are as follows:

  - USB 1: 18 meters (59 feet) [6]
  - USB 2: 30 meters (98 feet 5 inches)
  - USB 3: 18 meters (59 feet)

Since USB cables are not very scalable, their use is limited to home applications (Home Area Network or HAN) where they can be used for personal use and device interaction like phone to laptop, laptop to laptop, phone to phone, etc.

- Schematic View



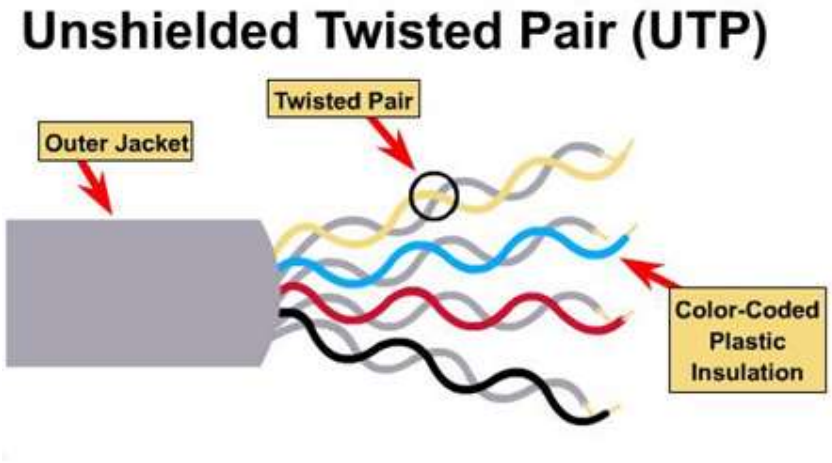
2. Twisted Pair Copper Cables

Twisted-pair cable is the most common type of cabling you can see in today's Local Area Networks (LAN) networks. A pair of wires forms a circuit that can transmit data. The pairs are twisted to provide protection against crosstalk. Crosstalk is the undesired signal noise generated by the electromagnetic fields of the adjacent wires. [8]

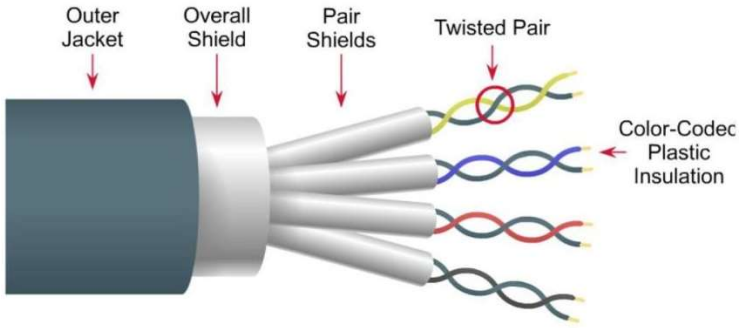
The two types of twisted pair cables widely used are:

- Unshielded twisted pair:

  Unshielded Twisted Pair (UTP) cable is the most common networking media. 'Unshielded' meaning it does not rely on physical shielding to block interference. Unshielded Twisted Pair (UTP) consists of four pairs of thin, copper wires covered in color-coded plastic insulation that are twisted together. The wire pairs are then covered with a plastic outer jacket. UTP cables are of small diameter and it does not need grounding. Since there is no shielding for UTP cabling, it relies only on "cancellation" to avoid noise. It is the more commonly used cable of the two, often utilized for both residential and business use. There are several UTP categories, which increase in bandwidth as you move up the scale, for example: CAT1 = up to 1Mbps | CAT2 = up to 4 Mbps | CAT5e = up to 1Gbps



- Shielded twisted pair:
  Shielded Twisted Pair (STP) cables additionally have an overall conducting metallic shields covering four twisted pair wires. There may be another conducting metallic shields covering individual twisted pairs also. These metallic shields block out electromagnetic interference to prevent unwanted noise from the communication circuit. Drain wires are also used in Shielded Twisted Pair (STP) cables together with metallic shields for grounding purpose. The drain wire provides a low-resistance connection to shield for better grounding. The main purpose of drain wire is to carry away unwanted interference noise to ground.



- Specifications
  Range:
  Up to 100 meters

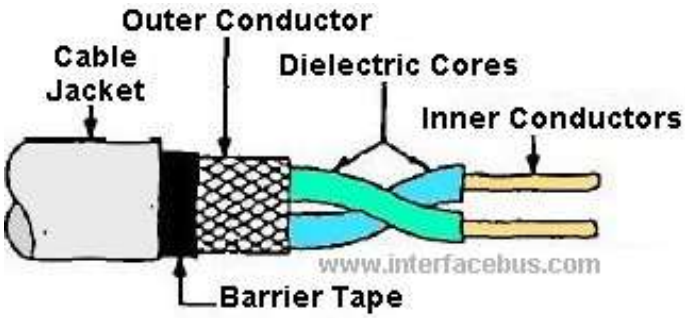
  Bandwidth:
  Up to 750 MHz

Modulation:
Line coding is used here. Line coding is the modulation of an electrical charge so that each side of a connection knows what is a one and what is a zero.

Data Transfer Rates:
Twisted pair cables can reach transfer rates of over 1000 Mbps (1 Gbps).

- Scalability
  It is a scalable LAN architecture.

- Schematic View



3. Ethernet

Ethernet is a family of computer networking technologies commonly used in local area networks (LAN), metropolitan area networks (MAN) and wide area networks (WAN). It is widely used in homes and industry, and interworks well with Wi-Fi. The Internet Protocol is commonly carried over Ethernet and so it is considered one of the key technologies that make up the Internet. [9]

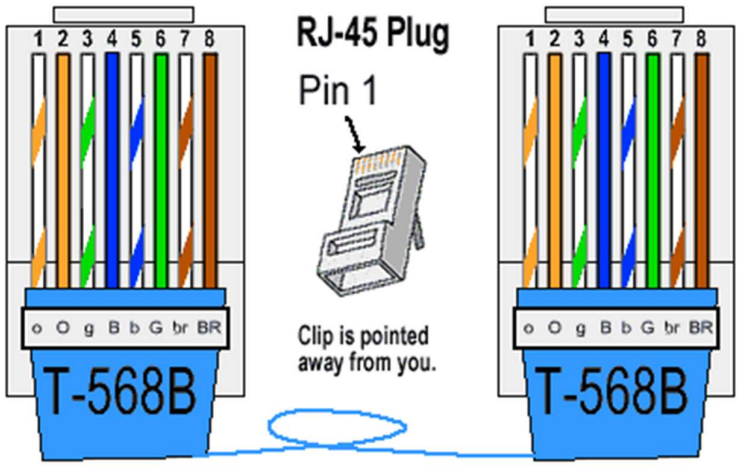
- Specifications
  Range:
  The physical medium ranges from bulky coaxial cable to twisted pair and optical fiber with a standardized reach of up to 40 km.

  Modulation:
  Most forms of Ethernet use pulse amplitude modulation (PAM) constellations. In PAM signal modulation, information is encoded in the amplitude of a series of signal pulses.

Data Transfer Rates:
The Ethernet physical encompasses multiple physical media interfaces and several orders of magnitude of speed from 1 Mbit/s to 400 Gbit/s.

- Scalability [10]
  Ethernet is a communication protocol for Local Area Network (LAN) using same media interfaces (mainly RJ45 or fiber). LAN are independent networks but may be linked within a WAN through Internet devices such as Routers.

- Schematic View



4. Fiber Distributed Data Interface
   Fiber Distributed Data Interface (FDDI) is a standard for data transmission in a local area network. It uses optical fiber as its standard underlying physical medium, although it was also later specified to use copper cable, in which case it may be called CDDI (Copper Distributed Data Interface). [11]
   - Specifications
     Medium:
     FDDI uses optical fiber as its physical medium.

     Range:
     200 kilometers

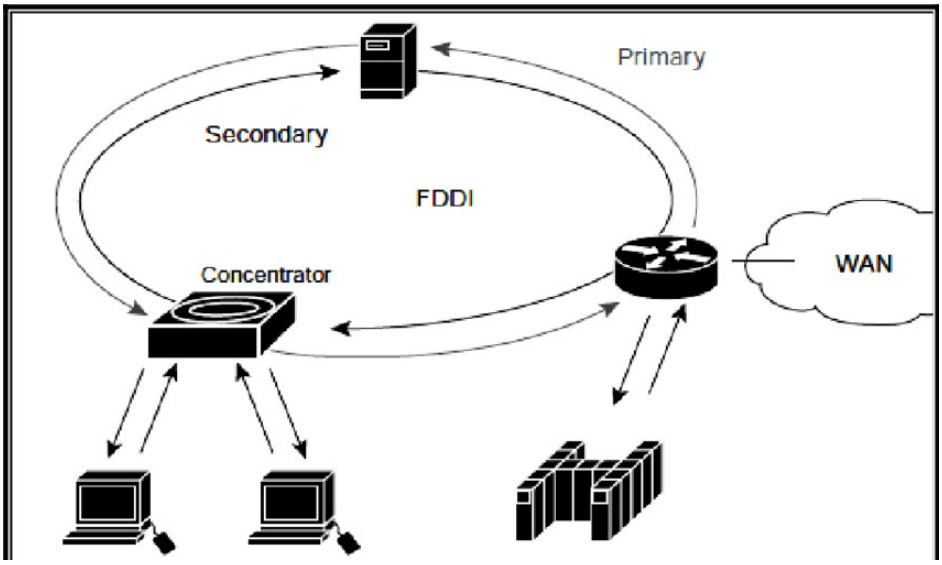
     Bandwidth:
     100Mbps

Data Transfer Rate:
FDDI can transport data at a rate of 100 Megabits per second.

Stations:
FDDI can support up to 500 stations on a single network.
Modulation:
FDDI Transmission on optical fiber is done through Intensity Modulation, that is, the optical power output of a source is varied in accordance with some characteristic of the modulating signal.

- Scalability [12]
  Fiber Distributed Data Interface (FDDI) is usually implemented as a dual token-passing ring within a ring topology (for campus networks) or star topology (within a building). It is applicable in large LANs that can extend up to 200 kilometers in diameter. FDDI is not often used as a wide area network (WAN) solution but is more often implemented in campus-wide networks as a network backbone. Typically, a computer-room contained the whole dual ring, although some implementations deployed FDDI as a metropolitan area network.
  FDDI was effectively made obsolete in local networks by Fast Ethernet which offered the same 100 Mbit/s speeds, but at a much lower cost and, since 1998, by Gigabit Ethernet due to its speed, and even lower cost, and ubiquity.

- Schematic View



Wireless connections:

1. Infrared networking

   Infrared (IR) is a wireless mobile technology used for device communication over short ranges. IR communication has major limitations because it requires line-of-sight, has a short transmission range and is unable to penetrate walls. IR transceivers are quite cheap and serve as short-range communication solutions. [13]

   - Specifications

     Range:

     Infrared communications span only short distances. When networking two infrared devices, they must be within a few feet of each other. Unlike Wi-Fi and Bluetooth technologies, infrared network signals cannot penetrate walls or other obstructions and work only within a direct line of sight. Anything that blocks that direct line between two IR devices also blocks IR communication.

     Modulation:

     All modern infrared remote-control designs use digital modulation. Two basic digital modulation technologies are Amplitude Shift Keying (ASK) and Frequency Shift Keying (FSK). ASK represents logic 1 and 0 by changing the carrier amplitude, and FSK represents these logic levels using two different carrier frequencies.

     Security:

     Infrared communication has high directionality and can identify the source as different sources emit radiation of different frequencies and thus the risk of information being diffused is eliminated.

     Data Transfer Rate: [15]

     Infrared technology uses in local networks exists in three forms that the Infrared Data Association (IrDA) recognizes:

     - IrDA-SIR: Slow-speed infrared that supports data rates up to 115 Kbps.
     - IrDA-MIR: Medium-speed infrared that supports data rates up to 1.15 Mbps.
     - IrDA-FIR: High-speed infrared that supports data rates up to 4 Mbps.

Usage:

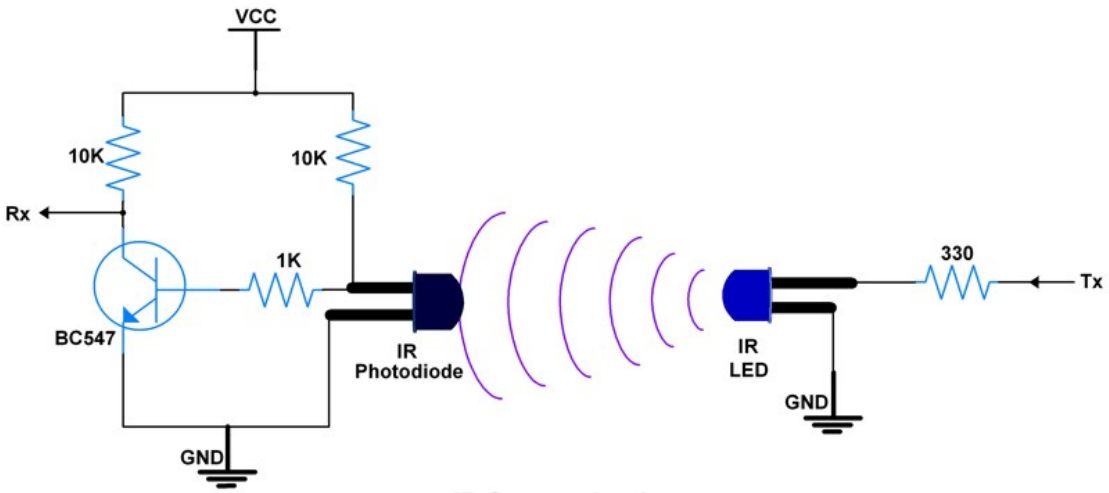
Computer infrared network adapters both transmit and receive data through ports on the rear or side of a device. Many laptops and personal hand-held devices had infrared adapters installed.

Infrared networks support direct two-computer connections only. Extensions to infrared technology, however, support more than two computers and semi-permanent networks.

- Scalability [14] [16]

  Infrared communications span only short distances of up to two feet and can only be successfully implemented when there is no object blocking the direct line between the two IR devices. As such, Infrared technology is not scalable and is only used in home applications (HAN).

- Schematic View



IR Communication

2. Z Wave

Z Wave is a wireless communications protocol used primarily for home automation. It is a mesh network using low-energy radio waves to communicate from appliance to appliance, allowing for wireless control of residential appliances and other devices, such as lighting control, security systems, thermostats, windows, locks, swimming pools and garage door openers. [18]

- Specifications

  Latency:

  Low latency transmission of small data packets (data rates up to 100kbit/s)

Range of use:
About 30 meters between nodes (40 meters with 500 series chip), message ability to hop up to four times between nodes, giving enough coverage for most residential houses

Modulation:
Modulation is frequency-shift keying (FSK) with Manchester encoding

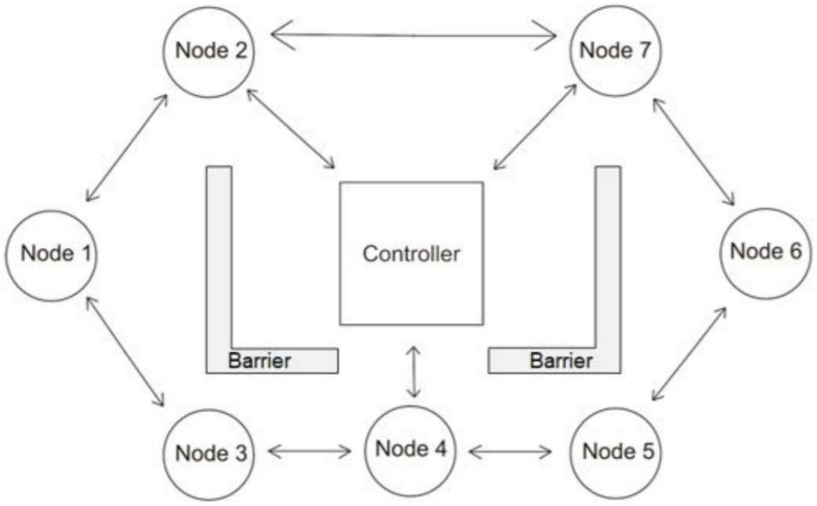
Frequency of operation:
868.42 MHz in Europe, at 908.42 MHz in North America, 865.2 MHz in India

Throughput:
40kbit/s, suitable for control and sensor applications

Data rates:
Include 9600 bps and 40 kbps with output power at 1mW or 0 dBm

- Scalability
  Z-Wave can be used within a network (Home Area Network or HAN) and can therefore be used to set up all areas of home automation. Possibly controlled by a single controller.
  A mesh topology allows any node to connect to any other node and allows multiple connections.
  A node must be in the range of another node and can communicate with adjacent nodes. A packet can hop over 4 nodes which effectively limits the distance between a controller and the farthest node.
  A node can forward packets to the adjacent nodes. However, to act as a forwarding node the node must be mains powered. Battery-powered nodes cannot forward packets.

- Schematic View



3. Li-Fi

Li-Fi (short for light fidelity) is wireless communication technology which utilizes light to transmit data and position between devices. In technical terms, Li-Fi is a light communication system that is capable of transmitting data at high speeds over the visible light, ultraviolet, and infrared spectrums. In its present state, only LED lamps can be used for the transmission of visible light. [19]

- Specifications

  Spectrum:

  Li-Fi uses visible light of electromagnetic spectrum between 400 THz and 800 THz as optical carrier for data transmission and illumination.

  Data Transfer:

  Communication rate more than 100 Mbps can be achieved by using high speed LEDs with the help of various multiplexing techniques. And this VLC data rate can be further increased to as high as 10 Gbps via parallel data transmission using an array of LED lights with each LED transmitting a different data stream.

  Layers:

  IEEE 802.15.7 defines physical layer (PHY) & media access control (MAC) layer for VLC/Li-Fi.

  Modulation: [20]

  The physical layer is divided into 3 types: PHY I, II, III and employ a combination of different modulation schemes.

- The PHY I was established for outdoor application and works from 11.67 kbps to 267.6 kbps.
- The PHY II layer permits reaching data rates from 1.25 Mbit/s to 96 Mbit/s.
- The PHY III is used for many emissions sources with a modulation method called colour shift keying (CSK). PHY III can deliver rates from 12 Mbit/s to 96 Mbit/s.
- The modulation formats recognized for PHY I and PHY II are on-off keying (OOK) and variable pulse position modulation (VPPM).
- The Manchester coding used for the PHY I and PHY II layers includes the clock inside the transmitted data by representing a logic 0 with an OOK symbol "01" and a logic 1 with an OOK symbol "10", all with a DC component.
- The DC component avoids light extinction in case of an extended run of logic 0's.

Range:

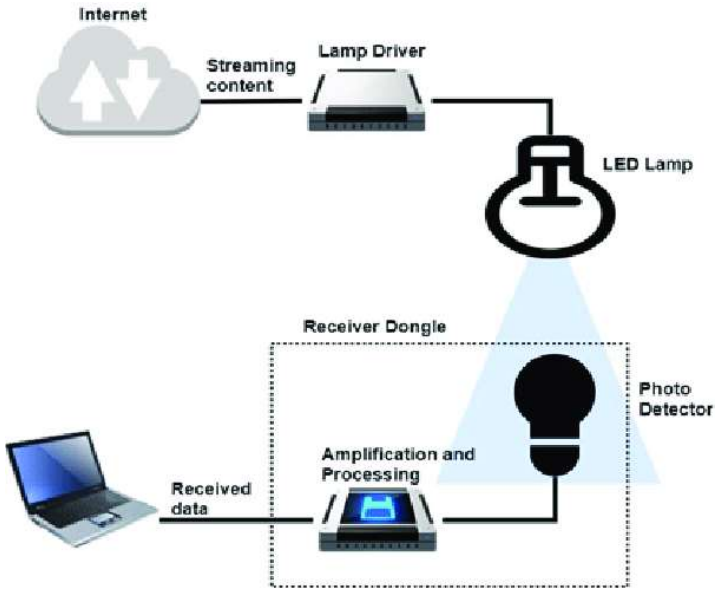
Light waves do not penetrate through walls and so Li-Fi has a much shorter range than Wi-Fi. The main purpose of VLC standard is to focus on medium-range communications for intelligent traffic systems at low-speed and on shortrange mobile to mobile and fixed to mobile communications at high speeds to exchange data. The range of Li-Fi depends on Light Intensity. It has a range of around 10 meters.

- Scalability [21]

  Li-Fi provides a stable data rate per user, providing robust, reliable wireless communication – something that Wi-Fi can struggle with as the radio spectrum becomes congested. Li-Fi provides an extra level of security as light cannot penetrate walls. The connection must be within line of sight and is enabled with a personal USB access key. Li-Fi offers scalable capabilities for up to 15 users within the coverage beam of one light point.

  Since access to a Li-Fi channel is limited to devices inside the room, it is predicted to mainly be used in future home applications. Hence, Li-Fi is a Home Area Network (HAN) interface. However, with new research going on, the applications can extend to vehicles, industrial and building automation, underwater applications, aviation, hospitals, advertising, and education.

- Schematic View



4. Wi-Fi (WLAN)

A wireless LAN (WLAN) is a wireless computer network that links two or more devices using wireless communication to form a local area network (LAN) within a limited area such as a home, school, computer laboratory, campus, or office building. This gives users the ability to move around within the area and remain connected to the network. Most modern WLANs are based on IEEE 802.11 standards and are marketed under the Wi-Fi brand name. [22]

- Specifications

  Range:

  Within a limited area such as a home, school, computer laboratory, campus, or office building. A typical wireless router in an indoor point-to-multipoint arrangement using 802.11n and a stock antenna might have a range of 50 meters (160 ft) or less. Outdoor point-to-point arrangements, through use of directional antennas, can be extended with many kilometers between stations. [22]

  Modulation: [23]

  Wi-Fi systems use two primary radio transmission techniques:

  - 802.11b (<=11 Mbps):

    The 802.11b radio link uses a direct sequence spread spectrum technique called complementary coded keying (CCK). The bit stream is processed with a special coding and then modulated using Quadrature Phase Shift Keying (QPSK).

- 802.11a and g (<=54 Mbps):
  The 802.11a and g systems use 64-channel orthogonal frequency division multiplexing (OFDM). In an OFDM modulation system, the available radio band is divided into several sub-channels and some of the bits are sent on each. The transmitter encodes the bit streams on the 64 subcarriers using Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), or one of two levels of Quadrature Amplitude Modulation (16, or 64-QAM). Some of the transmitted information is redundant, so the receiver does not have to receive all the sub-carriers to reconstruct the information.

Wi-Fi uses adaptive modulation and varying levels of forward error correction to optimize transmission rate and error performance. As a radio signal loses power or encounters interference, the error rate will increase. Adaptive modulation means that the transmitter will automatically shift to a more robust, though less efficient, modulation technique in those adverse conditions.

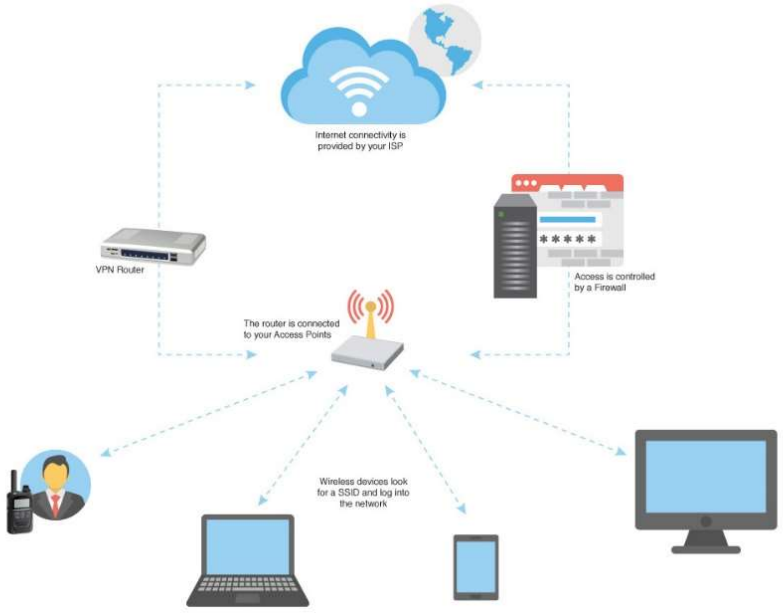
Frequencies:
Various frequencies, including, but not limited to, 2.4 GHz, 5 GHz, 6 GHz, and 60 GHz frequency bands. [24]

Data Transfer Rates
- 802.11b:
  1, 2, 5.5, 11Mbps
- 802.11a:
  6, 9, 12, 18, 24, 36, 48, 54 Mbps
- 802.11g:
  Varying modulation types: 6, 9, 12, 18, 24, 36, 48 and 54 Mbps; can revert to 1, 2, 5.5, and 11 Mbps using DSSS and CCK.
- 802.11n:
  1, 2, 5.5, 6, 9, 11, 12, 18, 24, 36, 48, 54 Mbps

- Scalability [25]
  Wi-Fi is intended for LAN applications, users scale from one to tens with one subscriber for each CPE device. Fixed channel sizes (20MHz). It has a limited area to cover. When Wi-Fi is scaled beyond Local Area Network, several problems arise:
  - WLAN uses radio frequency which can interfere with other devices which use radio frequency.

- The radiation of WLAN can be harmful to the environment.
- If there is rain or thunder, then communication may get interrupted.
- Signals may be affected by the environment as compared to using fiber optics.

- Schematic View



Conclusion:

- I have researched about the various types of wired and wireless physical interfaces.
- Based on range, data transfer rates, scalability and network architecture, there is a wide variety of physical interfaces available, which cater to almost every type of application.
- Some technologies have become obsolete because of the discovery of newer and better technologies, and research is being done on even better network interfaces. This shows that this field is continuously evolving.

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Li-Fi

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