Limited-broadcast Address

The only address in the block **255.255.255.255**/32 is called the *limited-broadcast* address. It is used whenever a router or a host needs to send a datagram to all devices in a network. The routers in the network, however, block the packet having this address as the destination; the packet cannot travel outside the network.

Loopback Address

The block **127.0.0.0/8** is called the *loopback* address. A packet with one of the addresses in this block as the destination address never leaves the host; it will remain in the host. Any address in the block is used to test a piece of software in the machine. For example, we can write a client and a server program in which one of the addresses in the block is used as the server address. We can test the programs using the same host to see if they work before running them on different computers.

Private Addresses

Four blocks are assigned as private addresses: 10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16, and 169.254.0.0/16. We will see the applications of these addresses when we discuss NAT later in the chapter.

Multicast Addresses

The block 224.0.0.0/4 is reserved for multicast addresses. We discuss these addresses later in the chapter.

18.4.4 Dynamic Host Configuration Protocol (DHCP)

We have seen that a large organization or an ISP can receive a block of addresses directly from ICANN and a small organization can receive a block of addresses from an ISP. After a block of addresses are assigned to an organization, the network administration can manually assign addresses to the individual hosts or routers. However, address assignment in an organization can be done automatically using the **Dynamic Host Configuration Protocol (DHCP).** DHCP is an application-layer program, using the client-server paradigm, that actually helps TCP/IP at the network layer.

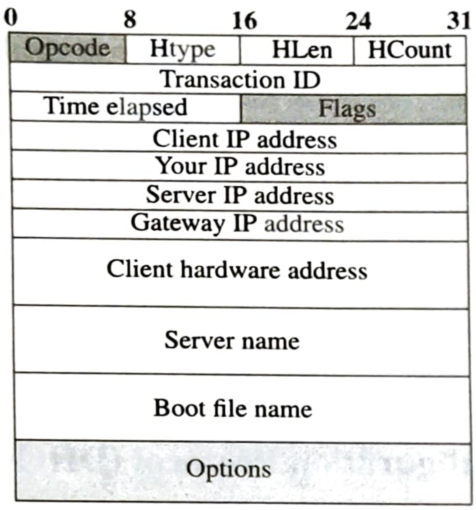
DHCP has found such widespread use in the Internet that it is often called a *plug-and-play protocol*. In can be used in many situations. A network manager can configure DHCP to assign permanent IP addresses to the host and routers. DHCP can also be configured to provide temporary, on demand, IP addresses to hosts. The second capability can provide a temporary IP address to a traveller to connect her laptop to the Internet while she is staying in the hotel. It also allows an ISP with 1000 granted addresses to provide services to 4000 households, assuming not more than one-forth of customers use the Internet at the same time.

In addition to its IP address, a computer also needs to know the network prefix (or address mask). Most computers also need two other pieces of information, such as the address of a default router to be able to communicate with other networks and the address of a name server to be able to use names instead of addresses, as we will see in Chapter 26. In other words, four pieces of information are normally needed: the computer address, the prefix, the address of a router, and the IP address of a name server. DHCP can be used to provide these pieces of information to the host.

DHCP Message Format

DHCP is a client-server protocol in which the client sends a request message and the server returns a response message. Before we discuss the operation of DHCP, let us show the general format of the DHCP message in Figure 18.25. Most of the fields are explained in the figure, but we need to discuss the option field, which plays a very important role in DHCP.

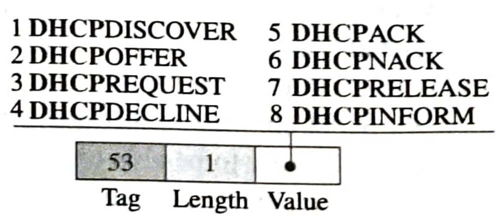
Figure 18.25 *DHCP message format*



Fields:
Opcode: Operation code, request (1) or reply (2)
Htype: Hardware type (Ethernet, ...)
HLen: Length of hardware address
HCount: Maximum number of hops the packet can travel
Transaction ID: An integer set by the client and repeated by the server
Time elapsed: The number of seconds since the client started to boot
Flags: First bit defines unicast (0) or multicast (1); other 15 bits not used
Client IP address: Set to 0 if the client does not know it
Your IP address: The client IP address sent by the server
Server IP address: A broadcast IP address if client does not know it
Gateway IP address: The address of default router
Server name: A 64-byte domain name of the server
Boot file name: A 128-byte file name holding extra information
Options: A 64-byte field with dual purpose described in text

The 64-byte option field has a dual purpose. It can carry either additional information or some specific vendor information. The server uses a number, called a **magic cookie,** in the format of an IP address with the value of 99.130.83.99. When the client finishes reading the message, it looks for this magic cookie. If present, the next 60 bytes are options. An option is composed of three fields: a 1-byte tag field, a 1-byte length field, and a variable-length value field. There are several tag fields that are mostly used by vendors. If the tag field is 53, the value field defines one of the 8 message types shown in Figure 18.26. We show how these message types are used by DHCP.

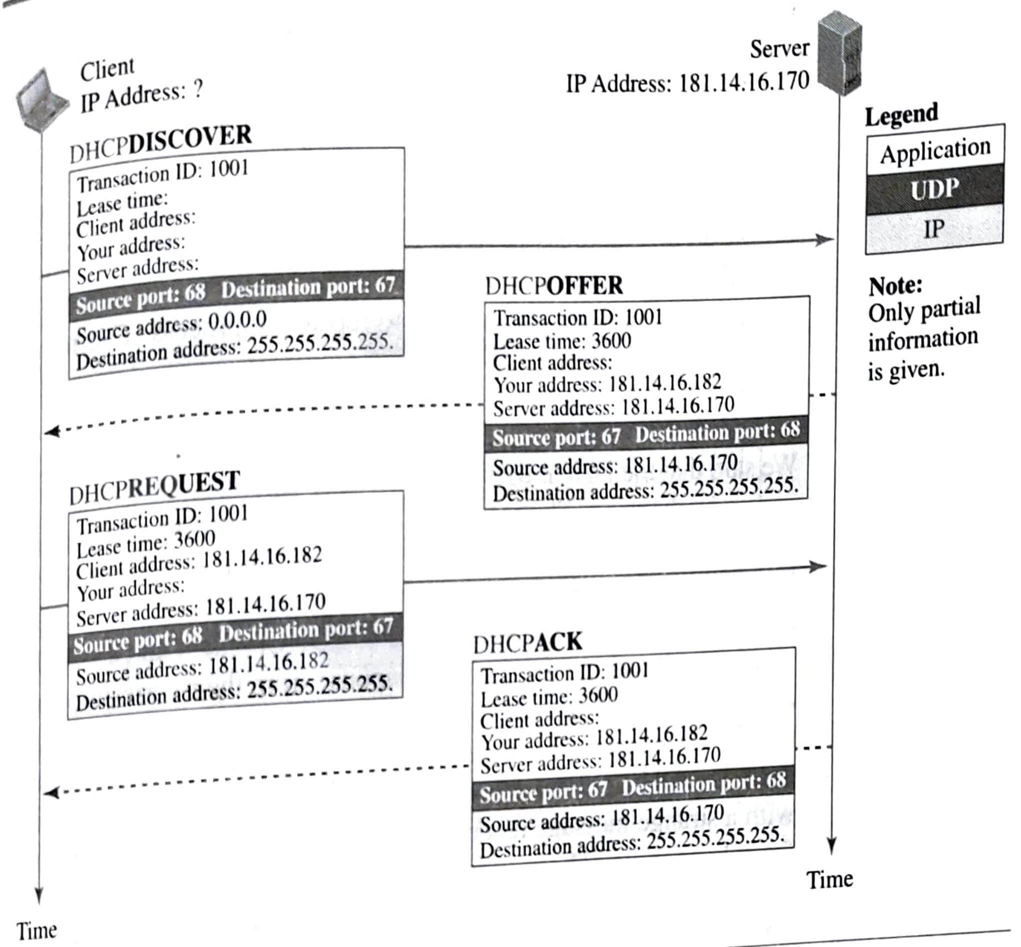
Figure 18.26 *Option format*



DHCP Operation

Figure 18.27 shows a simple scenario.

Figure 18.27 *Operation of DHCP*



1. The joining host creates a **DHCPDISCOVER** message in which only the transaction-ID field is set to a random number. No other field can be set because the host has no knowledge with which to do so. This message is encapsulated in a UDP user datagram with the source port set to 68 and the destination port set to 67. We will discuss the reason for using two well-known port numbers later. The user datagram is encapsulated in an IP datagram with the source address set to **0.0.0.0** ("this host") and the destination address set to **255.255.255.255** (broadcast address). The reason is that the joining host knows neither its own address nor the server address.
2. The DHCP server or servers (if more than one) responds with a **DHCPOFFER** message in which the your address field defines the offered IP address for the joining host and the server address field includes the IP address of the server. The message also includes the lease time for which the host can keep the IP address. This message is encapsulated in a user datagram with the same port numbers, but in the reverse order. The user datagram in turn is encapsulated in a datagram with the server address as the source IP address, but the destination address is a broadcast address, in which the server allows other DHCP servers to receive the offer and give a better offer if they can.

3. The joining host receives one or more offers and selects the best of them. The joining host then sends a **DHCPREQUEST** message to the server that has given the best offer. The fields with known value are set. The message is encapsulated in a user datagram with port numbers as the first message. The user datagram is encapsulated in an IP datagram with the source address set to the new client address, but the destination address still is set to the broadcast address to let the other servers know that their offer was not accepted.
4. Finally, the selected server responds with a **DHCPACK** message to the client if the offered IP address is valid. If the server cannot keep its offer (for example, if the address is offered to another host in between), the server sends a **DHCPNACK** message and the client needs to repeat the process. This message is also broadcast to let other servers know that the request is accepted or rejected.

Two Well-Known Ports

We said that the DHCP uses two well-known ports (68 and 67) instead of one well-known and one ephemeral. The reason for choosing the well-known port 68 instead of an ephemeral port for the client is that the response from the server to the client is broadcast. Remember that an IP datagram with the limited broadcast message is delivered to every host on the network. Now assume that a DHCP client and a DAYTIME client, for example, are both waiting to receive a response from their corresponding server and both have accidentally used the same temporary port number (56017, for example). Both hosts receive the response message from the DHCP server and deliver the message to their clients. The DHCP client processes the message; the DAYTIME client is totally confused with a strange message received. Using a well-known port number prevents this problem from happening. The response message from the DHCP server is not delivered to the DAYTIME client, which is running on the port number 56017, not 68. The temporary port numbers are selected from a different range than the well-known port numbers.

The curious reader may ask what happens if two DHCP clients are running at the same time. This can happen after a power failure and power restoration. In this case the messages can be distinguished by the value of the transaction ID, which separates each response from the other.

Using FTP

The server does not send all of the information that a client may need for joining the network. In the **DHCPACK** message, the server defines the pathname of a file in which the client can find complete information such as the address of the DNS server. The client can then use a file transfer protocol to obtain the rest of the needed information.

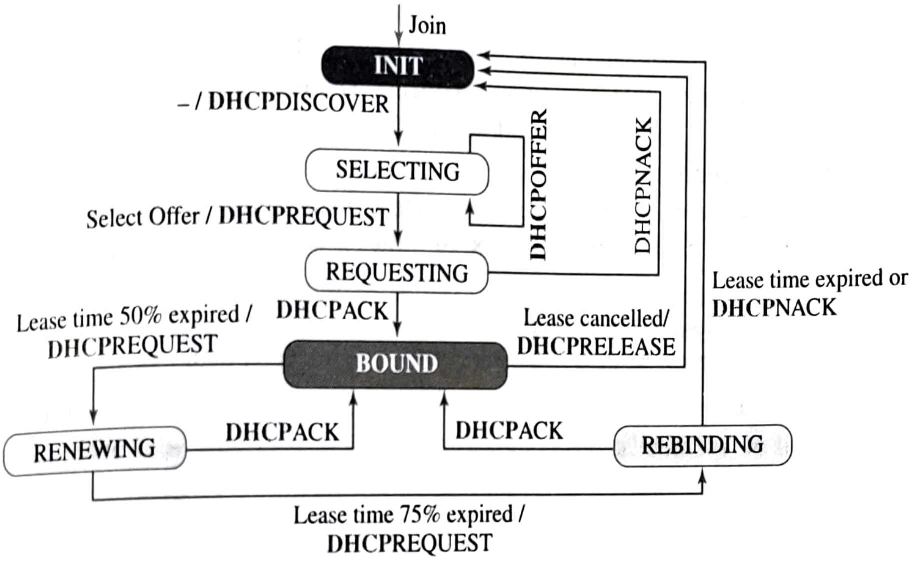
Error Control

DHCP uses the service of UDP, which is not reliable. To provide error control, DHCP uses two strategies. First, DHCP requires that UDP use the checksum. As we will see in Chapter 24, the use of the checksum in UDP is optional. Second, the DHCP client uses timers and a retransmission policy if it does not receive the DHCP reply to a request. However, to prevent a traffic jam when several hosts need to retransmit a request (for example, after a power failure), DHCP forces the client to use a random number to set its timers.

Transition States

The previous scenarios we discussed for the operation of the DHCP were very simple. To provide dynamic address allocation, the DHCP client acts as a state machine that performs transitions from one state to another depending on the messages it receives or sends. Figure 18.28 shows the transition diagram with the main states.

Figure 18.28 *FSM for the DHCP client*



When the DHCP client first starts, it is in the INIT state (initializing state). The client broadcasts a discover message. When it receives an offer, the client goes to the SELECTING state. While it is there, it may receive more offers. After it selects an offer, it sends a request message and goes to the REQUESTING state. If an ACK arrives while the client is in this state, it goes to the BOUND state and uses the IP address. When the lease is 50 percent expired, the client tries to renew it by moving to the RENEWING state. If the server renews the lease, the client moves to the BOUND state again. If the lease is not renewed and the lease time is 75 percent expired, the client moves to the REBINDING state. If the server agrees with the lease (ACK message arrives), the client moves to the BOUND state and continues using the IP address; otherwise, the client moves to the INIT state and requests another IP address. Note that the client can use the IP address only when it is in the BOUND, RENEWING, or REBINDING state. The above procedure requires that the client uses three timers: *renewal timer* (set to 50 percent of the lease time), *rebinding timer* (set to 75 percent of the lease time), and *expiration timer* (set to the lease time).

18.4.5 Network Address Resolution (NAT)

The distribution of addresses through ISPs has created a new problem. Assume that an ISP has granted a small range of addresses to a small business or a household. If the business grows or the household needs a larger range, the ISP may not be able to grant the demand because the addresses before and after the range may have already been allocated to other networks. In most situations, however, only a portion of computers in