

Dynamic Host Configuration Protocol

Technical White Paper



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Introduction

The phenomenal growth of the Internet over the past several years has driven the acceptance of the TCP/IP protocol suite (the basic communication standard of the Internet) into corporate networks. Corporations traditionally utilized a myriad of different protocols, however, the TCP/IP environment has emerged to become dominant within most organizations because it enables corporations to communicate more effectively and utilize Internet tools to increase efficiency.

The design of TCP/IP requires that every system using the protocol have a unique address that fits into the addressing scheme within the organization. Therefore, every address must be a member within a subnet made up of a grouping of logically associated computers.

One way to make system management simpler and less expensive is to move the management of the IP¹ addresses away from the client systems and onto centralized servers. In response to this need, the Internet Engineering Task Force (IETF) created the *Dynamic Host Configuration Protocol* (DHCP).

What Is DHCP?

DHCP uses a client/server relationship to allocate addresses, track their usage, and reclaim a predetermined list of IP addresses and other configuration information shared in a network of systems. Each organization has one or more DHCP servers with a range of predefined IP addresses, as well as other startup information or additional parameters. When a user boots a client system, that system broadcasts a request for a DHCP server to issue it an IP address.

1. IP is the Internet Protocol layer of the TCP/IP communication stack defined by the Internet Engineering Task Force (IETF).

In the most common situation, the DHCP server responds with an IP address and a specified period of time (called a lease) for which the client may use that address. By using DHCP technology, network managers move the configuration of network-related parameters to a centralized DHCP server, which is much more cost-effective from a management standpoint. DHCP manages the assignment and reclamation of an organization's IP address namespace, freeing network administrators to concentrate on other tasks. Figure 1 depicts a typical DHCP environment.

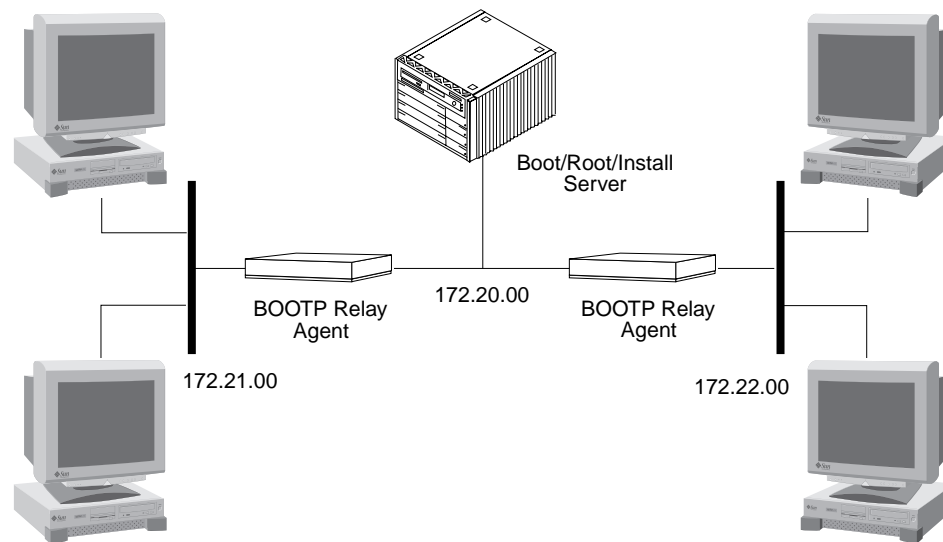


FIGURE 1 Topology of common DHCP client/server environment.

DHCP may also be used to pass additional information to a booting system. First, a client issues a boot request, which includes specific configuration information about the client. The server receives this information packet and compares the configuration information to a database of possible parameters, responding with additional data beyond the IP address (such as time zone or department-specific information).

IP addresses are normally divided into two types, *static* and *dynamic*. A static IP address is permanently assigned to a client, which means that the addresses and associated parameters do not change between system startups (reboots). They are often loaded into the startup information from the system disk of that machine, although they can also be supplied by a remote server. A dynamic address is not assigned to a client until it is booted and given the address by a server. Where the address is not supplied to the client *until* system startup, DHCP is the protocol of choice.

Systems that export services (print, file, Web, mail, etc.) are not particularly well-suited to DHCP client usage because changing addresses make it difficult to find these systems and complicate host-based access controls. Servers can use *static assignment with a lease* to consistently have DHCP issue the same address each time the server boots. This allows the centralized management of configuration parameters, even if the system is not using dynamic addresses.

History of DHCP

Historically, the assignment of Internet addresses to host machines required administrators to manually configure each machine and manually keep track of IP address assignments. While this is sufficient for small networks with a few systems, the overhead of manually managing a site's address name space becomes prohibitively expensive as the number of hosts increases.

DHCP was developed from an earlier protocol called *Bootstrap Protocol (BOOTP)*, which was used to pass information during initial booting to client systems. The BOOTP standard was originally released in 1985 based on work by John Gilmore of Sun Microsystems and Bill Croft of Stanford University. It allowed diskless clients (systems without any disk) to store configuration data in a centralized server. The BOOTP standard was designed to store and update static information for clients, including IP addresses.

The BOOTP server always issued the same IP address to the same client. As a result, while BOOTP addressed the need for central management, it did not address the problem of managing IP addresses as a dynamic resource.

To address the need to manage dynamic configuration information in general, and dynamic IP addresses specifically, the IETF standardized a new extension to BOOTP called Dynamic Host Configuration Protocol, or DHCP. DHCP servers utilize BOOTP packets, with DHCP-specific flags and data, to convey information to the DHCP clients.

To standardize the DHCP environment, the IETF issued a series of RFCs focused on DHCP extensions to the BOOTP technology. The most recent of these standards is RFC 2131, which was issued in March 1997. DHCP is still an area of active development and it is reasonable to assume that there will be additional RFCs related to the DHCP environment. Sun is working with other vendors to ensure that DHCP continues to be a standard supported by a large number of vendors.

Where DHCP Is Useful

The most common usage of DHCP is to move the management of IP addresses away from the distributed client systems and onto one or more centrally managed servers. These central servers maintain databases of parameter information (addresses, netmasks, etc.), eliminating the need for clients to store static network information on their machines. This specifically obviates the need to configure TCP/IP parameters into client machines. Since most client systems now ship from the factory with dynamically assigned IP addresses as the default configuration, the user need only boot the machine to be up and running with the TCP/IP protocol. This approach saves time configuring or debugging the network environment, thereby reducing the cost of ownership for client systems.

DHCP is particularly useful in the following environments:

- Sites that have many more TCP/IP clients than network administrators. By using DHCP, managers can more effectively manage a large community of client systems.
- Sites where laptops commonly move among networks within the site. By using DHCP, laptop users can plug into the network at any location and use a local DHCP-assigned IP address to communicate with the local systems.
- Sites that have fewer available TCP/IP addresses than they have clients that need them. Typically, this occurs in dial-up situations, such as an Internet service provider (ISP) environment, where there is a large community of potential users, but only a small percentage of them are online at any given time. Here, DHCP is used to issue the IP address to a client machine at the connection time, allowing the DHCP server to reuse the same address once the current client has logged off. Most ISPs have moved to this approach to reduce their need for scarce Internet addresses.
- Sites that frequently need to move the location of services from host to host. Since DHCP delivers the location of services, moving services from one machine to another and changing the appropriate DHCP configuration information means that any DHCP client will automatically pick up the change – without the administrator having to make a trip to the user's machine.
- Sites that support diskless clients. More details on this use of DHCP are provided in the *Client Implementation* section.
- Any combination of the above.

Why DHCP Is Important

According to a number of studies, the largest contributor to the total cost of computing is the administration of distributed clients. These studies, which focus on the cost of ownership for enterprise clients, indicate that the best way for corporations to reduce the cost of distributed computing is to move the administration of their client systems to centralized management servers. DHCP can play an important role in reducing the cost of ownership for large organizations by shifting the job of managing network configuration information from client systems to remote management by a small pool of system and network managers.

It is becoming increasingly difficult for organizations to acquire additional Internet addresses. Corporations must often justify the requirement for these additional addresses through a long and sometimes difficult process of needs definition. DHCP helps reduce the impact of the increasing scarcity of available IP addresses in two ways.

First, DHCP can be used to manage the limited number of standard, routable IP addresses that are available to an organization. It does this by issuing the addresses to clients on an *as needed* basis and reclaiming them when the addresses are no longer required. When a client needs an IP address, the DHCP server will issue an available address, along with a lease period during which the client may use the address. When the client is done with the address (or when the lease on the address expires), the address is put back in a pool and is available for the next client seeking an address.

Second, DHCP can be used in conjunction with Network Address Translation (NAT) to issue private network addresses to connect clients (through a NAT system) to the Internet. The DHCP server will issue an address to the client that will not route, such as 192.168.*.* or 10.*.*.*². The client will use a NAT system as the gateway machine, which packages up the request with the permanent address of the NAT system. When the response comes back from the Internet, the NAT server will forward the packet back to the client. DHCP enables this to be done without taking up valuable routable addresses and makes certain that all clients use consistent parameters, such as subnet masks, routers, and DNS servers.

2. Addresses in the range of 10.*.*, 172.16.*.* through 172.31.*.*, and 192.168.*.* are defined by IETF RFC 1918 as being reserved for private intranets and are not routed to the Internet.

Sun's Implementation of DHCP

Sun began shipping DHCP in 1994 as part of its Solstice PC-Admin™ product, and integrated it into the Solaris™ Operating Environment in version 2.6. In the latest release of the Solaris 8 Operating Environment, Sun has significantly improved the functionality of DHCP software, making it one of the best in the industry.

DHCP Implementation in the Solaris 8 Operating Environment

The Solaris Operating Environment implementation of the DHCP environment is consistent with the philosophy of traditional UNIX® utilities in that it is simple to use, yet flexible enough to be applied across a wide variety of different tasks. A system administrator can utilize this flexibility to solve an entire range of network and system configuration issues.

A good example of the flexibility of the Sun environment is the use of macros. Macros, which may be thought of as *containers* of configuration data, are keywords that the system manager can define to prompt the DHCP server to respond with specific configuration information. For example, a keyword might be the architecture of the client, such as "IA32_Solaris". When the DHCP sees this keyword in one of the configuration request packets, it responds with the network location of the Solaris Operating Environment x86 boot server.

Macros may be used in many different roles depending on the needs of the organization. They may be used to transfer departmental- or perhaps locale-specific information (such as time zone) to the client. Macros may also be layered so that one macro can call a series of additional macros. Since they can point to other macros, it is possible for common macros to be targeted by many other macros.

Sun's DHCP server implementation allows the association of configuration parameters with macros that are:

- Specific to a client's type (regardless of where it is located in the enterprise)
- Specific to the client's network
- Specific to the client itself
- Specific to the address
- Any combination of the above

This *scoping* hierarchy is a useful tool that enables administrators to organize their configuration data where needed.

The Sun DHCP server is designed to allow scaling up to the size of a network consisting of thousands of client systems. As stated previously, the DHCP packets are built on top of the BOOTP packet protocol. Since BOOTP packets are commonly passed over router links, it is possible for an entire corporation to be serviced by a small number of centralized DHCP servers.

Interoperability with Other Operating Environments

Since Sun's DHCP client and server technology is built in compliance with IETF RFC 2131, it works transparently with DHCP technology built by other vendors, provided they also comply with RFC 2131. This standard is clearly defined and commonly implemented, so that Sun DHCP software generally interacts seamlessly with DHCP software from other companies. In addition, Sun tests interoperability with other vendors on an annual basis during the vendor-neutral Connectathon event (www.connectathon.org). While Sun cannot warrant the specific implementations of other vendors, the Sun DHCP generally interoperates well with versions from other major vendors.

The DHCP server shipping with the last few versions of the Solaris Operating Environment can act as a server to Solaris software-based clients, most Microsoft Windows clients, clients from other UNIX vendors, Macintosh clients, and a number of other network clients. Many current ISPs are successfully using the Sun DHCP server to support large numbers of Microsoft Windows and Macintosh clients.

Key DHCP Improvements in the Latest Release

Sun has a long history with DHCP. As previously noted, the first Sun DHCP implementation was part of the Solstice PC-Admin layered product and was designed to help manage PC clients by using a system with the Solaris Operating Environment as a management system. The first version of DHCP that shipped directly with the Solaris Operating Environment was included in version 2.6. Keeping with Sun's history of continual product upgrades, Sun has made some major improvements in the Solaris 8 Operating Environment release.

To begin with, a new DHCP Manager package has been included that utilizes several new wizards and visual tools that make the DHCP environment much easier to manage. Where the earlier releases of DHCP required the modification of control files to manage the environment, many of these administration tasks have been simplified by the inclusion of a series of easy-to-use tools. More details on these enhancements will be covered in the *DHCP Administration using the DHCP Manager* section.

A new configuration protocol option has been added for the Solaris 8 Operating Environment network installation. In addition to the traditional Sun RARP/RPC Bootparams configuration model, DHCP configuration is now a supported installation option. Choosing DHCP configuration over RARP/RPC Bootparams frees administrators from the requirement to have a boot server or an install server on every network. Note that the selection of a configuration protocol is an either/or selection; no combination of the protocols is possible.

With the Solaris 8 Operating Environment, Sun now offers full-featured DHCP functionality in one easy-to-administer package.

Client Implementation

DHCP can be used to provide parameters above and beyond those required for network communication, such as parameters needed for remote installation of the Solaris Operating Environment on client systems.

Using DHCP to Install Software

DHCP can be used to help system administrators build or configure new software onto network-attached systems. This could take the form of a generic installation of software on a disk that needs to be customized by the DHCP server. Alternatively, it could be a totally empty disk that will be configured and built during installation using a remote source for the operating system. Either way, the DHCP server is used to store the configuration information so that when the system is booted for the first time, the DHCP server will provide all the configuration information required by the client for the building of software.

For this type of system, DHCP may be used in conjunction with the Solaris Operating Environment install server to automatically build the operating system on the client, including all of the parameters unique to this system. Through this method, the end user need only plug the computer in and power it on to build a fully customized environment, including an operating system and layered products. This method of software installation helps reduce the administration burden and cost of ownership for the client systems.

Using DHCP for Diskless Clients

It is sometimes beneficial to configure an environment to include diskless systems. The primary reasons to use diskless systems are to lower client costs by not requiring the use of disk drives and increase management and security through the central storage of application programs and user data.

In highly secure environments, such as classified government installations, as well as some equally guarded environments outside of the government, the ability to store data locally presents a security issue. Diskless workstations can be used to ensure that there is no data stored outside of the file server system managed by the institution's MIS department.

When there is no local storage (beyond the limited requirements of the bootstrap chips), a DHCP server can store the entire configuration for the booting of any number of diskless clients. Each system has a Media Access Control (MAC)³ address that is stored on the Ethernet card. In addition, many systems have the ability to store a limited amount of information in the bootstrap EPROMs (e.g., system architecture and preferred node name). This information can be passed to the DHCP server in the exchange of packets between the DHCP server and the client during the booting process. These packets, in turn, can be used to prompt the DHCP server to respond with some of the information stored in macros on the server. The information can be generic to all systems or can be targeted to a specific node. The macros can either contain all the configuration information that a system would need to boot or point to a location in the network for that information.

Note that macros also allow scoping by platform type (for example SUNW.Ultra-1). This feature is used to ensure that the right operating system binary is downloaded to the correct platform. With this capability, a system does not require local storage to boot with an entirely custom configuration unique to this system, which obviates the need for any local storage.

3. The MAC address is used in layer 2 of the OSI model to give the Ethernet card access to the media without higher levels or layers of software.

DHCP Administration Using the DHCP Manager

Historically, the way a DHCP server is configured is similar to the traditional method of managing systems, through Command Line Interface (CLI) utilities. While these utilities will continue to be supported in future releases, Sun has raised the bar by making the DHCP environment even easier to manage.

The DHCP server in the Solaris 8 Operating Environment comes with a series of wizard applications that enables the DHCP server to be easily configured by answering a simple set of questions. Once these questions have been answered, the data is stored in the traditional configuration files. This provides a system manager with the best of both worlds.

For example, if the administrator would like to continue to use the CLI commands, or has developed special scripts to manage the environment for the specific needs of the organization, these tools will still work. If the administrator is looking for an easier and more intuitive interface, the Sun DHCP Manager software includes the wizards and GUI-based tools to make the environment easy to manage.

Figure 1 shows the DHCP Manager using a wizard-type interface to add a new entry into the range of addresses that the DHCP server can issue. The instructions on the left part of the screen guide the user through the process. The point-and-click interface makes it very easy for the administrator to enter and display all of the data.

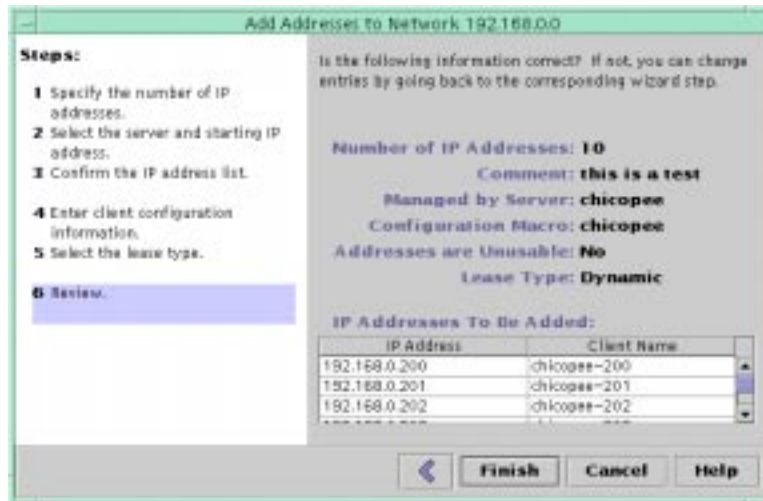


FIGURE 1 Adding a new entry to the range of addresses using a wizard.

In the previous section, *DHCP Implementation in the Solaris 8 Operating Environment*, there is a description of how macros can be used to help manage complex DHCP environments. Figure 2 shows how the DHCP Manager simplifies the process of maintaining macros and the associated data using a GUI interface to display and update data for the *mktsterv* macro. Whenever this macro is passed to the DHCP server, all of the associated option names and option values are returned to the client. The contents section of the screen can be used to add, delete, or change any of the data stored within the macro.



FIGURE 2 Macro information is displayed/updated through an easy-to-use interface.

The DHCP Manager is used to manage a range of client addresses and names in Figure 3. Notice that a single manager session can be used to manage the database for multiple boot servers. In this example, clients of both *chicopee* and *mktserve* are being managed concurrently. While an address is actively in use, the DHCP Manager tracks the current lease expiration and MAC address of the system using the address. The manager also tracks the macros currently associated with each client.

The screenshot shows the DHCP Manager application window. It has a menu bar with 'File', 'Edit', 'View', 'Service', and 'Help'. Below the menu bar are three tabs: 'Addresses', 'Macros', and 'Options'. The 'Addresses' tab is active, displaying a table with the following columns: 'Addresses', 'Client Name', 'Status', 'Expires', 'Server', 'Macros', 'Client ID', and 'Comments'. The table contains 28 rows of data, with the first row highlighted in blue. The first row shows the address '192.168.0.0' for client 'chicopee-2' with a status of 'Dynamic' and an expiration time of '1/13/00 1:18 PM'. The second row shows the address '10.0.0.0' for client 'chicopee-4' with a status of 'Unusable' and an expiration time of '1/13/00 1:11 PM'. The remaining rows show clients 'chicopee-3' through 'chicopee-28' with various statuses and expiration times. The 'Server' column contains 'chicopee' and 'mktserve'. The 'Macros' column contains 'chico...' and 'mkt...'. The 'Client ID' column contains hexadecimal strings. The 'Comments' column is empty for all rows. At the bottom of the window, it says '106 addresses loaded' and has 'Find' and 'Next' buttons.

Addresses	Client Name	Status	Expires	Server	Macros	Client ID	Comments
192.168.0.0	chicopee-2	Dynamic	1/13/00 1:18 PM	chicopee	chico...	0100105480F0002025E...	
10.0.0.0	chicopee-4	Unusable	1/13/00 1:11 PM	chico...	chi...	0100105480F0002025E...	
	chicopee-3	Dynamic	1/10/00 10:25 PM	chicopee	chico...	010050048330A02	
	chicopee-50	Dynamic		chicopee	chico...	00	
	chicopee-106	Dynamic		mktserve	chico...	00	
	chicopee-96	Dynamic		chicopee	chico...	00	
	chicopee-107	Dynamic		mktserve	chico...	00	
	chicopee-6	Bootp		chicopee	chico...	00	
	chicopee-10	Dynamic		chicopee	chico...	00	
	chicopee-11	Dynamic		mktserve	chico...	00	
	chicopee-12	Dynamic		mktserve	chico...	00	
	chicopee-13	Dynamic		mktserve	chico...	00	
	chicopee-14	Dynamic		mktserve	chico...	00	
	chicopee-15	Dynamic		mktserve	chico...	00	
	chicopee-16	Dynamic		mktserve	chico...	00	
	chicopee-17	Dynamic		mktserve	chico...	00	
	chicopee-18	Dynamic		mktserve	chico...	00	
	chicopee-19	Dynamic		mktserve	chico...	00	
	chicopee-20	Dynamic		mktserve	chico...	00	
	chicopee-21	Dynamic		chicopee	chico...	00	
	chicopee-22	Dynamic		chicopee	chico...	00	
	chicopee-23	Dynamic		chicopee	chico...	00	
	chicopee-24	Dynamic		chicopee	chico...	00	
	chicopee-25	Dynamic		chicopee	chico...	00	
	chicopee-26	Dynamic		chicopee	chico...	00	
	chicopee-27	Dynamic		chicopee	chico...	00	
	chicopee-28	Dynamic		chicopee	chico...	00	

FIGURE 3 Network addresses and related information are easily reviewed and updated through a graphical interface.

By using the DHCP Manager wizard applications and GUI-based interfaces, organizations can reduce the complexity of installing the DHCP server environment and lower the cost of managing the network environment.

DHCP Directions

Sun continues to invest in DHCP and over time, plans to include these investments as further enhancements to the product set. This section describes some areas where Sun is currently focusing engineering efforts.

IETF Activities

The IETF is continually looking for ways to improve DHCP software. As these improvements are standardized through future RFCs, Sun will evaluate the functionality of all improvements for potential inclusion in future product releases. Sun is an active member of the IETF development in the DHCP working group, and is helping to define new features of the protocol that will benefit Sun's customers.

Enterprise DHCP Service

Future versions of Sun's DHCP software may continue to be scaled up to larger computing environments. Enhancements might include a single DHCP server that could support a customer's entire enterprise-wide organizational needs.

One of the best ways to increase the performance of server applications is to improve the multithreading capability of the software. Multithreading allows a computing system to execute multiple copies of the application in an asynchronous fashion. In a traditional single-threaded application, each client must wait in line for any previous requests to be fully satisfied before the server starts on the next client's request. When there are multiple processors and the application has shared resources that need to be controlled by the application, a single-threaded task can only run on a single processor, negating the advantage of multiprocessor servers.

When a server application has been written to support *hot* multithreading, each client request is spawned off into another thread-based set of instructions that can potentially be run in parallel on another processor. This capability can dramatically increase the scalability of a single server system to concurrently handle a significant number of clients.

A new, dynamic object interface has been defined that allows support for new data storage services to be added, including support for Oracle, Sybase, and other database packages, without changing the DHCP service itself. Shared objects which export this public interface are known as *public modules*. If a new public module is added, and the DHCP service will locate it and offer it as a data storage alternative. Since the API is public, third parties are encouraged to write their own modules.

Public modules written for such enterprise databases as Oracle and Sybase will offer customers considerable flexibility regarding where they store their DHCP data. Some choices, such as databases, will offer higher capacity and potentially faster performance. Customers have a choice of which module meets the particular needs for their site. Since the public module interface must be MT-safe, the DHCP server will realize higher performance through the use of a threading model. The DHCP Manager will be updated so that transferring DHCP data from one public module-supported service to another will be an easy task.

Future versions of the DHCP server may include additional multithreading support, allowing the server to manage a much larger community of clients. Potentially, a single server will be able to handle the DHCP requirements of an enterprise consisting of many thousands of clients.

Name Service Integration

In the current DHCP environment, the DHCP server issues the IP addresses, while a separate name server stores the names associated with the network addresses. DHCP assigns Internet addresses from a pool, often placing a client in a specific subnet. However, the actual address assigned to a node may appear to be random in nature. The name of a client system in the name server is tied to the Internet address, but the DHCP server and the name server do not currently coordinate between the name of a node and its address. Therefore, the names that are issued to client systems appear random as well. If the client suggests a name, the suggestion is ignored.

In a soon-to-be-released update to DHCP software, when a client requests a name, the DHCP server will communicate with the name server in an attempt to ensure that the requested client system name is issued to the client. The name server will check to see if the requested name is currently in use. If the name is available, the name server will associate the actual address issued to the client with the requested name. If the name is not available, the DHCP server will create a similar unused name and will issue it to the client. Whatever name is actually issued to the client system will be communicated back to the client, so that the system name and the name server name are identical.

The name services that will likely be supported include DNS, NIS+, LDAP, and file-based name resolution.

DHCP for IPv6

One attribute that has made DHCP popular with customers is that it enables an organization to more carefully manage usage of limited IP addresses. Such limitation is typically felt by customers who are using Internet Protocol version 4 (IPv4).

In the near future, customers will begin using the Internet Protocol version 6 (IPv6), where a 128-bit addressing scheme should provide ample addresses for future requirements. While this may seem to reduce the need for DHCP, the requirement for dynamic configuration information during software installation and system boot will continue long after IPv6 is in general use.

A future release of the Sun DHCP environment may include support for communication over the IPv6 protocol. This will allow DHCP to provide concurrent boot capabilities for both IPv4 and IPv6 clients.

Conclusion

The Dynamic Host Configuration Protocol enables an organization to better control its computing environment. In particular DHCP can be used to manage IP addresses in an environment where these addresses are in short supply. When there are enough addresses, DHCP also can be used to move the assignment of TCP/IP configuration information away from the client systems and onto the server, where it may be centrally managed.

DHCP can be used to configure more than just TCP/IP information. It may be used to store virtually any type of configuration data, including information used during the installation of software or for storing system-specific parameters for diskless nodes. All of these uses move the management burden and cost for a distributed environment away from the client systems (where the cost of ownership is typically most expensive) to the more cost-effective control of centralized servers and their system administrators.

The Solaris 8 Operating Environment includes many enhancements to earlier releases of DHCP software from Sun. Management of the DHCP environment has been made simpler through the use of an improved GUI interface and management wizards. Through these new tools, customers can use DHCP to enable remote installation of software using standards-based tools, as well as continue to use in-house developed scripts or macros. These improvements have made Sun's DHCP server state of the art in the industry. Customers thinking of implementing DHCP in their organizations should plan to use the Solaris 8 Operating Environment as the platform for their DHCP environment.

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