Inside DHCP

by Laura Chappell
Senior Protocol Analyst, Protocol Analysis Institute

The Dynamic Host Configuration Protocol (DHCP) provides a means for automating host configuration settings such as the IP address and default gateway. (DHCP is defined by Request For Comments [RFC] 2131, which you can read at http://info.internet.isi.edu:80/in-notes/rfc/files/rfc2131.txt.) DHCP is the successor to the Bootstrap Protocol (BOOTP), which provided only static IP addresses based on the client's hardware address.

In NetWare 5™, DHCP takes on advanced responsibilities and capabilities when it is integrated with Domain Name System (DNS) and Novell Directory Services® (NDS™). This article examines the packet-level functionality of DHCP, using the NetWare 5 client bootup sequence as an example.

If you're accessing this page through a wireless connection or Radius dial-up connection, you can view the trace file used in this article. Download and UnZip DHCP.ZIP. This trace file is in the LANalyzer for Windows format. If you want to download the update for Novell's LANalyzer for Windows 2.2 (including enhanced DHCP decodes), visit http://www.packet-level.com.

DHCP Clients, Servers, and Relay Agents

DHCP clients send a discovery broadcast packet request to locate a DHCP server. This DHCP client and server process is a local communication because broadcast packets should not be forwarded by a router. In response to this broadcast packet, the DHCP server offers an address to the DHCP client.

The DHCP client then requests the following related address parameters:

- ? *Lease Time (LT).* This parameter determines how long the DHCP client may use the IP address.
- ? *Renewal Time (T1).* This parameter determines when the DHCP client must request an extension of the lease time (typically 1/2 of T1) from the DHCP server that originally granted the IP address lease.
- ? *Rebind Time (T2).* If the renewal is unsuccessful (because the DHCP server is down, for example), this parameter determines when the DHCP client should attempt to reacquire an IP address from any DHCP server.

If the DHCP server and the DHCP client are on separate networks, the DHCP address assignment process becomes a bit more complicated. In this case, the DHCP client sends the discovery broadcast packet on the local network. (See Figure 1.) Because the discovery broadcast packet cannot be routed, a special relay agent process (often referred to as the *BOOTP* or *DHCP relay agent process*) is used to enable communications between a DHCP client and a DHCP server on separate networks.

DHCP communications use the connectionless services of User Datagram Protocol (UDP) with the following port numbers:

- ? *UDP Port 67.* DHCP server (the port used for BOOTP server processes)
- ? *UDP Port 68.* DHCP client (same port used for BOOTP client processes)

DHCP communications also define a set of options, or tags, that indicate the information clients use DHCP to locate.

DHCP Options

Although DHCP is often looked at as the salvation from the manual agony of IP address assignment, DHCP actually offers much more capability. The name -- *Dynamic Host Configuration Protocol*--is an accurate definition. The following elements (referred to as *DHCP options*) can be configured using DHCP:

Option	Definition
1	Subnet Mask Value
2	Time Offset in Seconds from UTC
3	Default gateway addresses
6	DNS Server address
15	Client DNS domain name
19	Enable/Disable IP Forwarding
20	Enable/Disable Source Routing
23	Default IP Time to Live
28	Broadcast Address
35	ARP Cache Timeout
36	Ethernet Encapsulation
38	TCP Keepalive Interval
44	NETBIOS Name Servers
47	NETBIOS Scope
51	IP Address Lease Time (LT)
58	DHCP Renewal (T1) Time
59	DHCP Rebinding (T2) Time
62	NetWare/IP Domain Name
69	Simple Mail Transfer Protocol (SMTP) Server Addresses
70	Post Office Protocol (POP3) Server Addresses
72	WWW Server Addresses
85	Novell NDS Server
86	Novell NDS Tree Name
87	Novell NDS Context

For a complete list of the DHCP options registered with IANA, access Novell Connecting Points at BrainShare '99. Then access Today's Hot Links in the online Conference Daily, and download the DHCPTAG.DOC file.

Not all of the DHCP options are available to DHCP clients, unless they are configured to use the options. With Windows 95 DHCP client services, these options are not configurable: You can only select DHCP services or manual assignment of IP addresses. However, Novell's client 32 software for Windows 95 adds additional functionality: When requesting an IP address, the client can also use DHCP to request the NDS server, context, and tree.

DHCP for Address Assignment
When a DHCP client requests an IP address, the following process occurs:

1. The DHCP client discovers a DHCP server.
2. The DHCP server offers an IP address.
3. The DHCP client requests the IP address and lease time information.
4. The DHCP server replies, granting the address and supplying the lease time information.

DHCP Client Discovers a DHCP Server
During this process, the DHCP client broadcasts a DHCP discovery packet, which is sent to the broadcast address 0xFF-FF-FF-FF-FF-FF. This discovery packet uses the UDP source port 68 (DHCP client process) and UDP destination port 67 (DHCP server process).

Figure 2 shows a discovery packet. The DHCP client that sent this packet does not have an IP address (Client IP Address 0.0.0.0) and does not know the DHCP server's IP address (Server IP Address 0.0.0.0).

However, the DHCP client does have a client identifier 0x01-00-A0-CC-30-C8-DB, which is a combination of a circuit (0x01) and the client's Media Access Control (MAC) address (0x00-A0-CC-30-C8-DB). The DHCP server uses this client identifier to track DHCP clients and associate a specific hardware address with the assigned IP address.

DHCP Server Offers an Address
Figure 3 shows the DHCP server reply which offers an IP address (10.0.99.1) to the DHCP client. The DHCP server also provides its own IP address (Server Identifier 10.0.0.1), the offered address subnet mask (255.0.0.0) and the IP address lease time (0x0E01 = 3600 seconds).

At this point, the DHCP client may go to the next step and request address parameter information, or the DHCP client may reject the offered IP address (DHCPNAK). A DHCP client sends an address rejection only if the client has received DHCP offers from more than one DHCP server. Because the DHCP discovery packet is sent to the broadcast address, any DHCP server (on this side of a router) may answer the broadcast. If more than one DHCP server replies and offers an IP address, the DHCP client accepts only one IP address and sends a rejection packet to the other DHCP servers.

DHCP Client Requests (Accepts) the Offered IP Address and Calculates Times
Before the DHCP client begins using the new address, the client must calculate the

time parameters associated with a leased address--Lease Time (LT), Renewal Time (T1), and Rebind Time (T2). *Lease Time (LT).* The typical default lease time is 72 hours. You can use shorter lease times to conserve addresses.

Renewal Time (T1). The Renewal Time, or T1, parameter defines when the DHCP client attempts to renew the lease from the DHCP server that originally granted the lease. T1 defaults to (0.5 x LT). For example, if the lease time is 72 hours, T1 is 36 hours.

Rebind Time (T2). The Rebind Time, or T2, parameter defines when the DHCP client will attempt to renew the address from any DHCP server after the original DHCP server has not responded to the renewal requests within T2. T2 defaults to (0.875 x LT). For example, on a 72 hour lease, T2 is 63 hours into the lease time.

Naturally, T1 must always be less than T2. T2 must always be less than LT. (For more information about DHCP lease expiration, read RFC 2131, section 4.4.5 "Reacquisition and Expiration." You can access all RFCs by visiting http://www.rfc-editor.org or http://www.ietf.org.)

Server Replies, Granting the IP Address and Supplying Other Information
The DHCP server uses DHCP command 0x05 (ACK) to send the requested parameters to the DHCP client. (For a complete list of command options, see "DHCP Command Options" on p. 2. To view the information included in a DHCPACK packet, see packet 4 in the DHCP.TR1 file. In this packet, you can see that the DHCP server has now also supplied its domain name information. To view this trace file, access Novell Connecting Points at BrainShare '99. Then access Today's Hot Links in the online *Conference Daily,* and download the DHCP.TR1 file.)

Quick Quiz
Now that you understand LT, T1, and T2, figure out each of the LT, T1, and T2 values if the lease time is 3600 minutes. You'll find the answers at the end of this article.

The Duplicate Address Test
After the DHCP client has obtained an IP address and the associated time parameters from the server, the client should perform a Duplicate Address Test. The DHCP client performs this test by sending two Address Resolution Protocol (ARP) broadcasts in attempt to locate another device that already uses the client's newly assigned IP address.

If another device answers the ARP broadcasts, then the DHCP client cannot initialize the IP address to access the IP network. An error message appears on the client monitor. This error message indicates that a duplicate address has been found. In many DHCP client implementations, the error message includes the hardware address of the device that is already using the address.

The rest of this article provides tips for troubleshooting DHCP problems.

DHCP Troubleshooting

There are some inherent flaws in DHCP as well as some poor implementations which are specific to certain vendors' DHCP client or server code. The following list should help you identify the possible causes of DHCP-based problems.

- ? Duplicate addresses are assigned because a second DHCP server is brought up, and this server uses address assignments that overlap with another server's address assignments.
- ? Duplicate addresses are assigned because the DHCP client did not receive a reply to the DHCP discovery process. As a result, the DHCP client takes the last address that it successfully obtained from a DHCP server.
- ? Duplicate addresses are assigned because the DHCP client did not interpret the LT value properly and, therefore, never released the IP address. However, the DHCP server considered the IP address "free" when the LT expired and assigned the IP address to another client.
- ? There is an address depletion problem. The DHCP client sent a DHCP release that was dropped before it reached the DHCP server. The DHCP server does not free up the IP address for reuse.
- ? A security breach of confidential IP address assignments may have occurred. DHCP communications are not encrypted and the DHCP server was placed outside the firewall.

Of course, the best way to troubleshoot DHCP communications is to place a network analyzer on the network and examine the DHCP communications, one packet at a time. Using a network analyzer and examining DHCP communications at the packet level will help you understand, troubleshoot, and optimize your company's DHCP network design.

Answer to the Quick Quiz
LT = 60 minutes (3600 seconds)
T1 = 30 minutes (1800 seconds)
T2 = 52.5 minutes (3150 seconds)

DHCP Options

Dynamic Host Configuration Protocol (DHCP) communications are defined by the following option codes:

DHCP Command Option	Description
0x01: DHCP Discover	Client to locate available servers.
0x02: DHCP Offer	Server-to-client response to 0x01.
0x03: DHCP Request	Client broadcast to server, requesting offered parameters from one server specifically--as defined in the packet.

0x04: DHCP Decline	Client-to-server communication indicating invalid parameter, such as network address.
0x05: DHCP ACK	Server-to-client communication with configuration parameters, including assigned network address.
0x06: DHCP NAK	Server-to-client communication refusing request for configuration parameter.
0x07: DHCP Release	Client to server communication relinquishing network address and canceling remaining lease.
0x08: DHCP Inform	Client-to-server communication asking for only local configuration parameters; client already has externally configured address.

The typical DHCP address assignment process uses the following DHCP commands in the client bootup phase:

0x01	DHCP Discover
0x02	DHCP Offer
0x03	DHCP Request
0x05	DHCP ACK

IANA can assign more DHCP command options. (For more information, visit http://www.iana.org.)