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Experiment 1

Aim:

Study of different types of physical layer wired/wireless connections
As a part of study you must include following aspects of connection
- Specifications including range, modulation etc.
- Scalability showing their applicability in various network architecture e.g LAN, WAN, MAN, HAN etc.
- Provide Schematic view of physical connector

Introduction:

Physical layer in the OSI model plays the role of interacting with actual hardware and signaling mechanism. It is the lowest level in the OSI model. 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.

Physical layer provides its services to Data-link layer. Data-link layer hands over frames to physical layer. Physical layer converts them to electrical pulses, which represent binary data.The binary data is then sent over the wired or wireless media.

Transmission media:

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

Guided Media:

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

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.

Following are the various functions performed by the Physical layer of the OSI model.

1. **Representation of Bits:** Data in this layer consists of stream of bits. The bits must be encoded into signals for transmission. It defines the type of encoding i.e. how 0's and 1's are changed to signal.
2. **Data Rate:** This layer defines the rate of transmission which is the number of bits per second.
3. **Synchronization:** It deals with the synchronization of the transmitter and receiver. The sender and receiver are synchronized at bit level.
4. **Interface:** The physical layer defines the transmission interface between devices and transmission medium.
5. **Line Configuration:** This layer connects devices with the medium: Point to Point configuration and Multipoint configuration.
6. **Topologies:** Devices must be connected using the following topologies: Mesh, Star, Ring and Bus.
7. **Transmission Modes:** Physical Layer defines the direction of transmission between two devices: Simplex, Half Duplex, Full Duplex.

Types of Physical Layers Connection:

Wired:

1) Twisted Pair Copper Cables[1]:

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.

When a wire is carrying a current, the current creates a magnetic field around the wire. This field can interfere with signals on nearby wires. To eliminate this, pairs of wires carry signals in opposite directions, so that the two magnetic fields also occur in opposite directions and cancel each other out. This process is known as cancellation.

Color codes used for Twisted Pair wire's plastic insulation are Orange, Orange-White, Blue, Blue-White, Green, Green-White, Brown and Brown-White.

Twisted pair cables are the most cost-effective option of the three due to their lower bandwidth capacity and high attenuation.

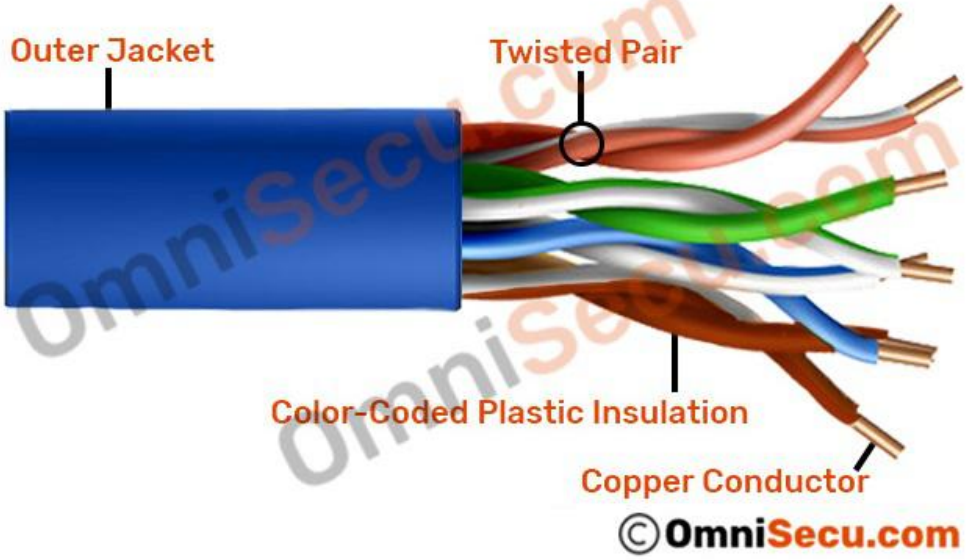
Two types of twisted pair cables are Unshielded Twisted Pair (UTP) and Shielded Twisted Pair (STP).

- 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 doesn't 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

Schematic view

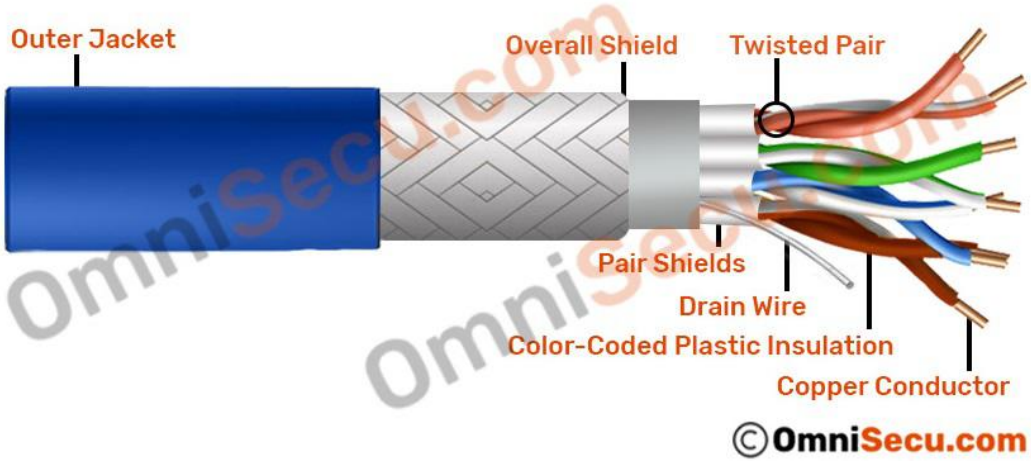


- Shielded twisted pair:

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 blocks 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.

Schematic view



Range – Up to 100m

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.

Scalability – It is scalable in LAN architecture.

2) Fiber Distributed Data Interface(FDDI)[2]:

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).

Features:

- FDDI uses optical fiber as its physical medium.
- It operates in the physical and medium access control (MAC layer) of the Open Systems Interconnection (OSI) network model.
- It provides high rate data transfer and can support thousands of users.

- It is used in LANs for long distance voice and multimedia communication.
- It uses ring based token passing mechanism and is derived from IEEE 802.4 token bus standard.
- It contains two token rings, a primary ring for data and token transmission and a secondary ring that provides backup if the primary ring fails. When a network has no requirement for the secondary ring to do backup, it can also carry data, extending capacity to 200 Mbit/s.
- FDDI technology can also be used as a backbone for a wide area network (WAN).

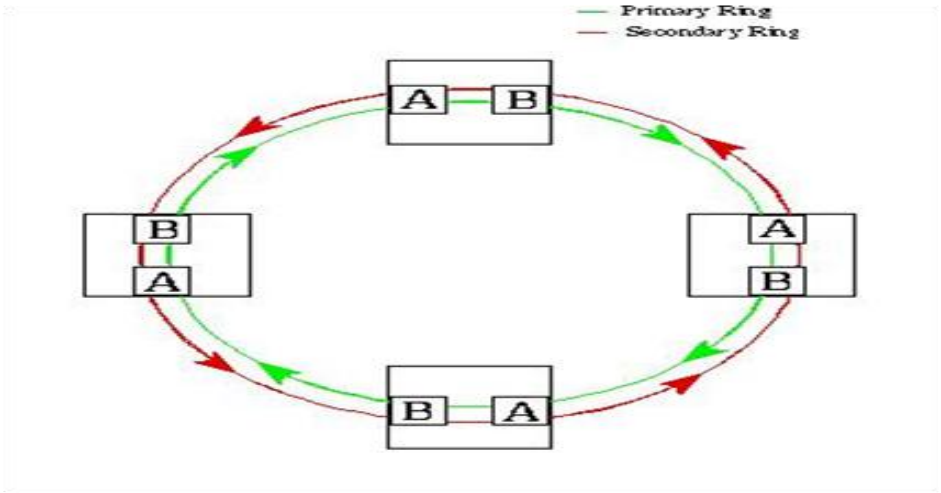
Range - 200km

Bandwidth - 100 Mbps

Scalability - 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. Designers normally constructed FDDI rings in a network topology such as a "dual ring of trees". A small number of devices, typically infrastructure devices such as routers and concentrators rather than host computers, were "dual-attached" to both rings. Host computers then connect as single-attached devices to the routers or concentrators. The dual ring in its most degenerate form simply collapses into a single device. For these reasons, 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



3) Fiber Optic Cable[3]:

Fiber optic cable, also called as optical fiber cable, is a type of Ethernet cable which consists of one or more optic fibers that are used to transmit data. Fiber optic cable transmits data as pulses of light go through tiny tubes of glass. The transmission capacity of optical fiber cable is 26,000 times higher than that of twisted pair cable. Fiber optic cable can be divided into single mode fiber (SMF) and multimode fiber (MMF). Single mode optical fiber has a small core, and only allows one mode of light to propagate at a time. While multimode fiber cable comes with a larger core and is designed to carry multiple light rays or modes at the same time.

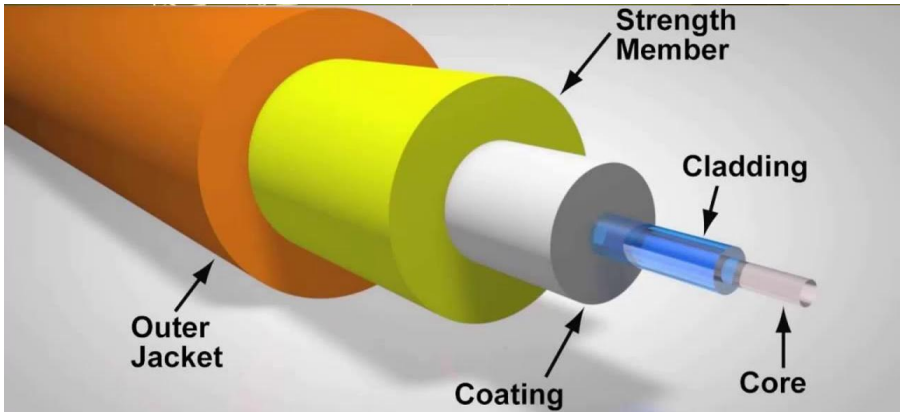
Range – Up to 80km.

Bandwidth – Up to 4700 MHz.

Modulation – An optical modulator is a device which is used to modulate a beam of light. Depending on the parameter of a light beam which is manipulated, modulators may be categorized into amplitude modulators, phase modulators, polarization modulators etc. Often the easiest way to obtain modulation of intensity of a light beam, is to modulate the current driving the light source, e.g. a laser diode. This sort of modulation is called direct modulation, as opposed to the external modulation performed by a light modulator. For this reason light modulators are, e.g. in fiber optic communications, called external light modulators.

Scalability – It is scalable in LAN architecture.

Schematic View:



4) Coaxial cable[4]:

Coaxial cable, or coax cable, is designed to transmit highfrequency signals. It’s comprised of a round copper conductor and three layers of insulation and shielding which prevents crosstalk from motors, lighting and other sources of EMI. With the shield construction, the coaxial cable can support longer cable lengths between two devices. Coax has 80X more transmission capacity than twisted pair cables.

Coaxial cable is used as a transmission line for radio frequency signals. Its applications include feedlines connecting radio transmitters and receivers to their antennas, computer network (e.g., Ethernet) connections, digital audio (S/PDIF), and distribution of cable television signals. One advantage of coaxial over other types of radio transmission line is that in an ideal coaxial cable the electromagnetic field carrying the signal exists only in the space between the inner and outer conductors. This allows coaxial cable runs to be installed next to metal objects such as gutters without the power losses that occur in other types of transmission lines. Coaxial cable also provides protection of the signal from external electromagnetic interference.

Range – Up to 500m

Bandwidth – Up to 4700 MHz.

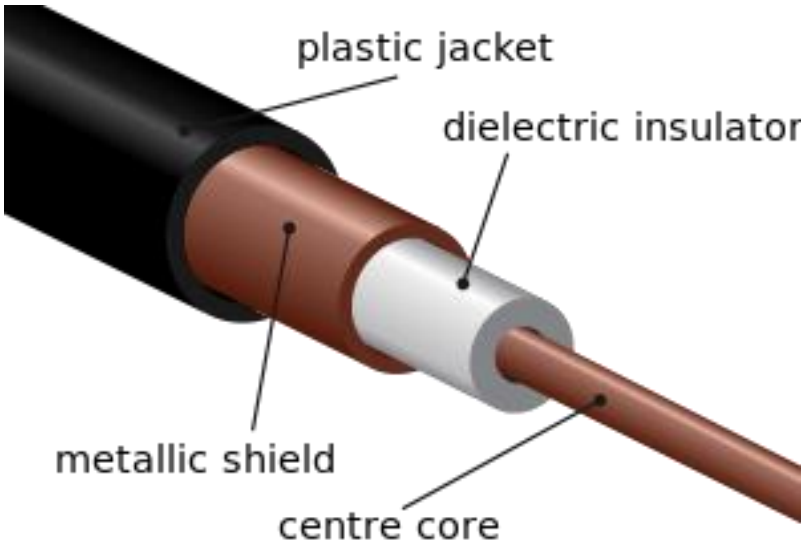
Modulation – 10 Mbit/s Ethernet uses Manchester coding. A binary zero is indicated by a low-to-high transition in the middle of the bit

period and a binary one is indicated by a high-to-low transition in the middle of the bit period. Manchester coding allows the clock to be recovered from the signal. However, the additional transitions associated with it double the signal bandwidth.

Scalability – There are two types of coaxial cable

1. RG8 used in LAN also known as thick Ethernet.
2. RG-58 used for LAN and known as thin Ethernet.

Schematic View:



Wireless:

Wireless physical layer refers to the layer which protects data to reach reliably from transmitter to the receiver in the presence of noisy channel environment. The channel incorporates various impairments which include fading,phase noise, frequency offset and so on. Hence the role of wireless physical layer is to incorporate features which facilitates data to be retrieved from the corrupted received packet/frame.

1) Wi-Fi(WLAN)[5]

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.

Wireless LANs have become popular for use in the home, due to their ease of installation and use. They are also popular in commercial properties that offer wireless access to their employees and customers.

The IEEE 802.11 has two basic modes for its operation:

A) *Infrastructure* mode: Most Wi-Fi networks are deployed in infrastructure mode. In infrastructure mode, mobile units communicate through a wireless access point (WAP) that serves as a bridge to other networks (such as the Internet or a local area network). Wireless clients, such as laptops and smartphones, connect to the WAP to join the network. The WAP usually has a wired network connection and may have permanent wireless connections to other WAPs.

B) *Ad hoc mode*: An ad hoc network is a network where stations communicate only peer to peer (P2P). There is no base and no one gives permission to talk.

Since wireless communication uses a more open medium for communication in comparison to wired LANs, the 802.11 designers also included encryption mechanisms: Wired Equivalent Privacy (WEP, now insecure), Wi-Fi Protected Access (WPA, WPA2, WPA3), to secure wireless computer networks.

Range – Within a limited area such as a home, school, computer laboratory, campus, or office building.

Modulation – WiFi systems use two primary radio transmission techniques.

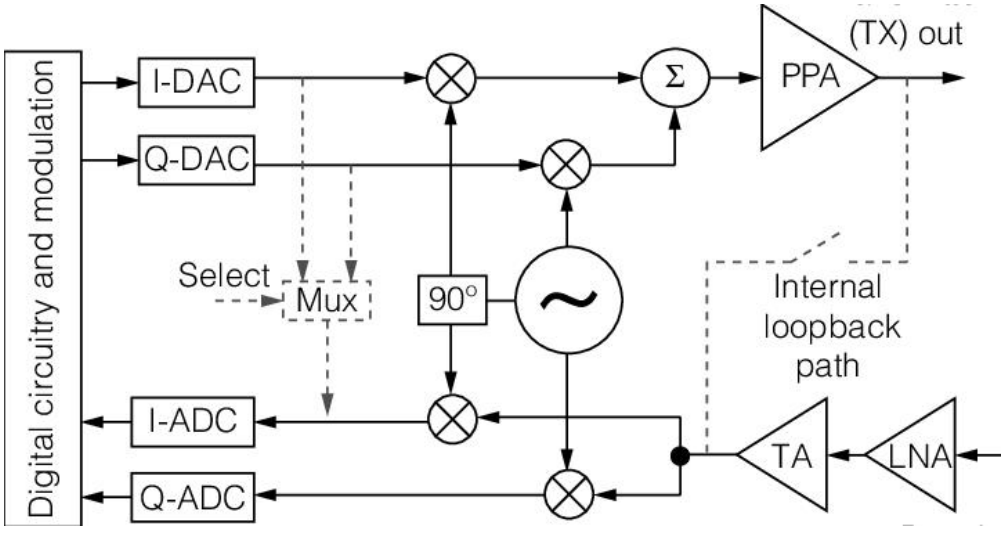
A) 802.11b (<=11 Mbps) − The 802.11b radio link uses a direct sequence spread spectrum technique called complementary coded keying (CCK). The bit stream is processed with a special

coding and then modulated using Quadrature Phase Shift Keying (QPSK).

B) 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 a number of 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 of 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.

Schematic view



2) Z-wave[6]

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.

Z-Wave is designed to provide reliable, low-latency transmission of small data packets at data rates up to 100kbit/s. The throughput is 40kbit/s (9.6kbit/s using old chips) and suitable for control and sensor applications.

In a Wi-Fi network, all nodes must be in the wireless range of the Wireless Access point, and they can only communicate through the access point. In Z-Wave, a node must be in the range of another node and can communicate with adjacent nodes. A packet can hop over 4 nodes which means effectively limits the distance between a controller and the farthest node.

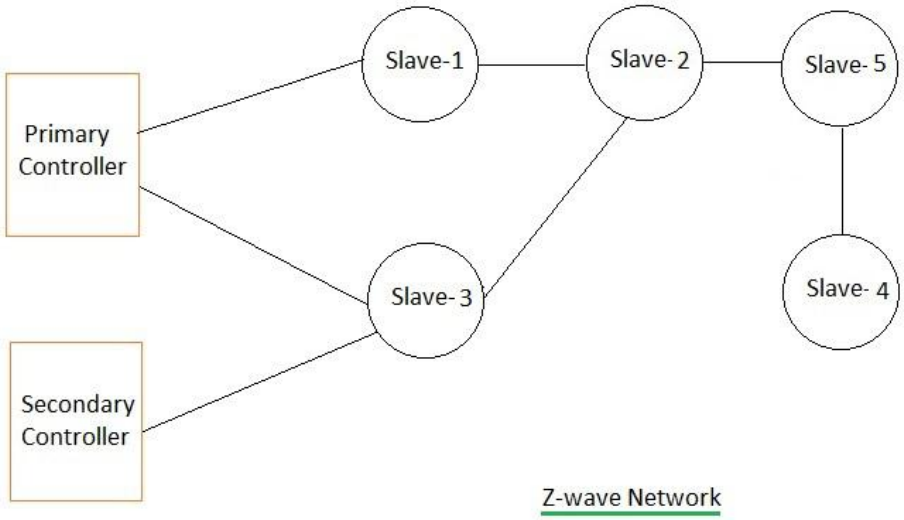
The z-wave network consists of controllers (one primary controller and more than one secondary controllers) and slaves. Controller devices are the nodes in a z-wave network which initiates control commands. It also sends out the commands to other nodes. The slave devices are the nodes which replies based on command received and also execute the commands. Slave nodes also forward the commands to other nodes in the network.

Range - 100m

Scalability - Z-Wave can be used within a network (Home Area Network, 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.

Modulation - Frequency-shift keying (FSK) with Manchester encoding.

Schematic view



3) WiMAX[7]:

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. The name "WiMAX" was created by the WiMAX Forum, which was formed in June 2001 to promote conformity and interoperability of the standard, including the definition of predefined system profiles for commercial vendors.The forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL". IEEE 802.16m or WirelessMAN-Advanced was a candidate for the 4G, in competition with the LTE Advanced standard. WiMAX can provide at-home or mobile Internet access across whole cities or countries. In many cases, this has resulted in competition in markets which typically only had access through an existing incumbent DSL (or similar) operator.

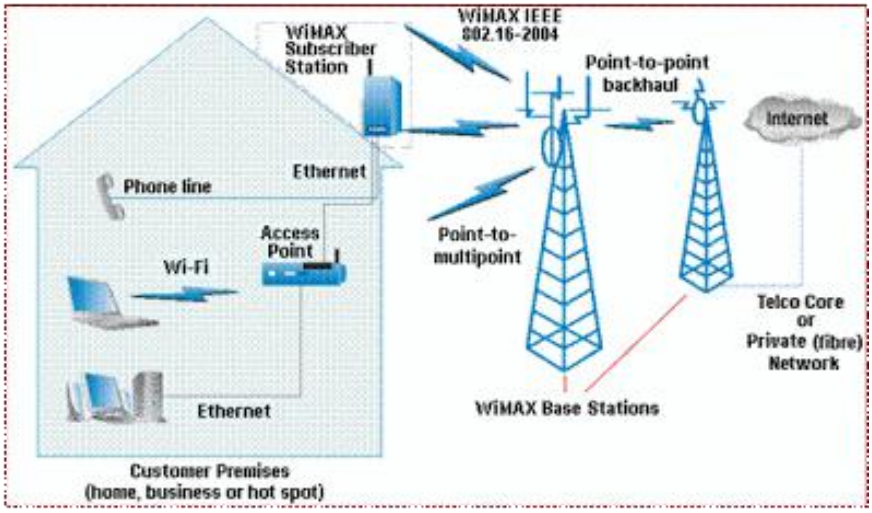
Range - 50km

Bandwidth - Upto 100Mbps

Modulation - Binary Phase Shift Keying, Quadrature Phase Shift Keying, Quadrature amplitude modulation

Scalability - 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.

Schematic View:



4) Zigbee[8]:

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

wireless data transfer. Its low power consumption limits transmission distances to 10–100 meters lineof-sight, depending on power output and environmental characteristics. Zigbee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. Zigbee is typically used in low data rate applications that require long battery life and secure networking (Zigbee networks are secured by 128 bit symmetric. Zigbee supports different network configurations for master to master or master to slave communications. And also, it can be operated in different modes as a result the battery power is conserved. Zigbee networks are extendable with the use of routers and allow many nodes to interconnect with each other for building a wider area network.

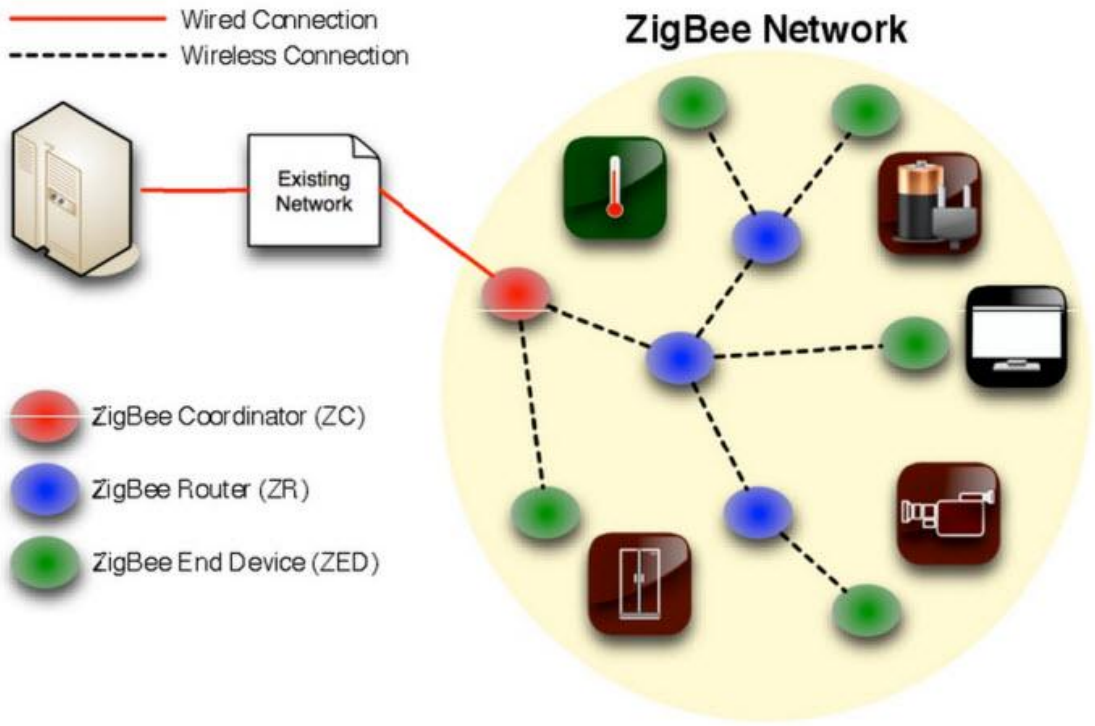
Range - 100m

Bandwidth - 250kbps

Modulation - Direct sequence spread spectrum

Scalability - ZigBee network scalability and reliability is achieved through mesh networking. Networks can scale to hundreds and thousands of devices and all will communicate using the best available path for reliable message delivery. If one path stops working, a new path is automatically discovered and used without stopping the system operation. This long-term reliability is critical for many building automation systems that are expected to last 20–30 years once installed.

Schematic View:



5) Li-Fi[9]:

Li-Fi is wireless communication technology which utilizes light to transmit data and position between devices. The term was first introduced by Harald Haas during a 2011 TEDGlobal talk in Edinburgh.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. Li-Fi is a derivative of optical wireless communications (OWC) technology, which uses light from light-emitting diodes (LEDs) as a medium to deliver network, mobile, high-speed communication in a similar manner to Wi-Fi.The LiFi market was projected to have a compound annual growth rate of 82% from 2013 to 2018 and to be worth over $6 billion per year by 2018.[5] However, the market has not developed as such and Li-Fi remains with a niche market, mainly for technology evaluation. In this technology, Wi-Fi signals are converted into light form and if your device is under this light then Wi-Fi works on your mobile. The main advantage of this technology is that when you turn on the light of your room, your Wi-Fi will limit only to your room and to your device, no other person will be able to use it and not like router the whole house would be under Wi-Fi signals when only

you want to use it in your room. You might think that if you want to close the light and then use this Wi-Fi technology, then scientists have solved your problem too. You can use this Light Wi-Fi in its very dim light also, so next time you want to text in dark, it will not be much of a problem. This technology will reach most of the places soon and will replace routers.

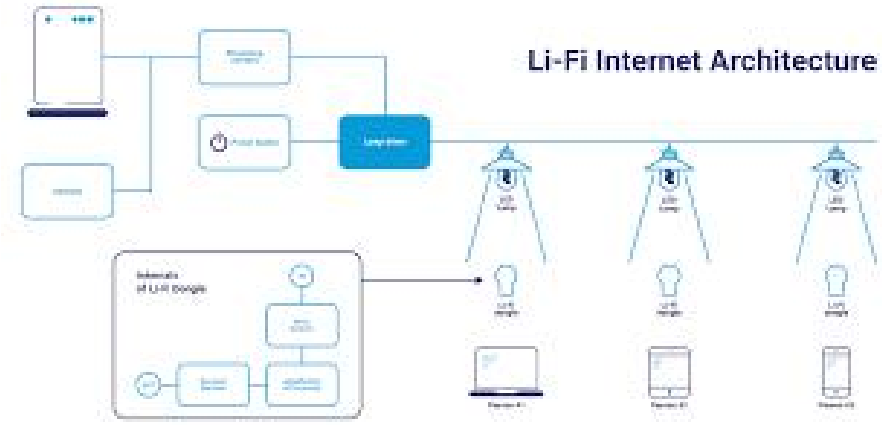
Range - 10m

Bandwidth - 1 Gbps

Modulation - on-off keying (OOK), pulse position modulation (PPM) and pulse amplitude modulation (PAM)

Scalability - LiFi offers scalable capabilities for up to 15 users within the coverage beam of one light point.

Schematic View:



6) 4G LTE[10]:

Long-Term Evolution (LTE) is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies. It increases the capacity and speed using a different radio interface together with core network improvements.

The following are some possible features of the 4G systems :

1. Support interactive multimedia, voice, video, wireless internet and other broadband services.
2. High speed, high capacity and low cost per bit.
3. Global mobility, service portability, scalable mobile networks.
4. Seamless switching, variety of services based on Quality of Service (QoS) requirements
5. Better scheduling and call admission control techniques.
6. Ad hoc networks and multi-hop networks.

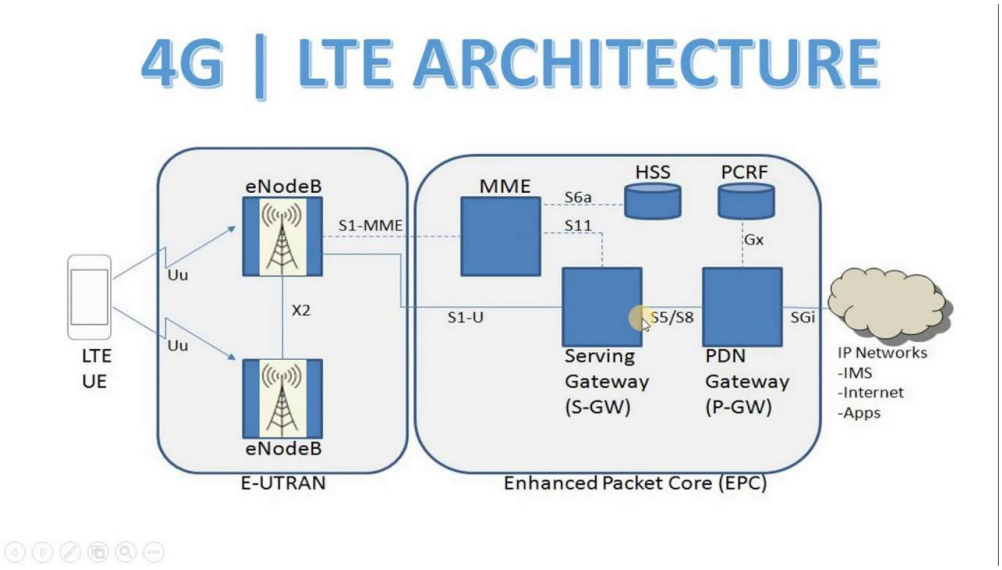
Range - LTE is required to support communication with terminals moving at speeds of up to 350 km/h, or even up to 500 km/h depending on the frequency band.

Bandwidth - 100 Mbps

Modulation - LTE uses Orthogonal Frequency Division Multiplexing (OFDM) for the downlink - that is, from the base station to the terminal to transmit the data over many narrow band careers of 180 KHz each instead of spreading one signal over the complete 5MHz career bandwidth.

Scalability - LTE has the ability to manage fast-moving mobiles and supports multi-cast and broadcast streams. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time-division duplexing (TDD). The IP-based network architecture, called the Evolved Packet Core (EPC) designed to replace the GPRS Core Network, supports seamless handovers for both voice and data to cell towers with older network technology such as GSM, UMTS and CDMA2000.

Schematic View:



7) Bluetooth[11]:

It is a Wireless Personal Area Network (WPAN) technology and is used for exchanging data over smaller distances. This technology was invented by Ericson in 1994. It operates in the unlicensed, industrial, scientific and medical (ISM) band at 2.4 GHz to 2.485 GHz. Maximum devices that can be connected at the same time are 7. Bluetooth ranges upto 10 meters. It provides data rates upto 1 Mbps or 3 Mbps depending upon the version. The spreading technique which it uses is FHSS (Frequency hopping spread spectrum).

It avoids interference from other wireless devices, has lower power consumption and no line of sight hence can connect through any obstacles.

A bluetooth network is called piconet and a collection of interconnected piconets is called scatternet.

Piconet: Piconet is a type of bluetooth network that contains one primary node called master node and seven active secondary nodes called slave nodes. Thus, we can say that there are total of 8 active nodes which are present at a distance of 10 metres. The communication between the primary and secondary node can be one-to-one or one-to-many. Possible communication is only between the master and slave. Slave-slave communication is not possible. It also have 255 parked

nodes, these are secondary nodes and cannot take participation in communication unless it get converted to the active state.

Scatternet: It is formed by using various piconets. A slave that is present in one piconet can be act as master or we can say primary in other piconet. This kind of node can receive message from master in one piconet and deliver the message to its slave into the other piconet where it is acting as a slave. This type of node is refer as bridge node. A station cannot be master in two piconets.

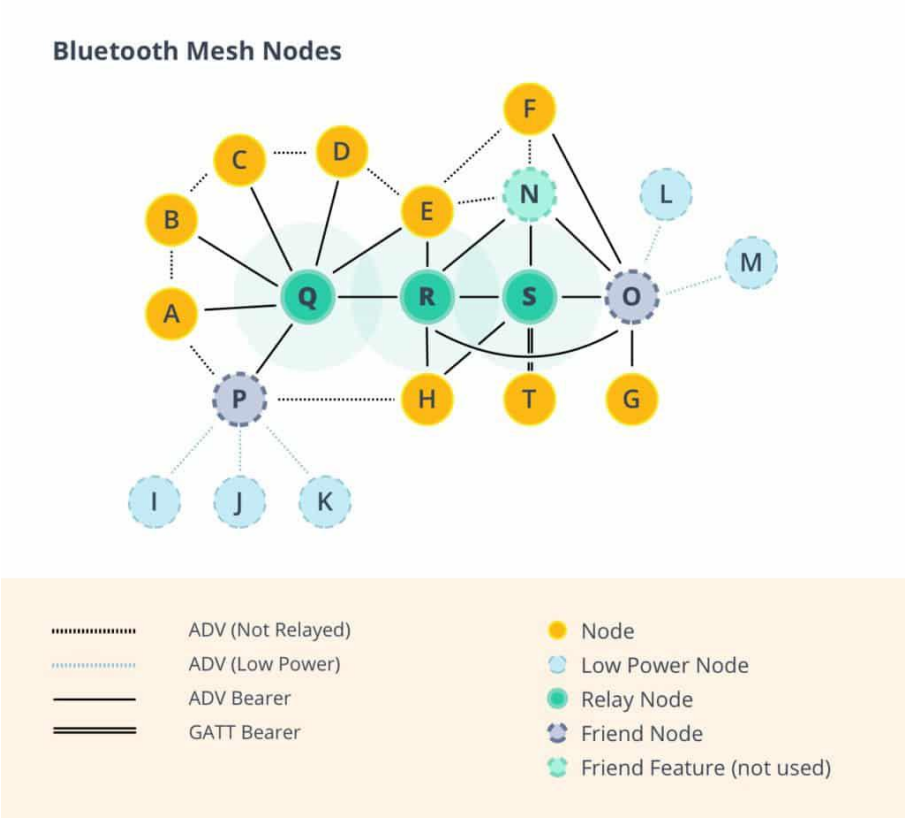
Range - 400m

Bandwidth - 2 Mbps

Modulation - Gaussian frequency shift keying

Scalability - Bluetooth it typically used in WPAN (Wireless Personal Area Network) to transfer data between devices.

Schematic View:



Types of networks:

1. Personal Area Network (PAN): The smallest and most basic type of network, a PAN is made up of a wireless modem, a computer or two, phones, printers, tablets, etc., and revolves around one person in one building. These types of networks are typically found in small offices or residences, and are managed by one person or organization from a single device.

2. Local Area Network (LAN): LANs are the most frequently discussed networks, one of the most common, one of the most original and one of the simplest types of networks. LANs connect groups of computers and low-voltage devices together across short distances (within a building or between a group of two or three buildings in close proximity to each other) to share information and resources. Enterprises typically manage and maintain LANs. Using routers, LANs can connect to wide area networks (WANs, explained below) to rapidly and safely transfer data.

3. Wireless Local Area Network (WLAN): Functioning like a LAN, WLANs make use of wireless network technology, such as Wi-Fi. Typically seen in the same types of applications as LANs, these types of networks don't require that devices rely on physical cables to connect to the network.

4. Campus Area Network (CAN): Larger than LANs, but smaller than metropolitan area networks (MANs, explained below), these types of networks are typically seen in universities, large K-12 school districts or small businesses. They can be spread across several buildings that are fairly close to each other so users can share resources.

5. Metropolitan Area Network (MAN): These types of networks are larger than LANs but smaller than WANs – and incorporate elements from both types of networks. MANs span an entire geographic area (typically a town or city, but sometimes a campus). Ownership and maintenance is handled by either a single person or company (a local council, a large company, etc.

6. Wide Area Network (WAN): Slightly more complex than a LAN, a WAN connects computers together across longer physical distances. This allows computers and low-voltage devices to be remotely connected to

each other over one large network to communicate even when they're miles apart. The Internet is the most basic example of a WAN, connecting all computers together around the world. Because of a WAN's vast reach, it is typically owned and maintained by multiple administrators or the public.

7. Storage-Area Network (SAN): As a dedicated high-speed network that connects shared pools of storage devices to several servers, these types of networks don't rely on a LAN or WAN. Instead, they move storage resources away from the network and place them into their own high-performance network. SANs can be accessed in the same fashion as a drive attached to a server. Types of storage-area networks include converged, virtual and unified SANs.

Conclusion:

I learnt about the various types of wired and wireless connections in terms of their specifications, features and scalability with respect to their application in network architectures and a schematic view of the connection.

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