💻 EXPERIMENT 1 💻

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

THEORY:

What does *Physical Layer* mean?
The physical layer is the first and lowest layer of the Open System Interconnection Model (OSI Model.)

The physical layer (also known as layer 1) deals with bit-level transmission between different devices and supports electrical or mechanical interfaces connecting to the physical medium for synchronized communication.
This layer plays with most of the network's physical connections—wireless transmission, cabling, cabling standards and types, connectors and types, network interface cards, and more —as per network requirements.

Wired connection: Wired communication refers to the transmission of data over a wire-based communication technology. Wired communication is also known as wireline communication.

Protocols under Wired Technology:
1) 802.3 (Ethernet)
2) 802.3u (Fast Ethernet)
3) 802.4 (Token Bus)
4) Fiber Distribution Data Interface (FDDI)

802.3 (Ethernet)

Ethernet is a set of technologies and protocols that are used primarily in LANs. It was first standardized in 1980s by IEEE 802.3 standard. IEEE 802.3 defines the physical layer and the medium access control (MAC) sub-layer of the data link layer for wired Ethernet networks. Ethernet is classified into two categories: classic Ethernet and switched Ethernet.
Classic Ethernet is the original form of Ethernet that provides data rates between 3 to 10 Mbps. The varieties are commonly referred as 10BASE-X. Here, 10 is the maximum throughput, i.e. 10 Mbps, BASE denoted use of baseband transmission, and X is the type of medium used. Most varieties of classic Ethernet have become obsolete in present communication scenario.

A switched Ethernet uses switches to connect to the stations in the LAN. It replaces the repeaters used in classic Ethernet and allows full bandwidth utilization.

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.

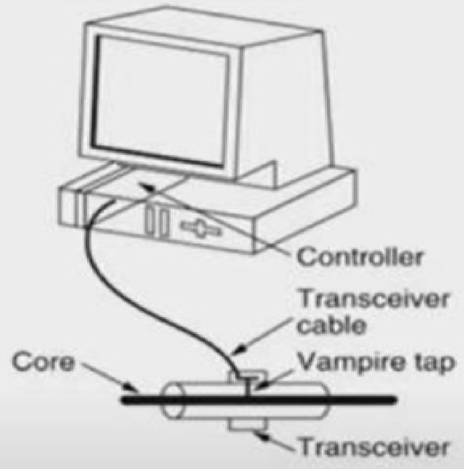


Fig. 3: 10Base5 [2]

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).

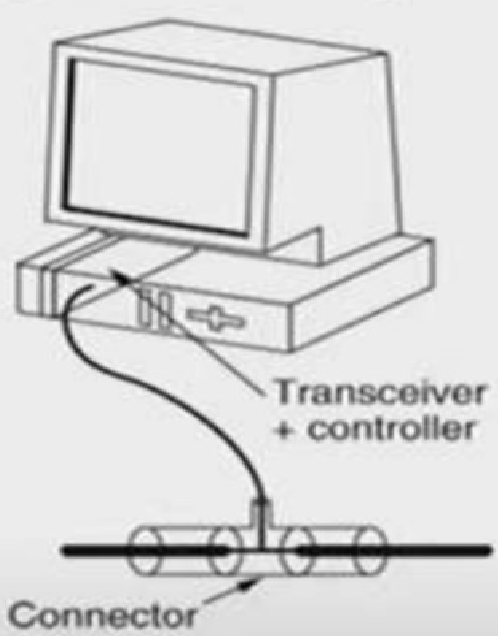


Fig. 4: 10Base2 [2]

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.

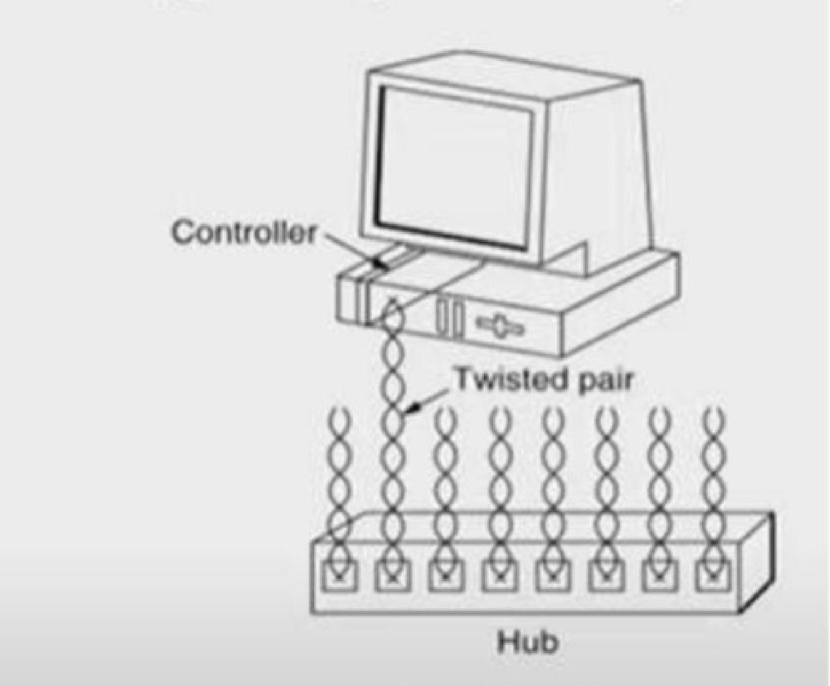


Fig. 5: 10BaseT [2]

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.

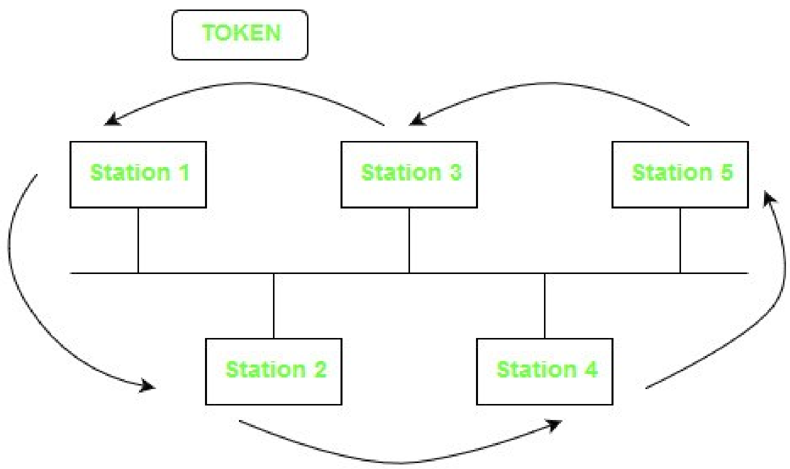
- Maximum distance between hub and station is 100m.
- It has a data rate of 125 Mbps.
- It uses MLT-3 encoding scheme along with 4B/5B block coding.

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.

802.4(Token Bus)

Token Bus (IEEE 802.4) is a popular standard for the token passing LANs. In a token bus LAN, the physical media is a bus or a tree and a logical ring is created using coaxial cable. The token is passed from one user to other in a sequence (clockwise or anticlockwise). Each station knows the address of the station to its "left" and "right" as per the sequence in the logical ring. A station can only transmit data when it has the token. The working of token bus is somewhat similar to Token Ring.The below diagram shows a logical ring formed in a bus based token passing LAN. The logical ring is shown with the arrows.



Physical Layer of the Token Bus

The conventional 75 ohm coaxial cable used for the cable TV can be used as the physical layer of the token bus. The different modulation schemes are used. They are, phase continuous frequency shift keying, phase coherent frequency shift keying, and the multilevel duo binary amplitude-modulated phase shift keying. Signal speeds in the range 1 Mbps, 5 Mbps, and 10 Mbps are achievable. The physical layer of the token bus is totally incompatible to the IEEE 802.3 standard.

MAC Sublayer Function

• When the ring is initialized, stations are inserted into it in order of station address, from highest to lowest.

• Token passing is done from high to low address.

• Whenever a station acquires the token, it can transmit frames for a specific amount of time.

• If a station has no data, it passes the token immediately upon receiving it.

• The token bus defines four priority classes, 0, 2, 4, and 6 for traffic, with 0 the lowest and 6 the highest.

• Each station is internally divided into four substations, one at each priority level *i.e.* 0,2,4 and 6.

• As input comes in to the MAC sublayer from above, the data are checked for priority and routed to one of the four substations.

• Thus each station maintains its own queue of frames to be transmitted.

• When a token comes into the station over the cable, it is passed internally to the priority 6 substation, which can begin transmitting its frames, if it has any.

• When it is done or when its time expires, the token is passed to the priority 4 substation, which can then transmit frames until its timer expires. After this the token is then passed internally to priority 2 substation.

• This process continues until either the priority 0 substation has sent all its frames or its time expires.

• After this the token is passed to the next station in the ring.

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.

Wireless connection: Wireless communication is the electromagnetic transfer of information between two or more points that are not connected by an electrical conductor. The most common wireless technologies use radio waves.

Protocols under Wireless Networks:
1) 802.11 Family (WiFi)
2) 802.15.1 (Bluetooth)
3) 802.15.4 (ZigBee)
4) Worldwide Interoperability for Microwave Access (WiMax) 802.16a

802.11 Family (WiFi)

IEEE 802.11 is part of the IEEE 802 set of local area network (LAN) protocols, and specifies the set of media access control (MAC) and physical layer (PHY) protocols for implementing wireless local area network (WLAN) Wi-Fi computer communication in various frequencies, including but not limited to 2.4 GHz, 5 GHz, 6 GHz, and 60 GHz frequency bands.

Although most people are familiar with the basic way that a home Wi-Fi network might work, it is not the only format for a WiFi network.

Essentially there are two basic types of Wi-Fi network:

- ***Local area network based network:*** This type of network may be loosely termed a LAN based network. Here a Wi-Fi Access Point, AP is linked onto a local area network to provide wireless as well as wired connectivity, often with more than one Wi-Fi hotspot.

  The infrastructure application is aimed at office areas or to provide a "hotspot". The office may even work wirelessly only and just have a Wireless Local Area Network, WLAN. A backbone wired network is still required and is connected to a server. The wireless network is then split up into a number of cells, each serviced by a base station or Access Point (AP) which acts as a controller for the cell. Each Access Point may have a range of between 30 and 300 metres dependent upon the environment and the location of the Access Point.

  More normally a LAN based network will provide both wired and wireless access. This is the type of network that is used in most homes, where a router which has its own firewall is connected to the Internet, and wireless access is provided by a Wi-Fi access point within the router,. Ethernet and often USB connections are also provided for wired access.

• ***Ad hoc network:*** The other type of Wi-Fi network that may be used is termed an Ad-Hoc network. These are formed when a number of computers and peripherals are brought together. They may be needed when several people come together and need to share data or if they need to access a printer without the need for having to use wire connections. In this situation the users only communicate with each other and not with a larger wired network.

As a result there is no Wi-Fi Access Point and special algorithms within the protocols are used to enable one of the peripherals to take over the role of master to control the Wi-Fi network with the others acting as slaves.

This type of network is often used for items like games controllers / consoles to communicate.

	802.11a	802.11b	802.11g	802.11n
Standard approved by IEEE	January 2000	December 1999	June 2003	Expected in 2007
Maximum data rate	54 Mbps	11 Mbps	54 Mbps	600 Mbps
Different data rate configurations	8	4	12	576
Typical range	75 feet	100 feet	150 feet	150 feet
Modulation technologies (1)	OFDM	DSSS, CCK	DSSS, CCK, OFDM	DSSS, CCK, OFDM+
RF band	5 GHz	2.4 GHz	2.4 GHz	2.4 GHz and 5 GHz
Number of spatial streams and antennas	1	1	1	Up to 4
Channel width	20 MHz	20 MHz	20 MHz	20 MHz or 40 MHz
Number of channels	23	3	3	26

802.15.1 (Bluetooth)

Bluetooth wireless technology is a short range communications technology intended to replace the cables connecting portable unit and maintaining high levels of security. Bluetooth technology is based on Ad-hoc technology also known as Ad-hoc Pico nets, which is a local area network with a very limited coverage.

WLAN technology enables device connectivity to infrastructure based services through a wireless carrier provider. The need for personal devices to communicate wirelessly with one another without an established infrastructure has led to the emergence of Personal Area Networks (PANs).

Bluetooth specification details the entire protocol stack. Bluetooth employs Radio Frequency (RF) for communication. It makes use of **frequency modulation** to generate radio waves in the **ISM** band.

Symbol of Bluetooth

An example of a Bluetooth device

The usage of Bluetooth has widely increased for its special features.

- Bluetooth offers a uniform structure for a wide range of devices to connect and communicate with each other.
- Bluetooth technology has achieved global acceptance such that any Bluetooth enabled device, almost everywhere in the world, can be connected with Bluetooth enabled devices.
- Low power consumption of Bluetooth technology and an offered range of up to ten meters has paved the way for several usage models.
- Bluetooth offers interactive conference by establishing an adhoc network of laptops.
- Bluetooth usage model includes cordless computer, intercom, cordless phone and mobile phones.

Spectrum

Bluetooth technology operates in the unlicensed industrial, scientific and medical (ISM) band at 2.4 to 2.485 GHZ, using a spread spectrum hopping, full-duplex signal at a nominal rate of 1600 hops/sec. the 2.4 GHZ ISM band is available and unlicensed in most countries.

Range

Bluetooth operating range depends on the device Class 3 radios have a range of up to 1 meter or 3 feet Class 2 radios are most commonly found in mobile devices have a range of

10 meters or 30 feet Class 1 radios are used primarily in industrial use cases have a range of 100 meters or 300 feet.

Data rate

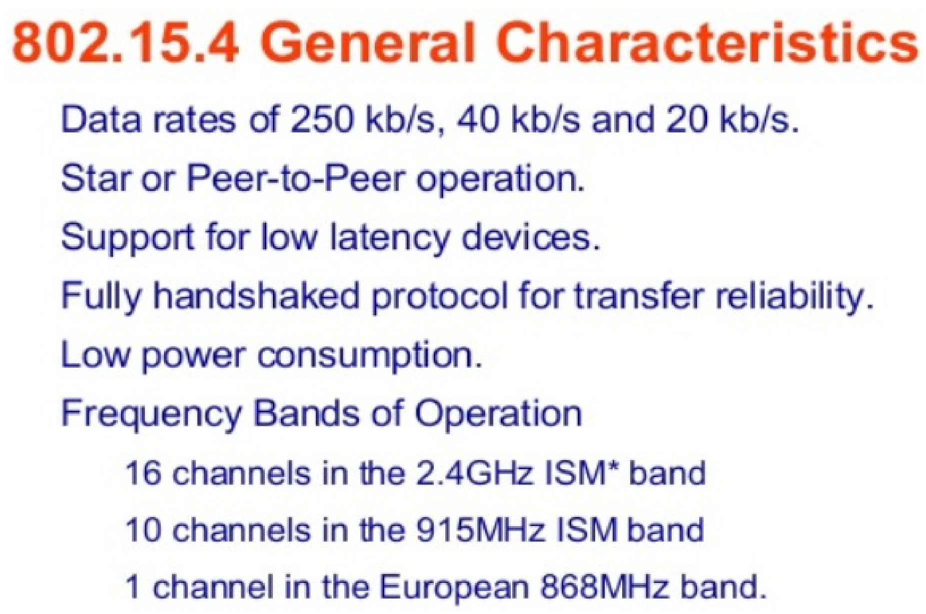
Bluetooth supports 1Mbps data rate for version 1.2 and 3Mbps data rate for Version 2.0 combined with Error Data Rate.

802.15.4 (ZigBee)

The IEEE 802.15.4 standard is aimed at providing the essential lower network layers for a wireless personal area network, WPAN. The chief requirements are low-cost, low-speed ubiquitous communication between devices.

IEEE 802.15.4 does not aim to compete with the more commonly used end user-oriented systems such as IEEE 802.11 where costs are not as critical and higher speeds are demanded and power may not be quite as critical. Instead, IEEE 802.15.4 provides for very low cost communication of nearby devices with little to no underlying infrastructure.

The concept of IEEE 802.15.4 is to provide communications over distances up to about 10 metres and with maximum transfer data rates of 250 kbps. Anticipating that cost reduction will require highly embedded device solutions, the overall concept of IEEE 802.15.4 has been devised to accommodate this.



IEEE 802.15.4 star topology

In the star topology, all the different nodes are required to talk only to the central PAN coordinator. Even if the nodes are FFDs and are within range of each other, in a star network topology, they are only allowed to communicate with the coordinator node.

Having a star network topology does limit the overall distances that can be covered. It is limited to one hop.

IEEE 802.15.4 peer to peer topology

A peer to peer, or p2p network topology provides a number of advantages over a star network topology. In addition to communication with the network coordinator, devices are also able to communicate with each other. FFDs are able to route data, while the RFDs are only able to provide simple communication.

The fact that data can be routed via FFD nodes means that the network coverage can be increased. Not only can overall distances be increased, but nodes masked from the main network coordinator can route their data via another FFD node that it may be able to communicate with.

Wireless Technology Comparison Chart

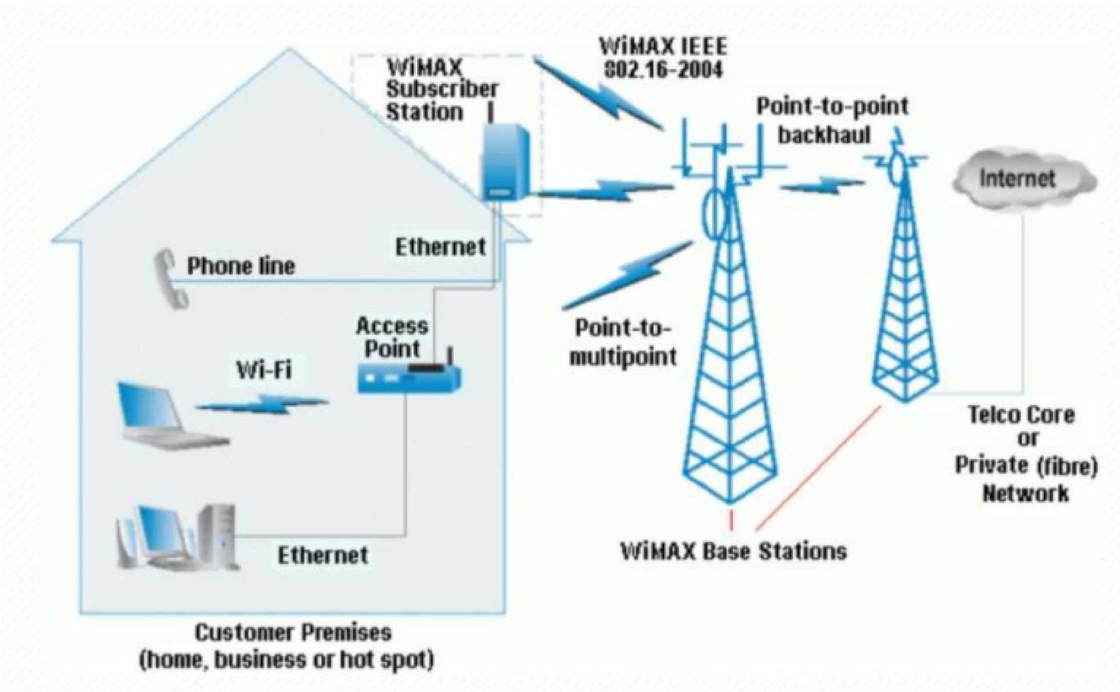
Standard	Bandwidth	Power Consumption	Protocol Stack Size	Stronghold	Applications
Wi-Fi	Up to 54Mbps	400+mA TX, standby 20mA	100+KB	High data rate	Internet browsing, PC networking, file transfers
Bluetooth	1Mbps	40mA TX, standby 0.2mA	~100+KB	Interoperability, cable replacement	Wireless USB, handset, headset
ZigBee	250kbps	30mA TX, standby 356 µA	34KB/14KB	Long battery life, low cost	Remote control, battery-operated products, sensors

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.

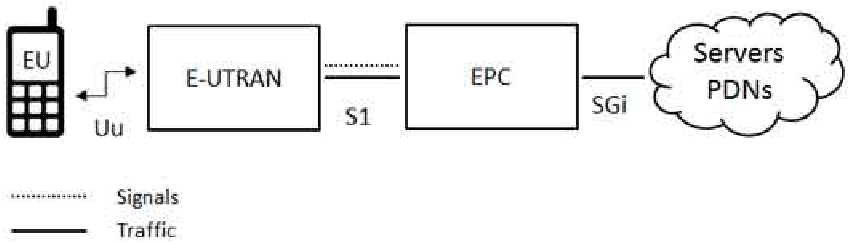
WiMax developed to provide wireless broadband access to buildings, either in competition to existing wired networks or alone in currently unserved rural or thinly populated areas. It can also be used to connect WLAN hotspots to the Internet. WiMAX is also intended to provide broadband connectivity to 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.

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).

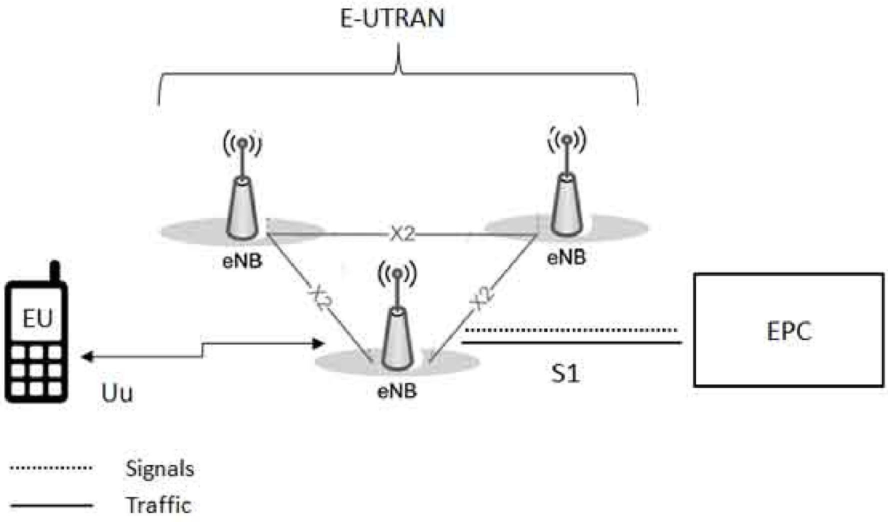
3) The Evolved Packet Core (EPC).

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)

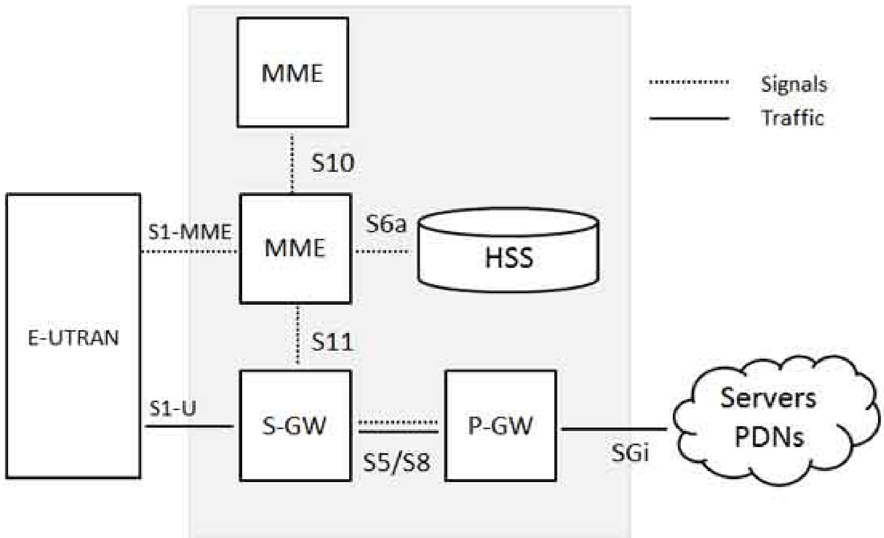
The architecture of evolved UMTS Terrestrial Radio Access Network (E-UTRAN) has been illustrated below.



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).

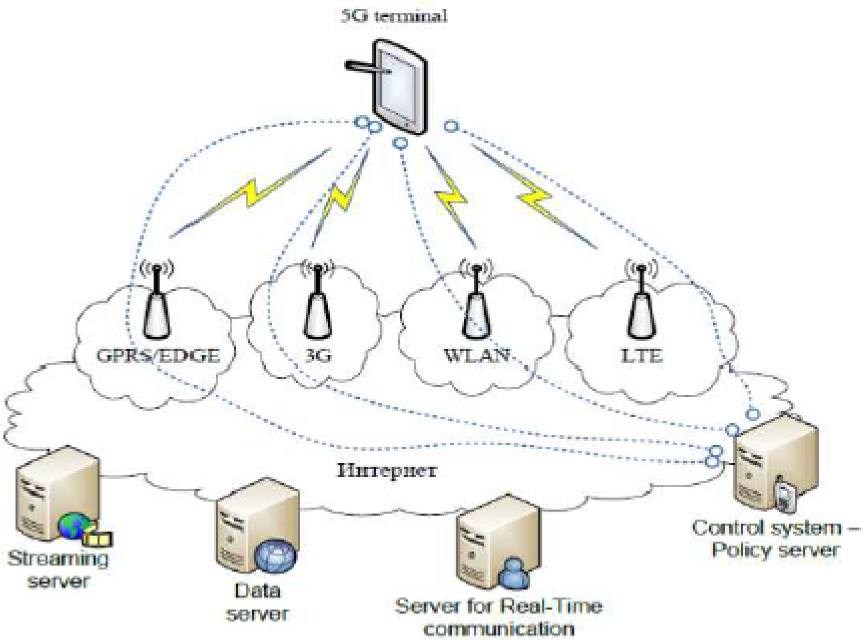


5G

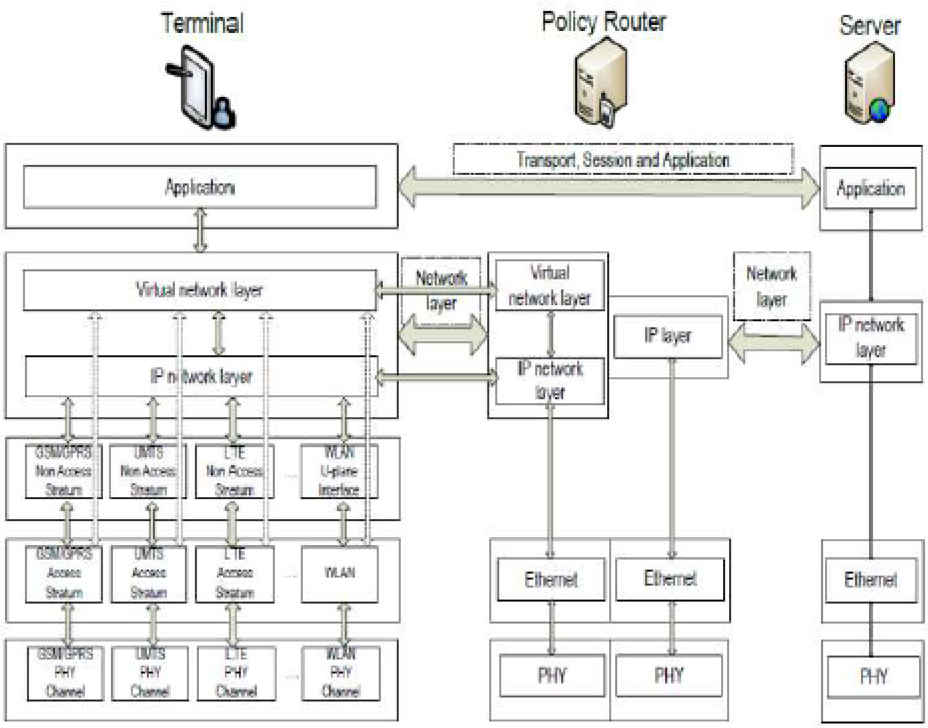
Architecture of 5G is highly advanced, its network elements and various terminals are characteristically upgraded to afford a new situation. Likewise, service providers can implement the advance technology to adopt the value-added services easily.

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).



CONCLUSION:

In the above experiment I learnt about the networking architecture of different types of wired and wireless physical layers.

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