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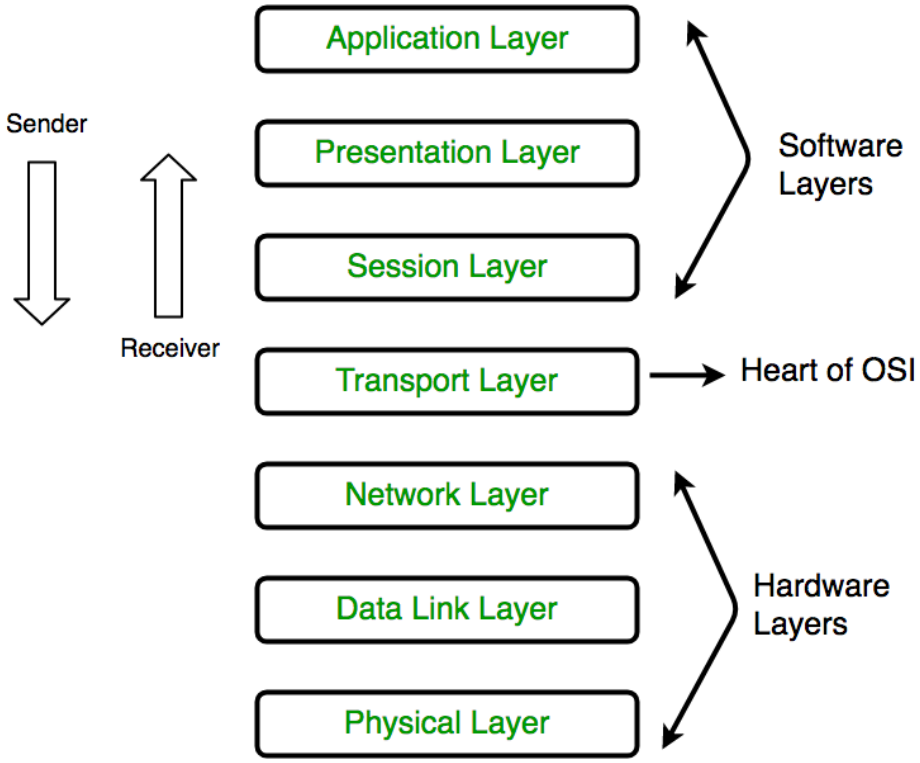
EXPERIMENT 1

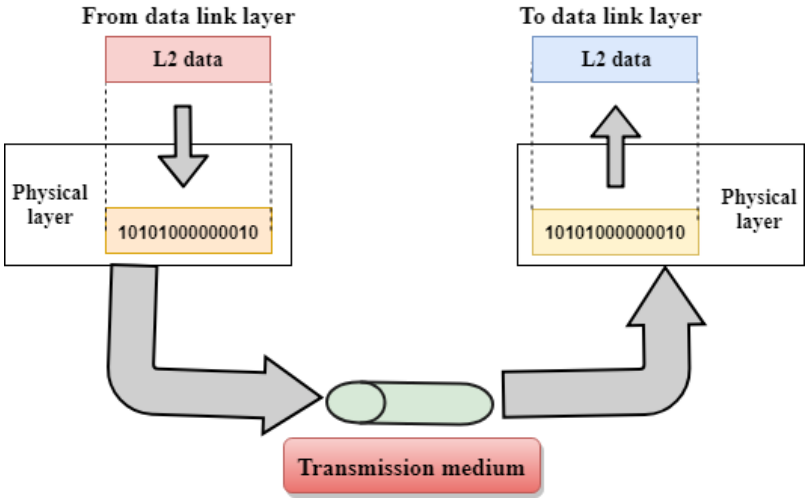
The Open Systems Interconnection (OSI) model :



The Open Systems Interconnection model (OSI model) is a conceptual model whose goal is the interoperability of diverse communication systems with standard communication protocols. The model partitions a communication system into abstraction layers. In this model, each layer serves the layer above it. The model is a product of the Open Systems Interconnection project at the International Organization for Standardization (ISO) .

We limit our discussion to the lowest layer at the foundation of the Computer Networks, and see how they are connected, and it's different forms, over transmission medium.

Physical Layer - OSI Reference Model :



Physical layer is the lowest layer of the OSI reference model and the only layer which provides hardware interaction. It is responsible for sending bits from one computer to another. The physical layer provides an electrical, mechanical, and procedural interface to the transmission medium. This layer is not concerned with the meaning of the bits and deals with the setup of physical connection to the network and with transmission and reception of signals . 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.

Wireless Transmission Media

Wireless networking is a method by which homes, telecommunications networks and business installations avoid the costly process of introducing cables into a building, or as a connection between various equipment locations. This implementation takes place at the physical level (layer) of the OSI model network structure. Advances in MOSFET technology, and the wide adoption of RF CMOS (radio frequency CMOS), power MOSFET and LDMOS (lateral diffused MOS) devices led to the increase of digital wireless networks by the 1990s, and further advances led to increased bandwidth in the 2000s. Most of the essential elements of wireless networks are built from MOSFETs, including the mobile transceivers, base station modules, routers, RF power amplifiers, telecommunication circuits, RF circuits, and radio transceivers, in networks such as 2G, 3G, and 4G.

Range and specifications of some wireless media :

1. Bluetooth

	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

Bluetooth is 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)
Bluetooth is a packet-based protocol with a master/slave architecture . One master may communicate with up to seven slaves in a piconet . All devices within a given piconet use the clock provided by the master as the base for packet exchange. The master clock ticks with a period of 312.5 µs , two clock ticks then make up a slot of 625 µs, and two slots

make up a slot pair of 1250 µs. In the simple case of single-slot packets, the master transmits in even slots and receives in odd slots. The slave, conversely, receives in even slots and transmits in odd slots.

Packets may be 1, 3 or 5 slots long, but in all cases the master's transmission begins in even slots and the slave's in odd slots . Bluetooth is a standard wire-replacement communications protocol primarily designed for low power consumption, with a short range based on low-cost transceiver microchips in each device. Because the devices use a radio (broadcast) communications system, they do not have to be in visual line of sight of each other; however, a quasi optical wireless path must be viable. Range is power-class-depe ndent, but effective ranges vary in practice.

Most Bluetooth applications are battery-powered Class 2 devices, with little difference in range whether the other end of the link is a Class 1 or Class 2 device as the lower-powered device tends to set the range limit . The Bluetooth Core Specification mandates a range of not less than 10 metres , but there is no upper limit on actual range. Manufacturers' implementations can be tuned to provide the range needed for each case.

2. Infrared technology

IR data transmission is employed in short-range communication among computer peripherals and personal digital assistants. These devices usually conform to standards published by IrDA , the Infrared Data Association .

Remote controls and IrDA devices use infrared light-emitting diodes (LEDs) to emit infrared radiation that is focused by a plastic lens into a narrow beam. The beam is modulated , i.e. switched on and off, to prevent interference from other sources of infrared (like sunlight or artificial lighting). The receiver uses a silicon photodiode to convert the infrared radiation to an electric current . It responds only to the rapidly pulsing signal created by the transmitter, and filters out slowly changing infrared radiation from ambient light.

Infrared communications are useful for indoor use in areas of high population density . IR does not penetrate walls and so does not interfere with other devices in adjoining rooms. Infrared is the most common way for remote controls to command appliances.Infrared remote control protocols like RC-5 , SIRC , are used to communicate with infrared.
Infrared lasers are used to provide the light for optical fiber communications systems . Infrared light with a wavelength around 1,330 nm (least dispersion) or 1,550 nm (best transmission) are the best choices for standard silica fibers. Free space optical communication using infrared lasers can be a relatively inexpensive way to install a communications link in an urban area operating at up to 4 gigabit/s . Free-space optics can be used for communications between spacecraft .

3. Wireless Fidelity(WiFi)

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 .

802.11 network PHY standards								
802.11 protocol	Release date	Frequency	Band-width	Stream Data Rate	Allowable MIMO streams	Modulation Antenna Tech.	Approx. range	
							In	Out
		(GHz)	(MHz)	Min-Max (Mbit/s)			(m)	(m)
802.11	Jun 1997	2.4	22	1-2	1	DSSS, FHSS	20	100
a	Sep 1999	5	20	6-54	1	OFDM	35	120
		3.7				(SISO)	—	5K
b	Sep 1999	2.4	22	1-11	1	DSSS (SISO)	35	140
g	Jun 2003	2.4	20	6-54	1	OFDM, DSSS (SISO)	38	140
n	Oct 2009	2.4/5	20	7.2 -72.2 (6.5- 65)	4	OFDM (MIMO)	70	250
			40	15 - 150 (13.5 - 135)			70	250
ac	**Dec 2013**	**5**	**20**	**7.2 - 96.3 (6.5 - 86.7)**	**8**	**OFDM (MU-MIMO)**	**35**	
			40	**15 - 200 (13.5 - 180)**			**35**	
			80	**32.5 - 433.3 (29.2 - 390)**			**35**	
			160	**65 - 866.7 (58.5 - 780)**			**35**	

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).The 802.11 standard provides several distinct radio frequency ranges for use in Wi-Fi communications: 900 MHz, 2.4 GHz, 5 GHz, 5.9 GHz, and 60 GHz bands . Each range is divided into a multitude of channels . Countries apply their own regulations to the allowable channels, allowed users and maximum power levels within these frequency ranges. The ISM band ranges are also often used. Channels can be shared between networks but only one transmitter can locally transmit on a channel at any moment in time.

An access point (or hotspot) often has a range of about 20 metres indoors while some modern access points claim up to a 150-metre range outdoors. Hotspot coverage can be as small as a single room with walls that block radio waves, or as large as many square kilometres using many overlapping access points with roaming permitted between them. Over time the speed and spectral efficiency of Wi-Fi have increased. As of 2019, at close range, some versions of Wi-Fi, running on suitable hardware, can achieve speeds of over 1 Gbit/s . Coverage in the larger area may require a group of access points with overlapping coverage. For example, public outdoor Wi-Fi technology has been used successfully in wireless mesh networks in London. An international example is Fon . Many traditional university campuses in the developed world provide at least partial Wi-Fi coverage. Carnegie Mellon University built the first campus-wide wireless Internet network, called Wireless Andrew , at its Pittsburgh campus in 1993 before Wi-Fi branding originated. In the early 2000s, many cities around the world announced plans to construct citywide Wi-Fi networks. There are many successful examples; in 2004, Mysore (Mysuru) became India's first Wi-Fi-enabled city. A company called WiFiyNet has set up hotspots in Mysore, covering the complete city and a few nearby villages.

4. Cellular Network

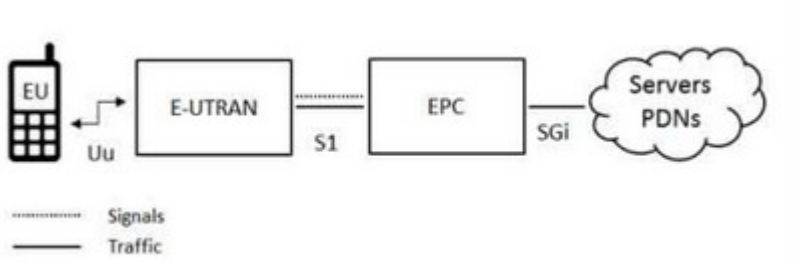
Cell input voltage	3.0–5.5 V	Max cell power	≤16 mA/3.0 V
Weight per cell	≤ 3.0 g	Skin thickness	3.3 mm
Cell surface	665 mm^2	Elastic gap	4.0 mm
Number of interfaces	Unlimited	Number of cells	Unlimited
Cell2cell bandwidth	4 Mbit/s	Interface bandwidth	1 Gbit/s
Cell2cell protocol	Custom	Interface protocol	UDP
Cell2cell packets	20 bytes	Ports per cell	4
Packet routing	Round robin	Power routing	Resistive

A cellular network or mobile network is a radio network distributed over land areas called cells, each served by at least one fixed-location transceiver , known as a cell site or base station . In a cellular network, each cell characteristically uses a different set of radio frequencies from all their immediate neighbouring cells to avoid any interference. When joined together these cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers (e.g., mobile phones, pagers , etc.) to communicate with each other and with fixed transceivers and telephonesanywhere in the network, via base stations , even if some of the transceivers are moving through more than one cell during transmission.

LTE(4G)

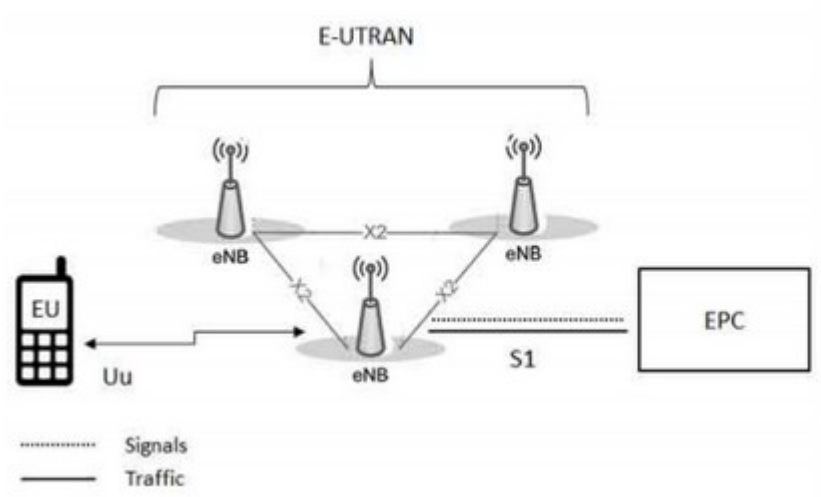
The evolved packet core communicates with packet data networks in the outside world such as
the internet, private corporate networks or the IP multimedia subsystem. The interfaces

between the different parts of the system are denoted Uu, S1 and SGi as shown below:



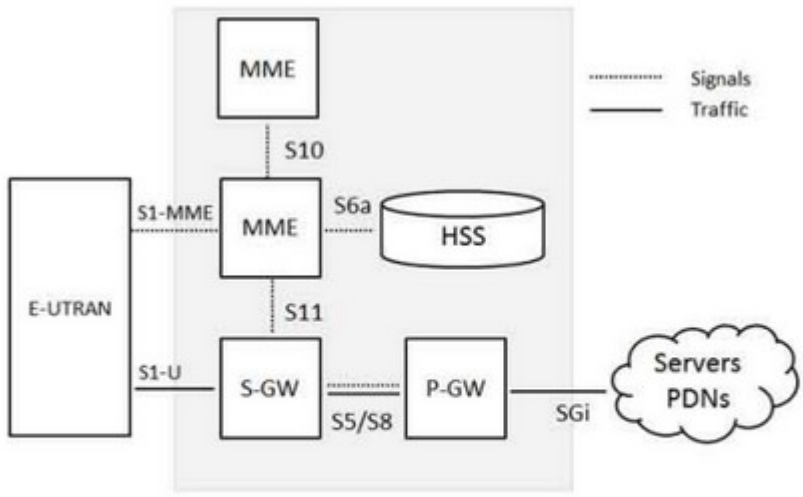
The high-level network architecture of LTE is comprised of following three main
components:
1) The User Equipment (UE).
2) The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).
3) The Evolved Packet Core (EPC).

The User Equipment (UE)
The internal architecture of the user equipment for LTE is identical to the one used by UMTS
and GSM which is actually a Mobile Equipment (ME). The mobile equipment comprised of
the following important modules:
The E-UTRAN (The access network)
The architecture of evolved UMTS Terrestrial Radio Access Network (E-UTRAN) has been
illustrated below.



The E-UTRAN handles the radio communications between the mobile and the evolved packet

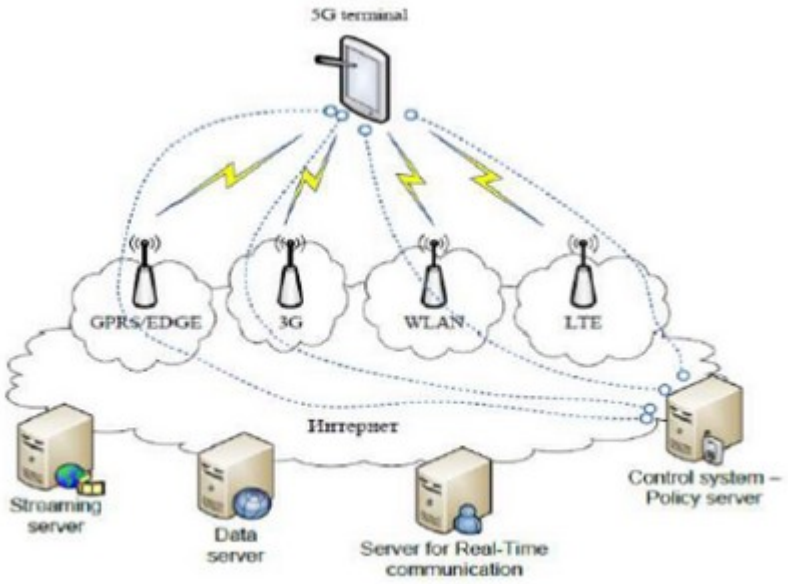
core and just has one component, the evolved base stations, called eNodeB or eNB. Each eNB
is a base station that controls the mobiles in one or more cells. The base station that is
communicating with a mobile is known as its serving eNB.
The Evolved Packet Core (EPC) (The core network)
The architecture of Evolved Packet Core (EPC) has been illustrated below. There are few
more components which have not been shown in the diagram to keep it simple. These
components are like the Earthquake and Tsunami Warning System (ETWS), the Equipment
Identity Register (EIR) and Policy Control and Charging Rules Function (PCRF).



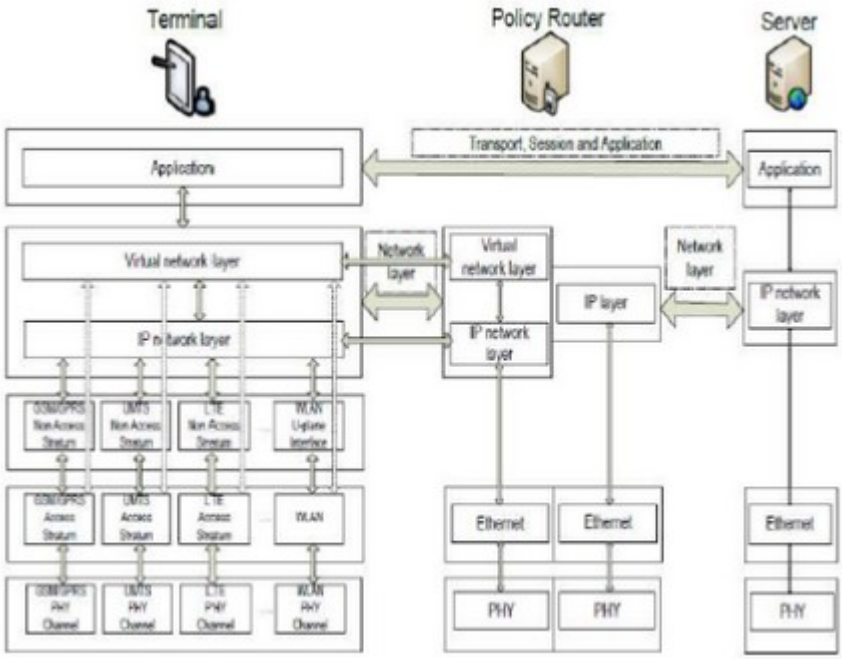
5G

5G

Architecture of 5G is highly advanced, its network elements and various terminals are characteristically upgraded to afford a new situation. Likewise, service providers can implement the advance technology to adopt the value-added services easily. However, upgradeability is based upon cognitive radio technology that includes various significant features such as ability of devices to identify their geographical location as well as weather, temperature, etc. Cognitive radio technology acts as a transceiver (beam) that perceptively can catch and respond radio signals in its operating environment. Further, it promptly distinguishes the changes in its environment and hence respond accordingly to provide uninterrupted quality service. As shown in the following image, the system model of 5G is entirely IP based model designed for the wireless and mobile networks.



The system comprising of a main user terminal and then a number of independent and autonomous radio access technologies. Each of the radio technologies is considered as the IP link for the outside internet world. The IP technology is designed exclusively to ensure sufficient control data for appropriate routing of IP packets related to a certain application connections i.e. sessions between client applications and servers somewhere on the Internet. Moreover, to make accessible routing of packets should be fixed in accordance with the given policies of the user (as shown in the image given below).



5. LiFi

TheLiFi considered as a WiFi with light being using light technology instead of Radio waves. It forms a new class of high intensity light source of solid state design bringing clean lighting solutions to general and specialty lighting. With energy efficiency, long useful lifetime, full spectrum and dimming, LiFi lighting applications work better compared to conventional approaches. The LiFi provide high efficiency communication system within confined spaces when compared to the WiFi, hence the two technologies can be considered complimentary.

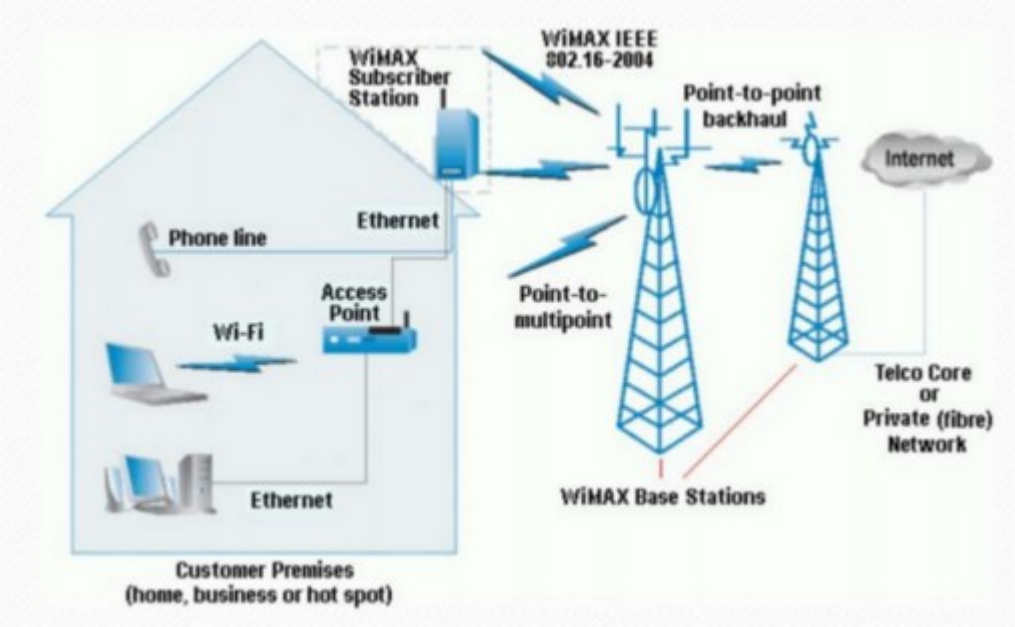
Parameters	Li-Fi
IEEE Standards	802.15.17
Frequency Band	100 X Tera HZ
Cots	Cheap
Data Trans. Medium	Light
Network Topology	Point-to-Point
Speed	1-3.5Gbps
Range	10 Meters
Security	High
Power Energy	Available
QoS	
Data rate	
Wireless spectrum reliability	
Reliability	High
Release Date	2011

The LiFi system uses standard LED light bulbs which are controlled by a driver that turns the LED on and off, or dims and brightens its light intensity. With Li-Fi enabled LED light bulbs, the driver is used to transmit encoded data by controlling the LED light. An optical sensor is used to receive the data, which is then decoded. This is conceptually similar to Morse code – but at rates of many millions of times a second, which is unperceivable to the human eye. The receiver has optics, and is fast enough to see' the light dimming and brightening, smart enough to decode the Li-Fi data, and then deliver it to the attached device such as a laptop computer. Devices can include both a transmitter and receiver to enjoy two-way communications [6].

6.Worldwide Interoperability for Microwave Access (WiMax) 802.16a

WiMAX is such an easy term that people tend to use it for the 802.16 standards and technology themselves, although strictly it applies only to systems that meet specific conformance criteria laid down by the WiMAX Forum. The 802.16a standard for 2-11 GHz is a wireless metropolitan area network (MAN) technology that will provide broadband wireless

connectivity to Fixed, Portable and Nomadic devices. It can be used to connect 802.11 hot spots to the Internet, provide campus connectivity, and provide a wireless alternative to cable and DSL for last mile broadband access.



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

WiMax Speed and Range

WiMAX is expected to offer initially up to about 40 Mbps capacity per wireless channel for both fixed and portable applications, depending on the particular technical configuration chosen, enough to support hundreds of businesses with T-1 speed connectivity and thousands of residences with DSL speed connectivity. WiMAX can support voice and video as well as Internet data.

WiMax developed to provide wireless broadband access to buildings, either in competition to existing wired networks or alone in currently unserved rural or thinly populated areas. It can also be used to connect WLAN hotspots to the Internet. WiMAX is also intended to provide broadband connectivity to mobile devices. It would not be as fast as in these fixed applications, but expectations are for about 15 Mbps capacity in a 3 km cell coverage area. With WiMAX, users could really cut free from today's Internet access arrangements and be able to go online at broadband speeds, almost wherever they like from within a MetroZone.

WiMAX could potentially be deployed in a variety of spectrum bands: 2.3GHz, 2.5GHz, 3.5GHz, and 5.8GHz.

Use of Wireless media in different network architectures

The different mediums discussed above are used in some network type or the other. Here are some interesting points about Wireless Network types :

1. Wireless PAN (Personal Area Network)

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. ZigBee also supports WPAN applications. Wi-Fi PANs are becoming commonplace (2010) as equipment designers start to integrate Wi-Fi into a variety of consumer electronic devices. Intel "My WiFi" and Windows 7 " virtual Wi-Fi" capabilities have made Wi-Fi PANs simpler and easier to set up and configure. New wireless technology from Intel called My WiFi, available to Centrino 2-based laptops, makes the computer's wireless adapter work concurrently as an adapter and a wireless router .

The technology enables users to simultaneously connect their laptops to multiple other peripheral devices , such as printers, photo frames, and cameras without a need for an access point or a wireless router.

Virtual Wifi allows you to share any Internet connection type , to keep all your devices online wherever you go, either via Wi-Fi, tethered 3G / 4G connection or wired Ethernet. You can even share a VPN connection over Wi-Fi to protect all your connected devices.

2. Wireless LAN (Local Area Network)

A wireless local area network (WLAN) links two or more devices over a short distance using a wireless distribution method, usually providing a connection through an access point for internet access. The use of spread-spectrum or OFDM technologies may allow users to move around within a local coverage area, and still remain connected to the network.

Products using the IEEE 802.11 WLAN standards are marketed under the Wi-Fi brand name . To connect to Wi-Fi , sometimes devices like a router or connecting HotSpot using mobile smartphones are used. Fixed wireless data (FWD) links are often a cost-effective alternative to leasing fiber or installing cables between the buildings . Fixed wireless technology implements point-to-point links between computers or networks at two distant locations, often using dedicated microwave or modulated laser light beams over line of sight paths. It is often used in cities to connect networks in two or more buildings without installing a wired link.

3. 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 .

4. Wireless MAN (Metropolitan Area Network)

Wireless metropolitan area networks are a type of wireless network that connects several wireless LANs. WiMAX (Worldwide Interoperability for Microwave Access) is a type of Wireless MAN and is described by the IEEE 802.16 standard. WiMAX can provide at-home or mobile Internet access across whole cities or countries. In many cases, this has resulted in competition in markets which typically only had access through an existing incumbent DSL (or similar) operator. Mobile WiMAX was a replacement candidate for cellular phone technologies such as GSM and CDMA , or can be used as an overlay to increase capacity. Fixed WiMAX is also considered as a wireless backhaul technology for 2G , 3G , and 4G networks in both developed and developing nations.

5. Wireless WAN (Wide Area Network)

Wireless wide area networks are wireless networks that typically cover large areas, such as between neighbouring 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 5.8Ghz band , rather than omnidirectional 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.

6. Global Area Network

A global area network (GAN) is a network used for supporting mobile across an arbitrary number of wireless LANs , satellite coverage areas , etc. The key challenge in mobile communications is handing off user communications from one local coverage area to the next. In IEEE Project 802, this involves a succession of terrestrial wireless LANs .

7. Global Satellite Network

Communication satellites are an important part of global networks. However, there are specific low Earth orbit (LEO) global satellite constellations , such as Iridium , Globalstar and Orbcomm , which are comprised by dozens of similar satellites which are put in orbit at regularly spaced positions and form a mesh network , sometimes sending and receiving information directly among themselves. Using VSAT technology, satellite internet access has become possible.

Wired Transmission Media :

Wired communication refers to the transmission of data over a wire - based communication technology . Examples include telephone networks , cable television or internet access , and fiber-optic communication . Most wired networks use Ethernet cables to transfer data between connected Pcs.

Local telephone networks often form the basis for wired communications and are used by both residential and business customers in the area. Many networks today rely on the use of fiberoptic communication technology as a means of providing clear signaling for both inbound and outbound transmissions and are replacing copper wire transmission.

In general, wired communications are considered to be the most stable of all types of communications services. They are relatively impervious to adverse weather conditions in comparison to wireless communication solutions. These characteristics have allowed wired communications to remain popular even as wireless solutions have continued to advance.

Range and specifications of some wired media :

1. Twisted Pair Cable

Categories/classes of twisted-pair cables

The categories and classes according to TIA/EIA 568A and EN 50173:

Standard TIA/EIA 568A	ISO 11801 EN50173	Connectors	Application	Band
cat. 1	Class A		Telephone services	up to 100 kHz
cat. 2	Class B		Voice services and older terminal systems	up to 1 MHz
cat. 3	Class C	RJ11 RJ12 RJ45	10BASE-T Ethernet, telephone cables	up to 16 MHz
cat. 4	-	RJ45	16 Mbps Token Ring	up to 20 MHz
cat. 5/5e	Class D	RJ45	FastEthernet 100Base-TX, GigabitEthernet 1000Base-T	up to 100 MHz
cat.6	Class E	RJ45	ATM622, GigabitEthernet 1000Base-T	up to 250 MHz
cat. 6A	Class E_A	RJ45	GigabitEthernet, 10-GigabitEthernet 10GBase-T	up to 500 MHz
cat. 7	F	GG45, TERA	10GBase-T, CCTV, 3-play services	up to 600 MHz
cat. 7A	F_A	GG45, TERA	10GBase-T, CATV up to 862 MHz, 3-play services, ready for 40G	up to 1 GHz

An Unshielded Twisted Pair (UTP) cable is made of two plastic insulated copper wires twisted together to form a single media. Out of these two wires, only one carries actual signal and anotheris used for ground reference. The twists between wires are helpful in reducing noise (electro-magnetic interference) and crosstalk. The UTP cables are connected by RJ45 connectors . In a Shielded Twisted Pair (STP) cable, the

twisted wire pair is additionally covered in a metal foil which increases the noise resistance.

UTP is also the most common cable used in computer networking . Modern Ethernet , the most common data networking standard, can use UTP cables. Twisted-pair cabling is often used in data networks for short and medium -length connections because of its relatively lower costs compared to optical fiber and coaxial cable .

As UTP cable bandwidth has improved to match the baseband of television signals, UTP is now used in some video applications, primarily in security cameras . As UTP is a balanced transmission line, a balun is needed to connect to unbalanced equipment, for example any using BNC connectors and designed for coaxial cable .

2. Coaxial Cable

Properties of Coaxial Cable Dielectrics
(c = speed of light in a vacuum)

Dielectric Type	Time Delay(ns/ft)	Propagation Velocity
Solid Polyethylene (PE)	1.54	0.659c
Foam Polyethylene (FE)	1.27	0.800c
Foam Polystyrene (FS)	1.12	0.910c
Air Space Polyethylene (ASP)	1.15-1.21	0.840c-0.880c
Solid Teflon (ST)	1.46	0.694c
Air Space Teflon (AST)	1.13-1.20	0.850c-0.900c

Coaxial cable, or coax is a type of electrical cable . It differs from other shielded cables because the dimensions of the cable and connectors are controlled to give a precise, constant conductor spacing, which is needed for it to function efficiently as a transmission line. The wrapped structure provides it a good shield against noise and crosstalk.

Coaxial cable is a type of transmission line , used to carry high-frequency electrical signals with low losses . It is used in such applications as telephone trunklines, broadband internet networking cables, high-speed

computer data busses , cable television signals, cable Internet and connecting radio transmitters and receivers to their antennas .

Coaxial cables provide high bandwidth rates of up to 450 mbps and are used in ethernet systems , namely the RG-58 (ThickEthernet) and RG-11 (Thick Ethernet).

3. Power Lines

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

- ○ Narrow band PLC
- ○ Broadband PLC

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

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

4. Fiber Optic Cable

			Specified Value	
Specification	**Tolerance**	**Unit**	1310 nm	1550 nm
Attenuation	Maks.	dB/km	≤0.35	≤0.21
Mode Field Diameter	±0.5	Mm	9.2	10.3
Choromatic Dispersion	Maks.	ps/(nm*km)	≤3.5	≤17
Cladding Diameter	±2	µm	125	-
Core / Cladding Concentricity Error	-	µm	1	-
Zero Dispersion Wavelength	-	Zayıflama	1300-1324	-
Cladding Non Circularity	Maks.	%	≤2	-
Coating Diameter	±15	µm	250	-
Cut off Wavelength	Maks.	µm	1150-1270	-

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.

In frared 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 with retappingis 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 (10_{15}b 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".Companies can lease or sell the unused fiber to other providers who are looking for service in or through an area.

Fiber Distribution Data Interface (FDDI)

Fiber Distributed Data Interface (FDDI) is a standard for data transmission in a local area network. It uses optical fiber as its standard underlying physical medium, although it was also later specified to use copper cable, in which case it may be called CDDI (Copper Distributed Data Interface), standardized as TP-PMD (Twisted-Pair Physical Medium- Dependent), also referred to as TP-DDI (Twisted-Pair Distributed Data Interface).

Features
• FDDI uses optical fiber as its physical medium.
• It operates in the physical and medium access control (MAC layer) of the OpenSystems Interconnection (OSI) network model.
• It provides high data rate of 100 Mbps and can support thousands of users.
• It is used in LANs up to 200 kilometers for long distance voice and multimedia communication.

• It uses ring based token passing mechanism and is derived from IEEE 802.4 token bus standard.
• It contains two token rings, a primary ring for data and token transmission and a secondary ring that provides backup if the primary ring fails.
• FDDI technology can also be used as a backbone for a wide area network (WAN).

How FDDI Works?

Fiber Distributed Data Interface (FDDI) is usually implemented as a dual token-passing ring within a ring topology (for campus networks) or star topology (within a building). The dual within a ring topology (for campus networks) or star topology (within a building). The dual ring consists of a primary and secondary ring. The primary ring carries data. The counter-rotating secondary ring can carry data in the opposite direction, but is more commonly reserved as a backup in case the primary ring goes down. This provides FDDI with the degree of fault tolerance necessary for network backbones. In the event of a failure on the primary ring, FDDI automatically reconfigures itself to use the secondary ring as shown in the illustration. Faults can be located and repaired using a fault isolation technique called beaconing. However, the secondary ring can also be configured for carrying data, extending the maximum potential bandwidth to 200 Mbps.

Stations connect to one (or both) rings using a media interface connector (MIC). Its two fiber ports can be either male or female, depending on the implementation. There are two different FDDI implementations, depending on whether stations are attached to one or both rings:

Single-attached stations (Class B stations): Connect to either the primary or secondary ring using M ports. Single-attached FDDI uses only the primary ring and is not as commonly deployed for network backbones as dual-attached FDDI. Single-attached stations are used primarily to connect Ethernet LANs or individual servers to FDDI backbones.

Dual-attached stations (Class A stations): Connect to both rings. The A port is the point at which the primary ring enters and the secondary ring leaves; the B port is the reverse. M ports provide attachment points for single-attached stations. Dual-attached FDDI uses both rings, with the secondary ring serving as a backup for the primary. Dual- attached FDDI is used primarily for network backbones that require fault tolerance.

Single- attached stations can be connected to dual-attached FDDI backbones using a dual- attached device called a concentrator or multiplexer. FDDI uses a timed token-passing technology similar to that of token ring networks as defined in the IEEE 802.5 standard. FDDI stations generate a token that controls the sequence in which other stations will gain access to the wire. The token passes around the ring, moving from one node to the next. When a station wants to transmit information, it captures the token, transmits as many frames of information as it wants (within the specified access period), and then releases the token. This feature of transmitting multiple data frames per token capture is known as a capacity allocation scheme, in contrast to the priority mechanism

used in the IEEE 802.5 token ring standard. Every node on the ring checks the frames. The recipient station then reads the information from the frames, and when the frames return to the originating station, they are stripped from the ring.

There can be up to 500 stations on a dual-ring FDDI network. The maximum circumference for an FDDI ring is 100 kilometers (or 200 kilometers for both rings combined), and there must be a repeater every 2 kilometers or less. Bridges or routers are used to connect the FDDI backbone network to Ethernet or token ring departmental LANs. For these reasons, FDDI is not often used as a wide area network (WAN) solution, but is more often implemented in campus-wide networks as a network backbone.

Some Technologies used in Wired media :

1. Universal Serial Bus

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

The Universal Serial Bus (USB) specification stipulates five data transfer rates:

- USB 1.0/Low-Speed: 1.5 Megabits per second (Mbps)
- USB 1.1/Full-Speed: 12 Mbps
- USB 2.0/Hi-Speed: 480 Mbps
- USB 3.0/SuperSpeed: 5 Gbps
- USB 3.1/SuperSpeed: 10 Gbps

When connecting devices with different USB versions, the data transfer rate will be limited by the slowest of the connected devices. This means that data transfer will occur at 12 Mbps when you connect a USB 2.0 device to a USB 1.1 device, even though the USB 2.0 device is capable of transferring data at 480 Mbps.

2. The Ethernet

The IEEE 802.3 working group approved the first Ethernet standard in 1983. Since then, the technology has continued to evolve and embrace new media, higher transmission speeds and changes in frame content:

- 802.3ac was introduced to accommodate VLAN and priority tagging.
- 802.3af defines Power over Ethernet (PoE), which is crucial to most Wi-Fi and Internet Protocol (IP) telephony deployments.
- 802.11a, b, g, n, ac and ax define the equivalent of Ethernet for WLANs.
- 802.3u ushered in 100BASE-T -- also known as Fast Ethernet -- with data transmission speeds of up to 100 Mbps. The term BASE-T indicates the use of twisted-pair cabling.

LAN Technology Specifications

Name	IEEE Standard	Data Rate	Media Type	Maximum Distance
Ethernet	802.3	10 Mbps	10Base-T	100 meters
Fast Ethernet/ 100Base-T	802.3u	100 Mbps	100Base-TX 100Base-FX	100 meters 2000 meters
Gigabit Ethernet/ GigE	802.3z	1000 Mbps	1000Base-T 1000Base-SX 1000Base-LX	100 meters 275/550 meters 550/5000 meters
10 Gigabit Ethernet	IEEE 802.3ae	10 Gbps	10GBase-SR 10GBase-LX4 10GBase-LR/ER 10GBase-SW/LW/EW	300 meters 300m MMF/ 10km SMF 10km/40km 300m/10km/40km

Ethernet is a family of computer networking technologies commonly used in local area networks (LAN), metropolitan areanetworks (MAN) and wide area networks (WAN). It was commercially introduced in 1980 and first standardized in 1983 as IEEE 802.3 . Ethernet has since been refined to support higher bitrates , a greater number of nodes, and longer link distances, but retains much backward compatibility . Over time, Ethernet has largely replaced competing wired LAN technologies such as Token Ring , FDDI and ARCNET .
The original 10BASE5 Ethernet uses coaxial cable as a shared medium , while the newer Ethernet variants use twisted pair and fiber optic links in conjunction with switches . Over the course of its history, Ethernet data transfer rates have been increased from the original 2.94 megabits per second (Mbit/s) to the latest 400 gigabits per second (Gbit/s). The Ethernet standards comprise several wiring and signaling variants of the OSI physical layer in use with Ethernet. Ethernet is widely used in homes and industry, and interworks well with Wi-Fi. The Internet Protocol is commonly carried over Ethernet and so it is considered one of the key technologies that make up the Internet .

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

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

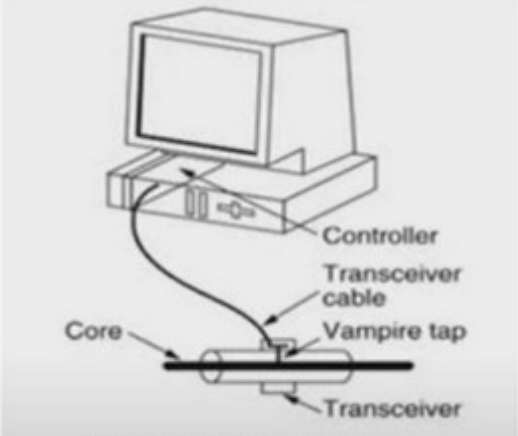


Fig. 3: 10Base5 [2]

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

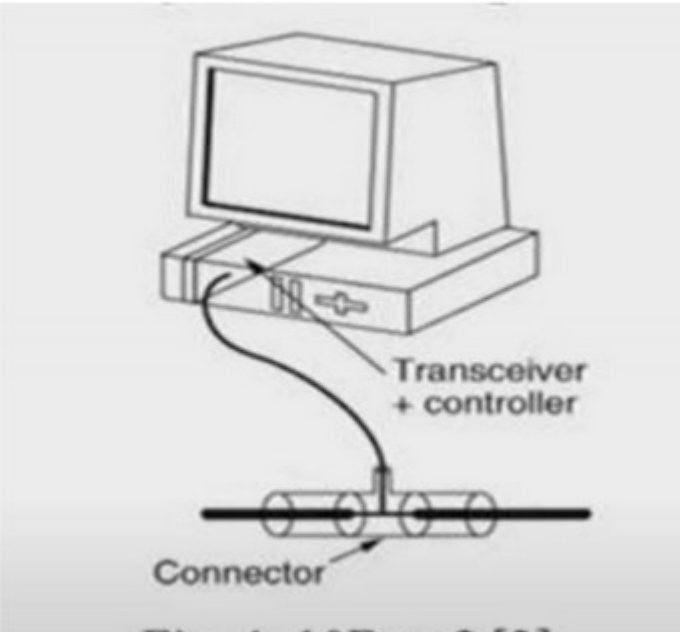


Fig. 4: 10Base2 [2]

IEEE 802.3i: This gave the standard for twisted pair (10BASE-T) that uses unshielded twisted pair (UTP) copper wires as physical layer medium. The further variations were given by IEEE 802.3u for 100BASE-TX, 100BASE-T4 and100BASE- FX.

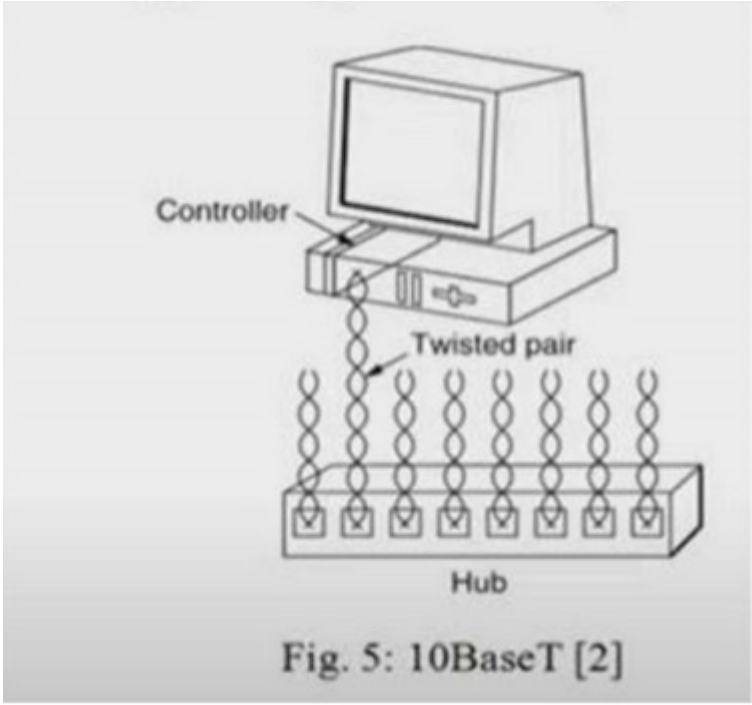


Fig. 5: 10BaseT [2]

IEEE 802.3i: This gave the standard for Ethernet over Fiber (10BASE-F) that uses fiber optic cables as medium of transmission.

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

208.3u (Fast Ethernet)

To encompass need of fast emerging software and hardware technologies, Ethernet extends itself as Fast-Ethernet. It can run on UTP, Optical Fiber, and wirelessly too. It can provide speed up to 100MBPS. This standard is named as 100BASE-T in IEEE 803.2 using Cat-5 twisted pair cable. It uses CSMA/CD technique for wired media sharing among the Ethernet hosts

and CSMA/CA (CA stands for Collision Avoidance) technique for wireless Ethernet LAN. Fast Ethernet on fiber is defined under 100BASE-FX standard which provides speed up to 100MBPS on fiber. Ethernet over fiber can be extended up to 100 meters in half-duplex mode and can reach maximum of 2000 meters in full-duplex over multimode fibers. Varieties of Fast Ethernet The common varieties of fast Ethernet are 100-Base-TX, 100-BASE-FX and 100-Base-T4.

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

100-Base-T4
• This has four pairs of UTP of Category 3, two of which are bi-directional and the other two are unidirectional.
• In each direction, three pairs can be used simultaneously for data transmission.
• Each twisted pair is capable of transmitting a maximum of 25Mbaud data. Thus the three pairs can handle a maximum of 75Mbaud data.
• It uses the encoding scheme 8B/6T (eight binary/six ternary).

100-Base-TX
• This has either two pairs of unshielded twisted pairs (UTP) category 5 wires or two shielded twisted pairs (STP) type 1 wires. One pair transmits frames from hub to device and the other from device to hub.
• Maximum distance between hub and station is 100m.
• It has a data rate of 125 Mbps.
• It uses MLT-3 encoding scheme along with 4B/5B block coding.

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

Use of Wired media in different network architectures :

The different mediums discussed above are used in used in various Network Architectures, often many are used in combination. Here are some interesting points about Wired Network types :

1. Wired Personal Area Network

Wired personal area networks provide short connections between peripherals. It mainly uses the USB cables to set up a small Personal network between the wired devices, but IEEE-1394 or Thunderbolt (interface) can also be used.

2. Wired LAN

Wired LAN is used within a limited area such as a residence, school, laboratory, university campus or office building. Typically Ethernet is the most common wired technology in use for wired local area networks. Historical network technologies include ARCNET , Token ring .

Early Ethernet (10BASE-5 and 10BASE-2) used coaxial cable . Shielded twisted pair was used in IBM's Token Ring LAN implementation. In 1984, StarLAN showed the potential of simple unshielded twisted pair by using category 3 cable —the same cable used for telephone systems. This led to the development of 10BASE-T (and its twisted-pair successors) and structured cabling which is still the basis of most commercial LANs today.

At the data link layer and physical layer , a wide variety of LAN topologies have been used, including ring , bus , mesh and star . Simple LANsgenerally consist of cabling and one or more switches . While opticalfiber cable is common for links between network switches , use of fiber to the desktop is rare.

3. Campus Area Network (CAN)

CAN computer network is made up of an interconnection of local area networks (LANs) within a limited geographical area, generally implemented using wired transmission media, optical fiber , copperplant, Cat5 cabling etc.The range of CAN is 1 km to 5 km.

College or university campus area networks often interconnect a variety of buildings, including administrative buildings, academic buildings, university libraries, campus or student centers, residence halls , gymnasiums , and other outlying structures, like conference centers ,

technology centers, and training institutes. Examples : the Stanford University Network at Stanford University , Project Athena at MIT , and the Andrew Project at Carnegie Mellon University Corporate CANs connect several buildings like Googleplex and Microsoft 's campus . Campus networks are normally interconnected with high speed Ethernet links operating over optical fiber such as gigabit Ethernet and 10 Gigabit Ethernet .

4. Metropolitan Area Network(MAN)

MAN is applied to the interconnection of local area networks (LANs) in acity into a single larger network. The term is also used to describe the interconnection of several local area networks in a metropolitan area through the use of point-to-point connections between them.

The telephone networks could not carry the spike that the LANs produced, so single-mode optical fiber lines were used to create MANs for companies with buildings across the city in MAN's early days. Metro Ethernet , where a fibre optic ring within a larger city was built as MAN backbone carrying Gigabit Ethernet , became common. The ring topology was implemented using the Internet protocol (IP), so that data could be rerouted if a link was congested or one of the links that was part of the ring failed Between 2002 and 2003 Sprint built three MAN rings to cover San Francisco , Oakland and San Jose , and in turn connected these three metro rings with a further two rings.

Metro Ethernet was effectively the extension of Ethernet protocols beyond the local area network (LAN) and the ensuing investment in Ethernet led to the deployment of carrier Ethernet , where Ethernet protocols are used in wide area networks (WAN). DE-CIX has gone on to establish carrier neutral metropolitan Internet Exchanges in New York , Madrid, Dubai , Marseille , Dallas, Hamburg, Munich , Düsseldorf, Berlin, Istanbul, Palermo , Lisbon,Mumbai , Delhi, Kolkata, Chennai, and Moscow

5. Storage Area Network (SAN)

A storage area network (SAN) or storage network is a computer network which provides access to consolidated, block-level data storage . SANs are primarily used to access storage devices, such as disk arrays and tape libraries from servers so that the devices appear to the operating system as direct-attached storage . SANs have their own networking devices, such as SAN switches. To access the SAN, so-called SAN servers are used, which in turn connect to SAN host adapters . Within the SAN, a range of data storage devices may be interconnected, such as SAN-capable disk arrays, JBODS and tape libraries .

When SANs were first built, hubs were the only devices that were Fibre Channel capable, but Fibre Channel switches were developed and hubs

are now rarely found in SANs. Switches have the advantage over hubs that they allow all attached devices to communicate
simultaneously, as a switch provides a dedicated link to connect all itsports with one another. When SANs were first built Fibre Channel had to be implemented over copper cables, these days multimode optical fibre cables are used in SANs

6. Wide Area Network (WAN)

A wide area network (WAN) is a telecommunications network that extends over a large geographical area for the primary purpose of computer networking . Wide area networks are often established with leased telecommunication circuits .

Typically, leased lines are used by businesses to connect geographically distant offices. An Internet leased line is a premium Internet connectivity product, normally delivered over fiber , which provides uncontended, symmetrical bandwidth with full-duplex traffic. It is also
known as an Ethernet leased line , dedicated line , data circuit or private line .

Many technologies are available for wide area network links. Examples include circuit-switched telephone lines, radio wave transmission, and optical fiber . New developments in technologies have successively increased transmission rates. In ca. 1960, a 110 bit/s (bits per second) line was normal on the edge of the WAN, while core links of 56 kbit/s to 64 kbit/s were considered fast. As of 2014, households are connected to theInternet with dial-up , asymmetric digital subscriber line (ADSL), cable , WiMAX , 4G or fiber . The speeds that people can currently use rangefrom 28.8 kbit/s through a 28K modem over a telephone connection tospeeds as high as 100 Gbit/s using 100 Gigabit Ethernet .

7. Global Network

Interconnected IP networks (principally the Internet , with estimated 2.5 billion users worldwide in 2014), and the GSM mobile communication network (with over 6 billion worldwide users in 2014) form the largest global networks of all.

Many applications run on several networks, such as VoIP (voice over IP).Mobile communication (voice and data) networks are also intimately intertwined, because the majority of 21st century cell phones have bothvoice and data (internet navigation and emailing) capabilities. Digitalglobal networks require huge carrying capacity in the main backbones . This is currently achieved by fiber optic cables.

Conclusion:

The OSI model and physical layer is studied. Learnt about wireless and wired transmission media. The range and specifications of the media is also mentioned.

Reference:

1) Gorry Fairhurst (2001-01-01). "Physical Layer". Archived from the original on 2009-06-18.

2) Iyengar, Shisharama (2010). Fundamentals of Sensor Network Programming. Wiley. p. 136.
3) "The Physical Layer | InterWorks". InterWorks. 2011-07-30. Retrieved 2018-08-14.

4) Shaw, Keith (2018-10-22). "The OSI model explained: How to understand (and remember) the 7 layer network model". Network World. Retrieved 2019-02-15.
5) "(PDF) DATA COMMUNICATION & NETWORKING". ResearchGate. Retrieved 2019-02-15.

6) Shekhar, Amar (2016-04-07). "Physical Layer Of OSI Model: Working Functionalities and Protocols". Fossbytes. Retrieved 2019-02-15.

7) Bayliss, Colin R.; Bayliss, Colin; Hardy, Brian (2012-02-14). Transmission and Distribution Electrical Engineering. Elsevier. ISBN .

8) "CCNA Certification/Physical Layer - Wikibooks, open books for an open world". en.wikibooks.org. Retrieved 2019-02-15.

9) Forouzan, Behrouz A.; Fegan, Sophia Chung (2007). Data Communications and Networking. Huga Media. ISBN .

10) https://www.lantronix.com/resources/networking-tutorials/ethernet-tutorial-networking-basics/