Local Area Networks- Introduction

- LANs are packet-switched networks.
- Packets are often called frames in LAN context.
- They have limited geographical extension, usually ≤ 1 km
- Offer a shared transmission medium to multiple stations.
- Each device connected to a LAN has unique address.
- Often controlled by only one owner / administrative entity.
- In most cases, an organization will have multiple LANs that need to be interconnected.
- The topologies that have been used for LANs are ring, bus, and star.
- Hubs and switches form the basic building blocks of most LANs.
- Some application areas:
    - Connect desktop computers to share files, emails.
    - Allow several computers to share printers, file servers.

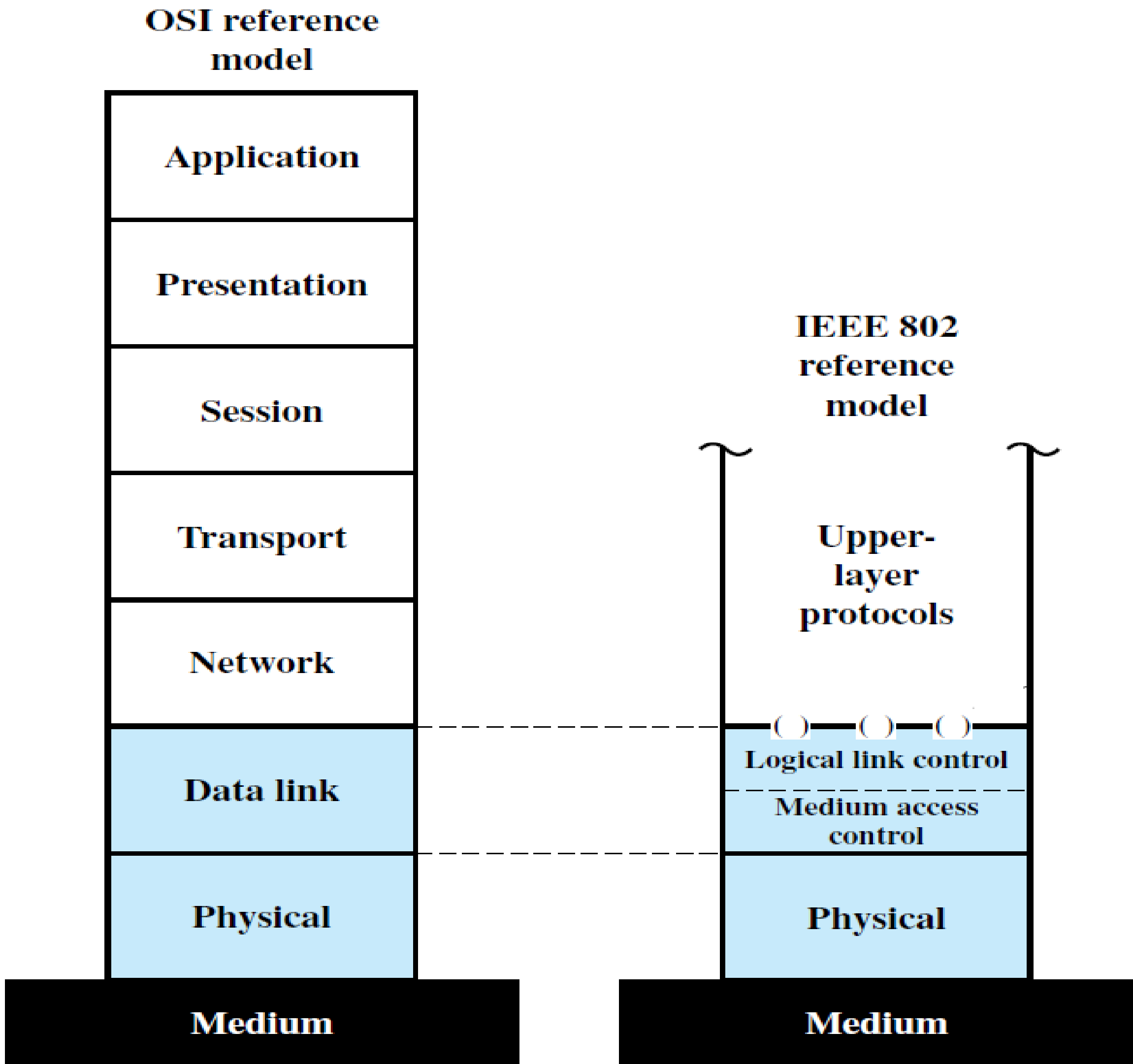
LAN Protocol Architecture

- Protocols defined for layer 3 and above are independent of underlying network topology.
- Hence, protocols designed for LANs are normally concerned with the data link layer and the physical layer.
- Organization working on LAN standard comply with the specifications of IEEE 802 reference model.
- LAN standards typically specify the following layers:
- Physical layer (PHY), specifying transmission media, data rates and network topologies.
- Medium Access Control (MAC) sublayer, specifying how stations share the transmission medium.
- Link layer (often called logical link control), providing error-control, flow-control, etc.

Data Link Layer

IEEE 802 Reference Model

- IEEE = Institute of Electrical and Electronics Engineers
- Some important standards series are:
- IEEE 802.1: Bridging, Network Management.
- IEEE 802.2: Logical Link Control (LLC)
- IEEE 802.3: Ethernet
- IEEE 802.11: Wireless LAN
- IEEE 802.15: Wireless Personal Area Network (WPAN), incl. Bluetooth

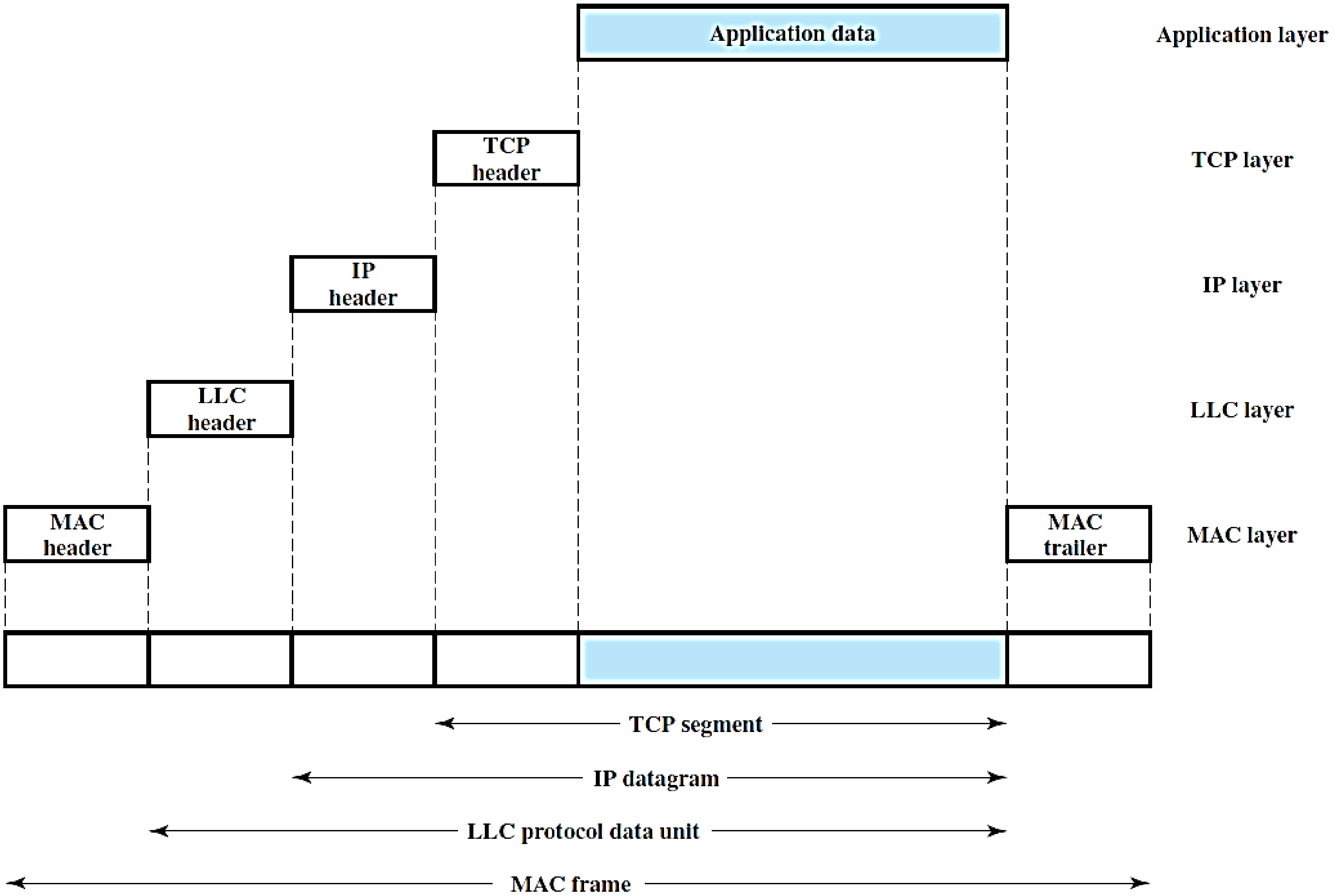


The Physical Layer

- The lowest layer of the IEEE 802 reference model corresponds to the physical layer of the OSI model and includes following functions:
  - Encoding/decoding of signals
  - Preamble generation/removal (for synchronization)
  - Bit transmission/reception
- In addition, the physical layer of the 802 model includes a specification of the transmission medium and the topology.
- Various transmission media, wired and wireless, are used in IEEE 802 standards.
- Wired transmission media includes twisted pair cabling (e.g. switched Ethernet), baseband coaxial cable, broadband coaxial cable and optical fibers.
- Wireless transmission media includes radio frequencies or infrared.

The Logical Link & MAC Layer

- Logical Link Layer - provides an interface to higher layers and perform flow and error control.
- Higher level data are passed down to LLC, which appends control information as a header, creating an LLC protocol data unit (PDU).This control information is used in the operation of the LLC protocol.
- MAC Layer - govern access to the LAN transmission medium.
- The entire LLC PDU is passed down to the MAC layer, which appends control information at the front and back of the packet, forming a MAC frame. The control information in the frame is needed for the operation of the MAC protocol.


Application data
Application layer
TCP header
TCP layer
IP header
IP layer
LLC header
LLC layer
MAC header
MAC trailer
MAC layer
TCP segment
IP datagram
LLC protocol data unit
MAC frame

MAC Frame Format

- The MAC layer receives a block of data from the LLC layer and is responsible for performing functions related to medium access and for transmitting the data.
- As with other protocol layers, MAC implements these functions making use of a protocol data unit at its layer. The PDU is referred to as a MAC frame.
- The exact format of the MAC frame differs somewhat for the various MAC protocols in use. The fields of this frame are:
  - MAC Control - This field contains any protocol control information needed for the functioning of the MAC protocol.
  - Destination MAC Address - The destination physical attachment point on the LAN for this frame.
  - Source MAC Address - The source physical attachment point on the LAN for this frame.
  - LLC - The LLC data from the next higher layer.
  - CRC - The Cyclic Redundancy Check field (also known as the frame check sequence, FCS, field). This is an error-detecting code, as we have already seen.

MAC Control	Destination MAC Address	Source MAC Address	LLC PDU	CRC

MAC & IP Address

- Each node has an IP address and each node's adapter(network interface) to its link has a link layer address, which is called as MAC address or LAN address or physical address.
- A MAC address is 6 bytes wide and is represented in hexadecimal notation e.g. 00-40-33-25-85-BB
- A MAC address is unique for each device and is permanently stored in adaptor's ROM. How does a company manufacturing adapters in ABC country make sure that it is using different addresses from a company manufacturing adapters in XYZ? The answer is IEEE manages the MAC address space. In particular, when a company wants to manufacture adapters, it purchases a chunk of the address space consisting of 2^{24} addresses for a nominal fee. IEEE allocates the chunk of 2^{24} addresses by fixing the first 24 bits of a MAC address and letting the company create unique combinations of the last 24 bits for each adapter.
- An adapter's MAC address has a flat structure unlike IP which is hierarchical. When an adapter wants to send a frame to some destination adapter, the sending adapter inserts the destination adapter's MAC address into the frame and then sends the frame into the LAN. When an adapter receives a frame, it will check to see whether the destination MAC address in the frame matches its own MAC address. If there is a match, the adapter extracts the enclosed datagram and passes the datagram up the protocol stack. If there isn't a match, the adapter discards the frame, without passing the network layer datagram up.
- However, sometimes a sending adapter does want all the other adapters on the LAN to receive and process the frame it is about to send. In this case, the sending adapter inserts a special MAC broadcast address into the destination address field of the frame. For LANs, the broadcast address is a string of 48 consecutive 1s (that is, FF-FF-FF-FF-FF-FF in hexadecimal notation).

Address Resolution Protocol

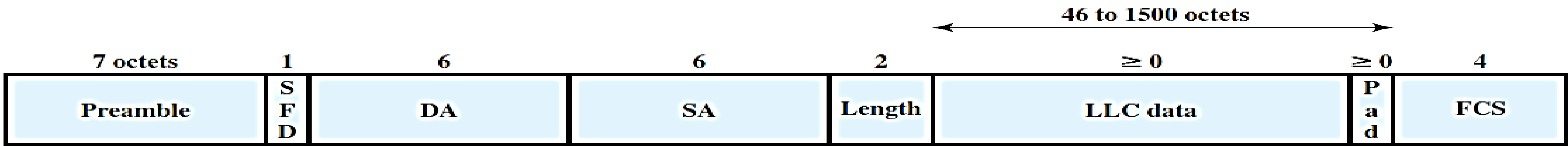
- The Address Resolution Protocol is designed to convert IP address to MAC address.
- Suppose a user wants to transmit a packet to its destination. The source device will first check its local ARP table /cache to determine if it already has a resolution of the destination device.
- If it does not know the link layer address of destination, the sender broadcasts an ARP Request message requesting the link layer address given the IP address. The destination is denoted by its IP address in the ARP request message.
- The message is received by each device on the local network. It is processed, with each device looking for a match on the destination IP address. Those that do not match will drop the message and take no further action.
- The one device whose IP address matches the contents of the destination IP Address of the ARP Request message will generate an ARP Reply message. The destination device will also add an entry to its own ARP table/cache containing the hardware and IP addresses of the source that sent the ARP Request. This saves the destination from needing to do an unnecessary resolution cycle later on. The destination device sends the ARP reply message as a unicast to the source device, as there is no need to broadcast it.
- The source device processes the reply from the destination. It stores this received MAC address and IP address to update its ARP cache for use in the future when transmitting to this device.

Ethernet LAN : IEEE 802.3 Standard

- Most widely used high speed LANs today developed by the IEEE 802.3 standards committee.
- The original Ethernet LAN was invented in the mid 1970s by Bob Metcalfe and David Boggs at Xerox PARC.
- The original Ethernet LAN used a coaxial bus to interconnect the nodes. Bus topologies for Ethernet persisted throughout the 1980s and into the mid 1990s. Ethernet with a bus topology is a broadcast LAN—all transmitted frames travel to and are processed by all adapters connected to the bus. Ethernet uses CSMA/CD (1 – persistent CSMA) for controlling media access.
- By the late 1990s, most companies and universities had replaced their LANs with Ethernet installations using a hub based star topology. In such an installation the hosts (and routers) are directly connected to a hub with twisted pair copper wire. Ethernet with a hub based star topology is also a broadcast LAN—whenever a hub receives a bit from one of its interfaces, it sends a copy out on all of its other interfaces. In particular, if a hub receives frames from two different interfaces at the same time, a collision occurs and the nodes that created the frames must retransmit.
- In the early 2000s Ethernet installations continued to use a star topology, but the hub at the center was replaced with a switch.
- Token ring, FDDI, and ATM were competitors of Ethernet and succeeded in capturing a part of the LAN market for a few years but Ethernet is by far the most prevalent wired LAN technology because of following reasons:
  - Token ring, FDDI, and ATM are more complex and expensive than Ethernet.
  - Ethernet provides higher data rates.
  - Ethernet hardware (in particular, adapters and switches) has become a commodity and is remarkably cheap.

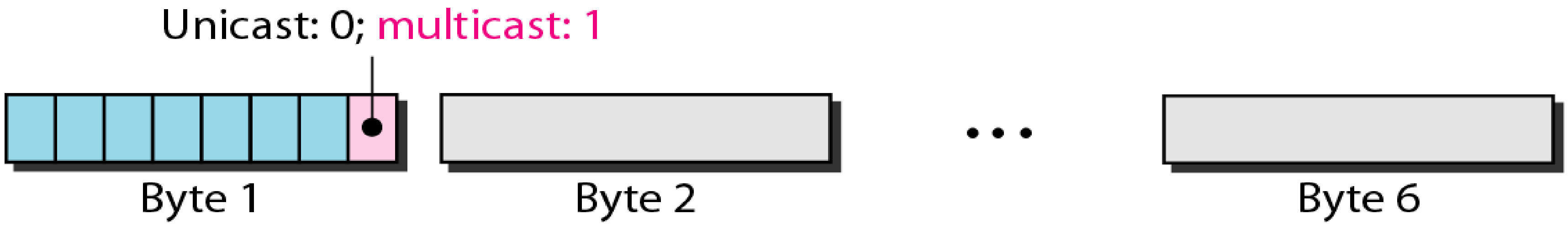
Ethernet Frame Format

- It consists of following fields:
- Preamble: A 7-octet pattern of alternating 0s and 1s used by the receiver to establish bit synchronization.
- Start Frame Delimiter (SFD): The sequence 10101011, which indicates the actual start of the frame and enables the receiver to locate the first bit of the rest of the frame.
- Destination Address (DA): Specifies the station(s) for which the frame is intended. It may be a unique physical address.
- Source Address (SA): Specifies the physical address of the station that sent the frame.
- Length/Type: Length of LLC data field in octets, or Ethernet Type field, The type field permits Ethernet to multiplex network layer protocols such as IPv4, AppleTalk, ARP etc.
- LLC Data: Data unit supplied by LLC. This field carries the IP datagram. The maximum transmission unit (MTU) of Ethernet is 1,500 bytes. The minimum size of the data field is 46 bytes. This means that if the IP datagram is less than 46 bytes, the data field has to be “stuffed” to fill it out to 46 bytes (padded with 0). When stuffing is used, the data passed to the network layer contains the stuffing as well as an IP datagram. The network layer uses the length field in the IP datagram header to remove the stuffing.
- Pad: Octets added to ensure that the frame is long enough for proper operation.
- Frame Check Sequence (FCS): A 32-bit cyclic redundancy check, based on all fields except preamble, SFD, and FCS.



Ethernet Addresses

- Address fields are 48 bits long.
- Each Ethernet adapter has its own address, typically burned into adapter hardware.
- Addresses are required to be globally unique.
- Each vendor gets own address range and assigns unique addresses from that range.
- Address representation as six colon separated bytes in hexadecimal representation, e.g. 00:0c:29:10:fb:f3
- Special addresses and address ranges:
  - Broadcast address: FF:FF:FF:FF:FF:FF
  - Addresses with first bit set to 1 but different from broadcast address are multicast addresses.
  - Addresses with first bit set to 0 are unicast addresses.



Ethernet Technologies

- The IEEE 802.3 committee has defined a number of physical configurations.
- To distinguish the various implementations that are available, the committee has developed a concise notation:

<data rate in Mbps><signaling method><maximum segment length in hundreds of meters or letters for special types of media>

e.g. 10Base5 or 10BaseT

- The first part of the acronym refers to the speed of the standard: 10, 100, 1000, or 10G, for 10 Megabit (per second), 100 Megabit, Gigabit, and 10 Gigabit Ethernet, respectively. “BASE” refers to baseband Ethernet, meaning that the physical media only carries Ethernet traffic; almost all of the 802.3 standards are for baseband Ethernet. The final part of the acronym refers to the physical media itself; Ethernet is both a link layer and a physical layer specification and is carried over a variety of physical media including coaxial cable, copper wire, and fiber. Generally, a “T” refers to twisted-pair copper wires.

Common Ethernet Technologies

- 10BASE5: 10 Mbps, 500 m segment length (coaxial cable) used in bus topology.
- 10BASE2: Similar to 10BASE5 but uses a thinner cable. 185 meter segment length.
- 10BASE-T: 10 Mbps and uses unshielded twisted pair in a star topology. Because of the high data rate and the poor transmission qualities of unshielded twisted pair, the length of a link is limited to 100 meters.
- 10BASE-F: 10 Mbps , fiber optics cable with star topology for interconnecting stations and repeaters with up to 2 km.
- Fast Ethernet refers to a set of specifications developed by the IEEE 802.3 committee to provide a low cost, Ethernet compatible LAN operating at 100 Mbps.
- 100BASE-X: For all of the transmission media specified under 100BASE-X, a unidirectional data rate of 100 Mbps is achieved transmitting over a single link (single twisted pair, single optical fiber). The 100BASE-X designation includes two physical medium specifications, one for twisted pair, known as 100BASE-TX, and one for optical fiber, known as 100-BASE-FX. 100BASE-TX makes use of two pairs of twisted-pair cable, one pair used for transmission and one for reception. Both STP and Category 5 UTP are allowed. 100BASE-FX makes use of two optical fiber cables, one for transmission and one for reception.
- The need for an even higher data rate resulted in the design of the Gigabit Ethernet protocol (1000 Mbps). Some of the physical layer options are: 1000Base-T,10GBase-S and more.