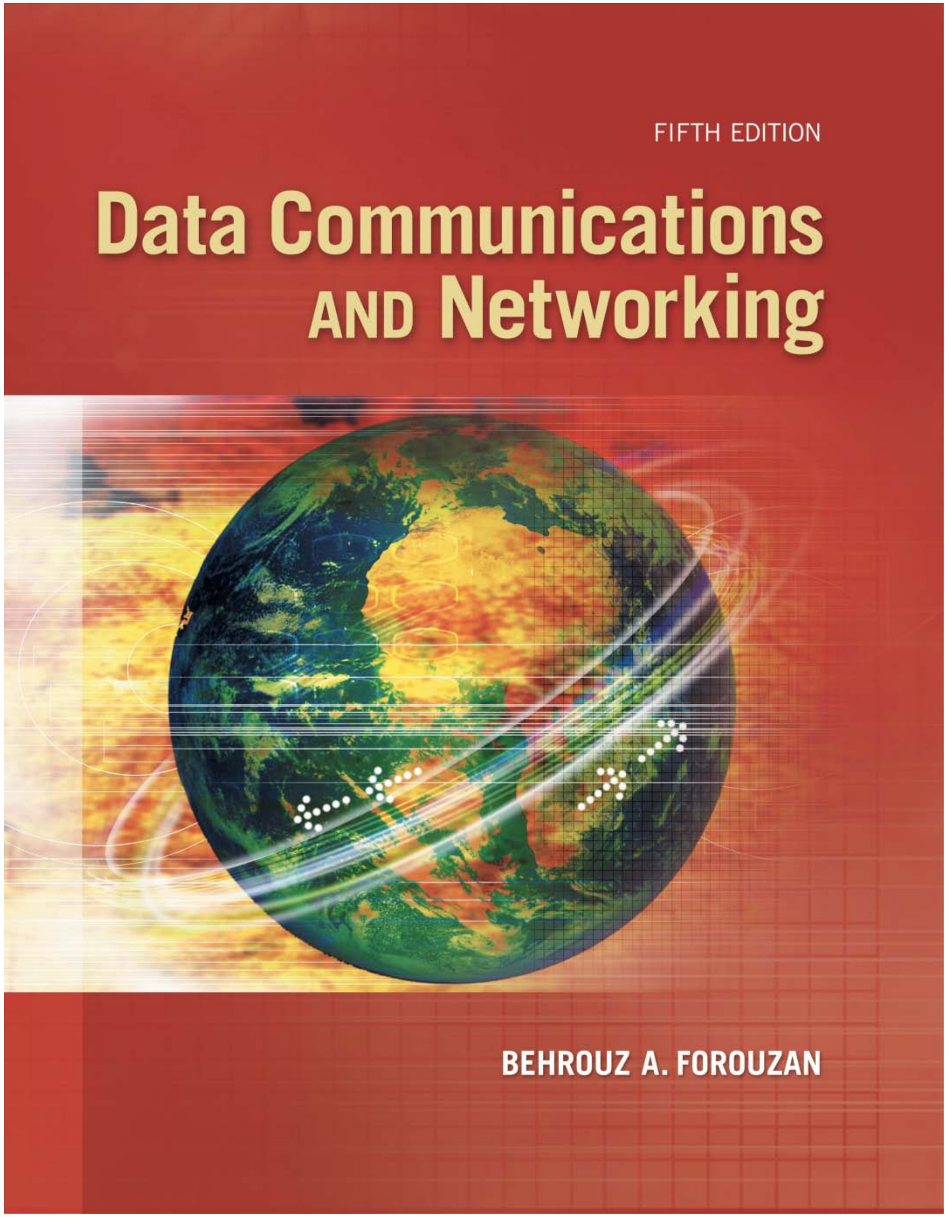
Chapter 13

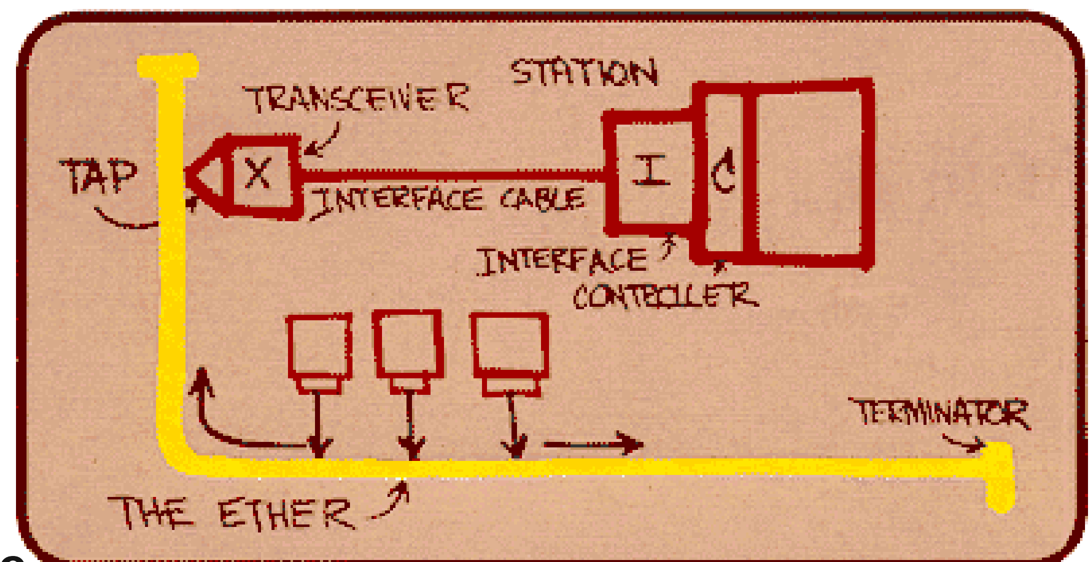
Wired LANs: Ethernet



Case Study: Ethernet

“dominant” LAN technology:

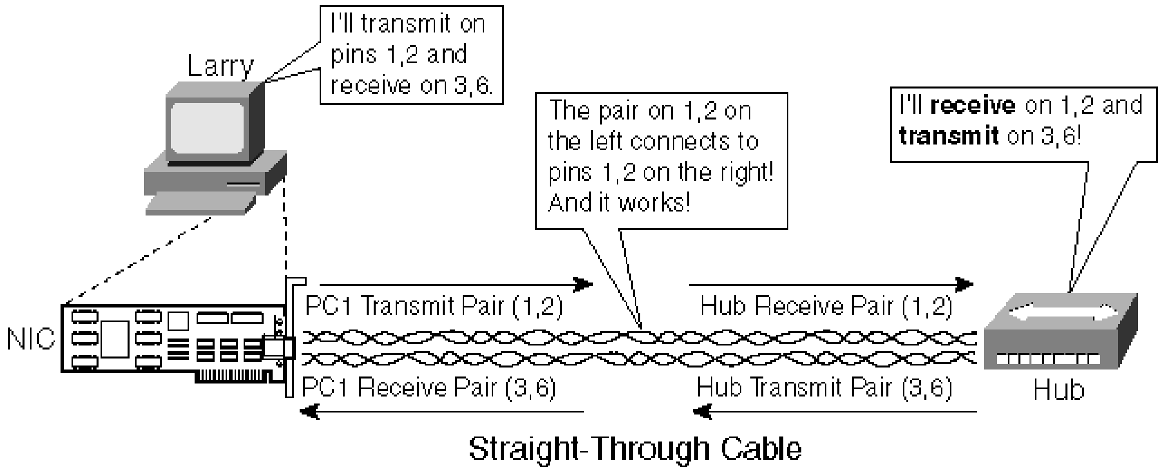
- cheap $20 for 100Mbs!
- first widely used LAN technology
- Simpler, cheaper than token LANs and ATM
- Kept up with speed race: 10, 100, 1000 Mbps, 10Gbps



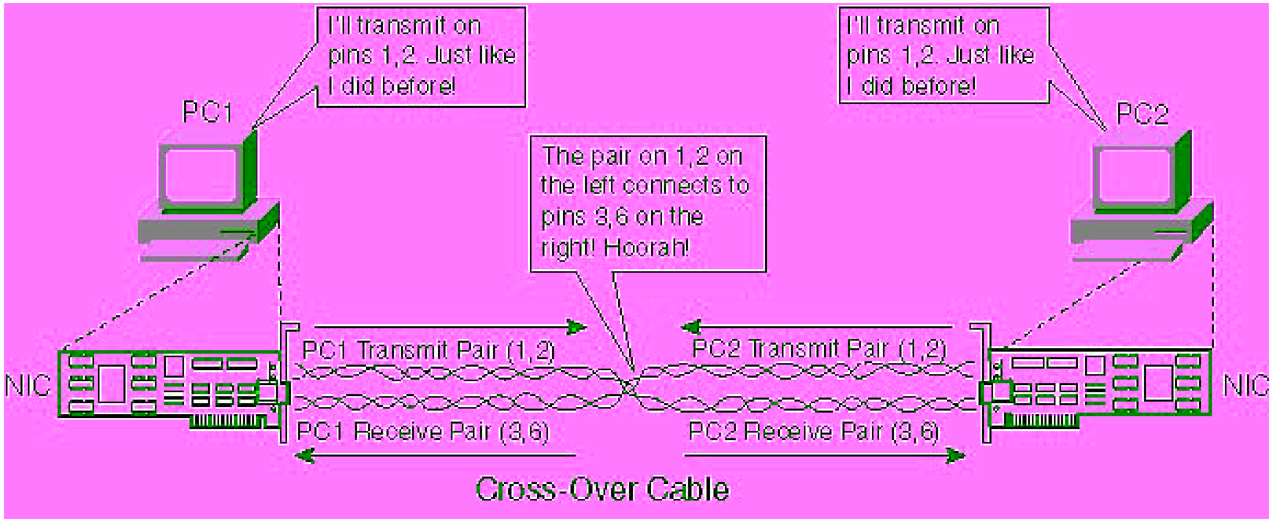
Original picture drawn by Bob Metcalfe, inventor of Ethernet (1972 – Xerox PARC)

3. LAN의 연결

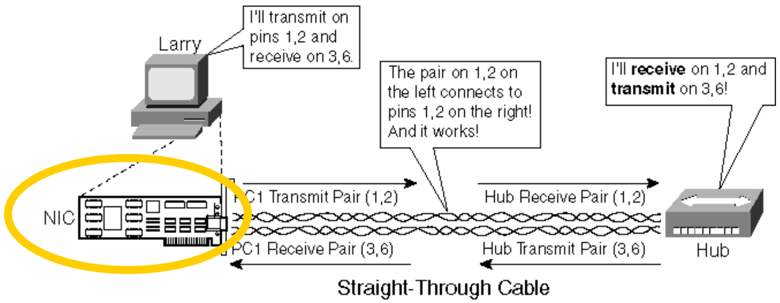
- **direct**

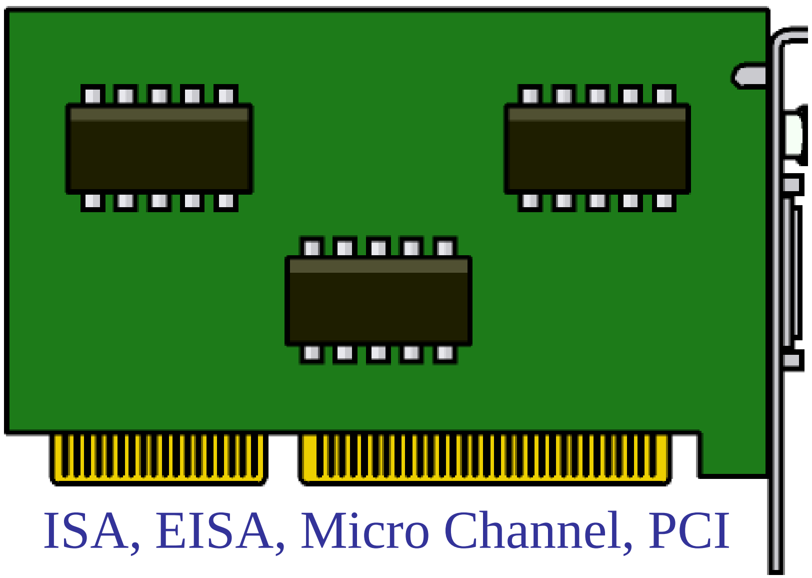


- cross



Network Interface Card (NIC)





ISA, EISA, Micro Channel, PCI

- Ethernet – 10Mbps
- Fast Ethernet - 100Mbps
  - 100BaseT
- Giga Ethernet – 1Gbps
- 10Giga Ethernet – 10Gbps

The 100Mb/s Ethernet Standard

Different physical layer options

Ethernet MAC Protocol

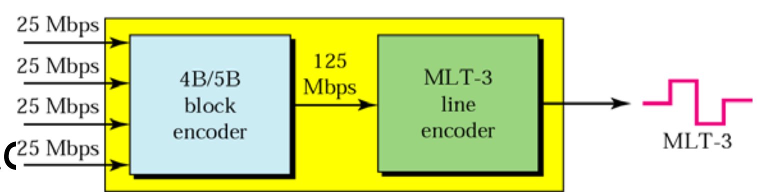
100Base-T4

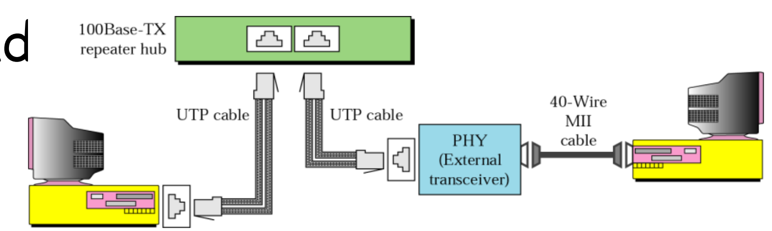
100Base-TX

100Base-FX

Up to 100m of cable per segment.

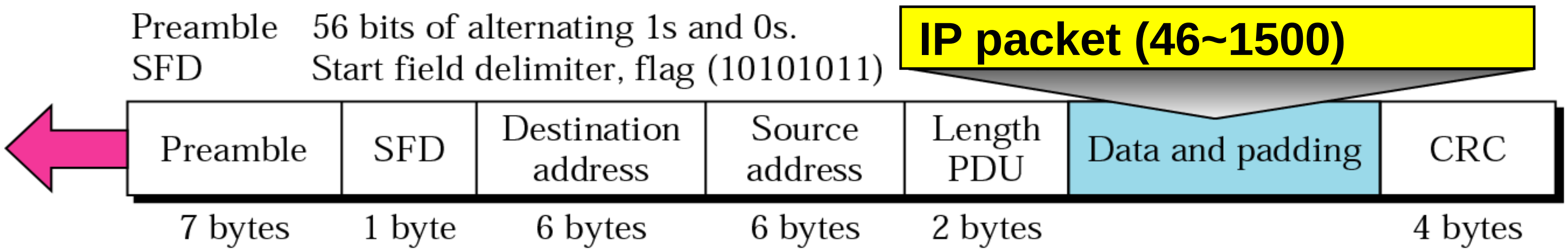
100Base-T4: Uses four pairs of voice grac
Category-3 cable .
100Base-TX: Uses two pairs of data grad
Category-5 cable.
100Base-FX: Uses two optical fibers.





Ethernet Frame Structure*

Sending adapter encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame

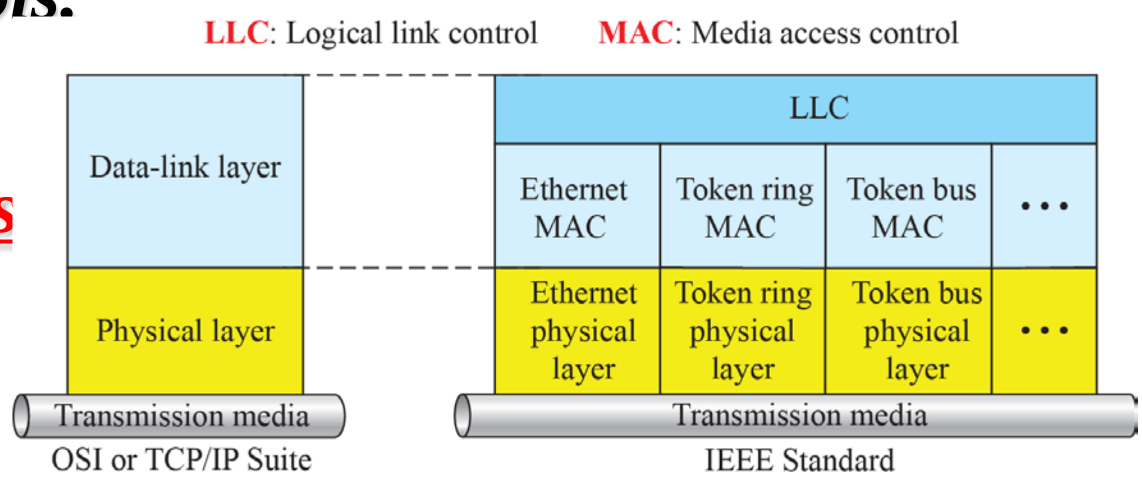


1. Preamble: (7bytes) trains clock-recovery circuits 10101010
2. Start of Frame Delimiter: indicates start of frame 10101011
3. Destination Address: 48-bit globally unique address assigned by manufacturer.
   1b=0: unicast/multicast
   multicast range [0x01 00 5E:0x0~7F FF F
   1b=1: local/global address

4. Type: Indicates protocol of encapsulated data (e.g. IP = 0x0800)
5. Pad: Zeroes used to ensure minimum frame length (=46bytes)
6. Cyclic Redundancy Check(4byte): check sequence to detect bit errors.

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.

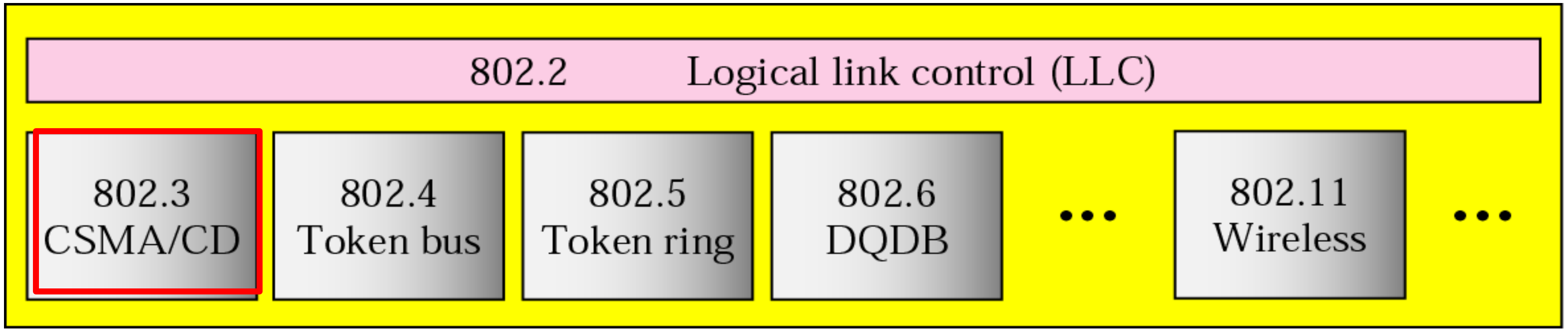


Topics discussed in this

Data Link Layer
Physical Layer

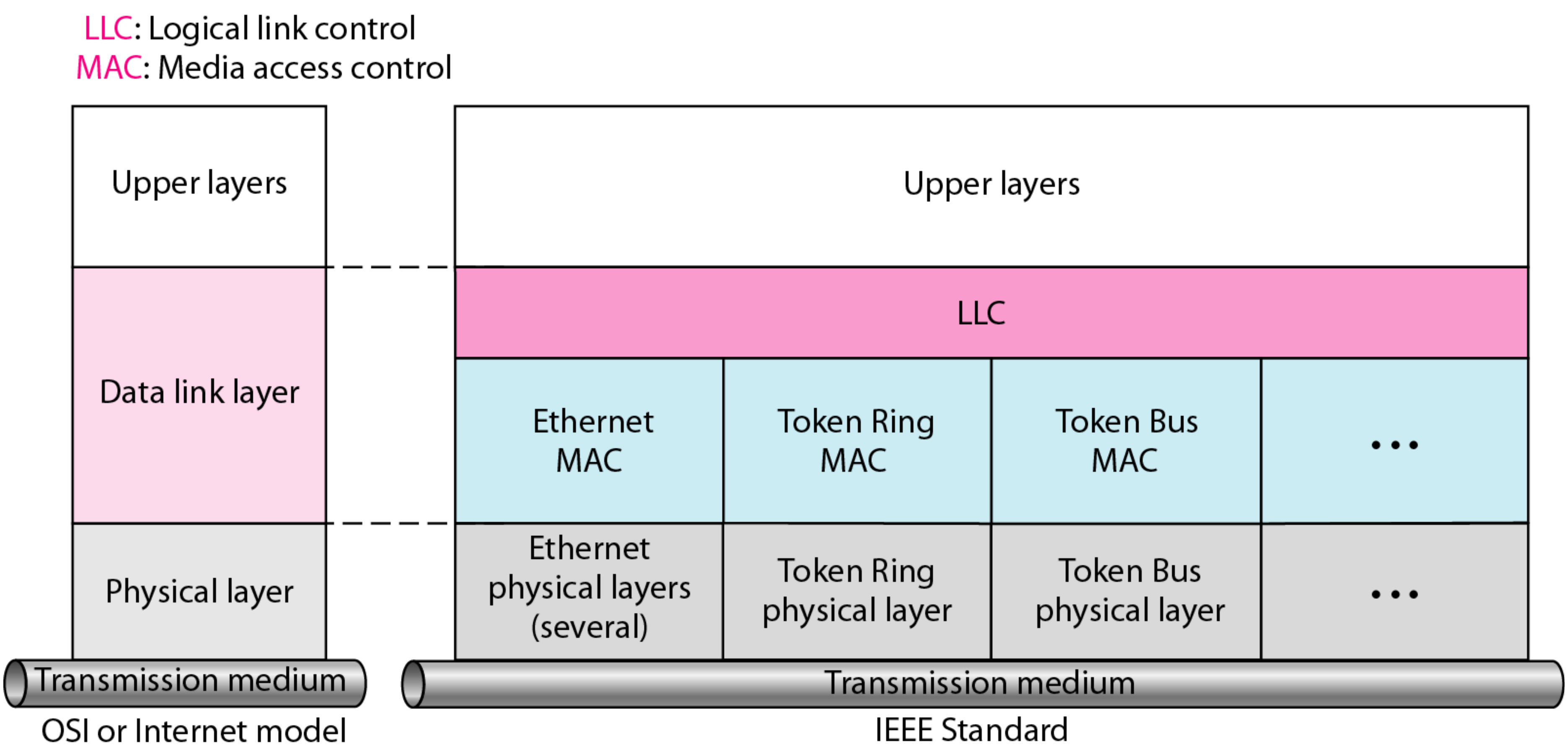
IEEE Project 802 Standards

- IEEE 802.1 High Level Interface
  - IEEE 802.1D Local Bridge (Spanning Tree Algorithm), IEEE 802.1G Remote Bridge
  - IEEE 802.1p Dynamic Multicast membership, IEEE 802.1Q Virtual LAN (VLAN)
- IEEE 802.2 LLC (Logical Link Control)
- **IEEE 802.3 CSMA/CD (Carrier Sense Multiple Access with Collision Detection**
- IEEE 802.4 Token-Bus
- IEEE 802.5 Token-Ring
- IEEE 802.6 DQDB (Distributed Queue Dual Bus)
- IEEE 802.7 Broadband Technical Advisory Group
- IEEE 802.8 Fiber Optic Technical Advisory Group
- IEEE 802.9 Integrated Voice and Data LAN Working Group
- IEEE 802.10 LAN Security Working Group
- IEEE 802.11 Wireless LAN
- IEEE 802.12 Demand-Priority (100VG-AnyLAN)
- IEEE 802.14 CATV Networks (HFC)

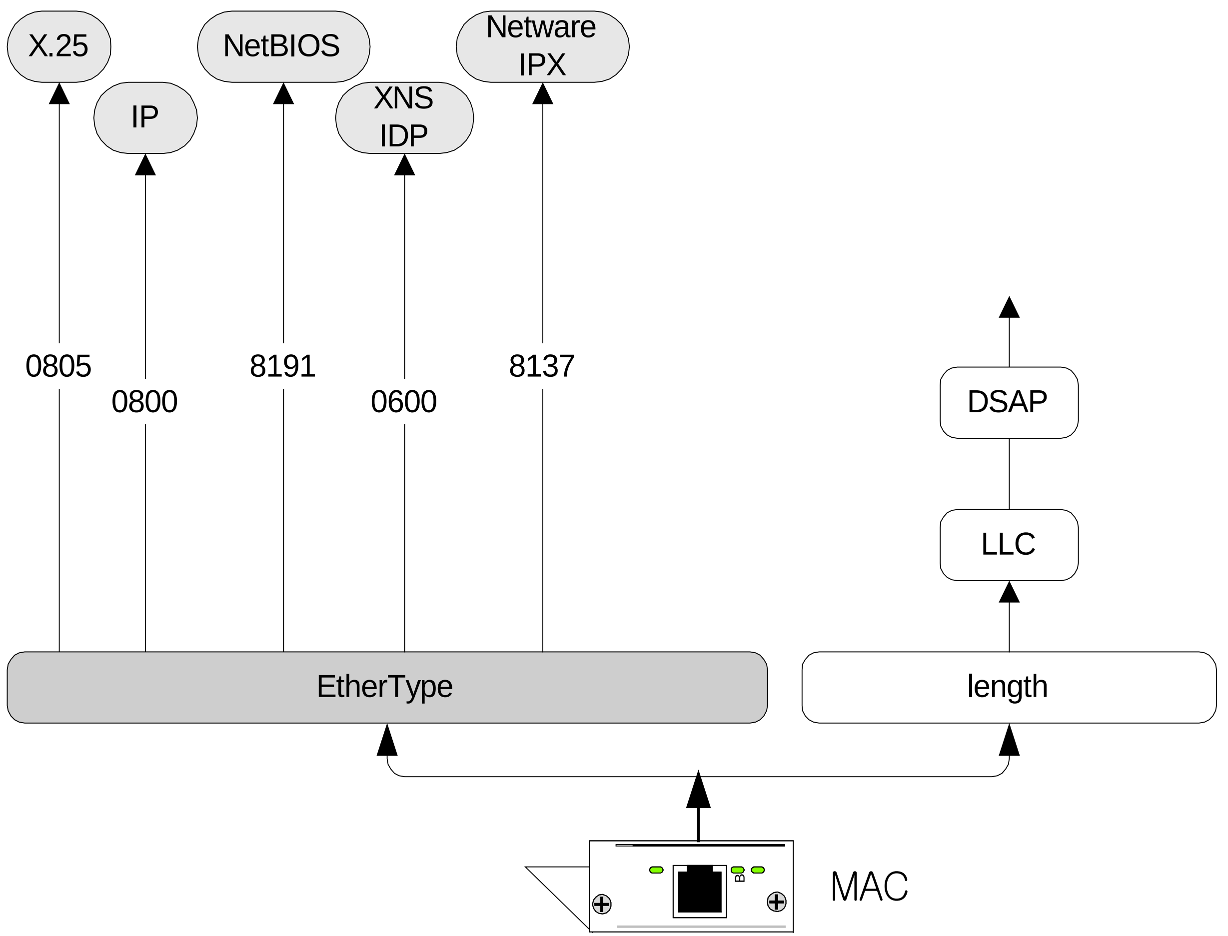


Project 802

Figure 13.1 *IEEE standard for LANs*

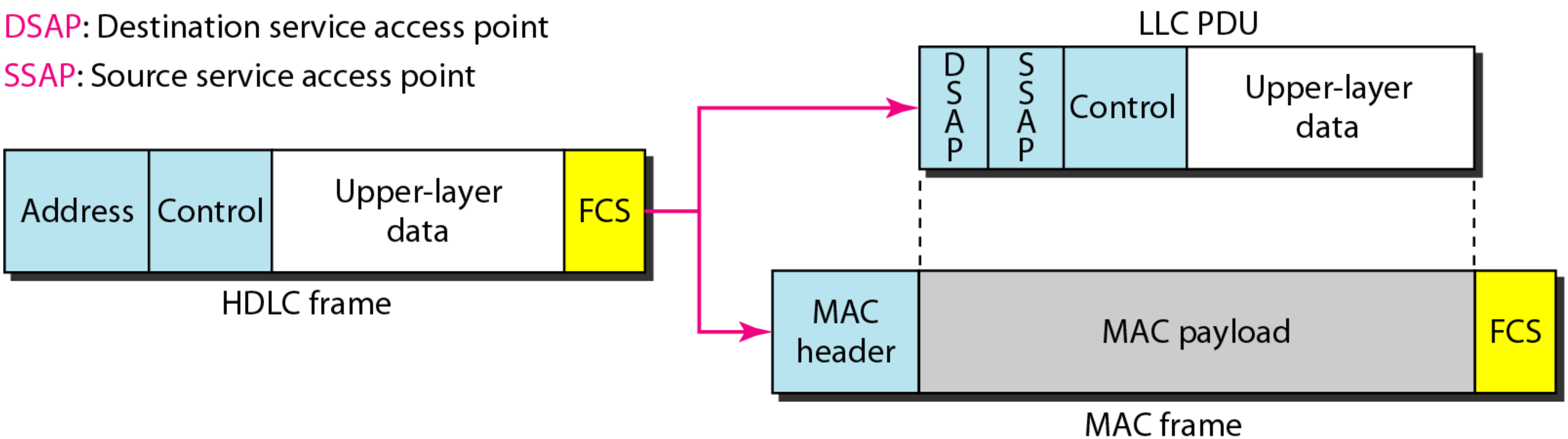


Protocol Multiplexing



참조 한국항공대학교 윤종호

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



13-2 STANDARD ETHERNET

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*

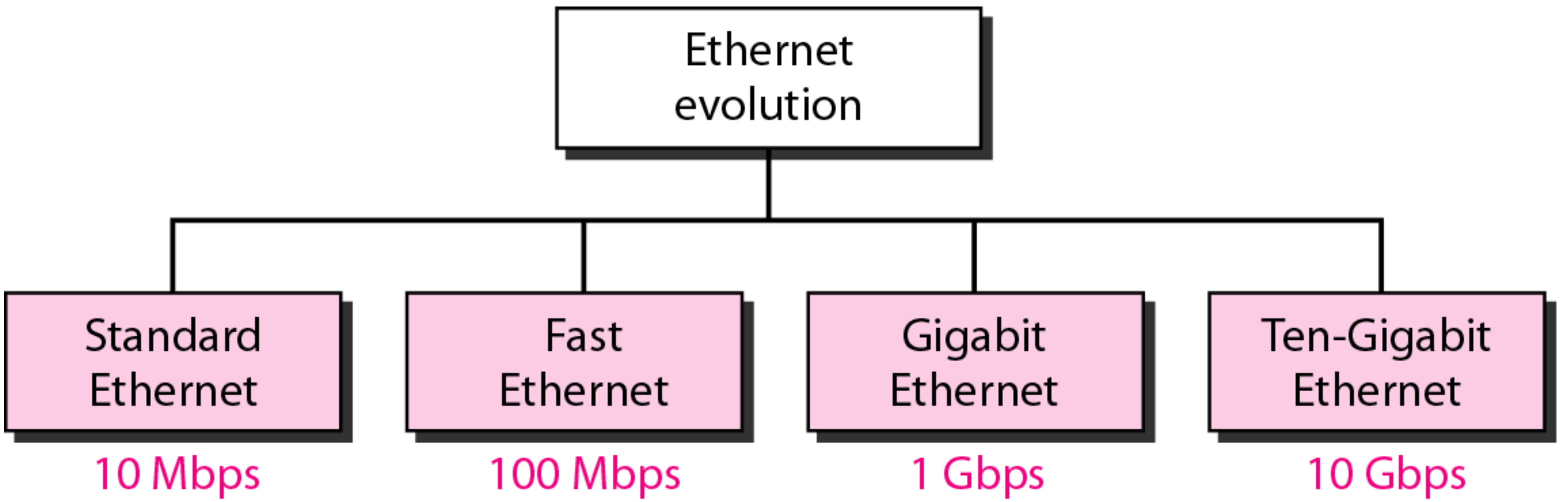


Figure 13.4 *802.3 MAC frame*

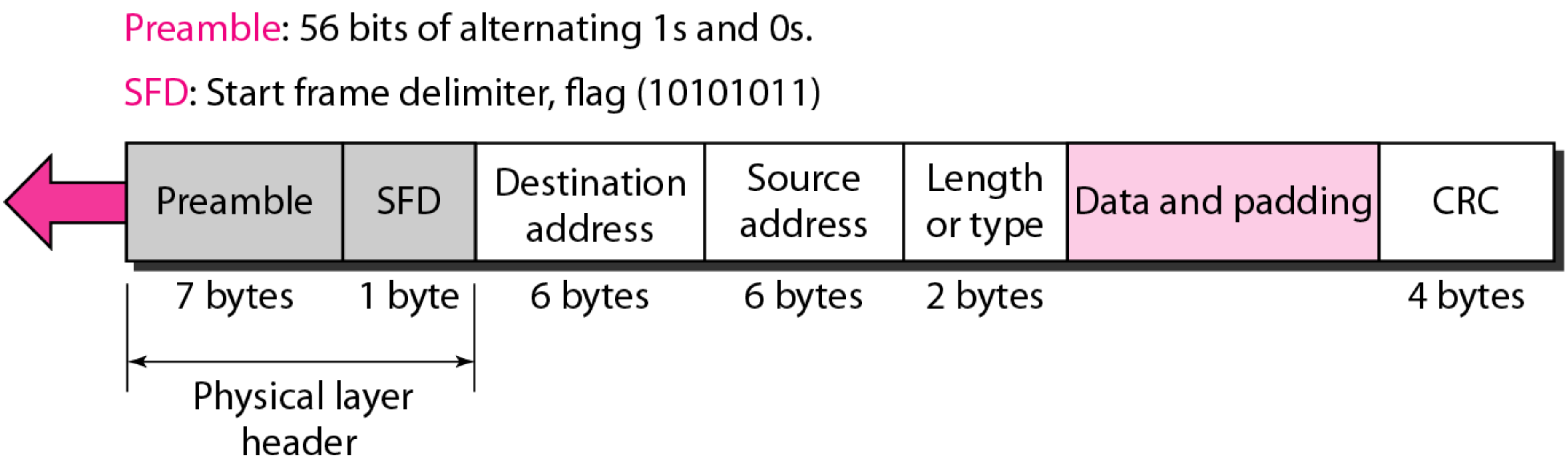
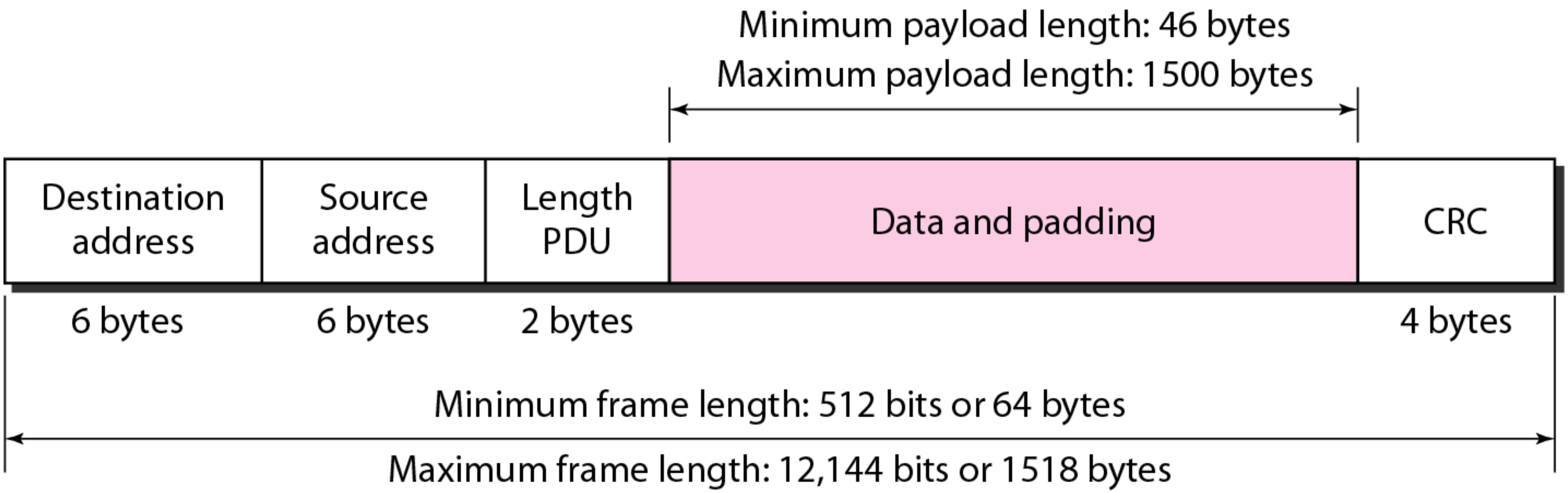


Figure 13.5 *Minimum and maximum lengths*



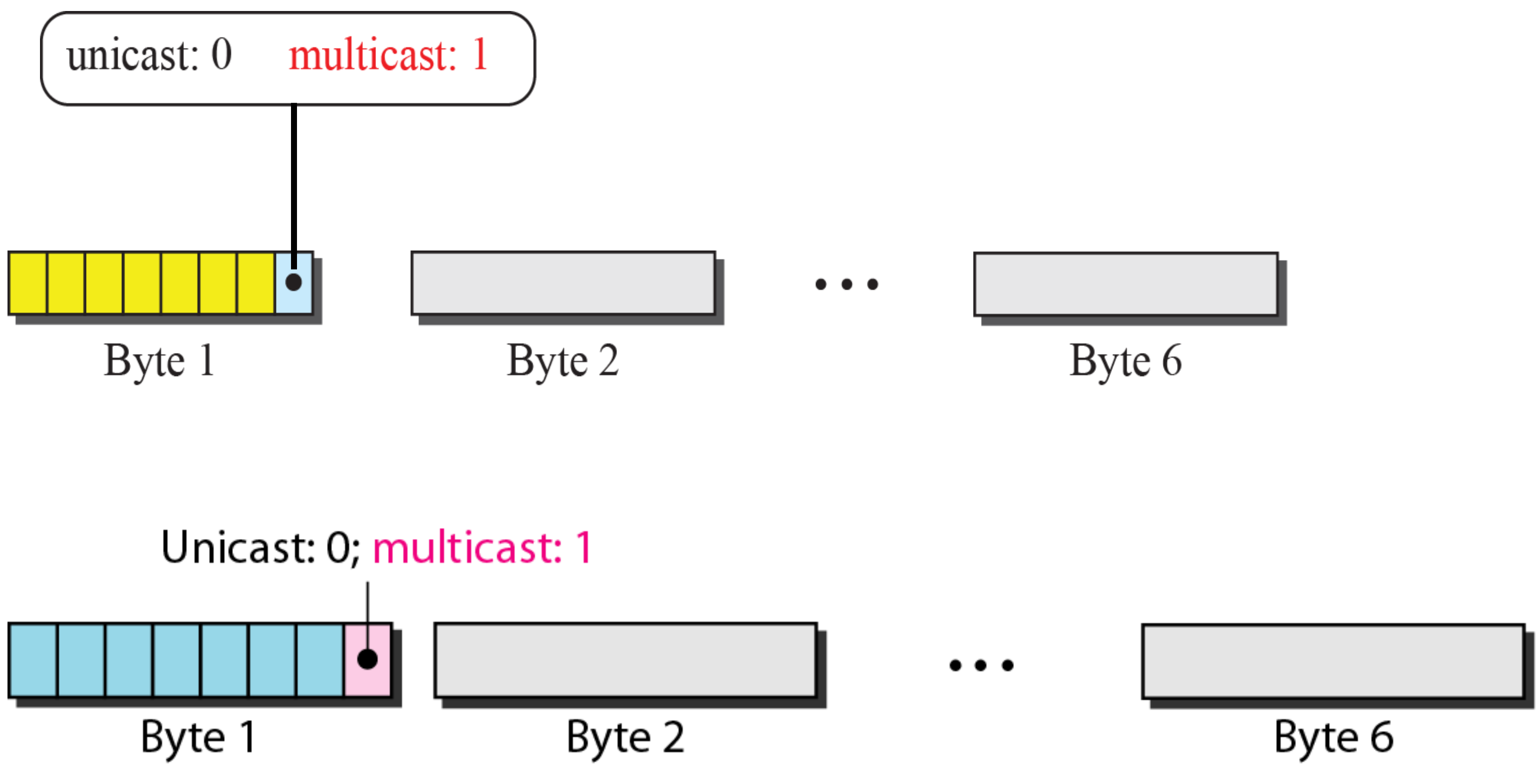
Frame length:
Minimum: 64 bytes (512 bits)
Maximum: 1518 bytes (12,144 bits)

Figure 13.6 *Example of an Ethernet address in hexadecimal notation*

$$\underbrace{\text{47:20:1B:2E:08:EE}}_{\text{6 bytes = 12 hex digits = 48 bits}}$$

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

Figure 13.7 *Unicast and multicast addresses*



Note

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.

Note

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*

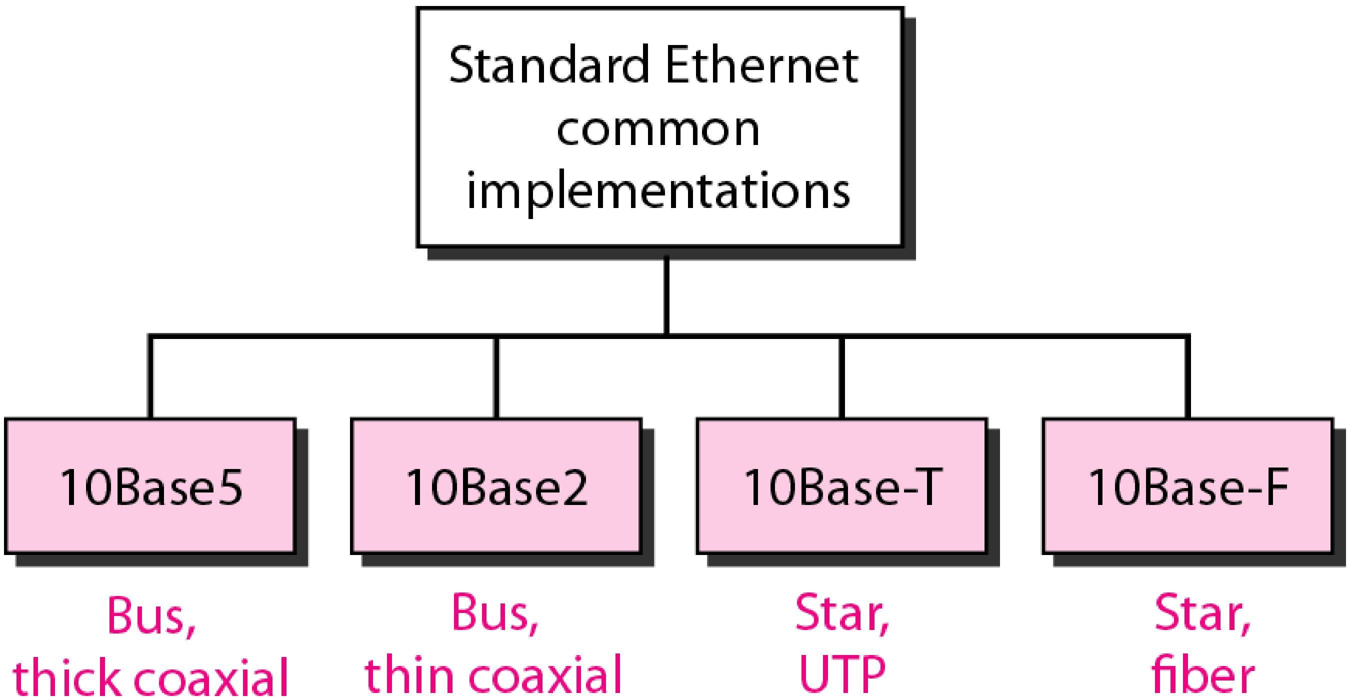


Figure 13.9 *Encoding in a Standard Ethernet implementation*

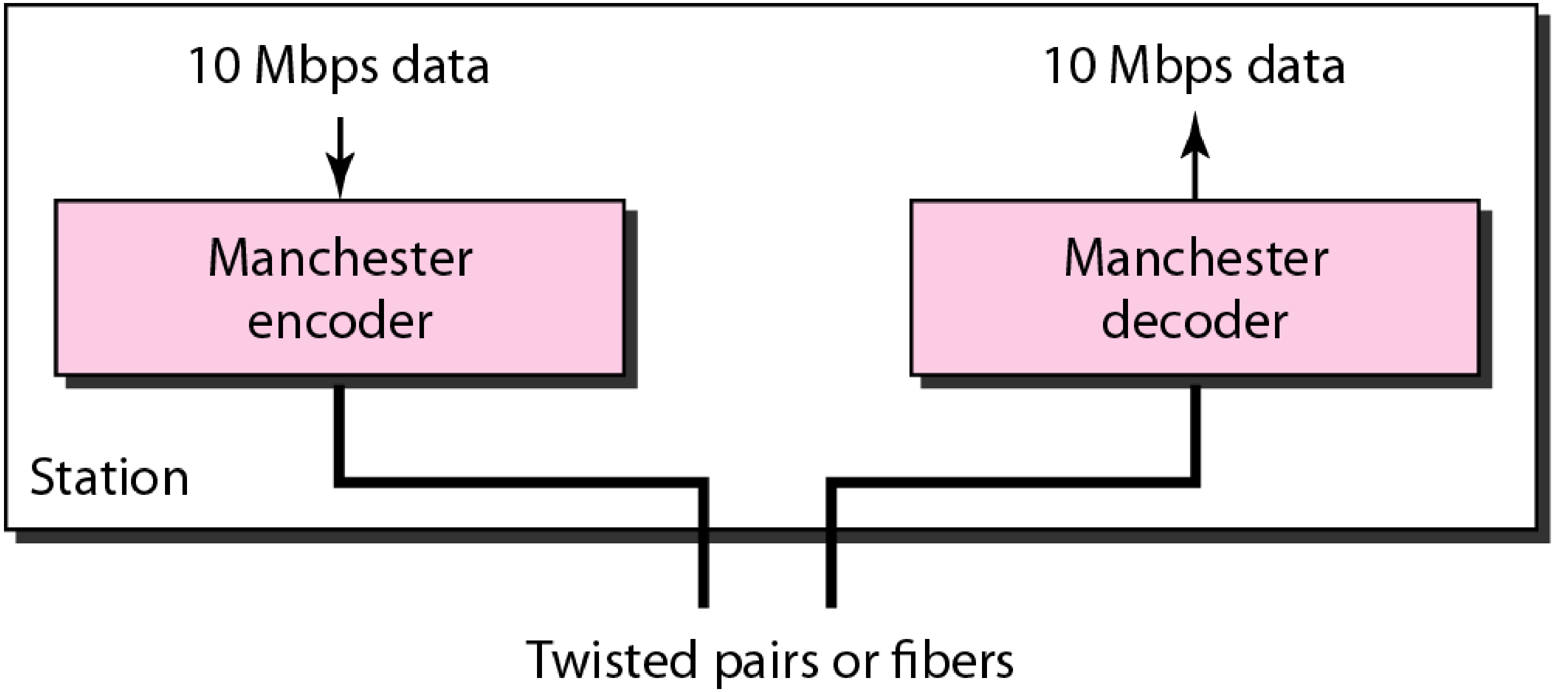


Figure 13.10 *10Base5 implementation*

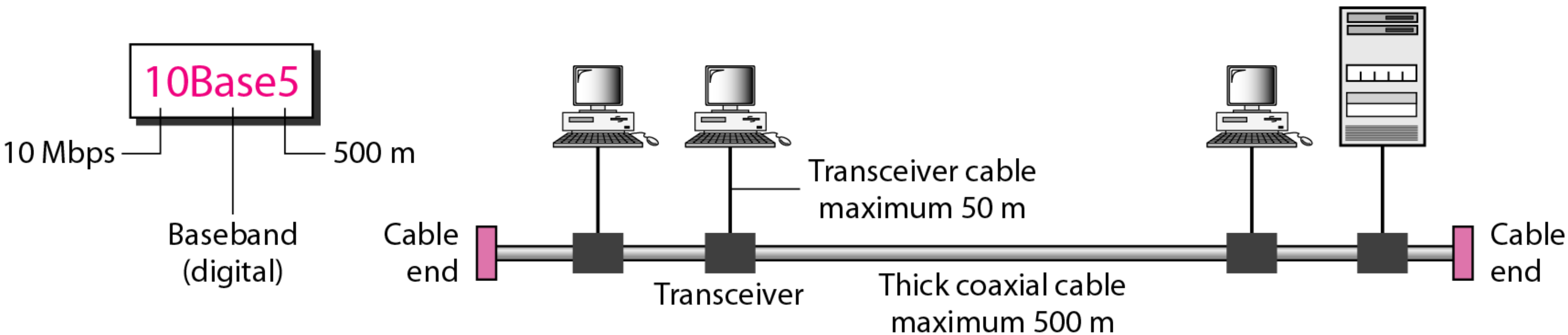


Figure 13.11 *10Base2 implementation*

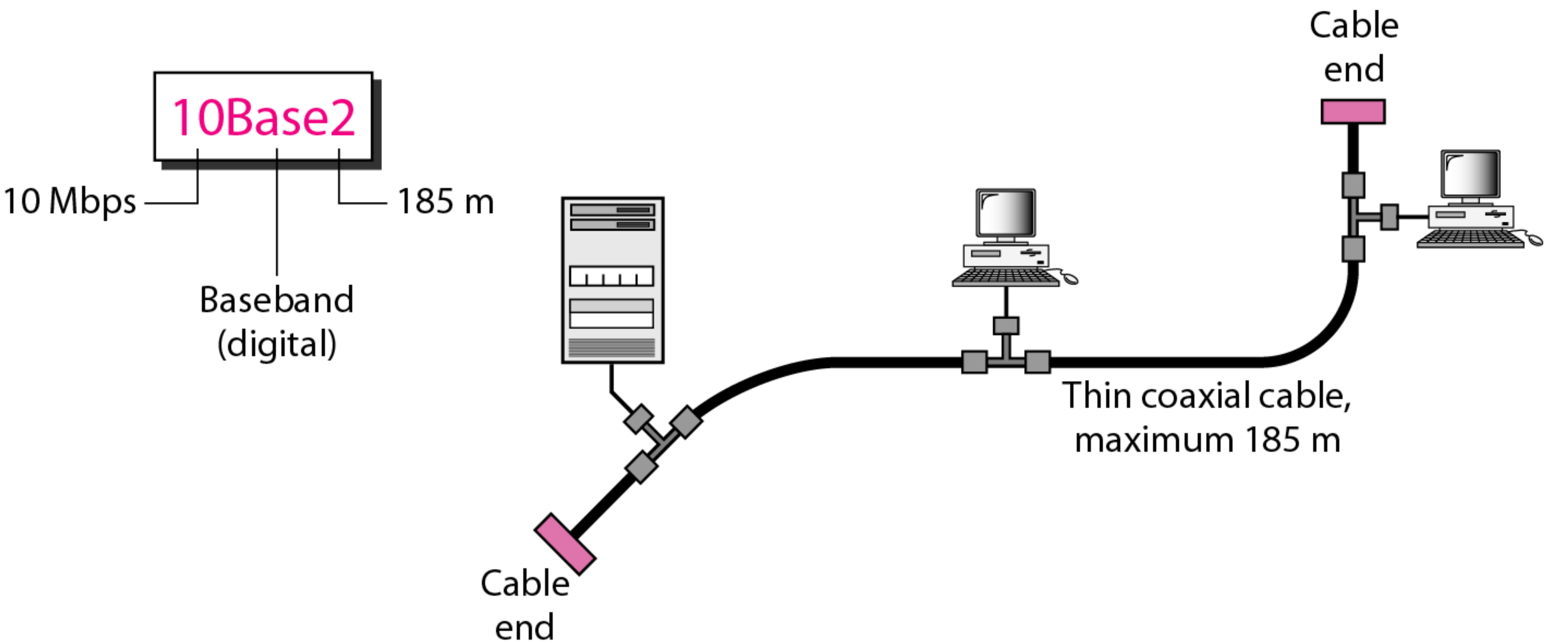


Figure 13.12 *10Base-T implementation*

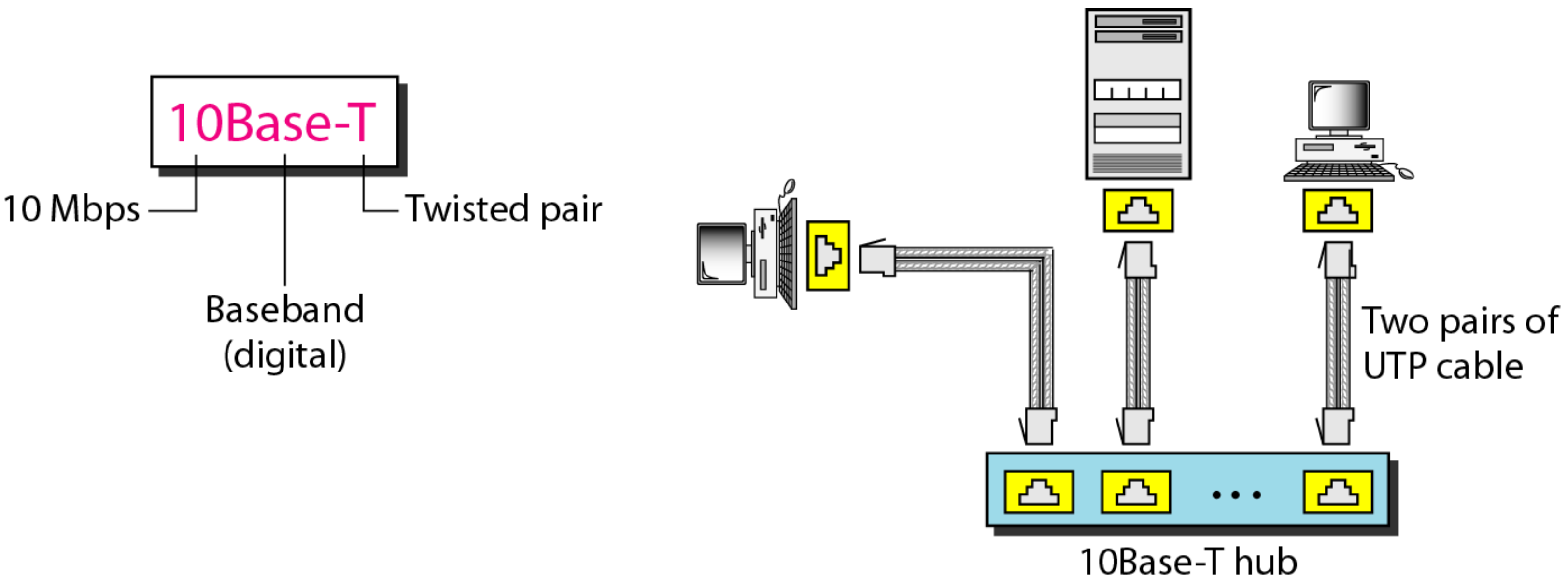


Figure 13.13 *10Base-F implementation*

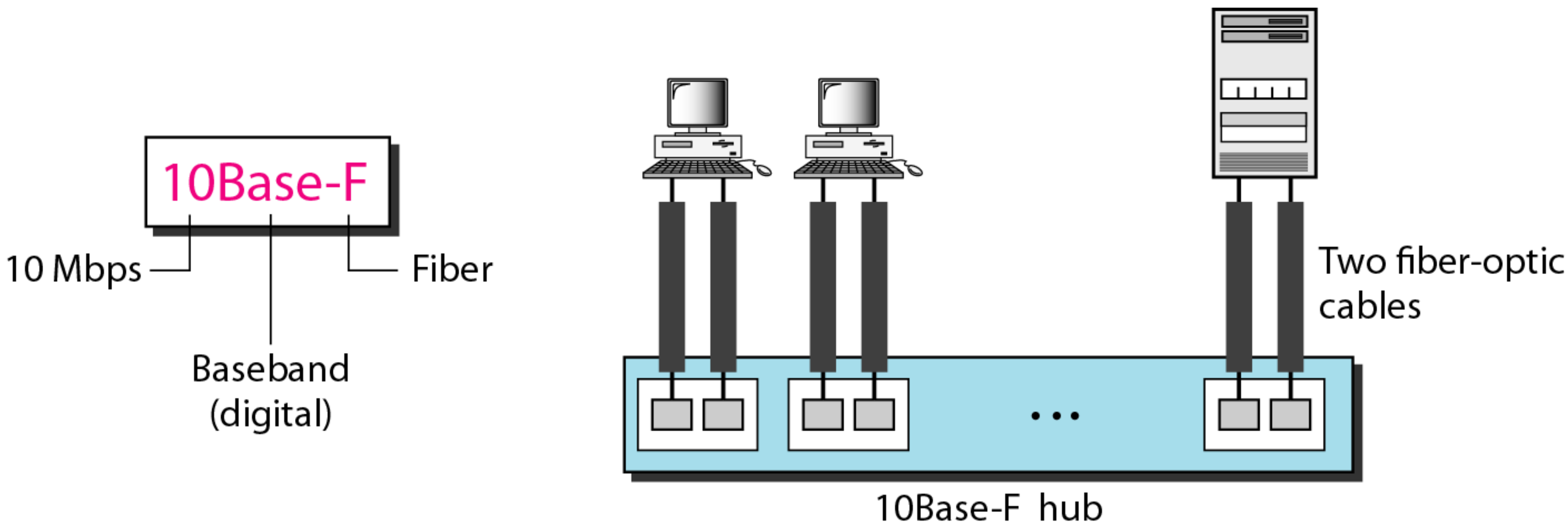


Table 13.1 *Summary of Standard Ethernet implementations*

Characteristics	*10Base5*	*10Base2*	*10Base-T*	*10Base-F*
Media	Thick coaxial cable	Thin coaxial cable	2 UTP	2 Fiber
Maximum length	500 m	185 m	100 m	2000 m
Line encoding	Manchester	Manchester	Manchester	Manchester

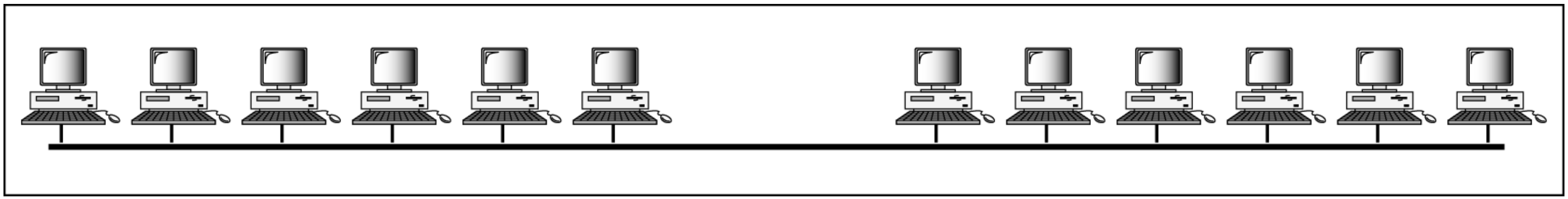
13.2.6 Changes in the Standard

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.

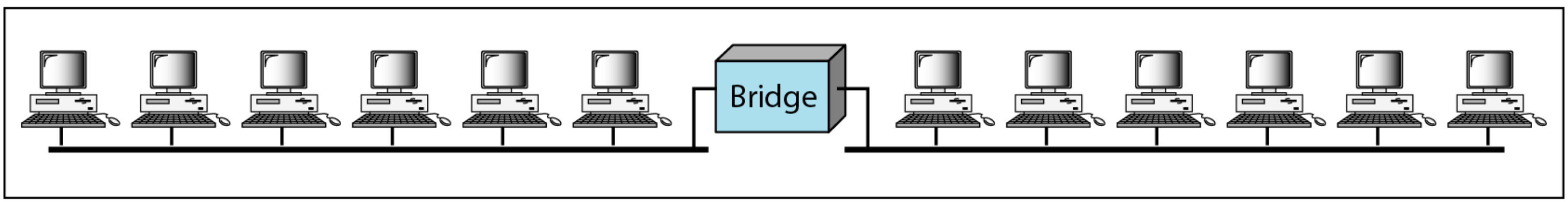
Topics discussed in this section:

Bridged Ethernet
Switched Ethernet
Full-Duplex Ethernet

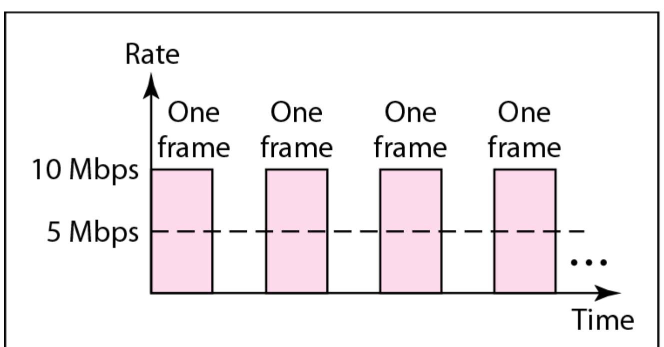
Figure 13.15 *A network with and without a bridge*



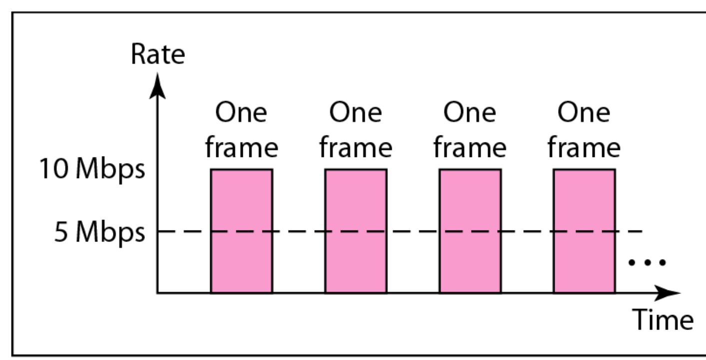
a. Without bridging



b. With bridging



a. First station



b. Second station

Figure 13.14 *Sharing bandwidth*

Figure 13.16 *Collision domains in an unbridged network and a bridged network*

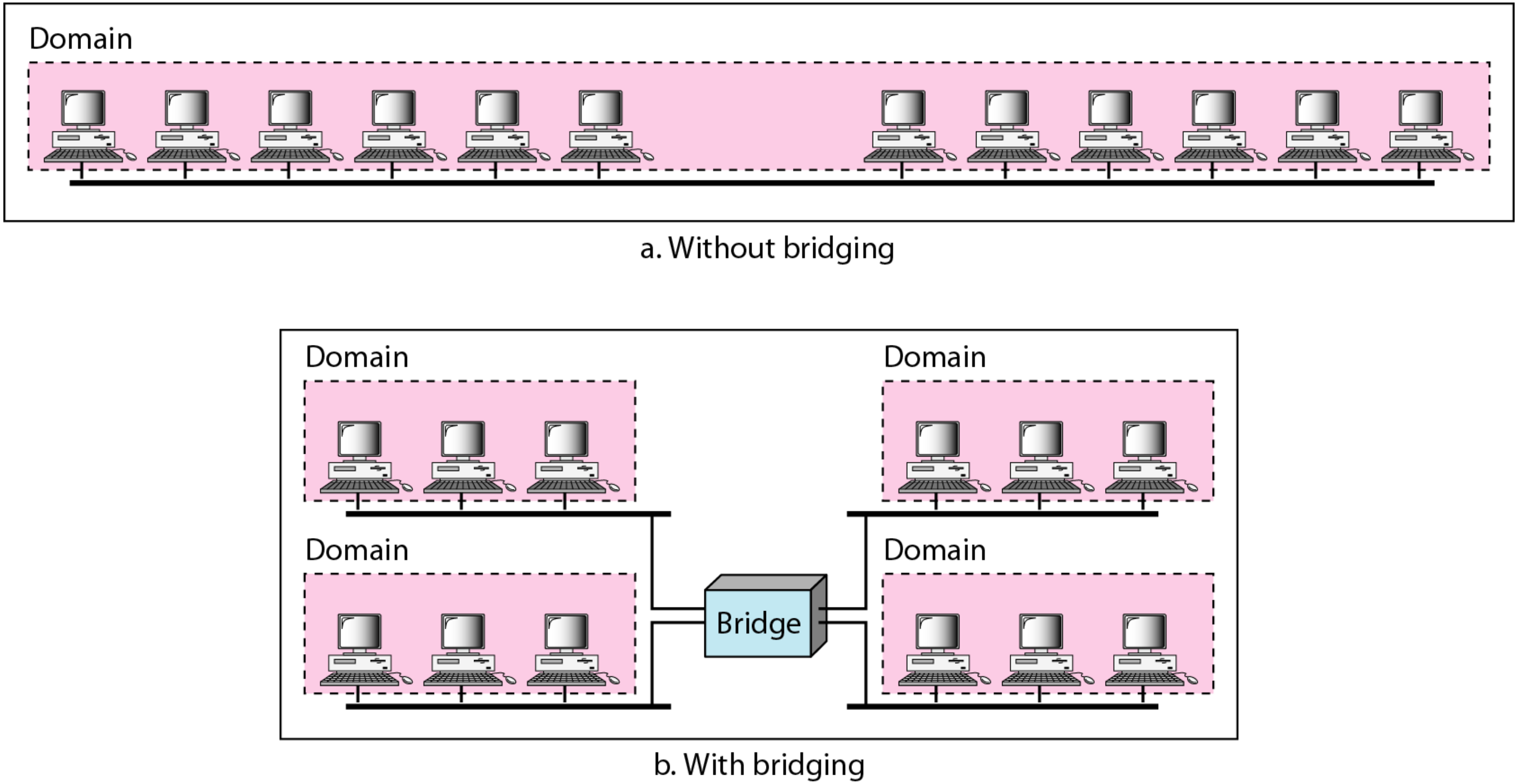


Figure 13.14: Switched Ethernet

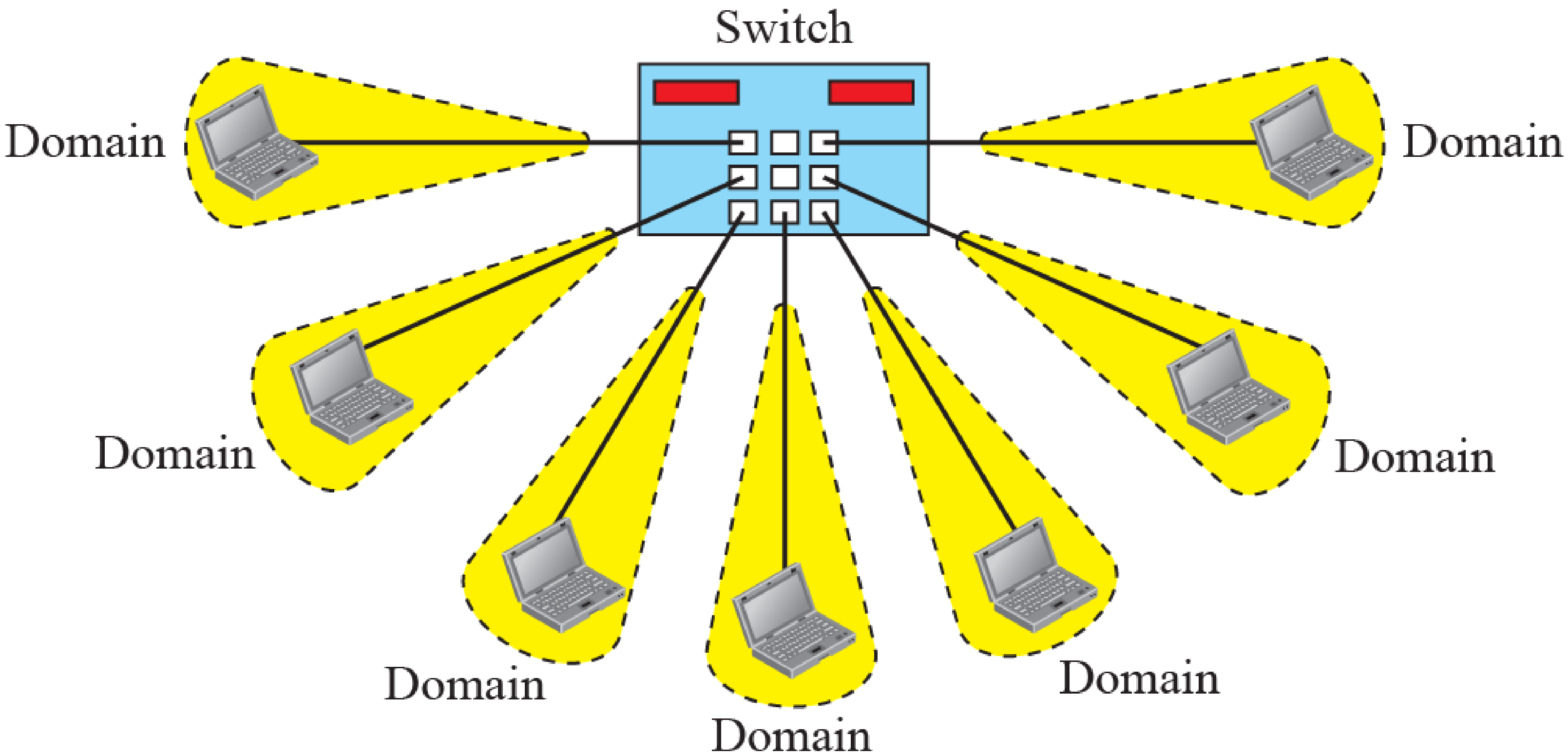
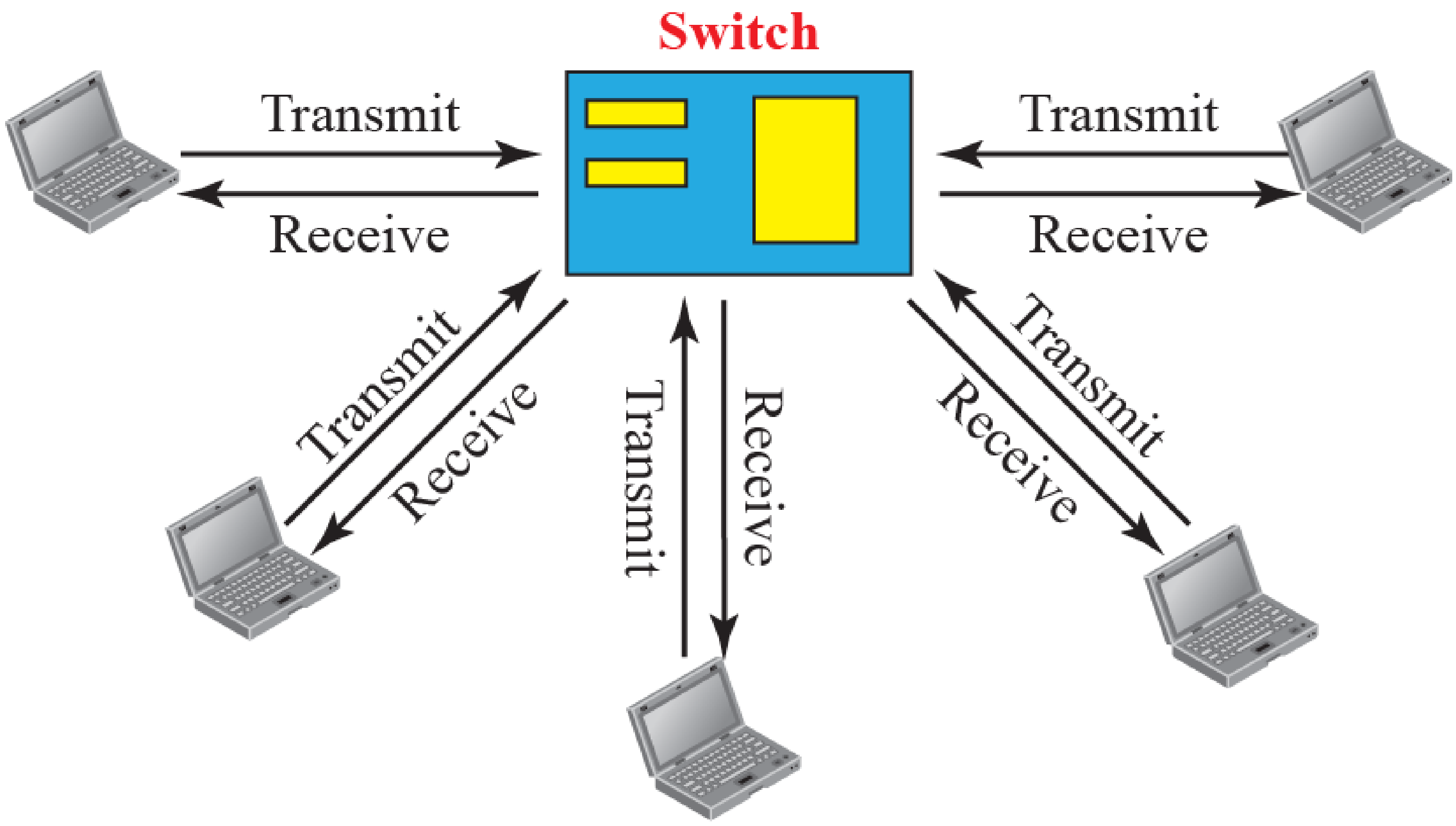


Figure 13.15: Full – duplex switched Ethernet



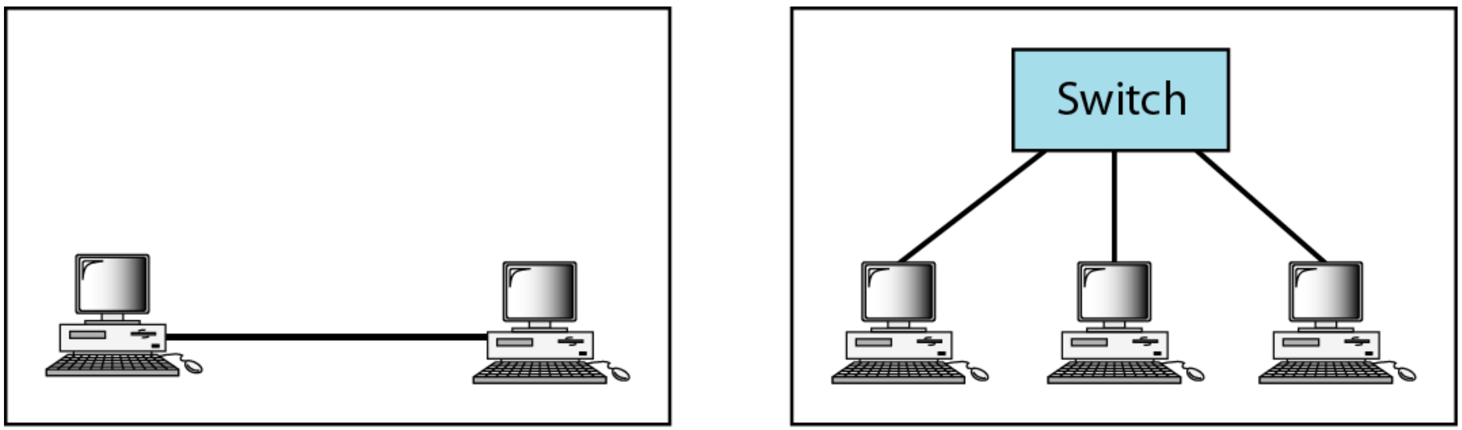
13-3 FAST ETHERNET

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.

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*

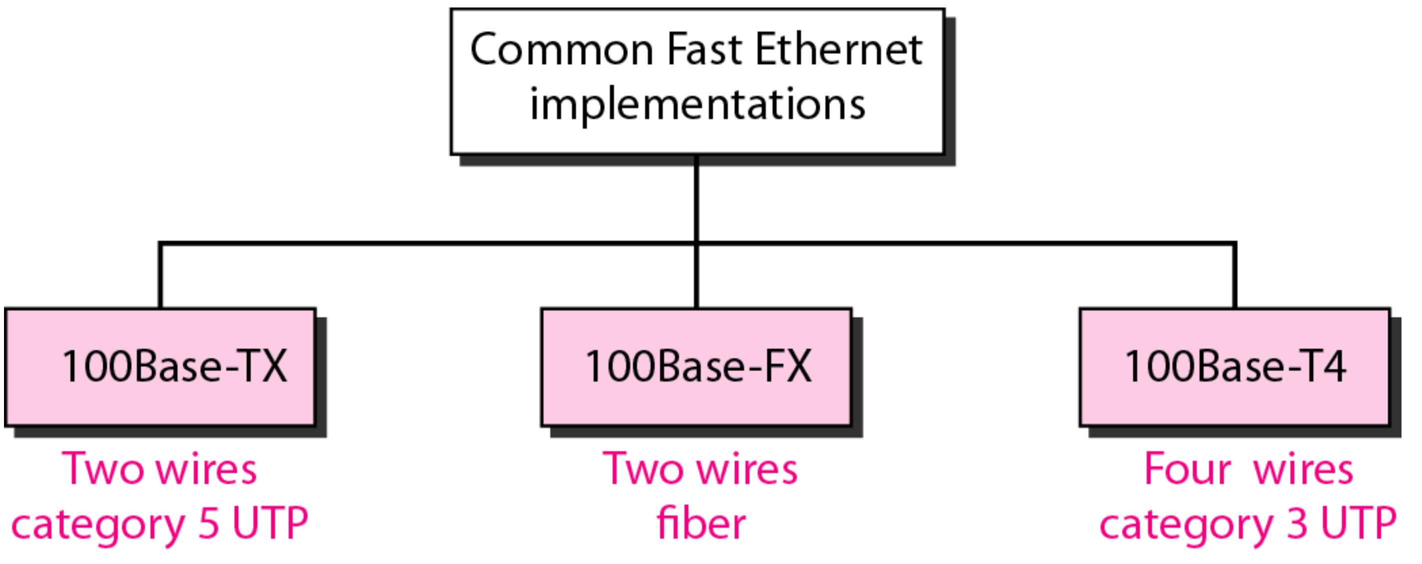


Figure 13.16: Encoding for fast Ethernet

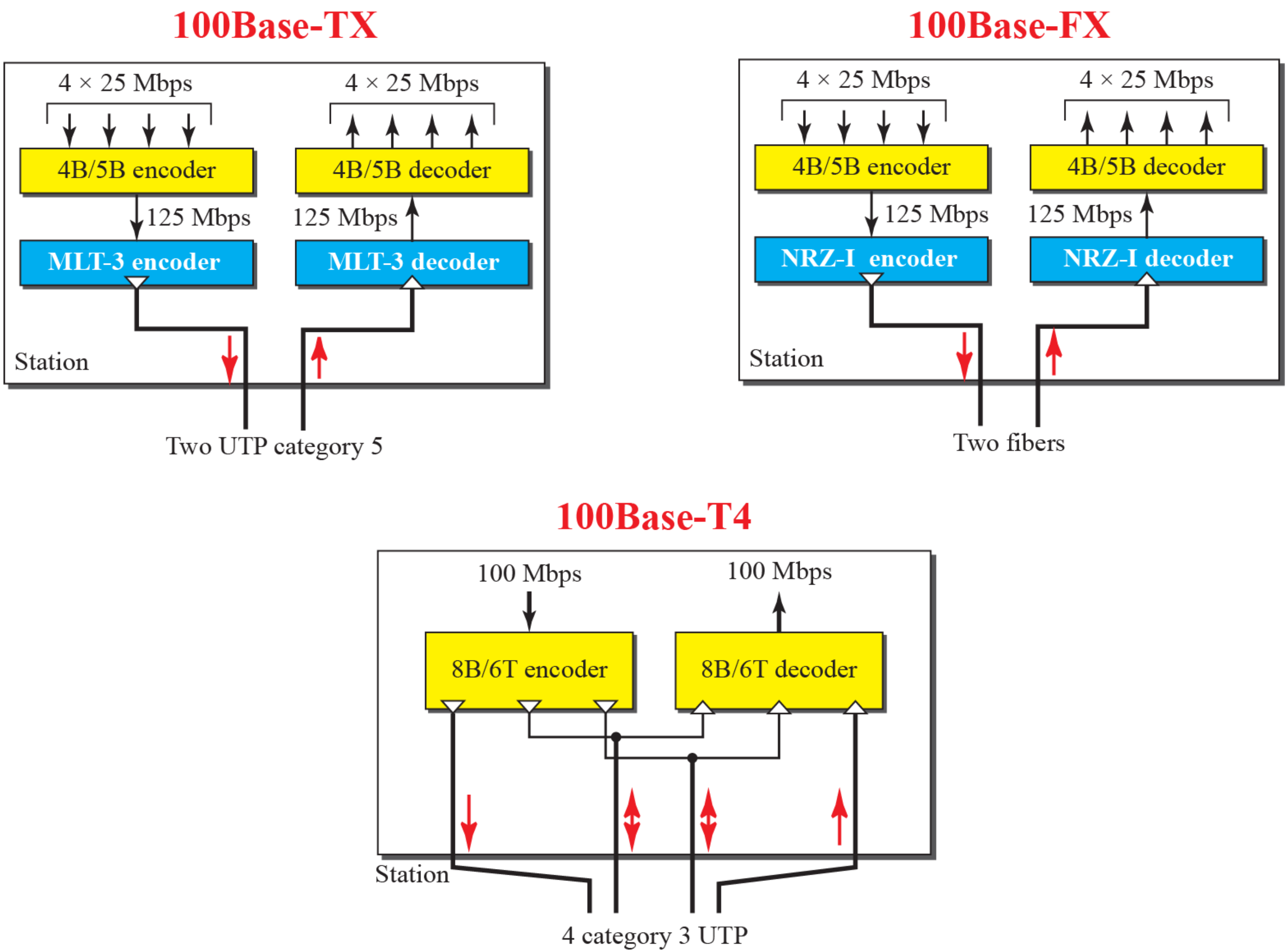


Figure 4.13 *Multitransition: MLT-3 scheme*

3 레벨의 신호 (+, 0, -) 과 3 가지 규칙을 사용하여 부호화

- 다음 비트가 0 이면 레벨 변화가 없다
- 다음 비트가 1 이고 현재 레벨이 0 이 아니면 다음 레벨은 0
- 다음 비트가 1 이고 현재 레벨이 0 이면 다음 레벨은 최근 0 이 아니었던 레벨의 역

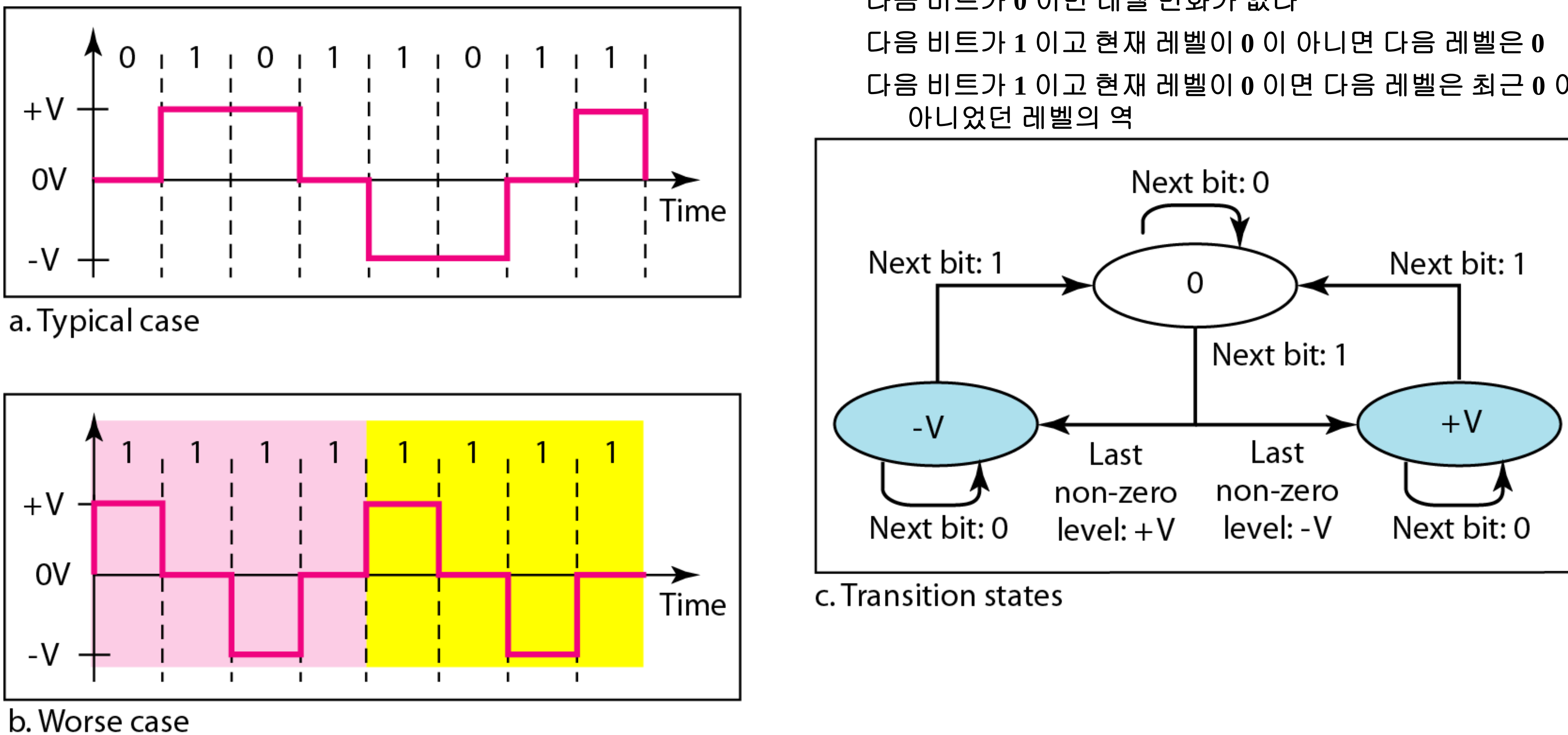


Figure 4.6 *Polar NRZ-L and NRZ-I schemes*

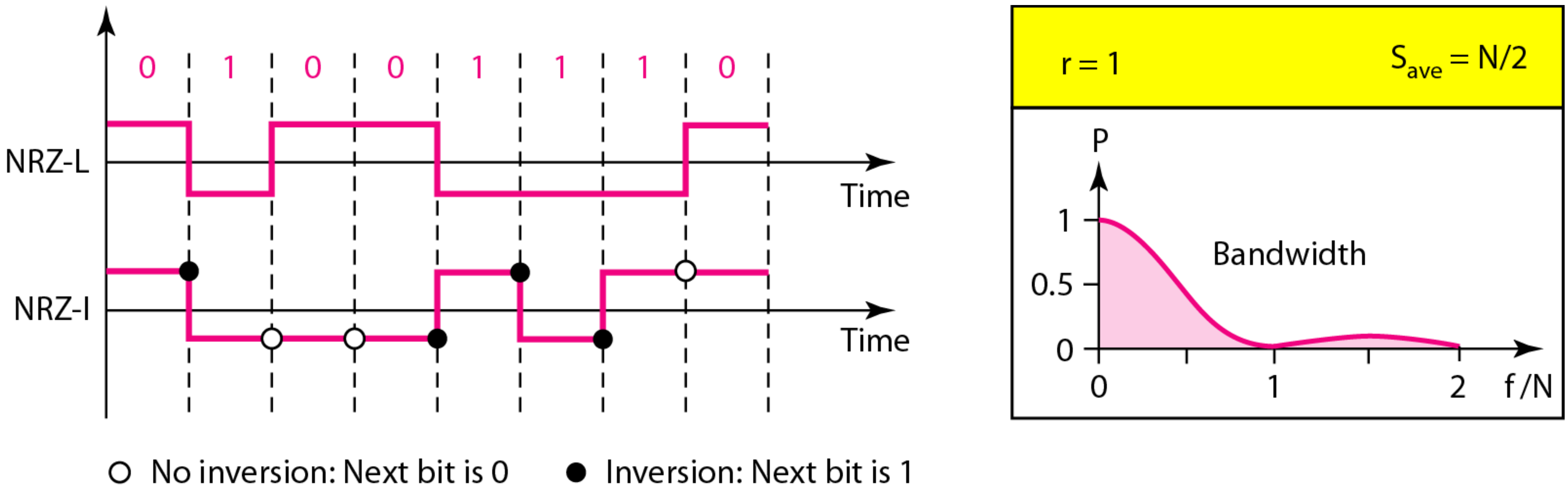
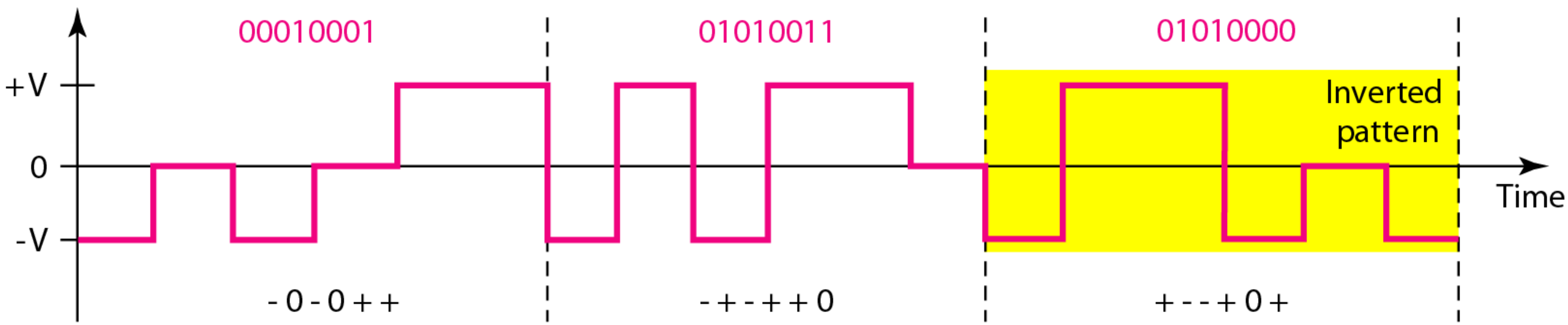


Figure 4.11 *Multilevel: 8B6T scheme*



8비트 → 6 비트 ternary

Figure 4.16 *Substitution in 4B/5B block coding*

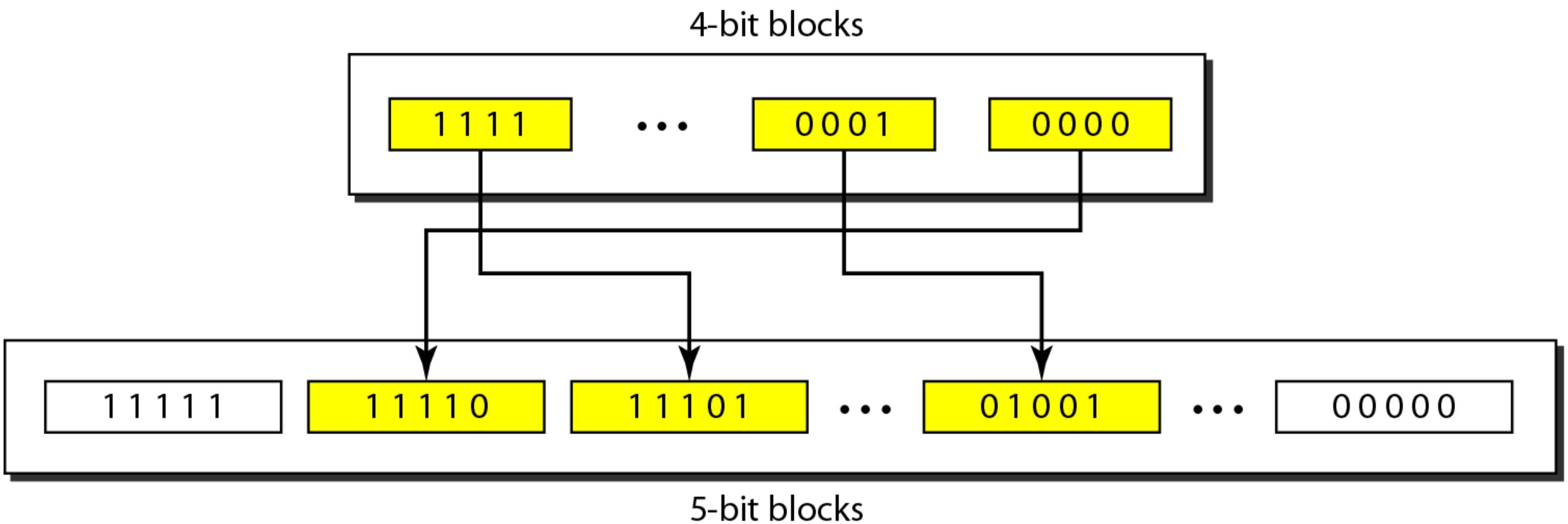


Table 4.2 *4B/5B mapping codes*

Data Sequence	*Encoded Sequence*	*Control Sequence*	*Encoded Sequence*
0000	11110	Q (Quiet)	00000
0001	01001	I (Idle)	11111
0010	10100	H (Halt)	00100
0011	10101	J (Start delimiter)	11000
0100	01010	K (Start delimiter)	10001
0101	01011	T (End delimiter)	01101
0110	01110	S (Set)	11001
0111	01111	R (Reset)	00111
1000	10010	**Invalid code**	
1001	10011		
1010	10110		
1011	10111		
1100	11010		
1101	11011		
1110	11100		
1111	11101		

Figure 4.15 *Using block coding 4B/5B with NRZ-I line coding scheme*

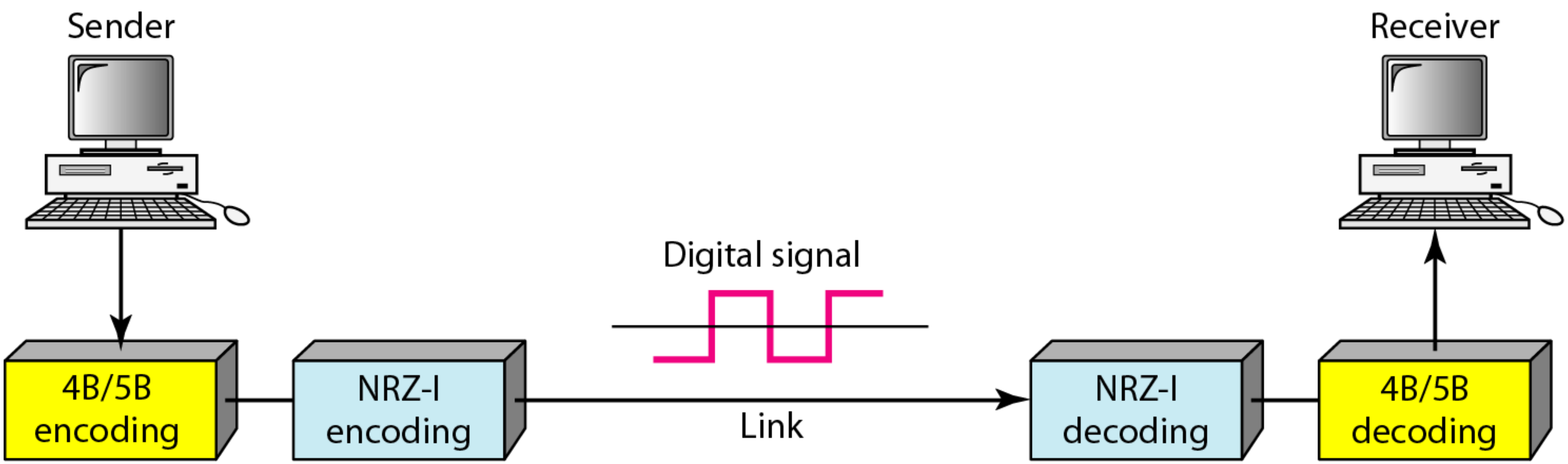


Table 13.2 *Summary of Fast Ethernet implementations*

Implementation	*Medium*	*Medium Length*	*Wires*	*Encoding*
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

13-4 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 the standard 802.3z.

Topics discussed in this section:

MAC Sublayer
Physical Layer
Ten-Gigabit Ethernet

Note

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*

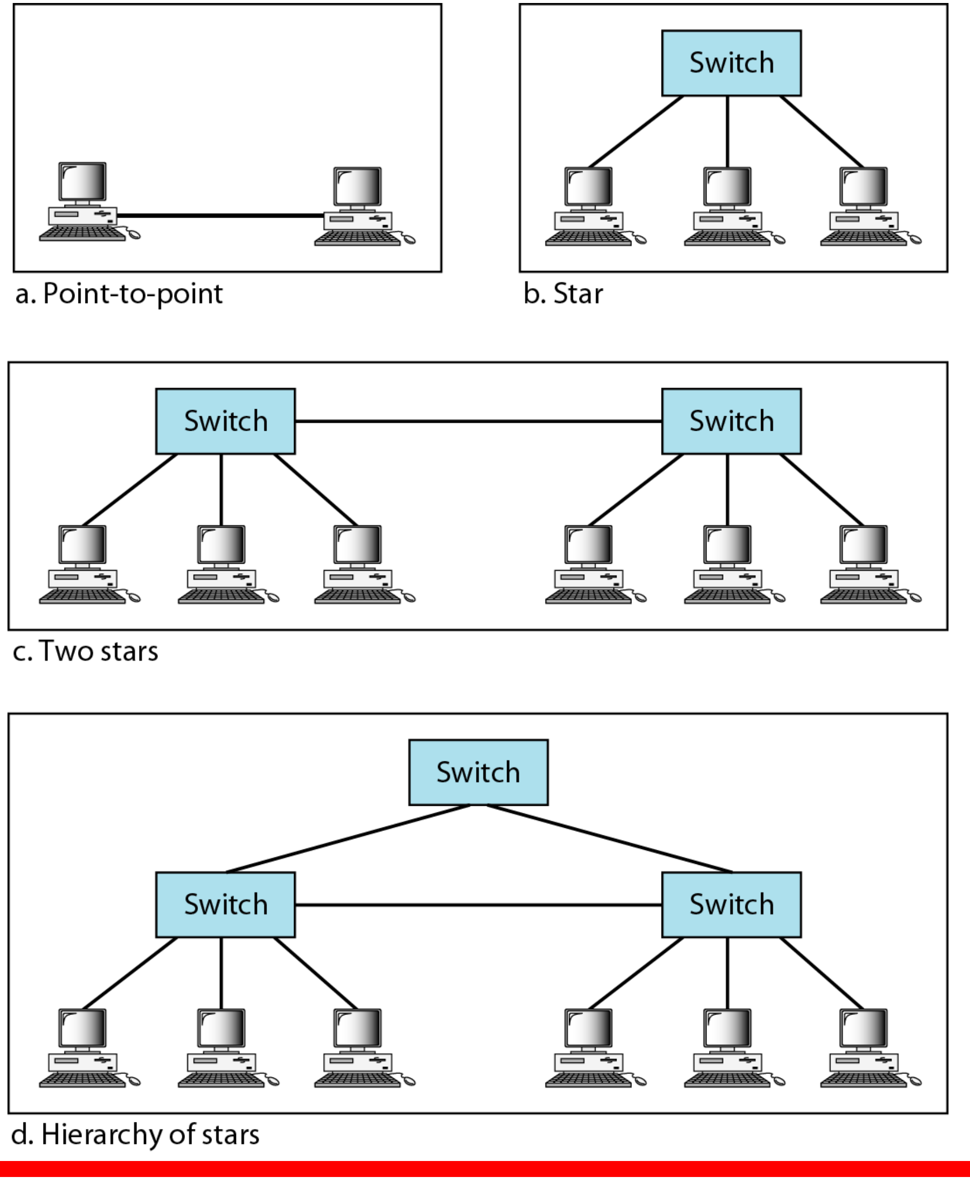


Figure 13.23 *Gigabit Ethernet implementations*

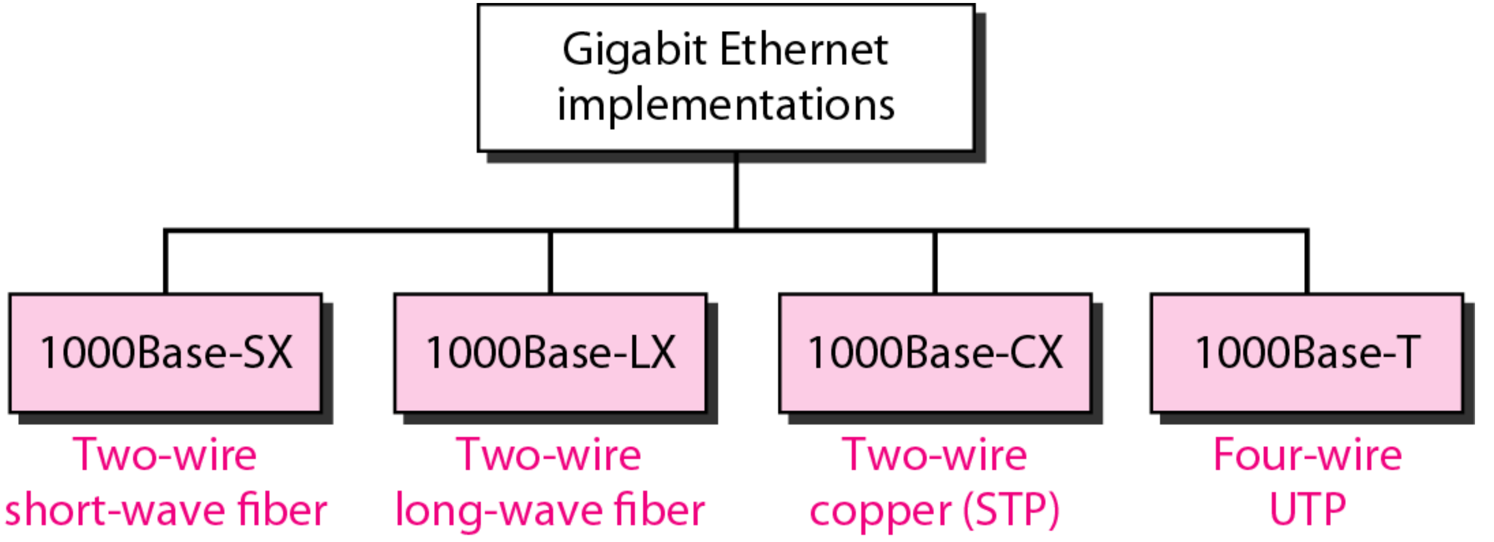


Figure 13.24 *Encoding in Gigabit Ethernet implementations*

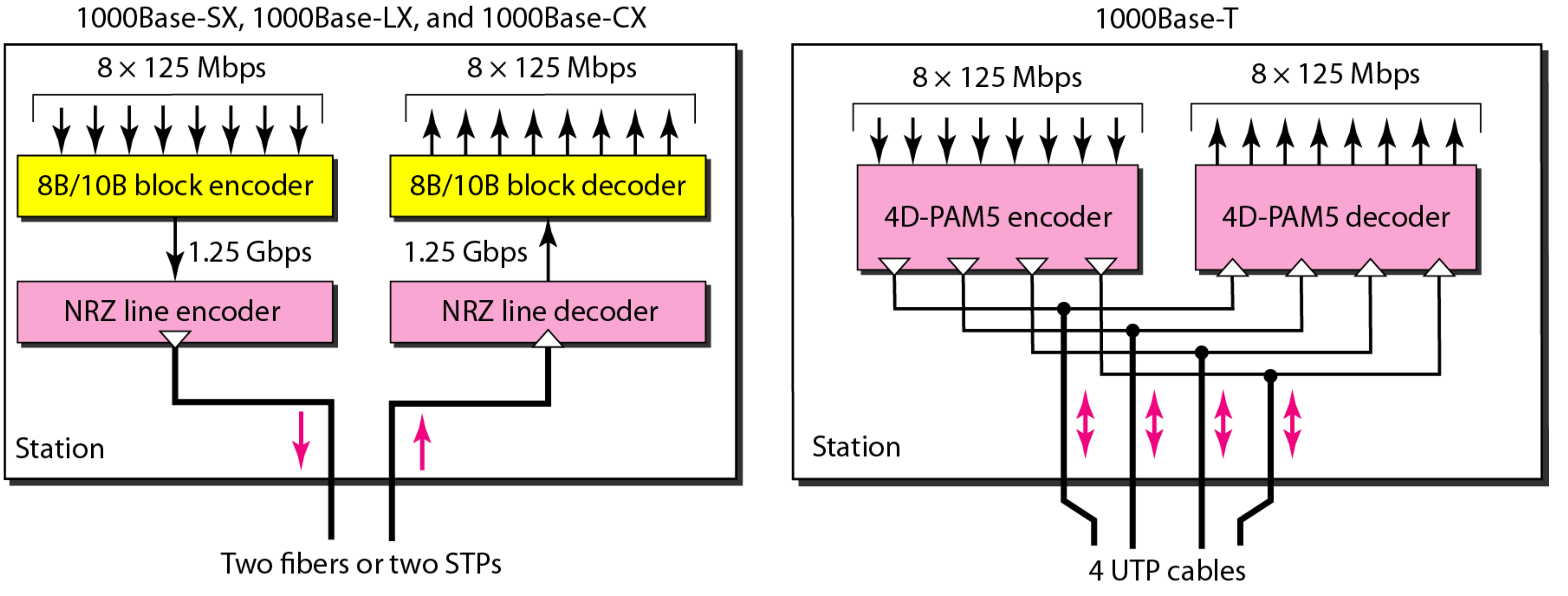
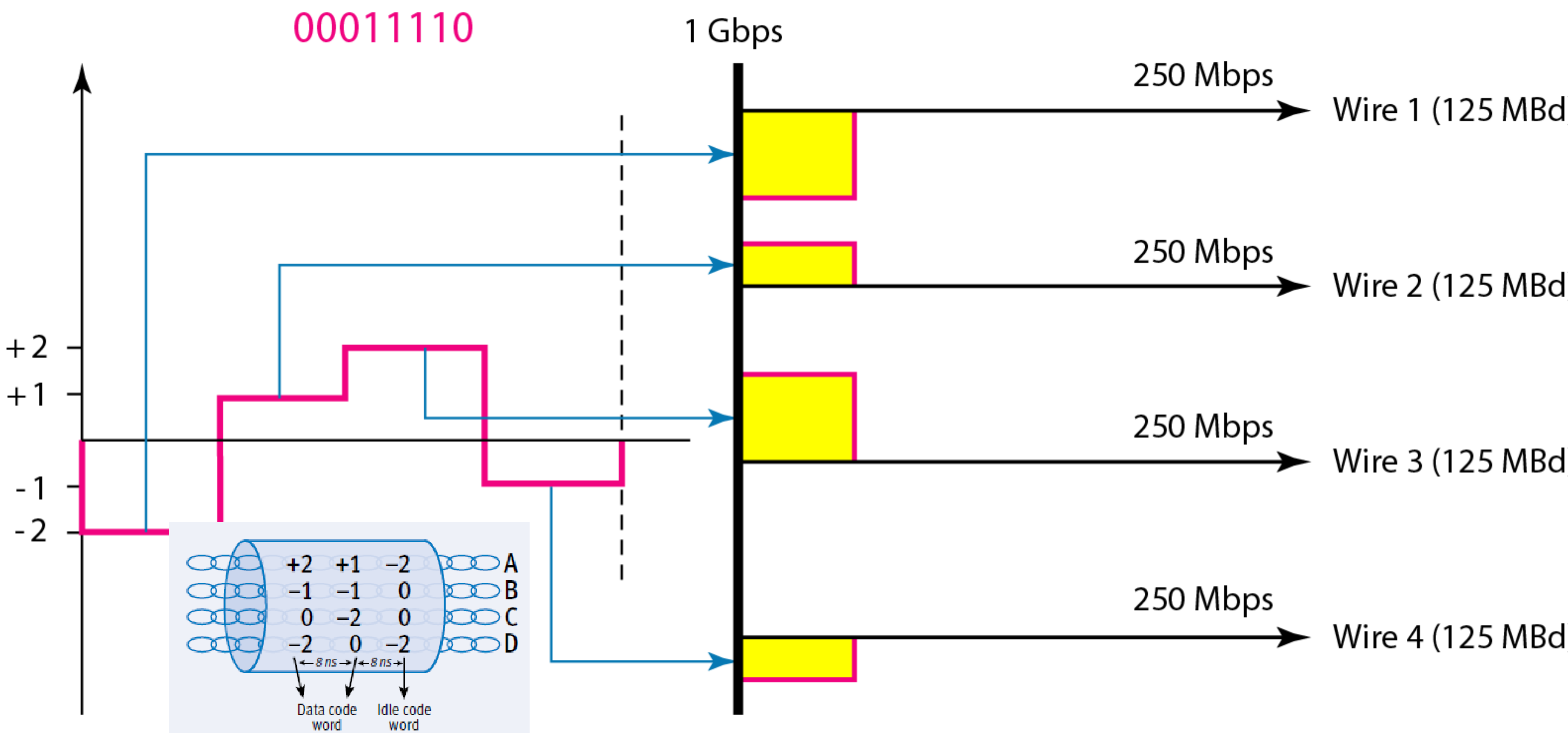


Figure 4.12 *Multilevel: 4D-PAM5 scheme*

기가 비트 **LAN** 용



Symbol	Mapped voltage level (volts)
−2	−1
−1	−0.5
0	0
+1	+0.5
+2	+1

4-Dimensional 5-level Pulse Amplitude Modulation (PAM)

Figure 4.14 *8B/10B Block coding concept*

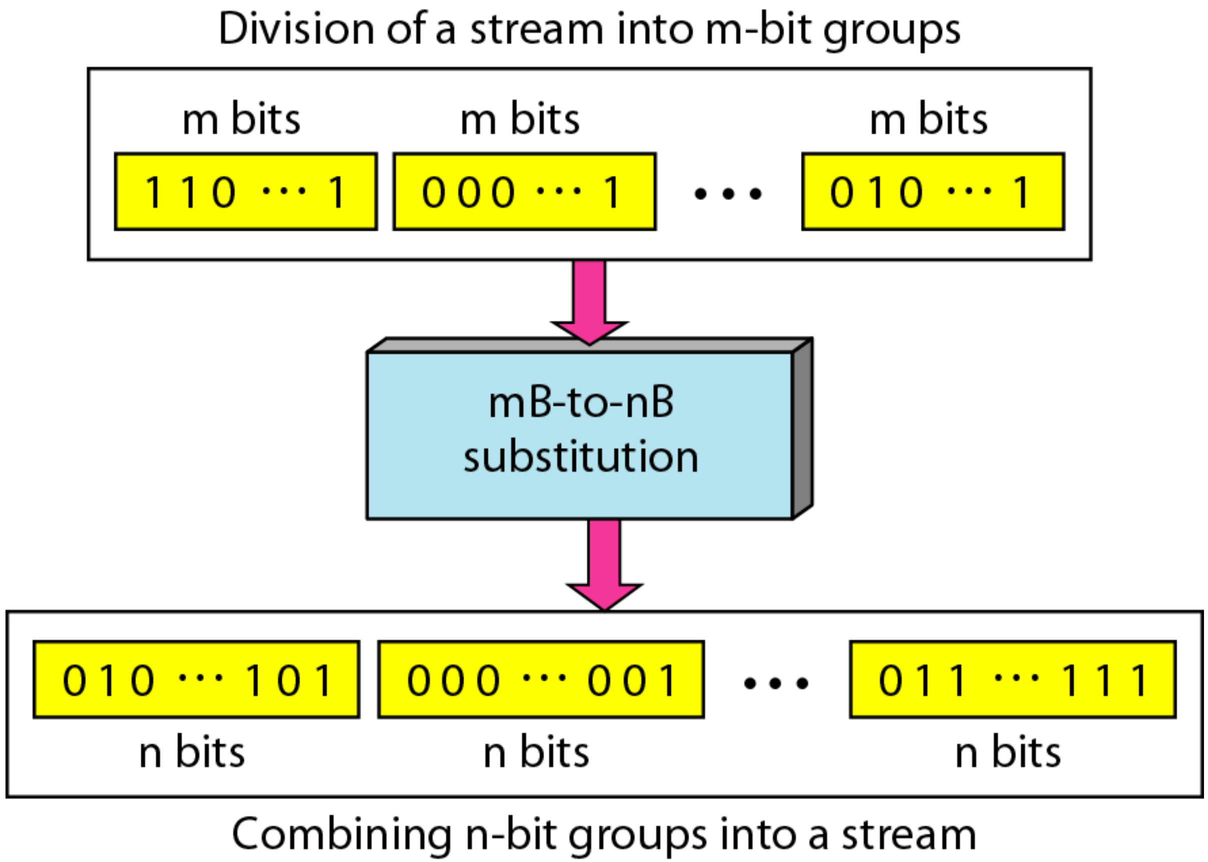
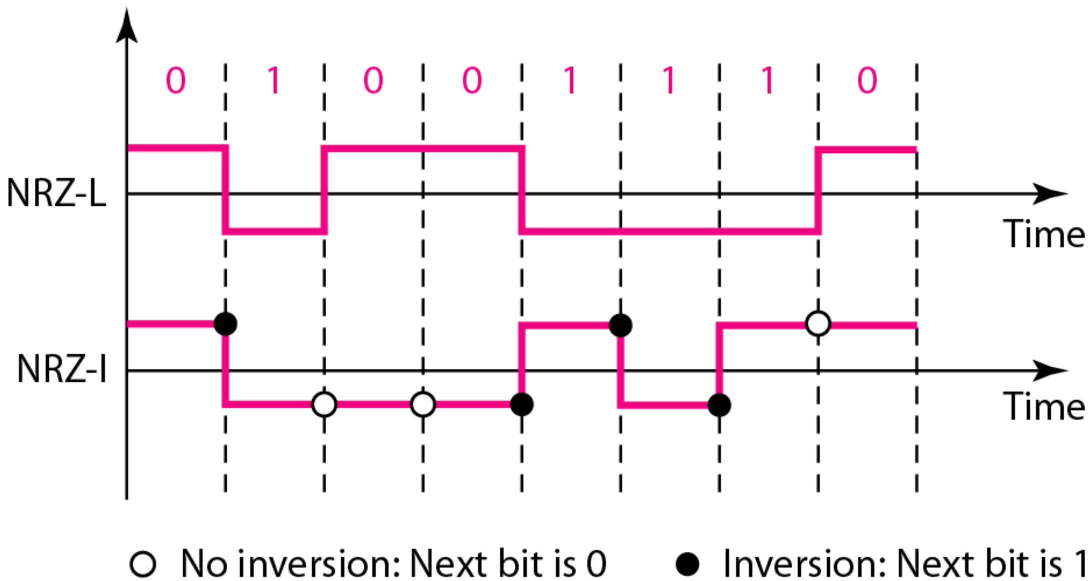


Figure 4.6 *Polar NRZ-L and NRZ-I schemes*



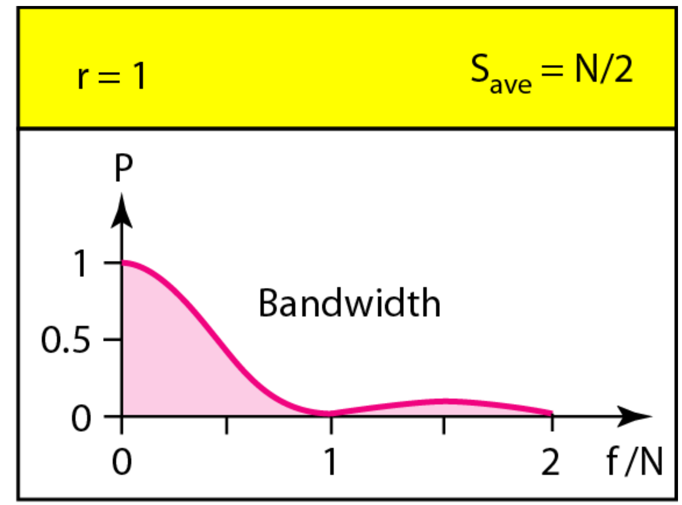


Figure 4.15 *Using block coding 8B/10B with NRZ-I line coding scheme*

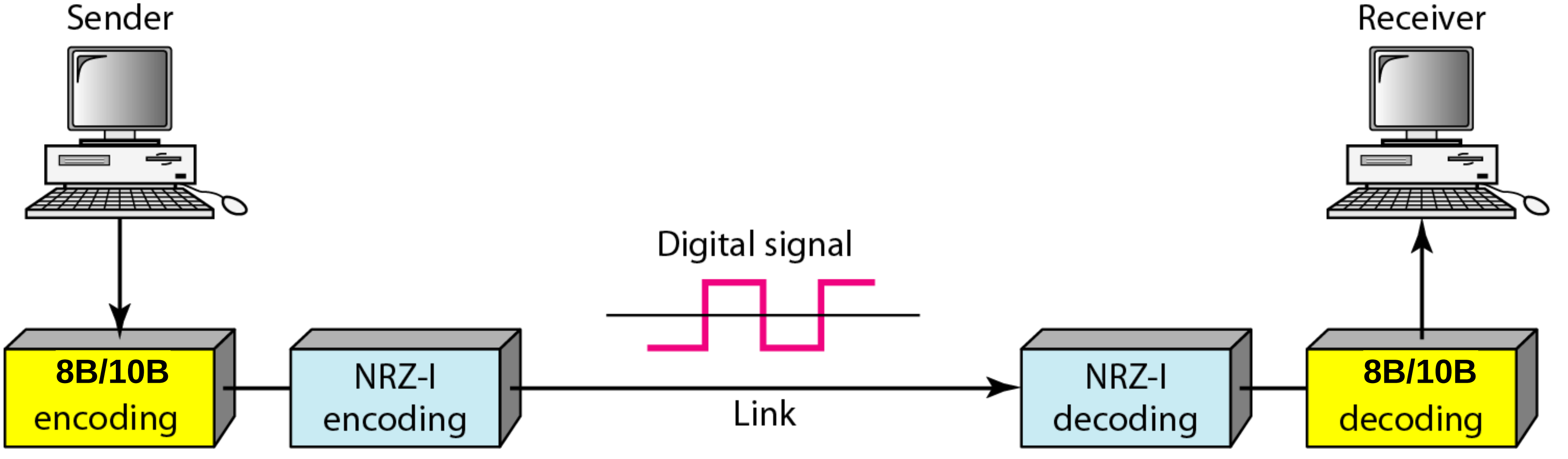


Table 13.3 ***Summary of Gigabit Ethernet implementations***

Implementation	*Medium*	*Medium Length*	*Wires*	*Encoding*
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

Table 13.4 ***Summary of Ten-Gigabit Ethernet implementations***

Implementation	*Medium*	*Medium Length*	*Number of wires*	*Encoding*
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