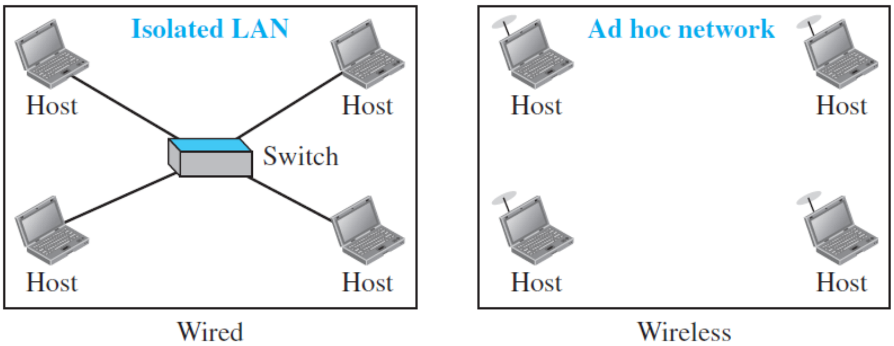
Data communication and Networks

Chapter 8: Wired LANs –Ethernet–

Chapter 9: Wireless LANs –WiFi–



8. Wired LANs –Ethernet–

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. The relationship of the 802 Standard to the TCP/IP protocol suite is shown in Figure 8.1. The IEEE has subdivided the data-link layer into two sub-layers: **logical link control (LLC)** and **media access control (MAC).**

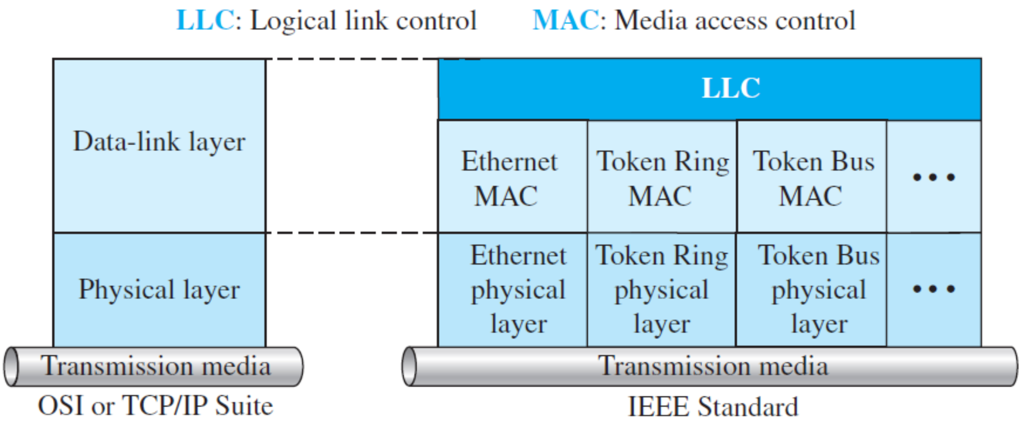


Figure 8.1 IEEE standard for LANs

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 Figure 8.2.

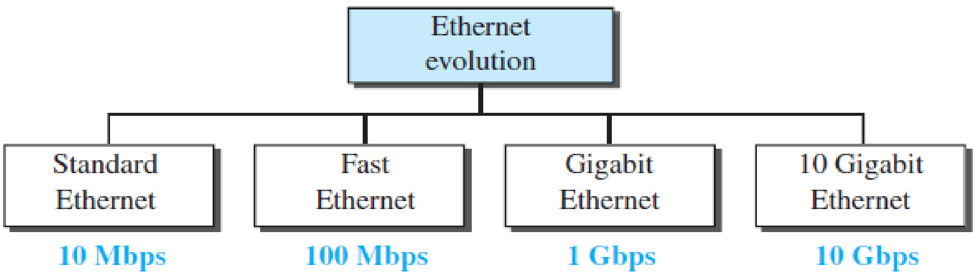


Figure 8.2 Ethernet evolutions through four generations

8.1 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.

8.1.1. 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. For example, the following shows an Ethernet MAC address:

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

Transmission of Address Bits

The transmission is left to right, **byte by byte**; however, for each byte, the least significant **bit** is sent first and the most significant **bit** is sent last. This means that the bit that defines an address as unicast or multicast arrives first at the receiver. This helps the receiver to immediately know if the packet is unicast or multicast.

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*. But 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

Unicast, Multicast, and Broadcast Addresses

A **source address** is always a *unicast address*—the frame comes from only one station. The **destination address**, however, can be *unicast*, *multicast*, or *broadcast*. Figure 8.3 if the least significant bit of the first byte in a destination address is 0, the address is unicast; otherwise, it is multicast. The broadcast address is a special case of the multicast address. A broadcast destination address is forty-eight 1s.

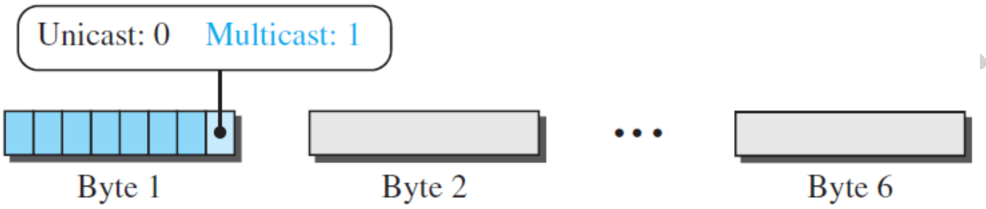


Figure 8.3 Unicast and multicast addresses

Example 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

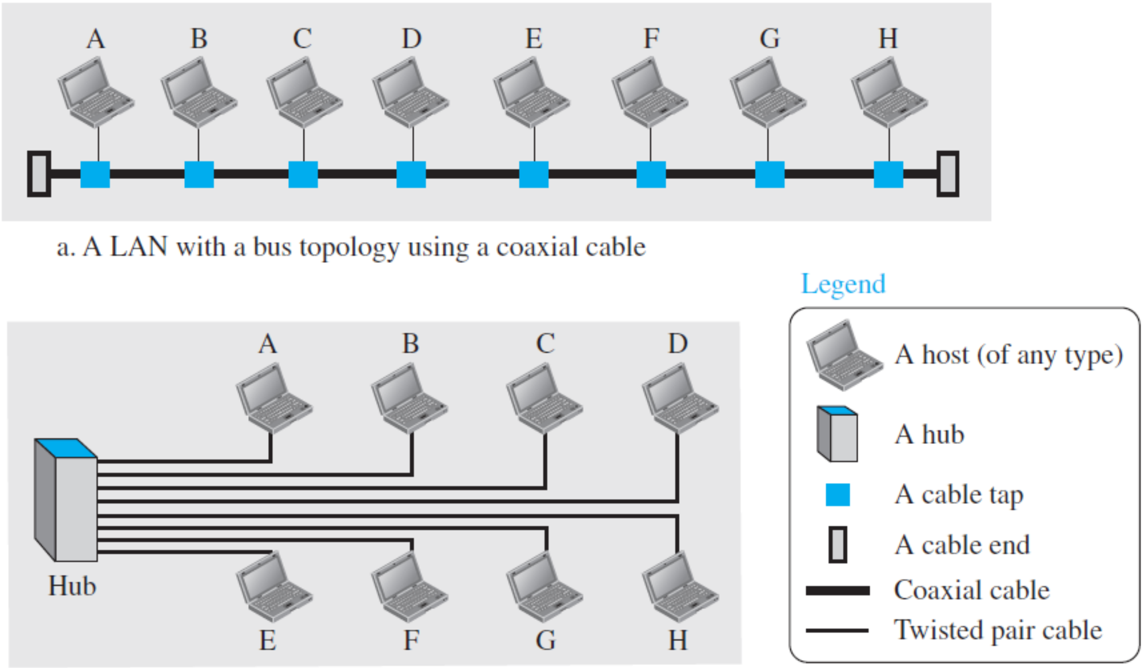
To find the type of the address, we need to look at the second hexadecimal digit from the left. If it is even, the address is unicast. If it is odd, the address is multicast. If all digits are Fs, the address is broadcast. Therefore, we have the following:

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.

Distinguish Between Unicast, Multicast, and Broadcast Transmission

Standard Ethernet uses a coaxial cable (bus topology) or a set of twisted-pair cables with a hub (star topology) as shown in Figure 8.4.

We need to know that transmission in the standard Ethernet is always broadcast, no matter if the intention is unicast, multicast, or broadcast. In the bus topology, when station A sends a frame to station B, all stations will receive it. In the star topology, when station A sends a frame to station B, the hub will receive it. Since the hub is a passive element, it regenerates the bits and sends them to all stations except station A.



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

b. A LAN with a star topology using a hub

Figure 8.4 Implementation of standard Ethernet

The question is, then, how the actual unicast, multicast, and broadcast transmissions are distinguished from each other. The answer is in the way the frames are **kept or dropped**.

- In a unicast transmission, all stations will receive the frame, the **intended recipient** keeps and handles the frame; the rest discard it.
- In a multicast transmission, all stations will receive the frame, the stations that are **members of the group** keep and handle it; the rest discard it.
- In a broadcast transmission, all stations (except the sender) will receive the frame and **all stations** (except the sender) keep and handle it.

8.1.2 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 uses the protocol CSMA/CD as an access method.

ان الـ CSMA/CD هو اختصار لـ Carrier Sense Multiple Access with Collision Detection وهو بروتوكول يتغلب على مشكلة التصادم (collision) و التي تحدث نتيجة ارسال بيانات من قبل عدد من ال hosts **في نفس الوقت**.

كيف يعمل الـ CSMA/CD ؟

يقوم الجهاز المرسل (Host) الذي يرغب بارسال البيانات بالتأكد من وجود اشارة في الواير او عدم وجودها (كما نعلم فان البيانات ترسل في النهاية كاشارة كهربائية) , في حالة عدم وجود اشارة فانه يبدأ بالارسال ويستمر في نفس الوقت بمراقبة الواير للتأكد من عدم وصول اشارة ثانية , في حالة اكتشافها لوجود اشارة ثانية (اي ان host اخر بدأ بعملية ارسال بيانات) فانه سيتوقف عن الارسال وترسل jam signal وهي عبارة عن اشارة تبلغ جميع ال hosts بحدوث الـ collision فتتوقف جميع ال hosts عن ارسال البيانات لفترة زمنية خاصة بكل host لتجنب حدوث الـ collision مرة اخرى عند معاودة الارسال. عند انتهاء الفترة الزمنية لل host الاول فانه يعاود عملية ارسال البيانات الى ان تنتهي فترة التوقف لل host الثاني والذي ايضا يعاود الارسال مرة اخرى بعد ان انتهى الـ host الاول من الارسال وبالتالي تجنبنا حدوث التصادم مرة اخرى.

8.1.3 Implementation

The Standard Ethernet defined several implementations, but only four of them became popular during the 1980s. Table 8.1 shows a summary of Standard Ethernet implementations.

Implementation	*Medium*	*Medium Length*
10Base5	Thick coax	500 m
10Base2	Thin coax	185 m
10Base-T	2 UTP	100 m
10Base-F	2 Fiber	2000 m

Table 8.1 Summary of Standard Ethernet implementations

In the term 10BaseX, the number defines the data rate (10 Mbps), the term *Base* means baseband (digital) signal, and X approximately defines either the maximum size of the cable in 100 meters (for example 5 for 500 or 2 for 185 meters) or the type of cable, T for unshielded twisted pair cable (UTP) and F for fiber-optic. The standard Ethernet uses a baseband signal, which means that the bits are changed to a digital signal and directly sent on the line.

8.2 Fast Ethernet (100 Mbps)

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 goals of Fast Ethernet can be summarized as follows:

1. Upgrade the data rate to 100 Mbps.
2. Make it compatible with Standard Ethernet.
   and other goals.

8.2.1 Access Method

Fast Ethernet is 10 times faster than Standard Ethernet. In order to achieve this, the Fast Ethernet came with two solutions (it can work with either choice):

1. The first solution was to totally drop the bus topology and use a passive hub and star topology but make the maximum size of the network 250 meters instead of 2500 meters as in the Standard Ethernet. This approach is kept for compatibility with the Standard Ethernet.

2. The second solution is to use a link-layer switch (instead of physical-layer hub) with a buffer to store frames and a full-duplex connection to each host to make the transmission medium private for each host. In this case, there is no need for CSMA/CD because the hosts are not competing with each other.

8.2.2 Implementation

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 for unshielded twisted pair (UTP), which is called *100Base-T4* (see Table 8.2).

Implementation	*Medium*	*Medium Length*	*Wires*
100Base-TX	UTP or STP	100 m	2
100Base-FX	Fiber	185 m	2
100Base-T4	UTP	100 m	4

Table 8.2 Summary of Fast Ethernet implementations

8.3 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 design can be summarized as follows:

1. Upgrade the data rate to 1 Gbps.
2. Make it compatible with Standard or Fast Ethernet.
   and other goals.

Implementation

Table 8.3 is a summary of the Gigabit Ethernet implementations. S-W and L-W mean short-wave and long-wave respectively.

Implementation	*Medium*	*Medium Length*	*Wires*
1000Base-SX	Fiber S-W	550 m	2
1000Base-LX	Fiber L-W	5000 m	2
1000Base-CX	STP	25 m	2
1000Base-T4	UTP	100 m	4

Table 8.3 Summary of Gigabit Ethernet implementations

8.4 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 Ethernet, such that it can be used as LAN and MAN. The IEEE committee created 10 Gigabit Ethernet and called it Standard **802.3ae**.

The goals of the 10 Gigabit Ethernet design can be summarized as upgrading the data rate to 10 Gbps. This data rate is possible only with fiber-optic technology at this time.

Implementation

10 Gigabit Ethernet operates only in full-duplex mode, which means there is no need for contention i.e., CSMA/CD is not used in 10 Gigabit Ethernet. Table 8.4 shows the summary of the 10 Gigabit Ethernet implementations.

Implementation	*Medium*	*Medium Length*	*Number of wires*
10GBase-SR	Fiber 850 nm	300 m	2
10GBase-LR	Fiber 1310 nm	10 Km	2
10GBase-EW	Fiber 1350 nm	40 Km	2
10GBase-X4	Fiber 1310 nm	300 m to 10 Km	2

Table 8.4 Summary of 10 Gigabit Ethernet implementations

9. Wireless LANs –WiFi–

Wireless communication is one of the fastest-growing technologies. The demand for connecting devices without the use of cables is increasing everywhere. In the following three sections, we make three comparisons between wired and wireless LANs depending on architecture, characteristics and access control.

9.1 Architectural Comparison

Let us compare the architecture of wired and wireless LANs to give some idea about the following issues:

Medium

In a wired switched LAN, with a link-layer switch, the communication between the hosts is **point-to-point** and **full-duplex** (bidirectional). In a wireless LAN, the medium is air, the signal is generally **broadcast**. When hosts in a wireless LAN communicate with each other, they are **sharing the same medium** (multiple access).

Hosts

In a wired LAN, before the host can use the services of the Internet, it needs to be physically connected to the Internet. In a wireless LAN, a host is not physically connected to the network; it can move freely and can use the services provided by the network. Therefore, the mobility are totally different issues.

Isolated LANs

A wired isolated LAN is a set of hosts connected via a link-layer switch (in the recent generation of Ethernet). A wireless isolated LAN, called an ***ad hoc network*** in wireless LAN terminology, is a set of hosts that communicate freely with each other. The concept of a link-layer switch does not exist in wireless LANs. Figure 9.1 shows two isolated LANs, one wired and one wireless.

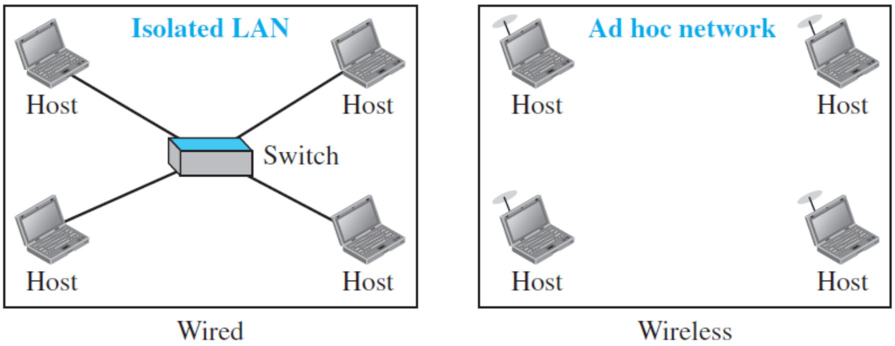


Figure 9.1 Isolated LANs: wired versus wireless

Connection to Other Networks

A wired LAN can be connected to another network or an internetwork such as the Internet using a router. In Figure 9.2, the wireless LAN is referred to as an *infrastructure network*, and the connection to the wired infrastructure, such as the Internet, is done via a device called an ***access point (AP)***.

Note that the role of the *access point* **is completely different** from the role of a *link-layer switch* in the wired environment. An ***access point*** is gluing two different environments together: one wired and one wireless.

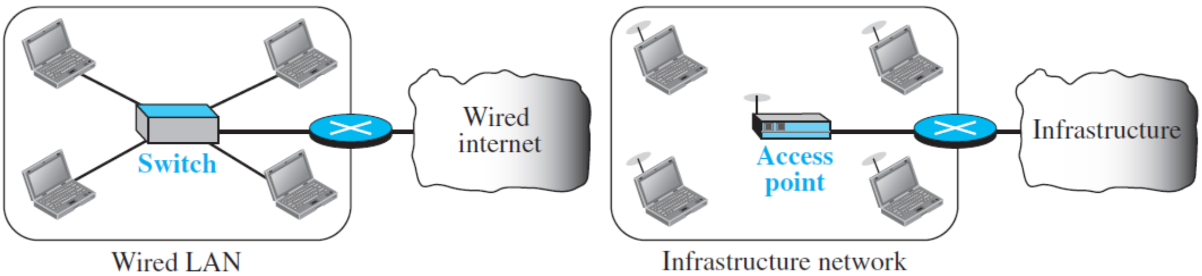


Figure 9.2 Connection of a wired LAN and a wireless LAN to other networks

Moving between Environments

In order to move from the wired environment to a wireless environment, we need to change the network interface cards designed for wired environments to the ones designed for wireless environments and replace the link-layer switch with an access point.

9.2 Characteristic Comparison

There are several characteristics of wireless LANs that either do not apply to wired LANs or can be ignored.

Attenuation

The strength of electromagnetic signals **decreases rapidly** ***because*** the signal disperses in all directions; only a small portion of it reaches the receiver.

Interference

Another issue is that a receiver may receive signals not only from the true sender, but also from **other senders** if they are using the same frequency band.

Multipath Propagation

A receiver may receive more than one signal from the **same sender** because electromagnetic waves can be reflected back from obstacles such as walls, the ground, or objects.

Error

With the above characteristics of a wireless network, we can expect that errors are **more serious issues** in a wireless network than in a wired network. For example, we can think about the error level in the measurement of **signal-to-noise ratio (SNR).**

9.3 Access control

In the previous chapter, we discussed that the Standard Ethernet (in wired LAN) uses the **CSMA/CD** algorithm. Because of some problems, the CSMA/C**D** does not work in wireless LANs. Therefore, the **C**arrier **S**ense **M**ultiple **A**ccess with **C**ollision **Avoidance** (**CSMA/CA**) was invented for wireless LANs.

ان طريقة تفادي التصادم (CSMA/C**A**) تُستخدم في الشبكات المحلية اللاسلكية وذلك من اجل التحكم بالوصول الى الوسط الناقل. قبل حدوث الارسال، يقوم الجهاز المُرسل Host بالتنصت على الشبكة من اجل تفادي حدوث اصطدام اشارته مع باقي الاشارات التي ممكن ان ترسلها باقي الاجهزة المرتبطة الى الشبكة اللاسلكية في نفس الوقت. فعلى عكس طريقة اكتشاف التصادم (CSMA/C**D**) التي تتعامل مع البث على الشبكة حالما يتم اكتشاف التصادم، فإن تقنية CSMA/CA هي التعامل مع حركة مرور الإشارات قبل إرسال الإشارة الحقيقية على الشبكة. فالمحطة تبث إشارة من أجل الاستماع إلى احتمال حدوث تصادم وإبلاغ الأجهزة الأخرى بالتوقف عن البث حتى ترسل تلك المحطة إشاراتها على الشبكة.

9.4 IEEE 802.11 project (wireless LAN)

IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data-link layers. Some countries, including the United States, use the term WiFi (short for wireless fidelity) as a synonym for wireless LAN.

9.4.1 Architecture

The standard defines two kinds of services:

1. Basic Service Set

IEEE 802.11 defines the **basic service set (BSS)** as the building blocks of a wireless LAN. A basic service set is made of stationary or mobile wireless stations and an optional central base station, known as the *access point (AP)*. Figure 9.3 shows two sets in this standard.

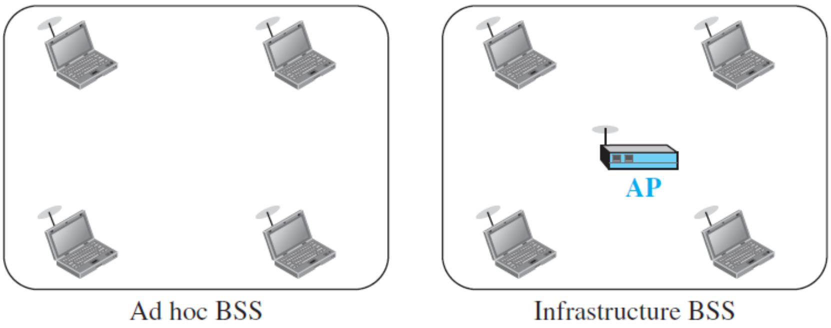


Figure 9.3 Basic service sets (BSSs)

The BSS without an AP is an independent network and cannot send data to other BSSs. It is called an *ad hoc architecture*. A BSS with an AP is sometimes referred to as an *infrastructure BSS*.

2. **Extended Service Set**

An **extended service set (ESS)** is made up of two or more BSSs with APs. In this case, the BSSs are connected through a *distribution system*, which is a wired or a wireless network. The distribution system connects the APs in the BSSs. Figure 9.4 shows an ESS.

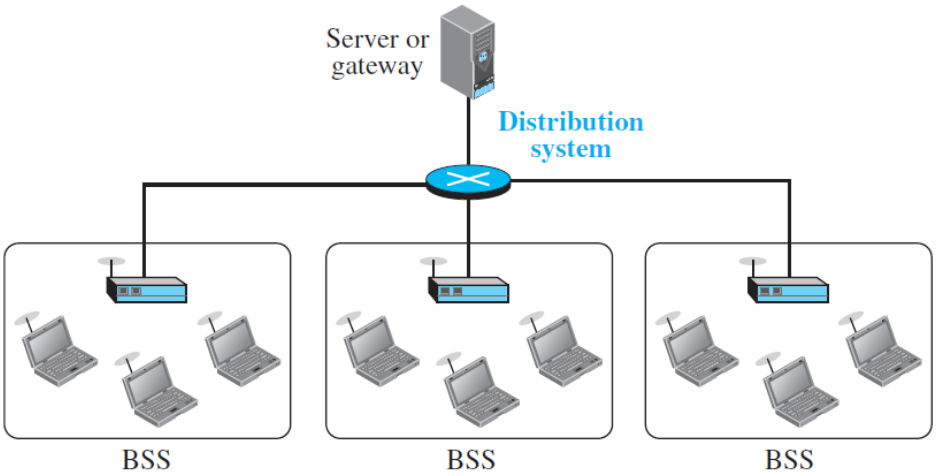


Figure 9.4 Extended service set (ESS)

9.5 Specification of IEEE 802.11

IEEE creates several specifications for the wireless LANs as described in the following:

IEEE 802.11 In 1997, the IEEE created the first WLAN standard with a maximum network **bandwidth of 2 Mbps** - too slow for most applications.

IEEE 802.11b IEEE expanded in July 1999, creating the 802.11b specification. It supports bandwidth up to **11 Mbps**, and uses radio signalling frequency (**2.4 GHz**).

IEEE 802.11a was created at the same time of 802.11b, but in a higher cost. IEEE 802.11a is usually found on business networks. It supports bandwidth up to **54 Mbps** and signals in frequency **5 GHz**.

IEEE 802.11g was created in 2002 to combine the best of both 802.11a and 802.11b. IEEE 802.11g supports bandwidth up to **54 Mbps**, and it uses the **2.4 GHz** frequency.

IEEE 802.11n (or "Wireless N") uses multiple wireless signals and antennas called *MIMO* (multiple-input multiple-output antenna) instead of one. It was created in 2009 with specifications providing for up to **300 Mbps** of network bandwidth.

IEEE 802.11ac is the newest generation of Wi-Fi which can utilize dual-band connections on both the 2.4 GHz and 5 GHz Wi-Fi bands. It offers bandwidth rated up to **1300 Mbps on the 5 GHz** band plus up to **450 Mbps on 2.4 GHz**.

WR543G Wireless AP/Client Router **IEEE 802.11b/g**

TP-LINK TL-WR940N **IEEE 802.11n** Wireless Router

LINKSYS WRT54G WIRELESS G BROADBAND ROUTER **54Mbps IEEE 802.11g** 4Router **2.4 GHz**)

Asus RT-AC3200 **IEEE 802.11ac** Ethernet Wireless Router **2.4, 5 GHz**