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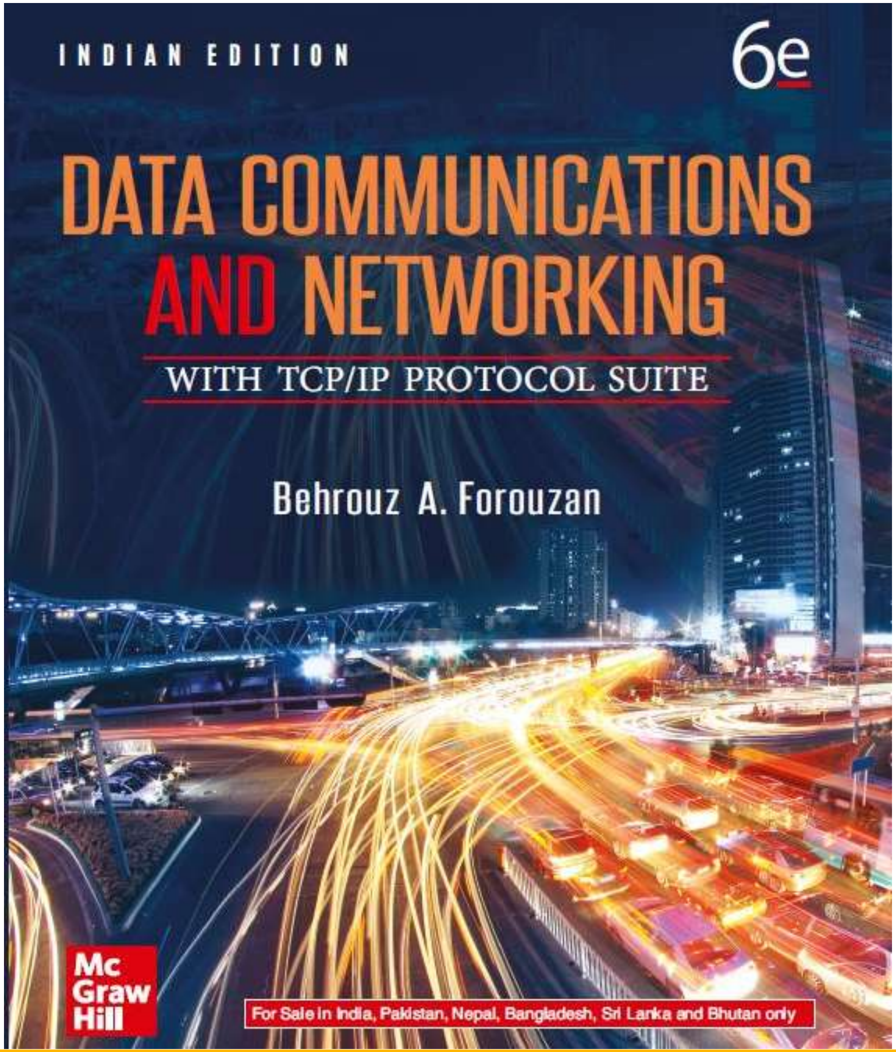
Chapter 04

Local Area Network: LANs

Data Communications and Networking, With TCP/IP protocol suite
Sixth Edition
Behrouz A. Forouzan



Chapter 4: Outline

4.1 ETHERNET

4.2 WIFI, IEEE 802.11 PROJECT

4.3 BLUETOOTH

4-1 ETHERNET

- *In Chapter 1, we learned that a local area network (LAN) is a computer network that is designed for a limited geographic area such as a building or a campus.*

- *In the 1980s and 1990s several different types of wired LANs were used. The IEEE has subdivided the data-link layer into two sub-layers: logical link control (LLC) and media access control (MAC).*

Figure 4.1 IEEE standard for LANs

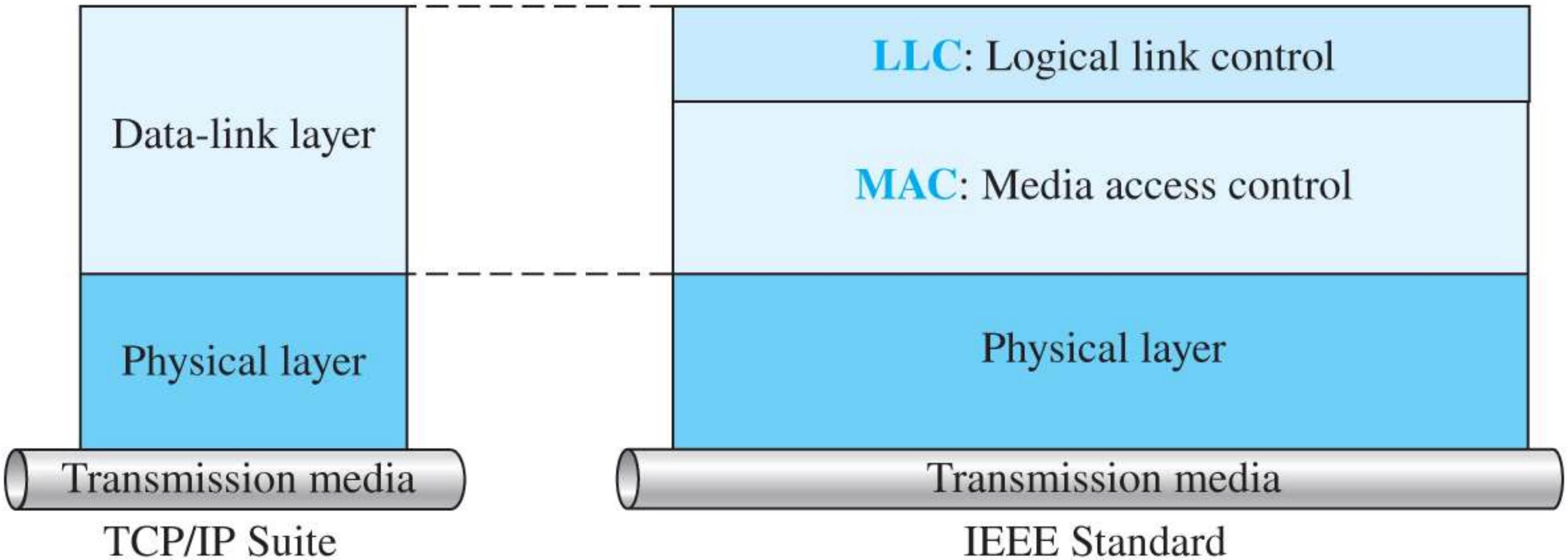


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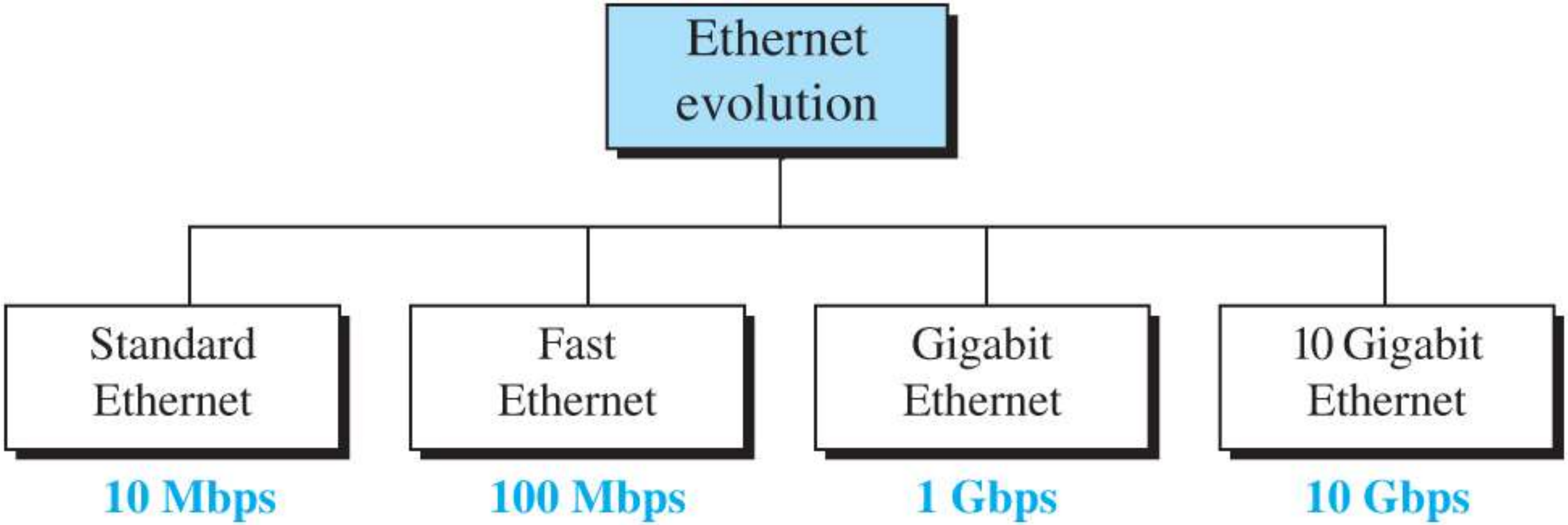
Figure 4.2 Ethernet evolution through four generations



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4.1.1 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. We discuss this standard version first.

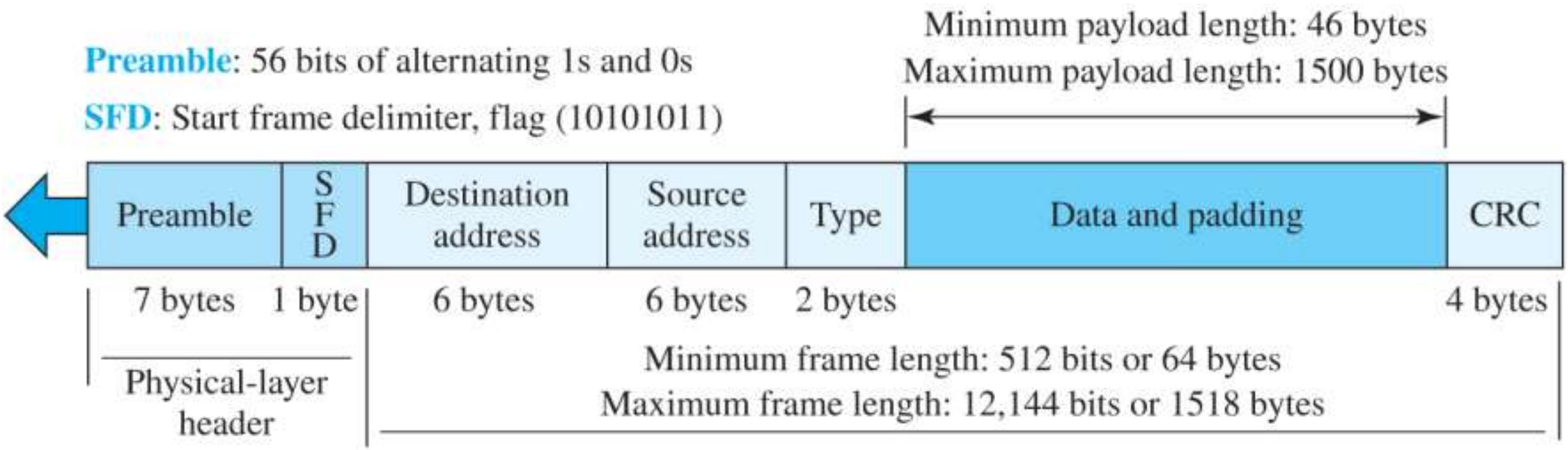
Connectionless and Unreliable Service

Ethernet provide a connectionless service, which means that the frames are sent independent of each other.

Frame Format *1*

The Ethernet frame contains seven fields, as shown in Figure 4.3.

Figure 4.3 Ethernet frame



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Frame Length

Ethernet has imposed restriction on maximum and minimum length to provide correct operation of CSMA/CD. An Ethernet frame has minimum length of 64 bytes. The maximum length limit is 1518 bytes (without preamble and SFD). This means that maximum payload is 1500 bytes.

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

Transmission of Address Bits

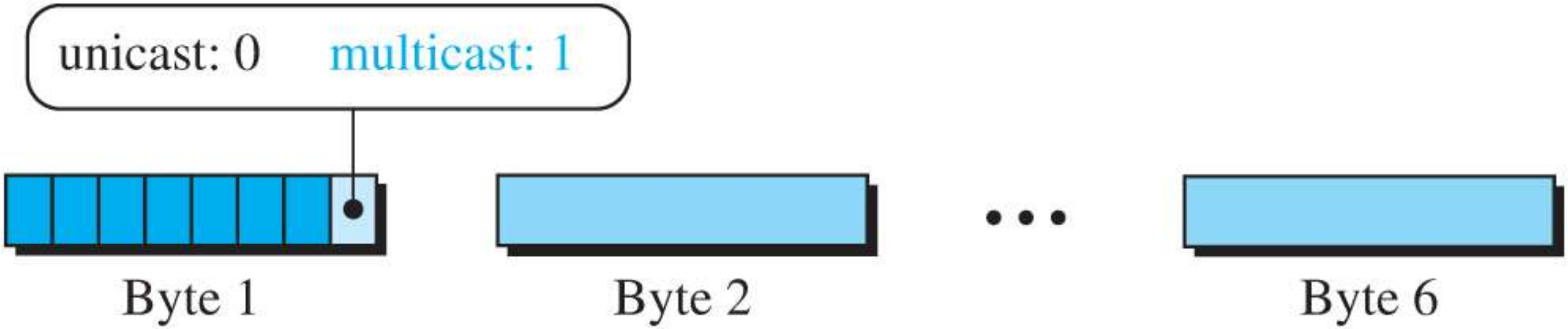
The way addresses are sent online is different from they way they are written in hexadecimal notation: Transmission is left to right, byte by byte; however, for each byte, the least significant bit that defines the address type is sent first.

Example 4.1

The example shows how how the address 47:20:1B:2E:08:EE is sent out online. 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**
Binary	01000111	00100000	00011011	00101110	00001000	11101110
Transmitted ←	11100010	00000100	11011000	01110100	00010000	01110111

Figure 4.4 Unicast and multicast addresses



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Example 4.2

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

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.

Implementation *1*

The standard Ethernet defines several implementation, but only four of them became popular.

Table 4.1 Summary of Standard Ethernet implementations

Implementation	*Medium*	*Medium Length(m)*	*Encoding*
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

4.1.2 Fast Ethernet (100 Mbps)

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.

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).

Auto-negotiation

A new feature added to Fast Ethernet is auto-negotiation. It allows two station to negotiate the mode or data rate of transmission.

Physical Layer *1*

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

Summary

Fast Ethernet implementation at the physical layer can be categorized as either two-wire or four-wire. The two-wire implementation can be either shielded twisted pair (STP), which is called 100Base-TX, or fiber-optic cable, which is called 100Base-FX. The four-wire implementation is designed only for unshielded twisted pair (UTP), which is called 100Base-T4. Table 4.2 is a summary of the Fast Ethernet implementations.

Table 4.2 Summary of Fast Ethernet implementations

Implementation	*Medium*	*Medium Length*	*Wires*	*Encoding*
100Base-TX	STP	100 m	2	4B/5B + MLT-3
100Base-FX	Fiber	185 m	2	4B/5B + NRZ-I
100Base-T4	UTP	100 m	4	Two 8B/6T

4.1.3 Gigabit Ethernet (1000 Mbps)

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.

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.

Full-Duplex Mode

In the full duplex mode, there is a central switch connected to all computers. There is no collision in this mode.

Half-Duplex Mode

In this mode, a switch can be replaced by a hub.

Physical Layer *2*

The physical layer in Gigabit Ethernet is more complex that the other version. We have different implementations.

Table 4.3 Summary of Gigabit Ethernet implementations

Implementation	*Medium*	*Medium Length(m)*	*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	2	4D-PAM5

4.1.4 10-Gigabit Ethernet

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.

***Implementation** 2*

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 4.4 shows a summary of the 10 Gigabit Ethernet implementations.

Table 4.4 Summary of 10-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

4-2 WIFI, IEEE 802.11 PROJECT

IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data-link layers. It is sometimes called wireless Ethernet. In some countries, including the United States, the public uses the term WiFi (short for wireless fidelity) as a synonym for wireless LAN. WiFi, however, is a wireless LAN that is certified by the WiFi Alliance.

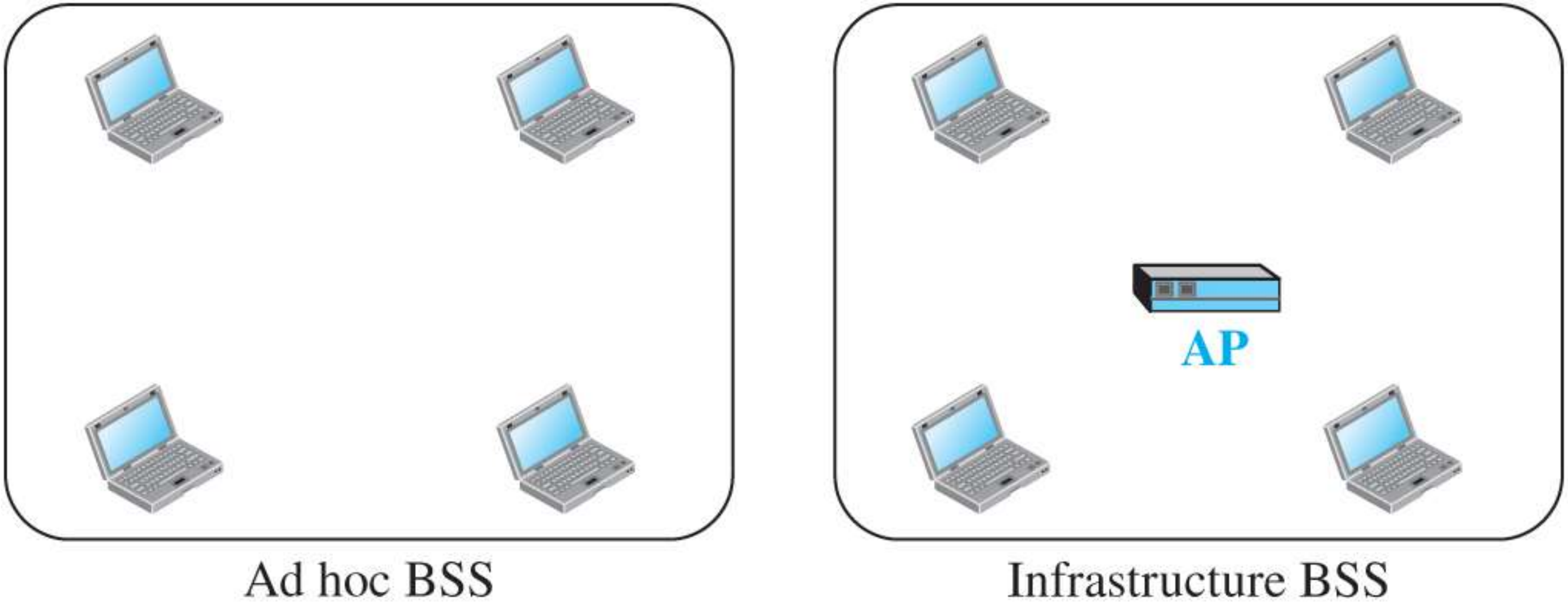
4.2.1 Architecture

The standard defines two kinds of services: the basic service set (BSS) and the extended service set (ESS).

Basic Service Set (BSS)

IEEE defines the basic service set as the building block of a wireless LAN. It also defines an optional base station known as the access point (AP).

Figure 4.7 Basic service sets (BSSs)



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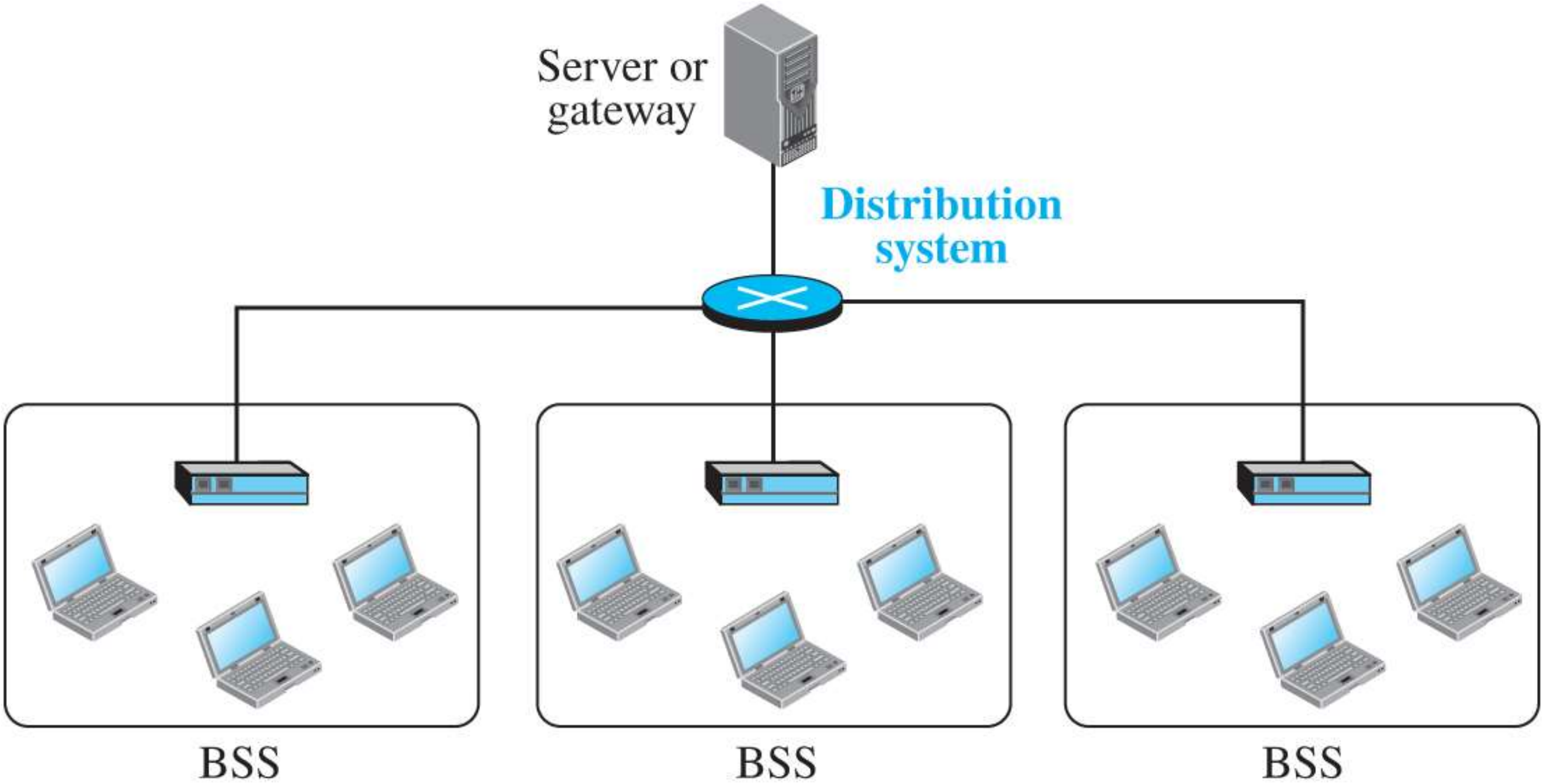
Extended Service Set (ESS)

An extended service set is made of two or more BSS with Aps that are connected together using a distribution system.

Figure 4.8 Extended service set (ESS)



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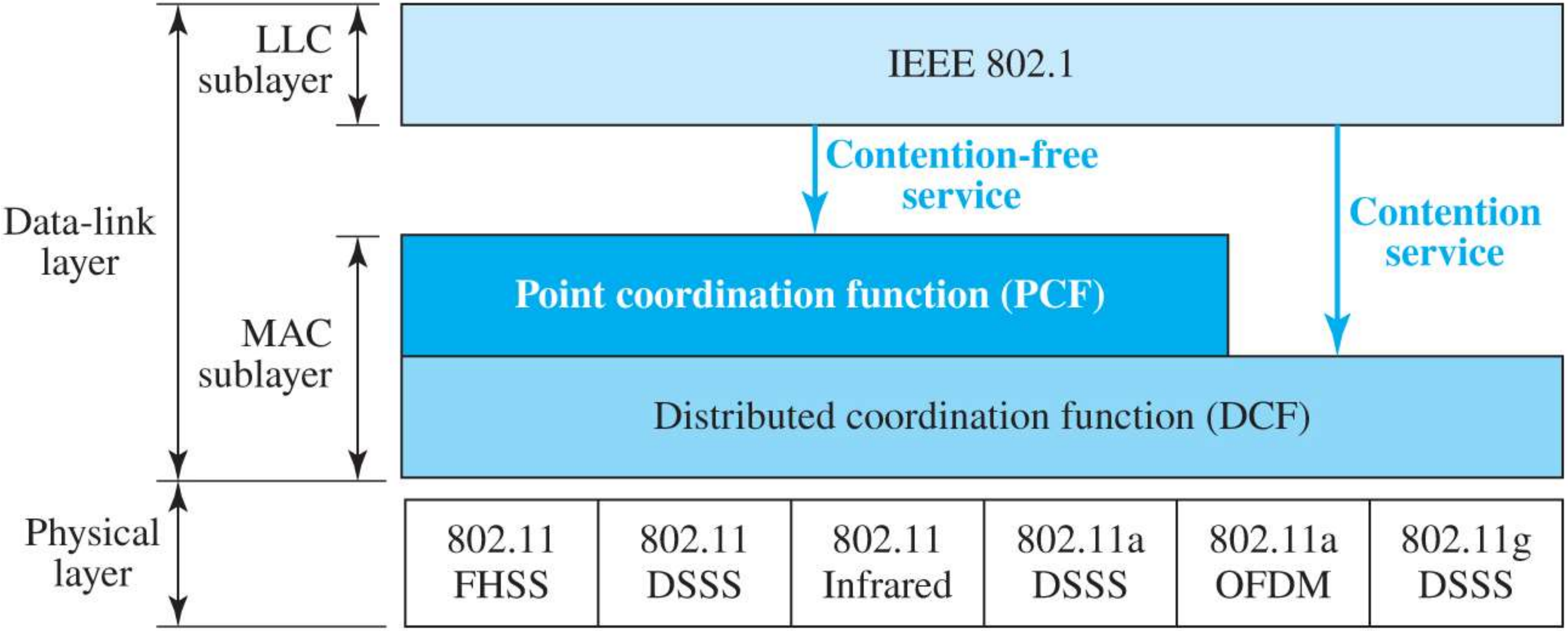
Station Type

IEEE defines three types of stations: no transition, BSS transition, and ESS transition.

4.2.2 MAC Sublayer

IEEE 802.11 defines two MAC sublayers: the distributed coordination function (DCF) and point coordination function (PCF). Figure 4.7 shows the relationship between the two MAC sublayers, the LLC sublayer, and the physical layer. We discuss the physical layer implementations later in the chapter and will now concentrate on the MAC sublayer.

Figure 4.9 MAC layers in IEEE 802.11 standard



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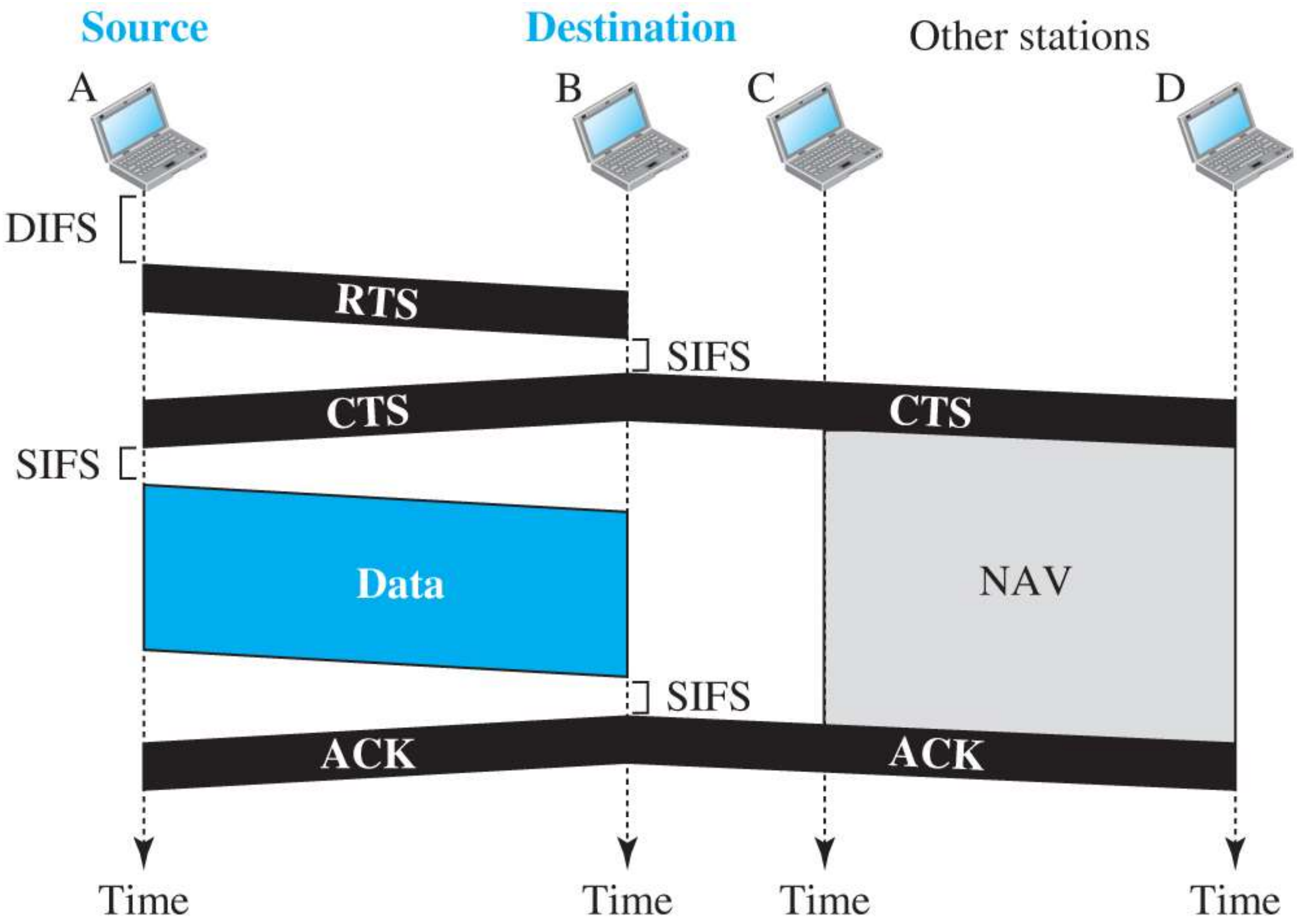
Distribution Coordination Function (DCF)

One of the two protocol defined by IEEE at the MAC sublayer is called distribution coordination function (DCF), which uses CSMA/CD.

Figure 4.10 CSMA/CA and NAV



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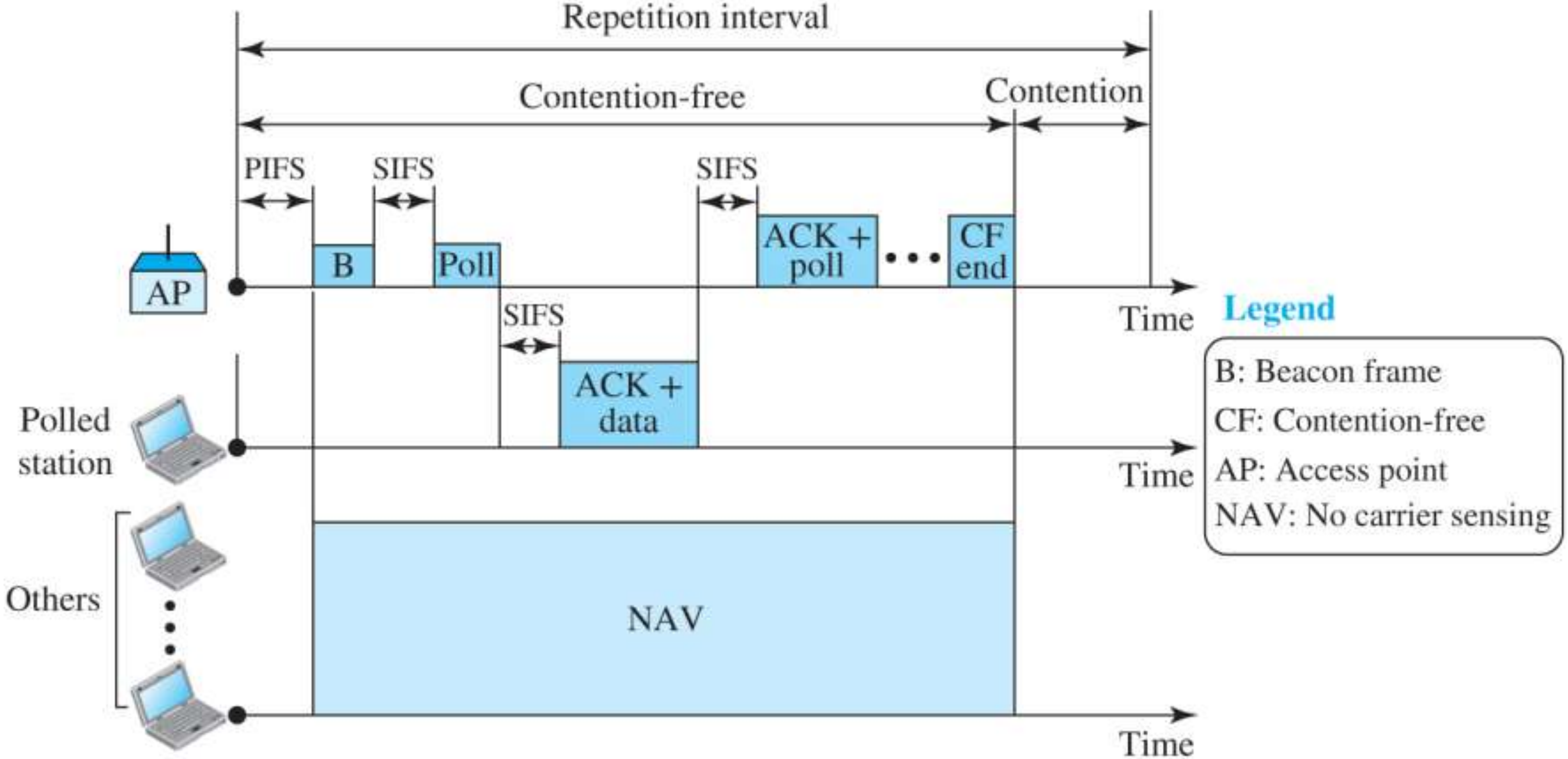
Point Coordination Function (PCF)

This is an optional access that can be implemented in an infrastructure network. PCF has priority over DCF. However, to allow DCF frame to get access to the network repetition interval has been added to the network as shown in Figure 4.9.

Figure 4.11 Example of repetition interval



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Fragmentation

The wireless environment is very noisy, so frames are often corrupted. A corrupted frame cannot be resubmitted. The protocol recommend fragmentation. The division of frame into smaller ones.

Frame Format *2*

The MAC layer frame consists of nine fields as shown in Figure 4.10.

Figure 4.12 Frame format

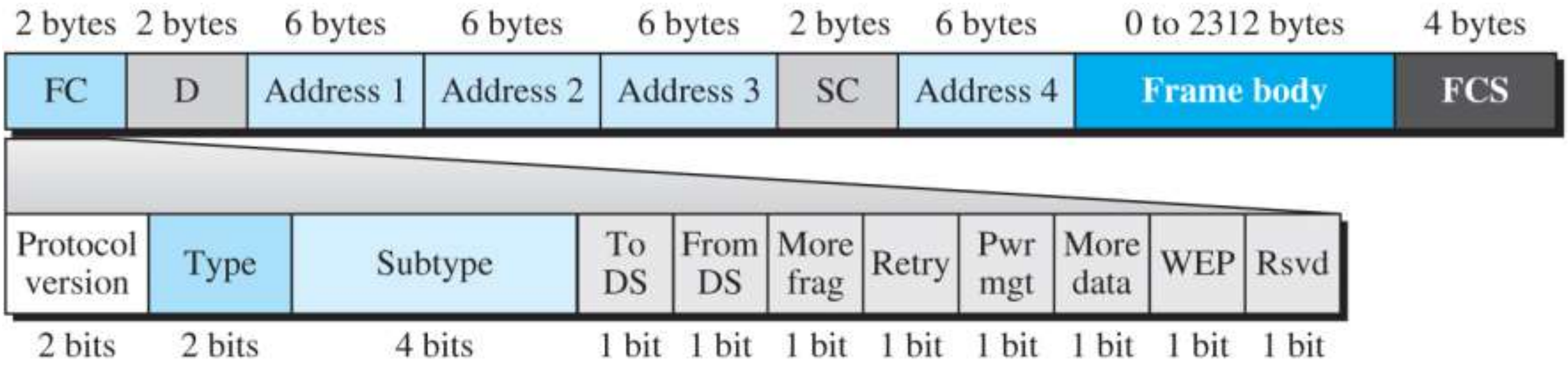

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Table 4.5 Subfields in FC field

Field	*Explanation*
Version	Current version is 0
Type	Type of information: management (00), control (01), or data (10)
Subtype	Subtype of each type (see Table 4.6)
To DS	Defined later
From DS	Defined later
More flag	When set to 1, means more fragments
Retry	When set to 1, means retransmitted frame
Pwr mgt	When set to 1, means station is in power management mode
More data	When set to 1, means station has more data to send
WEP	Wired equivalent privacy (encryption implemented)
Rsvd	Reserved

Frame Type

A wireless LAN defined by IEEE 802.11 has three categories of frames: management frames, control frames, and data frames.

Figure 4.13 Control frames

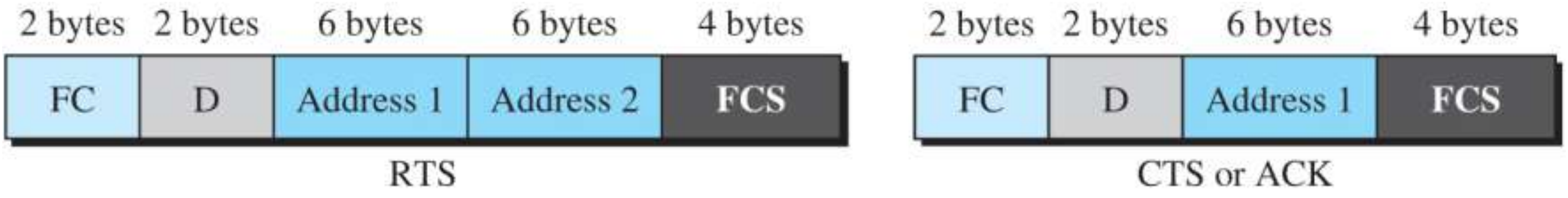

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Table 4.6 Values of subfields in control frames

Subtype	*Meaning*
1011	Request to send (RTS)
1100	Clear to send (CTS)
1101	Acknowledgment (ACK)

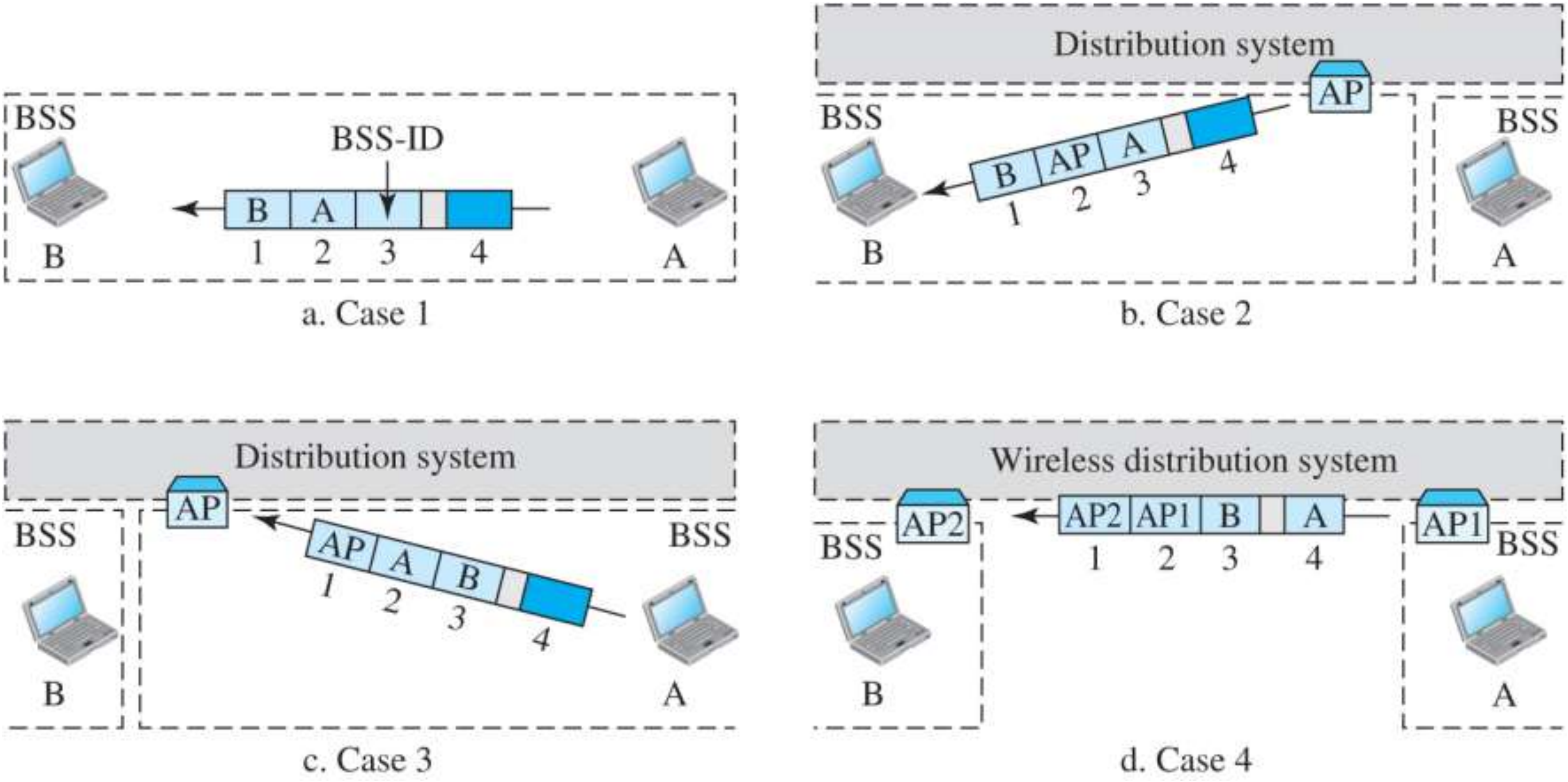
4.2.3 Addressing Mechanism

The IEEE 802.11 addressing mechanism specifies four cases, defined by the value of the two flags in the FC field, To DS and From DS. Each flag can be either 0 or 1, resulting in four different situations. The interpretation of the four addresses (address 1 to address 4) in the MAC frame depends on the value of these flags, as shown in Table 4.7.

Table 4.7 Addresses

To DS	*From DS*	*Address 1*	*Address 2*	*Address 3*	*Address 4*
0	0	Destination	Source	BSS ID	N/A
0	1	Destination	Sending AP	Source	N/A
1	0	Receiving AP	Source	Destination	N/A
1	1	Receiving AP	Sending AP	Destination	Source

Figure 4.14 Addressing mechanisms



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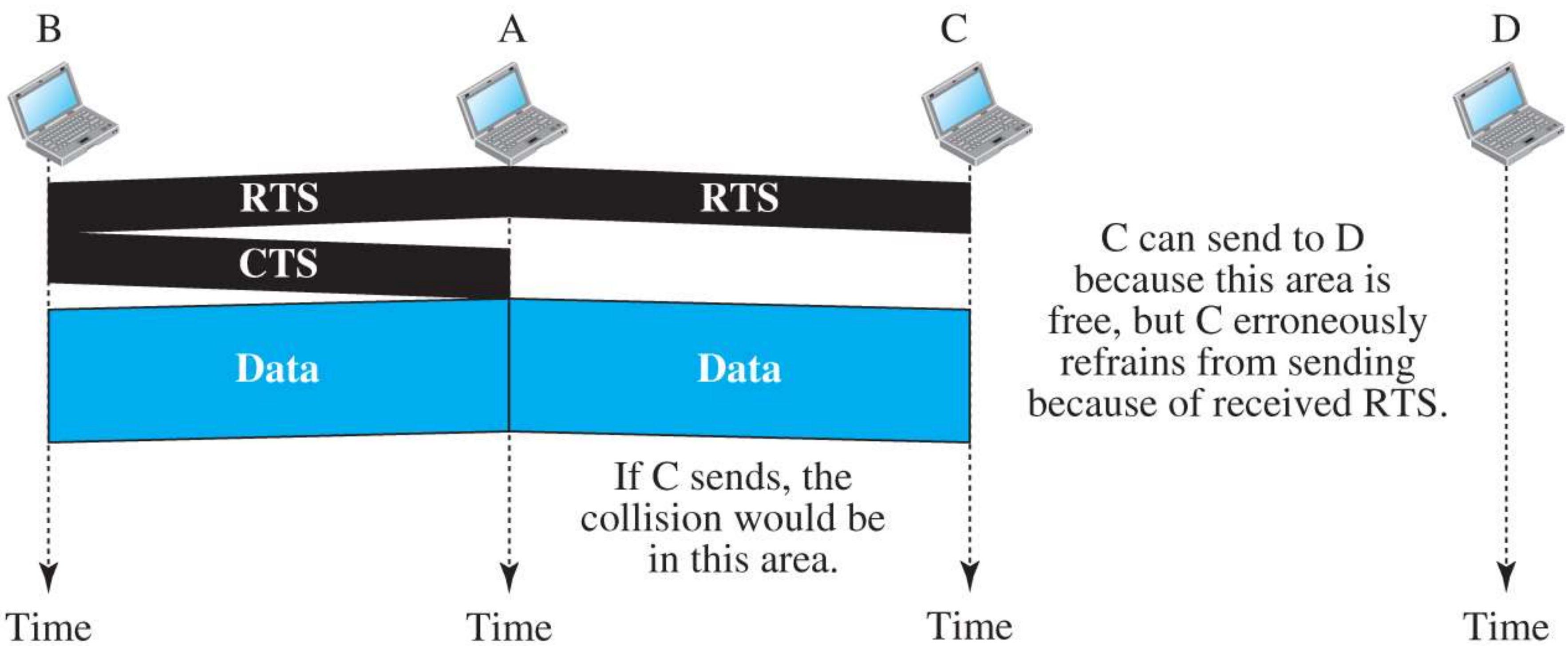
Exposed Station Problem

A similar problem to the hidden station problem is exposed station problem. In this problem, refrains using a channel when the channel is available.

Figure 4.15 Exposed station problem



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4.2.4 Physical Layer

We discuss six specifications, as shown in Table 4.8. All implementations, except the infrared, operate in the industrial, scientific, and medical (ISM) band, which defines three unlicensed bands in the three ranges 902–928 MHz, 2.400–4.835 GHz, and 5.725–5.850 GHz.

Table 4.8 Specifications

IEEE	*Technique*	*Band*	*Modulation*	*Rate (Mbps)*
802.11	FHSS	2.400–4.835 GHz	FSK	1 and 2
	DSSS	2.400–4.835 GHz	PSK	1 and 2
	None	Infrared	PPM	1 and 2
802.11a	OFDM	5.725–5.850 GHz	PSK or QAM	6 to 54
802.11b	DSSS	2.400–4.835 GHz	PSK	5.5 and 11
802.11g	OFDM	2.400–4.835 GHz	Different	22 and 54
802.11n	OFDM	5.725–5.850 GHz	Different	600

4-3 BLUETOOTH

Bluetooth is a wireless LAN technology designed to connect devices of different functions when they are at a short distance from each other. A Bluetooth LAN is an ad- hoc network. The devices, sometimes called gadgets, find each other and make a network called a piconet.

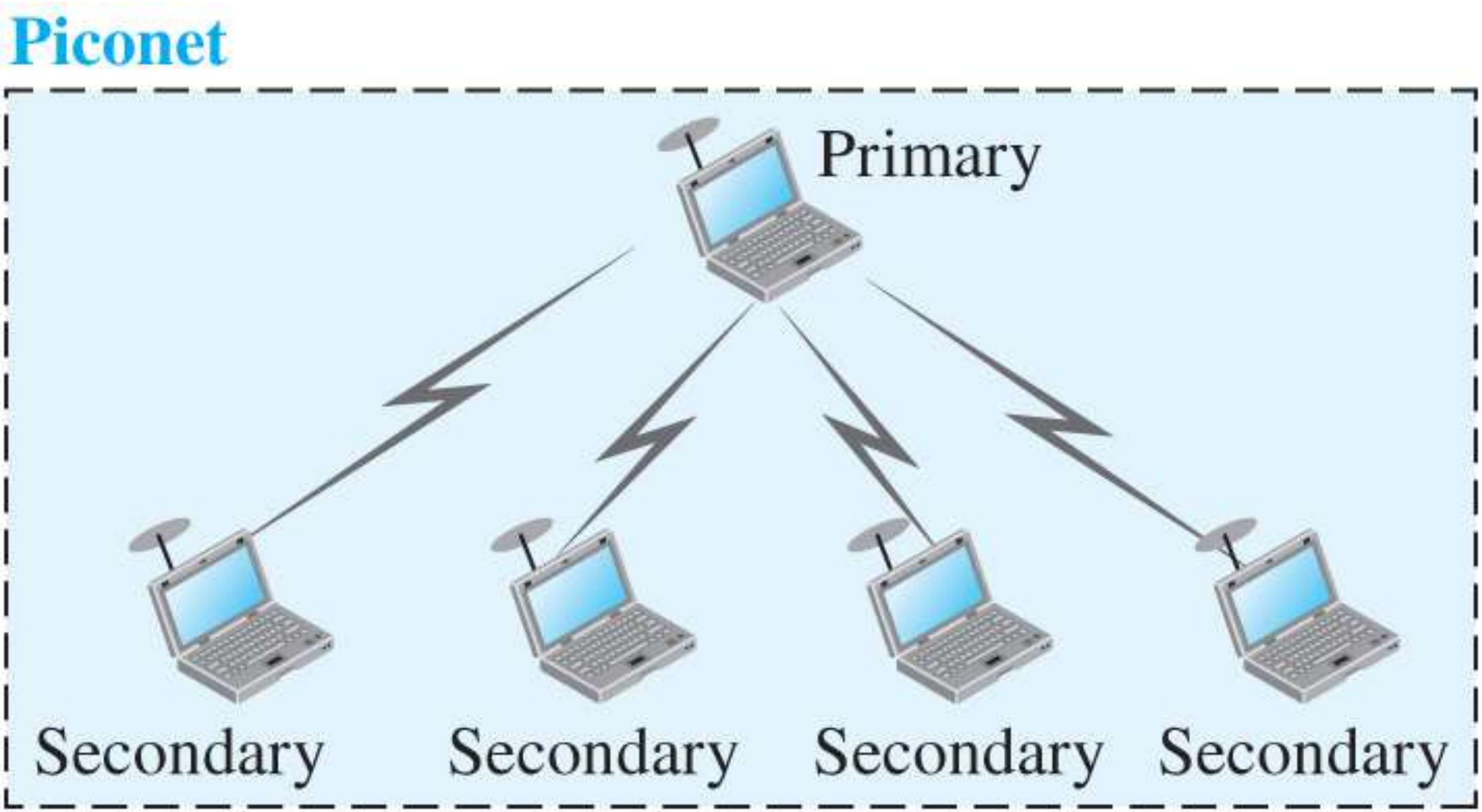
4.3.1 Architecture

Bluetooth defines two types of networks: piconet and scatternet.

Piconet

A Bluetooth network is called a piconet (a small net). It can have up to 8 stations, one of which is called the primary; the other are called the secondaries.

Figure 4.20 Piconet



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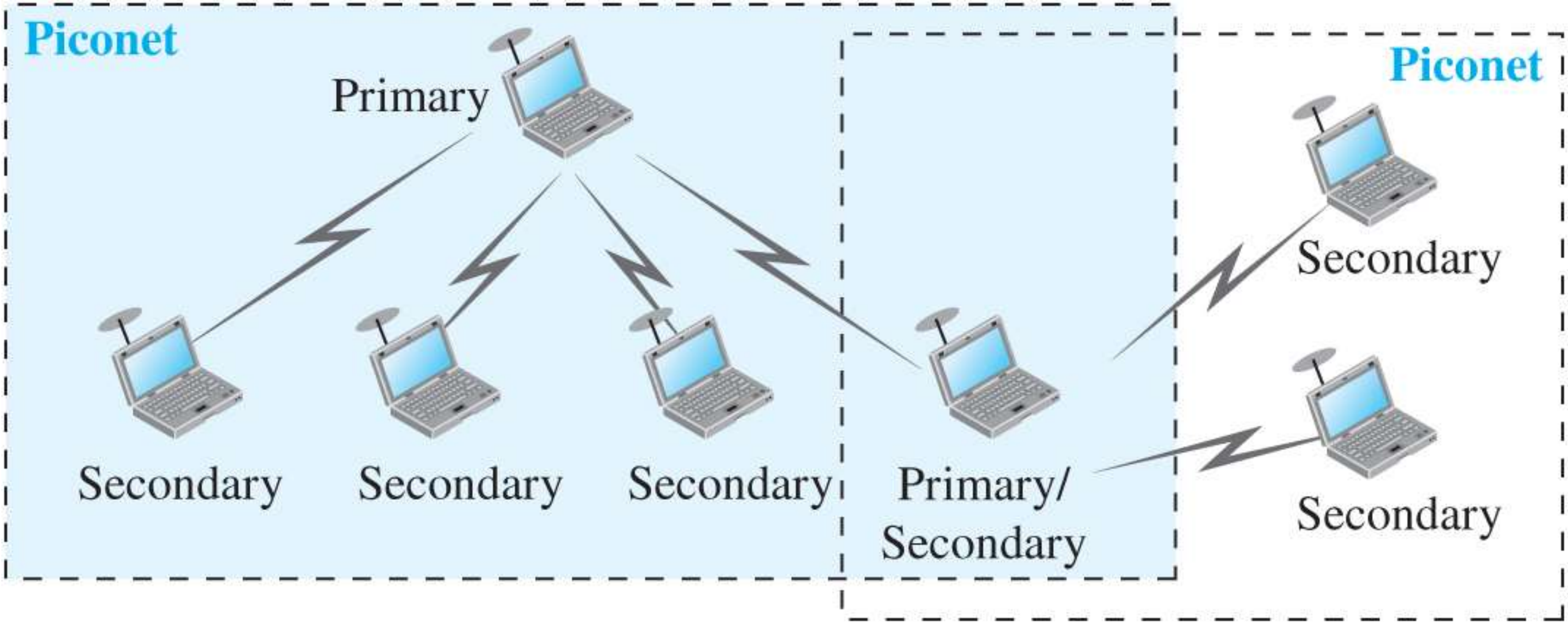
Scatternet

Piconets can be combined to create a scatternet. A secondary station in one piconet can be a primary in another one.

Figure 4.21 Scatternet



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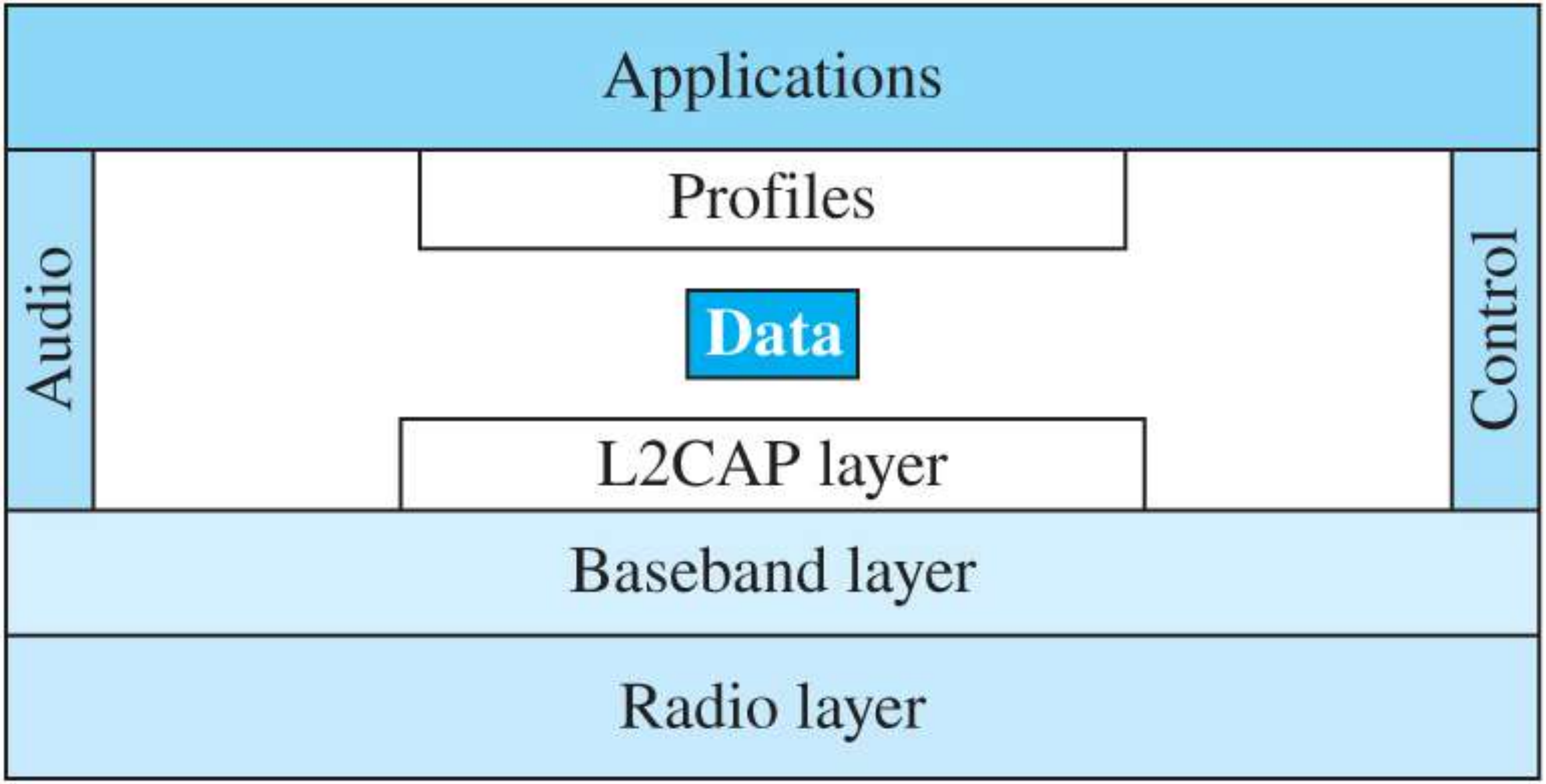
Bluetooth Devices

A Bluetooth device has a built-in short-range radio transmitter. The current rate is 1 Mbps with a 2.4-GHz bandwidth.

Bluetooth Layers

Bluetooth uses several layers that do not exactly match those of the Internet model we have defined in this book. Figure 4.16 shows these layers.

Figure 4.22 Bluetooth layers



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L2CAP

The Logical Link Control and Adaption Protocol is roughly equivalent to the LLC sublayer in LANs.

Figure 4.23 L2CAP data packet format

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Baseband Layer

The Baseband layer is roughly equivalent to MAC sublayer in LANs.

Figure 4.24 Single-secondary communication

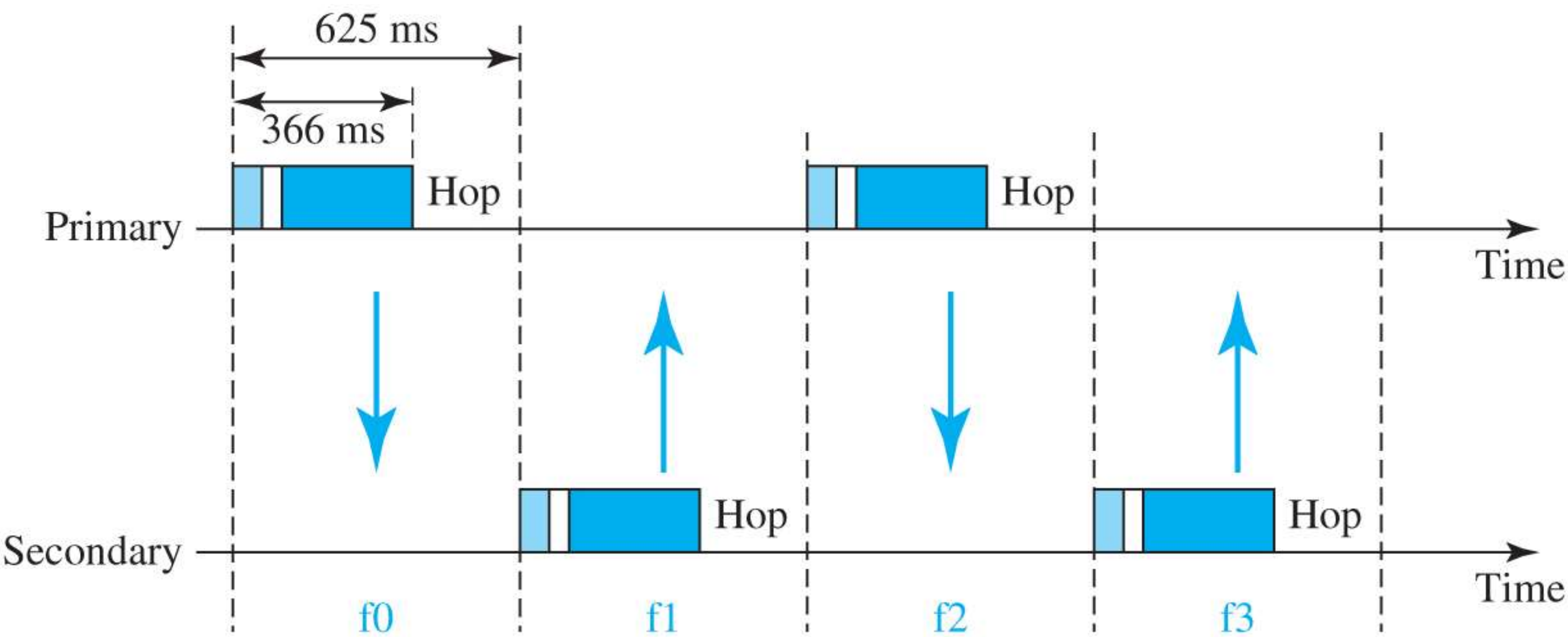

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Figure 4.25 Multiple-secondary communication

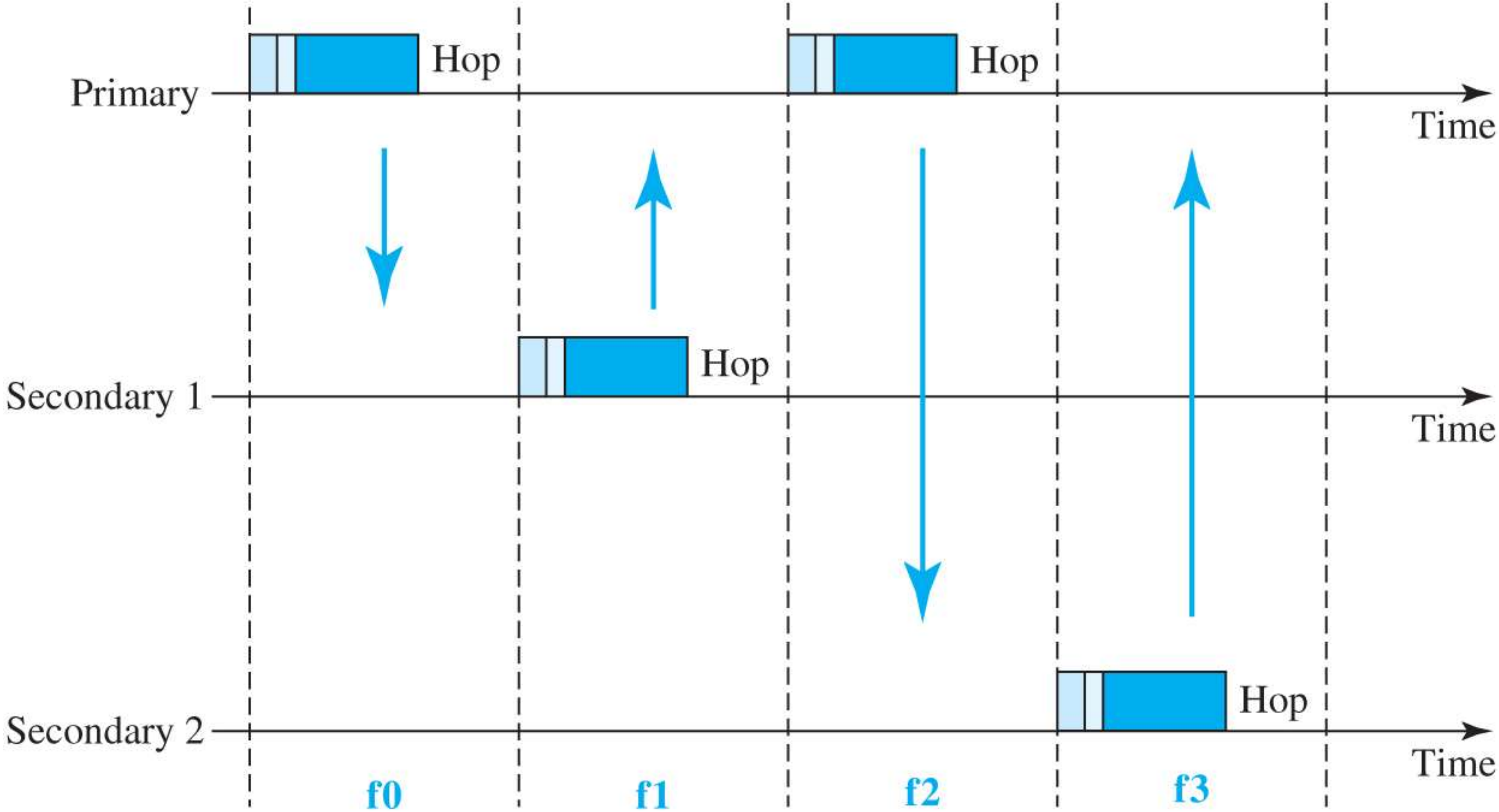

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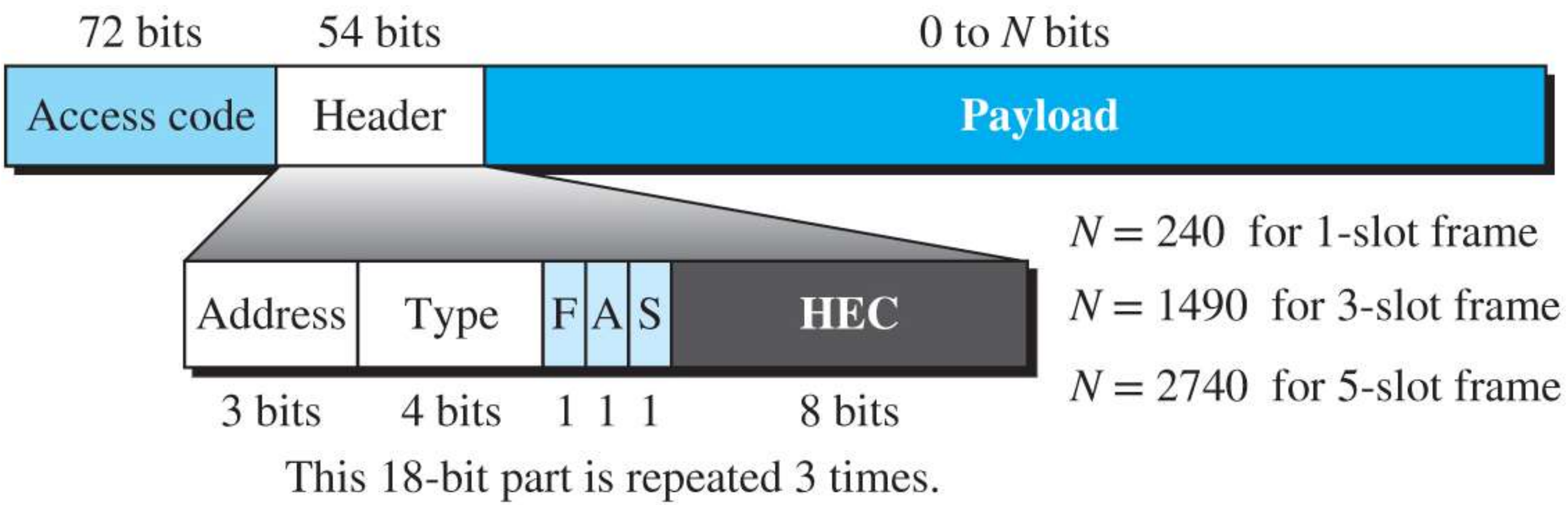
Figure 4.26 Frame format types



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Radio Layer

The radio layer is roughly equivalent to the physical layer of the Internet model. Bluetooth devices are low-power and have a range of 10 m.

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