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T E Computers

DCCN Lab

Experiment 1

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

In the seven-layer OSI model of computer networking, the physical layer or layer 1 is the first and lowest layer. The physical layer defines the means of transmitting raw bits over a physical data link connecting network nodes. The bit stream may be grouped into code words or symbols and converted to a physical signal that is transmitted over a transmission medium. The physical layer provides an electrical, mechanical, and procedural interface to the transmission medium.

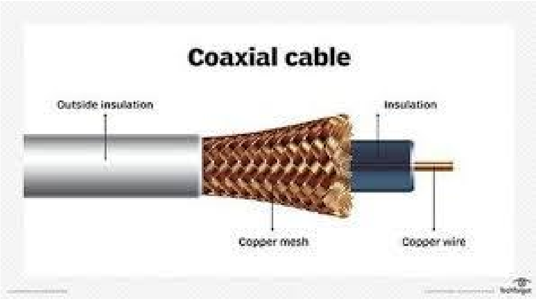
Functions of Physical Layer [1]

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

Types of Physical Layers (Wired):

Coaxial [2][3]
Coaxial cable consists of a copper conductor surrounded by a layer of flexible insulation, as shown in the figure. Over this insulating material is a woven copper braid, or metallic foil, that acts as the second wire in the circuit and as a shield for the inner conductor. This second layer, or shield, also reduces the amount of outside electromagnetic interference. Covering the shield is the cable jacket. All the elements of the coaxial cable encircle the center conductor. Because they all share

the same axis, this construction is called coaxial, or coax for short. Coax cables are used to attach antennas to wireless devices. This combined use of fiber and coax is referred to as hybrid fiber coax (HFC). In the past, coaxial cable was used in Ethernet installations. Today UTP offers lower costs and higher bandwidth than coaxial and has replaced it as the standard for all Ethernet installations.



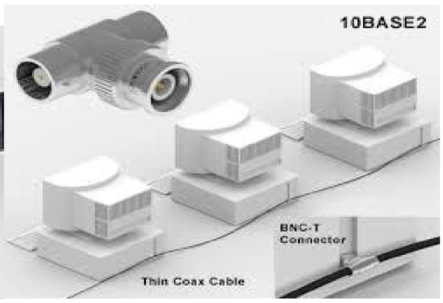
10BASE2 [4]

Is a variant of Ethernet (cheaper net) that uses thin coaxial cable terminated with BNC connectors to build a local area network.

The name 10BASE2 is derived from several characteristics of the physical medium. The 10 comes from the transmission speed of 10 Mbit/s. The BASE stands for baseband signaling, and the 2 for a maximum segment length approaching 200 m.

<u>Range:</u> The actual range is 185m.

<u>Network Design:</u> 10BASE2 coax cables have a maximum length of 185 meters (607 ft). The maximum practical number of nodes that can be connected to a 10BASE2 segment is limited to 30 with a minimum distance of 50 centimeters (20 in) between devices. In a 10BASE2 network, each stretch of cable is connected to the transceiver (which is usually built into the network adaptor) using a BNC T-connector, with one stretch connected to each female connector of the T. The T-connector must be plugged directly into the network adaptor with no cable in between. When wiring a 10BASE2 network, special care has to be taken to ensure that cables are properly connected to all T-connectors. Bad contacts or shorts are especially difficult to diagnose. A failure at any point of the network cabling tends to prevent all communications.

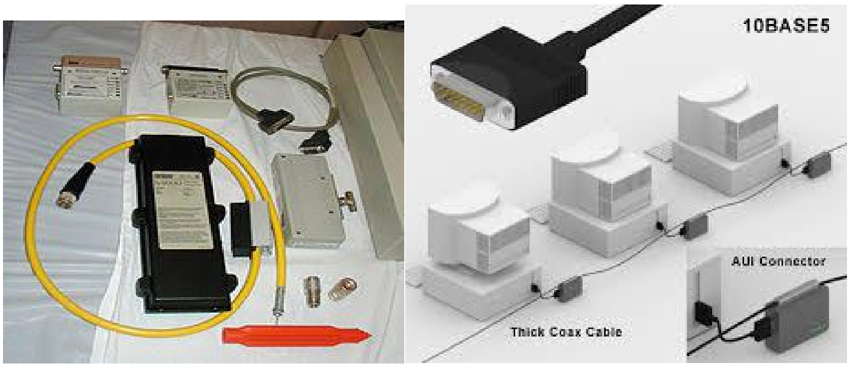


Schematic of 10BASE-2

10BASE5 [5]

Known as thick Ethernet or thick net was the first commercially available variant of Ethernet. The technology was standardized in 1982 as IEEE 802.3. 10BASE5 uses a thick and stiff coaxial cable up to 500 meters (1,600 ft) in length. Up to 100 stations can be connected to the cable using vampire taps and share a single collision domain with 10 Mbit/s of bandwidth shared among them. The system is difficult to install and maintain.

Range: The actual range is 500m.



Schematic of 10BASE-5

Twisted Pair

Shielded Twisted Pair: [6]

Another type of cabling used in networking is shielded twisted-pair (STP). As shown in the figure, STP uses two pairs of wires that are wrapped in an overall metallic braid or foil. STP cable shields the entire bundle of wires within the cable as well as the individual wire pairs. STP provides better noise protection than UTP cabling, however at a significantly higher price. For many years, STP was the cabling structure specified for use in Token Ring network installations. With the use of Token Ring declining, the demand for shielded twisted-pair cabling has also waned. The new 10 GB standard for Ethernet has a provision for the use of STP cabling. This may provide a renewed interest in shielded twisted-pair cabling.

10BASE-T [7]

The common names for the standards derive from aspects of the physical media. The leading number (10 in 10BASE-T) refers to the transmission speed in Mbit/s. BASE denotes that baseband transmission is used. The T designates twisted pair cable. Where there are several standards for the same transmission speed, they are distinguished by a letter or digit following the T, such as TX or T4, referring to the encoding method and number of lanes.

Range: The range is 100m.

Scalability: It is scalable in LAN architecture.

The 10BASE-T is the legacy version and further generations of it specifying their speed, range are given below:-

100BASE-T1: Speed of 100 Mbit/s and range of 15m.

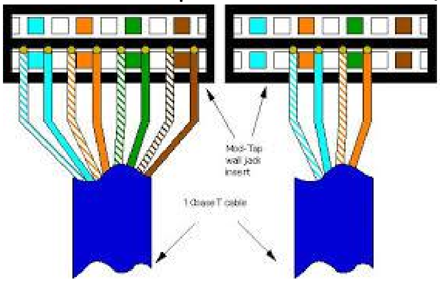
100BASE-TX: Speed of 100 Mbit/s and range of 100m.

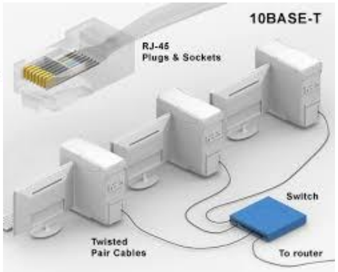
1000BASE-T: Speed of 1000 Mbit/s and range of 100m.

2.5GBASE-T: Speed of 2500 Mbit/s and range of 100m.

5GBASE-T: Speed of 5000 Mbit/s and range of 100m.

10GBASE-T: Speed of 10000 Mbit/s and range of 100m.
20GBASE-T: Speed of 20000 Mbit/s and range of 30m.
40GBASE-T: Speed of 40000 Mbit/s and range of 30m.

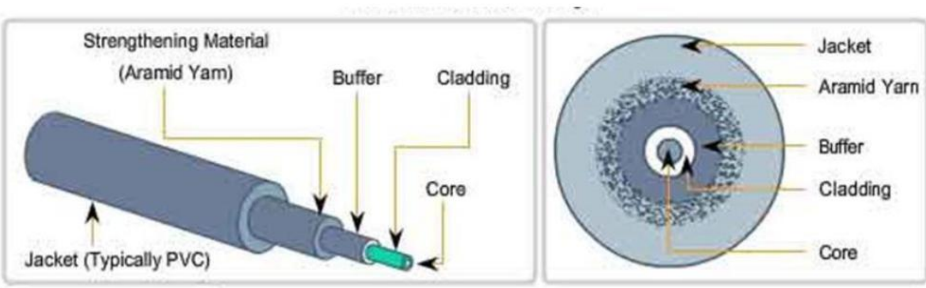




Schematic of 10BASE-T

<u>Fiber Optic Cable</u> [8]

Fiber-optic cabling uses either glass or plastic fibers to guide light impulses from source to destination. The bits are encoded on the fiber as light impulses. Optical fiber cabling is capable of very large raw data bandwidth rates. Most current transmission standards have yet to approach the potential bandwidth of this media. At present, in most enterprise environments, optical fiber is primarily used as backbone cabling for high-traffic point-to-point connections between data distribution facilities and for the interconnection of buildings in multi-building campuses. Because optical fiber does not conduct electricity and has low signal loss, it is well suited for these uses.



<u>10BASE-F:</u> [9]

Classic Ethernet is a family of 10 Mbit/s Ethernet standards, which is the first generation of Ethernet standards. In 10BASE-X, the 10 represents its maximum throughput of 10 Mbit/s, BASE indicates its use of baseband transmission, and X indicates the type of medium used.

<u>Range:</u> The range is 2000m.

<u>Scalability:</u> It is scalable in LAN and CAN architecture.

Ex: 10BASE-FL, 10BASE-FB, 10BASE-FP.

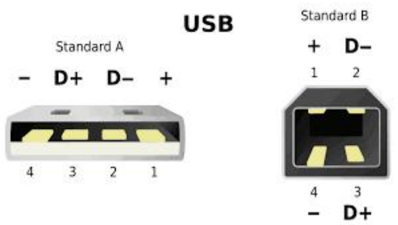
100BASE-FX: It uses multimode optical fiber. Maximum length is 400 meters for half-duplex connections (to ensure collisions are detected) or 2 kilometers for full-duplex.

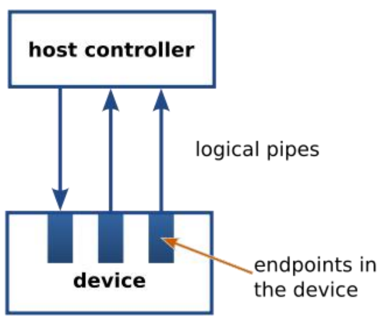
100BASE-BX10: It uses single mode optical fiber. Range is 10 kilometers for full-duplex only.

USB [10]

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.

USB Version	Year of Release	Data Rate
1.0	1996	1.5 Mbit/s
1.1	1998	1.5 - 12 Mbit/s
2.0	2001	1.5 - 480 Mbit/s
3.0	2011	5 Gbit/s
3.1	2014	10 Gbit/s
3.2	2017	20 Gbit/s
4.0	2019	40 Gbit/s





Types of Physical Layers (Wireless):

A wireless network is a computer network that uses wireless data connections between nodes. 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. admin telecommunications networks are generally implemented and administered using radio communication. This implementation takes place at the physical level (layer) of the OSI model network structure. Examples of wireless networks include cell phone networks, wireless local area networks (WLANs), wireless sensor networks, satellite communication networks, and terrestrial microwave networks.

Different Types of Wireless Networks are:

Wireless HAN [11]
A HAN, or home area network, is a network connecting devices within a home. These networks are a type of LAN. All the devices inside the household, including computers,
smart phones, game consoles, televisions, and home assistants that are connected to
The router is a part of the HAN.

Wireless CAN [12]
A CAN, or campus area network, usually comprises several LANs. They cover a campus, connecting several buildings to the main firewall. A university could use a CAN, as could a corporate headquarters. The CAN networks use fiber optic cables to interconnect within different buildings.

Wireless ad hoc network
A wireless ad hoc network, also known as a wireless mesh network or mobile ad hoc network (MANET), is a wireless network made up of radio nodes organized in a mesh topology. Each node forwards messages on behalf of the other nodes and each node performs routing. Ad hoc networks can "self-heal", automatically re-routing around a node that has lost power. Various network layer protocols are needed to realize ad hoc mobile networks, such as Distance Sequenced Distance Vector routing, Associativity- Based Routing, Ad hoc on-demand Distance Vector routing, and Dynamic source routing.
Major Types of wireless networks are:
Standard IEEE 802.11: Commonly referred to as Wi-Fi, is a Wireless LAN (WLAN) technology that uses a contention or non-deterministic system with a Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) media access process.
Standard IEEE 802.15: Wireless Personal Area Network (WPAN) standard, commonly known as "Bluetooth", uses a device pairing process to communicate over distances from 1 to 100 meters.
Standard IEEE 802.16: Commonly known as WiMAX (Worldwide Interoperability for Microwave Access), uses a point-to-multipoint topology to provide wireless broadband access.

Wireless PAN [13][14]

Wireless personal area networks (WPANs) connect devices within a relatively small area that is generally within a person's reach. For example, both Bluetooth radio and invisible infrared light provides a WPAN for interconnecting a headset to a laptop. Wi-Fi PANs are becoming commonplace (2010) as equipment designers start to integrate Wi-Fi into a variety of consumer electronic devices. Intel "My Wi-Fi" and

Windows 7"virtual Wi-Fi" capabilities have made Wi-Fi PANs simpler and easier to set up and configure. They are majorly operational on bluetooth technology.

Bluetooth is a wireless technology standard used for exchanging data between fixed and mobile devices over short distances using short-wavelength UHFradio 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. Bluetooth is managed by the Bluetooth Special Interest Group (SIG), which has more than 35,000 member companies in the areas of telecommunication, computing, networking, and consumer electronics. 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

Range: Bluetooth operates on a minimum range of 10 meters (33 feet) and has no constraint on the upper limit.

Modulation:

Software Requirements: Seeking to extend the compatibility of Bluetooth devices, the devices that adhere to the standard use an interface called HCI (Host Controller Interface) between the host device (e.g. laptop, phone) and the Bluetooth device (e.g. Bluetooth wireless headset).High-level protocols such as the SDP (Protocol used to find other Bluetooth devices within the communication range, also responsible for detecting the function of devices in range), RFCOMM (Protocol used to emulate serial port connections) and TCS (Telephony control protocol) interact with the baseband controller through the L2CAP Protocol (Logical Link Control and Adaptation Protocol). The L2CAP protocol is responsible for the segmentation and reassembly of the packets.

Hardware Requirements: The hardware that makes up the Bluetooth device is made up of, logically, two parts; which may or may not be physically separate. A radio device, responsible for modulating and transmitting the signal; and a digital controller. The digital controller is likely a CPU, one of whose functions is to run a Link Controller; and interfaces with the host device; but some functions may be delegated to hardware. The Link Controller is responsible for the processing of the baseband and the management of ARQ and physical layer FEC protocols. Bluetooth devices are fabricated on RF CMOS integrated circuit (RF circuit) chips.

Wireless local area network (WLAN): [15]
A wireless LAN (WLAN) is a wireless computer network that links two or more devices using wireless communication to form a local area network (LAN) within a limited area such as a home, school, computer laboratory, campus, or office building. This gives users the ability to move around within the area and remain connected to the network. Through a gateway, a WLAN can also provide a connection to the wider Internet. Most modern WLANs are based on IEEE 802.11 standards and are marketed under the Wi-Fi brand name. Wireless LANs have become popular for use

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

The different types of wireless network standards are:-

IEEE 802.11 network PHY standards [hide]

Frequency range, or type	PHY	Protocol	Release date[12]	Frequency (GHz)	Bandwidth (MHz)	Stream data rate[13] (Mbit/s)	Allowable MIMO streams	Modulation	Approximate range[citation needed] Indoor	Approximate range[citation needed] Outdoor
1–6 GHz	DSSS/FHSS[14]	802.11-1997	Jun 1997	2.4	22	1, 2	N/A	DSSS, FHSS	20 m (66 ft)	100 m (330 ft)
	HR-DSSS[14]	802.11b	Sep 1999	2.4	22	1, 2, 5.5, 11	N/A	DSSS	35 m (115 ft)	140 m (460 ft)
	OFDM	802.11a	Sep 1999	5	5/10/20	6, 9, 12, 18, 24, 36, 48, 54 (for 20 MHz bandwidth, divide by 2 and 4 for 10 and 5 MHz)	N/A	OFDM	35 m (115 ft)	120 m (390 ft)
		802.11j	Nov 2004	4.9/5.0[D][15][failed verification]					?	?
		802.11p	Jul 2010	5.9					?	1,000 m (3,300 ft)[16]
		802.11y	Nov 2008	3.7[A]					?	5,000 m (16,000 ft)[A]
	ERP-OFDM(, etc.)	802.11g	Jun 2003	2.4					38 m (125 ft)	140 m (460 ft)
	HT-OFDM[17]	802.11n	Oct 2009	2.4/5	20	Up to 288.8[B]	4	MIMO-OFDM	70 m (230 ft)	250 m (820 ft)[18][failed verification]
					40	Up to 600[B]				
	VHT-OFDM[17]	802.11ac	Dec 2013	5	20	Up to 346.8[B]	8	MIMO-OFDM	35 m (115 ft)[19]	?
					40	Up to 800[B]				
					80	Up to 1733.2[B]				
					160	Up to 3466.8[B]				
	HE-OFDM	802.11ax	September 2019 [20]	2.4/5/6	20	Up to 1147[F]	8	MIMO-OFDM	30 m (98 ft)	120 m (390 ft) [G]
					40	Up to 2294[F]				
					80	Up to 4804[F]				
					80+80	Up to 9608[F]				
mmWave	DMG[21]	802.11ad	Dec 2012	60	2,160	Up to 6,757[22] (6.7 Gbit/s)	N/A	OFDM, single carrier, low-power single carrier	3.3 m (11 ft)[23]	?
		802.11aj	Apr 2018	45/60[C]	540/1,080[24]	Up to 15,000[25] (15 Gbit/s)	4[26]	OFDM, single carrier[26]	?	?
	EDMG[27]	802.11ay	Est. May 2020	60	8000	Up to 20,000 (20 Gbit/s)[28]	4	OFDM, single carrier	10 m (33 ft)	100 m (328 ft)
Sub-1 GHz IoT	TVHT[29]	802.11af	Feb 2014	0.054–0.79	6–8	Up to 568.9[30]	4	MIMO-OFDM	?	?
	S1G[29]	802.11ah	Dec 2016	0.7/0.8/0.9	1–16	Up to 8.67 (@2 MHz)[31]	4		?	?
2.4 GHz, 5 GHz	WUR	802.11ba[E]	Est. Sep 2020	2.4/5	4.06	0.0625, 0.25 (62.5 kbit/s, 250 kbit/s)	N/A	OOK (Multi-carrier OOK)	?	?
Light (Li-Fi)	IR	802.11-1997	Jun 1997	?	?	1, 2	N/A	PPM	?	?
	?	802.11bb	Est. Jul 2021	60000-790000	?	?	N/A	?	?	?

Schematic of a WLAN

Wireless WAN [16]

Wireless wide area networks are wireless networks that typically cover large areas, such as between neighboring towns and cities, or city and suburb. These networks can be used to connect branch offices of business or as a public Internet access system. The wireless connections between access points are usually point to point microwave links using parabolic dishes on the 2.4 GHz and 5.8 GHz band, rather than unidirectional antennas used with smaller networks. A typical system contains base station gateways, access points and wireless bridging relays. Other configurations are mesh systems where each access point acts as a relay also. When combined with renewable energy systems such as photovoltaic solar panels or wind systems they can be stand alone systems.

5G technology: [17]

5G networks are digital cellular, in which the service area covered by providers is divided into small geographical areas called cells. Analog signals representing sounds and images are digitized in the telephone, converted by an analog-to-digital converter and transmitted as a stream of bits. All the 5G wireless devices in a cell communicate by radio waves with a local antenna array and low power automated transceiver (transmitter and receiver) in the cell, over frequency channels assigned by the transceiver from a pool of frequencies that are reused in other cells. The local antennas are connected with the telephone network and the Internet by a high-bandwidth optical fiber or wireless backhaul connection. As in other cell networks, a mobile device crossing from one cell to another is automatically "handed off" seamlessly to the new cell. 5G can support up to a million devices per square kilometer.

Range:

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

Modulation:

New radio frequencies

The air interface defined by 3GPP for 5G is known as New Radio (NR), and the specification is subdivided into two frequency bands, FR1 (below 6 GHz) and FR2 (mmWave), each with different capabilities.

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.

Frequency range 2 (> 24 GHz)

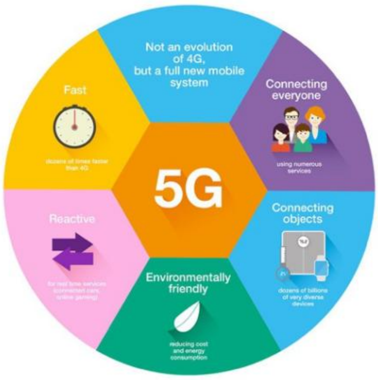
The minimum channel bandwidth defined for FR2 is 50 MHz and the maximum is 400 MHz, with two-channel aggregation supported in 3GPP Release 15. The higher the frequency, the greater the ability to support high data-transfer speeds.

FR2 coverage

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.

<u>Scalability:</u>

The ITU-R has defined three main application areas for the enhanced capabilities of 5G. They are Enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (URLLC), and Massive Machine Type Communications (mMTC). Only eMBB is deployed in 2020; URLLC and mMTC are several years away in most locations. Enhanced Mobile Broadband (eMBB) uses 5G as a progression from 4G LTE mobile broadband services, with faster connections, higher throughput, and more capacity. Ultra-Reliable Low-Latency Communications (URLLC) refers to using the network for mission critical applications that require uninterrupted and robust data exchange. Massive Machine-Type Communications (mMTC) would be used to connect to a large number of devices; 5G technology will connect some of the 50 billion connected IoT devices. Most cars will have a 4G or 5G cellular connection for many services. Autonomous cars do not require 5G, as they have to be able to operate where they do not have a network connection. While remote surgeries have been performed over 5G, most remote surgery will be performed in facilities with a fiber connection, usually faster and more reliable than any wireless connection.



<u>NFC</u> [18]

Near-Field-Communication (NFC) is a set of communication protocols for communication between two electronic devices over a distance of 4 cm (1 .5 in) 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. This is sometimes called NFC/CTLS or CTLS NFC, with contactless abbreviated CTLS. NFC can be used for sharing small files such as contacts, and bootstrapping fast connections to share larger media such as photos, videos, and other files.

Range: NFC is a set of short-range wireless technologies, typically requiring a separation of 10 cm or less.

Modulation:

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. NFC always involves an initiator and a target; the initiator actively generates an RF field that can power a passive target. This enables NFC targets to take very simple form factors such as unpowered tags, stickers, key fobs, or cards. NFC peer-to-peer communication is possible, provided both devices are powered. NFC tags contain data and are typically read-only, but may be writable. They can be custom-encoded by their manufacturers or use NFC Forum specifications. The tags can securely store personal data such as debit and credit card information, loyalty program data, PINs and networking contacts, among other information. The NFC Forum defines four types of tags that provide different communication speeds and capabilities in terms of configurability, memory, security, data retention and write endurance. Tags currently offer between 96 and 8,192 bytes of memory. As with proximity card technology, NFC uses inductive coupling between two nearby loop antennas effectively forming an air-core transformer. Because the distances involved are tiny compared to the wavelength of electromagnetic radiation (radio waves) of that frequency (about 22 meters), the interaction is described as near field. Only an alternating magnetic field is involved so that almost no power is actually radiated in the form of radio waves (which are electromagnetic waves, also involving an oscillating electric field); that essentially prevents interference between such devices and any radio communications at the same frequency or with other NFC devices much beyond its intended range. They operate within the globally available and unlicensed radio frequency ISM band of 13.56 MHz Most of the RF energy is concentrated in the ±7 kHz bandwidth allocated for that band, but the emission's spectral width can be as wide as 1.8 MHz in order to support high data rates. Working distance with compact standard antennas and realistic power levels could be up to about 20 cm (but practically speaking, working distances never exceed 10 cm). Note that because the pickup antenna may be quenched by nearby metallic surfaces, the tags may require a minimum separation from such surfaces. The ISO/IEC 18092 standard supports data rates of 106, 212 or 424 kbit/s.

The communication takes place between an active "initiator" device and a target device which may either be:

Passive

The initiator device provides a carrier field and the target device, acting as a transponder, communicates by modulating the incident field. In this mode, the target device may draw its operating power from the initiator-provided magnetic field.

Active

Both initiator and target device communicate by alternately generating their own fields. A device stops transmitting in order to receive data from the other. This mode requires that both devices include power supplies.

Scalability:

Commerce

NFC devices can be used in contactless payment systems, similar to those used in credit cards and electronic ticket smart cards and allow mobile payment to replace/supplement these systems.

Bootstrapping other connections

NFC offers a low-speed connection with simple setup that can be used to bootstrap more capable wireless connections. For example, Android Beam software uses NFC to enable pairing and establish a Bluetooth connection when doing a file transfer and then disabling Bluetooth on both devices upon completion.

Social networking

NFC can be used for social networking, for sharing contacts, text messages and forums, links to photos, videos or files and entering multiplayer mobile games.

Identity and access tokens

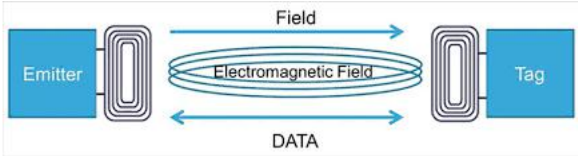
NFC-enabled devices can act as electronic identity documents and keycards. NFC's short range and encryption support make it more suitable than less private RFID systems.

Smartphone automation and NFC tags

NFC-equipped smart phones can be paired with NFC Tags or stickers that can be programmed by NFC apps. These programs can allow a change of phone settings, texting, app launching, or command execution.

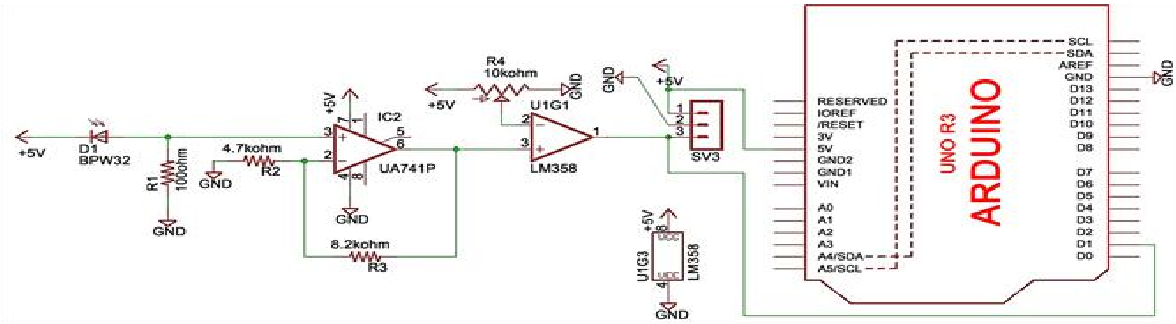
Gaming

NFC has been used in video games starting with Skylanders: Spyros' Adventure. These are customizable figurines which contain personal data with each figure, so no two figures are exactly alike. Nintendo's Wii U was the first system to include NFC technology out of the box via the GamePad.



Li-Fi [19]

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. Li-Fi has the advantage of being useful in electromagnetic sensitive areas such as in aircraft cabins, hospitals and nuclear power plants without causing electromagnetic interference. Both Wi-Fi and Li-Fi transmit data over the electromagnetic spectrum, but whereas Wi-Fi utilizes radio waves, Li-Fi uses visible, ultraviolet, and infrared light. While the US Federal Communications Commission has warned of a potential spectrum crisis because Wi-Fi is close to full capacity, Li-Fi has almost no limitations on capacity. The visible light spectrum is 10,000 times larger than the entire radio frequency spectrum. Researchers have reached data rates of over 224 Gbit/s, which was much faster than typical fast broadband in 2013. Li-Fi is expected to be ten times cheaper than Wi-Fi.

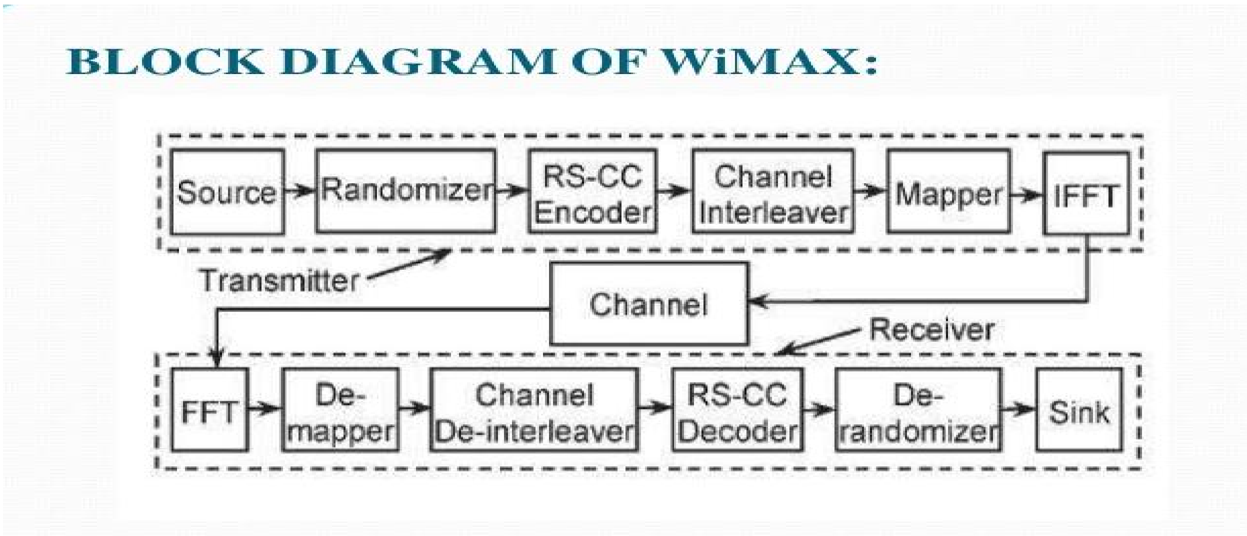


WIMAX [20]

WiMAX (Worldwide Interoperability for Microwave Access) is a family of wireless broadband communication standards based on the IEEE 802.16 set of standards, which provide multiple physical layer (PHY) and Media Access Control (MAC) options.

The name "WiMAX" was created by the WiMAX Forum, which was formed in June 2001 to promote conformity and interoperability of the standard, including the definition of predefined system profiles for commercial vendors. The forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL". IEEE 802.16m or WirelessMAN-Advanced was a candidate for the 4G, in competition with the LTE Advanced standard. WiMAX was initially designed to provide 30 to 40 megabit-per-second data rates, with the 2011 update providing up to 1 Gbit/s 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.

Physical layer:
The original version of the standard on which WiMAX is based (IEEE 802.16) specified a physical layer operating in the 10 to 66 GHz range. 802.16a, updated in 2004 to 802.16-2004, added specifications for the 2 to 11 GHz range. 802.16-2004 was updated by 802.16e-2005 in 2005 and uses scalable orthogonal frequency-division multiple access (SOFDMA), as opposed to the fixed orthogonal frequency-division multiplexing (OFDM) version with 256 sub-carriers (of which 200 are used) in 802.16d. More advanced versions, including 802.16e, also bring multiple antenna support through MIMO. (See WiMAX MIMO) This brings potential benefits in terms of coverage, self installation, power consumption, frequency reuse and bandwidth efficiency. WiMax is the most energy-efficient pre-4G technique among LTE and HSPA+.



Zigbee[21]

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. 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.The ZigBee Smart Energy 2.0 specifications define an Internet Protocol-based communication protocol to monitor, control,inform, and automate the delivery and use of energy and water. It is an enhancement of the ZigBee Smart Energy version 1 specifications. It adds services for plug-in electric vehicle charging, installation, configuration and firmware download, prepay services, user information and messaging, load control,demand response and common information and application.

Conclusion and References:

From this experiment I was able to have a deeper understanding of various types of physical layers in Networking and their respective fields of usage.

The above mentioned information has been taken from the following websites:-

1. https://www.studytonight.com/computer-networks/osi-model-physical-layer
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