

Wired LANs: Ethernet

1 ETHERNET PROTOCOL

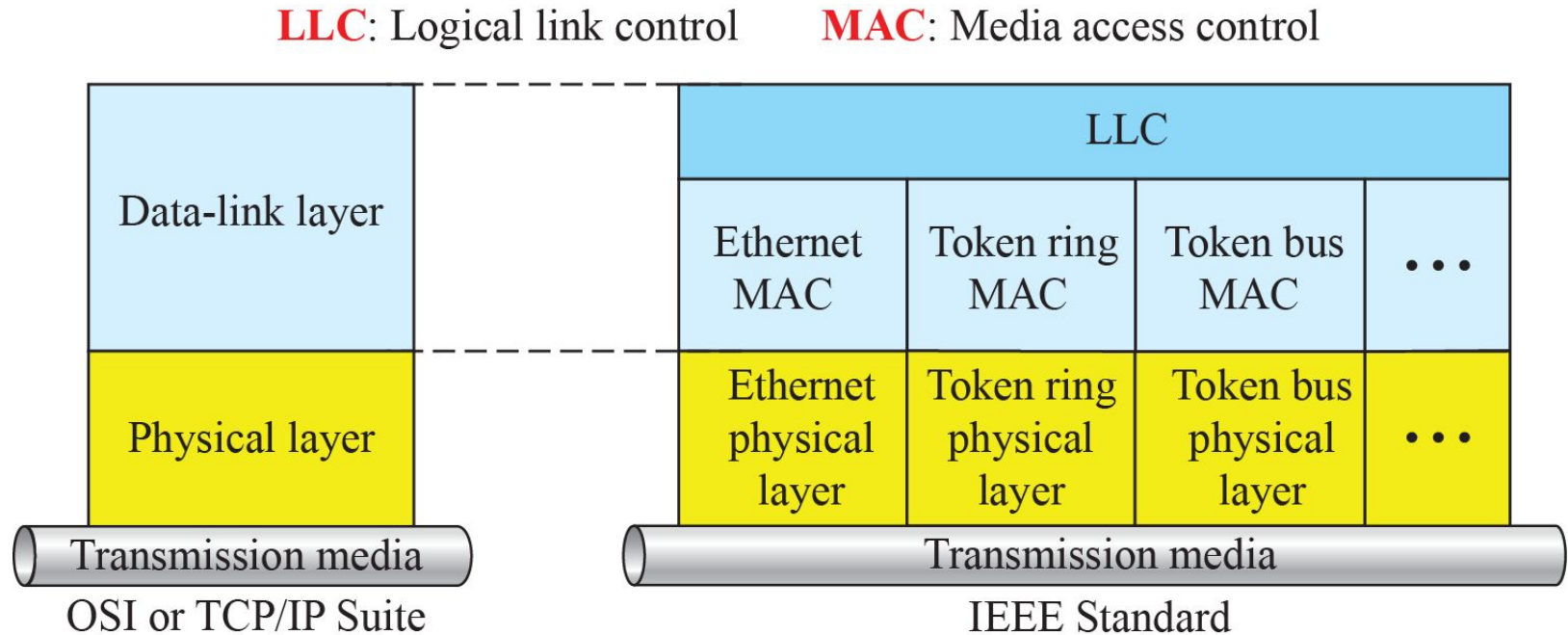
- ✓ *The data-link layer and physical layer are the territory of the local and wide area networks.*
- ✓ *This means that when we discuss these two layers, we are talking about networks that are using them.*
- ✓ *As we see in this course, we can have wired or wireless networks.*



1 IEEE Project 802

- ✓ *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 does not seek to replace any part of the OSI model or TCP/IP protocol suite.*
- ✓ *Instead, it is a way of specifying functions of the physical layer and the data-link layer of major LAN protocols.*
- ✓ *The relationship of the 802 Standard to the TCP/IP protocol suite is shown in next Figure.*

Figure 1: IEEE standard for LANs

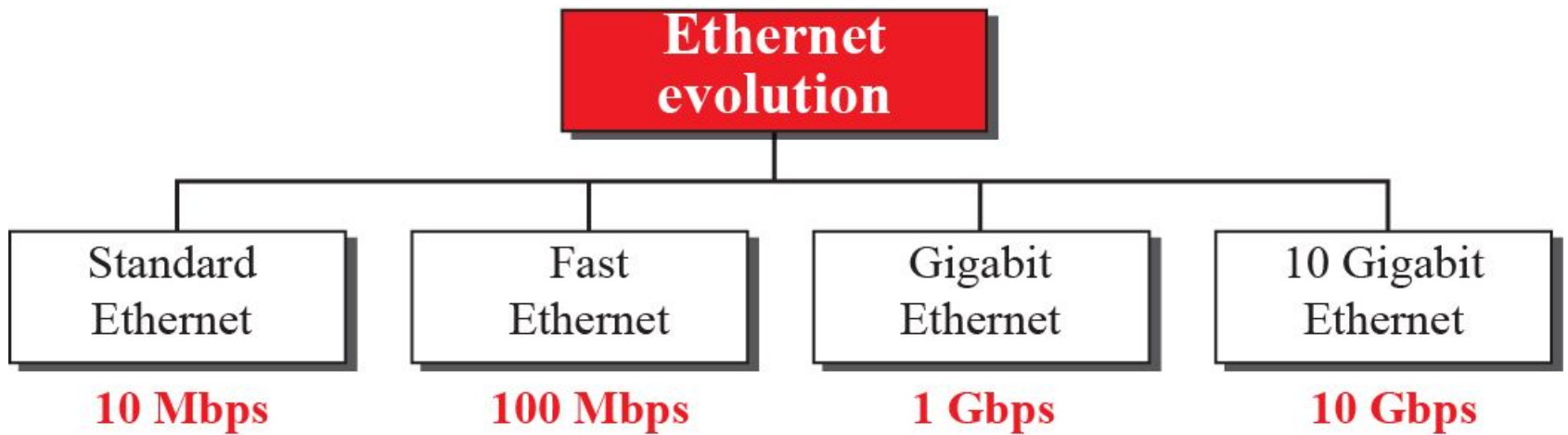




2 Ethernet Evolution

- ✓ *The Ethernet LAN was developed in the 1970s by Robert Metcalfe and David Boggs.*
- ✓ *Since then, it has gone through four generations:
Standard Ethernet (10 Mbps),
Fast Ethernet (100 Mbps),
Gigabit Ethernet (1 Gbps), and
10 Gigabit Ethernet (10 Gbps), as shown in next Figure.*

Figure 2 : Ethernet evolution



2 STANDARD ETHERNET

- ✓ *We refer to the original Ethernet technology with the data rate of 10 Mbps as the Standard Ethernet.*
- ✓ *Although most implementations have moved to other technologies in the Ethernet evolution, there are some features of the Standard Ethernet that have not changed during the evolution.*

2.1 Characteristics

Let us first discuss some characteristics of the Standard Ethernet.

Preamble: 56 bits of alternating 1s and 0s

SFD: Start frame delimiter, flag (10101011)

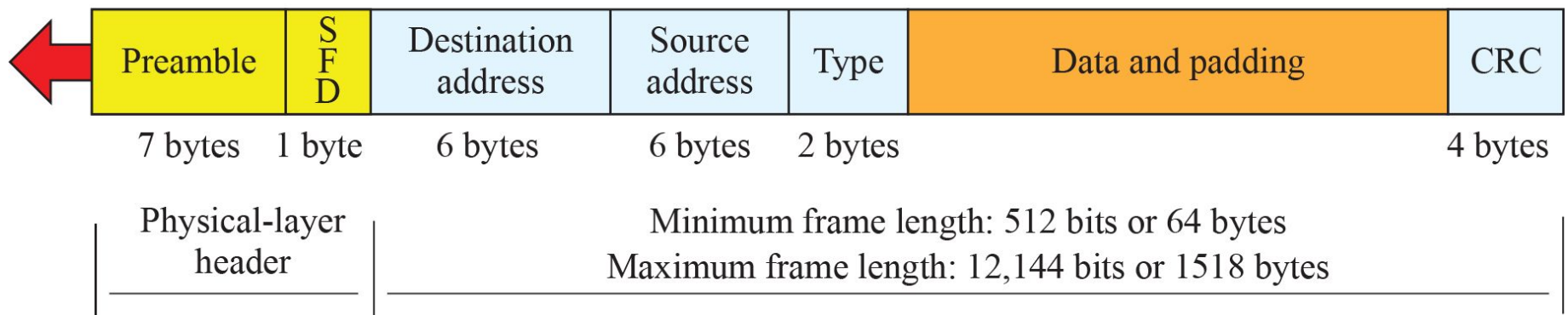


Figure 3: *Ethernet frame*

Example 1

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

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:

Hexadecimal	47	20	1B	2E	08	EE
Binarys	01000111	00100000	00011011	00101110	00001000	11101110
Transmitted ←	11100010	00000100	11011000	01110100	00010000	01110111

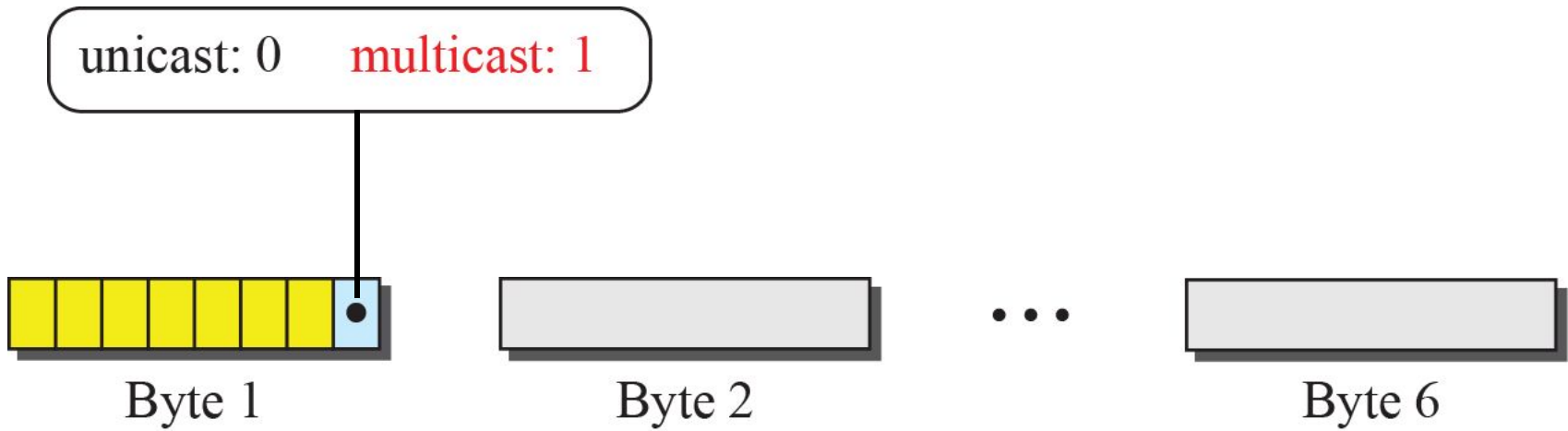


2.2 Addressing

Each station on an Ethernet network (such as a PC, workstation, or printer) has its own network interface card (NIC). The NIC fits inside the station and provides the station with a link-layer address. The Ethernet address is 6 bytes (48 bits), normally written in hexadecimal notation, with a colon between the bytes. For example, the following shows an Ethernet MAC address:

4A:30:10:21:10:1A

Figure 4: *Unicast and multicast addresses*



Example 2

Define the type of the following destination addresses:

. **4A:30:10:21:10:1A**

. **47:20:1B:2E:08:EE**

. **FF:FF:FF:FF:FF:FF**

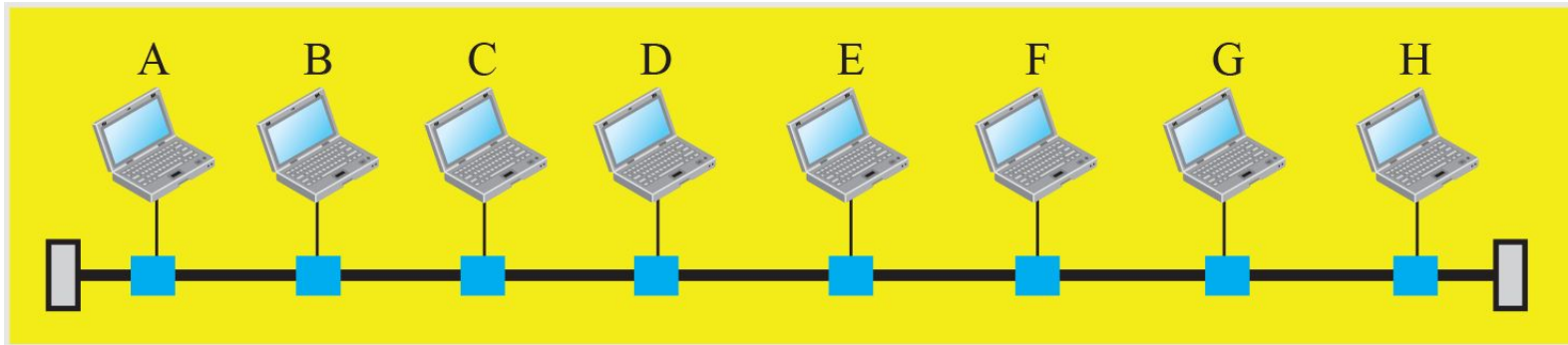
Solution

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 Fs, the address is broadcast. Therefore, we have the following:

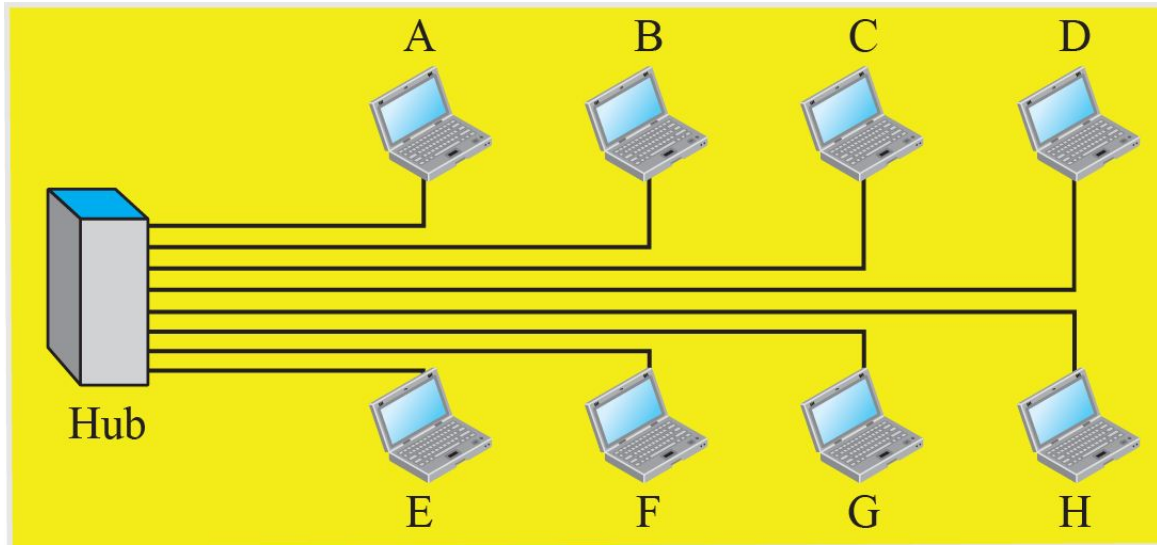
Example 2 (continued)

- a.** This is a unicast address because A in binary is 1010 (even).
- b.** This is a multicast address because 7 in binary is 0111 (odd).
- c.** This is a broadcast address because all digits are Fs in hexadecimal.

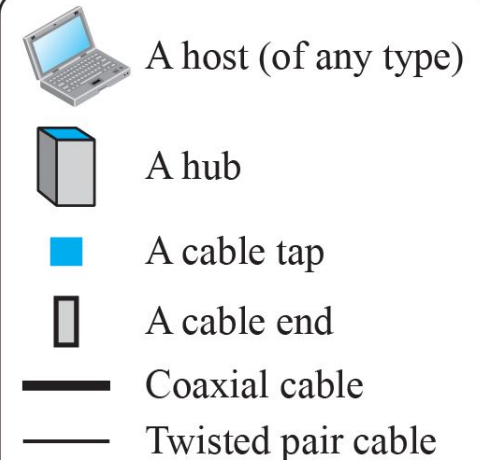
Figure 5: *Implementation of standard Ethernet*



a. A LAN with a bus topology using a coaxial cable



Legend



b. A LAN with a star topology using a hub



2.3 Access Method

- ✓ *Since the network that uses the standard Ethernet protocol is a broadcast network, we need to use an access method to control access to the sharing medium.*
- ✓ *The standard Ethernet chose CSMA/CD with 1-persistent method.*
- ✓ *Let us use a scenario to see how this method works for the Ethernet protocol.*



2.4 *Efficiency of Standard Ethernet*

The efficiency of the Ethernet is defined as the ratio of the time used by a station to send data to the time the medium is occupied by this station. The practical efficiency of standard Ethernet has been measured to be

$$\text{Efficiency} = 1 / (1 + 6.4 \times a)$$

Example 3

In the Standard Ethernet with the transmission rate of 10 Mbps, we assume that the length of the medium is 2500 m and the size of the frame is 512 bits. The propagation speed of a signal in a cable is normally 2×10^8 m/s.

$$\text{Propagation delay} = 2500 / (2 \times 10^8) = 12.5 \mu\text{s}$$

$$\text{Transmission delay} = 512 / (10^7) = 51.2 \mu\text{s}$$

$$a = 12.5 / 51.2 = 0.24$$

$$\text{Efficiency} = 39\%$$

The example shows that $a = 0.24$, which means only 0.24 of a frame occupies the whole medium in this case. The efficiency is 39 percent, which is considered moderate; it means that only 61 percent of the time the medium is occupied but not used by a station.



2.5 Implementation

The Standard Ethernet defined several implementations, but only four of them became popular during the 1980s. Table 1 shows a summary of Standard Ethernet implementations.

Table 1: Summary of Standard Ethernet implementations

<i>Implementation</i>	<i>Medium</i>	<i>Medium Length</i>	<i>Encoding</i>
10Base5	Thick coax	500 m	Manchester
10Base2	Thin coax	185 m	Manchester
10Base-T	2 UTP	100 m	Manchester
10Base-F	2 Fiber	2000	Manchester

Figure 6: *Encoding in a Standard Ethernet*

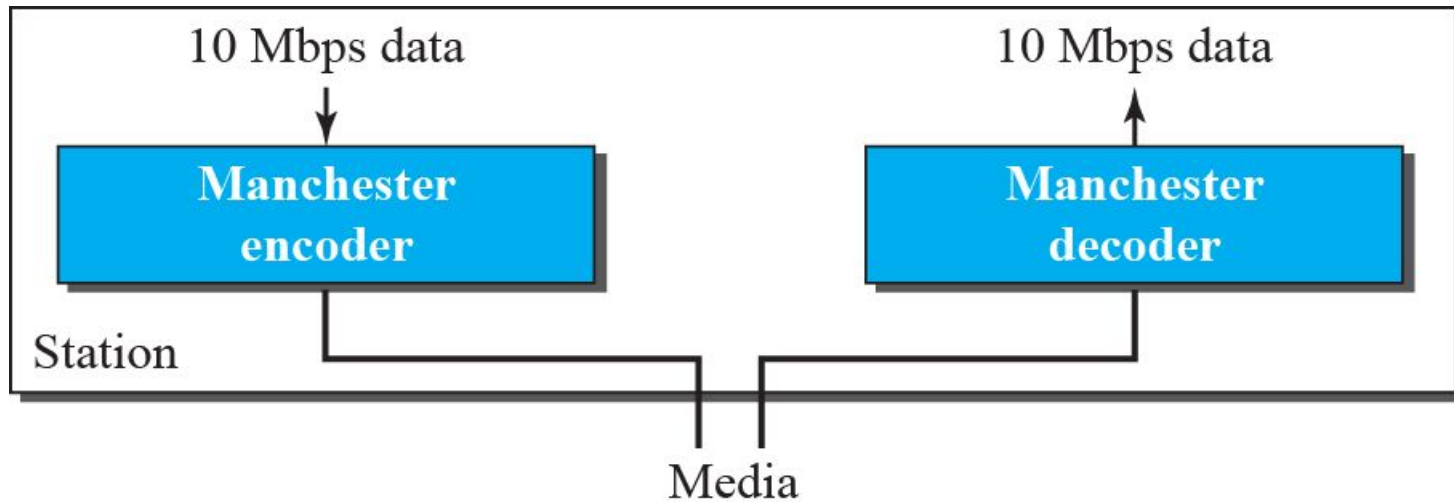


Figure 7: *10Base5 implementation*

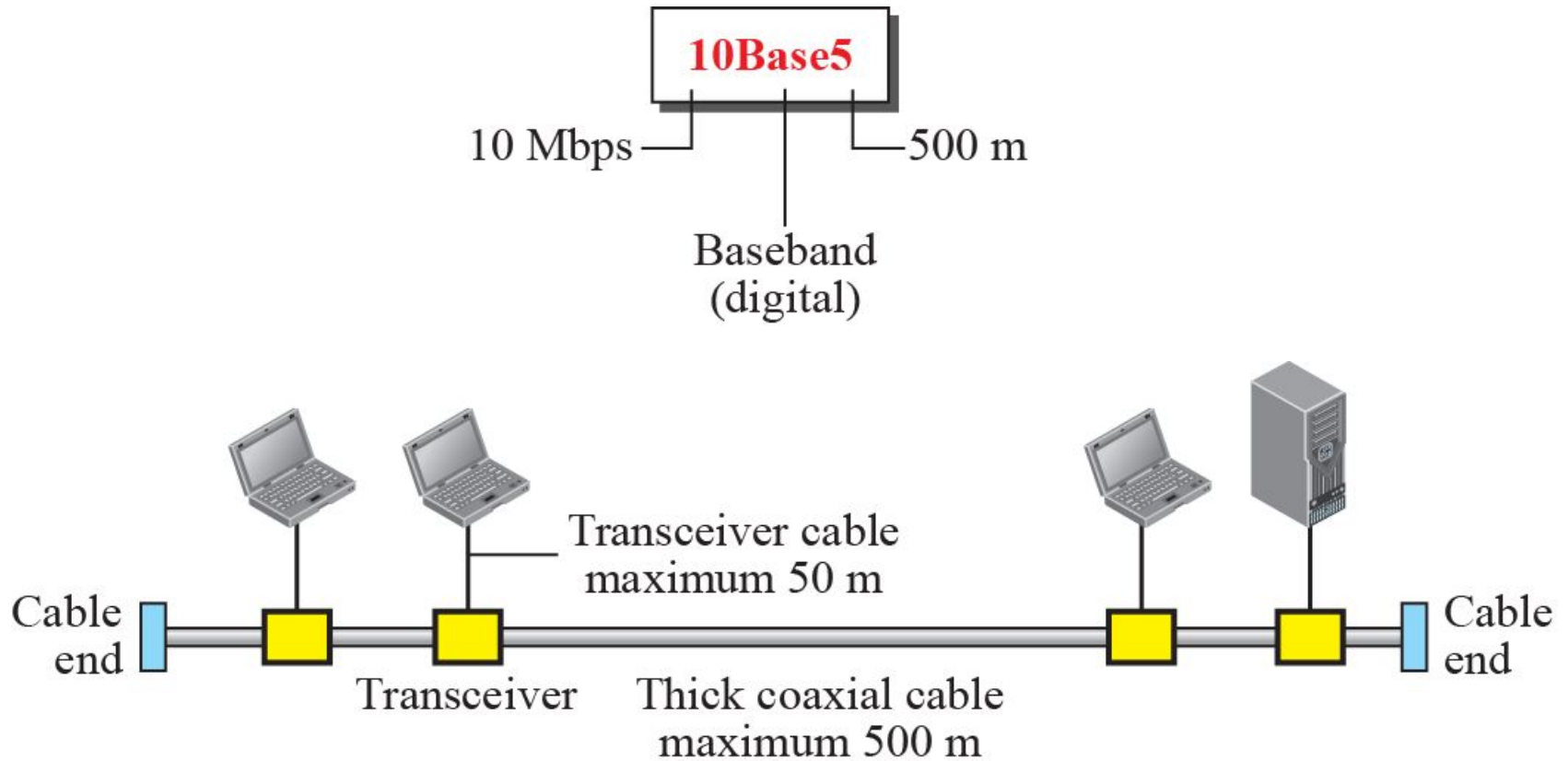


Figure 8: *10Base2 implementation*

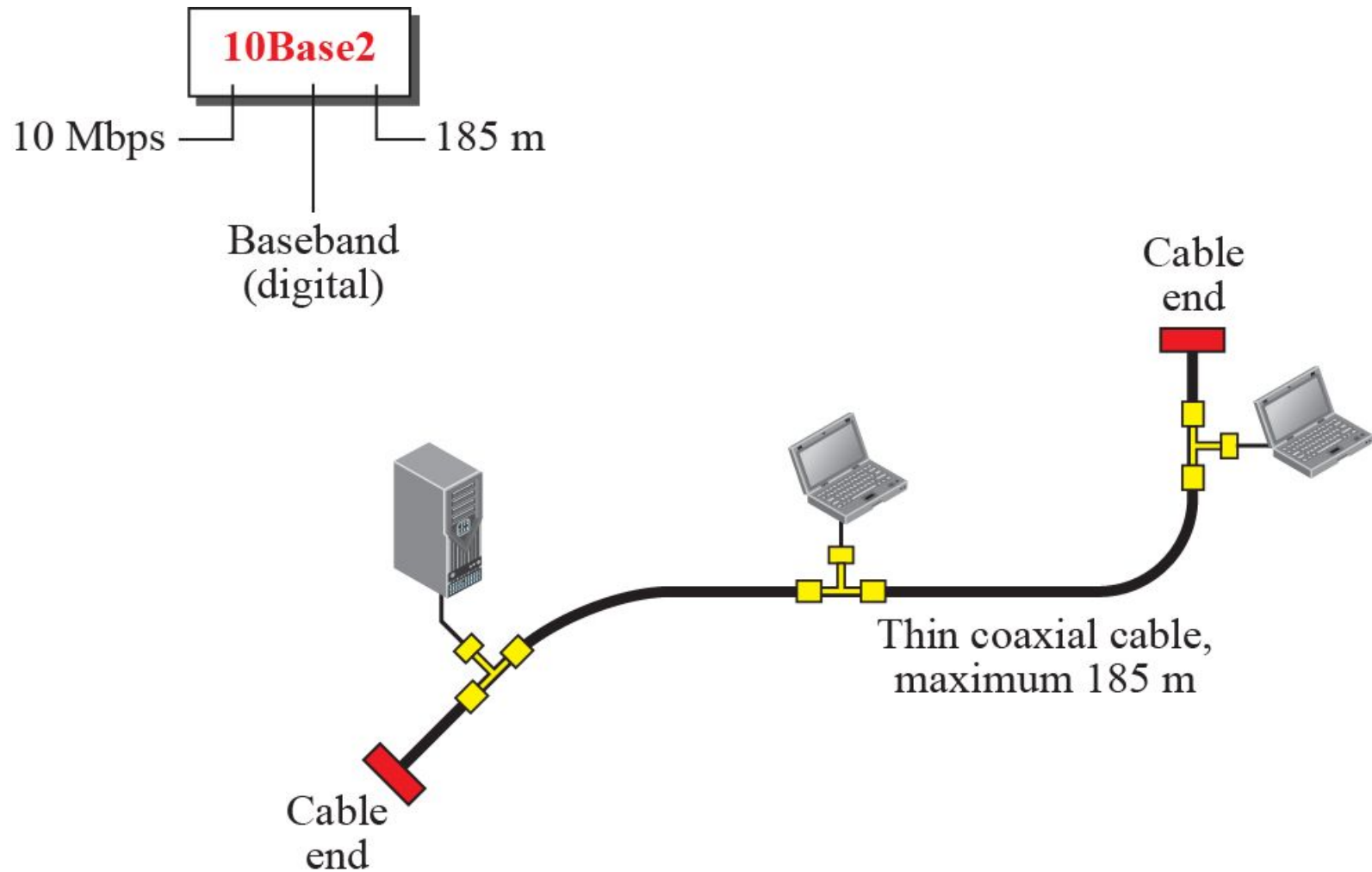


Figure 9: *10Base-T implementation*

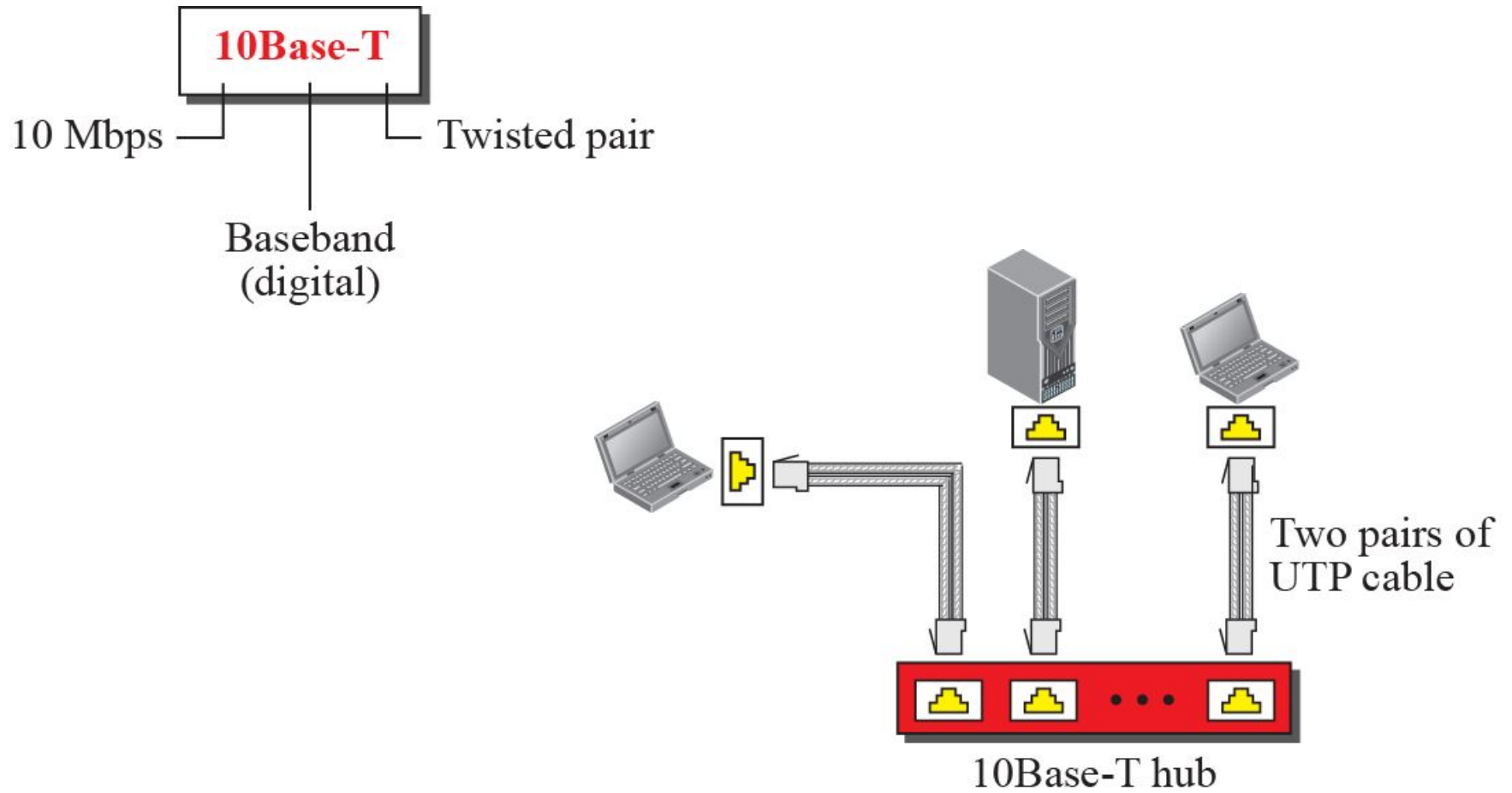
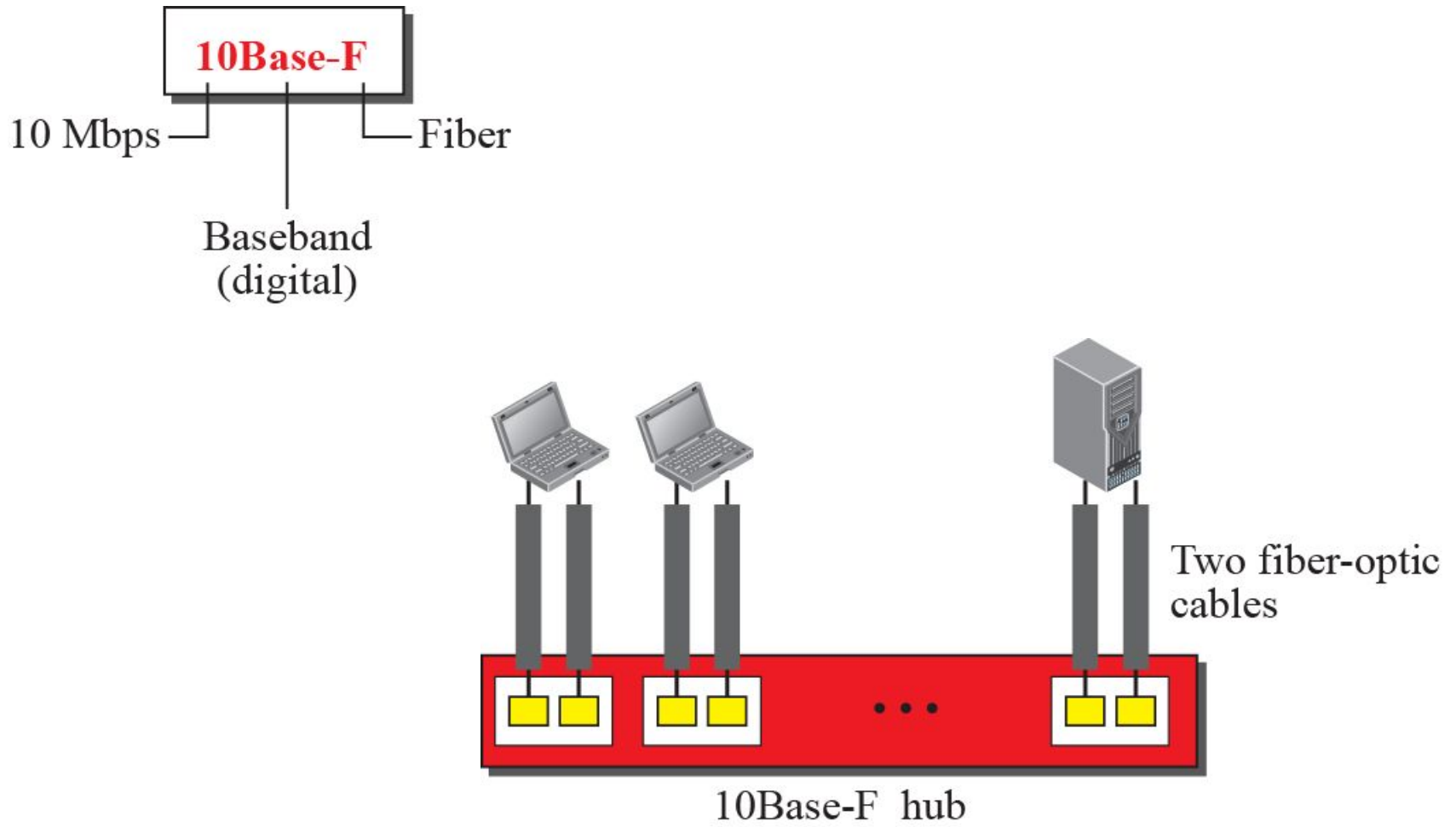


Figure 10: *10Base-F implementation*





2.6 *Changes in the Standard*

Before we discuss higher-rate Ethernet protocols, we need to discuss the changes that occurred to the 10-Mbps Standard Ethernet. These changes actually opened the road to the evolution of the Ethernet to become compatible with other high-data-rate LANs.

Figure 11: Sharing bandwidth

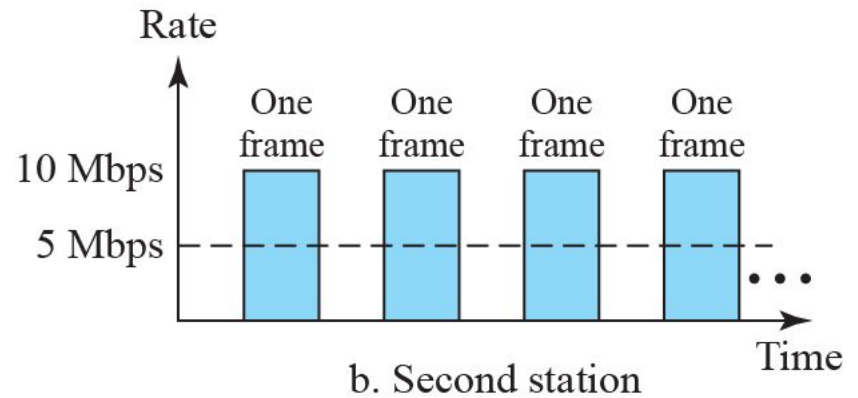
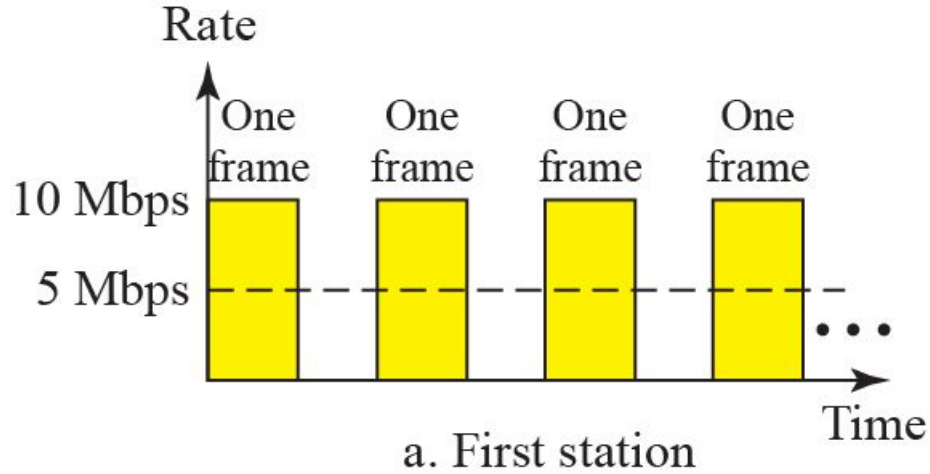
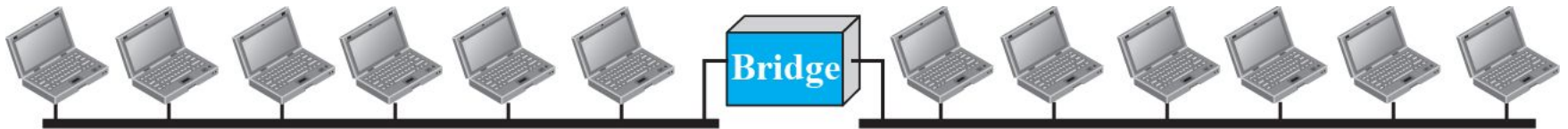


Figure 12: *A network with and without bridging*



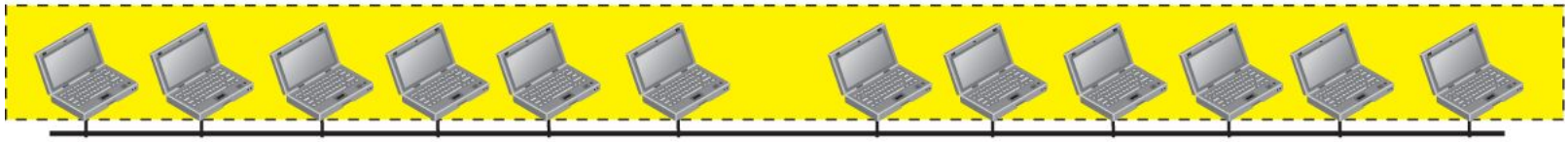
a. Without bridging



b. With bridging

Figure 13: *Collision domains*

Domain

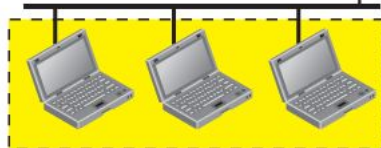


a. Without bridging

Domain



Domain



Domain



Domain

b. With bridging

Figure 14: *Switched Ethernet*

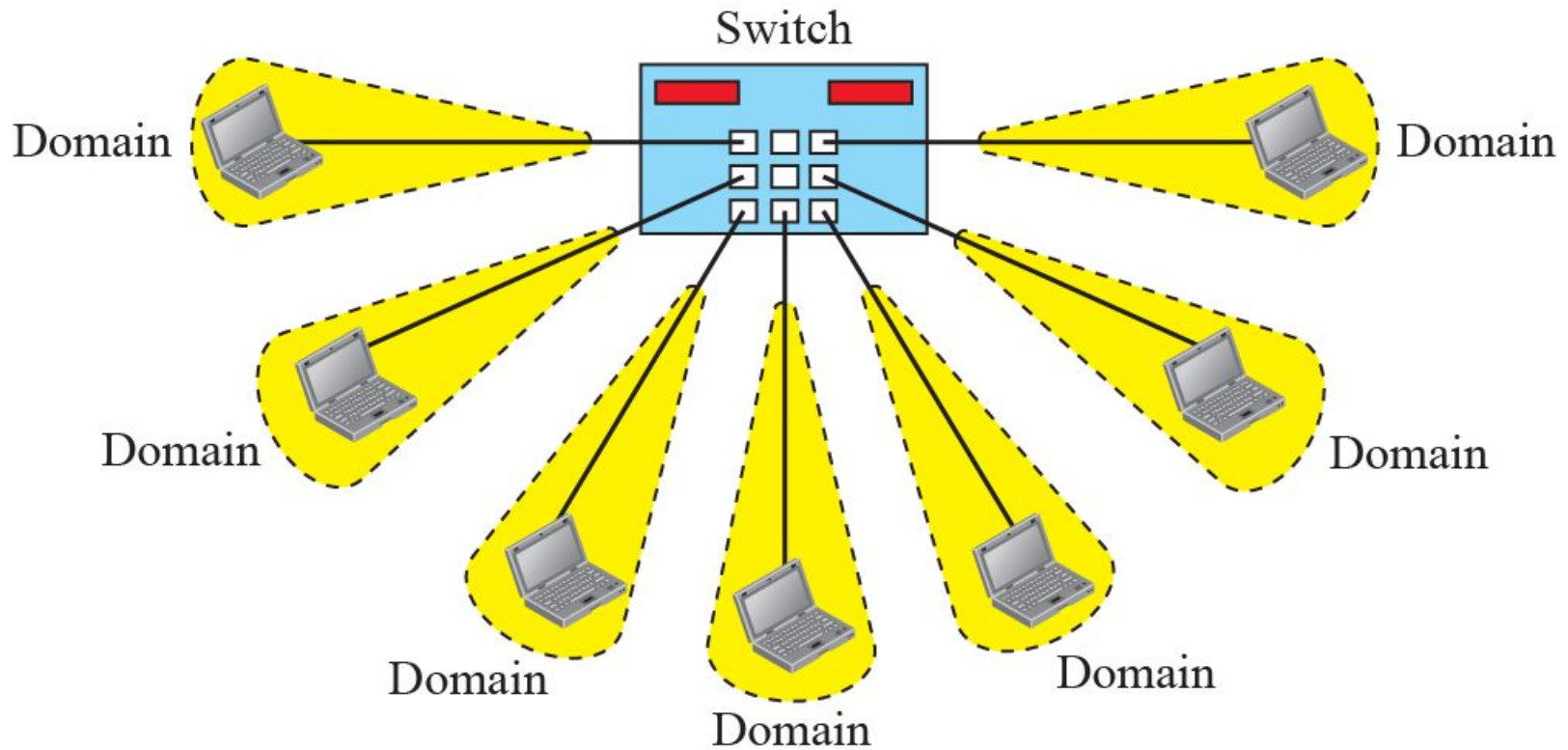
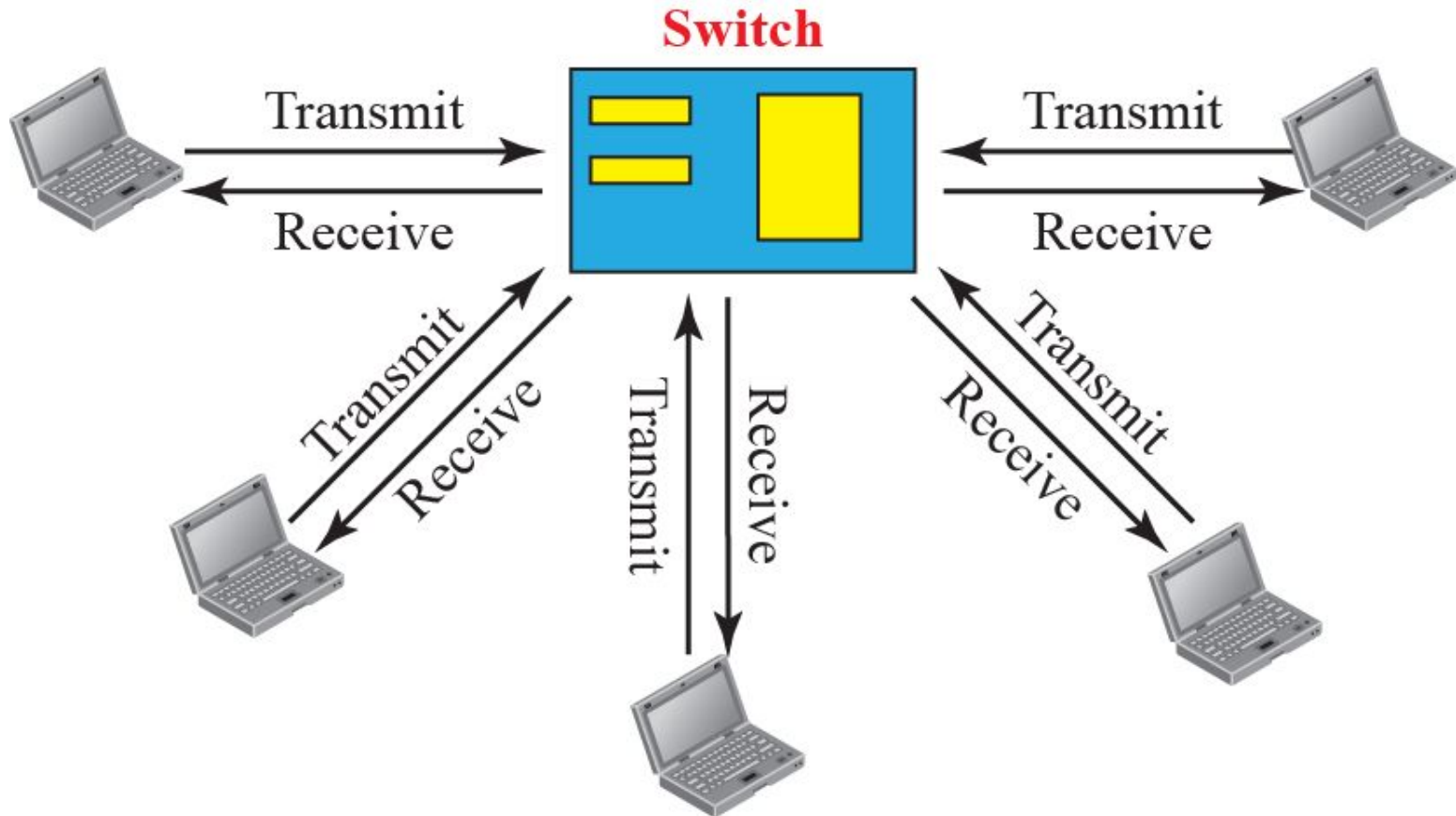


Figure 15: *Full – duplex switched Ethernet*



3 FAST ETHERNET

- ✓ *In the 1990s, Ethernet made a big jump by increasing the transmission rate to 100 Mbps, and the new generation was called the Fast Ethernet.*
- ✓ *The designers of the Fast Ethernet needed to make it compatible with the Standard Ethernet.*
- ✓ *The MAC sublayer was left unchanged. But the features of the Standard Ethernet that depend on the transmission rate, had to be changed.*



3.1 Access Method

- ✓ *We remember that the proper operation of the CSMA/CD depends on the transmission rate, the minimum size of the frame, and the maximum network length.*
- ✓ *If we want to keep the minimum size of the frame, the maximum length of the network should be changed.*
- ✓ *In other words, if the minimum frame size is still 512 bits, and it is transmitted 10 times faster, the collision needs to be detected 10 times sooner, which means the maximum length of the network should be 10 times shorter (the propagation speed does not change).*

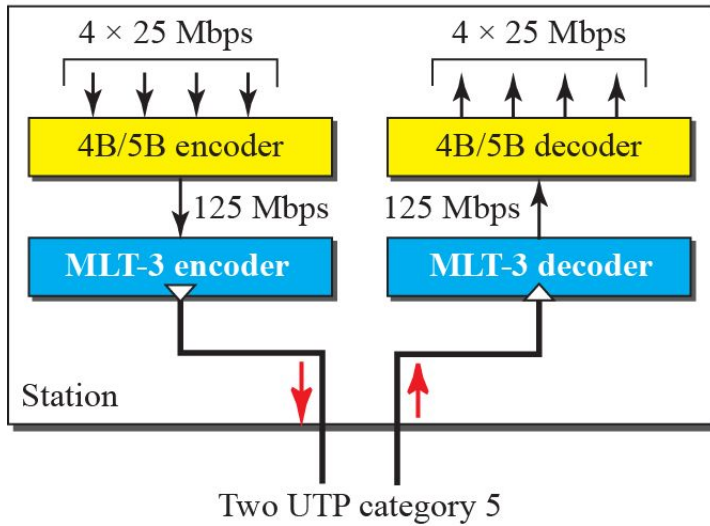


3.2 *Physical Layer*

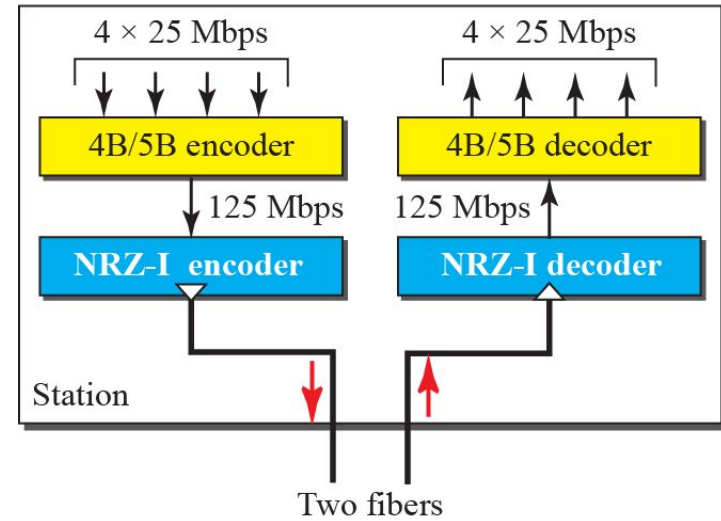
To be able to handle a 100 Mbps data rate, several changes need to be made at the physical layer.

Figure 16: Encoding for fast Ethernet

100Base-TX



100Base-FX



100Base-T4

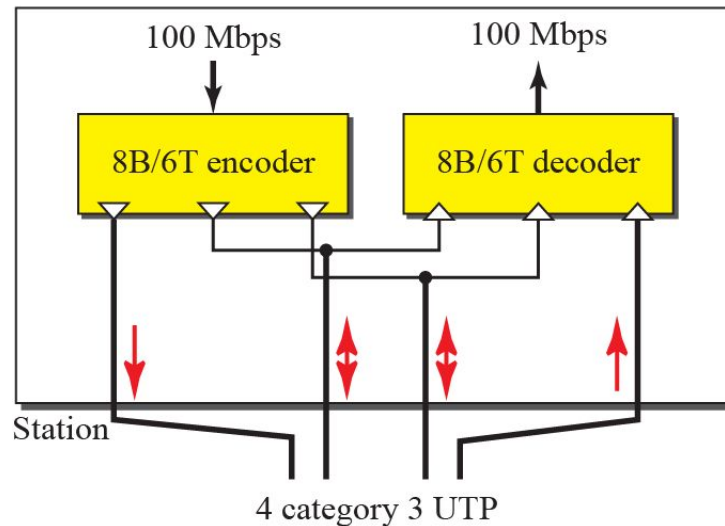




Table 2: Summary of Fast Ethernet implementations

<i>Implementation</i>	<i>Medium</i>	<i>Medium Length</i>	<i>Wires</i>	<i>Encoding</i>
100Base-TX	STP	100 m	2	4B5B + MLT-3
100Base-FX	Fiber	185 m	2	4B5B + NRZ-I
100Base-T4	UTP	100 m	4	Two 8B/6T

4 GIGABIT ETHERNET

The need for an even higher data rate resulted in the design of the Gigabit Ethernet Protocol (1000 Mbps).

The IEEE committee calls it the Standard 802.3z.

The goals of the Gigabit Ethernet were to upgrade the data rate to 1 Gbps, but keep the address length, the frame format, and the maximum and minimum frame length the same.



4.1 MAC Sublayer

- ✓ *A main consideration in the evolution of Ethernet was to keep the MAC sublayer untouched.*
- ✓ *However, to achieve a data rate of 1 Gbps, this was no longer possible.*
- ✓ *Gigabit Ethernet has two distinctive approaches for medium access: half-duplex and full-duplex.*
- ✓ *Almost all implementations of Gigabit Ethernet follow the full-duplex approach, so we mostly ignore the half-duplex mode.*

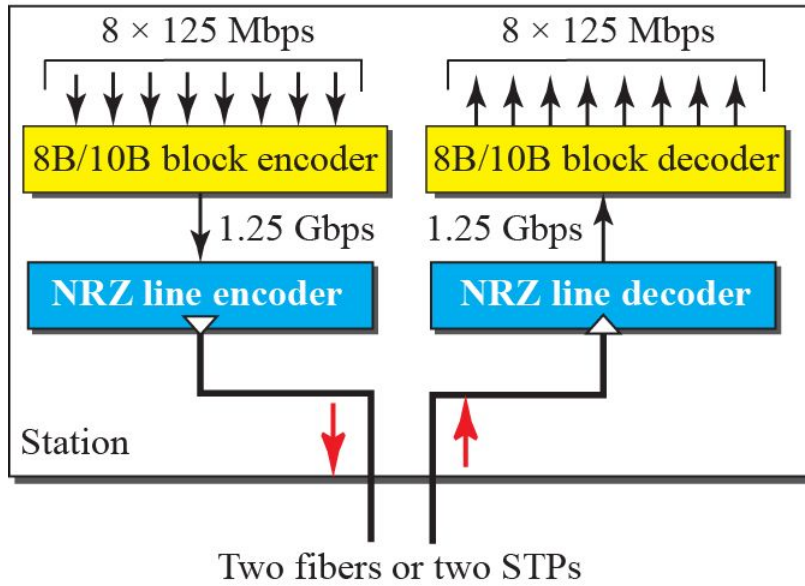


4.2 *Physical Layer*

The physical layer in Gigabit Ethernet is more complicated than that in Standard or Fast Ethernet. We briefly discuss some features of this layer.

Figure 17: Encoding in Gigabit Ethernet

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



1000Base-T

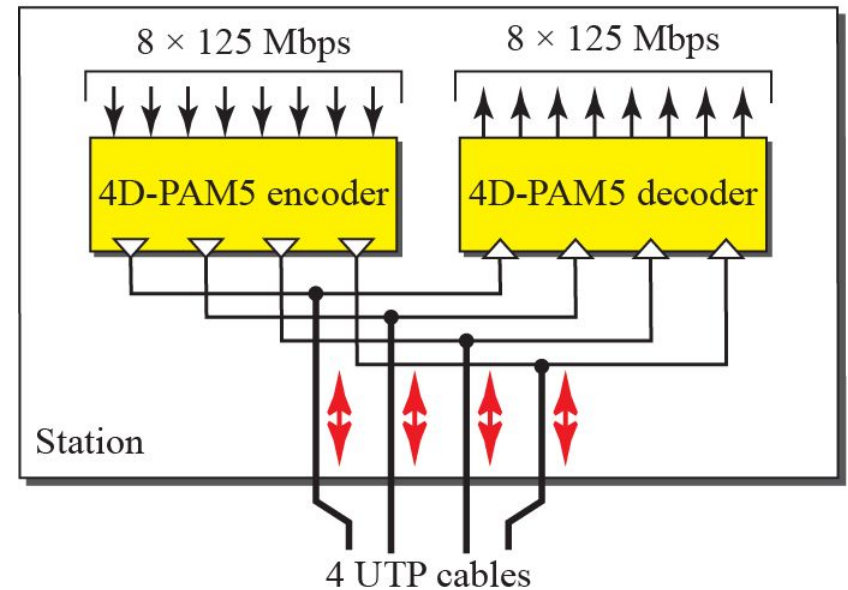




Table 3: Summary of Gigabit Ethernet implementations

<i>Implementation</i>	<i>Medium</i>	<i>Medium Length</i>	<i>Wires</i>	<i>Encoding</i>
1000Base-SX	Fiber S-W	550 m	2	8B/10B + NRZ
1000Base-LX	Fiber L-W	5000 m	2	8B/10B + NRZ
1000Base-CX	STP	25 m	2	8B/10B + NRZ
1000Base-T4	UTP	100 m	4	4D-PAM5

5 10-GIGABIT EHTERNET

- ✓ *In recent years, there has been another look into the Ethernet for use in metropolitan areas.*
- ✓ *The idea is to extend the technology, the data rate, and the coverage distance so that the Ethernet can be used as LAN and MAN (metropolitan area network).*
- ✓ *The IEEE committee created 10 Gigabit Ethernet and called it Standard 802.3ae.*



5.1 Implementation

- ✓ *10 Gigabit Ethernet operates only in full-duplex mode, which means there is no need for contention; CSMA/CD is not used in 10 Gigabit Ethernet.*
- ✓ *Four implementations are the most common: 10GBase-SR, 10GBase-LR, 10GBase-EW, and 10GBase-X4. Table 13.4 shows a summary of the 10 Gigabit Ethernet implementations.*



Table 4: Summary of 10-Gigabit Ethernet implementations

<i>Implementation</i>	<i>Medium</i>	<i>Medium Length</i>	<i>Number of wires</i>	<i>Encoding</i>
10GBase-SR	Fiber 850 nm	300 m	2	64B66B
10GBase-LR	Fiber 1310 nm	10 Km	2	64B66B
10GBase-EW	Fiber 1350 nm	40 Km	2	SONET
10GBase-X4	Fiber 1310 nm	300 m to 10 Km	2	8B10B