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Experiment No.1

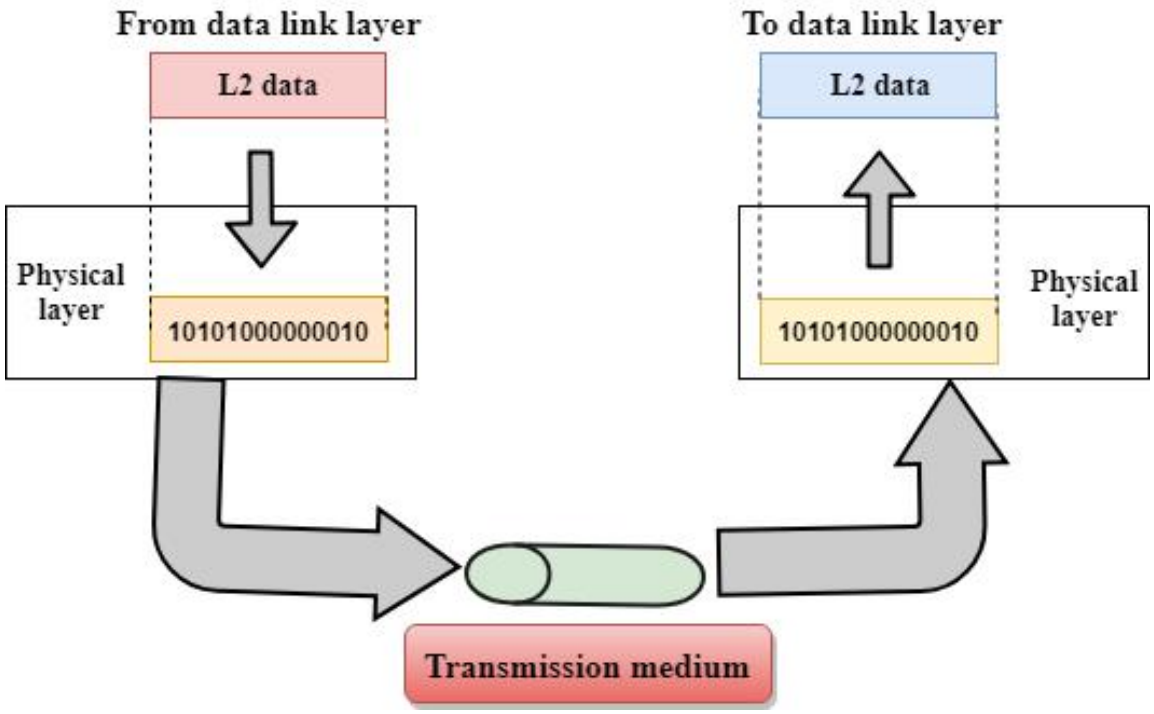
Aim: To study the different types of physical layers wired and wireless connections

Theory:

1. Physical Layers [1]

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

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.

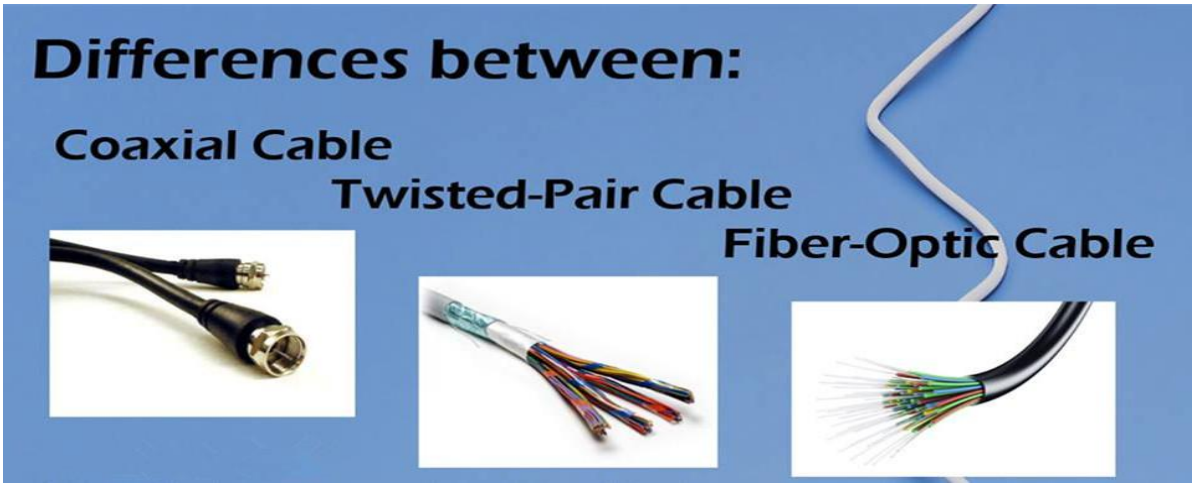


2. Wired Connections [3]

Wired connections are by far the most common. The main media in use are:

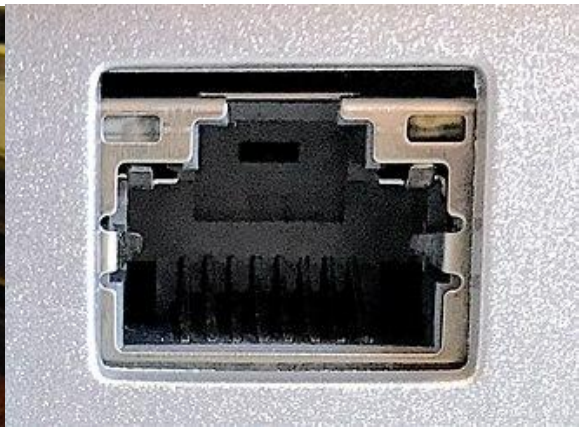
- **a. Coaxial cable,**
- **b. Twisted pairs**
- **c. Fibre optics**

For each of these, specific network technologies or specifications have been designed. The medium must have properties that will ensure a reasonable error performance for a guaranteed distance and rate of date delivery (i.e. speed). It must also support two-way or multiway communications.



Twisted pair cable	Co-axial cable	Optical fiber
1. Transmission of signals takes place in the electrical form over the metallic conducting wires.	1. Transmission of signals takes place in the electrical form over the inner conductor of the cable.	1. Signal transmission takes place in an optical forms over a glass fiber.
2. In this medium the noise immunity is low.	2. Coaxial having higher noise immunity than twisted pair cable.	2. Optical fiber has highest noise immunity as the light rays are unaffected by the electrical noise.
3. Twisted pair cable can be affected due to external magnetic field.	3. Coaxial cable is less affected due to external magnetic field.	3. Not affected by the external magnetic field.
4. Cheapest medium.	4. Moderate Expensive.	4. Expensive
5. Low Bandwidth.	5. Moderately high bandwidth.	5. Very high bandwidth
6. Attenuation is very high.	6. Attenuation is low.	6. Attenuation is very low.
7. Installation is easy.	7. Installation is fairly easy.	7. Installation is difficult.

2.1 Ethernet [13]

An ethernet cable is a common type network cable used with wired networks.Ethernet cables connect devices such as PCs, routers, and switches within a **local area network.** These physical cables are limited by length and durability.

It was commercially introduced in **1980** and first standardized in **1983** as **IEEE 802.3**. Ethernet has since been refined to support higher bit rates, a greater number of nodes, and longer link distances, but retains much backward compatibility. Over time, Ethernet has largely replaced competing wired LAN technologies such as **Token Ring** etc. The Ethernet physical layer encompasses multiple physical media interfaces and several orders of magnitude of speed from **1 Mbit/s to 400 Gbit/s**. The physical medium ranges from **bulky coaxial cable** to **twisted pair** and **optical fiber** with a standardized reach of up to 40 km. In general, network protocol stack software will work similarly on all physical layers.

Ethernet 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.

Ethernet Scalability :

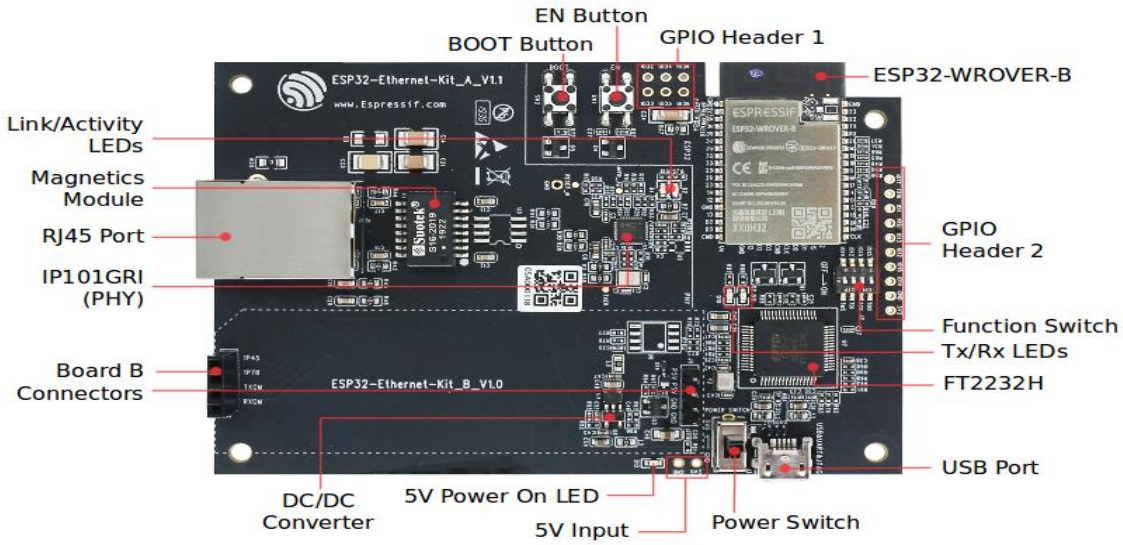
Ethernet is a family of computer networking technologies commonly used in local area networks (**LAN**), metropolitan area networks (**MAN**), and wide area networks(**WAN**). Ethernet is currently the most widely used technology in enterprise networking.

Unfortunately, it is widely acknowledged that Ethernet does not have the scalability to meet the emerging networking needs of large enterprises. Ethernet does not scale well to large networks. The flat MAC address space, whilst having obvious benefits for the user and administrator, is the primary cause of this poor scalability. Ethernet exhibits scalability issues on networks of more than a few thousand devices, such as costly and energy-dense address table logic and storms of broadcast traffic. Ethernet's inability to handle networks containing loops also presents a scalability problem.

Ethernet Schematic View :

The ESP32 Ethernet PHY interface is shown in the schematic below. It mainly consists of three sections:

- The PHY chip or interface
- The 50 MHz oscillator
- Jack and magnetics



The main sections of ESP32 Ethernet PHY interface are:

- Pull-up resistors on the ESP32 side of the PHY chip.

- Series termination resistors for reducing signal reflection and ringing.
- The 50-ohm pullups on the ethernet jack side of the PHY chip.
- Proper magnetic jack. Most ethernet jacks are low cost and do not contain any magnetics… you cannot use those directly. You will need external inductive components for using plain old **RJ-45 connectors**.

There are a number of versions of IEEE 802.3 protocol. The most popular ones are -

IEEE 802.3: This was the original standard given for 10BASE-5. It used a thick single coaxial cable into which a connection can be tapped by drilling into the cable to the core. Here, 10 is the maximum throughput, i.e. 10 Mbps, BASE denoted use of baseband transmission, and 5 refers to the maximum segment length of 500m.

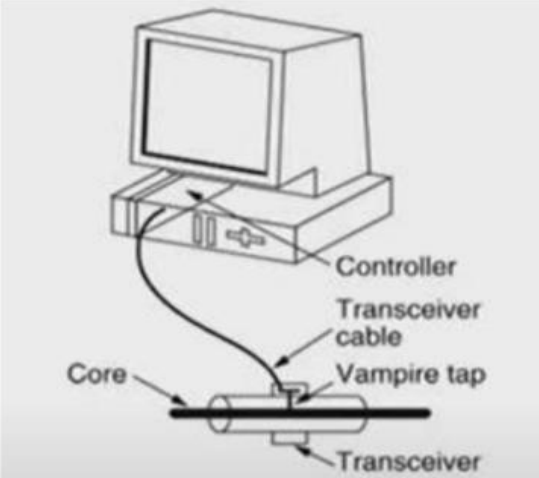


Fig. 3: 10Base5 [2]

IEEE 802.3a: This gave the standard for thin coax (10BASE-2), which is a thinner variety where the segments of coaxial cables are connected by BNC connectors. The 2 refers to the maximum segment length of about 200m (185m to be precise).

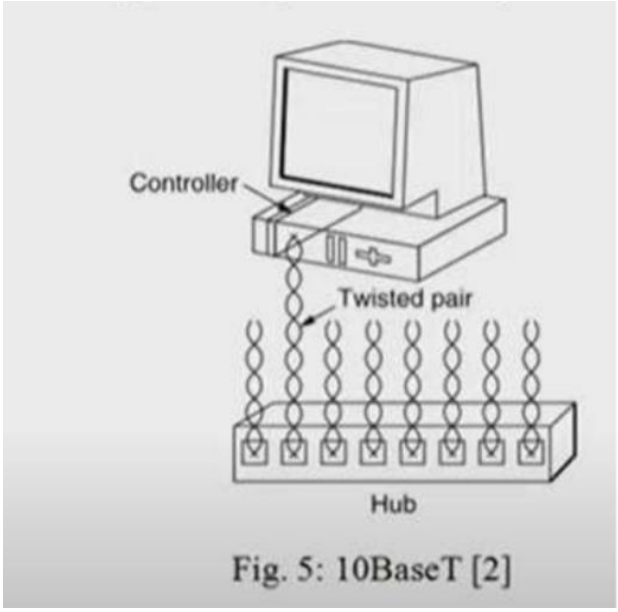


Fig. 5: 10BaseT [2]

IEEE 802.3i: This gave the standard for twisted pair (10BASE-T) that uses unshielded twisted pair (UTP) copper wires as physical layer medium. The further variations were given by IEEE 802.3u for 100BASE-TX, 100BASE-T4 and 100BASE-FX.

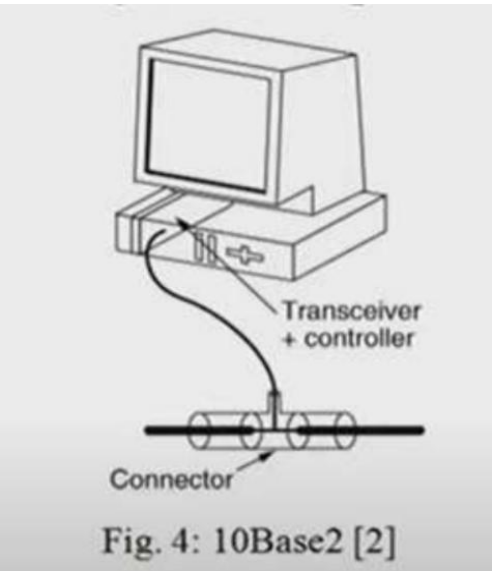


Fig. 4: 10Base2 [2]

Characteristic	Ethernet Value	IEEE 802.3 Values				
		10Base5	10Base2	1Base5	10BaseT	10Broad36
Data rate (Mbps)	10	10	10	1	10	10
Signaling method	Baseband	Baseband	Baseband	Baseband	Baseband	Broadband
Maximum segment length (m)	500	500	185	250	100 Unshielded twisted-pair wire	1800
Media	50-ohm coax (thick)	50-ohm coax (thick)	50-ohm coax (thin)	Unshielded twisted-pair wire	Unshielded twisted-pair wire	75-ohm coax
Topology	Bus	Bus	Bus	Star	Star	Bus

802.3u (Fast Ethernet) Ref(4, 5)

To encompass need of fast emerging software and hardware technologies, Ethernet extends itself as Fast-Ethernet. It can run on UTP, Optical Fiber, and wirelessly too. It can provide speed up to 100MBPS. This standard is named as 100BASE-T in IEEE 803.2 using Cat-5 twisted pair cable. It uses CSMA/CD technique for wired media sharing among the Ethernet hosts and CSMA/CA (CA stands for Collision Avoidance) technique for wireless Ethernet LAN.
Fast Ethernet on fiber is defined under 100BASE-FX standard which provides speed up to 100MBPS on fiber. Ethernet over fiber can be extended up to 100 meters in half-duplex mode and can reach maximum of 2000 meters in full-duplex over multimode fibers.

Varieties of Fast Ethernet

The common varieties of fast Ethernet are 100-Base-TX, 100-BASE-FX and 100-Base-T4.

name	100BaseT4	100BaseTX	100BaseFX
medium	4 Twisted pair (UTP-3)	2 Twisted pair (UTP-5)	2 multimode optical fibre
Max-length of transmission	100m	100m	2000m
Data rate	100mbps	100mbps	100mbps
Topology	Star	Star	Star
Physical connectors	RJ45	RJ45	ST
Fault tolerant	yes	yes	yes
Data flow	Half duplex	Full duplex	Full duplex

100-Base-T4

- This has four pairs of UTP of Category 3, two of which are bi-directional and the other two are unidirectional.
- In each direction, three pairs can be used simultaneously for data transmission.
- Each twisted pair is capable of transmitting a maximum of 25Mbaud data. Thus the three pairs can handle a maximum of 75Mbaud data.
- •t uses the encoding scheme 8B/6T (eight binary/six ternary).

100-Base-TX

- This has either two pairs of unshielded twisted pairs (UTP) category 5 wires or two shielded twisted pairs (STP) type 1 wires. One pair transmits frames from hub to device and the other from device to hub.
- Maximum distance between hub and station is 100m.

- It has a data rate of 125 Mbps.
- It uses MLT-3 encoding scheme along with 4B/5B block coding.

100-BASE-FX

- This has two pairs of optical fibers. One pair transmits frames from hub to the device and the other from device to hub.
- Maximum distance between hub and station is 2000m
- It has a data rate of 125 Mbps.
- It uses NRZ-I encoding scheme along with 4B/5B block coding.

2.2 Universal Serial Bus (USB) [2]

USB was designed to standardize the connection of peripherals like pointing devices, keyboards, digital still and video cameras. But soon devices such as printers, portable media players, disk drives and network adaptors to personal computers used USB to communicate and to supply electric power. It is a commonplace to many devices and has largely replaced interfaces such as serial ports and parallel ports.

USB 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.

❖ Other specifications :

- Two important aspects of USB are its support capability and total bandwidth. It is capable of supporting 127 devices and has a total bandwidth of 12 Mbit per second which is equal to 1.5 MB per second. Working of a 12 Mbit (full speed device) or a 1.5 Mbit (low-speed device) depends on the total bandwidth of the USB.
- USB 2.0 has a maximum signaling rate of 480 Mbit/s and USB 3.0 has a usable data rate of up to 4 Gbit/s (500 MB/s).

USB Scalability :

USB's are used in Personal Area Network(PAN).

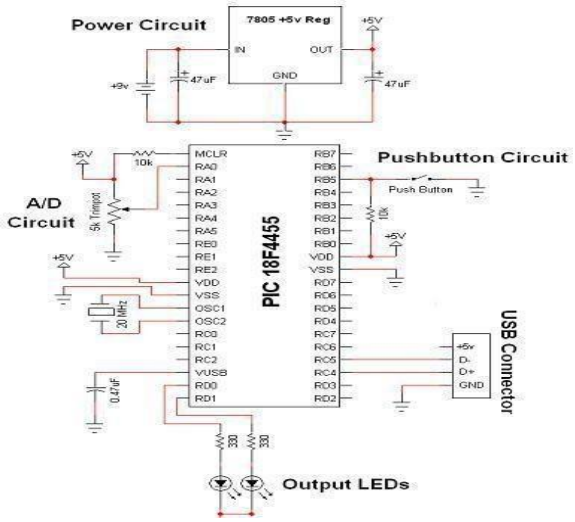
USB Schematic View :

Hardware design for USB is actually quite minimal, which is a big plus for us. However, what you quickly find out with USB is that the easy hardware design means the communication and control software is very complex. The main devices used in the circuit are the PIC 18F4455, USB Connector, and LM7805.

Schematic Specifics:

A. Power Circuit

The +5v output from the power circuit comes from the LM7805 regulator. Notice the 47uF capacitors on the input and output. These are meant to be DC filtering capacitors, which smooth out the constant DC voltage being fed to the microcontroller from the 7805 regulators.



B. USB Connection and Output LEDs

Make sure you double-check your USB pinout. A common mistake when wiring the PIC to the USB connector is getting the D+ and D- signals backward. So if you're sure that the PIC is running your perfect code, but the USB device isn't coming up properly, switch D+ and D-, it might just magically fix your problem! The output LEDs will be simple 'toggle' LEDs. The program running on our laptop will be able to toggle them on and off with the push of a button.

C. A/D and Push Button Circuits

The A/D circuit is a standard 3 pin, Connected to Power, Signal Out, and Ground circuit. The signal output goes into RA0 which is the Analog to Digital converter. After the PIC converts this signal it should send the data to the laptop via USB. The laptop will visually display the trimpot's value. The push-button will do a similar thing when the button is pushed, the laptop application should update with a notification that it has been pressed.

2.3 Power Lines [10]

Power Line communication (PLC) is Layer-1 (Physical Layer) technology which uses power cables to transmit data signals. In PLC, modulated data is sent over the cables. The receiver on the other end de-modulates and interprets the data. Because power lines are widely deployed, PLC can make all powered devices controlled and monitored. PLC works in half-duplex. There are two types of PLC:

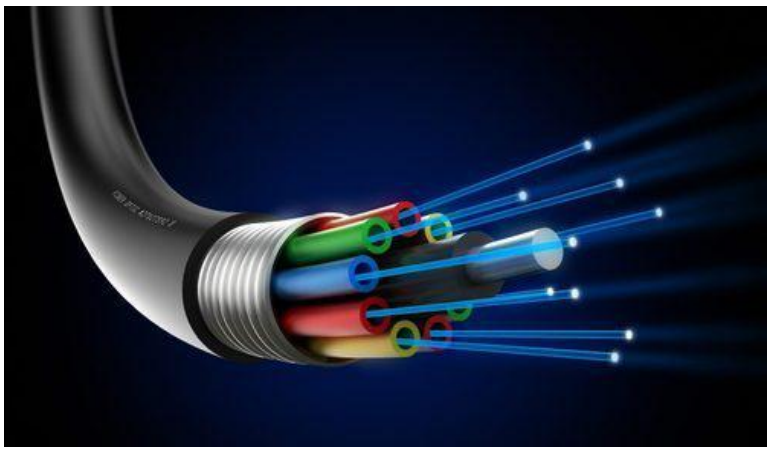
- **Narrow band PLC :**

Narrow band PLC provides lower data rates up to 100s of kbps, as they work at lower frequencies (3-5000 kHz).They can be spread over several kilometers.

- **Broadband PLC :**

Broadband PLC provides higher data rates up to 100s of Mbps and works at higher frequencies (1.8 – 250 MHz).They cannot be as much extended as Narrowband PLC.

2.4 Optical Fiber [12]



- An optical fiber is a flexible, transparent fiber made by drawing glass (silica) or plastic to a diameter slightly thicker than that of a human hair.
- Optical fibers are used most often as a means to transmit light between the two ends of the fiber and find wide usage in fiber-optic communications, where they permit transmission over longer distances and at higher bandwidths (data transfer rates) than electrical cables.

- Fibers are used instead of metal wires because signals travel along them with less loss, in addition, fibers are immune to electromagnetic interference, a problem from which metal wires suffer.
- 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.

Specifications

- **Range**: Up to 80km.

- **Bandwidth** up to 4700MHz. Available for home use in speeds up to 2 Gbps (2000Mbps). Business Internet available in much faster speeds.

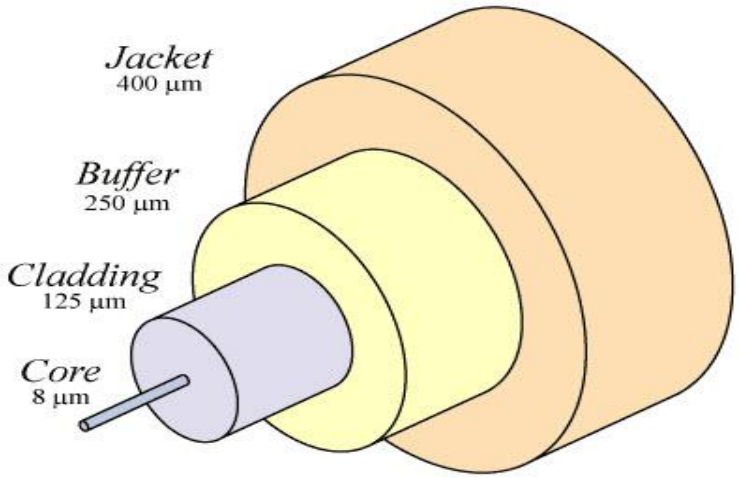
- **Modulation :**

- 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 CAN architecture.

Schematic View



3. WIRELESS CONNECTIONS

- Wireless networking is a method by which homes, telecommunications networks and business installations avoid the costly process of introducing cables into a building, or as a connection between various equipment locations. This implementation takes place at the physical level (layer) of the OSI model network structure.

- Advances in MOSFET technology, and the wide adoption of RF CMOS (radio frequency CMOS), power MOSFET and LDMOS (lateral diffused MOS) devices led to the increase of digital wireless networks by the 1990s, and further advances led to increased bandwidth in the 2000s.

- Most of the essential elements of wireless networks are built from MOSFETs, including the mobile transceivers, base station modules,routers, RF power amplifiers, telecommunication circuits, RF circuits,and radio transceivers, in networks such as 2G, 3G, and 4G.

3.1 Bluetooth [5,11]

Bluetooth wireless technology is a short range communications technology intended to replace the cables connecting portable unit and maintaining high levels of security. Bluetooth technology is based on **Ad-hoc technology** also known as **Ad-hoc Pico nets**, which is a local area network with a very limited coverage.

Symbol of Bluetooth

An example of a Bluetooth device

The usage of Bluetooth has widely increased for its special features.

- Bluetooth offers a uniform structure for a wide range of devices to connect and communicate with each other.
- Bluetooth technology has achieved global acceptance such that any Bluetooth enabled device, almost everywhere in the world, can be connected with Bluetooth enabled devices.

- Low power consumption of Bluetooth technology and an offered range of up to ten meters has paved the way for several usage models.
- Bluetooth offers interactive conference by establishing an adhoc network of laptops.
- Bluetooth usage model includes cordless computer, intercom, cordless phone and mobile phone.

Bluetooth Specifications :

❖ Range :

- The Bluetooth Core Specification mandates a range of not less than 10 meters (33 ft), but there is no upper limit on the actual range.

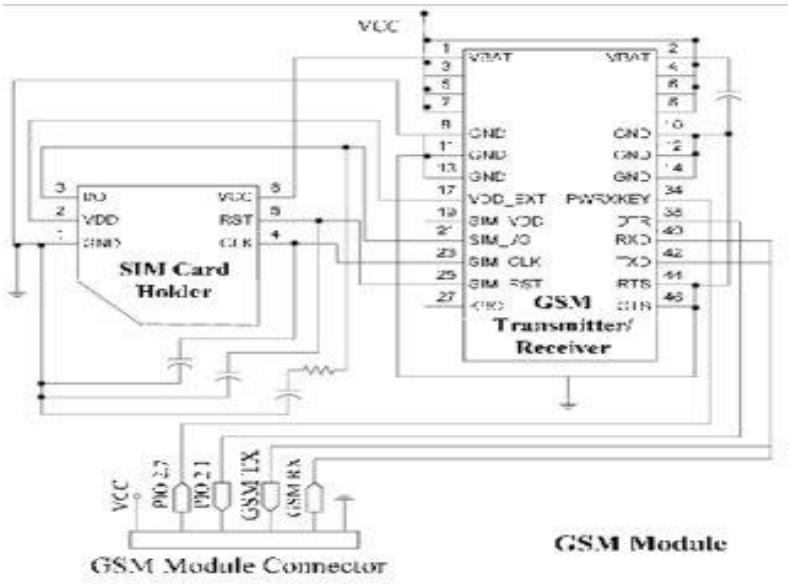
❖ Modulation :

- Originally, Gaussian frequency-shift keying (GFSK) modulation was the only modulation scheme available.
- Since the introduction of Bluetooth 2.0+EDR, π/4-DQPSK(differential quadrature phase-shift keying) and 8-DPSK modulation may also be used between compatible devices.
- Devices functioning with GFSK are said to be operating in basic rate (BR) mode where an instantaneous bit rate of 1 Mbit/s is possible. The term Enhanced Data Rate (EDR) is used to describe π/4-DPSK and 8-DPSK schemes, each giving 2 and 3 Mbit/s respectively.

Bluetooth Scalability :

- The primary constraining factor in the scalability of a system that uses any wireless communications technology concerns the fact that radio is a shared resource with a finite capacity.
- Bluetooth has been developed to facilitate wireless local area networks (LANs), in which the networks of different handheld computing terminals and mobile terminals can communicate and exchange data - even on the move or when there is no line-of-sight between the terminals.

Bluetooth Schematic View :



The Bluetooth Module is a low-power embedded Bluetooth v2.0+EDR module with a built-in high-output antenna. The module is a fully Bluetooth compliant device for data communication with a transmission power of up to +8dBm and receiver sensibility of down to -83dBm combined with low power consumption. The Bluetooth Module delivers opportunities for rapid ad-hoc connections and the possibility of automatic, unconscious, connections between WPCOMs. The complete circuit diagram of the Bluetooth Module is given in the figure.

3.2 Wi-Fi [6]

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 is a trademark of the non-profit Wi-Fi Alliance, which restricts the use of the term Wi-Fi Certified to products that successfully complete interoperability certification testing.

Wi-Fi Specifications :

The full list of versions of Wi-Fi is:

IEEE Standard	802.11a	802.11b	802.11g	802.11n	802.11ac	802.11ax
Year Released	1999	1999	2003	2009	2014	2019
Frequency	5 GHz	2.4 GHz	2.4 GHz	2.4 GHz & 5 GHz	2.4 GHz & 5 GHz	2.4 GHz & 5 GHz
Maximum Data Rate	54 Mbps	11Mbps	54 Mbps	600 Mbps	1.3 Gbps	10-12 Gbps

❖ 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.
- A general rule of thumb in home networking says that Wi-Fi routers operating on the 2.4 GHz band can reach up to 150 feet indoors and 300 feet outdoors. Older 802.11a routers that ran on 5 GHz bands reached approximately one-third of these distances.
- Newer 802.11n and 802.11ac routers that operate on both 2.4 GHz and 5 GHz bands reach greater distances.

❖ Modulation :

- WiFi 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 code keying (CCK).The bitstream 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 a number of sub-channels and some of the bits are sent on each.

- The transmitter encodes the bitstreams 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.

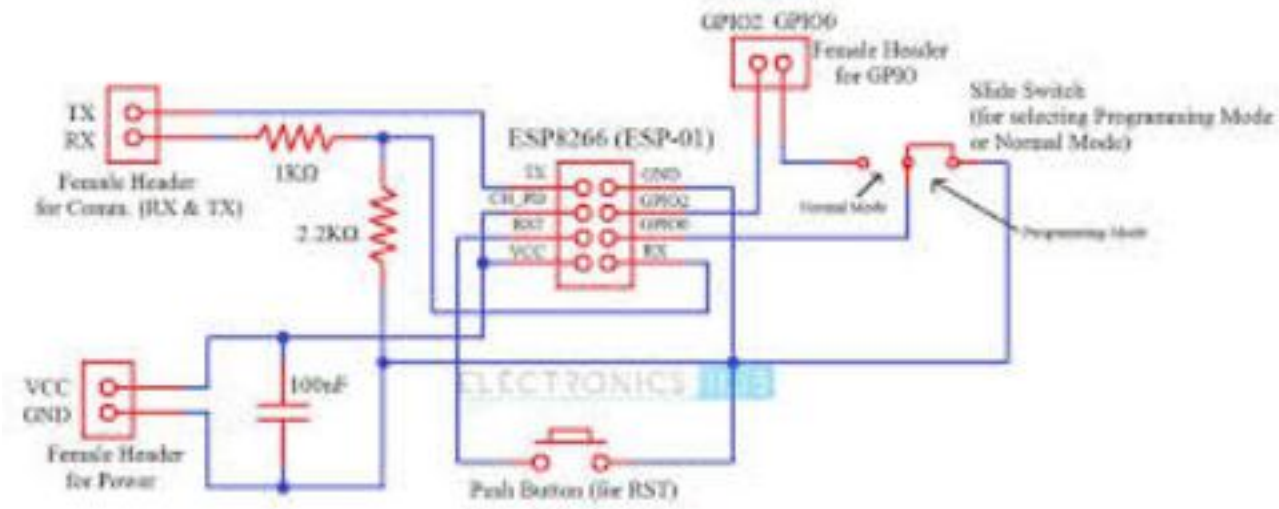
Wi-Fi Scalability :

- Compared to cell phones and similar technology, Wi-Fi transmitters are low power devices. In general, the maximum amount of power that a Wi-Fi device can transmit is limited by local regulations, such as FCC Part 15 in the US. Equivalent isotropically radiated power (EIRP) in the European Union is limited to 20 dBm (100 mW).

- To reach requirements for wireless LAN applications, Wi-Fi has higher power consumption compared to some other standards designed to support wireless personal area network (PAN) applications. For example, Bluetooth provides a much shorter propagation range between 1 and 100m[74] and so in general have a lower power consumption. Other low-power technologies such as ZigBee have fairly long range, but much lower data rate. The high power consumption of Wi-Fi makes battery life in some mobile devices a concern.

Wi-Fi Schematic View :

ESP8266 is a UART-WiFi transparent transmission module with ultralow power consumption, specially designed for the needs of a new connected world. It offers a complete and self-contained Wi-Fi networking solution, allowing it to either host the application or to offload all Wi-Fi networking functions from another application processor.



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.

3.3. Near Field Communication (NFC) [9]

- Near-Field-Communication (NFC) is a set of communication protocols for communication between two electronic devices over a distance of 4 cm or less. NFC offers a low-speed connection with simple setup that can be used to bootstrap more-capable wireless connections.

- NFC devices can act as electronic identity documents and keycards. They are used in contactless payment systems and allow mobile payment replacing or supplementing systems such as credit cards and electronic ticket smart cards. NFC tags are passive data stores which can be read, and under some circumstances written to, by an NFC device. They typically contain data (as of 2015 between 96 and 8,192 bytes) and are read-only in normal use, but may be rewritable.

- Like other "proximity card" technologies, NFC is based on inductive coupling between two so-called antennas present on NFC-enabled devices—for example a smartphone and a printer—communicating in one or both directions, using a frequency of 13.56 MHz in the globally available unlicensed radio frequency ISM band using the ISO/IEC 18000-3 air interface standard at data rates ranging from 106 to 424 kbit/s.

Specifications:

❖ Range :

- NFC is a set of short-range wireless technologies, typically requiring aseparation 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 use 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.

3.4 Cellular Networks [7,8]

- 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 thedevelopment of smartphones, cellular telephone networks routinely carry data in addition to telephone conversations:
- 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.
- In telecommunications, **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.

- LTE is sometimes known as **3.95G** and has been marketed both as "4G LTE" and as "**Advanced 4G**"
- **5G** is the fifth generation technology standard for cellular networks, which cellular phone companies began deploying worldwide in 2019, the planned successor to the 4G networks which provide connectivity to most current cellphones.
- Like its predecessors, 5G networks are cellular networks, in which the service area is divided into small geographical areas called **cells**. All 5G wireless devices in a cell are connected to the Internet and telephone network by radio waves through a local antenna in the cell.
- 5G speeds will range from **~50 Mbit/s** to over a gigabit/s. The fastest 5G is known as **mmWave**. As of July 3, 2019, mmWave had a top speed of 1.8 Gbit/s on AT&T's 5G network.

  - **Frequency range 1 (< 6 GHz)**

    The maximum channel bandwidth defined for FR1 is 100 MHz, due to the scarcity of continuous spectrum in this crowded frequency range. The band most widely being used for 5G in this range is 3.3–4.2 GHz. The Korean carriers are using 3.5 GHz although some millimeter wave spectrum has also been allocated.

  - **Frequency range 2 (> 24 GHz)**

    The minimum channel bandwidth defined for FR2 is 50 MHz and the maximum is 400 MHz, with two-channel aggregation supported in 3GPP Release 15. In the U.S., Verizon is using 28 GHz and AT&T is using 39 GHz. The higher the frequency, the greater the ability to support high data-transfer speeds.

5G [15]

In telecommunications, **5G** is the fifth generation technology standard for cellular networks, which cellular phone companies began deploying worldwide in 2019, the planned successor to the 4G networks which provide connectivity to most current cellphones. Like its predecessors, 5G networks are cellular networks, in which the service area is divided into small geographical areas called *cells*. All 5G wireless devices in a cell are connected to the Internet and telephone network by radio waves through a local antenna in the cell. The main advantage of the new networks is that they will have greater bandwidth, giving higher download speeds, eventually up to 10 gigabits per second (Gbit/s). Due to the increased bandwidth, it is expected that the new networks will not just serve cellphones like existing cellular networks, but also be used as general internet service providers for laptops and desktop computers, competing with existing ISPs such as cable internet, and also will make possible new applications in internet of things (IoT) and machine to machine areas. Current 4G cellphones will not be able to use the new networks, which will require new 5G enabled wireless devices.

Performance

❖ Speed

- 5G speeds will range from ~50 Mbit/s to over a gigabit/s. The fastest 5G is known as mmWave. As of July 3, 2019, mmWave had a top speed of 1.8 Gbit/s on AT&T's 5G network.
- Sub-6 GHz 5G (mid-band 5G), by far the most common, will usually deliver between 100 and 400 Mbit/s, but will have a much farther reach than mmWave, especially outdoors.
- Low-band spectrum offers the farthest area coverage but is slower than the others.
- 5G NR speed in sub-6 GHz bands can be slightly higher than the 4G with a similar amount of spectrum and antennas, although some 3GPP 5G networks will be slower than some advanced 4G networks, such as T-Mobile's LTE/LAA network, which achieves 500+ Mbit/s in Manhattan and Chicago. The 5G specification allows LAA (License Assisted Access) as well, but LAA in 5G has not yet been demonstrated. Adding LAA to an existing 4G configuration can add hundreds of megabits per second to the speed, but this is an extension of 4G, not a new part of the 5G standard.

❖ Latency

- In 5G, the "air latency"[20] in equipment shipping in 2019 is 8–12 milliseconds.[21] The latency to the server must be added to the "air latency" for most comparisons. Verizon reports the latency on its 5G early deployment is 30 ms:[22] Edge Servers close to the towers can reduce latency to 10–20 ms; 1–4 ms will be extremely rare for years outside the lab.

❖ Range

- 5G in the 24 GHz range or above use higher frequencies than 4G, and as a result, some 5G signals are not capable of traveling large distances (over a few hundred meters), unlike 4G or lower frequency 5G signals (sub 6 GHz). This requires placing 5G base stations every few hundred meters in order to use higher frequency bands. Also, these higher frequency 5G signals cannot penetrate solid objects easily, such as cars, trees, and walls, because of the nature of these higher frequency electromagnetic waves. 5G cells can be deliberately designed to be as inconspicuous as possible, which finds applications in places like restaurants and shopping malls.

Cell types		Deployment environment	Max. number of users	Output power (mW)	Max. distance from base station
5G NR FR2	**Femtocell**	Homes, businesses	Home: 4–8 Businesses: 16–32	indoors: 10–100 outdoors: 200–1000	10s of meters
	Pico cell	Public areas like shopping malls, airports, train stations, skyscrapers	64 to 128	indoors: 100–250 outdoors: 1000–5000	10s of meters
	Micro cell	Urban areas to fill coverage gaps	128 to 256	outdoors: 5000−10000	few hundreds of meters
	Metro cell	Urban areas to provide additional capacity	more than 250	outdoors: 10000−20000	hundreds of meters
Wi-Fi **(for comparison)**		Homes, businesses	less than 50	indoors: 20–100 outdoors: 200–1000	few 10s of meters

3.5 Zigbee [14]

- The IEEE 802.15.4 standard is aimed at providing the essential lower network layers for a wireless personal area network, WPAN. The chief requirements are low-cost, low-speed communication between devices.
- IEEE 802.15.4 does not aim to compete with the more commonly used end user-oriented systems such as IEEE 802.11 where costs are not as critical and higher speeds are demanded and power may not be quite as critical. Instead, IEEE 802.15.4 provides for very low cost communication of nearby devices with little to no underlying infrastructure.
- The concept of IEEE 802.15.4 is to provide communications over distances up to about 10 metres and with maximum transfer data rates of 250 kbps. Anticipating that cost reduction will require highly embedded device solutions, the overall concept of IEEE 802.15.4 has been devised to accommodate this.

802.15.4 General Characteristics

Data rates of 250 kb/s, 40 kb/s and 20 kb/s.
Star or Peer-to-Peer operation.
Support for low latency devices.
Fully handshaked protocol for transfer reliability.
Low power consumption.
Frequency Bands of Operation
- 16 channels in the 2.4GHz ISM* band
- 10 channels in the 915MHz ISM band
- 1 channel in the European 868MHz band.

❖ **IEEE 802.15.4 star topology**

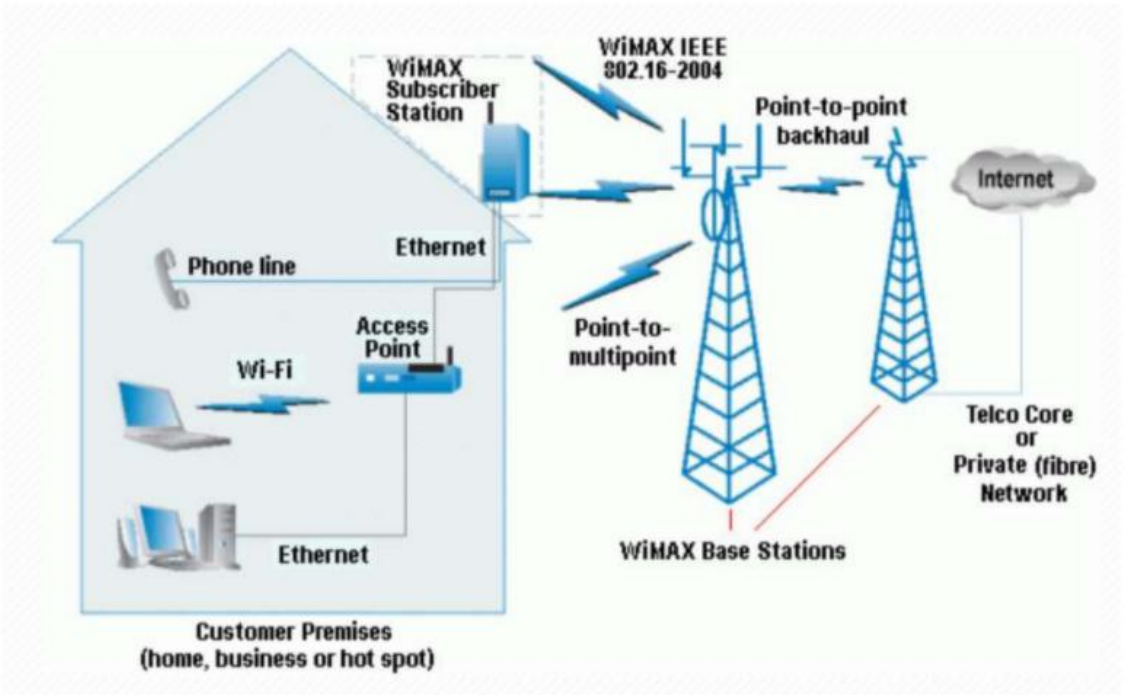
- In the star topology, all the different nodes are required to talk only to the central PAN coordinator. Even if the nodes are FFDs and are within range of each other, in a star network topology, they are only allowed to communicate with the coordinator node.

❖ **IEEE 802.15.4 peer to peer topology**

- A peer to peer, or p2p network topology provides a number of advantages over a star network topology. In addition to communication with the network coordinator, devices are also able to communicate with each other. FFDs are able to route data, while the RFDs are only able to provide simple communication.
- The fact that data can be routed via FFD nodes means that the network coverage can be increased. Not only can overall distances be increased, but nodes masked from the main network coordinator can route their data via another FFD node that it may be able to communicate with.

3.6 Worldwide Interoperability for Microwave Access (WiMax) 802.16a [16, 17]

- WiMAX is such an easy term that people tend to use it for the 802.16 standards and technology themselves, although strictly it applies only to systems that meet specific conformance criteria laid down by the WiMAX Forum.
- The 802.16a standard for 2-11 GHz is a wireless metropolitan area network (MAN) technology that will provide broadband wireless connectivity to Fixed, Portable and Nomadic devices.
- It can be used to connect 802.11 hot spots to the Internet, provide campus connectivity, and provide a wireless alternative to cable and DSL for last mile broadband access.



- Although Wi-Fi and WiMAX are designed for different situations, they are complementary. WiMAX network operators typically provide a WiMAX Subscriber Unit that connects to the metropolitan WiMAX network and provides Wi-Fi connectivity within the home or business for computers and smartphones. This enables the user to place the WiMAX Subscriber Unit in the best reception area, such as a window, and have date access throughout their property.

WiMax Speed and Range

- WiMAX is expected to offer initially up to about 40 Mbps capacity per wireless channel for both fixed and portable applications, depending on the particular technical configuration chosen, enough to support hundreds of businesses with T-1 speed connectivity and thousands of residences with DSL speed connectivity. WiMAX can support voice and video as well as Internet data.
- WiMax developed to provide wireless broadband access to buildings, either in competition to existing wired networks or alone in currently unserved rural or thinly populated areas. It can also be used to connect WLAN hotspots to the Internet.

WiMAX is also intended to provide broadband connectivity to mobile devices. It would not be as fast as in these fixed applications, but expectations are for about 15 Mbps capacity in a 3 km cell coverage area.

- With WiMAX, users could really cut free from today's Internet access arrangements and be able to go online at broadband speeds, almost wherever they like from within a MetroZone.
- WiMAX could potentially be deployed in a variety of spectrum bands: 2.3GHz, 2.5GHz,3.5GHz, and 5.8GHz

3.7 LiFi

- **Li-Fi** (short for *light fidelity*) 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.
- In terms of its end use, the technology is similar to Wi-Fi -- the key technical difference being that Wi-Fi uses radio frequency to induce a voltage in an antenna to transmit data. Whereas Li-Fi uses the modulation of light intensity to transmit data. Li-Fi can theoretically transmit at speeds of up to 100 Gbit/s. Li-Fi's ability to safely function in areas otherwise susceptible to electromagnetic interference (e.g. aircraft cabins, hospitals, military) is an advantage. The technology is being developed by several organizations across the globe.

❖ Initial and upcoming LiFi applications

- According to Li-Fi market research the global Li-Fi market is growing fast in its particular niche domains which do keep expanding though.

- A look at the main industries and LiFi use cases, as found by several reports, shows a picture that is relatively similar to the industries and initial use cases as reported in the press release of the IEEE study group launch. These include environments challenged by electromagnetic interference *(EMI)* such as hospitals *(think among others operating theaters)*, petrochemical plants and airplanes *(e.g. applications in*

aircraft cabins). They also include secure environments where RF *(radio frequency, used in Wi-Fi)* is not sanctioned.

❖ LIFI NETWORKS

- LiFi falls under the larger umbrella of VLC. Much of VLC research focuses on point-to-point communication. Furthermore, most VLC research assumes that the visible light spectrum is used for both uplink and downlink communication. In contrast, LiFi encompasses broader networked systems, including multiuser, bidirectional, multicast, or broadcast communication.

- While it uses the visible light spectrum for downlink, LiFi uses the infrared spectrum for the uplink. LiFi is enabled by an ecosystem of multiuser techniques, resource allocation algorithms, and security strategies.

- LiFi networks were designed from the start to work seamlessly with RF wireless networks, e.g., Wi-Fi, to enable efficient, opportunistic load balancing, and augmented capacity in heterogeneous networks

Conclusion :

From this experiment, I learned about the OSI Model,Physical Layer, the types of Wired and Wireless Connections. For each of these connections, I studied their specification, their scalability in the various network architecture, and their schematic view.

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