13-1  IEEE STANDARDS

In 1985, the Computer Society of the IEEE started a project, called Project 802, to set standards to enable intercommunication among equipment from a variety of manufacturers. Project 802 is a way of specifying functions of the physical layer and the data link layer of major LAN protocols.

Topics discussed in this section:

Data Link Layer
Physical Layer
Figure 13.1 *IEEE standard for LANs*

**LLC:** Logical link control  
**MAC:** Media access control

---

**Upper layers**

**Data link layer**

**Physical layer**

**Transmission medium**

**OSI or Internet model**

**IEEE Standard**
Figure 13.2 HDLC frame compared with LLC and MAC frames

DSAP: Destination service access point
SSAP: Source service access point

HDLC frame

MAC frame

LLC PDU

MAC payload

FCS
The original Ethernet was created in 1976 at Xerox’s Palo Alto Research Center (PARC). Since then, it has gone through four generations. We briefly discuss the Standard (or traditional) Ethernet in this section.

Topics discussed in this section:
- MAC Sublayer
- Physical Layer
Figure 13.3 Ethernet evolution through four generations

- Standard Ethernet (10 Mbps)
- Fast Ethernet (100 Mbps)
- Gigabit Ethernet (1 Gbps)
- Ten-Gigabit Ethernet (10 Gbps)
**Figure 13.4 802.3 MAC frame**

**Preamble**: 56 bits of alternating 1s and 0s.

**SFD**: Start frame delimiter, flag (10101011)

<table>
<thead>
<tr>
<th>Preamble</th>
<th>SFD</th>
<th>Destination address</th>
<th>Source address</th>
<th>Length or type</th>
<th>Data and padding</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 bytes</td>
<td>1 byte</td>
<td>6 bytes</td>
<td>6 bytes</td>
<td>2 bytes</td>
<td></td>
<td>4 bytes</td>
</tr>
</tbody>
</table>

**Physical layer header**
**Figure 13.5** Minimum and maximum lengths

<table>
<thead>
<tr>
<th>Destination address</th>
<th>Source address</th>
<th>Length PDU</th>
<th>Data and padding</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 bytes</td>
<td>6 bytes</td>
<td>2 bytes</td>
<td></td>
<td>4 bytes</td>
</tr>
</tbody>
</table>

- Minimum payload length: 46 bytes
- Maximum payload length: 1500 bytes
- Minimum frame length: 512 bits or 64 bytes
- Maximum frame length: 12,144 bits or 1518 bytes
Frame length:
Minimum: 64 bytes (512 bits)
Maximum: 1518 bytes (12,144 bits)
Figure 13.6  Example of an Ethernet address in hexadecimal notation

06:01:02:01:2C:4B

6 bytes = 12 hex digits = 48 bits
Figure 13.7 Unicast and multicast addresses

Unicast: 0; multicast: 1
The least significant bit of the first byte defines the type of address. If the bit is 0, the address is unicast; otherwise, it is multicast.
The broadcast destination address is a special case of the multicast address in which all bits are 1s.
Example 13.1

Define the type of the following destination addresses:

a. 4A:30:10:21:10:1A  
b. 47:20:1B:2E:08:EE  
c. FF:FF:FF:FF:FF:FF

Solution

To find the type of the address, we need to look at the second hexadecimal digit from the left. If it is even, the address is unicast. If it is odd, the address is multicast. If all digits are F’s, the address is broadcast. Therefore, we have the following:

a. This is a unicast address because A in binary is 1010.

b. This is a multicast address because 7 in binary is 0111.

c. This is a broadcast address because all digits are F’s.
Example 13.2

Show how the address 47:20:1B:2E:08:EE is sent out on line.

Solution
The address is sent left-to-right, byte by byte; for each byte, it is sent right-to-left, bit by bit, as shown below:

```
11100010 00000100 11011000 01110100 00010000 01110111
```
Figure 13.8 Categories of Standard Ethernet

Standard Ethernet
common implementations

10Base5
Bus, thick coaxial

10Base2
Bus, thin coaxial

10Base-T
Star, UTP

10Base-F
Star, fiber
Figure 13.9  *Encoding in a Standard Ethernet implementation*

- 10 Mbps data
- Manchester encoder
- Station
- Twisted pairs or fibers
- 10 Mbps data
- Manchester decoder
Figure 13.10 10Base5 implementation
Figure 13.11 10Base2 implementation
Figure 13.12 10Base-T implementation
Figure 13.13 10Base-F implementation
Table 13.1 *Summary of Standard Ethernet implementations*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>10Base5</th>
<th>10Base2</th>
<th>10Base-T</th>
<th>10Base-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>Thick coaxial</td>
<td>Thin coaxial</td>
<td>2 UTP</td>
<td>2 Fiber</td>
</tr>
<tr>
<td></td>
<td>cable</td>
<td>cable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum length</td>
<td>500 m</td>
<td>185 m</td>
<td>100 m</td>
<td>2000 m</td>
</tr>
<tr>
<td>Line encoding</td>
<td>Manchester</td>
<td>Manchester</td>
<td>Manchester</td>
<td>Manchester</td>
</tr>
</tbody>
</table>
The 10-Mbps Standard Ethernet has gone through several changes before moving to the higher data rates. These changes actually opened the road to the evolution of the Ethernet to become compatible with other high-data-rate LANs.

**Topics discussed in this section:**

- Bridged Ethernet
- Switched Ethernet
- Full-Duplex Ethernet
Figure 13.14  *Sharing bandwidth*

![Diagram showing sharing of bandwidth between two stations.](image)
Figure 13.15  A network with and without a bridge

a. Without bridging

b. With bridging
Figure 13.16  Collision domains in an unbridged network and a bridged network

a. Without bridging

b. With bridging
Figure 13.17  Switched Ethernet
**Figure 13.18** Full-duplex switched Ethernet
Fast Ethernet was designed to compete with LAN protocols such as FDDI or Fiber Channel. IEEE created Fast Ethernet under the name 802.3u. Fast Ethernet is backward-compatible with Standard Ethernet, but it can transmit data 10 times faster at a rate of 100 Mbps.

*Topics discussed in this section:*
- MAC Sublayer
- Physical Layer
Figure 13.19 *Fast Ethernet topology*

a. Point-to-point

b. Star
Figure 13.20  Fast Ethernet implementations

- 100Base-TX: Two wires, category 5 UTP
- 100Base-FX: Two wires, fiber
- 100Base-T4: Four wires, category 3 UTP
Figure 13.21  *Encoding for Fast Ethernet implementation*
Table 13.2  *Summary of Fast Ethernet implementations*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>100Base-TX</th>
<th>100Base-FX</th>
<th>100Base-T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>Cat 5 UTP or STP</td>
<td>Fiber</td>
<td>Cat 4 UTP</td>
</tr>
<tr>
<td>Number of wires</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Maximum length</td>
<td>100 m</td>
<td>100 m</td>
<td>100 m</td>
</tr>
<tr>
<td>Block encoding</td>
<td>4B/5B</td>
<td>4B/5B</td>
<td></td>
</tr>
<tr>
<td>Line encoding</td>
<td>MLT-3</td>
<td>NRZ-I</td>
<td>8B/6T</td>
</tr>
</tbody>
</table>
The need for an even higher data rate resulted in the design of the Gigabit Ethernet protocol (1000 Mbps). The IEEE committee calls the standard 802.3z.

Topics discussed in this section:
MAC Sublayer
Physical Layer
Ten-Gigabit Ethernet
In the full-duplex mode of Gigabit Ethernet, there is no collision; the maximum length of the cable is determined by the signal attenuation in the cable.
Figure 13.22  Topologies of Gigabit Ethernet

a. Point-to-point

b. Star

c. Two stars

d. Hierarchy of stars
Figure 13.23  Gigabit Ethernet implementations

- **1000Base-SX**: Two-wire short-wave fiber
- **1000Base-LX**: Two-wire long-wave fiber
- **1000Base-CX**: Two-wire copper (STP)
- **1000Base-T**: Four-wire UTP
Figure 13.24  Encoding in Gigabit Ethernet implementations

1000Base-SX, 1000Base-LX, and 1000Base-CX

8 x 125 Mbps

8B/10B block encoder

1.25 Gbps

NRZ line encoder

Station

Two fibers or two STPs

8B/10B block decoder

1.25 Gbps

NRZ line decoder

1000Base-T

8 x 125 Mbps

4D-PAM5 encoder

Station

4 UTP cables

8 x 125 Mbps

4D-PAM5 decoder
### Table 13.3  Summary of Gigabit Ethernet implementations

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>1000Base-SX</th>
<th>1000Base-LX</th>
<th>1000Base-CX</th>
<th>1000Base-T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>Fiber short-wave</td>
<td>Fiber long-wave</td>
<td>STP</td>
<td>Cat 5 UTP</td>
</tr>
<tr>
<td>Number of wires</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Maximum length</td>
<td>550 m</td>
<td>5000 m</td>
<td>25 m</td>
<td>100 m</td>
</tr>
<tr>
<td>Block encoding</td>
<td>8B/10B</td>
<td>8B/10B</td>
<td>8B/10B</td>
<td></td>
</tr>
<tr>
<td>Line encoding</td>
<td>NRZ</td>
<td>NRZ</td>
<td>NRZ</td>
<td>4D-PAM5</td>
</tr>
</tbody>
</table>
### Table 13.4 Summary of Ten-Gigabit Ethernet implementations

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>10GBase-S</th>
<th>10GBase-L</th>
<th>10GBase-E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>Short-wave 850-nm multimode</td>
<td>Long-wave 1310-nm single mode</td>
<td>Extended 1550-nm single mode</td>
</tr>
<tr>
<td>Maximum length</td>
<td>300 m</td>
<td>10 km</td>
<td>40 km</td>
</tr>
</tbody>
</table>