Wired and Wireless LANs

What is Project 802?

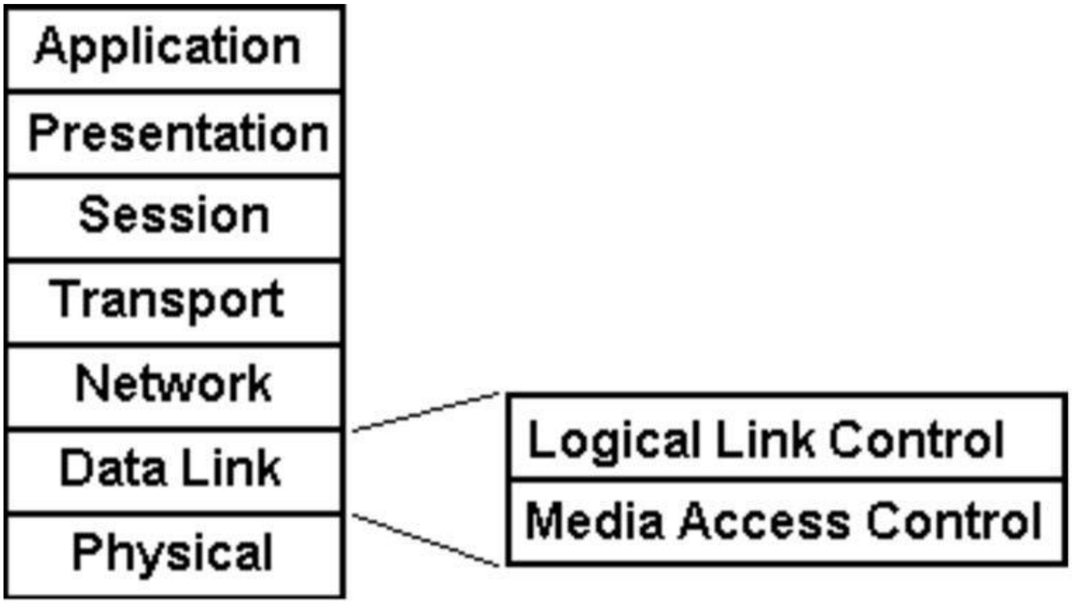
Project 802 is an ongoing project of the Institute of Electrical and Electronics Engineers (IEEE) for defining local area network (LAN) and wide area network (WAN) standards and technologies. The 802 specifications define the operation of the physical network components – cabling, network adapters, and connectivity devices such as hubs and switches.

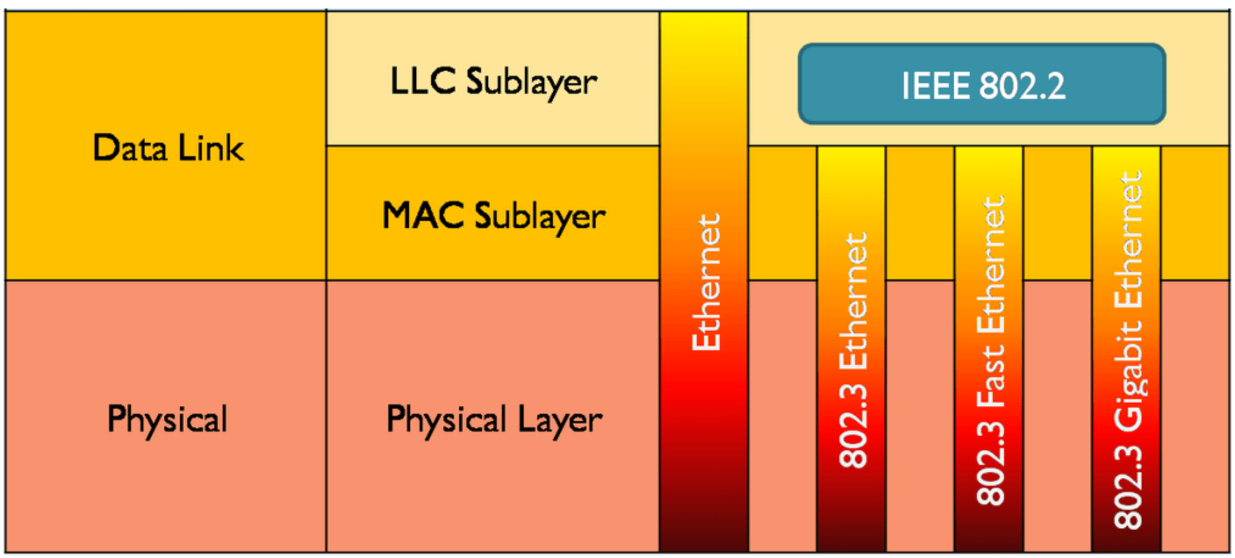
Project 802 has a number of subsections, including the following:

- **802.1:** Internetworking standards
- **802.2:** The logical link control (LLC) layer of the Open Systems Interconnection (OSI) reference model data-link layer
- **802.3:** Ethernet (Carrier Sense Multiple Access with Collision Detection)
- **802.4:** Token Bus LAN
- **802.5:** Token Ring LAN
- **802.6:** Metropolitan area network (MAN)
- **802.7:** Broadband technologies
- **802.8:** Fiber-optic technologies
- **802.9:** Integrated voice/data networks
- **802.10:** Network security standards and technologies
- **802.11:** Wireless networking technologies and standards
- **802.12:** Demand priority access technologies
- **802.14:** Cable television access

In fact, IEEE 802 splits the OSI Data Link Layer into two sub-layers named logical link control (LLC) and media access control (MAC), so the layers can be listed like this:

- Data link layer
    - LLC sublayer
    - MAC sublayer





Functions of LLC Sublayer

The technical definition for 802.2 is "the standard for the upper Data Link Layer sublayer also known as the Logical Link Control layer. It is used with the 802.3, 802.4, and 802.5 standards (lower DL sublayers)."

- The primary function of LLC is to multiplex protocols over the MAC layer while transmitting and likewise to de-multiplex the protocols while receiving.
- LLC provides hop-to-hop flow and error control.
- It allows multipoint communication over computer network.

- Frame Sequence Numbers are assigned by LLC.
- In case of acknowledged services, it tracks acknowledgements

Functions of MAC Layer

- It provides an abstraction of the physical layer to the LLC and upper layers of the OSI network.
- It is responsible for encapsulating frames so that they are suitable for transmission via the physical medium.
- It resolves the addressing of source station as well as the destination station, or groups of destination stations.
- It performs multiple access resolutions when more than one data frame is to be transmitted. It determines the channel access methods for transmission.
- It also performs collision resolution and initiating retransmission in case of collisions.
- It generates the frame check sequences and thus contributes to protection against transmission errors.

MAC Addresses

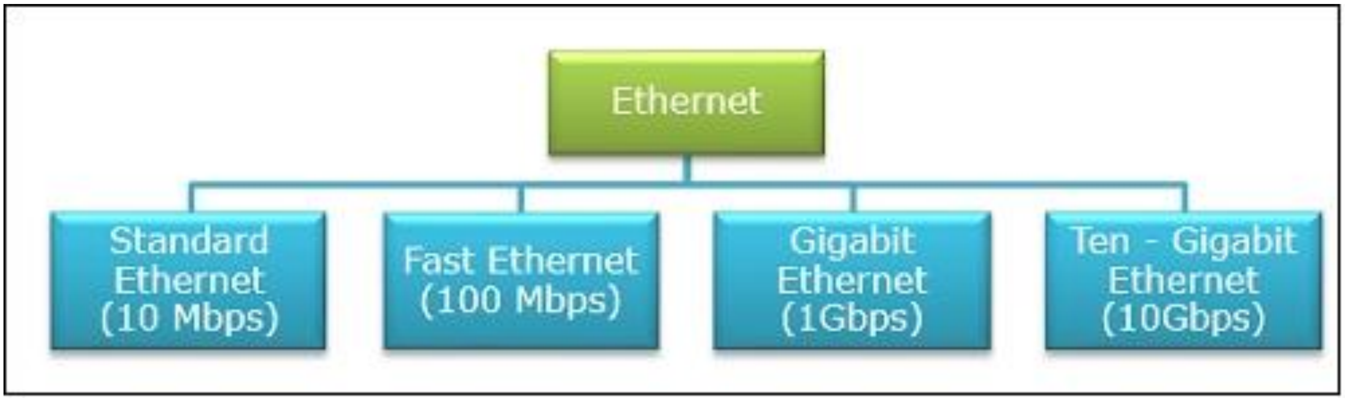
MAC address or media access control address is a unique identifier allotted to a network interface controller (NIC) of a device. It is used as a network address for data transmission within a network segment like Ethernet, Wi-Fi, and Bluetooth.

MAC address is assigned to a network adapter at the time of manufacturing. It is hardwired or hard-coded in the network interface card (NIC). A MAC address comprises of six groups of two hexadecimal digits, separated by hyphens, colons, or no separators. An example of a MAC address is 00:0A:89:5B:F0:11.

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.

Ethernet can also be used in MANs and even WANs. It was first standardized in the 1980s as IEEE 802.3 standard. Since then, it has gone through four generations, as shown in the following chart



The main parts of an Ethernet frame are

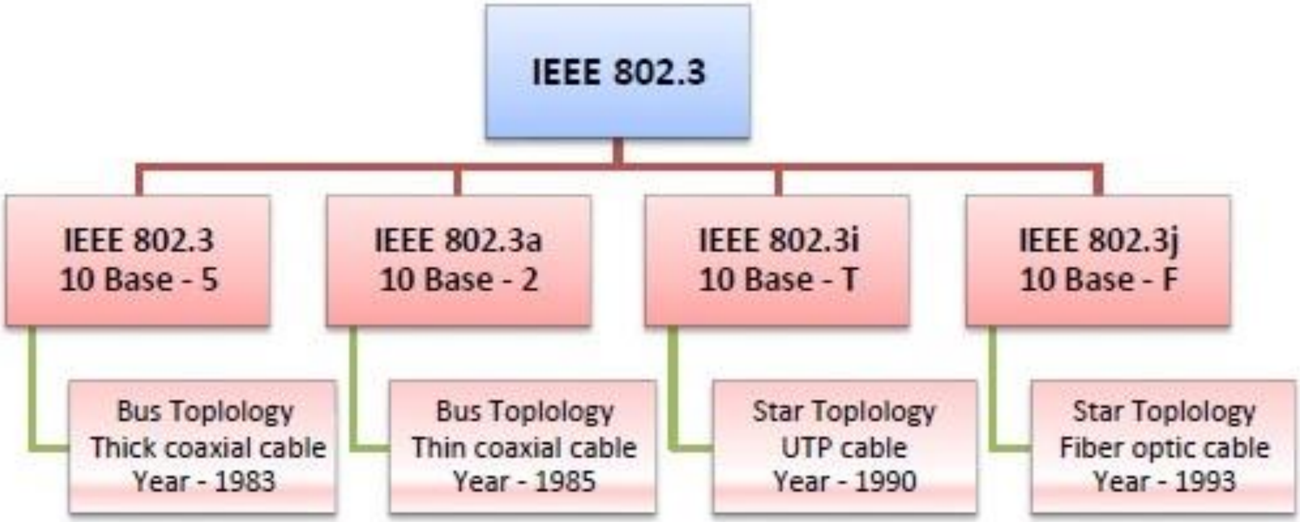
- **Preamble** – It is the starting field that provides alert and timing pulse for transmission.
- **Destination Address** – It is a 6-byte field containing the physical address of destination stations.
- **Source Address** – It is a 6-byte field containing the physical address of the sending station.
- **Length** – It stores the number of bytes in the data field.
- **Data and Padding** – this carries the data from the upper layers.
- **CRC** – It contains error detection information.

IEEE 802.3 Popular Versions

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.
- **IEEE 802.3a**: This gave the standard for thin coax (10BASE-2)
- **IEEE 802.3i**: This gave the standard for twisted pair (10BASE-T). The further variations were given by IEEE 802.3u for 100BASE-TX, 100BASE-T4 and 100BASE-FX.

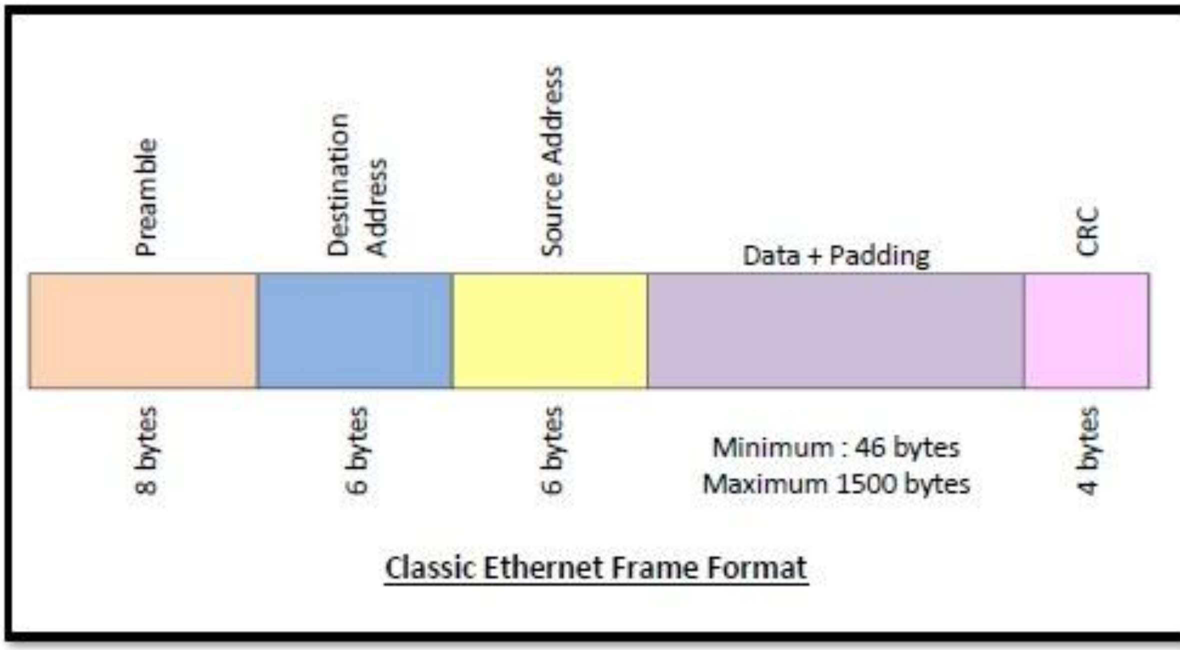
- **IEEE 802.3i**: This gave the standard for Ethernet over Fiber (10BASE-F) that uses fiber optic cables as medium of transmission.

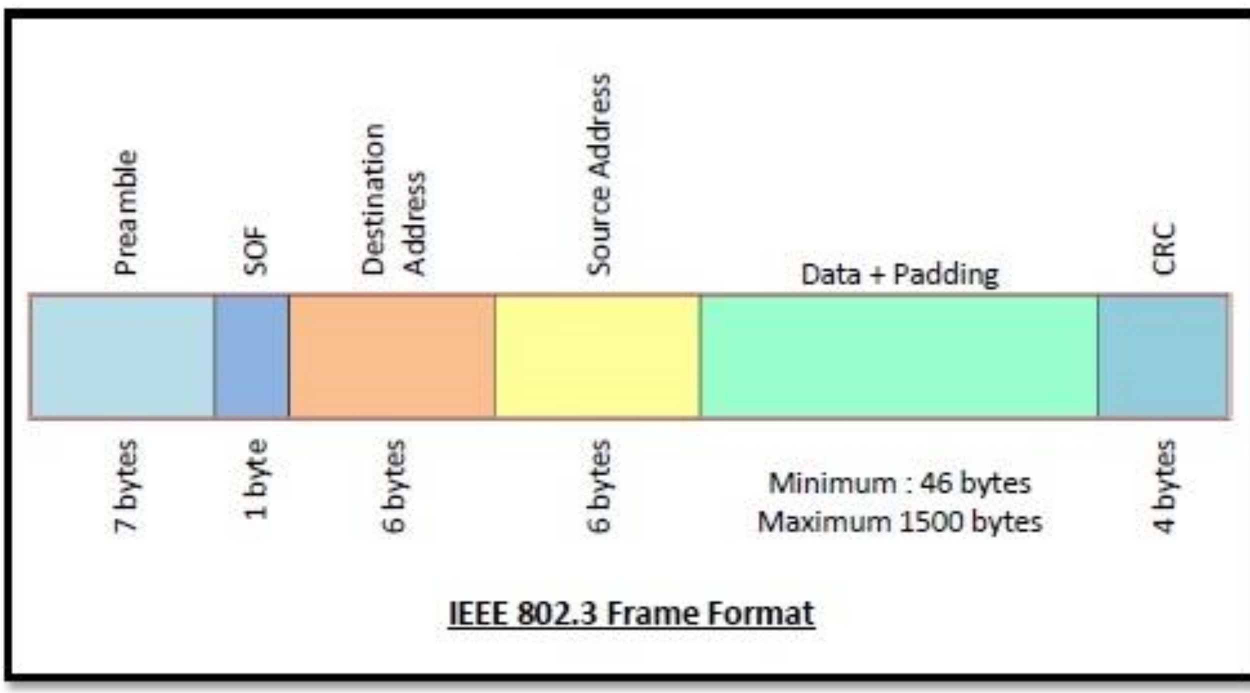


Frame Format of Classic Ethernet and IEEE 802.3

The main fields of a frame of classic Ethernet are -

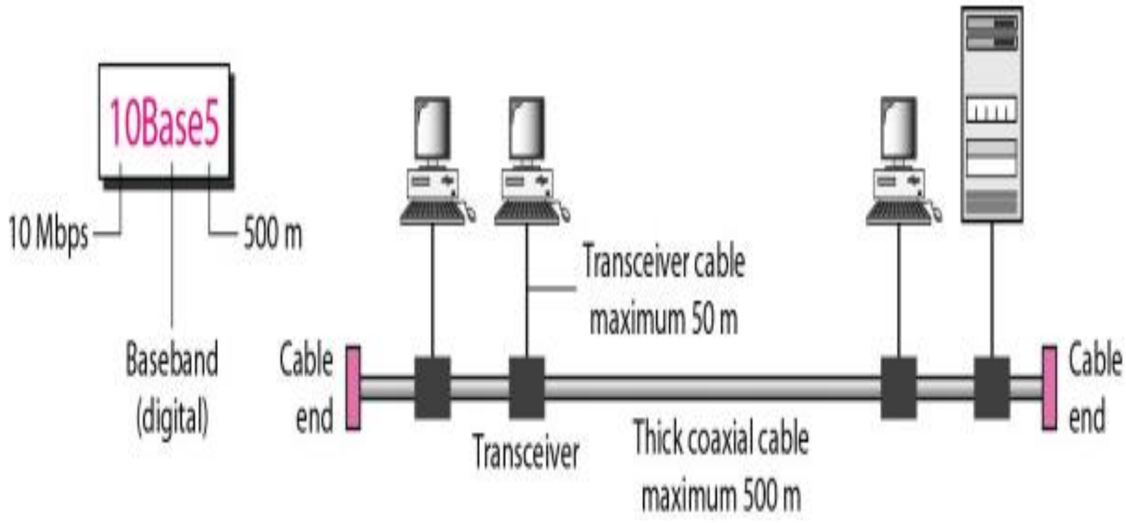
- **Preamble**: It is the starting field that provides alert and timing pulse for transmission. In case of classic Ethernet it is an 8 byte field and in case of IEEE 802.3 it is of 7 bytes.
- **Start of Frame Delimiter**: It is a 1 byte field in a IEEE 802.3 frame that contains an alternating pattern of ones and zeros ending with two ones.
- **Destination Address**: It is a 6 byte field containing physical address of destination stations.
- **Source Address**: It is a 6 byte field containing the physical address of the sending station.
- **Length**: It a 7 bytes field that stores the number of bytes in the data field.
- **Data**: This is a variable sized field carries the data from the upper layers. The maximum size of data field is 1500 bytes.
- **Padding**: This is added to the data to bring its length to the minimum requirement of 46 bytes.
- **CRC**: CRC stands for cyclic redundancy check. It contains the error detection information.





10Base5:

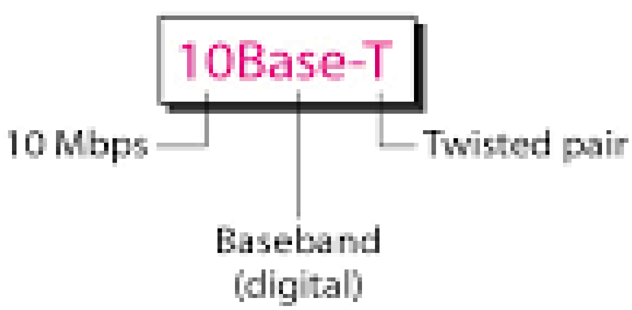
Thick Ethernet The first implementation is called 10Base5, thick Ethernet, or Thicknet. 10Base5 was the first Ethernet specification to use a bus topology with an external transceiver (transmitter/receiver) connected via a tap to a thick coaxial cable. Figure shows 10Base5 implementation.

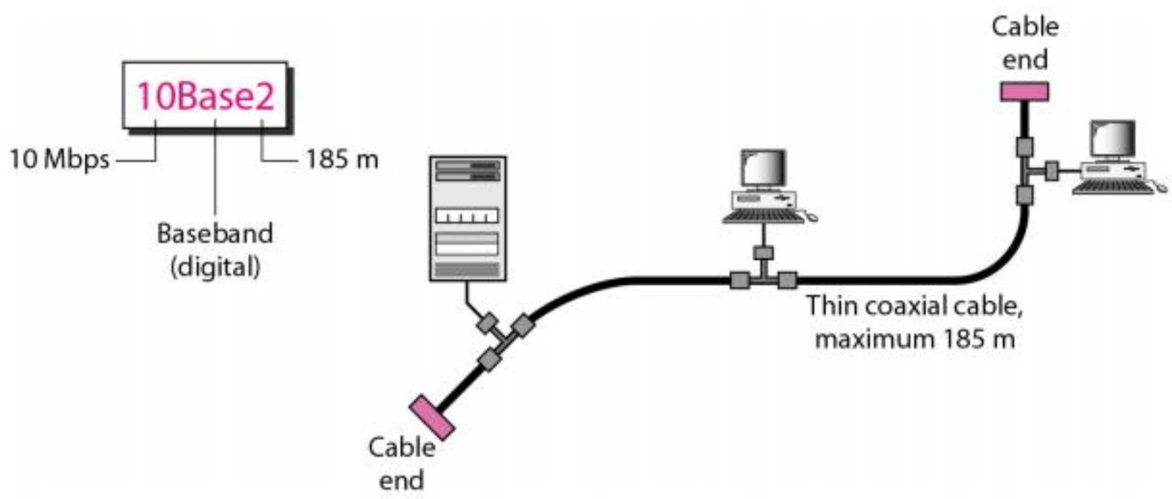


The transceiver is responsible for transmitting, receiving, and detecting collisions. The transceiver is connected to the station via a transceiver cable that provides separate paths for sending and receiving. This means that collision can only happen in the coaxial cable. The maximum length of the coaxial cable must not exceed 500 m; otherwise, there is excessive degradation of the signal. If a length of more than 500 m is needed, up to five segments, each a maximum of 500 meter, can be connected using repeaters.

10Base2:

The second implementation is called 10Base2, thin Ethernet, or Cheapernet. 10Base2 also uses a bus topology, but the cable is much thinner and more flexible. The cable can be bent to pass very close to the stations. In this case, the transceiver is normally part of the network interface card (NIC), which is installed inside the station. Figure shows the 10Base2 implementation.

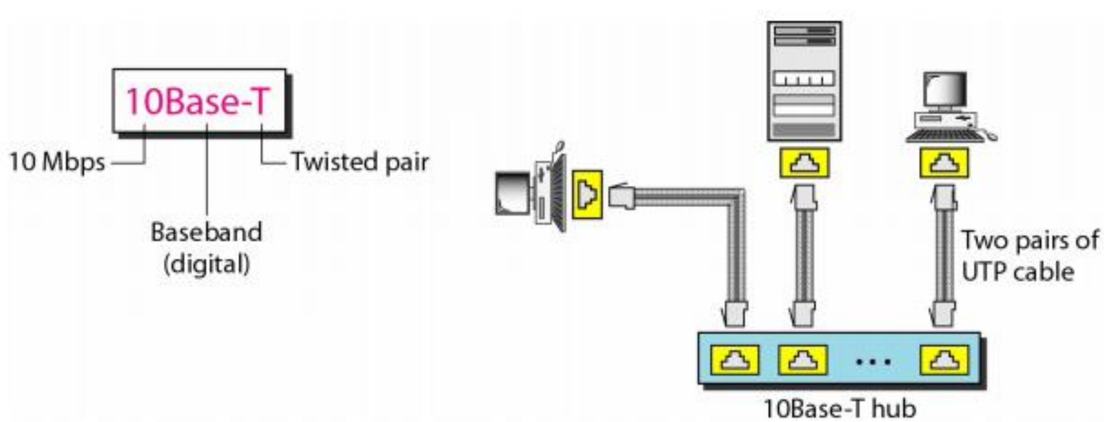




The collision here occurs in the thin coaxial cable. This implementation is more cost effective than 10Base5 because thin coaxial cable is less expensive than thick coaxial and the tee connections are much cheaper than taps. Installation is simpler because the thin coaxial cable is very flexible. However, the length of each segment cannot exceed 185 m (close to 200 m) due to the high level of attenuation in thin coaxial cable

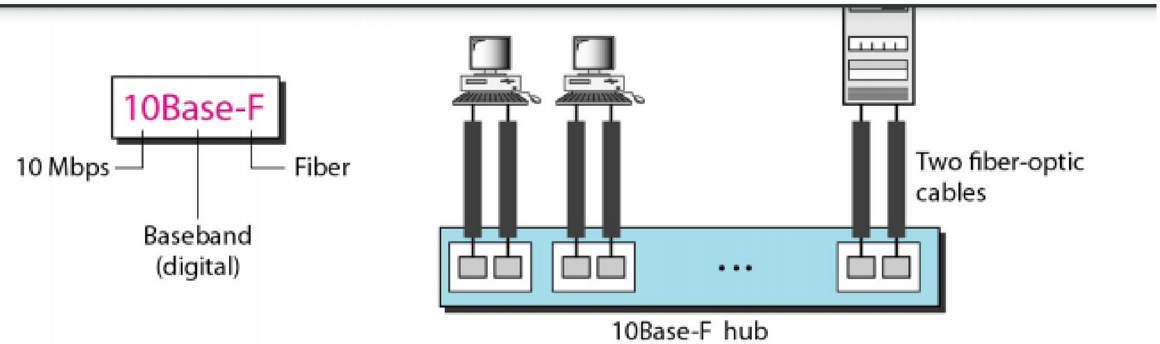
10Base-T:

Twisted-Pair Ethernet The third implementation is called 10Base-T or twisted-pair Ethernet. 1OBase-T uses a physical star topology. The stations are connected to a hub via two pairs of twisted cable, as shown in Figure. Two pairs of twisted cable create two paths (one for sending and one for receiving) between the station and the hub. Any collision here happens in the hub. Compared to 10Base5 or 10Base2, we can see that the hub actually replaces the coaxial cable as far as a collision is concerned. The maximum length of the twisted cable here is defined as 100 m, to minimize the effect of attenuation in the twisted cable.



10Base-F:

Fiber Ethernet 10Base-F uses a star topology to connect stations to a hub. The stations are connected to the hub using two fiber-optic cables, as shown in the figure

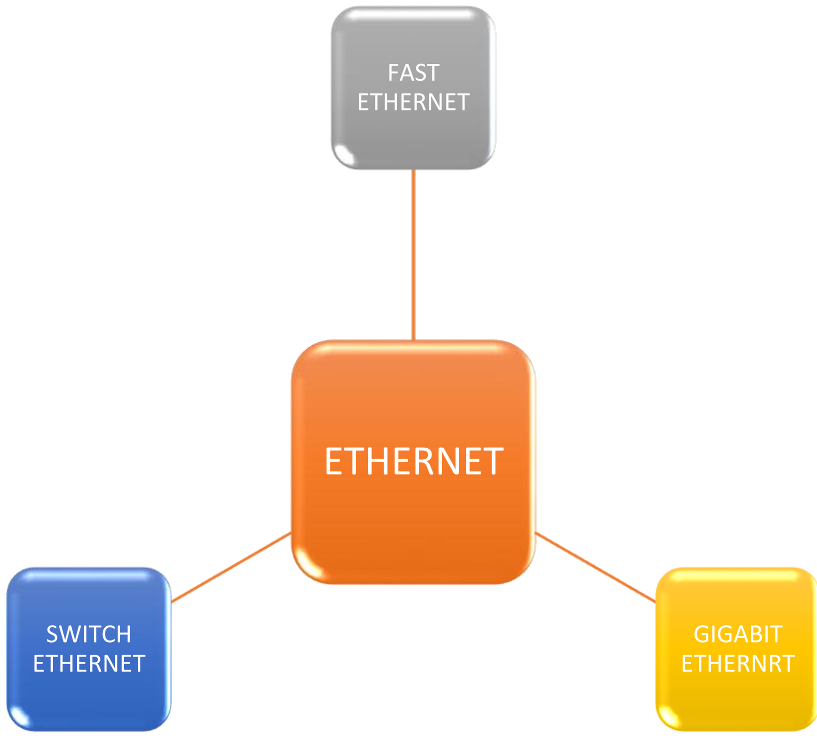


Summary of Standard Ethernet implementations

Characteristics	*10Base5*	*10Base2*	*10Base-T*	*10Base-F*
Media	Thick coaxial cable	Thin coaxial cable	2 UTP	2 Fiber
Maximum length	500 m	185 m	100 m	2000 m
Line encoding	Manchester	Manchester	Manchester	Manchester

Ethernet Are Several Types:

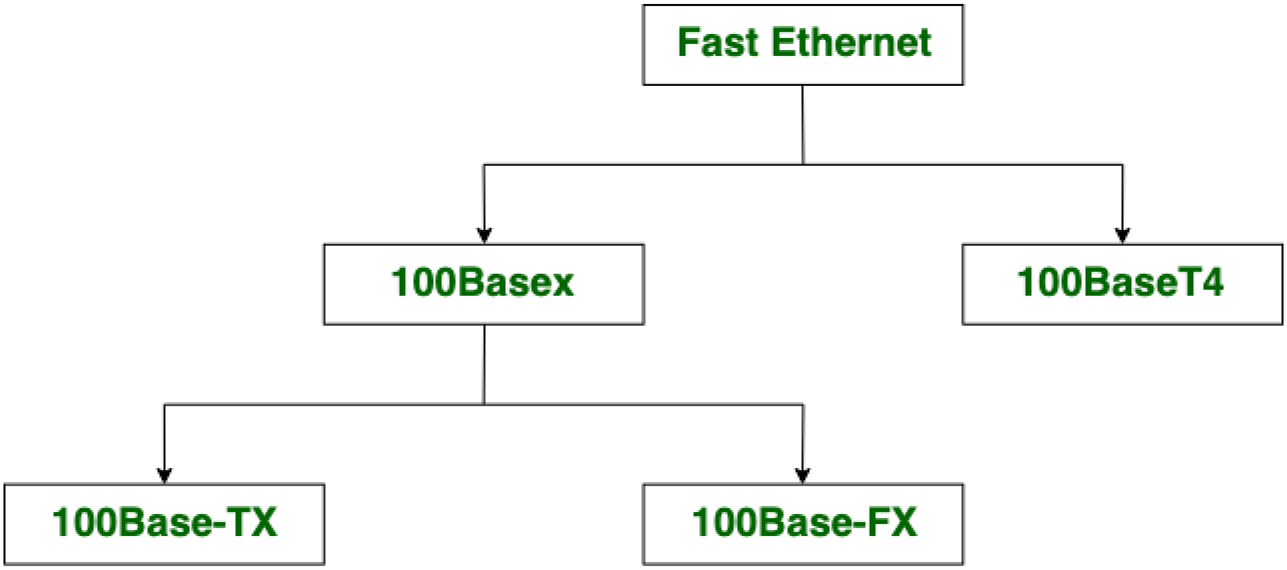
1. Fast Ethernet
2. Gigabit Ethernet
3. Switch Ethernet



Fast Ethernet is the Successor of 10-Base-T Ethernet. It is more popular than Gigabit Ethernet because its configuration and implementation is simple. It is faster than its successors. Its variants are:

1. 100Base-T4
2. 100Base-Tx
3. 100Base-Fx

The coverage limit of Fast Ethernet is up to 10 km and its round-trip delay in Fast Ethernet is 100 to 500 bit times.



Categories of Fast Ethernet

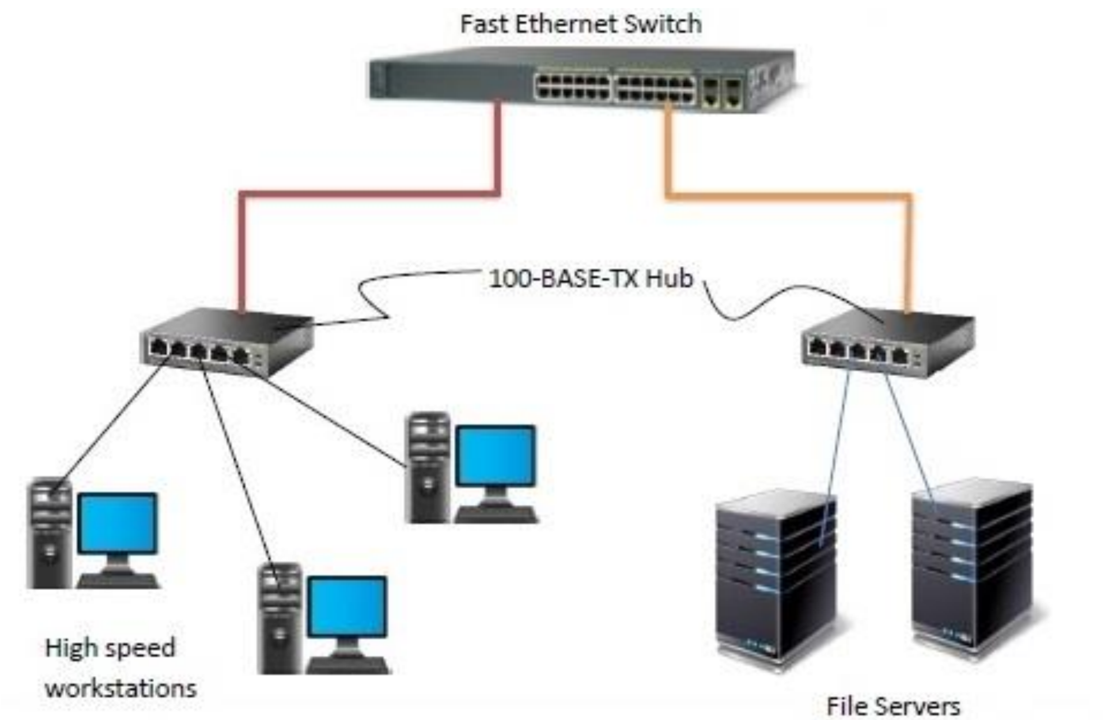
100BASE-TX

It is the technical name of Fast Ethernet over twisted pair cables. It is a predominant form of Fast Ethernet carrying data traffic at 100 Mbps (Mega bits per second) in local area networks (LAN). It was launched as the IEEE 802.3u standard in 1995. Here, 100 is the maximum throughput, i.e. 100 Mbps, BASE denoted use of baseband transmission, and TX denotes use of twisted pair cables in Fast Ethernet.

Properties

- This has either two pairs of unshielded twisted pairs (UTP) category 5 wires or two shielded twisted pairs (STP) type 1 wires.
- One of these pairs transmits frames from hub to the device and the other pair transmits from device to hub, thus providing full-duplex communication.
- Each network segment can have maximum length of 100m (328ft).
- It has a data rate of 125 Mbps.

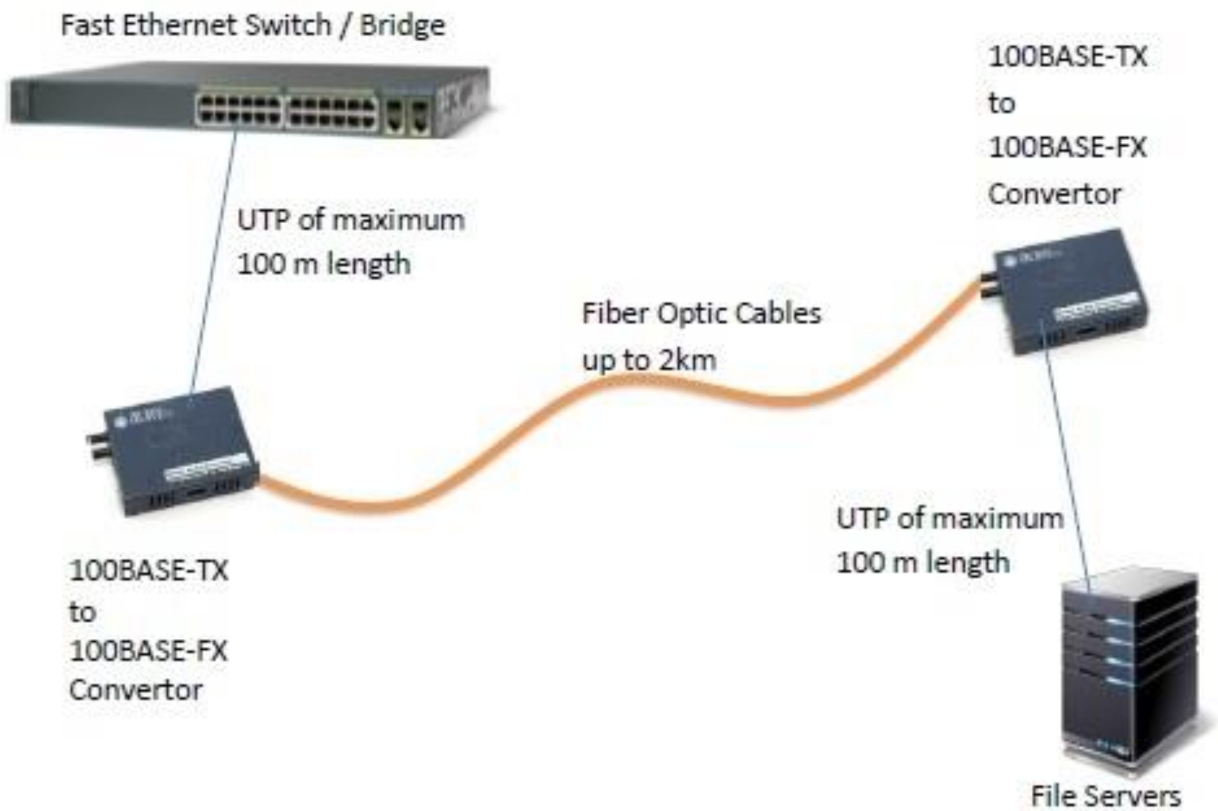
  The maximum fundamental frequency obtained is 31.25 MHz.
- It uses MLT-3 encoding and decoding scheme along with 4B/5B block coding. 4B/5B block coding imparts spectrum shaping and DC equalization.
- A cable connects only two nodes. Resulting in point-to-point connection topology. For connecting more than two nodes, a coupling element in used.



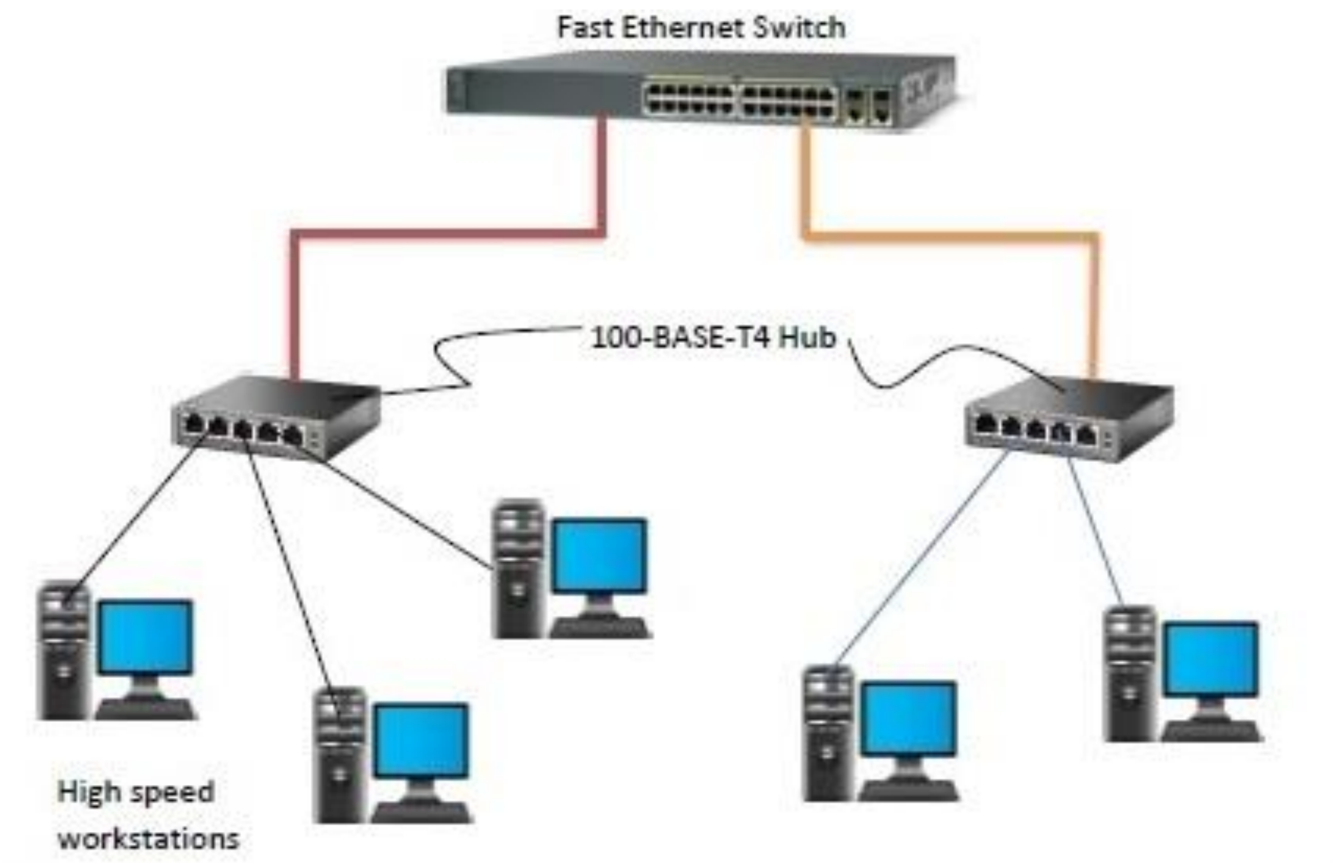
1000BASE-FX is the technical name of Fast Ethernet over fiber optic cables. It is a version of Fast Ethernet carrying data traffic at 100 Mbps (Megabits per second) in local area networks (LAN). It was launched as the IEEE 802.3u standard in 1995. Here, 100 is the maximum throughput, i.e. 100 Mbps, BASE denoted use of baseband transmission, and FX denotes use of optical fibers in Fast Ethernet.

Properties

- 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.
- In most Fast Ethernet applications, fiber optics is used for the long haul transmission, which the individual devices are connected by twisted pair copper wires, i.e. 100BASE-TX. This requires a convertor between the connections. The following diagram shows the set up required −



100BASE-T4 is the early implementation of Fast Ethernet over twisted pair cables, carrying data traffic at 100 Mbps (Megabits per second) in local area networks (LAN). It was launched as the IEEE 802.3u standard in 1995. Here, 100 is the maximum throughput, i.e. 100 Mbps, BASE denoted use of baseband transmission, and T4 denotes use of four twisted pair cables in Fast Ethernet.



Properties

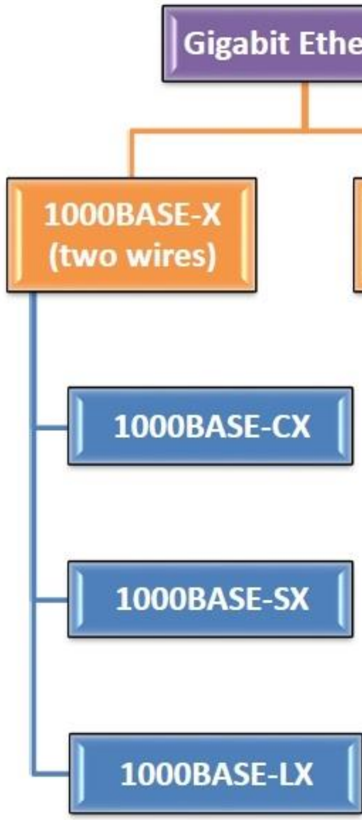
- This has four pairs of unshielded twisted pair of Category 3. i.e. voice grade.
- Two of these pairs are bi-directional and the other two are unidirectional. The two unidirectional wires are reserved for receiving and sending data respectively. In each direction, three pairs can be used simultaneously 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).

Gigabit Ethernet

In computer networks, Gigabit Ethernet (GbE) is the family of Ethernet technologies that achieve theoretical data rates of 1 gigabit per second (1 Gbps). It was introduced in 1999 and was defined by the IEEE 802.3ab standard.

Varieties of Gigabit Ethernet

The popular varieties of fast Ethernet are 1000Base-SX, 1000Base-LX, 1000BASE-T and 1000Base-CX.



1000BASE-CX

- Defined by IEEE 802.3z standard
- The initial standard for Gigabit Ethernet
- Uses shielded twisted pair cables with DE-9 or 8P8C connector
- Maximum segment length is 25 metres
- Uses NRZ line encoding and 8B/6B block encoding

1000BASE-SX

- Defined by IEEE 802.3z standard
- Uses a pair of fibre optic cables of a shorter wavelength having 770 – 860 nm diameter
- The maximum segment length varies from 220 – 550 meters depending upon the fiber properties.
- Uses NRZ line encoding and 8B/10B block encoding

1000BASE-LX

- Defined by IEEE 802.3z standard
- Uses a pair of fibre optic cables of a longer wavelength having 1270 – 1355 nm diameter
- Maximum segment length is 500 meters
- Can cover distances up to 5 km
- Uses NRZ line encoding and 8B/10B block encoding

1000BASE-T

- Defined by IEEE 802.3ab standard
- Uses a pair four lanes of twisted-pair cables (Cat-5, Cat-5e, Cat-6, Cat-7)
- Maximum segment length is 100 metres
- Uses trellis code modulation technique

Feature	**1000Base-SX**	**1000Base-LX**	**1000Base-CX**	**1000Base-T**
Medium	Optical fiber (multimode)	Optical fiber (single mode or multimode)	STP	UTP
Signal	Short wave Laser	Long Wave Laser	Electrical	Electrical
Max. Distance	550	550m (multimode) 5000(single mode)	25 m	25m

let's see the difference between Fast Ethernet and Gigabit Ethernet:

Fast Ethernet provides 100 Mbps speed.	Gigabit Ethernet offers 1 Gbps speed.
Fast Ethernet is simple configured.	While Gigabit Ethernet is more complicated than Fast Ethernet.
Fast Ethernet generate more delay comparatively.	Gigabit Ethernet generate less delay than Fast Ethernet.
The coverage limit of Fast Ethernet is up to 10 km.	While the coverage limit of Gigabit Ethernet is up to 70 km.
The round-trip delay in Fast Ethernet is 100 to 500 bit times.	While the round-trip delay in Gigabit Ethernet is 4000 bit times.
Fast Ethernet is the Successor of 10-Base-T Ethernet.	While Gigabit Ethernet is the successor of Fast Ethernet.

Difference between Classic Ethernet and Switch Ethernet:

Classic Ethernet is the original form of Ethernet that provides data rates between 3 to 10 Mbps. The stations are connected by hubs that allow each station to communicate with every other station in the LAN. There are a number of varieties of classic Ethernet, commonly referred as 10BASE-X. Here, 10 is the maximum throughput, i.e. 10 Mbps, BASE denotes use of baseband transmission, and X is the type of medium used.

The common varieties of classic Ethernet are −

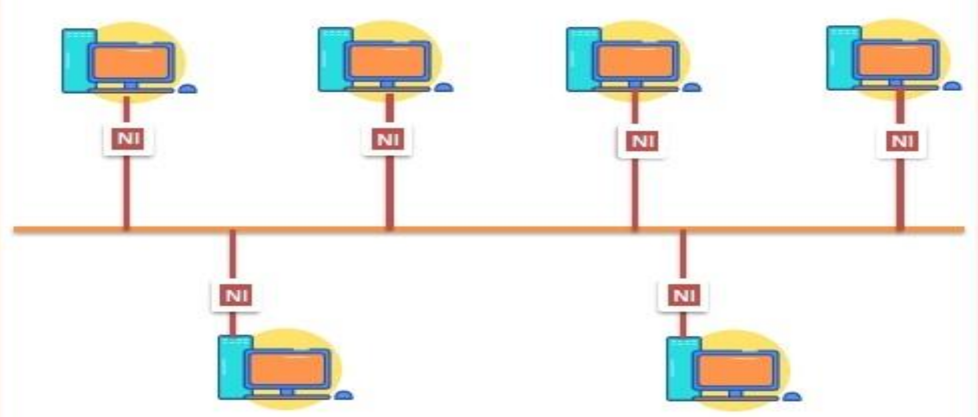
- Thick coax (10BASE-5)
- Thin coax (10BASE-2)
- Twisted pair (10BASE-T)
- Ethernet over Fiber (10BASE-F)

In switched Ethernet, the hub connecting the stations of the classic Ethernet is replaced by a switch. The switch connects the high-speed backplane bus to all the stations in the LAN. The switch-box contains a number of ports, typically within the range of 4 – 48. A station can be connected in the network by simply plugging a connector to any of the ports. Connections from a backbone Ethernet switch can go to computers, peripherals or other Ethernet switches and Ethernet hubs.

Architecture of classic Ethernet and switched Ethernet

Classic Ethernet is simplest form of Ethernet. It comprises of an Ethernet medium composed of a long piece of coaxial cable. Stations can be connected to the coaxial cable using a card called the network interface (NI). The NIs are responsible for receiving and transmitting data through the network. Repeaters are used to make end-to-end joins between cable segments as well as re-generate the signals if they weaken. When a station is ready to transmit, it places its frame in the cable. This arrangement is called the broadcast bus.

The configuration of classic Ethernet is illustrated as follows −

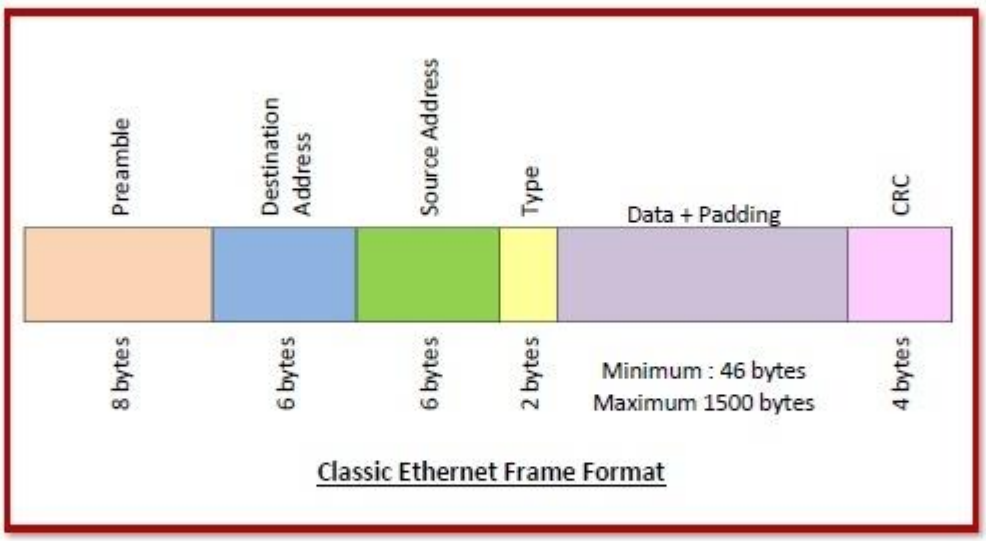


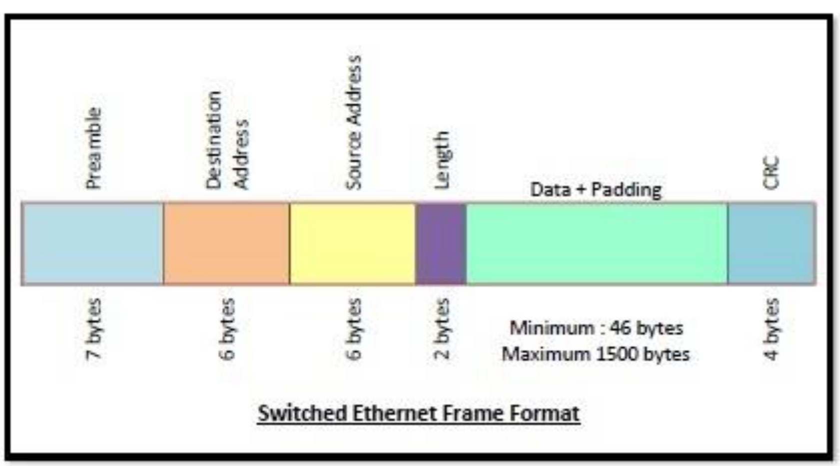
Architecture of Classic Internet

Frame Formats

The frames for transmission of both classic Ethernet and switched Ethernet are same except for one field. Both of them have seven fields. The difference between the two is that while classic Ethernet has a ‘Type’ field, switched Ethernet has ‘Length’ field. The fields are −

- **Preamble:** It is a 7 bytes starting field that provides alert and timing pulse for transmission.
- **Destination Address:** It is a 6 byte field containing physical address of destination stations.
- **Source Address:** It is a 6 byte field containing the physical address of the sending station.
- T**ype/Length:** It a 2 bytes field. In classic Ethernet it is ‘Type’ field that instructs the receiver which process to give the frame to. In switched Ethernet, it is ‘Length’ field that stores the number of bytes in the data field.
- **Data:** This is a variable sized field carries the data from the upper layers. The maximum size of data field is 1500 bytes.
- **Padding:** This is added to the data to bring its length to the minimum requirement of 46 bytes.
- **CRC:** CRC stands for cyclic redundancy check. It contains the error detection information.





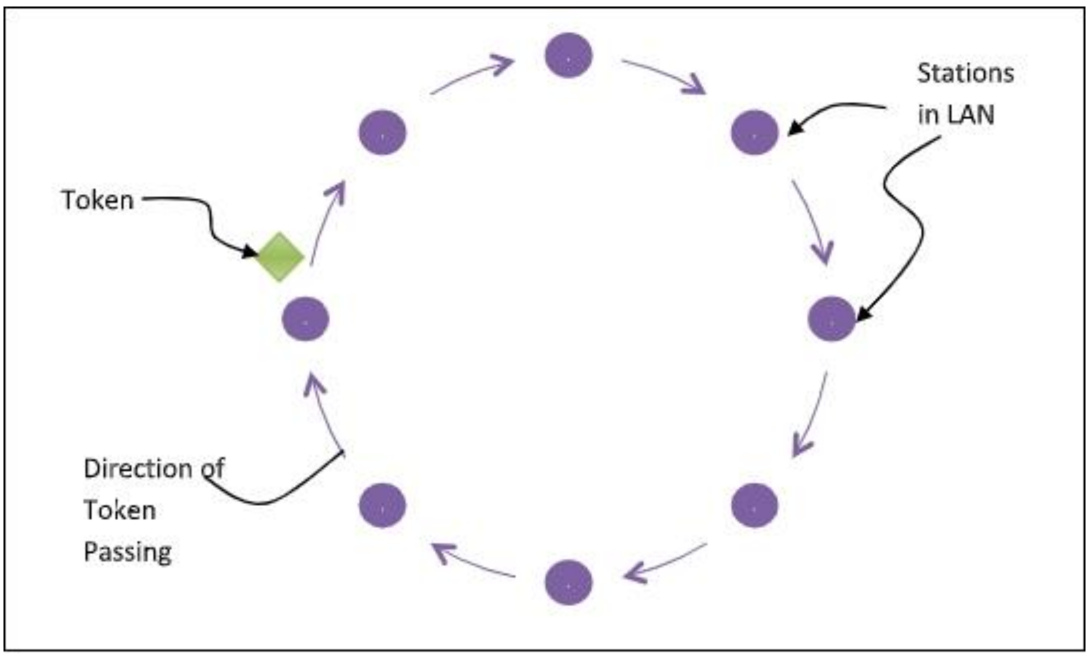
Token Ring

Token Ring (IEEE 802.5) is a communication protocol in a local area network (LAN) where all stations are connected in a ring topology and pass one or more tokens for channel acquisition.

A token is a special frame of 3 bytes that circulates along the ring of stations. A station can send data frames only if it holds a token. The tokens are released on successful receipt of the data frame.

Token Passing Mechanism in Token Ring

If a station has a frame to transmit when it receives a token, it sends the frame and then passes the token to the next station; otherwise it simply passes the token to the next station. Passing the token means receiving the token from the preceding station and transmitting to the successor station. The data flow is unidirectional in the direction of the token passing. In order that tokens are not circulated infinitely, they are removed from the network once their purpose is completed. This is shown in the following diagram −

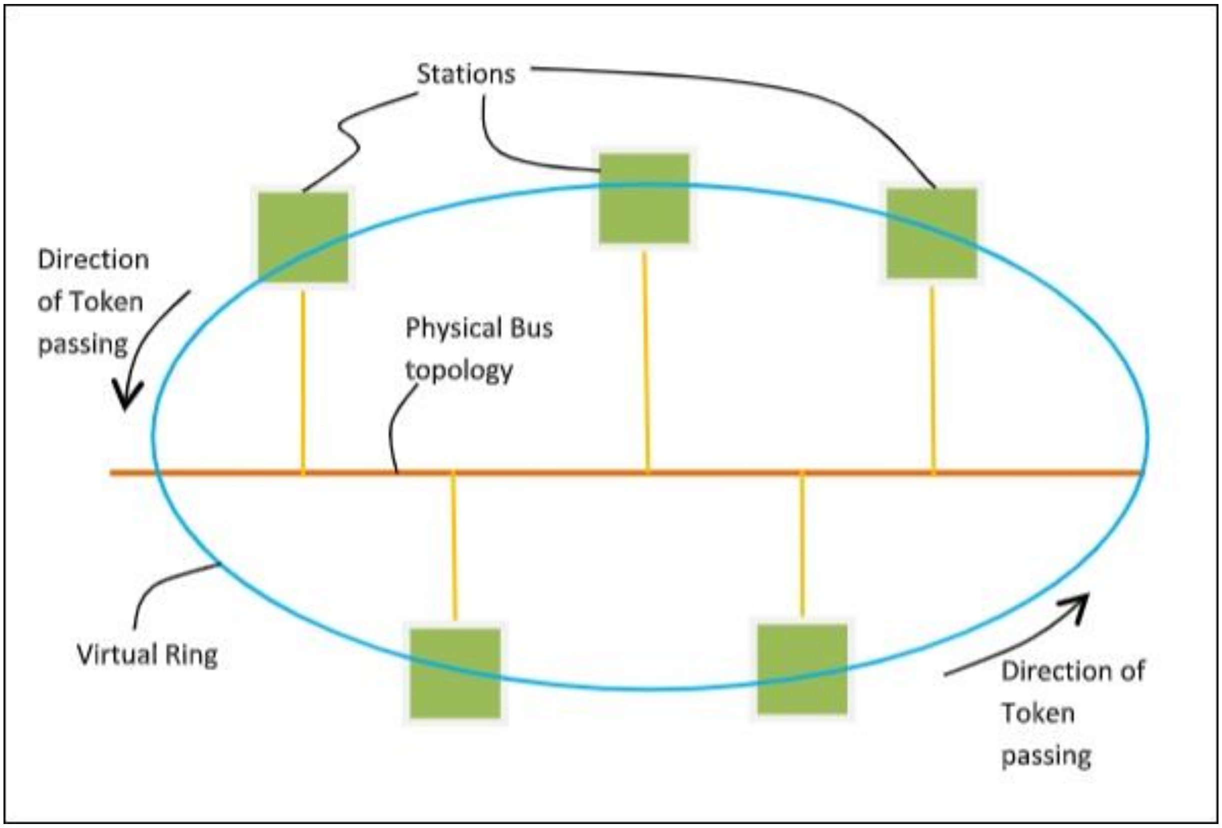


Token Bus

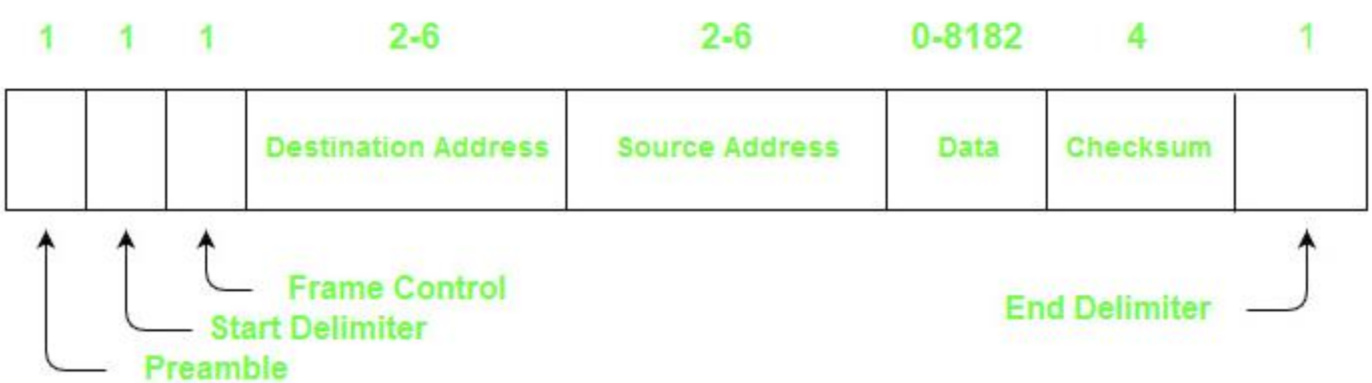
Token Bus (IEEE 802.4) is a standard for implementing token ring over virtual ring in LANs. The physical media has a bus or a tree topology and uses coaxial cables. A virtual ring is created with the nodes/stations and the token is passed from one node to the next in a sequence along this virtual ring. Each node knows the address of its preceding station and its succeeding station. A station can only transmit data when it has the token. The working principle of token bus is similar to Token Ring.

Token Passing Mechanism in Token Bus

A token is a small message that circulates among the stations of a computer network providing permission to the stations for transmission. If a station has data to transmit when it receives a token, it sends the data and then passes the token to the next station; otherwise, it simply passes the token to the next station. This is depicted in the following diagram −



Frame Format:
The various fields of the frame format are:



1. **Preamble –** It is used for bit synchronization. It is 1 byte field.
2. **Start Delimiter –** These bits marks the beginning of frame. It is 1 byte field.
3. **Frame Control –** This field specifies the type of frame – data frame and control frames. It is 1 byte field.
4. **Destination Address –** This field contains the destination address. It is 2 to 6 bytes field.
5. **Source Address –** This field contains the source address. It is 2 to 6 bytes field.
6. **Data –** If 2 byte addresses are used than the field may be upto 8182 bytes and 8174 bytes in case of 6 byte addresses.
7. **Checksum –** This field contains the checksum bits which is used to detect errors in the transmitted data. It is 4 bytes field.

8. **End Delimiter –** This field marks the end of frame. It is 1 byte field.

Differences between Token Ring and Token Bus

The token is passed over the physical ring formed by the stations and the coaxial cable network.	The token is passed along the virtual ring of stations connected to a LAN.
The stations are connected by ring topology, or sometimes star topology.	The underlying topology that connects the stations is either bus or tree topology.
It is defined by IEEE 802.5 standard.	It is defined by IEEE 802.4 standard.
The maximum time for a token to reach a station can be calculated here.	It is not feasible to calculate the time for token transfer.

FDDI stands for **Fiber Distributed Data Interface**.

It is a set of ANSI and ISO guidelines for information transmission on fiber-optic lines in Local Area Network (LAN) that can expand in run upto 200 km (124 miles). The FDDI convention is based on the **token ring protocol.**
In expansion to being expansive geographically, an FDDI neighborhood region arranges can support thousands of clients. FDDI is habitually utilized on the spine for a Wide Area Network (WAN).

An FDDI network contains **two token rings,** one for possible backup in case the essential ring falls flat. The primary ring offers up to 100 Mbps capacity. In case the secondary ring isn't required for backup, it can also carry information, amplifying capacity to 200 Mbps. The single ring can amplify the most extreme remove; a double ring can expand 100 km (62 miles).

Characteristics of FDDI

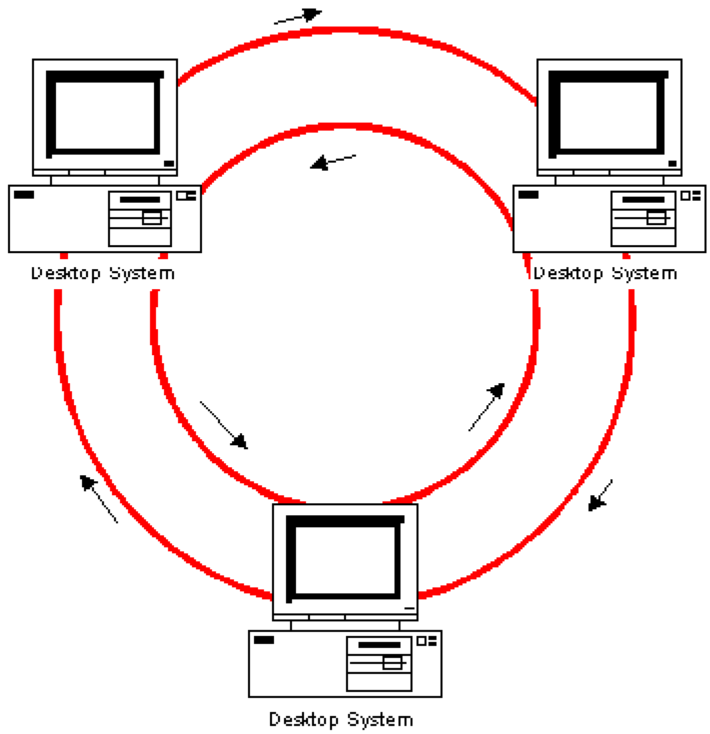
- FDDI gives 100 Mbps of information throughput.
- FDDI incorporates two interfaces.
- It is utilized to associate the equipment to the ring over long distances.
- FDDI could be a LAN with Station Management.

Advantages of FDDI

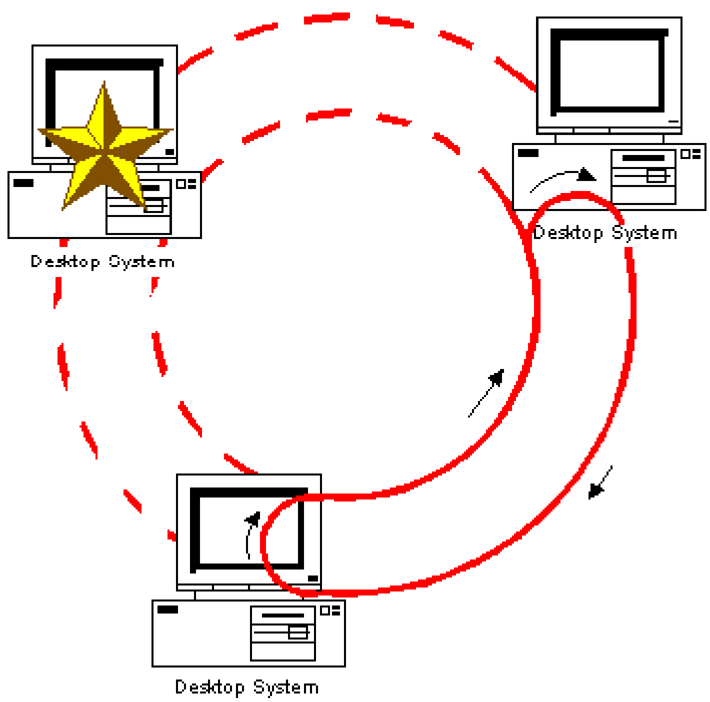
- Fiber optic cables transmit signals over more noteworthy separations of approximately 200 km.
- It is conceivable to supply the need to the work stations associated within the chain. Consequently based on the prerequisite a few stations are bypassed to supply speedier benefit to the rest.
- FDDI employments different tokens to make strides organize speed.
- It offers a higher transmission capacity (up to 250 Gbps). Thus it can handle information rates up to 100 Mbps.
- It offers tall security because it is troublesome to spy on the fiber-optic link.
- Fiber optic cable does not break as effectively as other sorts of cables.

Disadvantages of FDDI

- FDDI is complex. Thus establishment and support require incredible bargain of expertize.
- FDDI is expensive. Typically since fiber optic cable, connectors and concentrators are exceptionally costly.



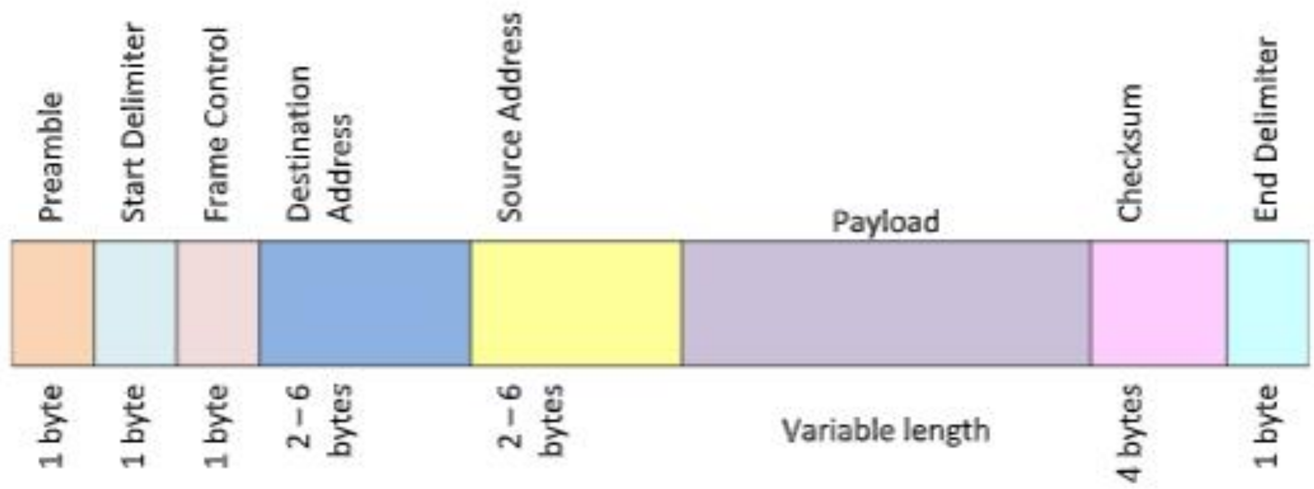
FDDI - all stations functioning



FDDI - one station is down

Frame Format

The frame format of FDDI is similar to that of token bus as shown in the following diagram −



FDDI Frame Format

The fields of an FDDI frame are −

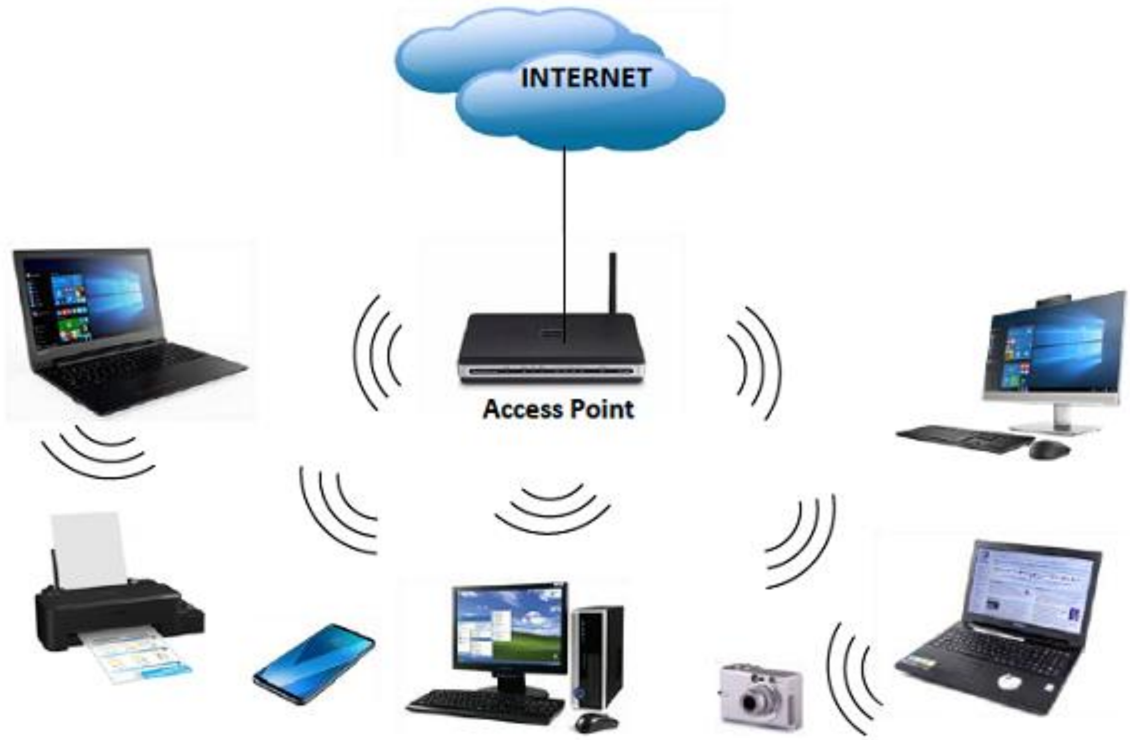
- **Preamble:** 1 byte for synchronization.
- **Start Delimiter:** 1 byte that marks the beginning of the frame.
- **Frame Control:** 1 byte that specifies whether this is a data frame or control frame.
- **Destination Address:** 2-6 bytes that specifies address of destination station.
- **Source Address:** 2-6 bytes that specifies address of source station.
- **Payload:** A variable length field that carries the data from the network layer.
- **Checksum:** 4 bytes frame check sequence for error detection.
- **End Delimiter:** 1 byte that marks the end of the frame

LAN Comparison:

Network	Access Method	Signaling	Data Rate	Error Control
Ethernet	CSMA/CD	Manchester	1,10 mbps	No
Fast Ethernet	CSMA/CD	Several	100 mbps	No
Gigabit Ethernet	CSMA/CD	Several	1 gbps	No
Token Ring	Token Passing	Differential Manchester	4,16 gbps	Yes
FDDI	Token Passing	NRZ_I	100 mbps	Yes

Wireless Technology

Computer networks that are not connected by cables are called wireless networks. They generally use radio waves for communication between the network nodes. They allow devices to be connected to the network while roaming around within the network coverage.



Types of Wireless Networks

- Wireless LANs − Connects two or more network devices using wireless distribution techniques.
- Wireless MANs − Connects two or more wireless LANs spreading over a metropolitan area.
- Wireless WANs − Connects large areas comprising LANs, MANs and personal networks.

Advantages of Wireless Networks

- It provides clutter-free desks due to the absence of wires and cables.
- It increases the mobility of network devices connected to the system since the devices need not be connected to each other.
- Accessing network devices from any location within the network coverage or Wi-Fi hotspot becomes convenient since laying out cables is not needed.
- Installation and setup of wireless networks are easier.

- New devices can be easily connected to the existing setup since they needn't be wired to the present equipment. Also, the number of equipment that can be added or removed to the system can vary considerably since they are not limited by the cable capacity. This makes wireless networks very scalable.
- Wireless networks require very limited or no wires. Thus, it reduces the equipment and setup costs.

Examples of wireless networks

- Mobile phone networks
- Wireless sensor networks
- Satellite communication networks
- Terrestrial microwave networks

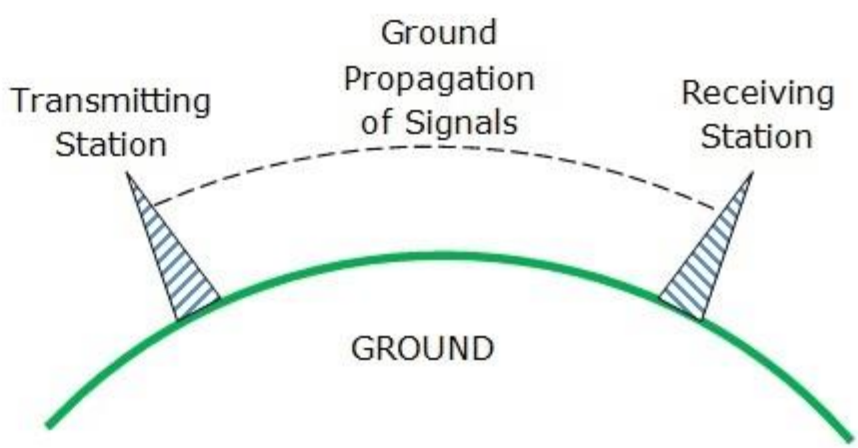
Wireless Transmission:

In wireless transmission media, data is transmitted in the form of electromagnetic waves that do not require any physical conductors for transmission. The waves are broadcast through free space and any device who has permission to connect can receive them.

The three ways in which unguided signals travel are −

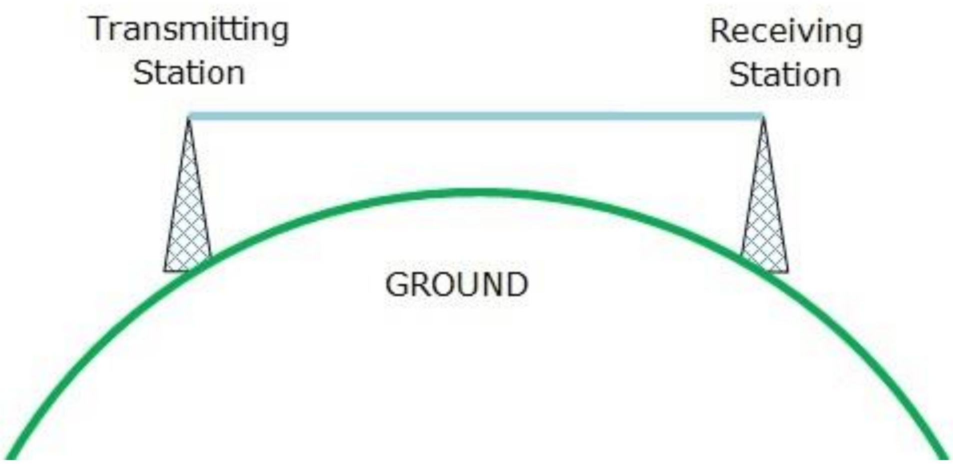
Ground Propagation:

It is a method of propagation, in which radio waves travel through the lowest layers of the atmosphere along the earth's surface, following the earth's curvature. The frequency of these signals is low (≤ 2MHz), and the distance they travel is directly proportional to the power in signal.



Sky Propagation:

In sky propagation, high frequency radio waves (2–30 MHz) are reflected back from the ionosphere towards the earth's surface. They can be used to transmit signals over a large geographical area since their distance is not bounded by the earth's curvature.



Line – of – Sight Propagation

In line – of – sight propagation, very high frequency waves (> 30 MHz) travel at straight lines from the source antenna (transmitter) to the destination antenna (receiver). These waves are easily disrupted by present of objects in their path. So the antennas are placed tall enough above obstructions. They are unidirectional facing each other.

Types of Waves

Radio Transmission

In the electromagnetic spectrum, all omnidirectional waves in the frequencies 3KHz to 1GHz are called radio waves. They are widely used for communications since they are easy to generate, can travel long distances and can penetrate buildings. Radio waves have omnidirectional antennas, i.e. antennas that can send signals in all directions.

The properties of radios waves vary according to their frequencies. However, radio waves at all frequencies are prone to interference from electrical equipments like motors etc.

Low and Medium Frequency Radio Waves

Low and medium frequency radio waves can pass through obstacles and have ground propagation. However, the power diminishes rapidly depending upon the distance from the source. This attenuation in power is called the path loss. AM radio uses LF and MF bands.

High Frequency Radio Waves

High frequency radio waves travel in straight lines and have sky propagation. However, they are affected by interferences and are affected by rains. The military communicates in the HF and VHF bands. They are also used for long distance broadcasting and FM radio.

Applications

Some of the areas of applications of radio waves are −

- Broadcasting and multicasting
- Fixed and mobile radio communications
- AM and FM radio
- Television
- Marine communication
- Wireless computer networks
- Cordless phones

Microwave Transmission

In the electromagnetic spectrum, waves within the frequencies 1GHz to 300GHz are called microwaves.

Features of Microwaves

- Microwaves travel in straight lines, and so the transmitter and receiver stations should be accurately aligned to each other.
- Microwave propagation is line – of – sight propagation. So, towers hoisting the stations should be placed so that the curvature of the earth or any other obstacle does not interfere with the communication.
- Since it is unidirectional, it allows multiple receivers in a row to receive the signals without interference.
- Microwaves do not pass through buildings. So, indoor receivers cannot be used effectively.
- Microwaves are often refracted by the atmospheric layers. The refracted rays take longer time to reach the destination than the direct rays. This causes out of phase transmission, called multipath fading.
- Microwaves need unidirectional antennas to send out signals. Two types of antennas are needed −
    - **Parabolic Dish Antenna** − It is used by the receiving station. It is parabolic in shape, which concentrates all energy to a small beam thus achieving a strong signal with high SNR.

    - **Horn Antenna** − It has a stem with a curved head. In sending stations, outgoing waves from the stem are broadcast by the curved head as a series of parallel beams. In the receiving station, the rays are collected by the curved head and deflected in the stem.

- **Applications**
    - Long distance telephone communication
    - Cellular phones
    - Television networks
    - Satellites
    - Wireless LANs

Infrared Transmission

Infrared waves are those between the frequencies 300GHz and 400THz in the electromagnetic spectrum. Their wavelengths are shorter than microwaves but longer than visible light. Infrared propagation is line of sight.

They cannot penetrate walls and sun's infrared rays interfere with these rays. So cannot be used for long – range communication. As their usage is confined within closed space, they do not need any government permissions for their applications.

Applications of Infrared Waves in Communications

- Remote controls for television, stereos and other home appliances.
- Wireless LANs
- Wireless modem, keyboard, mouse, printer etc.
- Fire detectors
- Night vision systems
- Intrusion detection systems
- Motion detectors

Light Transmission

Electromagnetic waves within the frequency range of 400 THz – 790 THz are detected by the human eye. Light transmission is line of sight propagation and is blocked by obstacles.

Laser Signals

Optical signaling can be obtained by laser signals. For example, the LANs in two buildings can be connected by installing laser signaling system on the rooftops. Laser rays are unidirectional. So both the transmitter and the receiver need perfectly aligned photo-emitter and photo-detector.

Visual Light Communication

A more used variant of light transmission is visual light communication (VLC). VLC refers to data communication using visible spectrum of the light. It is part of optical wireless communication, which refers to data communication using infrared, visible and ultraviolet lights. VLC uses florescent lamps or LEDs to generate optical signals. The signals are received by photodiodes.

Application

Communication using light signals is safe for eyes and cost effective. Also, it does not require any license for usage. So, it is increasingly being used for ubiquitous computing and IoT systems

IEEE 802.11 Architecture

The components of an IEEE 802.11 architecture are as follows

1) Stations (STA) − Stations comprise all devices and equipments that are connected to the wireless LAN. A station can be of two types:

- **Wireless Access Points (WAP) −** WAPs or simply access points (AP) are generally wireless routers that form the base stations or access.
- **Client. −** Clients are workstations, computers, laptops, printers, smartphones, etc.

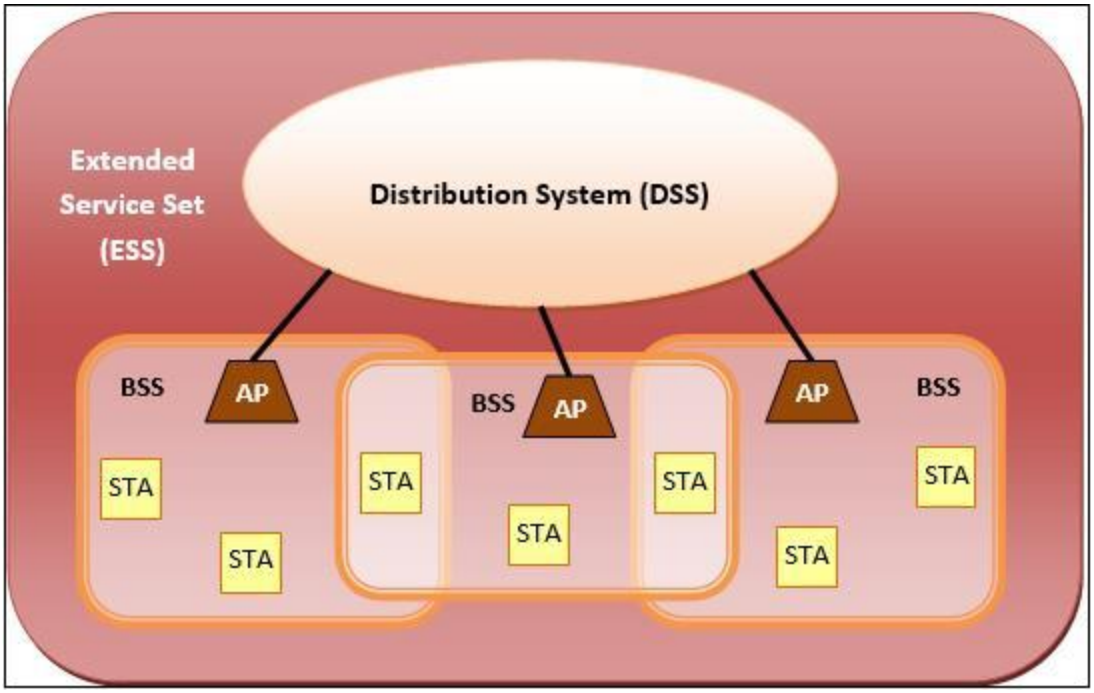
Each station has a wireless network interface controller.

2) Basic Service Set (BSS) −A basic service set is a group of stations communicating at physical layer level. BSS can be of two categories depending upon mode of operation:

- **Infrastructure BSS −** Here, the devices communicate with other devices through access points.
- **Independent BSS −** Here, the devices communicate in peer-to-peer basis in an ad hoc manner.

3) Extended Service Set (ESS) − It is a set of all connected BSS.

4) Distribution System (DS) − It connects access points in ESS.



Advantages of WLANs

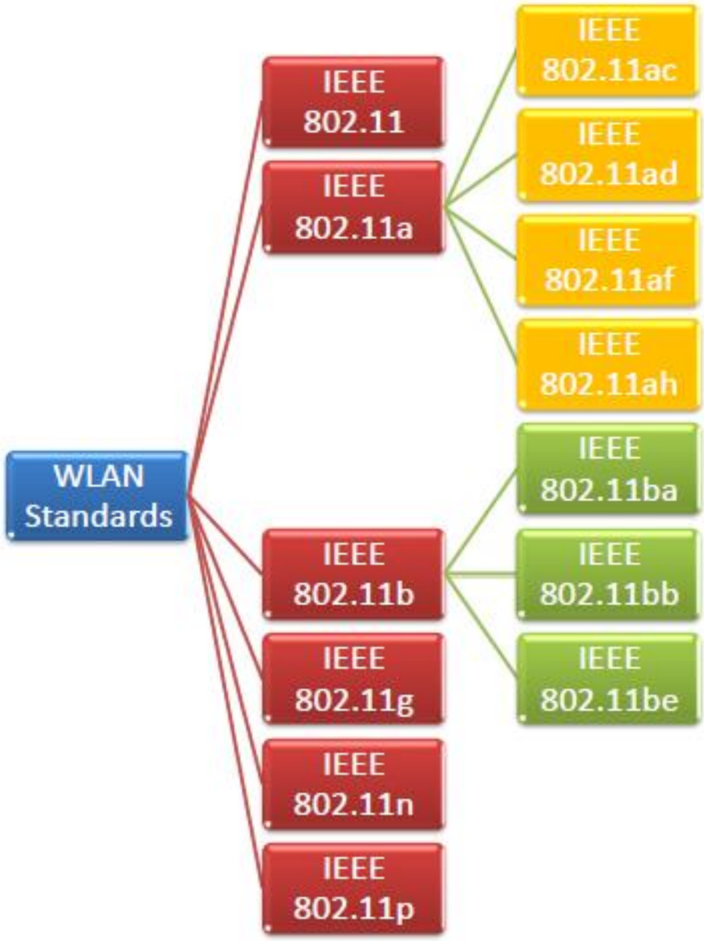
- They provide clutter free homes, offices and other networked places.
- The LANs are scalable in nature, i.e. devices may be added or removed from the network at a greater ease than wired LANs.
- The system is portable within the network coverage and access to the network is not bounded by the length of the cables.
- Installation and setup is much easier than wired counterparts.
- The equipment and setup costs are reduced.

Disadvantages of WLANs

- Since radio waves are used for communications, the signals are noisier with more interference from nearby systems.
- Greater care is needed for encrypting information. Also, they are more prone to errors. So, they require greater bandwidth than the wired LANs.
- WLANs are slower than wired LANs.

IEEE 802.11 standard, popularly known as WiFi, lays down the architecture and specifications of wireless LANs (WLANs). WiFi or WLAN uses high frequency radio waves for connecting the nodes.

There are several standards of IEEE 802.11 WLANs. The prominent among them are 802.11, 802.11a, 802.11b, 802.11g, 802.11n and 802.11p. All the standards use carrier-sense multiple access with collision avoidance (CSMA/CA). Also, they have support for both centralized base station based as well as ad hoc networks.



IEEE 802.11

IEEE 802.11 was the original version released in 1997. It provided 1 Mbps or 2 Mbps data rate in the 2.4 GHz band and used either frequency-hopping spread spectrum (FHSS) or direct-sequence spread spectrum (DSSS). It is obsolete now.

IEEE 802.11a

802.11a was published in 1999 as a modification to 802.11, with orthogonal frequency division multiplexing (OFDM) based air interface in physical layer instead of FHSS or DSSS of 802.11. It provides a maximum data rate of 54 Mbps operating in the 5 GHz band. Besides it provides error correcting code. As 2.4 GHz band is crowded, relatively sparsely used 5 GHz imparts additional advantage to 802.11a.

Further amendments to 802.11a are 802.11ac, 802.11ad, 802.11af, 802.11ah, 802.11ai, 802.11aj etc.

IEEE 802.11b

802.11b is a direct extension of the original 802.11 standard that appeared in early 2000. It uses the same modulation technique as 802.11, i.e. DSSS and operates in the 2.4 GHz band. It has a higher data rate of 11 Mbps as compared to 2 Mbps of 802.11, due to which it was rapidly adopted in wireless LANs. However, since 2.4 GHz band is pretty crowded, 802.11b devices faces interference from other devices.

Further amendments to 802.11b are 802.11ba, 802.11bb, 802.11bc, 802.11bd and 802.11be.

IEEE 802.11g

802.11g was indorsed in 2003. It operates in the 2.4 GHz band (as in 802.11b) and provides a average throughput of 22 Mbps. It uses OFDM technique (as in 802.11a). It is fully backward compatible with 802.11b. 802.11g devices also faces interference from other devices operating in 2.4 GHz band.

IEEE 802.11n

802.11n was approved and published in 2009 that operates on both the 2.4 GHz and the 5 GHz bands. It has variable data rate ranging from 54 Mbps to 600 Mbps. It provides a marked improvement over previous standards 802.11 by incorporating multiple-input multiple-output antennas (MIMO antennas).

IEEE 802.11p

802.11 is an amendment for including wireless access in vehicular environments (WAVE) to support Intelligent Transportation Systems (ITS). They include network communications between vehicles moving at high speed and the environment. They have a data rate of 27 Mbps and operate in 5.9 GHz band.