Computer Networks

Lecture 8

Local Area Network, IEEE 802.x

Local area network

A local area network (LAN) is a computer network that interconnects computers within a limited area such as a home, school, computer laboratory, or office building, using network media. The defining characteristics of LANs include their smaller geographic area, and non-inclusion of leased telecommunication lines.

Features

- Large throughput (1-10 Gbps)
- Small number of nodes (VGTU LAN ~3000 PC)
- Topology: bus, star

Local area network

LAN technologies include data link layer and physical layer

LAN technologies are specified in IEEE 802.x standads.

LAN technologies:

- Ethernet (802.3)
- Token Ring (802.5)
- FDDI (*Fibre Distributed Data Interface*)
- IEEE 802.11 (WLAN)

Data link layer

The Data Link layer provides a means for exchanging data over a common local media.

The Data Link layer performs two basic services:

- Allows the upper layers to access the media using techniques such as framing
- Controls how data is placed onto the media and is received from the media using techniques such as media access control and error detection

Data link layer

Layer 2 protocols specify the encapsulation of a packet into a frame and the techniques for getting the encapsulated packet on and off each medium. The technique used for getting the frame on and off media is called the media access control method.

The media access control methods described by the Data Link layer protocols define the processes by which network devices can access the network media and transmit frames in diverse network environments.

Data link sublayer

To support a wide variety of network functions, the Data Link layer is often divided into two sublayers: an upper sublayer and an lower sublayer.

The upper sublayer defines the software processes that provide services to the Network layer protocols.

The lower sublayer defines the media access processes performed by the hardware. Separating the Data Link layer into sublayers allows for one type of frame defined by the upper layer to access different types of media defined by the lower layer. Such is the case in many LAN technologies, including Ethernet.

The two common LAN sublayers are:

Logical Link Control and Media Access Control

Data link sublayer

Logical Link Control (LLC) places information in the frame that identifies which Network layer protocol is being used for the frame. This information allows multiple Layer 3 protocols, such as IP and IPX, to utilize the same network interface and media.

Media Access Control (MAC) provides Data Link layer addressing and delimiting of data according to the physical signaling requirements of the medium and the type of Data Link layer protocol in use.

Media Access Control

MAC defines procedures to access media and to transfer frames to another network devices.

MAC layer also defines **physical addresses of the nodes**.

Media access approaches:

- Random access method
- Deterministic method

Random access method

Refers to the ability to access data in random way it means that no special requirements are needed.

This method in decentralized and there is no device that is used to control access to the media.

Random access method

Disadvantages

A **collision** is the situation that occurs when two or more devices attempt to send a signal (packets) along the same transmission channel at the same time (simultaneously).

Collision can cause loss of the data and require retransmission.

Collisions are considered normal events in Ethernets, and the **CSMA/CD** (carrier sense multiple access/collision detection) protocol is designed to quickly restore the network to normal activity and use a built-in delay algorithm to make certain that the collision does not reoccur.

Deterministic method

Deterministic method is managed method for network access.

Algorithms:

- Token passing
  - Token is right to transfer data
  - Token is transfered in ring topology
  - Limited time to handle token
- Survey
  - Survey is used to find the node that wants to transfer data.

MAC address

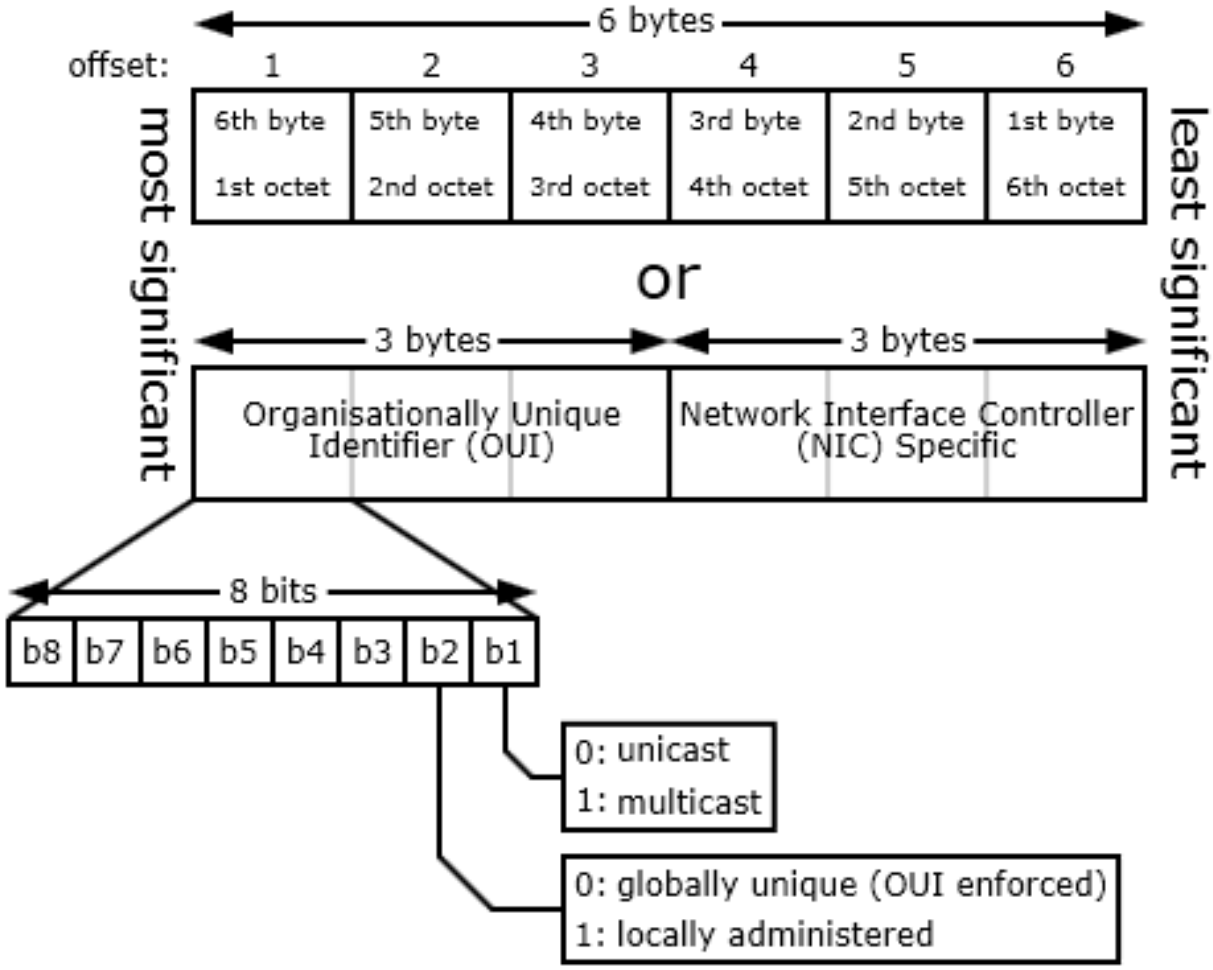
- Media access control address (MAC address) is a unique identifier assigned to network interfaces for communications on the physical network segment. MAC addresses are used as a network address for most IEEE 802 network technologies, including Ethernet and WiFi. Logically, MAC addresses are used in the media access control protocol sublayer of the OSI reference model.

MAC address

- MAC addresses are most often assigned by the manufacturer of a network interface controller (NIC) and are stored in its hardware, such as the card's read-only memory or some other firmware mechanism. If assigned by the manufacturer, a MAC address usually encodes the manufacturer's registered identification number and may be referred to as the burned-in address (BIA). It may also be known as an Ethernet hardware address (EHA), hardware address or physical address.

- A network node may have multiple NICs and each NIC must have a unique MAC address.

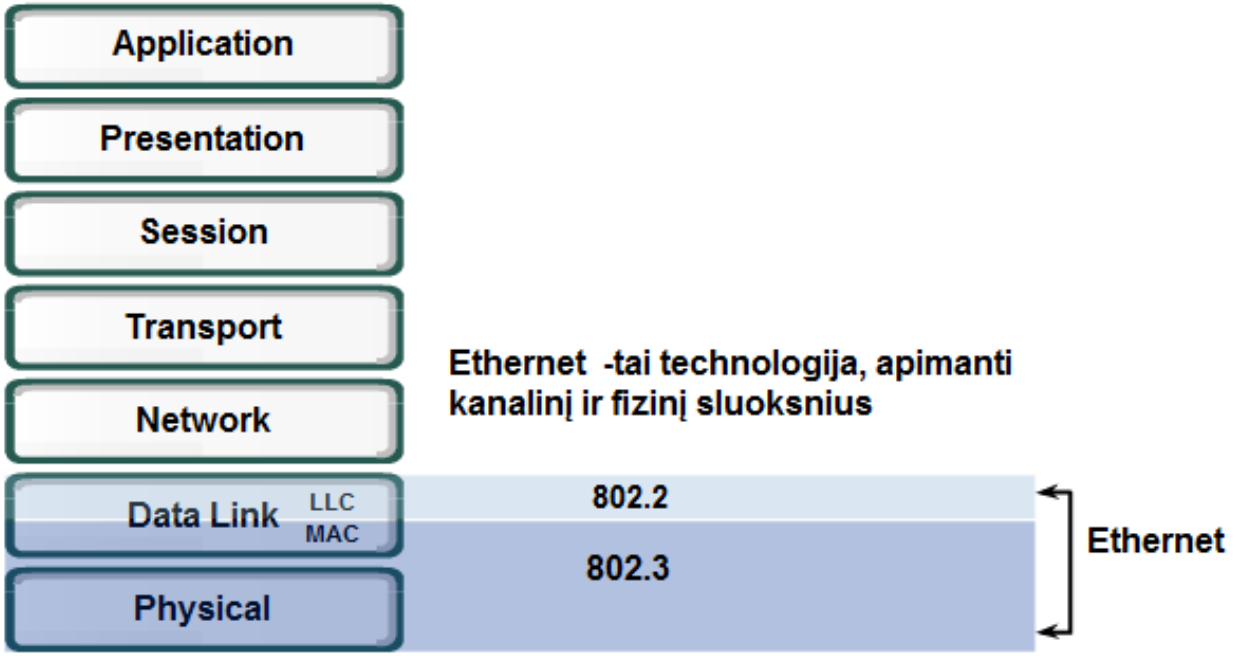
MAC address


6 bytes
offset:
1
2
3
4
5
6
6th byte
1st octet
5th byte
2nd octet
4th byte
3rd octet
3rd byte
4th octet
2nd byte
5th octet
1st byte
6th octet
most significant
least significant
or
3 bytes
3 bytes
Organisationally Unique Identifier (OUI)
Network Interface Controller (NIC) Specific
8 bits
b8
b7
b6
b5
b4
b3
b2
b1
0: unicast
1: multicast
0: globally unique (OUI enforced)
1: locally administered

Ethernet

Ethernet is a family of computer networking technologies for local area networks. It was commercially introduced in 1980 and first standardized in 1983 as IEEE 802.3 .

Ethernet bandwidth is 10, 100, 1000, 10,000 Mbps.



Ethernet history

Ethernet was developed at Xerox PARC in 1973. It was inspired by ALOHAnet, which Robert Metcalfe had studied as part of his PhD dissertation.

The idea was first documented in a memo that Metcalfe wrote in 1973, where he named it after the disproven luminiferous ether as an "omnipresent, completely-passive medium for the propagation of electromagnetic waves".

In 1975, Xerox filed a patent application listing Metcalfe, David Boggs, Chuck Thacker, and Butler Lampson as inventors.

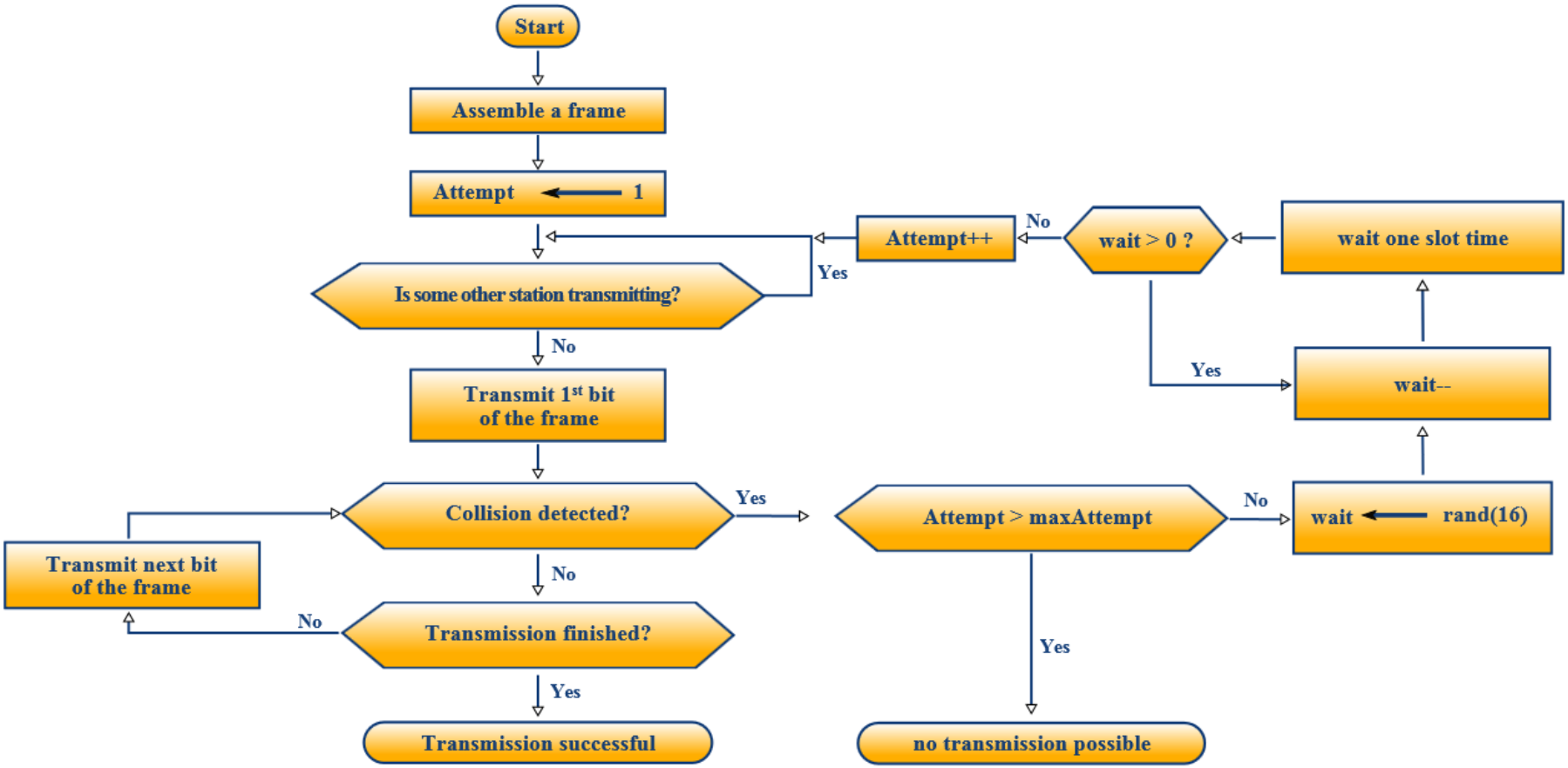
In 1976, after the system was deployed at PARC, Metcalfe and Boggs published a seminal paper.

CSMA/CD

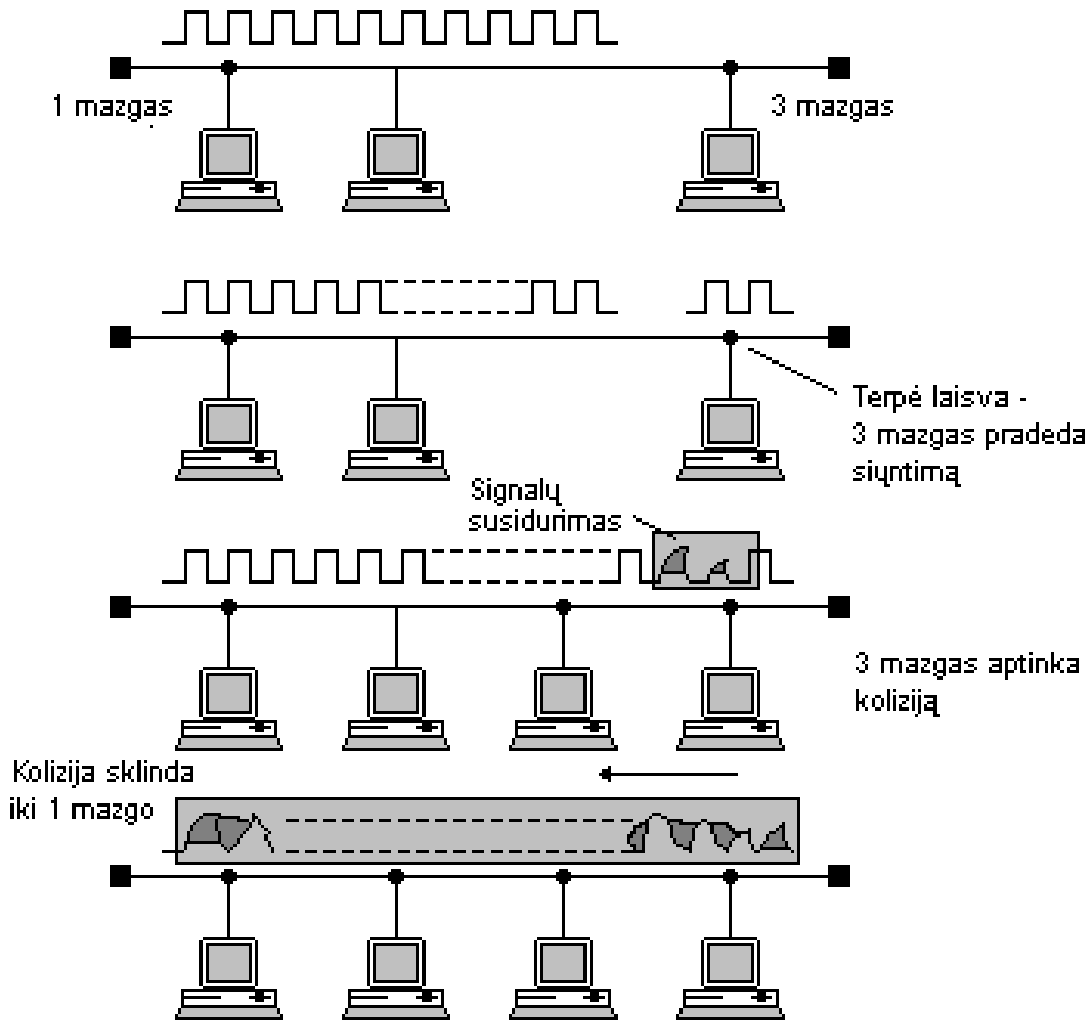
Carrier Sense Multiple Access With Collision Detection (CSMA/CD) is a media access control method used most notably in local area networking using early Ethernet technology. It uses a carrier sensing scheme in which a transmitting data station detects other signals while transmitting a frame, and stops transmitting that frame, transmits a jam signal, and then waits for a random time interval before trying to resend the frame.

CSMA/CD is a modification of pure carrier sense multiple access (CSMA). CSMA/CD is used to improve CSMA performance by terminating transmission as soon as a collision is detected, thus shortening the time required before a retry can be attempted.

CSMA/CD algorithm



Collision detection

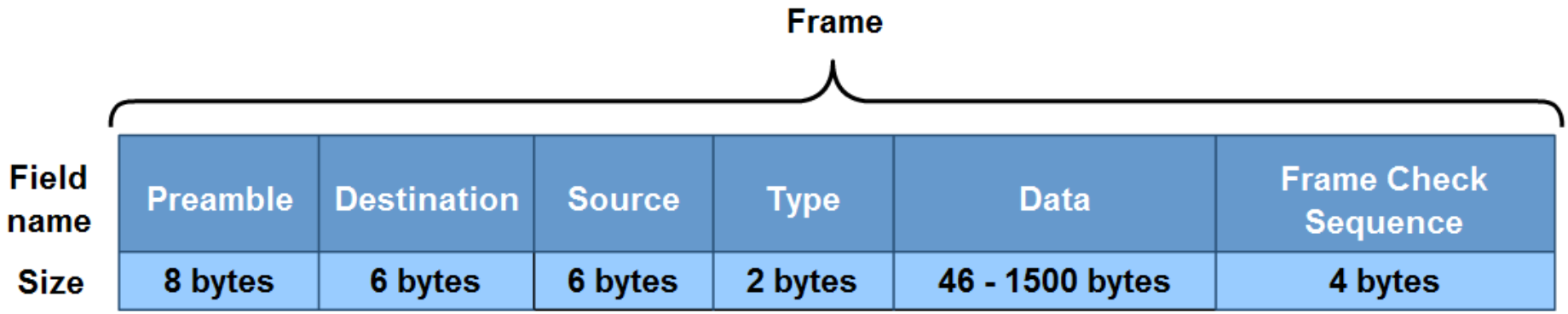


Collision domain

A **collision domain** is a logical area in a network in which packets can collide with one another. It is delimited by routers and network switches, and it can be comprised of a single segment of cable in an Ethernet network or it can include numerous repeaters and hubs.

Collision domain can be reduced when switches are used in the network instead of hubs.

Ethernet frame



Preamble - used for synchronization; also contains a delimiter to mark the end of the timing information.

Destination Address - 48 bit MAC address for the destination node.

Source Address - 48 bit MAC address for the source node.

Type - value to indicate which upper layer protocol will receive the data after the Ethernet process is complete.

Data or payload - this is the PDU, typically an IPv4 packet, that is to be transported over the media.

Frame Check Sequence (FCS) - A value used to check for damaged frames.

Performance of Ethernet

Ethernet frame 46-1500 bytes.

Frame size:

- min 46 + 26 = 72 bytes
- max 1500 + 26 = 1526 bytes

Bandwidth 10 Mbps, **frame transmission time T_k**:

- min $72*8 / 10^7 = 57{,}6 * 10^{-6}$ s
- max $1526*8 / 10^7 = 1220{,}8 * 10^{-6}$ s

Number of frames per second, 10 Mbps:

- min $1 / (57{,}6 * 10^{-6} + 9{,}6 * 10^{-6}) = 14880$ frames/sec
- max $1 / (1220{,}8 * 10^{-6} + 9{,}6 * 10^{-6}) = 813$ frames/sec

Efficiency

- min 14880 * 46 * 8 = **5,48 Mbps**
- max 813 * 1500 * 8 = **9,76 Mbps**

Ethernet specifications

Ethernet specifications:

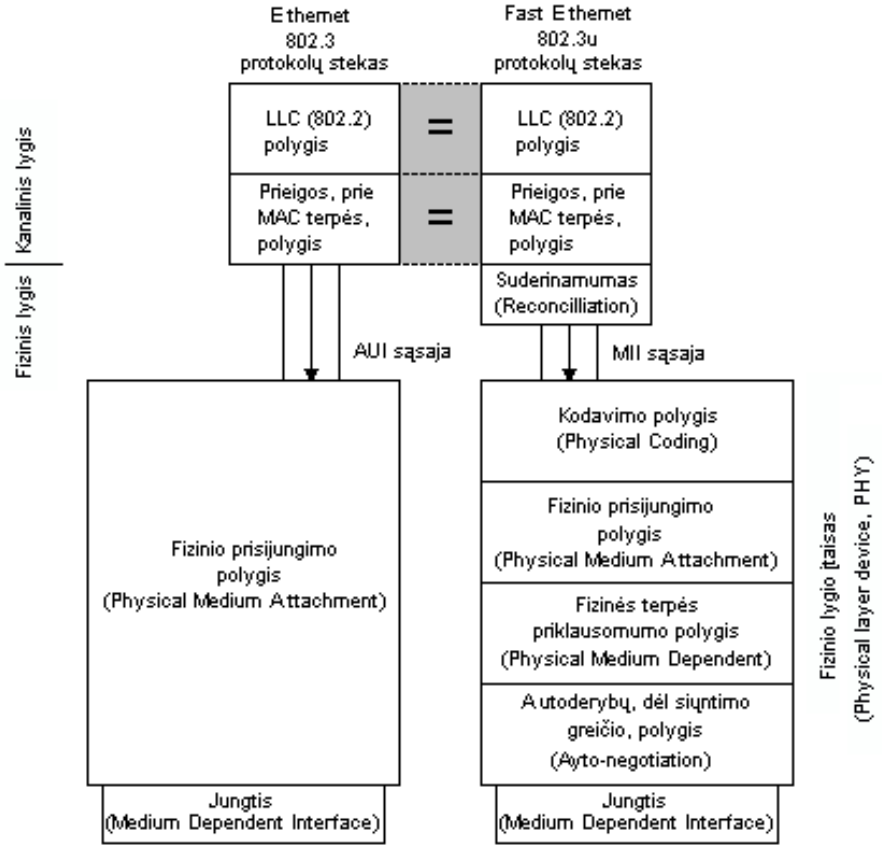
- **10Base-5**
- **10Base-2**
- **10Base-T**
- **10Base-F**

The **10** refers to its transmission speed of 10 Mbit/s.

The **BASE** is short for baseband signaling as opposed to broadband.

Fast Ethernet

Fast Ethernet (100 Mbps) is specified as IEEE 802.3u standard



Fast Ethernet

Fast Ethernet is an extension of the Ethernet standard. It runs on UTP data or optical fiber cable in a star wired bus topology, similar to 10BASE-T where all cables are attached to a hub.

Fast Ethernet provides compatibility with existing 10BASE-T systems, enabling plug-and-play upgrades from 10BASE-T. Fast Ethernet is sometimes referred to as 100BASE-X, where "X" is a placeholder for the FX and TX variants.

The standard specifies the use of CSMA/CD for media access control, although in practice all modern networks use Ethernet switches and operate in full-duplex mode.

The "100" refers to the transmission speed of 100 Mbit/s, while the "BASE" refers to baseband signaling.

Fast Ethernet specifications

- **100Base-T** is any of several Fast Ethernet standards for twisted pair cables.
- **100Base-TX** is the predominant form of Fast Ethernet, and runs over two wire-pairs inside a category 5 or above cable.
- **100Base-T4** early implementation of Fast Ethernet. It requires four twisted copper pairs, but those pairs were only required to be category 3 rather than the category 5 required by TX.
- **100Base-FX** is a version of Fast Ethernet over optical fiber. It uses a 1300 nm near-infrared (NIR) light wavelength transmitted via two strands of optical fiber, one for receive(RX) and the other for transmit(TX). Max length is 412 metres.

Gigabit Ethernet

Gigabit Ethernet (GbE or 1 GigE) is a term describing various technologies for transmitting Ethernet frames at a rate of a gigabit per second, as defined by the IEEE 802.3-2008 standard.

It came into use beginning in 1999, gradually supplanting Fast Ethernet in wired local networks, where it performed considerably faster.

There are five physical layer standards for Gigabit Ethernet using optical fiber (1000BASE-X), twisted pair cable (1000BASE-T), or shielded balanced copper cable (1000BASE-CX).

Gigabit Ethernet specifications

- **1000Base-X** is used in industry to refer to Gigabit Ethernet transmission over fiber, where options include 1000BASE-SX, 1000BASE-LX, 1000BASE-LX10, 1000BASE-BX10 or the non-standard -EX and -ZX implementations
- **1000Base-CX** 1000BASE-CX is an initial standard for Gigabit Ethernet connections with maximum distances of 25 meters using balanced shielded twisted pair. The short segment length is due to very high signal transmission rate. Although it is still used for specific applications where cabling is done by IT professionals, for instance the IBM BladeCenter uses 1000BASE-CX for the Ethernet connections between the blade servers and the switch modules, 1000BASE-T has succeeded it for general copper wiring use.

Gigabit Ethernet specifications

- **1000BASE-SX** is a fiber optic Gigabit Ethernet standard for operation over multi-mode fiber using a 770 to 860 nanometer, near infrared (NIR) light wavelength. The standard specifies a distance capability between 220 metres (62.5/125 μm fiber with low modal bandwidth) and 550 metres (50/125 μm fiber with high modal bandwidth). In practice, with good quality fiber, optics, and terminations, 1000BASE-SX will usually work over significantly longer distances.

Gigabit Ethernet specifications

- 1000BASE-LX is a fiber optic Gigabit Ethernet standard specified in IEEE 802.3 Clause 38 which uses a long wavelength laser (1,270–1,355 nm), and a maximum RMS spectral width of 4 nm.
- 1000BASE-LX is specified to work over a distance of up to 5 km over 10 μm single-mode fiber.
- 1000BASE-LX can also run over all common types of multi-mode fiber with a maximum segment length of 550m.

Gigabit Ethernet specifications

- 1000BASE-T (also known as IEEE 802.3ab) is a standard for Gigabit Ethernet over copper wiring.
- Each 1000BASE-T network segment can be a maximum length of 100 meters, and must use Category 5 cable or better (including Cat 5e and Cat 6).
- 1000BASE-T uses all four cable pairs for simultaneous transmission in both directions through the use of adaptive equalization and a five-level pulse amplitude modulation (PAM-5) technique. The symbol rate is identical to that of 100BASE-TX (125 megabaud) and the noise immunity of the five-level signaling is also identical to that of the three-level signaling in 100BASE-TX, since 1000BASE-T uses four-dimensional trellis coded modulation (TCM) to achieve a 6 dB coding gain across the four pairs.

Token Ring

Token ring is a protocol which resides at the data link layer. It uses a special three-byte frame called a token that travels around the ring.

Token-possession grants the possessor permission to transmit on the medium. Token ring frames travel completely around the loop.

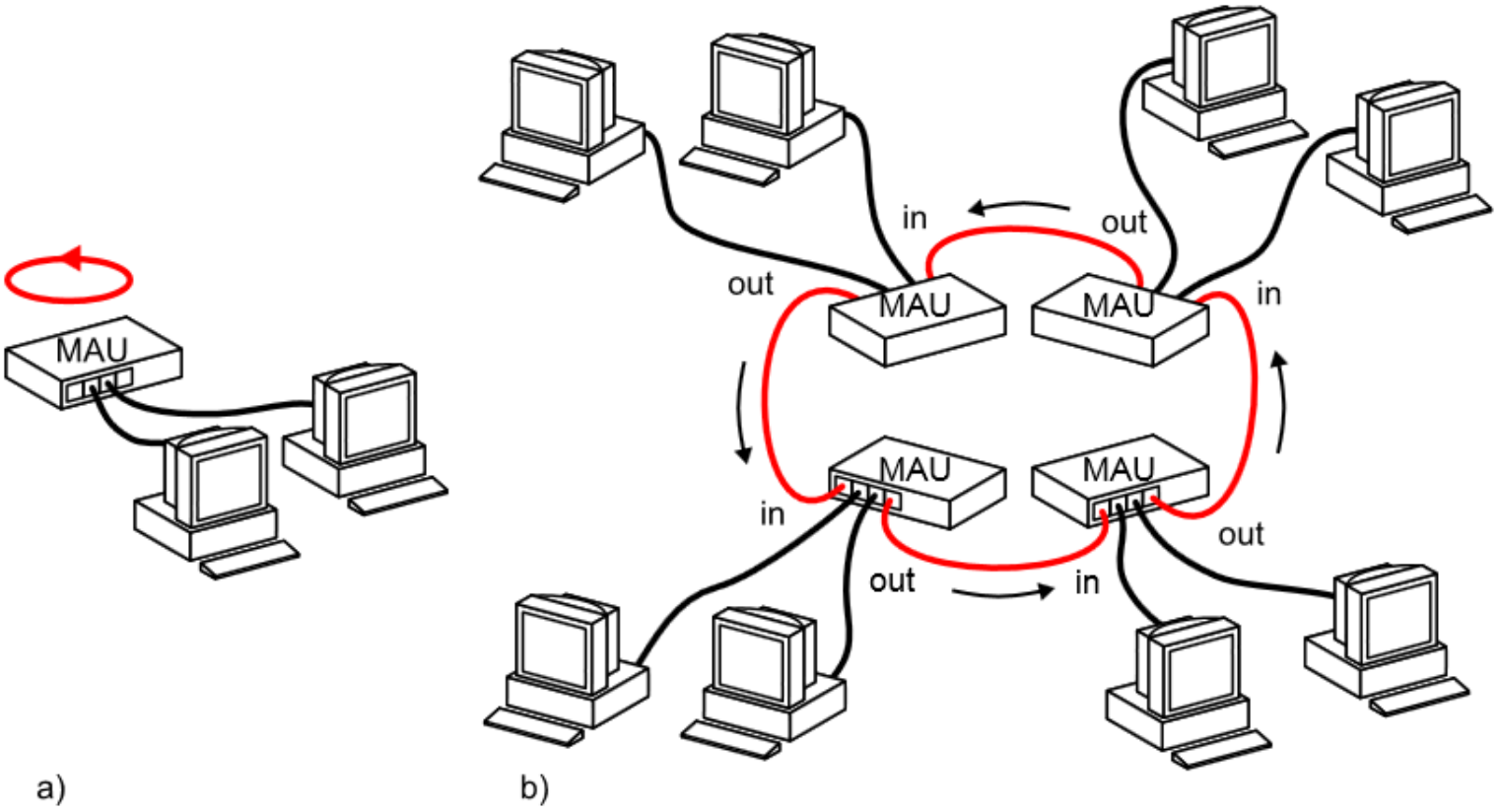
Initially used only in IBM computers, it was eventually standardized with protocol IEEE 802.5.

Token Ring

The data transmission process goes as follows:

- Empty information frames are continuously circulated on the ring.
- When a computer has a message to send, it seizes the token. The computer will then be able to send the frame.
- The frame is then examined by each successive workstation. The workstation that identifies itself to be the destination for the message copies it from the frame and changes the token back to 0.
- When the frame gets back to the originator, it sees that the token has been changed to 0 and that the message has been copied and received. It removes the message from the frame.
- The frame continues to circulate as an "empty" frame, ready to be taken by a workstation when it has a message to send.

Token Ring



IEEE 802 standard

802.1 – Internetworking, VLAN, QoS;

802.2 – Logical Link Control, LLC;

802.3 – Ethernet, CSMA/CD;

804.4 – Token Bus LAN ;

802.5 – Token Ring LAN;

802.6 – Metropolitan Area Network, MAN;

802.7 – Broadband Technical Advisory Group;

802.8 – Fiber Optic Technical Advisory Group;

802.9 – Integrated Voice and data Networks;

802.10 – Network Security;

802.11 – WLAN