Dynamic Host Configuration Protocol

A Technical White Paper

Contents

Chapter 1

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 become dominant within most organizations because it enables them 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 IP[1] 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).

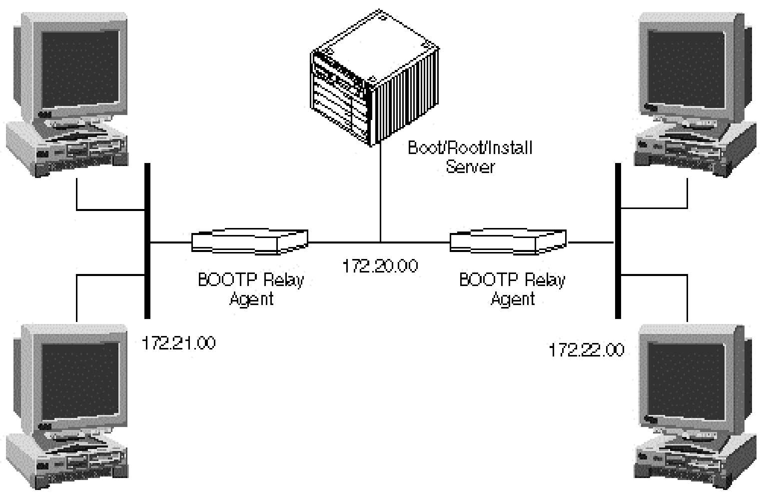
What Is DHCP?

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 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 1-1: depicts a typical DHCP environment.

Figure 1-1: 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 may 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, and so on) are not particularly well-suited to DHCP client usage, because changing addresses makes it difficult to find these systems and complicates 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 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 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 it. Sun is working with other vendors to ensure that DHCP continues to be a standard supported by a large number of companies.

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, and so on) 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, 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 users are online at any given time. Here, DHCP is used to issue the IP address to a client machine at 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 them 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 ideal 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 process of needs definition. DHCP helps reduce this problem in two ways:

First, DHCP can be used to manage the limited number of standard, routable IP addresses 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 expires), the address is put back in a pool so it is available for the next client.

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.*.*.*`[1]

The client uses 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 forwards the packet back to the client. DHCP enables this procedure without taking up valuable routable addresses, and makes certain that all clients use consistent parameters such as subnet masks, routers, and DNS servers.

1. 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.

Chapter 2

Sun's Implementation of DHCP

Sun Microsystems began shipping DHCP in 1994 as part of its Solstice™ PC-Admin product, and integrated it into the Solaris™ 2.6 Operating Environment (OE). In the latest release of the Solaris 9 OE, Sun has significantly improved the functionality of DHCP software, making it one of the best in the industry.

DHCP Implementation in the Solaris™ Operating Environment

The Solaris 9 OE 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 OE 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 locale-specific information (such as the 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 allows scaling up to the size of a network that consists 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.

Ease of Administration

The Solaris OE includes a DHCP Manager GUI that utilizes several wizards and visual tools that make the DHCP environment much easier to manage. More details on Solaris OE DHCP administration is covered in the "DHCP Administration using the DHCP Manager" chapter of this paper.

DHCP and Solaris OE Installation

The Solaris 9 OE network installation supports the use of DHCP to deliver configuration and installation parameters for the installation process. Unlike the traditional Sun RARP/RPC Bootparams configuration model, DHCP configuration frees administrators from the requirement of having a Solaris OE boot server on every network. Note that the selection of a configuration protocol is an either/or selection; no combination of the protocols is possible.

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 that 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. While Sun cannot warrant the specific implementations of other vendors, the Sun DHCP generally interoperates well with other versions.

The DHCP server shipping with the last few versions of the Solaris OE 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 OE as a management system. Sun has made major improvements in the Solaris 9 Operating Environment release, including:

- The details of the data storage mechanism used by the Solaris OE DHCP server have been exported as a public API, permitting third parties to provide modules that export this API, thus increasing the flexibility offered to administrators. ASCII and NIS+ modules are provided which implement the traditional data storage options offered by previous releases of Solaris. In addition, a new binary format module is provided which offers increased performance. Oracle and LDAP modules are planned to be available soon.
- The performance of the DHCP server has been increased.
- The DHCP server can be optionally configured to act as a DNS update proxy, interacting with any DNS service that implements IETF RFC 2136.
- The DHCP manager GUI has been updated to quickly and easily manage the conversion of DHCP data from one data storage service to another.
- The DHCP manager GUI now includes a method of exporting and importing DHCP service configurations, facilitating backup of configuration data and transfer of service from one server to another.
- The DHCP client can be optionally configured to request a desired hostname for each network interface it is asked to configure.

Chapter 3

Client Implementation

DHCP can be used to provide parameters above and beyond those required for network communication, such as those needed for remote installation of the Solaris OE 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 must 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 OE 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 turn 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 to increase management and security through the central storage of application programs and user data.

In highly secure environments, such as classified government installations, 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)[1] 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 (for example, 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 may be targeted to a specific node. The macros can contain either 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 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 local storage.

Requesting Hostnames

The Solaris OE DHCP client may be optionally configured to request that a desired hostname be registered in the DNS by a DHCP server on its behalf.

1. he MAC address is uf the OSI model to give the Ethernet card access to the media without higher levels or layers of software.

Chapter 4

Server Implementation

The Solaris OE DHCP server application supports *hot* multithreading, with each client transaction handled by a separate thread. This enables the server to concurrently handle hundreds of clients per second, depending on the *public module* in use.

The DHCP service encapsulates data storage access into a defined, public API. This architecture provides a public interface that allows support for new data storage services to be added, such as Oracle, Sybase, and other database packages, without requiring a revision of the DHCP service. The shared objects that export this public interface are public modules. If a new public module is added, and the DHCP service will automatically locate it and offer it as a data storage alternative. Since the API is public, third parties are encouraged to write their own modules.

The Solaris Operating Environment currently provides three public modules that enable the storage of DHCP data in ASCII files in a file system, binary files in a file system, or tables in NIS+. Soon, Sun will offer two additional public modules, which will enable the administrator to store DHCP data in an Oracle database or LDAP directory.

Public modules offer customers considerable flexibility regarding where they store DHCP data. Some choices, such as databases, also offer higher capacity and potentially faster performance. Customers have a choice of which module meets their particular needs. The DHCP Manager includes a wizard for transferring DHCP data from one public module- supported service to another quickly and easily.

DNS update proxy

The Solaris DHCP server can be optionally configured to register the hostnames suggested by DHCP clients and the IP addresses it assigns in any IETF RFC 2136-compliant DNS service.

Chapter 5

DHCP Administration Using the DHCP Manager

The DHCP server in the Solaris 9 OE comes with a series of wizard applications that enables the DHCP server to be easily configured by answering a simple set of questions. Once the questions are answered, the data is stored in the traditional configuration files.

Figure 5-2: Adding a new entry to the range of addresses using a wizard.

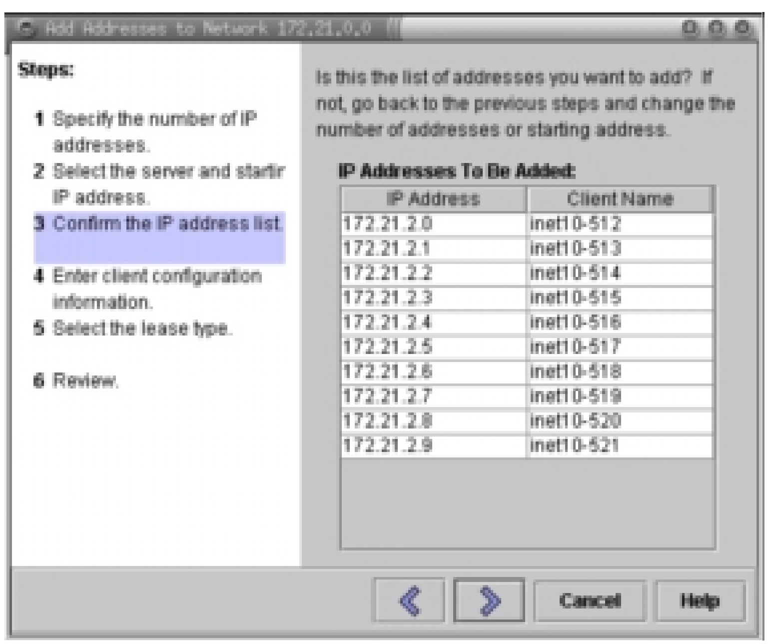


Figure 5-2: shows the DHCP Manager using a wizard-type interface to add a new entry into the range of addresses that the DHCP server can issue. The instructions on the left part of the screen guide the user through the process. The point-and-click interface makes it easy for the administrator to enter and display all of the data.

The previous section, "DHCP Implementation in the Solaris Operating Environment," included a description of how macros can be used to help manage complex DHCP environments. Figure 5-3: shows how the DHCP Manager simplifies the process of maintaining macros and the associated data by using a GUI interface to display and update data for the *mktserv* 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 the data stored within the macro.

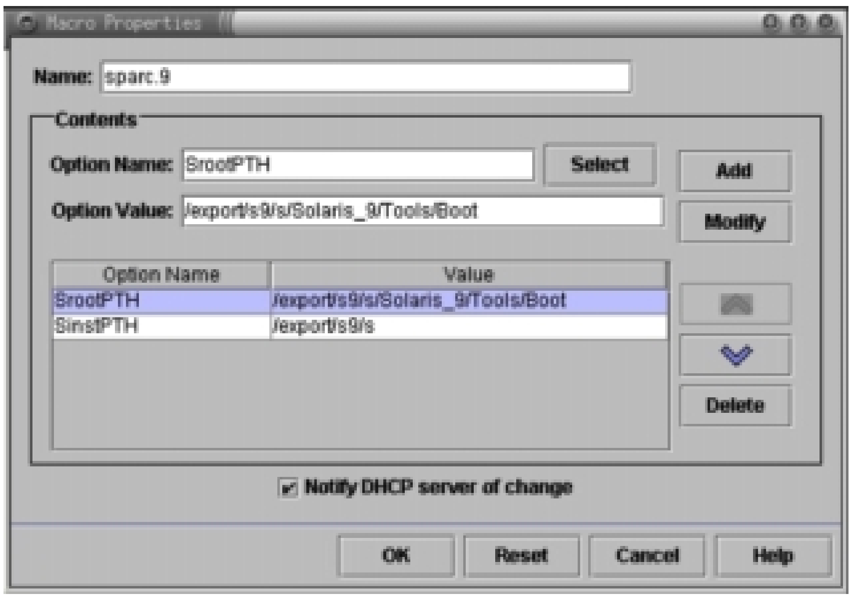


Figure 5-3: Macro information is displayed/updated through an easy-to-use interface

The DHCP Manager is used to manage a range of client addresses and names in Figure 5-4:. Note that a single manager session may be used to manage the database for multiple boot servers. In this example, clients of both *chicopee* and *mktserv* 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.

Figure 5-4: Network addresses and related information are easily reviewed and updated through a GUI.

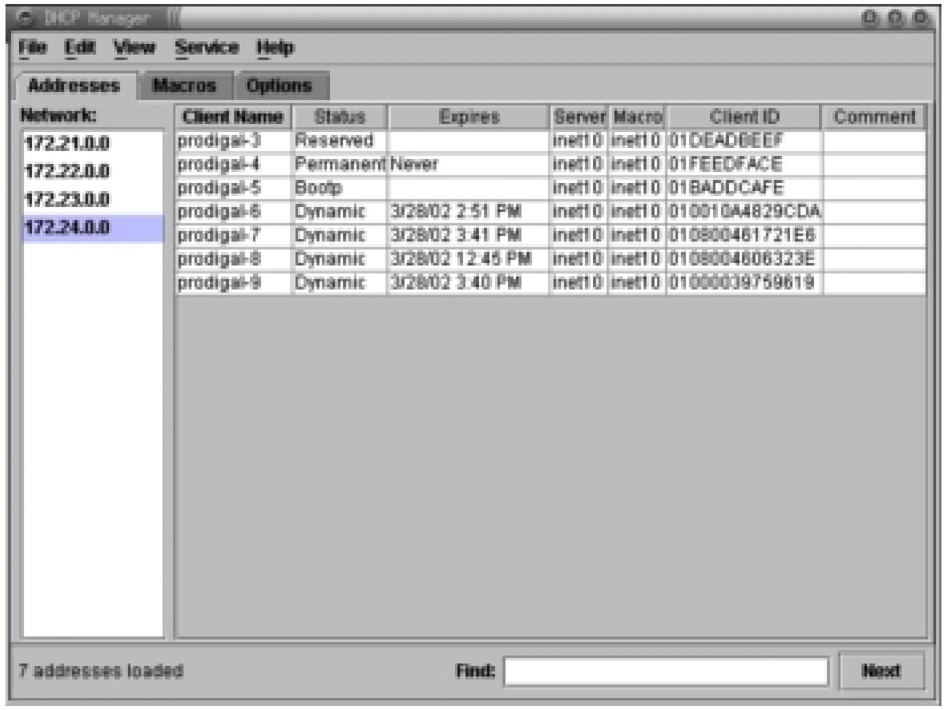


Figure 5-5: Review screen of export data dialog.

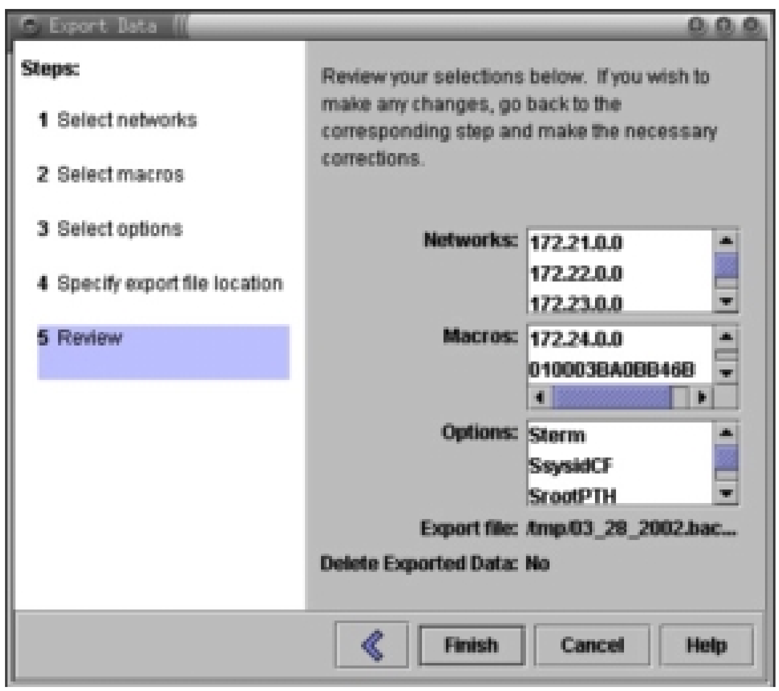


Figure 5-5: illustrates how the DHCP Manager can be used to export some or all of the DHCP service configuration to an archive file. This archive may serve as a backup of the DHCP service configuration. It can also be used to dump and copy a DHCP service configuration from one Solaris machine to another. The DHCP manager's import wizard can then be used to load the saved file.

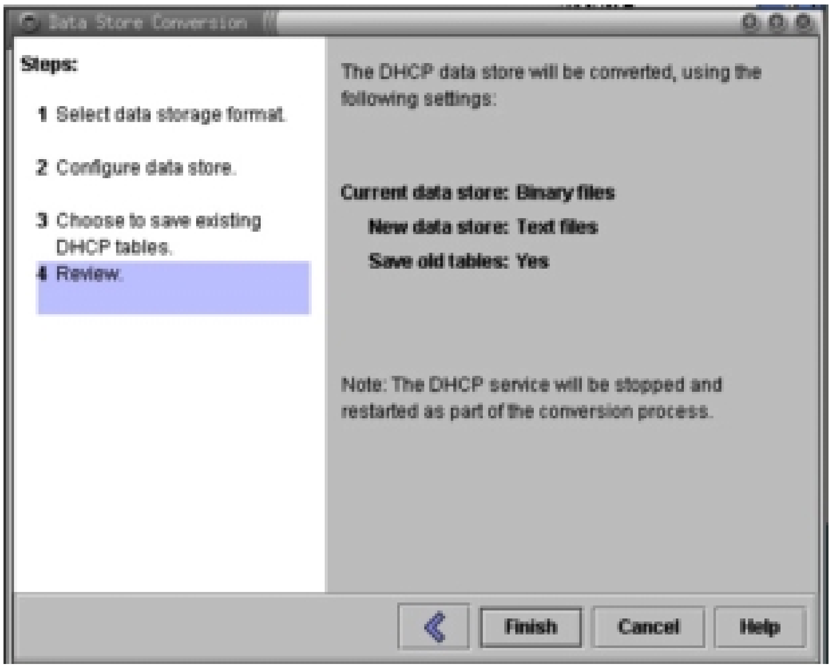


Figure 5-6: Data Store Conversion Wizard review screen.

The choice of data service for storing DHCP data is now encapsulated within a loadable public module that provides the interface between the DHCP service and the underlying data service. Public modules can be supplied separately from the DHCP service, so additional data service support is available to the DHCP service when new modules are installed. The Solaris 9 OE ships with public modules for ASCII files, binary files (high performance), and NIS+ tables. A public module for utilizing Oracle software and another for LDAP should be available shortly. Figure 5-6: shows the review screen of the conversion wizard.

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.

Chapter 6

DHCP Directions

Sun continues to invest in DHCP and over time, plans to offer further enhancements to the product set. This section describes the areas where Sun is currently focusing its 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.

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. This limitation is typically felt by customers 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.

Chapter 7

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 also be used to store virtually any type of configuration data, including information required during the installation of software or 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 9 Operating Environment includes many enhancements to earlier releases of DHCP software. Management of the DHCP environment has been enhanced 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 scripts or macros developed in-house. Customers thinking of implementing DHCP in their organizations should plan to use the Solaris 9 Operating Environment as the platform for their DHCP environments.

Chapter 8

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