Name: Shivangi Kochrekar
Batch: B
UID: 2018130020
Roll No.23:

Experiment 1

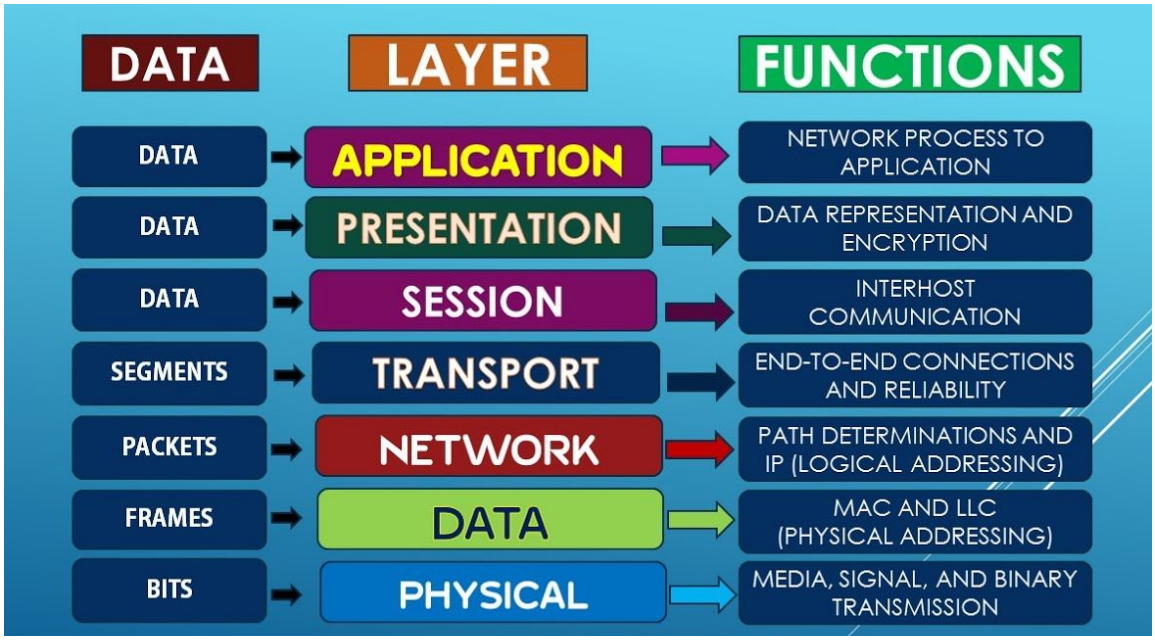
Aim: Study of different types of physical layer wired/wireless connections

1. **OSI Model-PHYSICAL LAYER (Ref 1 & 2)**

   The Open Systems Interconnection (OSI) model is a conceptual model created by the International Organization for Standardization which enables diverse communication systems to communicate using standard protocols. In plain English, the OSI provides a standard for different computer systems to be able to communicate with each other.

   The OSI model can be seen as a universal language for computer networking. It's based on the concept of splitting up a communication system into seven abstract layers, each one stacked upon the last.

   It is a 7 layer architecture with each layer having specific functionality to perform. All these 7 layers work collaboratively to transmit the data from one person to another across the globe.



Physical Layer (Layer 1): (Ref 2,3,4)

The lowest layer of the OSI reference model is the physical layer. It is responsible for the actual physical connection between the devices. The physical layer contains information in the form of bits. It is responsible for transmitting individual bits from one node to the next. When receiving data, this layer will get the signal received and convert it into 0s and 1s and send them to the Data Link layer, which will put the frame back together.

The physical layer is aimed at consolidating the hardware requirements of a network to enable the successful transmission of data. Network engineers can define different bit-transmission mechanisms for the physical layer level, including the shapes and types of connectors, cables, and frequencies for each physical medium.

Layer 1 is the first layer of the OSI Model, and therefore, the foundation upon which all higher-level functions are based. It translates the information that receives from the data-link layer (layer 2) into electromagnetic signals (binary data) to send them over the physical medium (wired or wireless media). These signals might consist of either digital signals (electrical pulses) or analog signals (continuous electromagnetic waves).

Examples of protocols that use physical layers include:

- Digital Subscriber Line.
- Integrated Services Digital Network.
- Infrared Data Association.
- Universal Serial Bus (USB.)
- Bluetooth.
- Controller Area Network.
- Ethernet.

2. WIRED CONNECTIONS(Ref 5)

Wired connections are by far the most common. The main media in use are coaxial cable, twisted pairs and 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.

2.1 ETHERNET (Ref 6, 7)

The Ethernet physical layer is the physical layer functionality of the Ethernet family of computer network standards. The physical layer defines the electrical or optical properties of the physical connection between a device and the network or between network devices. It is complemented by the MAC layer and the logical link layer.

The Ethernet physical layer has evolved over its existence starting in 1980 and 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.

Specifications:

- Range

  Over deployed multimode 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.

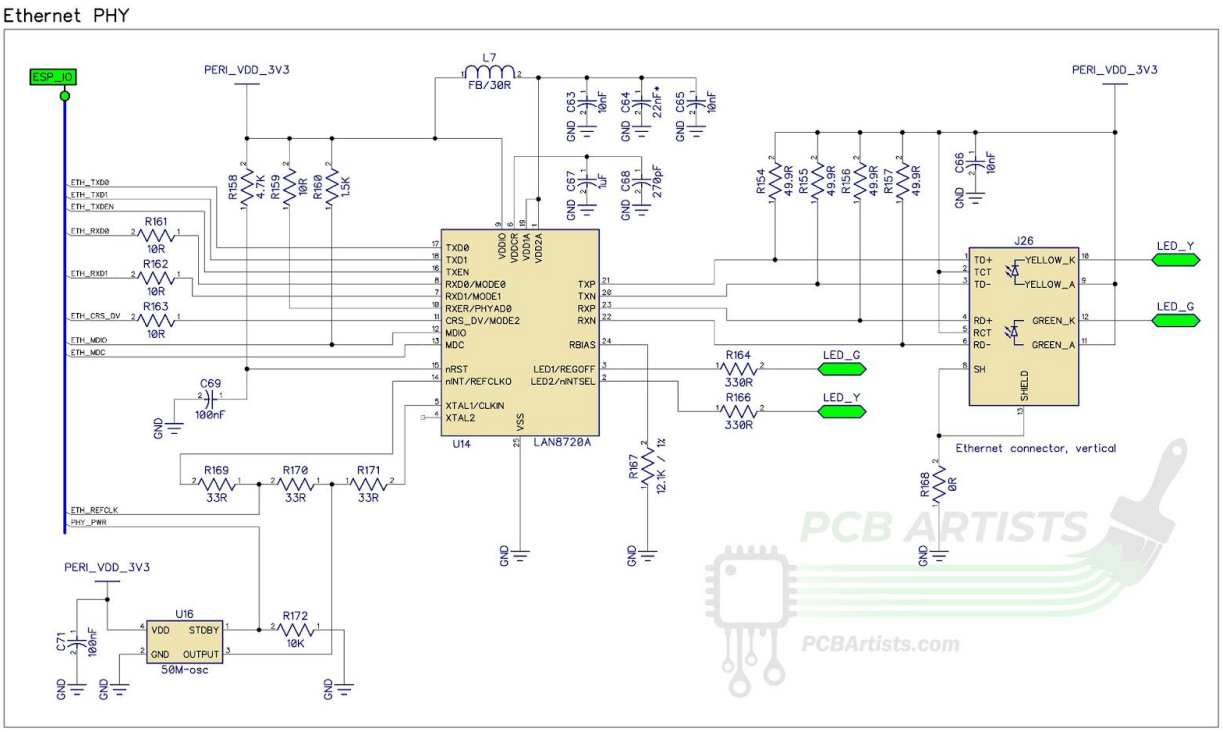
Scalability:

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.

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



2.2 USB (Ref 8,9)

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

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

Specifications

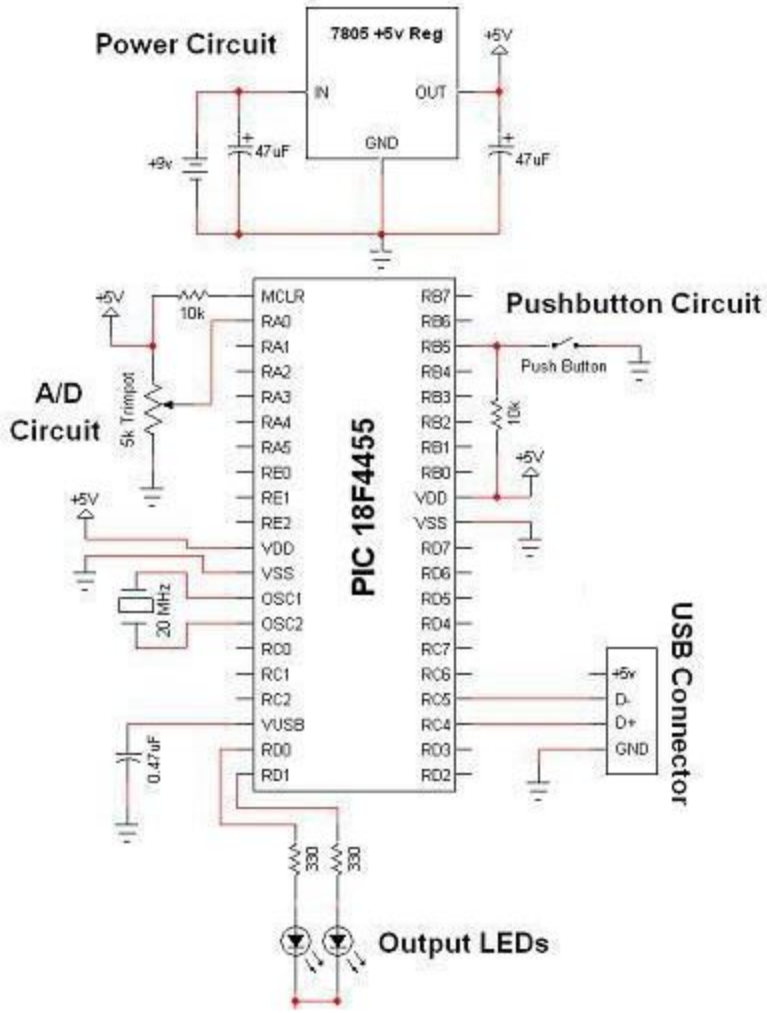
- Range:
    1. The USB 1.1 standard specifies that a standard cable can have a maximum length of 5 meters (16 ft 5 in) with devices operating at full speed (12 Mbit/s), and a maximum length of 3 meters (9 ft 10 in) with devices operating at low speed (1.5 Mbit/s).
    2. USB 2.0 provides for a maximum cable length of 5 meters (16 ft 5 in) for devices running at high speed (480 Mbit/s).
    3. 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 :
    1. At the input, the device communicates via MIDI and USB protocols. At the output is tension. Its value is managed by pulse-width modulation.
    2. Pulse-width modulation (PWM) is used for controlling the amplitude of digital signals in order to control devices and applications requiring power or electricity. It essentially controls the amount of power, from the perspective of the voltage component, that is given to a device by cycling the on-and-off phases of a digital signal quickly and varying the width of the "on" phase or duty cycle.
- Other specifications :
    1. 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.
    2. 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).

Scalability:

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

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, we'll see more about that in the theory and software sections. The main devices used in the circuit are the PIC 18F4455, USB Connector, and LM7805.



3. WIRELESS CONNECTIONS

Computer networks that are not connected by cables are called wireless networks. They generally use radio waves for communication between the network nodes. They allow devices to be connected to the network while roaming around within the network coverage.

3.1 BLUETOOTH (Ref 10,11)

Bluetooth is a wireless technology standard used for exchanging data between fixed and mobile devices over short distances using short-wavelength UHF radio waves in the industrial, scientific and medical radio bands, from 2.402 GHz to 2.480 GHz, and building personal area networks (PANs). It was originally conceived as a wireless alternative to RS-232 data cables.

The IEEE standardized Bluetooth as IEEE 802.15.1, but no longer maintains the standard. The Bluetooth SIG oversees development of the specification, manages the qualification program, and protects the trademarks. A manufacturer must meet Bluetooth SIG standards to market it as a Bluetooth device. A network of patents apply to the technology, which are licensed to individual qualifying devices

Specifications:

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

	BLUETOOTH V2.1	BLUETOOTH 4.0 (LE)	BLUETOOTH 5 (LE)
Range	Up to 100 m	Up to 100 m	Up to 400 m
Max range (free field)	Around 100 m (class 2 outdoors)	Around 100 m (outdoors)	Around 1,000m (outdoors)
Frequency	2.402 – 2.481 GHz	2.402 – 2.481 GHz	2.402 - 2.481 GHz
Max data rate	1- 3 Mbit/s	1 Mbit/s	2 Mbit/s
Application Troughput	0.7-2.1 Mbit/s	Up to 305 kbit/s	Up to 1,360 kbit/s
Topologies	Point-to-point, scatternet	Point-to-point, mesh network	Point-to-point, mesh network
Network Standard	IEEE 802.15.1	IEEE 802.15.1	IEEE 802.15.1

● Modulation

The format originally chosen for Bluetooth in version 1 was Gaussian frequency shift keying, GFSK, however with the requirement for higher data rates two forms of phase shift keying were introduced for Bluetooth 2 to provide the Enhanced Data Rate, EDR capability.

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

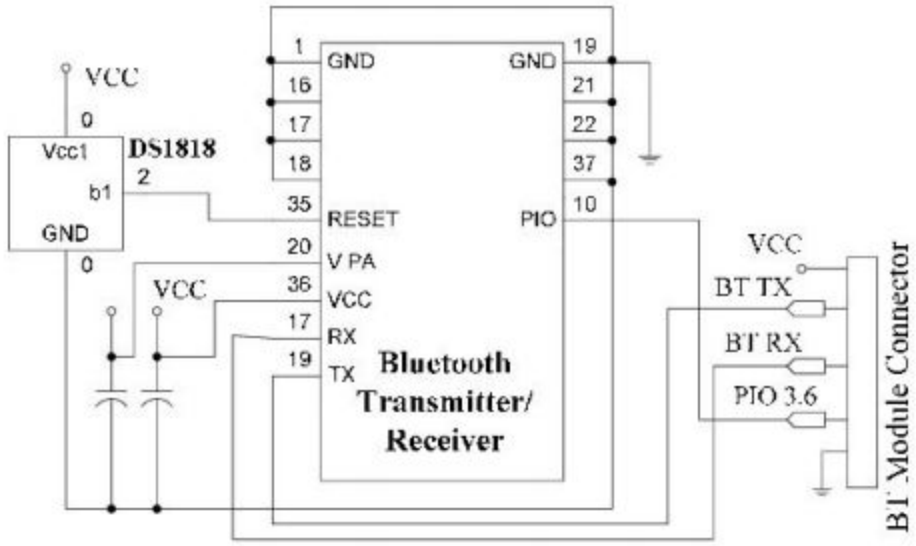
The Bluetooth modulation schemes and the general format do not lend themselves to carrying higher data rates. For Bluetooth 3, the higher data rates are not achieved by changing the format of the Bluetooth modulation, but by working cooperatively with an IEEE 802.11g physical layer. In this way data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

Scalability :

Bluetooth uses short-range radio waves. Uses in a WPAN include, for example, Bluetooth devices such as keyboards, pointing devices, audio headsets, printers may connect to smartwatches, cell phones, or computers. A Bluetooth WPAN is also called a piconet, and is composed of up to 8 active devices in a master-slave relationship (a very large number of additional devices can be connected in "parked" mode). The first Bluetooth device in the piconet is the master, and all other devices are slaves that communicate with the master. A piconet typically has a range of 10 metres (33 ft), although ranges of up to 100 metres (330 ft) can be reached under ideal circumstances. Long-range Bluetooth routers with augmented antenna arrays connect Bluetooth devices up to 1,000 feet.

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.



Bluetooth Module

3.2 Wireless Fidelity-WIFI (Ref 12)

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

Wi-Fi stations communicate by sending each other data packets: blocks of data individually sent and delivered over radio. As with all radio, this is done by the modulating and demodulation of carrier waves. Different versions of Wi-Fi use different techniques, 802.11b uses DSSS on a single carrier,

whereas 802.11a, Wi-Fi 4, 5 and 6 use multiple carriers on slightly different frequencies within the channel (OFDM).

Specifications:

Wi-Fi generations

Generation/IEEE Standard	Maximum Linkrate	Adopted	Frequency
Wi-Fi 6 (802.11ax)	600–9608 Mbit/s	2019	2.4/5 GHz 1–6 GHz ISM
Wi-Fi 5 (802.11ac)	433–6933 Mbit/s	2014	5 GHz
Wi-Fi 4 (802.11n)	72–600 Mbit/s	2009	2.4/5 GHz
Wi-Fi 3 (802.11g)	3–54 Mbit/s	2003	2.4 GHz
Wi-Fi 2 (802.11a)	1.5 to 54 Mbit/s	1999	5 GHz
Wi-Fi 1 (802.11b)	1 to 11 Mbit/s	1999	2.4 GHz

● Range

A wireless network's range can vary wildly depending on the type of network. A standard home network using one wireless router can serve a single-family dwelling, but often not much more.

Business networks with grids of access points can serve large office buildings, and wireless hotspots spanning several square miles have been built in some cities.

Wi-Fi can be used on several types of devices like personal computers, video game console, smart phones, digital camera, tablet computers etc. You can use Wi-Fi to create a hotspot within the range of 20 meters (66 feet).

● Modulation

WiFi systems use two primary radio transmission techniques.

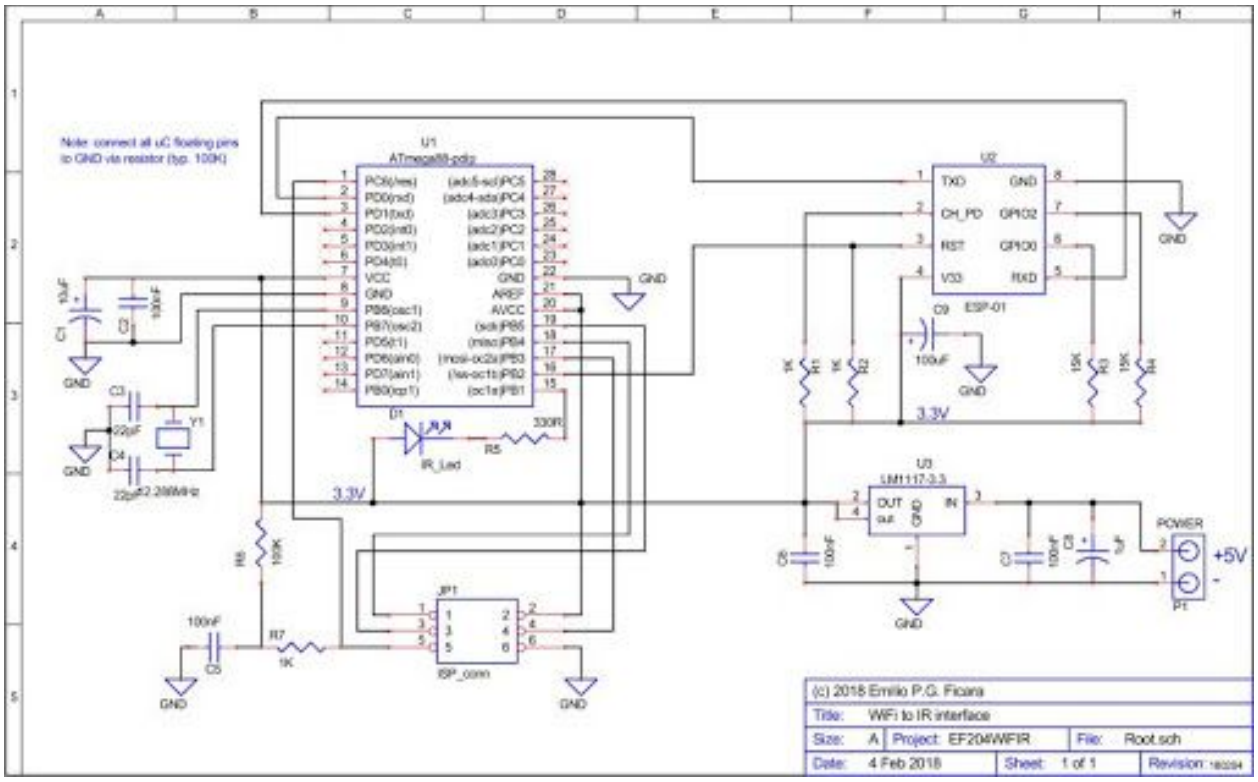
The bit stream is processed with a special coding and then modulated using Quadrature Phase Shift Keying (QPSK). ... 802.11a and g (<=54 Mbps) − The 802.11a and g systems use 64-channel orthogonal frequency division multiplexing (OFDM).

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.

Schematic View:



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 ZIGBEE(Ref 13)

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

Specification:

- **Range**

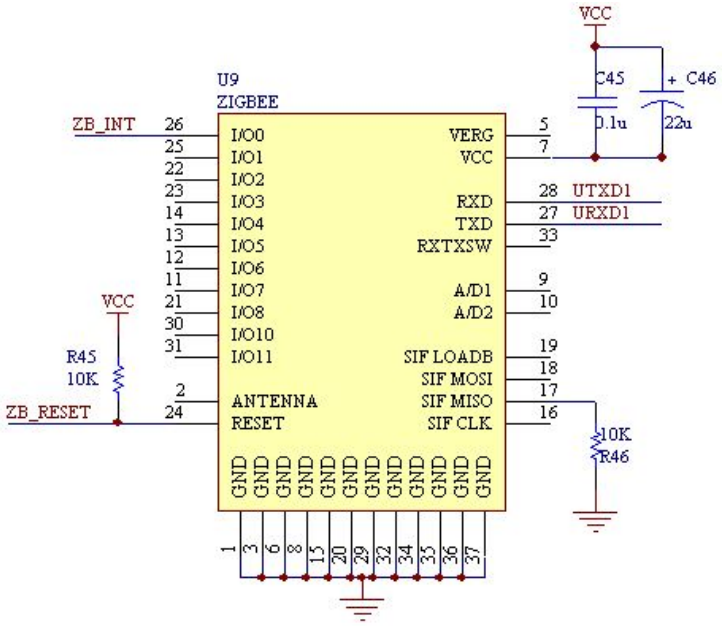
  Its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics. Zigbee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. Zigbee is typically used in low data rate applications that require long battery life and secure networking (Zigbee networks are secured by 128 bit symmetric encryption keys.) Zigbee has a defined rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

Scalability:

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

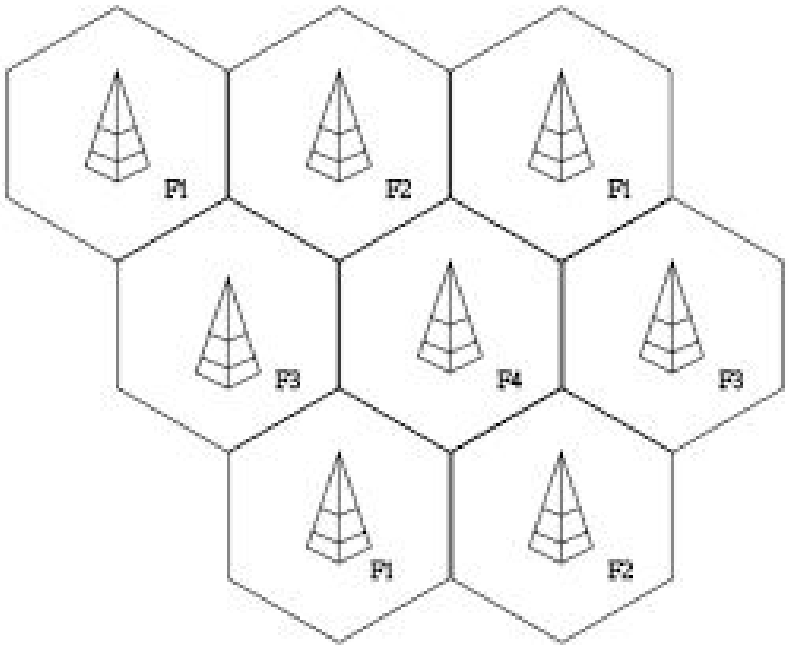
management systems, and other consumer and industrial equipment that require short-range low-rate wireless data transfer.

Schematic:



3.4 CELLULAR NETWORK (Ref 14,15)

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



Cellular networks offer a number of desirable features:

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

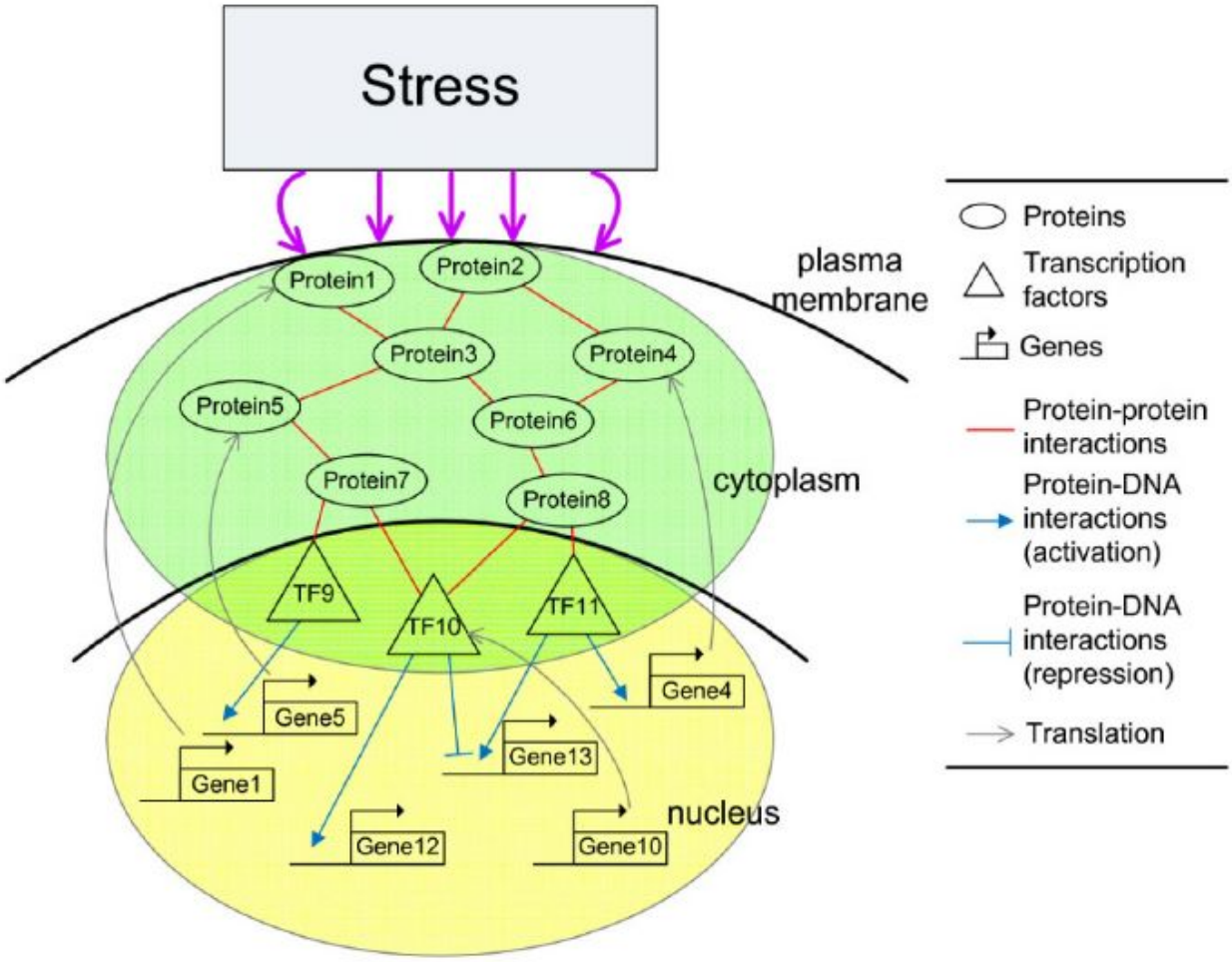
Specifications:

● Range

A cellular network is used by the mobile phone operator to achieve both coverage and capacity for their subscribers. Large geographic areas are split into smaller cells to avoid line of-sight signal loss and to support a large number of active phones in that area.

In cities, each cell site may have a range of up to approximately 1⁄2 mile (0.80 km), while in rural areas, the range could be as much as 5 miles (8.0 km). It is possible that in clear open
areas, a user may receive signals from a cell site 25 miles (40 km) away.

Schematic View:



References:

1. https://www.cloudflare.com/learning/ddos/glossary/open-systems-interconnection-model-osi/
2. https://www.geeksforgeeks.org/layers-of-osi-model/
3. https://www.studytonight.com/computer-networks/osi-model-physical-layer
4. https://www.techopedia.com/definition/8866/physical-layer
5. https://www.sciencedirect.com/topics/computer-science/wired-connection
6. https://en.wikipedia.org/wiki/Ethernet_physical_layer
7. https://searchnetworking.techtarget.com/definition/Ethernet
8. https://en.wikipedia.org/wiki/USB

9. https://www.cmd-ltd.com/advice-centre/usb-chargers-and-power-modules/usb-and-power-module-product-help/usb-data-transfer-guide/
10. https://en.wikipedia.org/wiki/Bluetooth
11. https://www.electronics-notes.com/articles/connectivity/bluetooth/radio-interface-modulation-channels.php
12. https://en.wikipedia.org/wiki/Wi-Fi
13. https://en.wikipedia.org/wiki/Zigbee
14. https://en.wikipedia.org/wiki/Cellular_network#:~:text=A%20cellular%20network%20or%20mobile,sites%20or%20base%20transceiver%20stations.
15. https://www.google.com/search?q=cellular+network+schematic+diagram&tbm=isch&ved=2ahUKEwi93dTJu6TrAhWLBHIKHU0FCAEQ2-cCegQIABAA&oq=cellular+network+schematic+diagram&gs_lcp=CgNpbWcQAzoECAAQQzoCCAA6BggAEAUQHjoGCAAQCBAeOgQIABAYUNvNA1jG7QNgp-8DaABwAHgAgAHiAYgBohOSAQYwLjE1LjGYAQCgAQGqAQtnd3Mtd2l6LWltZ8ABAQ&sclient=img&ei=0qI7X72sEYuJyAPNiqAI&rlz=1C5CHFA_enIN843IN843#imgrc=rvfKLhvSqkTUTM

Conclusion:

From this experiment, I learned about the 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.