Name : Vedant Vinay Mehta

Batch : B

Class: SE Computers

UID : 2018130028

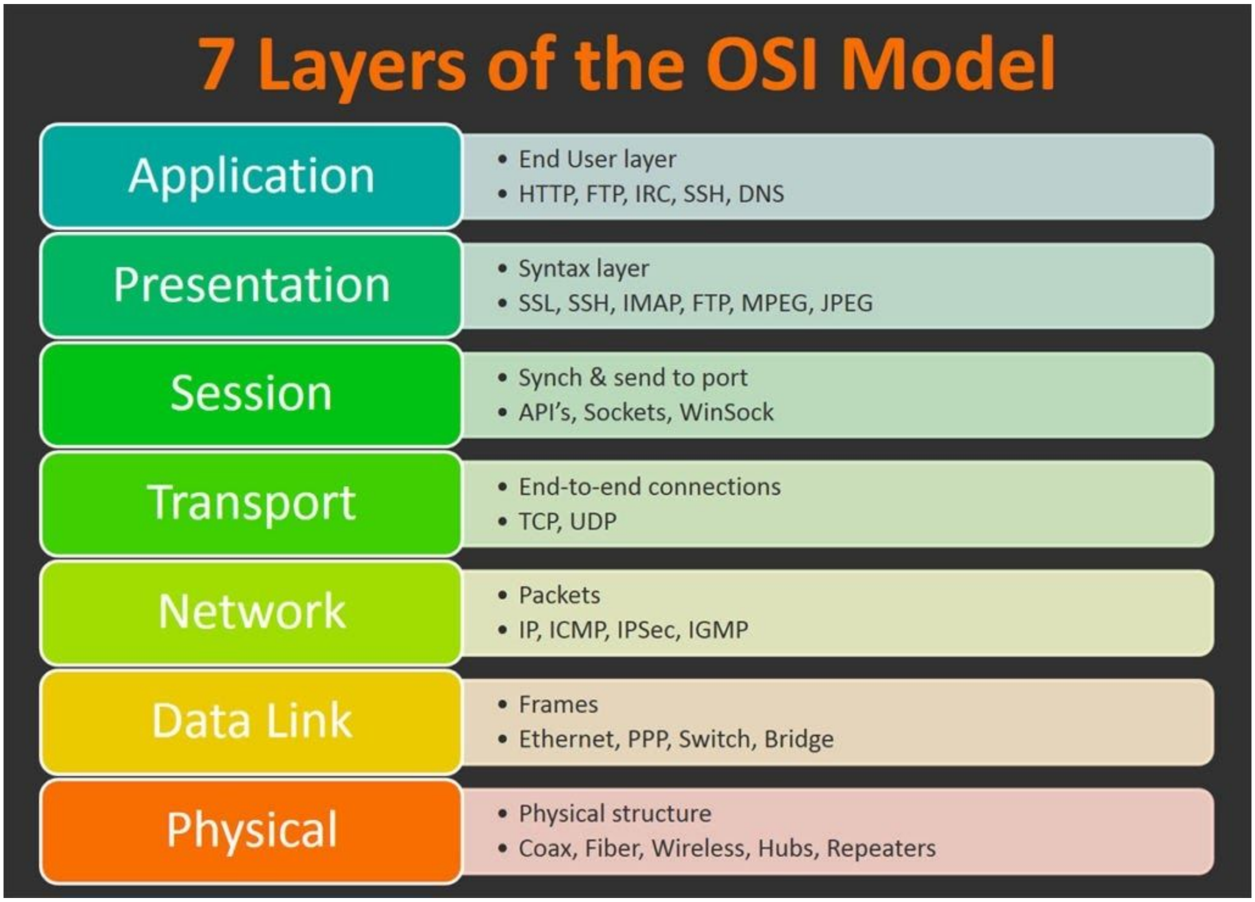
EXPERIMENT 1

Aim

Study the different types of physical layer wired and wireless connections.

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.



Physical Layer [2]

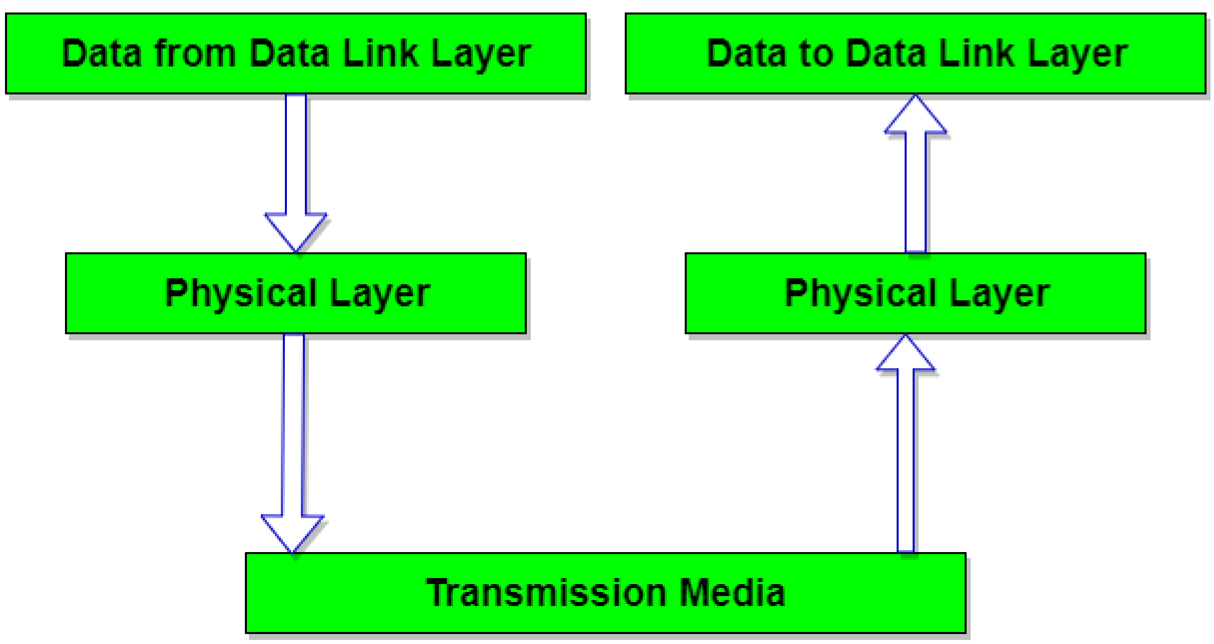
The lowest layer of the OSI reference model is the physical layer. It is responsible for the actual physical connection between the devices. The physical layer contains information in the form of bits. It is responsible for transmitting individual bits from one node to the next. When receiving data, 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.

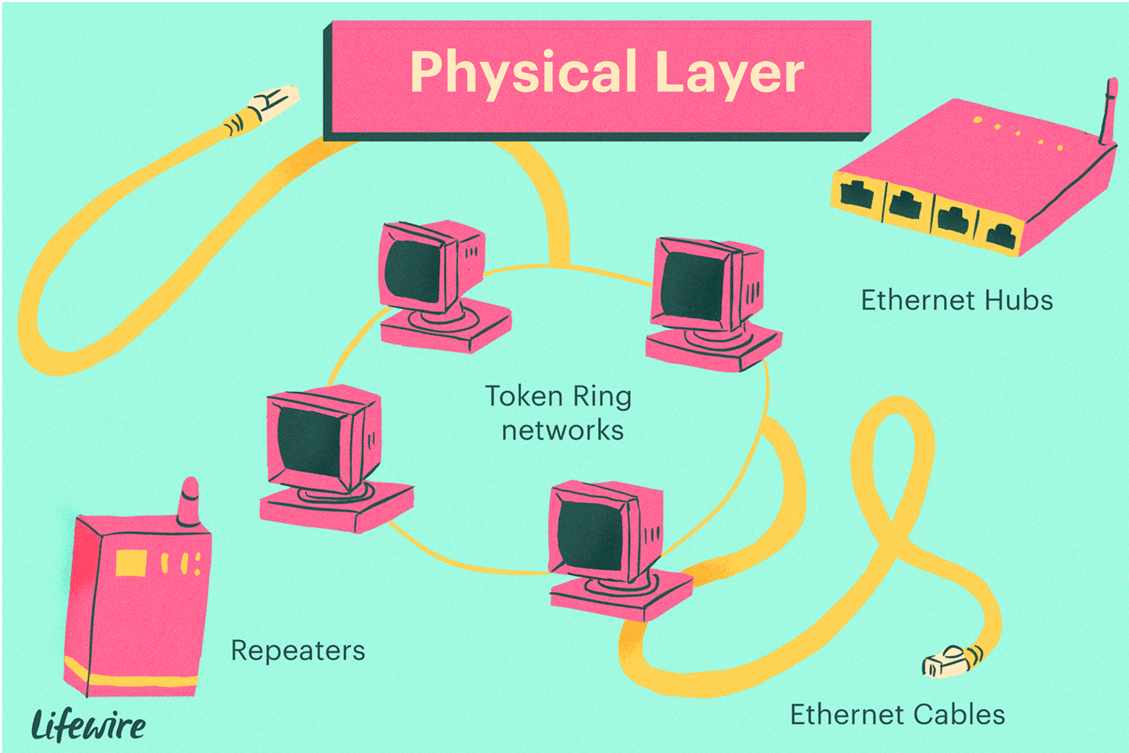
The functions of the physical layer are :

1. **Bit synchronization:** The physical layer provides the synchronization of the bits by providing a clock. This

clock controls both sender and receiver thus providing synchronization at bit level.

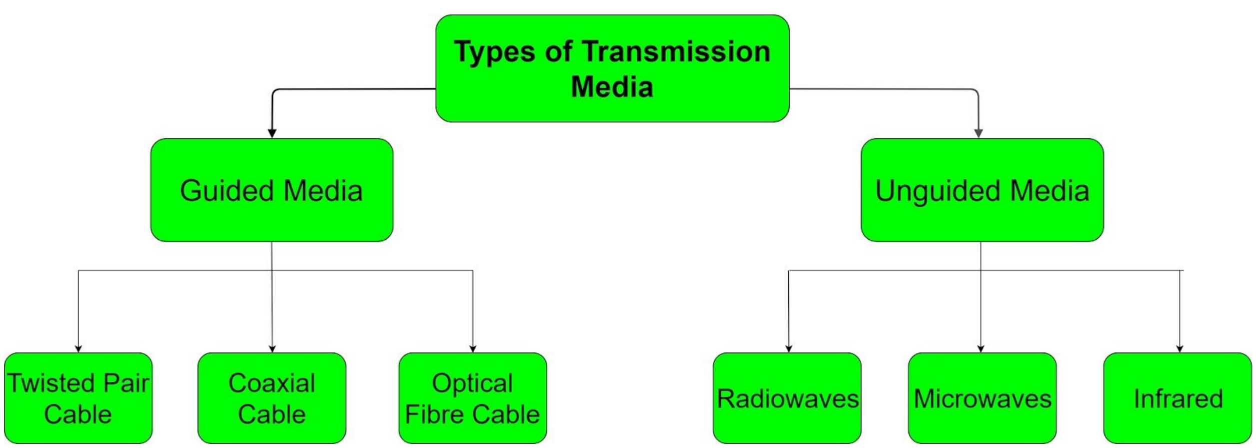
2. **Bit rate control:** The Physical layer also defines the transmission rate i.e. the number of bits sent per second.
3. **Physical topologies:** Physical layer specifies the way in which the different devices/nodes are arranged in a network i.e. bus, star or mesh topology.
4. **Transmission mode:** Physical layer also defines the way in which the data flows between the two connected devices. The various transmission modes possible are: Simplex, half-duplex and full-duplex





Types of Transmission Media for communication through physical layer

In data communication terminology, a transmission medium is a physical path between the transmitter and the receiver i.e it is the channel through which data is sent from one place to another. Transmission Media is broadly classified into the following types:



Wired Connections (Guided media) [3]

1) Twisted pair

A twisted pair can be used as a balanced line, which as part of a balanced circuit can greatly reduce the effect of noise currents induced on the line by coupling of electric or magnetic fields. The idea is that the currents induced in each of the two wires are very nearly equal. The twisting ensures that the two wires are on average the same distance from the interfering source and are affected equally. The noise thus produces a common-mode signal which can be cancelled at the receiver by detecting the difference signal only, the latter being the wanted signal.

Common-mode rejection starts to fail on untwisted wires when the noise source is close to the signal wires; the closer wire will couple with the noise more strongly and the receiver will be unable to eliminate it. This problem is especially apparent in telecommunication cables where pairs in the same cable lie next to each other for many miles. Twisting the pairs counters this effect as on each half twist the wire nearest to the noise-source is exchanged. Provided the interfering source remains uniform, or nearly so, over the distance of a single twist, the induced noise will remain common-mode.

The twist rate (also called pitch of the twist, usually defined in twists per metre) makes up part of the specification for a given type of cable. When nearby pairs have equal twist rates, the same conductors of the different pairs may repeatedly lie next to each other, partially undoing the benefits of twisting. For this reason it is commonly specified that, at least for cables containing small numbers of pairs, the twist rates must differ.[2]

In contrast to shielded or foiled twisted pair (typically S/FTP or F/UTP cable shielding), UTP (unshielded twisted pair) cable is not surrounded by any shielding. UTP is the primary wire type for telephone usage and is very common for computer networking.
Twisted pair can be used for transmitting either analog or digital signal and frequency range for twisted pair cable is 100 Hz to 5 MHz. The most common application of twisted pair cable IS m telephone system.
Range : 100 m

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

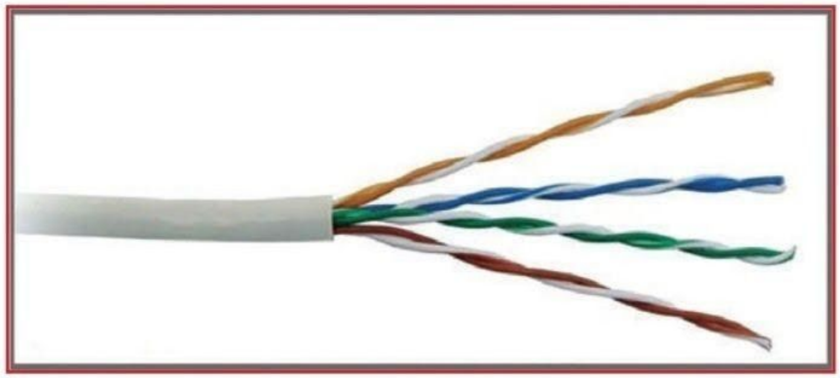


Figure 14.9 Unshielded Twisted Pair Cable

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 colored plastic insulation.It has high-speed capacity. Bandwidth is low when compared with Coaxial Cable. It provides less protection from interference.

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 signaling rate.
- It eliminates crosstalk. Disadvantages

- It is difficult to manufacture

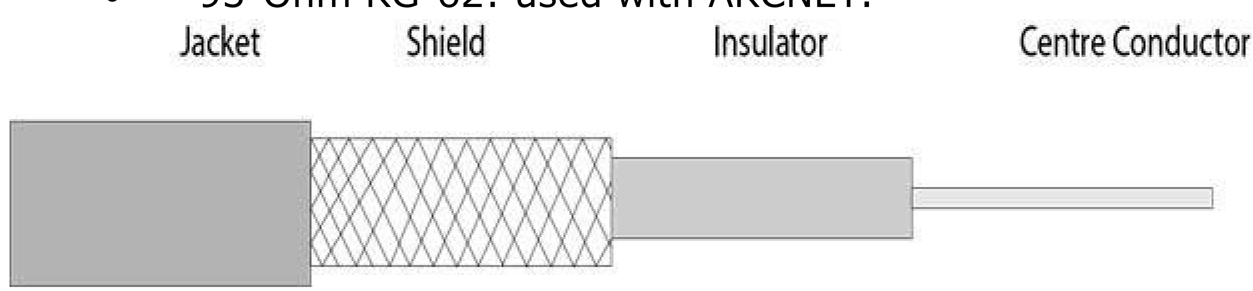
Figure 14.10 Shielded Twisted Pair

Scalability

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

2) Coaxial Cable

- 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.



Types of coaxial cables

There are numerous types of coaxial cables, some types include:

Hard-line coaxial cable- Which relies on round copper tubing and a combination of metals as a shield, such as aluminum or copper. These cables are commonly used to connect a transmitter to an antenna.

Triaxial cable- Which has a third layer of shielding that is grounded to protect signals transmitted down the cable.

Rigid-line coaxial cables- Which are made up of twin copper tubes that function as unbendable pipes. These lines are designed for indoor use between high-power radio frequency (RF) transmitters.

Radiating cable- Which mimics many components of the hard-line cable, but with tuned slots in the shielding matched to the RF wavelength at which the cable will operate. It is commonly used in elevators, military equipment and underground tunnels.

Uses of coaxial cables

In the home and small offices, short coaxial cables are used for cable television, home video equipment, amateur radio equipment and measuring devices. Historically, coaxial cables were also used as an early form of Ethernet, supporting speeds of up to 10 Mbps, but coax has been supplanted by the use of twisted pair cabling. However, they remain widely in use for cable broadband internet. Coaxial cables are also used in automobiles, aircraft, military and medical equipment, as well as to connect satellite dishes, radio and television antennae to their respective receivers.

3) Fiber Optic

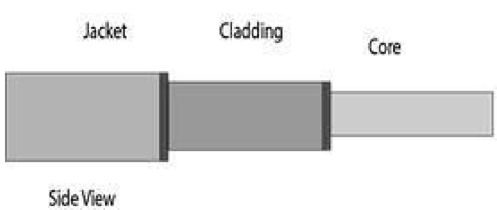
Fiber optic cable is a cable that uses electrical signals for communication.

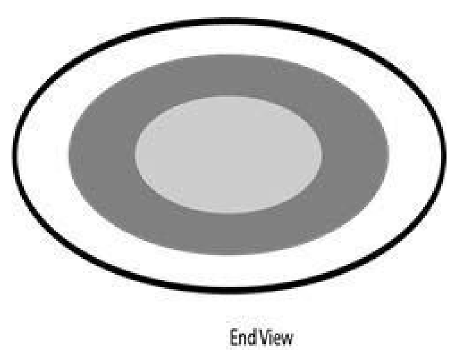
Fiber optic is a cable that holds the optical fibers coated in plastic that are used to send the data by pulses of light.

The plastic coating protects the optical fibers from heat, cold, electromagnetic interference from other types of wiring.

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of infrared light through an optical fiber. The light is a form of carrier wave that is modulated to carry information.Fiber is preferred over electrical cabling when high bandwidth, long distance, or immunity to electromagnetic interference is required. This type of communication can transmit voice, video, and telemetry through local area networks or across long distances.

Fiber optics provide faster data transmission than copper wires. Diagrammatic representation of fiber optic cable:





Optical fiber is used by many telecommunications companies to transmit telephone signals, Internet communication, and cable television signals. Researchers at Bell Labs have reached internet speeds of over 100 petabit × kilometer per second using fiber-optic communication

A fiber-optic cable, also known as an optical-fiber cable, is an assembly similar to an electrical cable, but containing one or more optical fibers that are used to carry light. The optical fiber elements are typically individually coated with plastic layers and contained in a protective tube suitable for the environment where the cable will be deployed.

Infrared light propagates through the fiber with much lower attenuation compared to electrical cables. This allows long distances to be spanned with few repeaters. Fiber is also immune to electrical interference; there is no cross-talk between signals in different cables and no pickup of environmental noise.

Non-armored fiber cables do not conduct electricity, which makes fiber a good solution for protecting communications equipment in high voltage environments, such as power generation facilities, or metal communication structures prone to lightning strikes, and also preventing problems with ground loops. They can also be used in environments where explosive fumes are present, without danger of ignition, and wiretapping is more difficult compared to electrical connections.

Different types of cable are used for different applications, for example, long distance telecommunication, or providing a high-speed data connection between different parts of a building. Digital global networks require huge carrying capacity in the main backbones which is currently achieved by fiber optic cables. In September 2012, NTT Japan demonstrated a single fiber cable that was able to transfer 1 petabit per second (101 5b its/s) over a distance of 50 kilometers. Modern fiber cables can contain up to a thousand fibers in a single cable, with potential bandwidth in the terabytes per second. In some cases, only a small fraction of the fibers in a cable may be actually "lit".

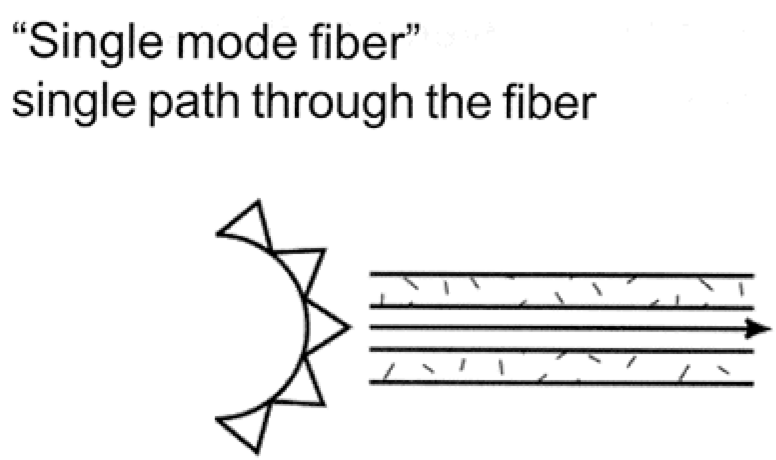
Optical fibre is rapidly replacing copper wires in telephone lines, internet communication and even cable TV connections because transmitted data can travel very long distances without weakening. Single node fibre optic cable can have maximum segment length of 2 kms and bandwidth of up to 100 Mbps Optical fiber transmission uses wavelengths that are in the near-infrared portion of the spectrum, just above the visible, and thus undetectable to the unaided eye. Typical optical transmission wavelengths are 850 nm, 1310 nm, and 1550 nm. Both lasers and LEDs are used to transmit light through optical fiber.

Single Mode cable is a single stand (most applications use 2 fibers) of glass fiber with a diameter of 8.3 to 10 microns that has one mode of transmission. Single Mode Fiber with a relatively narrow diameter, through which only one mode will propagate typically 1310 or 1550nm. Carries higher bandwidth than multimode fiber, but requires a light source with a narrow spectral width. Synonyms mono-mode optical fiber, single-mode fiber, single-mode optical waveguide, uni-mode fiber.

Single Modem fiber is used in many applications where data is sent at multi-frequency (WDM Wave-Division-Multiplexing) so only one cable is needed - (single-mode on one single fiber)

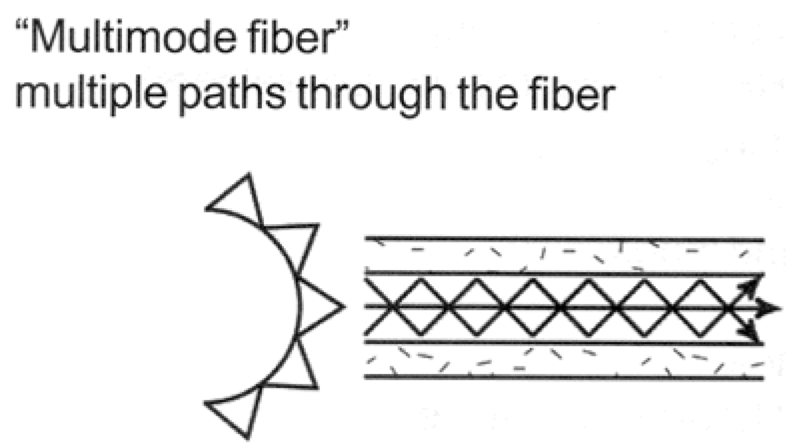
Single-mode fiber gives you a higher transmission rate and up to 50 times more distance than multimode, but it also costs more. Single-mode fiber has a much smaller core than multimode. The small core and single light-wave virtually eliminate any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fiber cable type.

Single-mode optical fiber is an optical fiber in which only the lowest order bound mode can propagate at the wavelength of interest typically 1300 to 1320nm jump to single mode fiber page



Multi-Mode cable has a little bit bigger diameter, with a common diameter in the 50-to-100 micron range for the light carry component (in the US the most common size is 62.5um). Most applications in which Multimode fiber is used, 2 fibers are used (WDM is not normally used on multi-mode fiber). POF is a newer plastic-based cable which promises performance similar to glass cable on very short runs, but at a lower cost.

Multimode fiber gives you high bandwidth at high speeds (10 to 100MBS - Gigabit to 275m to 2km) over medium distances. Light waves are dispersed into numerous paths, or modes, as they travel through the cable's core typically 850 or 1300nm. Typical multimode fiber core diameters are 50, 62.5, and 100 micrometers. However, in long cable runs (greater than 3000 feet [914.4 meters), multiple paths of light can cause signal distortion at the receiving end, resulting in an unclear and incomplete data transmission so designers now call for single mode fiber in new applications using Gigabit and beyond.



Fiber Type	Core Diameter	1 Gb Ethernet	10 Gb Ethernet	40 Gb Ethernet	100 Gb Ethernet
OM1 Multimode	62.5/125	275 Meters	33 Meters	Not Supported	Not Supported
OM2 Multimode	50/125	550 Meters	82 Meters	Not Supported	Not Supported
OM3 Multimode	50/125	550 Meters	300 Meters	100 Meters	100 Meters
OM4 Multimode	50/125	550 Meters	400 Meters	150 Meters	150 Meters
OM5 Multimode	50/125	550 Meters	400 Meters	150 Meters	150 Meters
Singlemode	9/125	Up to 2 Km using PSM4 transceiver			

Scalability

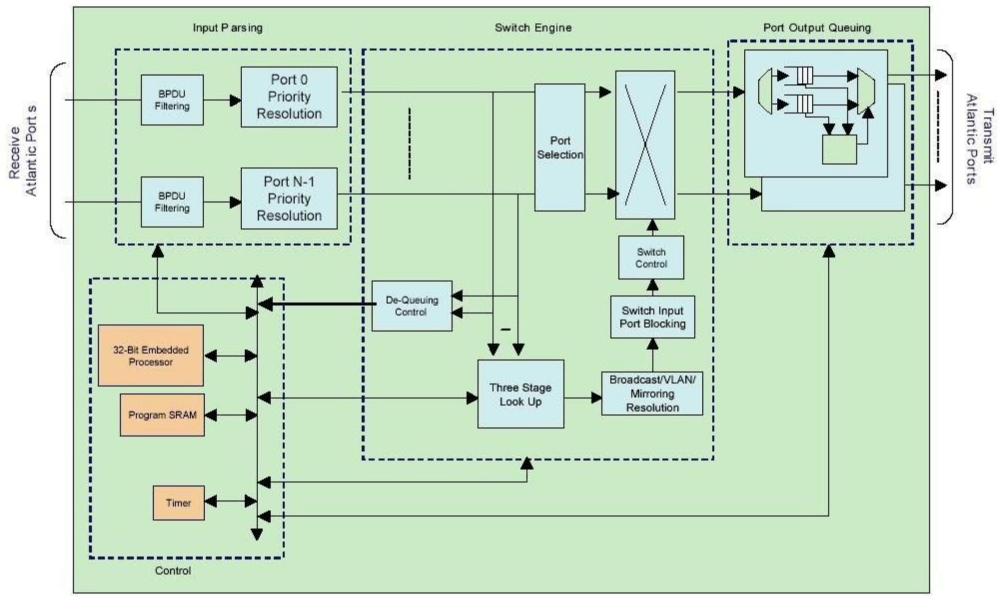
Used in CAN networks LAN and MAN networks.

Ethernet [4]

Ethernet is the traditional technology for connecting devices in a wired local area network (LAN) or wide area network (WAN), enabling them to communicate with each other via a protocol -- a set of rules or common network language. Ethernet describes how network devices can format and transmit data so other devices on the same local or campus area network segment can recognize, receive and process the information. An Ethernet cable is the physical, encased wiring over which the data travels.

Connected devices accessing a geographically localized network with a cable -- that is, with a wired rather than wireless

Figure 1: Ethernet Layer 2 Switch Block Diagram



connection -- likely use Ethernet. From businesses to gamers, diverse end users depend on the benefits of Ethernet connectivity, which include reliability and security. Schematic View

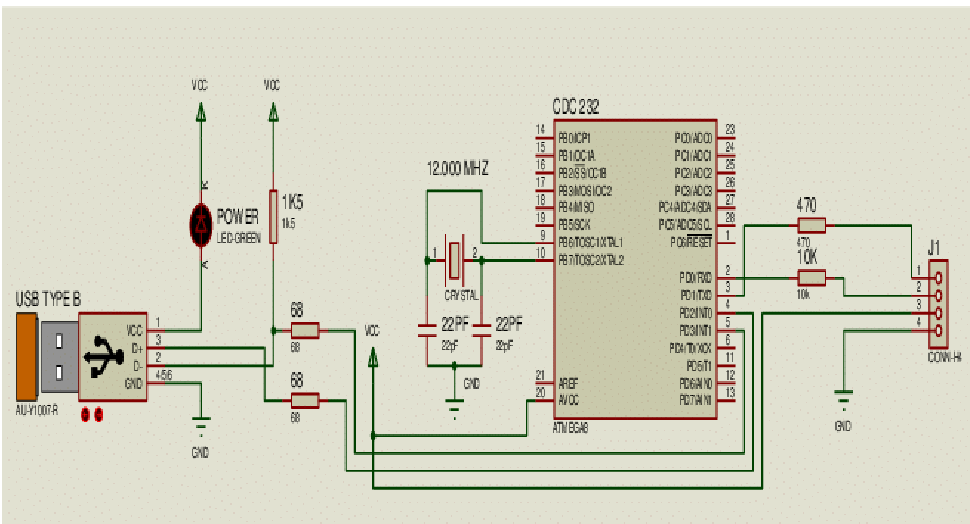
Specifications :

- Range: Over deployed multimode cabling ethernet supports ranges of between 240m 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.

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.

USB [5]



Short for **universal serial bus**, **USB** is a plug and play interface that allows a computer to communicate with peripheral and other devices. USB-connected devices cover a broad range; anything from keyboards and mice, to music players and flash drives. For more information on these devices, see our USB devices section.Schematic Diagram

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 and varying the width of the "on" phase or duty cycle.

Scalability

USBs are used mostly in Wired Personal Area Networks(WPAN).

Wireless Networks (Unguided Media) [6]

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.

Microwaves

Microwaves are a form of electromagnetic radiation with wavelengths ranging from about one meter to one millimeter. 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 unicasting (one to one). Mostly used for Cellular phones, Satellite networks, and Wireless LAN.

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 are called Infrared. Infrared waves are 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 keyboard to communicate with a computer.

Bluetooth [7]

A Bluetooth technology is a high speed low powered wireless technology link that is designed to connect phones or other portable equipment together. It is a specification (IEEE 802.15.1) for the use of low power radio communications to link phones, computers and other network devices over short distances without wires. Wireless signals transmitted with Bluetooth cover short distances, typically up to 30 feet (10 meters).
It is achieved by embedded low cost transceivers into the devices. It supports on the
frequency band of 2.45GHz and can support upto 721KBps along with three voice channels. This frequency band has been set aside by international agreement for the use of industrial, scientific and medical devices (ISM).rd-compatible with 1.0 devices.

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.

Scalability

Bluetooth has been developed to facilitate wireless personal area networks (PANs), 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.

Zigbee [8]

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 adhoc network.

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.

Its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics.[2] 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.

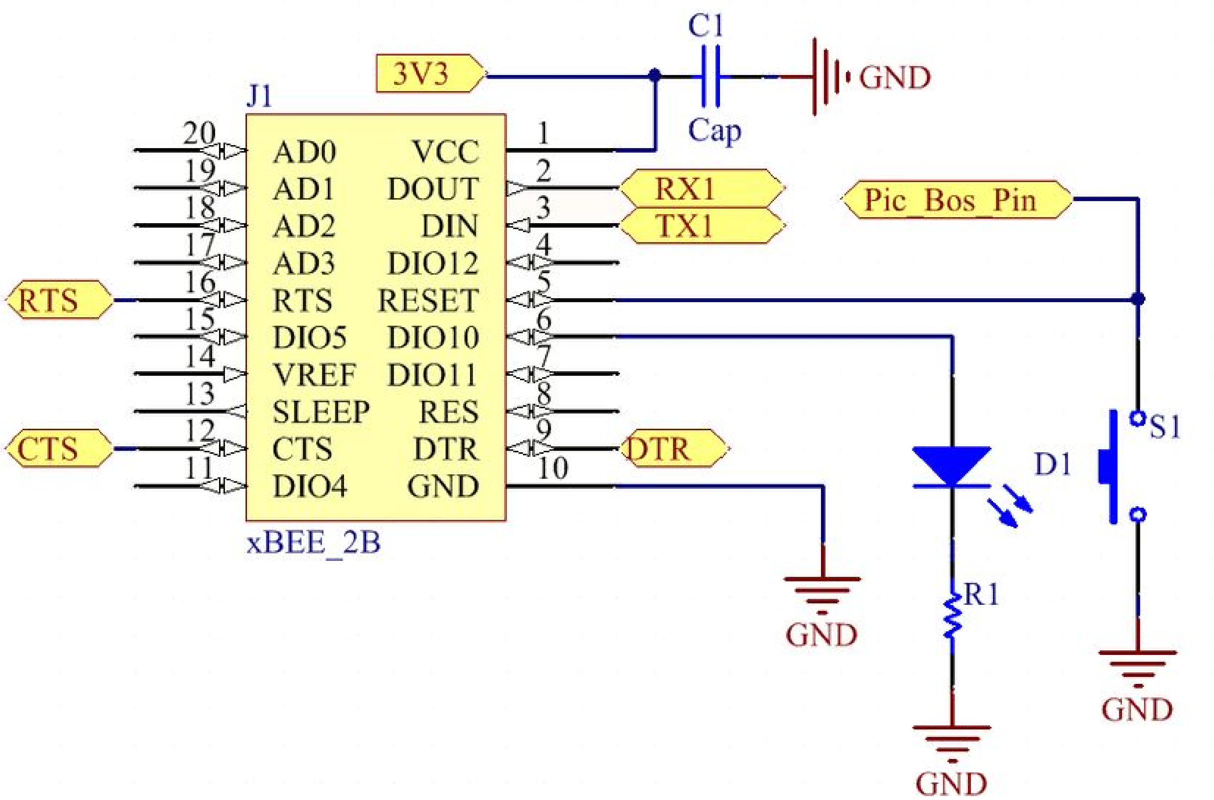
Zigbee is a low-cost, low-power, wireless mesh network standard targeted at battery-powered devices in wireless control and monitoring applications. Zigbee delivers low-latency communication. Zigbee chips are typically integrated with radios and with microcontrollers. Zigbee operates in the industrial, scientific and medical (ISM) radio bands: 2.4 GHz in most jurisdictions worldwide; though some devices also use 784 MHz in China, 868 MHz in Europe and 915 MHz in the US and Australia, however even those regions and countries still use 2.4 GHz for most commercial Zigbee devices for home use. Data rates vary from 20 kbit/s (868 MHz band) to 250 kbit/s (2.4 GHz band).

	ZigBee	Bluetooth	Wi-Fi
IEEE Standard	802.15.4	802.15.1	802.11 a,b,g,n
Battery Life (days)	100 to 1000	1 to 7	1 to 5
Network Size	65K	Less than a dozen	Dozens
Bandwidth	20 to 250 kbps	700+ kbps	10 to 100s mbps
Transmission Range	100+ meters	100 meters	10 meters

Standard	Bluetooth	UWB	Zigbee	Wi-Fi
IEEE spec..	802.15.1	802.15.3a	802.15.4	802.11a/b/g
Frequency band	2.4GHz	3.1-10.6 GHz	868/915 MHz; 2.4 GHz	2.4 GHz; 5 GHz
Max signal rate	1 Mb/s	110Mb/s	250kb/s	54Mb/s
Nominal range	10 m	10 m	10-100 m	100 m
Nominal TX power	0 - 10 dBm	-41.3 dBm/MHz	(-25) - 0 dBm	15 - 20 dBm
Number of RF channels	79	(1-15)	1/10;16	14(2.4GHz)
Channel bandwidth	1MHZ	500MHz-7.5GHz	0.3/0.6 MHz; 2 MHz	22MHz
Modulation type	GFSK	BPSK, QPSK	BPSK (+ ASK), O-QPSK	BPSK, QPSK COFDM, CCK, M-QAM
Spreading	FHSS	DS-UWB, MB-OFDM	DSSS	DSSS, CCK, OFDM
Coexistence mechanism	Adaptive freq. hopping	Adaptive freq. hopping	Dynamic freq. selection	Dynamic freq. selection transmit power control (802.11h)
Basic cell	Piconet	Piconet	Star	BSS
Extension of the basic cell	Scatternet	Peer-peer	Cluster tree-mesh	ESS
Max number of cell nodes	8	8	> 65000	2007
Data protection	16-bit CRC	32-bit CRC	16-bit CRC	32-bit CRC

Modulation

A 2.4-GHz two-point modulation IEEE 802.15.4 (Zigbee) compliant transmitter is presented. This sigma-delta fractional-N PLL based transmitter is optimized for both low-power and low-cost purposes. A novel closed-loop calibration scheme is proposed to minimize the gain mismatch between two modulation points, which is the main source of error in two-point modulation. Fabricated in a 0.15-mum CMOS process, the proposed transmitter achieves EVM less than 8% for 2-Mchips/s MSK modulated signal and consumes 5.5 mA under a 1.55-V regulated power supply. The core area is 0.8 times 1.1 mm 2 .



Scalability

Used fow Wireless PAN Networks

WIFI [9]

Wi-Fi is a wireless networking technology that allows devices such as computers (laptops and desktops), mobile devices (smartphones and wearables), and other equipment (printers and video cameras) to interface with the Internet. It allows these devices--and many more--to exchange information with one another, creating a network.

Internet connectivity occurs through a wireless router. When you access Wi-Fi, you are connecting to a wireless router that allows your Wi-Fi-compatible devices to interface with the Internet.
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.[2][3][4] As of 2010, the Wi-Fi Alliance consisted of more than 375 companies from around the world. As of 2009, Wi-Fi-integrated circuit chips shipped approximately 580 million units yearly.[6][needs update] Devices that can use Wi-Fi technologies include desktops and laptops, smartphones and tablets, smart TVs, printers, digital audio players, digital cameras, cars, and drones.

Specifications

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).

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.

LIFI [10]

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.[1]

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.[2]

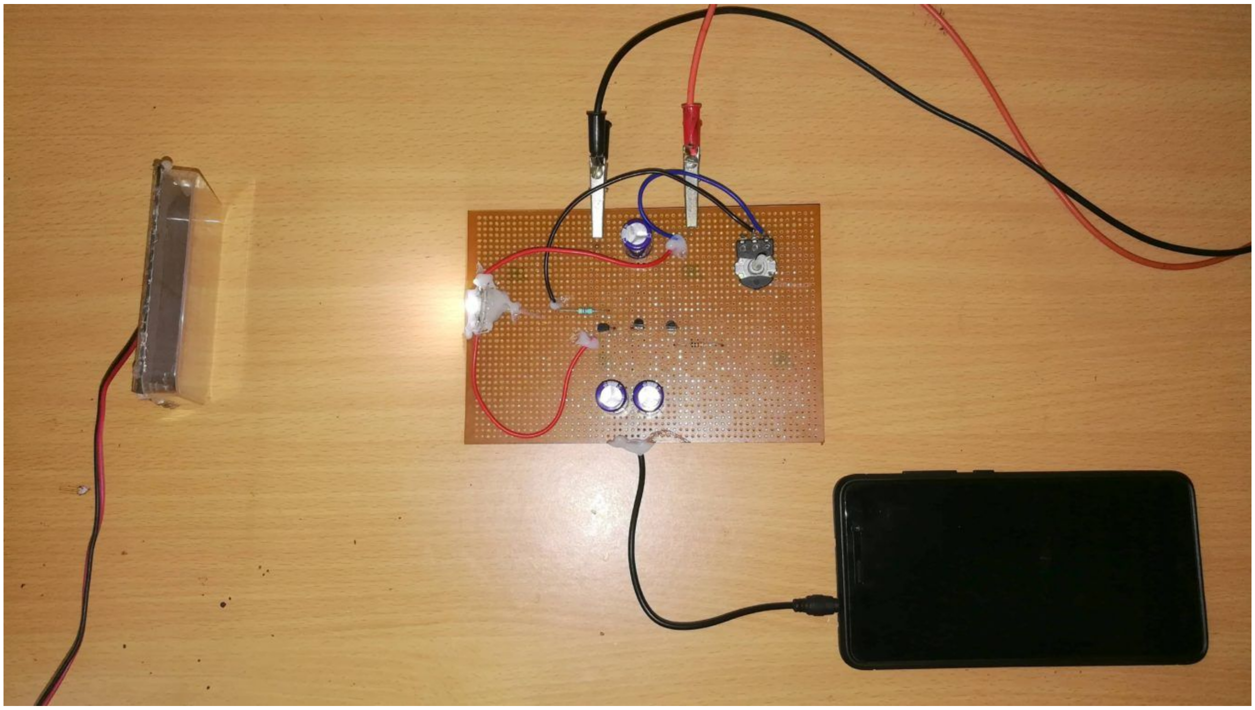
In terms of its end use, the technology is similar to Wi-Fi -- the key technical difference being that Wi-Fi uses radio frequency to induce a voltage in an antenna to transmit data. Whereas Li-Fi uses the modulation of light intensity to transmit data. Li-Fi can theoretically transmit at speeds of up 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.[3] The technology is being developed by several organizations across the globe.

Modulation

1. SINGLE-CARRIER MODULATION Widely used single-carrier modulation (SCM) schemes for LiFi include on-off keying (OOK), pulse position modulation (PPM) and pulse amplitude modulation (PAM), which have been studied in wireless infrared (IR)

communication systems .

OOK: OOK is one of the well known and simple modulation schemes, and it provides a good trade-off between system performance and implementation complexity. The 802.15.7 standard uses Manchester Coding to ensure the period of positive pulses is the same as the negative ones but this also doubles the bandwidth required for OOK transmission. Alternatively, for higher bit rates run length limited (RLL) coding is used which is more spectrally efficient. OOK dimming can be achieved by: i) Refining the ON/OFF levels: Dimming through refining the ON/OFF levels of the LED can maintain the same data rate, however, the reliable communication range would decrease at low dimming levels. ii) Applying symbol compensation: dimming by symbol compensation can be achieved by inserting additional ON/OFF pulses, whose duration is determined by the desired dimming level.



Parameter	Li-Fi	Wi-Fi
Spectrum Used	Visible Light	RF
Standard	IEEE 802.15.7	IEEE 802.11
Range	Based on Light Intensity (< 10m)	Based on Radio propagation & interference (< 300 m)
Data Transfer Rate*	Very high (~1 Gbps)	Low (100 Mbps-1 Gbps)
Power consumption	Low	High
Cost	Low	High
Bandwidth	Unlimited	Limited

Scalability :

Can be used for HAN, PAN

WIMAX [11]

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.[1] 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".[2] IEEE 802.16m or WirelessMAN-Advanced was a candidate for the 4G, in competition with the LTE Advanced standard.

WiMAX was initially designed to provide 30 to 40 megabit-per-second data rates,[3] with the 2011 update providing up to 1 Gbit/s[3] for fixed stations.

The latest version of WiMAX, WiMAX release 2.1, popularly branded as/known as WiMAX 2+, is a backwards-compatible transition from previous WiMAX generations. It is compatible and interoperable with TD-LTE.

Modulation

WiMAX modulation and coding is adaptive, enabling it to vary these parameters according to prevailing conditions. WiMAx modulation and coding can be changed on a burst by burst basis per link. To determine the required WiMAX modulation and coding scheme the channel quality feedback indicator is used. The mobile can provide the base station with feedback on the downlink channel quality and for the uplink, the base station can estimate the channel quality, based on the received signal quality.

Cellular Networks [12]

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. These base stations provide the cell with the network coverage which can be used for transmission of voice, data, and other types of content. A cell typically uses a different set of frequencies from neighbouring cells, to avoid interference and provide guaranteed service quality within each cell. When joined together, these cells provide radio coverage over a wide geographic area. This enables numerous portable transceivers (e.g., mobile phones, tablets and laptops equipped with mobile broadband modems, 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.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. Major telecommunications providers have deployed voice and data cellular networks over most of the inhabited land area of Earth. This allows mobile phones and mobile computing devices to be connected to the public switched telephone network and public Internet. Private cellular networks can be used for research or for large organizations and fleets, such as dispatch for local public safety agencies or a taxicab company.

Modulation:

Spatial modulation (SM) is a unique single-stream, multiple-input multiple-output (MIMO) transmission technique. One key property of the SM is that a single transmit antenna is activated at any given time, which completely avoids inter-channel interference in a single-user scenario. In the context of multi-user cellular networks, inter-cell interference (ICI) mitigation becomes the main challenge for the SM. Network MIMO is a technique that employs precoding to enable ICI cancellation among neighbouring cells. However, the cell-edge users might still experience a high level of the ICI due to the significant channel attenuation. In this paper, we propose a novel cooperative scheme based on the SM, named cooperative SM (CoSM). The basic concept is to reschedule the transmit antennas of multiple base stations for multiple co-channel users, so as to maximize the antenna diversity gain. Unlike the traditional antenna selection for a single user, the involvement of multiple users might cause conflict due to the selection of the same antenna. An antenna rescheduling scheme (ARS) is thus proposed to address this issue. The performance of the ARS is theoretically analyzed, and closed-form expressions are derived for the probability distribution of the received SNR. Also, a novel three-tier cellular architecture is proposed to accommodate the CoSM within the context of the network MIMO. Results show that the CoSM can improve signal-to-interference-plus-noise ratio by up to 4 dB over the network MIMO. In addition, compared with spatial multiplexing using the same ARS, the CoSM can halve the energy consumption while achieving the same bit error rate

Technology	1G	2G	3G	4G	5G
Start/Deployment	1970-80	1990-2004	2004-10	Now	Soon (probably by 2020)
Data Bandwidth	2Kbps	64 Kbps	2 Mbps	1 Gbps	Higher than 1 Gbps
Technology	Analog	Digital	CDMA 2000, UMTS,EDGE	Wi-Max, Wi-Fi, LTE	WWWW
Core Network	PSTN	PSTN	Packet N/W	Internet	Internet
Multiplexing	FDMA	TDMA/CDMA	CDMA	CDMA	CDMA
Switching	Circuit	Circuit,Packet	Packet	All Packet	All Packet
Primary Service	Analog Phone Calls	Digital Phone Calls and Messaging	Phone calls, Messaging, Data	All-IP Service (including Voice Messages)	High speed, High capacity and provide large broadcasting of data in Gbps
Key differentiator	Mobility	Secure, Mass adoption	Better Internet experience	Faster Broadband Internet, Lower Latency	Better coverage and no droped calls, much lower latency, Better performance
Weakness	Poor spectral efficiency, major security issue	Limited data rates, difficult to support demand for internet and e-mail	Real performance fail to match type, failure of WAP for internet access	Battery use is more, Required complicated and expensive hardware	?

Conclusion

I learned about the Physical layer, the types of Wired and wireless connections.

I also learnt about the technologies, specifications and schematic view of connections.

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