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TE Comps

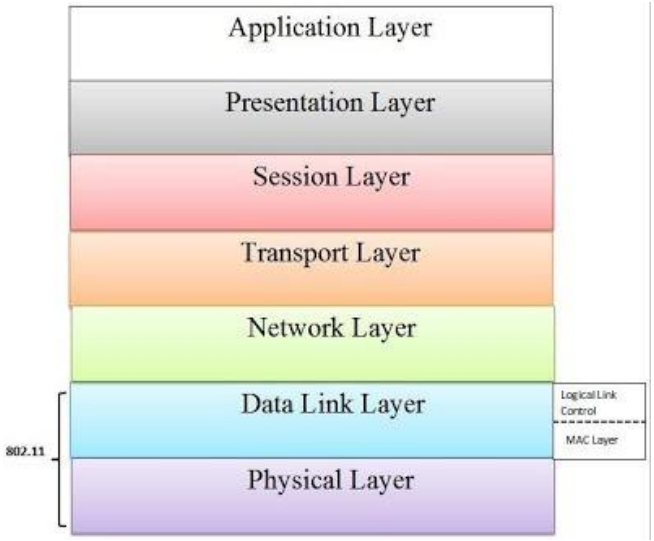
# Lab Assignment 1

**Aim –** To study different types of physical layer wired/wireless connections

**Theory-**

### Physical Layer – Introduction

In the seven-layer OSI model of computer networking, the physical layer or layer 1 is the first and lowest layer. The physical layer 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. The physical layer is aimed at consolidating the hardware requirements of a network to enable the successful transmission of data. [0]




### Wired Network Connections-

A wired network connection is described as a configuration that involves cables which establish a connection to the Internet and other devices on the network. Most wired networks use Ethernet cables to transfer data between connected PCs. In a small wired network, a single router may be used to connect all the computers. Larger networks often involve multiple routers or switches that connect to each other. [0]

## 1. Ethernet-

Ethernet is a system for connecting a number of computer systems to form a local area network, with protocols to control the passing of information and to avoid simultaneous transmission by two or more systems.[1]

### A. Range

There are different Ethernet standards. Their range have been specified below:

- 10Base2: These coaxial cables are like those used in television, but thinner. They are also called "thinnet" or "coax". Each computer has a "T" plugged into it, and cables plug into each side of the "T". Sometimes, instead of a "T", a vampire tap is used. It supports 10MBits per second transfer speed. 10BASE2 coax cables have a maximum length of 185 metres (607 ft). The maximum practical number of nodes that can be connected to a 10BASE2 segment is limited to 30 with a minimum distance of 50 centimetres (20 in) between devices. [5]
- 10BaseT: Cables look like thick phone cables, but with 8 copper wires instead of 2 or 4, and they go from each computer' to a Hub or a Switch. Supported speed is 10 MBit/second. 10BASET have a maximum length of 100m and uses twisted pair of wires. Up to 1024 stations can be connected to it and it offers a bandwidth of 10 Mbit/s.
- 10Base5- 10BASE5 uses a thick and stiff coaxial cable up to 500 meters (1,600 ft) in length. Up to 100 stations can be connected to the cable using vampire taps and share a single collision domain with 10 Mbit/s of bandwidth shared among them [2]

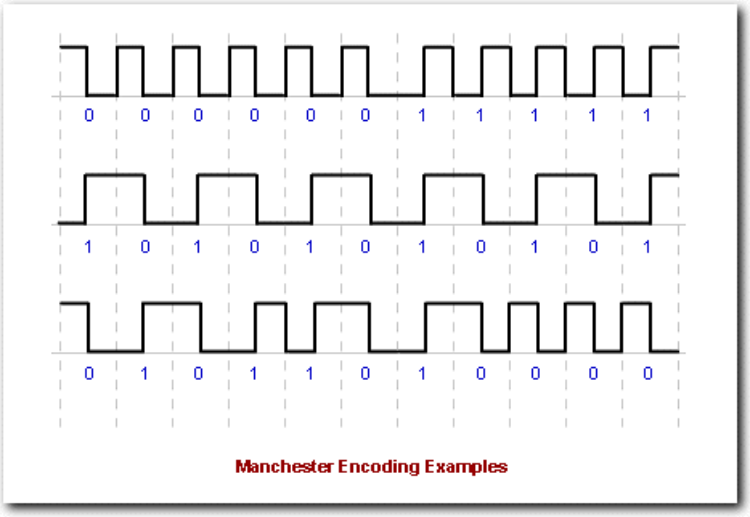
### B. Encoding

Manchester encoding is an encoding method commonly used on Legacy Ethernet networks.

There are two rules to follow using this encoding method...

- To send a logic '0' data bit, **increase** the voltage up from 0 to +V in the middle of the bit period.
- To send a logic '1' data bit, **decrease** the voltage down from +V to 0 in the middle of the bit period.

The diagram below illustrates this:-



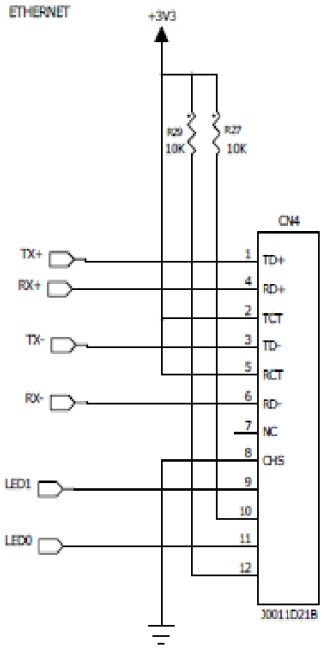

We can see that a high-to-low transition represents a logic '0' data bit and a low-to-high transition represents a logic '1' data bit. [4]

### C. Scalability

Ethernet is a family of computer networking technologies commonly used in local area networks (LAN), metropolitan area networks (MAN) and wide area networks (WAN).[1]

Ethernet is currently the most widely used technology in enterprise networking. Unfortunately, Ethernet exhibits scalability issues when used to build broadcast domains of more than a few thousand devices, such as costly and energy-dense address table logic and storms of broadcast traffic. The traditional method of avoiding such problems is the artificial subdivision of a network, but this introduces an administrative burden, requires significant routing equipment and with current protocols also precludes live migration. [3]

### D. Schematic View



## 2. IEEE 1394 (FireWire)–

Also widely referred to as FireWire, IEEE 1394 was approved by the Institute of Electrical and Electronics Engineers (IEEE) in 1995. It was originally conceived by Apple.

IEEE 1394 is similar to the first version of USB in many ways, but much faster. Both are hot-swappable serial interfaces, but IEEE 1394 provides high-bandwidth, high-speed data transfers significantly in excess of what USB offers. There are two levels of interface in IEEE 1394, one for the backplane bus within the computer and another for the point-to-point interface between device and computer on the serial cable. [6]

### A. Range –

Each IEEE 1394 bus segment may have up to 63 devices attached to it. Currently each device may be up to 4.5 metres apart; longer distances are possible with and without repeater hardware. Improvements to the current cabling are being specified to allow longer distance cables. Over 1000 bus segments may be connected by bridges thus providing a large growth potential. An additional feature is the ability of transactions at different speeds to occur on a single device medium. [7]

### B. Modulation

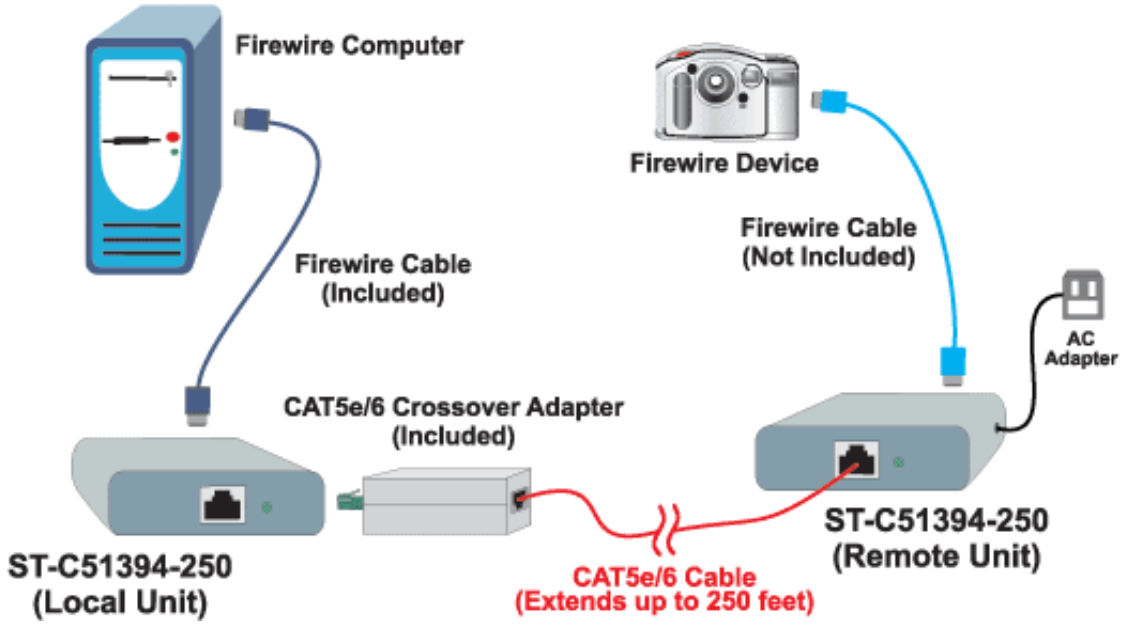
The current design in uses BPSK modulation at 2 GHz to transmit data across the transformer boundary, consuming approximately 15 mA. [8]

### C. Signalling

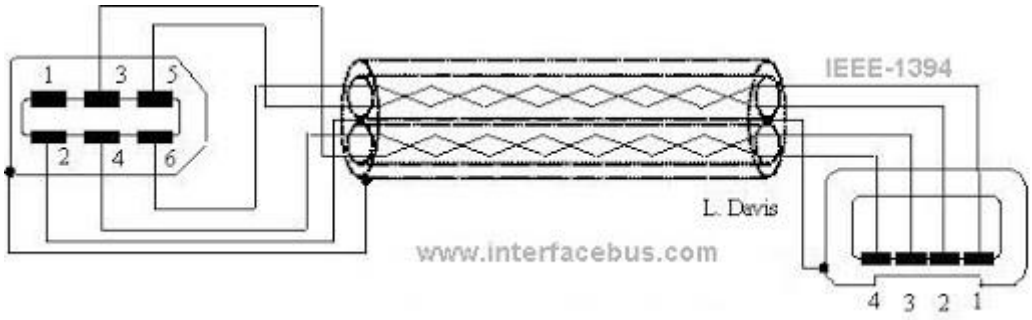
IEEE 1394 specifies two signalling mechanisms across the bus: common mode (DC) and differential. DC signalling means that a logical 1 is represented as a positive voltage, and a logical 0 is represented as zero voltage. In 1394, it is used for three purposes: device attachment and detection, speed signalling, and power management (suspend-resume). Differential signalling means that logic values are represented by the difference between two wires: if the voltage on one wire is greater than the next, then a logical 1 is represented, otherwise a logical 0 is represented. The advantage of this method is that power consumption is greatly reduced. As such, 1394 uses differential signalling for the majority of operations, such as bus reset, arbitration, configuration commands, and data packet transmission. [7]

### D. Scalbility

PAN To enable data exchange, modern devices such as smartphones, tablets, laptops, and desktop computers can be integrated into a network. This can be wired in the form of a Personal Area Network (PAN). Common transfer techniques include **USB** or **FireWire.** [8]




### E. Schematic View




## 3. Etherloop

**Etherloop** is a kind of DSL technology that combines the features of Ethernet and DSL. It allows the combination of voice and data transmission on standard phone lines. Etherloop uses half-duplex transmission, and as such, is less susceptible to interference caused by poor line quality, bridge taps, etc. [9]

### A. Range

**EtherLoop** offers a data transfer rate up to 6 Mbps over distances of up to 21,000 feet. Developed by Nortel, **EtherLoop**, unlike DSL, uses the half-duplex transmission of Ethernet. [10]

### B. Modulation

The Data Rate is determined by Modulation Level and Center Frequency

QPSK (QAM4) 2 bits/symbol

QAM16 4 bits/symbol:

1 Msymb/sec * 4bits/symb = 4Mbps

1.67 Msymb/sec * 4bits/symb = 6.67Mbps

QAM64 6 bits/symbol:

1.67 Msymb/sec * 6bits/symb = 10Mbps [11]

### C. Signalling

For high quality subscriber loops EtherLoop is designed to use a range of frequencies from approximately 30 kHz to 3 MHz. This frequency range is divided up into 10 overlapping frequency spectra, only one of which is active at any point in time. The lowest spectrum has a total frequency range of 62.5 kHz, and the highest has a frequency range of 1.667 MHz. Historically speaking, one Hertz is equivalent to one symbol per second, which would give EtherLoop a theoretical maximum symbol rate of 1.667 megasymbols per second. Using standard signal modulation techniques, such as BPSK, which support 1 data bit per symbol, this would translate to 1.667 megabits per second. [10]

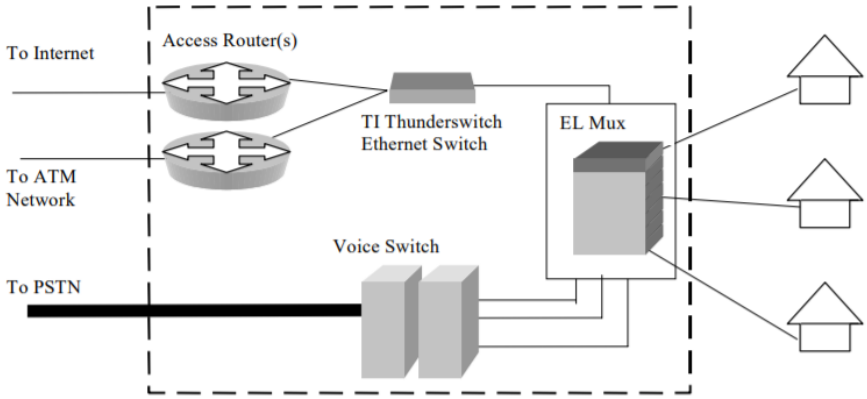
### D. Scalability

There are five major markets where long-range Ethernet is a viable product:

- Residential Internet Access
- SOHO (Small Office Home Office) Internet and corporate access
- Hotel/Hospitality/Lodging Internet Access
- CAN (Campus Area Network) deployment
- Data T1 Replacement (LAN extension) [13]

## Central Office Configuration

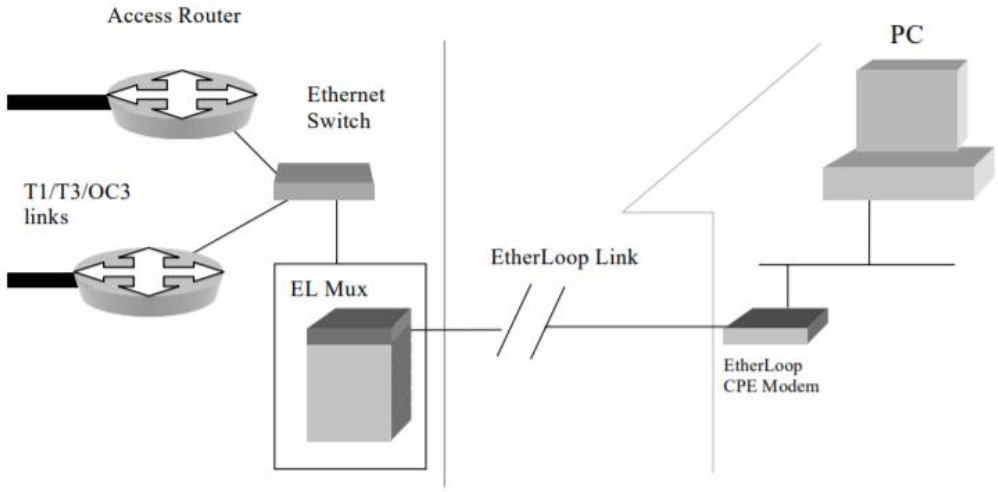
The EtherLoop CO configuration is relatively straightforward. Each subscriber is brought back to an EtherLoop Multiplexer shelf product, which is EtherLoop ready. The voice and data channels are separated, and the voice channel is passed on to the PSTN switch. The data channel is passed on to a TI ThunderSWITCH Ethernet switch, which then connects to any standard TCP/IP or ATM network. Depending on the needs of the customer, multiple networks can be attached, for example, some users may wish to use the public Internet, some may wish to use the telco's regional broadband network, and some may wish to connect to private corporate networks. [12]




modems, and the first stage of Ethernet packet multiplexing.

**Residential Access**

The Residential access model is the most straightforward. The end-user will typically have only one device connected to the EtherLoop link, which simplifies the overall architecture. [12]




**SOHO Corporate Access**

The SOHO model differs moderately from the residential access model. Typically, there will be a more extensive LAN in the subscriber's home/office than the residential user. In this case, modems must take on the additional responsibilities of bridging Ethernet traffic, keeping local traffic on the subscriber premises side of the link. This capability is already built into the EtherLoop modems. In that configuration, an external modem is more appropriate. [12]

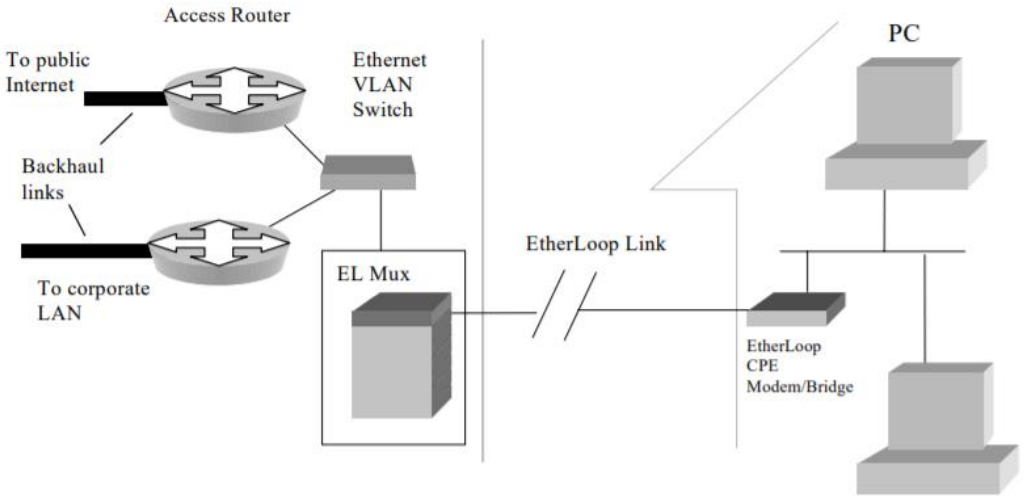
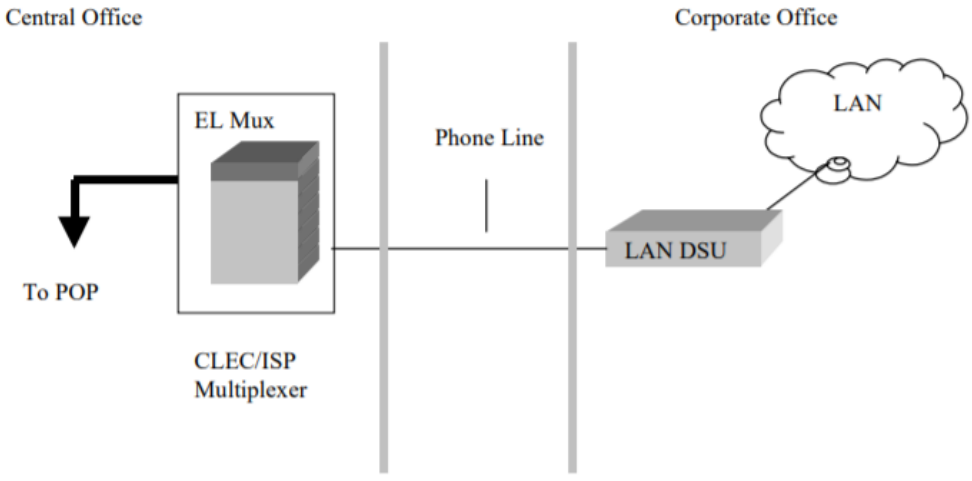


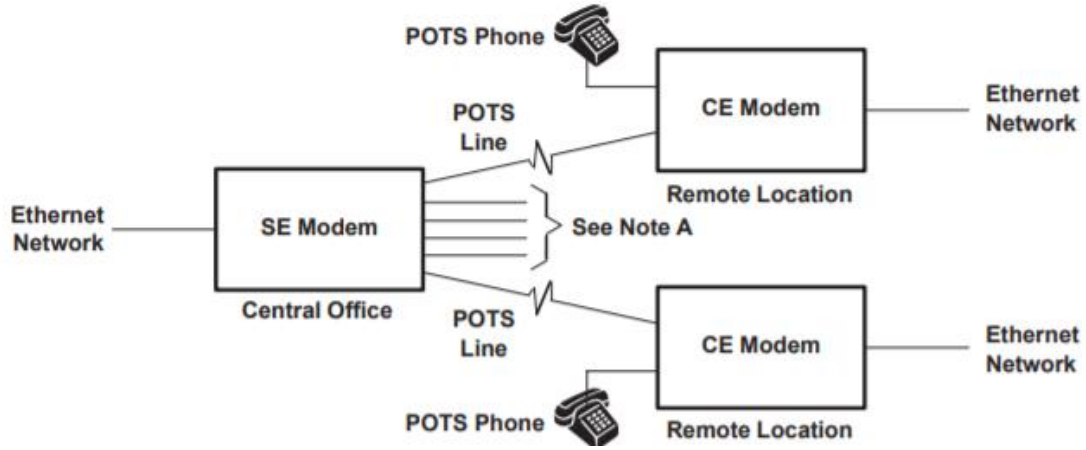

*Figure 5: SOHO Corporate Access*

**Campus Networks/T1 Replacement**

In a campus or downtown environment, EtherLoop can be used to provide data network access to corporations, universities or institutions at speeds of up to 10 megabits per second, over existing voice lines. In this environment, a rack-mounted EtherLoop LAN DSU will be installed at the customer premise, with a corresponding connection either in a central office, or at a nearby site, depending on the nature of the copper access regulations. [12]



### E. Schematic View




The above figure shows a typical system with an EtherLoop modem located at each end of the POTS line. Each EtherLoop modem has a 10Base-T Ethernet interface and is responsible for buffering Ethernet data before sending it over the POTS wire. The server-end (SE) EtherLoop modem is located in a central switching office and can communicate with several client-end (CE) EtherLoop modems, based on a round-robin arbitration scheme. The CE EtherLoop modem typically is located at a remote site. [12]

## 4. Coaxial Cable

**Coaxial cable**, or **coax** is a type of electrical cable consisting of an inner conductor surrounded by a concentric conducting shield, with the two separated by a dielectric (insulating material); many coaxial cables also have a protective outer sheath or jacket. The term "coaxial" refers to the inner conductor and the outer shield sharing a geometric axis. [14]

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, and connecting radio transmitters and receivers to their antennas. 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. [14]

### A. Range

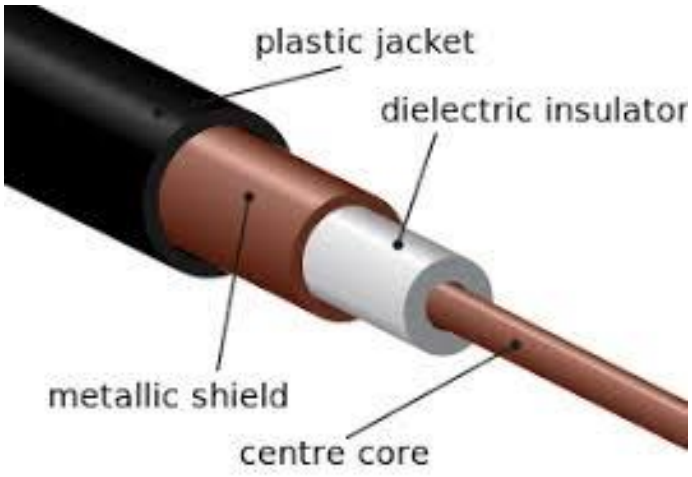
Coaxial cable can be cabled over longer distances than twisted-pair cable. For example, Ethernet can run approximately 100 meters (328 feet) using twisted-pair cabling. Using coaxial cable increases this distance to 500m (1640.4 feet). [15]

### B. Scalability

There are two types of coaxial cable

1. RG8 used in LAN also known as thick Ethernet.
2. RG-58 used for LAN and known as thin Ethernet. [15]

### C. Schematic View




## 5. Twisted Pair Cable

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. [16]

### A. Types-

There are two types of twisted pair cables −

a) **Unshielded Twisted Pair ( UTP ):** These generally comprise of wires and insulators. They are the defacto standard for Ethernet cabling system. UTP cables are twisted in helical fashion like a strand of a DNA. Twisted are introduced for a special purpose. UTP cables are also used in telephone lines. Unlike older landline telephones, there are no incidents of crosstalk in current landline phones due to UTP cables twisted design. In networking, the twists help avoid data leakage. The commonly used UTP copper cable is Cat5, Cat5e, Cat6, Cat6a and Cat7. [17]

- **Range-**

| UTP Category | Data Rate | Max. Length |
|---|---|---|
| CAT1 | Up to 1Mbps | - |
| CAT2 | Up to 4Mbps | - |
| CAT3 | Up to 10Mbps | 100m |
| CAT4 | Up to 16Mbps | 100m |
| CAT5 | Up to 100Mbps | 100m |
| CAT5e | Up to 1 Gbps | 100m |
| CAT6 | Up to 10Gbps | 100m |
| CAT6a | Up to 10Gbps | 100m |
| CAT7 | Up to 10Gbps | 100m |

- **Modulation -** Data is encoded using 4D-PAM5; four dimensions using PAM (pulse amplitude modulation) with five voltages, −2 V, −1 V, 0 V, +1 V, and +2 V.[12] While +2 V to −2 V may appear at the pins of the line driver, the voltage on the cable is nominally +1 V, +0.5 V, 0 V, −0.5 V and −1 V.[17]

**b) Shielded Twisted Pair ( STP ):** They have a braided wired mesh that encases each pair of insulated wires. Shielded' with a foil jacket to cancel any external interference. Used primarily for large-scale enterprises, high-end applications, and exterior cabling that will be exposed to environmental elements. [16]

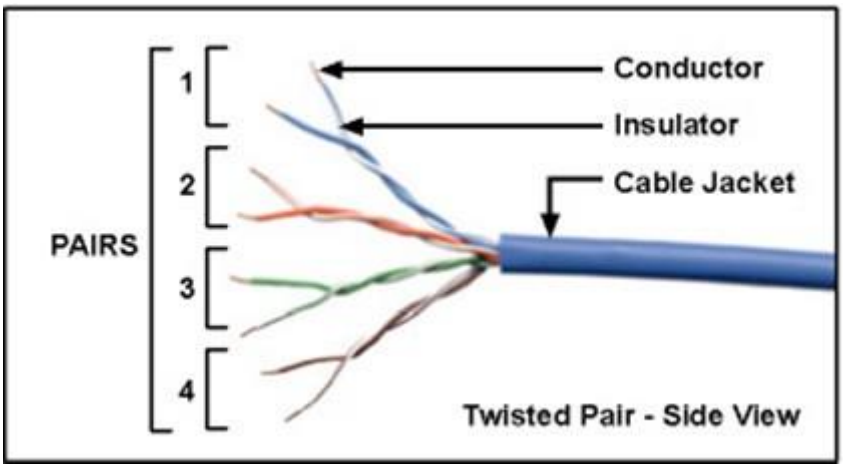
- Range – Up to 100m
- Bandwidth – Up to 750 MHz.
- Modulation – Line coding is used here. Line coding is the modulation of an electrical charge so that each side of a connection knows what is a one and what is a zero. [16]

**B. Scalability**

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 [17]

**C. Schematic View**



## 6. Fiber Distributed Data Interface (FDDI)

Fiber Distributed Data Interface (FDDI) is a set of ANSI and ISO standards for transmission of data in local area network (LAN) over fiber optic cables. [18]

### A. Specifications

● Transmission rate: 125 megabaud (100 Mb/s at the data link)

● Physical layer entities: 1000 (max)

● Total Ring length: 200 km (124 mi) (max)

● Transmission medium: Fiber optic or copper cable

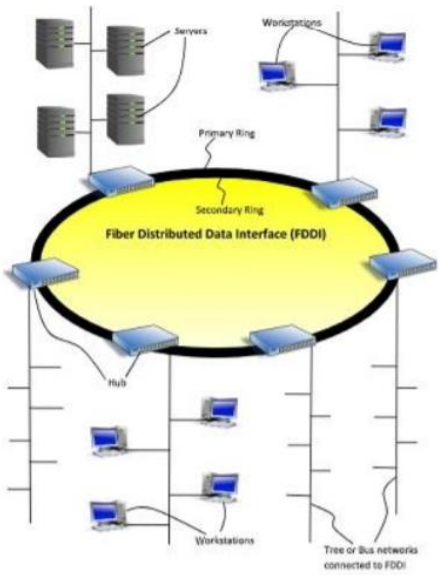
● Network topology: Dual ring of trees

● Media access method: Timed-token passing [18]

### B. Scalability

Fiber Distributed Data Interface (FDDI) is usually implemented as a dual tokenpassing ring within a ring topology (for campus networks) or star topology (within a building). It is applicable in large LANs that can extend up to 200 kilometers in diameter. Designers normally constructed FDDI rings in a network topology such as a "dual ring of trees". A small number of devices, typically infrastructure devices such as routers and concentrators rather than host computers, were "dual-attached" to both rings. Host computers then connect as single-attached devices to the routers or concentrators. The dual ring in its most degenerate form simply collapses into a single device. 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. Typically, a computer-room contained the whole dual ring, although some implementations deployed FDDI as a metropolitan area network. [19]

### C. Schematic View



## 7. 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* is a trademark of the non-profit Wi-Fi Alliance, which restricts the use of the term *Wi-Fi Certified* to products that successfully complete interoperability certification testing. [18]

### A. Range

Business networks with grids of access points can serve large office buildings, and wireless hotspots spanning several square miles have been built in some cities. The cost to build and maintain these networks increases significantly as the range increases, of course.

A general rule of thumb in home networking says that Wi-Fi routers operating on the 2.4 GHz band can reach up to 150 feet indoors and 300 feet outdoors. Older 802.11a routers that ran on 5 GHz bands reached approximately one-third of these distances. Newer 802.11n and 802.11ac routers that operate on both 2.4 GHz and 5 GHz bands reach greater distances.

Because it uses narrower wavelengths, a 5 GHz Wi-Fi connection is more susceptible to obstructions than 2.4 GHz connections, and so will usually have a slightly shorter effective range, typically, 10 to 15 feet shorter. [19]

### B. Modulation

WiFi can use different digital modulation schemes for data transmission. Environmental factors and protocol will define scheme selection. Below, we look at the principles behind modulation.

BPSK is used for lower bit rates with 802.11g clients. A low bit-rate would be negotiated for many reasons, those discussed later in the document. BPSK paired with half rate encoding, results in a bit-rate of 6Mbps. 9Mbps is achieved with BPSK and 3/4 code rate.

If the the signal strength exceeds the receiver sensitivity, a more complicated modulation scheme can be used. 802.11g can use up to 64QAM which uses both phase and amplitude modulation coherently, achieving 48Mbps and 54Mbps with a code rate of half and 3/4 respectively. An example constellation diagram for 64QAM is shown below. [19]

WiFi systems use two primary radio transmission techniques-

- 802.11b (<=11 Mbps) − The 802.11b radio link uses a direct sequence spread spectrum technique called complementary coded keying (CCK). The bit stream is processed with a special coding and then modulated using Quadrature Phase Shift Keying (QPSK).
- 802.11a and g (<=54 Mbps) − The 802.11a and g systems use 64-channel orthogonal frequency division multiplexing (OFDM). In an OFDM modulation system, the available radio band is divided into a number of sub-channels and some of the bits are sent on each. The transmitter encodes the bit streams on the 64 subcarriers using Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), or one of two levels of Quadrature Amplitude Modulation (16, or 64-QAM). Some of the transmitted

information is redundant, so the receiver does not have to receive all of the sub-carriers to reconstruct the information.

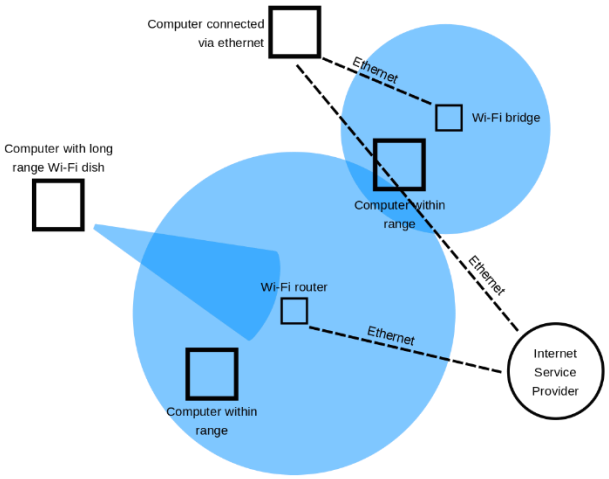
802.11n and 802.11ac use the same modulation principles as 802.11g. 802.11ac can negotiate up to 256QAM if the receiver sensitivity permits. In addition to modulation schemes, 802.11n and 802.11ac pair the modulation scheme with other technologies that enable even faster bitrates. The bit-rate for 802.11n and 802.11ac can be determined by the MCS value. The MCS value related to the receiver sensitivity is listed on the product data sheet. [19]

**C. Signalling**

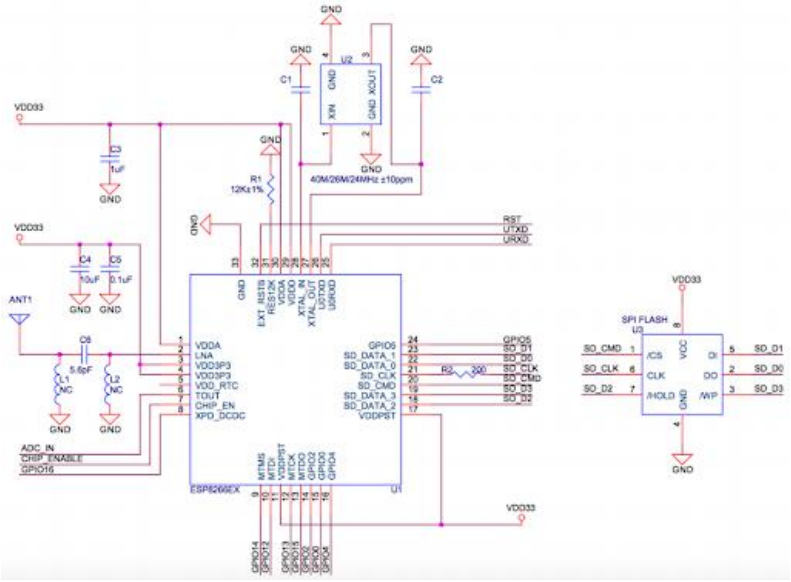
The radio waves which comprise WiFi signals make use of the 2.4 GHz and 5 GHz frequency bands. These are higher than the frequencies used for televisions or cell phones and allow more data to be carried than do the lower frequencies. [18]

**D. Scalability**

A **wireless LAN** (**WLAN**) is a wireless computer network that links two or more devices using wireless communication to form a local area network (LAN) within a limited area such as a home, school, computer laboratory, campus, or office building. This gives users the ability to move around within the area and remain connected to the network. Through a gateway, a WLAN can also provide a connection to the wider Internet. Most modern WLANs are based on IEEE 802.11 standards and are marketed under the Wi-Fi brand name. [18]



**E. Schematic View**



## 8. Bluetooth

**Bluetooth** is a wireless technology standard 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). It was originally conceived as a wireless alternative to RS-232 data cables. [20]

### A. Range [20]

| Class | Typ. range[2] (m) |
|---|---|
| **1** | ~100 |
| **1.5** | ~20 |
| **2** | ~10 |
| **3** | ~1 |
| **4** | ~0.5 |

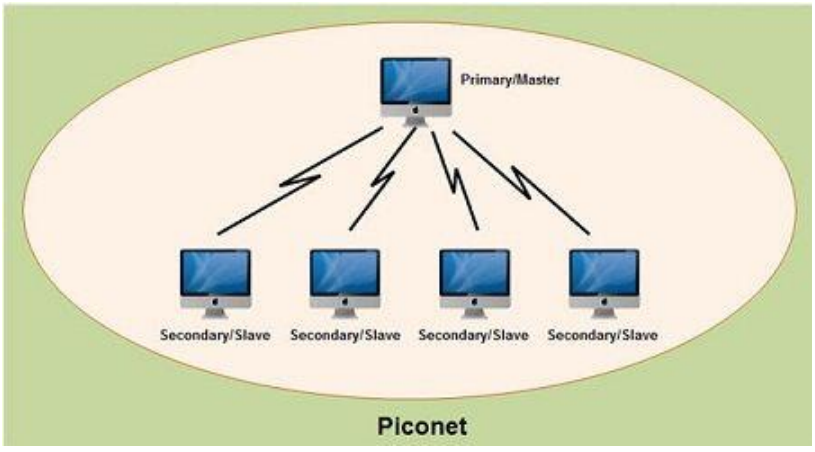
### B. Modulation and Signalling

Based on the modulation scheme, multiple symbols may be used to represent a single bit, or a single symbol could potentially represent multiple bits.

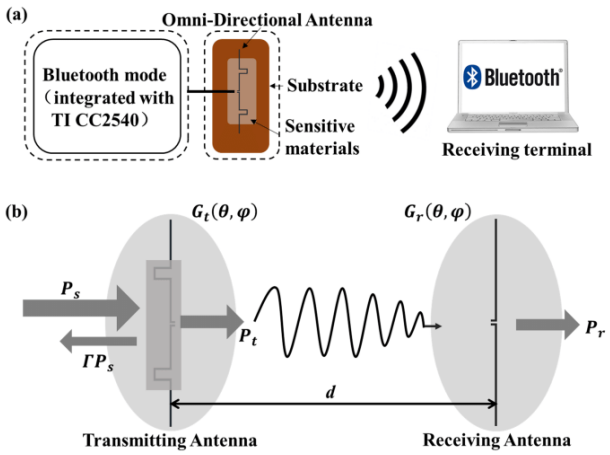
With BLE modulation specifically, a zero is coded to negative frequency deviation of at least 185kHz, and a 1 is coded to a positive frequency deviation of at least the same amount. At just the physical layer, BLE is capable of transmitting 1 million symbols per second. This translates to 1 Mbps assuming an encoding of 1 bit per symbol (which is standard for BLE). This threshold in the symbol rate is due to a limitation caused by intersymbol interference. Also, this is an idealized value that doesn't take into account factors such as packet overhead. [21]

### C. Scalability

To enable data exchange, modern devices such as smartphones, tablets, laptops, and desktop computers can be integrated into a network. This can be wired in the form of a Personal Area Network (PAN). The wireless variety is known as **Wireless Personal Area Network (WPAN)** and is based on technologies such as Bluetooth, Wireless USB, Insteon, IrDA, ZigBee, and Z-Wave. A wireless Personal Area Network, which can be achieved via Bluetooth, is called **Piconet**. PANs and WPANs usually only stretch over a few meters, and are therefore not suitable for connecting devices in different rooms or even buildings. [21]




### D. Schematic View



## 9. Z-Wave

**Z-Wave** is a wireless communications protocol used primarily for home automation. It is a mesh network using low-energy radio waves to communicate from appliance to appliance,[1] allowing for wireless control of residential appliances and other devices, such as lighting control, security systems, thermostats, windows, locks, swimming pools and garage door openers.[2][3] Like other protocols and systems aimed at the home and office automation market, a Z-Wave system can be controlled via the Internet from a smart phone, tablet or computer, and locally through a smart speaker, wireless keyfob, or wall-mounted panel with a Z-Wave gateway. [22]

### A. Range

Z-Wave has a range of 100 meters or 328 feet in open air, building materials reduce that range. The more line powered devices in your Z-Wave network, the better, as they also act as repeaters to extend the Z-Wave signal. Z-Wave's mesh networking allows a Z-Wave signal to "hop" through other Z-Wave products to reach the destination device to be controlled. Z-Wave supports up to 4 hops so the total home coverage will grow depending on the amount of Z-Wave products in the network. The maximum range with 4 hops is roughly 600 feet or 200 meters.[23]

### B. Modulation[22]

| Data Rate Designation | Modulation | Coding | Symbols |
|---|---|---|---|
| R1 | FSK | Manchester | Binary |
| R2 | FSK | NRZ | Binary |
| R3 | GFSK (BT=0.6) | NRZ | Binary |

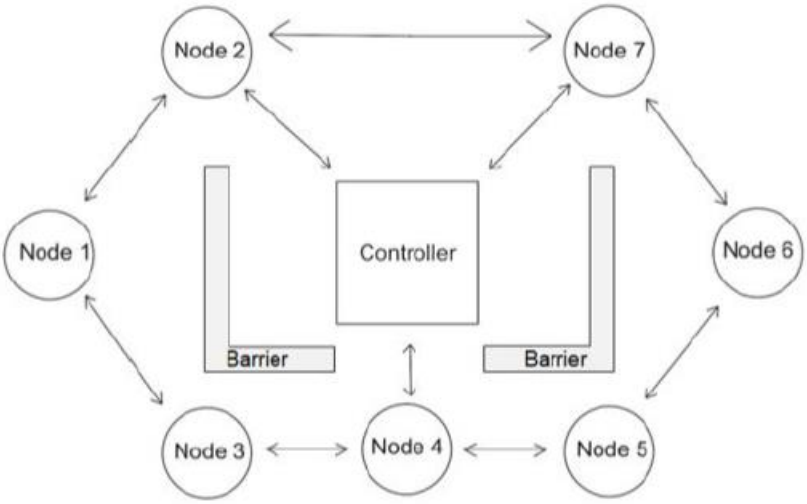
### C. Signalling

It operates at 868.42 MHz in Europe, at 908.42 MHz in the North America and uses other frequencies in other countries depending on their regulations. Data rates include 9600 bps and 40 kbps, with output power at 1 mW. [23]

### D. Scalability

Z-Wave can be used within a network (Home Area Network, HAN), and can, therefore, be used to set up all areas of home automation, possibly controlled by a single controller. A mesh topology allows any node to connect to any other node and allows multiple connections. [23]


### E. Schematic View



## 10. LTE

In telecommunications, Long-Term Evolution (LTE) is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies. It increases the capacity and speed using a different radio interface together with core network improvements. LTE is the upgrade path for carriers with both GSM/UMTS networks and CDMA2000 networks. The different LTE frequencies and bands used in different countries mean that only multi-band phones are able to use LTE in all countries where it is supported. [24]

### A. Range

LTE is required to support communication with terminals moving at speeds of up to 350 km/h, or even up to 500 km/h depending on the frequency band. The primary scenario for operation at such high speeds is usage on high-speed trains – a scenario which is increasing in importance across the world as the number of high-speed rail lines increases and train operators aim to offer an attractive working environment to their passengers. These requirements mean that handover between cells has to be possible without interruption – in other words, with imperceptible delay and packet loss for voice calls, and with reliable transmission for data services. These targets are to be achieved by the LTE system in typical cells of radius up to 5 km, while operation should continue to be possible for cell ranges of 100km and more, to enable wide-area deployments. [25]

### B. Modulation

LTE is based on Orthogonal Frequency Division Multiple Access (OFDM), and achieves high data rates by combining large bandwidths, higher order modulation and spatial multiplexing. There are multi path fading problems in UMTS so LTE uses OFDM in the downlink to overcome such problems. [26]

Orthogonal frequency-division multiplexing (OFDM) is a method for encoding digital data transmission which uses a large number of closely spaced carriers that are modulated with low rate data stream. By making the signal orthogonal to each other, the signals would not interfere with other signals and thus mutual interference is avoided. By carrying the data at a lower rate across all carriers, the effects of reflections and inter-symbol interference are also overcome. If some of the carriers are lost due to multi-path effects, then the data can be reconstructed by using error correction techniques. [26]

### C. Signalling

The LTE specification provides downlink peak rates of 300 Mbit/s, uplink peak rates of 75 Mbit/s and QoS provisions permitting a transfer latency of less than 5 ms in the radio access network. LTE has the ability to manage fast-moving mobiles and supports multi-cast and broadcast streams. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time-division duplexing (TDD). The IP-based network architecture, called the Evolved Packet Core (EPC) designed to replace

the GPRS Core Network, supports seamless handovers for both voice and data to cell towers with older network technology such as GSM, UMTS and CDMA2000.[21] The simpler architecture results in lower operating costs (for example, each E-UTRA cell will support up to four times the data and voice capacity supported by HSPA[22]).

Frequencies used for LTE-TDD range from 1850 MHz to 3800 MHz, with several different bands being used. [27]

### D. Scalability

**Wireless wide area network** (**WWAN**), is a form of wireless network. The larger size of a wide area network compared to a local area network requires differences in technology. Wireless networks of different sizes deliver data in the form of telephone calls, web pages, and streaming video.

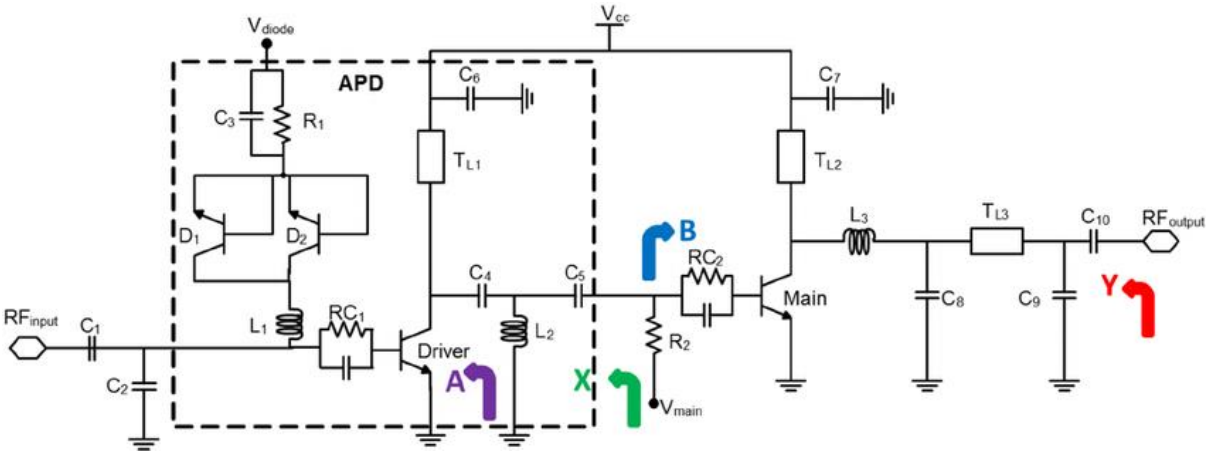
A WWAN often differs from wireless local area network (WLAN) by using mobile telecommunication cellular network technologies such as 2G, 3G, 4G LTE, and 5G to transfer data. These technologies are offered regionally, nationwide, or even globally and are provided by a wireless service provider. WWAN connectivity allows a user with a laptop and a WWAN card to surf the web, check email, or connect to a virtual private network (VPN) from anywhere within the regional boundaries of cellular service. Various computers can have integrated WWAN capabilities.

A WWAN may also be a closed network that covers a large geographic area. For example, a mesh network or MANET with nodes on buildings, towers, trucks, and planes could also be considered a WWAN. [24]

A WWAN may also be a low-power, low-bit-rate wireless WAN, (LPWAN), intended to carry small packets of information between things, often in the form of battery operated sensors.

Since radio communications systems do not provide a physically secure connection path, WWANs typically incorporate encryption and authentication methods to make them more secure. Some of the early GSM encryption techniques were flawed, and security experts have issued warnings that cellular communication, including WWAN, is no longer secure. UMTS (3G) encryption was developed later and has yet to be broken. [25]

### E. Schematic View



## 11. WiMax

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

The name "WiMAX" was created by the WiMAX Forum, which was formed in June 2001 to promote conformity and interoperability of the standard, including the definition of predefined system profiles for commercial vendors.[1] The forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL". IEEE 802.16m or WirelessMAN-Advanced was a candidate for the 4G, in competition with the LTE Advanced standard. [28]

### A. Range

WiMAX outdistances WiFi by miles. WiFi's range is about 100 feet (30 m). WiMAX will blanket a radius of **30 miles** (50 km) with wireless access. The increased range is due to the frequencies used and the power of the transmitter. Of course, at that distance, terrain, weather and large buildings will act to reduce the maximum range in some circumstances, but the potential is there to cover huge tracts of land. [29]

### B. Modulation [30]

| PARAMETER | DOWNLINK | UPLINK |
|---|---|---|
| **Modulation** | BPSK, QPSK, 16 QAM, 64 QAM; BPSK optional for OFDMA-PHY | BPSK, QPSK, 16 QAM; 64 QAM optional |

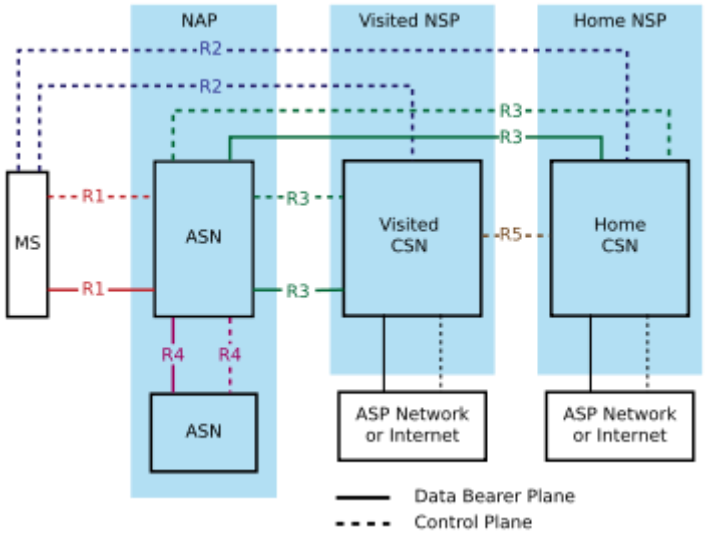
### C. Signalling

- Speed - 70 megabits per second
- Line-of-sight not needed between user and base station
- Frequency bands - 2 to 11 GHz and 10 to 66 GHz (licensed and unlicensed bands)[29]

### D. Scalability

WiMAX is the wireless solution for the next step up in scale, the metropolitan area network (MAN). A MAN allows areas the size of cities to be connected. WiMAX provides metropolitan area network (MAN) connectivity at speeds of up to 75 Mb/sec. WiMAX systems can be used to transmit signal as far as 30 miles. As WiMax can support data ranges across miles, it is well suited for a country such as India where telecom infrastructure is poor and last mile access is expensive. This ability lets ISPs players offer broadband access directly to homes without worrying about the problems of installing the last mile through optic fibre or cables. WiMax is also a big boon for telecom companies as it enables these companies to serve customers in rural areas without spending billions installing expensive infrastructure for minimal returns. [28]

### E. Schematic View




## 12. Zigbee-

Zigbee is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless IoT networks. The Zigbee standard operates on the IEEE 802.15. 4 physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz. [31]

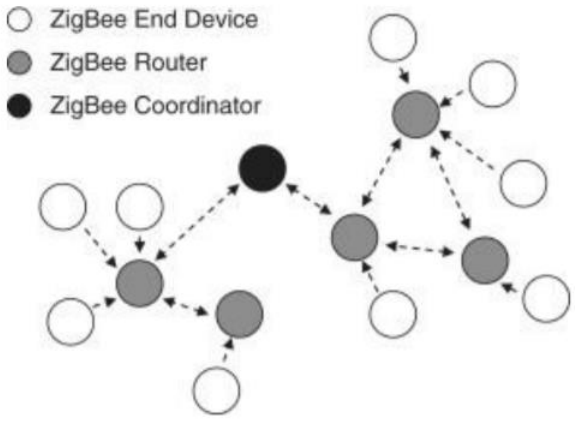
### A. Range-

Its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics. Zigbee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. Data range is 250 kbps and the number of nodes that can be connected are around 64,000. [31]

### B. Modulation-

Zigbee modulation is carried out through direct sequence spread spectrum (DSSS). The 2.4 GHz band, in which ZigBee transceivers are most commonly deployed, uses the OQPSK (offset quadrature phase-shift keying) modulation stream. [32]

### C. Schematic Diagram




## Conclusion

In this assignment, I have studied wired and wireless physical layers, their range, modulation, signalling and their scalability showing their applicability in various network architectures.

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