Layer2 (data-link layer) Protocols

The protocol operating at the data-link layer of the Open Systems Interconnection (OSI) reference model describes the nature of the network medium and performs the final preparation of outgoing data before it is transmitted. This protocol also receives incoming data, evaluates it, and, if necessary, passes it on to the appropriate network layer protocol. The most common data-link layer protocols are

1. Ethernet/ IEEE 802.3
2. Token Ring/ IEEE 802.5
3. Fiber Distributed Data Interface FDDI
4. IEEE 802.11 (for wireless LANS)

Ethernet/IEEE 802.3

Generally there are three Ethernet standards

- The oldest Ethernet standard designed to work with RG8 coaxial cables, it is developed by Digital Equipment Corporation, Intel, and Xerox, which came to be known as DIX Ethernet. DIX Ethernet also called Thicknet or 10Base5 first document was published in 1980.
- The DIX Ethernet II (or simply Ethernet II) standard, published in 1982, added a second physical layer option to the protocol using RG-58 coaxial cable. This standard is called thin Ethernet, Thinnet, Cheapernet, or 10Base2.
- Around the same time that these standards were published, the Institute of Electrical and Electronic Engineers (IEEE) develops an international standard define DIX Ethernet and DIX Ethernet II published in 1985 named IEEE 802.3. The other Ethernet physical layer standards including twisted pair and fiber optic cables with different transfer rates

The IEEE 802.3 standard differs only slightly from the DIX Ethernet standard. The IEEE standard contains additional physical layer options, as already noted, and some differences in the frame format. Development of the DIX Ethernet standards ceased after Ethernet II. When people use the term Ethernet today, it is understood that they actually mean IEEE 802.3 . The only element of the DIX Ethernet standard still in common use is the Ethernet II frame format.

Both the IEEE 802.3 and DIX Ethernet standards consist of the following three basic components:

- Physical layer specifications
- Frame format
- CSMA/CD MAC mechanism

➢ Physical Layer Specifications

The physical layer specifications included in the Ethernet standards describe the types of cables you can use to build the network, define the topology, and provide other crucial guidelines, such as the maximum cable segment length ,maximum speed, and encoding scheme. Physical Layer Specifications is an important part of building a reliable Ethernet network, because they limit the effects of problems like attenuation and crosstalk. Physical layer specifications also truly affect the MAC mechanism. Ethernet (IEEE 802.3) comes in four basic types according to bandwidth of each type. These are:

- Regular (standard) Ethernet: Bandwidth 10Mbps
- Fast Ethernet : Bandwidth 100Mbps
- Gigabit Ethernet : Bandwidth 1000Mbps (1Gbps)
- 10 Gigabit Ethernet : Bandwidth 10Gbps

Ethernet physical layer specifications are listed in the following table.

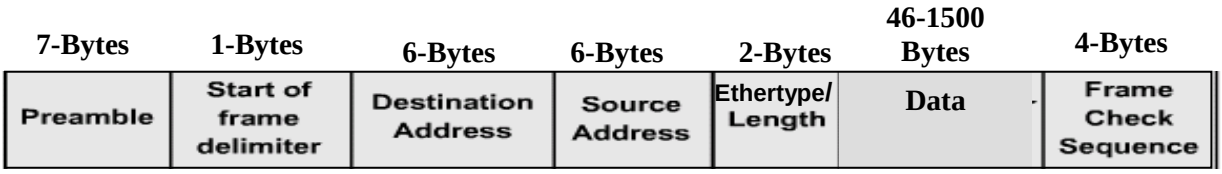
Type	Designation	Cable Type	Physical Topology	encoding	Maximum Segment Length
Standard Ethernet	10Base5	RG-8 coaxial	Bus	Manchester	500 m
	10Base2	RG-58 coaxial	Bus	Manchester	185 m
	10Base-T	Cat3, cat5 UTP	Star	Manchester	100 m
	10Base-F	Multimode fiber	Star	Manchester	100 m
Fast Ethernet	100Base-TX	Cat5, Cat5e, UTP	Star	4B/5B+MLT3	100 m
	100Base-FX	Multimode fiber	Star	4B/5B+NRZI	100 m
	100Base-T4	Cat3 UTP	Star	8B/6T	100 m
Gigabit Ethernet	1000Base-SX	Multimode fiber	Star	8B/10B+NRZL	550 m
	1000Base-LX	Singlemode fiber	Star	8B/10B+NRZL	5 km
	1000Base-CX	STP	Star	8B/10B+NRZL	25 m
	1000Base-T	Cat5e, Cat6 UTP	Star	4D-PAM5	100 m
10-Gigabit Ethernet	10GBase-S	Multimode fiber	Star	64B/66B	300 m
	10GBase-L	Singlemode fiber	Star	64B/66B	10 km

Notes

- The first number (for example in 10Base5, and 1000Base-T) stands for the Bandwidth (10Mbps for 10Base5 and 1000 Mbps for 1000Base-T).
- The term Base refers to baseband signaling.
- The last letter or number refers to the maximum segment length (500 meter for 10Base5) or to the media type (Twisted pair for 1000Base-T, Short wave for 10Gbase-S, Long wave for 10GBase-L, Extended for 10Gbase-E).

➢ Ethernet Frame

One of the primary functions of the Ethernet protocol is to encapsulate the data it receives from the network layer protocol in a frame, in preparation for its transmission across the network. The frame consists of a header, a footer (trailer), and the data comes from the network layer. Header and footer are divided into fields containing specific information needed to get each packet to its destination. Ethernet frame format is shown in the following Figure.



The functions and lengths of the Ethernet II and IEEE 802.3 frame fields are as follows:

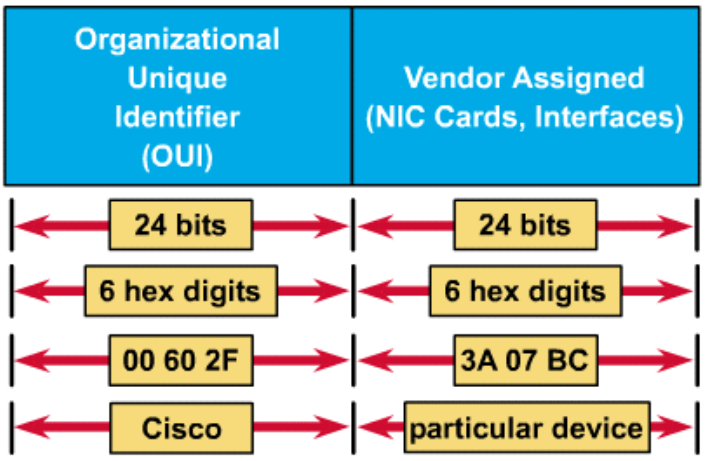
- **Preamble (7 bytes):** This field contains 7 bytes of alternating 0s and 1s, which the communicating systems use to synchronize their clock signals.
- **Start Of Frame (1 byte):** This field contains 6 bits of alternating 0s and 1s, followed by two consecutive 1s, which is a signal to the receiver that the transmission of the actual frame is about to begin.
- **Destination Address (6 bytes):** This field contains the 6-byte hexadecimal address of the network interface adapter on the local network to which the packet will be transmitted.
- **Source Address (6 bytes):** This field contains the 6-byte hexadecimal address of the network interface adapter in the system generating the packet.

- **Ethertype/Length (2 bytes):** In the DIX Ethernet frame, this field contains a code identifying the network layer protocol for which the data in the packet is intended. In the IEEE 802.3 frame, this field specifies the length of the data field (excluding the pad).
- **Data And Pad (46 to 1500 bytes):** This field contains the data received from the network layer protocol on the transmitting system. Ethernet frames (including the header and footer, except for the Preamble and Start Of Frame Delimiter) must be at least 64 bytes long; so if the data received from the network layer protocol is less than 46 bytes, the system adds padding bytes to bring it up to its minimum length.
- **Frame Check Sequence (4 bytes):** The Frame Check Sequence (FCS) field (4 bytes) is used to detect errors in a frame. It uses a cyclic redundancy check (CRC). The sending device includes the results of a CRC in the FCS field of the frame. The receiving device receives the frame and generates a CRC to look for errors.

➢ Addressing

Each of the Destination Address and Source Address fields use a 6-byte hardware addresses. This address coded into network interface adapters to identify systems on the network. Every network interface adapter has a unique hardware address (also called a Media Access Control(MAC) address, which consists of a 3-byte (6-hexadecimal characters) value called an Organizationally Unique Identifier (OUI), which is assigned to the adapter's manufacturer by the IEEE, plus another 3-byte (6-hexadecimal characters) value assigned by the manufacturer itself.

MAC address:
00-60-2F-3A-07-BC
or
00:60:2F:3A:07:BC



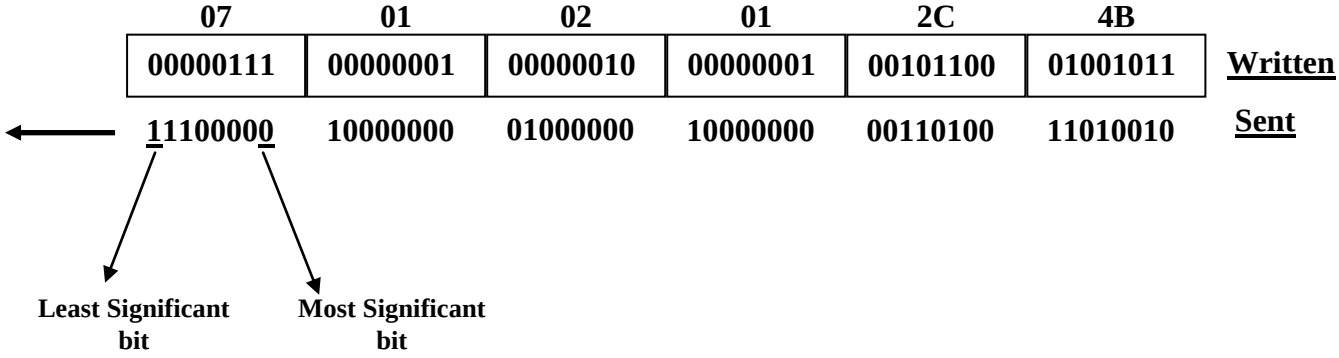
Ethernet, like all data-link layer protocols, is concerned only with transmitting packets to another system on the local network. So, we have two cases:

- If the packet's final destination is another system on the LAN, the Destination Address field contains the address of that system's network adapter.
- If the packet is destined for a system on another network, the Destination Address field contains the address of a router on the local network that provides access to the destination network. It is then up to the network layer protocol to supply a different kind of address (such as an Internet Protocol [IP] address) for the system that is the packet's ultimate destination.

Address Transmission:

MAC addresses are written in hexadecimal notation using a hyphen (-) or column (:) to separate bytes from each other. However the way addresses are sent is different from the way they are written. The transmission is left to right byte by byte starting with the least significant bit in each byte.

MAC address:
07-01-02-01-2C-4B

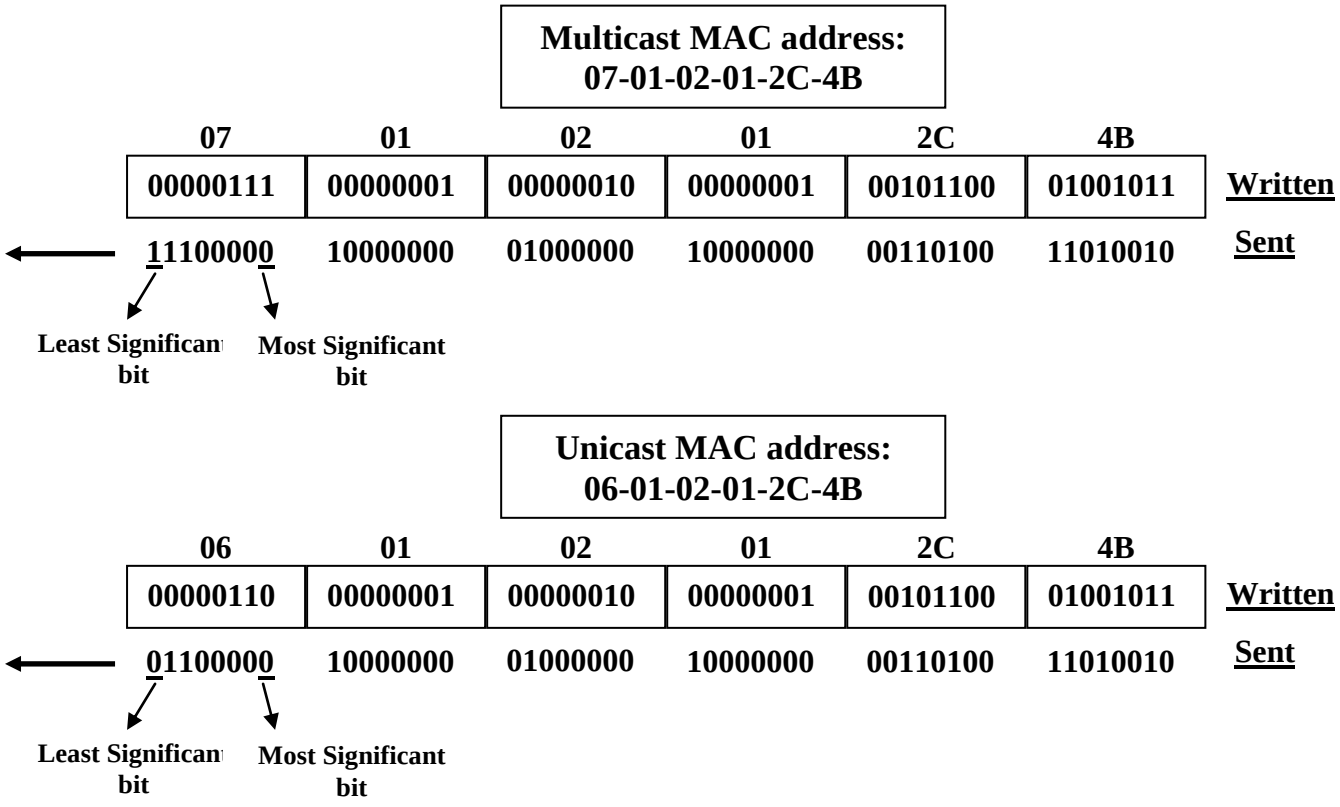


Types of MAC addresses

MAC addresses can be divided into unicast, multicast, and braodcast addresses.

Unicast address:- it is dedicated for single node, source address is of course a unicat address, but destination address can be unicast, multicast or broadcast.

Multicast address:- multicast destination address defines a group of nodes. If the first bit to be transmitted is one, the MAC address is multicast.



Broadcast address: it is a special multicast address consists of 48 ones (FF-FF-FF-FF-FF-FF). in case of broadcast destination address the recipient are the nodes in the network.

Slot time:-

It is an important factor that helps half-duplex standard and fast Ethernet networks to detect collisions. Slot time is the time occupied by the minimum length of an Ethernet frame (512 bit in standard and fast Ethernet). It depends on the bit time, so it varies with the type of Ethernet.

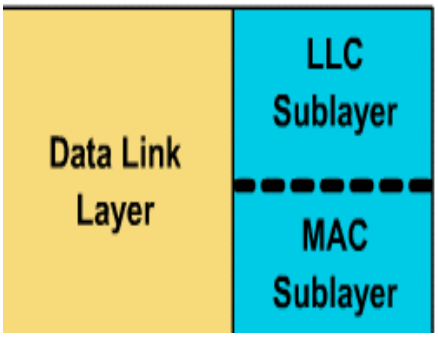
Ethernet type	Bandwidth	bit time	Slot time
Standard Ethernet	10Mbps	100 ns	51.2 micro s
Fast Ethernet	100Mbps	10 ns	5.12 micro s

➢ Ethertypes

The 2-byte field after the Source Address field is the primary difference between the DIX Ethernets and IEEE 802.3 standards. For any network that uses multiple protocols at the network layer, it is essential for the Ethernet frame to somehow identify which network layer protocol has generated the data in a particular packet. The DIX Ethernet frame does this simply by specifying an Ethertype in this field, using values like those shown in the following table .

Network Layer Protocol	Ethertype value (hexadecimal)
Internet Protocol (IP)	0800
Internetwork Packet Exchange (IPX)	8137

IEEE 802.3 takes a different approach. In this frame, the field after the Source Address specifies the length of the data in the packet. The frame uses an additional component, called the Logical Link Control (LLC), to identify the network layer protocol. Here the data-link layer is split into two sublayers; MAC sublayer and LLC sublayer.



The MAC sublayer is the part that contains the elements particular to the IEEE 802.3 specification, such as the Ethernet physical layer options, the frame, and the MAC mechanism. One of the main functions of the LLC sublayer is to define the network layer protocol. LLC is achieved by an additional 8-9 byte subheader that is carried within the Data field. This 8-9 byte subheader contains 2-byte field called Local Code that performs the same function as the Ethertype field in the Ethernet II header.

➢ Pause Packet:

Pause packet is used to slow down the flow of data frames between two devices at the ends of Ethernet full-duplex link. This mechanism is used overcome a temporary overload condition and not to prevent long or continuous congestion.

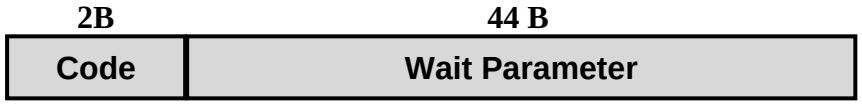
Pause packet depends a simple flow control method called "stop-start". In case of overloading, the station can ask the station on the other end to pause (stop) sending data frames for a specific time called "wait time". When the station receives pause packet, it

starts a timer and stops sending data frames until the timer expires. Then it resumes sending its data.

Even the paused station stops sending its data for the period of "wait time" it can still sending pause packets to ask other station to stop transmitting its data frames in the full duplex link.

In pause packet mechanism the station may send several pause packets. In this way that the last pause packet cancels the previous one. So, the station can ask to increase, decrease, or eliminate wait time.

Pause Packet Format



Code (2 Bytes): it is usually contains the hexadecimal code (0001).

Wait parameter (44 Bytes): this field used to find the wait time which is the multiplication of the value in the wait parameter field by the slot time.

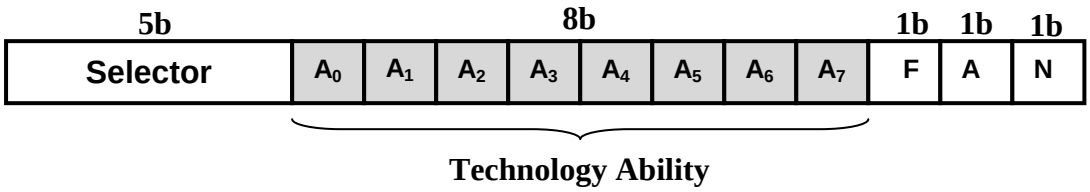
➢ Auto Negotiation:

Auto negotiation is a feature added to fast Ethernet networks. End and/or intermediate devices can use auto negotiation to decide the mode of transmission (half-duplex or full duplex) and the bandwidth (10Mbps or 100Mbps)

Auto negotiation rules:-

1. Two devices should be connected in a point-to-point link.
2. Negotiation covers only the link not the whole network.
3. Negotiation can occur only during link initialization.
4. Negotiation use separate frame format.
5. Each device in the link offers its capabilities for the other device.
6. Decision is based on common capabilities.

Auto negotiation frame format:



Selector (5b): this field used to describe the type of LAN. The code for Ethernet LANs is (10000).

Technology Ability (8b): a device advertising its capabilities can set one or more of the bits in this field.

Bit	Supported Technology
A_0	10Base-T
A_1	10Base-T full-duplex
A_2	100Base-TX
A_3	100Base-TX full-duplex
A_4	100Base-T4
A_5	Pause Operation
A_6	Reserved
A_7	Reserved

Fault (1b): this bit when set announces that a fault has been occur.

Acknowledged (1b): this bit when set indicates that the auto negotiation frame has received successfully.

Next Page (1b): this bit when set indicates that there is another negotiation frame coming.