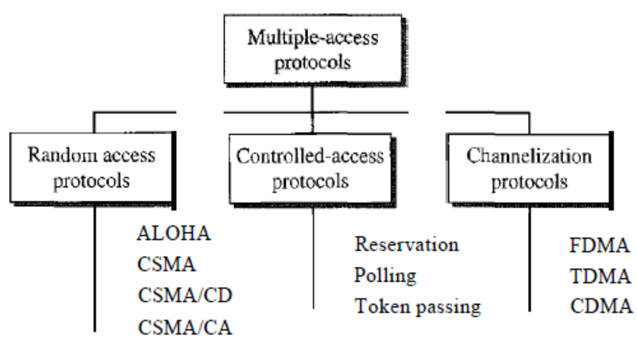
Multiple Accesses

When nodes or stations are connected and use a common link, called a multipoint or broadcast link, we need a multiple-access protocol to coordinate access to the link.

The problem of controlling the access to the medium is similar to the rules of speaking in an assembly. The procedures guarantee that the right to speak is upheld and ensure
that two people do not speak at the same time, do not interrupt each other, do not monopolize the discussion, and so on.
The situation is similar for multipoint networks. Many formal protocols have been devised to handle access to a shared link .We categorize them into three groups. Protocols belonging to each group are shown in Figure 12.2.

Figure 12.2 *Taxonomy ofmultiple-access protocols discussed in this chapter*

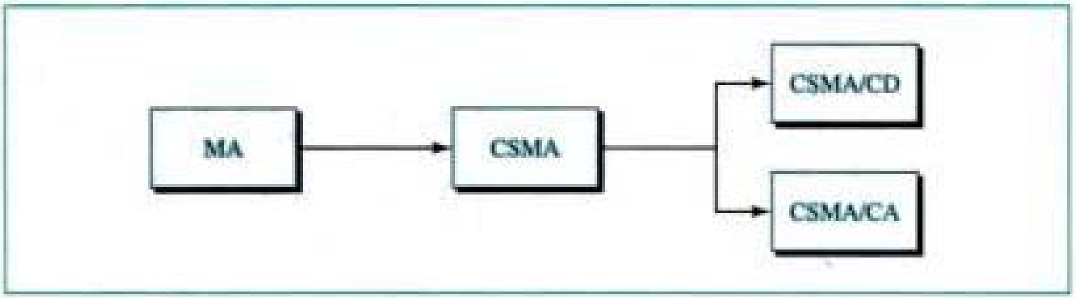


RANDOM ACCESS

In a random access method, each station has the right to the medium without being controlled by any other station. However, if more than one station tries to send, there is an access conflict-collision-and the frames will be either destroyed or modified. To avoid access conflict or to resolve it when it happens, each station follows a procedure that answers the following questions:

1- When can the station access the medium?
2- What can the station do if the medium is busy?
3- How can the station determine the success or failure of the transmission?
4- What can the station do if there is an access conflict?

Evolution of random-access methods



The random access methods we study in this chapter have evolved from a very interesting protocol known as ALOHA, which used a very simple procedure called multiple access (MA). The method was improved with the addition of a procedure that forces the station to sense the medium before transmitting. This was called carrier sense multiple access. This method later evolved into two parallel methods: carrier sense multiple access with collision detection (CSMA/CD) and carrier sense multiple access with collision avoidance (CSMA/CA). CSMA/CD tells the station what to do when a collision is detected. CSMA/CA tries to avoid the collision.

Multiple Access (MA)

ALOHA, the earliest random-access method, was developed at the University of Hawaii in the early 1970s. It was designed to be used on a radio (wireless) local area network (LAN) with a data rate of 9600 bps.

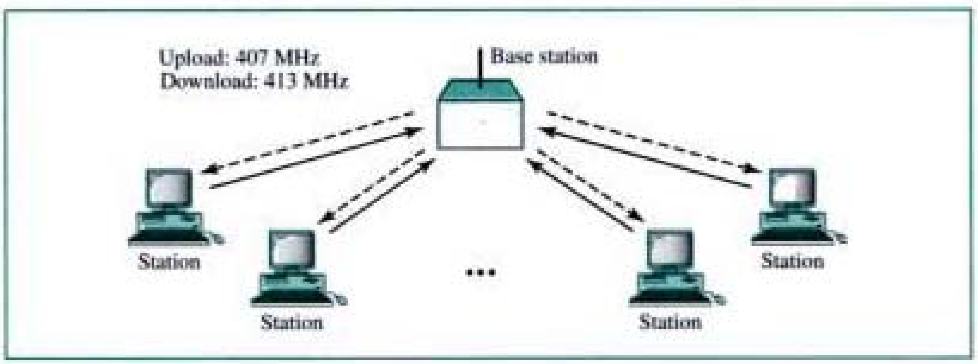
Figure 13.3 shows the basic idea behind an ALOHA network. A base station is the central controller. Every station that needs to send a frame to another station first sends it to the base station. The base station receives the frame and relays it to the intended destination. In other words, the base station acts as a hop. The uploading transmission (from a station to the base station) uses modulation with a carrier frequency of 407 MHz. The downloading transmission (from the base station to any station) uses a carrier frequency of 413 MHz.

It is obvious that there are potential collisions in this arrangement. The medium (air) is shared between the stations. When a station sends data at frequency 407 MHz to the base station, another station may attempt to do so at the same time. The data from the two stations collide and become garbled. The ALOHA protocol is very simple. It is based on the following rules:

- **Multiple access.** Any station sends a frame when it has a frame to send.
- **Acknowledgment.** After sending the frame, the station waits for an acknowledgment (explicit or implicit). If it does not receive an acknowledgment during the allotted time, which is 2 times the maximum propagation delay (the time it takes for the first bit of the frame to reach every station), it assumes that the frame is lost; it tries sending again after a random amount of time.

The protocol flowchart is shown in Figure 13.4. A station that has a frame to send sends it. It then waits for a period of time, which is 2 times the maximum propagation delay. If it receives an acknowledgment, the transmission is successful. If there is no acknowledgment during this period, the station uses a backoff strategy (explained later) and sends the packet again. After several tries, if there is no acknowledgment, the station gives up.

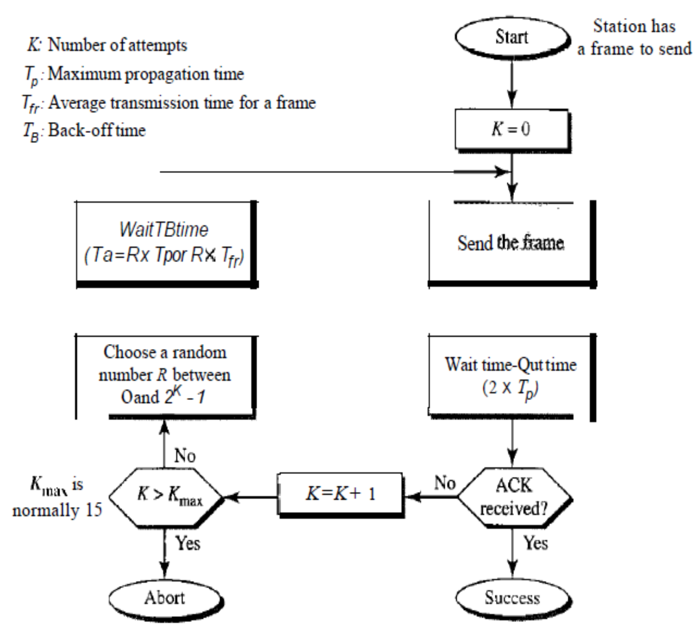
Figure 13.3 *ALOHA network*



It is obvious that we need to resend the frames that have been destroyed during transmission. The pure ALOHA protocol relies on acknowledgments from the receiver.
When a station sends a frame, it expects the receiver to send an acknowledgment. If the acknowledgment does not arrive after a time-out period, the station assumes that the frame (or the acknowledgment) has been destroyed and resends the frame.
A collision involves two or more stations. If all these stations try to resend their frames after the time-out, the frames will collide again. Pure ALOHA dictates that when the time-out period passes, each station waits a random amount of time before resending its frame. The randomness will help avoid more collisions. We call this time the back-off time T_B .
Pure ALOHA has a second method to prevent congesting the channel with retransmitted frames. After a maximum number of retransmission

attempts K max' a station must give up and try later. Figure 12.4 shows the procedure for pure ALOHA based on the above strategy.

Figure **12.4** *Procedure for pure ALOHA protocol*



The time-out period is equal to the maximum possible round-trip propagation delay, which is twice the amount of time required to send a frame between the two most widely separated stations (2 x Tp)' The back-off time TB is a random value that normally depends on K (the number of attempted unsuccessful transmissions). The formula for TB depends on the implementation. One common formula is the binary exponential back-off. In this method, for each retransmission, a multiplier in the range 0 to 2K - 1 is randomly chosen and multiplied by Tp (maximum propagation time) or Trr (the average time required to send out a frame) to find TB' Note that in this procedure, the range of the random numbers increases after each collision. The value of K max is usually chosen as 15.

Example 12.1

The stations on a wireless ALOHA network are a maximum of 600 km apart. If we assume that signals propagate at 3 x 108 mis, we find Tp = (600 x 105) / (3 x 108) = 2 ms. Now we can find the value of TB for different values of K.

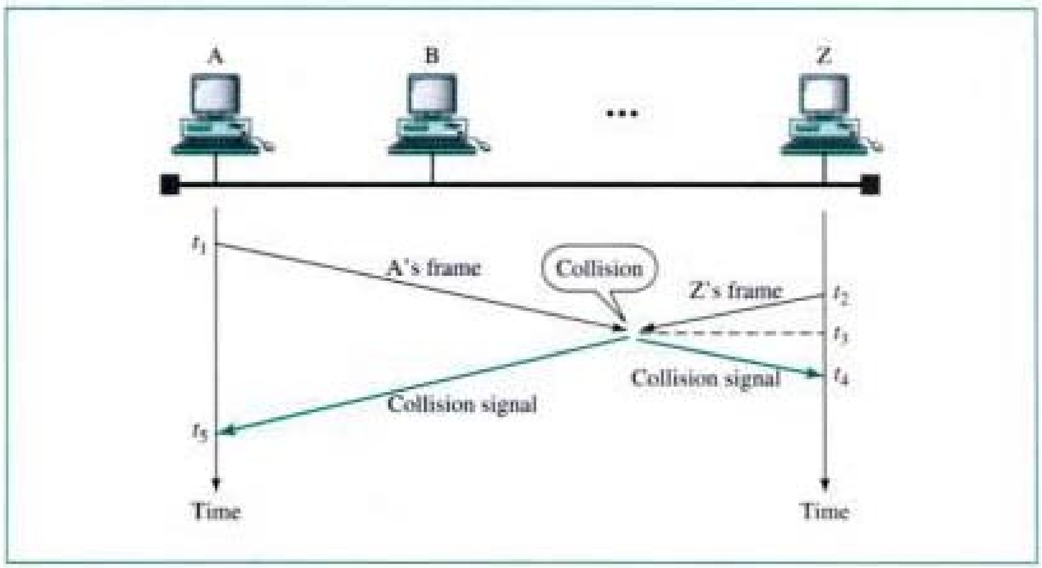
a. For K = 1, the range is {O, I}. The station needs to generate a random number with a value of 0 or 1. This means that TB is either °ms (0 x 2) or 2 ms (l x 2), based on the outcome of the random variable.

b. For K =2, the range is {O, 1, 2, 3}. This means that TB can be 0, 2, 4, or 6 ms, based on the outcome of the random variable.
c. For K =3, the range is to, 1,2,3,4,5,6, 7}. This means that TB can be 0,2,4, ... , 14 ms, based on the outcome of the random variable.
d. We need to mention that if K > 10, it is normally set to 10.

Carrier Sense Multiple Access (CSMA)

To minimize the chance of collision and, therefore, increase the performance, the CSMA method was developed. The chance of collision can be reduced if a station senses the medium before trying to use it. Carrier sense multiple access (CSMA) requires that each station first listen to the medium (or check the state of the medium) before sending. In other words, CSMA is based on the principle "sense before transmit" or "listen before talk."

Figure 13.5 *Collision in CSMA*

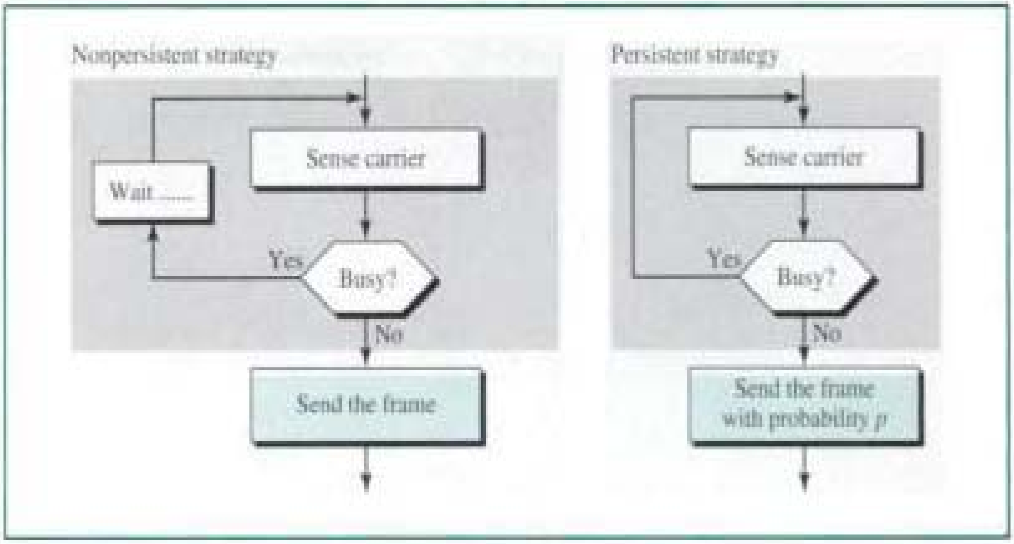


At time t_1, station A at the left end of the medium senses the medium. The medium is idle, so it sends a frame. At time t_2 ($t_2 > t_1$), station Z at the right end of the medium senses the medium and finds it idle because, at this time, propagation from station A has not reached station Z. Station Z also sends a frame. The two signals collide at time t_3 ($t_3 > t_2 > t_1$). Note that the result of the collision, which is a garbled signal, will also propagate now in both directions. It reaches station Z at time t_4 ($t_4 > t_3 > t_2 > t_1$) and station A at time t_5 ($t_5 > t_4 > t_3 > t_2 > t_1$).

Persistence Strategy

The **persistence strategy** defines the procedures for a station that senses a busy medium. Two substrategies have been devised: nonpersistent and persistent. (see Fig. 13.6).

Figure 13.6 *Persistence strategies*



Nonpersistent In a **nonpersistent strategy,** a station that has a frame to send senses the line. If the line is idle, the station sends immediately. If the line is not idle, the station waits a random period of time and then senses the line again. The nonpersistent approach reduces the chance of collision because it is unlikely that two or more stations wait the same amount of time and retry again simultaneously. However, this method reduces the efficiency of the network if the medium is idle when there are stations that have frames to send.

Persistent In a **persistent strategy,** a station senses the line. If the line is idle, the station sends a frame. This method has two variations: **1-persistent** and ***p*-persistent.**

In the 1-persistent method, if the station finds the line idle, the station sends its frame immediately (with a probability of 1). This method increases the chance of collision because two or more stations may send their frames after finding the line idle.

In the p-persistent method, if the station finds the line idle, the station may or may not send. It sends with probability p and refrains from sending with probability $1 - p$. For example, if p is 0.2, it means that each station, after sensing an idle line, sends with a probability of 0.2 (20 percent of the time) and refrains from sending with a probability of 0.8 (80 percent of the time). The station generates a random number between 1 and 100. If the random number is less than 20, the station will send; otherwise the station refrains from sending. The p-persistent strategy combines the advantages of the other two strategies. It reduces the chance of collision and improves the efficiency.

Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

The CSMA method does not specify the procedure following a collision. Carrier sense multiple access with collision detection (CSMA/CD) augments the algorithm to handle the collision.

Example 12.5

A network using CSMA/CD has a bandwidth of 10 Mbps. If the maximum propagation time (including the delays in the devices and ignoring the time needed to send a jamming signal, as we see later) is 25.611S, what is the minimum size of the frame?

Solution

The frame transmission time is Tfr = 2 x Tp =51.2 ~s. This means, in the worst case, a station needs to transmit for a period of 51.2 ~s to detect the collision. The minimum size of the frame is 10 Mbps x 51.2 !-ls =512 bits or 64 bytes. This is actually the minimum size of the frame for Standard Ethernet

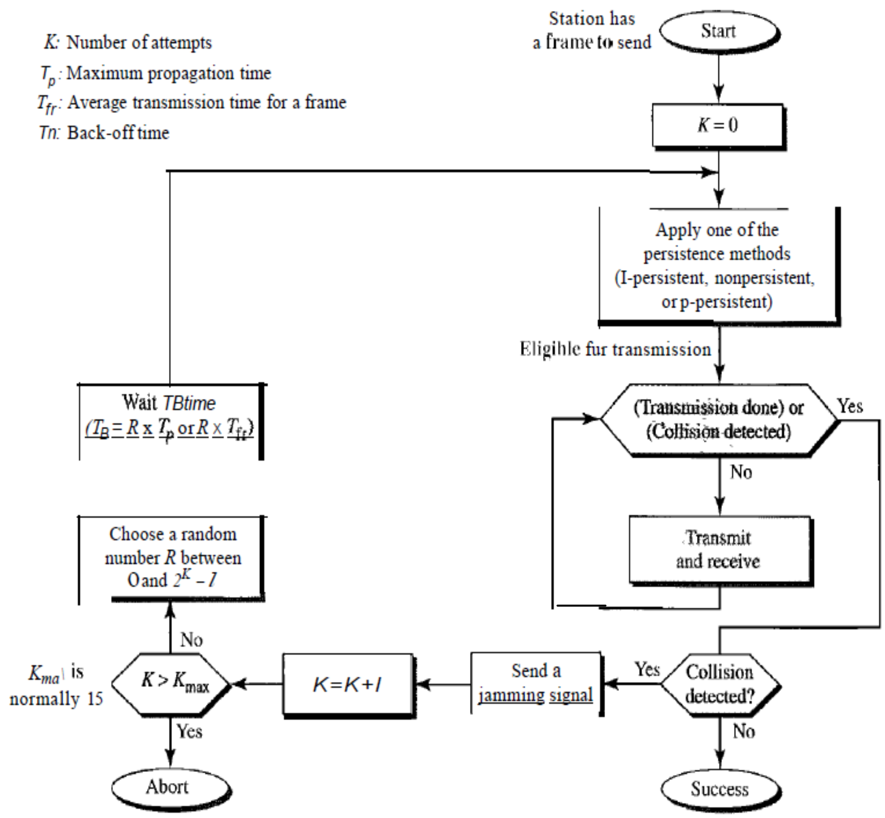
Procedure

Now let us look at the flow diagram for CSMA/CD in Figure 12.14. It is similar to the one for the ALOHA protocol, but there are differences.

The first difference is the addition of the persistence process. We need to sense the channel before we start sending the frame by using one of the persistence processes we discussed previously (I-persistent, or p-persistent). The corresponding box can be replaced by one of the persistence processes shown in Figure 12.11.

The second difference is the frame transmission. In ALOHA, we first transmit the entire frame and then wait for an acknowledgment. In CSMA/CD, transmission and collision detection is a continuous process. We do not send the entire frame and then look for a collision. The station transmits and receives continuously and simultaneously (using two different ports). We use a loop to show that transmission is a continuous process. We constantly monitor in order to detect one of two conditions: either transmission is finished or a collision is detected. Either event stops transmission. When we come out of the loop, if a collision has not been detected, it means that transmission is complete; the entire frame is transmitted. Otherwise, a collision has occurred.

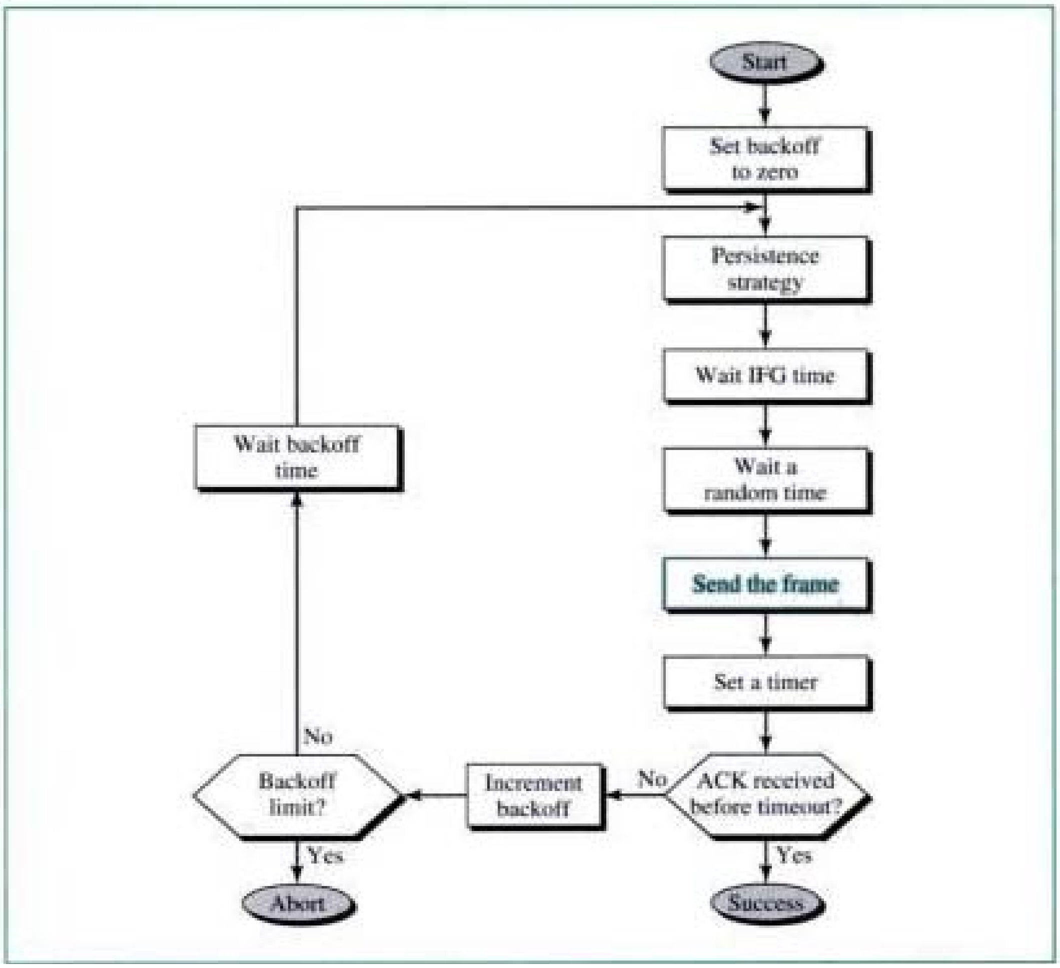
The third difference is the sending of a short jamming signal that enforces the collision in case other stations have not yet sensed the collision.


K: Number of attempts
Tp: Maximum propagation time
Tfr: Average transmission time for a frame
Tn: Back-off time
Station has a frame to send
Start
K = 0
Apply one of the persistence methods (I-persistent, nonpersistent, or p-persistent)
Eligible fur transmission
(Transmission done) or (Collision detected)
Yes
No
Transmit and receive
Collision detected?
Yes
No
Success
Send a jamming signal
K=K+I
K > Kmax
Kmax is normally 15
Yes
Abort
No
Choose a random number R between 0 and 2^K – 1
Wait TBtime (TB = R x Tp or R x Tfr)

CSMA/CA

The CSMA/CA procedure differs from the previous procedures in that there is no collision. The procedure avoids collision (see Fig. 13.8). The station uses one of the

Figure 13.8 *CSMA/CA procedure*



persistence strategies. After it finds the line idle, the station waits an IFG (interframe gap) amount of time. It then waits another random amount of time. After that, it sends the frame and sets a timer. The station waits for an acknowledgment from the receiver. If it receives the acknowledgment before the timer expires, the transmission is successful. If the station does not receive an acknowledgment, it knows that something is wrong (the frame is lost or the acknowledgment is lost). The station increments the value of the backoff parameter, waits for a backoff amount of time, and resenses the line.