EXPERIMENT 1

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SE COMPS

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

THEORY:

PHYSICAL LAYER Ref(1)

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.

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

802.3 (Ethernet) Ref(2, 3)

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 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.

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.

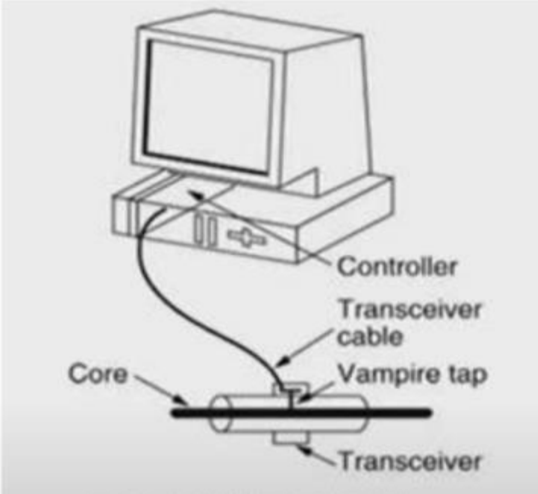


Fig. 3: 10Base5 [2]

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).

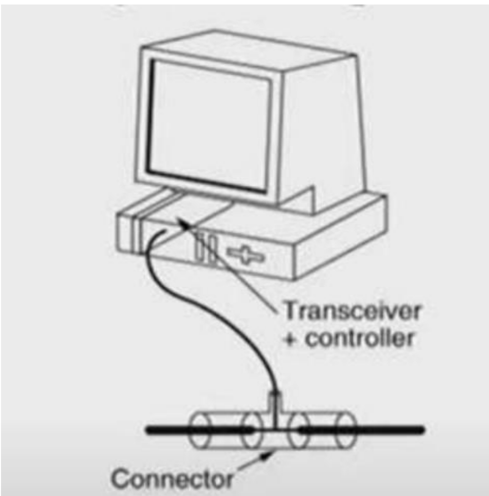


Fig. 4: 10Base2 [2]

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 and 100BASE-FX.

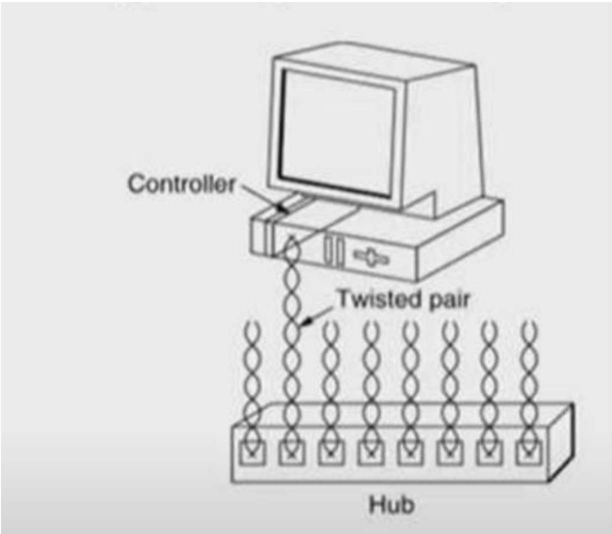


Fig. 5: 10BaseT [2]

Characteristic	Ethernet Value	IEEE 802.3 Values 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

<u>802.3u (Fast Ethernet)</u> Ref(4, 5)

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.

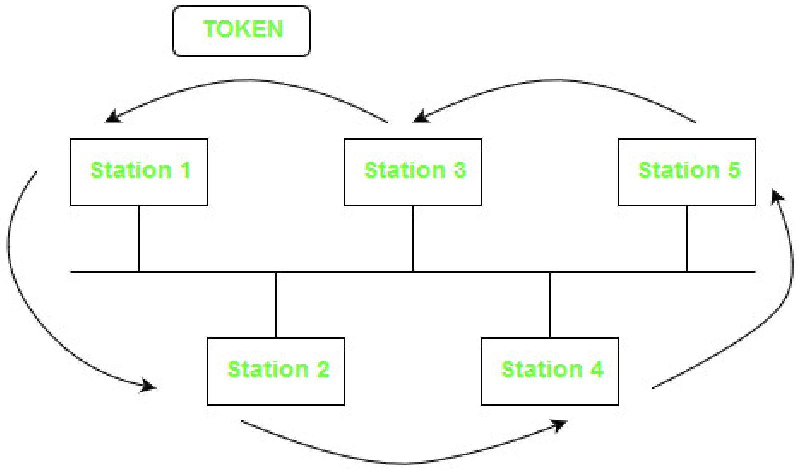
- It uses MLT-3 encoding scheme along with 4B/5B block coding.

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) Ref(6, 7)

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) Ref(8)

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.

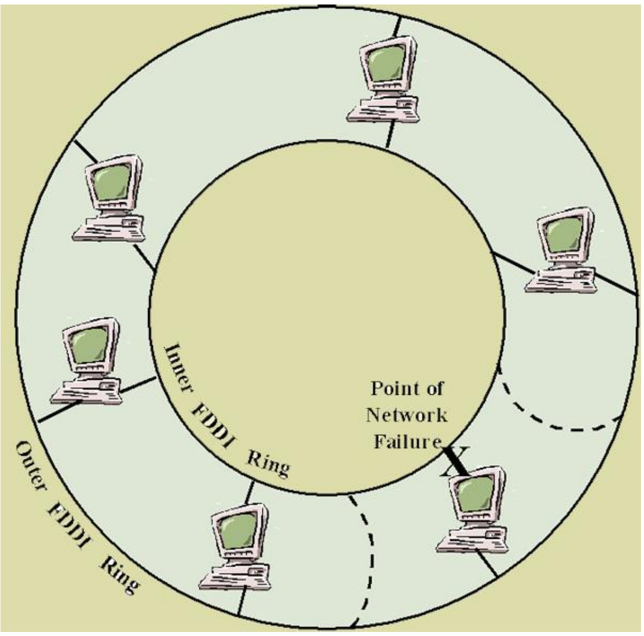
• It is used in LANs up to 200 kilometers for long distance voice and multimedia communication.

• 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).

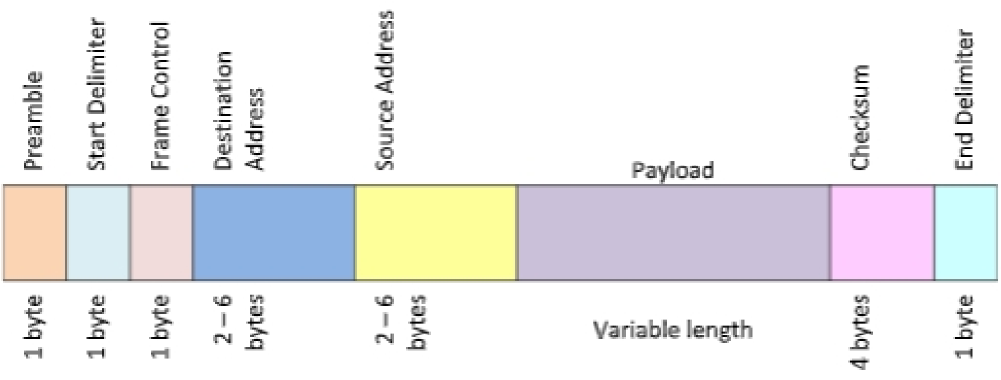
How FDDI Works?



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 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.

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.



FDDI Frame Format

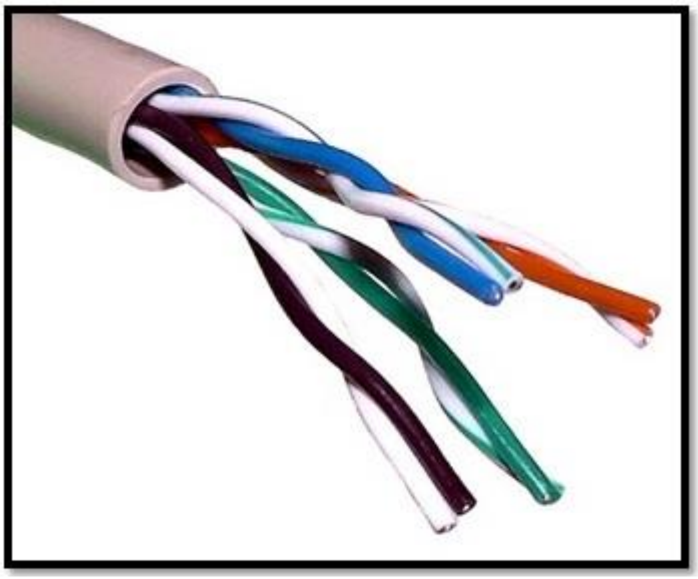
There can be up to 500 stations on a dual-ring FDDI network. The maximum circumference for an FDDI ring is 100 kilometers (or 200 kilometers for both rings combined), and there must be a repeater every 2 kilometers or less. Bridges or routers are used to connect the FDDI backbone network to Ethernet 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.

TWISTED PAIR CABLES REF(18,19)

Twisted-pair cable is the most common type of cabling you can see in today's Local Area Networks (LAN) networks. A pair of wires forms a circuit that can transmit data. The pairs are twisted to provide protection against crosstalk. Crosstalk is the undesired signal noise generated by the electromagnetic fields of the adjacent wires.

When a wire is carrying a current, the current creates a magnetic field around the wire. This field can interfere with signals on nearby wires. To eliminate this, pairs of wires carry signals in opposite directions, so that the two magnetic fields also occur in opposite directions and cancel each other out. This process is known as cancellation.

One of the earliest guided transmission media is twisted pair cables. A twisted pair cable comprises of two separate insulated copper wires, which are twisted together and run in parallel. The copper wires are typically 1mm in diameter. One of the wires is used to transmit data and the other is the ground reference.



Reason for Twisting

All transmissions are prone to noise, interferences, and crosstalks. When the wires are twisted, some part of the noise signals is in the direction of data signals while the other parts are in the opposite directions. Thus the external waves cancel out due to the different twists. The receiver calculates the difference in the voltages of the two wires for retrieving data. Thus a much better immunity against noise is obtained.

Applications of Twisted-Pair Cables

- In telephone lines
- In DSL lines

- In LANs

Types of Twisted–Pair Cables

There are two types of twisted pair cables −

- Unshielded Twisted Pair (UTP): These generally comprise of wires and insulators.
- Shielded Twisted Pair (STP): They have a braided wired mesh that encases each pair of insulated wires.

Categories of Twisted–Pair Cables

EIA has classified twisted pair cables into seven categories −

- Category 1 − UTP used in telephone lines with data rate < 0.1 Mbps
- Category 2 − UTP used in transmission lines with a data rate of 2 Mbps
- Category 3 − UTP used in LANs with a data rate of 10 Mbps
- Category 4 − UTP used in Token Ring networks with a data rate of 20 Mbps
- Category 5 − UTP used in LANs with a data rate of 100 Mbps
- Category 6 − UTP used in LANs with a data rate of 200 Mbps
- Category 7 − STP used in LANs with a data rate of 10 Mbps

LIFI Ref(20)

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.

Initial and upcoming LiFi applications

According to Li-Fi market research the global Li-Fi market is growing fast in its particular niche domains which do keep expanding though.

A look at the main industries and LiFi use cases, as found by several reports, shows a picture that is relatively similar to the industries and initial use cases as reported in the press release of the IEEE study group launch. These include environments challenged by electromagnetic interference *(EMI)* such as hospitals *(think among others operating theaters)*, petrochemical plants and airplanes *(e.g. applications in aircraft cabins)*. They also include secure environments where RF *(radio frequency, used in Wi-Fi)* is not sanctioned.

LIFI NETWORKS

LiFi falls under the larger umbrella of VLC. Much of VLC research focuses on point-to-point communication. Furthermore, most VLC research assumes that the visible light spectrum is used for both uplink and downlink communication. In contrast, LiFi encompasses broader networked systems, including multiuser, bidirectional, multicast, or broadcast communication. While it uses the visible light spectrum for downlink, LiFi uses the infrared spectrum for the uplink. LiFi is enabled by an ecosystem of multiuser techniques, resource allocation algorithms, and security strategies. These essential system components are illustrated in Fig. 3. LiFi networks were designed from the start to work seamlessly with RF wireless networks, e.g., Wi-Fi, to enable efficient, opportunistic load balancing, and augmented capacity in heterogeneous networks

Satellite Link Ref(21)

A satellite link refers to the technologies that help deliver satellite broadcasts over various frequency ranges, including the Ku band and C band, using various methods. Satellite systems allow the efficient delivery of audio and video as part of modern premium broadcast services.

A satellite modem is not the only device needed to establish a communication channel. Other equipment that are essential for creating a satellite link include satellite antennas and frequency converters.

Data Transmission

Data to be transmitted are transferred to a modem from Data terminal equipment (e.g. a computer). The modem usually has Intermediate frequency (IF) output (that is, 50-200 MHz), however, sometimes the signal is modulated directly to L-band. In most cases frequency has to be converted using an upconverter before amplification and transmission.

Data Modulation

A modulated signal is a sequence of *symbols*, pieces of data represented by a corresponding signal state, e.g. a bit or a few bits, depending upon the modulation scheme being used. Recovering a symbol clock (making a local symbol clock generator synchronous with the remote one) is one of the most important tasks of a demodulator.

Similarly, a signal received from a satellite is firstly downconverted (this is done by a Low-noise block converter - LNB), then demodulated by a modem, and at last handled by data terminal equipment. The LNB is usually powered by the modem through the signal cable with 13 or 18 V DC

Applications

Satellite modems are often used for home internet access.

There are two different types, both employing the Digital Video Broadcasting (DVB) standard as their basis:

- One-way satmodems (**DVB-IP** modems) use a return channel not based on communication with the satellite, such as telephone or cable.
- Two-way satmodems (**DVB-RCS** modems, also called **astromodems**) employ a satellite-based return channel as well; they do not need another connection. DVB-RCS is ETSI standard **EN 301 790**.

There are also industrial satellite modems intended to provide a permanent link. They are used, for example, in the Steel shankar network

Protocols under Wireless Networks

1) Family (WiFi)
2) Bluetooth
3) ZigBee
4) Worldwide Interoperability for Microwave Access (WiMax)
5) 5G
6) NFC

Family (WiFi) Ref(9, 10)

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

Bluetooth Ref(11, 12)

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.

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.

ZigBee 802.15.4 Ref(13)

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 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.

802.15.4 General Characteristics

- Data rates of 250 kb/s, 40 kb/s and 20 kb/s.
- Star or Peer-to-Peer operation.
- Support for low latency devices.
- Fully handshaked protocol for transfer reliability.
- Low power consumption.
- Frequency Bands of Operation
  - 16 channels in the 2.4GHz ISM* band
  - 10 channels in the 915MHz ISM band
  - 1 channel in the European 868MHz band.

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.

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.

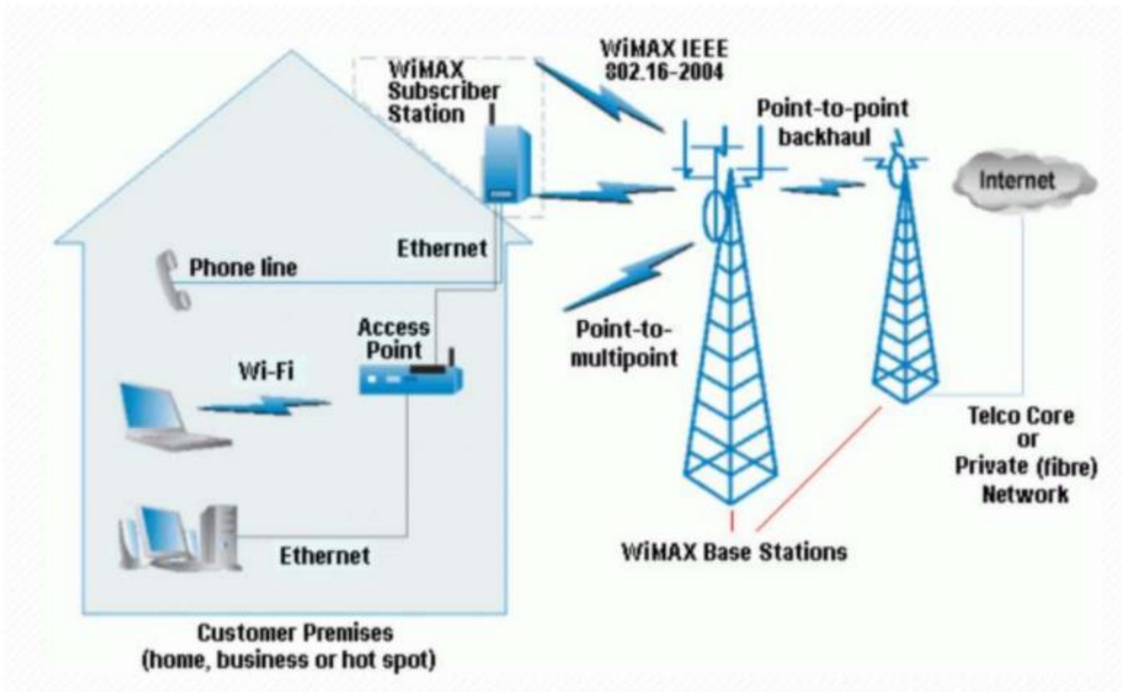
<u>Worldwide Interoperability for Microwave Access (WiMax) 802.16a</u>

Ref(14, 15)

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

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

5G Ref(16)

In telecommunications, **5G** is the fifth generation technology standard for cellular networks, which cellular phone companies began deploying worldwide in 2019, the planned successor to the 4G networks which provide connectivity to most current cellphones. Like its predecessors, 5G networks are cellular networks, in which the service area is divided into small geographical areas called *cells*. All 5G wireless devices in a cell are connected to the Internet and telephone network by radio waves through a local antenna in the cell. The main advantage of the new networks is that they will have greater bandwidth, giving higher download speeds, eventually up to 10 gigabits per second (Gbit/s). Due to the increased bandwidth, it is expected that the new networks will not just serve cellphones like existing cellular networks, but also be used as general internet service providers for laptops and desktop computers, competing with existing ISPs such as cable internet, and also will make possible new applications in internet of things (IoT) and machine to machine areas. Current 4G cellphones will not be able to use the new networks, which will require new 5G enabled wireless devices.

Performance

a. Speed

5G speeds will range from ~50 Mbit/s to over a gigabit/s. The fastest 5G is known as mmWave. As of July 3, 2019, mmWave had a top speed of 1.8 Gbit/s on AT&T's 5G network.

Sub-6 GHz 5G (mid-band 5G), by far the most common, will usually deliver between 100 and 400 Mbit/s, but will have a much farther reach than mmWave, especially outdoors.

Low-band spectrum offers the farthest area coverage but is slower than the others.

5G NR speed in sub-6 GHz bands can be slightly higher than the 4G with a similar amount of spectrum and antennas, although some 3GPP 5G networks will be slower than some advanced 4G networks, such as T-Mobile's LTE/LAA network, which achieves 500+ Mbit/s in Manhattan and Chicago. The 5G specification allows LAA (License Assisted Access) as well, but LAA in 5G has not yet been demonstrated. Adding LAA to an existing 4G configuration can add hundreds of megabits per second to the speed, but this is an extension of 4G, not a new part of the 5G standard.

b. Latency

In 5G, the "air latency"[20] in equipment shipping in 2019 is 8–12 milliseconds.[21] The latency to the server must be added to the "air latency" for most comparisons. Verizon reports the latency on its 5G early deployment is 30 ms:[22] Edge Servers close to the towers can reduce latency to 10–20 ms; 1–4 ms will be extremely rare for years outside the lab.

Range

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. Also, these higher frequency 5G signals cannot penetrate solid objects easily, such as cars, trees, and walls, because of the nature of these higher frequency electromagnetic waves. 5G cells can be deliberately designed to be as inconspicuous as possible, which finds applications in places like restaurants and shopping malls.

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
5G NR FR2	Pico cell	Public areas like shopping malls, airports, train stations, skyscrapers	64 to 128	indoors: 100–250 outdoors: 1000–5000	10s of meters
5G NR FR2	Micro cell	Urban areas to fill coverage gaps	128 to 256	outdoors: 5000−10000	few hundreds of meters
5G NR FR2	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

Near Field Communication (NFC) Ref(17)

Near-Field-Communication (**NFC**) is a set of communication protocols for communication between two electronic devices over a distance of 4 cm ($1\frac{1}{2}$ 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.

NFC RF signal parameters

NFC uses the global 13.56 MHz allocation as this is an unlicensed radio frequency ISM band.

Using ASK - amplitude shift keying, as the format for the NFC modulation, most of the RF energy is concentrated in the allowed 14 kHz bandwidth, although the sidebands may extend out as far as ± 1.8 MHz.

NFC RF signal coding & modulation

NFC employs two different coding systems on the RF signal to transfer data. In most cases a level of 10% modulation is used, with a Manchester coding format. However for an active device transmitting data at 106 kbps, a modified Miller coding scheme is used with 100% modulation. In all other cases Manchester coding is used with a modulation ratio of 10%.

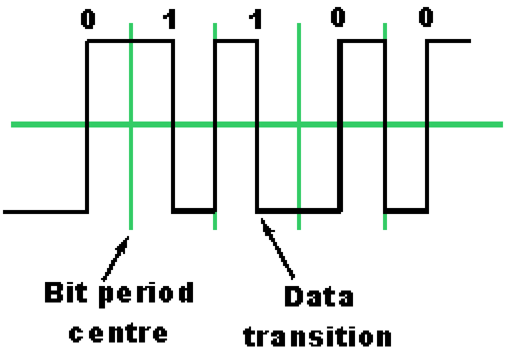
SUMMARY OF NFC RF SIGNAL CODING & MODULATION

DATA RATE KBPS	ACTIVE DEVICE	PASSIVE DEVICE
106	Modified Miller, 100%, ASK	Manchester, 10%, ASK
212	Manchester, 10%, ASK	Manchester, 10%, ASK
424	Manchester, 10%, ASK	Manchester, 10%, ASK

NFC and Manchester coding

Manchester coding is used for the majority of cases for the NFC communications. The Manchester coding utilises the two different transitions that may occur at the midpoint of a period. A low-to-high transition expresses a 0 bit, whereas a high-to-low transition stands for a 1 bit.

To achieve these conditions it is sometimes necessary to have a transition at the middle of a bit period. Transitions at the beginning of period are disregarded.



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CONCLUSION

From this experiment, I learned about the Physical Layer, the types of Wired and Wireless Connections. For each of these connections, I studied their specification, their scalability in the various network architecture, and their schematic view.