Experiment 1

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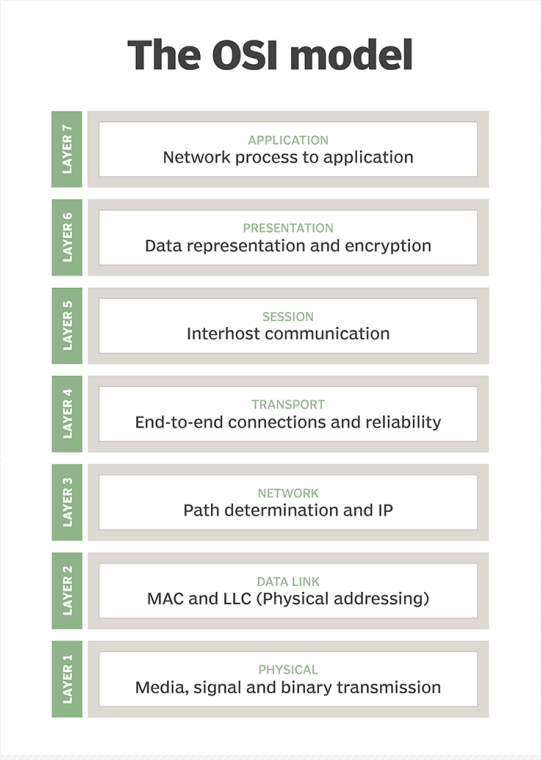
Aim: Study of different types of physical layer wired/wireless connections

Theory:

- ***What Is the OSI Model [1]***

The Open Systems Interconnection (OSI) model describes seven layers that computer systems use to communicate over a network. It was the first standard model for network communications, adopted by all major computer and telecommunication companies in the early 1980s

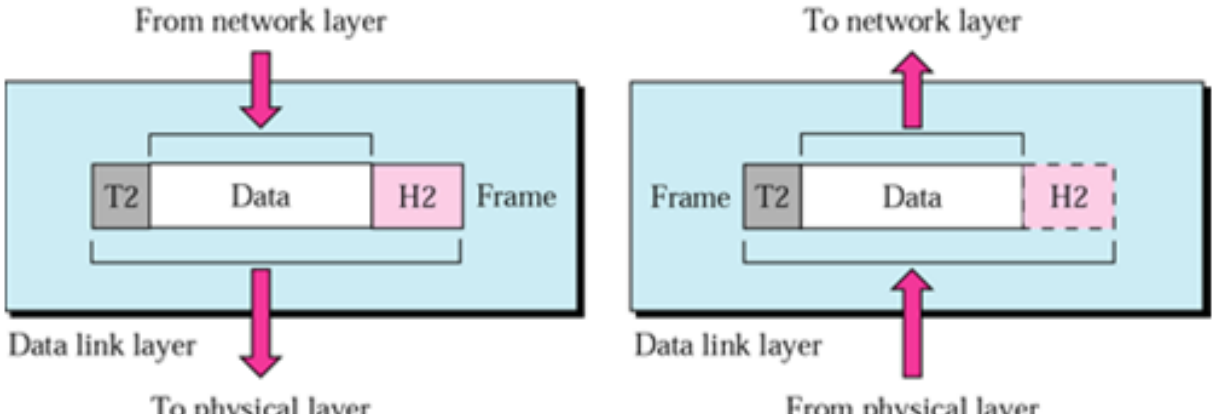
The modern Internet is not based on OSI, but on the simpler TCP/IP model. However, the OSI 7-layer model is still widely used, as it helps visualize and communicate how networks operate, and helps isolate and troubleshoot networking problems.



- ***Physical Layer [2,3]***

The physical layer is the lowest layer. This layer provides mechanical, electrical and other functional aids available to enable or disable, they maintain and transmit bits about physical connections. This may for example be electrical signals, optical signals (optical fiber, laser), electromagnetic waves (wireless networks) or sound. The techniques used are called technical transmission process. Devices and network components that are associated with the physical layer, for example, the antenna and the amplifier, plug and socket for the network cable, the repeater, the stroke, the transceiver, the T-bar and the terminator are (Terminator).

Its physical layer digital bit transfer is accomplished on a wireline or cable-free transmission path. The sharing of a transmission medium can be carried out on this layer by static multiplexing and dynamic multiplexing. This requires not only the specifications of certain transmission media (for example, copper cable, fiber optic cable, power grid) and the definition of connectors further elements. Furthermore, it must be resolved at this level, in what way a single bit to be transmitted.



This means the following: In computer networks today information is generally transmitted in the form of bit or symbol sequences. In copper cables and radio transmission, however, are modulated high frequency electromagnetic waves, the information carrier, in the optical waveguide light waves of a certain wavelength or different. The information carrier know no bit strings, but can take a lot more different states than just 0 or 1. For each type of transmission must therefore encoding are defined. That is due to the specification of the physical layer of a network.

Typical hardware on this layer: repeaters, hubs, cables, plugs,

Services

- Bit-by-bit or symbol-by-symbol delivery
- Modulation
- Line coding
- Bit synchronization
- Start-stop signalling
- Circuit switching
- Multiplexing
- Carrier sense and collision detection
- Physical **network topology,** like bus, ring, mesh or star network

In our further discussions we divide the Physical Layer into two categories as per medium of transmission, discuss their range and specifications and show their scalability and applicability in different architectures such as LAN, WAN, MAN, etc. The transmission medium can either be wired or wireless.

Wired Connections [4]

Signals being transmitted are directed and confined in a narrow pathway by using physical links. Wired connections are by far the most common. The main media in use are coaxial cable, twisted pairs and fibre optics It must also support two-way or multiway communications.

Features:

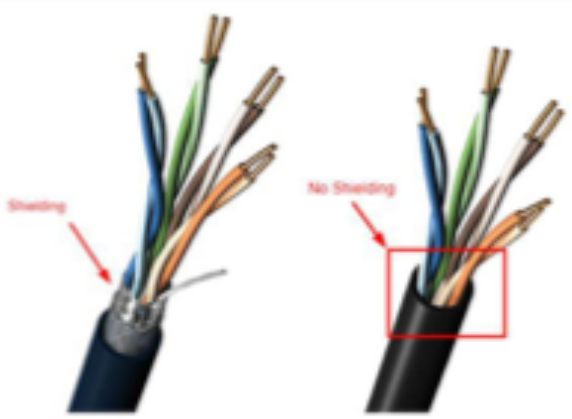
- High Speed
- Secure
- Used for comparatively shorter distances

There are 3 major types of Wired Media:

- Twisted Pair Cable
- Coaxial Cable
- Optical Fibre Cable

1) Twisted pair [5]

Twisted pair is a physical media made up of a pair of cables twisted with each other. A twisted pair cable is cheap as compared to other transmission media. Installation of the twisted pair cable is easy, and it is a lightweight cable. The frequency range for twisted pair cable is from 0 to 3.5KHz. It can either be a shielded or unshielded twisted pair.



Unshielded Twisted Pair Cable

It consists of two insulating copper wires (1mm thick). The wires are twisted together in a helical form to reduce electrical interference from a similar pair. Identification is the reason behind coloured plastic insulation.It has high-speed capacity. Bandwidth is low when compared with Coaxial Cable. It provides less protection from interference.

Scalability:

Higher grades of UTP are used in LAN technologies like Ethernet.

Shielded Twisted Pair Cable

This cable has a metal foil or braided-mesh. Electromagnetic noise penetration is prevented by a metal casing. Shielding also eliminates crosstalk. It is faster than unshielded and coaxial cable.

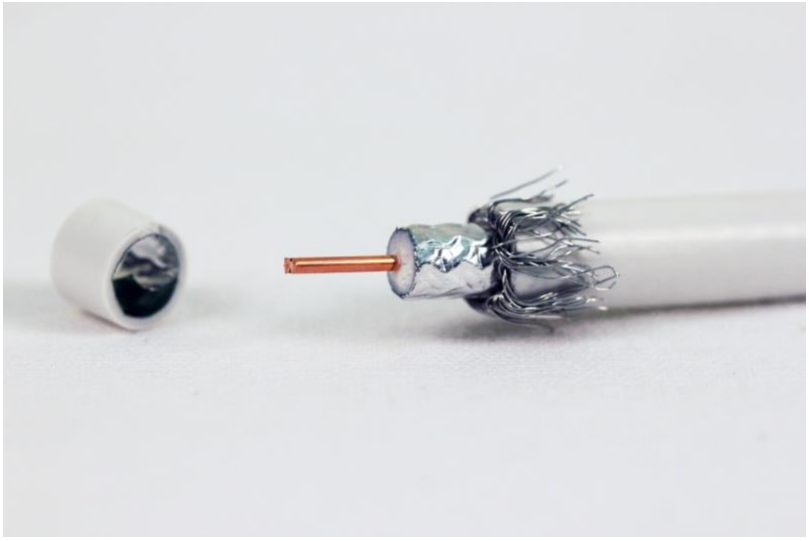
Advantages:

• It can be used for Analog or Digital transmission
• It increases the signalling rate.
• It eliminates crosstalk. Disadvantages
• It is difficult to manufacture

2) Coaxial Cable [5]

● Coaxial cable is a very commonly used transmission media, for example, TV wire is usually a coaxial cable.
● The name of the cable is coaxial as it contains two conductors parallel to each other.
● It has a higher frequency as compared to Twisted pair cable.

- The inner conductor of the coaxial cable is made up of copper, and the outer conductor is made up of copper mesh. The middle core is made up of a non-conductive cover that separates the inner conductor from the outer conductor.

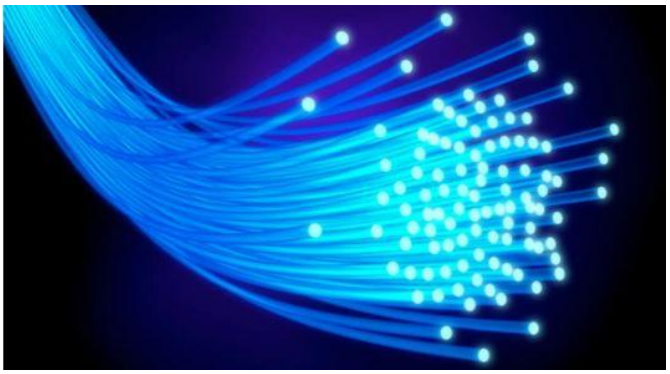


- The middle core is responsible for the data transferring whereas the copper mesh prevents EMI(Electromagnetic interference).
- The most common coaxial standards are:

• 50-Ohm RG-7 or RG-11: used with thick Ethernet.
• 50-Ohm RG-58: used with thin Ethernet
• 75-Ohm RG-59: used with cable television
• 93-Ohm RG-62: used with ARCNET.

3) Fiber Optic [5]

- Fiber optic cable is a cable that uses electrical signals for communication.
- Fiber optic is a cable that holds the optical fibers coated in plastic that are used to send the data by pulses of light.



- The plastic coating protects the optical fibers from heat, cold, electromagnetic interference from other types of wiring.
- Fiber optics provide faster data transmission than copper wires. Diagrammatic representation of fiber optic cable:

Scalability:
Used in CAN networks.

1) ETHERNET [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 the complemented by the MAC layer and 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.

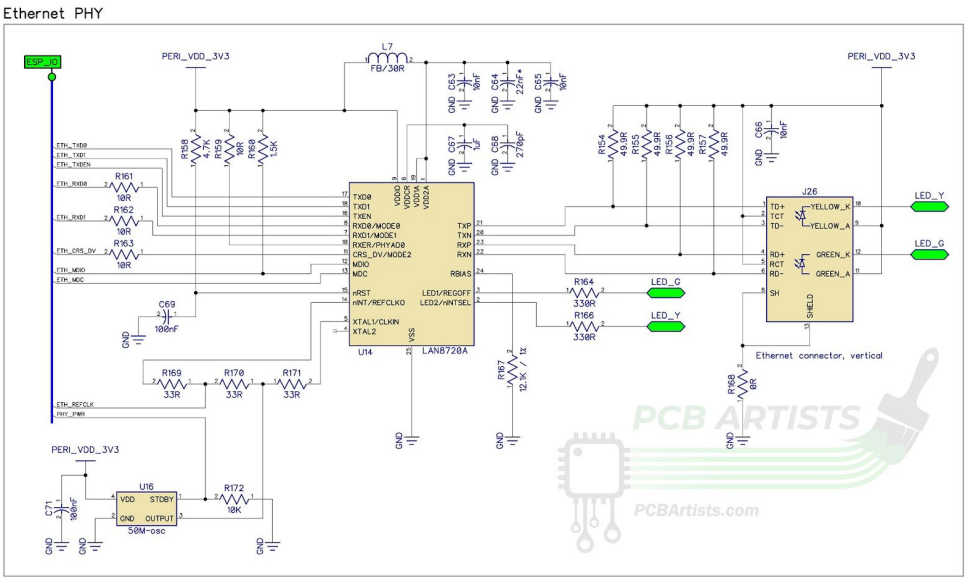
Scalability:

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) USB [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 :

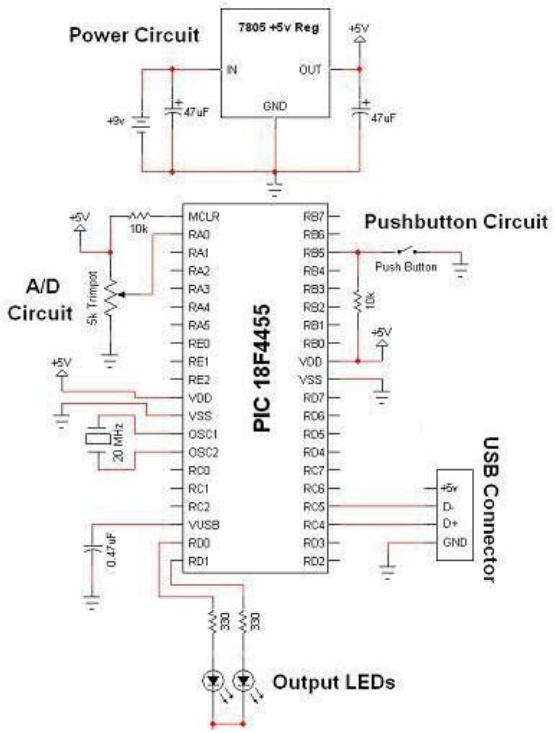
1. At the input, the device communicates via MIDI and USB protocols. At the output is tension. Its value is managed by pulse-width modulation.
2. Pulse-width modulation (PWM) is used for controlling the amplitude of digital signals in order to control devices and applications requiring power or electricity. 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.

Wireless Networks (Unguided Media) [10]

1) Radio waves

Radio wave **s** are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light. Electromagnetic waves from frequencies between 3 kHz and 1 GHz. Radio waves are omnidirectional (propagated in all directions). They can penetrate walls. They are useful for multicasting (one to many). Mostly used for wide area networks and mobile cellular phones.

2) Microwaves

Microwaves are a form of electromagnetic radiation with wavelengths ranging from about one meter to one millimetre. Electromagnetic waves from frequencies between 1 GHz and 300 GHz are called microwaves. Microwaves are unidirectional (sending and receiving antennas need to be aligned). Its propagation is line-of-sight (the sending and receiving antennas need to be properly aligned with each other.) Very high-frequency microwaves cannot penetrate walls. They are useful for uni-casting (one to one). Mostly used for Cellular phones, Satellite networks, and Wireless LAN.

3) Infrared

Infrared radiation (IR), is electromagnetic radiation (EMR) with longer wavelengths than those of visible light, and invisible to the human eye. Electromagnetic waves from frequencies between 300 GHz to 400 THz is called Infrared. Infrared waves is used for short-distance communication having high frequencies. They cannot penetrate walls. Infrared Data Association (IrDA) is used for communication between devices such as PCs, keyboards, mice, and printers. IrDA port allows wireless keyword to communicate with a computer.

1) BLUETOOTH [11,12]

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.

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.

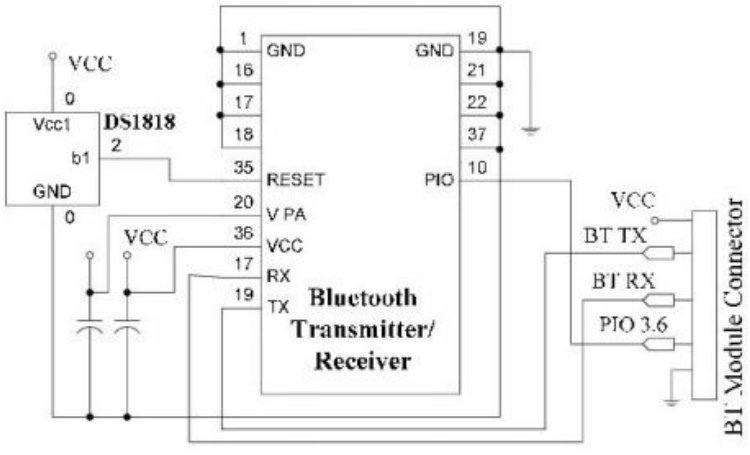
	BLUETOOTH V2.1	BLUETOOTH 4.0 (LE)	BLUETOOTH 5 (LE)
Range	Up to 100 m	Up to 100 m	Up to 400 m
Max range (free field)	Around 100 m (class 2 outdoors)	Around 100 m (outdoors)	Around 1,000m (outdoors)
Frequency	2.402 – 2.481 GHz	2.402 – 2.481 GHz	2.402 - 2.481 GHz
Max data rate	1- 3 Mbit/s	1 Mbit/s	2 Mbit/s
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

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



Bluetooth Module

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.

2) Wireless Fidelity-WIFI [13]

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).

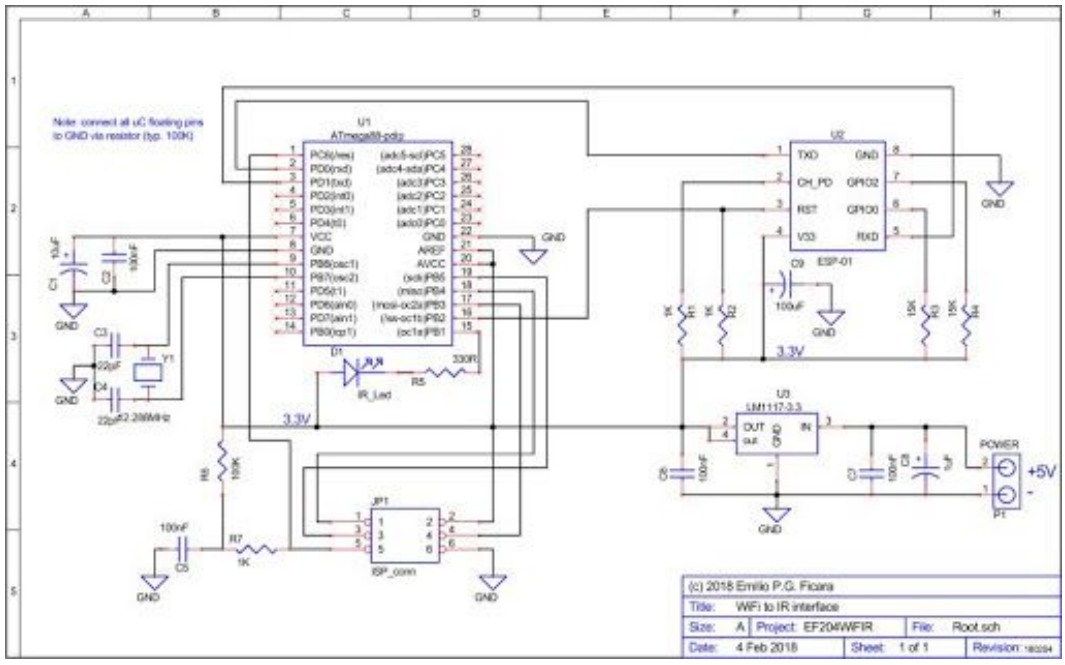
Scalability:

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) ZIGBEE [14]

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.

Specifications:

Range:

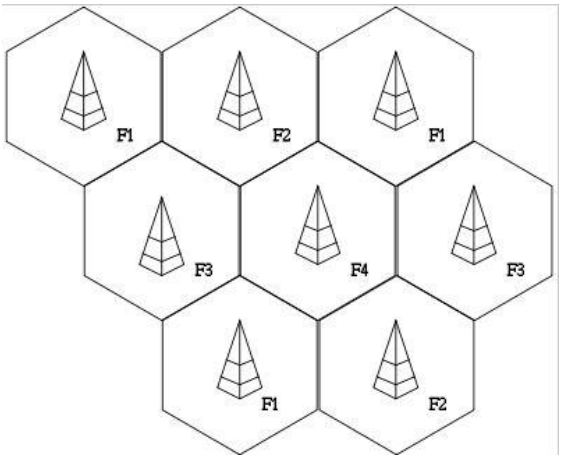
Its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics. Zigbee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. Zigbee is 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.

4) Cellular Network [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:

- 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
- Mobile devices use less power than with a single transmitter or satellite since the cell towers are closer
- Larger coverage area than a single terrestrial transmitter, since additional cell towers can be added indefinitely and are not limited by the horizon.

Specifications:

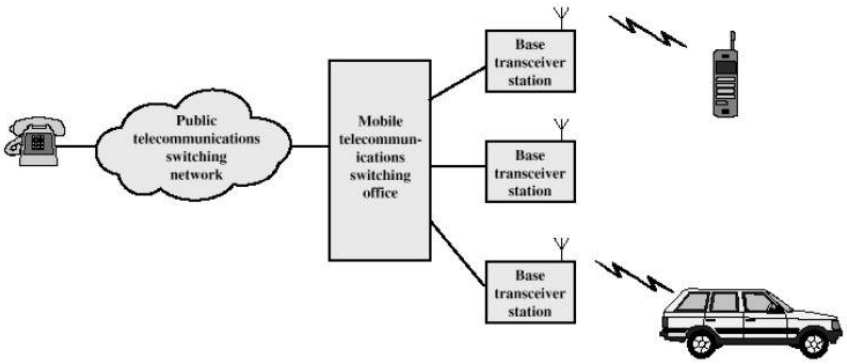
Range:

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- o

Cellular System Overview: [16]

f-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 ½ mile (0.80km), 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.



- Base Station (BS) – includes an antenna, a controller, and a number of receivers
- Mobile telecommunications switching office(MTSO) – connects calls between mobile units

Conclusion:

This experiment helped me learn about

- OSI model's physical layer
- Different types of wired and wireless connections
- These connections' scalability, specifications, etc.

References:

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Physical Layer**:**

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Twisted Pair, Coaxial, Fiber optics

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