Network Services

Part V

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CHAPTER 17

Internet Printing Protocol (IPP)

by Tim Parker

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The *Internet Printing Protocol* (IPP) is a new development in the TCP/IP suite of protocols. It is intended to make printing over a network or a larger internetwork much easier, based on IP addresses. Companies such as Hewlett-Packard have already introduced some devices that support the proposed IPP standards, and more are expected to arrive as IPP works toward a standard.

This chapter explains what IPP is and how it works. Although you may not have much need for IPP if you have a printer attached to your computer, it does show how network-based printing can be used.

History of IPP

IPP is the latest name attached to a series of developments, some competitive, that started in 1996 with Novell (makers of NetWare) approaching several printer companies to develop a new protocol for printing that would work over the Internet and IP. Several companies, such as Xerox, joined with Novell and developed a draft proposal and a development plan. Under Novell's stewardship, the project was called *Lightweight Document Printing Application*, or LDPA.

IBM, in the meantime, was working on a similar protocol that it called *HyperText Printing Protocol*, or HTPP. HTPP was so-named because it worked over the Web similarly to HTTP. Yet another similar effort was underway between Hewlett-Packard and Microsoft, who were developing a new print protocol for use with Windows 2000. To resolve the competing proposals and work under the Internet Engineering Task Force, the body that controls all protocols over the Internet, a *Printer Working Group* (PWG) was established. The PWG was made up of several printer and operating system companies. By pooling the best features of LDPA and HTPP together, the Internet Printing Protocol was developed.

The goal of the PWG is to form a universal standard for printing. The standard is not limited to using IP but could work under other protocols. The primary aim, though, is support for printing and print services over the Internet using IP. IPP uses HTPP as an adjunct to the next version of HTTP, called HTTP 1.1, instead of developing a completely separate protocol that sits on top of IPP. This leverages the features of HTTP 1.1 and makes implementation easier for vendors because most already are very familiar with HTTP. A new Multipurpose Internet Mail Extension (MIME) type called "application/ipp" is used for IPP.

Several targets exist for the Printer Working Group to include in the IPP specification. Tasks that IPP should support include:

- Allowing a user to determine what an IPP-based printer is capable of doing
- Allowing a user to submit a print job to an IPP printer
- Allowing a user to query the printer for the status of a print job
- Providing a facility for the user to cancel a queued print job

These four user-oriented goals cover everything a user would want to do, from determining which printers are available to sending, managing, and canceling print requests over the Internet, a LAN, or a WAN. Also part of the protocol is the ability to rapidly find accessible printers on a network or internetwork, and provide good security for the print requests and printers themselves.

Ideally, the goal of IPP is to create a client-side protocol. The server-side can be implemented in a number of ways, from a dedicated print server or from an IP-connected printer, for example. However, no change is planned to the underlying print spoolers and systems currently used, such as lpr and lpd under UNIX, or Windows' print handling system. IPP adds to these existing capabilities.

Longer-term goals for IPP are to include the ability to manage printers using IPP, provide print accounting systems, and even add commercial transaction capabilities.

Another goal of IPP is the translation of the LPR (Line PRinter) protocol onto IPP, and the translation of the IPP protocol onto LPR. However, there is no expectation to provide new IPP features to LPR clients, nor is there an explicit requirement to translate LPR extensions to IPP, beyond those features available in the 4.2BSD UNIX implementation of LPR.

Note

A number of RFCs are available with more details about IPP, all accessible from any RFC repository. See Appendix A, "RFCs and Standards," for more information about RFCs. In addition, the PWG has a Web site that includes current status and background information about IPP. The Web site can be found at `http://www.ietf.org/html.charters/ipp-charter.html`.

IPP and the End User

When IPP is widely deployed, users will find a whole new world of capabilities for printing. The IPP RFC breaks down the abilities you gain into six categories:

- Finding a printer
- Creating a local instance of the printer
- Viewing the printer status and capabilities
- Submitting a print job
- Viewing print status
- Altering the print job

With IPP you can find all accessible printers using your Web browser or another application that searches for IPP-capable printers. The IPP design goal is to allow you to find a printer by a number of methods, including searching by the printer's name, by a geographic location, or by attribute.

Searching for attributes will be useful in large organizations. For example, you may want to be able to print folio-size pages (11×17 inches) and with IPP you could search for an accessible printer with this capability. You could also search for printers supporting color, legal-sized page feeds, binding abilities, and any other supported attribute. With a little search refinement, you can search for any printer that meets a number of additional criteria, such as within walking distance of your office or within a particular domain (even across the country or continent). This type of search capability is not part of IPP, but it is an inevitable spin-off.

When you find the printer you want to send a print request to, you need to be able to let your local computer know about the printer and how to access it. This is known as creating a *local instance* of the printer. To some extent, the way this is done depends on the operating system, but the overall effect is to add the printer you've chosen to the list of available printers on your machine.

In some cases, you may need to download drivers for the printer. This is currently the case when you need to access a printer across a network under Windows 95/98/ME, for example, and the process using IPP will be the same. Under some operating systems, such as UNIX, Linux, and Windows NT/2000, a little more flexibility is built-in to the creation of a local instance. You may decide that you want the queue for the printer on a different machine than your own, or you may want to have the drivers and queue reside on your machine. IPP allows enough flexibility to meet all these requirements for setting up an instance of a printer.

After you have created a local instance of a printer, it will appear as though that printer is attached to your machine. With Windows, for example, the printer (regardless of how far away it is) will appear in the Printers control panel applet, on all print dialog boxes, and any other application that accesses the printer list. You will use it exactly like you would a printer connected by a parallel cable.

Before you use an IPP-enabled printer, you may want to verify its setup or configuration and find out how busy the printer is, what kind of paper is loaded, how much memory the printer has, whether it supports a particular page descriptor language (such as PostScript or PCL), and many other status issues. IPP provides for a mechanism to relay all this status and capability information back to the user. General status messages show whether the printer is online or off, and what the default settings for the printer are.

The way the status messages are shown on the screen, and how you interact with an application to query the printer, is not defined as part of the IPP specifications. Instead, IPP handles the passing of the messages and the type of content that is possible. However, with a properly executed client application, a user should be able to determine the current status of a printer anywhere in the world that they have access to, as well as the status of the print queue.

When you have created a local instance of a printer, you are going to want to send print requests to it. The primary advantage of IPP is that you can print to any printer that has a local instance just as you would a physically connected printer. Windows applications, for example, would all recognize the IPP-capable printers in their printer dialog, whether the printer is remote or not. Some aspects of printing to a remote printer are not handled by IPP, such as selecting the proper page descriptor language interpreter (usually handled by the printer automatically) and choosing the right printer driver (usually handled by the operating system).

After a print job has been queued, IPP allows you to obtain status messages from the printer or print server that show the current queue and allow you to remove items from the queue.

Using HP's Implementation of IPP

Hewlett-Packard has already made a version of IPP available to its printer customers through its Internet Printer Connection software. Internet Printer Connection is designed to allow users to configure and print to HP (and other so-equipped) printers over the Internet or an intranet (LAN or WAN). Internet Printer Connection implements IPP as a transport for data to be printed and for printer status messages. Internet Printer Connection is an upgrade to existing software, so it is easy to add to established LANs.

In order to use HP's Internet Printer Connection, you need to have a Windows NT machine as the management host and an IPP-enabled HP JetDirect print server. A Web browser is required for users. Not all JetDirect print servers work with Internet Printer Connection; only firmware versions X.07.16 or later work. Fortunately, firmware upgrades to the JetDirect print server are available from the HP Web site. Installation of Internet Printer Connection is simple: Run a downloaded file to install the software, and reconfigure the printers that are to be used through Internet Printer Connection.

When installed, Internet Printer Connection allows any user with proper rights to print to any IPP-enabled printer by using the printer's IP address, a hostname (if DNS is enabled for hostname lookups), or the printer's URL. The beauty of Internet Printer Connection is that you can access a printer anywhere in the world, assuming you have rights to do so. If you're in a hotel room in Germany, for example, you can queue a print request to a printer in your home office in San Francisco. The same applies to east coast and west coast offices sharing print requests with each other. The Internet takes care of routing the print jobs using IPP. As far as a user is concerned, the printer looks exactly like any other printer attached to the machine or network.

Summary

IPP is not widely deployed across the Internet. However, the progress that has been made and the development of implementations such as Hewlett-Packard's Internet Printer Connection all bode well for IPP. IPP promises to become part of the standard TCP/IP services and make remote printing much easier on a TCP/IP network.

CHAPTER 18

LDAP: Directory Services

by Mark Kadrich

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- What Are Directory Services? *442*
- Directory Services Over IP *443*
- The OSI X.500 Directory Model *446*
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The *Lightweight Directory Access Protocol* (LDAP) is an extremely powerful and robust protocol, and can be very complex in its implementation. A complete LDAP coverage can consume literally hundreds of pages. This chapter covers the salient points while trying to give an overview of the power and utility of LDAP.

Why Directory Services?

If you've been in the networking field for a while, you may have collected quite a wealth of information about different topics. The problem usually is not collecting this information, but rather organizing it and doing something useful with it when you need it. Like memos and other bits of paper, files tend to collect on your computer. To keep track of this information, you have probably created directories on your computer that represent bins of knowledge. You might have one for purchasing, one for manufacturing information, and another one for defects. Each bin represents a vertical line of knowledge pertaining to your discipline or career. This information is valuable to you because of what it represents: the collection of knowledge you have on a topic. However, the information you have is just part of a larger set of information.

With the proliferation of internetworking and the resulting explosion in information availability, collecting information has become a daily routine. You can collect information on whatever your discipline happens to be. New services offered by the Internet make searching for things easier than ever before. Search engines have made the chore of finding information about anything a point-and-click proposition. But now that you've found this information, how do you manage it? The answer is directory services.

What Are Directory Services?

You have used directory services before, although you might not have known it at the time. The phone book and the *TV Guide* are excellent examples of printed directories. In the case of the phone book, it's names, addresses, and phone numbers. In the case of *TV Guide*, it's times, names, descriptions, duration, subject, and content rating. You can even use the *TV Guide* to program your VCR. If you have a VCR equipped with VCR+, you can enter a directory number and the VCR will automatically program itself to record your selected program. This makes using the VCR and accessing the broadcast programming much easier to manage.

Like VCR+, LDAP offers a way to make locating things on the network significantly easier than other protocols, such as the Domain Name System (DNS). Unlike DNS, which just makes locating computers easier, LDAP allows you to keep information you find in a directory. LDAP directories contain information about users and their computers. Unlike the phone book and the *TV Guide*, LDAP directories are dynamic. The information they contain can be updated as necessary. LDAP directories are also distributed, which means they are less susceptible to failures.

Directory Services over IP

A number of other directory services run over the Internet Protocol (IP). IP is a system that uses numbers (actually, IP addresses) to identify computers and networks on the Internet. It is similar in function to identifying a room in a single apartment in an apartment complex. There is the building number, which is analogous to a network number; the apartment number, which is equivalent to the subnet number; and the room number, which can be thought of as the host number. For example, instead of saying 1234 Deep Creek Street, Apartment 128, you can use a name like John Smith to send your message.

If you've ever used a Web browser, you've used DNS. DNS functions in a manner similar to LDAP in that the client makes a request of the server and the server processes the request and returns an answer.

Figure 18.1 and Table 18.1 depict how IP addresses map to the DNS in a local lookup.

FIGURE 18.1
Local DNS lookup process.

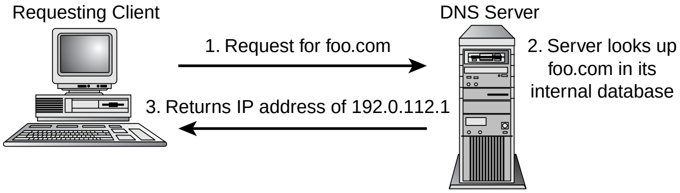
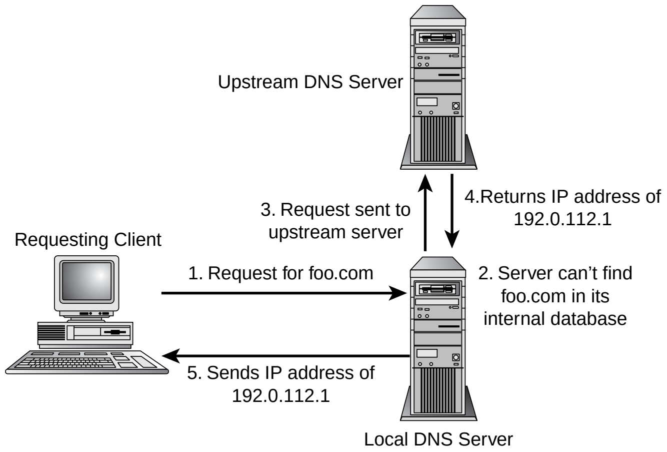


TABLE 18.1 Sample DNS Table Relating Hostnames to IP Addresses

Hostname	*IP Address*
`foo.com`	IN A 192.0.112.1
`foo`	IN A 192.0.112.1

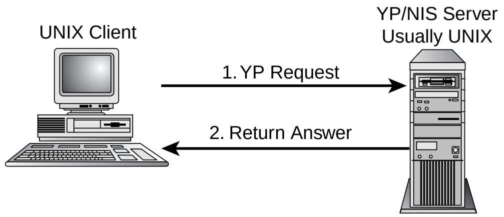
If a local server does not have the address, it will make a request of an upstream server, traversing an inverted tree very similar in structure to the one used by LDAP. This can be seen in Figure 18.2.

FIGURE 18.2
DNS lookup sent to upstream server.



Whois, finger, YP, NIS, NIS+, and DAP are also directory services that run over IP. You might remember the Yellow Pages, now commonly referred to as the *Network Information Service* (NIS). NIS is a service that identifies users, hosts, and in the case of NIS+, other information deemed pertinent by the system administrator. NIS is a service that enables administrators responsible for a large LAN or WAN to centralize user information. As shown in Figure 18.3, as a user logs in, a request is sent from the user's host to the YP server. This request would contain the user's information, such as UID (User Identifier, a number used to represent users internally under UNIX) and password, and host information. The YP server would send the resulting information back to the user's host, telling it to either permit or deny access to that host.

FIGURE 18.3
Yellow Pages, or Network Information Services, in a UNIX environment.



Administrators like this service because it leverages the network itself. Secondary NIS servers can be set up across the network, ensuring reliability and reducing latency delays. It became a standard operating procedure to set up local NIS servers in order to reduce downtime incurred because of outages and high traffic loads.

Master NIS servers "push" tables of user information out to the secondary servers at predefined intervals. This usually happens during the early hours of the day along with network backups and system updates.

Occasionally, a change needs to be made immediately to a user's profile. On those special occasions when a disgruntled employee is escorted out the door, system administrators require a method of immediately removing that user's access. Sometimes new users, such as contractors, need to have access granted so they can start working. Contractors usually get paid by the hour, so getting them up and running as soon as possible was seen as a positive economic move. For these reasons, and other reasons, NIS also allows for the manual updating of secondary servers. System administrators can make a change and use a manual push to update specific network servers.

Note

A manual push is just as dangerous as it is useful. On more than one occasion a harried system administrator has "fat fingered" the command and inadvertently removed access for a major portion of the user community. This may be an unexpected way to test the robust nature of your PBX and voicemail system!

Whois is a text-based directory that stores information about hosts, servers, IP addresses, and networks. A whois query will reveal a considerable amount of information. Things such as the names of contacts, billing addresses, phone numbers, and domain servers are usually stored in the whois database. Our test of the Macmillan whois generated the following entry:

```
Registrant:Macmillan Magazine Limited (MACMILLAN-DOM)
4-6 Crinan Street London EnglandN1 9XW
UK Domain Name: MACMILLAN.COM
Administrative Contact, Technical Contact, Zone Contact: Humphreys,
➥   Mark (MH177)
postmaster@MACMILLAN.COM +44 71 836 6633
Billing Contact: Humphreys, Mark (MH177)
➥   postmaster@MACMILLAN.COM +44 71 836 6633
Record last updated on 05-Aug-98.
Record created on 11-Aug-94.
Database last updated on 11-Jul-99 19:39:33 EDT.
Domain servers in listed order:
NS0-M.DNS.PIPEX.NET 158.43.129.77
NS1-M.DNS.PIPEX.NET 158.43.193.77
AUTH01.NS.UU.NET 198.6.1.81
```

The OSI X.500 Directory Model

LDAP evolved from the OSI X.500 model. In this section, an overview of X.500 and the terminology used to describe Directory services is presented so you can better understand LDAP.

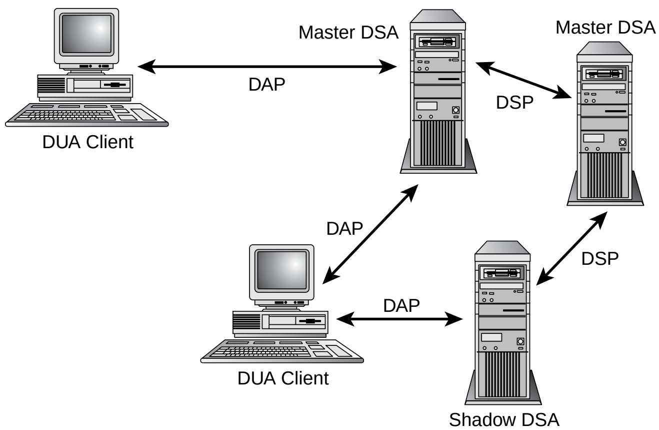
The OSI X.500 standard relies on code that sits on top of the Presentation Layer of the OSI stack to handle parsing and responses. Directly above the Presentation Layer, the *Association Control Service Element* (ACSE) and the *Remote Operation Service Element* (ROSE) enable the lower communication layers to exchange information via the OSI standard *Abstract Syntax Notation* (ASN.1). By standardizing on syntax as to how data is exchanged, ASN.1 provides a method for exchanging information between two disparate computer systems. This in turn enables the X.500 application to exchange information between computers on the network.

ASCE provides for the communication between two Application Layer entities. In the X.500 model, ROSE can facilitate the communication between Directory System Agents and Directory User Agents (see Figure 18.4).

The X.500 directory service model is comprised of three basic units. They are

- Directory Information Base (DIB)
- Directory System Agents (DSA)
- Directory User Agents (DUA)

FIGURE 18.4
X.500-based Directory Access Protocol components.



The information contained within the DIB is managed by DSAs so that DUAs can access and use it. DUAs use the *Directory Access Protocol* (DAP) to access DSAs. In this client/server type of arrangement, DUAs can be either people or other applications, such as an e-mail client. DSAs can communicate with other DSAs via *Directory System Protocols* (DSP) for the same reason that DNS servers communicate with each other. DSAs can be peers in a distributed environment. This provides for the extensibility that is required in today's large-scale networks.

Early X.500

In the 1980s, a group called the *International Telegraph and Telephone Consultative Committee* (CCITT) started an effort to store and retrieve information such as phone numbers and e-mail addresses.

Note

CCITT is now called ITU (International Telecommunications Union). The charter of ITU comes under the United Nations (UN).

At the same time, another group called *International Organization for Standardization* (ISO) started looking for a suitable service to support a name service for its OSI network. Eventually, the two groups realized that there was a duplication of effort and eventually merged their efforts into what is now the X.500 standards.

The result was a directory service that possessed some interesting qualities.

X.500's most important quality is that, as an open standard, it's not subject to the whims of individual vendors. Second, it is a general-purpose directory service capable of supporting a multitude of information. Third, it is extremely extensible and distributed. The X.500 solution was intended to support a wide and evolving network structure from the beginning, and it does that very well. Lastly, it supports a rich set of search capabilities that work within a secure framework. For a diagram of the major components, refer to Figure 18.4.

The X.500 solution was not without its problems. As was discovered early in its deployment, it was a complex solution requiring significant resources and planning. It was also intended for the OSI standard and not the TCP/IP standard used today. OSI never really took off and the speed and simplicity of TCP/IP was a hard combination to beat. It was obvious that some changes needed to be made to DAP.

Note

The initial specification of X.500 ran on OSI protocols and was deemed to be overly complex. As the TCP/IP protocols gradually displaced OSI communication protocols, a need was felt for a simpler version of X.500 that could run on TCP/IP protocols. This need was met by LDAP.

X.500 Today

The X.500 standards have evolved into a group of well-integrated specifications. The core of these was the *Directory Access Protocol* (DAP), which was supposed to be the center of all directory requests. The unfortunate aspect, or fortunate, depending on your perspective, of X.500 evolution was that it tried to solve all the problems at once. So a number of multiple and arcane services were provided by DAP that saw little use in a desktop environment. The full-scale implementation of DAP proved to be quite an ordeal for desktops. To relieve the complexity, an intermediary service was developed. LDAP was that bridge.

The Structure of LDAP

LDAP is intended to be simple. However, there is a strong similarity between X.500 and LDAP. LDAP uses Directory System Agents and Directory User Agents; however, in LDAP they are referred to as simply LDAP servers and clients. LDAP uses the same OSI architecture as well. The LDAP-enabled application sits atop the Presentation Layer and talks to the lower layers via the LDAP *Application Programming Interface* (API).

The basic elements of the LDAP service are

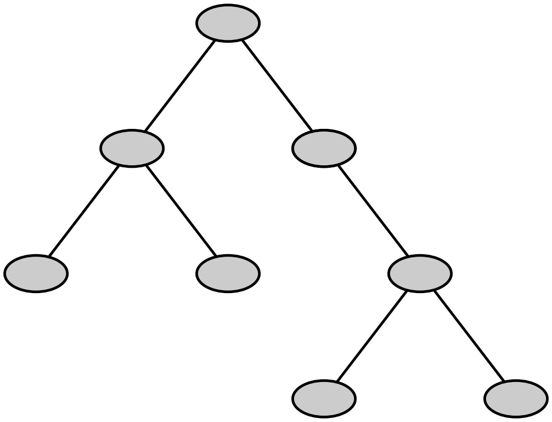
- LDAP server
- LDAP-enabled client

The main difference here is the reliance on an API instead of the stack “shim,” an addition to the IP stack, that connects X.500 and the communications stack. The main similarities are the structure of the network configuration and how the data is stored. Like X.500, LDAP services are hierarchical.

LDAP Hierarchy

The LDAP information structure is similar to that of the file system described earlier. In Figure 18.5, you can see that it starts at the top with a root, usually the organization itself. The basic unit of LDAP information is the *entry*. The entry is a collection of pertinent, real-world information about the object in question, in this case, the organization itself.

FIGURE 18.5
Inverted tree structure of LDAP directories.



In many cases, the directory structure mirrors the structure of the organization. It starts with a description of the organization and resolves down to detailed entries such as departments, resources, and eventually people.

Naming Structures

Within the directory entry is a set of attributes that describes a single trait of the selected object. Each attribute is composed of a type and one or more values. An attribute *type* describes the information contained within the attribute. *Values* are the data entered into the attributes. For example, an attribute is Telephonenumber and a value is 1 800 555 1234.

At the top of the directory structure is the suffix. This is called the *domain component*, or dc.

Object classes provide for the naming of elements in a way that is conducive to effective searches. For example,

```
objectclass=person
```

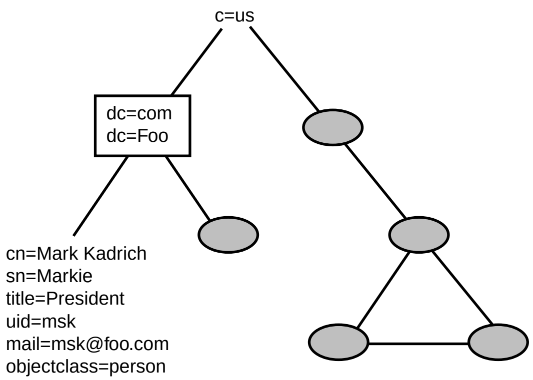
allows for the searching of all object classes defined as persons and not as servers or buildings, thereby making the search less time-consuming.

Following this convention is the attribute cn, for common name. As shown in Figure 18.6, the common name is usually the full name of the individual or resource.

A complete directory listing would start with a distinguished name, or dn, which contains the information about the object class and the individual or resource.

Because LDAP does not support linking from the top of the directory to other directories as DAP does, aliases support this function by making your entire DIT look like a leaf to other DITs.

FIGURE 18.6
Namespace example, Directory Information Tree.



Directory System Agents and Access Protocols

Initially, DSAs were the repositories of directory information. Directory Information Bases resided on DSAs. DSAs were accessed by Directory User Agents residing on client computers. Referring again to Figure 18.4, DUAs use DAP to access DSAs, which contain DIBs. Sounds simple enough, but there is more. DSAs were designed to be distributed. As the DIB grows, it might be necessary to move portions of it to other servers or to link other DSAs together. This is accomplished via a Directory Service Protocol. Unlike DAP, which is intended to support user queries, DSP is used to enable DSAs to exchange information, pass on requests, replicate or shadow directories, and provide for management.

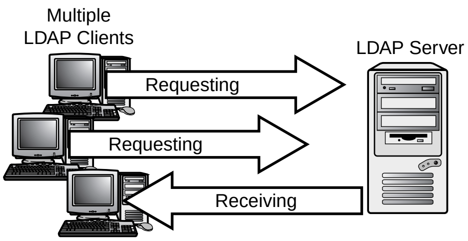
The Lightweight Directory Access Protocol

As previously discussed, LDAP evolved from earlier protocols. These earlier protocols, such as DAP, were developed prior to their deployment. Their complexity was the result of the architect's envisioned need for more information in a variety of formats.

The solutions proved to be too complex for the small desktop systems and too complex for administrators. The solution needed to be made simpler. The business community helped by whittling down the requirements to something that would work on a desktop, yet enable administrators to regain a large portion of configuration control that had been lost in the rush to distributed systems. The final solution was what has evolved into LDAP.

LDAP is a messaging protocol that is based on the client/server model of network computing. A server holds the information and relies on clients on the network to make requests based on their needs. The server formulates a response and sends it back to the client. Figure 18.7 shows how client requests are sent as independent messages to the server.

FIGURE 18.7
Basic LDAP messaging protocol.



Retrieving Information

The ability of users and their applications to retrieve current information creates a powerful and robust platform from which to build.

In the LDAP model, it is assumed that the data will be read many more times than it will be written. For this reason, LDAP is optimized for read access. In a normal LAN, services such as the DNS are high transaction services. In other words, other services depend on the ability of a directory service to answer requests for information.

As mentioned earlier, the LDAP protocol is a client/server–based protocol. This enables the server to be optimized for specific processes—in this case, searching and retrieving information and sending it out on the network. The LDAP server contains the information with little regard to extraneous processes and user interfaces other than those required to manage the data and the server.

The process is started by a client binding to the server and initiating a request for information. Binding is the process that establishes a session between a host and a server. Figure 18.8 demonstrates how the basic process works. The client constructs a request asking for a single entry, for example, a user's phone number, and sends this message to the server. The server responds to the request by sending a message with the requested information and a result code message. The result code message will tell whether the request was successful and, if not, what the error is.

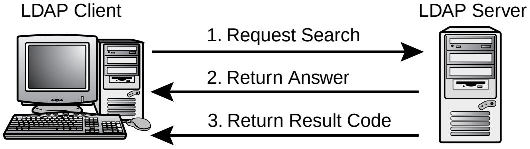


FIGURE 18.8
Basic LDAP protocol sequence.

In the case where multiple messages must be sent to the client to respond properly, the results are sent in multiple messages with the final message being a result code message, as shown in Figure 18.9.

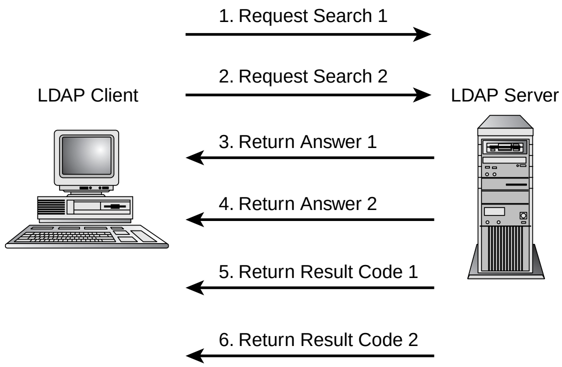


FIGURE 18.9
Multiple message requests via LDAP.

The nature of a message-based protocol is that it allows multiple messages to be sent at one time. The LDAP server will process these individual message requests and respond with individual answer messages and result code messages for each request.

LDAP allows requests to do some basic *interrogation* operations, *authentication* operations, and maintenance or *update* operations.

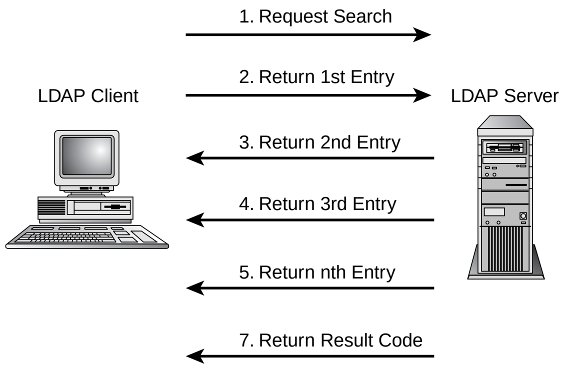
Under the heading of interrogation, LDAP provides *search* and *compare* operations. These operations enable the user to query the database.

Under the heading of authentication and control, LDAP provides for bind, unbind, and abandon. *Bind* is the very first thing that a client must do to initiate a session with the server. During this phase, the client will identify itself and present its credentials to the server. This works with the security protocols to prevent unauthorized access to your database.

Unbind tells the server that the client is finished with the LDAP session. The application that requested the LDAP information is satisfied with the results and the user has moved on to use the application.

When a client sends an *abandon* message, it is telling the server that it no longer needs the information. The user might have terminated the application that was requesting the information or the application might have abnormally ended, requiring the operating system to send the abandon message. Figure 18.10 shows the complete transaction from start to finish.

FIGURE 18.10
Multiple requests via one message.



Storing Information

Storing information falls under the heading of maintenance and population activities. LDAP provides for these operations by supporting the following three functions:

- **Add**—The Add function is just that, the ability to add new users and attribute values to an existing database.
- **Delete**—Delete removes attributes or entire entries from the database. This is useful when users leave the organization. However, most system administrators will simply set a user as inactive. This is done in case the “delete” operation needs to be undone.
- **Modify**—The Modify function will probably be the most used function of the system administrator. The Read function will be the second most utilized function by the user. The Modify function enables system administrators and users to modify information in the directory. Typically, users will only be able to modify a small subset of their information. Data items such as phone numbers and hair color are usually left to the users’ discretion.

One thing that should be given careful consideration is to whom these capabilities are given. You might want to allow some of your users the ability to modify their own information. This means that you should pay close attention to access rights as they pertain to user directories.

Access Rights and Security

During a recent test of Internet-accessible LDAP servers, it was discovered that for the most part, all LDAP servers were easily accessible. Any information security professional will tell you that the most dangerous thing to give someone is access. If a hacker can get to your server, he can own the data.

You must have a program that ensures that your server, whether a UNIX or an NT box, is configured in a secure manner. It is also recommended that a security policy that ensures continuous checks of your server is also in place. A number of commercially available applications will check your server for a large number of security vulnerabilities in your operating system as well as the database itself.

Access rights and how they are applied to users' directories are specific to the server application you are using. Take care to understand how your application and the operating system work together to provide security.

LDAP Server-to-Server Communications

Although many users will see only the client-to-server portion of the LDAP protocol, behind-the-scenes activities ensure that users can reliably query servers.

Reliability entails supporting a robust design that is not susceptible to single point failures. It also means keeping the latency to a minimum. Latency as it applies to reliability is a perception issue, at least from the user's perspective. If it takes too long for users to access a network-based service, they will complain that the network is broken and unreliable. By setting up your LDAP server as a single point of failure, your network may be susceptible to longer down times.

The LDAP Data Interchange Format (LDIF)

LDAP uses a standard method for generating message requests and responses. The messages are exchanged using ASCII text in a predefined format called *LDAP Data Interchange Format* (LDIF). A typical LDIF file looks like the following:

```
dn: uid=msk, ou=people, dc=starwizz, dc=com
objectclass: top
objectclass: person
objectclass: managementPerson
objectclass: corpmgntPerson
cn: Mark Kadrich
cn: markie
```

```
givenname: Mark
sn: Kadrich
uid: msk
mail: msk@starwizz.com
telephonenumber: +1 408 555 1212
description: President, Starwizz Enterprises

dn: uid=ma, ou=people, dc=starwizz, dc=com
objectclass: top
objectclass: person
objectclass: managementPerson
objectclass: corpmgntPerson
cn: Mitch Anderson
cn: mitchie
givenname: Mitch
sn: Anderson
uid: ma
mail: ma@starwizz.com
telephonenumber: +1 408 555 1212
description: Vice President, Starwizz Enterprises
```

The top line forms the Relative Distinguished Name (RDN), and can be used to trace the object, in this case a person, from his name to the organization. You will note that the format is similar to how e-mail addresses work with the resolution decreasing to the right. This is referred to as *little-endian* order. In this format, the least significant element is written first, with more significant elements being added to the right. For example, `msk@host.division.state.starwizz.com`.

LDAP Replication

Replication is a multifaceted service that provides for increased reliability and performance. By distributing your directory information throughout your network environment, you reduce your vulnerability to server- and network-related failures. As you can see in Figure 18.11, if a replica LDAP server fails, internal requests can be sent to one of the other LDAP replicas or to the master itself. Without the LDAP replicas, the clients on the A and B networks would be without LDAP service.

This is also beneficial from a performance perspective because local queries of the LDAP server do not have to pass through the router. Local requests are handled by local resources, thereby relieving the network of unneeded traffic. Moreover the response to local requests will be faster.

The replicas do not have to contain the entire directory tree. For purposes of security or maintenance, only specific portions of the DIT may be replicated. You can choose to replicate only those services running on their associated network. In Figure 18.11, Replica B would only contain directory entries specific to network B. Requests for information about services outside of network B would be passed on to the Master LDAP server.

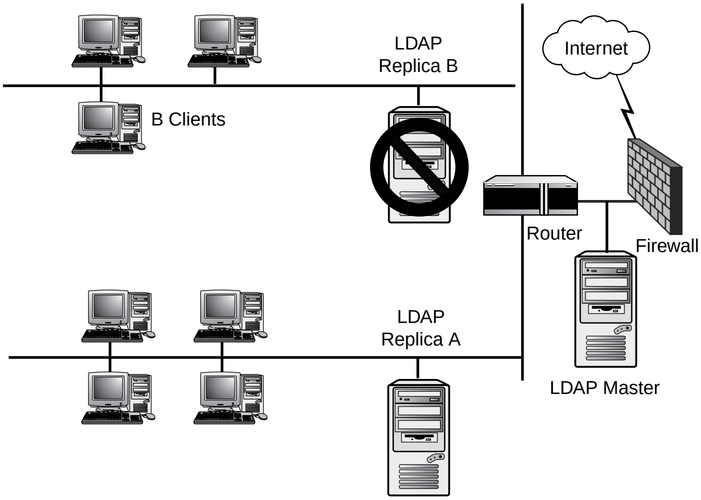


FIGURE 18.11
Distributed LDAP servers on a WAN provide redundancy and reliability.

Designing Your LDAP Service

Defining requirements is a live or die proposition. Spending the time to examine how your information environment works and how it will grow is time well spent.

Defining Requirements

As you look at the requirements for setting up your directory service, you should consider a number of areas. This solution is supposed to address the user community's needs as they apply to the information environment that the users work in. This means that you must consider the users and their tools. Consider the following list:

- User needs
- User expectations
- Application needs
- Deployment constraints
- Deployment issues
- Everything else

We have all had to deal with users and their expectations. All too often designers have given users lofty expectations in order to sell a solution to the user community. The solution was not based on the perceived needs of the users, but instead on someone else's idea of what would be a great solution. When the reality of the situation becomes apparent, the users are not happy. A successful solution must meet the user's expectations because they are the ones that ultimately decide whether you are successful.

Here we are considering LDAP-enabled applications and how they are deployed within the user's environment. You will, of course, have to consider what might come down the road at a later date, but making this part of the present set of solutions is not recommended. This is not to say that you shouldn't consider what new applications are being planned for. Rather, consider what impact these planned-for applications will have on the present design without trying to design a directory for every possible contingency.

You should also take into careful consideration the user's perception of how this data will be used and protected. The idea of what is personal and what is not personal information covers a broad spectrum within the user community. Accuracy is another concern. How often will the data be updated? Users will be expecting accurate data. Having said all this, trying to predict users' needs is a little like looking into a crystal ball. It only takes one major news article about some new whiz-bang application to change their minds.

Application needs are a major design element. The type of information and the frequency with which it is needed is a major factor that must be given careful consideration. In a manner very similar to how DNS drove the way applications used the Web, user applications will drive your design of the directory service with more force than anything else.

Designing the Schema

It is easy to say that you should include as much information as possible. However, the more information there is, the more information that must be sifted through to get the correct response to a query. You also don't want a minimal solution that might not meet the needs of the users and their applications.

Where data is obtained is just as important as the data itself. You want to avoid sources that cannot be verified or are not current. This leads to the consideration of other data sources within your organization. Areas such as HR and the helpdesk keep databases that might contain the same information. In database terms, this is *redundant* data.

The basic problems that bound your efforts are

- Too much information
- Too little information
- Incorrect information

This last item is a painful one to address because it concerns the quality of the information contained within your database. Sometimes it is more than a simple query by your Web browser. In some instances decisions are being made based on the information contained in your LDAP server. The implication is that decisions may be made on stale, out-of-date information. This can be catastrophic when you consider a worst-case scenario. Take, for example, the disgruntled employee that has been dismissed because he or she continually harassed his co-workers. Assume also that this disgruntled employee is a gun collector. Taking this one step further, your LDAP server talks to the computer that authenticates employee access to the building. It does not take a rocket scientist to see the potential for severe damage.

Setting a policy that ensures that your data will be contemporary and secure is a good idea. Remember that this database will most likely contain some personal information. You data policy should cover the following areas:

- Storage
- Access
- Modification
- Maintenance
- Legal
- Exceptions

The following sections briefly discuss guidelines for each of these.

Storage Guidelines

Storage guidelines address issues pertaining to what data will be stored in your database. Constraints on size and source may also be addressed here. An example would be that no data element larger then 15K would be stored in your database.

Note

LDAP allows you to store arbitrary binary data including JPEG and IMG files. These files take up a large amount of space. You must estimate the number of LDAP objects that will have these types of attributes that will take up space. This will give you an estimate about the amount of space the LDAP database will take up. LDAP databases can get quite large, and you need to provide for appropriate and frequent backups.

Access Guidelines

Access guidelines determine who can see and use the information. Once again, choosing to store sensitive information in your database becomes an acute concern.

Modification Guidelines

Modification guidelines determine who updates information as well as how information is updated in your database. The all-important question of whether to let users update their own information is generally addressed here. Methods for authentication and encryption (privacy of the link) should also be covered here.

Maintenance Guidelines

Maintenance of the data can be an interdepartmental issue, and a policy covering it can be extremely useful. It should state how often data is reviewed as well as how redundant data is reviewed. The problem of other databases, such as HR, containing out-of-sync data is handled here.

Legal Issues

Some data is more sensitive than other data, and disclosing it to the wrong party can cost an organization more than money. It can cost the organization its good name. Have your legal department review your database. It might take some time, but in the long run it's well worth it.

Exception Guidelines

A policy without a method to petition for change or exception has a life expectancy that can be measured in days. You should include a mechanism for granting exceptions and permanent changes. These changes should be authorized at the highest level possible. A director is a good place to start.

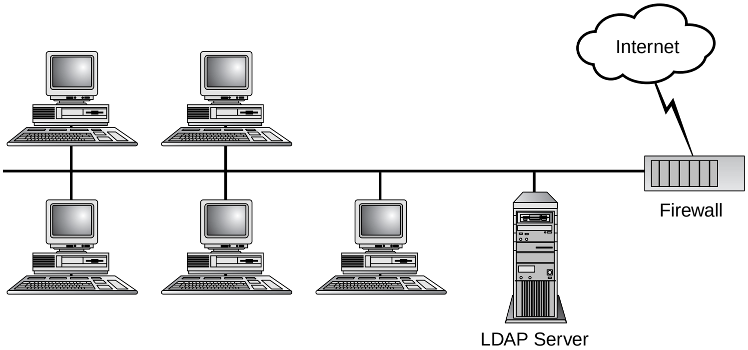
Performance

A service that takes forever to use will very quickly fall into disservice. When you consider the construction of your LDAP service, you must also consider the environment in which it will be used. Some questions that you should consider include

- What type of LAN/WAN will the LDAP server be used in?
- How many services will be using the LDAP server?
- How much money is there to spend on hardware?

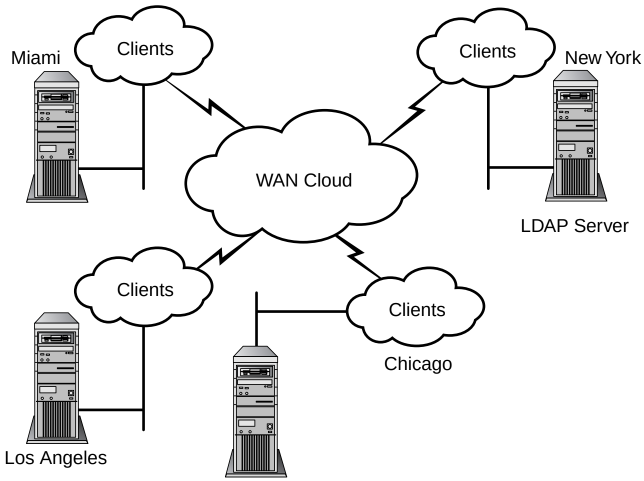
The type of LAN or WAN you will be attached to has a large bearing on how many LDAP servers you will need to support your users' requirements. In a simple LAN environment, one server might be all that is needed (see Figure 18.12). A single router connects the LAN to the Internet whereas a few network hubs connect the user's computers to the LAN. The firewall is a standard security device that controls the flow of traffic between the LAN and the Internet. See the section, "Security," later in this chapter for more information.

FIGURE 18.12
Simple LAN-based LDAP deployment.



In large organizations, having a more complex network than the one depicted in Figure 18.12 is quite common. Multiple routers connect internal WAN elements, each of which contains numerous LAN elements. Having thousands of computers distributed throughout the world using these techniques is quite possible. In a more complex environment such as this, you may consider using the inverted tree structure to deploy LDAP servers, as shown in Figure 18.13.

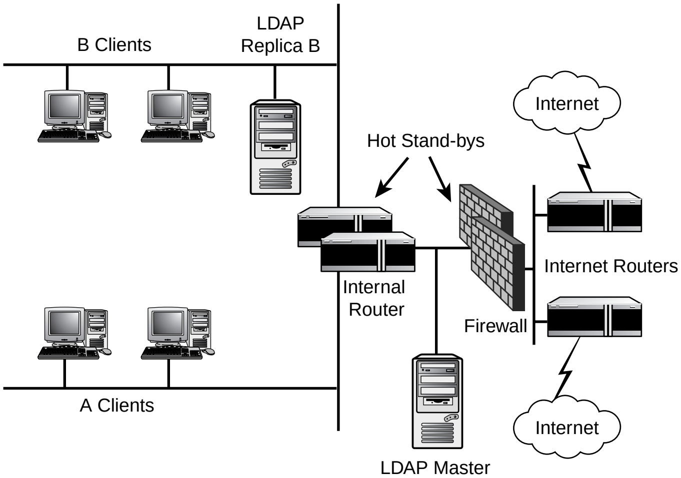
FIGURE 18.13
Complex WAN with distributed LDAP servers.



Network Abilities

Reliability and availability are sometimes referred to as the "abilities" of the network. Reliability directly affects availability. It stands to reason that if the server is unreliable, the service it provides may be unavailable. In the case of the network, it isn't just the server but also the devices that support the network. As discussed previously, some networks are large and distributed. To address availability, networks use redundant devices such as routers, switches, and *uninterruptible power supplies* (UPS). Not all devices are redundant. Some routers and switches, the expensive ones, can be equipped with redundant power supplies to address this most common element of failure. To address the network portion, two devices are used so that if one becomes disabled, the other will take over. This type of configuration is called *fail-over* and is referred to as high availability. As you can see in Figure 18.14, this sometimes involves multiple connections to the Internet.

FIGURE 18.14
Redundant routers and hot stand-by routers.



A more robust implementation is called *fault resilient.* Fault-resilient solutions generally use a fail-over type configuration but with care taken to ensure that redundancy within the device is as high as possible. An example of this would be two routers, each with dual power supplies, a UPS, and separate connections to the Internet.

Note

The basic disadvantage to these types of solutions is that you must spend twice as much money on hardware and software, and only one device is functional at a time.

The most reliable configuration is called *fault tolerant*, which means no single failure of any component will cause the total failure of the device.

A way to determine the level of reliability is by stating the permissible downtime. As you can see in Table 18.2, conventional servers can tolerate 3.5 days of downtime per year. Conversely, fault-tolerant systems are only down for *five minutes* per year.

An LDAP server should qualify for at least a designation of high availability. Fault resilient is, of course, much better.

TABLE 18.2 Reliability Designations as Measured by Time

Percent of Uptime	*Maximum Downtime per Year*	*Availability Designation*
99%	3.5 days	Conventional
99.9%	8.5 hours	High availability
99.99%	1 hour	Fault resilient
99.999%	5 minutes	Fault tolerant

Another way to mitigate single points of failure is to distribute your LDAP services throughout your network environment. A site on the West Coast would have its own server and a site on the East Coast would also have its own server. Both would report to the corporate server for updates and replication. This type of a configuration can take advantage of any network reliability factors, thereby increasing overall reliability. Refer to Figure 18.13 for an example of how this may look.

Security

Many systems have succumbed to trivial attacks, enabling some malevolent individual to steal precious information. An LDAP server is no different than any other server on the network—if it's improperly configured, anyone with a simple understanding of security exploits can access your data.

Security isn't just preventing unauthorized access to your data. It is a conscientious attitude of understanding risks, threats, mitigation, and benefit. You must make a risk versus benefit assessment each time the question of security comes up. You must also realize that many different levels of security exist. Some information is public, whereas other information is classified "burn before reading" because it is so sensitive. Other information will fall between these two extremes.

What is the issue? Simply put, LDAP enables an organization to put a huge amount of information into a service designed to provide answers in a reliable and expeditious manner. Thieves love that, especially if they can gain access to the information.

Threats

People usually associate computer security threats with hackers. This is not always the case. In reality, most security breaches are perpetrated from the inside by an organization's own people. A recent survey performed by Peter Shipley prior to the 1999 Blackhat Briefings conference indicated that a large number of corporate LDAP servers were accessible via the Internet. (The Blackhat Briefings are a yearly gathering of government, corporate, and private security professionals held in Las Vegas, Nevada.) Additionally, those that were accessible had little if no security enabled. Using a tool called nmap (available via the Internet), a scan using the command

```
nmap -P0 -p 636,639 192.168.0.0/24
```

revealed a large number of vulnerable servers. This same command, with your IP address, can be used to determine whether your servers are accessible from the Internet.

Note

If you download something from the Internet, especially from a hacker site, run it in a controlled environment before you turn it loose on the network. You may wind up being the recipient of a trojan horse or a virus if you don't. A *trojan horse* is a piece of software that masquerades as something that it is not. In other words, you may be downloading what you think is the greatest new tool when in reality you're downloading one tool and one piece of malicious code. For this reason, scanning all downloaded files with anti-virus software before using these files is a good idea.

Shipley also discovered that few, if any, servers were using secure methods of exchanging information. *Secure Sockets Layer* (SSL) is a standard method of encrypting information that will ensure that your data stays private.

There are a few basic types of security breaches. Because, like LDAP itself, this is an extremely complex field this section only covers the basics. Basic types of security breaches include

- Unauthorized access
- Unauthorized data modification
- Denial of Service attacks

Unauthorized access is access to your server by someone who does not have permission to do so. This is generally done for the purposes of stealing credentials, hijacking sessions, or embedding software.

Stealing credentials is very similar to password stealing except that it can be done on a much broader scale. The intruder can masquerade as the CIO or anyone else he wants to be. On more than one occasion, an individual has been terminated by someone he thought was his boss when in reality it was a fellow co-worker. By the time the error was discovered, the damage had been done. This is a sure way to create the disgruntled employee discussed earlier.

Although it requires physical access to the LAN, hijacking sessions can be accomplished after a user authenticates himself. The attacker simply inserts his packet stream to the server and sends a TCP reset to the unsuspecting user. The user thinks the network "hiccuped" and proceeds as usual. This is another reason to ensure a reliable network. A simple way to prevent session hijacking is to use encryption, such as SSL, to prevent access to the network packets. Another method is to encrypt all interactions on a network. This can be done using Virtual Private Networks (VPNs). VPNs create a tunnel or sleeve where all packet data between two endpoints are encrypted. VPNs are useful whenever the network has a security risk, such as with wireless networks. However, wireless networks are often slow, and the overhead of VPNs make them even slower.

Embedding software is generally the sign of a more sophisticated attacker. By leaving a trojan horse, attackers can do just about anything they want. Some trojans just sniff the network and send information back to the attacker, whereas others provide backdoor access to the system. Back doors will render most host security efforts useless.

Unauthorized modification of your data can be a severe hazard. By changing the "deliver to" account number, a hacker can have payroll diverted from the user's bank account to his private Swiss account.

Denial of Service, or DoS, attacks are attacks directed at stopping your LDAP server. The two types of DoS attacks that work at the application level are direct and indirect resource consumption.

In a direct resource consumption attack, a user continually makes requests for large amounts of data. By tying up the system resources, no one else can make requests. Placing limits on the number of directory resources any single client can use is a standard way to reduce the severity of this attack.

An indirect attack is harder to address because it doesn't attack the LDAP application itself. Rather, it attacks resources that the LDAP server uses. For example, assume that a trojan horse was introduced to the server and all it did was make disk requests. By denying access to the disk files, the attacker has effectively stopped the LDAP server. Preventing this type of attack requires adherence to the basic disciplines of security as stated earlier. Minimal software, a pedigreed operating system, and continued vigilance will at least make detecting these types of attacks easier.

Host Security

Host-level security is the first thing a hacker will look at, and it is probably the most overlooked aspect of a server's configuration. Depending on the environment, server software may need to be configured, compiled, and linked. This is particularly true in the UNIX environment, which uses the open source code philosophy. This means that the configuration of the operating system needs to be carefully checked. Unfortunately, all too often if the server runs, the configuration is assumed to be secure.

UNIX server security is a well-known subject. A number of good books have been written about it. Additionally, a number of commercially available software products are capable of reviewing the machine's configuration and providing you with directions to secure it.

Windows NT/2000 has similar products, although they aren't as pedigreed as their UNIX brethren. One reason is that Windows NT/2000 uses proprietary code (closed source code), and security bugs in the code remain undiscovered for a long time.

Note

If it doesn't need to be on the server to provide the service, remove it. Don't just disable unused software, *delete* it. Common services such as telnet and FTP should not be supported on your LDAP server.

Enable log generation and send the logs to a computer specifically set up to save and archive system logs.

Application Security

First and foremost: If it isn't needed, don't have it there.

This would seem like a simple rule to follow. However, many system administrators are pressed to use their systems to the fullest, thereby creating an insecure situation.

Other Security Issues

Physical security is another aspect that is overlooked. Because it's not a firewall or a file server, an LDAP server may not be afforded the same level of protection as other, more critical services. Remember that many of these services rely on LDAP, and it is for this very reason that LDAP servers should be monitored under lock and key.

Keep your LDAP servers in a locked room with controlled access. At a minimum, keyboard locks and password-enabled screen savers should be employed. If possible, deploy LDAP servers behind firewalls so access to them is controlled and protected.

Tools

Some tools that you can use to secure your server include

- Authentication
- Auditing
- Encryption

Authentication does not refer to just user IDs and passwords. Strong authentication systems, such as those from Secure ID and Axent Technologies, provide a token that exchanges a secure password that is only used one time. Each time the user accesses the system, he uses a new password. All the user has to remember is a simple PIN.

Auditing is the basics of security. By reviewing the audit logs of your system, you can determine whether any nefarious activity has taken place. Most security people will tell you that this task is boring and mind-numbing, but it is a necessary one.

Whit Diffie, the father of many encryption algorithms, said that "It was not encryption that was inherently weak, but how encryption was used that made it weak." This is significant when you consider that encryption is the foundation for many of our security tools. SSL uses encryption to make packets unreadable by anyone except for the designated computer. Certificates use encryption to validate, or digitally sign, documents thereby signaling to the recipient that the document is authentic.

Table 18.3 is a basic representation of how user access to information may be configured. System administrators have complete access to data, so although it isn't included in the chart, access to system administrator workstations should be protected with a strong authentication mechanism.

TABLE 18.3 LDAP Attributes and Their Associated Access Permissions and Protections

Attributes	*Assessor*	*Access Level*	*Security*
`cn`, `sn`, `givenName`, `middleInitial`, `name`	All	Read	None
`cn`, `sn`, `givenName`, `middleInitial`, `name`	SysAdmin	Read/Write	SSL and Certificate
`mail`	All authenticated	Read	Password
`mail`	SysAdmin	Read/Write	SSL and Certificate
`mail`	Self	Read/Write	Password
`homeAddress`, `homePhone`	All	User's choice	Password
`homeAddress`, `homePhone`	Self	Read/Write	Password
`postalAddress`, `telephoneNumber`	All	Read	Password
`postalAddress`, `telephoneNumber`	SysAdmin	Read/Write	SSL and Certificate
`salary`	Self	Read	Password
`salary`	Management	Read/Write	SSL and Certificate

LDAP Deployment

Deployment is the next bottleneck. You must work with the other departments that are responsible for network services and application readiness. In many instances, these departments will have windows designated specifically for deployment. Often they also have procedures for deployment of network services that must be met, such as testing and acceptance.

Consider the order in which the service will need to be deployed. If you are relying on the LDAP to support a workflow application, it is possible that some portions will not function properly without LDAP. Nothing angers a user more than a system saying that the user she is trying to reach doesn't exist when she can throw a phone book over a cubicle partition and hit him.

This can also be the area where politics must be considered. If each department has its own set of applications, you must be sure to consider the various sensitivities that drove the department to select its tools.

The Production Environment

Although many production environments are different, they do possess some similarities. First, they all contain people. Second, these people are there because they have a job to do. It's a business, so treat rolling out your LDAP service the same way. Start with a project plan that has some measurable elements and milestones. Above all else, manage to that plan. Use the plan as a blueprint to chart your course and measure your success.

Creating a Plan

The plan should have enough detail so that in the event that someone else must take over, it's not a coded mystery. A good plan will delineate a number of elements, such as

- Resources
- The project plan itself
- Success criteria
- Depending on your organization, a marketing plan

You can use a number of tools, such as Microsoft Project, to create a rollout plan that can combine the tasks and the resources in a way that makes it easy to see what is going on. Use a tool that provides the same utility, and you should be fine. Figure 18.15 is a sample of the basic steps you should follow. As you can see, resources are named in the plan. Prerequisite tasks are laid out prior to the rollout.

A good project plan can also be a great way of communicating status to management.

Establishing success criteria should happen based on the requirements. For example, is the LDAP server being added to address a new application? If so, the LDAP server cannot be used as a measure of success. Instead, the application actually being able to use the LDAP server is the ultimate measure of success.

ID	Task Name
1	Start project
2	Evaluate project worthiness
3	**Establish LDAP Team**
4	Establish team
5	Set success criteria
6	Develop contingency plan
7	Detail Project plan
8	**Top level design**
9	Analyze Environment
10	Identify Critical applications
11	Prioritize Application Needs
12	Esablish User requirements
13	Establish general database design
14	Establish naming criteria
15	Acquire network documentation
16	Establish replication requirements
17	**Detailed design**
18	Define schema elements
19	Detail namespace design
20	**Define replication needs**
21	Identify hardware requirements
22	Identify software requirements
23	Order hardware
24	Establish security schema
25	Establish maintenence requirements
26	Identify candidate LDAP servers
27	Evaluate candidate LDAP servers
28	Server Selected
29	Order software
30	**Deployment**
31	Install LDAP software
32	Populate database
33	Apha testa
34	Rework and debug
35	Beta test
36	Rework and debug
37	Cutover

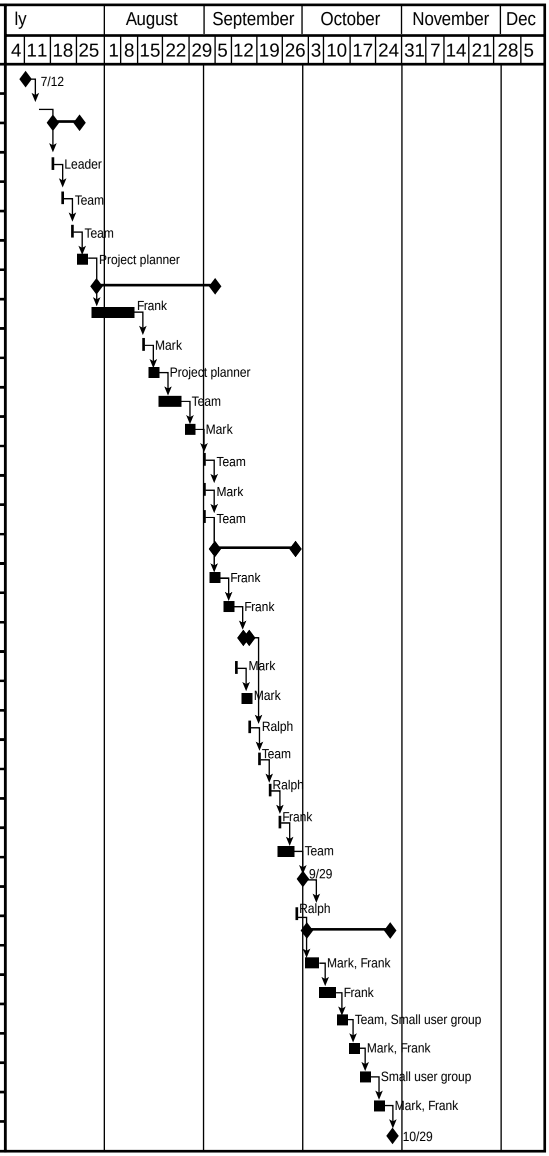


FIGURE 18.15 *Sample LDAP rollout plan.*

This is why a good marketing plan can help. A sponsor with the clout to make statements, publish e-mails, and send memos can be a huge advantage. The sponsor can help set expectations and fend off the naysayers, giving you the time needed to build a quality service.

Valuable Advice

Pay attention to detail! As the architect, uncovering the details specific to your organization is your responsibility.

There may be an urge to push your schedule. *Don't do that.*

During the rollout, you may discover that some things need to change. That's what the project plan is for—to help you understand the impacts of unknown situations and circumstances.

Don't hide anything. If something is broken or a mistake has been made, deal with it and move on. If they don't trust the messenger, they won't trust the message. In other words, if they don't trust you, they won't trust your service.

Manage to your plan. It is easy to get caught in the minutiae and lose focus. It's during those unfocused moments that the dreaded curse of "scope creep" begins to enter the project. A common mistake many project managers make is to get buried by details that had nothing to do with their project.

Be prepared. If possible, be prepared for the unexpected. Try to have an answer for different scenarios. A good project manager will play "what if" with the project. What if the hardware is late? What if my coder dies? What will you do? These are hard "what ifs," but a necessary process to go through.

Selecting LDAP Software

Like any other software, a selection process that addresses your internal needs is critical. Is the software a value-added proposition or just another application that adds little value. This is entirely up to you and the process you employ to select a vendor.

The basic areas of interest can be broken into the following elements:

- Core features
- Management features
- Security features
- Standards compliance

- Flexibility
- Reliability
- Interoperability
- Performance
- Extensibility
- Cost
- Other, generally political concerns

Core Features

Here you are looking to see whether the software will run on your selected hardware. The last thing you want to do is buy Windows NT/2000 software for a UNIX environment.

Does the software support the LDAP features that your applications need? If not, deselect it.

The ability to support replication features in your topology is a critical concern. If you plan on distributing LDAP servers throughout your enterprise, this item is high-priority.

How does the selected software support the introduction of data? Will you have to painstakingly enter every bit of data or are there import features?

Lastly, documentation and support need to be addressed. Will you have to install the software using inadequate or confusing installation instructions or is there adequate documentation supported by a trained helpdesk?

Management Features

Look for tools that make manipulating content easy. An additional benefit is the ability of the selected software to support scripting operations.

Difficult tasks, such as configuring security access rights, should have a tool to make the process less painful. This may even take the form of user profiles. Being able to designate a type of user and then copy it is a real time-saver.

Sometimes you aren't where you need to be to have a hands-on session with your server. This brings to mind remote management functions. Ensure that your candidate software supports *secure* remote management functionality, because you will be sending sensitive material across the network and you don't want unauthorized users stealing your information.

Security Features

Basic access controls are a must for an LDAP server. Ensure that you can accomplish the resolution or granularity required to control access. You may have to be able to grant access controls to specific users instead of to groups of users.

A robust LDAP server will support encryption capability, such as SSL or *transport layer security* (TLS). This critical feature is required if you are going to do any remote management or replication.

A broad range of authentication options is a prerequisite. Basic LDAP authentication, as well as certificates and password tokens, should be included as basic features.

Because you may want other administrators or even some users to take care of their own data, the ability to delegate is important.

Standards Compliance

Basically, the solution should comply with all relevant LDAPv2 and LDAPv3 RFCs. Check compliance to RFCs 1777 through 1779 and RFCs 2251 though 2256. Security specifications such as those called out in RFC 2222, Simple Authentication and Security Layer, should also be complied with. For the purposes of remote management function and network management, access via SNMP is a must.

You can find a good collection of LDAP information at `http://www.mozilla.org/directory/standards.html`.

A number of application programming interfaces (APIs) should be complied with, such as those for Java and C. However, a few nonstandard APIs, such as the Active Directory Services Interface (ADSI) from Microsoft, allows you to write programs in scripting languages supported by the Windows Scripting Host (WSH).

Flexibility

Few products work without some configuration. It is assumed that some aspects of your network are different from those of everyone else. The ability to address these configuration differences is important. Your selected LDAP product should be flexible enough to address your requirements. For example, can the configuration be tuned to address different hardware requirements? After all, not all machines will have 512 MB of RAM or more.

Another issue is that of adding or extending schemas. Can you manipulate the data structure without having to do a complete reinstall? New applications may bring new data elements and you may have to extend your schema to accommodate them.

Reliability

If one piece of data in the database is incorrect, the rest of the data is unreliable. If the server is unavailable, other applications that rely on it will not operate. To address this issue, you must ask some important questions. Will the server recover from a failure without losing any data? How does it process transactions?

The ability to run 24×7 is a must. Few users will tolerate your taking down the LDAP server that runs mission-critical applications so you can perform a backup.

Look for the ability to support fail-over or some other type of high-reliability solution. Although there is a hardware component to address, information must be exchanged between the primary server and the hot backup, a duplicate machine that contains a copy of the directory. Otherwise, you may have to deal with lost data and angry users after a failure.

Interoperability

Simply put, this is the LDAP server's ability to work with your applications and those that support it.

Note

Make your life easier and ask for proof. This may be in the form of existing customers or a demo lab. Whatever form it is in, make sure you see it work first. Many vendors claim to have high reliability solutions but they only work in specific environments. Make sure it works in your environment.

Performance

Because this service is network-based, standard questions regarding latency and throughput must be asked. You must know in advance what your users will tolerate in latency and delay. Then you must find out whether the server can meet those needs. Will it be able to handle the load of simultaneous connections without crashing? Does it have the ability to monitor its performance, and does it have the ability to change parameters to enhance performance?

Knowing the server's theoretical limit is a good idea. Much of a server's performance is linked to the hardware configuration, but at some point this changes. It may not have the internal buffers or handles that are required to go beyond a performance plateau. For the purposes of planning you need to know that limit.

Extensibility

Some applications make extending their capability beyond that of the original program easy. Some do it by supporting scripts, whereas others, like Netscape, use a software bus approach that enables the use of plug-in modules.

This ability can be very useful if you must develop your own application or address an existing homegrown application.

Cost

It would be nice if you could predict costs accurately by saying, “I’d like the blue one for $100.” Unfortunately, cost is not an easy item to predict, and projects are plagued with cost overruns. Vendors seem to have made it their mission to make costing-out LDAP servers as confusing as buying a new car! Some vendors charge by the number of seats, some charge by the number of servers, some charge by the number of entries. Some inspired vendors sell unlimited licenses. Usually, it’s a combination of all the above.

Don’t be surprised if there is a yearly charge for maintenance. Under that same consideration, think about the day-to-day activities that must be performed, such as backups and upgrades.

Some LDAP servers are tied to a particular operating system. This is the case with Microsoft’s Active Directory. You must have Windows 2000 Server to take full advantage of its features.

There is also the subject of the hardware on which the LDAP server runs. Some operating systems require a significant investment in hardware. Don’t forget to add that in.

Training and support must also be added in. Some vendors supply training for free but you must still pay for the administrator’s time.

Other, Generally Political Concerns

On the business side it’s always nice to consider the vendor from which you’re purchasing your product. Will it be around in a year? How big is this company? Will it be able to develop the product as new extensions for LDAP are published?

Consider how your vendor fits into the directory-enabled market. Although you will most likely be using products from other vendors, it’s nice to see a corporate commitment from your vendors. Your vendor should be spending money on research and development to ensure that its product remains compatible with the standard. The company should also be taking part in interoperability tests to ensure its products are compatible with other vendors’ products.

Summary

LDAP has the potential to be the Great Organizer of the network world. Being able to point applications at a single source of directory information relieves network administrators of a considerable burden. Not only does it make application designers' lives a lot easier, but it also makes the system administrator's life easier as well. System administrators will no longer have to manage multiple applications in order to ensure user connectivity. Users will see transparent connectivity to needed services and information.

However, LDAP is a sophisticated service that requires significant attention to detail. Planning and testing play a major role in a successful LDAP implementation.

As the network services grow, we will see a greater reliance on network-based directory services such as LDAP. Some day, it may even replace the phone book and the *TV Guide*.

CHAPTER 19

Remote Access Protocols

by Mark Kadrich

In This Chapter

- **Remote Connectivity** *478*
- **Remote Authentication Dial-In User Service (RADIUS)** *482*
- **Transporting IP Datagrams with SLIP, CSLIP, and PPP** *485*
- **Tunneled Remote Access** *493*

As the Internet has grown, so has the need to access it from any location. Often, this type of access is called *remote access*. In the beginning, remote access was performed using a terminal that was connected to a mainframe or minicomputer. This method of access was satisfactory as long as you were in a fixed location such as your office. As support staffs shrank, providing system administrators with access to corporate networks from home became imperative. Thus, remote access was born. This simple type of access was via the slow modems of the time, typically at 110 baud. (Baud rate and bits per second are close enough for the purposes of this discussion that they will be used interchangeably.) System administrators were now able to monitor system activity and make system-related changes from the relative comfort of their homes. A benefit to the organization was that critical systems could now have cost-effective 24×7 monitoring by individuals who could do something in the case of an emergency. That is, as long as that emergency wasn't the terminal services going down!

The late '70s and early '80s brought advances in technology that enabled modems to increase their throughput every couple of years. Like their sister integrated circuits the memory chip, they followed Moore's law by doubling in throughput capacity every couple of years.

Today's modems typically run at around 56K with their actual throughput being governed by the antiquated copper infrastructure of the *Public Switched Telephone Network* (PSTN). This aging infrastructure, in conjunction with the introduction of more advanced reliability and security requirements, has placed special emphasis on developing protocols that effectively allow for the transmission and reception of digital data.

Remote Connectivity

As alluded to earlier, a major component of a remote access solution is a modem. MOdulator/DEModulators (mo-dem) can take the form of many different types of devices. Basically, a modem changes the digital signals generated by your computer to those that can traverse the PSTN. Each end must have a compatible modem for this operation to work properly (see Figure 19.1). On the receiving end, the analog signals are demodulated into digital signals and fed to the receiving computer.

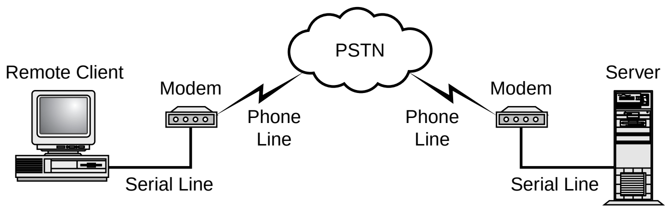
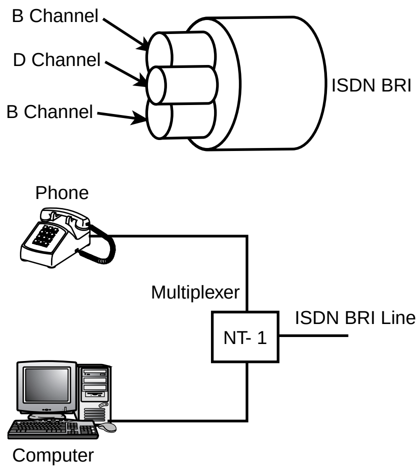


FIGURE 19.1
A basic modem and the PSTN network.

ISDN

Not all of these devices are compatible. A standard modem will not allow you to connect to an Integrated Services Digital Network (ISDN), and an NT-1 (network termination) will not allow you to connect to anything other than an ISDN line. However, ISDN offers some interesting benefits. A *Basic Rate Interface* (BRI) allows the subscriber to use analog phones as well as pure digital transmission of data. In the United States, a BRI consists of two 64K channels and one 16K channel that are *Time Division Multiplexed* (TDM) for an aggregate total of 144K bits per second (see Figure 19.2).

FIGURE 19.2
ISDN BRI configurations.

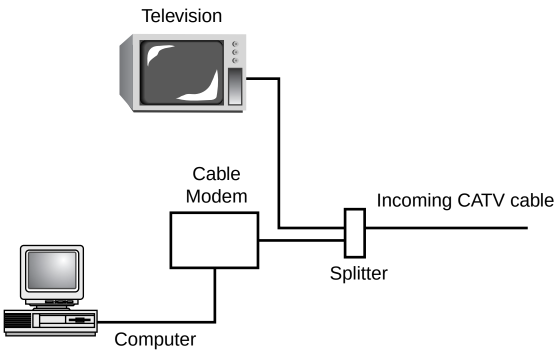


ISDN's versatility comes from the fact that at any given time all three channels can be used individually or the two 64K channels can be used together to supply a total of 128K of throughput. An interesting advantage of ISDN was that it could use the existing two-wire telephone wire that came to most businesses and homes. This was an important consideration for the businesses as well as the telephone companies that needed to provision ISDN. It meant that expensive upgrades to the existing PSTN would not be required. Although this was a wonderful solution to increasing the time that the existing PSTN would be able to provide service, the Internet revolution would apply additional stress as millions of consumers jumped online. ISDN's days were numbered.

Cable Modems

Cable modems have been in use for a couple of years now (see Figure 19.3). A cable modem takes advantage of the fact that many consumers have a broadband transmission medium, the TV cable, already in their homes.

FIGURE 19.3
Cable modem.



By taking advantage of the unused portion of the cable bandwidth as well as employing some interesting tricks of modulation, cable modems can supply users with access speeds at around 1Mbps. This is quite impressive in a home environment. Recent developments in software and operating systems allow multiple computers to take advantage of this single access point.

Cable modems connect the computer to the neighborhood cable line in much the same way that Ethernet used to connect computers via a coaxial cable. Everyone is on one data bus. This means that all the people in your neighborhood can potentially access your computer. Care should be taken to prevent this. One method is through *Network Address Translation* (NAT).

By using software that takes advantage of RFC 1918, "Address Allocation Techniques for Private Networks," commonly referred to as NAT, a home network can now provide each computer on the network with Internet access and security. This is convenient if you want to segregate users by age as, for example, a parent with a teenager might. As it turns out, today's computer receives just as much attention as yesterday's telephone.

Companies such as @Home have pioneered this type of access in a multitude of areas. Check with your local cable company to see whether you have this capability.

Digital Subscriber Loop (DSL)

Digital Subscriber Loop (DSL) is a relatively new service that offers a number of interesting versions of essentially the same capability. Using a price-based service-level model, DSL offers more throughput for more money. A 56K link can be acquired for about $50 per month and three times the capability can be bought for twice the cost. Table 19.1 shows a general price list of DSL connections based on throughput supplied. These are average listed prices and do not include any sales or special offers.

TABLE 19.1 General DSL Pricing List

Data Rate	*High*	*Low*
144	$124.00	$90.00
160	$149.00	$80.00
192	$169.00	$90.00
384	$199.00	$130.00
768	$359.00	$180.00
1.1	$399.00	$200.00
1.5	$359.00	$290.00

There are a number of different flavors of DSL, with *Asymmetric DSL* (ADSL) being the most popular. ADSL takes advantage of the notion that a typical user will download more than he will upload. When browsing the Web, users typically download more in graphics than they upload. Generally, most users will upload simple responses to Web queries. When you click a button on a Web page, you send a simple message back to the server telling it to do something, such as send back a picture or text. The exception to this is electronic mail. However, even with e-mail added to the mix, there is still typically a 10-to-1 ratio of downloaded versus uploaded data.

DSL was invented to address a number of unique problems that have cropped up since the Internet explosion, particularly that of capacity. The existing PSTN was built around the idea that most conversations would be about 10 minutes long, with the average household having at most two lines. This allowed the central offices (COs in telephony parlance) to be sized ratiometrically. In other words, if only 10 percent of the population was using a phone at any one time, the COs would only have to be large enough to support so many phone switches in the phone company racks.

Note

DSL is still experiencing some teething pains. When a DSL line is part of a cable bundle that is carrying an ISDN line, a significant amount of crosstalk between the lines reduces the effectiveness of the DSL line. Talk with your vendor before you commit to a DSL line.

An interesting benefit of DSL over cable modems is a consistency of throughput. Because you share the cable segment with your neighbors, as more of your neighbors get cable modems your effective throughput will decrease. Because DSL is a point-to-point connection to your service provider, it isn't as susceptible to this problem. However, DSL is still affected by how much bandwidth is available from the CO to the Internet. Also, your DSL connection point cannot be too far from the CO. Currently, this distance limitation is around 15,000 feet but is likely to change with advances in technology.

Radio Networks

Radio networks are offered through a plethora of technologies that range from cellular networks to pure radio modems, such as those offered by Ricochet and Metricom. Communicating with transceivers located on light poles in your neighborhood, Ricochet allows an appropriately equipped computer to communicate with the Internet without wires. Along with a cell phone and a pager, your office can be at any location. Although very convenient, the disadvantage is that this communication method is not secure.

Remote Authentication Dial-In User Service (RADIUS)

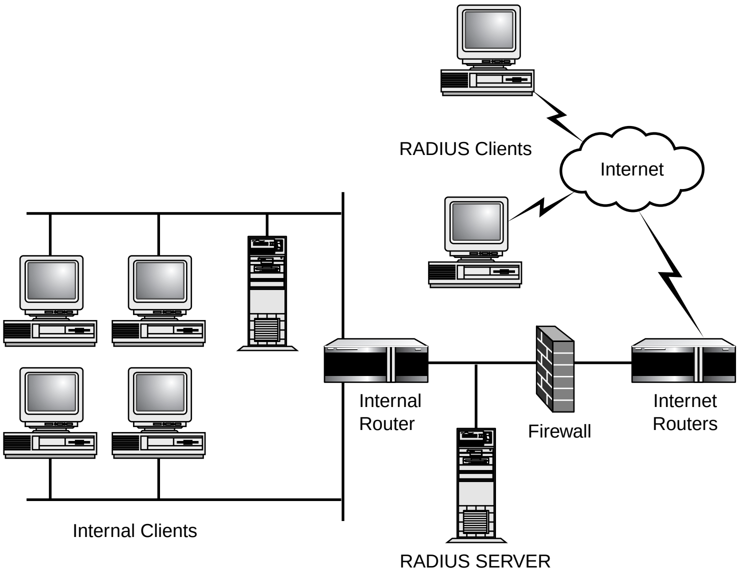
The *Remote Authentication Dial-In User Service* (RADIUS), RFC 2138, provides a number of important services to remote users. RADIUS is a client/server protocol originally developed by Livingston Enterprises in 1992. It was developed in response to the need to provide an enhanced method of authenticating users to their security devices.

RADIUS has grown to be a significant component in the system administrator's effort to provide enhanced confidence in the authentication process.

A RADIUS configuration will usually consist of a central database server and one or more dial-in servers (see Figure 19.4).

The database contains the three A's of information—Authentication, Authorization, and Accounting. *Authentication* information enables the network to identify users to the system. Although this information is generally stored in ASCII text files, RADIUS servers can communicate with password files and NIS+. *Authorization* information gives users access to servers and data, such as the corporate intranet server or the phone lists. *Accounting* information is used to keep track of user accesses, failed accesses, connect time, and so on.

FIGURE 19.4
The RADIUS client-server model.



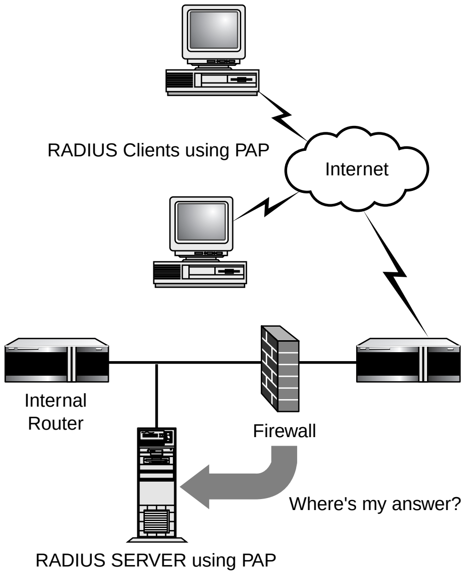
RADIUS Authentication

The RADIUS exchange is fairly straightforward. After the user has connected to the remote access server, the RAS server will prompt the user for a name and a password using the *Password Authentication Protocol* (PAP), or the *Challenge Handshake Authentication Protocol* (CHAP).

Password Authentication Protocol (PAP)

PAP is an older protocol that relies on passwords and user IDs and is documented in RFC 1334. After the user establishes the remote link, a user ID and password pair is sent to the RADIUS server. As shown in Figure 19.5, the access server continually sends the password and UID to the authentication server until a timeout occurs. If you are interested in security, this is not the protocol of choice. Passwords are sent "in the clear." In other words, there is no encryption of the user account and password information. This means that someone can record the transaction, discover the user account and password, or replay it later in order to gain access to your critical services. PAP is generally a fallback protocol that is used after protocols such as CHAP are attempted and failed.

FIGURE 19.5
PAP protocol exchange.

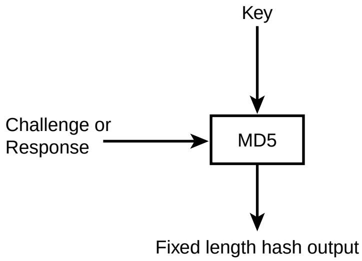


Challenge Handshake Authentication Protocol (CHAP)

CHAP is special in that it provides a stronger method of authenticating the user. CHAP is described in detail in RFC 1994. CHAP is a three-way handshake that sends a challenge code to the user and the user is expected to give the proper “handshake” response. After the user establishes the link, the server sends a “challenge” packet to the client. The client responds by calculating a response using a one-way hash function, such as MD5. The client sends the response to the server that has calculated the expected response. If the response from the client matches the response calculated by the server, the client is permitted access to the network. If the response doesn’t match that calculated by the server, access is denied. To ensure that the session hasn’t been hijacked, the CHAP protocol can be configured through the server to periodically re-authenticate the client. Unlike PAP, the authenticator controls the entire CHAP sequence and retries are rarely permitted.

This type of authentication prevents replay attacks such as the one discussed in the preceding section. Because each challenge is different, each calculated response is different. It should be noted that this protocol does rely on a shared secret. The secret is used as the key in the hashing function (see Figure 19.6) so it should be protected. The challenge value should follow two criteria: It should be unique and it should be unpredictable.

FIGURE 19.6
Diagram of hashing method.



The CHAP authentication method should be used if your intent is to access sensitive network resources or if you are concerned about security in general. As a matter of fact, according to the CHAP RFC 1994, PAP is actually obsolete as a password protocol when using PPP.

Account Information

Account information can take many forms, including user ID, password, temporal access restrictions, service authorizations, and auditing information.

We're all used to the usual UID and password information. RADIUS allows for the addition of auditing information. This information can be used to determine whether someone has tried to access systems that he shouldn't be accessing. You can also use the information to control when someone is permitted to access the network. If you have a receptionist who only requires access from 9 a.m. to 5 p.m., you can set the account information to reflect this. Any access outside of these limits isn't permitted. In effect, you reduce the available time of exposure of your network, thereby increasing security.

A similar effect can be obtained by using the database to limit access to various services. By entering a list of approved services, you can prevent access to unauthorized services. When users attempt to access a service they are not authorized for, they will be denied by the RADIUS server. This basic policy management provides for a centralized user database that can easily be updated.

Transporting IP Datagrams with SLIP, CSLIP, and PPP

A number of different protocols have been developed to move information from one point to another. The selection of a protocol depends on how much capability you require. The following sections discuss the history of remote access protocols and where we are today.

Serial Line Internet Protocol (SLIP)

SLIP was an early protocol used to connect remote users to a local host. RFC 1055 is an informational specification only because SLIP was already a de facto standard when RFC 1055 was written. SLIP was one of the first useful remote access protocols in that it provided for IP connectivity to the remote networks that were appearing in the early 1980s. Figure 19.7 shows how the Berkeley and Sun Microsystems operating systems used SLIP.

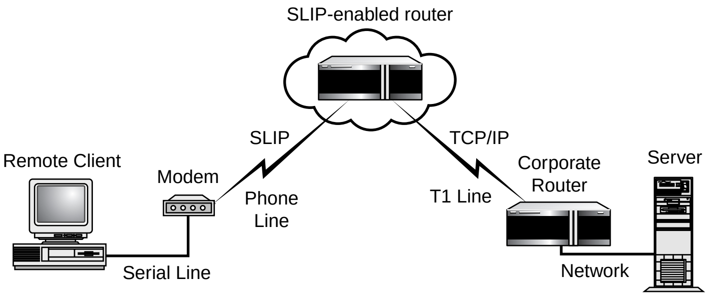


FIGURE 19.7
The SLIP protocol.

SLIP is a very simple-minded protocol because it was designed when networking was simpler, and the problem that was being solved was just to send IP datagrams across serial links. The entire RFC, including code, is only five pages long. All the SLIP protocol does is define how data is framed on a serial line. There is no error correction or detection, addressing, packet identification, or compression. Its sole purpose was to push packets across a serial line.

Note

It is important to realize that serial line protocols such as SLIP and PPP are Data-Link Layer protocols (OSI Layer 2). There is a need for these protocols because serial lines do not have an inherent Data-Link Layer protocol. This is in contrast to LAN protocols such as Ethernet and Token Ring that have a defined packet frame at the Data-Link Layer. Many serial lines use asynchronous communications at the Physical Layer where a character is framed in a start, stop, and an optional parity bit. You may be familiar with the Physical Layer framing of asynchronous communications where the modem is set to "N,8,2", which means No parity, 8 data bits, and 2 stop bits. Descriptions such as "N,8,2" describe the Physical Layer for serial lines. Consider this question: At the Data-Link Layer what protocol should be used for serial lines? In other words, how should the characters be grouped together in a frame of information, and what should be the format of this Data-Link packet? As you try to answer this question, you begin to realize that serial lines do not have any inherent Data-Link Layer protocol, and it is up to the protocol designer to design a format for serial lines. The earliest definition of Data-Link Layer protocol for serial lines is SLIP, which is discussed in this section. A later section describes PPP, which is in use today and replaces SLIP.

Due to SLIP's simple nature, a number of deficiencies make it less than desirable in a large-scale network implementation. The most onerous is that in a SLIP session, both ends of the session must know the other's IP address. Without it, there is no way to handle the routing issues. In modern networks this can be an issue, especially in a DHCP-based environment. However, this same simple nature makes SLIP easy to implement.

Datagrams are usually kept to less than 1006 bytes, well below the MTU size limit of many links. An additional concern is maximum modem speed. It is recommended that SLIP connections not exceed 19.2Kbps. In practice this limit is good to stay with. Higher speed connections benefit from the additional error checking provided by PPP.

Compressed SLIP (CSLIP)

CSLIP is a protocol that reduces transport overhead by using VanJacobsen TCP header compression to reduce the size of the combined TCP and IP header size from a 40 to 3–7-byte signature. Header compression is made possible because most of the packets have very little that changes in the TCP and IP header. Data compression, such as run-length encoding, can be used. This technique replaces strings of repeated characters with a single character and a count. This can be a big difference when you're sending lots of little packets, as can be the case with protocols like Telnet.

Point to Point Protocol (PPP)

Because of the issues and limitations of the SLIP protocols, it became apparent that a new protocol was needed. Thus PPP was born to replace SLIP.

The original RFC 1134 describing PPP was written in 1989 by Drew Perkins of Carnegie Mellon University. PPP is extremely versatile in that it will support the transmission of datagrams over point-to-point serial connections and the Internet. A *datagram* is a block of data similar in nature to a packet. By encapsulating datagrams, PPP remains independent of the medium and will support multiple non-IP protocols. Protocols such as UDP/IP, IPX/SPX, and even AppleTalk have taken advantage of PPP.

PPP Modes of Operation

To ensure that PPP could support virtually any type of user session, a number of capabilities were built in to provide different modes of operation. PPP has three basic modes of responding to a connection request:

- An immediate PPP link
- Autodetection
- Interactive

Immediate Link

As can be summarized from its description, immediate PPP provides PPP communication after answering the request. Any authentication must take place within the PPP protocol itself. This can be a dangerous connection method because authentication can be turned off. This would allow anyone to connect to your network.

Autodetection

In autodetection, the server will select among PPP, SLIP, interactive, or other protocols as configured by the system. The key benefit to this is once again versatility. By being able to support a wide selection of protocols, the network is now able to effectively deal with upgrade and migration issues. Instead of having to do a forcible cutover to PPP, a gradual migration of users and services can take place. Immediate conversion is sometimes called *slash cutover* because all the systems are configured to migrate to the same service at the same time. This is similar to flipping a switch at midnight, and has been the bane of many system administrators' lives because immediate conversion is not always smooth and something invariably goes wrong.

Interactive

Another benefit is the support for dumb terminals and terminal emulation users who must still access the network. Some database access programs still require access to legacy systems, so be aware of this ability.

At the beginning of the session, PPP will look to see whether it's dealing with an active or passive session. An active node will begin to transmit frames in an attempt to start handshaking with its peer. A passive node will wait for the other node to start the handshaking process. It is standard procedure to configure outbound nodes to be active, whereas inbound nodes can be either active or passive. An autodetecting dial-in server should be set to passive in order to determine the line protocol of the remote node.

For PPP to successfully begin the handshaking process, one of the nodes must assume the active mode. Be aware that not all software offers the choice of modes. NT RAS is a passive server, whereas Sun's Solaris PPP is an active server. If you are running PPP 2.3, you have the choice of active or passive modes.

PPP does support a form of encryption through the use of the Encrypting Control Protocol described in RFC 1962 and RFC 1968. PPP supports a number of encryption algorithms including DES. Both endpoints must support encryption and both must agree on the encryption algorithm. Care should be exercised; not all products support encryption because it is a PPP extension.

In contrast to SLIP, PPP also supports a fully developed list of services. They are

- Simultaneous support of multiple protocols
- Link configuration
- Error detection
- Compression
- Encryption
- Network information
- Authentication

As illustrated in Figure 19.8, PPP fits in the stack at the Data Link Layer interfacing the Physical and Network Layers.

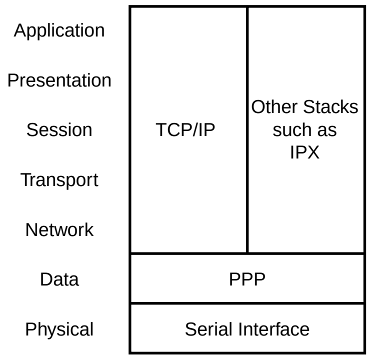
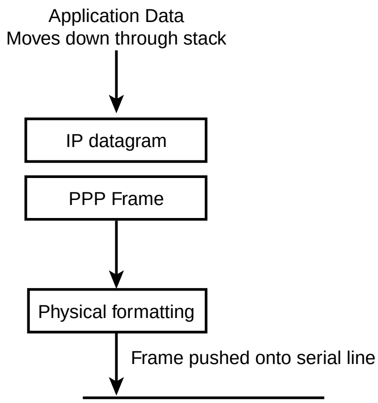


FIGURE 19.8
A TCP/IP stack with PPP connection services.

Using the stack in this way enables PPP to support multiple protocols. For example, an IP datagram would be encapsulated in a PPP frame, as shown in Figure 19.9.

FIGURE 19.9
Stack showing IP datagram being encapsulated and fed to wire.



IPX would function in exactly the same way. Instead of an IP datagram, an IPX datagram would be handed to the PPP-enabled Data Link Layer. This schema maintains the integrity of the stack while providing the versatility required in today's multiprotocol network environments.

PPP's flexibility is also demonstrated by the support provided to modify its operating parameters. In order to tune the link to its maximum capability, PPP can set a number of link configuration parameters such as the following:

- Maximum Receive Unit (MRU)
- Async Control Character Map (ACCM)
- Authentication Protocol
- Extensible Authentication Protocol (EAP)
- Quality Protocol
- Magic Number
- Protocol Field Compression
- Address & Control Field Compression
- FCS Alternative

Maximum Receive Unit (MRU)

The MRU tells the other node that the receiving end is capable of dealing with MTUs of a size different from the default of 1500 bytes. It should be noted that all implementations are required to accept a PPP information field of 1500 octets at all times. This is regardless of the values negotiated at connect time. As it turns out, calculating an MRU is a complicated process due to compression protocols that may inflate some types of data due to their substitution algorithms. Some implementations of PPP calculate MRUs based on the connection speed.

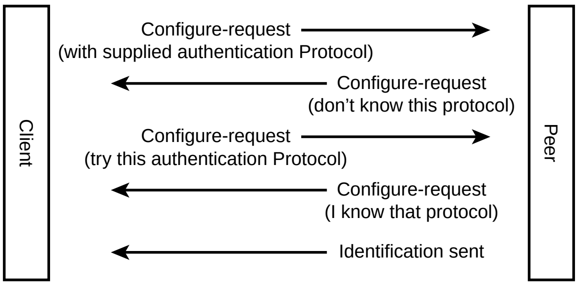
Async Control Character Map (ACCM)

Described in RFC 1662, the ACCM tells the peer what characters in the data stream should be "escaped" in order not to corrupt data. This is done to enable or disable the 32 ASCII control characters that live between 18 and 1F. Control sequences such as CONTROL-S and CONTROL-A (XON and XOFF) that normally act to stop and start flow sequences can corrupt data in strange and surprising ways.

Authentication Protocol

The authentication protocol in RFC, described in RFC 1661, is a way to tell the peer that it needs to identify itself before any further communication is permitted. The default for this option is no authentication. The sender can initiate a Configure-Request indicating to the peer that it needs the peer to identify itself using the indicated protocol. The receiver can issue a Configure-Nak to request another protocol, as depicted in Figure 19.10.

FIGURE 19.10
Authentication sequence.



At this point the sender can terminate the session or resend with a different protocol. Permitted authentication protocols are RFC 1334 PAP, RFC 1994 MD5 CHAP, MS CHAP, EAP, or SPAP. After the peer has responded with a Configure-Ack, it must respond using one of the listed protocols.

CHAP and PAP were described earlier, so the following sections provide a brief description of other authentication protocols and the remaining PPP fields.

Extensible Authentication Protocol (EAP)

Extensible Authentication Protocol (EAP), RFCs 2284 and 2484, is the proposed PPP authentication protocol as of 1999.

Postponing the algorithm selection until after the *Link Control Phase* (LCP), PPP builds a connection. Then, during the authentication phase, EAP interrogates the client for more information regarding specific authentication protocols. A major benefit of EAP is its ability to support back-end systems for authentication and encryption. This makes integrating PPP with RADIUS servers as well as other hardware- and software-based security tokens significantly easier.

Shiva PAP

Shiva PAP also has the ability to use hardware tokens but it seems that instead of releasing it to the public domain, Shiva will license it to select vendors. There is little documentation in the public domain.

MS CHAP

MS CHAP is basically regular CHAP using a different hashing algorithm. Instead of the usual MD5, MS CHAP uses either DES or MD4 depending on whether it is using the LAN form (DES) or the NT form (MD4). In either case, the response is generated using DES. This is similar to the standard form of CHAP except that standard CHAP uses MD5.

Quality Protocol

An interesting capability of PPP is its ability to measure *Quality of Service* (QoS) parameters. By telling the peer that you want to receive QoS information, you can monitor data loss and error rates. The default for this setting is "no protocol." The information provided is simple statistics regarding the link and its status.

Magic Number

The magic number is used in QoS requests as well as discard-requests and link quality packets. This number is chosen at random to identify the nodes to each other and to assist with error detection and loopback conditions. The default for this setting is "no number."

Protocol Field Compression

Protocol field compression performs a simple compression from a 16-bit protocol field to an 8-bit protocol field. The most significant bytes of the octet must be 0 in order for this to work. Only the least significant octet is transmitted. This is disabled by default.

Address & Control Field Compression

Another compression field, Address & Control Field, tells the peer that the fixed HDLC values of 0xff and 0x03 associated with this field can be omitted. As with the other values, the default is "off." In a latency-critical application, such as a real-time application, you can omit the unused portions of the address field this way. The end result is you save a few bytes in the transmission of packets.

FCS Alternative

The last option discussed here, FCS alternative, tells the peer that you want to receive a nonstandard default frame check sequence field. This is a Link Control Protocol configuration option that is usually absent because it isn't consistently addressed in all PPP implementations. It allows the peers to negotiate a 32-bit cyclic redundancy check (CRC) instead of the usual 16-bit CRC.

There are extensions that PPP supports but they are considered either flawed or obsolete. Use of these options should be examined carefully and other solutions should be explored if possible. These options are described in RFC 1570, RCF 1663, RFC 1976, and RFC 1990. They are

- Numbered Mode
- Multi-link Procedure
- Call-back
- Connect Time
- Compound Frames
- Nominal-Data-Encapsulation
- Multilink-MRRU
- Multilink-Short-Sequence-Number-Header-Format
- Multilink-Endpoint-Discriminator
- Proprietary
- DCE-Identifier
- Multi-Link-Plus Procedure
- Link Discriminator
- LCP Authentication Option

Tunneled Remote Access

In many cases, special techniques must be used in order to move data from one network to another. In some instances it's a simple matter of encasing one protocol inside of another, as in the case of IPX over IP (see Figure 19.11).

FIGURE 19.11
IPX over IP.

DLL Trailer	IPX Packet	UDP Header	IP Header	DLL Header

The native protocol, in this case IPX, does not have the ability to move data between IP internetworks. To solve this problem, IPX has an IP header appended to it in order to give it the information needed by the routers that will direct the packet to its ultimate destination. This common practice has been used since the early days of AppleTalk, and it has proven to be quite effective.

This type of solution is not without its drawbacks, however. Some applications are designed to deal directly with their native application. In our example, this would be Novell NetWare. Various implementations of IP have displayed idiosyncratic features that make the implementation less than straightforward. An example of this is once again portrayed with IPX running on Microsoft-enabled networks. In some instances of IPX on MS networks, unusual issues associated with timeouts and ghosting occurred. *Ghosting* is the effect of network resources appearing and disappearing at random intervals. This most commonly occurred with printers and was due to the incorrect distribution of network and printer drivers.

Herein lies the problem. Special attention to detail must be maintained because you are essentially using two or more network protocols to support your user community. One incorrectly installed or obsolete driver can be very difficult to diagnose and repair. More importantly, it can make the network seem unreliable—something to be avoided.

A few solutions to this problem have proven to be very effective in the past. First, use a remote management product that enables system administrators to install and manage remote nodes. Products from companies such as Vector Networks (`www.vector-networks.com`) and Traveling Software (`www.travelingsoftware.com`) provide additional capabilities that are not native to the desktop environment. These products feature remote control, remote management, remote software, and hardware inventory capabilities that can be leveraged to provide a reliable networking environment. One caveat though: These types of products bring with them their own risks. Misconfigured, they can allow unauthorized access to potentially sensitive information. Passwords must be strong, and administrative access should be given only to those who need it. If you are using ZENWorks for Desktop on a Novell network, it has built-in secure remote control management features.

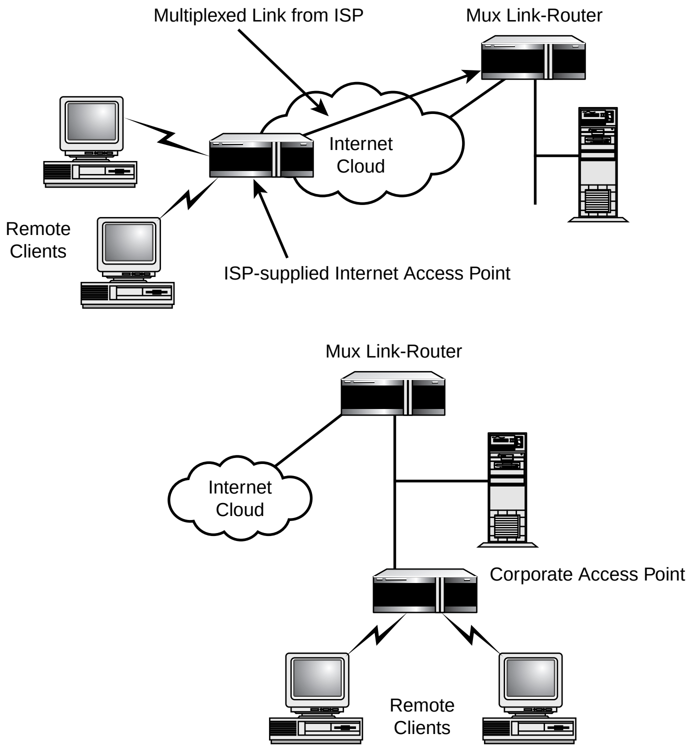
In some instances, you will need an elevated level of security. In these special circumstances you can take advantage of encrypting protocols such as PPTP and L2TP.

Point-to-Point Tunneling (PPTP)

PPTP is the result of cooperation between Ascend Communications, ECI Telematics, Microsoft, 3Com, and US Robotics. The group came to be known as the *PPTP Forum.* It was reasoned that PPTP would enable users and vendors to take advantage of the pervasive nature of the Internet. By supporting a standard, users would be able to dial in through their local ISP and securely tunnel through the Internet to their corporate network. This would reduce the requirement corporations had on generating and supporting their own remote access hardware.

It was hoped that PPTP would enable corporations to leverage the structure of the Internet by letting the ISPs do what they do well: connect individual users to the Internet. Corporations were then free to buy equipment that connected to the Metropolitan Area Networks, or MANs, and local loops to demultiplex incoming remote access connections. To them it looked like a link to another Internet site instead of a remote call. Figure 19.12 depicts the difference in architecture.

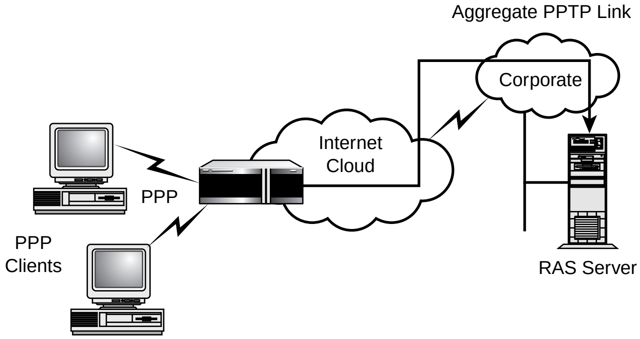
FIGURE 19.12
A network using a remote access box and one using a remote ISP and multiplexers and demultiplexers.



PPP Session Aggregation

PPTP is a client/server-based protocol that is specifically designed to tunnel through IP networks using PPP and Layer 2. PPTP has the interesting ability to support multiple PPP connections through a single PPTP tunnel. This works well in the ISP model where multiple remote users must be directed to a specific corporate entity (see Figure 19.13). These tunnels are generally referred to as *Virtual Private Networks* (VPNs).

FIGURE 19.13
PPTP supporting multiple users.



This would seem like a boon to most ISPs because PPTP requires out-of-band control on TCP port 1723 using the *General Routing Encapsulation* (GRE) protocol. However, GRE is not as pervasive as TCP or its cousin UDP, so many ISPs don't support it. Without this connection, PPTP will not operate.

The most popular implementation is to provide service between a dial-up *Point of Presence* (POP). In this way the ISP merely provides the IP service while the clients negotiate their own PPTP link with the private router. It should be noted that not all PPP software supports PPTP because it is a non-standard protocol. Microsoft's version in the Windows 98 and NT operating system is an example of a client and server that do support this service.

After the LCP functions have been dispatched, the physical connection is established, and the user is authenticated, PPTP relies on PPP to create the datagrams. PPTP then encapsulates the PPP packets for transmission through the IP tunnel.

Separate Control Channel

As mentioned earlier, PPTP uses two channels to support the connection: a data channel and a control channel. The control channel runs over the TCP link using port 1723. This channel contains information related to link status and management messages. These management messages are responsible for establishing, managing, and terminating the PPTP tunnel. This management channel supports the ability of PPTP to control the rate at which data is transported. This is useful if there is significant line noise or in case of a busy network creating lots of congestion that results in dropped packets.

Data is transmitted between the nodes via a data stream that is encapsulated in an IP envelope using GRE to control routing. Once again, not all ISPs support GRE so it may be up to the client and server to establish their own tunnels.

Multiprotocol Support

Another interesting feature of PPTP is its ability to support protocols such as NetBEUI, IPX, and for those that still use it, AppleTalk. Because PPTP is a Layer 2 protocol, it also includes a media header that enables it to operate over Ethernet or PPP connections.

Authentication and Privacy

As it turns out, encryption and key management are not part of the PPTP specification. PPTP relies on the authentication provided by PPP and relies on PPP to encrypt data as well. To enhance the privacy aspect of the PPP/PPTP duo, Microsoft has incorporated a new encryption method called the Microsoft Point-to-Point Encryption algorithm, which is based on the RSA RC4 encryption standard.

For authentication, PPTP uses CHAP, PAP, EAP, and MS-CHAP as supported by PPP.

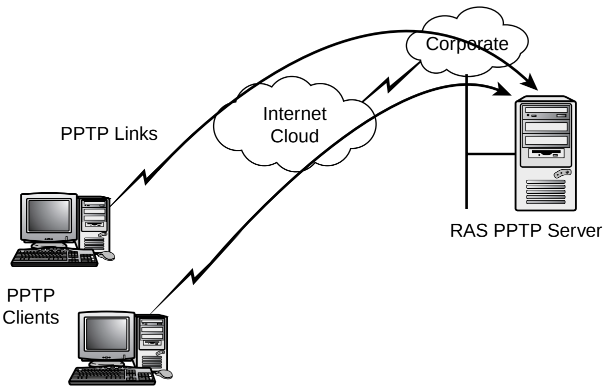
PPTP Tunnel Types

PPTP can support some basic tunnel connection configurations as discussed earlier. The type of tunnel is based on a few things. First and foremost is the ISP's ability to support the GRE requirements of PPTP. The next is the client's ability to support a PPTP connection. The user's computer will determine the end point of the tunnel: either an ISP's *Remote Access Server* (RAS) or his own computer. These two types of connections have come to be known as voluntary and compulsory tunnels.

Voluntary Tunnel

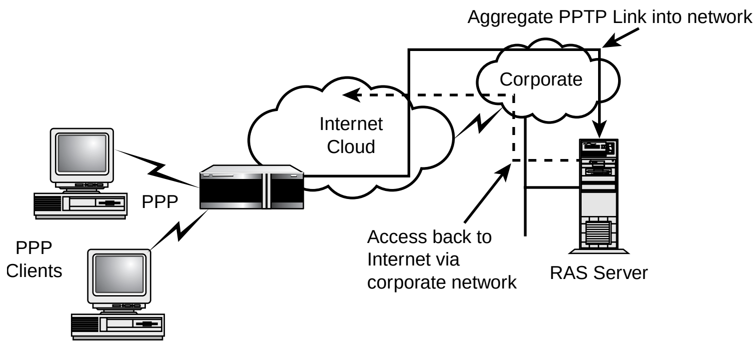
In a *voluntary* tunnel, the user initiates the PPTP connection to a corporate computer. However, this implies that the user must have a functional PPTP client such as those provided on the Windows 9X or the NT operating systems. There is no requirement for the ISP to provide anything other than basic IP services in this case (see Figure 19.14).

FIGURE 19.14
User to server PPTP over the Internet.



In the case where the ISP is providing a RAS server, the client need not have a PPTP client; only a PPP client is required. In a *compulsory* tunnel, the user connects to the ISP's RAS server and has no control over the tunnel (see Figure 19.15). In most cases the user doesn't even have knowledge of the PPTP tunnel's existence.

FIGURE 19.15
A compulsory tunnel.



Compulsory Tunnels

Compulsory tunnels have two subclasses: static and dynamic. Static tunnels use dedicated equipment and are also referred to as realm-based, or manual tunneling. A *realm* is part of a user's name and can be associated with a user's domain. The RAS server will use this information to determine where the termination point of the PPTP connection is. RAS servers must be manually configured to support this type of connection. The advantage to this is that corporations can control how users utilize the Internet. This method allows a user to connect to the corporate intranet in order to use corporate services. Connection to the Internet is at the discretion of the "powers that be." Access to the Internet is allowed through the corporate network (refer to Figure 19.15).

Dynamic tunnels are more efficient because the tunnel is only there when the need is there. The RAS server is linked to a RADIUS server in order to obtain user information. The tunnel is built based on the user's stored information. Information regarding usage and access controls is stored in the RADIUS server and is requested by the RAS server on demand.

Another advantage of compulsory tunnels is their ability to aggregate traffic. Multiple PPP clients can be combined into one PPTP connection back to the company intranet, thereby reducing bandwidth and its associated costs.

There is a disadvantage to compulsory tunnels that relates to security. The link from the client to the RAS server is not secure. However, the same could be said for a user utilizing a voluntary tunnel because there is nothing to stop him from connecting to the Internet, downloading a malicious bit of code, and *then* connecting to the corporate network.

The Layer 2 Tunneling Protocol (L2TP)

L2TP is very similar to PPTP in many respects. It combines PPTP with Cisco's *Layer 2 Forwarding* (L2F) protocol. L2F has an advantage over PPTP in that it isn't reliant on GRE. This means that it can be compatible with other media such as ATM and other packet-based networks such as X.25 and frame relay. However, it means that the specification must delineate how L2F packets are processed. The initial work leveraged UDP, placing L2F as a possible follow-up to PPTP.

L2F

In a similar manner to PPTP, L2F used PPP as the enabler supplying the initial connection and services such as authentication. Unlike PPTP, L2F used the *Terminal Access Controller Access-Control System* (TACACS) from the beginning. TACACS is another service born from necessity. A proprietary protocol from Cisco Systems, TACACS provides authentication, authorization, and accounting to support Cisco's router products. TACACS has some limitations, which are discussed later in the chapter.

L2F also makes use of tunnel connection definitions enabling it to support multiple tunnels within the L2F connection. In an effort to enhance the level of security, L2F supports an additional level of authentication. Instead of just the authentication at the PPP level, L2F adds authentication at the corporate gateway or firewall.

The benefits of L2F were carried over into the L2TP specification. L2TP uses the same method of connecting via PPP to support remote users. Leveraging the L2F work, L2TP uses its tunneling protocol. This feature becomes extremely significant when you consider the migration to ATM and frame relay networks that has been occurring over the past few years.

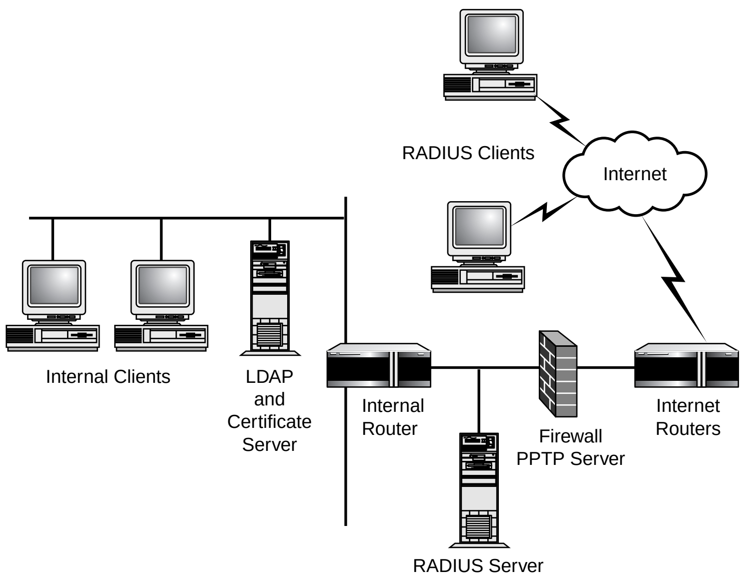
Authentication

Like PPTP, L2TP provides authentication through PPP. Using PAP, CHAP, and EAP to link to RADIUS servers, L2TP can be just as effective as PPTP. Adding to this level of effectiveness, L2TP adds TACACS, TACACS+, and IPSec-based services.

IPSec Support

IPSec is different from the other services in that it is an open specification that supports not only authentication, but privacy as well. IPSec is a considerably stronger security implementation than the simple PPP model. As you can see in Figure 19.16, L2TP has the ability to support a Public Key Infrastructure (PKI) by taking advantage of LDAP and strong authentication services. In short, a PKI is a way of managing public keys and the certificates they support. IPSec provides for the use of a number of different authentication and encryption tools such as the asymmetric encryption algorithms on which PKIs are based. However, although we will discuss these security mechanisms, PKI is well beyond the scope of this chapter and as such is not discussed here.

FIGURE 19.16
L2TP and PKI.



Like PPTP, L2TP relies on PPP to set up the connection. L2TP expects PPP to establish the physical connection, perform the initial authentication, create PPP datagrams, and upon termination, close the connection. This is where the similarity ends. L2TP will talk with the other node to determine whether the calling node is authorized and whether the endpoint is willing to support the L2TP connection. If not, the session is terminated.

Like PPTP, L2TP defines two different types of messages: control and data. Control messages are used to set up and maintain the tunnel and to control the transmission and reception of data. Unlike PPTP, which requires two channels, L2TP combines the data and control channels into one data stream. On an IP network this would have the appearance of packing both data and control into one UDP datagram, as shown in Figure 19.17.

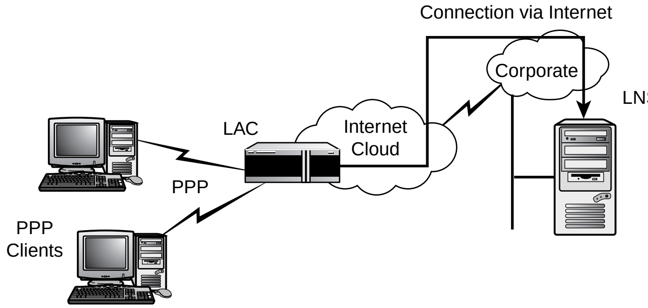
FIGURE 19.17
Example datagram of a UDP packet.

UDP Header	L2TP Header	PPP Header	IP Payload

The payload is essentially the PPP packet minus framing elements that are specific to the media. Because L2TP is a Layer 2 protocol, it must include a media header to indicate to the next layer how the packet is to be transmitted. Once again, this could be over Ethernet, frame relay, X.25, ATM, or the original PPP link. As you can see, this is quite versatile.

To alleviate network congestion, L2TP supports flow control. Flow control is implemented between an *L2TP Access Concentrator* (LAC), which functions as the network access server, and an *L2TP Network Access Server* (LNS), which has the role of providing corporate network access. Control messages contain information regarding transmission rates and buffering parameters. By exchanging this information, LACs and LNSs can regulate the flow of data and thereby control congestion (see Figure 19.18).

FIGURE 19.18
LACs and LNSs.

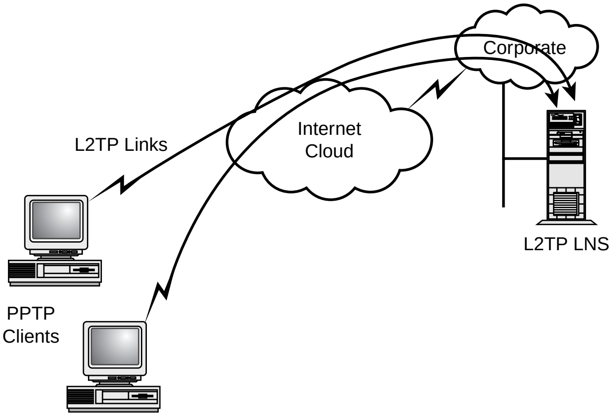


Another method of reducing network overhead employed by L2TP is by the compression of packet headers. You may recall the PPTP has a similar capability.

L2TP also supports two types of connection classes in a similar fashion to PPTP. L2TP supports voluntary and compulsory tunnels.

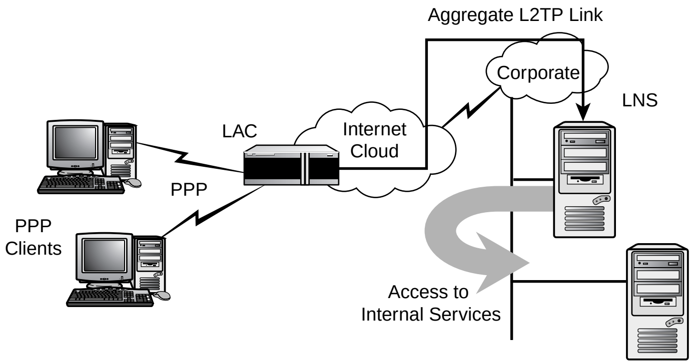
In a voluntary tunnel, the user initiates the L2TP connection from the user's computer. However, this implies that the user must have a functional L2TP client. There is no requirement for the ISP to provide anything other than basic connection services in this case (see Figure 19.19).

FIGURE 19.19
A user to server L2TP voluntary tunnel over the Internet.



In the case where the ISP is providing a LAC, the client need not have a L2TP client; only a PPP client is required. In a compulsory tunnel, the user connects to the ISP's LAC and has no control over the tunnel (see Figure 19.20). In most cases the user doesn't even have knowledge of the L2TP tunnel's existence.

FIGURE 19.20
Compulsory tunnel via ISP LAC.

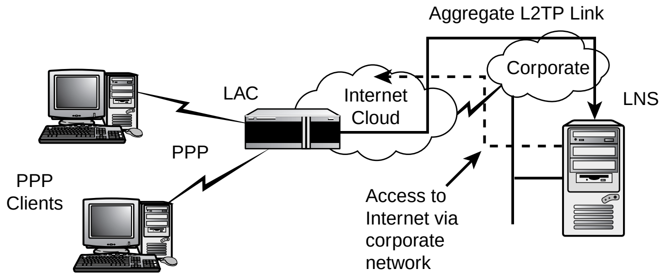


Compulsory tunnels have two subclasses: static and dynamic. Static tunnels use dedicated equipment. This is a poor use of resources because it ties up equipment even when the tunnel is not being used. Additionally, LACs must be manually configured to support this type of connection.

Dynamic tunnels are more effective because they only build the tunnel when the user needs it. User information is obtained by the LAC from an authentication server such as a RADIUS or TACACS server. There is a large advantage to using a compulsory dynamic tunnel in conjunction with an authentication server. Tunnels can be defined based on user information such as telephone numbers and authentication method. Authentication methods can include tokens and smart cards, a device we're seeing more of. Additionally, auditing and accounting can be performed in an effort to manage security and possibly finances. Auditing information could be the basis for departmental chargebacks for service or to help negotiate attractive rates from ISPs.

The advantage to this is the same as described in the preceding section. Users connect to the corporate intranet in order to use corporate services, and access to the Internet, if allowed, is through the corporate network (see Figure 19.21).

FIGURE 19.21
Compulsory L2TP connection to the Internet.



Once again, the advantage of using compulsory tunnels is traffic aggregation. Multiple connections can be combined into one L2TP tunnel back to the company intranet—bandwidth utilization is better and costs are lower.

We must remember that the disadvantage to compulsory tunnels is that the link from the client to the LAC server is not secure because it is a simple PPP link. As stated earlier, the same could be said for a user utilizing a voluntary tunnel. There is nothing to stop him from connecting to the Internet, downloading a malicious bit of code, and *then* connecting to the corporate network.

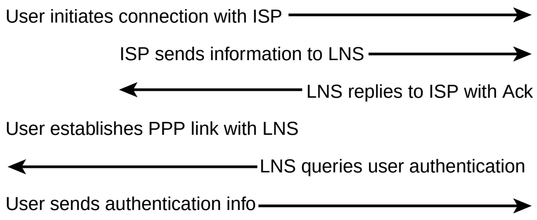
As was the case in the PPTP implementation, security must be addressed as a systems-level set of solutions. You cannot rely on technology as a sure way to provide security. Ignoring the cultural issues and processes will set you up for a security breach.

L2TP authentication via an ISP is somewhat more involved than that used by PPTP. In the initial contact with the ISP, the ISP can use one of three elements to identify the user:

- Phone number called from
- Phone number called
- Username or ID

After this has occurred, the ISP LAC will generate a new Call ID to identify the session within the tunnel and forward this information to the corporate network's LNS (see Figure 19.22).

FIGURE 19.22
The L2TP authentication sequence.



Then it's up to the corporate network to examine the information provided and decide whether to accept or reject the connection request. If the call is accepted, the next phase is PPP authentication. Although the endpoints have been identified and authenticated, it's important to note that messages are still passed in the clear. Anyone with a protocol analyzer can capture your data. Also, packets can be injected into the packet stream in an attempt to confuse or mislead the recipients. This is where IPSec can be used to prevent piracy.

Recall that PPP does provide encryption but it uses a shared secret to encrypt the data. Both parties must know this key for the process to work. This implies that some out-of-band method for key distribution must be employed. This is the case for L2TP tunnel authentication as well. Additionally, even using PPP encryption, L2TP does not protect the control information. Once again, IPSec can help.

IPSec

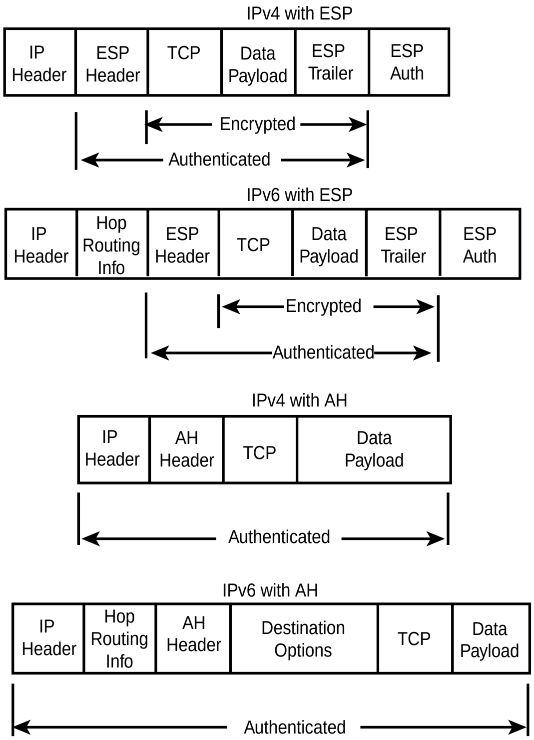
Because the TCP/IP protocol does not really offer any protection, a number of methods have sprung up over the years to fill this gap. However, these solutions did not offer cross-platform capability nor did they function reliably. To address this problem, the IETF has worked on a set of protocols that have come to be known as IPSec. Although this is not a section on Virtual Private Networks (VPN), a number of IPSec functions can be utilized by L2TP quite effectively, so this section will provide a brief overview of IPSec's features.

Originally designed to address the emerging IPv6 standard, RFCs 1825 through 1829 were published in 1995 and addressed how authentication and encryption would be performed on IP datagrams. Shortly thereafter, they were modified to address the Internet address scheme, IPv4, as it is today. These specifications divided the solution concept into two classes:

- Authentication
- Encryption

The authentication portion is addressed by an *Authentication Header* (AH) and the encryption element is addressed by the *Encapsulating Security Payload* (ESP). Each of these capabilities is represented by a different header that is applied to the IP packet, as shown in Figure 19.23.

FIGURE 19.23
IPSec packet header information.



Standards-Based Encryption

When used together, both of these capabilities can provide authentication and privacy. In addition to authentication and privacy, unlike the other authentication services discussed thus far, IPSec can also provide data integrity. *Data integrity* is the ability to determine whether the data has been modified in transit. This is very important if the data happens to be a corporate contract or your payroll deposit!

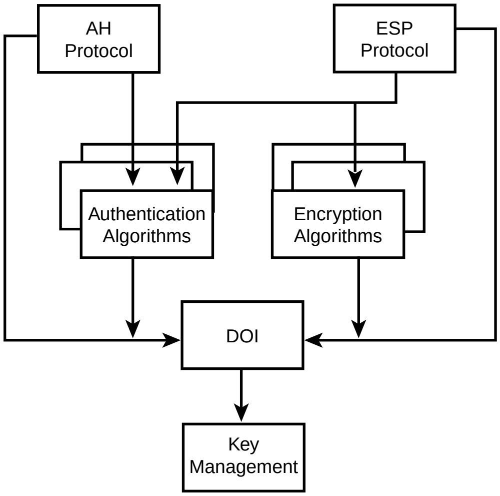
To ensure compatibility, the IPSec standard is built around a number of cryptographic standards:

- D-H, or Diffie-Hellmann, for key exchanges
- Public-key cryptographic algorithm for signing D-H key exchanges

- DES encryption
- MD5, SHA, and HMAC (Hash-based Message Authentication Code) for keyed hash algorithms
- Digital certificates

The main strength of this approach is versatility. As new algorithms are developed, they can plug into the IPSec architecture, as depicted in Figure 19.24.

FIGURE 19.24
IPSec architecture.



Establishing a Security Association

To start the process, both parties must establish a *Security Association* (SA). Although there are default settings for establishing a secure communications channel, IPSec provides for the negotiation of different key values, algorithms, and timing settings. To assist with the interpretation of the myriad values that are out there, IPSec uses a concept called the *Domain of Interpretation* (DOI) to assist with the standardization of these elements. This makes establishing the SA much easier. The SA determines the following:

- Authentication algorithm mode and keys used in the AH
- Encryption algorithm mode and keys used in the ESP
- Cryptographic synchronization parameters
- The protocol, algorithm, and key used for communications authentication
- The protocol, algorithm, and key used for communications privacy
- How often authentication and privacy keys are exchanged

- Authentication algorithm, mode, transform, and keys to be used by ESP
- Key lifecycles
- The lifetime of the SA
- The SA source address

Authentication

The AH offers a way to strongly authenticate the sender of the packet and the information contained within it. Using cryptographic hash functions to generate a checksum, this information is inserted with other control information between the IP header and any other packet headers (refer to Figure 19.23).

ESP

Because all the AH does is prove that the packet came from the sender and that the contents haven't been modified, it does little to protect the viewing of the packet content. This is the purpose of the ESP. The ESP will insert its information between the IP header and the rest of the packet, which is encrypted by the method specified in the *Security Parameter Index* (SPI). It should be noted that a number of different modes of operation yield some interesting capabilities. One mode of operation is *tunneling* (see Figure 19.25).

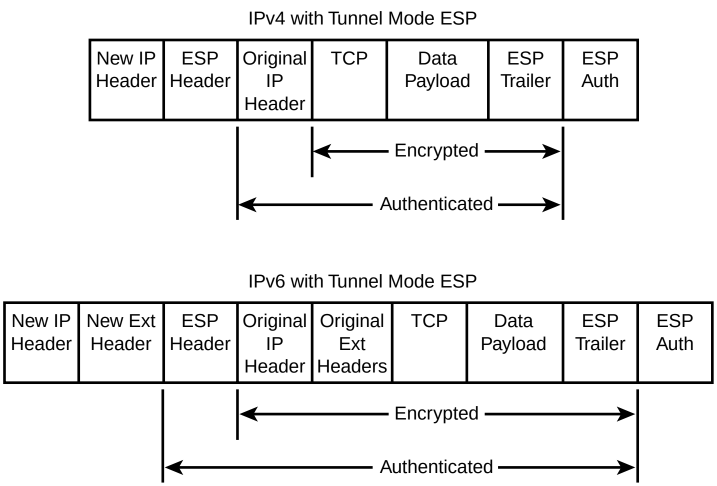


FIGURE 19.25
Tunneling IPSec.

Tunneling

In the tunneling mode, the entire packet is encrypted and authenticated and prefixed by the address of an intermediate gateway, such as a firewall. This prevents the disclosure of the ultimate destination to any would-be voyeurs. Because the entire packet including its headers is encrypted, the packet appears as data to another IP header. This IP header contains source and destination IP addresses of the tunnel endpoints and can be used to route the packet to its ultimate destination.

As you can see, IPSec offers a significant improvement over standard PPTP or L2TP security and is being widely used in products to build VPNs.

Summary

There are a number of ways to connect a remote user to a local LAN. SLIP, PPP, PPTP, and L2TP offer varying degrees of capability and protection.

PPP offers the basic services required to connect to a server and is significantly more capable than the earlier SLIP ever tried to be. With the ability to control the link and to support multiple protocols, PPP became the remote connection choice over SLIP in short order. SLIP, with its simple capabilities, may be suitable for dedicated terminal connections but it lacks the robust and versatile nature of PPP.

Adding to the capabilities of PPP, PPTP enables ISPs and corporate entities to more effectively leverage the Internet. By supporting more protocols, PPTP allows intranet services to extend to the homes and laptops of remote users. Taking advantage of remote authentication mechanisms such as PAP, CHAP, and RADIUS, PPTP offers the organization and increased control over who uses its network resources.

Adding yet again to the list of capabilities, L2TP combines the best of many protocols while leveraging the capabilities of the Internet and its related and varied media. Incorporating a strong security model as represented by IPSec, L2TP pushes the bar upward for remote access clients. As more capability is added to the network infrastructure, new methods must accompany them to ensure that they are not misused or misappropriated. L2TP promises to support that especially when used in conjunction with IPv6.

CHAPTER 20

Firewalls

by Tim Parker

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- **Using Firewalls** *512*
- **Securing Services** *515*
- **Building Your Own Firewall** *518*
- **Using Commercial Firewall Software** *519*

It is almost impossible to talk about networks, internetworks, and the Internet without hearing terms like firewall, gateway, or proxy server at some point. You've already seen what a gateway is and what it does, but we haven't touched on the subject of firewalls and proxy servers yet. Although firewalls and proxy servers don't really have much to do with TCP/IP specifically, they are used on TCP/IP-based networks as well as the Internet.

Therefore, it's worth taking a little time to explain what firewalls and proxy servers do, and how they work within a TCP/IP network. This chapter, along with Chapter 21, "Network and System Security," deals with the issues of protecting your network, hiding your information, and preventing damage to any data.

Securing Your Network

Firewalls and proxy servers, as well as encryption and authentication (covered in the next chapter), are all designed to provide security for your data. But why bother with security if you have nothing of value in your e-mails or on your gateway machine? The reason is simple: If you have a connection to the Internet, the Internet has a connection to you. This means that anyone on the Internet can potentially access your network if such access is not prevented. If there was no security set up on your gateway machine, anyone anywhere in the world with an Internet connection could use TCP/IP to travel through your gateway and onto any machine on your network. You probably have data that you don't want others to see stored somewhere on your network, so you need to consider security issues to prevent Internet users from accessing your network's interior.

When you set up security on a network you are actually trying to protect two things (and a third thing indirectly). The two things you are trying to protect are your data (stored throughout your network) and your equipment (anything connected to your network). If a hacker accesses your equipment, damage could result. The same applies to your data. You don't want to see your sensitive files flying all around the Internet as e-mail attachments, do you? Indirectly, you are also protecting your reputation, either individually or as a company. It wouldn't look very good for large companies like IBM or Hewlett-Packard if all their internal documents were freely available.

The most common type of security problem has already been mentioned—someone accessing your network over the Internet. Such unauthorized intrusions are the primary reason for good security. Intruders or hackers can get into your network and search your data, modify anything you have, and also cause physical damage to your systems. There are many ways intruders can access a network, ranging from exploiting known security holes in operating systems and applications to espionage. The primary role of security on a network, and the role specifically of a firewall, is to prevent unauthorized intrusion.

Another security problem is called *denial of service*. This is when hackers prevent you from using your own machines properly. Denial of service (DoS) has many forms. A typical example found on the Internet is flooding of a service such as e-mail, an FTP site, or a Web server. Flooding means that so much data is sent to the service that it is overwhelmed and either crashes or wastes time processing it so that legitimate users are denied access. Hackers routinely use e-mail flooding, in which thousands and thousands of e-mail messages are sent every hour to a target's e-mail server. The server flounders and the e-mail system is rendered unusable. The same technique works for most TCP/IP utilities such as FTP, Telnet, and Web servers. Another aspect of denial of service has to do with rerouting—instead of accessing a particular service on one machine, you are rerouted to another site. This can happen if DNS servers are compromised and where legitimate DNS names have incorrect (or illegitimate) IP addresses.

There are several ways to protect your network, its data, and its services. The one many people rely on is anonymity or obscurity. The reasoning is that if no one knows about your network and its contents, then the network is safe. This is "security through obscurity," and is false security, of course, because there are too many ways to discover what's on the Internet to keep yourself hidden for very long. It is naive to assume that hackers won't bother with your site because you think they'll find nothing of interest. The challenge of finding your data is all that most hackers need to get going.

The most widely used form of security is called host security, and has to do with securing each machine on the network separately. You rely on host security when you set up Windows access permissions, as well as UNIX file system permissions. Although host security can be used to secure individual machines, it is incorrect to assume that a whole network with individually secure machines is also secure. All it takes is one hole somewhere and the entire network may be open to hackers. Also, because host security is not equally applied across all machines, services can be exploited on a weak machine to access a strongly secure machine without any problem.

The Role of Firewalls

The level of security most of us should be looking at is network security. This means securing all points of access to the network first, then relying on host security inside as well. The key component of network security is the firewall—a machine that acts as the interface between the network and the Internet, with security its primary concern. A firewall has several roles to play:

- It restricts access to the network to a few locations.
- It prevents unauthorized users from gaining access to the network.
- It forces network traffic to leave for the Internet at particular, secure locations.

- It prevents denial-of-service attacks.
- It restricts what an Internet user can do on the network.

Firewalls are not restricted to network-to-Internet connections. They are also used for remote access servers (dial-in access) and network-to-network connections. The whole concept of the firewall is to channel all traffic in and out of your network through one or more particular locations that are set up to control access and services.

Using Firewalls

Many people think of a firewall as a single machine, and this can be the case for some networks. Dedicated single-box firewalls are available that do nothing more than act as a security gateway for your network. Alternatively, a single machine can run dedicated firewall software and nothing else. However, the term *firewall* has more to do with the functions performed than a physical device. A firewall may comprise several machines working together to control the network-Internet connection. Many different programs may be used to provide these firewall services. Firewalls may also do many tasks other than simply monitoring network access.

Firewalls are not foolproof. They are often vulnerable due to holes in their design that hackers can exploit. In addition, firewalls are often expensive to implement and require quite a bit of time to install and configure. However, the benefits most networks gain from the firewall far outweigh the problems.

Firewalls can do a lot for you. They provide a single point of security implementation for a network, so you can make changes in one location instead of on every machine (you can forbid anonymous FTP, for example). Firewalls can enforce security policies network-wide, preventing access to some Internet services for everyone inside the network, for example. Firewalls can't do some things for you, though, and you do need to understand the limitations. Firewalls are only good for the network-to-Internet connection. The firewall does nothing to stop people inside the network from doing anything they want to other machines on the network. Firewalls can't protect your network from intrusion if you have other connections, such as a Windows PC with a modem connecting to the Internet through an ISP (if it doesn't go through the firewall, you've circumvented the security a firewall offers). And a firewall can't prevent many common Internet-distributed problems, such as viruses and trojan horses.

The two basic ways to implement a firewall on a network are

- Build the firewall yourself from basic network services
- Buy a commercial product

The latter is by far the easiest, but also the most expensive. A typical firewall software package for a UNIX machine, for example, can cost upwards of $10,000 for a small network. As the network size grows, firewall software can cost 10 times that. The advantage to a commercial firewall package is simple: Most of the work has been done for you. You simply use menus to select the services you want to allow and deny, and the firewall software does it all for you. Building your own firewall means using the settings on the machine between the network and the Internet to perform these same tasks. Each service has to be tweaked manually to either allow or prevent access. For a UNIX machine, for example, this means working with the network configuration files and files such as `/etc/services` to prevent access to the network for some requests. Building your own firewall takes a lot of time, expertise, and quite a bit of experimentation. On the other hand, you don't have to spend lots of money for firewall software.

When setting up a firewall, either manually or from a commercial product, you will have several facets of security protection available to you. Whether you choose to implement them all is up to you. However, you should know what some of these facets, such as proxy servers and packet filters, mean. The next few sections look at these techniques in more detail.

Proxy Servers

A proxy server sits between the network and the Internet and accepts requests for a service, analyzes them, and forwards them on as allowed. The proxy service provides a replacement connection for the service, and as such acts as a proxy. For example, if you are inside a network and want to telnet to a host on the Internet, the proxy server accepts your request, decides whether to grant it, and then establishes the telnet session between itself and the target, as well as between itself and you. It gets in the middle, hides some information about you, and yet still allows the service to proceed through it. Proxy servers deal with services and applications, and as such are often called application-level gateways.

Why use a proxy server? Suppose you are on a highly secure project and want to hide information about the network you are on—its IP addresses, user logins, and so on—from the Internet in general. If you established a telnet session with a remote host through the Internet, your IP address would be transmitted in the packets. From the IP address, hackers can determine the size of your network, especially when they see a lot of different IP addresses going by. A proxy server changes your IP address to its own, and uses an internal table to resolve incoming and outgoing traffic to the proper destination. To someone on the outside, only a single IP address (the proxy server's) is visible. In other words, a proxy server, because of the way it works, also does Network Address Translation (NAT) functions.

Proxy servers are always implemented in software and need not be part of a firewall package, but usually are. Most commercial firewalls include proxy service capabilities. Most proxy server software does more than just act as a user's proxy; they can also control which applications are used and can block some incoming and outgoing data.

If you are building your own firewall, a number of packages are designed to allow you to do so. The most well known is SOCKS, which allows applications to work with a proxy conversion software package. Another popular package is TIS FWTK (Trusted Information Systems Internet Firewall Toolkit), which provides proxy servers pre-written for many TCP applications such as FTP and Telnet.

Packet Filters

A packet filtering system allows packets to go from the network to the Internet, and vice-versa, selectively. In other words, it allows some packets to be filtered out and not sent, whereas others are allowed through without hindrance. Packets are identified by the type of application that constructed them (some of the information is in the headers, as you saw in earlier chapters). The header of a TCP/IP packet contains the source and destination IP addresses, source and destination ports (which help identify the application), the protocol (TCP, UDP, or ICMP), and other information. If you have decided to block all FTP traffic in and out of your network, for example, the packet filtering software would detect anything with a port number of 20 or 21 and not allow it through. Packet filtering can be performed by the firewall software or by a router. In the latter case, the router is called a *screening* router.

The difference between a standard router and a screening router is in the way they examine packets. A normal router simply looks at the IP addresses and sends packets on the correct path to their destination. A screen router examines the header and not only figures out how to route to the destination but also whether it should, based on a set of rules. In other words, a screening router provides more than a Layer 3 functionality.

You might think you can get around a packet screening system by changing the port number, and to some extent this is possible. However, because the packet filter software is resident on your network, it can also figure out which interface the packet is going to and where it came from. So, even if the TCP port numbers are different, the packet filtering software can sometimes block the traffic properly.

You can use packet filtering software in a number of ways. The most common is to simply block a service such as FTP or Telnet. You can also specify machines that are to be blocked or let through. For example, if you find that a particular network has been the source of a lot of problems for you, you could instruct the packet filtering software to discard any packets from that network based on the IP address. In extreme cases, you can block all services, or permit only a few services, such as e-mail through the filter.

Securing Services

One of the key aspects of setting up a firewall is to decide which services are to be allowed to pass through the network-to-Internet connection, and which are to be restricted. For example: Are you going to allow FTP from outside the network to a machine inside? What about Web requests?

This section takes a very quick look at the primary services used over a firewall and the major security problems with each. You can decide whether you should allow or deny the service based on your own network's requirements.

Most network firewalls are set by default to allow six services to pass through:

- E-mail (SMTP)
- HTTP (World Wide Web access)
- FTP
- Telnet (remote access)
- Usenet (NNTP)
- DNS (hostname lookups)

These six are not without their security problems, as you will see in the following sections.

E-mail (SMTP)

E-mail is the most widely used service on the Internet, and it is very unlikely you will want to restrict access to e-mail through a firewall. There have been a number of security-related problems with mailers such as sendmail that are popularly used on the Internet, but because of the large amount of attention these problems have received, they have been fixed. So the mailers themselves are not very vulnerable to hacking, but the e-mail content is subject to the problem of viruses.

Most e-mail systems are implemented using Simple Mail Transfer Protocol (SMTP). Whenever an SMTP server handles mail, it is often done so either as a superuser account or as the account to which the e-mail is addressed. A clever hacker can exploit this change in permissions. Further, the most common SMTP server is sendmail, which runs under UNIX. You must implement the latest patches to sendmail to prevent exploitation by a hacker.

Also, another related problem is that the SMTP protocol does not provide for any authentication of the message header, and so it is easy for hackers and bulk-mail programs to forge message headers. Sendmail must be configured to check for valid e-mail or DNS names used in message headers. You can find the most recent updates to sendmail at `http://www.sendmail.org`.

Note

Recently, Microsoft's mail clients such as Outlook and Outlook Express have come under attack. Most of these attacks exploit the easy access to Outlook through scripting languages such as VBScript to do their damage. Typically, the mail client is "fooled" into executing some script to do its damage. The script can read the address book and send itself to the people listed in the address book.

HTTP: World Wide Web

Practically every network in the world has access to the Internet these days, and it is very likely you will not want to restrict access through a firewall from your internal network. Allowing access to the Web from machines inside your network doesn't pose much of a security risk other than downloads or Java applets with malicious designs, all of which should be taken care of with virus detectors on the receiving machines.

Of more importance is allowing Internet users into your network to access Web servers. This can prove to be a real security problem, and one of the best ways around the security issue is to use separate hosts outside the firewall to provide the Web services. Most of the Web servers currently available are reasonably secure, although a few holes are known that can be exploited by hackers. IIS from Microsoft has had a history of security holes that have to be fixed by applying service packs. An important security consideration is any extensions you load on your server for things such as Common Gateway Interface (CGI), which must be carefully secured with appropriate access permissions.

FTP

The File Transfer Protocol (FTP) is widely used on the Internet. However, the ability to transfer any file into the network from the Internet means that the incoming files could be laden with all kinds of programs, such as viruses and spoofs, that send information about the network back to a hacker. The FTP service itself is quite secure, but again, a few well-known holes must be patched by system administrators, depending on the version of FTP.

The more important problem with FTP is anonymous FTP, which allows anyone access to your FTP server with a guest login. Permissions for an anonymous FTP server have to be very tightly controlled; otherwise, a knowledgeable hacker can easily exploit the server.

Note

UNIX systems such as Linux are by default configured with the anonymous account “ftp,” whose home directory is set to /home/ftp. Anonymous access is confined to this home directory using the system chroot call so that guest users cannot access files outside this area. As a safety precaution, you should prevent system administrators from using their regular accounts for logging onto an FTP server. This is because FTP sends the user password information as clear text, which can be discovered by capturing packets. To prevent certain users such as root and sysadmin from logging on using their accounts, include their account names under the /etc/ftpusers file. You might also consider using ssh (secure shell) for doing all of your telnet and ftp sessions. Ssh sets up a VPN between the client and the service. On UNIX systems, sshd (secure shell daemon must be enabled and running). To get free implementations of ssh, visit the Web site www.ssh.com.

Finally, you should not allow Trivial FTP (TFTP) to be used across a network-to-Internet interface. Only a few applications use TFTP, and these are not likely to be used across the network. The reason for this is that TFTP does not require any user authentication. You must also ensure that TFTP access is confined to a specific area. On UNIX systems, TFTP by default is restricted to the directory /tftpboot.

Note

On UNIX systems, TFTP can be disabled by commenting out the TFTP service entries in /etc/inetd.conf or the /etc/xinetd.conf files and restarting the inetd or xinetd daemons.

Telnet

Telnet is widely used to allow a user to connect to another machine in a remote location and behave as if it is directly connected. The Telnet utility has one major drawback: All information is sent unencrypted. If Telnet sends a login and password, they are sent in the clear, allowing a hacker to intercept and exploit the information. Authentication protocols can be used to combat this problem, but Telnet is often exploited anyway because all kinds of information flies back and forth between the client and server.

The Berkeley utilities (`rlogin`, `rsh`, `exec`, and so on) are often used in place of Telnet. The Berkeley utilities rely on trusted hosts, which are not valid over the Internet. The Berkeley r-utilities are easily hacked and are very insecure, and should not be allowed to pass through a firewall.

Note

Instead of using Telnet, consider using ssh (secure shell), which enables encrypted sessions between clients and servers.

Usenet: NNTP

Network News Transfer Protocol (NNTP) is the most commonly used way to send and receive Usenet newsgroups and postings. If you plan to accept a newsfeed into your network, you will have to plan carefully in order to allow NNTP to be accepted with security in mind. NNTP is quite easily exploited by hackers to allow access to an internal network. Fortunately, securing NNTP is easy because the communications between NNTP hosts is almost always the same in each session.

A more important issue for Usenet users, especially in larger organizations, is keeping internal private newsgroups from being transferred out into the Internet. You may also want to restrict incoming newsgroups to a specific type. NNTP can be configured to allow any newsgroups to be accepted or rejected.

DNS

DNS is an integral part of larger networks, and ties in to Internet hosts for lookups. DNS by itself is not usually a security issue, although it can become one because of the protocols it piggybacks onto. Authentication methods can be installed to verify that requests are genuine and that there is no misdirection. For the most part, though, DNS is quite secure.

Building Your Own Firewall

You can construct your own Internet firewall, although you really need a very good knowledge of the operating system and TCP/IP. Windows 95 and Windows 98 make poor firewalls because of the design of the operating system itself. UNIX and Windows NT/2000 are better, although Windows NT/2000 is harder to properly configure than UNIX.

The steps you must follow to construct your own firewall under Windows NT/2000 or UNIX are far beyond the scope of this book. There are several books devoted solely to the subject, depending on the operating system you choose to use. For the most part, the process involves blocking all the services you don't want to allow into your network and configuring the firewall to prevent hackers from gaining access to the firewall itself. The process of building your own firewall takes a while to complete properly even when you know what is necessary.

Note

The following Web sites can help you in setting up your own firewall:

`http://www.linux-mag.com/1999-08/guru_01.html`

`http://www.linuxgazette.com/issue26/kunz.html#fire`

`http://hotwired.lycos.com/webmonkey/01/31/index2a_page4.html`

`http://tech.irt.org/articles/js149/`

`http://www.practicallynetworked.com/serving/firewall_config.htm`

`http://www.linuxworld.com.au/article.php3?tid=8&aid=160`

`http://www.isaac.cs.berkeley.edu/simple-firewall.html`

`http://www.ncmag.com/2001_05/ifolder51/settingup..html`

Using Commercial Firewall Software

Many firewall packages are available on the market, and they are usually quite expensive. An example of a firewall solution is Cyberguard from Cyberguard Corporation. Others include BorderManager from Novell, Checkpoint from Check Point Software Technologies, and Eagle firewall from Raptor Systems. Consult the Web site `http://www.thegild.com/firewall/` for other names of commercial firewall solutions.

Cyberguard is available for Windows NT/2000 and UNIX platforms (it started on UNIX and moved to NT/2000 recently). Cyberguard is popular because it is not only one of the most secure firewalls that have been tested, but it is also extremely easy to install, configure, and manage.

Note

For more information about Cyberguard, check out the company's Web site at `http://www.cyberguard.com`. You'll find a description of the package as .well as several white papers. For more information on firewalls and security problems with them, check the CERT (Computer Emergency Response Team) site at `http://www.cert.org`.

Cyberguard is particularly easy to install and configure on a Windows NT/2000 server, taking less than 15 minutes for simple network configurations. Cyberguard is designed to work with dual-homed hosts with one connection to the internal network and the other to the Internet (either directly or though an ISP). When installing the package, Cyberguard lets you choose one of three default security configurations, as shown in Figure 20.1.

FIGURE 20.1
Three Cyberguard default settings cover most Windows NT/2000 configurations where the interface is called SecureGuard.

After choosing one of these default settings, you can check all the settings it affects by stepping through the different screens and verifying the choices. Figure 20.2 shows you one of the settings screens showing how the choice affects Windows NT/2000 accounts and passwords.

After choosing a default, Cyberguard reboots your Windows NT/2000 server and the protection is in effect from that point on. As an administrator you can modify the behavior of any aspect of the firewall. Figure 20.3 shows the Packet-Filtering Rules screen that lets you specify which packets are to be passed and which are to be stopped. As you can see, Cyberguard makes good use of Windows dialogs to simplify what is normally a complicated process.

FIGURE 20.2

Choosing a Cyberguard default affects particular items, which you can see in a series of screens like this.

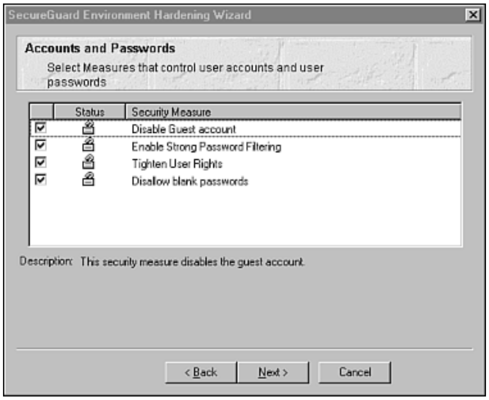
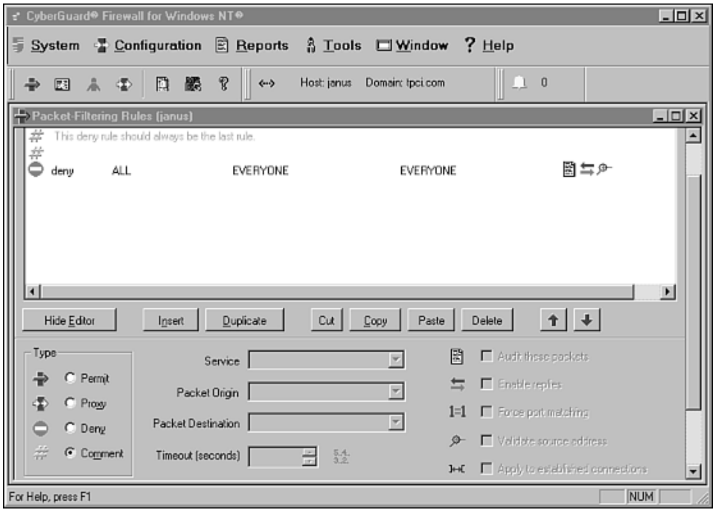


FIGURE 20.3

Cyberguard's packet filtering dialog lets you choose how to filter incoming and outgoing packets.



Proxy server behavior is just as easy to set up. Figure 20.4 shows Cyberguard's proxy server dialog. Selecting proxies to be used is as simple as choosing items from a list. In this figure, we are setting up the FTP proxy service.

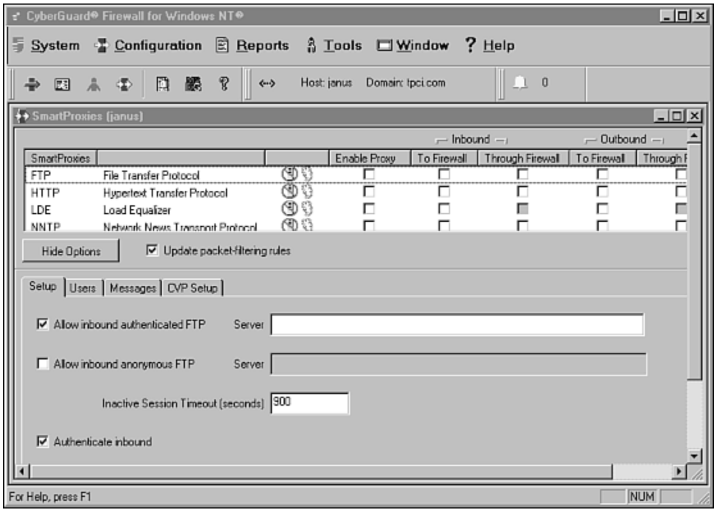


FIGURE 20.4
Cyberguard's proxy service window is easy to use and understand.

One other aspect of firewalls that Cyberguard excels at is DNS usage. As Figure 20.5 shows, you can set up DNS easily and even specify zones within a network.

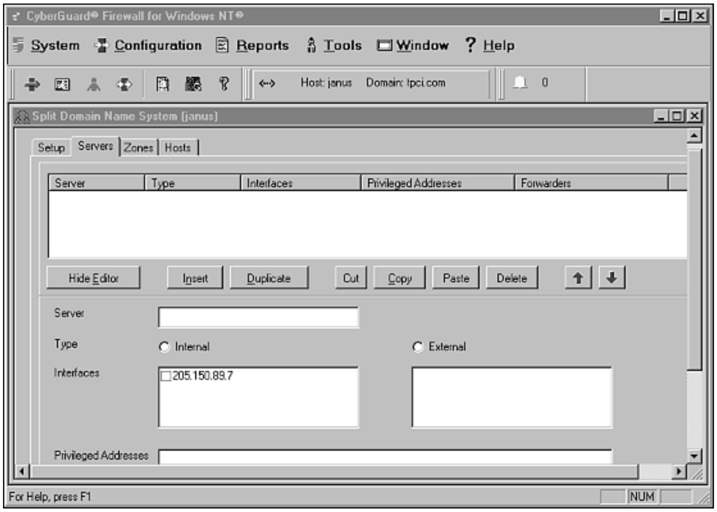


FIGURE 20.5
Setting up DNS through the Cyberguard GUI.

Many other commercial packages are available to act as firewalls. Many magazines that deal with networking conduct head-to-head tests on a regular basis. If you are looking for a commercial firewall, conduct a fair bit of research first because the quality of available firewall software varies enormously, as does the price.

CHAPTER 21

Network and System Security

by Tim Parker

IN THIS CHAPTER

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In the last chapter you saw how firewalls, proxy servers, and packet filters work. Firewalls are an important part of providing security to a network, preventing intrusion and access to sensitive data. However, blocking intruders into your network is only part of the security issue. You must consider many other things, including making sure any data you do send over the Internet cannot be read by unwanted parties, making sure that the person you are sending mail to (or receiving mail from) is the person you think he or she is, and providing extra levels of security inside your network in case someone does manage to get through your firewalls.

Gauging the amount of security you need is difficult in absolute terms. Although most operating systems offer basic file and directory protection, you may need encryption or other methods of locking up your system. There is no overall assessment of security levels, although the U.S. Department of Defense did try to assign different levels of security for its minicomputers and mainframes (most running versions of Unix or proprietary operating systems). The DoD defense levels and their description, in order of least to most security, are as follows:

- **D (minimal protection):** No provision for security or protection of data
- **C1 (discretionary security):** Users are identified by a login and access to files or directories can be controlled
- **C2 (controlled access):** C1 plus audit capabilities (record system activity) and assignment of administrator privileges to logins
- **B1 (labeled security):** C2 plus access controls that cannot be overridden
- **B2 (structured protection):** B1 plus security for all devices, support for trusted hosts, access controls for applications
- **B3 (security domains):** B2 plus ability to bundle system objects into discrete groups with access controls within that group
- **A1 (verified design):** B3 plus verified trusted system design of hardware and software

The A1 security level is generally regarded as unattainable, and no operating system currently is available that supports this level (at least to public knowledge). Most Unix systems and Windows NT can attain C2 security levels, and a few operating systems are certified for B1, but beyond that the constraints security imposes on the system become unmanageable.

So what can you do with your existing Windows, Macintosh, Unix, or Linux systems on a LAN? You need to take many steps to secure your systems as well as your applications from intrusions. If you are connected to the Internet through TCP/IP, you need to be aware of the security problems associated with that protocol and its applications.

This chapter starts by looking at the subject of encryption, one of the few ways of protecting your data from being read even if it is intercepted. After that, it looks at network security and TCP/IP application security.

Using Encryption

It is rare to find corporations and businesses that are not becoming more concerned about their data's security, especially with daily reports of hackers making their way into corporate networks, industrial espionage, and ex-employee sabotage. The need for tighter data security is especially important with the rapid rise of remote access work, where employees access corporate networks from home, hotels, or on the road through cellular services. You have to consider protecting the data that is being sent back and forth over the Internet and telephone lines, so that anyone who intercepts the data cannot read it. The only effective and relatively easy way to protect this data is with encryption.

Encryption has become a huge and lucrative business. Companies dedicated to encryption products are sprouting up all over the place, joining the few core companies that have pushed this technology for decades. Just a couple of years ago, getting really good encryption was difficult because intelligence agencies tried to prevent encryption algorithms from being too strong (hence preventing them from snooping themselves). Until a couple of years ago, it was illegal in the U.S. to export any encryption product that had anything better than 40-bit encryption because encryption systems are considered a weapon. With the ease of access to free or shareware encryption products through the Internet, though, as well as pressure from application and operating system vendors, 128-bit encryption products can now be distributed to all but a few countries. Even stronger encryption methods are available for selected countries, as well.

Without going into excessive detail at this point, encryption uses a key to scramble data, making it unreadable to someone who doesn't have the key to decode it. The longer the key, the more time necessary to crack the encryption code. Simple password encryption works well because the password must be known explicitly. When you scramble a message or data with the password, only that same password can decrypt the message.

If you are curious about how easy password-based encryption tools are to use, check out the CodedDrag software at `http://www.fim.uni-linz.ac.at/codeddrag/codedrag.htm`. An evaluation copy of CodedDrag is free, and registering the copy for unlimited use is a matter of making a small donation to the site's server fund. CodedDrag was developed at the University of Linz, Austria, and provides a very fast implementation of the *Data Encryption Standard* (DES) encryption tool. (In fact, CodedDrag offers DES, Triple-DES, and Blowfish encryption methods; the latter two are much more difficult to break than DES.) CodedDrag can be embedded as part of the Windows 95/98 or Windows NT desktop, adding encrypt and decrypt options to pop-up menus. After supplying a password to the system once, files are encrypted and decrypted so quickly you don't notice the process. In Windows 2000, the use of the NTFS version 5 filesystem enables you to use encryption to encrypt any file or folder contents by marking the file or folder for encryption. Only the user or recovery agent (Administrator accounts) can decrypt the files. The files are automatically decrypted when used and encrypted when they are closed.

Public-Private Key Encryption

Public-private key encryption is much more popular with Internet users because it allows for decoding of messages without knowing a different password for each. The way a public-private key system works is simple: You have two keys or password strings, one of which is freely available to anyone; the other string, your private key, is known only by you. For someone to send an encrypted message to you, they need your public key. The encryption software then scrambles the message based on your public key. After you receive the message, only the private key can unscramble it again, making you the only person who can read it. The public key cannot unscramble the message. When you want to send a message to someone else, you need his or her public key. To help spread this type of encryption, many users append their public keys to their email.

RSA Data Security

One of the earliest commercial products offering public-private key encryption tools was RSA Data Security (`http://www.rsa.com`), founded in 1977 by three MIT scientists. RSA is still in wide use, and is relatively inexpensive, very secure, and easy to use. The RSA software is available in several forms for different operating systems, but in its simplest form adds a few menu items to browsing tools like Windows Explorer. Selecting a file and using the Encrypt menu option automatically encrypts the document file after you enter a password. To decrypt, a menu option brings up a window asking for the password, and if correct, the restored file is available. Passwords can be stored to simplify the process.

Phil Zimmermann's PGP

One of the most famous encryption tools is Phil Zimmermann's Pretty Good Privacy (PGP). The U.S. government criminally charged Zimmermann because he made PGP freely available over the Internet. The case was eventually dropped, but it practically assured the widespread use of PGP, especially in other countries. PGP is available from many Web sites and it's not unusual to see PGP keys appended to email messages.

Symmetric Private Key Encryption

The most basic form of encryption is called *symmetric private key*. This is much like the decoder rings that were popular years ago. With a simple symmetric key a substitution code is used where some other letter replaces each letter. For example, all a's are replaced by x's, all b's are replaced by d's, and so on. The simplest form of a symmetric key chooses a new starting point for the alphabet and moves along in order (a becomes d, b becomes e, c becomes f, and so on).

More flexible symmetric keys randomize the substitution, and sometimes a password is used to figure out how the scrambling is achieved. Symmetric keys are easy to develop and they work quickly. Unfortunately, simple symmetric keys are the easiest to break. The reason is simple: Given a reasonable amount of text, you can figure out from letter frequency which letter mappings are used. The letter *e* is the most common in the language; if the scrambled text has mostly x's, you can assume x and e are mapped together. After you get a few of these mappings, other mappings start to become clear by looking at word fragments, much like a crossword puzzle. The same key is used for both encryption and decryption. To make symmetric keys more secure, more ways of scrambling the choice of each substitution have been developed.

DES, IDEA, and Others

IBM developed the Data Encryption Standard in 1976 for the U.S. government. The DES algorithm uses a 56-bit encryption key, which means that 72,057,594,037,927,936 keys are possible. The same key is used to encrypt and decrypt messages. DES is not a simple symmetric private key in that the substitution or mapping of letters changes with each letter. In theory, breaking DES has always been possible. There are 72 quadrillion possible combinations that need to be tested, but a group did rise to the challenge (and won $10,000 for its efforts) and proved that DES is not totally secure. More information about the DES challenge is available from `http://www.cryptography.com/des`.

Note

A machine built by Cryptography Research, Advanced Wireless Technologies, and EFF was used to demonstrate fast key searches for the DES. The DES Key Search Project developed specially designed hardware and software to search 90 billion keys per second, determining the key and winning the $10,000 RSA DES Challenge after searching for 56 hours.

In the Proceedings of DIMACS workshop on DNA computing, 1995, a paper was published that showed the use of molecular computing to recover the DES key

> in about 4 months of work given one arbitrary (plain-text, cipher-text) pair. Furthermore this paper showed that under a chosen plain-text attack, it is possible to recover the DES key in one day using some preprocessing. This method can be generalized to break any cryptosystem that uses keys of length less than 64 bits.

Triple DES encryption (3DES) that is a modification of the basic algorithm that uses more bits, effectively making it much more difficult to break.

The *International Data Encryption Algorithm* (IDEA) is probably the most secure algorithm in use today. Developed at the Swiss Federal Institute of Technology, IDEA uses a 64-bit block in a 128-bit key with a feedback operation to strengthen the algorithm. An enhanced version of IDEA called Triple IDEA is now available. The full IDEA algorithm takes a while to work, so several simplified versions have been developed. One popular system is Tiny IDEA. IDEA is believed to be stronger than both DES (56-bit keys) and triple-DES (112-bit keys). IDEA also has the distinction of being the conventional cipher used in PGP in conjunction with the RSA public key algorithm. Some characteristics of Tiny IDEA are

- Files are processed in place (effectively wiping the original).
- It uses 8 round IDEA in ciphertext feedback mode.
- The initialization vector is set to zeros.
- The feedback is done on 8-byte blocks.
- The IDEA key is the user key followed by '\r' and filled with zeros.
- It is optimized for size, not speed, but runs fast anyway.

For more information about Tiny IDEA and to download a free copy, go to `http://www.cypherspace.org/~adam/rsa/idea.html`.

CAST (named after the developers Carlisle Adams and Stafford Tavares) uses a 64-bit key and 64-bit block for encryption. There's a lot of stuff going on in the background with CAST, called S-boxes, which use 8- and 32-bit inputs. The details are not important here, especially because they take a whole book to explain. CAST has not been deciphered to date, but like IDEA it can be slower to encrypt and decrypt. For more details on CAST, go to `http://www.cs.wm.edu/~hallyn/des/sbox.html`.

An encryption system called Skipjack was developed by the National Security Agency specifically for the Clipper chip, which the U.S. government wanted to have included in all online devices (hence allowing monitoring). The Clipper chip was never implemented, but Skipjack systems are available. The details of Skipjack are classified, but it is known to be an 80-bit key with 32 rounds of processing. Skipjack uses two keys: one private and one master held by the government. In theory, it would take 400 billion years to break Skipjack using the best available hardware today. AT&T provides the Clipper chip (and hence Skipjack) to several manufacturers, including themselves.

RC2 and RC4 were secret algorithms developed by RSA Data Security. Unfortunately for them, the source code was posted on the Internet, making the secret not very well kept! RC4 was considered quite secure and was used by Netscape for its exported versions of Navigator. The encryption was broken by two different groups at about the same time, taking about eight days to accomplish the task.

Which is the fastest and most secure of the encryption algorithms mentioned? The most secure is a toss-up, with Triple DES, IDEA, Triple IDEA, and Skipjack all secure enough to make unauthorized decryption almost impossible. However, the overhead required to encrypt and decrypt is noticeable. If we consider DES to take one second to encrypt or decrypt a document, Triple DES requires 3 seconds, IDA 2.5 seconds, and Triple IDEA 4 seconds. This may seem short, but with large documents and many files, the delays that the more secure algorithms impose become noticeable. In theory, Skipjack is as fast as DES, but who wants to trust the government with the keys?

The primary public-private key encryption system in use today is RSA, named after the inventors (Rivest, Shamir, and Adleman, for those wanting to impress others with trivia). A close competitor is Phil Zimmermann's PGP. Both RSA and PGP can use very long keys, often 100 bits or more. The longer the key, the more time required to encrypt and decrypt, and the tougher the message is to decrypt without a key. Having 1024-bit keys is not unusual. The RSA Web site (`http://www.rsa.com/rsalabs/`) discusses the strength of the encryption based on key length. A 512-bit key can be broken with a fair bit of computing power, but it can be done. Longer keys (768-bit or 1024-bit) require more horsepower than most hackers (except governments) will have access to. In theory, any key system can be broken either through brute-force analysis or some lucky guesses based on the encrypted text, but for all intents and purposes both RSA and PGP are secure as long as long keys are used.

The Diffie-Hellman system is a *Key Exchange Algorithm* (KEA), which is used to control and generate keys for public key distribution. Diffie-Hellman doesn't encrypt or decrypt messages: Its only use is to generate secure keys. The process is easy, but does require both ends of a communication (sender and receiver) to work together to generate the keys based on prime numbers.

Authenticating with Digital Signatures

Besides encrypting data, another important security issue needs to be addressed—being able to confirm the identity of the person who sent (or who receives) a message. After all, encrypted misinformation is just as secure as encrypted valuable information. To help authenticate both senders and receivers, a system known as *digital signatures* is used. Digital signatures use public-private encryption, relying on the public key to allow anyone to verify the sender's identity because the message is coded with their private key.

The U.S. government developed and adopted a system called *Digital Signature Standard* (DSS), which, as the name suggests, offers digital signature authentication. DSS has a major flaw, though, in that it is easy to accidentally reveal your keys if the same random encryption number is chosen twice and a hacker has both messages using that random number. Even worse, the contents of the message are sometimes easy to decrypt.

The *Secure Hash Algorithm* (SHA) and *Secure Hash Standard* (SHS) were developed by the U.S. government also, but are more secure than DSS. SHS uses a hashing algorithm that involves 160-bit keys. Unfortunately, SHS is somewhat slow. Given the speed with which RSA and PGP work, it's hard to understand why anyone would adopt SHS.

Another approach to digital signatures is message digest algorithms, of which at least three are in general circulation (called MD2, MD4, and MD5). The MD series of algorithms generate a digital fingerprint based on the input. The fingerprint is a 128-bit code, called a message digest. No two messages will ever have the same message digest (in theory). MD5 is the most secure of the set, developed by RSA to use a special hashing algorithm. Microsoft uses MD4 in its Windows NT user files to encrypt password entries.

Note

MD4 has been cracked many times. Several utilities are available on the Web for doing just this to Windows NT's password file (such as `http://is-it-true.org/nt/atips/atips92.shtml` and `http://www.atstake.com/research/lc3/index.html`). To crack passwords under Windows 2000 consult article 9186 at `http://www.windowsitsecurity.com/Articles`. A savvy administrator can use these tools to test how secure the Windows networks are. The reason for inclusion of this note is that hackers are already aware of this weakness and revealing this information here does not make Windows systems more insecure.

Certificate servers manage public-private keys for companies or organizations and usually are readily accessible through the Internet. Several commercial certificate servers are available for Windows and UNIX platforms. One of the best is Netscape's. Netscape also makes a FAQ available that describes why you would want to use a certificate server and the features of its own product. Access the FAQ at `http://home.netscape.com/certificate`.

Finally, we end up with Kerberos. If you've been on the Web or installed servers before, you've run into the Kerberos name several times. Kerberos is a way of providing network security by controlling access to network services on a user level. A Kerberos server is located somewhere on the network (usually on a secure machine). Kerberos servers are sometimes called *Key Distribution Centers* (KDCs). Whenever a user makes a request for some network service, the Kerberos server authenticates that the user is who he claims to be and that the service is on the proper machine. The security of the Kerberos system is based on the use of a private key encryption system based on DES. Every client and server on the network has a private key that is checked with every Kerberos-controlled action. Kerberos requires a dedicated server and so usually appears on larger networks and those that need tight security controls.

Cracking Encrypted Data

The science (some would call it an art) of breaking cryptography systems is called *cryptanalysis*. The process is to try to read an encrypted message without knowing the keys that were used to generate the message in the first place. There are a number of ways to get a head start on the process of breaking codes, the most common being knowledge of either the message contents or some part of the key. If you know that a message deals with shares in ABC Company, for example, you can make much better educated guesses about what certain words in the encrypted message mean. This leads to a key to the encryption faster. This type of crypto-cracking is known as *plaintext* because you know part of the message and use that to leverage the key from the rest of the message.

Sometimes private keys are made known either accidentally or on purpose. Knowing some part of a key, or having a good idea of what the key may be composed of, helps shorten the cracking time, too. For example, if you know someone has the habit of using his children's names as keys, and you know the kids' names, you are very close to being able to decipher a message. Getting the keys is usually not too difficult, especially if the messages are going over the Internet. There are many ways to intercept IP packets, and eventually an idea of a user's keys may be intercepted. If a cracker can get partial keys or the public keys of both ends of a message route, the odds of breaking the entire message are much higher.

Failing these helpful tips, cryptanalysis proceeds in a brute-force method. A number of different methods are used to break messages, depending on the cracker's techniques, guesses about the message or key, and both the brainpower and horsepower at his disposal. The ciphertext method can be used when you have only the encrypted message to work with. Computers then try different keys to decipher the message, sometimes with help from the cracker who can guess at words in the message. Because most messages follow standard formats (how many different ways can you structure a business letter?), you may be able to use part of the encrypted message to help choose a key to break the entire contents.

If the encryption algorithm is known, a modified plaintext method can be used. With this method, the cracker encrypts a message with the same technique (but not the same key) as the target message. By repeating the process with different messages and keys, an idea of the key used to encrypt the target message can be developed. This technique works surprisingly well.

There are some mathematically complex methods of cracking messages that rely on the intricacies of public-private keys. There will be a relationship between the keys and the encrypted message, and this can be deduced given enough number-crunching ability. Mathematicians have written entire books about the science of breaking encryptions in a theoretical manner, many of which have been employed by scientists and engineers working for national security agencies.

Protecting Your Network

Most LANs are not thought of as a security problem, but they tend to be one of the easiest methods of getting into a system. If any of the machines on the network has a weak access point, all the machines on the network can be accessed through that machine's network services.

PCs and Macintoshes usually have little security, especially over call-in modems, so they can be used in a similar manner to access the network services. A basic rule about LANs is that it's impossible to have a secure machine on the same network as nonsecure machines. Therefore, any solution for one machine must be implemented for all machines on the network.

Logins and Passwords

The most common access method of breaking into a system through a network, over a modem connection, or while sitting in front of a terminal is through weak passwords. Weak (which means easily guessable) passwords are very common. When system users use these, even the best security systems can't protect against intrusion.

If you're managing a system that has several users, you should implement a policy requiring users to set their passwords at regular intervals (usually six to eight weeks is a good idea), and to use non-English words. The best passwords are combinations of letters and numbers that are not in the dictionary.

Sometimes, though, having a policy against weak passwords isn't enough. You might want to consider forcing stronger password usage by using public domain or commercial software that checks potential passwords for susceptibility. Third-party commercial and shareware tools for password enforcement are available for most operating systems.

If you are running a Unix or Linux operating system, you need to pay particular attention to the `/etc/passwd` and `/etc/group` files. These need to be set up with unused accounts locked out, and with passwords protecting all accounts, used or not.

Note

On Unix systems, you should run the pwconv utility, which makes use of shadow files to store the password information. Unlike the password file, the shadow files are not world readable.

Windows NT/2000 users need to properly implement user accounts through the User Manager for Domains or the Active Directory for Users and Computers, which allows you to set up both workgroup and domain accounts. Windows 95 and 98 users are in a bit of a bind because no real account security exists on those operating systems. Anyone can create a new account by sitting in front of the screen. Unless the Windows 95 or 98 machines are part of a domain controlled by a Windows NT system, the network's weak point will always be the Windows 95/98 clients.

File and Directory Permissions

Security begins at the file permission level and should be carried out carefully. Whether you want to protect a file from snooping by an unauthorized invader or another user, you should carefully set your file permissions for maximum security.

The way you set file and directory permissions varies depending on the operating system. On Unix and Linux systems you can use the `chmod` (change mode) command, whereas on Windows 95, 98, and NT/2000 systems you need to use the Access Control Lists (ACLs).

Modems are the most commonly used interface into every system (unless you're running completely standalone, or on a closed network). Modems are used for remote user access, as well as for network and Internet access. Securing your system's modem lines from intrusion is simple and effective enough to stop casual browsers.

The safest technique to prevent unauthorized access through modems is to employ a callback modem. A callback modem lets users connect to the system as usual; it then hangs up and consults a list of valid users and their telephone numbers before calling the user back to establish the call. Callback modems are quite expensive, so this is not a practical solution for many systems.

Callback modems have some problems, too, especially if users change locations frequently. Also, callback modems are vulnerable to abuse because of call-forwarding features of modern telephone switches.

The typical telephone modem can be a source of problems if it doesn't hang up the line properly after a user session has finished. Most often, this is a problem with the wiring of the modem or the configuration setup.

Wiring problems might sound trivial, but there are many systems with hand-wired modem cables that don't properly control all the pins, so the system can be left with a modem session not properly closed and a logout not completed. Anyone calling that modem continues where the last user ended. To prevent this kind of problem, make sure the cables connecting the modem to the machine are complete. Replace hand-wired cables that you are unsure of with properly constructed commercial ones. Also, watch the modem when a few sessions are completed to make sure the line hangs up properly.

Trust Relationships

In a trust relationship, one machine decides to allow users of another machine to access resources without having to log in again. The assumption is that valid users of one machine can be trusted by another machine. Trust relationships were developed years ago to simplify a user's access to network resources. Suppose you were logged on to one machine and needed a file or application from another. It would be inconvenient to have to enter a login and password each time you did this, and hence trust relationships permit you to access resources without having to log in to each machine. Trust relationships are not the same as running *Network Information Service* (NIS) or *Yellow Pages* (YP), which use a central user and password file.

Most operating systems allow trust relationships to be set up, with specific routines available for trusts included with Windows NT, Unix, and Linux. The problem with trust relationships is easy to see: If someone breaks into one machine, he can access any other machine that has a trust relationship with that machine.

Trust relationships can be two-way (both machines trust each other) or one-way (one machine trusts the other but not vice-versa). Entire networks can have trust relationships. For example, suppose you have three subnetworks in your company, one of which holds very secure information; the other two are regular, nonsecure users. To prevent having to log in to each network when accessing resources, trust relationships can be set up among the three, but you will probably want to prohibit a trust relationship from the nonsecure to the secure network (but allow the secure to access anything on the nonsecure networks). Your two nonsecure networks can have two-way trusts, and only one-way trusts from the secure to nonsecure. Windows NT and Unix permit setting up trusts quite easily.

From a security point of view, you have to make sure your trusts are set up to limit damage from intrusion from a trusted machine or network. A machine with sensitive information on it should never trust machines that are widely accessible.

UUCP on Unix and Linux Systems

The Unix UUCP program was designed with good security in mind. However, it was designed many years ago, and security requirements have changed considerably since then. A number of security problems have been found over the years with UUCP, many of which have been addressed with changes and patches to the system. Still, UUCP requires some system administration attention to ensure it is working properly and securely.

If you don't plan to use UUCP, remove the `uucp` user entirely from the `/etc/password` file or provide a strong password that can't be guessed (putting an asterisk as the first character of the password field in `/etc/passwd` effectively disables the login). Removing `uucp` from the `/etc/passwd` file won't affect anything else on the Linux system.

You should set permissions to be as restrictive as possible in all `UUCP` directories (usually `/usr/lib/uucp`, `/usr/spool/uucp`, and `/usr/spool/uucppublic`). Permissions for these directories tend to be lax with most systems, so use `chown`, `chmod`, and `chgrp` to restrict access only to the `uucp` login. The group and username for all files should be set to `uucp`. Check the file permissions regularly.

UUCP uses several files to control who is allowed in. These files (`/usr/lib/uucp/Systems` and `/usr/lib/uucp/Permissions`, for example) should be owned and accessible only by the `uucp` login. This prevents modification by an intruder with another login name.

The `/usr/spool/uucppublic` directory can be a common target for break-ins because it requires read and write access by all systems accessing it. To safeguard this directory, create two subdirectories: one for receiving files and another for sending. Further subdirectories can be created for each system that is on the valid user list, if you want to go that far.

Preparing for the Worst

Assuming someone does break into your network and causes damage on your machines, what can you do? Obviously, backups of the system are helpful because they let you recover any damaged or deleted files. But beyond that, what should you do?

First, find out how the invader got in, and secure that method of access so it can't be used again. If you're not sure of the access method, close down all modems and terminals and carefully check all the configuration and setup files for holes. There has to be one, or the invader couldn't have gotten in. Also check passwords and user lists for weak or outdated material.

If you are the victim of repeated attacks, consider enabling an audit system to keep track of how intruders get in and what they do. As soon as you see an intruder log in, force him off.

Finally, if the break-ins continue, call the local authorities. Breaking into computer systems (whether in a large corporation or a home) is illegal in most countries, and the authorities usually know how to trace the users back to their calling point. They're breaking into your system and shouldn't get away with it!

Summary

This chapter has discussed encryption and authentication, as well as some basic security precautions you need to consider. An awful lot falls under the TCP security banner, and this chapter only scratched the surface. If you want to know more about computer and network security, there are many books dedicated to the subject.

Implementing TCP/IP

PART VI

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CHAPTER 22

General Configuration Issues

by Kurt Hudson

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TCP/IP is the most widely used protocol, but it is also one of the more difficult to configure compared to other protocols. Consequently, the potential for configuration errors is great. This chapter explains the basic installation and configuration of the network card and networking services. Required and basic IP configuration parameters are described along with typical IP configuration errors. In addition, using IP connections to tunnel other protocols is explained. This chapter uses Windows 98 as an example operating system. Later chapters cover the individual operating systems in more detail. Windows 98 is used because of the reader's probable familiarity with the operating system. Not every one has upgraded to Windows ME, which was not very popular. And upgrading to Windows NT/2000 or Windows XP is not always possible because of the increased hardware requirements of these operating systems.

Installing a Network Card

In order for your computer to connect to and properly communicate on any network, you must configure the network card. There are several different types of network cards and the configuration of each varies slightly. However, all network cards must be installed physically (as hardware components), and logically configured with their software drivers.

Note

It is important to realize that if a computer has two or more network cards and you expect to communicate through both cards using TCP/IP, then both cards must be set up with separate IP addresses and other TCP/IP parameters.

The physical configuration typically involves turning off the PC, removing the CPU cover, and physically inserting the network card. On a laptop system, the physical installation may be as simple as inserting the PC Card into the appropriate slot. No matter what type of system you are configuring, the physical connection must be made.

After the physical connection is made, the resources for that network card must be assigned. Some network cards can be configured to obtain their resources automatically and others must be manually configured.

Network Cards

When you want to install a network card into your PC, you must first obtain the correct type of card. This means that you must know what type of hardware slots you have inside the PC. For a desktop PC, you will typically use an *Industry Standard Architecture*

(ISA) or *Peripheral Component Interconnect* (PCI) network card. The manufacturer's documentation for the motherboard or the PC will indicate which type of slots you have on board. You must then identify which slots are available (open) to receive a new card. You can place the network card in any open slot.

Note

Proper safety precautions must be taken when installing any device in a PC. You must turn off the power to the device before adding or removing components, and you should wear an electrostatic discharge wrist wrap. For more information on installing hardware, obtain a book that specifically discusses upgrading and repairing PCs.

After you know what type of slot you have available, you must also determine the type of network to which the card will be connected. The physical connection from the card to the network is typically referred to as the *transceiver type*. The standard connections to a network are *RJ-45*, *British Naval Connector* (BNC), and *Attachment Unit Interface* (AUI). The RJ-45 interface allows your network card to be connected to a twisted-pair network. The BNC connector allows your network card to be part of a thin-net coaxial network (a.k.a. 10Base-2 network). The AUI interface allows you to connect your card to a thick-net coaxial network (a.k.a. 10Base-5). You must know the type of network to which you will connect the network card in order to select a card with the appropriate interface.

Many network cards support multiple transceiver types. Some network cards require you to configure the appropriate transceiver type before you install the card. This is typically done via vendor-supplied configuration software or occasionally hardware jumpers (connectors) on the actual card. Be sure to check the network card documentation before installing the device. However, most network cards that have multiple transceiver types will automatically configure themselves by sensing the connection during the startup process.

After the card has been inserted into the appropriate slot and the transceiver is set (if required), the physical connection to the PC is complete. The next step is to configure the resources. However, you should know about a couple of other types of network cards before learning to configure resources; these are PC Cards, modems (a.k.a. dial-up adapters), and parallel port adapters.

PC Cards (PCMCIA Cards)

PC Cards were originally called PCMCIA (Personal Computer Memory Card International Association) cards. However, most people found the acronym too lengthy to remember, so the name was shortened to PC Card. PC Cards are most often used in laptop computers and are used for network cards, modems, and external hard drive support. The PC Card network interfaces typically have a media access unit that attaches to the PC Card and then to the actual network cable.

PC Card NICs utilize typical resources, such as a single IRQ and I/O range. However, PC Cards also require socket services and card services. Systems that support PC Cards will provide such services for these devices.

Modems

Modems can also function as network cards and are often referred to as dial-up adapters. When a modem connects to a remote network or the Internet, it functions as a network card. Modem configuration is a little different from that of other network cards because modems are typically configured to use serial communication ports such as COM1, COM2, COM3, or COM4. Many modems provide their own COM port so you must disable the COM port on the motherboard via the CMOS/BIOS settings. Modems also use whatever IRQ is assigned for the given COM port. Typically, COM1 and COM3 are configured for IRQ4. COM2 and COM4 use IRQ3 by default.

After the modem is installed, the dial-up networking components must be installed to configure the modem to transfer network traffic. Chapter 24, “Dial-Up Networking with Windows 98,” covers the installation and configuration of dial-up networking components.

Parallel Port Adapters

Some modems and other network devices such as routers can be connected to parallel ports (instead of the serial COM ports). Typically, these devices include a cable or transceiver for the parallel port to which the device connects. The configuration is similar to that of a COM port because the parallel ports also have default IRQ and I/O settings. The networking devices that utilize the parallel port often accept the default IRQ and I/O range used for that port.

Resource Configuration

Any network card that is installed in a PC must be configured with an IRQ line and I/O range. Typically, the manufacturer’s documentation explains the default IRQ and I/O range settings for the card. In order to get the card working with the operating system, you must determine whether that IRQ and I/O range is available. If the IRQ and I/O range are available, you should have no problem configuring the card. However, if the IRQ or the I/O range is not available, you must find settings that are open.

Newer network cards and other devices support *Plug and Play* (PnP), which means that resources (IRQ and I/O range) are configured automatically during the boot process. PnP must be supported by the operating system; Windows 95, Windows 98, and Windows 2000 do support PnP adapters. During the boot process, the operating system and the PnP device work together to configure a set of open resources for the device. If you do not have a PnP adapter, you will have to locate open resources and configure your device to support those resources.

Note

If you are configuring an Integrated Services Digital Network (ISDN), or other connection that can utilize a Universal Serial Bus (USB), you need only to locate a free I/O range for your device.

In Windows 98, it is quite simple to determine which resources are available by looking in the Device Manager. The Computer Properties dialog box in the Device Manager allows you to view the used IRQ and I/O ranges (see Figure 22.1).

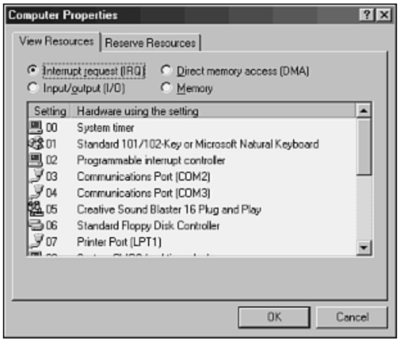


FIGURE 22.1
Use Device Manager to locate open resources.

To access the Computer Properties dialog box in Windows 98, follow these steps:

1. Right-click the My Computer icon on the desktop.
2. Choose Properties from the resulting menu.
3. Click the Device Manager tab.
4. Click the Properties button.

You can see which IRQs and I/O ranges are not in use by selecting the IRQ and Input/ Output (I/O) options. When you have determined which resources are open, consult the documentation for your network card to determine which resources it can be configured to accept. You may need to set jumpers, dip switches, or use the manufacturer's software to configure the correct resources for the network card.

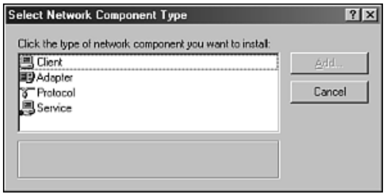
Installing the Adapter Software

After you have properly set the network card to use open resources on the operating system, you must install the network card drivers. Some operating systems ship with drivers for various network cards built-in, but most network cards come with their own drivers anyway. You can use the network drivers from the operating system (if available) from the manufacturer-provided media, or the manufacturer's Internet Web site.

If you were installing network card software inside Windows 98, you would follow these steps:

1. Right-click the Network Neighborhood icon.
2. Choose Properties from the resulting context menu.
3. From the Configuration tab of the Network dialog box, click Add.
4. In the Select Network Component Type dialog box, choose Adapter from the options listed and then click Add (see Figure 22.2).
5. The next dialog box presents you with a list of Manufacturers and Network Adapter types. Choose the appropriate combination or insert the manufacturer-provided disk into the CD-ROM or floppy drive and click Have Disk.
6. After you have the correct combination, or you have inserted the manufacturer-provided drivers, click OK to continue. During this operation, you may be required to configure the resources (IRQ and I/O range) for your network adapter.
7. After the software is installed, click OK on the Network dialog box and reboot the system, if necessary.

FIGURE 22.2
You must add a software adapter for your NIC.



After the network card driver is installed, you can begin to install and configure the software networking components, such as the appropriate redirector, server services (if any), and TCP/IP protocol suite.

Redirectors and APIs

A *redirector*, as its name implies, is a software component in the protocol stack that redirects local queries for resources over the network. That is to say, the redirector is an operating system component that allows the computer to obtain resources and services on the network. Sometimes the redirector is called the client or workstation service because it provides this functionality.

The redirector must be compatible with the type of network it is expected to utilize. Redirectors from different networking vendors are rarely interchangeable. On a heterogeneous network, this often means that client systems must be configured with multiple redirectors.

In order to facilitate the inclusion of multiple redirectors and to separate the protocol stack from application development, networking vendors have created interfaces inside the protocol stack. For example, Microsoft uses the NetBIOS interface to separate the protocol stack from the operating system code. Many different protocols and redirectors can be integrated through this interface. NetBIOS is called an *Application Programming Interface* (API) because it segregates the applications from the network components. This allows application developers to focus on the application they are writing instead of worrying about the underlying network on which the application may be used.

To install the appropriate redirector from the Windows 98 operating system, follow these steps:

1. Right-click the Network Neighborhood icon.
2. Choose Properties from the resulting context menu.
3. From the Configuration tab of the Network dialog box, click Add.
4. In the Select Network Component Type dialog box, choose Client from the options listed and then click Add.
5. The next dialog box presents you with a list of Manufacturers and Network Clients. This is essentially a list of network vendors and their respective network redirectors. Choose the appropriate pair and click OK.
6. You may have to map the correct location to the installation files. After you do, click OK. Click OK again, if necessary.
7. After the software is installed, click OK on the Network dialog box and reboot the system, if necessary.

Services

Services, like redirectors, are typically implemented at the top of the protocol stack in the TCP/IP Application Layer. Services such as *File Transfer Protocol* (FTP), *Hypertext Transfer Protocol* (HTTP), and Telnet all operate at the TCP/IP Application Layer. Services also benefit from APIs in the protocol stack because they can be developed independently of the underlying network.

File and printer sharing services are usually dependent upon the type of network that is supported. For example, NetWare networks require a different type of file and printer sharing services than do Microsoft networks. In the Windows 98 operating system, both Microsoft and NetWare file and printer sharing services are available and their installation process is very similar to that of the installation of a redirector. The only difference is that the component selected in the Select Network Component Type dialog box should be Service instead of Client.

NIC Interfaces

In the early days of networking, protocol stacks did not display modularity. Instead of utilizing separate redirectors, services, and protocols, the protocol stack was a single monolithic software component that provided a far more limited set of functionality. Each vendor only produced software that worked with one type of network.

One of the first and most obvious limitations of this type of networking was the inability to utilize multiple transport protocols. In order to work around such limitations, networking vendors and standards organizations, such as the International Organization of Standardization (ISO), worked to provide modularity in the protocol stack.

The early solutions produced two interfaces that are still in use today—Open Datalink Interface (ODI) and *Network Driver Interface Specification* (NDIS). ODI was developed by Novell to allow its networking components to utilize multiple protocols with one or more network cards. NDIS is part of the Microsoft protocol stack that allows multiple protocols and multiple network cards to be bound on the same computer system.

Network and Transport Protocols

In addition to the correct adapter software, redirector, and service, you must have a protocol in order to communicate with the other systems on the network. The protocol you install will depend on the type of network to which you are connecting and the other systems with which your system must communicate. You must ensure that the network supports the protocol you install. In order for two systems to communicate with each other, they must have common protocols.

Because the focus of this book is the TCP/IP protocol suite, this section deals with configuration issues for TCP/IP.

IP Configuration Requirements

The most basic configuration requirements for TCP/IP include the IP address and subnet mask. These two items may be all that you need to configure to communicate on a local network with TCP/IP.

The IP address must be set correctly for the local segment in order for your computer to be able to communicate properly. Your system must be configured with a unique IP address and have the appropriate subnet mask. The subnet mask for any individual system should be identical to the mask of other systems on the same subnet in order for those machines to communicate. In addition, the IP address should be unique for the subnet, but it must contain the correct network identifier and subnet identifier (if used). It is the subnet mask that determines the correct network identifier. For example, the subnet mask 255.255.0.0 specifies that the first two octets of the IP address identify the network segment (a.k.a. subnet address). If the first two octets identify the network, the last two octets should uniquely identify a host on that network segment. Consider the combinations shown in Table 22.1.

TABLE 22.1 IP Address and Subnet Mask Configuration

Hostname/IP Address	*Subnet Mask*
HostA/192.168.1.12	255.255.0.0
HostB/192.168.2.17	255.255.255.240
HostC/192.168.1.250	255.255.0.0
HostD/192.168.2.30	255.255.255.240
HostE/192.168.2.33	255.255.255.240

In the example in Table 22.1, HostA and HostC are on the same logical network (network ID 192.168.0.0). HostB and HostD are on the same logical subnet (subnet ID 192.168.1.16). HostE is on a different logical network than the other hosts (subnet ID 192.168.1.32). If all of these hosts were on the same physical cable, HostA and HostC would be able to communicate with each other, and HostB and HostD would be able to communicate with each other. No other combinations of communication could occur because of the difference in logical subnets.

An Example of Subnetting

The reason that HostE is not on the same subnet as HostD and HostB may not be readily apparent. However, if you review Chapter 4, "Names and Addresses in an IP Network," you will see that the network identifier when using the mask 255.255.255.240 is at every 16th number starting with 16 and ending with 224. The valid network identifiers and ranges for 192.168.1.0 subnetted with 255.255.255.240 are as follows:

```
192.168.1.16 with host range 192.168.1.17 - 192.168.1.30
192.168.1.32 with host range 192.168.1.33 - 192.168.1.46
192.168.1.48 with host range 192.168.1.49 - 192.168.1.62
192.168.1.64 with host range 192.168.1.65 - 192.168.1.78
192.168.1.80 with host range 192.168.1.81 - 192.168.1.94
192.168.1.96 with host range 192.168.1.97 - 192.168.1.110
192.168.1.112 with host range 192.168.113 - 192.168.1.126
192.168.1.128 with host range 192.168.1.129 - 192.168.1.142
192.168.1.144 with host range 192.168.1.145 - 192.168.1.158
192.168.1.160 with host range 192.168.1.161 - 192.168.1.174
192.168.1.176 with host range 192.168.1.177 - 192.168.1.190
192.168.1.192 with host range 192.168.1.193 - 192.168.1.206
192.168.1.208 with host range 192.168.1.209 - 192.168.1.222
192.168.1.224 with host range 192.168.1.225 - 192.168.1.238
```

Notice that this creates 14 logical subnets with 14 hosts on each subnet. If you look at 192.168.1.33 and 192.168.1.30, you will see they are on different logical subnets.

In order for hosts on the same local network to communicate, they must have unique host identifiers and identical network/subnet identifiers. In order for hosts to communicate with other hosts on remote segments (across a router), they must both be configured with default gateway addresses.

Configuring a Default Gateway Address

If you want your system to be able to communicate with remote networks, or with network segments on a LAN separated by a router, you must configure a default gateway address. The default gateway address is typically the IP address of the local router. However, in instances where more than one router is configured for a local segment, the default gateway is the preferred path for communications bound for remote networks.

A host on the network uses its subnet mask to determine whether a communication is bound for a local or remote segment. If the subnet identifier for the destination is the same as the local network identifier, the communication is transmitted on the local segment. However, if the subnet identifier is different, the communication is sent to the default gateway. The default gateway is typically a router that forwards the packet to the appropriate destination or next hop along the path to the ultimate destination.

In order to communicate with the default gateway appropriately, the local host must be configured with a valid and unique IP address, the correct subnet mask, and the address of the default gateway. If any of these items are incorrect, the host will have problems communicating on the network. The default gateway address must be an address on the local segment. In other words, you cannot configure a remote host as your system's default gateway.

If your system can communicate with local hosts, but is unable to communicate with remote hosts, there is usually a problem with the default gateway or its configuration. Potential problems with the default gateway include the following:

- The default gateway is offline.
- The cable or interface connecting the default gateway and local segment is not functioning properly.
- The default gateway address is incorrect on the client.
- The default gateway address is not configured on the client.
- The *Address Resolution Protocol* (ARP) cache entry for the router is incorrect. This is usually solved by rebooting the client, unless the client uses a static entry in the ARP cache.

Most of those configuration issues are easy to understand and correct. However, the incorrect ARP cache entry might be overlooked. You must remember that all communications on the local segment are eventually conducted between two *Media Access Control* (MAC) hardware addresses. If the network interface for the default gateway was changed and clients continued to use the hardware address of the old interface, they would fail to communicate with the default gateway. Typically, rebooting the client system would refresh the ARP cache and cause the client to resolve the MAC address again. However, if the operating system were configured to insert a static ARP entry for the default gateway, a simple reboot would not correct the problem. In such a case, the file that was entering the static entry into the ARP cache would have to be updated.

Configuring the Name Server Address

Another important item to configure on a TCP/IP host is the IP address of the name server. The two basic types of name servers are *Domain Name System* (DNS) servers and *Windows Internet Name Service* (WINS) servers. DNS servers convert Internet-style hostnames into IP addresses so that communications take place between TCP/IP hosts. WINS servers convert NetBIOS names (used with Microsoft networks) to IP addresses. DNS services and servers are detailed in Chapter 6, “DNS: Name Services”; WINS servers and services are covered in Chapter 7, “WINS.”

For the individual IP host, it is important that you configure the correct IP address of the appropriate name server. Microsoft clients may require both the IP address of a DNS server and the IP address of a WINS server in order to properly resolve computer names to IP addresses. If you can communicate with a host using its IP address but not its computer name, there is a name resolution problem. This problem could be caused by any of the following issues:

- The name server address is incorrect on the client.
- The name server is down.
- A router between the name server and your system is down (not allowing communications to pass through), but the host to which you are connecting is not on the other side of that router.
- A physical connection problem exists between your system and the name server, but not between your system and the system to which you are connecting.
- The name for the system to which you are trying to connect is not correctly configured in the name server or is not listed with the name server.

Configuring the Mail Server Address

If you want to send and receive mail from the local host, you must configure the address of the mail server with your mail application. Messages transmitted on TCP/IP networks typically run through the *Simple Mail Transfer Protocol* (SMTP). Clients typically receive mail using the *Post Office Protocol* (POP) or *Internet Message Access Protocol* (IMAP). Typically, the configuration for incoming mail is either POP or IMAP, not both.

Most Internet mail applications allow you to decide whether you will use the hostname of the mail server or the IP address. For example, you can either enter `mail.server.com` or `192.168.1.50` to access the mail server. Many *Internet Service Providers* (ISPs) use the same mail server for both incoming and outgoing mail, but some utilize different servers for each function. In order to ensure that your system can both send and receive mail, you must configure the address(es) of the mail server(s) correctly.

Registering Your Domain Name

If you plan to communicate on the Internet using a specific domain name, such as `domain.com`, you must register with the InterNIC. Typically, you arrange the registration of your domain name through an ISP. It usually handles the necessary paperwork to set up your domain name. However, the information necessary to register a domain name is available on the Web via the InterNIC at `http://www.internic.net`.

IP Configuration Variations

Some devices and operating systems natively support TCP/IP and expect it to be configured as the device or operating system is configured. The configuration concepts previously described are essentially the same; however, their implementation is often different. One type of device that anticipates IP configuration during a typical setup routine is a router, such as a Cisco router. Because routers have multiple interfaces, the configuration is done on a per-interface basis. During the Cisco automated setup routine, called the System Configuration Dialog, you have the option to configure IP on each interface. Alternatively, you can bypass this screen and enter Cisco IOS commands directly at the command line to configure an interface.

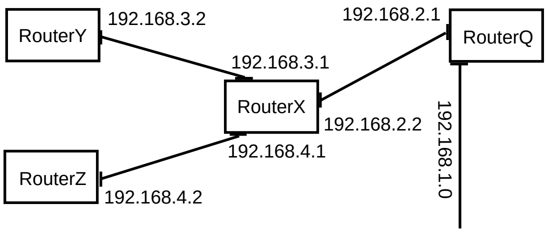
There are also variations on configuring IP addresses and subnet masks on different systems. For example, when configuring the IP subnet mask for an address on a Cisco router, you do not enter the entire 32-bit mask (on the menu interface) because the default mask is assumed. For example, if you are configuring the IP address 192.168.1.1 for an interface on a Cisco router, you need not enter 255.255.255.0 as a subnet mask. Because the address is a known Class C address, the default subnet mask 255.255.255.0 is assumed. You will be given the opportunity to enter only the number of additional bits that you would like to subnet. For example, for a subnet mask of 255.255.255.240 you would enter the number 4 because that is 4 bits beyond the default subnet mask.

In addition, when you are reviewing the IP settings on some devices, you may not always see dotted-decimal subnet masks. You can either see the binary format of the subnet mask or *Classless InterDomain Routing* (CIDR) format. The binary format is simply the numbers represented as binary digits. For example, 255.255.240.0 becomes 11111111.11111111.11110000.00000000. CIDR format shows the IP address followed by the number of bits that are masked. For example, 192.168.1.1 with the subnet mask 255.255.255.240 would be represented as 192.168.1.1/28 because 28 masked binary digits are in the subnet mask.

Configuring the Routing Table

Routing table problems can also cause communication trouble on IP networks. Many routers are automatically configured by dynamic routing protocols such as *Routing Information Protocol* (RIP) and *Open Shortest Path First* (OSPF). However, when routes are statically entered by an administrator, the potential for typos increases the chance that there could be errors in the routing table. Other than typos in the routing table, configuring the wrong interface for the next hop is a common problem. Consider the network configuration shown in Figure 22.3.

FIGURE 22.3
Use Route Print to locate routing table configuration problems.



RouterX Routing Table

Network	Mask	Interface
192.168.4.0	255.255.255.0	192.168.4.1
192.168.3.0	255.255.255.0	192.168.3.1
192.168.2.0	255.255.255.0	192.168.2.2
192.168.1.0	255.255.255.0	192.168.2.2

The problem with the routing table of RouterX is subtle but will cause problems on the network. Notice that the last line shown in the RouterX routing table example shows that communications bound for network 192.168.1.0 go through interface 192.168.2.2, but this is incorrect. The router is supposed to route communication to the correct next hop. From the perspective of RouterX, the next hop to 192.168.1.0 is the interface on RouterQ, which has an IP address of 192.168.2.1. If this configuration problem is not corrected, packets destined for network 192.168.1.0 going through RouterX will fail.

Notice that because RouterX is connected to all other segments shown in its routing table, it uses its own interfaces to connect to those segments. Only when the router is not directly connected to the segment will it use the interface of another router to pass communications to the remote segment.

In order to correct the configuration problem illustrated in Figure 22.3, you would correct the interface to which RouterX sends communications destined for network 192.168.1.0. The corrected line for the routing table would be

```
192.168.1.0  255.255.255.0  192.168.2.1
```

IP Encapsulation of Foreign Protocols

IP can be used to encapsulate other Network Layer protocols in order for them to be sent over the network. One example of this is the IPX over IP tunnel. Novell NetWare networks natively use the IPX/SPX protocol. If you want to connect two Novell NetWare LANs over the Internet, you can use an IPX over IP tunnel.

The word *tunnel* actually describes the concept of what happens in such a configuration. After the higher layer protocols are encapsulated in the IPX packet, the entire set is then encapsulated into an IP packet for routing over the network to a remote IPX network. Figure 22.4 illustrates this concept.

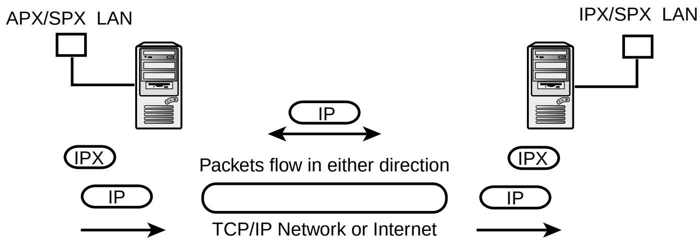


FIGURE 22.4
You can use the IPX over IP tunnel to effectively create an IPX WAN.

A server on each side of the TCP/IP network must be configured to package/unpackage the IPX over IP packets. When NetWare servers are used to do this, they use an IP Tunnel driver. The following lines are typically added to the `NET.CFG` file on the NetWare server to enable this:

```
Link Driver IPTUNNEL
        Gateway 192.168.1.50
Protocol IPXODI
         Bind #2
```

The first part indicates the gateway machine that will be used to unwrap the packets at the remote site. The second part binds `IPXODI` to the second defined driver, which is the IP Tunnel driver. In addition to those changes to the `NET.CFG`, the TCP/IP protocol suite (`tcpip`) must be installed and loaded on the server as well as the IP Tunnel driver (`iptunnel`).

Note

Unix and Linux servers can also support the IPX over IP tunnel. This is often done when the systems are running IPX applications over the Internet, rather than routing between LANs. The application that provides this support is called `ipxtunnel` and is available from `sunsite.unc.edu` and elsewhere on the Internet.

In addition to sending IPX over TCP/IP networks, other protocols besides the normal TCP/IP protocol suite can be encapsulated in IP packets. Microsoft uses the *Point-to-Point Tunneling Protocol* (PPTP) to encrypt communications between hosts connected on the Internet. Other choices are to use L2TP in combination with IPSec to build a secure tunnel. This type of tunneling secures communications going over the Internet. Many firewalls employ similar encryption techniques by encapsulating proprietary protocols between two remote points on the Internet. This allows companies to have a secure connection, or *Virtual LAN* (VLAN), over the Internet. The encapsulation makes it more difficult (some say virtually impossible) for hackers to spy on communications transferred over these VLAN connections.

Summary

When you set up a host on an IP network, there are many items to configure. If you haven't already installed and configured the network card, you must consider the configuration of the hardware resources. In addition, you may need to check your system's open resources IRQ and I/O range in order to determine which resources are available. Software drivers from the manufacturer are often required in order to properly configure network cards; however, the Windows operating systems contain the necessary drivers for many different network cards.

When you have the network card and driver configured, you may need to install a redirector and additional services. The actual redirector and services that you install depend on the type of network to which you are connecting and the services you want to provide on that network.

If you intend to communicate on an IP network, you must either have a device that natively supports IP or you must install the TCP/IP protocol suite. If the device natively supports IP, the configuration of the protocol is typically part of the setup routine. The absolute requirements to get an IP host to operate on an IP network are the IP address and subnet mask. If you intend for your system to communicate with IP hosts on remote networks, you must also configure a default gateway. The default gateway is the destination for packets that are to be routed to remote segments. The default gateway is the IP address of a router on the local segment that has the capability to forward packets to remote networks and/or other routers. For your host to communicate via the computer or hostname of a remote system, you must have some type of name resolution. The address of the name server must be entered into the client configuration in order to obtain name resolution services.

CHAPTER 23

Configuring TCP/IP for Windows 95 and Windows 98

by Kurt Hudson

IN THIS CHAPTER

- **Windows 98 Network Architecture** *560*
- **Configuring Windows 98 for TCP/IP** *566*

This chapter covers the Windows 98 networking component configuration. Emphasis is placed on two main areas: network software driver configuration and TCP/IP settings. In addition, the Windows 98 network architecture is addressed. Specific configuration information such as TCP/IP static files and some Windows 98 Registry locations is also covered.

Note

Windows 95 and Windows 98 are virtually identical when it comes to configuring networking components. The information contained in this chapter can be easily applied to either operating system.

Windows 98 Network Architecture

The Windows 98 network architecture is based around two main interfaces: NetBIOS (Network Basic Input/Output System) and NDIS (Network Device Interface Specification). Additionally, the main protocol used by the highest layers of Microsoft networking (which, of course, applies to Windows 98) is *Server Message Blocks* (SMBs). A basic picture of the Windows 98 protocol stack is compared to the OSI Network Model in Figure 23.1.

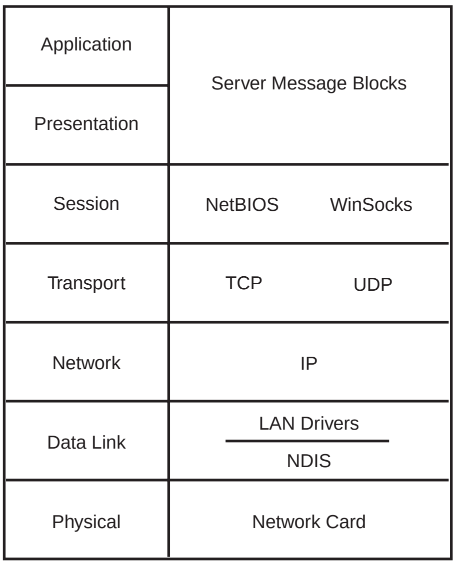


FIGURE 23.1
Above the Transport Layer and at the Data Link Layer, Microsoft's implementation of TCP/IP is unique.

The figure illustrates how those components fit into the TCP/IP protocol stack. Several other transport and network protocols could have been inserted where TCP, UDP, and IP were placed in the graphic because the NDIS Layer allows multiple protocols to be bound to one or more network adapters. The purpose of the NetBIOS Layer is to provide protocol independence for NetBIOS applications. Microsoft network designers wanted to make the building of network applications as independent as possible from the protocol in use. This enables application developers to focus on the application they are building and not worry about which network protocol stack is to be used.

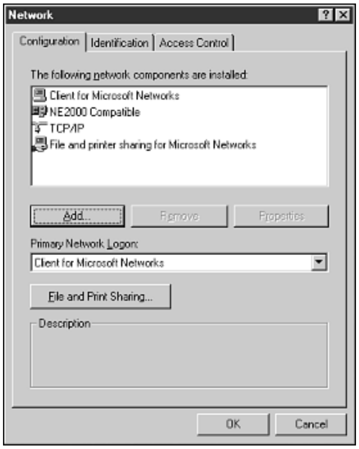
Notice that WinSocks (Windows Sockets) has also been added to the Session Layer of the model in the graphic. Microsoft developed the Windows Sockets interface to allow the use of existing applications and utilities for TCP/IP with Microsoft clients. For example, utilities such as ping and tracert use the Windows Sockets interface to access the protocol stack.

The items in the Windows 98 protocol stack that the user or administrator can configure and control are limited to the LAN drivers, Network and Transport protocols, and type of network card. SMB, NetBIOS, and NDIS are permanent fixtures of Windows 98 networking. In addition, when Microsoft TCP/IP is installed, the Windows Sockets interface is automatically added.

Therefore, the main components that the user can add are network card (software drivers), protocol, and type of networking services (client and server components). The software components listed in the Network dialog box of Windows 98, as shown in Figure 23.2, illustrate this point. As this chapter progresses, you will learn more about each of these software components.

FIGURE 23.2

The Windows 98 Network dialog box is the central configuration point for most network settings in Windows 98.



Installing the Network Card

In Chapter 22, “General Configuration Issues,” the installation of the physical network card was described. In addition, the software configuration of the network card resources and drivers through Windows 98 were also described. In this section, the various methods for adding and configuring network card software are briefly revisited and expanded upon.

Note

In this section, it is assumed that you have already inserted the physical network card into the computer. In addition, you should know the card manufacturer name, Web site address, and the model number of the card.

As explained in the preceding chapter, before you install the software for the network card, ensure that you have determined which interrupt request lines (IRQ) and I/O ranges are available. You can use the Device Manager to make this determination (see Chapter 22 for the exact steps). You may have to configure the network card via a software utility provided by the manufacturer to set the proper IRQ and I/O range before you begin.

Using the Add New Hardware Wizard

The Add New Hardware Wizard can be used to install the proper software for your network card. To access the Add New Hardware Wizard, open the Control Panel by clicking Start, selecting Settings, then choosing Control Panel.

1. Double-click the Add New Hardware icon to begin.
2. The Add New Hardware Wizard first asks you to close all other open applications. After you have done so, click Next to continue.

   The subsequent screen indicates that Windows will search for Plug and Play devices on your system. If you have installed a Plug and Play network adapter, the system should find it and automatically configure the IRQ and I/O address range for the adapter. If you do not have a Plug and Play adapter, you will have to manually configure the resources for the card.
3. Click Next to continue.
4. If you see your network card listed, select it by clicking the icon representing the device in the Devices window.

   Choose the Yes, the Device Is In the List radio button and click Next. This should automatically install and configure your Plug and Play network adapter.

If you don't see your network card listed, choose the No, the Device Isn't In the List radio button and click Next. If you had to choose "No..." you do not have a Plug and Play network adapter.

For non–Plug and Play adapters the subsequent screen will ask whether you want Windows to run detection routines to locate your network adapter. The only problem here is that the detection routines might cause your computer to freeze and you will have to reboot. Still, if Windows 98 can successfully detect the adapter, you won't have to select it from a list of devices.

5. If you would like Windows 98 to attempt to detect your adapter, be sure that Yes (Recommended) is selected, and click the Next button. If your network card is detected, it can then be confirmed and configured.

   If, however, you know exactly which network card you need to install or you have a driver from the NIC manufacturer that you would like to install, choose No, I Want to Select the Hardware from a List option; then, click the Next button.

   Assuming your device wasn't in the list (or you skipped detection), you will be presented with a dialog box that will allow you to choose your device from a list of possible devices.

6. In this dialog box, scroll down to the Network Adapters icon, select it by clicking the icon, and then click Next to continue.

   The next screen presents a list of manufacturers on one side and models on the other.

7. Select the correct network card manufacturer and model from each list. For example, if the network card you installed is a 3COM 3C509 ISA adapter, you would select "3COM" from the list of manufacturers and then scroll down in the second window to locate "3COM Etherlink III ISA (3C509/3C509b) in ISA mode" from the list of models.

8. To continue, click OK.

Your other option is to click the Have Disk button to install a driver that was provided by the hardware vendor.

You will then be asked to insert a floppy disk, CD-ROM, or map the path to the software drivers. When you do, you can continue the installation process. You may also be asked to select and confirm the appropriate driver files from the software disk. Refer to the network card manufacturer documentation to determine the correct driver file.

Note

You may be asked to set or confirm the adapter resource settings before you proceed. After you have confirmed these settings, click the Next button to continue.

After the driver has been located and installed by the Windows 98 Add New Hardware Wizard, a confirmation dialog box will appear. The dialog box informs you that installation was completed successfully and you can click the Finish button in order to conclude the installation process. You should be able to reboot your system immediately, or you can choose to wait. The installation of the network card driver won't take effect until your system is rebooted.

Manually Adding the Network Card

The process for installing a network adapter manually in Windows 98 was detailed in Chapter 22. (The detailed steps to install network driver software manually are not repeated here.) Briefly stated, instead of using the Add New Hardware Wizard, you use the Network icon in the Control Panel. This opens the Network dialog box. You can then click Add, select the adapter, and install the appropriate driver. After you click the Add button on the Network dialog box, the process is nearly identical to adding a non–Plug and Play adapter via the Add New Hardware Wizard.

Using 16-Bit Network Drivers

If you have an old network adapter that you must use in your Windows 98 system, you may have to use the old 16-bit drivers. This solution is not optimal and should be avoided whenever possible. However, Windows 98 does provide the old configuration files, such as `AUTOEXEC.BAT`, `CONFIG.SYS`, and `SYSTEM.INI`, so that legacy (pre–Windows 95) software and hardware can be used.

The configuration of a legacy network adapter is quite simple. First, run the setup or installation program that was provided by the network card manufacturer. This should install the appropriate driver and update the old configuration files. If you have to update those configuration files manually, an easy way to access all of them at once is to use the SYSEDIT program. To access SYSEDIT, type **`SYSEDIT`** in the Run dialog box (Start, Run). SYSEDIT automatically opens all the legacy configuration files in the SYSEDIT window via Notepad. You can then make the necessary modifications.

Altering the Network Card Configuration Settings

You can modify the network card resources via the Device Manager in Windows 98. After the network card is installed, you should see an icon for the device in the Device Manager.

1. To access the Device Manager, click the System icon in the Control Panel or right-click the My Computer icon and choose Properties.
2. Click the Device Manager tab.
3. Click the plus sign by the Network Adapters icon in the Device Manager. You should then see the installed network adapters.
4. Double-click the adapter you want to modify.

The actual number of configuration tabs you see for the card depends on the card and configuration options. However, most devices have three tabs:

- *General*—This tab gives you information about the current operational status of the device (for example, working properly or resource conflict).
- *Driver*—This tab allows you to change or update the network card driver.
- *Resources*—This tab allows you to change the resource configuration of the network card.

When Windows 98 Fails to Boot

If the network card is causing a configuration conflict, you may have difficulty when you reboot the system. Some hardware drivers can cause the Windows 98 system to fail during the boot process. At that point, your option is to try Windows 98 Safe Mode. Typically, this option is activated by default if Windows 98 discovers that a boot failure occurred. However, if you must activate this option manually, you can press the F8 key during the boot process.

Note

Your window of opportunity to press the F8 key is limited, so you should probably press it repeatedly after the system boots. If you see the Windows 98 splash screen that says Starting Windows 98, you missed it.

Pressing F8 during the boot process should take you to the Windows 98 Startup menu where you can select from several options. Safe Mode is probably the best first option to reset your network adapter.

Safe Mode gives you the same familiar Windows 98 interface that you were working in when you first configured the network adapter. Use this mode to locate any network resource problem. If the problem concerns a 16-bit driver, use SYSEDIT to access the configuration files. If the problem concerns 32-bit network drivers, use the Device Manager to reconfigure the resources.

If you cannot fix or determine the error via Safe Mode, you may have to create a `bootlog.txt` file to determine why Windows 98 is failing to boot. It could be that you installed the wrong driver file. To generate a bootlog:

1. Choose Logged... from the Windows 98 Startup menu.
2. Reboot the system and let it fail.
3. Boot into Safe Mode or Command Prompt Only and locate the `bootlog.txt` file that should be in the root directory (C:\).
4. Read the file with a text editor such as DOS Edit or Windows Notepad. You should be able to determine where the failure occurred by going to the bottom of the file to see the last driver that Windows 98 attempted to load before failing.

If you determine that the network card driver is failing to load, obtain the appropriate driver. Ensure the driver was not corrupted. You may want to run Windows 98 ScanDisk to ensure disk surface errors are not causing corruption on your drivers. Be sure the driver you have installed is good. Check the network card vendor Web site for known configuration errors or call its support line.

If you determine that there is a hardware resource conflict, you must reset the resources of the network card or the conflicting device. If both devices require the same hardware resources, you may have to choose between one device and another to resolve the conflict. When you have rectified the situation, you can reboot the system and expect it to operate correctly.

Configuring Windows 98 for TCP/IP

The basic configuration of TCP/IP for Windows 98 is quite simple and can be done via easy-to-use graphical interfaces. However, some of the configuration parameters can only be modified by editing the Windows 98 Registry and/or configuration files. In this section, both the easy graphical configuration and the more complex Registry editing are explored and explained.

Before You Start

Prior to installing TCP/IP on your Windows 98 system, you should know the basics about your network segment. You must use an IP address and subnet mask that is available for the given segment unless you plan to use a Dynamic Host Configuration Protocol (DHCP) server. If DHCP is implemented, you must determine which options will be automatically configured by the DHCP server.

In addition to the correct IP address and subnet mask, you will require an address for the default gateway (also known as the local router) if you plan on contacting hosts on remote segments. Again, if DHCP is being used, you must find out whether the IP address of the router will be automatically configured. If not, you will have to add this manually to your local TCP/IP configuration.

If you need to connect to hostnames on the network, you must also have the address for a DNS server that will provide name resolution services. Otherwise, you will have to configure a HOSTS file to list all the IP addresses and hostnames to which you would like to connect. You will also require some form of NetBIOS name resolution, such as a WINS server or LMHOSTS file. Both the DNS server and WINS server addresses can be released by the DHCP server, if that service is in use on the local network.

After you have all this information, you are ready to install the TCP/IP protocol suite. Be sure that you know where your Windows 98 CD or installation files are located because you will need those to install the protocol.

Installing TCP/IP

In Windows 98, the TCP/IP protocol suite can be installed from the Network dialog box. You can access this dialog box from the Windows 98 Desktop Network Neighborhood icon or from the Control Panel. To access the dialog box from the Desktop, right-click the Network Neighborhood icon and choose Properties. To access the Network dialog box from the Control Panel (Start, Settings, Control Panel), double-click the Network icon. Then, follow these steps:

1. From the Network dialog box, click the Add button.
2. Select Protocol from the Select Network Component Type dialog box and click the Add button on that dialog box. You are presented with a list of protocol options.
3. Choose Microsoft from the list of manufacturers and TCP/IP from the list of network protocols. Click OK to proceed.
4. You may have to enter the path to the Windows 98 source files. Enter this path or use the Browse button to locate the files. Click OK and the protocol will be added.
5. Click OK on the Network dialog box and you will be asked to reboot your system. Confirm the reboot to complete the installation process.

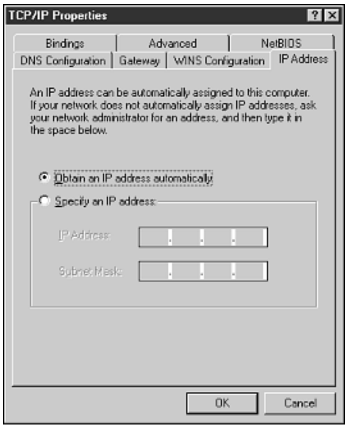
The installation for the TCP/IP protocol suite for Windows 98 doesn't ask whether you want to configure DHCP; it defaults to it. Therefore, if you are not using DHCP on your IP segment, you will have to reboot and reconfigure your TCP/IP settings.

Configuring Microsoft TCP/IP

To configure the Microsoft TCP/IP settings, such as IP address, subnet mask, and default gateway, you must again access the Network dialog box. After the TCP/IP protocol is installed, you should see it appear under the Configuration tab. If you have more than one network adapter or even a dial-up adapter, TCP/IP will automatically bind to all available cards. If you want to unbind the protocol from any adapter, locate the icon that shows the protocol with an arrow pointing to the specific adapter. Highlight the icon that represents the TCP/IP bound to the adapter and click the Remove button. After you close the Network dialog box by clicking OK, the binding modification is implemented. However, if you click Cancel on the Network dialog box, the changes you have made won't be implemented.

To configure the TCP/IP protocol manually for your network card, double-click the icon from the list that shows TCP/IP bound to your network card. (Alternatively, you can select the icon and click the Properties button.) This action opens the TCP/IP Properties dialog box (see Figure 23.3).

FIGURE 23.3
You can use the TCP/IP Properties dialog box to configure your TCP/IP settings.



The IP Address tab is the default tab of the TCP/IP Properties dialog box. On this property sheet you can either set your system to use DHCP or manually configure the IP address and subnet mask. This is because the absolute minimum configuration information that the DHCP server provides is an IP address and subnet mask. Of course, the DHCP server can provide additional options such as the address of the default gateway if configured to do so.

Gateway Configuration

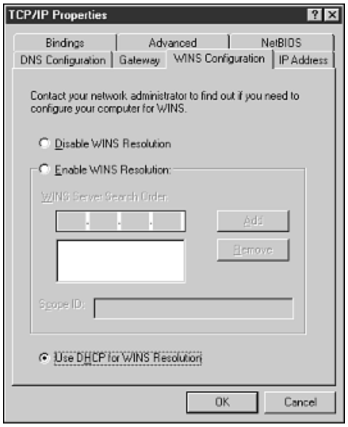
If you want to configure the default gateway manually, click the Gateway tab. On the Gateway property sheet you can configure one or more default gateway addresses for your computer. The address at the top of the list will be the default gateway, and the other gateway addresses will only be used if the default gateway is unavailable. The order in which the gateway addresses appear is the order in which they will be contacted (top to bottom).

WINS Configuration

You should also configure a WINS server, if one is available, for your Windows 98 machine. The WINS server will allow you to resolve NetBIOS computer names to IP addresses. NetBIOS is the required network interface for Microsoft operating systems prior to Windows 2000. You will need some type of NetBIOS name resolution if you are using Windows 98 with the TCP/IP protocol suite. NetBIOS name resolution, along with WINS and the LMHOSTS file, is described in Chapter 7, "WINS."

The WINS Configuration tab on the TCP/IP Properties dialog box allows you to enable WINS resolution and enter the IP address(es) for your WINS server(s) (see Figure 23.4). When you have configured WINS resolution, the Windows 98 computer will use the first available WINS server to resolve the NetBIOS name. If the first WINS server on the list is not available, the next name server will be contacted. Other WINS servers are only contacted in the event that the previous WINS server cannot be contacted. If any WINS server provides an answer, even if the answer is that the name doesn't exist in the database, no other WINS servers will be contacted.

FIGURE 23.4
The WINS Configuration tab allows you to set WINS Server addresses or use the DHCP Server for WINS services.



On the WINS Configuration tab you will also see a text box labeled Scope ID, which you should leave blank in most cases. This setting refers to the NetBIOS scope identifier, which can be any combination of alphanumeric characters that is appended to the NetBIOS computer name. For example, if you entered 123ABC as the scope ID, and your system's NetBIOS computer name was Server2, the full name of your system would be Server2.123ABC. The interesting point to note about the NetBIOS scope identifier is that Microsoft systems using TCP/IP will only be able to communicate with other Microsoft systems that have the same scope identifier. Furthermore, because the scope identifier changes the computer name, you could actually configure another computer on the network using the same name, Server2, with a different scope identifier. Due to the name and connectivity confusion that it can create, the NetBIOS scope ID is rarely used.

By default, the Use DHCP for WINS Resolution radio button is checked. This means that the DHCP server is considered to be the WINS server and is expected to provide both services. If this is not the case, you should configure the correct IP address of the WINS server in the text boxes provided.

WINS Resolution can also be disabled. Disabling WINS is appropriate when WINS is not being used on the network for name resolution. By disabling WINS, you will prevent the system attempting to find a WINS server on the network. If you have WINS enabled, and no WINS servers are present on the network, the WINS client will waste time checking for a WINS server.

DNS Configuration

In addition to NetBIOS names, you may need to be able to resolve hostnames (for example, `www.InformIT.com`). This is especially important if you are connecting to the Internet or have non-Microsoft systems on your network. To configure your system for hostname resolution, click the DNS Configuration tab (see Figure 23.5).

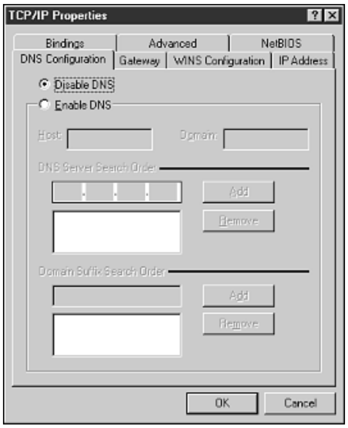


FIGURE 23.5
You can enable, disable, or configure DNS settings via the DNS tab.

If you click the Enable DNS radio button, you will be able to enter a host and domain name for your Windows 98 computer. Typically, you will want to use the same hostname for your computer as the NetBIOS computer name. If you decide to use a different NetBIOS name, you will make connectivity troubleshooting more complex because some utilities attempt to contact the computer via its hostname and others use its NetBIOS name.

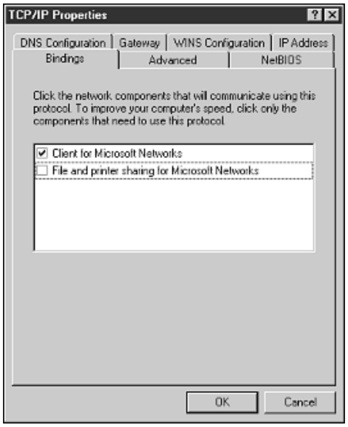
You can enter the address(es) of Domain Name System (DNS) servers that can be used to resolve hostnames to IP addresses. The address entry works the same way as the WINS server entry on the WINS Configuration tab. Enter the IP addresses for the DNS servers you want to use for name resolution. If the first DNS server answers, no other DNS servers will be contacted even if the first DNS server doesn't have a mapping for the IP address. The other DNS servers will only be contacted in the event that the first DNS server is not available (that is, offline).

When DNS services are not provided on the network, you may decide to disable (or leave disabled) DNS Name Resolution. If the network is connected to the Internet, the client will require a DNS server in order to resolve Web addresses like `http://www.microsoft.com`. However, if connections to domain names or hostnames is not required or desired, then DNS could be disabled. On an internal Microsoft-only network, DNS would not be needed unless internal Web servers with hostnames or domain names were being utilized.

Bindings Configuration

The Bindings tab of the TCP/IP Properties dialog box allows you to control which services the protocol can communicate with. For example, if you want to use TCP/IP to obtain network services, but do not want to share files over TCP/IP, you would configure your bindings as shown in Figure 23.6.

FIGURE 23.6
If you don't want to share files over TCP/IP, unbind the File and Printer Sharing service from TCP/IP.



Notice that the box for File and Printer Sharing for Microsoft Networks is unchecked and the Client for Microsoft Networks box is checked. This means that you can use TCP/IP to connect to other Microsoft systems sharing files or printers, but they cannot use TCP/IP to connect to your local files or printers.

Installing File and Printer Sharing for Microsoft Networks

If you do not have File and Printer Sharing for Microsoft Networks installed, you will not see it in the Binding tab, and other Microsoft clients will not be able to connect to your system for file or printer sharing. To install File and Printer Sharing for Microsoft networks, follow these steps:

1. Open the Network dialog box (right-click Network Neighborhood and choose Properties from the resulting context menu).
2. Click the Add button.
3. Click the Service icon and then click the Add button.
4. Choose Microsoft from the list of Manufacturers and ensure that File and Printer Sharing for Microsoft Networks is added under Network Services.
5. Click OK and enter the path to the installation files, if requested.
6. Click OK to confirm the path and again to confirm installation.
7. Reboot the system as requested.

Advanced Configuration

The Advanced tab has only one useful configuration option—the Set This Protocol to Be the Default Protocol check box. If you select this option, your client system will attempt to use TCP/IP before using any other configured protocols. If you have only TCP/IP installed, it will automatically be the default protocol.

NetBIOS

The NetBIOS tab is not really a configuration tab at all. For Microsoft clients prior to Windows 2000, NetBIOS is an essential part of the Microsoft Networking components using the TCP/IP protocol suite. The option to uncheck NetBIOS over TCP/IP is grayed out (not available) and the box is permanently checked. It is possible to enable or disable NetBIOS support for the IPX/SPX- compatible protocol, but not for TCP/IP.

Static Configuration Files

As described in Chapter 7, the `HOSTS` and `LMHOSTS.SAM` files are located in the Windows root directory.

Note

If you cannot find the Windows directory, keep in mind that sometimes it is not named "Windows." If you want to locate the Windows directory, you can type **`%windir%`** inside the Run dialog box. Click the Start button, then click Run to open the Run dialog box.

Another static configuration file that is located in the Windows root directory is the `SERVICES` file (notice that it does not have a file extension). The services file corresponds to RFC 1700 listing the Well Known Port Numbers for TCP and UDP services. The file itself says that it relates to RFC 1060, but that RFC was revised by RFC 1700 (`http://www.ietf.org/rfc/rfc1700.txt`). The `SERVICES` file lists various services, port numbers, and protocols established in the RFCs for Well Known services. For example, the FTP and FTP-data ports (21/TCP and 20/TCP, respectively) are listed in this file. The built-in Microsoft FTP client will use this file in order to determine which port to use for FTP communications. A change to this file will create a change in the default port accessed via the command-line FTP utility. However, this `SERVICES` file is not used by all TCP/IP-related utilities. As a matter of fact, the specific utility must be configured to access this file. Most third-party utilities and even the Microsoft Internet Explorer Web browser do not access the `SERVICES` file.

Registry Settings

Most of the important TCP/IP configuration options that are not available through the TCP/IP Properties dialog box are available only through the Windows 98 Registry. In this section, you learn about some of the more common TCP/IP configuration settings that can be configured via the Windows 98 Registry.

Note

If you want to reference a Microsoft document that describes even more configuration parameters for TCP/IP in the Windows 98 Registry, search for Knowledge Base Article Q158474 on the Microsoft support Web site at `www.microsoft.com/support` or obtain a copy of Microsoft TechNet.

All the parameters discussed in this section can be configured at HKEY_LOCAL_MACHINE\System\CurrentControlSet\Services\VxD\MSTCP in the Windows 98 Registry (shown in Figure 23.7). To edit the Windows 98 Registry:

1. Click Start and choose Run.
2. Type **REGEDIT** in the Run dialog box and click OK.

   Note: REGEDIT can be typed in upper- or lowercase and will still work. For the vast majority of commands, Windows 98 is not case sensitive and any executable, such as REGEDIT, can be run without regard to case.

Note

Changes made to the Registry could cause the system to fail and may even prevent the system from restarting properly. Therefore, only modify Registry settings that you understand or practice on a system that is not of critical importance. Before editing your Registry, you can save it by exporting it. To export your Registry, follow these steps:

1. Click Start, then choose Run.
2. In the Run dialog box, type **REGEDIT**.
3. After the Registry Editor is open, click the Registry menu item and select Export Registry File.
4. Enter a name for your file, for example **SaveReg**.
5. Set the location where you would like to save the file via the Save In selection box. Probably the easiest location is the desktop.
6. Click the Save button.
7. Close the Registry Editor. You should be able to see your file (RegSave.reg) on the desktop or the directory in which you saved it.

If after editing the Registry you find that the system doesn't operate properly, you can double-click your saved Registry file to revert to your old configuration.

If you want to back up the actual files that form the Registry, you can locate the system.dat and user.dat files in the Windows directory and copy them to an alternate location. If the system won't boot after you make the changes, you can copy the system.dat and user.dat file back to the Windows directory.

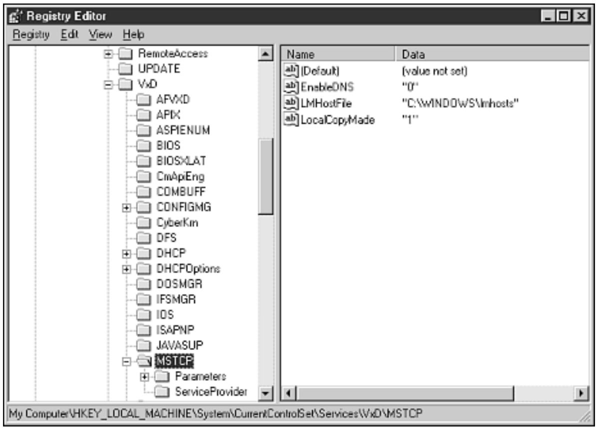


FIGURE 23.7
Use `Regedit.exe` *to modify TCP/IP Configuration Parameters in the Registry.*

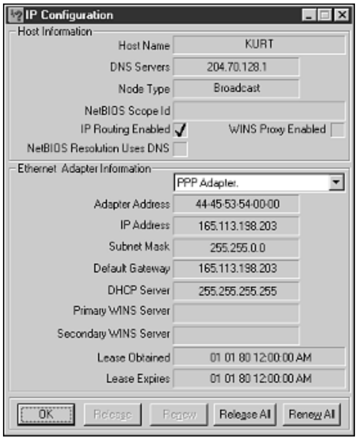
Enable Routing

If you want to use Windows 98 as a static router, you can configure the setting in the Windows 98 Registry. To do so, you must go to the MSTCP key in the Registry and add a string value named `EnableRouting` and set that value to **`1`**. Here's how you do this:

1. Click Start and choose Run.
2. Type **`REGEDIT`** in the Run dialog box.
3. Click the plus signs to expand the Registry keys to access and select the MSTCP key (refer to Figure 23.7).
4. Go to the Edit menu and choose New, String Value.
5. A new value should appear on the right-hand side of the Registry Editor. Rename this value **`EnableRouting`**, then press Enter.
6. Double-click the EnableRouting icon.
7. In the Value Data text box, type **`1`**.
8. Click OK and close the Registry Editor.

To confirm that your Registry change to enable routing actually worked, use WINIPCFG. Launch WINIPCFG from the Run dialog box; click the More Info button. You should see that the IP Routing Enabled check box is checked (see Figure 23.8).

FIGURE 23.8
After you have enabled IP routing in the Registry, you can confirm the change via WINIPCFG.



Windows 98 and Microsoft TCP/IP do not come with any routing protocols such as Routing Information Protocol (RIP) or Open Shortest Path First (OSPF). Therefore, if you want to update your Windows 98 routing table, you will have to do it manually. To add static routes to your new router, you must use the route command:

1. Open a command prompt.
2. Type **`route /?`**.
3. Press Enter to learn more.

If you enable routing, you can also configure the routing buffer size, which defaults to 73,216. If you want to modify the routing buffer, add the string value `RoutingBufSize` to the MSTCP location and set the value. You can also set the `RoutingPackets` number, which is the number of packets that can be routed simultaneously (default is 50).

Random Adapter

Another Registry parameter that can be used for a Windows 98 computer configured with multiple network adapters is the `RandomAdapter` setting. This allows your Windows 98 system to report back a random address from its set of IP addresses no matter which network card received the request. This setting can be useful when you are attempting to load-balance services among multiple network adapters. To configure this setting, add the string value `RandomAdapter` to the MSTCP key and set the value to **`1`**. By default, the Windows 98 network cards will report the address that received the resolution request.

Ping will verify your basic connectivity. To ensure that your protocol is operating correctly, first ping your loopback address.

1. Open a command prompt by typing **`command`** in the Run dialog box and pressing Enter. A command prompt window will be displayed.
2. Type **`Ping 127.0.0.1`** and press Enter.

You should receive a response from your system. If you do not, you should reinstall the TCP/IP protocol suite. If you do receive a response, then ping your own IP address. Again, WINIPCFG can be used to obtain your IP address.

If both your loopback and your local system address work, you should try to ping your local default gateway. If the gateway responds, then ping a host on a remote network. After you have done this, you will have verified your TCP/IP installation and connectivity. If you have configured name resolution, such as DNS and WINS, you can also ping those servers to ensure they are operational.

If you have trouble using ping to get a response from a remote host, the tracert utility can be quite useful. Tracert can be used from the command line to trace the route to a remote host from your local system. Tracert will issue successive ICMP messages with progressively larger TTL values. This enables the request to work its way from your local system to the remote system, reporting its progress as it goes. If the request stops anywhere along the way, you will have a good idea of where in the network the problem is located.

In order to test your name resolution configuration, you can use ping or tracert with computer hostnames to verify your DNS name resolution. You can attempt to map a drive to a Microsoft server name to ensure that NetBIOS name resolution is working properly. If there is a problem with either operation, check the respective server and your configuration.

NBTSTAT

The NBTSTAT utility stands for NetBIOS over TCP/IP Status. This utility can be used to check several items concerning your TCP/IP configuration. To access the utility, open a command prompt and type **`NBTSTAT /?`**. You will receive a list of options that can be used with the `NBTSTAT` command.

You can check your NetBIOS name cache with the `NBTSTAT -c` command. By default, the resolved NetBIOS names to IP addresses will be maintained in the name cache for 360,000 milliseconds (6 minutes). You can modify this by adding the `CacheTimeout` value to the MSTCP Registry key and configuring a different number. You can purge and preload the NetBIOS name cache via the `NBTSTAT -R` command. If you have an `LMHOSTS` file configured with #PRE entries, they will be added to the name cache after you issue the `NBTSTAT -R` command.

Note

LMHOSTS entries are described in the LMHOSTS.SAM file in the Windows root directory. Open the LMHOSTS.SAM file with Notepad or another text editor to learn more.

Another useful option available through the NBTSTAT command is the ability to list the name table of a remote or local host. Type **NBTSTAT -A** followed by the IP address of the computer for which you would like to list the name table. If you prefer to use the remote computer name, type **NBTSTAT -a** followed by the remote system's computer name. You can also type your own system's computer name or IP address to check the name table. This command will also list the remote system's MAC address.

NETSTAT

NETSTAT is a useful utility to check TCP, UDP, and IP connections. For example, you can use the command NETSTAT -p TCP to check the status of your TCP protocol; you will receive a list of TCP ports in use. You can issue the command NETSTAT -s to get a full status list of all protocols.

ARP

All local IP addresses must be resolved to MAC addresses. You can use ARP to see the MAC addresses of local systems that exist in your local ARP cache. ARP cache entries remain for two minutes when an IP address is resolved once, but not used again. If the IP address is used again within the two minutes, the ARP entry gets a life of ten minutes. You can also add static entries to the ARP cache, which will remain until the system is rebooted. Static entries allow you to reduce the number of ARP broadcasts for MAC addresses that occur on the local segment. You can see the syntax for adding a static ARP entry by typing **ARP /?** at the Windows 98 command prompt.

Summary

Microsoft produces its own version of the TCP/IP protocol suite for the Windows 98 operating system. Microsoft's TCP/IP protocol uses include support for NetBIOS and the Windows Sockets interfaces to support both NetBIOS- and UNIX-style utilities (such as ping and tracert). Also, the Microsoft IP protocol stack includes NDIS, which allows multiple protocols to be bound to one or more adapter cards.

To install and configure the TCP/IP protocol suite, you must access the Network dialog box. You can use the Add button to install the protocol suite. If you need to configure the protocol suite after installation, use the Network dialog box to access the icon for the protocol. Double-click to access the TCP/IP Properties dialog box and configure the options via the configuration tabs.

If the settings you want to configure are not available via the TCP/IP Properties sheet, then you will probably have to configure them via the Windows Registry Editor. The Microsoft Knowledge Base article Q158474 (available at `http://support.microsoft.com/support/kb/articles/q158/4/74.asp`) describes the Windows 98 TCP/IP Registry configuration options.

In the next chapter, you will learn how to configure Windows 98 to connect to the Internet via Dial-Up Networking. Many of the concepts you learned in this chapter will apply to the next one, but you will see that configuring the dial-up adapter is a little different than configuring a LAN network adapter.

CHAPTER 24

Dial-Up Networking with Windows 98

by Kurt Hudson

IN THIS CHAPTER

- **Dial-Up Adapter Configuration** *582*
- **Dial-Up Networking Installation** *583*
- **Scripting** *590*
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- **Troubleshooting Dial-Up Connections** *599*

In the previous chapter you saw how to install and configure the TCP/IP Protocol Suite settings for Windows 98 hosts. In this chapter, the discussion of Windows 98 and TCP/IP continues with the focus on remote access. In Windows 98 the remote access service (RAS) is called *Dial-Up Networking* (DUN). You will learn about DUN, how to configure TCP/IP to work with DUN, and the line protocols that are part of DUN.

This chapter focuses on Windows 98 because of its large installed base. Even though Microsoft has announced successors to Windows 98 such as Windows ME/2000/XP, people have been slow to adopt these newer OSs. This chapter therefore focuses on Windows 98 in spite of the fact that Microsoft does not support the older operating systems.

Dial-Up Adapter Configuration

Before you configure the Dial-Up Adapter components, you must install your Dial-Up Adapter or modem. Although you could use the Add New Hardware icon in the Control Panel to install your modem, using the Modems icon, which is also in the Control Panel, is easier. Double-click the Modems icon to open the Modems Properties dialog box (see Figure 24.1).

FIGURE 24.1
Configuring the Dial-Up Adapter starts with installing the modem.

If you click the Add button, you can allow Windows to detect your modem. If you already know the type of modem you have, or you plan to install the driver from a file provided by the manufacturer, you should select the Don't Detect My Modem; I Will Select It From a List check box. Click Next to continue. If Windows is not able to detect your modem, or if you didn't let Windows try to detect your modem, the Install New Modem dialog box will list Manufacturers and Models (see Figure 24.2). Notice that you can also use a serial or parallel cable between two PCs with DUN, if you like. Choose the manufacturer and modem that match your hardware configuration or click the Have Disk button and install the driver from the hardware vendor. Click Next to continue.

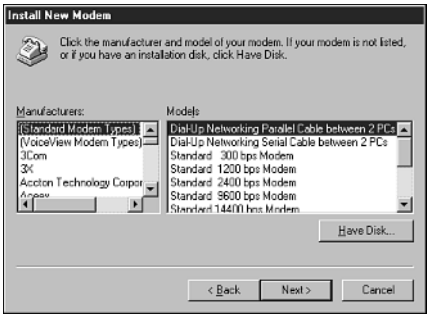


FIGURE 24.2
Select the correct modem from the choices presented.

Next, you are asked to select the appropriate port for your modem configuration. Choose the correct port and click Next to continue. When you have successfully installed the modem, click the Finish button to continue.

If you need to configure your modem further, you can click the Modems icon in the Control Panel and double-click the modem that appears in your list. This will open a modem properties dialog box and you can verify and/or set the connection speed, dialing features, type of ring, and call forwarding features (see Figure 24.3). When you have your modem installed and properly configured, you can continue with DUN configuration.

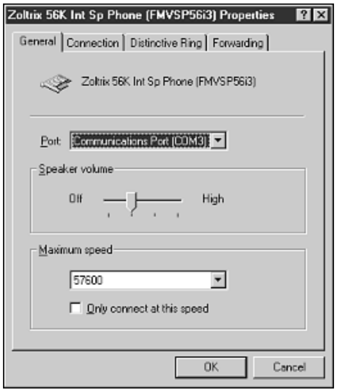


FIGURE 24.3
Ensure that you set the modem configuration to match your needs.

Dial-Up Networking Installation

To begin the installation and configuration process for DUN, double-click the My Computer icon on the desktop. Then, follow these steps:

1. Double-click the icon labeled Dial-Up Networking to access the Dial-Up Networking folder, which contains the Make New Connection icon.

2. To configure a DUN connection, double-click the Make New Connection icon. This action initializes the Make New Connection dialog box (see Figure 24.4).

   If you don't see the DUN folder, you may have to add Dial-Up Networking to your configuration. To do so, click Start, Settings, Control Panel and then double-click the Add/Remove Programs folder. Click the Windows Setup. In the Components window, double-click the icon labeled Communications. Ensure that the Dial-Up Networking check box is selected. Click OK twice to confirm that you would like to add DUN to your configuration. You may also be asked to enter the path to your Windows 98 source files.

Note

If you don't have a modem installed and you attempt to configure a Dial-Up Networking connection, DUN will automatically launch the Install New Modem wizard.

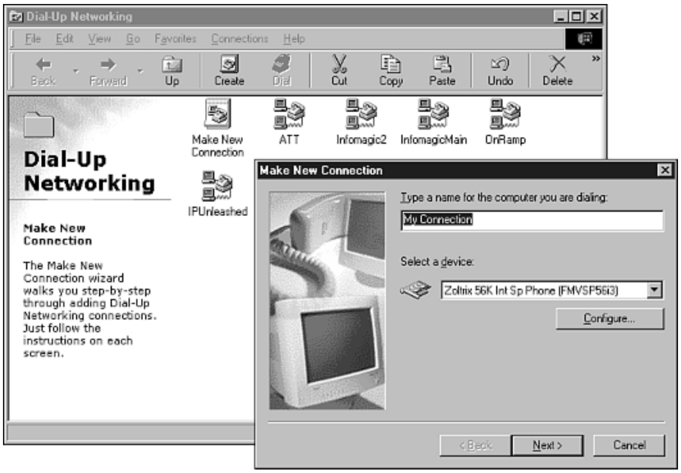


FIGURE 24.4
You must enter your dialing and location information in the Make New Connection dialog box.

The first item you can enter is a friendly name for this Dial-Up Connection.

3. Type something that clearly identifies the connection because this will become the name of the connection icon. For example, notice the various connection icons shown in Figure 24.4 (InfomagicMain, ATT, OnRamp, and so on).
4. Select the modem you would like to use for the Dial-Up Networking connection.

5. Click Next to continue.

   The next dialog box asks you to input a phone number you would like to dial.
6. Enter the area code and phone number, or change the country and enter the correct dialing information. This should be the phone number of your Internet service provider (ISP) or the remote access services (RAS) server to which you intend to connect.
7. Click Next to continue.
8. Click the Finished button to confirm your new connection.

You should see your new connection icon appear in the Dial-Up Networking folder. To further configure or modify the Dial-Up Networking connection, select the representative icon and choose File, Properties from the menu bar. You should see the following four tabs on your connection dialog box:

- General
- Server Types
- Scripting
- Multilink

Each of these is described in the following sections.

General Tab

If you want to change the phone number, modify the modem settings, or change the modem you are using for the connection, use the General tab. You can even click the Configure button to edit the configuration of your modem from the General tab, if necessary.

Server Types

After the Dial-Up Networking connection has been created, Windows 98 DUN connections usually require additional configuration via the Server Types dialog box. The Server Types dialog box allows you to configure the type of server to which you will be connecting, as well as the TCP/IP and protocol options that will be used.

You can access the Server Types dialog box through the Properties of your Dial-Up connection icon, as noted in the following steps:

1. Open the Dial-Up Networking dialog box.
2. Right-click the connection you would like to configure.
3. Choose Properties from the resulting context menu.
4. In the resulting dialog box, choose the Server Types tab (see Figure 24.5).

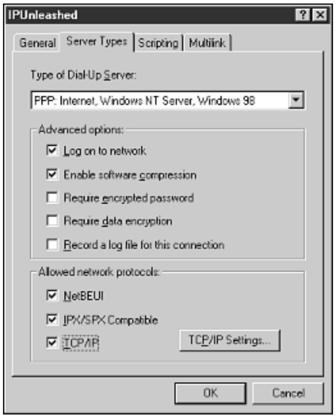


FIGURE 24.5
Although it isn't shown in the wizard, configuring the DUN Server is an important item for most dial-up connections.

Here you can configure the type of server that you intend to contact. The options in the Type of Dial-Up Server drop-down menu are

- PPP: Internet, Windows NT Server, Windows 98
- SLIP: Unix Connection
- CSLIP: Unix Connection with IP Header Compression
- NRN: NetWare Connection version 1.0 and 1.1

The NRN: NetWare Connection version 1.0 and 1.1 option supports only IPX/SPX-compatible protocol connections. The Windows for Workgroups and Windows NT 3.1 options support only NetBEUI connections. Because these two options do not support TCP/IP connections, they are not discussed further. SLIP, CSLIP, and PPP are detailed in the following sections.

SLIP and CSLIP

The *Serial Line Internet Protocol* (SLIP) and the *Compressed SLIP* (CSLIP) are typically associated with Unix RAS servers. If your ISP or Unix RAS server supports either SLIP or CSLIP, you can choose these connection options for your Windows 98 client. However, Microsoft RAS servers, such as Windows 98 and Windows NT, do not support inbound SLIP connections. Essentially, Microsoft has included a SLIP client, but not SLIP services. If you want to connect to a Microsoft RAS server, you will have to use a PPP connection.

Note

SLIP and CSLIP are not part of the default Windows 95 installation. If you want CSLIP and/or SLIP support in Windows 95, you will have to install Dial-Up Scripting Tool, which is on the Windows 95 CD-ROM. To add this support, go to the Add/Remove Programs icon in the Control Panel, click the Windows Setup tab, and then click the Have Disk option. Set the installation path to your Windows 95 CD-ROM drive letter under the `\admin\apptools\dscript` directory and click OK. Choose the SLIP and Scripting for Dial-Up Networking option and click the Install button.

The main difference between SLIP and CSLIP is that CSLIP supports IP header compression and SLIP does not. This makes CSLIP faster than SLIP over dial-up connections. Other than this difference, through Windows 98, SLIP and CSLIP provide the same functionality and configuration options. When you select SLIP or CSLIP from the Type of Dial-Up Server drop-down menu, you will notice that the Enable Software Compression and both encryption selections are not available. This is because SLIP and CSLIP do not provide the capability to perform additional data compression or encryption.

SLIP and CSLIP can only transmit one network protocol at a time. Therefore, the options to transport IPX/SPX and NetBEUI are unavailable if either CSLIP or SLIP is chosen from the Type of Dial-Up Server drop-down menu. Only TCP/IP can be used with SLIP and CSLIP in Windows 98.

SLIP does not provide a mechanism for error correction. SLIP relies on the physical hardware and the error correction capabilities of TCP/IP to maintain data integrity. Furthermore, there are no built-in compression algorithms for SLIP. CSLIP does provide limited compression of the IP header only, but not of the data contained within the packet.

PPP

Point-to-Point Protocol (PPP) is the default connection method for Windows 98 DUN clients. PPP is a line protocol that encapsulates, and is used for the transmission of, other protocol datagrams via a point-to-point connection. PPP can support one or more protocols. It can even host multiple network protocols simultaneously. By default, the Windows 98 RAS client is configured to use all three protocols (NetBEUI, IPX/SPX, and TCP/IP). However, for the sake of network efficiency, you should select as few protocols as possible for your connection. For this book, the assumption is that you will choose TCP/IP.

In addition to supporting multiple network protocols, PPP provides a Data Link Layer protocol, the *Link Control Protocol* (LCP), which is responsible for configuring and monitoring the line connection. This means that PPP is more reliable than its predecessor, SLIP. PPP does contain more information and overhead than SLIP, but due to more advanced compression techniques, PPP connections are faster and more efficient than SLIP connections.

Note

The option to enable software compression is selected by default on Windows 98 PPP connections, but is not available on SLIP or CSLIP connections.

PPP connections also allow you to configure additional security for your passwords and data. The Require Encrypted Password and Require Data Encryption check boxes are available for PPP connections, but they are not an option for SLIP or CSLIP connections (refer to Figure 24.5).

If your ISP or remote RAS server allows you to use SLIP, CSLIP, or PPP, your best choice would be to use PPP. PPP is more efficient, more flexible, and more secure than the other two line protocols.

Advanced Options

The Advanced Options section on the Server Types tab allows you to configure certain dial-up options and security features based on the type of dial-up server you configured. As previously mentioned, choosing PPP: Internet, Windows NT Server, Windows 98 offers the highest number of configuration options. The Advanced Options are described in the following list:

- *Log on to Network*—This option is mainly used when you are connecting to a Windows NT RAS server, Windows for Workgroups RAS server, or NetWare network. If you must log on to the remote network, you should ensure that this option is selected. However, the Log on to Network option is not typically required for Internet connections. Although the default option is to log on to the network, if you are making a connection to an ISP, deselect the Log on to Network check box to speed connection time.
- *Enable Software Compression*—This option is available for PPP, but not SLIP or CSLIP connections. Software compression increases the speed of your dial-up connection. Compression should only be disabled if the RAS server doesn't support it.

- *Require Encrypted Password*—PPP connections support password encryption. If this option is selected the client attempts to use the *Challenge Handshake Authentication Protocol* (CHAP) encryption to transmit its password. This will only work if both the client and server are configured to support encrypted authentication. If this option is cleared, the client can still use the *Password Authentication Protocol* (PAP), which is less secure than CHAP. The client will only use PAP if the RAS server requests it.
- *Require Data Encryption*—This option is available for PPP connections and forces data encryption. If selected, the client will only connect with servers that support data encryption. This typically does not work for Internet dial-up connections. However, if a Windows 98 server is directly dialing into a Windows NT RAS server that supports data encryption, this option can be enabled to encrypt data transferred over the PPP connection. SLIP and CSLIP do not support this option.
- *Record a Log File for This Connection*—If you are connecting to the Internet, you will probably want to configure additional TCP/IP settings for your dial-up connection. You can configure a static IP address for your system, and the IP addresses of name servers and WINS servers. These options can be established for any line protocols that utilize TCP/IP (PPP, SLIP, and CSLIP). Click the TCP/IP Settings button to open the TCP/IP Settings dialog box and configure these options for your dial-up connection (see Figure 24.6).

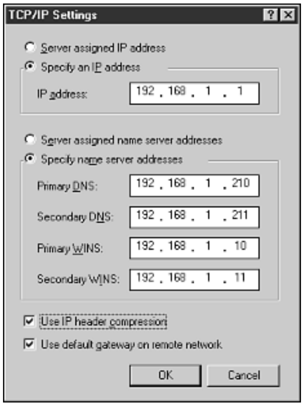


FIGURE 24.6
Typically, you will have to configure the TCP/IP Settings sheet, especially the DNS server IP addresses.

If your ISP, or the RAS server to which you are connecting, allows you to configure your own static IP address, click the Specify an IP Address radio button. Configure the static IP address you have been assigned in the IP Address box below that radio button.

One of the most important additional configuration items for Internet connections via DUN is to configure a name server. The name server allows your system to resolve hostnames (`www.microsoft.com`) to IP addresses. This is important if you want to establish connections to host or domain names. Your ISP should provide you with the IP addresses of its name servers.

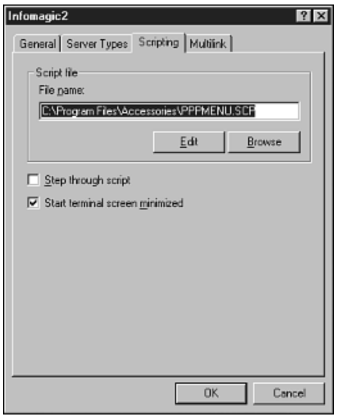
If you are not connecting to the Internet, you may still need to configure a name server IP address to obtain hostname resolution. You may also need to configure WINS server address(es) to obtain NetBIOS name resolution. Check with the administrator of the RAS server to which you are connecting to get the appropriate connection settings information (that is, the address of the WINS or DNS servers on the remote network).

Scripting

Most ISPs today support the Microsoft Dial-Up Networking method of passing the username and password directly from the DUN connection dialog box. However, some providers may still expect their clients to use a terminal window or script in order to connect to their servers. Each DUN connection (that doesn't use the VPN adapter) has a Scripting tab as part of its property sheets. The Scripting tab allows you to map the path for the script to be used for connecting to the ISP (see Figure 24.7). ISPs that require terminal login usually provide a dial-up script for their clients.

On the Scripting tab you can also enable a terminal window pop-up during the dial-up connection negotiation process. This allows you to enter your username and password, which should log you in to your ISP RAS server.

FIGURE 24.7
You can use or modify one of the available scripts in the Program Files\Accessories directory.



Note

You can learn more about writing scripts for DUN connections via the `script.doc` file in the Windows directory.

Multilink

PPP Multilink allows you to combine the bandwidth capabilities of multiple dial-up devices to increase your effective connection throughput. With Multilink, you can combine two or more modems, ISDN lines, or any combination thereof to increase your connection speed.

Note

The PPP Multilink support in Windows 98 conforms to the Internet Engineering Task Force (IETF) standard defined in RFC 1717.

Although you can use different types of dial-up connections with Multilink, you will achieve the best performance by using identical dial-up adapters. This is because Multilink only makes use of the highest common connection speed. For example, if you connect at 48,000 bps with one modem and 28,000 bps with the other, the connection of 28,000 bps will be used on both modems. If you choose to combine two ISDN B-channels to form a single Multilink connection, you will not be able to use the other channel for fax or voice communications.

One of the most important issues with Multilink is that your ISP or remote RAS server must be configured to support Multilink; otherwise, the Multilink connection will fail. If you are connecting to an ISP, you should contact your provider to determine whether its servers support PPP Multilink connections.

To configure Multilink, you must have multiple dial-up adapters configured in your system. Each dial-up adapter must be connected to its own telephone line or ISDN line. The steps to configure an additional device for a Multilink connection are as follows:

1. Open the Dial-Up Networking folder.
2. Right-click the dial-up connection for which you would like to enable Multilink. Choose Properties from the resulting context menu.
3. Click the Multilink tab.

4. Click the Add button. If the Add button is disabled, Windows 98 does not recognize that you have more than one dial-up adapter configured. Ensure that you have more than one dial-up adapter (modem) configured for your system.
5. In the Edit Extra Device dialog box, select the device that you would like to add to this connection. The device you select will work with the device you have already configured for this connection. If you are planning to use two ISDN lines, choose the new ISDN line number in this dialog box.
6. When you have correctly configured the additional device(s), see Figure 24.8. Click OK to close the Multilink dialog box.

FIGURE 24.8
If you want to configure multiple dial-out lines you must configure Multilink.

After you have properly configured the Multilink and your dial-up adapters, you can make your Multilink DUN connection. Double-click the icon representing the Multilink DUN connection that you configured, and then click the Connect button. DUN will connect using the primary device and follow with the secondary device.

To determine whether your Multilink connection is operational, double-click the Dial-Up Networking Connection icon displayed in the taskbar. In the Connected To dialog box, click the Details button to view your connection information. This should display the type of connection, the adapters, and network protocol in use.

PPTP

The purpose of implementing the *Point-to-Point Tunneling Protocol* (PPTP) is to provide a secure connection between two hosts on a network connection. The typical example for this provides a virtual private network (VPN) connection between two hosts over the Internet. The connection between the two hosts is “private” because they are the only devices involved in the encryption and decryption of the packets transferred over the connection. The encryption algorithm is negotiated between the two PPTP hosts and known only to those hosts. Even though the data is transferred over the public Internet, the connection is considered secure and private between those two points. This doesn't mean that the usefulness of PPTP is limited to the Internet, because PPTP could also be employed between two hosts on an internal private network.

Note

PPTP is not completely immune to security breaches. However, in order for a hacker to decode PPTP packets, the hacker must know or predict some of the data that is transmitted over the PPTP connection. Then, the hacker would use that "known" packet to decode the encrypted data that flows between the PPTP hosts. This is certainly more difficult and time consuming than simply collecting data packets and reading the data inside with a protocol analyzer.

Like PPP, PPTP can support multiple network protocols such as IP, IPX, and NetBEUI. However, the PPTP connection is limited to two computers, one at each end of the connection. Additionally, even if you are using a private LAN connection to host your VPN, you will require a Dial-Up Networking connection using your virtual private network adapter (software component) in Windows 98. Both ends of the PPTP connection must be configured to use DUN or RAS with PPTP.

Although PPTP can be used in a variety of scenarios, the three main configuration scenarios for PPTP connections are

- PPTP Client to ISP to PPTP Server. You establish this type of connection by connecting your PPTP dial-up client to an ISP. Then, establish a virtual private networking connection over the Internet to a PPTP server. The PPTP server should be attached to the Internet and remote target network. When the dial-up client has established the PPTP connection with the server, it can access the remote network securely over the Internet.
- Creating a VPN Within a Permanent LAN or WAN Connection. If your client system is on the same network, (using a permanent connection), you can use Dial-Up Networking to connect directly to that server over your existing permanent connection. This gives you the ability to encrypt your data within this permanent connection.

- ISP to PPTP Server. Some ISPs support PPTP connections to remote networks. Therefore, by simply dialing in to the ISP with a typical DUN connection, your data may actually be encrypted over the Internet. This is, of course, something that the ISP must configure and it doesn't affect the DUN client configuration. In this scenario, the DUN client does not need to configure PPTP or the virtual private networking adapter locally.

The most common of these three scenarios is the first scenario. Typically, the desire to encrypt data from one remote dial-up client to a RAS server is the most critical need. If you are connecting to an ISP using PPTP, the remote PPTP server to which you are connecting must have an established valid IP address. Otherwise, you will be unable to connect to the PPTP server over the Internet.

In the following sections, the basic installation, configuration, and connection steps for establishing a VPN over PPTP are described.

Installing and Configuring PPTP

There are a few items to consider before you begin to configure a PPTP connection. Probably the most significant item is that a VPN over PPTP is only possible if both hosts support PPTP. If the RAS server to which you are attempting to connect does not provide PPTP support, your VPN will not work.

PPTP connections can be made over dial-up connections, Ethernet networks, or Token Ring networks. However, all PPTP connections make use of the Dial-Up Networking (or RAS in the case of Windows NT) components. Therefore, DUN or RAS and PPTP support must be installed and configured in order to establish a PPTP connection. PPTP also requires the use of PPP, so you must configure and have available a dial-up connection and server that supports PPP.

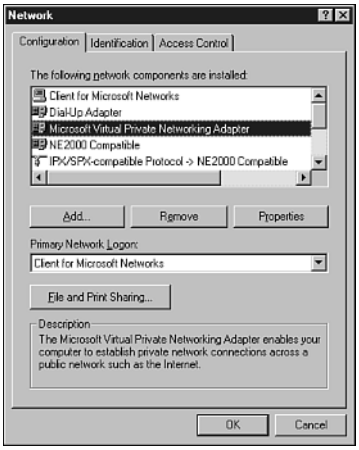
PPTP clients must still be authenticated as remote clients in order to connect over PPTP. This is true even if the client is on the same LAN as the PPTP server.

To install PPTP support, you must add a virtual private networking adapter. This adapter is installed as if it were a physical device, similar to a modem. It is also configured through DUN as if it were a physical device. The steps to install VPN support on a Windows 98 client system are as follows:

1. Right-click the Network Neighborhood icon on the desktop and choose Properties from the resulting context menu.
2. Click Add in the Network dialog box.
3. Choose Adapter and click Add in the Select Network Component Type dialog box.

4. On the left-hand side of the Select Network Adapters dialog box, locate Microsoft in the list of Manufacturers.
5. On the right-hand side of the dialog box, select Microsoft Virtual Private Networking Adapter.
6. Click OK. The adapter should now be added to your Network dialog box configuration (see Figure 24.9).
7. Confirm and/or close all remaining dialog boxes.

FIGURE 24.9
You must install the VPN adapter as a separate component.



After you have installed the Microsoft VPN adapter, you must configure a separate dial-up connection to utilize that adapter. The steps to configure a Dial-Up Networking connection for the VPN adapter are as follows:

1. Open the Dial-Up Networking folder (My Computer, Dial-Up Networking).
2. Click the Make New Connection icon.
3. Type the name for your connection. This name is for your reference only, so choose something that makes sense to you.
4. In the Select a Device selection box, choose Microsoft VPN Adapter. Click Next to continue.
5. Enter the hostname or IP address of the PPTP server to which you plan to connect. Click Next to continue.
6. Click Finish to finalize your configuration.

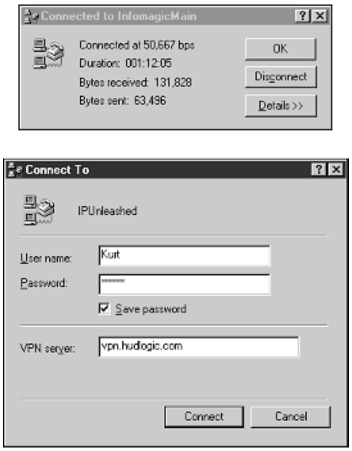
After both your VPN adapter is installed and the Dial-Up Networking connection using VPN is configured, you can establish your VPN with a PPTP server.

Making the PPTP Connection

If you are connecting through a Dial-Up Networking connection, you must first connect using your Dial-Up Networking connection, and then connect using your VPN connection (see Figure 24.10).

1. After you've connected to your ISP, click the PPTP connection icon you created with the name of your PPTP server.
2. Type the User Name and Password for the remote network.
3. Click the Connect button and your secure PPTP connection should be established over your existing connection to the ISP.

FIGURE 24.10
You must make a VPN connection after you establish the network connection.



After you are connected to the PPTP server on the remote network, the traffic from your workstation is routed via the Internet directly to the PPTP server. Within the remote network, the PPTP server routes traffic to the correct location. Because the connection is made directly to the remote network via the Internet, you may no longer be able to access the Internet. You will only be able to access the Internet if your remote network will allow it.

ISP Provided PPTP Connection

If your ISP provides a PPTP connection to the remote server, you do not need to configure a PPTP connection on your workstation. Your ISP will be able to tell you whether they provide this service.

The data you send to the ISP will not be PPTP encrypted in this case. However, the ISP's PPTP connection to the remote server will encrypt the data before passing it over the Internet.

To make this type of PPTP connection, you need only configure the Dial-Up Networking connection to your ISP. There is no need to configure a VPN connection on the workstation. The ISP must handle the configuration of the PPTP connection to your remote PPTP server.

PPTP Over LAN Connections

If you are connected via a LAN or permanent WAN connection to your PPTP server, you can still use PPTP to encrypt your data as previously mentioned. The data transferred between your workstation and the PPTP server will be encrypted over the permanent network connection. The PPTP connection allows you access to any system to which the PPTP server is connected. Therefore, you could create a separate virtual private network within your network. This type of additional security is usually desirable for the personnel departments of larger companies to ensure employee privacy.

In order to create your connection to the PPTP server, you must still configure Dial-Up Networking and add a VPN adapter. The PPTP server must also have configured dial-up (or RAS) services over a VPN adapter. Then, you must configure a dial-up connection to the PPTP server, as previously described. Finally, launch the dial-up connection in order to connect to the PPTP server.

PPTP Over Firewalls and Routers

If you must connect to your PPTP server via a firewall, router, or proxy server, you may need to enable the appropriate TCP port and IP protocol ID. As specified by the Internet Assigned Numbers Authority (IANA), PPTP traffic is sent over TCP port 1723 and the IP protocol ID for PPTP traffic is 47. If you enable the correct TCP port and IP protocol ID, you should be able to send VPN traffic through your router, proxy server, or firewall.

Windows 98 Dial-Up Server

Windows 98 also has a Dial-Up Server that you can use to host a dial-up connection. You can install the DUN server from the Windows 98 Add/Remove Programs icon. To install the DUN server in Windows 98, follow these steps:

1. Open the Control Panel (Start, Settings, Control Panel).
2. Double-click the Add/Remove Programs icon.
3. Click the Windows Setup tab.
4. Double-click Communications.

5. Select the Dial-Up Server check box.
6. Click OK twice to install the components.
7. Enter the path to the Windows 98 installation files and click OK to begin installation.

After you have added the DUN Server to your configuration, you can access it through the Dial-Up Networking folder. Click the Connections drop-down menu from that folder and select Dial-Up Server. You will see a dialog box similar to the one shown in Figure 24.11.

FIGURE 24.11
Windows 98 has a Dial-Up Networking Server that can be added to the DUN configuration.

The configuration options for the DUN server are fairly limited. As you can see in the figure, you can enable or disable the service by clicking either the Allow Caller Access or No Caller Access radio button. If you allow caller access, you can configure a password for the dial-up connection. This would be a share-level protection, meaning that all users would enter the same password to establish a connection with the DUN server. The server can host only one connection at a time.

If you click the Server Type button on the Dial-Up Server dialog box, you will see two additional options. You can Enable Software Compression and Require Encrypted Password for the connection. You can also choose the type of dial-up server that you would like your system to support. You can configure the DUN server as a PPP: Internet, Windows NT Server, Windows 98 DUN server. The default option is the former and is the only option that supports TCP/IP over the dial-up connection. No other configuration options are available via the Windows 98 DUN server. Even though you may have multiple dial-up adapters configured on your Windows 98 DUN server, the server will not support Multilink connections.

Note

The DUN server for Windows 95 is part of the Windows 95 Plus! Pack CD-ROM.

For more advanced RAS features and support, consider using the Windows NT RAS server, which does support Multilink, multiple dial-in connections, and data encryption.

Troubleshooting Dial-Up Connections

There are a few items to keep in mind when you are troubleshooting problems with dial-up connections. Some of these issues are obvious but often overlooked. For example, if the hardware is not functioning correctly, a DUN connection cannot occur. If the modem is disconnected, or improperly configured, DUN connections will certainly fail.

When troubleshooting a DUN problem, first confirm the modem configuration and operation. If possible, have the modem connect to another location. If you establish that the modem is working correctly, you can move to troubleshooting the DUN components. To verify modem operation, you can use the More Info button on the Diagnostics tab of the Modem control panel applet.

Confirming the DUN Configuration

If the modem is working and properly configured, the next item to check is the DUN settings. Right-click the connection that is not working in the Dial-Up Networking folder and choose Properties. Confirm that the correct phone number and area code are entered on the General tab. Remember that Windows 98 DUN will dial long distance if this phone number shows an area code other than the one configured for DUN. If the area code is giving you trouble, you can uncheck the Use Area Code and Dialing Properties check box on the General tab.

Ensure that the correct modem is selected in the DUN configuration box. You should also click the Configure button to ensure that the settings you see are correct for the modem. It is possible to install the modem driver twice and configure it different ways. Ensure that the configuration for the modem is correct.

Click the Server Types tab to confirm that the appropriate settings are configured here. Ensure that you are attempting to connect to the right type of server. Check with your ISP or the RAS server administrator to determine the correct settings.

If data encryption is not supported by the RAS server, your connection will fail if Require Data Encryption is selected. If your password is not being accepted by the remote server, try changing the Require Encrypted Password check box setting. Another troubleshooting step is to try clearing the Enable Software Compression check box. Some RAS servers do not support this feature and clearing this box might solve the problem.

The Log on to Network check box is not required for most ISP connections, but shouldn't cause a problem if it is checked. However, you should clear this check box if your ISP or RAS server does not require you to log on.

PPP Logging

If you are using a PPP connection, you can click the Record a Log File for This Connection check box to troubleshoot the PPP connection. When this check box is selected, a `PPPLOG.TXT` file will be created in your Windows root directory. The `PPPLOG.TXT` documents the connection process and helps you to identify where the connection is failing. Microsoft has produced a Knowledge Base article (Q156435) titled "How to Interpret the PPPLOG.TXT file." You can locate this article on the Microsoft TechNet CD or online at `www.microsoft.com/support`. Search for the article identifier Q156435.

Summary

Windows 98 Dial-Up Networking allows you to connect to remote systems over dial-up connections. The DUN client software can be used to connect to a wide variety of RAS servers, including SLIP, CSLIP, and PPP. PPP is the default and most efficient of the DUN connections you can make with Windows 98. Most ISPs now support PPP connections; however, Windows 98 does support CSLIP and SLIP client connections as well.

To configure DUN, you must first install a dial-up networking device. Because DUN is considered networking, you add the DUN adapter through the Network dialog box. If you don't have a modem installed, the DUN setup routine will launch the modem wizard. After you have configured both the modem and the dial-up adapter software, you can create the DUN connection.

To create a DUN connection, you must go to the Dial-Up Networking folder and use the Make New Connection wizard. After creating the connection, you will most likely have to modify the properties of your DUN connection. For example, you may need to configure a static IP address for your client system or add the IP addresses of DNS or WINS servers for name resolution. You can also configure encryption, compression, and the type of server to which you will be connecting in the DUN connection properties dialog box. If you have more than one DUN-capable device installed on your system, you can also enable Multilink via the DUN connection properties.

Windows 98 supports PPTP, which can provide a secure connection between two points on a public or private network. To use PPTP, both the client system and the server must support and configure PPTP and a VPN adapter. The PPTP connection can be made over a permanent LAN or WAN connection or a dial-up connection. Either way, the network or dial-up network connection is established before the PPTP connection. A separate VPN adapter and Dial-Up Networking connection is required to implement the VPN.

When troubleshooting your dial-up connection, do not neglect modem verification. If the modem is not configured or functioning correctly, the dial-up connection will consistently fail. After you have verified the modem settings and driver, check the DUN configuration. Ensure that you have the appropriate server type configured. Also, ensure that your client is not attempting to use encryption or compression that is not supported by the RAS server. If you cannot see the configuration problem for a PPP configuration, enable logging on the Server Types tab of your DUN connection properties. Attempt your connection, and then review the `PPPLOG.TXT` file in your Windows root directory. You should then be able to determine the point at which your connection is failing.

CHAPTER 25

Configuring TCP/IP for Windows NT

by Kurt Hudson

IN THIS CHAPTER

- **Windows NT Versions** *604*
- **Architecture** *604*
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This chapter covers how Microsoft TCP/IP is applied and used on Windows NT systems. The troubleshooting tools and Microsoft TCP/IP architecture that apply to Windows 98 are also true for Windows NT; therefore, you are encouraged to read Chapter 23, “Configuring TCP/IP for Windows 95 and Windows 98,” and Chapter 24, “Dial-Up Networking with Windows 98,” before proceeding with this chapter. In this chapter you learn how to configure and implement TCP/IP on a Windows NT server. You also learn how to install and configure the DHCP server, TCP/IP printing, and other TCP/IP-related services on the Windows NT server.

Windows NT Versions

Several different versions of Windows NT as well as different product types exist within the Windows NT category. For example, Windows NT Server, Windows NT Workstation, and Windows NT Enterprise are all different products. Divisions also exist within the product line, such as Windows NT 4, Windows NT 3.51, and so on.

Note

The discussion in this chapter assumes the use of Windows NT Server 4 unless otherwise specified. Other versions and/or products in the Windows NT category are mentioned only when noteworthy differences exist between them and Windows NT 4. For the majority of the discussion presented in this chapter, the Microsoft TCP/IP protocol suite is implemented identically in all version 4 releases of Windows NT.

Architecture

The Microsoft TCP/IP architecture for Windows NT is the same as it is for Windows 98. Therefore, the architecture of the Microsoft TCP/IP protocol suite presented in Chapter 23 applies here. One important point meriting another mention is that NetBIOS is part of the Microsoft TCP/IP protocol suite in Windows NT systems prior to Windows 2000.

Installation

The default protocol for Windows NT 4 is TCP/IP, so it is typically added during the installation process. However, skipping the installation of networking components during setup, or installing a different protocol during the installation process is possible. The configuration of the protocol during installation and after installation is nearly identical.

The only noticeable difference is that the configuration process is automated during the setup routine and doesn't allow you to configure as many options as you could after the process is complete. Given that you have more control over your TCP/IP installation after you have installed the product, this chapter focuses on installing and configuring the protocol as if it were not added during the installation process.

Note

If you did not install any networking components during the Windows NT installation process, you will be prompted to run the Network Configuration wizard, which is identical to the process skipped during installation.

Before you install the TCP/IP protocol you should be ready with configuration information, unless you are using DHCP to configure your protocol. Even if DHCP is employed on the network, you may still have to configure a few additional options such as a DNS and/or WINS server address. However, the DHCP server could also set these options.

Installing the TCP/IP Protocol Suite

To install the TCP/IP protocol suite, you can use the Network icon in the Control Panel or the Network Neighborhood icon on the Windows NT Desktop. Follow these steps:

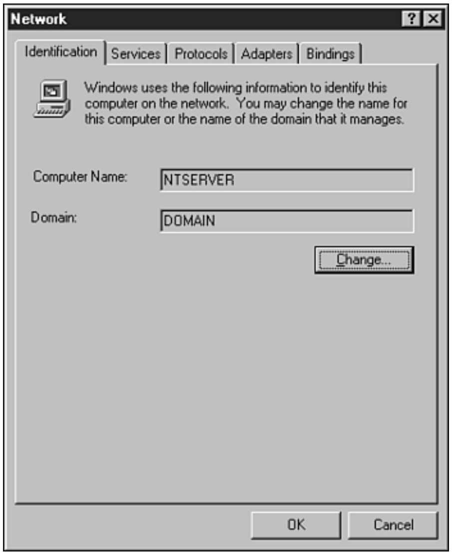
1. To use the Network icon in the Control Panel, open the Control Panel by clicking Start, Settings, Control Panel.
2. Inside the Control Panel, double-click the Network icon. The Network dialog box opens (see Figure 25.1). (Another way to open the Network dialog box is to right-click the Network Neighborhood icon, then choose Properties from the resulting context menu.)

You can configure several network settings via the Network dialog box. The following sections describe the configurable setting in each tab of the Network dialog box.

Identification Tab

The first tab you see on the Network dialog box is the Identification tab. This is similar to the Identification tab in Windows 98 (as described in the previous chapter). The Identification tab shows the NetBIOS name of the computer and either the workgroup or domain name of which the computer is a member. Do not confuse the domain name shown here with the DNS domain name. The domain name shown on the Identification tab is specific to Microsoft networking and is part of the user and computer account administration system.

FIGURE 25.1
Use the Network dialog box to configure your Windows 98 network settings.



Services Tab

The Services tab is used for installation and in some cases configuration of services related to the network. For example, this is where you would install the DNS server service, WINS server service, and even some additional TCP/IP services. These services are discussed in greater detail as this chapter progresses.

Bindings Tab

The Bindings tab illustrates the services, adapters, and protocols that have been linked (bound) together in the system. Essentially, the binding programmatically associates components so that they may be used together. You can use the Bindings tab to bind or unbind protocols from adapters or services. You can even unbind services from adapters.

Note

When placing a Windows NT system on the Internet via a dial-up adapter, unbinding the server service from the WAN adapter is wise. Doing so keeps your Windows NT system more secure because it will not advertise its shared directories on the Internet, nor will it allow connectivity over NetBIOS via the Internet.

Adapters Tab

The Adapters tab illustrates the devices you have configured in the Windows NT system. You will see both network adapters and dial-up networking (DUN) equipment listed under this tab. If you must install a network adapter or update a network driver, you can do so from this tab. Some adapters also allow you to manage physical resource settings through this tab. Other cards may need to be manually set or configured via a vendor-specific installation program. You can also use the Adapters tab to remove a network device.

Protocols Tab

The Protocols tab of the Network dialog box is where you install and configure the Microsoft TCP/IP protocol suite. To install the TCP/IP protocol from the Network dialog box, follow these steps:

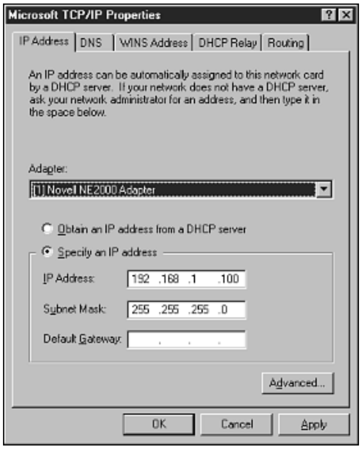
1. Click the Protocols tab.
2. Click the Add button.
3. Choose TCP/IP Protocol from the list of network protocols (select by clicking).
4. Click the OK button.
5. Confirm or enter the path to the Windows NT installation files and click the Continue button.
6. Click Close on the Network dialog box and reboot as requested.

After you have finished installing the protocol, you will be asked to configure your TCP/IP settings. In the next section, TCP/IP configuration is explained.

Configuring TCP/IP

After you have installed the TCP/IP protocol suite, you will be asked whether you want to configure the protocol. Whether or not you decide to at that time, you can return to the Network dialog box to configure the protocol at any time. On the Protocols tab, double-click the TCP/IP Protocol icon. The Microsoft TCP/IP Properties dialog box appears, as shown in Figure 25.2.

FIGURE 25.2
The Microsoft TCP/IP Properties dialog box gives you several configuration options.



The five tabs on the Microsoft TCP/IP Properties dialog box are

- IP Address
- DNS
- WINS Address
- DHCP Relay
- Routing

The following sections describe each of these tabs.

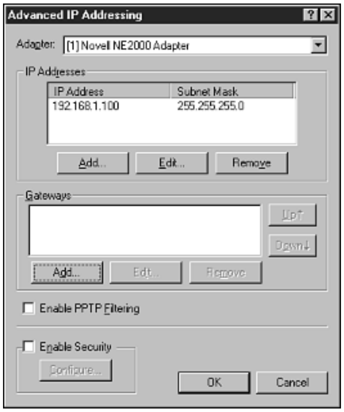
IP Address

This tab allows you to configure your system's IP address, subnet mask, and default gateway settings. You can also choose to utilize DHCP to obtain your IP configuration, in which case the IP address and subnet mask fields are made unavailable. However, the default gateway can be configured whether you have decided to use DHCP or to manually configure your settings. You can also enter a default gateway address, whether or not you are using DHCP. If you manually enter a default gateway, it will override any default gateway setting if it has been configured on the DHCP server.

Advanced IP Addressing

If you click the Advanced button on the IP Address tab, you will open the Advanced IP Addressing dialog box (see Figure 25.3). This dialog box allows you to configure multiple IP addresses for any one of your installed network adapters. You can also set different default gateways for each card.

FIGURE 25.3
The Advanced IP Addressing dialog box allows you to configure multiple IP addresses and separate default gateways.



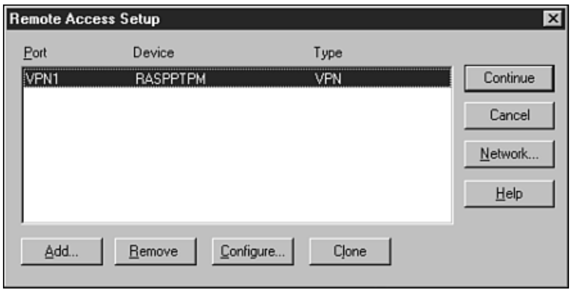
Notice that you can select the network card you are configuring in the Adapter selection box. This enables you to configure different settings for each card you have installed in your Windows NT Server.

Enable PPTP Filtering

The Enable PPTP Filtering check box allows you to force the given network card to accept only PPTP packets and discard all others. Essentially, this option turns the network adapter into a PPTP-only link, which means that only PPTP clients will be able to communicate with the given adapter.

To make this feature work correctly, you would still have to install the Point to Point Tunneling Protocol from the Protocols tab on the Network dialog box. If RAS has not been installed before you install PPTP, the RAS installation routine will be launched automatically. Unlike Windows 98, it is the installation of the protocol that allows you to create a PPTP connection. (In Windows 98, it is the installation of a Virtual Private Network adapter.) After the protocol is added, you will have a VPN adapter installed (see Figure 25.4).

FIGURE 25.4
When a VPN adapter is installed, you can see it graphically.



After you have installed PPTP and RAS, you can modify settings via the Network dialog box. For example, if you want to increase the number of Virtual Private Networks you will allow, click the Protocols tab and double-click the Point to Point Tunneling Protocol icon. This action opens the PPTP Configuration dialog box, in which you can change the number of VPNs you are allowing. If you want to configure your RAS settings, click the Services tab and then double-click the Remove Access Service icon. This opens the Remote Access Setup dialog box, where you can configure protocols, network settings, and adapters.

Note

RAS server installation and configuration is covered in greater detail later in this chapter. Refer to Chapter 24 for a more in-depth discussion of PPTP and VPN.

Enable Security

Another setting on the Advanced IP Addressing dialog box (refer to Figure 25.3) is the Enable Security check box. Selecting this allows you to click the Configure button, which opens the TCP/IP Security dialog box (see Figure 25.5).

FIGURE 25.5
You can restrict access to specific ports and protocols via the TCP/IP Security dialog box.

You can select which adapter you would like to configure your TCP/IP security options via the Adapter selection box. There are also three different columns where you can configure additional restrictions. The default setting is to permit all TCP and UDP ports and all IP protocol identifiers. However, if you want to secure the network card so only specific ports and protocol identifiers are allowed to pass through the network card, you can select the appropriate Permit Only button and enter the number of the port to permit. Notice that after you configure a restriction you can only enable ports; all others in that category will be denied. Essentially, this means that you cannot selectively deny ports, you can only selectively enable ports after globally denying all ports.

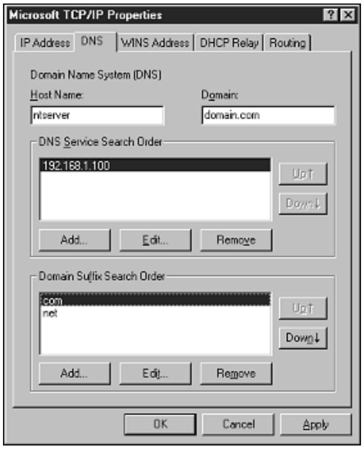
As an example, if you wanted to allow anyone to access a Web server attached to your Windows NT Server, you would click Permit Only on the first column and add 80 into the list. Then, you would select Permit Only in the UDP column and not enter any numbers. This would effectively limit your Windows NT server to receiving only TCP Port 80 traffic on that network card. All other traffic would be denied.

> **Note**
>
> TCP Port 80 is the well-known port for HTTP (Web) services. To review the other well-known port settings, see RFC 1700.

DNS

To configure your IP client's DNS settings, click the DNS tab on the Microsoft TCP/IP Properties dialog box (see Figure 25.6). This tab allows you to configure the hostname and DNS domain name for your computer.

FIGURE 25.6
The DNS tab allows you to configure the computer's hostname, domain name, and the name services it will use to resolve names.



The default hostname is the same as the NetBIOS computer name (on the Network dialog box Identification tab). You should leave the NetBIOS and hostnames the same because the computer will be easier to identify on the network. For example, if you tried to troubleshoot a connectivity problem for a system that had a hostname that was different than the NetBIOS name, you would see the NetBIOS name when looking in Network Neighborhood. However, if you tried to use `ping` on the computer name, the hostname of the system would be assumed by the `ping` utility.

DNS Service Search Order

In the DNS Service Search Order window you can configure the IP addresses of the DNS servers you would like to provide hostname resolution services. If your local Windows NT Server installation is providing DNS services, you can configure the local host address here. You can also add additional addresses of DNS servers in case one fails. The DNS client only queries additional DNS servers if the previous DNS server is unavailable. If the client receives a response from its DNS server, even a negative response, the DNS client will not attempt to contact additional DNS servers by default.

Domain Suffix Search Order

The Domain Suffix Order configuration box allows you to set the order in which you would like your client to search the DNS structure when seeking name resolution. Setting this feature is usually not required. For example, if most of the Internet sites you access by name are United States Air Force (military) sites, you may want to place AF.MIL at the top of your search order list. This tells the DNS server to search the AF.MIL structure first.

Note

You can modify the order of IP addresses or domain suffixes via the Up and Down arrows to the right of each of the DNS Service Search Order and/or the Domain Suffix Search Order windows. You should modify the order so that DNS suffixes that are more frequently used should be at the top of the list.

WINS Address

You can configure the WINS servers, by IP address, that your client will use for name resolution. In Windows NT 4 systems, you can only type a primary and/or secondary WINS address into the dialog box. The secondary WINS server is another WINS server on the network queried for name resolution if the primary WINS server is down. The terms *primary* and *secondary* are relative to the order in which the WINS client will access them, but there is no difference in the WINS server installations.

Enable DNS for Windows Resolution

If the Enable DNS for Windows Resolution check box is selected, your WINS client will attempt to resolve NetBIOS computer names via the `hosts` file. After the `hosts` file, your system will check the DNS server. Use this option if your primary name resolution method on the network is DNS. An example of this would be a network that has mostly

Unix machines with some Windows machines. Some DNS servers can be configured with a $WINS directive that can forward unresolved name queries to a specific WINS server.

Enable LMHOSTS Lookup

If you want your client to search an `LMHOSTS` file for NetBIOS name resolution, you can select the Enable LMHOSTS Lookup check box. You can also click the Import LMHOSTS file button to browse your network and copy an `LMHOSTS` file to your local system.

Note

For more information on NetBIOS and hostname resolution via Microsoft clients, see Chapter 7, "WINS."

Scope ID

You should leave the Scope ID text box blank unless you want to limit communications for your Windows NT system. The scope ID allows you to segregate communications at the NetBIOS level on your network. Only systems with the same NetBIOS scope ID can communicate on your network. By default, all systems can communicate because they have the same scope ID (nothing). However, you can enter any alphanumeric combination here to set a scope ID for your computer. If you do, you will only be able to communicate with computers that have an identical scope ID.

The scope ID is actually appended to the computer name for the system. Therefore, setting multiple systems to the same computer name, but with different NetBIOS scope ID fields, is possible. However, realize that those computers will be unable to communicate with one another.

DHCP Relay

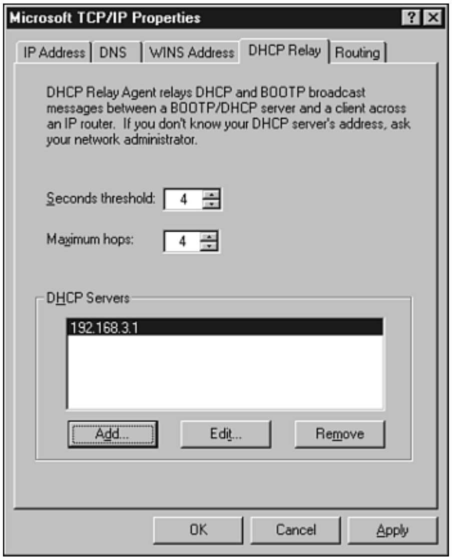
The Dynamic Host Configuration Protocol (DHCP), as described in Chapter 8, "Automatic Configuration," provides dynamic IP address and subnet mask configuration for clients. However, because DHCP relies on broadcasts, sometimes routers can prevent DHCP requests from correctly traversing network segments. RFC 1542 defines the service that a router should provide in order to allow DHCP packets to be appropriately handled. However, not all routers support this RFC. Therefore, when these RFC 1542 non-compliant routers separate a DHCP client and DHCP server, the client cannot get an address without some type of workaround.

As a workaround for networks that use routers that do not support RFC 1542, Windows NT computers can be used as DHCP Relays. The function of a DHCP Relay is to forward a DHCP request to a DHCP server. The DHCP Relay modifies the ‘giaddr field of the DHCP Request packet, which indicates the subnet identifier of the requesting client. Then, the DHCP Relay forwards that packet directly to the DHCP server. The DHCP server uses the ‘giaddr field to assign an appropriate address and sends the request back to the DHCP Relay, which forwards it to the requesting client system.

Enabling DHCP Relay

If you want to enable your system as a DHCP Relay, enter the IP address(es) of the DHCP server(s) on your network in the DHCP Servers window via the Add button (see Figure 25.7). You can also configure the maximum number of hops your DHCP request packet should travel before being discarded and the number of seconds your system will wait for a response.

FIGURE 25.7
The DHCP Relay tab allows you to enable DHCP Relay services on your NT system for your subnet.



Installing the DHCP Relay Agent Service

In addition to entering a DHCP server address, you must also install the DHCP Relay Agent service. This can be done through the Network dialog box Services tab. The specific steps to install the DHCP Relay Agent are as follows:

1. Right-click the Network Neighborhood icon on the desktop.
2. Choose Properties from the resulting context menu.
3. Click the Services tab on the Network dialog box.
4. Click the Add button.
5. Select DHCP Relay Agent from the list of network services.
6. Click the OK button to confirm your selection.
7. Confirm or enter the path to the Windows NT installation files and click the Continue button.
8. Click Close on the Network dialog box and reboot the system as requested.

Routing

The Routing tab is the last configuration tab on the Microsoft TCP/IP Properties dialog box. There is only one check box on the entire configuration tab labeled Enable IP Forwarding, which can either be checked or cleared. When checked, the Windows NT system is enabled as an IP router. If the system has multiple network cards, packets can be routed from one segment to another via the Windows NT system.

Windows NT Server 4 supports static routing and dynamic routing via the *Routing Information Protocol* (RIP). If you want to utilize RIP, you must install it via the Services tab on the Network dialog box (click the Add button and choose RIP for Internet Protocol). The Enterprise version of Windows NT 4 includes the routing protocol *Open Shortest Path First* (OSPF). RIP and OSPF allow your system to dynamically build its routing table via an information exchange with other RIP or OSPF routers. If you do not use RIP or OSPF, you will have to build and maintain the routes to remote networks manually.

You can obtain OSPF in a downloadable product called Routing and Remote Access Service (RRAS) for Windows NT 4. This product is a free update to Windows NT RAS and offers additional capabilities as well as the OSPF support. See `http://www.microsoft.com/ntserver/nts/downloads/winfeatures/rras/rrasdown.asp?RLD=188` for more information.

Note

You can find Registry settings for Microsoft TCP/IP on Windows NT via Knowledge Base article Q120642 on the Microsoft support site at `www.microsoft.com/support` or on the Microsoft TechNet CD-ROM.

Simple TCP/IP Services

You can install the Simple TCP/IP Services from the Services tab of the Network dialog box. This is actually a separate component of services that can be added to your system after the installation of the TCP/IP Protocol.

Adding Simple TCP/IP Services

To add the Simple TCP/IP Services, follow these steps:

1. Click the Services tab on the Network dialog box and then click Add.
2. Choose Simple TCP/IP Services from the list of components and then click OK.
3. Enter or confirm the path to your Windows NT installation files and click Continue.
4. Click Close on the Network dialog box and reboot as requested.

You should then see Simple TCP/IP Services listed in the Network Services window. The Simple TCP/IP Services include Character Generator (RFC 864), Daytime (RFC 867), Echo (RFC 862), Discard (RFC 863), and Quote of the Day (RFC 863).

Remote Access Services (RAS)

Windows NT can be a RAS server and client. The RAS software is built into the product. The Windows NT RAS server software can host up to 256 connections on Windows NT Server 4, but is limited to hosting only one connection when running on Windows NT Workstation 4.

You can use the following steps to install RAS on your Windows NT 4 system:

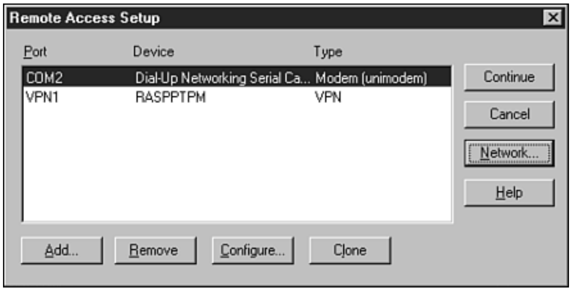
1. To install RAS you must open the Network dialog box (right-click the Network Neighborhood icon, and then choose Properties).
2. RAS is a network service, so click the Services tab of the Network dialog box.
3. Click the Add button and choose Remote Access Service from the list of installable network services.
4. Click OK. Confirm or enter the path to your Windows NT installation files and click the Continue button.
5. Click Close on the Network dialog box and reboot as requested.

When you are installing RAS you must select, or add and select, a RAS-capable device. If you do not have a RAS-capable device when you install RAS, the Modem Wizard program will guide you through adding a modem to your Windows NT System. This process is nearly identical to the process for installing a modem via Windows 98, described in the previous chapter.

Configuring Your RAS Server

After the modem and RAS are installed, you can configure your RAS server via the Network dialog box Services tab. Double-click the Remote Access Service icon to open the Remote Access Setup dialog box (see Figure 25.8).

FIGURE 25.8
You can configure, add, or remove RAS devices from the Remote Access Setup dialog box.



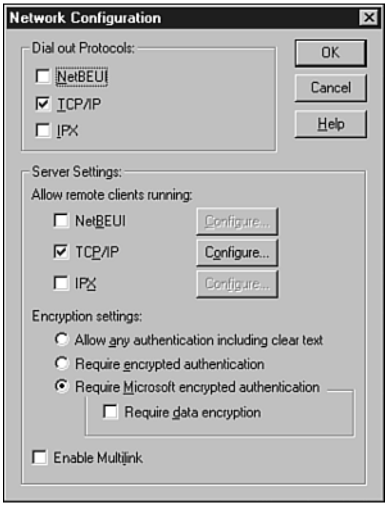
From the Remote Access Setup dialog box you can Add, Remove, or Configure your RAS-capable devices. You can also configure whether to allow inbound, outbound, or both direction RAS capabilities. You can also configure the Network protocols that will be allowed and how they will be implemented on the RAS server.

If you click the Add button on the Remote Access Setup dialog box, you can choose to install a modem or X-25 device for RAS access. If you choose to install a modem, the Modem Wizard will be launched. The X-25 option allows you to configure an X-25 packet-switching connection. ISDN devices are considered modems, so use the Install Modem icon to add your ISDN device.

If you click the Configure button, you can configure the capabilities for your RAS device's port. The Configure Port Usage dialog box allows you to configure your device to dial out, receive calls, or both. The default setting for Windows NT Server is to allow inbound calls only. The default setting for Windows NT Workstation is to allow outbound calls only. If you do enable outbound calling, you will enable RAS from the logon dialog box. This option allows remote users to establish a dial-up connection and log in to their remote network at the same time they are logging in to their local system.

If you click the Network button on the Remote Access Setup dialog box, you will be able to configure the network protocols allowed for your system (see Figure 25.9). For your RAS client, you enable the use of NetBEUI, TCP/IP, and/or IPX. The Server Settings section allows you to enable and configure NetBEUI, TCP/IP, and IPX for your dial-up connections.

FIGURE 25.9
The TCP/IP Network Configuration dialog box allows you to configure IP settings that will be unique to your RAS connection.



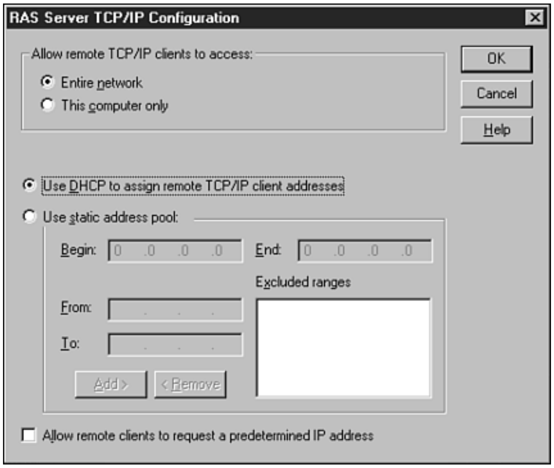
Note

The options you can configure in the Network Configuration dialog box depend on the type of access you allowed via the Configure Port Usage dialog box. For example, if you are set to Receive Calls Only, then your options on the Network Configuration dialog box will be limited to the Server Settings section. Likewise, the protocols that are enabled by default on the Network Configuration dialog box are the protocols that you have installed on your system.

Each of the protocols you configure can limit the access of the remote client to the local server or allow them access to the entire network. The TCP/IP options allow you to use DHCP to assign IP addresses to RAS clients, or you can configure a range of addresses to be released to RAS clients. There is also an option to allow remote clients to request a predetermined (static) IP address (see Figure 25.10).

Also, on the Network Configuration dialog box you can set different authentication types for your system. For example, you can allow any authentication type (including clear text), require encrypted authentication, or require Microsoft encryption. If you decide to enable Microsoft encryption, only Microsoft operating systems will be able to participate in the RAS connections. Also, with Microsoft encryption, you can configure data encryption. For the widest range of compatibility for dial-in users, you should allow any authentication.

FIGURE 25.10
When allowing dial-in access on your Windows NT Server, you must configure the RAS Server TCP/IP Configuration dialog box.



If some of your clients will be using Multilink connections, you can enable inbound Multilink connections by checking the Multilink check box on the Network Configuration dialog box.

When you are finished making changes, click OK to confirm and click the Continue button on the Remote Access Setup dialog box to commit all changes.

DHCP Server

The Windows NT Server product can be used as a DHCP server. The DHCP server service is part of the installable network services for the Windows NT server. One condition for installing the DHCP server service is that the DHCP server must have a statically configured IP address. In other words, a DHCP server cannot obtain its IP address from another DHCP server.

Note

DHCP was explained in Chapter 8. This chapter focuses on installing and configuring DHCP on the Windows NT server, not on the benefits or potential pitfalls of using DHCP.

Installing the DHCP Server Service

In Windows NT, the DHCP server service is installed as a networking service. To install a networking service, you must access the Services tab of the Network dialog box. The steps to install the DHCP server service are as follows:

1. Right-click the Network Neighborhood icon on the desktop, and then click Properties.
2. Click the Services tab on the Network dialog box.
3. Click the Add button on the Services tab.
4. Choose the Microsoft DHCP Server from the list of network services.
5. Click OK.
6. Enter or confirm the path to the Windows NT Server installation files and click the Continue button. Reboot as requested.

Controlling the DHCP Server Service

After the DHCP server service is installed, you can see the service listed in the Services dialog box. You can access the Services dialog box by double-clicking the Services icon in the Control Panel. The DHCP server service is listed as Microsoft DHCP Server. If you highlight the service in the list you can stop, start, and pause the service. You can also review its current operational status and configure how the service will be started.

To stop a running service, highlight that service and click the Stop button on the Services dialog box. You can also pause the running service by using the Pause button. Pause means that the service cannot make any new connections, but existing connections will be maintained. Stop means that all existing connections will be dropped and all new connections will be refused. You can also choose to continue the service, but that is only available when the service has been paused.

If you highlight a service and click the Startup button, you can configure how that service will be run. You can choose between automatic, manual, and disabled. Automatic services start automatically during the boot process. Manual services must be started by the administrator, and disabled means that the service will not start until the Service Type designator is changed.

There is also an option for the service to log on with the credentials of a user account. This is only necessary when the service must perform functions that require certain privileges to accomplish its tasks. For example, if a service is used to automatically back up files and folders, it most likely requires the rights to access those files. If the service is able to log on to the system with the correct user permission(s), (that is, backup files and folders), the service can perform its job.

You can also stop, start, pause, and continue the service from the Services interface via the Stop, Start, Pause, and Continue buttons. If you pause the service, you can use the Continue button to enable that service again. When a service is paused, existing connections will continue to work, but no new connections to the service can be made. When you stop a service, all existing connections are dropped and no new connections are allowed.

Command-Line Functions

You can also stop, start, pause, and continue the DHCP service from the command line.

Note

The discussion of command-line functions in this section applies to Windows NT and Windows 2000 alike.

Use the following commands from the Windows NT Server command prompt to initiate these activities:

- `net start DHCP` This starts the DHCP server service.
- `net stop DHCP` This stops the DHCP server service.
- `net pause DHCP` This pauses the DHCP server service.
- `net continue DHCP` This resumes the DHCP service.

Compressing the DHCP Database

The DHCP database is similar to the WINS Database, as described in Chapter 7. Both DHCP and WINS use `.mdb` file extensions on their databases; therefore, the filename for the DHCP database is `DHCP.MDB`. Whenever either database becomes larger than 30MB, it is time to compress the database to keep it performing effectively. You can use the JetPack command to reduce the size of the DHCP or WINS database. To compress the DHCP database, you must first stop the DHCP service. When the service is stopped, use the `Jetpack dhcp.mdb temp.mdb` command to compress the database. You should issue that command from the `%systemroot%\system32\DHCP` directory.

Note

Typically, the `%systemroot%` directory in Windows NT is named WINNT. However, it is possible that the directory can go by another name. To determine the name of the `systemroot` directory, you can type `%systemroot%` in the Run dialog box to open the proper directory. You can also use that command from the command prompt. You can literally type `CD %systemroot%\system32\DHCP` to select the appropriate directory.

Administering DHCP

You can administer DHCP via the DHCP Manager in the Administrative Tools list of the Start menu (Start, Program Files, Administrative Tools). After DHCP has been installed and the system has been restarted, the DHCP Manager will appear in the Start menu. Click the DHCP Manager selection to open the DHCP Manager application, shown in Figure 25.11.

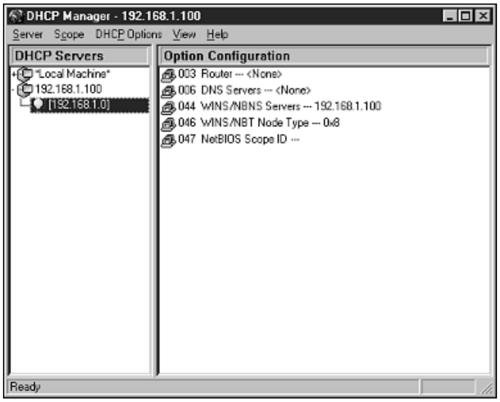


FIGURE 25.11
The main configuration utility for DHCP in Windows NT 4 is the DHCP Manager.

Adding Servers

After installing DHCP, the first thing you must do is add a DHCP server to the DHCP Manager. The DHCP Manager can be used to manage multiple DHCP servers, but you must add them to the list, including your local DHCP server. To add your server, click the Server menu, then choose Add. Enter the IP address for your DHCP server, then click the OK button.

Before you will be able to provide any addresses to DHCP clients, you will have to add a scope with a range of available addresses.

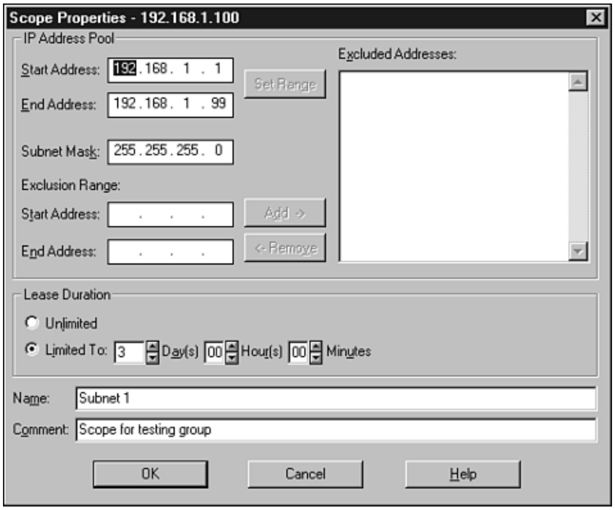
Configuring Scopes

To add a scope to your DHCP server, follow these steps:

1. Click the Scope selection on the toolbar, then choose Create. The Scope Properties dialog box opens (see Figure 25.12).
2. Enter the first address (Start Address) you would like to make available to clients on that network location.
3. Next, enter the last address (End Address) in that range you would like to make available to network clients. You must also enter a subnet mask, so that the DHCP server can determine the subnetwork identifier for the address range.
4. You can also enter a range of IP addresses within the scope range you want to exclude from the scope. Use the Exclusion Range Start Address and End Address to configure this, if desired.

You can configure a Lease Duration for this range of addresses. The duration is the length of time you would like the clients to be able to use the address before they have to renew it. Clients will actually attempt to renew their addresses after half the lease is expired. If they don't get an answer by the expiration of 7/8ths of the lease period, the client will contact any available DHCP server for a new address. When the lease does expire, if the client could not obtain a new address or renewal prior to that, the client will release the address and consequently be unable to communicate via TCP/IP on the network. You can also decide to give clients unlimited leases, which means they will keep their address after it is assigned.

FIGURE 25.12
A DHCP scope defines the range of addresses you would like to release on a per-segment basis.



The Name and Comment text boxes at the bottom of the DHCP Options: Scope dialog box can be left blank. These items are only used for administrative reference and have no bearing on the operation of the scope.

Note

When you configure a scope, you will be prompted to activate that scope. You can choose Yes to activate the scope. Otherwise, you can use the Scope menu to activate or deactivate your scopes.

Global and Scope Options

By default, the DHCP server will only provide an IP address and a subnet mask. However, the DHCP server can provide many more configuration options. If you would like to configure options for every scope on your DHCP server, follow these steps:

1. Click the DHCP Options menu on the DHCP Manager toolbar and choose Global.
2. If you want to add options to certain ranges of addresses, choose Scope from the DHCP Options menu.

Depending on the Windows NT Service Pack you have installed, you can configure over 65 different options for your DHCP scopes. The most common options to release for Microsoft clients are Router (003), DNS Servers (006), WINS/NBNS Servers (044), and WINS/NBT Node Type (046). After you have chosen your options, select each in the Active Options window and click the Value button to configure the addresses and required settings, if any. For example, if you want to release the address of the default gateway for a particular scope of addresses, follow these steps:

1. Click DHCP Options and select Scope.
2. Choose 003 Router from the list of Unused Options.
3. Click the Add button to move the 003 Router option to the list of Active Options.
4. Select 003 Router in the list of Active Options and click the Value button.
5. Click the Edit Array button and enter the IP address of the default gateway in the new IP Address text box.
6. Click Add to add it to the list of default gateways.
7. Alternately, you can enter the Server Name of the default gateway, instead of the IP address. Then, click the Resolve button, which will return the IP address of the default gateway, if name resolution is available for that server and IP address.

You can configure other options to be released by your Windows NT Server using a similar method.

Static Addresses

If you want to configure a permanent address for one or more clients on your network, you can use the Add Reservations selection under the Scope menu in the DHCP Manager. The following shows the steps to reserve IP addresses:

1. After you click Add Reservations, you will see the Add Reserved Clients dialog box.
2. Complete the IP address in the IP Address text box, ensuring that it's the address you want to reserve for the client.
3. In the Unique Identifier text box, you must enter the MAC address of the network card you would like to release the IP address to.
4. You can also enter the name of the DHCP client to which you are releasing this address and a comment, if desired.

After you have reserved an address for a DHCP client in your scope, the address will be released only to the DHCP client with a network card using that MAC address. If you want to review the reservations you have made for clients, click the Scope menu on the DHCP Manager, then choose Active Leases. You will first see all the active leases your DHCP server has provided. However, you can click the Show Reservations Only check box to view only the addresses you have reserved. You can also use this dialog box to sort, refresh, and reconcile addresses.

Using Microsoft DNS

The Windows NT Server product also includes an installable Domain Name System (DNS) service. This service provides RFC 974, 1034, and 1035 standard DNS support and provides hostname resolution over TCP port 53. In addition, the DNS server files can be configured through a graphical interface.

Note

Chapter 6, "DNS: Name Services," describes the concepts and structure of DNS. This chapter does not focus on the concepts of DNS, but rather the installation and operation of the Microsoft DNS server.

Installing DNS

Because the Microsoft DNS server service is considered a networking service, it can be added through the Network dialog box. To add Microsoft DNS to your Windows NT Server version 4, follow these steps:

1. Right-click the Network Neighborhood icon on the desktop and select Properties from the resulting context menu.
2. Click the Services tab on the Network dialog box.
3. Click the Add button on the Services tab.
4. Choose Microsoft DNS Server from the list of network services and click OK.
5. Confirm or enter the path to your Windows NT installation files and click Continue.
6. After the service is added to the list of installed network services, click the Close button on the Network dialog box.
7. Click Yes to reboot your system and complete the installation process.

After the service is installed, you will find the DNS Manager in the Start Menu, Programs, Administrative Tools section. Click the DNS Manager to begin configuring the DNS server. Before you can set up your DNS files, you must add your server to the list of DNS servers. To add your server, click the DNS menu, then choose New Server. You can enter the hostname of the server or the IP address.

Creating a Zone

After your server appears in the list, you can create a zone for your server so that you can begin entering records. To create a zone on your server, follow these steps:

1. Right-click the icon representing your server in the Server List of the DNS Manager.
2. Choose New Zone from the resulting menu.
3. Select the appropriate type of zone you would like to create. If you choose secondary, you will have to enter the appropriate zone and server for which you would like this system to be secondary. Click Next to continue.
4. Enter the name of your zone in the following dialog box, and then press the Tab key and the Zone File name will be automatically filled in. Click Next to continue.
5. Click Finish to complete the process. You will immediately see that the Start of Authority (SOA) and Name Server (NS) records for your server have been entered in the list (see Figure 25.13).

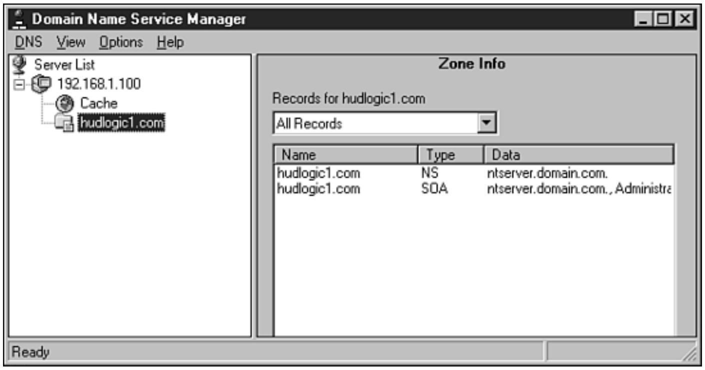


FIGURE 25.13
To configure your Windows NT 4 DNS server, use the Domain Name Service Manager.

Everything you enter through the DNS Manager creates properly formatted DNS configuration files in the `%windir%\system32\DNS` directory. You can take a look at your zone text file by accessing this directory. Your zone file will have the name of your zone followed by the file extension `.dns`. For example, if your domain name is `domain2.com`, then your zone file would be named `domain2.com.dns`.

To ensure that your DNS text configuration files and the DNS Manager interface are synchronized, you can right-click your DNS server icon in the Server List of the DNS Manager, then choose Update Server Data Files. This action synchronizes the interface with the data files.

Note

If your DNS server disappears from the DNS Manager, you can typically recover it by adding the name or IP address of the server as a New Server. This usually brings back all the old data files from the `%windir%\system32\DNS` directory. Conversely, if you ever need to remove your DNS server, remove the service from the Network dialog box, and then delete the `%windir%\system32\DNS` directory.

Creating Zone Records

To create records for your zone:

1. Right-click the icon that shows your zone name.
2. Choose New Record. The New Resource Record window opens (see Figure 25.14).
3. You can add the record type of your choice. For example, to add a new host address record, select A Record from the list and enter the IP address and hostname.

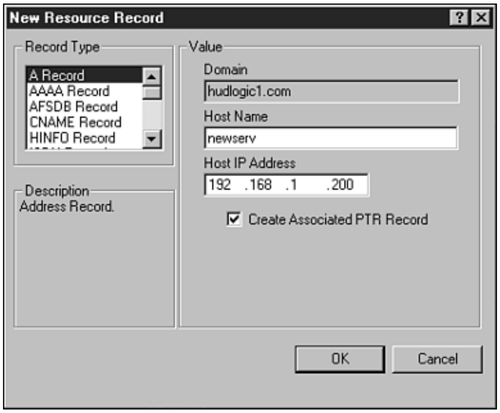


FIGURE 25.14
Use the New Record option to add a new resource record (a.k.a. address and hostname to your DNS database).

You may notice a check box to add a PTR record for the new A Record. This allows you to automatically create an `in-addr.arpa` entry for new hosts. Doing this saves you the time of creating a PTR manually. However, to have this done for you automatically, you must first create the `in-addr.arpa` domain for your server.

Configuring Inverse Domain Name Resolution

To configure inverse name resolution for your server, you must create an `in-addr.arpa` domain. This is done by inverting the network portion of your IP address and appending `in-addr.arpa`. After you do, Microsoft DNS will identify this as an inverse name resolution domain and configure your name resolution text files accordingly. To create an `in-addr.arpa` domain, follow these steps:

1. Right-click the icon that represents your server and choose New Zone.
2. Select the Primary radio button and click the Next button.
3. Enter your network identifier in reverse and the suffix `.in-addr.arpa`. Figure 25.15 shows how this would look for the network 192.168.1.0.
4. Press the Tab key to get the correct Zone File name, then click the Next button to continue.
5. Click Finish and notice that your Inverse Name resolution domain has been created.

After you have created the inverse name resolution domain, PTR records can be automatically added to your `in-addr.arpa` domain during hostname creation.

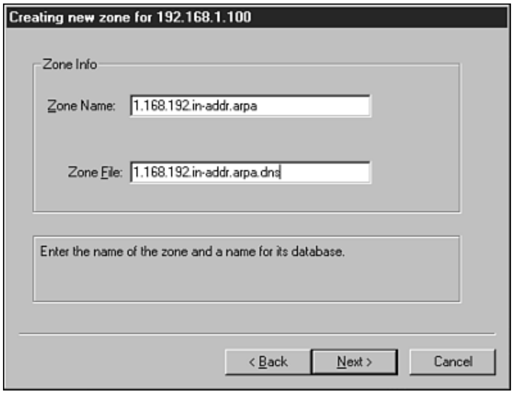


FIGURE 25.15
To configure name lookup from the IP address, you must implement an inverse name resolution domain.

Configuring DNS to Contact a WINS Server

Microsoft DNS can also be used with the Microsoft WINS server to enhance name resolution capabilities. You can configure the DNS server to call the WINS server to resolve the hostname of the *fully qualified domain name* (FQDN). For example, in the name `server1.domain.com`, DNS would have to resolve the `domain.com` portion, but could call the WINS server to ascertain the IP address for `server1`.

To configure your Microsoft DNS to contact a WINS server, follow these steps:

1. Right-click the name of your zone, and then choose Properties.
2. Click the WINS Lookup or WINS Reverse Lookup tab to configure the address(es) of your WINS server(s). If you click a normal zone, the WINS Lookup tab appears. If you click an `in-addr.arpa` zone, the WINS Reverse Lookup tab appears.
3. Choose WINS Resolution and enter the IP address of your WINS server. You can enter multiple WINS servers here. Click the Add button after each entry. For WINS Reverse Lookup (WINS-R), you need only check Use WINS Reverse Lookup and configure the domain name for which this will be used.

After you have configured these options, your DNS server will be able to get supplemental name resolution services from the WINS server.

Adding Secondary Name Servers

If you add a secondary server to your domain, you can configure the primary server to send it updates. To do so, you must add the IP address of the secondary name server to the property sheet of the primary name server. To do this, perform the following steps:

1. Right-click your zone and choose Properties.
2. Next, click the Notify tab and enter the secondary server's IP address(es) to the Notify List.
3. After this is complete, the primary server will automatically update the secondary server.

FTP and HTTP Services

In Windows NT Server versions prior to Windows NT 4, Microsoft shipped an individually installable FTP server. In Windows NT 4, the FTP server is part of the *Internet Information Server* (IIS) product. The IIS version that ships with Windows NT 4 is called IIS 2.0, but the latest independent version of IIS is version 4. With IIS 4, you can install an HTTP and FTP server. The HTTP server provides support for Web clients over the HTTP 1.1 protocol. Microsoft calls its HTTP support the WWW Publishing Service because it is used to publish Web pages and sites on the Internet. The FTP server is also part of the IIS 4 and later products, and you can use it to share files to FTP clients on the Internet.

IIS is tightly integrated in the Windows NT environment and the FTP and WWW services appear in the Control Panel Services applet when they are installed. You can also manage the services via the *Microsoft Management Console* (MMC), which can be launched from the Start Menu, Programs, Administrative Tools section.

TCP/IP Printing Services

Windows NT can provide TCP/IP Printing services to Microsoft and Unix clients on the network. Installation of a TCP/IP Printing device has several steps. First, you must install the TCP/IP Printing Service from the Network dialog box Services tab. Then, you must configure an LPR port via the Printers folders.

Installing TCP/IP Printing Services

To install the TCP/IP Printing service from Microsoft, follow these steps:

1. Right-click the Network Neighborhood icon, and then choose Properties.
2. Click the Services tab on the Network dialog box.
3. Click the Add button on the Services tab.
4. Select Microsoft TCP/IP Printing from the list of network services.
5. Click the OK button to install the service.

6. Confirm or enter the path to the Windows NT Server installation files and click Continue.
7. Click Close on the Network dialog box and reboot as requested.

Installing LPR Services

After you have installed the Microsoft TCP/IP Printing service, you must still configure your printer to provide LPR services on the printer port. Follow these steps to install LPR printing services:

1. Choose Printers from the Start Menu (Start, Settings, Printers).
2. Double-click the Add Printer icon, unless you already have a printer installed. (If you already have a printer installed, right-click the icon for your printer, choose Properties, and then select Ports. Skip to step 4.)
3. Ensure that the My Computer radio button is selected, and then click the Next button. (By doing this you are indicating that your system will be the printer server.)
4. Click the Add Port button.
5. Select LPR Port from the list of available ports, and then click the New Port button.
6. Enter the IP address of your server in the top text box.
7. Enter a name for your LPR printer. This can be any name, but making it the same name as the printer would be wise.
8. Click OK to confirm the installation. If you see an error message that the printer cannot be contacted, click OK. (If you already have a printer installed, click the OK button, and the process is complete.)
9. Choose the correct manufacturer and printer from the list and click OK.
10. Click the Shared radio button to make this printer available to other clients on the network. Then enter the name under which it will be shared. It is wise to use the same name for the printer, the share, and the LPR queue, which is the default.
11. Click the Next button to continue.
12. Decide whether or not you would like to print a test page by choosing the corresponding radio button. Then, click the Finish button.
13. You may need to map the path to your Windows NT installation files and click the OK button. You should then see your printer appear in the Printers folder.

You can print to the TCP/IP Printing device using an LPR printing client. This is common on Unix operating systems. Microsoft also provides an LPR client for Windows NT. To learn the syntax of the LPR command, open a command prompt and type **`LPR /?`**.

If you wanted to print your `BOOT.INI` file on an LPR printer named LPRPRINT, which resided on an NT Server named NTSERV, you would issue the following command:

```
lpr -S NTSERV -P LPRPRINT -d BOOT.INI
```

Be careful when issuing the command because the names are not case sensitive, but the switches (`-S`, `-P`, and `-d`) are.

Summary

Windows NT uses NetBIOS over Microsoft TCP/IP to provide compatibility with other IP networks. The Microsoft TCP/IP Architecture is consistent between Windows 98 and Windows NT version 4. Microsoft TCP/IP clients use both NetBIOS computer names and hostnames to provide compatibility with the Internet and other TCP/IP networks, as well as Microsoft networks.

Network computer names, services, adapters, bindings, and protocols are configured and managed via the Network dialog box. You can install the TCP/IP protocol suite via the Protocols tab on the Network dialog box. After you have added the protocol, you can double-click its icon on the Protocols tab to configure the TCP/IP options.

On the Identification tab of the TCP/IP Properties dialog box, you can configure the IP address, subnet mask, and default gateway. On the DNS tab you can set the hostname, which should be the same as your NetBIOS computer name (located on the Identification tab of the Network dialog box). You can also configure your DNS domain name, the DNS servers to be used for name resolution, and the order in which names should be resolved. The WINS tab allows you to configure the address of a Primary and Secondary WINS server to provide NetBIOS name resolution. You can also decide whether your system will use an `LMHOSTS` file and/or DNS to resolve NetBIOS names. The DHCP Relay tab allows your system to relay DHCP requests to remote segments passing through RFC 1542 non-compliant routers. You must install the DHCP Relay Agent before this feature will be operational. You can also enable IP routing via the Enable IP Routing check box on the Microsoft TCP/IP Properties dialog box Routing tab.

Windows NT Server can also provide DHCP and Microsoft TCP/IP printing services. These items can be installed via the Network dialog box Services tab. To configure DHCP services, you must use the DHCP Manager after the service is installed. To configure the TCP/IP printer, you must enable an LPR port via the Printers folder after installing the Microsoft TCP/IP Printing service.

Windows 2000 promises the end of NetBIOS over TCP/IP. The sole naming convention required for Windows 2000 will be Internet-style hostnames. The administrative structure will also be changed and Dynamic DNS will be added.

CHAPTER 26

Configuring TCP/IP for Windows 2000

by Karanjit S. Siyan, Ph.D.

IN THIS CHAPTER

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- **IP Security and Filtering** *646*
- **Configuring Name Resolution Services in Windows 2000** *648*
- **Other Support Files for TCP/IP Services** *664*
- **Installing and Configuring the FTP Server Service** *671*
- **Configuring TCP/IP to Print from Windows 2000 to Unix Printers** *675*
- **Using TCP/IP Command-Line Tools** *679*

This chapter addresses how the network components and TCP/IP protocols are installed and configured on Windows. Windows 2000 workstations are also covered. Normally TCP/IP should be installed during the installation of network services when installing the operating system. However, in some situations a standalone computer must connect with a network after the addition of suitable networking hardware. In this case you must explicitly install TCP/IP software.

This chapter also teaches you how to configure the TCP/IP stack to make use of name services such as Windows Internet Naming Service (WINS) and Domain Name System (DNS).

Installing TCP/IP

A Windows 2000 installation automatically includes the TCP/IP protocol stack if you choose to install any network services. This section discusses the procedures for installing and configuring the Windows 2000 TCP/IP protocol stack. You must install the TCP/IP protocol stack manually only if you have previously removed it but now need to add support for TCP/IP services. Follow these steps:

1. Log on to the Windows 2000 computer as an Administrator user.
2. Select Start, Settings, Network and Dial-Up connections. Right-click on Local Area Network and choose Properties. The Local Area Connection Properties dialog box appears (see Figure 26.1). Alternatively, you can right-click on My Network Neighborhood and choose Properties. Then right-click on Local Area Connection and choose Properties.
3. If you are reinstalling the TCP/IP protocol stack, click the Install button. The Select Network Component Type dialog box appears (see Figure 26.2). Select Protocol and click the Add button. You should see a list of protocols you can add from the Select Network Protocol screen.
4. Select TCP/IP Protocol and choose OK.
5. Complete the remaining procedure as instructed onscreen.

The TCP/IP protocol is now installed. Your next step is to configure at least the basic TCP/IP settings.

FIGURE 26.1
The Local Area Connection Properties dialog box.

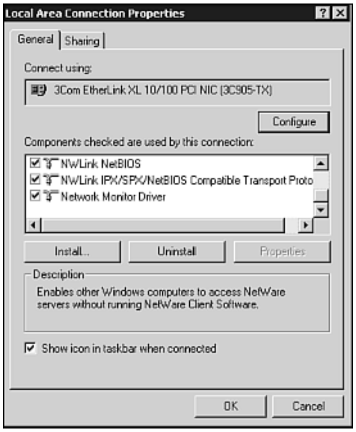
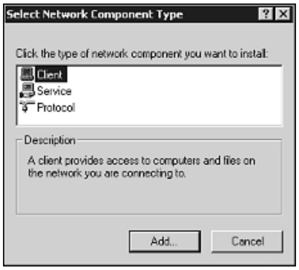


FIGURE 26.2
The Select Network Component Type dialog box.



Configuring the IP Address

Every network interface the TCP/IP protocol stack communicates with is described by a set of IP parameters. These parameters include the IP address, subnet mask, default gateway, and IP address of name servers—the domain name settings. You must specify, at minimum, the IP address and subnet mask settings for each network interface.

You can set IP parameters in two ways: manually or automatically. Setting IP parameters manually (also called *statically*) requires that you keep a proper log of the IP address parameter settings for each computer and that each network interface is assigned a unique IP address. Making mistakes in setting IP parameters is easy if you are not careful, and these mistakes can be costly in terms of the time required to troubleshoot the settings. For this reason, many networks prefer the automatic way of setting IP parameters from a central server, such as a DHCP server.

If you're not using DHCP to assign a TCP/IP address to the Windows 2000 Server dynamically, the Internet Protocol (TCP/IP) Properties dialog box appears (see Figure 26.3).

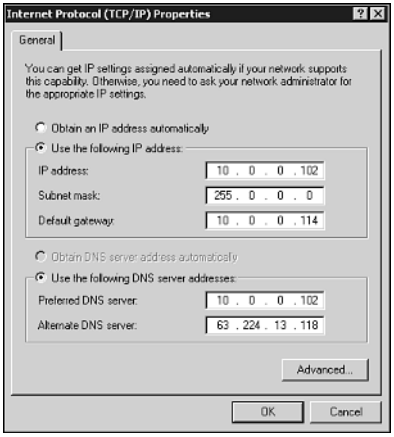


FIGURE 26.3
The Internet Protocol (TCP/IP) Properties dialog box.

You can also display this dialog box by highlighting the Internet Protocol (TCP/IP) in the Local Area Connection Properties dialog box. In this dialog box, you specify the IP address, subnet mask, and default gateway address of the network interface. The IP address, subnet mask, and default gateway parameter settings should be consistent with the network on which the Windows 2000 computer is connected. For example, if the network to which the Windows 2000 computer is connected is described by a network address of `192.120.12.0/255.255.255.255`, the IP address setting for the computer on such a network is restricted to these IP addresses:

- `192.120.12.1` to `192.120.12.254`
- With a subnet mask of `255.255.255.0`

The default gateway should also have an IP address that is in this range, because it needs to be on the same network that the Windows 2000 computers connect to.

The IP address range described previously is the legal range of addresses for the network `192.120.12.0/255.255.255.0`.

Follow these steps for configuring the IP address:

1. If a DHCP server is already on the network and you want to use it to configure the Windows 2000 computer, you should choose the Obtain an IP Address automatically option. A DHCP server contains TCP/IP configuration information for other TCP/IP hosts. When a TCP/IP host starts, it requests its configuration information from the DHCP server.

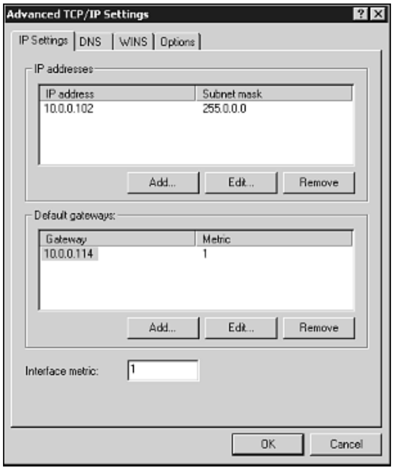
If you choose Obtain an IP Address automatically, the Windows 2000 computer obtains the IP address and subnet mask values from the DHCP server. If you enter values for the IP address and subnet mask, you effectively disable the DHCP client and will not download any information from the DHCP server.

If no DHCP server is yet on the network, or if you are installing the Windows 2000 server for use as a DHCP server, you must set the IP address and subnet mask manually. Enter the IP address and subnet mask for the Windows 2000 server's network interface as shown in Figure 26.3.

2. If your network is connected to other TCP/IP networks or subnetworks, you must specify a value for the Default Gateway field so that you can reach the other networks. TCP/IP recognizes whether the destination address is on another network and forwards the packet to the default gateway (or default router, correctly speaking). (The term *default gateway* is still used because historically the devices now known as routers were called gateways.)
3. If you have multiple network adapters, each must be configured individually. Specify the IP address configuration (IP address, subnet mask, default gateway, use of DHCP server) for each adapter bound to the TCP/IP protocol by selecting the network cards in the Adapter field one at a time.
4. Click the Advanced button if you want to configure multiple IP addresses for a single network adapter, multiple default gateways for a network adapter, or security options. Select the network adapter to configure from the Adapter field in the Advanced TCP/IP Settings dialog box (see Figure 26.4). Note that the IP configuration settings in this dialog box apply to only the selected network adapter. You can enter the WINS/DNS information in the advanced dialog box. The procedure for doing this task is discussed later in this chapter.
5. You can enter multiple IP addresses and subnet masks for the selected adapter by entering the IP address and subnet mask values in the IP Address and Subnet Mask boxes in the Advanced TCP/IP Settings dialog box (refer to Figure 26.4) and clicking the Add button.

   Multiple IP addresses and subnet masks are particularly useful when you want a single physical system to look like several systems. The mail server might be `199.245.180.1`, for example; the DNS server, `200.1.180.2`; and the FTP server, `203.24.10.3`. Also, multiple IP addresses and subnet masks can help during the transition to a different IP network number assignment for the network. You also can use multiple IP addresses if your network consists of multiple logical IP networks. During the transition phase, having both IP network numbers be applicable is useful.

FIGURE 26.4
The Advanced TCP/IP Settings dialog box.



6. If you must specify alternative default gateways, you can enter the IP addresses of the default gateways in the Default Gateways field in the Advanced TCP/IP Settings dialog box (refer to Figure 26.4) and choose the corresponding Add button.

   The default gateway field is the IP address of a router on the local network. When a packet is sent to an IP address that is not on the local network and not specified in the local routing table at the Windows 2000 computer, the default gateway is used. If you have specified multiple default gateways, they are tried in the order in which they are listed if an attempt to use a particular gateway is unsuccessful. You can change the order in which the default gateways are tried by selecting a gateway's address and moving it using the Up and Down buttons.

Note

To remove an IP address and subnet mask combination, highlight it and click the Remove button.

Note

To remove a gateway, highlight it and choose the Remove button.

IP Address Assignment When DHCP Server Fails

The Windows 2000 DHCP client handles IP address assignment differently if a DHCP server cannot be found. If the Windows 2000 computer is installed to obtain an IP address automatically, the following steps occur:

1. When the client is installed, it attempts to locate a DHCP server. Many TCP/IP networks use DHCP servers that are administratively configured to lease IP addresses and set other information.
2. If the attempt to locate a DHCP server fails, the Windows 2000 DHCP client autoconfigures with a selected IP address from the IANA-reserved class B network of `169.254.0.0` with the subnet mask `255.255.0.0`. This unregistered private address is registered to Microsoft. The DHCP client uses Address Resolution Protocol (ARP) to perform a Duplicate Address Test (DAT) to ensure that the IP address it has chosen is not already in use. If the address is in use, the client selects another IP address and tries again, as many as ten times. When the DHCP client has selected an address that is not in use, it configures the interface with this address. Meanwhile, it continues to check for a DHCP server in the background every five minutes. If a DHCP server is found, the autoconfiguration information is released, and the configuration offered by the DHCP server is used instead.

If the DHCP client has previously obtained a lease from a DHCP server, the following modified sequence of events occurs:

1. If the client's lease has not expired at boot time, the client tries to renew its lease with the DHCP server. If the client fails to locate a DHCP server during the renewal attempt, it tries to ping the default gateway, which is listed in the lease. If pinging the default gateway succeeds, the DHCP client assumes that it is still located on the same network where it obtained its current lease and continues to use the lease; but for some reason the DHCP server is unavailable. The client attempts to renew its lease in the background when half its assigned lease time has expired. The renewal attempt at half the lease interval is part of the standard DHCP operation.
2. If the attempt to ping the default gateway fails, the client assumes that it has been moved to a network that has no DHCP services available. It then autoconfigures itself as described previously using the `169.254.0.0/24` network. After the client is autoconfigured, it continues to try to locate a DHCP server every 5 minutes in the background.

Configuring the DNS Settings

Users can specify DNS names for computers that the Windows 2000 computers can resolve to their corresponding IP addresses. The Windows 2000 computers have a DNS client, also called the *name resolver*, that issues a request to the DNS server for resolving the DNS names. The Windows 2000 computers need to be configured with at least the IP address of one DNS server. Because name resolution is critical to the operation of Windows 2000 computers, you should have a secondary DNS server on the network in case the first DNS server is down.

If you want to configure Windows 2000 computers with addresses of DNS servers, select the DNS tab from the Microsoft TCP/IP Properties dialog box. DNS is the most commonly used name-resolution method on the Internet and other Unix-based networks. If you enable DNS name resolution, you must have a DNS server that the Windows 2000 computer can contact or have the Windows 2000 computer configured as a DNS server. The Windows 2000 computer needs to know the IP address of the DNS server. The IP address of the DNS server is specified on the TCP/IP DNS tab. This section discusses the DNS client software.

If you are using DHCP servers for setting the IP parameters, you can also use DHCP to configure DNS settings for the Windows clients.

When accessing other TCP/IP hosts on the network, you can use their IP addresses. Users typically find it easier to remember and use symbolic names for computers rather than IP addresses. This is why the computer names usually are used for Windows 2000 computers rather than just IP addresses. The DNS is used for naming TCP/IP nodes, such as Windows 2000 computers and Unix hosts. The naming scheme is hierarchical and consists of names such as `wks1.kinetics.com` or `wks2.cello.org`. DNS is the most widely used name service for Unix hosts and on the Internet. If you plan to use your Windows 2000 computer on a Unix network or the Internet, you should configure your Windows 2000 computer to use DNS. TCP/IP applications written to use the Windows Sockets API (such as Internet Explorer, File Transfer Protocol [FTP], and Telnet) use DNS or the local HOSTS file to resolve symbolic names.

When TCP/IP is installed on a Windows 2000 computer, the DNS client software for resolving DNS names is also installed. The DNS client software is, in addition to dynamic name resolution, used for resolving NetBIOS computer names through WINS servers and NetBIOS over TCP/IP. When you configure DNS on a Windows 2000 computer, it applies to all network adapters installed on the computer.

The following steps outline the procedure to follow in configuring your Windows 2000 computer to use DNS client software:

1. Select the DNS tab from the Advanced TCP/IP Settings dialog box (refer to Figure 26.4). The DNS tab is displayed (see Figure 26.5).

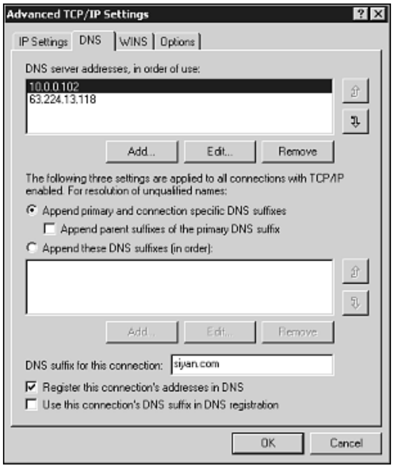


FIGURE 26.5
The DNS tab in the Advanced TCP/IP Settings dialog box.

2. Click the Add button to add the DNS server IP addresses. To change an IP address, click Edit; to remove an IP address from the DNS server list, click Remove. The purpose of this dialog box is to manually set one or more DNS servers. The DNS servers are identified by their IP addresses. The DNS client attempts to resolve DNS names by contacting the first DNS server on the list. If the DNS name cannot be resolved, it tries to contact the second client, and so on, until all the DNS servers have been tried. You can change the order of the DNS servers by clicking the up and down buttons.

   The next three settings apply to all TCP/IP connections and deal with the resolution of unqualified domain names.

   The Append primary and connection specific DNS suffixes option is used to specify that unqualified domain names will have the parent DNS domain name appended. If the name of the computer is NTWS1 and the parent domain name is `KINETICS.COM`, the host name that is searched for is `NTWS1.KINETICS.COM`. With this option the name is searched for in only the parent domain. If the host name cannot be resolved, no further searches for the name are performed.

The purpose of the Append these DNS suffixes (in order) option is used to specify a list of DNS suffixes that can be appended to the unqualified domain name in order to resolve it. If you need to change the search order of the domain suffixes, highlight the domain name and use the up and down buttons to move the domain name. To remove a domain name, highlight it on the list and click the Remove button. To edit a domain name suffix, highlight it and click Edit.

In the DNS suffix for this connection field, you can specify the DNS suffix to be used for this connection. You have the additional options of setting the option labeled Register this connection's address in DNS, which makes a host entry for this IP address and the connection's DNS name with the DNS server. When you register this DNS name, you can use the DNS suffix with the host name by enabling the option labeled Use this connection's DNS suffix in DNS registration.

Optional Domain Name

The domain name is optional because a small organization not connected to the Internet doesn't need to use hierarchical domain names. As shown here, the domain name is combined with the host name to create a fully qualified domain name (FQDN) for the computer:

FQDN = host name + domain name

The FQDN for host NTWS1 is the following in the domain name `KINETICS.COM`:

FQDN = NTWS1 + `KINETICS.COM` = `NTWS1.KINETICS.COM`

When the Windows 2000 computer uses a DNS query to resolve a name that is a simple host name without the domain extension, the domain name specified in the Domain Name field is appended to the host name.

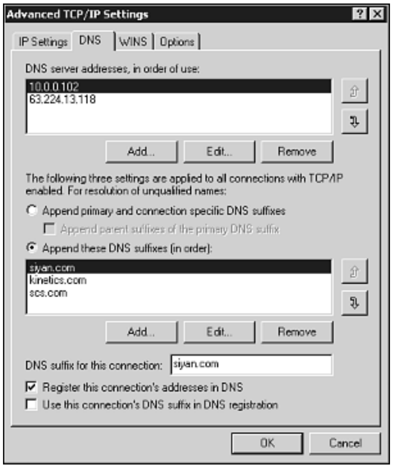
The domain name can be any combination of A to Z letters, 0 to 9 digits, and the hyphen (-), using the period (.) character as a separator.

Note

Host name to IP address mappings are stored on DNS servers. The Berkeley r-utilities, such as rcp, rsh, and rexec, use the host names for authentication. In host names, you cannot use some characters that you can use in Windows 2000 computer names, particularly the underscore. If you are connected to the Internet, you should use registered DNS names.

Figure 26.6 shows a sample DNS configuration for the host NTS. The local domain name is `SIYAN.COM`. The DNS servers are `10.0.0.102` and `63.224.13.118`. First, the DNS server with IP address `10.0.0.102` is used to resolve a name. If this server can't resolve the name to its IP address, the DNS server at `63.224.13.118` is used. The domain suffix search order is `SIYAN.COM`, `KINETICS.COM`, and `SCS.COM`. In some earlier Windows clients (Windows 95 without Winsock2 and Windows NT earlier than SP5), the DNS resolver contacts the second DNS server only if the first DNS server does not respond. On these clients, if the first DNS server cannot resolve a name, the client does not try to resolve the name using the second DNS server.

FIGURE 26.6
Sample DNS settings in the Advanced TCP/IP Settings dialog box.



3. Click OK after you set the DNS configuration options.

Windows 2000 DNS implements negative caching. If a DNS server cannot resolve the query, succeeding queries for that name are answered negatively for a duration specified by the Registry parameter NegativeCacheTime (a default of 300 seconds).

Configuring the WINS Address

If you have Windows Internet Name Services (WINS) servers installed on the network, you can use WINS servers in combination with name query broadcasts to resolve computer names. The WINS server is an example of a NetBIOS Name Server (NBNS) type of server used for resolving NetBIOS names, as per the rules specified in RFC 1001 and RFC 1002.

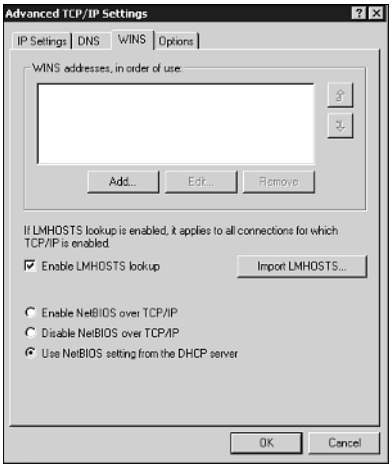
Windows 2000 clients and Windows NT, Windows 95, and Windows 98 clients with the Active Directory upgrade installed no longer need to use the NETBIOS namespace. WINS is still required for down-level clients to find servers and vice-versa. When no more down-level clients are in the enterprise, the WINS servers can be turned off. Down-level clients are Windows 95, Windows 98, and Windows NT clients.

If you are not using the WINS server, the Windows 2000 computer uses name query broadcasts and the local LMHOSTS file to resolve computer names to IP addresses. Broadcast resolution is confined to the local network. The name query broadcasts use the b-node for NetBIOS over TCP/IP.

To configure the WINS address, follow these steps:

1. To specify that you are using WINS servers, enter the IP addresses of the primary and other backup secondary WINS servers on the WINS tab of the Advanced TCP/IP Settings dialog box (see Figure 26.7). The secondary WINS server is used as a backup in case the primary WINS server cannot respond. Select Add to add the WINS IP addresses. Use the up and down arrow keys to change the order the WINS servers are searched.

FIGURE 26.7
The WINS tab in the Advanced TCP/IP Settings dialog box.



2. You can use the local file LMHOSTS for resolving NetBIOS computer names on Windows networks. If you want to use the LMHOSTS file, enable the Enable LMHOSTS Lookup check box. You can import computer names and IP addresses from an existing LMHOSTS file by clicking the Import LMHOSTS button and specifying the directory path for the LMHOSTS file. You can use the Import LMHOSTS option when you have already created an LMHOSTS file for the computer names on your network and want to use the information in this file for all computers on the network.

3. If a computer is configured to use DHCP, you can specify whether NetBIOS settings will be taken from the DHCP server by setting the option Use NetBIOS setting from the DHCP server.
4. You can set the options Enable NetBIOS over TCP/IP or Disable NetBIOS over TCP/IP. These options do just what they sound like. The operation of NetBIOS over TCP/IP is described in RFCs 1001 and 1002. Applications that use the Winsock interface do not need NetBIOS, and you can safely disable this option. Newer applications are directly hosted on TCP/IP, which means that they are written to use the TCP/IP stack directly without involving NetBIOS. The Windows 2000 services use DNS to resolve names and do not need NetBIOS name resolution. On a pure Windows 2000 network that does not use any NetBIOS-specific applications, you can disable NetBIOS over TCP/IP. Disabling it has the advantage of less network traffic caused by NetBIOS. Also, the Windows 2000 computer does not have to expend resources supporting the NetBIOS protocol.

Note

By default the LMHOSTS file is in the \%SystemRoot%\SYSTEM32\DRIVERS\ETC directory. If you are using a WINS server, the LMHOSTS file is consulted last after trying the WINS server. Using LMHOSTS files works well for Windows networks that have a small number of computers and for networks that do not experience many changes, although using LMHOSTS files is problematic for larger, more dynamic networks. Keeping all the different computers' LMHOSTS files in sync becomes difficult on a larger network, and creating situations in which two computers (even ones sitting next to each other) might have different views of the network becomes all too easy. Also if you are using DHCP to assign IP addresses, the IP address specified in the LMHOSTS file might not be valid for a specified host that might be on a different subnet.

Configuring the DHCP Relay in Windows NT

Note

Although most of the tabs in the Windows 2000 Advanced TCP/IP Settings dialog box are similar to those for Windows NT, they have some differences. Notably, Windows NT has the DHCP Relay tab and the Routing tab. In Windows 2000, the DHCP relay and routing functions are configured using the Routing and Remote Access tool. If you have down-level computers in a mixed-mode domain (Windows 2000 and Windows NT 4 computers in a domain) environment, this section and the next one are useful.

IP Security and Filtering

Windows 2000 provides IP security and filtering for the TCP/IP protocol. To access these capabilities, access the Options tab in the Advanced TCP/IP Settings dialog box (see Figure 26.8) by clicking the Advanced button in the Internet Protocol (TCP/IP) properties. You get to the Internet Protocol (TCP/IP) Properties dialog box by highlighting the Internet Protocol (TCP/IP) in the Local Area Network properties and clicking Properties.

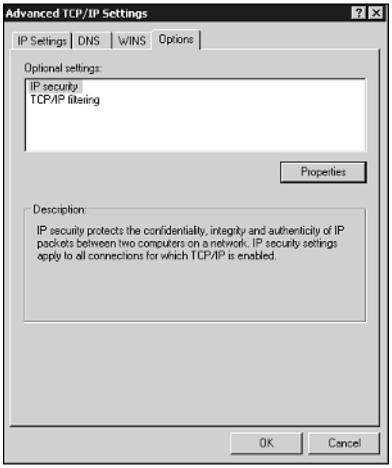


FIGURE 26.8
The Options tab in the Advanced TCP/IP Settings dialog box.

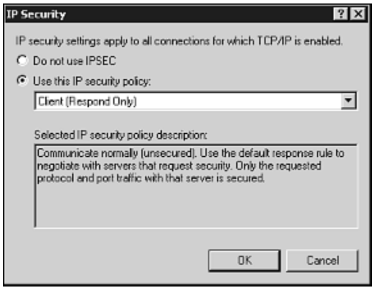
The IP Security option protects the confidentiality, integrity, and authenticity of IP packets between two computers on a network. These security settings apply to all connections for which TCP/IP has been enabled. Highlight the IP Security option, click the Properties button, and on the IP Security screen (see Figure 26.9), select the Use this IP security policy button. Your choices are Client (Respond Only), Secure Server (Request Security), and Server (Request Security).

Note

You might want to disable routing when connected to multiple networks if the Windows NT and Windows 2000 server is performing an important function (such as being a Web server), and you do not want it to use CPU cycles to deal with other tasks that you already have other systems dedicated to performing.

You should also disable routing on firewalls and proxy servers. You do not want the packets to bypass the firewall or proxy software that subjects the packet to the network security policy. If routing is enabled, the packets could be forwarded by the router regardless of any restrictions on the packet placed by the firewall/proxy software.

FIGURE 26.9
The IP Security screen.



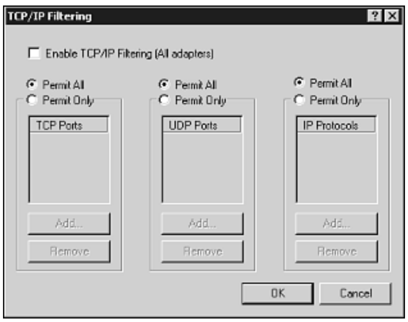
The Client (Respond Only) option communicates normally in an unsecured session. If the server requests IP security, then the requested protocol and port traffic with that server will be secured.

The Secure Server (Request Security) option requires that security on IP traffic be enabled using Kerberos trust. Untrusted communication with unsecured clients is not permitted. Because many hosts on the Internet are not enabled for Kerberos trust, using the Secure Server (Request Security) option effectively disables communication with the majority of hosts on the Internet.

The Server (Request Security) option requests that security on IP traffic be enabled using Kerberos trust. Untrusted communications with unsecured clients is permitted with clients that do not respond to the request.

To configure TCP/IP filtering, highlight it on the Options tab in the Advanced TCP/IP Settings dialog box and click Properties. The TCP/IP Filtering screen appears (see Figure 26.10). Set the Enable TCP/IP Filtering (All adapters) option. The default is to permit all TCP ports, User Datagram Protocol (UDP) ports, and IP protocols. To permit connections on only specific TCP ports, UDP ports, or IP protocols, check the appropriate Permit only option. Click the Add button and add the TCP port, UDP port, or IP protocol to the permitted list.

FIGURE 26.10
The TCP/IP Filtering screen.



Setting up filtering is appropriate if you want to accept traffic for only some well-defined services with specific port numbers. You can find the official port and protocol numbers in the RFC 1700, "Assigned Numbers." By default, all TCP ports, UDP ports, and the IP protocol are enabled, which means that the Windows 2000 computer accepts packets destined to any TCP or UDP port in an IP packet. To change the default values, select the option Permit Only and use the Add and Remove buttons to edit the criteria for filtering IP packets.

Configuring Name Resolution Services in Windows 2000

In the previous section you learned how to specify the Windows Internet Name Service (WINS) server and Domain Name System (DNS) server in the Internet Protocol (IP) configuration parameters for Windows 2000 computers. WINS and DNS servers are used for resolving names on a Windows network. Two additional files, LMHOSTS and HOSTS, are useful in configuring name resolution. For small networks that do not have a WINS or DNS server, you can use the LMHOSTS and HOSTS files for name resolution because they can be edited using a text editor to provide name-to-IP-address mappings.

Another point to note is that network basic input output system (NetBIOS) name resolution using WINS is not needed in pure Windows 2000 networks (native mode) that use DNS for name resolution instead. However, in mixed-mode networks consisting of Windows 2000 and Windows NT computers, you might need to provide NetBIOS name resolution for older clients, which is the primary reason for discussing NetBIOS name resolution in this chapter.

NetBIOS Services

NetBIOS provides name services, datagram services, and session services (see Table 26.1). When NetBIOS is run over Transmission Control Protocol (TCP), the name and datagram services use ports 137 and 138 of the User Datagram Protocol (UDP) Transport Layer protocol. The session services use port 139 of the TCP Transport Layer protocol. Name and datagram services use UDP because the nature of the traffic generated by these services tends to be request-reply oriented. Also, name services make frequent use of broadcasts to resolve names, and UDP is better suited than TCP for handling broadcasts. On large networks, broadcasts can be a problem because they can lead to broadcast storms. For this reason, many routers are configured by default to block broadcasts. The procedure for configuring a router to block broadcasts is router specific.

TABLE 26.1 NetBIOS Services

Service Name	*Port*	*Protocol*	*Short Name*
NetBIOS Name Service	137	UDP	nbname
NetBIOS Datagram Service	138	UDP	Nbdatagram
NetBIOS Session Service	139	TCP	Nbsession

The session services in NetBIOS use TCP; TCP guarantees data delivery, whereas UDP does not. Also, the model of a TCP session more accurately reflects the behavior of a NetBIOS session. Both TCP and NetBIOS issue open primitives to open a connection and the close primitive to close a connection.

A given computer can have several processes. Processes that provide services are *application services*. Some of these application services are registered as NetBIOS names. Windows 2000 allows as many as 250 NetBIOS names to be registered on a computer. Some examples of application services on a Windows computer are

- Server Service—Identifies the application service that is running; typically refers to the service that allows the sharing of files and printers on the computer.
- Workstation Service—Enables a workstation to act as a client and use services provided by the server service on another computer.
- Messenger Service—Receives and displays messages for names registered on the computer.

The maximum length of NetBIOS names is 16 characters. The first 15 characters specify the NetBIOS name, and the last character is a byte that specifies the type of the NetBIOS name. This 1-byte identifier can have a value from 0 to 255. The following list shows the names of some services that can be registered (the numbers in brackets are the hexadecimal values of the 1-byte identifiers):

- Computername[0x00]—The Workstation service registered for the computer
- Computername[0x03]—The Messenger service registered for the computer
- Computername[0x06]—The remote access service (RAS) Server Service registered for the computer
- Computername[0x1F]—The NetDDE Service registered for the computer
- Computername[0x20]—The Server service registered for the computer
- Computername[0x21]—The RAS Client service registered for the computer
- Computername[0xBE]—The Network Monitor Agent service registered for the computer

- Computername[0xBF]—The Network Monitor Application service registered for the computer
- Domainname[0x00]—Registers the computer as a member of the domain name or workgroup
- Domainname[0x1E]—Used to facilitate browser elections
- Domainname[0x1B]—Registers the computer as the domain master browser

Note

Initially NetBIOS referred to computer names only. There was only a single user for a computer. A message sent to the computer was received by the sole user on the computer.

As networks grew large with many users, NetBIOS names were added for the user and the workgroup or domain. The NetBIOS username allowed a user to receive a message. If more than one instance of the username existed (if the user logged in several times), only the first username that was registered received the message.

The workgroup or domain name was added in order to group different systems under a common name to provide easier browsing, manageability, and domain security in the Windows NT domain model. These group names are registered as NetBIOS names on the network.

In Windows 2000, NetBIOS is still used when you are using mixed-mode domains that include Windows NT domains and computers. This is the reason NetBIOS is discussed in this section.

In a native Windows 2000 domain, there is no need to configure or use NetBIOS because name resolution is performed using DNS.

Because Active Directory in Windows 2000 is self-configuring, no additional configuration needs to be done. However, Active Directory does depend on DNS, which must be configured separately.

- Domainname[0x1C]—Registers the computer as a domain controller
- Domainname[0x1D]—Registers the computer as the local subnetwork's master browser
- Username[0x03]—The username registered by the messenger for the logged-on username
- Group—The group name
- \\-__MSBROWSE__[01h]—The master browser

For example, consider that user Phylos on Windows 2000 Professional workstation WS1 in domain KINETD wants to retrieve files from a Windows 2000 server named ADS, using the universal naming convention (UNC) name of the file, \\ADS\sharename. The username "Phylos [0x03]" uses the workstation service with NetBIOS name "WS1 [0x00]" to be first authenticated by the domain controller with the NetBIOS name "KINETD [0x1C]." After the authentication, the workstation service "WS1 [0x00]" communicates with the server service "ADS [0x20]" to retrieve files.

Types of Name Resolution Methods

Windows 2000 name resolution methods can be grouped into these categories:

- Standard resolution, sometimes called host name resolution
- Specific resolution, sometimes called NBT NetBIOS name resolution

These methods are discussed in the following sections.

Standard Resolution

The standard resolution method is used by Unix systems and software ported from Unix to the Windows environment. The standard resolution method is performed in this order:

1. Local hostname
2. Using the HOSTS file
3. Using DNS
4. NetBIOS name resolution, if DNS fails

The local host is the name of the locally configured machine. The name to be resolved is first checked to determine whether it is the name of the local machine.

Note

In Windows 2000, DNS name resolution is performed by the DNS Client service. This service implements the DNS resolver, which issues the Windows socket calls `gethostbyname()` and `getnamebyhost()`.

If the name to be resolved is not that of the local machine, the HOSTS file is consulted. The HOSTS file is a table of mappings of IP addresses and hostnames. The format of the HOSTS file is taken from the 4.3 Berkeley Software Distribution (BSD) Unix HOSTS file. The HOSTS file is consulted by applications such as Telnet, FTP, and ping.

The HOSTS file is not kept at a central location. Instead, each computer is required to maintain its own HOSTS file. If it is to be changed for the network, it must be changed on all computers on the network.

If the name to be resolved is not found in the HOSTS file, a name query is sent to the DNS server. The DNS servers hold, among other things, the name-to-IP-address mappings in a distributed database on the network. Most DNS servers on the Internet are Unix based, although DNS implementations are available on platforms, such as Windows 2000.

Specific Resolution

The specific resolution method is unique to Windows networks. It consists of a combination of these methods:

- Local broadcast
- WINS
- LMHOSTS file

The local broadcast is a broadcast request sent on the local network requesting the IP address of the name that is to be resolved. The computer that recognizes its name in the broadcast request responds with its IP address. If no such computer exists, no response to the broadcast is received and the local broadcast is unable to resolve the name to its IP address. The local broadcast is also called the broadcast node (b-node) name resolution method.

The WINS is an example of a NetBIOS Name Server (NBNS). The most common example of NBNS is the WINS implementation on Windows NT and Windows 2000 servers. NBNS name resolution is specified by Request for Comments (RFCs) 1001 and 1002.

Note

Hosts files are not commonly used on most networks, but are used on very small networks. DNS is more commonly used for name resolution for TCP/IP applications.

Note

Before doing name resolution, a check is made if the NetBIOS name being resolved is a local name, in which case no name resolution needs to be done.

The results of previous name queries are stored in the name cache. Before performing a name resolution, a check is also made to see whether the answer is already in the name cache—if it is, the name resolution is not attempted.

The LMHOSTS file is a table of mappings between IP addresses and NetBIOS names. The structure of the LMHOSTS file is similar to the HOSTS file, with the added distinction that it contains a number of additional directives to make name resolution configuration easier. Windows 2000 checks the LMHOSTS file only when other name resolution methods fail.

The exact order in which the specific name resolution method is implemented depends on the name resolution configuration for the Windows 2000 computer. These name resolution methods include b-node, peer node (p-node), mixed node (m-node), and hybrid node (h-node). The following list describes each method:

- In the b-node name resolution, only broadcast packets are used for name registration and resolution. Because broadcasts can quickly flood the network, this name resolution mode is best for small local networks that do not have a WINS server. To configure your network to use this mode, ensure that no WINS servers are on the network and that the Windows computers are configured to not use WINS. That is, for the Windows client computers, ensure that you do not specify the IP address of a WINS server.
- The p-node name resolution uses WINS servers exclusively to resolve names. If the name cannot be resolved using WINS, other name resolution methods are not attempted.
- The m-node name resolution is a combination of b-node and p-node methods. First, the b-node name resolution method is attempted. If the b-node fails, the client resorts to using p-node name resolution. This method tends to generate broadcast traffic first and then attempt WINS resolution. It is suitable for small networks that have a WINS server and where it is known that the WINS server's database has not been updated for some time with new hostname entries.

Note

LMHOSTS files are not commonly used on most networks, but are used on very small networks. DNS is more commonly used for name resolution for TCP/IP applications.

Note

B-node broadcasts work only on local subnets unless the connecting routers to other subnets are enabled to forward broadcasts.

Note

Note that in the p-node and b-node methods, either the p-node or b-node method is attempted. If these methods fail, the other methods, such as LMHOSTS, are still attempted.

Note

You could use this node type for small regional offices on the far side of a WAN link, if they have local resources or servers.

- The h-node name resolution is also a combination of b-node and p-node methods. However, this method first tries the p-node name resolution. If the p-node method fails, the client resorts to using b-node name resolution. This method tends to generate broadcast traffic as a last resort because the first attempt is to contact a WINS server. This method, the most efficient, is suitable for larger networks that have a reliable WINS server and in which it is known that the WINS server's database has been updated with new hostname entries.

Configuring the NetBIOS Name Cache

A Windows 2000 computer requesting name resolution first consults a special area in memory, the NetBIOS name cache. This data area contains a list of computer names and their IP addresses. Because this information is cached in memory, found information is quickly retrieved. The name cache entries come from two sources:

- Answers to resolved name queries
- Preloading of the name cache from the LMHOSTS file using the #PRE directive

With the exception of the preloaded name cache entries, all other entries are timed out and flushed from the cache. The default timeout period is ten minutes. Readers familiar with the Address Resolution Protocol (ARP) will recognize that the NetBIOS name cache acts in a similar manner.

To purge and reload the name cache, you can use this command:

```
Nbtstat -R
```

The -R option is case sensitive. Another option, -r, is used for displaying name resolution statistics.

The two Registry entries that can be used to configure the name cache parameters are under this Registry key:

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\NetBT\Parameters
```

Note

For small networks with low network traffic and a lack of qualified administrators, using the b-node method for name resolution is adequate.

For larger networks, the h-node method is the most efficient because it tries direct name resolution using WINS first (p-node). Only when WINS fails to resolve the name is the b-node method attempted. For a properly configured WINS server, the h-node method generates the least amount of network traffic.

The name cache entries are

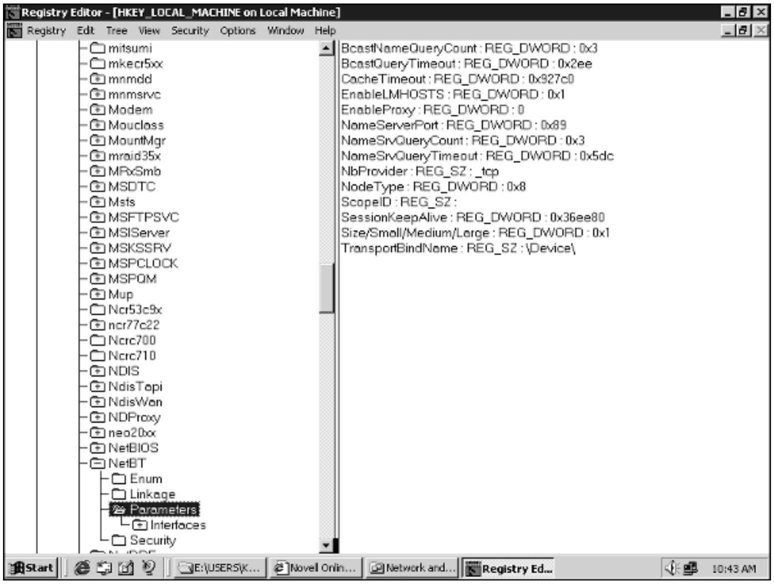
- Size/Small/Medium/Large. This entry is used to specify the number of names kept in the name cache. The settings are for small, medium, and large. Small corresponds to a value of 1 and sets the name size cache to 16 names. Medium corresponds to a value of 2 and sets the name size cache to 64 names. Large corresponds to a value of 3 and sets the name size cache to 128 names. The default value is 1, which is adequate for many networks. The parameter type is REG_DWORD.
- CacheTimeout. This entry is used to specify the number of seconds an entry will remain in the name cache. The default value is 0x927c0 (600,000 seconds, or ten minutes), which is adequate for many networks. The parameter type is REG_DWORD.

These parameter entries and others for NetBT are shown in Figure 26.11. Note that if a Registry parameter value is not listed, its default value is taken.

Configuring the Name Broadcasts

If the name resolution process does not find the name to be resolved in the name cache, it might send a broadcast if it is configured as b-node, m-node, or h-node. NetBIOS broadcasts a Name Query packet to the local network on UDP port 137 (refer to Table 26.1). Every computer on the local subnet processes the broadcast packet. If a computer on the network is configured for the NetBIOS over TCP/IP (NetBT) protocol, the NetBIOS module in the computer receives the broadcast. The NetBIOS module compares the name request with the name of the registered NetBIOS names. If there is a match, the NetBIOS module sends a Positive Name Query Response packet.

FIGURE 26.11
NetBT Parameters entry keys.



Receiving more than one response indicates a duplicate NetBIOS name, which is reported on the computer console of the computer that receives the response. It is interesting to note that the Name Query broadcast is processed by every computer up to the Session Layer, whether or not the computer has the answer. Therefore, the broadcast not only generates network traffic but also results in wasted central processing unit (CPU) cycles on many computers.

The two Registry entries that can be used to configure the name query broadcast parameters are under this Registry key:

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\NetBT\Parameters
```

The broadcast entries are

- BcastNameQueryCount. This entry is used to specify the number of times the system tries to send a Name Query broadcast. The default value is 3, which is adequate for networks with small to moderate network traffic loads. The parameter type is REG_DWORD.
- BcastQueryTimeout. This entry is used to specify the number of seconds to wait before retrying the Name Query broadcast. The default value is 7.5 seconds and is listed in 1/100-second intervals. The parameter type is REG_DWORD.

Configuring the LMHOSTS File

On small Windows 2000 networks (with as many as 30 computers) that use NetBIOS over TCP/IP, the name resolution for computer names typically is provided by the b-node method or the LMHOSTS file. If you have WINS servers on the networks, it is not necessary to use the LMHOSTS file, except as a backup. The use of LMHOSTS is adequate for small networks, where maintaining the LMHOSTS file is a simple task. On larger networks, however, keeping the LMHOSTS files updated can become a laborious task, and you should consider other name resolution techniques, such as DNS or WINS.

Note

If network traffic loads are consistently high and you see repetitions of the same unresolved NetBIOS name query, you should consider increasing the BcastNameQueryCount and BcastQueryTimeout parameters. For the BcastQueryTimeout parameter, increase the value by 0.5 to 1 second; for the BcastNameQueryCount parameter, increase the value by 1. You can monitor network traffic by using a protocol analyzer tool, such as Network Monitor, which comes with Windows 2000 Server and System Management Server (SMS).

Understanding the Syntax of the LMHOSTS File

The LMHOSTS file contains mappings between Windows 2000 NetBIOS names and their IP addresses. The file is located in the %SystemRoot%\SYSTEM32\DRIVERS\ETC directory and is compatible with the LMHOSTS file syntax used in Microsoft local area network (LAN) Manager 2.x.

The following is an example of the Windows 2000 LMHOSTS file that is installed on Windows 2000 computers:

```
# Copyright (c) 1993-1999 Microsoft Corp.
#
# This is a sample LMHOSTS file used by the Microsoft TCP/IP for Windows.
#
# This file contains the mappings of IP addresses to computernames
# (NetBIOS) names.  Each entry should be kept on an individual line.
# The IP address should be placed in the first column followed by the
# corresponding computername. The address and the computername
# should be separated by at least one space or tab. The "#" character
# is generally used to denote the start of a comment (see the exceptions
# below).
#
# This file is compatible with Microsoft LAN Manager 2.x TCP/IP lmhosts
# files and offers the following extensions:
#
```

```
#      #PRE
#      #DOM:<domain>
#      #INCLUDE <filename>
#      #BEGIN_ALTERNATE
#      #END_ALTERNATE
#      \0xnn (non-printing character support)
#
# Following any entry in the file with the characters "#PRE" will cause
# the entry to be preloaded into the name cache. By default, entries are
# not preloaded, but are parsed only after DNS fails.
#
# Following an entry with the "#DOM:<domain>" tag will associate the
# entry with the domain specified by <domain>. This affects how the
# browser and logon services behave in TCP/IP environments. To preload
# the host name associated with #DOM entry, it is necessary to also add a
# #PRE to the line. The <domain> is always preloaded although it will not
# be shown when the name cache is viewed.
#
# Specifying "#INCLUDE <filename>" will force the RFC NetBIOS (NBT)
# software to seek the specified <filename> and parse it as if it were
# local. <filename> is generally a UNC-based name, allowing a
# centralized lmhosts file to be maintained on a server.
# It is ALWAYS necessary to provide a mapping for the IP address of the
# server prior to the #INCLUDE. This mapping must use the #PRE directive.
# In addition the share "public" in the example below must be in the
# LanManServer list of "NullSessionShares" in order for client machines to
# be able to read the lmhosts file successfully. This key is under
# -\machine\system\currentcontrolset\services\lanmanserver\parameters\
Â nullsessionshares
# in the registry. Simply add "public" to the list found there.
#
# The #BEGIN_ and #END_ALTERNATE keywords allow multiple #INCLUDE
# statements to be grouped together. Any single successful include
# will cause the group to succeed.
#
# Finally, non-printing characters can be embedded in mappings by
# first surrounding the NetBIOS name in quotations, then using the
# \0xnn notation to specify a hex value for a non-printing character.
#
# The following example illustrates all of these extensions:
#
# 102.54.94.97     rhino         #PRE #DOM:networking  #net group's DC
# 102.54.94.102    "appname          \0x14"            #special app server
# 102.54.94.123    popular            #PRE             #source server
# 102.54.94.117    localsrv           #PRE             #needed for the include
#
# #BEGIN_ALTERNATE
# #INCLUDE \\localsrv\public\lmhosts
# #INCLUDE \\rhino\public\lmhosts
# #END_ALTERNATE
#
```

```
# In the above example, the "appname" server contains a special
# character in its name, the "popular" and "localsrv" server names are
# preloaded, and the "rhino" server name is specified so it can be used
# to later #INCLUDE a centrally maintained lmhosts file if the "localsrv"
# system is unavailable.
#
# Note that the whole file is parsed including comments on each lookup,
# so keeping the number of comments to a minimum will improve performance.
# Therefore it is not advisable to simply add lmhosts file entries onto the
# end of this file.
```

Comments are preceded with the `#` character. If the first several characters following `#` match any of the keywords explained in Table 26.2, the characters are treated as commands to perform special processing. Because the keywords are preceded with the comment character, the contents of the files are compatible with the syntax used by the HOSTS file. The HOSTS file is used by Windows Socket applications and Unix applications.

TABLE 26.2 LMHOSTS Keywords

Keyword	*Description*
#PRE	This keyword is added after an entry in LMHOSTS to preload the entry into the name cache. Entries that do not have a #PRE keyword are not preloaded into the name cache and are parsed only after WINS and Name Query broadcasts fail to resolve a name. You must preload entries that are added using the #INCLUDE statement. #PRE, therefore, must be appended for entries in the files referenced in #INCLUDE statements; otherwise, the entry is ignored.
#DOM: domain_name	This keyword is used to identify that the computer name is that of a domain controller. domain_name is the name of the Windows 2000 domain of which the computer is a domain controller. #DOM affects the behavior of the Browser and Logon services on a network consisting of network segments joined by routers.
#INCLUDE filename	The specified filename is processed for computer name mappings. The filename can use UNC names, which enables the mappings file to be on remote computers. If the computer referenced in the UNC name is outside the local broadcast region, you must include a mapping for the computer name in the LMHOSTS file so that the name can be found. You can add #PRE for the UNC computer name mapping to ensure that it is preloaded. Entries that appear in the INCLUDE file must be preloaded using the #PRE keyword, or else the entries are ignored.

TABLE 26.2 Continued

Keyword	*Description*
#BEGIN_ALTERNATE	This keyword is used to mark the beginning of a group of #INCLUDE statements. The name resolver attempts to use the #INCLUDE statements in the order in which they are listed. Any single successful attempt to use one of the #INCLUDE statements causes the group to succeed, in which case none of the other #INCLUDE statements in the group are processed. If none of the files in the #INCLUDE statement can be accessed, an event is added to the event log indicating that the inclusion failed. You can examine this event log by using the Event Viewer program.
#END_ALTERNATE	This keyword marks the end of the #INCLUDE block. Every #BEGIN_ALTERNATE must have a corresponding #END_ALTERNATE.
\0xnn	This keyword is the escape code for including nonprintable characters in NetBIOS names. The NetBIOS names that use this code must have quotes around the names. Use this code only for special device names and custom applications. When using this notation, remember that the NetBIOS name in quotes is padded with spaces if it is fewer than 16 characters.

Notice that the previous sample LMHOSTS file has this entry:

```
102.54.94.102    "appname        \0x14"   #special app server
```

Eight spaces of padding are between the name and the special character; the total length of the name is 16 characters.

The code `0x14` is the 1-byte identifier identifying the application service.

Understanding How the LMHOSTS File Is Processed

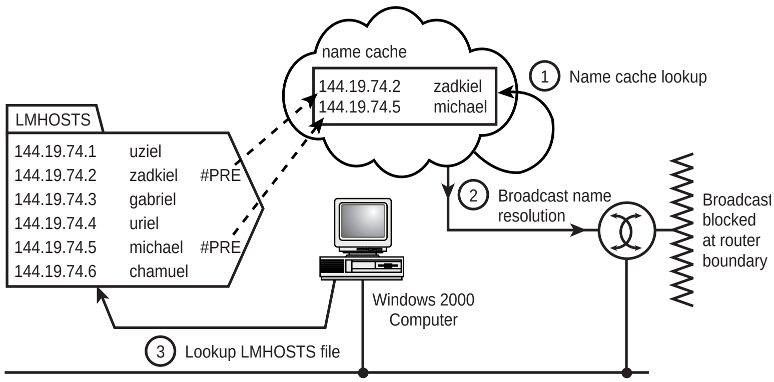
The LMHOSTS file is particularly useful if the network segment on which the Windows 2000 client resides does not have a WINS server. In this case, broadcast name resolution is used. Broadcast name resolution makes use of IP-level broadcast packets that are usually blocked by IP routers. The broadcast name resolution, therefore, never is transmitted beyond a router boundary. To solve this problem, Windows 2000 name resolution operates in the following manner when a WINS server is not specified:

1. Windows 2000 maintains a local cache of names that is initialized during system startup. The name cache is consulted first to see whether the name can be resolved. You can use the #PRE directive to load the name cache, as explained later in this chapter.

2. If no matching entry is in the name cache, Windows 2000 uses network broadcasts to resolve names. The broadcast name resolution is called the b-node broadcast protocol and is documented in RFCs 1001 and 1002.
3. If broadcast name resolution fails, the LMHOSTS file is parsed and any matching entry is used.
4. If no matching entry is in the LMHOSTS file, name resolution fails and an error message is generated.

Figure 26.12 illustrates the name resolution for the LMHOSTS file.

FIGURE 26.12
LMHOSTS name resolution.



The name cache is initialized with entries that are marked with the #PRE keyword in the LMHOSTS file. For example, the LMHOSTS file could contain the following entries, with only some entries marked with the #PRE keyword:

```
144.19.74.1    uziel
144.19.74.2    zadkiel    #PRE
144.19.74.3    gabriel
144.19.74.4    uriel
144.19.74.5    michael    #PRE
144.19.74.6    chamuel
```

You might want to preload entries for hosts such as servers that are always expected to be up. By preloading these entries, the names are in the name cache, and it avoids rereading the file to perform name resolution.

In this LMHOSTS file, the mappings for host zadkiel and michael are preloaded into the name cache on system startup. If the Windows 2000 computer needs to resolve the names zadkiel and michael, no broadcast packets are generated because the name cache provides the name resolution. If the Windows 2000 computer needs to resolve the names uziel, gabriel, uriel, and chamuel, broadcast name resolution is used. If broadcast name resolution is unsuccessful, the LMHOSTS file is parsed for these names. When a non-preloaded name is resolved by parsing the LMHOSTS file, it is cached for a period of time so that it can be reused. Names resolved through broadcasts are also saved in the cache until the timeout period expires.

The preloaded cache has a limit of 100 entries. If more than 100 entries in the LMHOSTS file are marked with #PRE, only the first 100 entries are preloaded. Additional entries are not loaded in the name cache, but are resolved if the LMHOSTS file is parsed.

If you have made changes to the LMHOSTS file in terms of the entries marked with the #PRE keyword, you can purge and reload the name cache by using this command:

```
nbtstat -R
```

The advantage of using `nbtstat` is that you can preload the cache without restarting the Windows 2000 computer.

If you use the -RR option, the NetBIOS names registered by the computer are refreshed:

```
nbtstat -RR
```

Strategy for Using Common LMHOSTS Files

The LMHOSTS file is kept on the local Windows 2000 computer in the %SystemRoot%\SYSTEM32\DRIVERS\ETC directory. The maintenance of this local LMHOSTS file on every computer can become a problem when frequent changes are made.

The use of the #INCLUDE statement can simplify the maintenance of the LMHOSTS file. You could keep the LMHOSTS file on a Windows 2000 server named AKS and include the following reference to this file on other Windows 2000 computers:

```
#INCLUDE \\AKS\ETC\LMHOSTS
```

In this example, ETC is the shared name of the %SystemRoot%\SYSTEM32\DRIVERS\ETC directory on the AKS computer. The advantage of this approach is that all common names that need to be preloaded are kept in a common file. If the AKS computer is not in the broadcast region, you must include a specific mapping for it. If the NTKS has an IP address of 134.21.22.13, for example, you could use these entries in the LMHOSTS file:

```
134.21.22.13    AKS          #PRE
#INCLUDE     \\AKS\ETC\LMHOSTS
```

To ensure that the common LMHOSTS file is always available, you can replicate this file to other Windows 2000 computers using the Windows 2000 replicator service. The common LMHOSTS file must be on a Windows 2000 server (either Windows 2000 Server or Windows 2000 Advanced Server) because only the Windows 2000 server can act as an export server for replication.

If you have redundant servers, you need to specify that the LMHOSTS file can be found on any of the redundant servers. In this situation, using the #BEGIN_ALTERNATIVE and #END_ALTERNATIVE commands comes in handy. Recall from Table 26.1 that these statements mark a block of #INCLUDE statements so that any one of the #INCLUDE statements can be used.

Consider the following example, in which an alternative list of LMHOSTS files is specified on Windows 2000 computers on a network segment:

```
134.21.22.13    AKS          #PRE
134.21.22.14    AC1          #PRE
134.21.22.15    AC2          #PRE

#BEGIN_ALTERNATIVE
#INCLUDE \\AKS\ETC\LMHOSTS    # Main source of LMHOSTS file
#INCLUDE \\AC1\ETC\LMHOSTS    # Backup 1
#INCLUDE \\AC2\ETC\LMHOSTS    # Backup 2
#END_ALTERNATIVE
```

In this example, the LMHOSTS file on AKS is assumed to be replicated to backup Windows 2000 computers AC1 and AC2. The shared name for the %SystemRoot%\SYSTEM32\DRIVERS\ETC directory is ETC on all the Windows 2000 computers. The block inclusion is successful if any of the files on the three Windows 2000 computers is available. If the file is not available because the Windows 2000 computers are down or an incorrect path is specified, an event is added to the Windows 2000 computer's event log.

Configuring the HOSTS File

The HOSTS file is used by Unix TCP/IP-derived tools, such as PING and NETSTAT, to resolve hostnames to their IP addresses.

The HOSTS file syntax is similar to the syntax of the LMHOSTS file. The HOSTS file is also in the same directory (%SystemRoot%\SYSTEM32\DRIVERS\ETC) as the LMHOSTS file. The HOSTS file syntax differs from the LMHOSTS file in the following ways:

- No special tags (such as #PRE and #DOM) are in the HOSTS file.
- You can define several alias names for an IP address by listing the names on the same line separated by spaces.

The general syntax of each line in the HOSTS file can be either of the following:

```
IPAddress    Name1 [Name2 ... NameN] # Comment
# Comment
```

Name2 and NameN are optional aliases for the name Name1. As with the LMHOSTS configuration file, anything after the symbol # is treated as a comment.

The following is an example of a HOSTS file:

```
# Copyright (c) 1993-1999 Microsoft Corp.
#
# This is a sample HOSTS file used by Microsoft TCP/IP for Windows.
#
# This file contains the mappings of IP addresses to host names. Each
# entry should be kept on an individual line. The IP address should
# be placed in the first column followed by the corresponding host name.
# The IP address and the host name should be separated by at least one
# space.
#
# Additionally, comments (such as these) may be inserted on individual
# lines or following the machine name denoted by a '#' symbol.
#
# For example:
#
#      102.54.94.97     rhino.acme.com          # source server
#       38.25.63.10     x.acme.com              # x client host

127.0.0.1       localhost
199.245.180.1    ntws1
199.245.180.2    ntws2
199.245.180.3    ntws3
199.245.180.4    ntws4
199.245.180.5    ntws5
199.245.180.6    ntws6 phylos anzimee
ntsmain ntc ntcontroller
```

Other Support Files for TCP/IP Services

As mentioned earlier in this chapter, the HOSTS file must be configured for many Unix-based services ported to Windows 2000. In addition to the HOSTS file, three other files can be used by the Windows 2000 port of Unix-based services: the NETWORKS, PROTOCOL, and SERVICES files that are in the %SystemRoot%\SYSTEM32\DRIVERS\ETC directory. For the most part, you do not need to configure these files unless you want to add symbolic names for networks, or you are a software developer porting new services and protocols to the Windows environment.

The NETWORKS File

The NETWORKS file is used to identify the networks that exist on the internetwork (a network consisting of several networks, usually connected through routers). The NETWORKS file is similar in concept to the HOSTS file. Whereas the HOSTS file contains the association between host addresses and hostnames, the NETWORKS file contains the association between network addresses and network names.

Each line in the NETWORK text file contains information in this format:

```
network_name       network_number[/subnet_mask]       alias #comment
```

`network_name` is an identifier representing the name of the network, and `network_number` is the netid part of the IP address for the network. The network name cannot contain a tab, space, or number (#) character and must be unique in the NETWORKS file.

`subnet_mask` is the subnet mask for the network. It can be expressed in dotted decimal or dotted hexadecimal notation. The square brackets ([]) in the previously stated syntax for the NETWORKS file entry indicate that the subnet mask is optional. If the subnet mask is left out, a default mask indicates that no subnet mask is being used.

The optional alias identifies other names by which this network is known. Usually the `network_name` is in lowercase characters and an alias is included that lists the service in uppercase characters.

#comment is used to place comments. All characters between the # and the end of the line are ignored and treated as comments. The #comment can occur on a line by itself.

The network names specified in the NETWORKS file can be used in configuration utilities and commands that deal with the network address. For example, the network name can be used as an alternative to using the network addresses. This file can be modified by network administrators to enable the use of network names in configuration commands and utilities rather than use the network addresses, which are more difficult to remember.

Note

The NETWORKS file is useful when you want a symbolic display of network values, such as when you are using tools like the route command to display routing tables.

The following is an example of a NETWORKS file:

```
# Copyright (c) 1993-1999 Microsoft Corp.
#
# This file contains network name/network number mappings for
# local networks. Network numbers are recognized in dotted decimal form.
#
# Format:
#
# <network name>  <network number>     [aliases...]  [#<comment>]
#
# For example:
#
#    loopback     127
#    campus       284.122.107
#    london       284.122.108

loopback                127
Kinet                199.245.180
SCSnet               200.24.4.0
MyNet                   144.19
```

The PROTOCOL File

The PROTOCOL file is used to identify the names of protocols and the corresponding protocol number. The protocol number for the Internet suite of protocols is the value protocol identifier (protocol ID) field of the IP header. The protocol ID field is used to identify the upper-layer protocol that uses the Internet Protocol.

The PROTOCOL file accompanies the TCP/IP protocol module and contains common protocols; you should not have to modify the file.

Each line in the PROTOCOL text file contains information in this format:

```
protocol_name       protocol_number       [alias]    #comment
```

`protocol_name` is an identifier representing the name of the protocol, and `protocol_number` is the number used in the IP header to identify the protocol. The protocol name cannot contain a tab, space, or number (#) character and must be unique in the PROTOCOL file.

The optional alias identifies other names by which this protocol is known. Usually the `protocol_name` is in lowercase characters and an alias is included that lists the service in uppercase characters.

Note

The symbolic names of networks in the NETWORKS file are aliases for the networks. The symbolic names, rather than the IP addresses, are displayed when TCP/IP commands for displaying routing tables are executed.

#comment is used to place comments. All characters between the # and the end of the line are ignored and treated as comments. #comment can occur on a line by itself.

A sample PROTOCOL file for Windows 2000 is listed next:

```
# Copyright (c) 1993-1999 Microsoft Corp.
#
# This file contains the Internet protocols as defined by RFC 1700
# (Assigned Numbers).
#
# Format:
#
# <protocol name>  <assigned number>  [aliases...]   [#<comment>]

ip       0     IP       # Internet protocol
icmp     1     ICMP     # Internet control message protocol
ggp      3     GGP      # Gateway-gateway protocol
tcp      6     TCP      # Transmission control protocol
egp      8     EGP      # Exterior gateway protocol
pup      12    PUP      # PARC universal packet protocol
udp      17    UDP      # User datagram protocol
hmp      20    HMP      # Host monitoring protocol
xns-idp  22    XNS-IDP  # Xerox NS IDP
rdp      27    RDP      # "reliable datagram" protocol
rvd      66    RVD      # MIT remote virtual disk
```

The SERVICES File

The SERVICES file is used to identify the following:

- Names of services
- The transport protocol
- The port number used by the service

The names of services are programs that run in the Process/Application Layer of the TCP/IP model (sometimes called the DoD model). Examples of these services are Telnet, FTP, Simple Mail Transport Protocol (SMTP), and SNMP. These services can use a Transport protocol, such as TCP or UDP. The SERVICES configuration file identifies the Transport protocol that is used. Some services are available through both the TCP and UDP transport protocols. In this case, the service is listed twice: once for the TCP protocol and once for the UDP protocol. The port number identifies the application service that uses the Transport protocol.

Note

The PROTOCOL file is useful for TCP/IP application code ported from the Unix environment. Some of the BSD Sockets code uses the PROTOCOL file to get the protocol number for the TCP and UDP transports, whereas other TCP/IP code directly hard-codes these protocol number values.

This SERVICES file accompanies the TCP/IP protocol module and contains common TCP/IP services; you should not have to modify the file.

Each line in the SERVICES text file contains information in this format:

```
service              port/transport              [alias]    #comment
```

`service` is an identifier representing the name of the service. Examples of service values are Telnet, FTP, FTP-DATA, SMTP, and SNMP. The service name cannot contain a tab, space, or number (#) character and must be unique in the SERVICES file.

The optional `alias` identifies other names by which this service is known.

`#comment` is used to place comments. All characters between the # and the end of the line are ignored and treated as comments. `#comment` can occur on a line by itself.

A sample SERVICES file for a Windows 2000 computer is shown next:

```
# Copyright (c) 1993-1999 Microsoft Corp.
#
# This file contains port numbers for well-known services defined by IANA
#
# Format:
#
# <service name>  <port number>/<protocol>  [aliases...]   [#<comment>]#
```

```
echo              7/tcp
echo              7/udp
discard           9/tcp    sink null
discard           9/udp    sink null
systat           11/tcp    users                #Active users
systat           11/tcp    users                #Active users
daytime          13/tcp
daytime          13/udp
qotd             17/tcp    quote                #Quote of the day
qotd             17/udp    quote                #Quote of the day
chargen          19/tcp    ttytst source        #Character generator
chargen          19/udp    ttytst source        #Character generator
ftp-data         20/tcp                         #FTP, data
ftp              21/tcp                         #FTP, control
telnet           23/tcp
smtp             25/tcp    mail                 #Simple Mail Transfer
                                                ➥ Protocol
time             37/tcp    timserver
time             37/udp    timserver
rlp              39/udp    resource             #Resource Location
                                                ➥Protocol
nameserver       42/tcp    name                 #Host Name Server
nameserver       42/udp    name                 #Host Name Server
nicname          43/tcp    whois
domain           53/tcp                         #Domain Name Server
domain           53/udp                         #Domain Name Server
bootps           67/udp    dhcps                #Bootstrap Protocol Server
bootpc           68/udp    dhcpc                #Bootstrap Protocol Client
tftp             69/udp                         #Trivial File Transfer
gopher           70/tcp
finger           79/tcp
http             80/tcp    www www-http         #World Wide Web
kerberos         88/tcp    krb5 kerberos-sec    #Kerberos
kerberos         88/udp    krb5 kerberos-sec    #Kerberos
hostname        101/tcp    hostnames            #NIC Host Name Server
iso-tsap        102/tcp                         #ISO-TSAP Class 0
rtelnet         107/tcp                         #Remote Telnet Service
pop2            109/tcp    postoffice           -#Post Office Protocol -
                                                ➥Version 2
pop3            110/tcp                         -#Post Office Protocol -
                                                ➥Version 3
sunrpc          111/tcp    rpcbind portmap      #SUN Remote Procedure Call
sunrpc          111/udp    rpcbind portmap      #SUN Remote Procedure Call
auth            113/tcp    ident tap            #Identification Protocol
uucp-path       117/tcp
nntp            119/tcp    usenet               #Network News Transfer
                                                ➥Protocol
ntp             123/udp                         #Network Time Protocol
epmap           135/tcp    loc-srv              #DCE endpoint resolution
epmap           135/udp    loc-srv              #DCE endpoint resolution
netbios-ns      137/tcp    nbname               #NETBIOS Name Service
netbios-ns      137/udp    nbname               #NETBIOS Name Service
```

```
netbios-dgm      138/udp    nbdatagram          #NETBIOS Datagram Service
netbios-ssn      139/tcp    nbsession           #NETBIOS Session Service
imap             143/tcp    imap4               #Internet Message Access
                                                ➥Protocol
pcmail-srv       158/tcp                        #PCMail Server
snmp             161/udp                        #SNMP
snmptrap         162/udp    snmp-trap           #SNMP trap
print-srv        170/tcp                        #Network PostScript
bgp              179/tcp                        #Border Gateway Protocol
irc              194/tcp                        #Internet Relay Chat
                                                ➥Protocol
ipx              213/udp                        #IPX over IP
ldap             389/tcp                        -#Lightweight Directory
                                                ➥Access Protocol
https            443/tcp    MCom
https            443/udp    MCom
microsoft-ds     445/tcp
microsoft-ds     445/udp
kpasswd          464/tcp                        # Kerberos (v5)
kpasswd          464/udp                        # Kerberos (v5)
isakmp           500/udp    ike                 #Internet Key Exchange
exec             512/tcp                        #Remote Process Execution
biff             512/udp    comsat
login            513/tcp                        #Remote Login
who              513/udp    whod
cmd              514/tcp    shell
syslog           514/udp
printer          515/tcp    spooler
talk             517/udp
ntalk            518/udp
efs              520/tcp                        #Extended File Name Server
router           520/udp    route routed
timed            525/udp    timeserver
tempo            526/tcp    newdate
courier          530/tcp    rpc
conference       531/tcp    chat
netnews          532/tcp    readnews
netwall          533/udp                        #For emergency broadcasts
uucp             540/tcp    uucpd
klogin           543/tcp                        #Kerberos login
kshell           544/tcp    krcmd               #Kerberos remote shell
new-rwho         550/udp    new-who
remotefs         556/tcp    rfs rfs_server
rmonitor         560/udp    rmonitord
monitor          561/udp
ldaps            636/tcp    sldap               #LDAP over TLS/SSL
doom             666/tcp                        #Doom Id Software
doom             666/udp                        #Doom Id Software
kerberos-adm     749/tcp                        #Kerberos administration
kerberos-adm     749/udp                        #Kerberos administration
kerberos-iv      750/udp                        #Kerberos version IV
```

```
kpop              1109/tcp                         #Kerberos POP
phone             1167/udp                         #Conference calling
ms-sql-s          1433/tcp                         #Microsoft-SQL-Server
ms-sql-s          1433/udp                         #Microsoft-SQL-Server
ms-sql-m          1434/tcp                         #Microsoft-SQL-Monitor
ms-sql-m          1434/udp                         #Microsoft-SQL-Monitor
wins              1512/tcp                         -#Microsoft Windows
                                                   ➥Internet Name Service
wins              1512/udp                         -#Microsoft Windows
                                                   ➥Internet Name Service
ingreslock        1524/tcp    ingres
l2tp              1701/udp                         #Layer Two Tunneling
                                                   ➥Protocol
pptp              1723/tcp                         -#Point-to-point
                                                   ➥tunnelling protocol
radius            1812/udp                         -#RADIUS authentication
                                                   ➥protocol
radacct           1813/udp                         #RADIUS accounting protocol
nfsd              2049/udp    nfs                  #NFS server
knetd             2053/tcp                         #Kerberos de-multiplexor
man               9535/tcp                         #Remote Man Server
```

Note

If you are installing a new TCP service that is a direct port of a Unix application on Windows 2000, the new service might expect to see its port and transport protocol definition in the SERVICES file. You might have to add a line in the SERVICES file describing the new service, if the installed service does not automatically add its description to the SERVICES file.

Installing and Configuring the FTP Server Service

Windows 2000 servers (both Windows 2000 Server and Windows 2000 Advanced Server) and Windows 2000 Professional workstations can be set up as FTP servers to enable files in the Windows 2000 computer to be accessed by FTP clients. The FTP clients can be other Windows 2000 computers, Unix computers, disk operating system (DOS) or Windows computers, Macintosh computers, and VMS computers.

The Windows 2000 FTP Server service supports all FTP client commands, is implemented as a multithreaded Win32 application, and complies with RFCs 959, “File Transfer Protocol (FTP),” and 1123, “Requirements for Internet Hosts,” which describe the FTP protocols and services.

FTP servers use the user accounts of the host operating system. In the case of Windows 2000, the FTP user accounts are the domain accounts created on the FTP computer and the FTP anonymous user account.

The FTP Server is a part of the Microsoft Internet Information Server (IIS). The following section includes some general installation and utilization information.

Installing and Configuring the FTP Server Service on Windows 2000 Server

You can choose to install the FTP Service and other Internet services when you do your original Windows 2000 installation. Select the Internet Information Server box during installation when you are selecting the Windows components to install. The FTP Server automatically is installed as a part of IIS.

If you have already installed Windows 2000 Server without the Internet Information Server, you can add IIS now. Because the FTP Server service relies on the TCP/IP protocol, you must install and configure the TCP/IP protocol before you can install FTP Server services.

Note

In Windows 2000 most FTP service parameters can be configured using the IIS console in the Computer Management tool and the Internet Services Manager tool. In Windows NT some of the more advanced parameters had to be configured using the Registry. You do not have to resort to using the Registry in Windows 2000.

All FTP Service parameters are under the Registry key HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\ Services\MSFTPSRV\Parameters.

If the FTP Server is not installed, install IIS and follow these steps to configure the default FTP site:

1. Log in as an Administrator user.
2. Select Start, Settings, Control Panel.
3. Double-click Add/Remove Programs, and then click Add/Remove Windows Components. You should see the Windows Components Wizard.
4. Enable IIS and select Details. Make sure that the FTP Server is checked.
5. Click OK. Click Next on succeeding screens (ensure that a Windows 2000 distribution CD is in your drive), and then click Finish to complete the installation.

6. Reboot the Windows 2000 computer. View the list of services on the Windows 2000 computer to verify that the FTP Server service has started. You can view a list of services that are running by selecting Computer Management from the Administrative Tools applet in the Control Panel. Open the Services and Applications folder.
7. Double-click on the Services icon in the right pane, and verify that the FTP Publishing Service has started.
8. From the Computer Management screen, open the Services and Applications\IIS folder.
9. Right-click on Default FTP Site (it might also be labeled FTP Site #1) and select Properties. The Default FTP Site Properties screen appears.
10. You can specify a description in the Description field or change an existing description. In the IP Address field, select the IP address of the Windows 2000 computer. Leave the TCP port number set to 21; it is the default port number for accepting TCP control connections at the FTP server.
11. In the Connection box, specify the number of simultaneous FTP sessions to the FTP server. The number of connections can be limited to a specified number, or it can be unlimited. Use this field to perform appropriate load balancing. Restricting the number of FTP connections to between 50 and 250 connections is common practice to avoid overwhelming a server.
12. Use the Connection Timeout field to specify how long an FTP user can remain connected without generating any activity before being disconnected. The default value is 900 seconds (15 minutes). A value of 0 disables the idle timeout feature. The value is used primarily for security reasons to reduce the threat of unattended FTP sessions.
13. Select Enable Logging to control the FTP session log and the format of the log messages (Microsoft IIS Log File, Open Database Connectivity (ODBC) Logging, or W3C Extended Log File).
14. Select the Security Accounts tab to set who can access the FTP server.
15. Enable the option Allow Anonymous Connections to allow users with the user account named anonymous or FTP to log on to the FTP server. A user is not required to enter a password while logging on as an anonymous user, even though the user is prompted for an e-mail address as a password.
16. Use the Password field to specify the password for the user account specified in the Username field.

17. Enable the Allow Only Anonymous Connections check box option if you want only anonymous user logons to ensure that Windows 2000 users do not log on with their Windows 2000 username and password. Remember that FTP passwords are not encrypted and that if they are used on the network, security can be compromised. By default, this option is disabled. You can set the Allow IIS to control password option.
18. In the FTP Site Operators box, you can grant operator privileges to Windows user accounts for this FTP site by clicking the Add button. By default the operators are members of the local Administrators group.
19. Select the Messages tab to specify messages the user sees at logon (Welcome field) and logout (Exit field) and the number of maximum connections allowed if the limit is exceeded (Maximum Connections field).
20. Select the Home Directory tab to specify the folder to which the user connects when she logs in. You can specify that the home directory be on the local computer or a share on another computer. You can specify Read, Write, or Log visits permissions on the home directory and whether the user sees an MS-DOS–style or Unix-style directory listing.
21. Select the Directory Security tab to specify TCP/IP access restrictions of granted or denied from the specified IP address and subnet mask. First check the option Granted access or Denied access, and then click the Add button. In the Deny Access On dialog box, enable the Single computer or Group computer option, and then specify the IP address and (optionally) subnet mask for a group of computers. Click OK to close the boxes.

Note

The username *anonymous* is reserved on the Windows 2000 computer for anonymous logon. You cannot, therefore, use a Windows 2000 user account named anonymous. In the Username field, specify the name of the Windows 2000 user account to be used for the user who logs on as anonymous. Access permissions for the anonymous FTP user are the same as that for the specified user. By default, the IUSR_computername account is used for the anonymous user.

Configuring TCP/IP to Print from Windows 2000 to Unix Printers

Windows 2000 supports printing to Unix printers on the network. The print jobs are sent using the TCP/IP protocol. Windows 2000 printing support for Unix printers conforms to RFC 1179, "Line Printer Daemon Protocol."

To print to a Unix computer, only one Windows 2000 computer (workstation or server) needs to have the TCP/IP protocol installed and configured in addition to the Microsoft TCP/IP Printing Service. This Windows 2000 computer then acts as the print gateway for other Microsoft clients (see Figure 26.13). The other Microsoft clients do not need TCP/IP installed on them to use the print gateway. Figure 26.13 shows that the computer named AKS has TCP/IP print support and has defined the shared printers \\AKS\Unix_PR1 and \\AKS\Unix_PR2. These printers correspond to a directly connected Unix printer and to a printer attached to a Unix computer. Other Microsoft clients connect to the shared printers as though they were Microsoft print devices. A print job sent to the shared printer names \\AKS\Unix_PR1 and \\AKS\Unix_PR2 is redirected by AKS to the corresponding Unix printer.

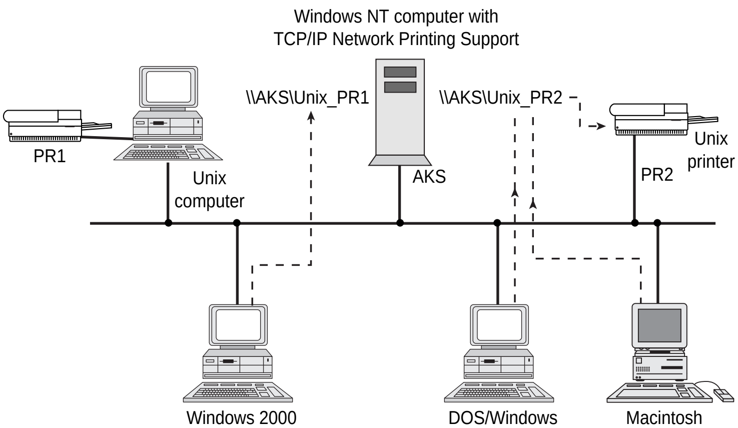


FIGURE 26.13
TCP/IP printing under Windows 2000.

Installing and Configuring TCP/IP Printing

TCP/IP printing is installed at the time of Windows 2000 installation as part of the Other Network File and Print Services Windows components. If it has not been installed, follow these steps to install this component:

1. Log in as an Administrator user.
2. Select Start, Settings, Control Panel.
3. Double-click Add/Remove Programs and then click Add/Remove Windows Components. You should see the Windows Components Wizard.
4. Enable Other Network File and Print Services and select Details. Make sure that the Print Services for Unix option is checked.
5. Select OK. Ensure that the Windows 2000 distribution CD is in the CD-ROM drive. Keep clicking Next and then click Finish. This step installs the selected components.

The following steps outline the process for configuring TCP/IP printing on a Windows 2000 computer to use the Print Services for Unix service running on another Windows 2000 computer or the equivalent line printer daemon (LPD) service running on a Unix machine:

1. Log in as an Administrator user on the Windows 2000 computer (Windows 2000 Server or Workstation).
2. Select Start, Settings, Printers.
3. Double-click the Add Printer icon. When the Add Printer Wizard appears, click Next.
4. The Local or Network Printer screen appears. Select either local or network management of the printer, and then click the Next button. If you select the Local option, the Wizard tries to detect plug-and-play printers. If it does find any, you have to make the selection manually.
5. The Printer Wizard finally displays a list of available printer ports. Enable the Create a new port option. From the Type drop-down list, select LPR port and then click Next.

   You should see the Add LPR compatible printer dialog box.
6. In the Name or address of server providing LPD field, enter the DNS name or IP address of the Unix device (host or directly attached printer) on which the LPD service is running. The LPD service is the line printer daemon service, which acts as a Unix print server.

Note

If you are printing to a networked printer that supports LPR, you do not need to install this service. It is required only if the printer queue is hosted on a generic Unix host.

7. In the Name of printer or print queue on that server field, enter the Unix printer name on that computer system.
8. Choose OK after filling in the Add LPR compatible printer dialog box. If the LPD service is not enabled, a message lets you know. Select OK.
9. Select the manufacturer from the Manufacturers list and the printer from the Printers list by highlighting the appropriate choices on the Add Printer Wizard screen. Click the Next button after you finish.
10. The Add Printer Wizard displays the printer name and asks whether you want it to be the default printer. Select Yes or No, and then click the Next button.
11. The Add Printer Wizard now enables you to choose whether this printer will be shared on the network. Select Share as or Do not share this printer. Type the share name in the Share Name field. By default, the share name is the same as the printer name you entered earlier. Click Next.
12. The Location and Comment screen appears. This printer name is seen by other Microsoft clients. Complete the Location and Comment fields to describe the location and printer capabilities. Click Next.
13. Optionally, you can print a test page. This step is recommended in order to verify that your configuration is accurate. Select Yes or No, click Next, and then click the Finish button.
14. Choose OK if your test page printed, or troubleshoot the printing process. The new printer icon should appear. To examine the printer settings, right-click on the printer icon and select Properties.
15. On the Device Settings tab, you can make changes such as selecting the form type, form source, and printer memory that are specific to the printer you are using. Choose OK to save your changes. Make any other changes.

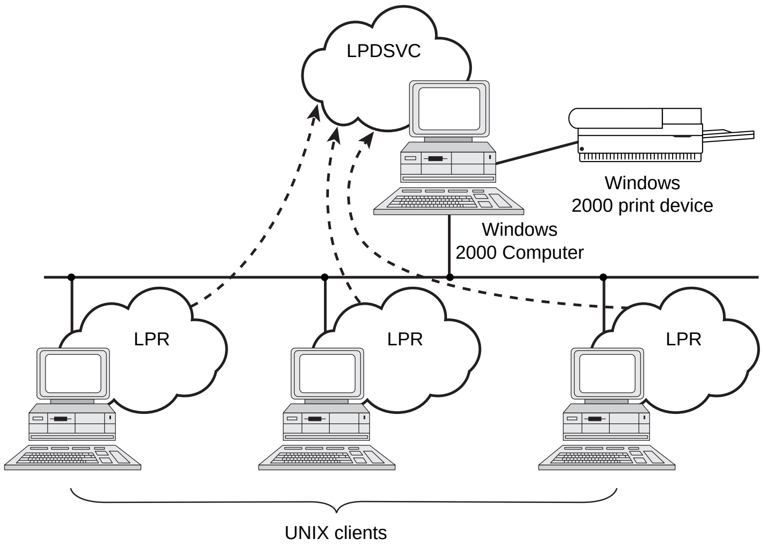
    The TCP/IP printer is configured. You can close the Printers window.

Printing to a Windows 2000 Computer from a Unix Computer

The preceding section outlined the configuration procedure for printing to a Unix printer from Microsoft clients. On a network consisting of a mix of Unix computers and Microsoft clients, you might need to print from a Unix client to a Windows 2000 printer.

To print from a Unix client to a Windows 2000 computer, you must have TCP/IP Print Server Services running on the Windows 2000 computer. Unix print clients expect to communicate with a Unix LPD. You can start the Windows 2000 LPDSVC service, which emulates a Unix line-printer daemon. Figure 26.14 shows how Unix clients can print to a Windows 2000 computer.

FIGURE 26.14
Printing from Unix to a Windows 2000 computer.

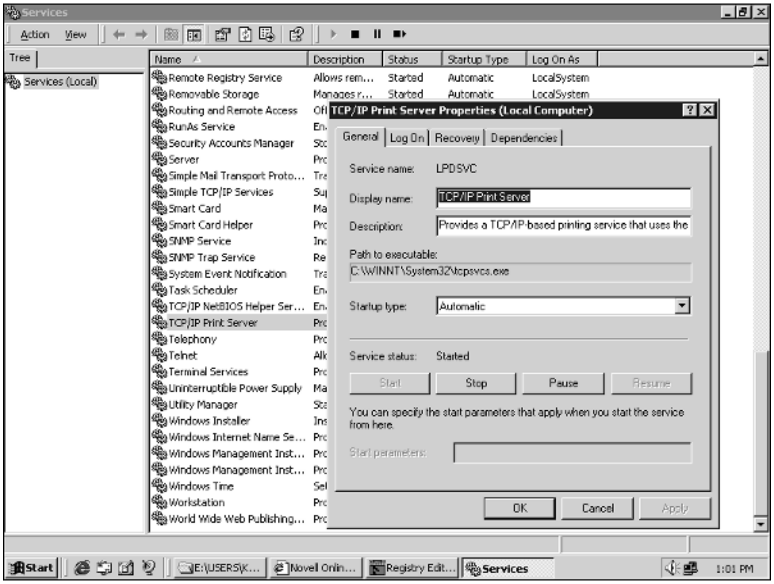


You can start, pause, continue, or stop the Windows 2000 LPDSVC by using these NET commands:

- NET START LPDSVC
- NET PAUSE LPDSVC
- NET CONTINUE LPDSVC
- NET STOP LPDSVC

Alternatively, you can use the Services icon in the Control Panel to start, pause, continue, or stop the lpdsvc. The LPDSVC is called TCP/IP Print Server in the Server Properties dialog box (see Figure 26.15). By default, this service is started automatically. You can use the Startup type field in the Server Properties dialog box to change the startup conditions of this service when the Windows 2000 computer is started.

FIGURE 26.15
The TCP/IP Print Server services properties.



On the Unix printer, you must use the appropriate Unix command, usually lpr, to submit print jobs to the Windows 2000 computer. Consult your Unix documentation for the details of this command. The general syntax of the lpr command is

```
lpr -s NTHost -P NTPrinter filename
```

NTHost is the DNS name of the Windows 2000 computer running the LPDSVC; NTPrinter is the name of the Windows 2000 printer created on NTHost; and filename is the name of the Unix file to be printed.

Using TCP/IP Command-Line Tools

Windows 2000 comes with a number of TCP/IP command-line tools. They are, for the most part, based on their Unix counterparts. If you have used these tools on Unix computers, you are already familiar with their function.

In addition to command-line tools, Windows 2000 supports simple TCP/IP services, such as ECHO, DAYTIME, CHARGEN, and DISCARD. These services are available on most Unix computers. You must, however, install them in Windows 2000 using the Simple TCP/IP Services option.

Windows 2000 supports these command-line tools:

- arp
- hostname
- ipconfig
- lpq
- lpr
- nbtstat
- netstat
- ping
- route
- tracert
- finger
- rcp
- rexec
- rsh
- ftp
- tftp
- telnet
- pathping

Although the ftp, rexec, and telnet utilities require authentication, the passwords are not encrypted before they are sent. Using these utilities, therefore, is a potential security risk. You should try to use different user accounts for these utilities so that the Windows 2000 user account passwords are not compromised. In Windows 2000, Telnet supports encrypted authentication. You should use encrypted authentication if there is a significant risk that the Telnet user account password will be compromised.

This section describes the installation of the Simple TCP/IP services and then the basic command-line tools.

Simple TCP/IP Services is part of the Network Services Windows component installed during the Windows 2000 installation. The following steps outline the process for installing Simple TCP/IP Services, if you have not already done so:

1. Log in as an Administrator user.
2. Select Start, Settings, Control Panel.
3. Double-click Add/Remove Programs, and then click Add/Remove Windows Components. You should see the Windows Components Wizard.
4. Enable Network Services and select Details. Make sure that the Simple TCP/IP Services option is checked (see Figure 26.16).

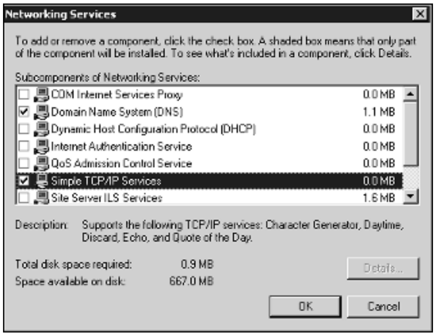


FIGURE 26.16
Simple TCP/IP Services option.

5. Click OK. Ensure that the Windows 2000 distribution CD is in the CD-ROM drive. Keep clicking Next, and then click Finish. This step installs the selected components.

Note

The Simple TCP/IP Services are CHARGEN, DAYTIME, DISCARD, ECHO, and QUOTE. You can use these services as diagnostics tools.

The CHARGEN service uses TCP port number 19. If you make a connection to this port using Telnet, you see a display of 95 printable American Standard Code for Information Interchange (ASCII) characters cycle on your screen. The following Telnet command makes a connection to the CHARGEN service running on the remote computer:

```
telnet remote 19
```

You can use CHARGEN as a debugging tool for testing to ensure that the remote computer is operational up to the TCP layer.

The DAYTIME service uses TCP port number 13. If you make a connection to this port using Telnet, you see an ASCII representation of the current time on the remote machine. The following Telnet command makes a connection to the DAYTIME service running on the remote computer:

```
telnet remote 13
```

You can use this command to see the time on the remote computer and to verify that you have connectivity up to the TCP layer on the remote machine.

The DISCARD service uses TCP port number 9. If you make a connection to this port using Telnet, any data you send is discarded. The DISCARD service acts as a data “sink,” or “black hole.” The following Telnet command makes a connection to the DISCARD service running on the remote computer:

```
telnet remote 9
```

TCP port 9 can be used as a null port for testing programs. For example, you can use the DISCARD service to receive TCP test messages that are not important to store or display and can be safely discarded.

The ECHO service uses TCP port number 7. If you make a connection to this port using Telnet, any data you send is echoed back. You can use this tool as a debugging tool to see whether messages sent to the remote computer can be returned intact. The following Telnet command makes a connection to the ECHO service running on the remote computer:

```
telnet remote 7
```

After you make this connection, you should type a few characters and see whether they are echoed back.

The QUOTE service uses TCP port number 17. If you make a connection to this port using Telnet, it sends you a Quote of the Day message taken randomly from the file %SystemRoot%\System32\Drivers\Etc\Quotes. You can use this tool as a debugging tool to see whether messages can be sent from the remote computer. The following Telnet command makes a connection to the QUOTE service running on the remote computer:

```
telnet remote 17
```

After you make this connection, you should see a Quote of the Day message.

Summary

Configuring TCP/IP for Windows 2000 involves the configuration of basic TCP/IP parameters, such as the IP address, subnet mask, default gateways, and name servers. Windows 2000 computers need to know about at least one default gateway to go beyond the current network. In a native-mode network consisting only of Windows 2000 computers, the only name server the Windows 2000 computer needs to know about is the DNS server. However, if you need connectivity to older Windows clients and servers, the Windows 2000 computers need to be configured with WINS. In Windows 2000 networks, knowledge of NetBIOS name resolution is still important for backward compatibility.

Although the Windows 2000 Active Directory depends on TCP/IP, no configuration needs to be done to the TCP/IP protocol stack other than to specify the DNS server that will be used for name resolution.

CHAPTER 27

IP Support in Novell NetWare

by Joe Devlin and Emily Berk

In This Chapter

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- **Legacy Solutions: IP for NetWare 3.x through 4.x** *685*
- **NetWare 5/NetWare 6—IP and All the Comforts of Novell** *690*
- **Installation Options** *691*
- **Tools That Aid in IP Migration** *694*
- **Migration Strategies** *697*

Arguably the father of all modern network operating systems, Novell's NetWare is a reliable product that has been evolving for almost 18 years. Today, NetWare is installed on almost five million servers and 81 million workstations worldwide.

Novell and TCP/IP

Novell's adoption of TCP/IP has come slowly and in stages. In 1987, Novell shipped release 3.11 of NetWare with built-in support for IP tunneling and the availability of the TCP/IP stack and TCP/IP application services such as FTP and NFS. Since that time, Novell has added a wide variety of TCP/IP solutions to its network operating systems. Many of these older solutions remain useful. Novell builds reliable operating systems, and it is common practice in the NetWare world to leave old servers running as departmental solutions while assigning new servers the more demanding jobs of wide area or Internet management.

IP and NetWare 4

NetWare 4 represented Novell's first serious attempt to produce an operating system that fully embraced the Internet. NetWare 4 introduced Novell Directory Services (NDS), a facility that simplifies management of a wide variety of network resources running on a wide area network full of NetWare, NT, and Unix servers. NDS caught the attention of network managers everywhere and added luster to Novell's image as a company that delivers useful solutions that seemed beyond the technical ability of Microsoft.

NetWare 4 less successfully incorporated mainstream Internet development tools into NetWare. NetWare 4.11 (dubbed IntranetWare), which began shipping in October 1996, bundled a grab bag of Internet-related utilities including the NetWare Web Server, NetWare FTP server, and NetWare Internet Access Services (NIAS). Novell also threw in tools for connecting NetWare servers and clients to Internet devices running under TCP/IP.

NDS was a huge success. But a single Novell 4.x server running NDS is quite capable of managing an impressive conglomeration of Novell 3.x, NT, and Unix servers. Corporations wanted to enable their Novell servers to talk TCP/IP, but that could be accomplished in any number of ways using either NetWare 3.x or 4.x servers. There was just no compelling reason to migrate all the way to NetWare 4.x. That incentive came with the introduction of NetWare 5 and Pure IP.

NetWare 6, released in 2001, builds on the capabilities of NetWare 5 and adds iFolder, iPrinter, Storage Area Network (SAN), Remote Management, built-in clustering and a host of other services. However, the basic TCP/IP protocol support is the same as in NetWare 5. Therefore, in this chapter the discussion on TCP/IP services for NetWare 5 also apply to NetWare 6.

NetWare 5/NetWare 6 and the Pure IP Initiative

NetWare 5 represented a major change in Novell's relationship with IP. IPX, Novell's old native communications protocol, is elegant, bulletproof, and easy to use. But IP has taken the world by storm. Novell read the writing on the wall and redesigned NetWare from the ground up making IP (not IPX) its core communications protocol.

NetWare 5 was shipped in September 1998 as a "Pure IP" solution, and NetWare 6, shipped in 2001, also uses pure IP. The term "Pure" indicates that IPX encapsulation is no longer required. Novell's application service protocol NCP (NetWare Core Protocol) is carried directly over TCP/IP.

NetWare 5 uses IP services for discovery, addressing, and data transfer. Compared to the Windows NT NetBIOS routing or the IPX encapsulation used by earlier versions of NetWare, NetWare's Pure IP offers direct, unimpeded access to other IP-based networks, including Unix platforms and the Internet. The result is better performance, lower costs, and simpler management for companies that rely on IP for communications.

Novell has done a good job of extending familiar management tools such as NDS so that they work better in this new TCP/IP-centered world. NetWare also embraces other standards-based technologies such as SLP, DHCP, and DNS and has extended them to support IP and IPX networks and hybrids. Nor has Novell abandoned the huge installed base of IPX-based NetWare 3.x and 4.x servers. Although IP is now the default communications protocol, NetWare 5 remains fully compatible with older versions of NetWare built around IPX.

Legacy Solutions: IP for NetWare 3.x through 4.x

IPX/SPX (often shortened to IPX) is Novell's historical counterpart to TCP/IP. It serves as the core communications protocol for all NetWare 3.x and 4.x servers. IPX is reliable and stable, but has become much less popular than TCP/IP. Novell began bundling support for IPX to TCP/IP connectivity into NetWare in 1987. Since that time, Novell has introduced quite a few IPX to TCP/IP bridge products, each with its own capabilities. Table 27.1 summarizes the strengths and appropriate uses for each of the major IPX to TCP/IP bridges.

TABLE 27.1 Major IPX to TCP/IP Bridge Products

Tool	*Definition*	*When Indicated*	*When Inappropriate*
IP Tunneling	Server wraps TCP/IP header around each outgoing IPX packet and de-encapsulates incoming packets.	Good for establishing communications between two IPX-based Novell Networks linked by a TCP/IP backbone or via an Internet connection. Well-suited for connecting a small number of servers.	Does not provide workstation to workstation TCP/IP connectivity. Not appropriate for connecting large numbers of servers.
IP Relay	Encapsulates IPX communications within TCP/IP packets, which can be transmitted across an IP backbone.	Optimized to support permanently enabled connections such as leased lines; IP relays are commonly used to create virtual private networks.	IP relays offer the same advantages and disadvantages as IP tunneling, but are better suited for use with larger networks.
LAN Workplace	Provides concurrent access to TCP/IP and NetWare IPX resources by giving client TCP/IP applications the ability to read and write to TCP/IP as well as IPX stacks.	Client installation provides access to TCP/IP resources by non-networked PCs. Server installation supports centralized installation, configuration, and maintenance of IP resources.	Network managers must be comfortable with both IPX and TCP/IP to use this product.
IPX-IP Gateway	The gateway converts IPX communications into TCP/IP communications and routes them to their proper destination.	Because the only IP address that needs to be assigned is that of the gateway itself, standard IPX users connecting through the gateway are free to use standard Web browsers or other WinSock compliant TCP programs as if TCP/IP were configured on their desktops.	Requires the installation of both server and client software. Workstations are forced to communicate with IP hosts through the gateway, which adds overhead to all communications sessions.

TABLE 27.1 Continued

Tool	*Definition*	*When Indicated*	*When Inappropriate*
NetWare/ IP	Encapsulates all IPX communications within IP.	Because the IPX stack is still available on each workstation, old IPX-based applications can still communicate directly with that stack.	Requires the installation of several independent cooperating client and server components.

IP Tunneling

To establish communication between two IPX-based Novell Networks linked by TCP/IP backbones or via an Internet connection, *IP tunneling* is the way to go. Every version of NetWare, starting with 3.11, supports IP tunneling. With this solution, IPX-based workstations address their normal IPX packets to either a local or remote tunnel server. The server running the IPX-Tunnel software listens for IPX packets. When it finds one, it wraps a TCP/IP header around that packet and routes it off across the TCP/IP network to the specified address. Typically, a NetWare Loadable Module, `IPTUNNEL.NLM`, is used to implement Novell Tunneling. The `IPTUNNEL` driver on the server encapsulates IPX/NCP packets inside an IP frame, then adds a User Datagram Protocol (UDP) header, an IP header, and an IP checksum field for a cyclic redundancy check (CRC).

Each tunnel server uses a standard IP address so that packets can be routed back and forth between those servers, via the Internet or through a TCP/IP-based backbone. When the packet arrives at the other end, the receiving IPX tunnel partner strips off the TCP/IP header and forwards the clean IPX packet to its final destination.

The primary advantage of IP tunneling is that it provides IP/IPX interconnectivity with minimal impact on network administrators and users. For example, you need not install any special client software at the workstation level to implement tunneling. In fact, workstations never need to know their IPX data packets were ever encapsulated. As a result, all existing IPX applications should operate just as they did in a pure IPX world.

The primary disadvantage of IP tunneling is that it does not provide workstation-to-workstation TCP/IP connectivity. Still, it is a reliable, low-cost solution that works well, especially when used for connecting a small number of servers. The encapsulation process used to create a tunnel does add overhead and additional management and troubleshooting duties to the job of maintaining the network. Thus, tunneling is not appropriate for connecting large numbers of servers.

IP Relay

Novell's IP Relay solution builds upon the core features provided by IP tunneling. Like tunneling, it utilizes server-level encapsulation of IPX communications within TCP/IP packets, which are then transmitted across an IP backbone. The difference is that IP relays are optimized to support connections between permanently enabled paths of communications such as the leased lines commonly used to connect branch and main offices or suppliers to a manufacturer. IP relays are commonly used to create virtual private networks that work without any need to install and maintain expensive client-side software. In all other respects, IP relays offer the same advantages and disadvantages as IP tunneling. Novell's IP Relay product is included as part of the NetWare MultiProtocol Router (MPR) version 2.0 and higher and is integrated with the WAN version of NetWareLink Services Protocol.

IP Relay uses encapsulation, but its point-to-point WAN design makes it much easier to deploy and administer than IP tunneling. An IP Relay network is best implemented in a star or hub design with IP Relay loaded on the hub server and on the destination (remote) servers. The hub server is provided with a table of all the IP address for each destination server. The destination servers do not need to be provided with the IP address for the hub server. Remote servers can be run in listen mode waiting for the moment when the hub opens the communication line.

Designed for point-to-point LAN architectures, IP Relay generates substantially less traffic than a tunneling solution and simplifies the installation and administration process. As a result, IP Relay scales up better than tunneling does.

LAN WorkPlace

Novell's LAN WorkPlace products provide Windows, NT/2000, and DOS users with concurrent access to both TCP/IP and NetWare IPX resources. LAN WorkPlace products do not encapsulate IPX datagrams within a TCP/IP header. Instead, it uses client-side software capable of reading and writing both TCP/IP and IPX stacks. Thus, LAN WorkPlace can be used to allow DOS, Windows, and NT workstations to use TCP/IP to access both Unix hosts and to examine NetWare drives.

LAN WorkPlace can be installed either at the workstation or the server level. Installed on a PC, LAN WorkPlace provides even non-networked PCs with access to TCP/IP resources. When installed on a server, LAN WorkPlace enables all network users to access TCP/IP resources. The server installation also enables NetWare network supervisors to perform centralized installation, configuration (including workstation IP address assignment), and maintenance.

The downside of LAN WorkPlace is that it does not actually transform IPX networks into TCP/IP networks. Instead, it adds TCP/IP connectivity separately and independently from any support provided for IPX connectivity. This means that managing a LAN WorkPlace network requires all the skills it would take to manage separate IPX and TCP/IP networks.

IPX-IP Gateway

Novell began bundling its IPX-IP Gateway product into NetWare 4.0 in 1996. This solution requires the installation of components on the server (the gateway) and on the client (redirector). However, only the gateways require IP addresses. The gateway then handles all TCP/IP and IPX addressing and routing to and from clients.

The beauty of the IPX-IP Gateway is that it saves network administrators from having to deal with the headache of IP addressing (because only the gateways need IP addresses). Routing by the gateway is thorough enough that any connected IPX workstation is free to use a standard Web browser or other WinSock-compliant TCP programs just as if TCP/IP were configured natively at the desktop.

Routing all IP communications though a gateway does add a layer of overhead to all communications sessions. It also creates a situation in which the gateway can serve as a simple firewall. By tying into Novell's NDS directory utility, the IPX-IP Gateway provides the network administrator with a single console from which all user-, group-, and organizational-access rights can be defined and monitored.

NetWare/IP

First introduced as an add-on for NetWare 3.1x and NetWare 4.x in 1993, NetWare/IP was designed specifically to integrate NetWare services into a TCP/IP environment. It is also shipped as a component of Novell's MultiProtocol Router.

NetWare/IP more thoroughly integrates NetWare 3.x or 4.x services into a TCP/IP environment than any of the previously described approaches. It does so by using both encapsulation and transmission of standard IP packets. It is also a solution that requires more effort than the previously described solutions. For example, NetWare/IP requires the installation of several independent cooperating client and server components.

The NetWare/IP client software consists of a TCP/IP stack (`TCPIP.EXE`), a module called `NWIP.EXE`, and either the NetWare shell (`NETX.EXE`) or the NetWare DOS Requester (VLMs). The NetWare/IP client architecture remains the same as traditional NetWare client architecture at the Hardware, ODI, and Application Layers. The Transport Layer, however, is altered, using the UDP-TCP/IP protocol stack (`TCPIP.EXE`) (also used in Novell's LAN WorkPlace products), in place of the traditional IPX addressing scheme.

This solution also bundles and builds upon Novell versions of standard IP management utilities. For example, Domain Name System (DNS), a distributed look-up service, is used to centralize hostname-to-IP address information. Domain SAP Server (DSS) maintains a database used to store and disseminate IPX SAP information to NetWare/IP clients and servers.

NetWare 3.x and 4.x services, such as file, print, and directory services, advertise themselves via Novell's *Service Advertising Protocol* (SAP). Every 60 seconds, these services broadcast a packet that lists name, service type, and address information. When a NetWare/IP server boots, it advertises itself to the rest of the network by sending the SAP record directly to its nearest DSS using UDP.

With NetWare/IP, all IPX communications are encapsulated within IP. Because the IPX stack is still available on each workstation, old IPX-based applications can still communicate directly with that stack. Because it operates under an IP encapsulation, those same IPX applications can also be accessed by users logging in using TCP/IP. There are, of course, limitations to what the TCP/IP emulation can do. For example, applications that depend on IPX broadcast mechanisms will not work properly when they are sent through an IP router.

NetWare 5/NetWare 6—IP and All the Comforts of Novell

NetWare 5 and NetWare 6's native support for pure TCP/IP is a neat trick. Novell has completely redesigned the operating system and the management tools shipped as part of that operating system so that it can be configured as a pure IP network, as a pure IPX network, or as a hybrid that supports both protocols simultaneously. All the old IPX dependencies have been removed from the operating system's core. Close hooks between NetWare's Core Protocols (NCP) and TCP/IP have been added wherever they are appropriate. As a result, all the NetWare services available in previous versions are now available over TCP/IP.

Pure IP

The NetWare 5 and NetWare 6 operating system and associated management tools such as NDS now feature full native support for TCP/IP. The operating system, clients logged in to the operating system, and applications running on that operating system can communicate with each other using TCP/IP as the only communication protocol stack. There is no longer a need to resort to IPX encapsulation, routing, tunneling, or gateways. These tricks got the job done for earlier versions of NetWare and are still used by most other (non-Unix) operating systems, but they also consumed network bandwidth and impacted hardware resources. Using only IP traffic on the wire reduces software and hardware routing requirements, expands network bandwidth, frees you from the need to support multiple protocols, and provides greater opportunities for remotely connecting to the Internet and your own corporate intranets.

Multiple Protocols

Although IP is now the default communications protocol, Novell has not cut its ties to the millions of users of NetWare 3.x, 4.x, and older IPX-based tools. Hooks to IPX remain in NetWare 5 and NetWare 6 so they can be turned back on by those who need them. With NetWare 5 and NetWare 6, you can move to an IP-only environment without having to convert every IPX-based application or needlessly disrupt enterprise operations. Or, you can choose to install IPX as the default and completely avoid issues that must be dealt with when migrating to IP. You can also operate in a hybrid environment and slowly move away from IPX and into IP as needs require or as new skills are developed.

Installation Options

When you install NetWare 5 or NetWare 6, you choose one of three modes:

- IP
- IP/IPX
- IPX

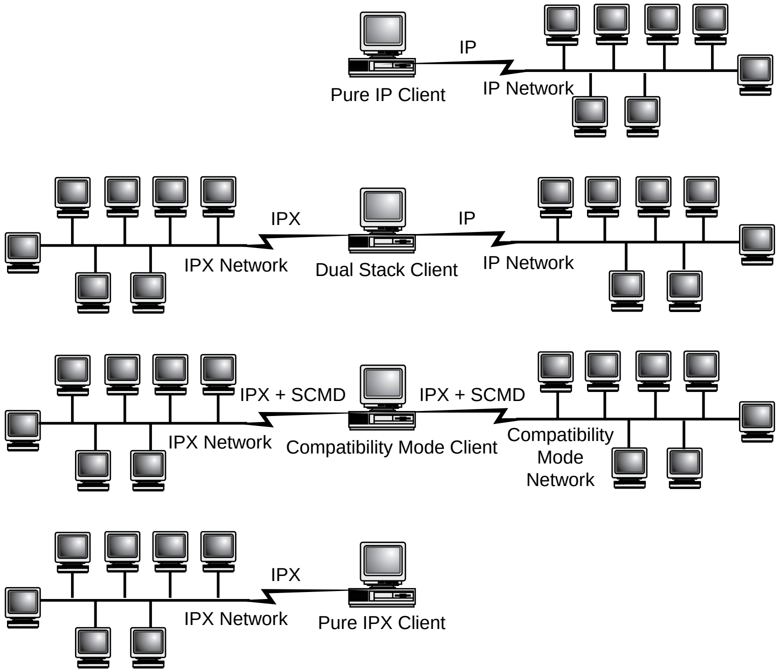
The choice you make determines how NetWare binds itself to protocol stacks and to network adapters but does not determine which protocol stacks are loaded in the system. For example, systems that are installed using the IP-only install option have both the TCP/IP and the IPX stacks loaded but only the TCP/IP stack is bound to the network adapter. In this case, IP is the native protocol. The IPX stack is loaded here to give the system the ability to execute IPX applications and to connect with IPX systems through use of the Novell Migration Agent.

Systems installed with the IP and IPX option are configured to establish NCP connections over either the TCP/IP stack or over the IPX stack.

By providing for simultaneous access to both IPX and TCP/IP, NetWare 5 and NetWare 6 maintain support for existing IPX-bound applications and all IP and IPX routing investments as necessary. NetWare 5 and NetWare 6 also bundle Compatibility Mode routines (described in detail later), which can be used to manage IPX-based applications on a network installed using the Pure IP installation. Another bundled facility, the NetWare Migration Agent, provides a mechanism for supporting communication between two networks, one installed as a pure IP network and one based upon the IPX protocol.

Figure 27.1 illustrates the IP/IPX installation options.

FIGURE 27.1
NetWare 5 IP/IPX installation options.



IP-Only Installation of NetWare 5 and NetWare 6

Customers awash in IP-based communications may find that NetWare 5 and NetWare 6's IP-only installation simplifies their lives immensely, eliminating multiple protocols and freeing up valuable network bandwidth. The IP-only configuration allows the server to communicate directly with any client or server that uses TCP/IP stacks. The IPX stack is loaded but not bound to the network card. You can use Novell's bundled Compatibility Mode utility to execute IPX-based applications, but first you'll need to install the Migration Agent (a Novell gateway) to connect to IPX-bound servers or clients. Benefits include the fact that managing a single protocol requires less hardware and software, lessens management overhead, makes more efficient use of bandwidth, increases performance, and lowers cost. Pure IP also tends to be more efficient when networks get very large.

What You Need to Know Before Installing

When you enable TCP/IP as part of the NetWare 5 and NetWare 6 installation, you are asked to enter a standard IP address for the server. Both TCP/IP and the IPX stacks are loaded but only the TCP/IP stack is bound to the network adapter. The IPX stack is used to allow applications written with IPX in mind to run and to provide Novell's Migration Agent to facilitate connections to users logging in from an IPX-only network.

IPX-Only Installation

For small networks, and even some medium-sized ones, IPX remains an attractive solution. The administrative costs of setting up and maintaining a small IPX network are much lower than doing the same for a similarly scaled TCP/IP network. NetWare uses dynamic updates to eliminate much of the burden of administering IPX. For example, adding new devices and interconnecting network segments is easy. Add the name of the new device to the local `AUTOEXEC.NCF` file and the server takes over the job from there. IPX broadcasts updates every 60 seconds providing each server and router on the network with the information it needs to update its internal tables, letting them know how to reach that new device.

All this automation does add a certain amount of overhead. As the number of connections increases, so, too, does the overhead of all those updates. Thus, TCP/IP is undoubtedly a more appropriate solution for very large networks. But users of more moderate needs should consider staying in the IPX camp.

Obviously, a NetWare 5 or NetWare 6 server installed in IPX-Only mode can communicate with other IPX servers and clients efficiently and without translation. It can also, albeit less efficiently, communicate with servers and clients running pure TCP/IP by using the intermediation of the bundled Novell Migration Agent (described in detail later).

What You Need to Know Before Installing

If you choose to make an IPX-only install, you are asked to select an internal IPX address for the server, just as was required in a NetWare 3.x or 4.x installation.

Hybrid IPX/IP Installations

Novell has a long history of providing solutions that allow transmission of both TCP and IPX communications across a single network. Anyone faced with the daunting task of managing such a hybrid network will find a lot to like in NetWare 5 and NetWare 6.

Servers and clients installed using the NetWare 5 and NetWare 6 hybrid IP/IPX installation can communicate using either protocol. This approach allows the NetWare 5 or NetWare 6 server to freely exchange messages with any well-behaved IP or IPX server or client. Such a server can also execute applications written with IPX in mind.

Hybrid installations are complicated by the fact that users are given a great deal of freedom to choose which IP and IPX addressing schemes they want their new network to support. As might be expected, the more options installed, the greater the overhead. Thus, most network administrators install only those features their networks are most likely to use on a regular basis.

Some breakdowns are inevitable if you try to establish communications between two hybrid NetWare 5 or NetWare 6 servers configured by different people at different times. For example, complications may arise when routing messages sent out by a Pure IP NetWare client configured to use a pure IP addressing scheme are sent to another server connected to NetWare clients that were configured to recognize only IPX addressing schemes. These kinds of mismatches can be easily rectified by the Migration Agent utility, which Novell bundles into NetWare 5 and NetWare 6. The Migration Agent automatically translates cross-protocol communications as needed. Use of the Migration Agent does impose overhead. The key to an efficient installation is to configure the network so that it includes all facilities needed on a regular basis and to pass all infrequently encountered IP/IPX translations off to utilities such as the Migration Agent.

What You Need to Know Before Installing

If you choose to install both the IP and IPX option, the system is configured to establish NetWare Core Protocol connections over either the TCP/IP stack or over an IPX stack. You will need to provide both an internal IPX address and a standard IP address for the server.

Tools That Aid in IP Migration

Novell realizes that the jump from IPX to TCP/IP will be a big one for much of its user base. It is trying to make the transformation as easy as possible by bundling a host of transformation tools along with NetWare 5 and NetWare 6. Some of these are updates of old familiar tools. For example, NDS has been reworked so that it can track and support TCP/IP resources as well as IPX resources. Novell has extended NDS's reach by creating links between NDS and other standard IP utilities bundled with NetWare. These utilities include Novell's versions of DNS, DDNS, and DHCP. SLP is another standard IP utility that has been revised to work in a NetWare IP/IPX environment. Novell's Compatibility Mode and Migration Agent provide collections of routines that can perform on-the-fly translations between IPX and TCP/IP.

NDS

Novell's NetWare Directory Services is a global and extensible directory service that provides a central console from which network administrators can view and manage all sorts of network resources distributed across a single network or across a mixed array of NT/2000, NetWare, and Unix networks organized as a WAN. First introduced as part of NetWare 4, the NDS database contains complete information about every user, object, and other resource within its reach. NetWare 5 has extended NDS's reach so that it is now capable of managing a mixture of IP and IPX devices and sessions.

DNS

The Domain Name System is commonly used to match user-defined system names with their unique IP network or Internet addresses. The NetWare DNS server can be coupled with a non-NetWare DNS server as either a primary or a slave. Facilities are provided to allow bi-directional transfer of data between primary and secondary servers. Allowing this sort of transfer of information can significantly reduce the cost of incorporating a NetWare 5 network into a larger enterprise-wide network.

DHCP

Dynamic Host Configuration Protocol is a protocol that automatically assigns and tracks IP addresses and other configuration data in network devices. DHCP options can be set at the enterprise, subnet, or client level. For example, you can allocate a specific amount of time that DHCP clients will be allowed to use a particular IP address. Frequent reallocation of IP resources can be used to purge inactive resources, and thus allow a large number of clients to share a limited number of IP addresses.

DDNS

NetWare 5 and NetWare 6's Dynamic DNS (DDNS)) helps coordinate the functions of the Novell DNS and DHCP facilities. For example, DDNS updates DNS information on-the-fly, matching address changes made via DHCP. The DHCP services in NetWare also provide NDS configuration information to clients, such as their initial context, NDS server name, and tree name.

SLP

On mixed IP/IPX servers, NetWare 5 and NetWare 6 use a standard Internet protocol called *Service Location Protocol* (SLP) to provide naming and discovery services. SLP does not provide name resolution services like DNS or NDS. Its purpose is to discover infrastructure services such as NDS servers, DNS servers, DHCP servers, NDPS registration servers, and various protocol gateways.

SLP provides backward compatibility with the services and applications of SAP (Novell's old IPX-specific discovery agent). Pure IP networks that don't require backward compatibility don't need to run SLP. IPX-only installations can continue to use SAP and may have no need for SLP.

Compatibility Mode

Compatibility Mode provides on-demand IPX support to Pure IP NetWare 5 and NetWare 6 networks. It does so by encapsulating IPX datagrams inside a UDP stack so they can be carried across networks wired for TCP/IP, and by resolving RIP and SAP requests through the use of the Service Location Protocol.

Both client and server compatibility drivers are installed automatically as part of any Pure IP NetWare 5 or NetWare 6 install. When not in use, Compatibility Mode drivers (the `SCMD.NLM` module) lie dormant, with no appreciable effect on network communications. Encapsulation is performed only when IPX-specific support is required. All traffic that does not require IPX-specific support is automatically routed through IP without encapsulation.

The beauty of Compatibility Mode is that it makes phased migrations feasible. You can make the move to pure IP at your own pace, secure in the knowledge that Compatibility Mode will bridge occasional protocol mismatches whenever they occur.

Compatibility Mode drivers are brought into play as soon as any linked client or server is asked to pass an IPX protocol stack across wiring set up to handle TCP/IP-only communications. This happens, for example, when a message formatted for IPX arrives at the firewall door and asks to be routed to a user inside the IP network. Compatibility Mode can also be used to provide backbone support. For example, it can allow two disconnected IPX networks to pass information back and forth through an IP-only network. Compatibility Mode also provides facilities to ensure backward compatibility with NetWare 3.x bindery services.

Migration Agent

The Migration Agent performs two essential services. First, it translates between IP and IPX. Second, it provides a bridge between the old and new naming and discovery services (NetWare's SLP and NetWare 4's SAP).

The Migration Agent is only needed when you want to link the two logical worlds of IP and IPX. It provides emulation that prevents IPX protocol families from populating the IP world, and it replaces SAP and RIP packets on behalf of IPX clients. The Migration Agent uses IP and IPX addresses and the routing information contained in IPX packets to send each packet to the appropriate destination.

NetWare 5 and NetWare 6 servers installed with the Migration Agent enabled can communicate directly with other systems without regard to the install option used during installation. They are also capable of routing network traffic between IP and IPX systems.

Migration Strategies

Gradual migration is probably the best choice for most users and is possible because Novell vows to continue support for existing IPX installations. However, the arrival of NetWare 5 and then NetWare 6 built around a Pure IP infrastructure provides just one more acknowledgement that IPX's days are numbered and that TCP/IP will quickly become dominant even in the world of NetWare networks. The question that NetWare users now face is how fast to move into the TCP/IP camp. Fortunately, Novell is providing users with lots of options. You can make the transition slowly or in one fell swoop. What's important is that you think before you migrate.

Using a Test Platform

Do not conduct migration experiments on your mission-critical network. Most Novell networks have evolved slowly and tend to be a mixture of old and new software and hardware that no one person fully understands. Working out all your migration issues on a working network is not a good idea. The use of a test migration platform can save you from a lot of grief. Better to isolate and cure your IPX withdrawal symptoms on a lab guinea pig rather than with some user working on a mission-critical problem. It is worthwhile to start with a test platform installed using NetWare's Pure IP mode (no IPX stacks installed). Test to see which of your legacy applications can run as-is or with aid of a free or low-cost upgrade. Try running the applications that fail on the test platform installed in the hybrid IPX/IP mode.

Suggested Migration Scenarios

If everything runs just fine on your Pure IP test platform, you may decide to upgrade your whole network to Pure IP in one fell swoop. Chances are, the only networks that fit into this category will be small ones—networks that provide little more than simple file and print sharing capabilities.

Larger networks, on the other hand, are best migrated slowly and incrementally. The trick is to select small network segments that can operate autonomously. For example, one good approach is to start the migration by removing IPX from the network backbone and replacing it with IP. The advantage to this approach is that backbones are not likely to be running messy IPX-bound applications and the migration should be fairly straightforward.

A Pure IP backbone can be used to connect one or more IPX-based servers as long as a Novell Migration Agent is installed wherever IP segments touch IPX. The Migration Agent performs encapsulation and any other conversions required to send IPX messages across an IP pipe. With luck, a backbone migration will result in a drastic cut in the administrative costs associated with maintaining IPX over the backbone and set you up nicely for your next attempted segment migration.

Another approach is to start by migrating a few network segments that would most benefit from the move to IP, say, for example, your company's Internet server. The idea here is to provide management with a good, clean success story to validate the move toward IP. The downside of this approach is that because the backbone remains untouched, administrative costs may not be offset as quickly.

The most difficult part of the migration will come when you try to set up your IP network so that it can run legacy applications. Although NetWare 5 and NetWare 6 are designed so that all core protocols can be addressed using IP, many legacy applications write directly to the IPX stack or make use of older IPX utilities such as SAP and the Novell Bindery. Whenever possible, it makes sense to replace such older applications with newer versions written with IP in mind.

The sad fact is that many useful legacy applications are sure to be IPX-bound and that IP-friendly versions of many of those applications will not be available. Such programs can be accommodated by using NetWare's IPX Compatibility Mode. Be aware, however, that Compatibility Mode incurs a certain amount of overhead. For example, the compatibility drivers are dependent upon the proper installation of SLP. Setting up a SLP infrastructure will take time. On the other hand, SLP is an Internet standard of increasing importance and the likelihood is that its usefulness will increase as more and more applications take advantage of the services it provides.

Summary

This chapter began with a discussion of the various ways that IPX-based NetWare servers (NetWare 3.x and 4.x) can operate in a world that is rapidly moving to IP. The second part of the chapter focused on NetWare 5 and NetWare 6. It discussed how to migrate from an IPX-based NetWare 3.x or 4.x network to a Pure IP–based NetWare 5 and NetWare 6 networks. It also described the facilities Novell provides to allow IP and IPX to interoperate. We described some of the components and tools Novell bundles along with NetWare 5 and NetWare 6 to help users make the move toward IP. The chapter ended with a discussion of migration strategies that can be used to move from IPX to IP.

CHAPTER 28

Configuring TCP/IP for Linux

by Tim Parker

IN THIS CHAPTER

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Linux is a popular public domain Unix version for Intel-based systems. It has also been ported to other processors such as SPARC, Alpha, Motorola 6800, Power PC, ARM, Hitachi SuperH, IBM S/390, MIPS, HPPA-RISC, Intel IA-64, DEC-VAX, AMD x86-64, and other processor architectures.

A Linux system consists of a kernel component, called the Linux kernel, and system tools and applications. The Linux kernel is controlled by Linus Torvalds and a close group of kernel programmers. However, many distributions of Linux exist. Each of these distributions uses the standard Linux kernel but differs in the bundling of system utilities and application software. The Linux kernel aims at POSIX and Single Unix Specification (SUS) compliance.

The Linux kernel is popularly available as a key component of distributions such as RedHat, Debian, Mandrake, Susie, Slackware, and so on. These distributions bundle the Linux kernel along with system utilities and application software. Most of the system utilities come from the GNU project, which produces some of the highest quality software ever written and is based on an open source license. To learn more about the open source license consult `http://www.eff.org` and related sites.

Because Linux is a Unix-like operating system, it is capable of acting as both client and server on a TCP/IP system.

Without going into excessive detail about the Linux operating system, this chapter looks at how you can configure your Linux machine to act as both client and server for a TCP/IP-based network, as well as provide both PPP and SLIP support.

The version of Linux distribution used as an example in this chapter is the SlackWare CD-ROM distribution, although the procedure is the same for RedHat and many other Linux distributions. For the purposes of this chapter, it is assumed you have properly installed Linux and its networking components.

Note

Linux is an "infinitely" configurable system, and some of the distributions also differ in the manner in which Linux system services are bundled and started. Linux kernels have version numbers such as 2.0, 2.2, and 2.4. The "2" in the version number represents a major release from the previous version. The number after the "." represents a minor release with even numbers, such as 2.0, 2.2, 2.4, implying a stable release of the Linux kernel.

Odd numbers for the minor version are used for kernel versions with experimental features that have not been completely tested. Therefore, kernel versions 2.1 and 2.3 are "experimental" kernels. Deploying experimental kernels in a production environment is not generally considered a good idea.

You can get the latest Linux kernel from `http://www.kernel.org` and its mirror sites.

Distributions such as RedHat, Debian, Mandrake, and Slackware take a Linux kernel and add system utilities, and start up scripts and applications around it. They differ in the manner in which these services are added and configured. These distributions have their own version numbers. For example, RedHat 7.0 used a Linux 2.2 kernel whereas RedHat 7.2 uses the 2.4 kernel.

Preparing Your System for TCP/IP

Before configuring TCP/IP on your Linux system, you need to perform a few small steps to ensure that your filesystem is ready. The first step is to make sure the networking software has been installed. You can install the network package through the setup program, as shown in Figure 28.1. Selecting the networking option installs the applications you need to use TCP/IP under Linux.

Note

Other distributions, notably RedHat, now have a GUI installation that makes installing the Linux system easier for the novice.

After the network software has been installed, you might have to reboot your system.

FIGURE 28.1
The Linux setup program lets you install the networking software easily.

Some versions of Linux (notably those that use the 2.0 kernel and many of the latest releases) require a `/proc` filesystem for networking to function properly. Most Linux kernels that inherently support networking automatically create the `/proc` filesystem when the operating system is installed, so you shouldn't have to do anything more than make sure it is properly mounted by the kernel. (The `/proc` filesystem is a quick interface point for the kernel to obtain network information, as well as to help the kernel maintain tables usually kept in the subdirectory `/proc/net`.) You can verify that your Linux version uses the `/proc` filesystem by trying to do a "cd /proc" command to change to the `/proc` directory, as shown in Figure 28.2.

FIGURE 28.2
If you can change into the `/proc` *filesystem and obtain a directory listing, the filesystem exists and TCP/IP can be configured properly.*

```
merlin:~# cd /proc
merlin:/proc# ls
1/          46/         73/         80/          kcore      pci
174/        49/         74/         cpuinfo      kmsg       self/
24/         51/         75/         devices      ksyms      stat
38/         55/         76/         dma          loadavg    uptime
40/         6/          77/         filesystems  meminfo    version
42/         7/          78/         interrupts   modules
44/         72/         79/         ioports      net/
merlin:/proc#
```

If you can't change into `/proc`, it probably doesn't exist (assuming you have access permissions, of course). If the `/proc` filesystem was not created for you by the Linux installation routine, you have to rebuild the kernel and select the `/proc` option. Change to the Linux source directory (such as `/usr/src/Linux`) and run the kernel configuration routine with this command:

```
make config
```

If you have X-Windows running and properly configured, you can run the following GUI-based configuration process:

```
make xconfig
```

When you are asked whether you want `procfs` support (or a similarly worded question), answer `yes`. If you do not get asked about the `/proc` filesystem support, and the `/proc` directory is not created on your filesystem, you need to upgrade your kernel to support networking.

The `/proc` filesystem should be mounted automatically when your Linux system boots. To force the `/proc` filesystem to be mounted automatically, edit the `/etc/fstab` file and add a line similar to this (if it isn't already there):

```
none          /proc          proc          defaults
```

Another step you should take before configuring TCP/IP is to set the system's hostname. To set the hostname, use this command:

```
hostname name
```

`name` is the system name you want for your local machine. If you have a full domain name assigned to your network and your machine, you can use that name for your system. For example, if your Linux machine is attached to the domain `yacht.com` and your machine's name is `spinnaker`, you can set the full domain name using this command:

```
hostname spinnaker.yacht.com
```

If you don't have a fully qualified domain name, you can make up your own domain name as long as you are not connected to the Internet. (A made-up domain name does not have any meaning outside your local area network.) Alternatively, you do not have to assign a domain at all for your machine, but can simply enter this short name:

```
hostname spinnaker
```

An entry is made in the `/etc/hosts` file to reflect your machine's name. You should verify that your machine's name appears in that file. You also need to know the IP address assigned to your machine. You should have a unique IP address ready for your Linux machine for use in the configuration process.

One file that you might need to work with if you plan to direct information across many networks is `/etc/networks`. The `/etc/networks` file contains a list of all the network names your machine should know about, along with their IP addresses. Applications use this file to determine target networks based on the network name. The `/etc/networks` file consists of two columns for the symbolic name of the remote network and its IP address. Most `/etc/networks` files have at least one entry for the loopback driver that should be on every Linux system (the loopback driver is used as a default IP address by some Linux applications and is discussed in more detail later in this chapter). A sample `/etc/networks` file looks like this:

```
loopback        127.0.0.0
merlin-net      147.154.12.0
BNR             47.0.0.0
```

This sample file has two networks entered in it with their network IP addresses. Only the network portion of the IP address is specified, leaving the host component of the IP addresses set to zeros.

Network Interface Access

You need to make the network interface accessible to the operating system and its utilities. This is done with the `ifconfig` command. When run, `ifconfig` makes the Network Layer of the kernel work with the network interface by giving it an IP address, and then issuing the command to make the interface active. When the interface is active, the kernel can send and receive data through the interface.

You need to set up several interfaces for your machine, including the loopback driver and the Ethernet interface (I assume you are using Ethernet throughout this chapter, but you can use other interfaces). The `ifconfig` command is used for each interface in order. The syntax of the `ifconfig` command is

```
ifconfig interface_type IP_Address
```

where *`interface_type`* is the interface's device driver name (such as `lo` for loopback, `ppp` for PPP, and `eth` for Ethernet). *`IP_Address`* is the IP address used by that interface.

After the `ifconfig` command has been run and the interface is active, you use the `route` command to add or remove routes to the kernel's routing table. This is necessary to enable the local machine to find other machines. The syntax of the `route` command is

```
route add|del IP_Address
```

where either `add` or `del` is used to add or remove a route from the kernel's routing table, and `IP_Address` is the remote route being affected.

You can display the current contents of the kernel's routing table by entering the `route` command with no arguments. For example, if your system is set up only with a loopback driver, you will see this:

```
$ route
Kernel Routing Table
Destination    Gateway   Genmask   Flags  MSS  Window  Use Iface
loopback         *       255.0.0.0   U    1936  0       16  lo
```

Note

You can also display the routing table using the following command:

```
netstat -rn
```

The `-r` option displays the routing table and the `-n` option displays IP addresses instead of symbolic names.

The columns with which you should be concerned are the destination name, which shows the name of the configured target (in this case `loopback`), the mask to be used (`Genmask`), and the interface (`Iface`, in this case `/dev/lo`). You can force `route` to display the IP addresses instead of symbolic names by using the `-n` option:

```
$ route -n
Kernel Routing Table
Destination    Gateway   Genmask   Flags  MSS  Window  Use Iface
127.0.0.1         *      255.0.0.0   U    1936  0       16  lo
```

As mentioned earlier in this section, a typical Linux network configuration includes a loopback interface (which should exist on every machine) and a network interface such as Ethernet. You can set these interfaces up in order.

Setting Up the Loopback Interface

A loopback interface should exist on every machine. It is used by some applications that require an IP address in order to function properly, which may not exist if the Linux system is not configured for networking. The loopback driver is also used as a diagnostic utility by some TCP/IP applications. The loopback interface has the IP address 127.0.0.1, so the `/etc/hosts` file should have an entry for this interface.

Note

A loop back address is any address of the form 127.*x.x.x* where *x* is a number from 0 to 255. The address of 127.0.0.1 is commonly used as a loopback address for historical reasons. This was the format in which the loopback address was specified in the `/etc/hosts` file on Unix systems.

A loopback driver might have been created by the kernel during software installation, so check the `/etc/hosts` file for a line similar to this:

```
localhost          127.0.0.1
```

If such a line exists, the loopback driver is already in place and you can continue to the Ethernet interface. If you are not sure about the `/etc/hosts` file, you can use the `ifconfig` utility to display all the information it knows about the loopback driver. Use this command:

```
ifconfig lo
```

You should see several lines of information. If you get an error message, the loopback driver does not exist.

If the loopback interface is not in the `/etc/hosts` file, you need to create it with the `ifconfig` command. The following command creates the necessary line in `/etc/hosts`:

```
ifconfig lo 127.0.0.1
```

You can view the specifics of the newly created loopback driver with `ifconfig`. For example, the following command shows the loopback driver's typical configuration:

```
$ ifconfig lo
lo              Link encap: Local Loopback
inet addr 127.0.0.1 Bcast {NONE SET] Mask 255.0.0.0
UP BROADCAST LOOPBACK RUNNING  MTU 2000 Metric 1
RX packets:0 errors:0 dropped:0 overruns:0
TX packets:0 errors:0 dropped:0 overruns:0
```

As long as the loopback driver's details are shown as output from the `ifconfig` command, all is well with that interface. After checking the `ifconfig` routine, you should add the loopback driver to the kernel routing tables with one of these two commands:

```
route add 127.0.0.1
route add localhost
```

It doesn't matter which command you use. As a quick check that all is correct with the loopback driver, you can use the `ping` command to check the routing. If you issue this command:

```
ping localhost
```

you should see output like this:

```
PING localhost: 56 data bytes
64 bytes from 127.0.0.1: icmp_seq=0.  ttl=255 time=1 ms
64 bytes from 127.0.0.1: icmp_seq=1.  ttl=255 time=1 ms
64 bytes from 127.0.0.1: icmp_seq=2.  ttl=255 time=1 ms
64 bytes from 127.0.0.1: icmp_seq=3.  ttl=255 time=1 ms
64 bytes from 127.0.0.1: icmp_seq=4.  ttl=255 time=1 ms
64 bytes from 127.0.0.1: icmp_seq=5.  ttl=255 time=1 ms
64 bytes from 127.0.0.1: icmp_seq=6.  ttl=255 time=1 ms
64 bytes from 127.0.0.1: icmp_seq=7.  ttl=255 time=1 ms
^C
 localhost PING Statistics
7 packets transmitted, 7 packets received, 0% packet loss
round-trip (ms) min/avg/max = 1/1/1
```

The `ping` command's progress was interrupted by issuing a Ctrl+C. If you get no output from the `ping` command, the `localhost` name wasn't recognized. Check the configuration files and route entry again and repeat the ping to the loopback address.

Setting Up the Ethernet Interface

You can follow the same procedure to set up the Ethernet driver. You use `ifconfig` to tell the kernel about the interface, and then add the routes to the remote machines on the network. If the network is attached to your machine, you can test the connections immediately with the `ping` command.

Set up the Ethernet interface using `ifconfig`. To make the interface active, use the `ifconfig` command with the Ethernet device name (usually `eth0`) and your IP address. For example, use the following command to set up your system with the IP address 147.123.20.1:

```
ifconfig eth0 147.123.20.1
```

You don't have to specify the network mask with the `ifconfig` command because it can deduce the proper value from the IP address. If you want to provide the network mask value explicitly, append it to the command line with the keyword `netmask`:

```
ifconfig eth0 147.123.20.1 netmask 255.255.255.0
```

You can check the interface with the `ifconfig` command using this Ethernet interface name:

```
$ ifconfig eth0
eth0                 Link encap 10Mps: Ethernet Hwaddr
inet addr 147.123.20.1 Bcast 147.123.1.255 Mask 255.255.255.0
UP BROADCAST RUNNING  MTU 1500 Metric 1
RX packets:0 errors:0 dropped:0 overruns:0
TX packets:0 errors:0 dropped:0 overruns:0
```


You might notice in the output that the broadcast address is set based on the local machine's IP address. This is used by TCP/IP to access all machines on the local area network at once. The *Maximum Transfer Unit* (MTU) size is usually set to the maximum value of 1500 (for Ethernet networks).

Next, you need to add an entry to the kernel routing tables to let the kernel know the local machine's network address. The IP address that is used with the `route` command to do this is that of the network as a whole, without the local identifier. To set the entire local area network at once, the `-net` option of the `route` command is used. In the case of the IP addresses shown earlier, the command is

```
route add -net 147.123.20.0
```

This command adds all the machines on the local area network identified by the network address 147.123.20 to the kernel's list of accessible machines. If you didn't do it this way, you would have to manually enter the IP address of each machine on the network.

An alternative is to use the /etc/networks file to specify only the network portions of the IP addresses. The /etc/networks file might contain a list of network names and their IP addresses. If you have an entry in the /etc/networks file for a network called foobar_net, you could add the entire network to the routing table with this command:

```
route add foobar_net
```

Using the /etc/networks file approach has the security problem that any machine on that network is granted access. This may not be what you want.

After the route has been added to the kernel routing tables, you can try the Ethernet interface. To ping another machine (assuming you are connected to the Ethernet cable, of course), you need either its IP address or its name (which is resolved either by the /etc/hosts file or a service like DNS). The command and output looks like this:

```
tpci_sco1-45> ping 142.12.130.12
PING 142.12.130.12: 64 data bytes
64 bytes from 142.12.130.12: icmp_seq=0.  time=20.  ms
64 bytes from 142.12.130.12: icmp_seq=1.  time=10.  ms
64 bytes from 142.12.130.12: icmp_seq=2.  time=10.  ms
64 bytes from 142.12.130.12: icmp_seq=3.  time=20.  ms
64 bytes from 142.12.130.12: icmp_seq=4.  time=10.  ms
64 bytes from 142.12.130.12: icmp_seq=5.  time=10.  ms
64 bytes from 142.12.130.12: icmp_seq=6.  time=10.  ms
^C
 142.12.130.12 PING Statistics
7 packets transmitted, 7 packets received, 0% packet loss
round-trip (ms) min/avg/max = 10/12/20
```

If you don't get anything back from the remote machine, verify that the remote is connected and you are using the proper IP address. If all is well there, check the configuration and route commands. If that checks out, try pinging another machine.

After these steps are completed, your Linux system should be able to access any machine on the local area network through TCP/IP. If you are on a small network, that's all you really have to do. On larger networks, or those that implement special protocols or employ gateways, you need to take a few more configuration steps. These steps are covered in the following sections.

If you want to allow a few other machines on the TCP/IP network to access your Linux machine, you can put their names and IP addresses in the /etc/hosts file. Figure 28.3 shows a sample /etc/hosts file with a name and possible variations (such as godzilla and godzilla.tpci), and its IP address. That machine (which can be any operating system running TCP/IP) can now connect to your Linux system using telnet, ftp, or a similar utility. Of course, a user on the remote machine can't log in unless you set up an account for him. If the name of a remote machine is in the /etc/hosts file, you can also telnet or ftp to that machine using either its name or IP address.

FIGURE 28.3
This `/etc/hosts` file lets remote machines connect to the Linux server.

```
merlin:/etc# cat hosts
#
# hosts         This file describes a number of hostname-to-address
#               mappings for the TCP/IP subsystem. It is mostly
#               used at boot time, when no name servers are running.
#               On small systems, this file can be used instead of a
#               "named" name server. Just add the names, addresses,
#               and any aliases to this file...
# By the way, Arnt Gulbrandsen <agulbra@nvg.unit.no> says that 127.0.0.1
# should NEVER be named with the name of the machine. It causes problems
# for some (stupid) programs, irc and reputedly talk. :^)
#

# For loopbacking.
127.0.0.1       localhost
147.120.0.1             merlin.tpci.com merlin
147.120.0.2     pepper pepper.tcpi.com
147.120.0.3     megan megan.tcpi.com
147.120.0.4     godzilla godzilla.tcpi.com
# End of hosts.
merlin:/etc#
```

Name Service and Name Resolver

TCP/IP uses the `/etc/hosts` file to resolve symbolic names into IP addresses. For example, when you give the name `darkstar` for a target machine, TCP/IP examines the `/etc/hosts` file for a machine of that name, and then reads its IP address. If the name isn't in the file, you can't send data to it.

Suppose you connect to several different machines. Adding all those entries to the `/etc/hosts` file can be tiresome and difficult, and maintaining the files as changes occur in the networks can be even more bothersome. On those rare instances where you need to connect to only about a dozen machines, maintaining the `/etc/hosts` file is all that you need. To solve the general name resolution problem, BIND was developed. BIND (Berkeley Internet Name Domain service) was developed to help resolve the IP addresses of remote machines. BIND was later developed into DNS (Domain Name System). Most Linux distributions implement the BIND version, although a few DNS-specific versions of software are appearing. Both BIND and DNS are complex subjects and involve many details that simply are not of interest to most Linux users. If you already have a DNS server on your network, or if you intend on using an ISP's DNS server, you do not need to configure your machine to run BIND. However, you should at least configure your machine to use a DNS server, because entering host names of all sites that are of interest to you in the `/etc/hosts` file is a tedious process. The name resolver is the DNS client, and in the case of Linux, is a set of library routines that are called whenever an application needs to resolve a name using DNS. The name resolver is configured using the `/etc/resolv.conf` file.

Typical contents of this file include a search directive and name server directives. The search directive takes the following form:

```
search domain1 domain2 domainN
```

The *domain1*, *domain2*, and *domainN* are replaced by a list of the domain name suffixes the name resolver will append to a hostname that is not in its Fully Qualified Domain Name (FQDN) form. As an example, consider the following search directive:

```
search xyz.com us.xyz.com europe.xyz.com
```

If a name such as www.abc.com is used, it is in the FQDN form and has a full domain name abc.com suffixed to the host name, `www`. In this case, the search directive is not used. However, if a TCP/IP service uses the name `www`, it is not in the FQDN form. In this case, the search directive will try to resolve this as first `www.xyz.com`, then `www.us.xyz.com`, and finally `www.europe.xyz.com`. If any of these names is properly resolved, there is no need to search for other names.

The DNS server the name resolver uses is specified by the `nameserver` directive:

```
nameserver IPaddress
```

The *`IPaddress`* is the IP address of the DNS server. For example, if the first DNS server has an IP address of 199.231.13.10, then this directive will appear as the following:

```
nameserver 199.231.13.10
```

Up to three DNS servers can be specified, each with its own `nameserver` directive on a line by itself. For example, if the second and third DNS servers are 199.231.13.20 and 199.231.13.15, the full set of name server directives would appear as

```
nameserver 199.231.13.10

nameserver 199.231.13.20

nameserver 199.231.13.15
```

Combining the full set of search and `nameserver` directives, the example `/etc/resolv.conf` will have the following contents:

```
search xyz.com us.xyz.com europe.xyz.com

nameserver 199.231.13.10

nameserver 199.231.13.20

nameserver 199.231.13.15
```

You can also configure whether the name resolution process will consult the `/etc/hosts` file first and then DNS, or first DNS and then the `/etc/hosts` file. This order can be controlled by configuring the `/etc/nsswitch.conf` file.

For larger systems, or if you want to run the full Internet services available to your Linux machine, you need to configure BIND properly. Luckily, BIND usually needs to be configured only once, and then it can be ignored. You need the BIND software, which is usually included in the distribution software. The BIND package includes all the files and executables, as well as a copy of the BIND Operator's Guide (BOG) that you can consult for information on how to configure BIND database files.

Gateways

When two or more local area networks are connected, they use a gateway. A *gateway* is a machine that acts as the connection between the two networks, routing data between the two based on the IP address of the destination machine. You have to make some changes to the network configuration files whenever your local machine is going to use a gateway, as well as if your machine is going to act as a gateway.

To use the services of another machine as a gateway, you have to tell the routing tables about the gateway and the networks that it connects to. The simplest use of a gateway is one used to connect to the rest of the world, such as the Internet. This is configured with the `route` command like this:

```
route add default gw net_gate
```

`net_gate` is the name of the machine on your local area network that acts as the gateway. The gateway machine follows the keyword `gw` in the `route` command. The use of the word `default` in the command indicates that the kernel's routing table should assume that all networks can be reached through that gateway.

If you want to configure a gateway to another local area network, the name of that network should be in the `/etc/networks` file. For example, if you have a gateway machine called `gate_serv` that leads from your own local area network to a neighboring network called `big_corp` (and an entry exists in the `/etc/networks` file for `big_corp` with its network IP address), you could configure the routing tables on your local machine to use `gate_serv` to access `big_corp` machines with this command:

```
route add big_corp gw gate_serv
```

An entry should be made on the remote network's routing table to reflect your network's address; otherwise, you would only be able to send data and not receive it.

If you want to set up your local machine to act as a gateway itself, you need to configure the two network connections your machine is joining. This usually requires two network boards, PPP connections, or SLIP connections in some combination. Assume your machine is going to act as a simple gateway between two networks called `small_net` and `big_net`, and you have two Ethernet cards installed in your machine. You configure both Ethernet interfaces separately with their respective network IP addresses (for example, your machine might have an IP address on `big_net` of 163.12.34.36, whereas on `small_net` it might have the IP address 147.123.12.1).

You should add the two network addresses to your `/etc/hosts` file to simplify network name resolution. For the networks and IP addresses mentioned, you will have the following two entries in the `/etc/hosts` file:

```
163.12.34.36              merlin.big_net.com merlin-iface1
147.123.12.1              merlin.small_net.com merlin-iface2
```

This example shows the fully qualified domain names in the `/etc/hosts file` (this example assumes the machine has the name `merlin` on both networks, which is perfectly legal). You can also add shorter forms of the name, as well (such as `merlin`, `merlin.big_net`, and so on). Finally, the interface names have been included for convenience (so `merlin-iface1` is the first interface on `merlin`, and `merlin-iface2` is the second).

You then use the `ifconfig` commands to set up the connections between the interface and the names used in the `/etc/hosts` file:

```
ifconfig eth0 merlin-iface1
ifconfig eth1 merlin-iface2
```

These commands assume that the Ethernet device `/dev/eth0` is for the interface to `big_net` and `/dev/eth1` is for `small_net`.

Finally, the kernel routing table must be updated to reflect the two network names. The commands for this example are shown here:

```
route add big_net
route add small_net
```

When these steps are completed, you can use your machine as a gateway between the two networks. Other machines on either network can also use your machine as a gateway between the two networks.

Using Graphical Tools to Configure Network Interfaces

The procedures described so far show how network interfaces are configured from scratch from the command line. When a Linux system starts, you seldom have to issue these commands, because the startup scripts for the Linux system distribution will execute them in the startup scripts. These startup scripts are shell (bash, actually which is the Born Again Shell) scripts, and differ from distribution to distribution. Some distributions use the BSD Unix-style startup scripts (such as Slackware) whereas others use the System VR4 Unix-style startup scripts (such as RedHat). The details of the startup script change from distribution to distribution. Even within the same distribution, different versions of the distribution sometimes make radical changes in their startup scripts.

However, many distributions come with a graphical tool to simplify network configuration. These tools will automatically make changes so that your Linux system startup scripts will find the appropriate TCP/IP parameters.

The following sections discuss the use of netcfg and linuxconf in configuring TCP/IP for Linux.

Using netcfg

One of the first graphical tools for configuring Linux is netcfg. Simply run netcfg from the command line to start it, and explore its structure. Figure 28.4 shows the netcfg starting menu. The netcfg tool can be used to configure names, hosts, interfaces, and routing.

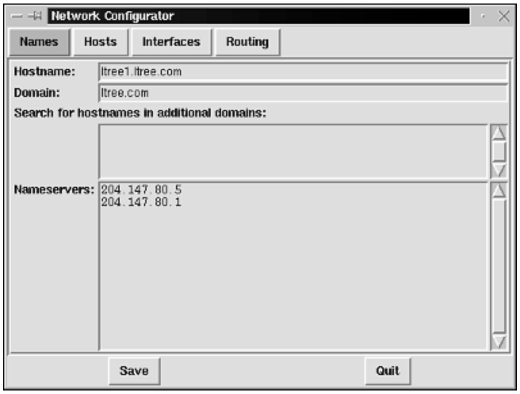
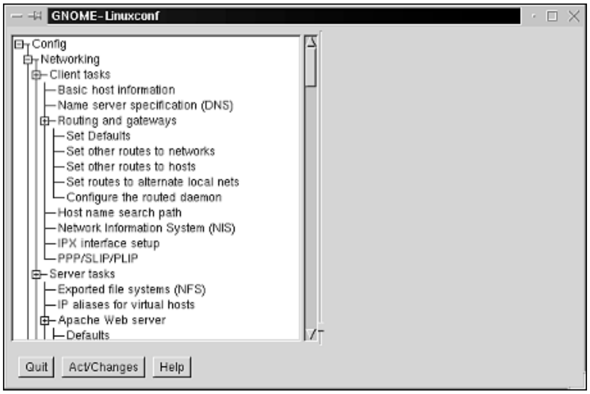


FIGURE 28.4
The GUI tool netcfg.

Using linuxconf

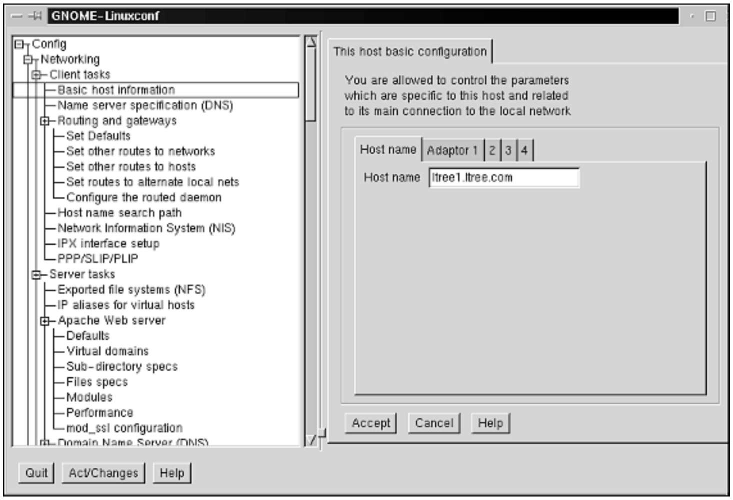
Another very powerful tool is linuxconf, which can be used to configure networking and perform most system administration tasks. This is a worthwhile tool to master because it can quickly perform both routine and complex tasks. Simply run linuxconf from the command line. Your X-Windows Desktop Manager such as KDE or GNOME may already have linuxconf in one of the program groups, in which case you can select it with a mouse and run the program. Figure 28.5 shows the starting screen of linuxconf.

FIGURE 28.5
The GUI tool linuxconf.



To change host names, expand the directory tree by making the selections Config, Networking, Client tasks, Basic host information (see Figure 28.6).

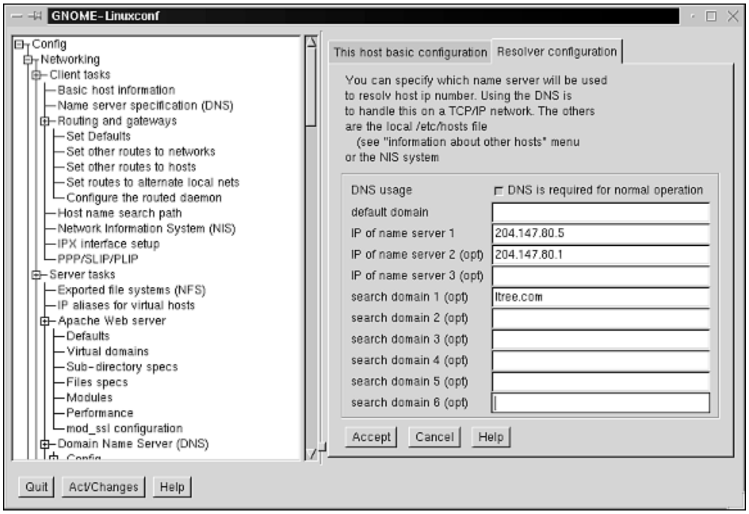
FIGURE 28.6
Linuxconf—Basic Host Configuration.



To configure the name resolver, expand the directory tree by making the selections Config, Networking, Client tasks, Name server specification (DNS) (see Figure 28.7).

FIGURE 28.7

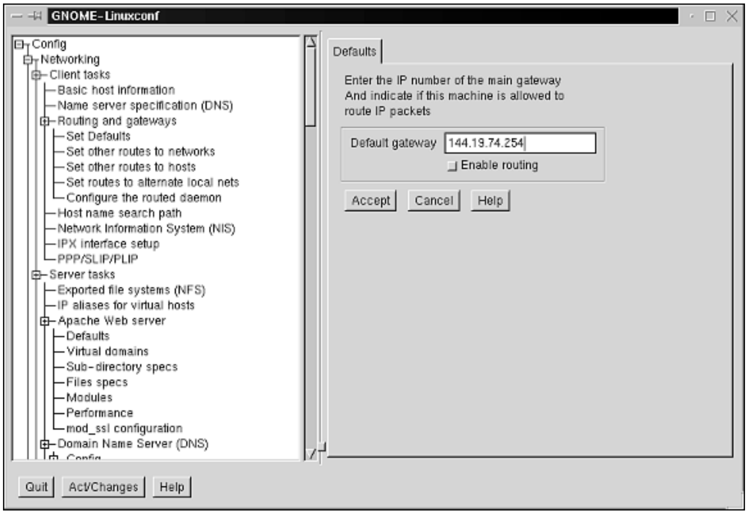
Linuxconf—Configuring name resolver.



To configure host routing, expand the directory tree by making the selections Config, Networking, Client tasks, Routing and gateways, Set Defaults (see Figure 28.8).

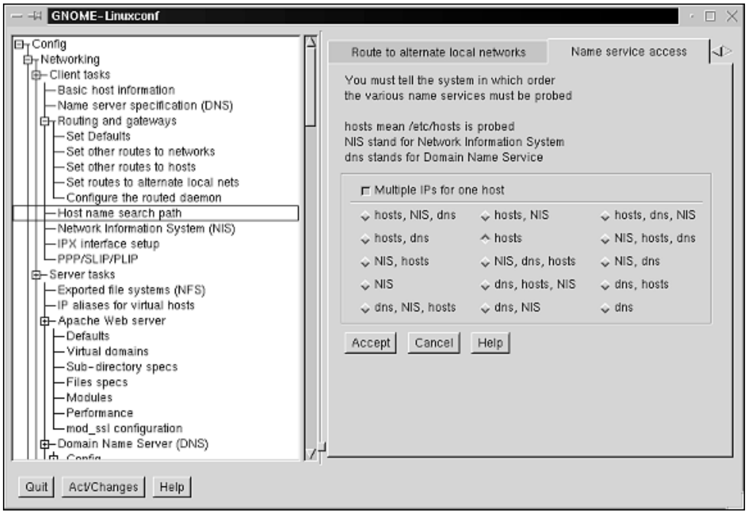
FIGURE 28.8

Linuxconf—Configuring default router.



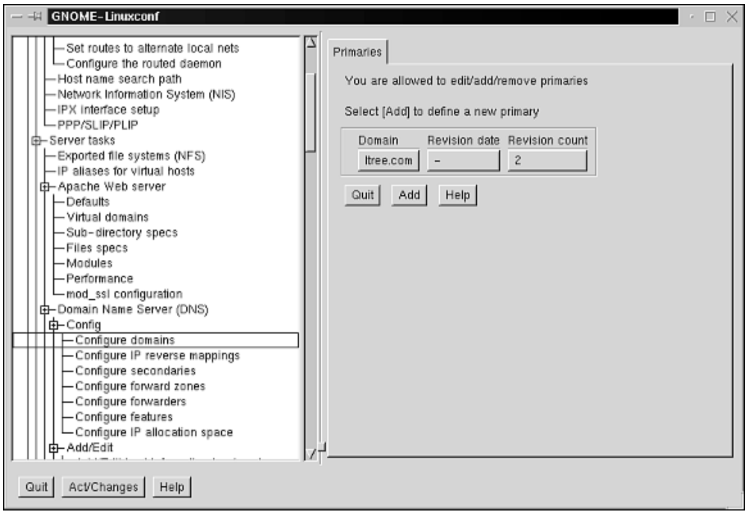
To configure the order of name resolution, expand the directory tree by making the selections Config, Networking, Client tasks, Host name search path (see Figure 28.9).

FIGURE 28.9
Linuxconf—Host name search path.



You can even configure BIND if you expand the directory tree by selecting Config, Networking, Server tasks, Domain Name Server (DNS), Config (see Figure 28.10). You can configure domains, IP reverse mappings, secondaries, forward zones, features, and IP allocation space. However, if you are serious about learning to configure BIND, you should learn the syntax of the BIND startup file (`/etc/named.boot` for BIND 4 and `/etc/named.conf` for BIND 8 and 9), and the syntax of the zone data files, and learn to edit these files directly.

FIGURE 28.10
Linuxconf—Configuring BIND.



Configuring SLIP and PPP

The configuration and setup for either Serial Line Internet Protocol (SLIP) or Point-to-Point Protocol (PPP) follows the general TCP/IP configuration you have just completed. Both SLIP and PPP work over a modem, establishing a modem link with a remote system, and then invoking either the SLIP or PPP protocols. You can configure SLIP and PPP when you are configuring the general TCP/IP files, or you can wait until you need to set them up for SLIP or PPP access. Not all installations require SLIP or PPP, although many Internet service providers prefer SLIP or PPP access from small systems.

Setting Up the Dummy Interface

A dummy interface is a trick used to give your machine an IP address to work with when it uses only SLIP and PPP interfaces. A dummy interface solves the problem of a standalone machine whose only valid IP address is the loopback driver (127.0.0.1). Although SLIP and PPP can be used for connecting your machine to the outside world, when the interface is not active you have no internal IP address that applications can use.

Creating a dummy interface is simple. If your machine has an IP address already assigned for it in the `/etc/hosts` file, all you need to do is set up the interface and create a route. The two commands are shown here:

```
ifconfig dummy machine_name
route add machine_name
```

where *machine_name* is your local machine's name. This creates a link to your own IP address. If you do not have an IP address for your machine in the `/etc/hosts` file, you should add one before you create the dummy interface. Add a line with your machine name and its aliases along with the IP address, such as this line:

```
147.120.0.34    merlin   merlin.tpci.com
```

Setting Up SLIP

SLIP can be used with many dial-up Internet service providers, as well as for networking with other machines. When a modem connection is established, SLIP takes over and maintains the session for you. The SLIP driver is usually configured as part of the Linux kernel. The Linux SLIP driver also handles CSLIP, a compressed SLIP version that is available with some implementations. The SLIP driver is usually installed into the Linux kernel by default, but some versions of Linux require you to rebuild the kernel and answer Yes to a question about SLIP and CSLIP usage. You can use CSLIP only when both ends of a connection employ it; many Internet service providers offer both CSLIP and SLIP support, but you should check with them first. CSLIP packs more information into packets than SLIP, resulting in a higher throughput.

For Linux systems that use SLIP, a serial port has to be dedicated to the device. That serial port cannot be used for any other purpose. The kernel uses a program called `SLIPDISC` (SLIP discipline) to control the SLIP serial port and block other non-SLIP applications from using it.

The easiest way to dedicate a serial port for SLIP is the `slattach` program. This takes the device name of the serial port as an argument. For example, to dedicate the second serial port (`/dev/cua1`) to SLIP, you would issue this command:

```
slattach /dev/cua1 &
```

The command is sent into background by the ampersand. Failure to send to background means the terminal or console the command was issued from is not usable until the process is terminated. You can embed the `slattach` command in a startup file.

When the attachment has own succeeded, the port is set to the first SLIP device `/dev/sl0`. By default, most Linux systems set the SLIP port to use CSLIP. If you want to override this default, use the `-p` option and the SLIP name:

```
slattach -p slip /dev/cua1 &
```

You must make sure that both ends of the connection use the same form of SLIP. For example, you cannot set your device for CSLIP and communicate with another machine running SLIP. If the versions of SLIP don't match, commands like `ping` fail.

After the serial port has been set for SLIP usage, you can configure the network interface using the same procedure as normal network connections. For example, if your machine is named `merlin` and you are calling a system named `arthur`, you issue these commands:

```
ifconfig sl0 merlin-slip pointopoint arthur
route add arthur
```

The preceding `ifconfig` command configures the interface `merlin-slip` (the local address of the SLIP interface) to be a point-to-point connection to `arthur`. The `route` command adds the remote machine called `arthur` to the routing tables. You can also issue a `route` command to set the default route to `arthur` as a gateway:

```
route add default gw arthur
```

If you want to use the SLIP port for access to the Internet, it has to have an IP address and an entry in the `/etc/hosts` file. That gives the SLIP system a valid entry on the Internet.

When the ifconfig and route commands have been executed, you can test and use your SLIP network. If you decide to remove the SLIP interface in the future, you must remove the routing entry, use ifconfig to take down the SLIP interface, and then kill the slattach process. The first two steps are done with these commands:

```
route del arthur
ifconfig sl0 down
```

The termination of the slattach process must be done by finding the process ID (PID) of slattach (with the ps command), and then issuing a kill command.

Some Linux versions own include a utility called dip (dial-up IP) that helps automate the steps shown earlier, as well as provide an interpretive language for the SLIP line. Many versions of dip are currently available.

Setting Up PPP

PPP is a more talented own protocol than SLIP and is preferable unless your connection cannot support PPP. Linux divides the PPP functions into two parts: one for the *High-Level Data Link Control* (HDLC) protocol that helps define the rules for sending PPP datagrams between the two machines, and one for the PPP daemon, called pppd, which handles the protocol once the HDLC system has established communications parameters. In addition, Linux uses a program called chat that calls the remote system. As with SLIP, PPP establishes a modem link between the two machines, and then hands over the control of the line to PPP.

It is best to use PPP with a special user account for optimum protection and behavior. This is not necessary, and you can easily use PPP from any account, but for more secure operation you should consider creating a PPP user. First, you need to add a new user to the /etc/passwd file. A sample /etc/passwd entry for the PPP account (with UID set to 201 and GID set to 51) looks like this:

```
ppp:*:201:51:PPP account:/tmp:/etc/ppp/pppscript
```

In this case, the account is set with no password and a home directory of /tmp (because no files are created). The startup program is set to /etc/ppp/pppscript, a file you create with the contents like this:

```
#!/bin/sh
mesg n
stty -echo
exec pppd -detach silent modem crtscts
```

The first line forces execution of the script into the Bourne shell. The second command turns off all attempts to write to the PPP account's `tty`. The `stty` command is necessary to stop everything the remote sends from being echoed again. Finally, the `exec` command runs the `pppd` daemon (which handles all PPP traffic). You will see the `pppd` daemon and the options later in this section.

PPP requires you to establish a modem connection to the remote machine before it can take over and handle the communications. Several utilities are available to do this, the most commonly used of which is `chat`.

To use `chat`, you have to assemble a command line that tells `chat` how to talk to a modem and connect to the remote system. For example, to call a remote machine with a Hayes-compatible modem (using the AT command set) at the number 555-1234, you use the following command:

```
chat "" ATZ OK ATDT5551234 CONNECT "" ogin: ppp word: secret1
```

All the entries are in a `send-expect` format, with what you send to the remote specified after what you receive from it. The `chat` script always starts with an expect string, which you must set to be empty because the modem won't talk to you without any signal to it. After the empty string, you send the `ATZ` (reset) command, wait for an OK back from the modem, then send the `dial` command. When a `CONNECT` message is received back from the modem, the login script for the remote machine is executed. You send a blank character, wait for the `ogin:` (login) prompt, send the login name `ppp`, wait for the `word:` (password) prompt, then send your password. After the login is complete, `chat` terminates but leaves the line open.

Note

Why use "ogin" and "word" instead of "login" and "password" in the script? The best reason is so that case differences on the remote system are not important, so that both "login" and "Login" are treated the same way. The shortening of "password" lets some characters get lost without causing a lock-up or failure of the session.

If the other end of the connection doesn't answer with a login script as soon as its modem answers, you might have to force a `break` command down the line to jog the remote end:

```
chat -v "" ATZ OK ATDT5551234 CONNECT ""
ogin:-BREAK-ogin: ppp word: secret1
```

To set up a PPP connection, you need to invoke the pppd. If you have a PPP connection already established and your machine is logged in to a remote using the PPP account, you can start the pppd. If you assume your local machine is using the device /dev/cua1 for its PPP connection at 38,400 baud, you would start up the pppd with this command:

```
pppd /dev/cua1 38400 crtscts defaultroute
```

This command tells the Linux kernel to switch the interface on /dev/cua1 to PPP and establish an IP link to the remote machine. The crtscts option, which is usually used on any PPP connection above 9,600 baud, switches on hardware handshaking.

Because you need chat to establish the connection in the first place, you can embed the chat command as part of the pppd command if you want. This is best done when reading the contents of the chat script from a file (using the -f option). For example, you could issue the following pppd command:

```
pppd connect "chat -f chat_file" /dev/cua1 38400
-detach crtscts modem defaultroute
```

The chat_file contains this string:

```
"" ATZ OK ATDT5551234 CONNECT "" ogin: ppp word: secret1
```

You will notice a few modifications to the pppd command other than the addition of the chat command in quotation marks. The connect command specifies the dial-up script that pppd should start with, and the -detach command tells pppd not to detach from the console and move to background. The modem keyword tells pppd to monitor the modem port (in case the line drops prematurely) and hang up the line when the call is finished.

The pppd begins setting up the connection parameters with the remote by exchanging IP addresses, and then setting communications values. After that is done, pppd sets the Network Layer on your Linux kernel to use the PPP link by setting the interface to /dev/ppp0 (if it's the first PPP link active on the machine). Finally, pppd establishes a kernel routing table entry to point to the machine on the other end of the PPP link.

PPP has quite a few options, as well as some files and authentication processes that might be required for you to connect to some remote systems. This subject involves far too much detail to cover here, so you should consult a book such as *Linux System Administrator's Survival Guide* for more information.

Summary

When you have followed the steps shown in this chapter, your TCP/IP connection is properly configured. You can now use your Linux system as a client onto other TCP/IP machines or allow others to connect to your Linux server. This chapter also has looked briefly at PPP and SLIP, both modem-based protocols you can use to connect to the Internet.

Using TCP/IP Applications

Part VII

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CHAPTER 29

Whois and Finger

by Neal S. Jamison

In This Chapter

- **Understanding the Whois Protocol** *726*
- **Expanding Whois** *734*
- **Using Finger** *735*

Finding information on the Internet is getting easier thanks to the multitude of search engines, meta-search engines, intelligent agents, and more. However, with the ever-growing number of users, hosts, and domains, locating information about people, host computers, and domains can be difficult. Two TCP/IP application-level protocols can help: Whois and Finger. Whois can be used to gather information about specific hosts and domains. Finger, on the other hand, can be used to find out specific information about people on Internet hosts. Both are discussed in this chapter.

Understanding the Whois Protocol

Whois is the TCP/IP protocol and service used to gather information about Internet hosts and domains. Originally designed to be the "white pages" of the Internet, Whois was once (and still is in some cases) used in conjunction with large personnel databases. However, the growth of the Internet made maintaining such personnel databases impossible, so Whois information was limited to hosts and domains. Today, popular Whois databases contain information such as host and domain points-of-contact, organizations, and addresses. Whois is also used when registering a domain to determine whether the domain is already in use.

The Whois protocol runs on well-known TCP port 43, and is defined in RFC 954. Additional information on whois and the related finger command can be found in the following RFCs:

2167—Referral Whois (RWhois) Protocol V1.5. S. Williamson, M. Kosters, D. Blacka, J. Singh, K. Zeilstra. June 1997.

1834—Whois and Network Information Lookup Service, Whois++. J. Gargano, K. Weiss. 1995.

1835—Architecture of the WHOIS++ service. P. Deutsch, R. Schoultz, P. Faltstrom, C. Weider. 1995.

1913—Architecture of the Whois++ Index Service. C. Weider, J. Fullton & S. Spero. 1996.

1914—How to Interact with a Whois++ Mesh. P. Faltstrom, R. Schoultz & C. Weider. 1996.

1288—The Finger User Information Protocol. D. Zimmerman. 1991.

Internet Registration

Internet Registration can be a somewhat confusing topic with no one party in complete control of the Internet. (For more information on the major players of the Internet, refer to Chapter 2, "TCP/IP and the Internet.") This confusion has an impact on the traditional Whois service because each major registrar party maintains its own database.

Understanding Domain Names

Internet domain names are composed of levels. The most common U.S. top-level domains are `.com`, `.edu`, `.gov`, `.mil`, `.net`, and `.org`. There are also country-code top-level domains, such as `us` (United States), `ca` (Canada), `nl` (The Netherlands), `de` (Germany), and `int` (International; see RFC 1591). Second-level domains further define the top level, as in `ibm.com`, `mit.edu`, `nasa.gov`, and `army.mil`. Third-level domains go one step further, as in `whois.nic.mil` and `www.internic.net`.

An organization called the *Council of Registrars* (CORE) has introduced other top-level domains known as *generic top-level domains* (gTLD). They are

`.firm`—For businesses, or firms

`.shop`—For businesses offering goods for sale

`.web`—For entities emphasizing activities related to the World Wide Web

`.arts`—For cultural- and entertainment-related organizations

`.rec`—For recreation/entertainment-related organizations

`.info`—For entities providing information services

`.name`—For those wanting individual or personal nomenclature; that is, a personal nom de plume

`.biz`—For registering businesses

`.tv`—For TV related businesses

`.coop`—For cooperatives

`.museum`—For museums

`.pro`—For professionals (accountants, lawyers, physicians)

`.aero`—For air transport industry

For more information on this initiative, refer to `http://www.icann.org/`.

The InterNIC (operated by Network Solutions, Inc.) has been the primary registrar for the top-level domains since 1993. The InterNIC is overseen by the *National Telecommunications & Information Administration* (NTIA), part of the Department of Commerce. The InterNIC has delegated some of its responsibility to other official registrars (such as the Department of Defense NIC, and the Asia-Pacific NIC). More recently, there have been other initiatives that could break up the InterNIC even further. One such initiative, known as the *Shared Registry System* (SRS), strives to introduce fair and open competition to the domain registration process. One of the leading competitors is Register.com. Visit its Web site (`http://www.register.com/`) for more information.

All of this fair competition and delegation is great for the registration process, but it tends to complicate the Whois service. As previously mentioned, each registrar maintains its own database of registrants. For example, the InterNIC Whois database doesn't contain any military domains, and vice versa. The end result of this is that you have to know which database is most likely to have the information you are looking for, and target your query to that database.

Using NIC Handles

The InterNIC assigns a nickname, or handle, to everyone who is registered as a domain point-of-contact.

My NIC handle is NJ1181. Querying the InterNIC Whois database for my handle returns the following:

```
Jamison, Neal (NJ1181)  jamisonn@ANVI.COM
AnviCom, Inc.
7921 Jones Branch Dr.
Suite G-10
McLean, VA 22102
```

The Whois Databases

Several databases exist in which you can find Whois information. As discussed earlier, most of the major Whois databases only list information as it pertains to registered Internet hosts and domains. However, some databases out there contain more detailed "white pages" information.

The InterNIC

The primary source of host and domain registration information for the United States is the InterNIC, currently maintained by Network Solutions, Inc. As previously mentioned, the InterNIC has the authority to register all top-level domains in the United States. As such, its database contains information on a large majority of domains.

For more information on the InterNIC, refer to Chapter 2 or `http://www.internic.net/`.

The InterNIC Whois server is at `whois.internic.net`.

The U.S. Department of Defense

The Department of Defense *Network Information Center* (NIC) maintains registry information for all `.mil` hosts. The DoD NIC is currently maintained by the Boeing Corporation. For more information on the DoD NIC, refer to `http://whois.nic.mil/`.

The U.S. DoD Whois server is `whois.nic.mil`.

The U.S. Federal Government

The U.S. Federal Government NIC maintains registry information for all `.gov` and `.fed` hosts. This NIC is currently maintained by the *General Services Administration* (GSA). For more information, refer to `http://whois.nic.gov/`.

The U.S. Government Whois server is `whois.nic.gov`.

RIPE (Réseaux IP Européens)

RIPE is the European Network Coordination Center. For more information on RIPE, refer to `http://www.ripe.net/`.

RIPE's Whois server is `whois.ripe.net`.

The Asia Pacific Network Information Center (APNIC)

The APNIC is the registrar for the Asia-Pacific region. For more information on APNIC, go to `http://www.apnic.net/`.

APNIC's Whois server is `whois.apnic.net`.

Other Whois Servers

Many other Whois databases contain white-page information for corporations, universities, and other organizations. A complete list of Whois servers is compiled by Matt Power of M.I.T. and can be located at `ftp://sipb.mit.edu/pub/whois/whois-servers.list`.

Web-Based Whois

Although the Whois protocol and service has been around much longer than the Web, several Web-based interfaces exist to help you query Whois databases and find the information you need.

Table 29.1 lists several Web-based Whois clients.

TABLE 29.1 Major Web-Based Whois Client Sites

Site	*URL*
InterNIC	`http://www.networksolutions.com/cgi-bin/whois/whois/`
IANA	`http://www.isi.edu:80/in-notes/usdnr/rwhois.html`
RIPE (European)	`http://www.ripe.net/db/whois.html`
APNIC (Asia-Pacific)	`http://www.apnic.net/apnic-bin/whois.pl`
U.S. Military	`http://www.nic.mil/cgi-bin/whois`
U.S. Government	`http://www.nic.gov/cgi-bin/whois`

Allwhois.com

With all the databases out there, deciding which one to use can sometimes be difficult. But maybe it doesn't matter. There is a site on the Web called Allwhois.com (`http://www.allwhois.com`) that allows you to search all the major Whois databases at once. Figure 29.1 shows the Allwhois.com homepage.

FIGURE 29.1
The Allwhois.com homepage.

As you will see later, an enhancement to the Whois service, known as *referral Whois* (RWhois) can help as well.

Command-Line Whois

Although the command-line version of the Whois client has found competition on the Web, it is still included in many modern operating systems and TCP/IP suites. The following sections describe the whois command and its variants.

The Unix `whois` Command

The standard Unix Whois client is `whois`. The following describes the syntax of the whois command:

Usage: `whois [ -h host ] identifier`

Options: `-h`—Specifies the whois server.

Prefixing the identifier with certain characters will limit your search. For example, to search for names only, prefix the identifier with a period (.). Table 29.2 lists allowed characters and how their use will limit your search. These characters can be combined as well.

TABLE 29.2 Characters Used to Limit `whois` Searches

Character	*Definition*
.	Search for names only.
!	Search for handles only.
*	Search for groups or organizations only.

The upcoming "Examples" section will allow you to see these defining characters in action.

`fwhois`

`fwhois` (Finger Whois) is an open source Whois client for BSD Unix systems written by Chris Cappuccio. It is freely available over the Internet, and can easily be added to your Unix system. The following describes the syntax of the `fwhois` command.

Usage: `fwhois user[@<whois.server>]`

Examples

In this first example you can use the Unix `whois` command to query for people, for example, with the last name "jamison" and first name "neal." By not specifying a particular server (using the `-h` option), `whois` will search the InterNIC by default. The following shows the output of the `whois` command:

```
% whois jamison,n
[rs.internic.net]
```

```
The Data in Network Solutions' WHOIS database is provided by Network
Solutions for information purposes, and to assist persons in obtaining
information about or related to a domain name registration record.
Network Solutions does not guarantee its accuracy.  By submitting a
WHOIS query, you agree that you will use this Data only for lawful
purposes and that, under no circumstances will you use this Data to:
(1) allow, enable, or otherwise support the transmission of mass
unsolicited, commercial advertising or solicitations via e-mail
(spam); or  (2) enable high volume, automated, electronic processes
that apply to Network Solutions (or its systems).  Network Solutions
reserves the right to modify these terms at any time.  By submitting
this query, you agree to abide by this policy.

Jamison, Neal (NJ795)          jamisonns@PATRIOT.NET
Jamison, Neal (NJ1181)         jamisonn@ANVI.COM

To single out one record, look it up with "!xxx", where xxx is the
handle, shown in parenthesis following the name, which comes first.
```

Then (still using Unix `whois`) you can pick the record that you want to learn more about. Notice the use of the defining character "!", escaped with the "\" character to prevent it from being processed by the Unix shell:

```
% whois \!NJ1181
[rs.internic.net]
The Data in Network Solutions' WHOIS database is provided by Network
Solutions for information purposes, and to assist persons in obtaining
information about or related to a domain name registration record.
Network Solutions does not guarantee its accuracy.  By submitting a
WHOIS query, you agree that you will use this Data only for lawful
purposes and that, under no circumstances will you use this Data to:
(1) allow, enable, or otherwise support the transmission of mass
unsolicited, commercial advertising or solicitations via e-mail
(spam); or  (2) enable high volume, automated, electronic processes
that apply to Network Solutions (or its systems).  Network Solutions
reserves the right to modify these terms at any time.  By submitting
this query, you agree to abide by this policy.
Jamison, Neal (NJ1181)         jamisonn@ANVI.COM
   AnviCom, Inc.
   7921 Jones Branch Dr.
   Suite G-10
   McLean, VA 22102
   Record last updated on 20-Feb-99.
   Database last updated on 20-Aug-99 04:31:00 EDT.
```

This is my InterNIC record.

`fwhois` can be used to achieve the same results. In this example, I will query for information about a popular space agency:

```
% fwhois nasa.gov
```

```
[rs.internic.net]
The Data in Network Solutions' WHOIS database is provided by Network
Solutions for information purposes, and to assist persons in obtaining
information about or related to a domain name registration record.
Network Solutions does not guarantee its accuracy.  By submitting a
WHOIS query, you agree that you will use this Data only for lawful
purposes and that, under no circumstances will you use this Data to:
(1) allow, enable, or otherwise support the transmission of mass
unsolicited, commercial advertising or solicitations via e-mail
(spam); or  (2) enable high volume, automated, electronic processes
that apply to Network Solutions (or its systems).  Network Solutions
reserves the right to modify these terms at any time.  By submitting
this query, you agree to abide by this policy.
No match for "NASA.GOV".
```

Note that I forgot to specify the U.S. Federal Government server. Trying again, I do use the following:

```
% fwhois nasa.gov@whois.nic.gov
[nic.gov]
National Aeronautics and Space Administration (NASA-DOM)
   NASA Marshall Space Flight Center
   MSFC, AL 35812

   Domain Name: NASA.GOV
   Status: Active
   Administrative Contact:
      Pirani, Joseph L.  (JLP1)
      JOSEPH.PIRANI@MSFC.NASA.GOV

   Domain servers in listed order:

   E.ROOT-SERVERS.NET            192.203.230.10
   NS1.JPL.NASA.GOV              137.78.160.9
   NS.GSFC.NASA.GOV              128.183.10.134
   MX.NSI.NASA.GOV               128.102.18.31
%
```


Telnet-Based `whois`

Many Whois servers used to have a Telnet interface. Using Telnet to connect to the Department of Defense Network Information Center Whois server (`whois.nic.mil`) now results in the following:

```
% telnet whois.nic.mil
Trying 207.132.116.6...
Connected to is-1.nic.mil.
Escape character is '^]'.
The telnet service to nic.mil has been discontinued.
For WHOIS usage, please use the online web form at
```

```
http://nic.mil
On Unix platforms, you can also use the WHOIS client service,
included with most operating systems.
$ whois -h nic.mil 'keyword'
Connection closed by foreign host.
```

However, some Telnet-accessible Whois services are still out there. One such service is found at `whois.ripe.net`. The following shows the use of the Telnet version of `whois`.

```
% telnet whois.ripe.net
Trying 193.0.0.200...
Connected to joshua.ripe.net.
Escape character is '^]'.
***********************************************************************
* RIPE NCC
*
* Telnet-Whois Interface to the RIPE Database
*
* Most frequently used keys are: IP address or prefix (classless),
* network name, persons last, first or complete name, NIC handle,
* and AS<number>.
*
* Use 'help' as key to get general help on the RIPE database.
* Contact <ripe-dbm@ripe.net> for further help or to report problems.
***********************************************************************

Enter search key [q to quit]:
```

Expanding Whois

Whois provides a rich protocol and service that allows us to query specific Whois databases for information pertaining to registered hosts, domains, and in some cases, people. However, Whois has some weaknesses. For instance, determining the right database to use for your query can sometimes be difficult. This problem can make finding the information you are looking for difficult. Two protocols expand on Whois:

- Referral Whois (RWhois)
- WHOIS++

They are briefly explained in this section.

Referral Whois (RWhois)

Due to the size of the Internet, maintaining one single database of all the host, domain, and user information is impossible. In order to keep the size and maintenance of the Whois databases to manageable proportions, a decentralized approach is necessary.

RWhois is a Directory Services protocol and service that extends the Whois concept to allow single queries to any number of decentralized Whois databases. RWhois accomplishes this in much the same manner as the Domain Name Service (DNS). If one RWhois database does not contain the information needed to satisfy the query, it can refer the query to another database. This process repeats until the proper database is found and the query is answered.

For more information on RWhois, see RFC 2167 or `http://www.rwhois.net/`.

WHOIS++

WHOIS++ is an extension to the traditional Whois protocol and service whose goal is to permit Whois-like servers to make available more detailed and structured information.

WHOIS++ is specified by RFCs 1834, 1835, 1913, and 1914.

Using Finger

Finger is the name for both a protocol and a program that allow us to find out the status of hosts or users on the Internet. It is typically used to find out whether an Internet user is logged on or to locate his e-mail address or username. Finger runs on TCP port 79.

One of the simpler TCP/IP services, a Finger client/server session resembles the following:

- The Finger client sends a request to the Finger server.
- The server opens a connection to the client.
- The client sends a one-line query.
- The server searches local "user account" files for information, and returns the results.
- The server closes the connection.

Telnet can be used to demonstrate the simplicity, as in the following example:

```
% telnet host.mydomain.com 79
Trying...
Connected to host.mydomain.com.
Escape character is '^]'.
jamisonn
Login: jamisonn                     Name: Neal Jamison
Directory: /users/home/jamisons         Shell: /bin/tcsh
On since Mon Aug 16 19:20 (EDT) on ttyp4 from pool180-128
No mail.
No Plan.
Connection closed by foreign host.
%
```

Finger is specified in RFC 1288.

CSO Eases Burden of Researching Information

CSO is an electronic phonebook database concept developed at the University of Illinois Computing and Communications Services Office. A CSO server maintains the phonebook data and runs a program called `qi` (query interpreter) that receives query requests and sends back information. The client runs a program called `ph` that sends requests to the server. `ph` has been ported to many major platforms, and several client products (for example, Eudora and Mosaic) incorporate the `ph` client. Look for CSO `qi`/`ph` to catch on and make finding information about people even easier.

For more information, refer to the `ph` FAQ at `http://www.landfield.com/faqs/ph-faq/`.

The `finger` Command

The Unix command `finger` is used to find information about local and remote users. This section concentrates on using `finger` to look up remote users.

Solaris `finger`

In the Solaris operating system, the client command of the finger protocol is appropriately named `finger`. The `finger` command requests a connection with the server, and after the connection is opened, `finger` passes along a one-line query. The following shows the syntax of the Solaris `finger` command:

Usage:

```
finger [ -bfhilmpqsw ] [ username...  ]

finger [-l ] [ username@hostname1[@hostname2...@hostnamen]

finger [-l ] [ @hostname1[@hostname2...@hostnamen] ...  ]
```

Note

When using finger to look up remote users, only the -l option is allowed.

Options:

- `-b`—Suppresses long format printout.
- `-f`—Suppresses the header.
- `-h`—Does not print the `.project` file.
- `-i`—Similar to short format except that only the login name, terminal, login time, and idle time are printed.
- `-l`—Forces long output format.
- `-m`—Matches arguments only on username (not first or last name).
- `-p`—Does not print the `.plan` file.
- `-q`—Forces quick output format (similar to short format except that only the login name, terminal, and login time are printed).
- `-s`—Forces short output format.
- `-w`—Does not print the full name.

Example:

```
$finger jamisonn@mydomain.com
Login name: jamisonn   In real life: Neal Jamison
Directory: /www/home/jamisonn   Shell: /bin/csh
On since Aug  3 13:21:37 on pts/1 from hostname1
No unread mail
Project:  AlphaBeta Project
Plan: To finish this AlphaBeta project.
$
```

Linux `finger`

The Linux version of `finger` is similar to the Solaris implementation. The following shows the syntax of the Linux `finger` command:

Usage:

```
finger [-lmsp] [user ...] [user@host ...]
```

Options:

- `-s`—Displays the user's login name, real name, terminal name and write status (as an * after the terminal name if write permission is denied), idle time, login time, office location, and office phone number.
- `-l`—Displays the information described for the `-s` option plus the user's home directory, home phone number, login shell, mail status, and the contents of the files `.plan`, `.project`, and `.forward` from the user's home directory.

- -p—Prevents the -l option of finger from displaying the contents of the .plan and .project files.
- -m—Prevents matching of usernames. User is usually a login name; however, matching will also be done on the users' real names, unless the -m option is supplied. All name matching performed by finger is non–case sensitive.

If no options are specified, finger defaults to the -l style output if operands are provided; otherwise it defaults to the -s style. Note that some fields might be missing in either format if information is not available for them.

If no arguments are specified, finger will print an entry for each user currently logged in to the system.

Example:

```
$finger jamisonn@mydomain.com
Login name: jamisonn    In real life: Neal Jamison
Directory: /www/home/jamisonn     Shell: /bin/csh
On since Aug  3 13:21:37 on pts/1 from hostname1
No unread mail
Project:  AlphaBeta Project
Plan: To finish this AlphaBeta project.
$
```

The Finger Daemon

fingerd and in.fingerd are the daemons that listen for finger requests. These daemons are invoked by inetd. Sometimes Finger (the Finger daemon) is disabled by site administrators for "privacy" reasons. Fingering a site with Finger disabled will produce results similar to the following:

```
$ finger jamisonn@host.mydomain.com
[host.mydomain.com]
Connection refused.
$
```

Solaris in.fingerd

in.fingerd is the Solaris finger daemon. It is controlled by inetd, where it waits for a connection request. When a request is made, in.fingerd passes the query along to finger, which locates the requested information among the system files. in.fingerd responds to the client and then closes the connection. The following shows how to start the in.fingerd daemon.

Usage: /usr/sbin/in.fingerd

Options: None

Table 29.3 lists the `in.fingerd`-related files/commands.

TABLE 29.3 Commands and Files Related to `in.fingerd`

File/Command	*Description*
`.plan`	User-defined file
`.project`	User-defined file that can contain information about projects
`/var/adm/utmp`	User and accounting information
`/etc/passwd`	System password file that contains user information
`/var/adm/lastlog`	Last login time

Linux `fingerd`

The Linux `fingerd` is similar to the Solaris `in.fingerd`. The following shows how to start the `in.fingerd` daemon.

Usage: `fingerd [-wul] [-pL path]`

Options:

- `-w`—Provides welcome banner to include system status (that is, `uptime`).
- `-u`—Rejects requests of the form `finger @hostname`.
- `-l`—Logs `finger` requests.
- `-p`—Provides an alternate location for `fingerd` to find the local `finger` command.

Finger in a Non-Unix Environment

As with most TCP/IP commands and utilities, Finger was born in a Unix environment. However, several non-Unix parties have made Finger available within other operating systems. Table 29.4 lists two applications that provide Finger and URLs to help you find more information.

TABLE 29.4 Non-Unix Finger Software

Manufacturer	*URL*
Hummingbird Communications LTD	`http://arctic.www.hummingbird.com/products/nc/nfs/index.html`
Trumpet Winsock	`http://www.trumpet.com.au/`

There are also several Web interfaces to Finger or Finger gateways. Some that I've come across include the following:

- `http://www.cs.indiana.edu/finger/`
- `http://webrunner2.webabc.com/cgi-bin/finger`

Figure 29.2 shows a Web-to-Finger gateway in action.

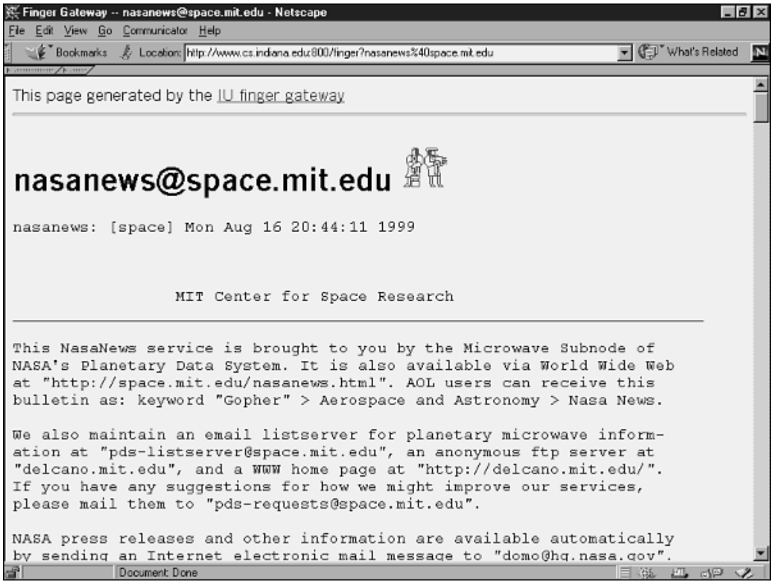

FIGURE 29.2
NASA News via the Indiana University Finger gateway.

Finger Fun

Occasionally, you will stumble upon someone who uses a TCP/IP tool to accomplish a job it wasn't really designed for. The following example shows how some smart (and caffeinated) college students put Finger to use. The output has been slightly truncated for space:

```
% finger coke@cs.wisc.edu
[cs.wisc.edu]
[coke@lime.cs.wisc.edu]
Login name: coke                        In real life: Coke

Directory: /var/home/coke              Shell: /var/home/cokead/bin/coke

On since Aug 10 11:47:46 on term/a          3 hours 6 minutes Idle Time
```

```
Plan:
This Coke (tm) machine is computer operated.  It is available to SACM
members, Computer Sciences personnel, and CS&S building support staff.
(Plus anyone else who asks really nice. :-)


If you do not have an account set up or your account is below $.40,
then you can leave a check made out to SACM in a sealed envelope in
the SACM mailbox (fifth floor) with your email address and an initial
password.  The Coke machine will email you when your account has been
created/updated.

Contents of the Coke machine:
  Coke, Diet Coke, Mendota Springs Lemon (sparkling mineral water),
  Sprite, Barq's Root Beer, Cherry Coke, Nestea Cool
%
```

Another, perhaps more useful use of Finger can be found at Pacific Northwest Seismograph Network. Again, the output here has been truncated:

```
% finger quake@geophys.washington.edu
[geophys.washington.edu]

Earthquake Information (quake)
Plan:
The following catalog is for earthquakes (M>2) in Washington and Oregon
produced by the Pacific Northwest Seismograph Network, a member of the
Council of the National Seismic System.  PNSN support comes from the
US Geological Survey, Department of Energy, and Washington State.
Additional catalogs and information for the PNSN (as well as other networks)
are available on the World-Wide-Web at URL:`http://www.geophys.washington.edu/'
For specific questions regarding our network send E-mail to:
              seis_info@geophys.washington.edu
DATE-TIME is in Universal Time (UTC) which is PST + 8 hours. Magnitudes are
reported as duration magnitude (Md).  QUAL is location quality A-excellent,
B-good, C-fair, D-poor, *-from automatic system and may be in error.
Updated as of Tue Sep 18 09:00:12 PDT 2001
 DATE-(UTC)-TIME   LAT(N) LON(W)   DEP  MAG QUAL COMMENTS
yy/mm/dd hh:mm:ss   deg.   deg.    km   Ml
01/07/31 05:07:32  47.73N 117.44W   0.6 2.2  AC  FELT    7.4 km NNW of Spokane,
01/08/01 14:29:48  47.71N 117.44W   0.6 2.2  AD  FELT    5.9 km NNW of Spokane,
01/08/02 15:35:23  47.72N 122.38W  27.0 2.2  BA   14.3 km WNW of Kirkland, Wa
01/08/13 11:47:28  48.25N 120.02W   7.2 2.3  CD   35.3 km WSW of Okanogan, WA
01/08/15 00:37:29  47.66N 122.41W  26.1 2.2  BA    9.6 km  NW of Seattle, WA
01/08/19 06:17:32  48.25N 121.61W   1.7 3.0  CC  FELT    1.0 km WSW of Darringt
01/08/20 06:14:09  45.29N 120.14W   8.8 2.1  BD    6.8 km NNE of Condon, OR
01/08/25 17:52:34  48.23N 121.60W   2.7 2.1  CC  FELT    2.1 km   S of Darringt
01/08/30 03:47:31  48.23N 121.62W   4.8 2.7  CC  FELT    2.9 km  SW of Darringt
01/08/31 14:39:17  47.02N 121.86W  17.9 2.1  BA   20.9 km NNW of Mt Rainier, WA
01/09/06 21:40:44  45.78N 124.54W  35.1 2.9  CD   65.7 km  NW of Tillamook, OR
01/09/08 17:30:41  48.85N 125.15W  10.0 2.5  CD   64.4 km ESE of Tofino, BC
```

```
01/09/09 04:06:29  48.19N 122.68W  56.4 2.3  BA   35.5 km  SW of Mount Vernon,
01/09/10 21:46:58  47.34N 123.05W  46.2 2.3  BA   35.3 km NNW of Olympia, WA
01/09/12 20:38:21  45.30N 121.72W   2.7 2.0  BB    8.1 km SSW of Mt Hood, OR
01/09/12 21:26:43  45.30N 121.72W   4.5 2.3  BB    8.2 km SSW of Mt Hood, OR
01/09/14 10:52:14  45.30N 121.72W   5.1 2.1  BB    8.4 km SSW of Mt Hood, OR
01/09/14 11:22:57  45.30N 121.73W   5.2 2.9  BA    8.0 km SSW of Mt Hood, OR
01/09/15 12:21:09  45.30N 121.72W   4.2 2.5  BB    8.1 km SSW of Mt Hood, OR
01/09/15 19:51:03  47.71N 120.07W   4.0 2.5  BB   12.7 km ENE of Entiat, WA
```

Summary

This chapter explained two of the major protocols and command sets used to locate information about hosts, domains, and users. Whois is the service/protocol primarily used to gather information about registered hosts and domains. This information usually is limited to registering organizations, points-of-contact, and mailing addresses. Whois was originally designed to be a white-pages information service for all Internet users. However, the growth of the Internet has complicated that. Referral Whois (RWhois) and WHOIS++ expand traditional Whois in an attempt to make Whois a more complete white-pages service. Many organizations, such as corporations and universities, effectively use Whois to provide directory services within their organization.

Finger is the service/protocol used to gather information about Internet hosts and their users. As shown, Finger can be used to determine whether a user is logged on, as well as to gather information about that user such as his last login time, phone number, or his “plan.” Finger can also be used to represent other types of information. As shown, Finger can be used to get weather forecasts, current news, or even to check the status of a drink vending machine.

CHAPTER 30

File Transfer Protocols

by Anne Carasik

IN THIS CHAPTER

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Sending files from one system to another is a very important part of networking. You could use e-mail attachments to do this, but this is an indirect way, and not as efficient as direct file transfer. If you want more immediate results, you'll want to use a file transfer protocol. This includes the Internet *File Transfer Protocol* (FTP) and *Trivial File Transfer Protocol* (TFTP). Remote copying is covered in Chapter 32, "Using the R-Utilities."

The Role of FTP and TFTP in Today's World

Because many users use the HTTP protocol to transfer files between servers, file transfer applications such as FTP and TFTP are not as popular as they once were. However, not all systems are running Web servers, so FTP and TFTP are still needed to transfer files back and forth, with or without a Web server. Also, it should be noted that HTTP is not as efficient as FTP for file transfer operations. If the URL (Uniform Resource Locator) embedded in the HTML tags is specified using the ftp protocol (for example, `ftp://ftp.xyz.com`), then the FTP client on the system will be invoked to do file transfers.

Even with the Web, transferring files to a server is still difficult. Many of the Web commands are not as robust as FTP and do not enable as many options and functions.

The file transfer command-line applications allow you to transfer files without having to install a Web server on your system. And for most Unix and Linux systems, FTP comes installed.

Because most of these commands are not graphically based (some programs exist that do the same thing but with a graphical interface), FTP is best illustrated by using the command-line–based client that comes with Unix. One such popular tool is Cute-FTP. However, regardless of whether the FTP client is graphical or command-line oriented, they all use FTP commands for their underlying operation.

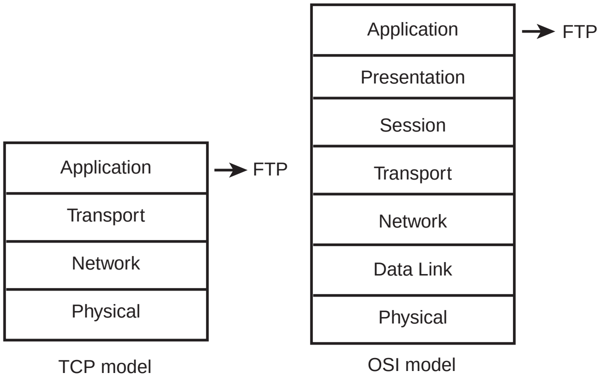
Even though TFTP is not used nearly as much as FTP, both are discussed in this chapter.

Transferring Files with FTP

FTP is the standard method of transferring files on the Internet and on IP networks. Back in the early days of the Internet before the World Wide Web became popular, people used command-line applications to run file transfers. One of the most common applications besides mail (SMTP) was FTP.

FTP is a TCP/IP application, which means it works on Layer 7 of the OSI model and Layer 4 of the TCP model. FTP is defined by RFC 959, and it uses TCP for transport instead of UDP. FTP is located on the Application Layer of both the OSI and TCP models (see Figure 30.1).

FIGURE 30.1
Where FTP sits on the OSI and TCP models.



Originally, FTP was the file transfer protocol between computers on the ARPANET, the predecessor to the Internet. The ARPANET was an older network that the United States Department of Defense ran from the 1960s through the 1980s. Back then, the primary function of FTP was to transfer files efficiently and reliably among hosts. FTP still provides this reliability today, and it also allows remote storage for files. This enables you to work on one system and store the files somewhere else. For example, if you have a Web server and you want to retrieve the HTML files and CGI programs to work with on your local computer, you just need to get those files from the storage site (which is the remote Web server).

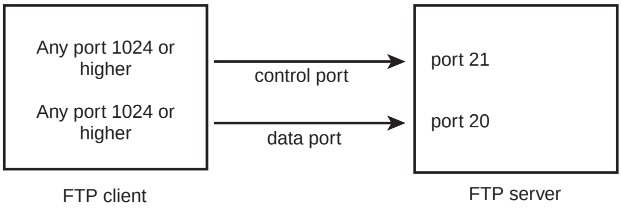
When you're done, you can send the files back to the Web server via FTP. This way you don't have to be logged in and working on the remote computer, as you would with Telnet.

FTP Connections

When you open an FTP connection, you are connecting to two ports: ports 20 and 21. These two ports have two different functions—port 20 is the data port and port 21 is the control port.

Figure 30.2 illustrates how the FTP client connects to the FTP daemon on the remote server.

FIGURE 30.2
How FTP client and server connect.



The Control Port

The control port for FTP is used for exchanging commands and replies to those commands. It is analogous to a drill sergeant and his or her recruits: The drill sergeant barks out the commands, and the recruits reply to those commands.

In FTP, if you send a command such as `get thisfile`, the response you get will be

```
200 PORT command successful.
150 Opening ASCII mode data connection for .message (127 bytes).
226 Transfer complete.
local: .message remote: .message
135 bytes received in 1.4 seconds (0.09 Kbytes/s)
```

Notice that the control port uses commands that are appended at the beginning with `PORT`. This signifies that the commands go through port 21 instead of the data port. In some FTP implementations, commands are allowed through the data port through passive (`PASV`) commands, not through the control commands (`PORT`).

This communication is used to show you the status of the data, what mode it's in, the transfer status, and the amount of data received. This connection uses the Telnet Protocol, defined in RFC 495.

The `PASV` commands for some FTP implementations allow a "raw" FTP connection, which does not use the commands that the user is familiar with. This enables someone to do file transfers using only one port, port 20, instead of both 20 and 21.

Note

The real use of the PASV command is to make FTP firewall-friendly. In normal FTP operation, the FTP client sends a PORT command to the FTP server that identifies the endpoint to which the FTP server must create a data connection. This is often called a *back connection*. Because the data endpoint on the client side is a temporary port that can be anywhere in the range of 1024 to 65535, the firewall does not know of this and cannot allow access to a specific port if it does not know the port number. The problem is solved by the FTP server issuing the PASV command, which puts the FTP server in a "passive mode." The PASV command identifies the server endpoint for the data connection to the FTP client. The FTP client then makes an active FTP connection to the server data endpoint. Because firewalls typically allow outgoing connections to any port number, FTP operation proceeds smoothly.

A user can use the same commands with the PASV connection; however, the "csooked" connection of using the control commands is a lot more secure and manageable because an administrator can set which commands are accessible to the user.

The Data Port

The data port is where the FTP data (files) is sent to the FTP server (ftpd).

Note

The FTP server, ftpd (or in.ftpd), is a Unix server daemon. This may be different with other operating systems.

This differs from the control port, which is where a user interface sends commands. When you're transferring files via FTP, the files themselves, not the commands, are being sent through port 20, the data port.

Connections to the data port are known as *passive* connections, which have their own set of commands. All the data connection knows is the mode of the file, the type of the file, and the number of files transferred. You can also send only a portion of a file, even though there aren't very many practical uses for doing so.

When waiting for a connection, the passive data process listens on the data port (port 20) for a connection from the control process to open a data connection. The passive connection is opened at the same time as the control connection.

In this case, commands are sent through the control port. But, you can control the data port directly with the passive FTP commands.

Passive FTP Commands

The PASV command is not used by the user; the PORT command is the user interface. FTP servers are required to support passive commands (RFC 1123), although not all of them do.

You can call these commands by telnetting to port 21 like this:

```
tigerlair:/home/stripes- telnet localhost 21
```

Next, you'll see

```
Trying 1.2.3.4...
Connected to localhost.
Escape character is ë^]í
220 mysystem.tigerlair.com FTP server (SunOS 5.6) ready.
```

Next, all the commands you type will have to be passive commands.

Now, PWD will display your current directory:

```
PWD
257 "/home/stripes" is current directory.
```

If you use the CDUP passive FTP command, it will change you to the parent directory:

```
CDUP
250 CWD command successful.
```

Now, PWD will display your current directory:

```
PWD
257 "/home" is current directory.
```

You can now see the other users' home directories.

You won't see the commands appended at the beginning with PORT because you are not using the control port—instead, you are accessing the data port directly.

Connecting with FTP Clients

To open a connection with FTP, run the `ftp` command followed by the hostname. The syntax for FTP is

```
ftp [options] [hostname]
```

For example, if I want to FTP to `ftp.tigerlair.com`, I would run the following command:

```
tigerlair:/home/stripes- ftp ftp.example.org
```

If you want the FTP client to do something that it usually doesn't do, you would use one of the options. Table 30.1 lists the available options for FTP clients.

TABLE 30.1 FTP Command-Line Options

Option	*What It Does*
`-d`	Enables debugging
`-i`	Turns off prompting
`-n`	Disables auto-login
`-v`	Shows responses from remote server
`-g`	Disables wildcards (globbing)

If you wanted to use your FTP client to disable an auto-login (where the FTP client automatically prompts you for a username and login) that does not prompt during multiple file transfers, your command would be

```
ftp -i -n ftp.example.org
```

So, let's go back to the original example of using the FTP client without any options:

```
tigerlair:/home/stripes- ftp ftp.example.org
```

The next message you get should be this:

```
Connected to ftp.example.org.
220 ftp.example.org FTP Server (Version wu-2.4.2-VR16(1)
Wed Apr 7 15:59:03 PDT 1999) ready.
Name (ftp.example.org:stripes):
```

When you see this, you'll see that the default login FTP uses for the remote site is your local account name (in this case, `stripes`). If it is something different, you'll want to type it in here:

```
Connected to ftp.example.org.
220 ftp.example.org FTP Server (Version wu-2.4.2-VR16(1)
Wed Apr 7 15:59:03 PDT 1999) ready.
Name (ftp.example.org:stripes): ahc
Password:
```

Note

Do not use example.org as an FTP site. It is used for illustration purposes only. If you want to play with FTP without being destructive on a remote system, you can use your own by running an FTP client that connects to a local host. This assumes that the FTP server is running on the same machine as the client.

You'll be prompted for your password; make sure you type it correctly. It won't appear onscreen, and it won't even be masked with asterisks as you type.

Next, you should have an FTP prompt that looks like this:

```
ftp>
```

This will enable you to input commands to transfer files. This is known as the *command interpreter*.

FTP Command Interpreter

The FTP command interpreter enables you to be in an interactive mode with the FTP client. This enables you to send the client commands to open and close certain connections, transfer files, change the transfer file type, and so on without leaving FTP.

Table 30.2 lists commands available to you when you use FTP in interactive mode.

TABLE 30.2 FTP Commands

Option	*What It Does*
`!<local command>`	Executes a shell on the local system
`$<macro>`	Executes a macro
`account [password]`	Applies an extra user/password to get additional access to the remote system
`ascii`	Sets file transfer mode to ASCII
`append localfile [remotefile]`	Appends the localfile to the remotefile (file on the remote computer)
`bell`	Rings bell after file transfer
`binary`	Sets file transfer mode to binary
`bye`, `exit`	Exits, ending remote connection
`case`	Toggles case sensitivity
`close`, `disconnect`	Closes a remote connection
`cd <directory>`	Changes directory on remote system
`cdup`	Changes to the parent directory
`debug <level>`	Sets the debugging level
`dir`	Prints the directory
`delete <filename>`	Removes file from remote computer
`get <filename>`	Retrieves a file from the remote system to the local system
`glob`	Toggles wildcards for file transfer

TABLE 30.2 Continued

Option	*What It Does*
hash	Prints "#" for each 1,024 bytes transferred
help	Prints a help file
lcd <directory>	Changes directory on local system
ls	Prints directory of remote computer
lpwd	Prints working directory of local computer
macdef <macroname>	Defines a macro
mdel <filename(s)>	Deletes multiple files
mdir <filename(s)>	Prints directory listing of multiple files
mget <filename(s)>	Retrieves multiple files from the remote system to the local system
mkdir <directory>	Creates directory on remote computer
mput <filename(s)>	Transfers multiple files to remote computer
open <site>	Opens a connection to <site>
prompt	Interactive prompting control
put <filename>	Transfers file to remote computer
pwd	Displays present working directory
user [user] [password]	Logs in to the remote system
verbose	Toggles verbose mode

With all of these commands at your disposal, you'll find you can do a lot with FTP. To give you an idea of how all this information is used, the next section shows you an example of an FTP session.

An Example of an FTP Session

Not all of your FTP sessions will be this involved—this example is designed to show you some of the things you can do when you're using FTP. The first thing you'll want to do is open up access to a remote FTP site, as shown here:

```
tigerlair:/home/stripes- ftp ftp.example.org
Connected to ftp.example.org.
220 ftp.example.org FTP Server (Version wu-2.4.2-VR16(1)
Wed Apr 7 15:59:03 PDT 1999) ready.
Name (ftp.example.org:stripes): ahc
Password:
230 User ahc logged in.
ftp>
```

Now that you have access, you'll want to see what files are on the remote site. The two ways to list files are `ls` and `dir`. Note that we are making an FTP connection to a Unix system. Here's what an `ls` output looks like:

```
ftp> ls
200 PORT command successful.
150 ASCII data connection for /bin/ls (1.2.3.4,52262) (0 bytes).
ISS-SOLARIS.TAR
Mail
ar302sol.tar.Z
c-files.tar.gz
debug.ssh
deshadow.c
e205-pdf.pdf

226 ASCII Transfer complete.
468 bytes received in 0.0077 seconds (59.35 Kbytes/s)
ftp>
```

The `dir` command creates the following output:

```
ftp> dir
200 PORT command successful.
150 ASCII data connection for /bin/ls (1.2.3.4,52263)    (0 bytes).
total 56220
drwxr-xr-x  16 ahc    users   1536 May 25    09:22 .
drwxr-xr-x   6 root    other         512 Oct 27     1998 ..
-rw-------   1 ahc    users    168 May  7    11:26 .Xauthority
-rw-r--r--   1 ahc    users    424 Dec  2    14:43 .alias
-rw-r--r--   1 ahc    users    313 Jun  2     1998 .cshrc
drwxr-xr-x  11 ahc    users    512 May  7    11:27 .dt
-rwxr-xr-x   1 ahc    users   5111 Nov  2     1998 .dtprofile
drwx------   2 ahc    users    512 Jan 27    15:04 .elm
-rw-r--r--   1 ahc    users    174 Dec  2    14:45 .login
-rw-r--r--   1 ahc    users    556 Dec  2    15:32 .tcshrc
-rw-------   1 ahc    users3655680 Jan  4    08:27 ISS-SOLARIS.TAR
drwx------   2 ahc    users    512 Dec  8    16:01 Mail
-rw-r--r--   1 ahc    users5919933 Nov  3     1998 ar302sol.tar.Z
-rw-------   1 ahc    users  14605 May 13    10:43 c-files.tar.gz
-rw-------   1 ahc    users   1818 Mar  8    12:09 debug.ssh
-rw-r--r--   1 ahc    users   2531 Jan  7    10:07 deshadow.c
-rw-r--r--   1 ahc    users  54532 Nov 19     1998 e205-pdf.pdf
-rw-r--r--   1 ahc    users 898279 Jan  6    09:50 neotr122.zip
226 ASCII Transfer complete.
3830 bytes received in 0.047 seconds (79.06 Kbytes/s)
ftp>
```

Not only did this give you more information about the files listed in `ls`, but `dir` listed the Unix hidden files, or dot files, as well.

Note

On Unix, `ls` and `dir` will list your files, but `dir` will give you more information about the files, including last modification date, owner, permissions, and size. If you're making an FTP connection to a Windows NT/2000 or Windows 9x system, `ls` will work a little differently. You may want to use `dir` to list the files.

Now that you've seen a list of files, you want to get one from the remote system and place it in your local computer. You'll want to check your local directory to make sure you're putting the file in the right directory.

```
ftp> !pwd
/home/stripes
ftp>
```

You want to put these files in your home directory, which is where you are. Now, get the file:

```
ftp> get notes
200 PORT command successful.
150 ASCII data connection for notes (1.2.3.4,52264) (210 bytes).
226 ASCII Transfer complete.
local: notes remote: notes
226 bytes received in 0.019 seconds (11.81 Kbytes/s)
ftp>
```

The filename for the remote file does not change on the local system unless you specify the filename to change. To do that, use the following syntax:

```
get remotefilename localfilenameyouwant
```

So, if you want to get another file called `notes`, you'll want to rename one of the files. Now that you have a file called `notes` on your local system, you either want to rename it or rename the remote file when it hits your local system. In this case, call the second file you're getting `notes2`. You can see from the output that FTP will tell you what the local file is called and what the remote file is called.

```
ftp> get notes notes2
200 PORT command successful.
150 ASCII data connection for notes (1.2.3.4,52264) (210 bytes).
226 ASCII Transfer complete.
local: notes2 remote: notes
226 bytes received in 0.019 seconds (11.81 Kbytes/s)
ftp>
```

Those `notes` files are text files. You can see that FTP uses ASCII to transfer by default. This ensures that the files transferred are text files. What if you want to transfer a binary file? You can change the file type by telling FTP.

```
ftp> bin
200 Type set to I.
```

Type I is binary, and type A is ASCII. Binary files include executables, compressed files, and library files. Basically, a binary file is not readable by humans.

Now that you have your file type set to binary, you can transfer binary files.

```
ftp> get vr40a.exe windowsfile.exe
200 PORT command successful.
150 Binary data connection for vr40a.exe (1.2.3.4,52265) (2338635 bytes).
226 Binary Transfer complete.
local: windowsfile.exe remote: vr40a.exe
2338635    bytes received in 1.4 seconds (1593.23 Kbytes/s)
ftp>
```

Note that FTP will tell you whether your transfer is ASCII or binary. If you want to set the file type back to ASCII, just type, **`ascii`**.

```
ftp> ascii
200 Type set to A.
```

```
Insert code
```

Note

You should transfer text files in the ASCII mode because this takes account of the end-of-line conventions in different operating systems and does the end-of-line conversions automatically. For example, Unix systems use a single <LF>(line feed) as an end-of-line character. On the other hand, Windows systems use a <CR><LF> combination character sequence where <CR> is the Carriage Return and <lf> is the Line Feed character. When you transfer a file from a Unix system to a Windows system in the ASCII mode, the extra carriage return will automatically be added for the end of the line. Similarly, when you transfer a file in the ASCII mode from a Windows to a Unix system, the extra carriage return for the end of line will be removed.

Because main frames do use the EBCDIC code instead of the ASCII code for characters, you must use the `ebcdic` command instead of the `ascii` command for mainframes.

Transferring a binary file in the ascii mode is a mistake, because this will perform end-of-line conversions which can add or remove carriage return characters in the transferred file. Altering a binary file will corrupt it.

This works well if you want to get one file. What do you do if you want to get multiple files? If you want to get every file that begins with "s", for example, you use `get s*`. Unfortunately, your result is the following:

```
ftp> get s*
550 s*: No such file or directory.
```

The response shows that this does not work. For FTP to recognize "globbing" or wildcards, you need to use `mget` to get multiple files, as shown in the following:

```
ftp> mget s*
mget s3-Solaris.tar?
```

Notice that prompting is enabled by default, and occurs any time you ask to `get` or `put` multiple files. Now to get every file that follows, you need to type **y** after being prompted to get the file:

```
mget s3-Solaris.tar? y
200 PORT command successful.
150 ASCII data connection for s3-Solaris.tar
(127.0.0.1,52452) (0 bytes).
226 ASCII Transfer complete.
mget sendmail.8.9.2.tar.gz? y
200 PORT command successful.
150 ASCII data connection for sendmail.8.9.2.tar.gz
(127.0.0.1,52453) (0 bytes).
226 ASCII Transfer complete.
mget solsniffer.c? y
200 PORT command successful.
150 ASCII data connection for solsniffer.c
(127.0.0.1,52454) (0    bytes).
226 ASCII Transfer complete.
mget spade110.exe? y
200 PORT command successful.
150 ASCII data connection for spade110.exe
(127.0.0.1,52455) (8192 bytes).
226 ASCII Transfer complete.
mget sun-sniff.c? y
200 PORT command successful.
150 ASCII data connection for sun-sniff.c
(127.0.0.1,52456) (8192 bytes).
226 ASCII Transfer complete.
ftp>
```

Responding with a 'y' is tedious, especially if you're trying to get a large number of files. To get rid of the prompting, type **prompt**.

```
ftp> prompt
Interactive mode off.
```

Now, if you do the same command again, you won't get prompted—thus, the file transfer moves a lot faster:

```
ftp> mget s*
200 PORT command successful.
150 ASCII data connection for s3-Solaris.tar
(127.0.0.1,52458) (0 bytes).
226 ASCII Transfer complete.
200 PORT command successful.
150 ASCII data connection for sendmail.8.9.2.tar.gz
(127.0.0.1,52459) (0 bytes).
226 ASCII Transfer complete.
200 PORT command successful.
150 ASCII data connection for solsniffer.c
(127.0.0.1,52460) (0 bytes).
226 ASCII Transfer complete.
200 PORT command successful.
150 ASCII data connection for spade110.exe
(127.0.0.1,52461) (0 bytes).
226 ASCII Transfer complete.
200 PORT command successful.
150 ASCII data connection for sun-sniff.c
(127.0.0.1,52462) (0 bytes).
226 ASCII Transfer complete.
ftp>
```

This is much quicker and less tedious than using the prompting mode.

Note

If you are going to overwrite a file (in the preceding example, you did, but with the same file), FTP will not warn you ahead of time that you're going to overwrite a file.

Now that you've learned how to download files, you should learn to upload files to a remote FTP server. To do this, use the command `put`:

```
ftp> mput h2obj.jpg
200 PORT command successful.
150 Binary data connection for h2obg.jpg (1.2.3.4,52270).
226 Transfer complete.
local: h2obg.jpg remote: h2obg.jpg
1194 bytes sent in 0.019 seconds (60.82 Kbytes/s)
ftp>
```

This will send a local file to a remote system. If you want to send more than one file, use `mput`:

```
ftp> mput dd*
mput debug.ssh? y
200 PORT command successful.
150 ASCII data connection for debug.ssh    (1.2.3.4,52266).
226 Transfer complete.
mput deshadow.c? y
200 PORT command successful.
150 ASCII data connection for deshadow.c (1.2.3.4,52267).
226 Transfer complete.
ftp>
```

Just like `mget`, you need to turn off prompting so you do not have to type "y" or "n" for each file you want to transfer:

```
ftp> prompt
Interactive mode off.
ftp> bin
200 Type set to I.
ftp> mput k*
200 PORT command successful.
150 Binary data connection for kayaking.jpg (1.2.3.4,52268).
226 Transfer complete.
200 PORT command successful.
150 Binary data connection for key.tar (1.2.3.4,52269).
226 Transfer complete.
ftp>
```

Note

If a command involves transferring files (`get`, `put`, or `delete`), just put an "m" in front of it to transfer multiple files.

Note

Before uploading files using FTP, you must have permissions to copy files to the remote FTP server. FTP uses the remote FTP server's authentication system when you log on as an FTP user. This means that if you are logging on as user linda, the user account linda must exist on the remote FTP server. If linda wants to upload files, she must have the "write" permission to the directory where she wants to upload files.

On TFTP servers, you need to additionally ensure that a filename already exists that will be overwritten by the uploaded file. You need to have access to the remote system with sufficient permission to create an empty file. On Unix systems, you can create an empty file by issuing the touch command:

```
touch nameoffile
```

Some development tools (such as the Borland C++ compiler for Windows) also contain the Windows version of the 'touch' utility.

If you want to get rid of a file on the remote system (and you have the permissions to do so), you can delete it very easily. You can use the `delete` command, which can be abbreviated `del`:

```
ftp> del h2obg.jpg
250 DELE command successful.
ftp>
```

If you want to delete multiple files, use `mdel`. Again, the prompt command has the same effect on `mdel` as it does on `mget` or `mput`.

```
ftp> mdel s*
250 DELE command successful.
250 DELE command successful.
250 DELE command successful.
ftp>
```

Note

As with overwriting a file, you are not warned that you are about to delete a file on the remote system.

Not only can you move files back and forth between the remote and local systems, but you can also create and remove directories. To create a directory, use the `mkdir` command:

```
ftp> mkdir morestuff
257 MKD    command    successful.
```

You can also move around in different directories. Similar to Unix and Windows command line (the command interpreter formerly known as DOS), you use `cd` to change between directories.

```
ftp> cd     morestuff
250 CWD    command    successful.
```

If you're lost and you want to see which directory you're in, use the `pwd` command for the remote system:

```
ftp> pwd
257 "/home/ahc/morestuff" is current directory.
```

If you are doing file transfers for a big file, you may want to enable hashing. This will show you that FTP is still awake even though it may be sitting there idle for minutes or even hours on end. To do this, just type **`hash`**:

```
ftp> hash
Hash mark printing on (8192 bytes/hash mark).
```

If you `put` or `get` a file with hashing, you can see its progress through the file transfer:

```
ftp> put sendmail.8.9.2.tar.gz
200 PORT command successful.
150 Binary data connection for sendmail.8.9.2.tar.gz (1.2.3.4,52271).
#################################################################
226 Transfer complete.
local: sendmail.8.9.2.tar.gz remote: sendmail.8.9.2.tar.gz
1063534    bytes sent in 0.56 seconds (1870.03 Kbytes/s)
ftp> pwd
```

If you're done using this site, but you don't want to exit FTP—you just want to close the connection. Type **`close`**, and you will disconnect from the remote system but stay at the FTP command interpreter:

```
ftp> close
221 Goodbye.
ftp>
```

Note that you still have your `ftp>` prompt. So, to open a connection to another host, use the `open` command:

```
ftp> open another-example.org
Connected to another-example.org.
220 another-example.org FTP server (SunOS 5.6) ready.
Name (localhost:ahc):
331 Password required for ahc.
Password:
230 User ahc logged in.
ftp>
```

Now you're on a totally different system. You can do the same commands, but what you find should be different than the first system you were on.

When you're completely done with FTP, just type **`quit`** or **`bye`**, as shown here:

```
ftp> quit
221 Goodbye.
```

FTP Security

Even though FTP is about being able to access files, you don't want to enable someone to make a mess of your system. FTP comes with some basic access control, but it does not solve the fundamental security problems with FTP.

FTP always uses clear-text authentication, meaning that your passwords are sent non-encrypted through the network. This is a very big security problem. Improperly configured anonymous FTP environments that allow users to snoop around areas that they shouldn't be able to access, and having two ports open for the FTP server instead of just one like most TCP/IP network services, are also security problems.

Another important aspect of FTP security is the fact that FTP uses the local operating system user account and password information for authentication unless you are logging on as an anonymous user. Because FTP sends password information as plain text, the regular user account password can be compromised.

The `/etc/ftpusers` File

If you want to control who has access to a specific account on your FTP server, you'll want to use the `/etc/ftpusers` file. This file contains a list of users who cannot use FTP. It does not restrict the users from other applications including rsh, telnet, and Secure Shell (ssh).

A good `/etc/ftpusers` file should look something like this:

```
tigerlair:/home/stripes- cat /etc/ftpusers
root
uucp
bin
```

This should keep the administrative accounts and accounts you don't want from trying to exploit FTP.

Using `.netrc`

The `.netrc` file is used for automating logging into a remote host for FTP. This file sits in the user's home directory and is used to get to different systems without typing in a username or password. The file should have the permissions 700 (with no one able to read or write to it except for the owner).

The file format for the `.netrc` file looks like this:

```
machine <machinename> login <username> password <mypassword>
```

So, if I wanted to set one up for example.org, it would look something like this:

```
tigerlair:/home/stripes- cat .netrc
machine example.org login ahc password stuff
```

Because `.netrc` is popular for logging into accounts, it can be used safely for anonymous FTP sites, which do not require a password other than your e-mail address. Also, anonymous FTP sites only provide you with public information—nothing you should be privy to without a password.

Caution

In the world we live in today, having a `.netrc` file is a bad idea. It contains passwords readable by anyone, and therefore, an account can be compromised quite easily.

Using Different FTP Clients

The preceding example is the standard FTP client that comes with operating systems such as Unix, Windows, and VMS. Additionally, it should function in a similar fashion with few differences depending on what operating system you're using. The following sections cover some of these differences.

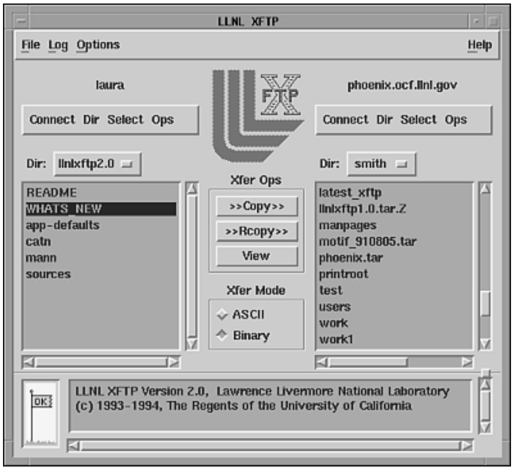
Unix

On Unix, two different FTP clients can provide more functionality than a vanilla FTP client can: `Ncftp` and `xftp`.

`Ncftp` automates anonymous FTP logins, so you don't have to type a password (being your e-mail address) or have to worry about keeping a `.netrc` file. It also provides some text-based graphics that include a status bar on file transfers and has additional benefits including command-line editing. `Ncftp` is available at `http://www.ncftp.com`.

The `xftp` program provides a graphical user interface (GUI) to the FTP client. This enables you to use an FTP client without dealing directly with the command interpreter. See Figure 30.3 for a screen shot of `xftp`. The `xftp` program is available from `http://www.llnl.gov/ia/xdir_xftp/xftp.html`.

FIGURE 30.3
A screenshot of an active `xftp` *session.*



Windows and Macintosh Clients

There are a few Windows and Macintosh FTP clients. Many of them have GUIs similar to `xftp`, which allows you to drag and drop files to and from the remote and local systems.

There is also a command-line feature FTP for some implementations of Windows. Others will pop up an Internet Explorer window, which does not give you full FTP functionality.

Table 30.3 is a partial list of the FTP clients for Windows and Macintosh.

TABLE 30.3 FTP Clients for Windows and Macintosh

FTP Client	*Web Site*
WS-FTP Pro	`http://www.ipswitch.com`
fetch	`http://www.dartmouth.edu/pages/softdev/fetch.html`
CuteFTP	`http://www.cuteftp.com`
FTPPro2000	`http://www.ftppro.com`

E-mail

Believe it or not, you can use an FTP client through e-mail. FTPmail makes FTP available to users with only e-mail access to the Internet. This way someone with only e-mail access can obtain files from an FTP site without having to use FTP directly.

Some servers on the Internet offer an FTPmail service to Internet users. These servers have an FTPmail account, and users can include FTP requests in e-mail messages addressed to this account (they would use commands similar to the command interpreter for FTP).

FTP sessions are carried out in response to the mailed FTP requests, and the results are sent back to users via their e-mail address. If FTPmail fails to connect to the FTP server, an e-mail message is sent to the user explaining why it failed.

Several sites offer the FTPmail service, and anyone with access to e-mail can use them. Please use the service in your country.

Table 30.4 lists some of the FTPmail servers and where they are located.

TABLE 30.4 FTPmail Servers

FTPmail Server	*Country*
`ftpmail@grasp.insalyon.fr`	France
`ftpmail@doc.ic.ac.uk`	United Kingdom
`ftpmail@decwrl.dec.com`	United States

FTP Servers and Daemons

After you have an understanding of the FTP client, you can get a better understanding of the FTP server and how it functions. Because FTP has to be controlled by a server, you should keep in mind some basic things about running an FTP server.

Unix and Linux

On Unix and Linux, the FTP daemon, `in.ftpd`, is usually run by the Internet Super-daemon, `inetd`. Because `inetd` listens for the connection instead of the `in.ftpd`, it's able to manage connections more securely. For more information on `inetd`, see Chapter 39, "Protocol Configuration and Tuning."

So, in `/etc/inetd.conf`, you will have a line that looks like this:

```
ftp    stream tcp        nowait root    /usr/sbin/in.ftpd.    in.ftpd
```

This is the line that starts `in.ftpd`. You can pass `in.ftpd` some options, including `-d` for debugging, `-l` for logging to syslogd, and `-t` to change the inactivity timeout period.

Windows NT/2000

There are FTP servers for NT/2000 and Windows 95 and 98 as well. This includes FTP Serv-U (available at `http://www.ftpserv-u.com`) and War FTP daemon (available at `http://www.jgaa.com/tftpd.htm`).

Anonymous FTP Access

Anonymous FTP sites are an important part of the Internet, even today with the popularity of the Web. An infinite number of anonymous FTP sites are available to retrieve various information, files, and software. One of the most popular anonymous FTP sites is `wuarchive.wustl.edu`.

Many anonymous FTP sites have files publicly available because they are trying to distribute files without the inconvenience of issuing passwords and usernames to the growing number of people on the Internet.

Anonymous FTP Servers

Anonymous FTP servers provide a public site for files. Back before the Web became the driving force of the Internet, gopher (a menu-driven Internet application) and FTP were the main ways people obtained files and information from the Internet.

As a result, anonymous FTP became very popular, and it is still used today. Anonymous FTP servers need to have a separate environment and disk space that is completely separate from the system files. This is known as a `chrooted` environment.

For example, a Unix system will have `/usr` and `/etc` directories. So will the anonymous FTP server on the Unix system. But the files stored in the `/etc` directory of the Unix system are *not* the same as the `/etc` directory in the anonymous FTP server. This is because ftp clients access is limited to the home directory of the ftp user account, which is typically `/home/ftp`. The `/etc` and `/public` files of the FTP server are under `/home/ftp`, and appear as `/home/ftp/etc` and `/home/ftp/public`.

Keep in mind that this means that system files are not stored in the anonymous FTP directory. This environment is set aside specifically for FTP to create an environment that is completely separate from the vital parts of the operating system.

Anonymous FTP Clients

For convenience, anonymous FTP allows people to enter "anonymous" or "ftp" as a username, and an e-mail address for the password (`stripes@tigerlair.com`, for example).

There are also access restrictions for anonymous FTP. Usually the users are only allowed to access public files, not system or configuration files for security reasons.

The following illustrates an anonymous FTP session and an example of a banner for an anonymous FTP site:

```
tigerlair:/home/stripes- ftp wuarchive.wustl.edu
Connected to wuarchive.wustl.edu.
220 wuarchive.wustl.edu FTP server (Version wu-2.4.2-academ[BETA-16]
```

```
(1) Wed Apr 1 08:28:10 CST 1998) ready.
Name (wuarchive.wustl.edu:stripes): anonymous
331 Guest login ok, send your complete e-mail address as password.
Password:
230-  If your FTP client crashes or hangs shortly after login please try
230-  using a dash (-) as the first character of your password.  This
230-  will turn off the informational messages that may be confusing your
230-  FTP client.
230-
230-  This system may be used 24 hours a day, 7 days a week.  The local
230-  time is Wed May 26 12:02:37 1999.  You are user number 23 out of a
230-  possible 500.  All transfers to and from wuarchive are logged.  If
230-  you don't like this then please disconnect.
230-
230-  Wuarchive is currently a Sun Ultra Enterprise 2 Server.
230-
230-  Wuarchive is connected to the Internet over a T3 (45Mb/s) line from
230-  STARnet and MCI. Thanks to both of these groups for their support.
230-
230-  Welcome to wuarchive.wustl.edu, a public service of Washington
230-  University in St. Louis, Missouri USA.
230-
230-
230-
230 Guest login ok, access restrictions apply.
Remote system type is Unix.
Using binary mode to transfer files.
ftp>
```

Because of the popularity of the Web, many anonymous FTP sites are used through a Web browser instead of the FTP client itself.

Tip

You don’t have to type your entire e-mail address as a password. You only need to type

```
yourusername@
```

For example, you could enter

```
stripes@
```

instead of

```
stripes@tigerlair.com
```

Using TFTP

TFTP can be used to transfer files within a Local Area Network. TFTP is Trivial FTP, which is used for transferring files as well. TFTP uses UDP as its transport protocol and transmits data on UDP port 69.

Because TFTP does not use any form of login validation by usernames, TFTP has its share of security problems. Today the most common usage is to send router access lists from the workstation to the router itself or configure the router. It is also used to boot diskless systems by downloading the operating system for the diskless system from a TFTP server. One advantage of TFTP over FTP is that it is simpler and less complex (also has less features) than FTP, and is easy to embed in the ROM of network cards for a diskless workstation.

Caution

Do not turn on TFTP unless you absolutely need it. It has some security issues, including accessibility to your password files, if you're not careful. By default, TFTP is restricted to the `/tftpboot` directory as a rudimentary form of security. If you disable this restriction, a TFTP client can have access to other parts of the filesystem without going through authentication. A dangerous situation!

TFTP is currently in version 2, and is specified in RFC1350. Unlike FTP, which uses TCP, TFTP uses UDP. As a result, TFTP is simple and compact. Like FTP, TFTP is run through `inetd`.

Each packet exchange between the client and the server begins with a client request to the server to read or write a file. Those are the only choices.

Files are transferred in either *octet* or *netascii* mode. In netascii mode, data lines consist of ASCII text terminated by a carriage return and line feed (CR/LF).

How TFTP Differs from FTP

TFTP does not have the functionality that FTP does. For example, TFTP does not give you the ability to use wildcards, create or remove directories, or even remove files. It also does not prompt you for a username or password; thus, access is restricted by other means (TCP Wrappers, for example).

Because of its simplicity, routers use TFTP to transfer access lists and router configurations through this protocol. Because routers do not have logins (unless you're running TACACS+ or RADIUS for access control), it's easier to work on an editor than to manually type in each line on a router.

TFTP Commands

If you understand FTP, TFTP will not be difficult to pick up. TFTP has very few commands, which are listed in Table 30.5. Many of them are similar to FTP.

TABLE 30.5 TFTP Commands

Command	*Description*
`ascii`	Sets mode to netascii (text)
`binary`	Sets mode to octet (non-text)
`connect`	Connects to remote TFTP
`mode`	Sets file transfer mode
`put`	Sends file to the remote site
`get`	Gets a file from the remote site
`quit`	Exits TFTP
`rexmt <value>`	Sets per-packet value for timeout
`status`	Shows the status of the server
`timeout <seconds>`	Sets transmission timeout (seconds)
`trace`	Turns on packet tracing
`verbose`	Toggles verbosity

Summary

File transfers are important for sending files to different systems on a TCP/IP network. TCP/IP uses the File Transfer Protocol (FTP) and the Trivial File Transfer Protocol (TFTP) as the main ways to send files through a TCP/IP network.

FTP, which uses TCP to transfer files, requires that two ports be open: port 20 for the data port and port 21 for the control port. The data port is used only for transferring files, whereas the control port is used to send commands and messages.

TFTP, which uses UDP to transfer files, requires that only port 69 be open for TFTP. TFTP is a much simpler protocol than FTP, and does not have as much functionality. However, TFTP is commonly used with routers to manage access lists and configurations. It is also used to boot diskless systems.

In the next chapter, Telnet is discussed. This will give you more of an understanding of another type of interactive TCP/IP network service.

CHAPTER 31

Using Telnet

by Neal S. Jamison

In This Chapter

- **Understanding the Telnet Protocol** *770*
- **The Telnet Daemon** *773*
- **Using Telnet** *774*
- **Advanced Topics** *780*

Although terminal emulation isn't used as widely today as it once was, it is still a necessary tool for accessing shell accounts and other multiuser systems. Telnet is also used as the basis of other protocols such as X-Windows that establish a session with an X-client. Telnet is the ultimate thin client because all execution takes place on the Telnet server. Telnet is often used as a troubleshooting tool as well. This chapter discusses the terminal emulation service of the Internet: the TCP/IP Telnet protocol and its associated programs.

Understanding the Telnet Protocol

Telnet is one of the original TCP/IP protocols. In fact, RFC 15 (written in 1969!) provides some interesting reading on the subject. Telnet is currently specified in RFC 854.

The Telnet protocol was created to simplify the connection to remote hosts. If you had an IBM mainframe, you needed IBM terminals to connect to that mainframe. If you had a DEC, you needed DEC terminals. The result was similar to the diagram in Figure 31.1.

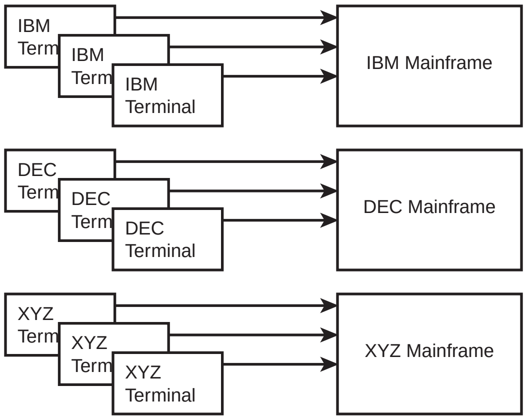


FIGURE 31.1
An unwieldy network prior to the creation of Telnet.

What was needed was a terminal emulation service that could speak all the proprietary language sets. This would allow a user to sit at one terminal and work on many disparate host systems. Enter Telnet.

Telnet is the standard Internet application protocol for logging in to remote hosts. It provides the encoding rules and other services necessary to link a user's system with a remote host.

Telnet uses the reliable TCP transport mechanism because it must maintain a reliable, stable connection. The Telnet server listens, by default on well-known TCP port 23. The Telnet client can be configured to connect to any other port on which another service is running. This enables you to use the Telnet client to send commands to a specific application service. This technique enables Telnet to be used for troubleshooting the application services.

Telnet can operate in any of the following modes:

- Half Duplex
- Character-at-a-time
- Line-at-a-time (a.k.a. Kludge Line Mode)
- Linemode

Half Duplex mode is obsolete.

In Character-at-a-time mode, each character typed is immediately sent to the remote host for processing and then echoed back to the client. This can be painfully cumbersome over slow networks, but is a common default with many implementations.

In Line-at-a-time mode, text is echoed locally, and completed lines are sent to the remote host for processing.

In Linemode, character processing is done on the local system, under the control of the remote system.

Additional details on Telnet can be found in the following RFCs:

15 Network subsystem for time sharing hosts. C.S. Carr. 1969.

854 Telnet Protocol Specification. J. Postel, J.K. Reynolds. 1983.

855 Telnet Option Specifications. J. Postel, J.K. Reynolds. 1983.

856 Telnet Binary Transmission. J. Postel, J.K. Reynolds. 1983.

857 Telnet Echo Option. J. Postel, J.K. Reynolds. 1983.

858 Telnet Suppress Go Ahead Option. J. Postel, J.K. Reynolds. 1983.

859 Telnet Status Option. J. Postel, J.K. Reynolds. 1983.

860 Telnet Timing Mark Option. J. Postel, J.K. Reynolds. 1983.

861 Telnet Extended Options: List Option. J. Postel, J.K. Reynolds. 1983.

1123 Requirements for Internet hosts—application and support. R.T. Braden. 1989.

1184 Telnet Linemode Option. D.A. Borman. 1990.

1205, 5250 Telnet interface. P. Chmielewski. 1991.

1372 Telnet Remote Flow Control Option. C. Hedrick, D. Borman. 1992.

1408 Telnet Environment Option. D. Borman, Editor. 1993.

1411 Telnet Authentication: Kerberos Version 4. D. Borman, Editor. 1993.

1412 Telnet Authentication: SPX. K. Alagappan. 1993.

1416 Telnet Authentication Option. D. Borman, Editor. 1993.

1571 Telnet Environment Option Interoperability Issues. D. Borman. 1994.

1572 Telnet Environment Option. S. Alexander. 1994.

2066 TELNET CHARSET Option. R. Gellens. 1997.

2217 Telnet Com Port Control Option. G. Clark. 1997.

For some slightly less-serious Telnet information, refer to the following RFCs:

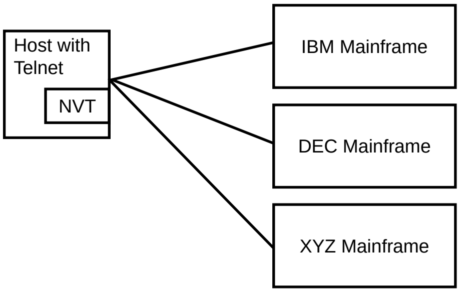
748 Telnet randomly-lose option. M.R. Crispin. 1978.

1097 Telnet subliminal-message option. B. Miller. 1989.

The Network Virtual Terminal

Because we use many different types of computers with many different keyboards as well as other input devices, Telnet's task is non-trivial. Our input devices and computers speak a variety of languages, from different dialects of ASCII to EBCDIC. This makes interoperability very difficult. The *Network Virtual Terminal* (NVT) was created to simplify this problem. Clients, servers, and their respective network virtual terminals work as depicted in Figure 31.2.

FIGURE 31.2
Terminal-to-host connections simplified by Telnet and the NVT.



The NVT takes the input from the client system and converts it into a universal language. The NVT on the host end takes the universal language and converts it into the proprietary language understood by the host.

The NVT allows any proprietary client to talk with any proprietary host, and vice versa.

The Telnet Daemon

As with other TCP/IP client/server services, Telnet depends on the presence of a daemon to respond to client requests. In the Unix world, that daemon is `telnetd` (or `in.telnetd`). The Telnet daemon is the Telnet server that responds to requests from the Telnet client. By default, the Telnet daemon runs on port 23.

The following usage and option information for `in.telnetd` was taken from the Linux operating system man page. Please consult your operating system documentation or man pages for more information specific to your implementation.

Usage: `/usr/sbin/in.telnetd [-hns] [-a authmode] [-D debugmode] [-L loginprg] [-S tos] [-X authtype] [-edebug] [-debug port]`

Options:

`-a authmode`—Specifies the mode to use for authentication. Note that this option is only useful if `telnetd` has been compiled with support for authentication. The following are valid values for `authmode`:

- `debug`—Enables authentication debugging.
- `user`—Only allows connections when the remote user can provide valid authentication information to identify the remote user, and is allowed access to the specified account without providing a password.
- `valid`—Only allows connections when the remote user can provide valid authentication information to identify the remote user.
- `other`—Only allows connections that supply some authentication information.
- `none`—This is the default state. Authentication information is not required.
- `off`—Disables the authentication code.

`-D debugmode`—This option may be used for debugging purposes. This allows `telnetd` to print out debugging information to the connection, allowing the user to see what `telnetd` is doing. There are several possible values for `debugmode`:

- `options`—Prints information about the negotiation of telnet options.
- `report`—Prints the options information, plus some additional information about what is going on.
- `netdata`—Displays the data stream received by telnetd.
- `ptydata`—Displays data written to the pseudo-terminal.

`-e debug`—Enables encryption debugging.

`-h`—Disables the printing of host-specific information before login has been completed.

`-L loginprg`—This option may be used to specify a different login program. By default, `/bin/login` is used.

`-n`—Disables TCP keep-alives. Normally, `telnetd` enables the TCP keep-alive mechanism to probe connections that have been idle for some period of time to determine whether the client is still there, so that idle connections from machines that have crashed or can no longer be reached can be cleaned up.

`-s`—This option is only enabled if `telnetd` is compiled with support for SecurID cards. It causes the `-s` option to be passed on to `login`, and thus is only useful if `login` supports the `-s` flag to indicate that only SecurID validated logins are allowed. This is usually useful for controlling remote logins from outside a firewall.

`-S tos`—Sets the IP type-of-service (TOS) option for the Telnet connection to the value `tos`.

`-X authtype`—This option is only valid if `telnetd` has been built with support for the authentication option. It disables the use of `authtype` authentication, and can be used to temporarily disable a specific authentication type without having to recompile `telnetd`.

Using Telnet

Telnet is very simple to use. In fact, its use typically consists of three very simple tasks:

- Run a Telnet client command to initiate the session.
- Enter a login ID and password.
- When you are done, terminate the session.

Telnet has two modes: input and command. However, in most situations, the only user interaction with Telnet is in starting and stopping the session and working within the remote operating system or program through input mode.

The Unix `telnet` Command

This section discusses the usage and options associated with a Linux implementation of `telnet`. You will find that most implementations are very similar; however, you should check your documentation or man page for information specific to your `telnet` command. The following shows the syntax of the `telnet` command:

Usage: `telnet [-8ELadr] [-S tos] [-e escapechar] [-l user] [-n tracefile] [host [port]]`

Options:

-8—Requests 8-bit operation.

-E—Disables the escape character functionality.

-L—Specifies an 8-bit output data path.

-a—Attempts automatic login. Passes the username via the USER variable if supported by the remote host.

-d—Sets the initial value of the debug toggle to TRUE.

-r—Emulates rlogin.

-S tos—Sets the IP type-of-service (TOS) option for the Telnet connection to the value specified by tos.

-e escapechar—Sets the escape character to the value specified by escapechar.

-l user—Specifies user as the user to log in as on the remote system. Similar to the -a option.

-n tracefile—Opens tracefile for recording trace information.

Host—Specifies a host to contact over the network.

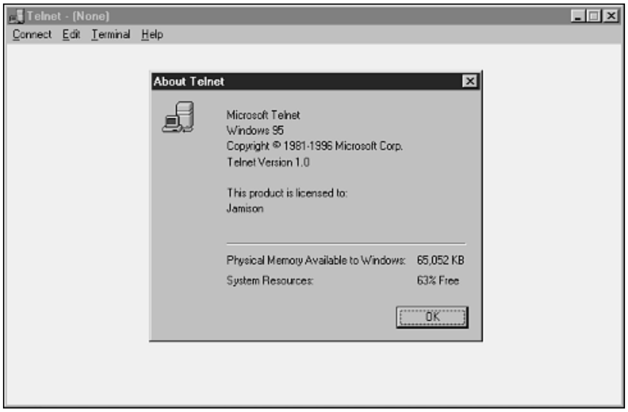
Port—Specifies a port number or service name to contact. If not specified, the well-known port 23 is used.

Telnet GUI Applications

Several popular GUI Telnet applications can provide non-Unix users with the client program and make using Telnet even easier. Two popular versions are Microsoft Telnet and CRT. Microsoft Telnet comes with the Microsoft Windows operating system (Windows NT/2000, Windows 98, and so on). CRT is a shareware application from VanDyke Technologies that is easily downloaded from common Windows shareware Web sites.

Figures 31.3 and 31.4 show these two applications in action.

FIGURE 31.3
The very common Microsoft Telnet application.



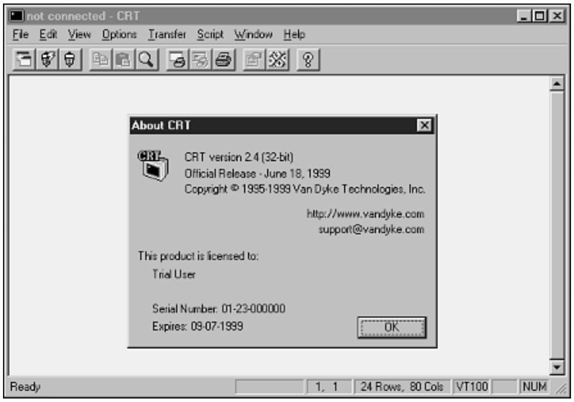


FIGURE 31.4
Another popular terminal emulation application. (CRT by Van Dyke Technologies, Inc.)

Telnet Commands

Due to Telnet's simple user interface, there is really no reason for the general user to issue any of the following commands. As mentioned earlier, most (if not all) of your Telnet session will be spent in input mode, talking to the remote operating system or program. Advanced users or systems administrators may find some of the commands (such as `TOGGLE`) helpful when troubleshooting problems.

You can retrieve the Telnet commands by executing the `HELP` command while in command-line mode. For example:

```
$ telnet
telnet> help
Commands may be abbreviated.  Commands are:

close           close current connection
logout          forcibly logout remote user and close the connection
display         display operating parameters
mode            try to enter line or character mode ('mode ?' for more)
open            connect to a site
quit            exit telnet
send            transmit special characters ('send ?' for more)
set             set operating parameters ('set ?' for more)
unset           unset operating parameters ('unset ?' for more)
status          print status information
toggle          toggle operating parameters ('toggle ?' for more)
slc             set treatment of special characters

z               suspend telnet
environ         change environment variables ('environ ?' for more)
telnet>
```

You can get help on any specific command by issuing the command followed by a ?, as in the following example:

```
telnet> mode ?
format is:  'mode Mode', where 'Mode' is one of:

character       Disable LINEMODE option
                (or disable obsolete line-by-line mode)
line            Enable LINEMODE option
                (or enable obsolete line-by-line mode)

                These require the LINEMODE option to be enabled
isig            Enable signal trapping
-isig           Disable signal trapping
edit            Enable character editing
-edit           Disable character editing
softtabs        Enable tab expansion
-softtabs       Disable character editing
litecho         Enable literal character echo
-litecho        Disable literal character echo

?               Print help information
telnet>
```

Table 31.1 describes the complete Telnet command set.

Note

The Telnet command and option information found in Tables 31.1, 31.2, and 31.3 was gathered from the Linux operating system man page for `telnet`. Please consult your operating system documentation or man pages for more information specific to your implementation.

TABLE 31.1 Telnet Commands

Command	*Description*
`CLOSE`	Closes the connection to the remote host.
`DISPLAY`	Displays specified operating parameters.
`ENVIRON`	Changes or propagates environment variables.
`HELP` (or `?`)	Shows helpful information (also, `COMMAND ?` can be issued to get help on a specific command).
`LOGOUT`	Forcibly logs out the remote user and closes the connection. Similar to `CLOSE`.
`MODE`	Asks the server to enter line or character mode.

TABLE 31.1 Continued

Command	*Description*
`OPEN`	Opens a connection to the specified host.
`QUIT`	Closes the session and exits Telnet.
`SEND`	Transmits special protocol character sequences. See Table 31.3 for `SEND` sequences.
`SET`	Sets operating parameters. See also `UNSET`.
`SLC`	(Set Local Characters) Sets definition and/or treatment of special characters.
`STATUS`	Shows current status information such as hostname, mode, and so on.
`TOGGLE`	Toggles operating parameters. See Table 31.2 for some common parameters.
`UNSET`	Unsets operating parameters. See also `SET`.
`Z`	Suspends Telnet (the suspended command can be resumed with `fg`).
`! [command]`	Executes the specified shell command. If no command is specified, a sub-shell is opened.

Some of the Telnet commands, such as `TOGGLE` and `SEND`, require further options. Table 31.2 lists some of the common Telnet `TOGGLE` command options, and Table 31.3 lists the Telnet `SEND` command option set.

The `TOGGLE` command toggles (TRUE or FALSE) specified options.

TABLE 31.2 A Few Common Telnet `TOGGLE` Options

Command	*Description*
`debug`	Toggles socket level debugging. The initial value for this toggle is FALSE.
`skiprc`	When the `skiprc` toggle is TRUE, Telnet does not read the `.telnetrc` file. The initial value is FALSE.
`?`	Displays the legal toggle commands.

The `SEND` command is used to transmit commands and options to the remote host. Table 31.3 lists the `SEND` command options.

TABLE 31.3 Telnet `SEND` Command Options

Command	*Description*
`EOF`	End-of-file
`SUSP`	Suspend current process (job control)
`ABORT`	Abort process

TABLE 31.3 Continued

Command	*Description*
EOR	End of record
SE	Suboption end
NOP	No operation
DM	Data mark
BRK	Break
IP	Interrupt process
AO	Abort output
AYT	Are you there?
EC	Escape character
EL	Erase line
GA	Go ahead
SB	Suboption begin
WILL	Option negotiation
WONT	Option negotiation
DO	Option negotiation
DON'T	Option negotiation
IAC	Data byte 255

Examples of Using Telnet

The following example demonstrates the negotiation that goes on behind the scenes. This verbose output is achieved by using the `TOGGLE OPTIONS` command:

```
% telnet
telnet> toggle options
Will show option processing.
telnet> open host1.mydomain.com
Trying...
Connected to host1.mydomain.com.
Escape character is '^]'.
SENT DO SUPPRESS GO AHEAD
SENT WILL TERMINAL TYPE
SENT WILL NAWS
SENT WILL TSPEED
SENT WILL LFLOW
SENT WILL LINEMODE
SENT WILL NEW-ENVIRON
```

```
SENT DO STATUS
RCVD DO TERMINAL TYPE
RCVD DO TSPEED
RCVD DO XDISPLOC
SENT WONT XDISPLOC
RCVD DO NEW-ENVIRON
RCVD WILL SUPPRESS GO AHEAD
RCVD DO NAWS
SENT IAC SB (terminated by -1 -16, not IAC SE!) NAWS 0 95 (95) 0 29 (29)
RCVD DO LFLOW
RCVD DONT LINEMODE
RCVD WILL STATUS
RCVD IAC SB (terminated by -1 -16, not IAC SE!) TERMINAL-SPEED SEND
RCVD IAC SB (terminated by -1 -16, not IAC SE!) ENVIRON SEND
SENT IAC SB (terminated by -1 -16, not IAC SE!) ENVIRON IS
RCVD IAC SB (terminated by -1 -16, not IAC SE!) TERMINAL-TYPE SEND
RCVD DO ECHO
SENT WONT ECHO
RCVD WILL ECHO
SENT DO ECHO

Access to this system is restricted to authorized users only.
login:
```

Advanced Topics

This section discusses several Telnet-related topics of interest. These topics include security, Telnet applications, and using Telnet to access other popular TCP/IP services.

Security

As with all TCP programs and applications, Telnet comes with security issues. However, tools are available to help better secure Telnet, or to replace it altogether.

TCP Wrappers

TCP Wrappers (known sometimes as `tcpd`) are a collection of tools that wrap around the TCP daemons (such as `in.telnetd`) and provide monitoring and filtering for TCP programs. Using TCP Wrappers, you can configure your system to respond only to Telnet requests coming from specific network computers or domains. TCP Wrappers were created by Wietse Venema.

Wrapper functionality comes preinstalled on some systems. Depending on your operating system, you may need to download and install TCP Wrappers yourself. The following sections describe how to configure the `/etc/hosts.allow` and `/etc/hosts.deny` files for TCP wrappers.

Configuring the `/etc/hosts.allow` and `/etc/hosts.deny` Files

The `/etc/hosts.allow` and `/etc/hosts.deny` files are used by the host access or TCP Wrapper program to determine who can and cannot run certain commands on your computer. For example, your `hosts.deny` file might contain:

```
In.telnetd:   All
```

and your `hosts.allow` file would contain

```
in.telnetd:   *.mydomain.com
```

In the preceding example, the entry in the `hosts.deny` file denies Telnet access to everyone. The `hosts.allow` entry overrides the `hosts.deny` entry for hosts coming from `mydomain.com`.

For more information on TCP Wrappers, refer to `ftp://ftp.porcupine.org/pub/security/index.html`.

Secure Shell

Secure Shell (SSH) is a secure alternative to Telnet. Due to its use of encryption mechanisms, such as the Data Encryption Standard (DES) and RSA host authentication, SSH can protect hosts from several common attacks, such as IP spoofing and password interception. SSH creates a Virtual Private Network (VPN) between the client and server.

SSH is free for non-commercial use. For more information on SSH, refer to `http://www.ssh.fi/sshprotocols2/` and `www.openssh.org`.

Telnet Applications

Telnet is often used to access remote applications. Hytelnet is an index of Telnet-accessible libraries and other resources around the world. Although somewhat displaced by the popularity and ease of access of the Web, many of these sites are still available.

Figures 31.5 and 31.6 show Hytelnet 6.9 for Windows in action.

Hytelnet can also be accessed via the Web at `http://www.lights.com/hytelnet/`.

Other Telnet applications include interfaces for Whois and Finger. For more information, refer to Chapter 29, “Whois and Finger.”

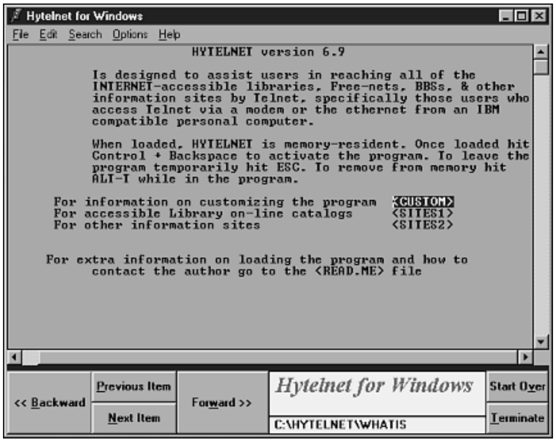


FIGURE 31.5
A little bit about Hytelnet for Windows.

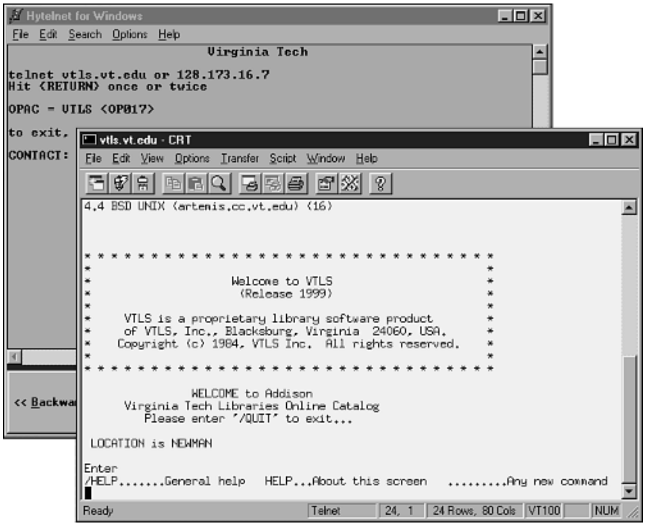


FIGURE 31.6
Using Hytelnet for Windows and CRT to access an online library.

Using Telnet to Access Other TCP/IP Services

While Telnet uses TCP port 23 to achieve its primary function, the Telnet daemon listens and responds to other well-known TCP ports as well. This allows Telnet to be used in conjunction with the other TCP/IP services. Table 31.4 shows the TCP port numbers of some of the common TCP/IP services that work with Telnet.

TABLE 31.4 Ports of Common, Telnet-Enabled TCP Services

Service	*Port*
FTP	21
SMTP	25
Whois	43
Finger	79
HTTP	80

Telnet can be used to connect to these services by issuing Telnet commands of the following form:

```
telnet hostname port
```

or

```
telnet hostname service
```

In the latter usage example, the service (for example, SMTP) is used instead of the port number (for example, 25). The Telnet server on the host looks up the service number in a system file (`/etc/services` on most Unix systems) and opens a connection to the port mapped to the requested service. The following sections discuss this further and show some examples.

Sending Mail with Telnet

You can use Telnet to connect to the well-known SMTP port 25. Postmasters and administrators often do this to troubleshoot mail problems. The following example demonstrates using Telnet to connect to the SMTP port and run a `VRFY` (verify) command. For more information on SMTP, refer to Chapter 35, “Internet Mail Protocols.”

```
$ telnet host.mydomain.com SMTP
Trying...
Connected to host.mydomain.com.
Escape character is '^]'.
220 host.mydomain.com ESMTP Sendmail 8.8.8+Sun/8.8.8; 8 Aug 1999 17:14
vrfy jamisonn
250 Neal Jamison <jamisonn@host.mydomain.com>
quit
221 host.mydomain.com closing connection
Connection closed by foreign host.
```

By executing the necessary SMTP commands, you can even use this method to send messages.

Finger

Telnet can also be used to connect to the finger port (79) of a remote host, as shown in the following example:

```
$ telnet host1.mydomain.com 79
Trying ...
Connected to host1.mydomain.com.
Escape character is '^]'.
jamisonn
Login: jamisonn                         Name: Neal Jamison
Directory: /users/home/jamisonn         Shell: /bin/tcsh
On since Sun Aug  8 17:16 (EDT) on ttyp7 from pool180-68
No mail.
No Plan.
Connection closed by foreign host.
```

After the connection was established, the one-line query (`jamisonn`) was entered. The Finger server responded with the answer to the query. This could come in handy if you find yourself in an environment without a Finger client. For more information on Finger, refer to Chapter 29.

Surfing the Web with Telnet

Telnet can also be used to connect to the HTTP port (80) of a Web server, as shown in the following example:

```
$ telnet mywebserver.com 80
Trying...
Connected to mywebserver.com.
Escape character is '^]'.
GET /
<HTML>
<HEAD>
<TITLE>Makoa Corporation</TITLE>
</HEAD>
<BODY>
<H1>Welcome to Makoa Corporation</H1>
<p>
This is the homepage of Makoa Corporation.
<br><br>
</BODY>
</HTML>

Connection closed by foreign host.
```

After the connection was established, the HTTP command `GET /` was entered. This requested the root document of the Web server. Unless you can translate HTML as well as your Web browser can, this will be of no use to you. It is shown here for demonstration purposes only and for checking whether the HTTP server is alive on TCP port 80. For more information on HTTP, refer to Chapter 36, "The HTTP (World Wide Web) Service."

Summary

This chapter described in detail the TCP/IP terminal emulation protocol, Telnet. As discussed, Telnet solved the ever-growing problem of terminal incompatibilities that was common at the time the Internet was born. Thanks to Telnet and the Network Virtual Terminal, scientists and researchers went from having several computer terminals on their desk to having just one.

This chapter presented the syntax and options associated with the common Unix Telnet client and server commands, and although they are rarely used by the end user, presented descriptions of the Telnet commands.

Security was touched upon, as was the subject of Telnet applications. It was demonstrated how you can use Telnet to connect to and use several other TCP/IP services, such as SMTP mail, Finger, and HTTP.

The chapter also included a complete listing of Telnet-related RFCs, including the original: RFC 15 from 1969.

CHAPTER 32

Using the R-Utilities

by Neal S. Jamison

In This Chapter

- **Understanding R-Commands** *788*
- **Alternatives to Using R-Commands** *792*
- **R-Command Reference** *793*
- **Achieving R-Command Functionality in Non-Unix Environments** *800*

As you know by now, TCP/IP is the suite of protocols that allows computers to communicate with each other. But it takes more than just communication protocols to build an internet. There must be Application Layer programs that utilize the TCP/IP protocols and services, and it's these programs that perform the high-level communication. This chapter discusses a particular set of programs that allow remote computers to communicate in different ways.

Understanding R-Commands

The r-commands were born from the Berkeley BSD Unix community, where they were created to allow computer programmers and users to run sessions and commands on remote (hence the "r" in r-commands) computers. These commands are prevalent today in and around the Unix and TCP/IP community, and still perform their duties as originally designed. The r-commands allow us to copy files from one system to another, execute commands on remote computers, and even create login sessions on remote computers. Unlike telnet and ftp, however, these commands can be configured to run without requiring user interaction (that is, typing username and password).

The commonly used r-commands are listed in Table 32.1.

TABLE 32.1 The Unix R-Commands

Command	*Description*
`rsh`	Remote Shell: Executes a program on a remote computer. Sometimes referred to as `rshell`, `remsh`, or `rcmd` on some non-BSD Unix distributions, where `rsh` refers to the restricted shell.
`rcp`	Remote Copy: Copies files from one computer to another. Provides functionality similar to ftp.
`rlogin`	Remote Login: Logs in to a remote computer. `rlogin` provides functionality similar to telnet.
`rup`	Remote Uptime: Shows the status of a remote computer.
`ruptime`	Remote Uptime: Shows the status of a remote computer. (Similar to `rup`.)
`rwho`	Remote Who: Displays the current users on a remote computer.
`rexec`	Remote Execution: Same as `rsh`, but requires a password.

Security Implications

The theory behind the r-commands is that of "host equivalency." Computers are configured to allow specific "trusted" hosts and users to transparently log in and run commands. This approach has several problems: Your system becomes as weak as the weakest trusted host, and in the event of improper configuration, you might inadvertently give access to others. Another problem with the r-commands is that in many cases, when a user is not trusted and is asked to enter a password, that password is sent over the network as clear, unencrypted text. This clear text transmission could be intercepted by someone snooping your network and used to gain unauthorized access.

Because of the security implications of the r-commands, most experts recommend that they be disabled. However, because they are still commonly used, this chapter focuses on their proper configuration and use. It will also offer an alternative in the event that you choose to disable the commands as recommended (see "Alternatives to Using R-Commands" later in this chapter).

For more information on proper configuration, see the "R-Command Reference" section later in this chapter.

Note

Because of the many unique "flavors" of operating systems available, this chapter discusses the r-commands as they are implemented in Linux. The concept and use of the commands is very similar, regardless of your chosen operating system. Consult your OS documentation for specific commands and/or options.

Disabling the R-Commands

If you choose to disable the r-commands, you must comment-out the related lines in the `/etc/inetd.conf` file. The lines are commented by placing a "#" at the beginning of the line. Here is a sample `/etc/inetd.conf` file with the proper lines commented (note that the file has been slightly abbreviated to save space):

```
#
# inetd.conf   This file describes the services that will be available
#    through the INETD TCP/IP super server.  To reconfigure
#    the running INETD process, edit this file, then send the
#    INETD process a SIGHUP signal.
# Version:   @(#)/etc/inetd.conf   3.10   05/27/93
# Authors:   Original taken from BSD Unix 4.3/TAHOE.
#   Fred N. van Kempen, <waltje@uwalt.nl.mugnet.org>
# Modified for Debian Linux by Ian A. Murdock <imurdock@shell.portal.com>
# Modified for RHS Linux by Marc Ewing <marc@redhat.com>
#
```

```
# <service_name> <sock_type> <proto> <flags> <user> <server_path> <args>
# Echo, discard, daytime, and chargen are used primarily for testing.
#
# These are standard services.
#
ftp     stream  tcp   nowait  root   /usr/sbin/tcpd   in.ftpd -l -a
telnet  stream  tcp   nowait  root   /usr/sbin/tcpd   in.telnetd
#
# Shell, login, exec, comsat and talk are BSD protocols.
#
#shell  stream tcp    nowait  root   /usr/sbin/tcpd  in.rshd
#login  stream tcp    nowait  root   /usr/sbin/tcpd  in.rlogind
#exec   stream tcp    nowait  root   /usr/sbin/tcpd  in.rexecd
#
...
```

As you can see, a "#" comment character has been placed at the beginning of the lines that start `in.rshd`, `in.rlogind`, and `in.rexecd`, respectively.

Note

You must be the superuser to modify the files and run the commands discussed in this chapter.

After commenting out the r-command daemons, you will need to restart the `inetd` daemon. This is accomplished by running the following command:

```
killall -HUP inetd
```

The Role of Daemons in Unix

In Unix, a daemon is a program that runs in the background and waits for some event to take place. By definition, a daemon is an intermediary between man and a divine being. In the Unix world, it is an intermediary between two events or processes. An example daemon is `in.rlogind`, which waits for an `rlogin` request. Upon receiving a request, `in.rlogind` attempts to authenticate the user. If the user is trusted, he or she is allowed access. Otherwise `in.rlogind` denies the request.

Securing the R-Commands

If you decide that you can't live without the functionality of the r-commands, you can take some extra steps to make them as secure as possible. Here are some methods you can use:

- TCP wrappers
- Kerberos authentication
- Data Encryption Standard (DES)

TCP Wrappers

TCP wrappers (known sometimes as `tcpd`) are a host access control mechanism that "wraps" around the TCP daemon and provides monitoring and filtering for TCP programs. Using TCP wrappers, you can configure your system to respond only to r-command requests coming from specific network computers or domains.

Wrapper functionality typically comes preinstalled on most Linux distributions (see `http://howto.tucows.com/LDP/LDP/LG/issue46/pollman/tcpwrappers.html` or the man page for `host_access(5)` for more details). Depending on your operating system, you might need to download and install them yourself.

Configuring the `/etc/hosts.allow` *and* `/etc/hosts.deny` *Files*

The `/etc/hosts.allow` and `/etc/hosts.deny` files are used by the host access or TCP Wrapper program to determine who can and cannot run certain commands on your computer. The basic syntax of an entry to these files is

```
daemon : client
```

For example, your `hosts.deny` file might contain

```
All:   All
```

and your `hosts.allow` file would contain

```
in.telnetd:   All
in.ftpd:   All
in.rshd:   *.mydomain.com
in.rlogind   *.mydomain.com
in.rexecd   *.mydomain.com
```

In this example, the `hosts.deny` entry of `All: All` specifies that everyone is denied access to everything. This might seem extreme at first, but then we examine the `hosts.allow` file, which overrides the severity of the `deny` file. It states that everyone should be allowed to enter the system using the interactive telnet and ftp programs, but only hosts in the trusted domain, `mydomain.com`, should be allowed to attempt the trusted r-commands.

This section has presented just an overview of the options and functionality supported by host access and TCP Wrappers. Consult your operating system documentation for more information.

> **Exploiting Systems with IP Spoofing**
>
> *IP spoofing* is a technique used to "spoof" or fool a computer system into thinking that incoming requests or data are coming from a trusted computer, when actually they are not. It is commonly used to exploit trusted systems like those utilized by the r-commands and TCP Wrappers.
>
> The methods involved in IP spoofing are beyond the scope of this chapter, but in general, the impostor must somehow modify the network packet headers to make them appear as if they are coming from a trusted network.

Kerberos Authentication

In an attempt to better secure the r-commands, many distributions of `rsh`, `rcp`, and `rlogin` are now using *Kerberos authentication*.

Kerberos is an authentication system that allows two parties to exchange secure information across an unsecured network. Each communicating party is assigned a ticket, which is embedded in messages and used in place of a password to identify the sender.

For more information about Kerberos, refer to `http://web.mit.edu/kerberos/www/`.

Data Encryption Standard (DES)

Certain distributions of `rsh` can be configured to use a powerful encryption standard known as DES. Created in the 1970s, DES provides a strong level of encryption.

For more information on DES, refer to `http://www.itl.nist.gov/fipspubs/fip46-3.htm`.

Alternatives to Using R-Commands

With all the security ramifications of using the r-commands, you are probably thinking that there must be an alternative. Well, there is: Secure Shell (SSH).

Secure Shell is a secure way to log in to remote computers, execute remote commands, and copy remote files. You can achieve the same functionality with SSH as you can using the less secure `rlogin`, `rsh`, and `rcp`.

What makes SSH secure is its use of encryption mechanisms such as the Data Encryption Standard (DES) and RSA host authentication. These mechanisms allow SSH to protect your system against several common attacks, such as

- IP spoofing
- Interception of clear text passwords
- Manipulation of data

RSA Public Key/Private Key Authentication

Short for Rivest, Shamir, and Adelman, the inventors of the algorithm, RSA provides public key/private key encryption. The basic idea is that data encrypted with the public key can only be decrypted with a private key. In the case of host authentication, the sending host encrypts a random string of data using the public key of the receiving (remote) host. If the remote host can successfully decrypt it using its private key, the two hosts know without a doubt that they are legitimate.

For more information on RSA, refer to `http://www.rsa.com/`. For a good introduction to public key/private key encryption, refer to `http://www.rsa.com/rsalabs/pkcs/`.

SSH versions 1 and 2 are free for non-commercial use. For more information on SSH, refer to `http://www.ssh.fi/sshprotocols2/`.

R-Command Reference

This section presents the syntax and usage of the r-commands. As mentioned earlier, this information is gleaned from the Linux operating system. Refer to your own man pages or documentation for usage and options specific to your operating system of choice.

R-Command Daemons

Table 32.2 lists several daemons that must be running (or enabled to be run by `inetd`) on the server in order for the r-commands to function properly. See your server documentation or man pages for more information.

TABLE 32.2 R-Command Daemons

Daemon	*Description*
`rshd`	Remote shell server. Provides remote execution without authentication.
`rlogind`	Remote login server. Provides remote login without authentication.
`rwhod`	System status server.
`rstatd` (or `rcp.rstatd`)	Remote status server.

rsh

The remote shell command (`rsh`) allows the execution of commands on a remote system. The following shows the syntax for using the `rsh` command:

> **Note**
>
> `rsh` is sometimes referred to as `rshell`, `remsh`, or `rcmd` on some Unix distributions, where `rsh` refers to the unrelated restricted shell.

Usage: `rsh [-Kdnx] [-k realm] [-l username] host [command]`

Options:

- `-K`—Disables Kerberos authentication.
- `-d`—Enables socket debugging.
- `-n`—Redirects input from `/dev/null`.
- `-k`—Causes the remote Kerberos ticket to be obtained in the specified realm instead of the remote host's realm.
- `-l`—Allows the remote username to be specified, instead of using the current username.
- `-x`—Enables DES encryption if available.

If no command is specified, the user is given an `rlogin` session. The following example shows how to use a `rsh` command:

Example:

```
%rsh hostname1 who
jamisonn   pts/1   Jul 26 09:13    (hostname2)
evanm      pts/13  Jul 25 12:30    (hostname3)
```

This example executes the `who` command on the remote host `hostname1`. The output shows two users currently using `hostname1`.

rcp

Remote copy (`rcp`) copies files from one machine to another. It can be thought of as a non-interactive ftp. The following shows the syntax for using the `rcp` command:

Usage: `rcp [-px] [-k realm] file1 file2`

```
rcp [-px] [-r] [-k realm] file ... directory
```

The format for a file or directory is *`username@hostname:filepath`*.

Options:

- `-r`—Performs a recursive copy (the destination must be a directory).
- `-p`—Attempts to preserve the modification times and modes of the source files.
- `-k`—Causes the remote Kerberos ticket to be obtained in the specified realm instead of the remote host's realm.
- `-x`—Enables DES encryption if available.

The following shows an example of using the `rcp` command:

Example:

```
%rcp /home/jamisonn/report jamison@hostname2:report
```

This example would copy the file `report` from my local home directory to my home directory on the remote `hostname2`.

rlogin

`rlogin` starts a terminal session on a remote host. The following shows the syntax for using the `rlogin` command:

Usage: `rlogin [-8EKLdx] [-e char] [-k realm] [-l username] host`

Options:

- `-8`—Allows an eight-bit input data path.
- `-E`—Prevents the use of an escape character.
- `-K`—Disables Kerberos authentication.
- `-L`—Allows the rlogin session to be run in "litout" mode.
- `-d`—Enables socket debugging.
- `-e`—Allows the user to specify an escape character, which is "~" by default.
- `-k`—Causes the remote Kerberos ticket to be obtained in the specified realm instead of the remote host's realm.
- `-x`—Enables DES encryption if available.

The following shows an example of using the `rlogin` command:

Example:

```
%rlogin -l jamisonn hostname1
```

This example would create a login session for the user `jamisonn` on the remote host `hostname1`.

The `rlogind` daemon must be enabled on the remote host.

rup

`rup` displays the status of the specified remote system. If no host is specified, `rup` returns the status of all hosts on the network. The following shows the syntax for using the `rup` command:

Usage: `rup [-dhlt] [host ...]`

Options:

- `-d`—Displays the local time for the host.
- `-h`—Sorts output alphabetically by hostname.
- `-l`—Sorts output by load average.
- `-t`—Sorts output by uptime.

Example output:

```
% rup hostname1
hostname1   up 15 days, 11:13,  load average: 0.21, 0.26, 0.19

%rup -d hostname1
hostname1   4.08pm  up 15 days, 11:13,  load average: 0.21, 0.26, 0.19
```

The `rstatd` (or `rpc.rstatd`) daemon must be enabled on the remote host in order for `rup` to work properly.

ruptime

`ruptime` is similar in function to `rup`. The following shows the syntax for using the `ruptime` command:

Usage: `ruptime [ -alrtu ]`

Options:

- `-a`—Displays hosts that have been idle for an hour or more.
- `-l`—Sorts output by load average.

`-r`—Reverses sort order.

`-t`—Sorts output by uptime.

`-u`—Sorts output by number of users.

The `rwhod` daemon must be enabled on the remote host in order for `ruptime` to work properly.

rwho

`rwho` displays users logged in to remote systems. Its output is similar to the Unix `who` command. By default, `rwho` only displays users who have actively used the system in the last hour. The following shows the syntax for using the `rwho` command:

Usage: `rwho [-a]`

Options:

`-a`—Displays all users, including those who have been idle for more than an hour.

The `rwhod` daemon must be enabled on the remote host in order for `rwho` to work properly.

rexec

`rexec` is similar in functionality to `rsh`, but it requires the entry of a password. The following shows the syntax of the `rexec` command:

Usage:

rexec [username@hostname] [**-DNn**] [**-l** username] [**-p** password] command

rexec [**-DNn**] [**-l** username] [**-p** password] [username@hostname] command

Options:

-D—Enables socket debugging on the TCP sockets used for communication with the remote host. This option also displays the user name sent to the **rexecd** service (or daemon).

-l `username`—Specifies the remote username to be used when executing the command. This can also be specified by including `username@hostname` on the command line.

-N—Does not generate a separate standard error stream. All output is sent to standard output. This is useful when you are running an interactive command. For example,

```
rexec -N localhost cmd
rexec -N localhost sh -i
```

-n—Redirects input from the special device `/dev/nul`.

-p `password`—Specifies the password of the specified user on the remote host.

If no password is specified, the `~/.netrc` file is checked for "machine hostname login username password string" combination. If a password is not found, the user is prompted to enter a password.

Related Files

Several files must be configured properly in order for the r-commands to run, including the following:

- `/etc/hosts`
- `/etc/hosts.equiv`
- `.rhosts`
- `/etc/hosts.allow` and `/etc/hosts.deny`

These files are discussed in the following sections.

/etc/hosts

It is vital that the communicating computers each know about the other. This is accomplished via entries in the `/etc/hosts` file. If `hostname1` wants to allow `hostname2` to run the r-commands, `hostname1` must have an entry for `hostname2` in its `/etc/hosts` file, and vice versa.

/etc/hosts.equiv

The `hosts.equiv` file specifies the hosts and users that are allowed (or denied) transparent r-command privileges. An improperly configured `hosts.equiv` file could open your system to everyone.

The basic format for the `/etc/hosts.equiv` file is

```
[+ | -][hostname][username]
```

Preceding *hostname* or *username* with a + allows trusted access from that host or user. Similarly, preceding *username* with a – denies trusted access from that host or user. Table 32.3 shows several sample entries with brief explanations of the result.

TABLE 32.3 `hosts.equiv` Entries and Their Results

Entry	*Result*
`Hostname1`	Allows all users from `Hostname1` trusted access
`-Hostname1`	Denies trusted access to all users from `Hostname1`
`Hostname2 -root`	Denies trusted access to the user `root` coming from `Hostname2`
`Hostname2 +admin`	Gives trusted access to the user `admin` coming from `Hostname2`
`-root`	Denies access to the user `root` from any system
`+admin`	Allows access by the user `admin` coming from any system
`+`	Grants trusted access to everyone (Dangerous!)
`-`	Denies trusted access to everyone

Note

Some distributions may come with the + entry in the `hosts.equiv` file. This tells your system that any system is a trusted host, and can be very dangerous. If you have a + entry in your `hosts.equiv` file, remove it.

.rhosts

The `.rhosts` file is identical to the `hosts.equiv` file. However, `.rhosts` files are used to allow or deny trusted access to a specific user account, whereas the `hosts.equiv` file specifies the entire system.

A common use of the `.rhosts` file is to allow a user trusted access to multiple systems upon which the user has accounts. For example, the user has an account on `hostname1` with the username of `jamison`. On another system, `hostname2`, he might have an account under the username `jamisonn`. Creating `.rhosts` files in each of the accounts could allow you to grant yourself trusted access to the other system.

A sample `.rhosts` file in `jamison`'s home directory on `hostname1` would look like

```
hostname2 +jamisonn
```

On `hostname2` the file in the `jamisonn` home directory would contain the entry

```
hostname1 +jamison
```

These two files would allow you trusted privileges on each system.

One of the weaknesses of the r-command's use of trusted hosts and users is that it is not too difficult to spoof the system into thinking you are someone or are coming from somewhere you are not. In the preceding example, if an intruder were to gain access to the first system, `hostname1`, as either `jamison` or the superuser, that intruder would have free access to `hostname2`. This is an example of user spoofing. IP or hostname spoofing, or making it seem as if you are coming from a trusted host, is not quite as straightforward, but unfortunately it's often used to exploit these types of trusted systems.

The `/etc/hosts.allow` and `/etc/hosts.deny` Files

These files are used by the host access or TCP Wrapper program to determine who can and cannot run certain commands on your computer. For a more complete description of these files and their syntax, refer to the "TCP Wrappers" section earlier in this chapter. The following shows several examples of using the hosts.allow and hosts.deny files:

Example `/etc/hosts.deny`:

```
All:All
```

Example `/etc/hosts.allow`:

```
in.telnetd: All
in.ftpd: All
in.rshd: *.mydomain.com
in.rlogind: *.mydomain.com
```

In these examples, the `hosts.deny` file sets the stage by disallowing everyone for everything. This is a good security practice. The `hosts.allow` file then opens telnet and ftp to anyone, and allows hosts coming from the trusted domain `mydomain.com` to run the r-commands.

Achieving R-Command Functionality in Non-Unix Environments

The r-commands are inherently found in Unix environments. However, they are starting to appear in other TCP/IP products, such as the Microsoft TCP/IP component of Windows NT/2000. Several third-party products are available that will allow other systems to achieve r-command functionality.

Table 32.4 shows several vendors and manufacturers, and a URL for more information. In some cases these programs are shareware, so the author is listed in place of a manufacturer.

TABLE 32.4 Third-Party R-Command Products

Manufacturer	*URL*
Hummingbird Communications LTD	`http://www.hummingbird.com/products/nc/inetd/`
Denicomp Systems	`http://www.denicomp.com/products.htm`
Didier CASSEREAU	`http://www.loa.espci.fr/winnt/rshd/rshd.htm`
Markus Fischer	`http://www.uni-paderborn.de/StaffWeb/getin`

Summary

This chapter introduced you to the Unix r-commands that you can use to log in to remote computers, copy remote files, and execute other remote commands. There are some large security implications of running these commands and services that must not be ignored. As such, this chapter offered alternatives such as the secure shell (SSH). It discussed using r-commands in non-Unix environments, and numerous URLs were provided throughout the chapter to enable you to seek out more information on your own.

The command summaries provided throughout the chapter are unique to the Linux environment. Be sure to check your own documentation and Unix man pages for information specific to your environment.

CHAPTER 33

Filesystem-Sharing Protocols: NFS and SMB/CIFS

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IN THIS CHAPTER

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TCP/IP provides the services and protocols that allow computers to share data with one another. It was this capability that sparked the Internet revolution that we are enjoying today. One of the most useful applications of TCP/IP is the *Network File System*, more commonly known as NFS.

What Is NFS?

NFS is a distributed filesystem that allows computers to share resources over a TCP/IP network: It allows NFS client applications to transparently read and write files that reside on NFS servers. Prior to its implementation, the only way for computers to share data was either to duplicate or centralize the data, or to distribute the data via a network of homogeneous computers. There were clearly downsides to all of these options—duplication of data wasted space and could cause real consistency problems, centralization of data meant costly mainframes and dumb terminals, and who wanted to be limited by a homogeneous network?

Along came NFS, which allowed us to share data independent of platform, and all of our problems were solved.

Note

For the purpose of this text, a "filesystem" is a set of organized data files grouped together in a directory structure. For example, in Unix, /usr is a filesystem.

NFS servers share resources, making them available for use by clients on the network. As discussed later, NFS can be used on both LANs and WANs. NFS was designed to be operating system- and hardware-independent, allowing a wide range of computers to share resources. The basic NFS service is actually made up of two protocols: Mount and NFS.

A Brief History of NFS

NFS was introduced by Sun Microsystems in 1984. It was first implemented under Sun's 4.2BSD (more commonly known as SunOS). Due to its popularity and a need in the industry for such a protocol, it was soon ported to a wide variety of operating environments. By 1986, NFS allowed shared resources over 16 different hardware platforms using five different operating systems. Today, NFS runs on many different hardware and OS platforms, and it has even been enhanced to run over the Web.

Why NFS?

NFS was created to allow computers to share resources. At the time of its development (the early 1980s) the computer industry was rapidly changing. Cheap CPUs and client/server technology were allowing the industry to decentralize their computing environments. However, while processors were getting cheaper, large capacity storage systems were still relatively expensive. Something was needed that would allow the computers to share storage and data while still maximizing their individual processing power. NFS was the answer.

Implementation—How NFS Works

NFS uses the protocols and services provided by TCP/IP. NFS runs on the Application Layer of the OSI model, as shown in Table 33.1.

TABLE 33.1 NFS on the OSI Layer Model

Layer	*Name*	*Function*
1	Application	NFS
2	Presentation	XDR
3	Session	RPC
4	Transport	UDP, TCP
5	Network	IP
6	Data Link	Many choices
7	Physical	Many choices

Due to the greater performance of the utilitarian UDP transport protocol, NFS was originally designed to use UDP instead of the TCP transport protocol. However, although UDP works well on reliable local area networks, it does have drawbacks when running over less reliable WANs such as the Internet. Recent advances in TCP now enable NFS to run efficiently using the more reliable transport protocol. Starting with Solaris 2.6, Sun Microsystems now uses NFS over TCP. TCP support was added to NFS, in NFS version 2, but was not optimized. NFS version 3 optimized TCP support and removed the arbitrary block size limitation of 8KB. The latest version of NFS is version 4.

Note

For more information about UDP and TCP, please refer to Chapter 9, "Overview of the IP Family of Protocols."

Remote Procedure Calls (RPC) and External Data Representation (XDR)

To be wholly platform-independent, NFS relies on the workhorses of the lower OSI layers. The Session Layer *Remote Procedure Call* (RPC) and Presentation Layer *External Data Representation* (XDR) provide the network connections for NFS and the format of the data sent over these connections. In short, they are used to allow NFS to work over a wide range of different platforms. This chapter examines each of these from the bottom up.

Understanding RPC

RPC operates at the Session Layer of the OSI stack, and provides computer systems with a set of procedures that can be called as if they were local. Using RPC, a local computer or application can call and use a service running on a remote computer. RPC provides an entire library of procedures that allow higher-level applications to run without needing to know the lower-level details of the remote system. It is this level of abstraction that allows the application-level NFS to be platform-independent.

Understanding XDR

The External Data Representation library is responsible for translating the RPC data between heterogeneous computer systems. XDR designates a standard data representation that all computers understand.

Together, RPC and XDR provide the client/server relationship required by NFS.

Hard Mounts Versus Software Mounts

As explained in a previous section, the stateless nature of NFS allows clients and client applications to recover from periods of server unavailability. The type of the mount determines how your client or client applications will respond when the server becomes unavailable. Mount types will be discussed again in the "Common NFS Problems and Solutions" section later in this chapter.

Hard Mounts

In the event that the NFS server or resource becomes unavailable, a hard-mounted resource will result in RPC calls being tried and retried indefinitely. When the server responds, the RPC will succeed and the next procedure will be executed. If there are persistent server or network problems, the hard mount can result in a constant wait state, which will cause the NFS client application to appear to be hung. Also the mount retries will contribute to network traffic. There is an option that can be specified to make a hard mount interruptible.

Soft Mounts

With a soft-mounted resource, repeated RPC failures will result in the NFS client application failing as well, which can result in unreliable data. They should not be used with filesystems that are writeable, or from which mission-critical data or executable programs will be read.

Note

The following section contains data similar to Unix man page information. For more complete information, see the man pages for the specific files and programs.

NFS Files and Commands

This section introduces you to the daemons, programs, and files that are used by NFS. Due to the fact that NFS is so closely tied to Unix, the following sections will demonstrate the steps to share and use NFS resources with two popular Unix operating systems: Sun Solaris 2.x and Linux. A discussion about other implementations, including PC-based clients, appears in the later section "Related Protocols and Products."

How Daemons Work

In Unix, a *daemon* is a program that runs in the background and waits for some event to take place. By definition, a daemon is an intermediary between man and a divine being. In the Unix world, it is an intermediary between two processes. An example of a daemon is a print process that waits for a print job to enter the queue or, in the case of NFS, waits for a client to request a filesystem.

NFS Daemons

There are several server daemons that work together to make NFS work. They are described in the following sections for the Solaris and Linux operating systems.

Solaris 2.x

The following Solaris daemons are used to listen for, handle, and maintain NFS requests. The Solaris server daemons are started with the script `/etc/init.d/nfs.server`.

nfsd

`nfsd` is the server daemon that listens for NFS client requests. The following shows the syntax of running the `nfsd` daemon:

Usage: `/usr/lib/nfs/nfsd [ -a ] [ -c #_conn ] [ -l listen_backlog ] [ -p protocol ] [ -t device ] [ nservers ]`

Options:

`-a`—Starts an NFS daemon over all available connectionless and connection-oriented transports, including UDP and TCP.

`-c #_conn`—Sets the maximum number of connections allowed to the NFS server over connection-oriented transports. By default, the number of connections is unlimited.

`-l`—Sets connection queue length for the NFS TCP over a connection-oriented transport. The default value is 32 entries.

`-p protocol`—Starts an NFS daemon over the specified protocol.

`-t device`—Starts an NFS daemon for the transport specified by the given device.

`Nservers`—Specifies the maximum number of requests that can be handled concurrently.

Related files: `/etc/init.d/nfs.server`; the shell script that starts `nfsd`.

mountd

`mountd` answers requests for NFS access information and filesystem mounts. It reads `/etc/dfs/sharetab` to determine the availability of filesystems. The following shows the syntax of running the `mountd` daemon:

Usage: `/usr/lib/nfs/mountd [ -v ] [ -r ]`

Options:

`-v`—Runs in verbose mode, logging to the console.

`-r`—Rejects client requests.

Related files: `/etc/dfs/sharetab` (see the "NFS-Related Files" section later in this chapter).

statd

`statd` works with `lockd` to provide crash and recovery for the file locking service. `statd` is a client daemon. The following shows the syntax of running the `statd` daemon:

Usage: `/usr/lib/nfs/statd`

Related files: `lockd`

lockd

`lockd` is part of the NFS lock manager, which helps support locking of NFS files. `lockd` is a client daemon. The following shows the syntax of running the `lockd` daemon:

Usage: `/usr/lib/nfs/lockd [ -g graceperiod ] [ -t timeout ] [ nthreads ]`

Options:

`-g graceperiod`—The number of seconds a client has to reclaim a lock after the server reboots. (Default 45)

`-t timeout`—The number of seconds a client should wait before retransmitting a lock request. (Default 15)

`nthreads`—The number of threads available to respond to lock requests. (Default 20)

Related files: `statd`

Linux

The following Linux daemons are used to listen for, handle, and maintain NFS requests. Their use and syntax are very similar to the daemons found in Solaris.

rpc.nfsd

`rpc.nfsd` is the server daemon that handles NFS requests. The following shows the syntax of running the `rpc.nfsd` daemon:

Usage: `/usr/sbin/rpc.nfsd [-f exports-file] [-d facility] [-P port] [-R dirname] [-Fhlnprstv] [--debug facility] [--exports-file=file] [--foreground] [--help] [--allow-non-root] [--re-export] [--public-root dirname] [--no-spoof-trace] [--port port] [--log-transfers] [--version] [numservers]`

Options:

`-f exports-file`—Specifies the exports file. By default, this is `/etc/exports`.

`-h` or `–help`—Provides a help summary.

`-l` or `--log-transfers`—Logs all file transfer information.

`-n` or `--allow-non-root`—Allows incoming NFS requests to be honored even if they do not originate from reserved IP ports.

`-P portnum` or `--port portnum`—Makes `nfsd` listen on `port portnum` instead of the default port 2049 or the one listed in `/etc/services`.

`-p` or `–promiscuous`—Instructs the server to serve any host on the network.

`-v` or `–version`—Reports the current version number of the program.

`numservers`—Allows you to run several instances of `nfsd` in parallel.

Related files: `exports`, `mountd`

rpc.mountd

`rpc.mountd` receives mount requests and checks for the availability of the NFS filesystem in `/etc/exports`. If the requested resource is available, `rpc.mountd` creates a file handle and adds the entry to `/etc/rmtab`. Upon receipt of a `UMOUNT` request, `rpc.mountd` removes the entry from `/etc/rmtab`. The following shows the syntax of running the `rpc.mountd` daemon:

Usage: `/usr/sbin/rpc.mountd [ -f exports-file ] [ -d facility ] [ -P port ] [ -Dhnprv ] [ --debug facility ] [ --exports-file=file ] [ --help ] [ --allow-non-root ] [ --re-export ] [ --no-spoof-trace ] [ --version ]`

Options:

Please refer to the previous command, `rcp.nfsd`, for `rcp.mountd` command options.

Related files: `/etc/exports`, `/etc/rmtab`

rpc.statd

Refer to the Solaris implementation of `statd` for more information on this daemon.

rpc.lockd

Refer to the Solaris implementation of `lockd` for more information on this daemon.

biod

`biod` starts a specified number of asynchronous block I/O daemons on an NFS client. These daemons perform read-ahead and write-behind operations on the NFS filesystem.

These operations help improve NFS performance. The following shows the syntax of running the `biod` daemon:

Usage: `/usr/etc/biod [numdaemons]`

NFS-Related Files

Several server and client files must be modified in order to successfully share or mount NFS filesystems.

Solaris 2.x Files

The following sections describe the files used in Solaris to define and track NFS resources.

/etc/dfs/dfstab

The `dfstab` file contains a list of `share` commands that control the export of NFS filesystems. For more information on `share`, see the “Solaris 2.x Server Commands” section later in this chapter.

Example:

```
share  -F nfs  -o rw=engineering  -d "home dirs"  /export/home2
```

/etc/dfs/sharetab

`sharetab` contains an entry for every filesystem shared by the `share` command. It is automatically generated by the system. Each entry in the `sharetab` file contains the following fields:

- `pathname`—The pathname of the shared resource.
- `resource`—The name by which remote systems can access the resource.
- `fstype`—The type of the shared resource.
- `specific_options`—Specific options that were used when the resource was shared.
- `description`—A description of the shared resource, provided when the resource was shared.

Example:

```
/export/home2    -       nfs     rw=engineering  "Engineering Home"
```

/etc/rmtab

`rmtab` contains a listing of NFS filesystems that are currently mounted by clients. It, too, is generated by the system. It contains lines in the form of

```
hostname:fsname
```

Example:

```
engineering5:/export/home2
```

/etc/vfs/vfstab

`vfstab` is the file used to describe the local and remote systems to be mounted. This is an NFS client file. Entries in the `vfstab` file contain the following fields:

- device to `mount`
- device to `fsck`
- `mount` point
- filesystem type
- `fsck` pass
- `mount` at boot
- `mount` options (see the section "NFS-Client Commands" for `mount` options)

Example:

```
servername:/export/home2   -   /export/home   NFS   -   y   -
```

Linux Files

The following files are used in Linux to define and track NFS resources.

/etc/exports

`exports` is the access control list of files that can be exported to NFS clients. Each line in the `exports` file contains an NFS resource and the hosts that are allowed to mount it. A list of access options can be specified in parentheses, but is not required. There is an extensive list of options and parameters that can be used to manage access to the resource. Please refer to your specific documentation for details.

Example:

```
/users/home host.mydomain.com(ro)
```

This example indicates that the host `host.mydomain.com` is allowed to mount the `/users/home` file system in read-only mode.

/etc/rmtab

`rmtab` contains a list of NFS filesystems that are currently mounted by clients. It is maintained by the system. The format of the file is

```
hostname:resource
```

Example:

```
datahouse.anvi.com:/users/home
```

/etc/fstab

`/etc/fstab` contains an entry for every filesystem to be utilized by the system. It is the Linux equivalent of `vfstab`. Each entry in the `fstab` file contains the following fields:

- `remote filesystem`—The path name of the remote resource.
- `mountpoint`—The local mount point for the remote resource.
- `fstype`—The type of the remote resource (for example, nfs).
- `mount_options`—Specific options to be associated with the filesystem.
- `dump option`—Indicates whether the filesystem should be dumped (backed up). A default value of 0 indicates that it should not.
- `fsck pass`—Indicates at which pass `fsck` should check the filesystem. A default value of 0 indicates that the filesystem should not be checked by `fsck`.

Consult your man pages or documentation for a complete list of options and other `fstab` information.

Example:

```
solaris:/www   /mnt   nfs   rsize=1024,wsize=1024,hard,intr   0   0
```


NFS Server Commands

After the required daemons are running and necessary files modified, sharing and mounting NFS resources is easy.

Creating Shared Resources

Before NFS resources can be used by the clients on your network, they must be shared by the NFS server. The following sections explain the commands for Solaris and Linux that are used to share (that is, export) these resources.

Solaris 2.x Server Commands

The following Solaris commands are used to share and monitor NFS resources.

share

The `share` command makes a specified filesystem available to client systems. The following shows the syntax for the `share` command:

Usage: `share [ -F FSType ] [ -o specific_options ] [ -d description ] [ pathname ]`

Options:

`-F FSType`—Specifies the filesystem type.

`-o specific_options`—Used to control access of the shared resource. They can be any of the following:

`rw` Pathname is shared read/write.

`rw=client[:client]` Pathname is shared read/write only to the specified clients.

`Ro` Pathname is shared read-only.

`ro=client[:client]` Pathname is shared read-only only to the listed clients.

`-d description`—Used to provide a description of the resource being shared.

Example:

```
share  -F nfs  -o rw=engineering  -d "home dirs"  /export/home2
```

shareall

`shareall` shares the resources from the specified file, the standard input, or the default `dfstab` file. The following shows the syntax for `shareall` command:

Usage: `shareall [-F FSType[,FSType...]] [- | file]`

Options:

`-F FSType`—The filesystem type.

`[- | file]`—If the `-` is used, `shareall` takes its input from standard input. If a file is specified, `shareall` takes its input from there. If none is specified, `shareall` uses the default `dfstab` file (`/etc/dfs/dfstab`) .

showmount

`showmount` lists all clients that have mounted a filesystem from the server upon which the command is run. The following shows the syntax for the `showmount` command:

Usage: `/usr/sbin/showmount [ -ade ] [ hostname ]`

Options:

`-a`—Prints all remote mounts.

`-d`—Lists directories that have been remotely mounted.

`-e`—Prints the list of shared filesystems.

Linux Server Commands

The following Linux commands are used to share and monitor NFS resources.

exportfs

`exportfs` causes the `/etc/exports` file to be reread by the system. Some Linux distributions don't have `exportfs`. If this is your case, you can create a short shell script that achieves the same functionality.

```
#!/bin/sh
killall -HUP /usr/sbin/rpc.mountd
killall -HUP /usr/sbin/rpc.nfsd
```

Note

In RedHat 7 (and higher distributions), you can restart the nfs services, which causes the `/etc/exports` file to be read again, by running the following script:

```
/etc/rc.d/init.d/nfs restart
```

Besides `restart` the script accepts arguments such as `start` and `stop`, which have the obvious meanings.

showmount

`showmount` checks the mount daemon on an NFS server for information about the currently mounted filesystems. The following shows the syntax for the showmount command:

Usage: `/usr/sbin/showmount [ -adehv ] [ --all ] [ --directories ] [ --exports ] [ --help ] [ --version ] [ host ]`

Options:

- `-a or –all`—Lists the client hostname and mounted directory in host:dir format.
- `-d or –directories`—Lists only the directories mounted by a client.
- `-e or –exports`—Shows the list of exported filesystems.
- `-h or –help`—Provides helpful information.
- `-v or –version`—Reports the current program version.
- `--no-headers`—Suppresses the descriptive headings from the output.

Unsharing Resources

There will come a time when you will want to prevent a filesystem from being mounted. You can use the reject (`-r`) option with the `mount` command, as discussed previously, or you can simply unshare the resource.

Solaris 2.x

The following sections describe the Solaris commands used to unshare NFS resources.

`unshare`

`unshare` makes a shared filesystem unavailable. The following shows the syntax for the `unshare` command:

Usage: `unshare [ -F FSType ] [ -o specific_options ] [ pathname | resourcename ]`

If `–F FSType` is unspecified, `unshare` will use as a default the `FSType` of the first entry in the `/etc/dfs/dfstab` file. The `–o specific options` depend on the `FSType` used. See your specific documentation for more information.

unshareall

`unshareall` unshares shared resources of type `FSType`. The following shows the syntax for the `unshareall` command:

Usage: `unshareall [-F FSType[,FSType...]]`

If called without a specific `FSType`, `unshareall` unshares all shared resources.

Using `showmount` to Verify

`showmount` can be used to verify that the filesystem is no longer mounted by any clients. Refer to the syntax in the previous section.

Unsharing with Linux `exportfs`

Linux lacks any official command to unshare a shared resource. The best way to achieve this functionality is to edit the share file (`/etc/exports`), removing the filesystem that you no longer want to be shared. Then run `exportfs` to have the system reread the share file. If your Linux system lacks the `exportfs` command, you can create an equivalent shell script:

```
#!/bin/sh
killall -HUP /usr/sbin/rpc.mountd
killall -HUP /usr/sbin/rpc.nfsd
```

NFS Client Commands

The following sections show the client commands used to mount or unmount an NFS resource.

Note

It is important that the mount point (empty directory) upon which you will be mounting your resources is created beforehand.

Mounting NFS Resources

The following commands can be used to mount a shared resource.

`mount` (Solaris/Linux)

`mount` is used to mount remote NFS filesystems. The following shows the syntax for the `mount` command:

Usage (Solaris):

```
mount [ -p | -v ]

mount [ -F FSType ] [ generic_options ] [ -o specific_options ] [ -O ]
special | mount_point

mount [ -F FSType ] [ generic_options ] [ -o specific_options ] [ -O ]
special mount_point

mount -a [ -F FSType ] [ -V ] [ current_options ] [ -o specific_options ]
[ mount_point. . . ]
```

Usage (Linux):

`mount [-hV]` (print help and version)

```
mount -a [-fFnrsvw] [-t vfstype]

mount [-fnrsvw] [-o options [,...]] device | dir

mount [-fnrsvw] [-t vfstype] [-o options] device dir
```

The Solaris and Linux versions of `mount` are similar in function but have some extensive and unique options. Please refer to your specific documentation or man page for more information.

The easiest way to mount a resource is to specify its mount point or device as specified in the `vfstab` or `fstab` files.

For example, assume the following entry in a Solaris `vfstab` file:

```
remotehost:/export/home2   -   /export/myhome   NFS   -   y   -
```

This filesystem could be easily mounted by executing one of the following commands:

```
# mount /export/myhome
```

```
# mount remotehost:/export/home2
```

`mountall` (Solaris)

`mountall` will `mount` all the resources specified in your `vfstab` file. The following shows the syntax for the `mountall` command:

Usage: `mountall [ -F FSType ] [ -l|-r ] [ file_system_table ]`

Options:

- `-F FSType`—In this case, NFS.
- `-l`—Mounts all local filesystems.
- `-r`—Mounts all remote filesystems.
- `file-system-table`—By default, `/etc/vfstab`.

How Automounting Works

It is possible to set up a special NFS daemon and have it monitor the need for a remote NFS filesystem. This process is called *automounting*. When an unmounted remote filesystem is required by an application or user, the automounter automatically mounts it from the NFS server. When the remote filesystem is not being used, the automounter unmounts it. There are many benefits to automounting, including better network utilization and easier administration.

Automounting is available in both Solaris and Linux, and with most other Unix platforms as well. Refer to your operating system documentation or Unix man pages for more information.

Unmounting NFS Resources

The following sections describe the commands used to unmount a shared resource.

`umount` (Solaris/Linux)

`umount` unmounts a mounted resource. The following shows the syntax for the `umount` command:

Usage (Solaris):

```
umount [ -V ] [ -o specific_options ] special | mount_point
```

```
umount -a [ -V ] [ -o specific_options ] [mount_point. . . ]
```

Usage (Linux):

`umount [-hV]` (print help and version)

```
umount -a [-nrv] [-t vfstype]
```

```
umount [-nrv] device | dir [...]
```

Like `mount`, `umount` in Linux and Solaris are very similar but have some unique options. Please refer to your specific documentation or `man` page for information.

Also like `mount`, `umount` can be run using only the mount point or device as specified in the `vfstab` or `fstab` files.

For example, assume the following entry in a Linux `fstab` file:

```
remotehost:/export/home2   /export/myhome   nfs
rsize=1024,wsize=1024,hard,intr   0   0
```

This filesystem could be easily unmounted by executing one of the following commands:

```
# umount /export/myhome
```

```
# umount remotehost:/export/home2
```

`umountall` (Solaris)

`umountall` will unmount all of your mounted file systems. Useful options allow you to specify only to unmount remote file systems, or even just those that are mounted from the specified host. The following shows the syntax for the `umountall` command:

Usage:

```
umountall [ -k ] [ -s ] [ -F FSType ] [ -l|-r ]
```

```
umountall [ -k ] [ -s ] [ -h host ]
```

Options:

`-k`—Attempts to kill any processes that are using the filesystem.

`-s`—Does not unmount filesystems in parallel.

`-F FSType`—Only unmounts filesystems of type `FSType` (NFS in this case).

`-l`—Only unmounts local filesystems.

`-r`—Only unmounts remote filesystems.

`-h host`—Only unmounts remote filesystems from host.

A Practical Example: Sharing and Mounting an NFS Filesystem

This section puts what you've just learned into practice. You will share a filesystem from a Solaris 2.6 system and mount it on a Linux (RedHat 6.0) system.

First you need to edit the `/etc/dfs/dfstab` file to add an entry for your filesystem. The entry you will add is

```
share  -F nfs   -d "WWW Directory"  /www
```

This entry will share the filesystem `/www`.

After adding the line to your `dfstab`, a quick execution of the `shareall` command will make the `/www` filesystem ready for remote mounting.

```
#shareall
```

Running `share` will verify that it is, in fact, exported.

```
#share

-                /www   "WWW Directory"
```

Now you need to ensure that the proper daemons are running. On the Solaris server, you need to have `nfsd` and `mountd` running. The Unix `ps` command will allow you to see their status.

```
#ps -ef
```

The `ps` command shows a listing of all active processes, in which you can find your NFS daemons, as shown in the following output:

```
root 27282     1  0 08:10:59 ?        0:00 /usr/lib/nfs/nfsd -a 16
root 27280     1  1 08:10:59 ?        0:00 /usr/lib/nfs/mountd
```

If they are not running (indicated by their absence from the output of the `ps` command), they can be started using the NFS `init` procedure:

```
#/etc/init.d/nfs.server start
```

Now you are ready to move over to your Linux client and mount the shared resource.

On the Linux machine, a properly executed `mount` command will do the trick.

```
mount -o rsize=1024,wsize=1024 solaris:/www /mnt
```

And to unmount the filesystem:

```
umount /mnt
```

To make the mount more permanent, you can add an entry to the `/etc/fstab` file.

```
solaris:/www   /mnt   nfs   rsize=1024,wsize=1024,hard,intr   0   0
```

This entry specifies that we want to mount the NFS `/www` filesystem from the server Solaris on the mount point `/mnt`. The `hard,intr` options specify that the mount must be a hard, interruptible mount (more reliable in the event of a server problem).

That's how easy it is. Now, as we all know, in the real world there are problems. NFS is no different. The next section describes some of the common problems you might encounter, and the solutions for these problems.

Common NFS Problems and Solutions

This section introduces you to some of the trials and tribulations of setting up NFS in a Unix environment. Several common problems and solutions are offered. Because of the number of daemons and files that must be running and/or configured properly, NFS can sometimes be challenging to perfect. Most of the problems you experience at first will involve trying to get the resource mounted.

Unable to `mount`

Mounting problems are most likely caused by either improper configuration or a network problem.

When troubleshooting mount problems, unless you have some suspicion as to where the problem may lie (like you tried to configure the `vfstab` file without looking at the instructions), starting at the top is sometimes best.

Verify that you can contact the NFS server. The `ping` command is useful to ensure that connectivity exists but only tests connectivity at the IP Layer.

If you have access to the server, verify that the proper daemons are running. See the "NFS Daemons" section earlier in this chapter for more details. Ensure that the resource is shared properly by using the `share` command or its equivalent. If it is not shared, examine the server configuration files (`dfstab` or `exports`). Refer to the "NFS-Related Files" section earlier in this chapter for more details. Make sure that the client is known to the server. The client hostname should reside in the `/etc/hosts` file in the same form as it is in the configuration file. For example, if the server specifies that the system named *loco* is allowed to mount a resource, ensure that *loco* is in the `hosts` file. NFS can be picky—even if *loco.mydomain.com* is in the file, so, too, must be *loco*.

If you don't have access to the server, you may need to call upon your friendly Systems Administrator for help.

Assuming that you can get to the NFS server and all is well there, it's time to examine the client configuration. Again, ensure that the necessary daemons are running and that the files (`fstab` or `vfstab`) are properly configured. Check for name consistency between the `hosts` file and the NFS configuration files.

Unable to `unmount`

If you ever find yourself unable to unmount a resource, the first thing you will need to do is make sure that you are not using that resource. The most logical use of a resource is sometimes the easiest to overlook. In this case you will receive an ambiguous message that says that the filesystem is busy. Check all open shells and terminals, and make sure there are no open "file manager" programs viewing the filesystem. Also make sure there are no editors using files resident on the filesystem. As you find these, terminate them and try again. Don't forget to check the shell you are working in—the System Administrator's equivalent of losing your glasses on your head.

Hard Mounts Versus Soft Mounts

NFS filesystems can be mounted using either the *hard* or *soft* method. As was stated earlier, the hard mount is the most reliable, and is preferred if you are mounting resources for writing or accessing mission-critical files or programs. However, if a resource is mounted hard and the server crashes or the network connection is otherwise dropped, any programs (or users) accessing that resource will hang. This can be undesirable. By default, NFS resources are mounted hard.

The opposite of a hard mount is a soft mount. With soft mounts, broken communication between the client and server will cause the programs using the NFS resource to abort. However, soft mounts on unreliable networks can result in undesirable results as well.

A solution to this problem is to `mount` your NFS resources using the `hard` and `intr` options. These `mount` command options will result in a hard mount that will respond to an interrupt and terminate.

Related Protocols and Products

Due to the popularity of NFS and the need for shared resources among different computer platforms, many tools based upon and similar to NFS have been created. This section goes over a few of the highlights.

WebNFS

Sun Microsystems has recently introduced WebNFS, an enhanced version of the NFS protocol. WebNFS provides greater scalability, reliability, and performance over the Internet than its predecessor, NFS. WebNFS also works through firewalls—a challenge for the RPC-based NFS. WebNFS requires NFS version 3 or higher. WebNFS is supported by the major independent Internet vendors including Netscape, Novell, Apple, IBM, and other NFS vendors. WebNFS 1.2 includes a JavaBean component, dependent on Java 2 SDK.

For more information, visit `http://www.sun.com/webnfs/`.

PC-NFS and Other Client Software

PC-NFS by Sun Microsystems is an NFS client product for non-Unix computers. It allows your non-Unix systems to take advantage of your organization's shared resources. It relies on the daemon `pcnfsd`, which is shipped with several Sun products.

Note

If `pcnfsd` is not available for your NFS server, you might need to find the source code for `pcnfsd` on the Internet, and compile and install it. On Linux systems, the `pcnfsd` is called `rpc.pcnfsd`.

Many other NFS client products are available. Table 33.2 lists some of these and provides a Web address for more information.

TABLE 33.2 A Sampling of NFS Client Products

Product	*Vendor*	*URL*
Solstice NFS Client	Sun Microsystems	`http://www.sun.com/netclient/nfs-client/`
Reflection NFS Connection	WRQ	`http://www.wrq.com/`
NFS Maestro	Hummingbird Communications, Ltd.	`http://www.hcl.com/products/nc/nfs/`
Omni-NFS	Xlink Technology	`http://www.xlink.com/`

SMB and CIFS

SMB, or Service Message Block, is a public standard developed by IBM, Microsoft, and others that allows computers to share filesystems, printers, and other resources. SMB is natively supported by Windows NT, OS/2, and Linux, and is supported by many other systems through the use of third-party software.

For more information on SMB, refer to `http://www.samba.org/cifs/docs/what-is-smb.html`.

The Common Internet File System (CIFS) is being developed by a team of vendors (Microsoft, SCO, and more) as a public version of the SMB protocol. The initial implementation is expected to be very similar to NT LM (the LAN Manager component in Microsoft NT), with improved support for sharing resources over the Internet.

For more information on CIFS, visit `http://msdn.microsoft.com/library` and search for CIFS./.

Some products that implement SMB are

- Samba
- Windows for Windows NT, 95/98/ME/2000/XP
- LAN Manager

Samba Supports SMB and CIFS Protocols

Samba is an "open source" client/server product that supports the SMB and CIFS protocols. It is available under the GNU General Public License.

Samba allows you to easily share server resources, such as filesystems and printers, with clients on your network.

For more information, visit `http://www.samba.org`.

Other Products

Several other products are out there that allow computers to share resources. Other than NFS and SMB, most of these do not readily support disparate computer platforms. Examples of these other protocols are AppleTalk, Decnet, NetWare, and more.

Summary

This chapter has discussed NFS, its history, and its implementation. The NFS-related daemons, files, and other programs were introduced, and you walked through a practical example of sharing and mounting an NFS filesystem. Several related programs and protocols were discussed, such as client NFS programs and the SMB protocol.

Due to the number of daemons, files, and options associated with NFS and its suite of commands, this chapter touched briefly on troubleshooting NFS problems and left you with some references to allow you to learn more about NFS.

Using IP Based Applications

PART VIII

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CHAPTER 34

Integrating TCP/IP with Application Services

by Bernard McCargo

IN THIS CHAPTER

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- **Integrating TCP/IP with Legacy Applications** *832*
- **Using TCP/IP with Other Networks** *832*

TCP/IP is a layered set of protocols. In order to understand what this means, it is useful to look at an example. A typical situation is sending mail. First, there is a protocol for mail. This defines a set of commands that one machine sends to another—for example, commands to specify who the sender of the message is, who it is being sent to, and the text of the message. However, this protocol assumes that there is a way to communicate reliably between the two computers. Mail, like other application protocols, simply defines a set of commands and messages to be sent. It is designed to be used with TCP and IP.

TCP is responsible for making sure that the commands get through to the other end. It keeps track of what is sent, and retransmits anything that did not get through. If any message is too large for one datagram, such as the text of the mail, IP will split it up into several datagrams.

IP takes care of fragmentation and reassembly of the datagram if the MTU size of an intermediate network is smaller than the datagram size. However, it is the function of TCP to ensure that the datagrams making up the message are assembled correctly at the destination.

Because reliability is needed for many applications, the applications are put together into a separate protocol, rather than being part of the specifications for sending mail. You can think of TCP as forming a library of routines that applications can use when they need reliable network communications with another computer. Similarly, TCP calls on the services of IP. Although the services that TCP supplies are needed by many applications, there are still some kinds of applications that don't need the full reliability of TCP such as those applications that depend on UDP. However, there are some services that every application needs, so these services are put together into IP. As with TCP, you can think of IP as a library of routines that TCP calls on, but which is also available to applications that don't use TCP. This strategy of building several levels of protocol is called *layering*. Think of the application programs such as mail, TCP, and IP as being separate layers, each of which calls on the services of the layer below it. Generally, TCP/IP applications use four layers:

- An application protocol such as mail.
- A protocol such as TCP that provides services needed by many applications.
- IP, which provides the basic service of getting datagrams to their destination.
- The protocols needed to manage a specific physical medium, such as Ethernet or a point-to-point line.

The following sections describe the function of these layers.

Using a Browser As the Presentation Layer

The Presentation Layer performs certain functions that are requested sufficiently often to warrant finding a general solution for these functions, rather than letting each user solve the problems. In particular, unlike all the lower layers, which are just interested in moving bits reliably from here to there, the Presentation Layer is concerned with the syntax and semantics of the information transmitted.

A typical example of a presentation service is encoding data in a standard, agreed-upon way. Most user programs do not exchange random binary bit strings. They exchange things such as names, dates, amounts of money, and invoices. These items are represented as character strings, integers, floating-point numbers, and data structures composed of several simpler items. Different computers have different codes for representing character strings, integers, and so on. In order to make it possible for computers with different representations to communicate, the data structures to be exchanged can be defined in an abstract way, along with a standard encoding to be used "on the wire." The Presentation Layer handles the job of managing these abstract data structures and converting from the representation used inside the computer to the network standard representation.

The Presentation Layer is also concerned with other aspects of information representation. For example, data compression can be used to reduce the number of bits that have to be transmitted and cryptography is frequently required for privacy and authentication.

Note

Although encryption can be considered a Presentation Layer function, it is not exclusively a Presentation Layer function. Many of the standards, such as IPSec, implement encryption as part of the Network Layer (IPv6) or a sublayer between the Network Layer and Transport Layer (IPv4).

In questioning how the browser is used as the Presentation Layer, some browser-specific issues need to be examined. Frames are an artifact of browser presentation. To the server (HTTP server included) they don't come into play. The server is just getting content for a URL and placing it where the browser says to place it. If you knew what pages you had dumped into the frames the user is viewing, you could write an action handler to create an instance of the page in the other frame and have it do something for you.

Integrating TCP/IP with Legacy Applications

Integrating TCP/IP with legacy applications is becoming the norm. Vendors such as Novell are integrating TCP/IP as a standard protocol as seen in products such as NetWare 5 and NetWare 6. Some companies have protocol converters (also sometimes called gateways) to integrate TCP/IP with other protocols.

Integrated TCP/IP support for applications offers users the following benefits:

- Eases TCP/IP protocol selection by fully integrating protocol selection into the application installation process.
- Simplifies IP address management through DHCP/BootP server software by continually providing a pool of IP addresses that are automatically allocated to users as needed.
- Allows mobile users with a SLIP or PPP connection to use the Internet to access application servers anywhere in the world.
- Improves wide-area network performance by eliminating unnecessary broadcast traffic, freeing bandwidth on wide-area connections and improving throughput.
- Enables users to connect to heterogeneous IP-based network devices such as servers and printers attached to Unix hosts.
- Leverages existing client stacks to provide full access to network resources for a wide variety of desktop clients, including DOS, Windows 3.1, Windows for Workgroups, Windows 9x, and Windows NT/2000 Server and Workstation.

Using TCP/IP with Other Networks

TCP/IP is sometimes only one of a number of protocols used in any given network. The interactions between TCP/IP (and its associated protocols) and the other protocols that may be working are important. The layers of a TCP/IP protocol are designed to be independent of each other, allowing mixing of protocols. When a message is to be sent over the network to a remote machine, each protocol layer builds on the packet of information sent from the layer above, adding its own header and then passing the packet to the next lower layer. After being received over the network (packaged in whatever network format is required), the receiving machine passes the packet back up the layers, removing the header information one layer at a time.

As the packet travels up the layers, protocol information in the lower layers is used to identify which upper layer protocol should process the packet.

Replacing any layer in the protocol stack requires that the new protocols work with all the other layers, as well as perform all the required functions of that layer (for example, duplicating the services of the replaced protocol). The process begins with a message of some form from an *Upper Layer Protocol* (ULP) that itself is passing a message from an application higher up. As the message is passed to TCP, it adds its own header information and passes to the IP Layer, which does the same. When the IP message is passed to the Ethernet Layer, Ethernet adds its own information at the front and back of the message and sends the message out over the network. When working with other operating systems or network architectures, replacing one or more layers in the TCP/IP structure with layers from another system is often necessary.

The following are examples of services that use different layers of the network.

NetBIOS and TCP/IP

NetBIOS resides above the TCP or UDP protocol, although it usually has solid links into that layer (so the two layers cannot be cleanly separated). NetBIOS acts to connect applications together in the upper layers, providing messaging and resource allocation.

Three Internet port numbers are allocated for NetBIOS. These are for the NetBIOS name service (port 137), datagram service (port 138), and session service (port 139). There is also the provision for a mapping between Internet's *Domain Name Service* (DNS) and the *NetBIOS Name Server* (NBNS). The NetBIOS Name Server is used to identify PCs that operate in a NetBIOS area. In the interface between NetBIOS and TCP, a mapping between the names is used to produce the DNS name.

On Windows machines, IP can be configured to run above NetBIOS, eliminating TCP or UDP entirely and running NetBIOS as a connectionless service. In this case, NetBIOS takes over the functions of the TCP/UDP Layer, and the upper-layer protocols must have the data integrity, packet sequencing, and flow control functions. In this architecture, NetBIOS encapsulates IP datagrams. Strong mappings between IP and NetBIOS are necessary so that NetBIOS packets reflect IP addresses. (To do this, NetBIOS codes the names as `IP.nnn.nnn.nnn.nnn`.)

This type of network requires that the upper-layer protocols handle all the necessary features of the TCP protocol, but the advantage is the network architecture is simple and efficient. For some networks, this type of approach is well suited, although the development of suitable ULPs can be problematic at times.

Note

However, the reliance on NetBIOS creates its own sets of problems. NetBIOS is often implemented at the protocol level in terms of the NetBEUI protocol. NetBEUI is a non-routable protocol, which means that it does not scale very well for building large networks. Another problem with NetBIOS is its excessive use of broadcasts. Broadcasts can consume network bandwidth, and many routers by default block broadcasts. In the case of Windows NT domains, the fact that broadcasts do not propagate across routers led to the rule of each subnet having its own master browser—an unnecessary complication. Starting with Windows 2000, Microsoft has eliminated the use of NetBIOS. You can configure SMB (Server Message Block) and MS-RPC (Microsoft Remote Procedure Call) to run purely on an IP network without using NetBIOS over TCP/IP (NBT). In Windows 2000 networks, NetBIOS is only required for supporting down-level clients such as Windows NT and Windows 9x.

IPX and UDP

Novell's NetWare networking product has a protocol similar to IP called the *Internet Packet Exchange* (IPX), which is based on Xerox's XNS. IPX usually uses UDP for a connectionless protocol, although TCP can be used when combined with LLC Type 1.

The stacking of the layers (with IPX above UDP) ensures that the UDP and IP headers are not affected, with the IPX information encapsulated as part of the usual message process. As with other network protocols, a mapping is necessary between the IP address and the IPX addresses. IPX uses a network and host number of four and six bytes, respectively. These are converted as they are passed to UDP.

It is possible to reconfigure the network to use IPX networks by using TCP instead of UDP, and substituting the connectionless LLC Type 1 protocol. When using this layer architecture, IP addresses are mapped using ARP.

Summary

Many applications need a mechanism to open a connection to a specified computer, log into it, and tell it what file you want, and control the transmission of the file. This is done by application protocols. The application protocols run on top of TCP/IP. That is, when they want to send a message, they give the message to TCP. TCP makes sure it gets delivered to the other end reliably. Because TCP and IP take care of all the networking details, the application protocols can treat a network connection as if it were a simple byte stream, like a terminal or phone line.

CHAPTER 35

Internet Mail Protocols

by Neal S. Jamison

In This Chapter

- **Electronic Mail** *836*
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- **Client Mail Retrieval with POP and IMAP** *845*
- **Advanced E-mail Topics** *849*

Electronic mail is by far the most prevalent use of the Internet today. Whether it's a message to your boss, your insurance agent, your bank teller, or your long-distance relatives and friends, there is no doubt that e-mail has changed the way we communicate.

Electronic Mail

Person-to-person communication is a fact of life. We must communicate with our family members, friends, and peers. Without a doubt, one of the most important technologies to emerge from the information age is electronic mail or, more familiarly, e-mail. E-mail messages are flying around the world as I write this, delivering business and personal communication to the desktops of millions.

This section briefly introduces the concept of e-mail, and looks at its evolution into what it is today. It introduces the standards that make e-mail work and the standard-making groups who bring it all together.

History of E-mail

The Internet was developed to improve communication between the scientists and government technologists who were in charge of its creation. And although e-mail wasn't the first way that they communicated, it can be argued that e-mail is the most widely used application on the Internet. The Internet has blossomed into much more than an e-mail–transport mechanism.

The earliest e-mail systems were little more than programs designed to copy a message into a user's mailbox. At that time, users were all local to one machine. One user on a multiuser computer could send a message to another user on that same computer. That was it. This functionality was carried to LANs through the development of products such as cc:Mail and other similar proprietary e-mail systems. A short time later, a component known as a gateway was introduced to allow users of one e-mail server to send and receive messages to and from other servers. Gateways were built to allow different types of e-mail systems to communicate. cc:Mail users could utilize the gateway to send messages to Microsoft Mail users in other organizations. But these gateways were still sending and receiving proprietary–formatted messages. What the world needed was a standard.

The Standards and the Groups Who Make Them

There are really two standards in electronic mail. X.400, developed by the International Telecommunications Union–Telecommunications Standards Sector (ITU-TSS) and the International Organization for Standardization (ISO), and the Simple Mail Transfer

Protocol (SMTP), developed through the early research and development efforts of the Internet and made standard by the Internet Engineering Task Force (IETF). The following sections discuss both of these standards.

X.400

First specified by the ITU in 1984 and later updated in 1988, X400 is a complex, robust protocol for electronic messaging. However, due to its complexity and a current lack of vendor support, it has not enjoyed the popularity and widespread adoption that SMTP has. For that reason, this chapter only briefly introduces X.400 and will go into far greater detail on the Internet standard SMTP.

E-mail Terminology 101

The e-mail world uses a few special terms to describe the components of an e-mail system:

User Agent (UA)—The e-mail client program that runs on the user's computer and is used to create and read e-mail messages.

Message Transfer Agent (MTA)—The e-mail server. The MTA stores and forwards messages.

Message Store (MS)—Stores messages until read or otherwise processed by the recipient.

X.400 messages can contain highly structured information and attachments. X.400 messages carry attributes that specify terms of delivery and add value to the message. Example attributes are

- Sensitivity and importance level
- Priority
- Expiration date
- Delivery and receipt notification
- Reply-by date

Like the structure of the message, X.400 addressing is somewhat complex. Table 35.1 shows the common attributes that make up an X.400 address.

TABLE 35.1 Common X.400 Attributes

Attribute	*Description*
G	Given name
I	Initial
S	Surname
Q	Generation (Jr., Sr.)
CN	Common name
O	Organization
OU	Organizational unit
P	Private management domain
A	Administrative management domain
C	Country

Consider this example:

```
C=US;A=XXX;P=Acme;O=Acme;OU=IT;S=Jamison;G=Neal;
```

In this sample address, my country is the United States (C=US); my administrative domain, or the company that offers the X.400 service I am using, is XXX (A=XXX); my private domain is Acme (P=Acme); my organization or employer is Acme (O=Acme); and the organizational unit is the IT department (OU=IT). My name needs no explanation. Compare this to my SMTP address of `jamisonn@mycompany.com`.

The Role of Directory Services

One of the complications of the X.400 standard is the address scheme. Unlike an SMTP address (`username@domain.com`), X.400 addresses can be quite complex. Enter the directory services: X.500 and the Lightweight Directory Access Protocol (LDAP). These protocols specify a standard format for the structure of global directories. X.400 mail systems can use these directories to look up correspondents.

For more information on X.500 and LDAP, see Chapter 18, "LDAP: Directory Services," refer to RFC 2256, or visit the International Telecommunication Union at `http://www.itu.int/`.

X.400's complex structure gives it several distinct advantages and disadvantages.

The advantages are as follows:

- Great for supporting applications where data must be complex and/or secure (such as e-commerce)
- Strong security
- Reliable non-delivery notification
- International standardization

The disadvantages are as follows:

- Often expensive to implement
- High administration and configuration overhead
- Lack of vendor support
- Many of X.400's great features (such as security) are not yet incorporated into products

For more information on X.400, refer to the International Telecommunication Union at `http://www.itu.int/`.

The Simple Mail Transport Protocol (SMTP)

The Internet standard for e-mail is the Simple Mail Transport Protocol (SMTP). SMTP is the application-level protocol that handles message services over TCP/IP networks. SMTP was defined in 1982 by the Internet Engineering Task Force (IETF) and is currently specified in RFCs 821 and 822.

SMTP uses TCP port 25.

Note

Although SMTP is the most prevalent of the e-mail protocols, it lacks some of the rich features of X.400. A primary weakness of standard SMTP is the lack of support for non-text messages.

MIME and SMTP

MIME (Multipurpose Internet Mail Extensions) supplements SMTP and allows the encapsulation of multimedia (non-text) messages inside a standard SMTP message. MIME uses Base64 encoding to convert complex files into ASCII.

MIME is a relatively new standard, and although it is supported by almost all UA applications at this time, there is the chance that your e-mail application does not support MIME. If that is the case, you will likely use one of the other encoding methods (BinHex or uuencode) described later in this chapter.

MIME is described in RFCs 2045–2049.

S/MIME

A new specification for MIME exists that allows it to support encrypted messages. S/MIME is based on RSA's public key encryption technology and helps prevent messages from being intercepted and forged.

RSA Public Key/Private Key Authentication

Short for Rivest, Shamir, and Adelman, the inventors of the algorithm, RSA provides public key/private key encryption. The basic idea is that data encrypted with the public key can only be decrypted with a private key. With S/MIME, the sending UA encrypts a random string of data using the public key of the receiving (remote) user or UA. The recipient UA then decrypts the message using the private key.

For more information on RSA, refer to `http://www.rsa.com/`.

S/MIME is currently specified in RFCs 2311 and 2312.

Other Encoding Standards

Several other standards exist for encoding non-ASCII messages. The more popular of these are BinHex and uuencode.

BinHex stands for Binary Hexadecimal and is considered by some to be a Macintosh version of MIME. Uuencode stands for Unix-to-Unix Encoding because of its Unix origin, although it is now supported by many non-Unix platforms. Although MIME, uuencode, and BinHex do have several fundamental differences, they accomplish the same primary goal—allowing non-text files to be sent in text messages. The method you use will depend upon your mail UA and the UAs used by your target recipients. Fortunately, most modern UAs take care of the encoding and decoding for us.

SMTP Commands

Part of the simplicity of SMTP is that it uses a small number of commands. Table 35.2 lists these commands.

TABLE 35.2 SMTP Commands as Specified in RFC 821

Command	*Description*
HELO	Hello. Used to identify the sender to the receiver. This command must accompany the hostname of the sending host. In the extended protocol (ESTMP), the command EHLO is used instead. See the "Extended SMTP" section later in the chapter for more information.
MAIL	Initiates a mail transaction. Arguments include the "from" field or the sender of the mail.
RCPT	Identifies the recipient of the message.
DATA	Announces the beginning of the actual mail data (the body of the message). The data can contain any 128-bit ASCII code and is terminated with a single line containing a period (.).
RSET	Aborts (resets) the current transaction.
VRFY	Used to confirm a recipient user.
NOOP	This "no operation" command specifies no action.
QUIT	Closes the connection.
SEND	Lets the receiving host know that the message must be sent to another terminal.
The following commands are specified, but not required, by RFC 821:	
SOML	Send or mail. Tells the receiving host that the message must be sent to other terminals or mailboxes.
SAML	Send and mail. Tells the receiving host that the message must be sent to other terminals and mailboxes.
EXPN	Used to expand a mailing list.
HELP	Requests helpful information from the receiving host.
TURN	Requests that the receiving host take on the role of the sending host.

SMTP command syntax is simple as well, as you can see in the following SMTP example:

```
220 receivingdomain.com ñ
    Server ESMTP Sendmail 8.8.8+Sun/8.8.8; Fri, 30 Jul 1999 09:23:01
HELO host.sendingdomain.com
250 receivingdomain.com Hello host, pleased to meet you.
```

```
MAIL FROM:<username@sendingdomain.com>
250 <username@sendingdomain.com>Ö Sender ok.
RCPT TO:<username@receivingdomain.com>
250 <username@receivingdomain.com>Ö Recipient ok.
DATA
354 Enter mail, end with a ì.î on a line by itself
Here goes the message.
.
250 Message accepted for delivery
QUIT
221 Goodbye host.sendingdomain.com
```

The resulting mail message would look something like:

```
From username@sendingdomain.com Fri Jul 30 09:23:39 1999
Date: Fri, 30 Jul 1999 09:23:15 -0400 (EDT)
From: username@sendingdomain.com
Message-Id: <199907301326.JAA13734@mail.receivingdomain.com>
Content-Length: 23

Here goes the message.
```

SMTP Status Codes

When a sending MTA issues SMTP commands to the receiving MTA, the receiving MTA responds with special status codes to let the sender know what is happening. Table 35.3 lists the SMTP reply codes as specified in RFC 821. These codes are grouped by status, as defined by the first digit in the code (5xx for failure, 4xx for temporary problem, 1xx–3xx for success).

TABLE 35.3 SMTP Reply Codes

Code	*Description*
211	Help reply, system status
214	Help message
220	Service ready
221	Closing connection
250	Requested action okay
251	User not local, forwarding to `<path>`
354	Start mail input
421	Service not available
450	Action not taken, mailbox busy
451	Action aborted, local error

TABLE 35.3 Continued

Code	*Description*
452	Action not taken, insufficient storage
500	Command unrecognized or syntax error
501	Syntax error in parameters or arguments
502	Command not supported
503	Bad sequence of commands (given out of order)
504	Command parameter not supported
550	Action not taken, mailbox unavailable
551	Not a local user
552	Aborted: Exceeded storage allocation
553	Action not taken, mailbox name not allowed
554	Transaction failed

The numeric codes are defined in the RFC. However, the accompanying text, while suggested in the RFC, is left up to the postmasters and MTA administrators to define. Sometimes they get a little creative.

Extended SMTP

SMTP has proven itself to be a strong, useful e-mail protocol. However, there is a recognized need for extensions to standard SMTP. RFC 1869 spells out a means by which extensions can be added to SMTP. It does not list specific extensions, but rather provides a framework for the addition of necessary commands. An example is the `SIZE` command. This extension allows a receiving host to limit the size of incoming messages. Without ESMTP this would not be possible.

When a system connects to an MTA, it can provide the extended version of the `HELO` command, `EHLO`. If the MTA supports extended SMTP (ESMTP), it will respond with a list of commands it will support. If it does not support ESMTP, it provides an error (500 Command not recognized) and the sending host reverts back to SMTP. The following is a sample ESMTP transaction:

```
220 esmtpdomain.com ñ
    Server ESMTP Sendmail 8.8.8+Sun/8.8.8; Thu, 22 Jul 1999 09:43:01
EHLO host.sendingdomain.com
250-mail.esmtpdomain.com Hello host, pleased to meet you
250-EXPN
250-VERB
250-8BITMIME
```

```
250-SIZE
250-DSN
250-ONEX
250-ETRN
250-XUSR
250 HELP
QUIT
221 Goodbye host.sendingdomain.com
```

Table 35.4 describes the common ESMTP commands.

TABLE 35.4 Common ESMTP Commands

Command	*Description*
EHLO	Extended version of HELO
8BITMIME	Indicates 8-bit MIME transport
SIZE	Used to specify the size limit of the message

Examining SMTP Headers

You can learn a wealth of information by closely examining the headers of your SMTP messages. Not only can you see whom the message is from, the subject, the date sent, and the intended recipient, you can see every stopping point made by the message en route to your mailbox. RFC 822 specifies that the header contain, at a minimum, the sender (From), the date, and a recipient (TO, CC, or BCC).

Note

Technically, TO and CC are identical. CC (Carbon Copy) is a historical term that dates back to a time when everything was typed on typewriters and carbon paper was used to produce duplicates.

BCC (Blind Carbon Copy) Received header allows you to see everywhere a message has been prior to arriving at your inbox. It can be a great troubleshooting tool. Consider the following example:

```
From someone@mydomain.COM Sat Jul 31 11:33:00 1999
Received: from host1.mydomain.com by host2.mydomain.com (8.8.8+Sun/8.8.8)
   with ESMTP id LAA21968 for <jamisonn@host2.mydomain.com>;
   Sat, 31 Jul 1999 11:33:00 -0400 (EDT)
Received: by host1.mydomain.com with Internet Mail Service (5.0.1460.8)
   id <KNJ6NT2Q>; Sat, 31 Jul 1999 11:34:39 -0400
Message-ID: <C547FF20D6E3D111B4BF0020AFF588113101AF@host1.mydomain.com>
```

```
From: "Your Friend" <someone@mydomain.COM>
To: "'jamisonn@host2.mydomain.com'" <jamisonn@host2.mydomain.com>
Subject: Hello There
Date: Sat, 31 Jul 1999 11:34:36 -0400
```

In this example, you can see that a message was sent from `someone@mydomain.com`. From `mydomain.com`, the message was delivered to `host1`. That message was then received by `host2` from `host1`, where it was delivered to me. At each stop along the way, the receiving host is required to add its header, which must include a date/time stamp. It is interesting to note that in the preceding example, there is a discrepancy in timestamps. `Host2` (my computer) reports that it received the message at 11:33:00. `Host1` reports that it received the message at 11:34:36, over a minute after I received the message. This is due to a lack of clock synchronization between the two hosts.

Advantages and Disadvantages of SMTP

Like X.400, SMTP has several primary advantages and disadvantages.

The advantages are as follows:

- SMTP is very popular.
- It is supported on many platforms by many vendors.
- SMTP has low implementation and administration costs.
- SMTP has a simple addressing scheme.

The disadvantages are as follows:

- SMTP lacks certain types of functions.
- SMTP lacks the security specified in X.400.
- Its simplicity limits its usefulness.

Client Mail Retrieval with POP and IMAP

In the early days of Internet e-mail, users were required to log in to their e-mail server and read their messages there. Mail programs were usually text-based, and lacked the user-friendliness that many users were used to. To solve this problem, some protocols were developed that enable you to have your mail messages delivered directly to your computer desktop. These UA retrieval protocols also come in very handy when a user "roams," or works at several different computers.

Two widely used methods are Post Office Protocol (POP) and Internet Mail Access Protocol (IMAP).

The Post Office Protocol (POP)

POP allows local mail UAs to connect to the MTA and pull mail down to your local computer, where you can read and respond to the messages. POP was first defined in 1984, then updated by POP2 in 1988. The current standard is POP3.

POP3 UAs connect via TCP/IP to the server (typically port 110). The UA enters a username and password (either stored internally for convenience or entered each time by the user for stronger security). After authorized, the UA can issue POP3 commands to retrieve and delete mail.

POP3 is a receive-only protocol. POP3 UAs use SMTP to send mail to the server.

POP3 is defined by RFC 1939.

Table 35.5 lists the POP3 commands.

TABLE 35.5 POP3 Commands

Command	*Description*
`USER`	Specifies the username
`PASS`	Specifies the password
`STAT`	Requests the mailbox status (number of messages, size of messages)
`LIST`	Lists an index of the messages
`RETR`	Retrieves the specified messages
`DELE`	Deletes the specified messages
`NOOP`	Does nothing
`RSET`	Undeletes messages (rollback)
`QUIT`	Commits changes and disconnects

The Internet Mail Access Protocol (IMAP)

POP3 is a very good and simple protocol for retrieving messages to your UA. However, its simplicity results in a lack of several desired features. For instance, POP3 only works in offline mode, meaning that the messages are downloaded to the UA and deleted from the server.

Note

Some implementations of POP3 support a "pseudo-online" mode that allows the messages to be left on the server.

The Internet Mail Access Protocol (IMAP) picks up where POP3 leaves off. IMAP was first conceived in 1986 at Stanford University. IMAP2 was first implemented in 1987. IMAP4, the current specification, was accepted as an Internet standard in 1994. IMAP4 is currently specified in RFC 2060. IMAP4 is found at TCP port 143.

Table 35.6 lists the IMAP4 commands as specified in RFC 2060.

TABLE 35.6 IMAP4 Commands

Command	*Description*
CAPABILITY	Requests a list of supported functionality
AUTHENTICATE	Specifies an authentication mechanism
LOGIN	Provides username and password
SELECT	Specifies the mailbox
EXAMINE	Specifies mailbox in read-only mode
CREATE	Creates a mailbox
DELETE	Deletes a mailbox
RENAME	Renames a mailbox
SUBSCRIBE	Adds mailbox to active list
UNSUBSCRIBE	Removes mailbox from active list
LIST	Lists mailboxes
LSUB	Lists subscribed mailboxes
STATUS	Requests mailbox status (number of messages, and so on)
APPEND	Adds a message to the mailbox
CHECK	Requests a mailbox checkpoint
CLOSE	Commits deletions and closes mailbox
EXPUNGE	Commits deletions
SEARCH	Searches mailbox for messages meeting specified criteria
FETCH	Fetches parts of a specified message

TABLE 35.6 Continued

Command	*Description*
`STORE`	Changes data of specified messages
`COPY`	Copies message to another mailbox
`NOOP`	Does nothing
`LOGOUT`	Closes the connection

POP3 Versus IMAP4

There are many fundamental differences between POP3 and IMAP4. Depending on your UA, your MTA, and your needs, you might use one or the other, or even both. The advantages of POP3 are

- It is very simple.
- It is widely supported.

Due to its simplicity, POP3 is often limited. For example, it can only support one mailbox, and the messages must be deleted from the server (although many implementations support a "pseudo-online" mode allowing messages to be left on the server).

IMAP4 has several distinct advantages:

- Stronger authentication
- Support for multiple mailboxes
- Greater support for online, offline, or disconnected modes of operation

IMAP4's online mode support allows UAs to download only a subset of the messages from the server, search for and download only messages matching a certain criteria, and so on. IMAP4 also allows a user or UA to move messages between server folders and delete certain messages. IMAP4 is much better suited for the mobile user who needs to work at several different computers, or the user who needs to access and maintain several different mailboxes.

The major drawback to IMAP4 today is that it is not widely deployed by ISPs, not withstanding the fact that many IMAP4 clients and servers exist today.

Advanced E-mail Topics

As e-mail use becomes more prevalent, so do its related topics. This section introduces several topics that concern e-mail users. These topics include security, junk mail, and other types of e-mail services.

Security

As in every other aspect of computer networking, e-mail security has become an important subject. It is vital that we have mechanisms to ensure the safe and reliable delivery of e-mail.

Encryption

As discussed earlier, S/MIME provides a means of encrypting e-mail data. This encryption protects the data and ensures that it arrives as intended.

Another method of encrypting messages is Pretty Good Privacy (PGP). PGP uses public key/private key pairs to encrypt and decrypt messages. A sender encrypts a message with the recipient's public key. The recipient uses her private key to decrypt the message. For more information or to obtain PGP, see `http://www.pgp.com/`.

Digital signatures (also known as digital IDs) can be used to certify that a message is really from its apparent author. Digital signatures also utilize key pair encryption. For more information on digital signatures, refer to `http://www.verisign.com/client/index.html`.

Refer to RFCs 1421–1424 for more information on e-mail privacy and encryption.

Content Filters

There are also e-mail content filters that work much like firewalls. They scan incoming and outgoing messages to ensure that they meet the criteria set up by e-mail policy administrators and postmasters. An example use of this type of tool is a high-tech corporation that is concerned about data getting out and into a competitor's hands. This corporation could use the e-mail filter to make sure that certain types of attachments (for example, blueprints or design documents) are not sent out. Other uses are to block out offensive messages (based on keywords) or spam, and to scan for virus-infected or otherwise inappropriate attachments.

Viruses

E-mail viruses have become a very hot subject with the outbreak of many computer and e-mail–specific viruses. Although transmitting a virus through e-mail ASCII text is impossible, embedding a virus in an e-mail attachment is possible. Many of these viruses exploit the macro programming capabilities of e-mail clients such as the e-mail clients from Microsoft (Outlook and Outlook Express).

Note

The Melissa virus demonstrated to many e-mail users the importance of scanning all e-mail attachments for viruses.

For more information on viruses in general, refer to the Internet Society's site at `http://www.isoc.org/internet/issues/viruses/`.

Forgeries

Due to the weak security of SMTP, forging e-mail messages or giving them the appearance that they are coming from someone other than you is easy. Using the `telnet` command to connect to the SMTP port is possible. After connected, the counterfeiter can issue the commands in the same manner that your MTA would. Consider the following SMTP transaction:

```
$ telnet mail.mydomain.com 25
Trying...
Connected to mail.mydomain.com.
Escape character is '^]'.
220 mail.mydomain.com ñ Server ESMTP Sendmail 8.8.8+Sun/8.8.8;
    Fri, 30 Jul 1999 09:23:01
help
214-This is Sendmail version 8.8.8+Sun
214-Topics:
214-    HELO    EHLO    MAIL    RCPT    DATA
214-    RSET    NOOP    QUIT    HELP    VRFY
214-    EXPN    VERB    ETRN    DSN
214-For more info use "HELP <topic>".
help mail
214-MAIL FROM: <sender> [ <parameters> ]
214-    Specifies the sender.  Parameters are ESMTP extensions.
214-    See "HELP DSN" for details.
214 End of HELP info
helo fakedomain.com
250 mail.mydomain.com Hello realhost.mydomain.com, pleased to meet you
mail from:<charlatan@fakedomain.com>
```

```
250 <charlatan@fakedomain.com>... Sender ok
rcpt to:jamisonn
250 jamisonn... Recipient ok
data
354 Enter mail, end with "." on a line by itself
This is not really from charlatan@fakedomain.com.
.
250 MAA07012 Message accepted for delivery
quit
221 mail.mydomain.com closing connection
Connection closed by foreign host.
$
```

Notice that the real hostname was known and disclosed in the 250 response to the `HELO` command. The resulting e-mail sent to user `jamisonn` appears as follows:

```
From charlatan@fakedomain.com Sun Aug  1 12:18:08 1999
Date: Sun, 1 Aug 1999 12:17:43 -0400 (EDT)
From: charlatan@fakedomain.com
Message-Id: <199908011617.MAA07012@realhost.mydomain.com>
Content-Length: 50

This is not really from charlatan@fakedomain.com.
```

Although at first glance it appears as if the message is from `charlatan@fakedomain.com`, closer inspection of the header reveals the real hostname in the `Message-Id` line.

A warning to those who may think this is worth trying: Savvy postmasters and administrators have sophisticated wrapping and logging mechanisms that can reveal the true sender or even make forgery impossible. Forging e-mail is not a good idea and the preceding example is provided to show only that it is possible.

Spam and Other Junk

You might have noticed lately that your electronic mailbox is starting to resemble your non-electronic mailbox in one annoying way: It is starting to fill up with junk mail.

Junk mail, or spam as it is referred to in netspeak, is a real problem. Our mailboxes are bombarded with sales pitches, get-rich-quick schemes, and other unwanted and unsolicited annoyances. Our e-mail addresses are being sold or otherwise shared without our consent in the same manner that our physical addresses are shared. The result is an inbox full of junk.

An interesting method of blocking those annoying messages is through the use of “bozo filters” and “kill files.” These cute-sounding mechanisms are actually tools included with some mail UAs that will allow you to block messages that meet certain criteria. The most common variety works by reading the SMTP header of the incoming message and looking up the sender's address or subject keywords in your bozo file. If the message is not an offender, it is allowed through. However, if the message is from a bozo or contains a bozo subject, it is either deleted or stored in a bozo mailbox in case you want to do anything about it later.

Outside of these mechanisms, you can do some other things to fight spam. However, they are beyond the scope of this chapter. Refer to `http://spam.abuse.net/` or see the Internet Society's spam page at `http://www.isoc.org/internet/issues/spamming/` for more information.

Anonymous E-mail Services or Remailers

Anonymity on the Internet is a topic that raises some ethical questions. There are those who insist that anonymity should be provided, and those who insist that all actions must be traceable. Of course, the subject gets even more heated when it comes to person-to-person communication like e-mail.

Programs and services are available on the Internet that allow you to send e-mail anonymously. The most basic of these services utilize programs that strip the SMTP headers from your message and send it along to your intended recipient. This provides an untraceable message path, but it also provides no way for the recipient to reply, which could be good or bad depending on your objective.

More advanced services actually store a database of their anonymous users. Each user is assigned an ID, which allows him to send messages anonymously (as long as the database is properly safeguarded). The mapping of an anonymous ID back to the user's actual e-mail address allows recipients to respond.

Another form of anonymous e-mail can be accomplished through the use of online service and e-mail providers. There is a recent outcropping of "free" e-mail services (for example: Hotmail, Yahoo!, Usanet, and so on) that allow you to pick your own handle, or e-mail username. There is nothing to say that you have to use your real name or even any portion of it. By using a handle other than your true name, you can send e-mail almost anonymously.

Summary

This chapter explained in detail the Internet e-mail protocol: SMTP. It briefly explained the history of e-mail to demonstrate how far we have come. Some attention was given to X.400, a powerful but underutilized e-mail specification. SMTP was explained through a look at its command set, response codes, and methods of encoding non-text data. We looked at two methods of retrieving mail from the message transfer agent (MTA) or message store (MS): the utilitarian POP3 and the more powerful IMAP4.

Several e-mail–related issues were discussed. E-mail security issues were explored with special attention paid to encryption, content filtering, and viruses. We looked into spam and provided some pointers to help you deal with this nuisance. Finally, a section was included to point you to the Internet e-mail–related RFC documents, as well as the Web sites of groups responsible for the protocols we use today.

CHAPTER 36

The HTTP (World Wide Web) Service

by Neal S. Jamison

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The World Wide Web is often referred to as the killer application of the 1990s. No other technology or tool has opened so many doors, putting as much information literally right at our fingertips. The phenomenal growth of the Web is evidence of the importance and potential of Internet technologies.

The World Wide Web

The World Wide Web. The Information Super Highway. The Net. No matter what you prefer to call it, there is no doubt that the Web is the biggest thing to hit since the dawn of the personal computing revolution. From a small physics lab in the early 1990s to an estimated 200 million users today, the Web has come a long way in its short lifetime. In 1995, we surfed blindly around a few thousand Web sites and thought we were really getting somewhere. Today, with the help of intelligent search engines we navigate and quickly find exactly what we are looking for, and in some cases, order it, and even pay for it online. And this is just the beginning.

This section discusses the World Wide Web and its short but turbulent history.

Brief History of the Web

The World Wide Web was initially developed at CERN, the European Laboratory for Particle Physics. It was created to help improve file sharing and communication among physicists. In 1993, the National Center for Supercomputing Applications (NCSA) developed the first graphic Web browser, Mosaic. The development of this Web client launched the World Wide Web as we know it today.

Who's Who—The Creators and Maintainers of the Web

Tim Berners-Lee is the CERN employee credited with the invention of the Web. He wrote the first Web server, and in doing so, defined the languages and protocols of the Web. He also wrote the first basic WWW client.

The first popular Web server (NCSA HTTPd) was created by Rob McCool at the National Center for Supercomputing Applications. That server went on to become the base for the Apache Web server, the most prevalent server on the Web today. The first graphical browser was also created at NCSA by Marc Andreessen, who later founded Netscape Communications Corporation, makers of Netscape Navigator.

Tim Berners-Lee now serves as the Director of the *World Wide Web Consortium* (W3C), an organization largely responsible for the continuing enhancement of the Web and its protocols and standards. For more information about the W3C and its important work, visit its Web site at `http://www.w3c.org/`.

Another important group is the Internet Engineering Task Force (IETF). From its charter, "the Internet Engineering Task Force is a loosely self-organized group of people who make technical and other contributions to the engineering and evolution of the Internet and its technologies" (Source: `http://www.ietf.org/tao.html`). As such, they play a role in the evolution of the Web, and more specifically, HTTP. For more information on the role that the IETF plays, refer to `http://www.ics.uci.edu/pub/ietf/http/`.

Others are responsible as well for the continued development and standardization of the Internet and Web. They include the *Internet Architecture Board* (IAB), the *Internet Society* (ISOC), and the *Internet Research Task Force* (IRTF).

The Web Explosion

In mid-1994, it was estimated that there were approximately 3 million people using the Web, which at the time consisted of about 3,000 Web sites. July 2001 estimates by Nielsen/NetRatings (`http://www.nielsen-netratings.com/`) indicate that the home use Internet population now exceeds 257 million.

Note

In the numbers previously quoted, "people" actually refers to hosts. Counting the number of actual people on the Web is hard; counting host computers is easier, and everyone agrees that there is at least one user per host.

The Web has grown from an immature but promising medium used by a handful of scientists and engineers to a stable, securable environment suitable for e-commerce and other vital functions. And as computer and network technology improves, we can expect to see these populations increase, and the Web used for much more.

Uniform Resource Locators

The key to finding information on the Web is knowing how Web servers and browsers refer to server and file locations. The Web uses a schema known as *Uniform Resource Locators* (URL) to identify Web pages and other resources.

Here is an example URL:

```
http://www.w3c.org/Protocols/index.html
```

This URL, which would take you to the Web site of the World Wide Web Consortium, is broken down into the following segments:

```
Protocol:// servername.domain/ directory/ file
```

In the preceding example:

- The protocol is `http`.
- The full domain name is `www.w3c.org`.
- The directory is `Protocols`.
- The file is `index.html`.

> **Note**
>
> Most Web servers are configured to automatically provide default pages. In most cases, the default page is called `index.html`. However, other defaults include `home.html`, `default.html`, `home.htm`, and `index.htm`. With this option turned on and configured, a URL for `http://www.w3c.org/Protocols/` would return the `index.html` file found in the `Protocols` directory.

Other common URLs are

```
ftp://servername/directory/file
```

```
ftp://username@servername/directory/file
```

```
telnet://servername
```

```
news://newsservername/newsgroup
```

These examples represent URLs that request a document via anonymous FTP, request a document via FTP using "username," request telnet access to a server, and request access to the Usenet newsgroup, respectively.

It is also possible to pass data within a URL to be used by the server. A typical use of this would be the passing of parameters to a server-side function; for example

```
http://servername/directory/file.html?username=Jamison&uid=300
```

This URL would send to the page `file.html` two key-value pairs: a username of Jamison and a UID of 300.

Sometimes it is necessary to include special characters such as spaces or slashes (/) in the URL. In this case, these special characters must be "encoded" to prevent problems on the server end. The process of encoding (sometimes referred to as hexadecimal encoding) involves replacing these special characters with their hexadecimal equivalents. For example, suppose we want to pass a user's full name on the URL:

```
http://servername/directory/file.html?name=Neal%20Jamison
```

In this example the space between Neal and Jamison has been replaced with its hexadecimal equivalent 20. This practice of passing information on the URL is commonly used with *Common Gateway Interface* (CGI) programs. For more information on CGI, see the section "The Languages of the Web," later in this chapter.

Web Servers and Browsers

Web servers are the content providers of the Web. In response to a request from a client, a Web server provides data in some form or another. In most cases, this data takes the form of a page of *Hypertext Markup Language* (HTML). Servers can provide other forms of documents, such as images, sound, application files, or even video. Web browsers are the clients of the Web. Browsers include the software necessary to communicate with the Web server, and to translate and display the content returned by the server. Table 36.1 shows some of the leading servers found on the Web today. Table 36.2 shows the leading browsers.

TABLE 36.1 Popular Web Servers

Server	*URL for More Information*
Apache	`http://www.apache.org`
Microsoft Internet Information Server (IIS)	`http://www.microsoft.com/ntserver/techresources/ webserv/default.aspNetscape Enterprise Server http://home.netscape.com/enterprise/`

TABLE 36.2 Popular Web Browsers

Browsers	*URL for More Information*
Netscape Navigator	`http://home.netscape.com/browsers/`
Microsoft Internet Explorer	`http://www.microsoft.com/windows/ie/`
Opera	`http://opera.nta.no/`

Apache and the Internet Philosophy of Freedom

It's no surprise that the leading Web server on the Internet is "free." The Internet was born of hackers and scientists who embraced free thinking and free software. As of October 2001, over 57 percent of the Web servers surveyed are running Apache. The next closest Web server is Microsoft IIS with 30 percent.

The success of Apache and other free software products, such as the Perl programming language and Linux operating system, has relaunched the free software or "Open Source" movement. Software products that are now available under this movement include Netscape Navigator (`http://www.mozilla.org`) and the AOL Web server (`http://www.aolserver.com`). Other companies to join the initiative include Sun Microsystems and IBM.

For more information on the philosophy of free software, refer to `http://www.gnu.org/philosophy/`.

For more information about Apache, see `http://www.apache.org/`. Linux information can be found at `http://www.linux.com/` and `http://www.linux.org/`.

The protocol used for communication between Web servers and browsers is the *Hypertext Transfer Protocol* (HTTP).

Understanding HTTP

HTTP is the protocol that allows Web servers and browsers to exchange data over the Web. It is a request/response protocol, meaning the server waits for and responds to client requests. HTTP does not maintain a connection with the client. HTTP predominantly uses reliable TCP connections, most often on TCP port 80. These client/server transactions can be divided into four basic steps: 1) the browser connects to the server, 2) the browser requests a document from the server, 3) the server responds to the browser, and 4) the connection is dropped. HTTP is a stateless protocol in that it does not maintain any information about the connections.

This section discusses the current recognized standard version of HTTP.

HTTP/1.1

Note

At the time of this writing, HTTP/1.1 is the current standard, and as such will be the version discussed here. It is described in RFC 2616, which can be found at `http://www.w3c.org/Protocols` and at `http://www.rfc-editor.org`.

To make communication possible between the server and the client, the HTTP protocol establishes a language of the Web that is made up of request and response messages.

Client Request

A client request contains the following information:

- Request Method
- Request Header
- Request Data

The Request Method is the program to be applied to the specified URL or Web page. The methods available are shown in Table 36.3.

TABLE 36.3 HTTP Request Methods

Method	*Description*
GET	Requests the specified document.
HEAD	Requests only the document head.
POST	Requests that the server accept the specified document as an executable and pass it some information.
PUT	Replaces the contents of the specified document with data from the client.
DELETE	Requests that the server delete the specified page.
OPTIONS	Allows the client to see the capabilities or requirements of the server.
TRACE	Used for testing—allows the client to see how the message was retrieved.

The header information is optional, and is used to provide the server with additional information about the client. Request headers are shown in Table 36.4.

TABLE 36.4 HTTP Request Headers

Header	*Description*
Accept	The type of data the client will accept.
Authorization	Includes authentication information like username and password.
User-Agent	The type of client software being used.
Referer	The Web page from which the user is coming. (Yes, it is misspelled.)

If the method used requires data from the client (for example, POST) the client follows the header with data. Otherwise the client waits for a response from the server.

Server Response

Server responses also contain several key items:

- Status code
- Response Header
- Response Data

HTTP defines several groups of status codes to communicate back to the browser. Table 36.5 lists these codes.

TABLE 36.5 HTTP Status Codes

Informational (1xx)	
100	Continue
101	Switching Protocols
Successful (2xx)	
200	OK
201	Created
202	Accepted
203	Non-Authoritative Information

Table 36.5 Continued

Successful (2xx)	
204	No Content
205	Reset Content
206	Partial Content
Redirection (3xx)	
300	Multiple Choices
301	Moved Permanently
302	Moved Temporarily
303	See Other
304	Not Modified
305	Use Proxy
Client Error (4xx)	
400	Bad Request
401	Unauthorized
402	Payment Required
403	Forbidden
404	Not Found
405	Method Not Allowed
406	Not Acceptable
407	Proxy Authentication Required
408	Request Timeout
409	Conflict
410	Gone
411	Length Required
412	Precondition Failed
413	Request Entity Too Large
414	Request URI Too Long
415	Unsupported Media Type

TABLE 36.5 Continued

Server Error (5xx)	
500	Internal Server Error
501	Not Implemented
502	Bad Gateway
503	Service Unavailable
504	Gateway Timeout
505	HTTP Version Not Supported

Response headers provide the client with information about the server and/or the requested document. Headers are shown in Table 36.6. All headers are terminated with a blank line.

TABLE 36.6 HTTP Response Headers

Method	*Description*
Server	Information about the Web server.
Date	The current date/time.
Last Modified	The date/time that the requested document was last modified.
Expires	The date/time that the requested document expires.
Content-type	The MIME type of the data.
Content-length	The size (in bytes) of the data.
WWW-authenticate	Used to tell the client the information that is required for authentication (for example, username, password).

If the client has requested data, that data will follow. Otherwise the server closes the connection.

MIME and the Web

Multipurpose Internet Mail Extensions (MIME) are used on the Web to specify the classification of a chunk of data (for example, a file or Web page). MIME allows you to send data in formats other than plain text. Thanks to MIME, you can send and receive Web pages that contain non-ASCII data such as sound, video, images, applications, and more.

When Web browsers and servers communicate, they discuss MIME types. The browser can send information about the MIME types it can accept in the request header. The server tells the client the MIME type of the data it is about to send.

Table 36.7 lists some of the MIME types commonly seen on the Web.

TABLE 36.7 Common MIME Types on the Web

MIME Type	*Description*
text/plain	Plain ASCII text
text/html	HTML text
image/gif	GIFF image
image/jpeg	JPEG image
application/msword	Microsoft Word
video/mpeg	MPEG video
audio/wave	Wave audio
application/x-tar	TAR compressed data

Sample HTTP Communication

Now that you've seen the things that a server and browser can say to one another and the types of data they can share, here's an example of the protocol in action.

The Request

In this example, the browser is requesting the document identified by the URL `http://www.hostname.com/index.html`. All requests end with a single blank line, as shown here:

```
GET /index.html HTTP/1.1
Accept: text/plain
Accept: text/html
User-Agent: Mozilla/4.5 (WinNT)
               (blank line)
```

The browser is using the GET method to request the document `/index.html`. The browser indicates that it will accept only plain text and HTML data, and that it is using the Mozilla/4.5 (Netscape) engine.

The Response

The server responds with a status code, some header information (followed by a blank line), and if applicable, the requested data. This first example assumes the data was found:

```
HTTP/1.1 200 OK
Date Sunday, 15-Jul-99 12:18:03 GMT
Server: Apache/1.3.6
MIME-version: 1.0
Content-type: text/html
Last-modified: Thursday, 02-Jun-99 20:43:56 GMT
Content-length: 1423
               (blank line)
<HTML>
<HEAD>
<title>Example Server-Browser Communication</title>
</HEAD>
<BODY>
...
```

This next example assumes the document was not found:

```
HTTP/1.1 404 NOT FOUND
Date Sunday, 15-Jul-99 12:18:03 GMT
Server: Apache/1.3.6
```

Advanced Topics

This section briefly discusses some of the advanced topics of the Web. These advanced topics include server-side functionality and mechanisms for securing information.

Server-Side Functionality

Web servers can provide a wide range of data to the browser. Typical content includes HTML pages, video, audio, and images. This data can come from static pages and files, or can be dynamically generated at the time of the request. Dynamic content allows pages to be built that are specific to the actual request for the page. For example, a request to a hypothetical telephone directory would generate a very specific page responding to that request. Several technologies are commonly used to prepare dynamic data. These include

- Common Gateway Interface (CGI)
- Application Programming Interface (API)

- Java Servlets
- Server-Side JavaScript
- Server-Side Includes

For more information about these technologies, see "The Languages of the Web," later in this chapter.

SSL and S-HTTP

Secure Socket Layer (SSL) and *Secure HTTP* (S-HTTP) are two protocols used to send sensitive data over the Web.

SSL, developed by Netscape Communications Corporation, uses private key encryption to send sensitive data securely. It is concerned with securing the connection. SSL-based servers are identified by the https protocol in the URL instead of http.

For more information on SSL, refer to `http://home.netscape.com/security/techbriefs/ssl.html`.

S-HTTP is an enhanced version of HTTP. Its concern is sending secure messages. Not all browsers and servers support S-HTTP.

The Languages of the Web

HTTP provides a specific set of rules by which Web servers and browsers communicate. However, it is the programming languages of the Web that make that communication interesting and provide us, the users of the Web, with the information we are looking for. The most common Web language is HTML. But there are others that are used either in conjunction with HTML or alone to provide us with rich content. Some of these languages are discussed in the following sections.

HTML

Hypertext Markup Language is a standard language that is understood by all Web browsers. It consists of a set of tags that specify the look of Web page content. HTML is platform independent, and therefore is highly transportable from one computer environment to another. These characteristics have allowed HTML to become the true language of the Web.

Note

HTML is an application of SGML, or *Standard Generalized Markup Language*. SGML is the international standard for the markup of electronic text. With SGML you can create *Document Type Definitions* (DTDs), such as HTML.

HTML uses tags to specify the appearance of information. Tag syntax is as follows:

```
<tag>information</tag>
```

where <tag> begins the type specification and </tag> ends it. Tags can be nested as well.

An example HTML Web page follows:

```
<html>
<head>
<title>Sample Page</title>
</head>
<body>
<h1>Hello World</h1>
<b1>Bold text</b1>
<i>Italics</i>
<u>Underlined text</u>
<li>List Item 1</li>
<li>List Item 2</li>
</body>
</html>
```

This example shows the simplicity of HTML. Tags are used around information to specify its style, font type, color, and more. For more information on HTML, refer to http://www.builder.com/.

XML

Extensible Markup Language (XML) is a subset of SGML that enables generic SGML to be served over the Web. XML can be thought of as SGML without some of the more complex and less used specifications. A simple XML document looks like this:

```
<?xml version="1.0" standalone="yes"?>
<conversation>
<greeting>Hello, world!</greeting>
<response>Hello to you too!</response>
</conversation>
```

Although XML is relatively new, it is gaining support. Microsoft Internet Explorer 5 supports XML, and a version of Mozilla (Netscape's Open Source browser) does as well.

There is a Mozilla-based browser called DocZilla (`http://www.doczilla.com`) which reads HTML, XML, and SGML. DocZilla contains extra components providing parsing and displaying SGML/XML documents on-the-fly without a precompilation step.

For more information on XML, see the W3C site at `http://www.w3.org/XML/`, `www.xml.org`, or visit Peter Flynn's XML FAQ at `http://www.ucc.ie/xml/`.

CGI

The Common Gateway Interface is a standard that allows the passing of data from a Web server to a CGI-based program. CGI programs can be written in almost any language, but are typically written in C or Perl. Typical uses for CGI scripts are to retrieve information from a Web page, process that information, then turn around and provide some information back to the user.

For more information on CGI, visit `http://www.w3.org/CGI/`.

Perl

Perl is an open-source programming language that is very commonly used on the Web. Due to its text processing capabilities, it was originally written as a language for Unix systems administrators to help simplify the mundane tasks they have to do. That text-processing power also comes in handy with CGI programs on the Web.

An example Perl CGI script that outputs information to the user follows:

```
#!/usr/local/bin/perl
#
#   helloworld.pl: CGI output sample program.
#

# Print the CGI response header, required for all HTML output
# Follow with an extra \n, to send a blank line
print "Content-type: text/html\n\n" ;

# Print simple HTML to STDOUT
print <<EOF ;
<html>
<head><title>CGI Results</title></head>
<body>
<h1>Hello, world.</h1>
</body>
</html>
EOF

exit ;
```

For more information, visit The Perl Institute at `http://www.perl.org/perl.html`.

Java

Java, created by Sun Microsystems, is an object-oriented language similar to C++. Java's design, which strives to be easier to code and more robust than C++, makes it a perfect tool for Web development. For more information on Java, refer to `http://java.sun.com/`.

Java can be used on the Web in two primary ways: on the client or on the server. A client-side Java program (known as an *applet*) is downloaded from the server to the client where it is executed in a special, protected area known as the sandbox. Due to the often-large size of the applet, this can be too time-consuming. For security reasons, applets are also limited in the functions they can perform on the client. For instance, an applet is never allowed write access to the client computer, and it is unable to run local programs as well.

The alternative is to run Java on the server in the form of applications called *servlets*. Although servlets may require more processing power on the part of the Web server, they drastically cut the time required to get the data to the client, and get around some of the security restrictions placed on applets. Servlets are often preferable over CGI programs due to performance. Servlets remain in memory after execution, making subsequent executions faster. CGI programs do not remain in memory.

JavaScript

JavaScript was developed by Netscape Communications Corporation to enable Web programmers to add interactive content to their pages. The common client-side variation can be used to add Web page-hit counters, rollover buttons, and other forms of interactive content. JavaScript can also perform some of the functions usually handled by a CGI program. For example, error checking on a Web form: Instead of sending the data back to the server to verify its completeness or correctness, it is more efficient to do so on the client via JavaScript. The following example shows how that would work:

```
<html>
<head>
<script language="JavaScript">
<!--Hide

function testsomething(form) {
if (form.something.value == "")
   alert("I said something!")
else
   alert("Thank you!");
```

```
}
// -->
</script>
</head>
<body>
<form name="example">
Enter something:<br>
<input type="text" name="something"><br>
<input type="button" name="button" value="Test Input"
   onClick="testsomething(this.form)">
<P>
</body>
</html>
```

There is a variation of JavaScript known as Server-Side JavaScript. This variation runs on the Web server and performs CGI-like functions. Netscape Enterprise Server has powerful built-in Server-Side JavaScript capabilities. For more information on JavaScript (as well as many other technologies) see `http://developer.netscape.com/tech/`.

Active Server Pages

Microsoft Active Server Pages are a somewhat simplified way to incorporate CGI-like functionality into your Web pages. Unlike CGI, which demands some programming prowess, ASP can be implemented using simpler scripting languages such as JScript, VBScript, and Visual Basic.

For more information on ASP and its supporting languages, please refer to `http://msdn.microsoft.com/workshop/server/asp/ASPover.asp`.

The Future of the Web

Although it is only a few years old, the Web has shown tremendous growth. Hidden just beyond that growth, however, is a tremendous potential for more growth and expansion. While the statistical numbers of the Web will continue to rise, so, too, will the capabilities. Initiatives such as HTTP-ng, IPv6, IIOP, and more will ensure that the Web advances. At this time, the possibilities are endless.

HTTP-ng

The next generation of HTTP, aptly named HTTP-ng, will be a more secure, faster replacement for HTTP. It will provide more functionality, making it better suited for commercial application. Some of the enhancements will include

- Improved modularization
- Improved network efficiency

- Improved security and authentication
- Simple structure

For more information on HTTP-ng, refer to `http://www.w3.org/Protocols/HTTP-NG/`.

IIOP

The *Internet Inter-ORB* (Object Request Broker) *Protocol* (IIOP) promises to give us a much more efficient way to access data via the Web. Unlike HTTP, which can only pass text over the Web, IIOP can pass more complex data such as arrays and other objects. IIOP is designed to implement CORBA (Common Object Request Broker Architecture) via the Web. CORBA allows programmers to develop reusable, platform-independent applications.

For more information on IIOP and CORBA, please refer to the Object Management Group at `http://www.omg.org/`.

IPv6

The next generation of the Internet is underway. Internet Protocol version 6 (IPv6), also known as IPng, will upgrade the current Internet Protocol (20-year-old IPv4) in many ways, including

- Increased address space
- Improved security/privacy
- Improved network Quality of Service (QoS)

For more information on IPv6, refer to `http://www.ipv6.org/`.

IPP

The *Internet Printing Protocol* (IPP) was conceived by Novell and Xerox, and developed by the IETF. IPP is interesting because it is based on HTTP/1.1. IPP provides a means for users to accomplish several common printing functions:

- Determine available printers
- Submit and cancel print jobs
- Get status feedback on print jobs

For more information on IPP, refer to the IETF at `http://www.ietf.org/html.charters/ipp-charter.html`.

XML

An exciting development for Web-related software is the Extended Markup Language (XML). XML is used to represent structured data. Structured data includes things like spreadsheets, address books, configuration parameters, financial transactions, and technical drawings. XML enables you to specify a set of rules for designing text formats that let you structure your data. XML is a data representational language and not a programming language. XML is Unicode compliant and makes it easy for a computer to generate data, read data, and ensure that the data structure is unambiguous.

XML is similar to HTML in its use of *tags*, which are keywords bracketed by “<” and “>” and *attributes* of the form `name="value"`. In HTML the tag specifies how the tagged text will display in a browser. In XML the tags are only used to delimit pieces of data, and the interpretation of the data is left to the application that reads it. For example, if you see “`<p>`” in an XML file, do not assume it is a paragraph. Depending on the context, it may be a price, a parameter, a person, and so on.

XML is too vast a topic to cover in this chapter. You can get more information on XML from `www.xml.org`.

Summary

This chapter has introduced you to the World Wide Web and the technologies that make it possible. We have discussed Uniform Resource Locators (URL) and how they are used to retrieve information from the Web. We have looked into Web servers and browsers, and the communication protocol that allows them to transfer information. HTTP/1.1 was explained in detail. We have explored some of the languages of the Web, such as HTML, Perl, and Java. We have also looked toward the future with HTTP-ng, IIOP, and other revolutionary technologies that promise to change the Web for the better. Web URLs have been cited throughout this chapter, and you, the reader, are encouraged to seek out those Web sites and learn more about the exciting technologies that have helped spark the information revolution.

CHAPTER 37

The NNTP (Network News) Service

by Daniel Baker

IN THIS CHAPTER

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- **Newsgroups and Hierarchies** *877*
- **The Network News Transfer Protocol** *879*
- **Spamming and News Blackholing** *884*

This chapter covers a variety of topics that are major factors in how Usenet news operates. Usenet news is one of the oldest forms of Internet communication still available today. Additionally, this chapter covers how you can directly interface with a *Network News Transfer Protocol* (NNTP) server.

Although NNTP wasn't the original protocol for Usenet news traffic, it has made all the prior transportation methods such as Unix-to-Unix Copy Protocol (UUCP) quite obsolete.

Usenet News

Usenet news, created in 1979 by two Duke University graduate students, is one of the oldest and most popular Internet services today. Usenet allows Internet-wide group discussions in a text-based communication format. In this respect, it is very similar to public, group e-mails.

Usenet discussions are not real-time; there is sometimes a delay during the transfer of articles from site to site. However, this delay is typically insignificant, and does not impede the ability of Internet users to carry on a discussion.

In recent years, Usenet has experienced substantial growing pains due to its popularity and the expansion of the Internet. Many years ago, hosting a news server required only an occasional Internet connection, a single computer, and 20 to 100 megabytes of disk space. Today, most Internet service providers (ISPs) have a number of Usenet servers; they typically operate a couple of backbone news boxes that handle communication between your site and other Internet sites, and additionally have several client servers that provide Usenet article data to the end user. To provide high-quality Usenet content, a Usenet client server must now have full-time, multi-megabit Internet connections, at least half a gigabyte of memory, 50 gigabytes of disk space, and several high-end processors.

Technical limitations aren't the only source of problems with Usenet. A lack of centralized management, unsolicited commercial messages, and a typically uneducated user base make it very difficult for Usenet to scale to the size that is required.

Note

UsenetII, a new Usenet, attempts to solve most of Usenet's problems by setting up restrictions and controls that allow it to head in the right direction. The UsenetII Web site is `www.usenet2.org`.

Although better alternatives have not been proposed, it is widely agreed that Usenet uses an inefficient method of storing and transferring articles. Currently, every Usenet server gets a copy of every article posted within the hierarchies that it carries.

Articles are transferred from server to server via a method known as *peering*. News administrators can negotiate peering between sites and decide which Usenet hierarchies they want to exchange with another site. It is common for a news server to have from 1–200 peers. For every article that a server receives, it connects to each one of its peers (with the exception of the peer that sent the article to it) and offers the article to the peering site via the NNTP command, `ihave`.

Note

Because of this storage method, even a small Usenet article takes an astounding amount of storage space. Assuming, for example, that there are 1,500 Usenet servers on the Internet, a reasonably sized post of 2,500 bytes will take 3.75 megabytes (2500 bytes x 1500 servers) of storage space, Internet-wide. (This figure only calculates for storage on servers and doesn't include storage space used by clients that read the article.) A CD-quality song (about 3.5 megabytes) post to Usenet takes up 5.25 gigabytes. A major motion picture (about 1.2 gigabytes) post takes up 1.95 terabytes.

Newsgroups and Hierarchies

Usenet discussion groups are divided into literally tens of thousands of newsgroups, which are traditionally organized in a hierarchy format by category. However, there are a number of "root" top-level hierarchies. The main hierarchies are referred to as the "big seven."

Table 37.1 shows the "big seven" top-level hierarchies, along with a general description of what is expected within each hierarchy. Table 37.2 shows some of the other major hierarchies that are active on Usenet.

TABLE 37.1 "Big Seven" Top-Level Hierarchies

Name	*Description*
comp	Computing
misc	Miscellaneous
news	Usenet administration
rec	Recreation
sci	Science
soc	Society
talk	General discussion

TABLE 37.2 Other Popular Hierarchies

Name	*Description*
alt	Uncontrolled hierarchy with "alternative" newsgroups
bionet	Biology
clari	Live news information from Reuters, Associated Press, and so on
k12	Kindergarten through twelfth grade

To minimize confusion, it is both customary and convenient to separate different languages into different hierarchies. Thus, countries often have separate hierarchies, as shown in Table 37.3.

TABLE 37.3 Language and Country Hierarchies

Name	*Description*
ch	Switzerland
fr	France
de	Germany

Most of the top-level hierarchies have restrictive controls to ensure that only authorized administrators create and delete newsgroups. However, the largest hierarchy, alt, does not have any official or effective methods to do so. Regardless, a news server administrator has to decide whether he or she wants to enforce the restrictions for the hierarchy in question. The administrator then must configure his or her server accordingly. However, conflicting choices by news server administrators can often cause inconsistencies within hierarchies. For example, some servers may think a newsgroup exists, whereas others don't because there is an inconsistency in leniency between news server administrators on hierarchy rules. Such inconsistencies are extremely confusing to users and make Usenet administration difficult.

Note

It's a very good idea to have a firm understanding of a hierarchy's policies for newsgroup management before issuing any control messages. *Control messages* are Usenet messages that are intended to be parsed by a Usenet server's newsgroup management scripts. Control messages can request that a server create a new newsgroup (`newgroup`), delete an existing newsgroup (`rmgroup`), cancel a Usenet post (`cancel`), or other management requests.

Given the wide range of topics that the Usenet hierarchies cover, you can easily find a newsgroup to discuss most specialized interests. For example, over 350 newsgroups contain “unix” in the name. Among the most popular are `comp.unix.solaris` and `comp.unix.aix`. Such names provide a clear indication of the group’s primary focus. `comp` indicates a computer-related discussion group, whereas `unix` indicates that the groups within that second-level hierarchy will be related to Unix-based operating systems. `solaris` indicates Sun Microsystems’s Solaris. Accordingly, it can be stated that `comp.unix.solaris` is for the computer-related, Unix-based discussion of Solaris.

The hierarchy names can also offer a user key indications as to what type of content is allowed within a group. For example, every group within the `alt.binaries` hierarchy is for binary postings such as computer programs, audio files, pictures, and so on. Unless otherwise stated, it can be safely assumed that a group is for ASCII English text.

Note

It is extremely poor form to post binary content to a non-binary newsgroup. For example, posting an audio clip file to `alt.tv.seinfeld` would represent a substantial inconvenience to news administrators and defeat the purpose of a tiered hierarchy organizational system. However, posting that same file to `alt.binaries.sounds.tv` would be considered appropriate and would be the most effective way of transferring the file over Usenet.

Now that you know the basics of what Usenet is and how it is organized, we can begin to take a look at how Usenet transfers article data.

The Network News Transfer Protocol

The *Network News Transfer Protocol* (NNTP) is the most common way for news servers and news clients to transfer Usenet article data. NNTP is an ASCII protocol that typically communicates on TCP port 119. Although directly interfacing with news servers in NNTP (as is demonstrated in this section) is possible, typically a news user agent handles all NNTP services (posting, reading, and so on) for the user. Example NNTP clients for Unix users are `tin` and `trn`, whereas Windows users typically use Netscape, Forte’s Free Agent, and Microsoft’s Outlook Express.

This section covers a variety of NNTP-related topics, including

- Retrieving newsgroup lists
- Retrieving specific Usenet articles
- Posting messages to Usenet

This should give you a solid understanding of the base structure of NNTP functionality.

Retrieving Newsgroups

In order to retrieve a list of newsgroups from an NNTP server, you must first establish a connection with an NNTP server, enable reader mode, and then request the "active" list.

To establish a connection, type

```
unixbox% telnet news.utb.edu 119
```

You should see the following:

```
200 news.utb.edu DNEWS Version 5.5c6, S0, posting OK
```

At this point, enter

```
MODE reader
```

and the following is displayed:

```
200 DNews is in reader mode - posting ok.
```

After the preceding status line appears, type the command to list the Usenet groups:

```
LIST active
```

At this point, the NNTP server will list all Usenet groups that it carries.

```
215 list of newsgroup follows
alt.test 0000000967 0000000947 y
comp.unix 0000000343 0000000343 y
comp.unix.admin 0000094331 0000094080 y
comp.unix.advocacy 0000068422 0000068413 y
comp.unix.aix 0000162768 0000162368 y
comp.unix.amiga 0000019141 0000019132 y
comp.unix.aux 0000023507 0000023502 y
comp.unix.bsd.bsdi.announce 0000000090 0000000091 m
comp.unix.bsd.bsdi.misc 0000009195 0000009192 y
comp.unix.bsd.freebsd 0000000201 0000000197 y
comp.unix.bsd.freebsd.announce 0000000955 0000000955 m
```

When you're done, type

```
QUIT
```

The NNTP server will end the session as follows:

```
205 closing connection - goodbye!
```

Note

Most news servers carry a very large number of newsgroups. Having 30,000 to 60,000 newsgroups in a server's active file is not unreasonable. When you issue the `LIST active` command, the server may produce a large file totaling several megabytes. It would be optimal to avoid unnecessarily fetching this file for the sake of bandwidth on both sides of the connection.

The server explains that it is listing the newsgroups in form "group high low flags." High and low is the local article number range that the NNTP server currently has available for reading by NNTP clients. Flags show the control status on the newsgroup; "m" means moderated and "y" means unmoderated.

Note

There are many more NNTP commands than those mentioned in this chapter. You can learn about these additional commands by typing **`HELP`** when you are connected to an NNTP server. Most client servers will respond with a list of available commands and any arguments required for their use.

Retrieving Messages

Usenet messages can be retrieved from an NNTP server by connecting, selecting a group, and then requesting an article ID. After receiving that article, a user can either continue requesting subsequent articles by ID, or by issuing the `next` command.

To establish a connection, type

```
unixbox% telnet news.utb.edu 119
```

You should see the following:

```
200 news.utb.edu DNEWS Version 5.5c6, S0, posting OK
```

At this point, enter

```
MODE reader
```

and the following is displayed:

```
200 DNews is in reader mode - posting ok.
```

After the preceding status line appears, type the command to tell the news server which newsgroup you want to access:

```
GROUP alt.test
```

The server should respond with some information about the group in question:

```
211 386 603537 603922 alt.test selected
```

The second number in the response is the number of articles in this group that the server currently has. The third and fourth are the beginning and ending range of the article numbers. There is a discrepancy in the total number of articles being held and the range of article numbers because some articles get canceled after the server has received them. They have an article number, but are no longer being held on the server.

At this point, you can pick any number within the given range and request the article, as shown:

```
ARTICLE 603922
```

You should see the following:

```
220 603922 <3c0d06c5@newsreader.utb.edu> article retrieved - head and body f
ws
From: "Gary Kercheck" <gary.kercheck@aei.com>
Newsgroups: alt.test
Subject: test
Date: Tue, 4 Dec 2001 09:31:36 -0800
Lines: 3
Organization: Sekidenko
X-Priority: 3
X-MSMail-Priority: Normal
X-Newsreader: Microsoft Outlook Express 5.50.4807.1700
X-MimeOLE: Produced By Microsoft MimeOLE V5.50.4807.1700
NNTP-Posting-Host: 65.162.27.214
X-Original-NNTP-Posting-Host: 65.162.27.214
Message-ID: <3c0d06c5@newsreader.utb.edu>
X-Trace: newsreader.utb.edu 1007486661 65.162.27.214 (4 Dec 2001 11:24:21 -0
Path: newsreader.utb.edu
Xref: news.utb.edu alt.test:603922
.
```

At this point, you can either continue your NNTP session, or exit by typing **QUIT**.

As shown, you must only specify a group and the article number in order to receive article data.

The Path header shows what route that message took to reach your NNTP client server. The route begins on the right and moves left with hostnames or aliases separated by exclamation points. In the preceding example, the article was posted to news.distributed.net and took two hops to reach news.cuckoo.com, the example NNTP client server.

The NNTP-Posting headers identify which client connected to the NNTP client server. The example indicates that the host, at 65.162.27.214, posted the article on 4 Dec 2001 11:24:21.

The next command can also be used to request that the server increment the article number and output the header and body of that message.

Posting Messages

You can post messages to Usenet by connecting to the NNTP server, enabling reader mode, and issuing a POST command. Once that is done, the article can be typed as usual. Only the From, Newsgroups, and Subject headers are required for a post. However, many other headers are standard and are used by news clients.

```
unixbox% telnet news.utb.edu 119
200 news.utb.edu DNEWS Version 5.5c6, S0, posting OK

MODE reader

200 DNews is in reader mode - posting ok.
```

Now, you need to let the NNTP server know that you want to enter article post mode:

```
POST
```

The following is displayed to acknowledge your request:

```
340 Ok, recommended ID 3c0d21df@newsreader.utb.edu
```

At this point, you can begin your Usenet post. Before your article data, you will need to enter your headers, which minimally include From, Newsgroups, and Subject.

```
From: Karanjit
Newsgroups: alt.test
Subject: Updated test!

This is a generic test!
- Karanjit
.
240 article posted ok
```

You end the post by entering only a period on a blank line:

```
.
```

If all is well with your article, the NNTP server should confirm that your post was a success:

```
240 article posted ok
```

You can then exit your session:

```
QUIT
```

As shown, only minimal amounts of information are necessary for a Usenet post.

It is noteworthy that the final period in the post is the termination character. It must be on its own line and begin with the period in order for the NNTP server to realize that the period signifies the end of the file.

The next section takes a look at some of the key problems with Usenet today. Because of the inherent design of Usenet, there are no official administrators of the entire infrastructure; specific hierarchy administrators handle administration, and thus problems are tackled with a variety of different approaches.

Spamming and News Blackholing

Massive advertisements ("spamming") posted to Usenet are a serious problem. Rogue corporations are taking advantage of the free medium and posting advertisements to inappropriate groups. These inappropriate advertisements waste massive amounts of the resources of news servers, and are frustrating to end users who have to filter through a huge number of advertisements to reach the desired content.

Some news administrators are attempting to take care of this problem by *blackholing*, or ignoring, sites that allow Usenet spamming, create Usenet spam, or relay Usenet spam. Blackholing is very much what it sounds like; it means that sending traffic is sent to a "black hole" of sorts. Any site that enforces the blackholing policies ignores a site that is blackholed. This puts major pressure on the sites involved to stop the spamming; an ISP's news server is blackholed when it fails to take action against an abusive customer.

Another technique to discourage spam involves canceling inappropriate articles. Programs called *cancelbots* attempt to identify commercial posts and, upon detection, issue a control message that requests that Usenet servers delete the article in question.

As these policies and methods become more widespread and accepted, they'll eventually make it nearly impossible for spammers to post advertisements to Usenet.

Note

MAPS RBL (`http://mail-abuse.org/rbl/`) is one of the largest organizations organizing such blackholing.

Summary

Aside from providing a public discussion forum, over the years, Usenet has transferred an extraordinary amount of knowledge and information that is readily available to the entire Internet user-base. Web sites such as Deja (now acquired by Google, `http://groups.google.com/googlegroups/deja_announcement.html /`) archive all Usenet posts and then allow you to search through literally years of Usenet data. Given the broad topics covered by Usenet, Deja's archive contains an article on almost every topic imaginable. Recent implementations such as this reinforce the belief that Usenet can still prove useful.

Usenet is a conceptually wonderful service that has a great deal of potential. However, there are still a number of significant issues that need to be handled before Usenet can be successful, manageable, and scalable. There is no question that these issues can be tackled and handled in a way that will allow Usenet to prosper and reach its full potential.

The next chapter covers a variety of administration issues involved in running Web site services. Specifically, you will learn the fundamentals of Apache Web server, Netscape enterprise Web server, and Microsoft Internet Information server.

CHAPTER 38

Installing and Configuring the Web Server

by Neal S. Jamison

IN THIS CHAPTER

- A Quick Look at How Web Servers Work *888*
- The Popular Web Servers *891*
- Running the Apache HTTP Web Server *892*
- Exploring Other Web Servers *904*

The World Wide Web has become by far the most popular service available on the Internet. Many individuals are taking to the Web to gather information, search for jobs, shop, and even trade stocks. Businesses are flocking to the Web to meet increasing consumer demand. This chapter instructs you on installing, configuring, and running the most popular Web server on the Internet: the Apache HTTP Server.

A Quick Look at How Web Servers Work

The World Wide Web works largely in part due to a TCP/IP protocol called the *Hypertext Transmission Protocol* (HTTP). HTTP is a request/response service that allows clients (browsers) and Web servers to exchange information. A Web server is a software program that listens for requests from a browser, and provides data in HTML format via HTTP. A typical HTTP session is as follows:

- The browser connects to the server.
- The browser requests a file or some other information.
- The server responds and drops the connection.

For example, a browser sends an HTTP `GET` request for a file called `index.html`:

```
GET /index.html HTTP/1.1
Accept: text/plain
Accept: text/html
User-Agent: Mozilla/4.5 (WinNT)
          (blank line)
```

The server answers with an HTTP response that includes the requested file:

```
HTTP/1.1 200 OK
Date Sunday, 15-Jul-99 12:18:03 GMT
Server: Apache/1.3.6
MIME-version: 1.0
Content-type: text/html
Last-modified: Thursday, 02-Jun-99 20:43:56 GMT
Content-length: 1423
     (blank line)
<HTML>
<HEAD>
<title>Example Server-Browser Communication</title>
</HEAD>
<BODY>
     ...
```

After the file is transmitted, the connection is closed. HTTP is a stateless protocol, meaning no information about the browser or the session is maintained (beyond what the server writes to its log file).

By default, HTTP runs on TCP well-known port 80.

Web Server Nomenclature

This section explains a few Web server–related terms that you will see either later in this chapter or in other Web server documentation.

Web Server

A Web server is a computer that serves documents (Web pages) over the Internet using the HTTP protocol. The term *Web server* can be used to refer to the computer (a combination of hardware and Web server software) or to the software package itself (for example, the Apache Web server).

Browser

A browser is the client program of the Web. Common browsers include Lynx, Netscape Communicator, Opera, and Microsoft Internet Explorer.

URL

A URL is the universal address used to reference Web pages. For example, `http://www.apache.org/`. See the "What Exactly Is a URL?" sidebar later in this chapter for more information.

Server Root

A server root is the location on the computer where the Web server resides. By default all log and configuration files, as well as the daemon and other supporting documents, will fall below the root; for example, `/usr/local/apache` or `c:\netscape\suitespot\https-myserver`.

Document Root

A document root is the top location on the Web server from where Web pages are served. This is the directory that will be explored given a URL of the form `http://www.yourserver.com/`.

Port

TCP/IP services use ports to make connections and pass information. By default HTTP uses port 80, although it can be configured to use any unused port number between 1 and 65535. Other common ports are Telnet (23), SMTP e-mail (25), and FTP (21).

Virtual Host (or Virtual Server)

Most Web servers have the ability to represent more than one domain. This is done using the concept of virtual hosts, in which one Web server can serve multiple sites. Virtual hosts are commonly used by Internet service providers (ISPs) as a low-cost alternative to having a separate Web server for every customer.

Secure Sockets Layer (SSL)

SSL is a protocol developed by Netscape to allow data to be sent over the Web securely. SSL uses public-key technology to encrypt the data passed over the connection.

MIME—Multipurpose Internet Mail Extensions

MIME allows Web servers and browsers to exchange files that are not in HTML or ASCII format, such as Microsoft Word documents and images.

For more information on HTTP and Web servers, refer to Chapter 36, "The HTTP (World Wide Web) Service."

What Exactly Is a URL?

The Web uses an addressing schema known as the *Uniform Resource Locator* (URL) to identify Web pages and other resources.

Consider a sample URL:

```
http://www.apache.org/docs/index.html
```

This URL, which would take you to the Apache Group's documentation page, is broken down into the following segments:

```
Protocol:// servername.domain/ directory/ file
```

Or, in the above example:

- Protocol: `http`
- Full domain name: `www.apache.org`
- Directory: `docs`
- File: `index.html`

The Popular Web Servers

There's a lot of talk in the press about the war to rule the Internet. On the server side, however, it's not Microsoft or Netscape server products in the front. In fact, it's not a commercial product at all. The Web server world is largely dominated by a free, open source server called Apache.

Open Source Software

In the beginning, the Internet was based upon a philosophy of freedom. Ideas were free. Help was free. Even software was free. This freedom inspired growth and advancement. Computer scientists and engineers fed off of a synergy created by great minds coming together to solve a common problem. As the Net grew, so did the opportunity to use it as a business tool. But business tools are supposed to help a business gain a competitive advantage, and that is something that not many are willing to share. Therefore, our corporate culture quickly conquered the philosophy of freedom. But a few projects live on, enjoying the synergy. One of the main ideas behind open source is that thousands of programmers on the Net can foster the growth and improvement process of a software program better than one small group of corporate programmers.

Some of the popular open source software projects today include the following:

- **Apache Web server:** The most popular Web server on the Internet
- **Linux:** An increasingly popular operating system
- **Perl:** The programming language of the Web (also enjoyed by many Unix systems administrators, and by savvy Windows system administrators as a powerful scripting language).

For more information on open source, refer to `http://www.opensource.org/`.

An Internet consulting firm, Netcraft Ltd. (`http://www.netcraft.com/`), regularly surveys the Web to see the types of Web server software that Web sites are running. Table 38.1 shows the results of the most recent Netcraft survey for active Web sites.

Note that iPlanet is the sum of sites running iPlanet-Enterprise, Netscape-Enterprise, Netscape-FastTrack, Netscape-Commerce, Netscape-Communications, Netsite-Commerce & Netsite-Communications. And Microsoft is the sum of sites running Microsoft-Internet-Information-Server, Microsoft-IIS, Microsoft-IIS-W, Microsoft-PWS-95, & Microsoft-PWS.

TABLE 38.1 Web Server Market Share for August 2001 (30,775,624 Sites Surveyed)

Server	*Market Share*
Apache	60.33%
Microsoft	28.29%
iPlanet	4.29%
Zeus	1.53%

Running the Apache HTTP Web Server

The Apache Web server is an open source server based upon the once-popular NCSA httpd server. Apache is now one of the most popular, robust, and feature-rich servers available, and it's free! No wonder Apache powers more than half of the Web servers on the Internet.

Downloading, Installing, and Configuring Apache

This section walks through the download, installation, and configuration of the Apache HTTP Web server in a Linux environment.

Note

Because Apache was originally designed for Unix and is still predominantly a Unix-based Web server, this section deals mostly with installing and configuring Apache in a Unix environment (specifically Linux). At the time of this writing, Apache 1.3.22 is available for Win32, but is not as stable as the Unix port. There is a very brief discussion on installing Apache for Windows at the end of this section. However, if you are serious about running a Web server in a Windows environment, you should consider a more robust server, such as Microsoft's Internet Information Server, O'Reilly's WebSite, or Netscape's Enterprise Server.

If you are running the Linux operating system, there is a very good chance that your installation included the Apache Web server. If it did, great. You are on your way. However, it would be to your benefit to uninstall Apache and start over for two reasons:

1) The version that came with your installation may be outdated or improperly configured; and 2) Downloading, compiling, and installing Apache will give you great insight into how it works. So, with that in mind, let's get started. First, let's examine a few requirements:

- **Disk Space**—You will need at least 12MB of temporary disk space. After installation, Apache will require approximately 3MB of space, plus whatever space is required to store your Web pages.
- **ANSI C Compiler**—You will need to have an ANSI C compiler installed and properly configured. The GNU C compiler is recommended. See `http://www.gnu.org/` to obtain GCC. If you do not have an ANSI C compiler, see the following section.

Downloading Apache

Apache can be downloaded from the main Apache site (`http://www.apache.org/`) or any of its mirror sites.

Note

It will be faster to download from a mirror site that is geographically close to you. See `http://www.apache.org/mirrors/` for a list of mirror sites.

You will need to decide whether you want to download the full source code to compile yourself, or if you want to skip the compilation step and download just the binaries.

Note

If you are going to download a precompiled binary, make sure you do that from the official Apache site or one of its mirrors. Other binaries may be out there that are improperly compiled, and may even contain security holes.

The following example illustrates how to download the source.

Go to `http://www.apache.org/dist/httpd/`. You will see a list of available files. Select the version you want to download, and click it to begin the download. The following is a sample list of files for an Apache release.

```
Announcement.html          21-May-2001 19:11  7.2K  Apache 1.3 Release note
Announcement.txt           20-May-2001 05:07  6.4K  Apache 1.3 Release note
Announcement2.html         04-Apr-2001 13:05  4.2K  Apache 2.0 Release note
Announcement2.txt          04-Apr-2001 13:05  4.2K  Apache 2.0 Release note
```

```
Apache-1.3-docs.pdf.gz        03-Apr-2000 13:03  1.4M  Apache 1.3.12 document>
CHANGES_1.3                   20-May-2001 05:08  367K  List of changes in 1.3
CHANGES_2.0                   04-Apr-2001 13:05  415K  List of changes in 2.0
KEYS                          28-Mar-2001 11:57   43K  Developer PGP keys
apache_1.3.19.tar.Z           28-Feb-2001 06:11  2.9M  1.3.19 compressed sour>
apache_1.3.19.tar.Z.asc       28-Feb-2001 06:11  248   PGP signature
apache_1.3.19.tar.Z.md5       28-Feb-2001 06:11   61   MD5 hash
apache_1.3.19.tar.gz          28-Feb-2001 06:11  1.8M  1.3.19 gzipped source
apache_1.3.19.tar.gz.asc      28-Feb-2001 06:11  248   PGP signature
apache_1.3.19.tar.gz.md5      28-Feb-2001 06:11   62   MD5 hash
apache_1.3.19.zip             28-Feb-2001 10:34  2.4M  1.3.19 pkzipped source
apache_1.3.19.zip.asc         28-Feb-2001 10:32  477   PGP signature
apache_1.3.20.tar.Z           15-May-2001 10:12  3.0M  Current Release 1.3.20
apache_1.3.20.tar.Z.asc       15-May-2001 10:19  477   PGP signature
apache_1.3.20.tar.Z.md5       21-Sep-2001 04:47   61   MD5 hash
apache_1.3.20.tar.gz          15-May-2001 10:12  1.9M  Current Release 1.3.20
apache_1.3.20.tar.gz.asc      15-May-2001 10:19  477   PGP signature
apache_1.3.20.tar.gz.md5      21-Sep-2001 04:46   62   MD5 hash
apache_1.3.20.zip             15-May-2001 12:42  2.5M  Current Release 1.3.20
```

Note

You can use the MD5 checksum to ensure that you are getting the actual package as intended by the author. This is especially important if you are downloading a precompiled binary. Doing this will depend upon your operating environment. In Linux, you can run the following command:

```
# md5sum apache_1.3.6.gz
b4114ed78f296bfe424c4ba05dccc643  apache_1.3.6.tar.gz
```

Compare the output with the contents of the md5 file on the Apache site (in this case `apache_1.3.6.gz.md5`). If they are the same, everything is fine. If they differ, you should attempt the download again.

After you have the Apache package downloaded into a temporary directory, you will need to expand the archive using `gzip` or `uncompress` (whichever corresponds to the format you downloaded), and `tar`.

Note

`gzip` (GNU zip) is a free compression tool provided under GNU's General Public License. Due to its superior compression abilities, it is very popular in the Unix and Internet communities.

To obtain `gzip` or to learn more about this popular utility, refer to `http://www.gzip.org/`.

Compiling and Installing Apache

The easiest way to compile and install Apache is by using the Apache Autoconf-style Interface (APACI) available with Apache versions 1.3 and higher. The APACI provides an "out-of-the-box" type installation process.

Note

You can still compile and install Apache using the older method. Instructions for doing so are in the `INSTALL` file in the `src` directory.

To install Apache using the APACI, change directory to the new temporary directory that contains the Apache files. In most cases you will not need to edit the `Configuration` file unless you want to install any special modules beyond those that are installed by default. However, if you receive installation errors, read through the documentation in the `Configuration` file. Common options that may need attention are `EXTRA_CFLAGS`, `LIBS`, `LDFLAGS`, `INCLUDES`, and `CC`. Review the `INSTALL` file in this directory for more information.

To begin the installation process, run the following command:

```
# ./configure -prefix=PREFIX
```

where `PREFIX` is the target root directory for your Web server (for example, `/usr/local/apache`).

Then build the Apache package using `make`:

```
# make
```

Note

If `make` is not in your path (that is, you get a `command not found` response), you will need to add `make` to your path (probably `/usr/bin/` or `/usr/ccs/bin`). The procedure for doing this will vary based on the shell you are running. For bash, run

```
# PATH=$PATH:/usr/ccs/bin/
# export PATH
```

`make` will take several minutes, depending on the speed of your system. After it is complete, you are ready to install Apache. Run the `make` command:

```
# make install
```

This will install the Apache Web server and its related files under the `PREFIX` directory specified in the first step. When this step is complete, you are ready to configure Apache for your specific environment.

Configuring Apache

Apache uses three primary configuration files. They are

- `access.conf`—Controls access to your Web server's resources.
- `httpd.conf`—The primary configuration file. This tells Apache how to run.
- `srm.conf`—Specifies which resources you want to offer on your site.

To get your server up and running initially, these files need very little editing if any at all. Some of the configuration items, or server directives, that may need editing are detailed in the following sections. The configuration files are very well documented, and you should be able to identify the directives that need to be changed by reading through the files. Refer to `http://www.apache.org/docs/` for more information on configuring Apache. For information on performance tuning for the Apache server, refer to `http://httpd.apache.org/docs/misc/perf-tuning.html`.

> **Note**
>
> In the most recent version of Apache, all three configuration files are collapsed into one file: `httpd.conf`. The contents of `httpd.conf` are discussed in the next section.

`httpd.conf`

The `httpd.conf` file contains the directives that tell Apache how to run. Some of the directives that may need your attention are

- **ServerName**—The name of your Web server.

  ```
  ServerName www.mydomain.com
  ```

- **ServerType**—Options are standalone or inetd. A standalone server will run all the time. A ServerType of inetd will cause the server to run only when it is requested. Standalone is recommended for best performance.

  ```
  ServerType standalone
  ```

- **Port**—By default, HTTP servers run on port 80. However, you may prefer to run your server on a non-standard port. One reason to do so would be to "hide" your server from the public. If you were to run your server on a non-standard port, say

1234, your users would need to know the port and include it in the URL to access your pages. Valid port numbers are unused port numbers in the range 1–65535, although typically the first 1024 are reserved.

```
Port 80
```

- **User**—This specifies which user the Apache server will run as. There are security implications to this directive because Apache will take on the privileges of its controlling user. Many Unix systems have a user called "nobody" just for this purpose. If your system does not have an unprivileged user, you should create one.

  ```
  User nobody
  ```

- **ServerAdmin**—This should be set to the administrative user. Apache will send mail to this user in the event of any problems.

  ```
  ServerAdmin root
  ```

- **ServerRoot**—The root directory of the Apache installation. All of your configuration files and log files will be stored under this root unless you instruct Apache otherwise.

  ```
  ServerRoot /usr/local/apache
  ```

- **ErrorLog**—The location and name of the error logfile.

  ```
  ErrorLog logs/error.log
  ```

- **TransferLog**—The location and name of the transfer (or access) logfile.

  ```
  TransferLog logs/access.log
  ```

- **Timeout**—The length of time (in seconds) that the Web server will wait for a browser to respond before assuming the connection is dead. The default value is 300 seconds.

  ```
  Timeout 300
  ```


The following directives are used to control Apache's resources. Historically they were contained in the `srm.conf` file, although newer releases of Apache combine them all in the `httpd.conf` file. Some of the more interesting directives are

- **DocumentRoot**—The root directory of your Web server's document tree.

  ```
  DocumentRoot  /usr/local/apache/htdocs/
  ```

- **DirectoryIndex**—If a user requests a URL from your server that ends in a path, the Web server will attempt to serve a document that matches DirectoryIndex. For example, loading `http://www.apache.org/` results in the file `index.html` being served to your browser.

  ```
  DirectoryIndex index.html
  ```

- **IndexIgnore**—By default, if a user requests a URL from your server that ends in a path and there is no `index.html` file available, the Web server will present the user with a listing of files in the directory. There may be files there that you don't want displayed (such as `.htaccess`, or `README` files). The server will not display files set in the IndexIgnore directive.

```
IndexIgnore .??* *~ *# HEADER* README* RCS CVS *,v *,t
```

The `access.conf` file is historically where you would set up access rules to your entire Web server, or parts thereof. Recent releases of Apache also include these directives in the `httpd.conf` file.

Consider the following block:

```
<Directory /><Directory />
    Options FollowSymLinks
    AllowOverride None
      </Directory></Directory>
```

This block is similar to what you may find in a typical `access.conf` file. The `<Directory />` tag opens the container. Every directive in the file before a `</Directory>` tag will apply to the directory `/`. In this example, Apache is instructed to follow symbolic links for this directory and to prohibit other control files from overriding settings.

Consult the Apache documentation that came with your Web server for more information on using `access.conf` to control access to your site.

Starting and Stopping Apache

Once Apache is compiled, installed, and configured, you are ready to go. You can start Apache by running the following command:

```
# PREFIX/bin/apachectl start
```

where `PREFIX` is the ServerRoot.

A quick check of the processes should verify that it was started.

```
# ps -ax | grep http
 3514  ?  S    0:00 /usr/local/apache/bin/httpd
16201  ?  S    0:00 /usr/local/apache/bin/httpd
16635  ?  S    0:00 /usr/local/apache/bin/httpd
16661  ?  S    0:00 /usr/local/apache/bin/httpd
16662  ?  S    0:00 /usr/local/apache/bin/httpd
      ...
```

Using your Web browser, point to your newly installed Web server by loading the ServerName URL (`http://www.yourdomain.com/` or `http://localhost/`). If Apache is properly configured and running, you will see the test page in Figure 38.1.

FIGURE 38.1
The Apache test page.

You can stop Apache by running the following command:

```
# PREFIX/bin/apachectl stop
```

/etc/rc.d

You can use the `rc.d` system to automatically start Apache for you. Some versions of Unix or Linux will have an `httpd.init` file (for example, `/etc/rc.d/init.d/httpd.init` in Red Hat Linux) already installed. If this is true in your case, you will need to edit the file to ensure it knows where your `httpd` executable file resides.

For most systems, a simple entry such as

```
/usr/local/apache/bin/apachectl start
```

in your `/etc/rc.d/rc.local` file will suffice.

Downloading Precompiled Apache

If you prefer to download a precompiled binary, go to `http://www.apache.org/dist/httpd/binaries/`. You will see a list of available operating environments. The following is a sample directory structure of Apache binaries available for different operating environments.

```
aix/                    20-Jun-2001 11:47     -
aux/                    06-May-2000 12:56     -
beos/                   02-Nov-2000 02:17     -
```

```
bs2000-osd/             23-Jan-2001 01:26    -
bsdi/                   18-Oct-2000 00:22    -
cygwin/                 12-Jun-2001 01:22    -
darwin/                 10-Apr-2001 21:11    -
dgux/                   12-Jun-2000 03:47    -
digitalunix/            12-Jun-2000 03:47    -
freebsd/                31-May-2001 01:47    -
hpux/                   20-Jun-2001 13:25    -
irix/                   13-Oct-2000 04:57    -
linux/                  21-Aug-2001 08:18    -
macosx/                 10-Apr-2001 21:11    -
macosxserver/           30-Oct-2000 17:42    -
netbsd/                 12-Jun-2000 03:47    -
netware/                21-May-2001 16:52    -
openbsd/                13-Oct-2000 04:59    -
os2/                    19-May-2001 11:37    -
os390/                  03-Aug-2000 12:01    -
osf1/                   12-Jun-2000 03:47    -
qnx/                    31-May-2001 01:22    -
reliantunix/            22-May-2001 01:26    -
rhapsody/               30-Oct-2000 17:42    -
sinix/                  22-May-2001 01:26    -
solaris/                20-Jun-2001 13:28    -
sunos/                  24-Feb-2000 18:27    -
unixware/               13-Oct-2000 04:58    -
     win32/                  03-Sep-2001 08:25    -
```

Enter the directory that corresponds to your operating environment. You will then see a list of available formats and versions similar to the following:

```
apache_1.3.1-sparc-whatever-linux.README       06-Apr-2000 14:05  522
apache_1.3.1-sparc-whatever-linux.tar.gz       06-Apr-2000 14:05  1.3M
➥GZIP compressed file
apache_1.3.12-i686-whatever-linux2.README      06-Apr-2000 14:05  1.8K
apache_1.3.12-i686-whatever-linux2.tar.gz      06-Apr-2000 14:05  2.6M
➥GZIP compressed file
apache_1.3.14-i686-whatever-linux2.README      13-Oct-2000 04:57  1.8K
apache_1.3.14-i686-whatever-linux2.tar.gz      13-Oct-2000 03:21  2.8M
➥GZIP compressed file
apache_1.3.14-i686-whatever-linux2.tar.gz.asc  13-Oct-2000 03:10  292
➥PGP signature
apache_1.3.20-i686-whatever-linux22.README     20-Jun-2001 11:36  1.9K
➥Current Release 1.3.20
apache_1.3.20-i686-whatever-linux22.tar.gz     20-Jun-2001 11:36  3.1M
➥Current Release 1.3.20
apache_1.3.20-i686-whatever-linux22.tar.gz.asc 20-Jun-2001 11:36  477
➥PGP signature
apache_1.3.20-ia64-whatever-linux22.README     21-Aug-2001 08:15  2.1K
➥Current Release 1.3.20
apache_1.3.20-ia64-whatever-linux22.README.asc 21-Aug-2001 08:18  293
```

```
➥PGP signature
 apache_1.3.20-ia64-whatever-linux22.tar.gz     21-Aug-2001 08:16  3.4M
➥Current Release 1.3.20
 apache_1.3.20-ia64-whatever-linux22.tar.gz.asc 21-Aug-2001 08:17  293
➥PGP signature
 apache_1.3.20-ia64-whatever-linux22.tar.gz.md5 21-Aug-2001 08:16   84
➥MD5 hash
 apache_1.3.6-armv4l-whatever-linux2.README     06-Apr-2000 14:05  1.9K
 apache_1.3.6-armv4l-whatever-linux2.tar.gz     06-Apr-2000 14:05  2.2M
➥GZIP compressed file
 apache_1.3.6-i586-whatever-linux2.README       06-Apr-2000 14:05  1.9K
 apache_1.3.6-i586-whatever-linux2.tar.gz       06-Apr-2000 14:05  2.1M
➥GZIP compressed file
 apache_1.3.6-i686-whatever-linux2.README       06-Apr-2000 14:05  1.9K
 apache_1.3.6-i686-whatever-linux2.tar.gz       06-Apr-2000 14:05  2.1M
➥GZIP compressed file
 apache_1.3.6-mips-whatever-linux2.README       06-Apr-2000 14:05  1.9K
 apache_1.3.6-mips-whatever-linux2.tar.gz       06-Apr-2000 14:05  2.2M
➥GZIP compressed file
 apache_1.3.6-sparc-whatever-linux2.README      06-Apr-2000 14:05  1.9K
 apache_1.3.6-sparc-whatever-linux2.tar.gz      06-Apr-2000 14:05  2.1M
➥GZIP compressed file
 apache_1.3.9-alpha-whatever-linux2.README      06-Apr-2000 14:05  1.8K
 apache_1.3.9-alpha-whatever-linux2.tar.gz      06-Apr-2000 14:05  3.5M
➥GZIP compressed file
 apache_1.3.9-alpha-whatever-linux2.tar_gz.asc  06-Apr-2000 14:05  286
➥PGP signature
 apache_1.3.9-i586-whatever-linux2.README       06-Apr-2000 14:05  1.8K
 apache_1.3.9-i586-whatever-linux2.tar.gz       06-Apr-2000 14:05  2.3M
➥GZIP compressed file
 apache_1.3.9-i586-whatever-linux2.tar_gz.asc   06-Apr-2000 14:05  286
➥PGP signature
 apache_1.3.9-i686-whatever-linux2.README       06-Apr-2000 14:05  1.8K
 apache_1.3.9-i686-whatever-linux2.tar.gz       06-Apr-2000 14:05  2.3M
➥GZIP compressed file
 apache_1.3.9-i686-whatever-linux2.tar_gz.asc   06-Apr-2000 14:05  286
➥PGP signature
 apache_1.3.9-mips-whatever-linux2.README       06-Apr-2000 14:05  1.8K
 apache_1.3.9-mips-whatever-linux2.tar.gz       06-Apr-2000 14:05  2.5M
➥GZIP compressed file
 apache_1.3.9-sparc-whatever-linux2.README      06-Apr-2000 14:05  1.8K
 apache_1.3.9-sparc-whatever-linux2.tar.gz      06-Apr-2000 14:05  2.7M
➥GZIP compressed file
 apache_1.3.9-sparc-whatever-linux2.tar_gz.asc  06-Apr-2000 14:05  286
     ➥PGP signature
```

Select the version you want and download it into a temporary directory on your system.

Installing and Configuring Precompiled Apache

After you have downloaded the package, you are ready to install and configure Apache. First, in the temporary directory, unpack (using `uncompress` or `gzip`, and `tar`) the package you have just downloaded.

To install Apache, run the shell script `install-bindist.sh`. If you prefer that Apache be installed into a directory other than the default directory (`/usr/local/apache/`), you must specify the target directory (ServerRoot) on the command line. See the `INSTALL` file for more information.

```
# ./install-bindist.sh [ServerRoot]
```

After the Apache Web server is installed, you can configure, start, and stop Apache using the steps outlined in the previous sections.

Using Apache for Windows

This section instructs you on downloading, installing, and configuring Apache for a Microsoft Windows platform.

Note

Apache for Windows is still not as stable as the Unix version. It is not optimized for performance, and may contain bugs that could leave your system vulnerable to a security attack. If you prefer to run your Web server in a Microsoft environment, it is recommended that you use Microsoft IIS or one of the other Windows-compatible servers.

See "Exploring Other Web Servers" at the end of this chapter or refer to `http://webcompare.internet.com/` for a complete list of Web servers.

Downloading Apache for Windows

You can download a precompiled version of Apache for Win32 from `http://www.apache.org/dist/httpd/binaries/win32/`.

Download the file to a temporary directory or to your Windows Desktop.

Installing Apache for Windows

To begin installation, run the self-extracting executable you have just downloaded. You will be prompted for a directory into which Apache is to be installed. Either accept the default or change to your preferred directory. If the directory does not yet exist, the installer will make it for you.

Next you will be asked for the name under which Apache should be found in the Start menu. Again, either accept the default or change it to your preferred name.

Choose your preferred installation type. "Typical" installs everything except the source code. "Minimum" does not install the manuals or the source code. "Custom" will allow you to specify what is installed (the manuals, source code, and so on).

Configuring Apache for Windows

After you install Apache for Windows, you will probably want to edit the configuration files. As with the Unix version, the three configuration files are

- `access.conf`
- `httpd.conf`
- `srm.conf`

These files are self-documenting, and a read through them will enable you to see what needs to be configured. No edits are required to run the Apache Web server. Refer to the "Configuring Apache" section earlier in the chapter for more information.

Starting Apache for Windows

Apache for Windows can be started in several ways:

- From the Windows Start menu
- From a DOS console (Command Prompt)
- As an NT Service

Running Apache from the Start Menu and/or DOS Console

To start Apache from the Start menu, select the Start Apache option. This will run a DOS console window in which Apache will be started, and the window will remain active as long as Apache is running. To stop or restart Apache, open another console window and run

```
apache -k shutdown
```

or

```
apache -k restart
```

Similarly, Apache can be started from a DOS console by running the command

```
apache -k start
```

The console will remain active as long as Apache is running.

Running Apache as an NT Service

Before Apache can be run as an NT service, it must be installed as a service. From a DOS console, run

```
apache -i -n "Apache Webserver"
```

To remove Apache as a service, run

```
apache -u -n "Apache Webserver"
```

After Apache is installed as an NT service, you can configure, start, and stop the Apache service using the Services utility in the Windows Control Panel.

Exploring Other Web Servers

Although Apache holds a large market share in the Internet Web server arena, many other Web server products are out there for you to choose from. This section briefly describes a few of the most popular Web servers.

- **Netscape Enterprise Server**—Netscape's most robust Web server (see also FastTrack). Environment: HP-UX, Solaris, NT. (`http://www.iplanet.com/products`)
- **Netscape FastTrack**—Netscape's entry-level Web server (see also Enterprise). Environment: Unix, Windows 95/98, NT. (`http://www.iplanet.com/products`)
- **Microsoft Internet Information Server (IIS)**—A popular server for Windows NT. Environment: NT Server. (`http://www.microsoft.com/`)
- **Microsoft Personal Web Server (PWS)**—An entry-level Web server; however, not recommended for high-traffic sites. Environment: Windows. (bundled in NT 4.0 Option Pack). (`http://www.microsoft.com/`)
- **AOLserver**—A small, free server with support for Web application development. Environment: Unix, Linux. Open Source. (`http://www.aolserver.com`)
- **Zeus**—A full-featured Web server with support for secure virtual servers. Environment: Unix. (`http://www.zeus.co.uk/products/zws/`)
- **O'Reilly WebSitePro**—A full-featured server, great for Web application development. Environment: Windows 95/98, NT. (`http://website.ora.com/`)
- **Stronghold**—A commercial, secure version of Apache. Environment: Unix. (`https://www.c2.net/products/sh3/`)
- **WebSTAR**—WebSTAR from StarNine Technologies is a full-featured Web server for the Macintosh environment. (`http://www.webstar.com/`)

For more information on these specific Web servers and many more, please refer to the URLs included in the previous descriptions or use the following sites:

- Webserver Compare, the definitive guide to HTTP server specs: `http://webcompare.internet.com/`
- Server Watch, the quintessential resource for Internet servers: `http://serverwatch.internet.com/`

Summary

With the World Wide Web still doubling in size every year, there appears to be no end in sight. And experts agree that we've only scratched the surface of what's possible using the Internet and the Web. In a short time we have gone from a very small number of "information-only" sites on the Web to many millions of sites offering a wealth of information and services. People use the Web on a daily basis for research, shopping, banking, and much more.

Everything you do on the Web is brought to you by Web servers like those discussed in this chapter. In fact, over half of the sites on the Web use Apache, the Web server featured in this chapter. The goal of this chapter was to provide you with the information you need to download, install, configure, and run the Internet's most popular Web server. There was some discussion about Web servers in general, and a short introduction to some of the top Web servers out there at the time of this writing. Hopefully, you will take what you have learned in this book, particularly this chapter, and become part of the fastest growing, most life-changing technology yet to be seen: The World Wide Web.

Operating and Administering a TCP/IP Network

PART IX

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CHAPTER 39

Protocol Configuration and Tuning on Unix Systems

by Anne Carasik

IN THIS CHAPTER

- **System Initialization Issues** *910*
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With any system, you need to know how the system initializes and where the configuration files are located. This will help you fine-tune your network configuration and help with troubleshooting. Also, there are some details to consider that may not be directly related to networking, but to the system itself, when configuring and fine-tuning your network setup.

System Initialization Issues

When you're booting up a Unix or a Linux system, you have many issues to consider. Among them are network daemons—when they start up, what starts them, and which daemons are running.

Each flavor of Unix has a "grandfather" process, known as `init`. The `init` process starts all other processes on the Unix system, including the user shells and the networking processes.

The `init` Process and `/etc/inittab`

Two things make up Unix: files and processes. In Unix, all other processes fork from `init`—eventually, all processes link back to `init` through their parents. Figure 39.1 illustrates how the `init` process is linked to the others.

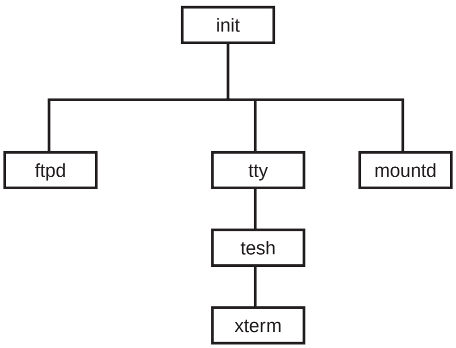

FIGURE 39.1
The `init` process and the child processes.

Because the `init` process is the last step in the boot process, after all the filesystems have been checked and the disks mounted, `init` determines into which user mode (single or multiuser) to go. Some Unix systems use a configuration script for `init`, the `/etc/inittab` file, which follows:

```
# inittab       This file describes how the INIT process should set up
#               the system in a certain run-level.
#
# Author:       Miquel van Smoorenburg, <miquels@drinkel.nl.mugnet.org>
#               Modified for RHS Linux by Marc Ewing and Donnie Barnes
#
```

```
# Default runlevel. The runlevels used by RHS are:
#   0 - halt (Do NOT set initdefault to this)
#   1 - Single user mode
#   2 - Multiuser, without NFS (The same as 3, if you do not
                                 have networking)
#   3 - Full multiuser mode
#   4 - unused
#   5 - X11
#   6 - reboot (Do NOT set initdefault to this)
#
id:3:initdefault:

# System initialization.
si::sysinit:/etc/rc.d/rc.sysinit

l0:0:wait:/etc/rc.d/rc 0
l1:1:wait:/etc/rc.d/rc 1
l2:2:wait:/etc/rc.d/rc 2
l3:3:wait:/etc/rc.d/rc 3
l4:4:wait:/etc/rc.d/rc 4
l5:5:wait:/etc/rc.d/rc 5
l6:6:wait:/etc/rc.d/rc 6

# Things to run in every runlevel.
ud::once:/sbin/update

# Trap CTRL-ALT-DELETE
ca::ctrlaltdel:/sbin/shutdown -t3 -r now

# When our UPS tells us power has failed, assume we have a few minutes
# of power left.  Schedule a shutdown for 2 minutes from now.
# This does, of course, assume you have powerd installed and your
# UPS connected and working correctly.
pf::powerfail:/sbin/shutdown -f -h +2
"Power Failure; System Shutting Down"

# If power was restored before the shutdown kicked in, cancel it.
pr:12345:powerokwait:/sbin/shutdown -c
"Power Restored; Shutdown Cancelled"


# Run gettys in standard runlevels
1:2345:respawn:/sbin/mingetty tty1
2:2345:respawn:/sbin/mingetty tty2
3:2345:respawn:/sbin/mingetty tty3
4:2345:respawn:/sbin/mingetty tty4
5:2345:respawn:/sbin/mingetty tty5
6:2345:respawn:/sbin/mingetty tty6

# Run xdm in runlevel 5
# xdm is now a separate service
x:5:respawn:/etc/X11/prefdm -nodaemon
```

In this `/etc/inittab` file for Red Hat Linux, you can see that the networking starts at run-level 3. For most Unix flavors, run-level 3 starts the networking processes including the Internet daemon (`inetd`), NFS, DNS, and Sendmail.

The `rc` Scripts

In order to start running child processes, `init` will run the start-up scripts, known as the `rc` scripts. These scripts start up desired network processes so that the Unix system is no longer "standalone."

In Red Hat Linux and other System V–based systems such as HP-UX, `init` will start running any networking start-up scripts in the `/etc/rc.d/rc3.d` directory. Other systems may call networking scripts in other files like `rc.M` (for multiuser) or `rc.inet` (for Internet). This is all operating system dependent.

For this example, we'll stick with Red Hat Linux for consistency. Because this book is on networking, we'll take a look at the `/etc/rc.d/rc3.d/` directory.

```
[root@tigerlair stripes]# ls /etc/rc.d/rc3.d/
K05innd          K20rwalld   K45arpwatch
K80random   S40atd   S85sound
K08autofs      K20rwhod   K45named   K85netfs
S40crond      S90xfsK10xntpd       K25squid
K50snmpd   K88ypserv   S50inet
S99linuxconfK15postgresql  K30mcserv   K55routed
K89portmap  S55sshd      S99local
K20bootparamd  K30sendmail   K60lpd
K96pcmcia   S72amdK20nfs          K34yppasswdd   K60mars-new   S05apmd
S75keytableK20rstatd      K35dhcpd   K75gated   S10network
S85gpm
K20rusersd     K35smb      K80nscd

   S30syslog   S85httpd
```

All of these files start up a particular service. For run-level 3, many features are started in addition to networking. For the networking, you can see which daemons are started by what follows the `S##` or `K##` (K is for Kill and S is for Start). The sequence numbers are for starting and stopping in a particular order.

These scripts also specify which options the network daemon is going to use when it's first started.

Note that a start-up script or kill script does not need to have a counterpart. For example, `S50inet` does not have a `K50inet`. Here's what the `S50inet` looks like:

```
#! /bin/sh
#
# inet          Start TCP/IP networking services. This script
```

```
#               sets the hostname, creates the routes and
#               starts the Internet Network Daemon & RPC portmapper.
#
# Author:       Miquel van Smoorenburg, <miquels@drinkel.nl.mugnet.org>
#               Various folks at Red Hat
#
# chkconfig: 345 50 50
# description: The internet superserver daemon (commonly called inetd) \
#              starts a variety of other internet services as needed. \
#              It is responsible for starting many services, including \
#              telnet, ftp, rsh, and rlogin. Disabling inetd disables \
               all of the services it is responsible for.
# processname: inetd
# pidfile: /var/run/inetd.pid
# config: /etc/sysconfig/network
# config: /etc/inetd.conf


# Source function library.
. /etc/rc.d/init.d/functions

# Get config.
. /etc/sysconfig/network

# Check that networking is up.
if [ ${NETWORKING} = "no" ]
then
        exit 0
fi

[ -f /usr/sbin/inetd ] || exit 0

# See how we were called.
case "$1" in
  start)
        echo -n "Starting INET services: "
        daemon inetd

        echo
        touch /var/lock/subsys/inet
        ;;
  stop)
        # bringing down NFS filesystems isn't
        # inet's problem I don't know
        # why this script used to do that -- ewt

        echo -n "Stopping INET services: "
        killproc inetd

        echo
        rm -f /var/lock/subsys/inet
```

```
        ;;
  status)
        status inetd
        ;;
  restart|reload)
        killall -HUP inetd
        ;;
  *)
        echo "Usage: inet {start|stop|status|restart|reload}"
        exit 1
esac

exit 0
```

A kill script for `K45named` looks like this:

```
#!/bin/sh
#
# named
# This shell script takes care of starting and stopping
#                 named (BIND DNS server).
#
# chkconfig: 345 55 45
# description: named (BIND) is a Domain
# Name Server (DNS)  that is used to resolve
# host names to IP addresses.
# probe: true

# Source function library.
. /etc/rc.d/init.d/functions

# Source networking configuration.
. /etc/sysconfig/network

# Check that networking is up.
[ ${NETWORKING} = "no" ] && exit 0

[ -f /usr/sbin/named ] || exit 0

[ -f /etc/named.conf ] || exit 0

# See how we were called.
case "$1" in
  start)
        # Start daemons.
        echo -n "Starting named: "
        daemon named
        echo
        touch /var/lock/subsys/named
        ;;
  stop)
```

```
        # Stop daemons.
        echo -n "Shutting down named: "
        killproc named
        rm -f /var/lock/subsys/named
        echo
        ;;
  status)
        /usr/sbin/ndc status
        exit $?
        ;;
  restart)
        /usr/sbin/ndc restart
        exit $?
        ;;
  reload)
        /usr/sbin/ndc reload
        exit $?
        ;;
  probe)
        # named knows how to reload intelligently;
        # we don't want linuxconf
        # to offer to restart every time
        /usr/sbin/ndc reload >/dev/null 2>&1 || echo start
        exit 0
        ;;

  *)
        echo "Usage: named {start|stop|status|restart}"
        exit 1
esac

exit 0
```


Note

Please note that not all Unix systems have their start-up scripts in the same location. Some may have them in `/etc`, `/etc/rc`, or other system-specific locations.

Most of the scripts at different run levels in the directories such as `/etc/rc.d/rc3.d` are symbolic links to scripts in the directory `/etc/rc.d/init.d`. For example, the `/etc/rc.d/rc3.d/S50inet` script is a symbolic link to the following file:

```
../init.d/inet
```

When the `S50inet` is executed, the script file `../init.d/inet` is called with the `'start'` argument.

Similarly, `/etc/rc.d/rc3.d/S53named` is a symbolic link to the `../init.d/named` script. When the `S53named` is executed, it executes the `../init.d/named` script with the `'start'` argument. When the system is shutting down, the `/etc/rc.d/rc3.d/K45named` is executed. This file is also a symbolic link to the `../init.d/named` script. But when the `K45named` script is executed, the `../init.d/named` script is executed with a `'stop'` argument. This is why within each of these scripts there is logic to handle the `'start'`, `'stop'` and other arguments passed to the script. Knowing this, you can use the scripts in `/etc/rc.d/init.d` to stop and start different services. For example, if you want to stop BIND services, you can use the following command:

```
/etc/rc.d/init.d/named stop
```

If BIND is not running, you can start it using

```
/etc/rc.d/init.d/named start
```

After making changes to the BIND (named) database files, you can restart it using

```
/etc/rc.d/init.d/named restart
```

Configuration Files

In order to get your network working properly, you need to pay careful attention to the configuration files. On Unix, you need to pay attention to several important configuration files. These include

- `/etc/inetd.conf`
- `/etc/services`
- `/etc/protocols`
- `/etc/hosts.equiv`
- `/etc/resolv.conf`
- `/etc/exports`

Other Unix systems will have other configuration files; however, this differs from operating system to operating system.

Defining Network Protocols in `/etc/protocols`

In order to define which network protocols run on your Unix system, you need to define them in the `/etc/protocols` file. Most of these should run fine on your system; however, you should not need to define anything by hand—this should be done by the system at setup.

Note that these are IP protocols—no non-IP protocols are listed here (such as AppleTalk, NetWare, or SNA).

The following is a sample /etc/protocols file:

```
# /etc/protocols:

#
# Internet (IP) protocols
#
#   from: @(#)protocols   5.1 (Berkeley) 4/17/89
#
# Updated for NetBSD based on RFC 1340, Assigned Numbers (July 1992).

Ip      0      IP         # internet protocol, pseudo protocol
                                                number
icmp    1      ICMP          # internet control message protocol
igmp    2      IGMP         # Internet Group Management
ggp     3      GGP         # gateway-gateway protocol
ipencap     4      IP-ENCAP   # IP encapsulated in IP
                                                (officially ''IP'')
st          5      ST         # ST datagram mode
tcp      6      TCP         # transmission control protocol
egp      8      EGP         # exterior gateway protocol
pup      12      PUP         # PARC universal packet protocol
udp      17      UDP         # user datagram protocol
hmp      20      HMP         # host monitoring protocol
xns-idp   22      XNS-IDP         # Xerox NS IDP
rdp      27      RDP          # "reliable datagram" protocol
iso-tp4   29      ISO-TP4         # ISO Transport Protocol class 4
xtp      36      XTP         # Xpress Tranfer Protocol
ddp      37      DDP         # Datagram Delivery Protocol
idpr-cmtp   39   IDPR-CMTP   # IDPR Control Message Transport
rspf   73   RSPF      #Radio Shortest Path First.
vmtp   81   VMTP      # Versatile Message Transport
ospf   89   OSPFIGP      # Open Shortest Path First IGP
ipip   94   IPIP      # Yet Another IP encapsulation
encap   98   ENCAP      # Yet Another IP encapsulation
```

Recognizable Hosts in /etc/hosts

For some local systems, you may want to define some hosts that can be discovered by name without needing the Domain Name Service (DNS). In order to do this, you need to have an /etc/hosts file.

A barebones /etc/hosts will look like this:

```
127.0.0.1   localhost   loopback
```

This will define the localhost, or loopback, which is the default IP address for the host you are currently on. The IP address 127.0.0.1 is defined by default for localhost.

To add another host, use the following syntax:

```
IPaddress   hostname   alias
```

You need to have the IP address of the host, the hostname assigned to it, and any aliases you want. A sample `/etc/hosts` file will look something like this:

```
# a sample /etc/hosts file
127.0.0.1   localhost      loopback
1.2.3.4      wednesday.addams.com   mymachine
1.2.3.5      pugsley.addams.com   yourmachine
1.2.3.6      gomez.addams.com   hismachine
1.2.3.7      cousinit.addams.com   itsmachine
1.2.3.8      morticia.addams.com   hermachine
```

So, if a telnet session were done to `yourmachine`, it would connect to `pugsley.addams.com`. With the alias, you don't have to type in the entire domain name.

Note

You don't have to include the fully qualified domain name if the system in your `/etc/hosts` file is on the local network.

The file `/etc/nsswitch.conf` controls the order in which the name resolution is performed. For example, you can specify that `/etc/hosts` should be searched before DNS, or DNS should be searched before `/etc/hosts`. The simplest way to configure the name resolution order under Linux is to use the linuxconf configuration tool.

TCP/IP and `/etc/services`

In order to determine what type of TCP/IP services are offered on your Unix system, you need to set the appropriate services you want running on your system. You can do this two different ways: from the `/etc/services` file and from the `inetd` configuration file, `inetd.conf`, which is discussed later in this chapter.

The `/etc/services` file assigns specific ports to network services such as FTP, Telnet, time server, name server, Secure Shell, finger, and others.

Many of these services are commonly assigned to the same port and are known as well-known ports. This includes any network service that runs at port 1024 or lower.

Other network services that are not nearly as common are also included in the `/etc/services` file. The syntax for a listing in the `/etc/services` file looks like this:

```
networkservice      portnumber/tcporudp
```

First you define your network service (such as Telnet, echo, SMTP), and then you define the port number. After the port number, you need to define whether the service uses either TCP or UDP.

The following is a sample `/etc/services` file:

```
# /etc/services:
#
# Network services, Internet style
#
# Note that it is presently the policy of IANA to assign a
# single well-known port number for both TCP and UDP;
# hence, most entries here have two entries
# even if the protocol doesn't support UDP operations.
# Updated from RFC 1700, ''Assigned Numbers'' (October 1994).
# Not all ports
# are included, only the more common ones.

tcpmux      1/tcp            # TCP port service multiplexer
echo      7/tcp
echo      7/udp
discard      9/tcp      sink null
discard      9/udp      sink null
systat      11/tcp      users
daytime      13/tcp
daytime      13/udp
netstat      15/tcp
qotd      17/tcp      quote
msp      18/tcp            # message send protocol
msp      18/udp            # message send protocol
chargen      19/tcp      ttytst source
chargen      19/udp      ttytst source
ftp-data   20/tcp
ftp      21/tcp
fsp      21/udp      fspd
ssh      22/tcp            # SSH Remote Login Protocol
ssh      22/udp            # SSH Remote Login Protocol
telnet      23/tcp
# 24 - private
smtp      25/tcp      mail
# 26 - unassigned
time      37/tcp      timserver
nameserver   42/tcp      name      # IEN 116
whois      43/tcp      nicname
domain      53/tcp      nameserver   # name-domain server
domain      53/udp      nameserver
bootps      67/tcp            # BOOTP server
bootpc      68/tcp            # BOOTP client
tftp      69/udp
gopher      70/tcp            # Internet Gopher
```

```
finger      79/tcp
www      80/tcp      http      # WorldWideWeb HTTP
www      80/udp            # HyperText Transfer Protocol
link      87/tcp      ttylink
kerberos   88/tcp      kerberos5 krb5   # Kerberos v5
kerberos   88/udp      kerberos5 krb5   # Kerberos v5
supdup      95/tcp
# 100 - reserved
pop-3      110/tcp            # POP version 3
sunrpc      111/tcp      portmapper   # RPC 4.0 portmapper TCP
sunrpc      111/udp      portmapper   # RPC 4.0 portmapper UDP
auth      113/tcp      authentication tap ident
sftp      115/tcp
nntp      119/tcp      readnews untp   # USENET News Transfer
                                                                Protocol
ntp      123/tcp
netbios-ns   137/tcp            # NETBIOS Name Service
netbios-dgm   138/tcp            # NETBIOS Datagram Service
netbios-ssn   139/tcp            # NETBIOS session service
imap2      143/tcp      imap      # Interim Mail Access Proto v2
imap2      143/udp      imap
snmp      161/udp            # Simple Net Mgmt Proto
snmp-trap   162/udp      snmptrap   # Traps for SNMP
cmip-man   163/tcp            # ISO mgmt over IP (CMOT)
bgp      179/tcp            # Border Gateway Proto.
irc      194/tcp            # Internet Relay Chat
qmtp      209/tcp            # The Quick Mail Transfer Protocol
#
# Unix specific services
#
exec      512/tcp
biff      512/udp      comsat
login      513/tcp
who      513/udp      whod
shell      514/tcp      cmd      # no passwords used
syslog      514/udp
printer      515/tcp      spooler      # line printer spooler
talk      517/udp
ntalk      518/udp
route      520/udp      router routed   # RIP
#
# Kerberos (Project Athena/MIT) services
# Note that these are for Kerberos v4, and are unofficial.  Sites running
# v4 should uncomment these and comment out the v5 entries above.
#
kerberos4   750/udp      kerberos-iv kdc   # Kerberos (server) udp
kerberos4   750/tcp      kerberos-iv kdc   # Kerberos (server) tcp
kerberos_master   751/udp            # Kerberos authentication
kerberos_master   751/tcp            # Kerberos authentication
passwd_server   752/udp            # Kerberos passwd server
krb_prop   754/tcp            # Kerberos slave propagation
```

```
krbupdate   760/tcp      kreg      # Kerberos registration
kpasswd      761/tcp      kpwd      # Kerberos "passwd"
#
# Services added for the Debian GNU/Linux distribution
poppassd   106/tcp            # Eudora
poppassd   106/udp            # Eudora
ssmtp      465/tcp            # SMTP over SSL
rsync      873/tcp            # rsync
rsync      873/udp            # rsync
simap       993/tcp            # IMAP over SSL
spop3      995/tcp            # POP-3 over SSL
socks      1080/tcp         # socks proxy server
socks      1080/udp         # socks proxy server
icp      3130/tcp         # Internet Cache Protocol (Squid)
icp      3130/udp         # Internet Cache Protocol (Squid)
ircd      6667/tcp         # Internet Relay Chat
ircd      6667/udp         # Internet Relay Chat
```

`inetd` and `/etc/inetd.conf`

On Unix, many network services are started by the Internet super daemon `inetd`. In order for `inetd` to know what to run, it needs to read its configuration file `inetd.conf`, which is usually located in the `/etc` directory.

Note

Because of `inetd`'s ability to launch other network daemons, there is a desire to use `inetd` all the time. However, there are times when this will decrease performance enough that it may not be worth it. For example, Secure Shell takes quite a large performance hit because of the cryptographic keys it has to spin off.

On some Linux systems, the `inetd` daemon is replaced by an extended `inetd` daemon called `xinetd`. The configuration for this daemon is in the `/etc/xinetd.conf` file.

For most network daemons, `inetd` is fine to use to watch the other network daemons. Daemons go through `inetd` instead of using their own daemon because `inetd` can listen for all sockets, instead of the network daemons having to listen for themselves.

This prevents too many daemons sitting around and waiting for a socket to bind to, and it also prevents sockets from being let in randomly. In a way, `inetd` acts like a security guard in a corporation, letting in only the people that should go in and directing everyone else to the right area. This makes security easier, and also makes the traffic (bandwidth) much more manageable.

Figure 39.2 illustrates how `inetd` acts like the security guard for networking processes.

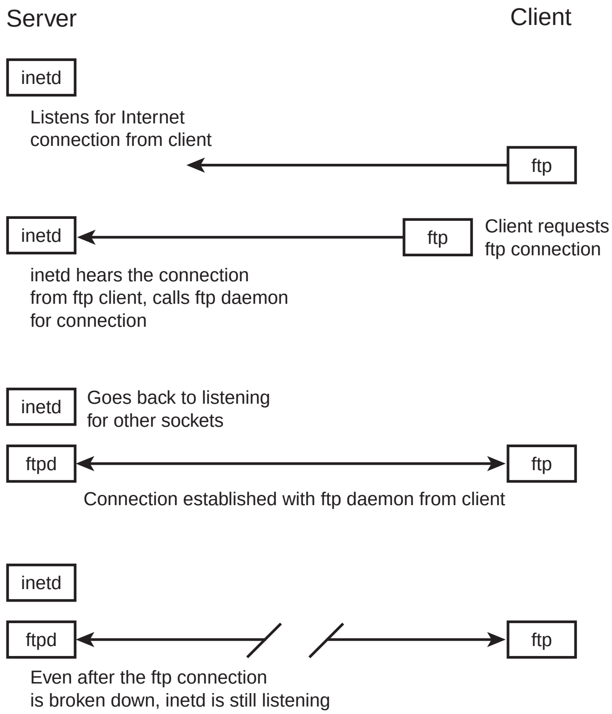

FIGURE 39.2
The `inetd` process management.

Because `inetd` doesn't know which of the network daemons you want to run, you need to define them in `/etc/inetd.conf`. The format for an entry in `/etc/inetd.conf` looks like this:

```
nameofservice sockettype protocol flags user serverpath arguments
```

So, for the ftp daemon, the syntax looks like this:

```
ftp stream tcp nowait root /usr/sbin/tcpd in.ftpd -l -a
```

This translates to the ftp protocol, which uses the socket type `stream` and runs as `root`. The server path is located at `/usr/sbin/tcpd` and the arguments it takes are `in.ftpd -l -a`. Note that there are no flags. If there are no flags, the option is skipped completely. The `/usr/sbin/tcpd` is a TCP wrapper daemon that controls access to the service specified in the argument to tcpd. Access to service is controlled by the `/etc/hosts.deny` and `/etc/hosts.allow` file. Using the TCP wrapper, you can specify a security policy, which controls who can access the specified service.

A portion of my `inetd.conf` file looks like this:

```
#
# Authors:   Original taken from BSD Unix 4.3/TAHOE.
#       Fred N. van Kempen, <waltje@uwalt.nl.mugnet.org>
#
echo   stream   tcp   nowait   root   internal
echo   dgram   udp   wait   root   internal
discard   stream   tcp   nowait   root   internal
discard   dgram   udp   wait   root   internal
daytime   stream   tcp   nowait   root   internal
daytime   dgram   udp   wait   root   internal
chargen   stream   tcp   nowait   root   internal
chargen   dgram   udp   wait   root   internal
time   stream   tcp   nowait   root   internal
time   dgram   udp   wait   root   internal

# These are standard services.
#
ftp   stream   tcp   nowait   root   /usr/sbin/tcpd   in.ftpd -l -a
telnet   stream  tcp    nowait  root    /usr/sbin/tcpd   in.telnetd
#
# Shell, login, exec, comsat and talk are BSD protocols.
#
shell   stream   tcp   nowait   root   /usr/sbin/tcpd   in.rshd
login   stream   tcp   nowait   root   /usr/sbin/tcpd   in.rlogind
#exec   stream   tcp   nowait   root   /usr/sbin/tcpd   in.rexecd
#comsat   dgram   udp   wait   root   /usr/sbin/tcpd   in.comsat
talk   dgram   udp   wait   root   /usr/sbin/tcpd   in.talkd
ntalk   dgram   udp   wait   root   /usr/sbin/tcpd   in.ntalkd
#dtalk   stream   tcp   waut   nobody   /usr/sbin/tcpd   in.dtalkd
#
# Pop and imap mail services et al
#
#pop-2   stream  tcp     nowait  root    /usr/sbin/tcpd   ipop2d
pop-3   stream  tcp     nowait  root    /usr/sbin/tcpd   ipop3d
imap    stream  tcp     nowait  root    /usr/sbin/tcpd   imapd
#
# The Internet UUCP service.
#
#uucp   stream   tcp   nowait   uucp   /usr/sbin/tcpd
     /usr/lib/uucp/uucico   -l
#
# Tftp service is provided primarily for booting.  Most sites
# run this only on machines acting as "boot servers." Do not uncomment
# this unless you *need* it.
#
#tftp   dgram   udp   wait   root   /usr/sbin/tcpd   in.tftpd
#bootps   dgram   udp   wait   root   /usr/sbin/tcpd   bootpd
#
# Finger, systat and netstat give out user information which may be
```

```
# valuable to potential "system crackers."  Many sites choose to disable
# some or all of these services to improve security.
#
finger   stream   tcp   nowait   root   /usr/sbin/tcpd   in.fingerd
#cfinger stream   tcp   nowait   root   /usr/sbin/tcpd   in.cfingerd
#systat   stream   tcp   nowait   guest   /usr/sbin/tcpd   /bin/ps   -auwwx
#netstat   stream   tcp   nowait   guest   /usr/sbin/tcpd
     /bin/netstat   -f inet
#
# Authentication
#
auth   stream   tcp   nowait   nobody
     /usr/sbin/in.identd in.identd -l -e -o
#
# End of inetd.conf
```

Note that by default many of these network daemons are commented out with the `#`. This means that you should not run these commands unless you're absolutely sure of what you're doing. They are considered a security risk either because they are easy to use to gain access to or bring down your system.

Note

Daemons usually run as either the `nobody` or `root` users. The `nobody` user is a guest user with limited privileges. Make sure that you are especially careful with running daemons that run as `root`, because root users have full access to the system.

If you make any changes to the `/etc/inetd.conf` file, such as commenting out a network daemon or adding an additional one, you will need to restart `inetd` by sending it the HUP signal, like this:

```
# killall -HUP inetd
```

Recognizable Networks in `/etc/networks`

Not many systems use this, but you can define your networks in the `/etc/networks` file. This will help you organize which networks your system connects to.

The DNS Client and `/etc/resolv.conf`

To get DNS name resolution working, you need to have your DNS client configured properly. In order to do this, you need to have an `/etc/resolv.conf` file.

In the `/etc/resolv.conf` file, you will have your domain name defined, your nameserver (either your primary or your primary and secondary), and any other directives it needs.

Basically, this allows your system to perform domain name lookups, such as converting `www.example.com` to its IP address, as shown here:

```
search example.com sub.example.com
nameserver 200.1.1.1
nameserver 200.1.1.2
nameserver    200.1.1.3
```

The search directive specifies the domain suffixes that will be used if an attempt is made to resolve a name that is not fully qualified. For example, if you try to access a server by its name, s100, then DNS will try to resolve it first as s100.example.com, and then as s100.sub.example.com. The nameserver directive can be used to specify up to three DNS servers. The DNS servers are queried in the order in which they are specified by the nameserver directive.

Note

Even though `/etc/resolv.conf` pertains to DNS, you need to make sure it is set properly. Test your DNS with `nslookup`, `dig`, `dnsquery`, or whatever other tools you can find.

Otherwise, you may end up with vexing problems that do not relate to DNS.

Summary

Some of the most important issues concerning network administration include system initialization, configuration files, and making the right changes in the right places.

It is important to know where the networking functionality starts up on your system. In Unix, there are run levels that define the services the system is capable of running. This includes knowing which run level starts up your networking functionality. On some systems, it starts up on run-level 3; others start up at different run levels, including multi-user (defined as "M"). The run level configuration is defined in the `/etc/inittab` file on some Unix systems.

For networking, it is also critical for bandwidth and security reasons to make sure that the configuration files are set up properly. On Unix, this includes the Internet super daemon configuration in `inetd.conf`, the DNS client configuration in `/etc/resolv.conf`, the accessible networks in `/etc/networks`, the hosts in `/etc/hosts`, and the network services in `/etc/services`.

After you have your TCP/IP network services set up, you'll learn how to manage the name service with DNS, learn about network management and its protocol SNMP, and learn how to secure and debug a TCP/IP network.

CHAPTER 40

Implementing DNS

by Tim Parker

In This Chapter

- **The Name Server** *928*
- **Resource Records** *929*
- **Name Resolver** *931*
- **Configuring a Unix or Linux DNS Server** *932*
- **Windows and DNS** *940*

Instead of tediously remembering and entering the IP address of every service-providing host on your network, you can enter hostnames using the *Domain Name System* (DNS). If assigned meaningfully, hostnames can be easily remembered and used.

The Domain Name System, as its name implies, works by dividing the Internet namespace into a set of domains, which can be further divided into subdomains. The first set of domains is called the top-level domains, and they are familiar to anyone who's browsed the Web or used the Internet. Seven top-level domains are in regular use:

- `arpa`—Internet-specific organizations
- `com`—Commercial enterprises
- `edu`—Educational organizations
- `gov`—Governmental bodies
- `mil`—Military organizations
- `net`—Service providers
- `org`—Noncommercial organizations

In addition to these top-level domains, there are dedicated top-level domains for each country. These are usually identified by a short form of the country's name, such as `.ca` for Canada and `.uk` for the United Kingdom. Beneath the top-level domains is another level for the individual organizations within each top-level domain (such as `ibm.com` and `linux.org`). The domain names are all registered with the *Network Information Center* (NIC) and are unique to the network.

The Name Server

Each DNS name server manages a distinct area of a network (or an entire domain, if the network is small). The domains over which a name server is authoritative is called a *zone*. Several zones may be managed by one name server, with each zone consisting of one or more domains. Within each zone, there is almost always a designated secondary or backup name server, with the two (primary and secondary) name servers holding duplicate information. The name servers within a zone communicate using a zone transfer protocol.

DNS operates by having a set of nested zones. A name server communicates with other name servers. Each name server also knows the address of at least one other name server. Each zone has at least one name server responsible for knowing the address information for each machine within that zone.

When a user application needs to resolve a symbolic name into a network address, a query is sent by the application to the DNS resolver, which then communicates the query to the name server. The name server checks its own tables and returns the network address corresponding to the symbolic name. If the name server doesn't have the information it requires, it can send a request to another name server. Both the name servers and the resolvers use database tables and memory caches to maintain information about the machines in the local zone, as well as recently requested information from outside the zone.

When a name server receives a query from a resolver, the name server can perform several types of operations. Name resolver operations fall into two categories: nonrecursive (or iterative) and recursive.

A *recursive* operation is one in which the name resolution request must be answered with the required information or error message. The server that receives the request can query other DNS servers for information. On obtaining the answer (or no answer) the server that received the request forwards the answer to the requestor. *Nonrecursive* (or *iterative*) operations performed by the name server include a full answer to the resolver's request, a referral to another name server (which the resolver must send a query to), or an error message.

When a recursive operation is necessary, the name server contacts another name server with the resolver's request. The remote name server will reply to the request with either a network address or a negative message indicating failure. In recursion, DNS rules prohibit a remote name server from sending a referral to yet another name server.

Resource Records

The information required to resolve symbolic names is maintained by the name server in a set of resource records, which are entries in a database.

Note

Resource records (often abbreviated RR) are inputted through text files called zone data files. After the text files are read by the DNS information, they are cached in the DNS server memory in the form of tables that are designed for fast retrieval. Typically, some form of the "hash" table that can be accessed via fast indexes is maintained.

You saw the structure of resource records earlier, so the information isn't repeated here.

Address fields used by DNS, such as in the address resource record type, use a special format called IN-ADDR-ARPA. This allows reverse mapping from the address to the hostname as well as host-to-address mapping. To understand IN-ADDR.ARPA, it is useful to begin with a standard-format resource record. One of the simplest types of resource record is for the address (type A). The following is an extract from an address file:

```
TPCI_HPWS1    IN    A    143.12.2.50
TPCI_HPWS2    IN    A    143.12.2.51
TPCI_HPWS3    IN    A    143.12.2.52
TPCI_GATEWAY  IN    A    143.12.2.100
              IN    A    144.23.56.2
MERLIN        IN    A    145.23.24.1
SMALLWOOD     IN    A    134.2.12.75
```

Each line of the file represents one resource record. In this case, they are all simple entries that have the machine's symbolic name (alias), the class of machine (IN for Internet), A to show it is an address resource record, and the Internet address. The entry for the machine `TPCI_GATEWAY` has two corresponding addresses because it is a gateway between two networks. The gateway will have a different address on each of the networks, hence two resource records in the same file.

This type of file makes name-to-address mapping easy. The name server simply searches for a line that has the symbolic name requested by the application and returns the Internet address at the end of that line. The databases are indexed on the name, so these searches proceed very quickly.

Searching from the address to the name is not quite as easy. If the resource record files were small, time delays for a manual search would not be appreciable, but with large zones there can be thousands or tens of thousands of entries. The index is on the name, so searching for an address would be a slow process. To solve this reverse-mapping problem, IN-ADDR.ARPA was developed. IN-ADDR.ARPA uses the host address as an index to the host's resource record information. When the proper resource record is located, the symbolic name can be extracted.

IN-ADDR.ARPA uses the PTR resource record type to point from the address to the name. There may be one of these pointer indexes maintained on each name server. An example of a number-to-name file follows:

```
23.1.45.143.IN-ADDR.ARPA.    PTR    TPCI_HPWS_4.TPCI.COM
1.23.64.147.IN-ADDR.ARPA.    PTR    TPCI_SERVER.MERLIN.COM
3.12.6.123.IN-ADDR.ARPA.     PTR    BEAST.BEAST.COM
143.23.IN-ADDR.ARPA          PTR    MERLINGATEWAY.MERLIN.COM
```

The Internet addresses are reversed in the IN-ADDR.ARPA file for ease of use. As shown in the sample file, specifying the complete address for a gateway is not necessary because the domain name will provide enough routing information.

Name Resolver

The DNS client is called the name resolver. As far as user applications are concerned, resolving the symbolic names into actual network addresses is easy. The application sends a query to a process called the name resolver, or resolver (which sometimes resides on another machine). The name resolver may be able to resolve the name directly, in which case it sends a return message to the application. If the resolver cannot determine the network address, the resolver communicates with the name server (which might contact another name server).

The resolver is intended to replace existing name resolution systems on a machine, such as the `/etc/hosts` file. The replacement of these common mechanisms is transparent to the user, although the administrator must know whether the native name resolution system or DNS is to be used on each machine so the correct tables can be maintained.

When the resolver acquires information from a name server, it stores the entries in its own cache to reduce the need for more network traffic if the same symbolic name is used again (as is often the case with applications that work across networks). The amount of time the name resolver stores these records is dependent on the Time-to-Live (TTL) field in the resource records sent, or on a default value set by the system.

When a name server cannot resolve a name, it may send back a message to the resolver (in case of an iterative query) with the address of another name server in the Authority field of the message. The resolver must then address a message to the other name server in the hopes of resolving the name. The resolver can ask the name server to conduct the query itself by setting the RD (recursive) bit in the message. The name server can refuse or accept the request.

The resolver uses UDP in its query process. However, transfers of large amounts of information such as in-zone transfer, may require the use of TCP because of its higher reliability.

Under the Unix and Linux operating systems where DNS originated, several different implementations of the name resolver are in use. The resolver supplied with the original BSD versions of Unix was particularly limited, offering neither a cache nor iterative query capabilities. To solve these limitations, the *Berkeley Internet Name Domain* (BIND) server was added in 4.2 BSD Unix. BIND provides both caching and iterative query capabilities in three different modes: as a primary server, as a secondary server, or as a caching-only server (which doesn't have a database of its own, only a cache). The use of BIND on BSD systems allowed another process to take over the workload of name resolution, a process that may be on another machine entirely.

Note

Note that current development of BIND and its evolution is managed by the Internet Software Consortium (`www.isc.org`). BIND is available for Unix as well as the MS Windows operating systems.

Configuring a Unix or Linux DNS Server

Configuring a DNS server requires a number of files and databases to be modified or created. The process is time-consuming, but luckily has to be done only once for each server. The files involved in most DNS setups, and their purposes, are

- `named.hosts`—Defines the domain with hostname-to-IP mappings
- `named.rev`—Uses IN-ADDR.ARPA for IP-to-hostname mappings
- `named.local`—Used to resolve the loopback driver
- `named.ca`—Lists root domain servers
- `named.boot` (for BIND 4) and `named.conf` for (BIND 8 and higher)—Used to set file and database locations

With the exception of `named.boot` and `named.conf` files, these filenames are examples, but they can be changed to suit your own personal needs. The primary file in the list is `named.boot` (BIND 4) or `named.conf` (BIND 8 and higher), which is read when the system boots up and defines the other files in the set. Therefore, any filename changes are reflected in these files. Each of the previously listed files is a database with entries in the form of a resource record.

Entering the Resource Records

For a typical server configuration, you will use standard names and network layouts. DNS allows you to get very complex, but it's easier to see what the files and resource records are doing with a simple layout.

An SOA resource record is placed in the `named.hosts` file. Semicolons in the record are used for comments. This resource record has been formatted as one field per line to make its entries clear, although this is not necessary. This resource record defines an upper boundary of the `tpci.com` domain with `server.tpci.com` as the primary name server for the domain, `root.merlin.tpci.com` as the e-mail address of the person responsible for the domain, and the rest of the entries identified by comments.

```
tpci.com.   IN   SOA     server.tpci.com.
     root.merlin.tpci.com. (
     2  ; Serial number
     7200 ; Refresh (2 hrs)
     3600 ; Retry (1 hr)
     151200 ; Expire (1 week)
     86400 ); min TTL
```

Note that the information from the serial number to the TTL field is enclosed in parentheses. This is part of the command syntax and must be included to indicate the parameter order.

In addition to the SOA RR, the `named.hosts` file contains Address (A) records. These records are used for the actual mapping of a hostname to its IP address. A few address resource records will show the format of these entries:

```
artemis     IN     A    143.23.25.7
merlin      IN     A    143.23.25.9
pepper      IN     A    143.23.25.72
```

The hostnames are typically not given as fully qualified domain names because the server can deduce the full name. If you want to use the full domain name, you must follow the name with a period. The machines shown in the preceding example would be given as follows using fully qualified domain names:

```
artemis.tpci.com.     IN     A    143.23.25.7
merlin.tpci.com.      IN     A    143.23.25.9
pepper.tpci.com.   A    143.23.25.72
```

The Pointer (PTR) resource record is used to map an IP address to a name using IN-ADDR.ARPA. A single PTR RR helps make this clear. The record indicates that the machine named `merlin` has the IP address 147.120.0.7:

```
7.0.120.147.in-addr.arpa IN PTR merlin.tpci.com.
```

The name server resource records point to the name server that has authority for a particular zone. Name server (NS) records are used when a large network has several subnetworks each with its own name server. An entry looks like this:

```
tpci.com.   IN   NS  merlin.tpci.com.
```

This record indicates that the DNS server for the `tpci.com` domain is called `merlin.tpci.com`. If there were several subnets used in `tpci.com`, there would be an NS RR for each subnet.

Completing the DNS Files

As you know, DNS uses a number of files to hold resource records describing the zones used by DNS. The first file of interest is `named.hosts`, which contains the SOA, NS, and A resource records. All entries in the `named.hosts` file must begin in the first character position of each line. Here's a sample `named.hosts` file with comments added to show the records:

```
; named.hosts files
; Start Of Authority RR
tpci.com.IN SOA merlin.tpci.com.
root.merlin.tpci.com. (
2  ; Serial number
7200 ; Refresh (2 hrs)
3600 ; Retry (1 hr)
151200 ; Expire (1 week)
86400 ); min TTL
;
; Name Service RRs
tpci.com.   IN   NS  merlin.tpci.com.
subnet1.tpci.com. IN NS goofy.subnet1.tpci.com.
;
; Address RRs
artemis     IN     A    143.23.25.7
merlin      IN     A    143.23.25.9
windsor     IN     A    143.23.25.12
reverie     IN     A    143.23.25.23
bigcat      IN     A    143.23.25.43
pepper      IN     A    143.23.25.72
```

The first section sets the SOA record that defines the parameters for time-to-live, expiry, refresh, and so on. It sets the name server for the `tpci.com` domain to be `merlin.tpci.com`. The second section uses the name service resource records to define the name server for the `tpci.com` domain as `merlin.tpci.com` (the same as the SOA) and a subdomain of tpci called `subnet1`, for which the name server is `goofy.subnet1.tpci.com`. The third section has a list of the address record name-to-IP address mapping. There will be an entry in this section for each machine on the network.

The `named.rev` file provides the reverse mapping of IP address to machine name and is composed of pointer resource records. The same format as the `named.hosts` file is followed, except for the swapping of name and IP address, and the conversion of the IP address to IN-ADDR.ARPA style. The equivalent `named.rev` file for the `named.hosts` file shown earlier looks like this:

```
; named.rev files
; Start Of Authority RR
23.143.in-addr.arpa.    IN    SOA     merlin.tpci.com.
          root.merlin.tpci.com. (
          2  ; Serial number
          7200 ; Refresh (2 hrs)
          3600 ; Retry (1 hr)
          151200 ; Expire (1 week)
          86400 ); min TTL
;
; Name Service RRs
23.143.in-addr.arpa.   IN   NS  merlin.tpci.com.
100.23.143.in-addr.arpa.   IN NS goofy.subnet1.tpci.com.
;
; Address RRs
9.25.23.143.in-addr.arpa.   IN   PTR merlin.tpci.com.
12.25.23.143.in-addr.arpa.  IN   PTR windsor.tpci.com.
23.25.23.143.in-addr.arpa.  IN   PTR reverie.tpci.com.
43.25.23.143.in-addr.arpa.  IN   PTR bigcat.tpci.com.
72.25.23.143.in-addr.arpa.  IN   PTR pepper.tpci.com.
```

There must be a separate `named.rev` file for each zone or subdomain on the network. These files can have different names or be placed in different directories. If you have only a single zone, one `named.rev` file is all that's needed.

The `named.local` file contains an entry for the loopback address (which is usually set to the IP address 127.0.0.1, even though any address of the form 127.x.x.x will do). This file must contain information about the IN-ADDR.ARPA mapping of the loopback driver, as well as a domain again (because the `named.rev` file doesn't cover the 127 network). A `named.local` file looks like this:

```
; named.local files
; Start Of Authority RR
0.0.127.in-addr.arpa. IN
SOA merlin.tpci.com.
root.merlin.tpci.com. (
2  ; Serial number
7200 ; Refresh (2 hrs)
3600 ; Retry (1 hr)
151200 ; Expire (1 week)
86400 ); min TTL
;
; Name Service RR
0.0.127.in-addr.arpa.   IN   NS  merlin.tpci.com.
;
; Address RR
1.0.0.127.in-addr.arpa.   IN   PTR localhost.
```

This file then provides the mapping from the machine named `localhost` to the IP address 127.0.0.1.

The `named.ca` file is used to specify the name of root servers that the system can resort to. The machines specified in the `named.ca` file should be stable and not subject to rapid change. A sample `named.ca` file looks like this:

```
; named.ca
; servers for the root domain
;
.  99999999  IN   NS  ns.nic.ddn.mil.
   99999999  IN   NS  ns.nasa.gov.
   99999999  IN   NS  ns.internic.net
; servers by address
;
ns.nic.ddn.mil.   99999999   IN  A  192.112.36.4
ns.nasa.gov.      99999999   IN  A  192.52.195.10
ns.internic.net.  99999999   IN  A  198.41.0.4
```

In this file, only three DNS servers have been specified. A normal `named.ca` may have a dozen or so name servers, depending on their proximity to your system.

For operational requirements of root servers, consult RFC 2870. The following is a complete list of root servers. The root servers are placed in the ROOT-SERVERS.NET domain. The root servers are A.ROOT-SERVERS.NET to M.ROOT-SERVERS.NET making up a total of 13 root servers. Their locations are as follows:

East Coast of USA:	
A.ROOT-SERVERS.NET	NSF-NSI. Herndon, VA
C.ROOT-SERVERS.NET	PSI. Herndon, VA
D.ROOT-SERVERS.NET	UMD. College Park, MD
G.ROOT-SERVERS.NET	DISA. Boeing, VA
H.ROOT-SERVERS.NET	US Army. Aberdeen, MD
J.ROOT-SERVERS.NET	NSF-NSI. Herndon, VA

West Coast of USA:	
E.ROOT-SERVERS.NET	NASA. Moffet Field, CA
F.ROOT-SERVERS.NET	ISC. Woodside, CA
B.ROOT-SERVERS.NET	DISA-USC. Marina Del Rey, CA
L.ROOT-SERVERS.NET	DISA-USC. Marina Del Rey, CA

Europe:	
K.ROOT-SERVERS.NET	LINX/RIPE. London, UK
I.ROOT-SERVERS.NET	NORDU. Stockholm, Sweden

Asia:	
M.ROOT-SERVERS.NET	WIDE. Keio, Japan

The current list of root servers can be obtained from the site `ftp://ftp.rs.internic.net/domain/named.root`. The zone data file for the root servers is shown here:

```
;       This file holds the information on root name servers needed to
;       initialize cache of Internet domain name servers
;       (e.g. reference this file in the "cache  .  <file>"
;       configuration file of BIND domain name servers).
;
;       This file is made available by InterNIC registration services
;       under anonymous FTP as
;           file                /domain/named.root
;           on server           FTP.RS.INTERNIC.NET
;       -OR- under Gopher at    RS.INTERNIC.NET
;           under menu          InterNIC Registration Services (NSI)
;              submenu          InterNIC Registration Archives
;           file                named.root
;
;       last update:    Aug 22, 1997
;       related version of root zone:   1997082200
;
;
; formerly NS.INTERNIC.NET
;
.                        3600000  IN  NS    A.ROOT-SERVERS.NET.
A.ROOT-SERVERS.NET.      3600000      A     198.41.0.4
;
; formerly NS1.ISI.EDU
;
.                        3600000      NS    B.ROOT-SERVERS.NET.
B.ROOT-SERVERS.NET.      3600000      A     128.9.0.107
;
; formerly C.PSI.NET
;
.                        3600000      NS    C.ROOT-SERVERS.NET.
C.ROOT-SERVERS.NET.      3600000      A     192.33.4.12
;
; formerly TERP.UMD.EDU
;
.                        3600000      NS    D.ROOT-SERVERS.NET.
D.ROOT-SERVERS.NET.      3600000      A     128.8.10.90
;
; formerly NS.NASA.GOV
;
.                        3600000      NS    E.ROOT-SERVERS.NET.
E.ROOT-SERVERS.NET.      3600000      A     192.203.230.10
;
; formerly NS.ISC.ORG
;
.                        3600000      NS    F.ROOT-SERVERS.NET.
F.ROOT-SERVERS.NET.      3600000      A     192.5.5.241
;
```

```
; formerly NS.NIC.DDN.MIL
;
.                        3600000      NS    G.ROOT-SERVERS.NET.
G.ROOT-SERVERS.NET.      3600000      A     192.112.36.4
;
; formerly AOS.ARL.ARMY.MIL
;
.                        3600000      NS    H.ROOT-SERVERS.NET.
H.ROOT-SERVERS.NET.      3600000      A     128.63.2.53
;
; formerly NIC.NORDU.NET
;
.                        3600000      NS    I.ROOT-SERVERS.NET.
I.ROOT-SERVERS.NET.      3600000      A     192.36.148.17
;
; temporarily housed at NSI (InterNIC)
;
.                        3600000      NS    J.ROOT-SERVERS.NET.
J.ROOT-SERVERS.NET.      3600000      A     198.41.0.10
;
; housed in LINX, operated by RIPE NCC
;
.                        3600000      NS    K.ROOT-SERVERS.NET.
K.ROOT-SERVERS.NET.      3600000      A     193.0.14.129
;
; temporarily housed at ISI (IANA)
;
.                        3600000      NS    L.ROOT-SERVERS.NET.
L.ROOT-SERVERS.NET.      3600000      A     198.32.64.12
;
; housed in Japan, operated by WIDE
;
.                        3600000      NS    M.ROOT-SERVERS.NET.
M.ROOT-SERVERS.NET.      3600000      A     202.12.27.33
; End of File
```

This file can be pasted into `named.ca`. The servers specified in the `named.ca` file are each identified by two entries, one giving the root domain (the period) followed by the name server name; the other has the name server IP address. The time-to-live is set very large because these servers are expected to be always available.

The `named.boot` (or `named.conf`) file is used to trigger the loading of the DNS daemons and to specify the primary and secondary name servers on the network. A sample `named.boot` file looks like this:

```
; named.boot
directory     /usr/lib/named
primary    tpci.com     named.hosts
primary    25.143.in-addr.arpa     named.rev
primary    0.0.127.in-addr.arpa     named.local
cache   .     named.ca
```

The first line of the `named.boot` file has the keyword directory followed by the directory of the DNS configuration files. Each following line with the keyword *primary* tells DNS the files that it should use to find configuration information. The first line, for example, sets `named.hosts` as the file for locating the primary server of `tpci.com`. The IN-ADDR.ARPA information is kept in the file `named.rev` for the 143.25 subnet. The localhost information is in `named.local`, and finally the server and name cache information is in `named.ca`.

A secondary name server is configured only slightly differently than a primary server. The difference is in the `named.boot` file, which points back to the primary server.

Starting the DNS Daemons

The final step in the DNS configuration is to ensure the DNS daemon called `named` is loaded when the system boots. This is usually done through the `rc` startup scripts. Most versions of Unix and Linux have the routines for DNS startup already entered in the startup script, usually in the form of a check for the `named.boot` (or `named.conf`) file. If the `startup` file exists, the DNS daemon `named` starts. The code for checking the `named.boot` file usually looks like this:

```
# Run DNS server if named.boot exists
if [ -f /etc/inet/named.boot -a -x /usr/sbin/in.named ]
then
   /usr/sbin/in.named
fi
```

The exact directory paths and options may be different in your `rc` script, but the command should check for the `named.boot` file and start `named` if it exists.

Configuring a Client

Configuring a Unix or Linux machine to use a primary DNS server for resolution is a quick process. First, the `/etc/resolv.conf` file is modified to include the primary server's address. For example, a `resolv.conf` file may look like this:

```
domain tpci.com
nameserver   143.25.0.1
nameserver   143.25.0.2
```

The first line establishes the domain name, which is followed by the IP addresses of available name servers. You could also replace the domain directive with the more flexible search directive that allows you to specify more than one domain suffix as noted earlier. In this example, this file points to two name servers on the 143.25 subnet.

Windows and DNS

Windows NT, Windows 95, and Windows 98 can all act as clients of a DNS server by simply filling in the DNS server's IP addresses in the DNS tab of the Networking applet. Multiple DNS servers can be specified, and they are searched in the order shown in the DNS page tab. The DNS servers can be either inside your network or an ISP's DNS server leading out to the Internet. Of course, the ISP's server won't know the makeup of your internal network.

There is the ability to configure Windows to act as a DNS server using add-on applications, but in a Windows-only network, DNS is not as easy to configure and set up as WINS and DHCP. In a heterogeneous network of Windows and Unix machines, installing DNS on a Unix machine is much better, both because of performance reasons and also because of the architecture of the operating systems.

Note

In Windows 2000 Server, DNS is used for resolving Active Directory domain names and services. Windows 2000 uses Dynamic DNS but the manner in which it updates the service records is non-standard, leading to all kinds of "interesting" problems while you're trying to integrate Windows 2000 and Unix servers.

Summary

DNS is a little complicated to set up on a server but clients are much easier. Considering the benefits DNS bestows, it is usually well worth the time and energy required to install and configure it on a network. Unix and Linux are ideally suited to roles as DNS servers, whereas Windows machines work well as clients.

CHAPTER 41

TCP/IP Network Management

by Bernard McCargo

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When a network came from a single vendor, that vendor was responsible for its support. Thus it used to be that AT&T and the local telephone company took responsibility for the telecommunication lines, IBM managed the mainframe in the accounting department, and DEC managed the minicomputers in the engineering department. The network manager simply identified the malfunctioning system, and the appropriate vendor would solve the problem.

Today's internetworks are far more difficult to manage for three reasons:

- Centralized data processing has been replaced by distributed systems.
- The divestiture of AT&T in 1984 dramatically changed the way customers manage their telecommunication circuits. Today's internetwork manager must interface with the LEC (Local Exchange Carriers), IXC (Inter-Exchange Carriers), and other providers, such as Packet Switched Public Data Networks (PSPDN).
- The economic growth of the data communications industry has dramatically increased the number of vendors in the marketplace.

All of these developments increase the likelihood of finger-pointing between vendors.

Both vendors and standards bodies have proposed solutions to these challenges. The predominant standard, ISO 7498-4, defines five functional management areas:

- **Fault management**—Deals with detection, testing, and correction of network failures.
- **Accounting management**—Allocates network costs to the responsible party.
- **Configuration management**—Maintains the current status of all elements within the network.
- **Performance management**—Collects and logs statistical information regarding system performance.
- **Security management**—Protects network resources and controls access to the network.

Various standards bodies have developed protocols to support these standards. However, the most popular network management protocol is the *Simple Network Management Protocol* (SNMP), which was developed by the Internet (TCP/IP) community. Its popularity is largely due to its simplicity: The initial version of SNMP defines only five commands/responses. Thus, it makes network management as painless as possible by minimizing the amount of management data transmitted between network elements and the management console. Later versions added a few extra commands for making it easy for SNMP Management stations to collect information from other SNMP Management stations.

Finally, vendors in the data communications industry have developed network management systems that incorporate standard protocols, such as SNMP, into proprietary architectures. Major players in this market include AT&T (Unified Network Management Architecture—UNMA), DEC now part of Compaq, which may merge with Hewlett-Packard) (Management Control Center—DECmcc), Hewlett-Packard (OpenView Network Management), Bay Networks (Optivity), Cisco Systems (Cisco Works), and IBM (NetView). Look for growth in this area as internetwork complexity increases.

Note that this chapter discusses how to develop a network management plan and the tools needed to manage a network. Although this chapter discusses network management tools, the SNMP protocol is not discussed in detail. The formal definition of SNMP and its protocols are covered in Chapter 42 “SNMP: The Network Management Protocol.”

Developing a Plan for Network Monitoring

All of these factors—centralized versus distributed computing architectures, wideband transmission facilities, specialized workstations, multiple protocols, new methods for LAN/WAN connectivity, and dissimilar network management systems—can result in an interesting mixture. The internetwork may use a combination of cabling types, including twisted pair, coax, and fiber optics. The LAN hardware may include incompatible access methods, such as CSMA/CD (IEEE 802.3) and token passing (IEEE 802.5). Connectivity devices such as bridges may use different algorithms, such as spanning tree (IEEE 802.3) or source routing (IEEE 802.5). The electronic mail package from one network operating system may not communicate with one from its competitor. So how do you analyze the internetwork stew to ensure that your]network performs well?

You might start by defining what it means to have a network that “performs well.” The question could be answered in a number of ways. To end users, it probably means sub-second response time. To (non-systems) managers, it may mean adequate equipment at a low price. To administrators, it most certainly means a network that doesn’t require a lot of attention to keep running. To network engineers the answer lies between bandwidths, forwarding rates, latency, and the like.

In designing a well-performing network monitoring system, user expectations and organizational constraints must indeed be considered the starting point. The designer’s task is to negotiate a series of trade-offs to build a system that meets reasonable expectations. The expression “A chain is only as strong as its weakest link” certainly applies to networks. All components must be balanced for optimum performance.

Some of the issues directly affecting network performance that the designer must look at are network bandwidth, hardware capacity, and applications. These areas are key in the implementation of a network baseline. The network baseline is a healthy snapshot of the network, which can be used for comparative analysis when a problem occurs.

Investigating Network Problems and Network Troubleshooting

As internetworks continue to become distributed, offer higher bandwidths, and support more protocols, network managers must be prepared to adjust their network support departments and to purchase new analysis tools.

Distributed networks require companies to change the structure of centralized MIS departments. Individual locations need their own network management staff to handle user-related problems, while the headquarters location can be better equipped to analyze internetwork failures.

The development of high-bandwidth connectivity has reduced the economic life of existing network analysis and management equipment. When the typical WAN link was an analog circuit, for example, a network administrator suspecting a problem on that circuit would test it for compliance with analog transmission parameters, such as impulse noise, envelope delay distortion, and phase jitter. But today's digital circuits that constitute the high-bandwidth pipes require entirely different techniques to analyze completely different transmission parameters. For example, T1/T3 circuits must be tested for proper data framing and improperly generated signals, such as bipolar violations (BPVs), and special data encoding, such as B8ZS (bipolar with eight zero substitution). If the transmission medium is optical fiber, rather than twisted pairs or coaxial cable, the analyzer needs an optical rather than an electrical interface.

The following are some general guidelines that provide a framework to help you get started:

- **Define the problem.** You can't troubleshoot a problem that you can't clearly describe.
- **Develop a solution.** Proceed carefully and methodically to solve the problem.
- **Document your work.** You can learn from the past.
- **Disseminate the results.** Others can benefit from your experiences.

Network Management Tools

Network management tools are very complicated, and become more complicated as you increase the number of protocols that they must monitor. Multiprotocol internetworks will require more intelligent analyzers. Analyzers that once handled a single protocol suite, such as SNA, must now take care of several, such as SNA, DECnet, and TCP/IP. To understand this trend, you need a little background on how analyzers work and the direction in which they have been developing.

Using Protocol Analyzers

A protocol analyzer works as follows. The analyzer attaches to the internetwork in a passive mode and captures the information transmitted between various devices. This information can be divided into two categories:

- **Data**—The data comes from an end-user process, such as an electronic mail message.
- **Control**—The control information assures that the data transfer obeys the rules of the protocols.

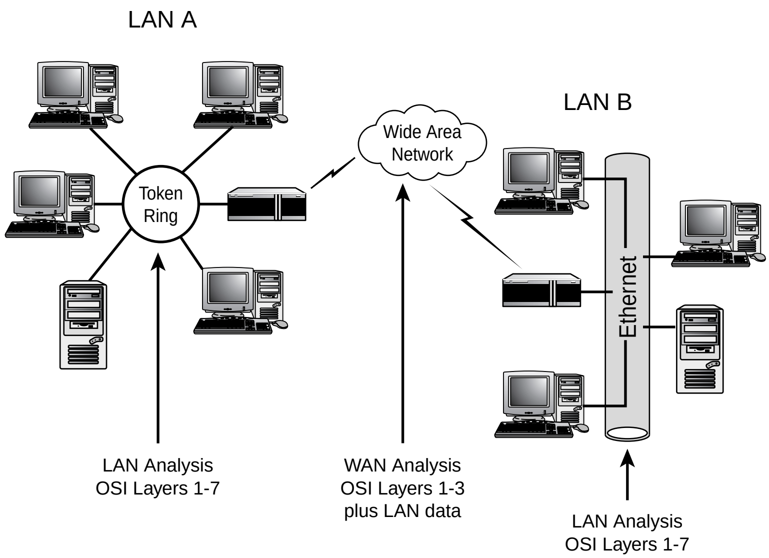
For this reason, the control information is often called *protocol control information* (PCI), and it is unique to each protocol. Thus, if seven protocols were associated with a particular internetwork function, there would be seven unique PCI elements. These elements, usually called *headers*, are transmitted along with the data inside the Data Link Layer frame. The data to be transmitted originates at the Application Layer, and is therefore called *Application Data* (AD). The *Application Header* (AH) is then appended to the data, and that combination (AH + AD) is passed to the next lowest layer (that is, the Presentation Layer). The Presentation Layer treats this information (AH + AD) as its data, and appends its own header (the *Presentation Header*, or PH). The result is PH + AH + AD. The process continues until the entire frame is constructed with the appropriate PCI from each layer.

The protocol analyzer's job is simply to unravel the PCI and display it in a user-understandable format. However, as discussed later in this chapter, the unraveling process has become quite complex.

The capabilities of protocol analyzers have been evolving over time. First-generation analyzers were actually datascopes that simply decoded a datastream and produced a hexadecimal display on the CRT. They had no user-friendly interface. The second generation added analysis capabilities up to OSI Layer 3. They could decode bit-oriented protocols, and users could program them to perform various tests, based upon their troubleshooting requirements. These tests, for instance, might restrict the data captured to the communication from one specific workstation or one particular protocol, such as the Internet Protocol (IP). Third-generation analyzers can decode and process protocols up to and including OSI Layer 7 and provide a user-friendly interface that facilitates programming and report generation.

Fourth-generation protocol analyzers are better suited for handling complex network topologies consisting of LANs, MANs, and WANs. Some of the fourth-generation protocol analyzers have some Artificial Intelligence capability to suggest the existence of a problem and its possible solution. MANs and WANs encompass OSI Layers 1–3, although higher layer information, such as signaling or network management data, may also be present. LANs cover OSI Layers 1–7 (see Figure 41.1). A MAN/WAN analyzer must be able to decode the PCI at the Physical, Data Link, and Network Layers. Thus, it will test the way the packets traverse the communications subnetwork (Layers 1–3), but it won't decode the information contained within those packets. It is the end users on LAN workstations that are interested in the information inside the packets. Workstations run a network operating system, such as Novell's NetWare or Windows NT/2000, that include protocols up to and including Layer 7.

FIGURE 41.1
LAN and WAN analysis.



To properly diagnose a problem between a workstation on LAN A and a server on LAN B connected by the WAN, a LAN analyzer must decode those higher layers.

The testing requirements of LANs and WANs also differ because of the types of failures that typically occur. LAN failures tend to be repetitive, whereas WAN breakdowns may be one-time events. A final difference is the way the analyzer is physically attached to the LAN, MAN, or WAN. MAN/WAN analyzers are usually used in equipment rooms or central offices where space is limited. (For that reason, they are often designed for both vertical and horizontal use.) LAN analyzers are typically used on a desktop.

Expert Systems

In order to maintain good performance on complex internetworks, network analyzers must become increasingly intelligent. All analyzers contain quite a bit of embedded knowledge of interface characteristics, protocols, interactions between protocols, and so on. They use these to provide help screens, invoke test sequences, or extract protocol information on one port and use it with information extracted from another. But the smartest protocol analyzers (such as the fourth-generation protocol analyzers) are those that use expert systems.

True expert systems are able to use a set of rules, combined with their knowledge of the network and its operation, to diagnose and solve network problems. The expert system's knowledge comes from a variety of sources, including a theoretical database (for example, the IEEE standards by which the network should operate); a network-specific database (topological information regarding the network nodes); and the user's previous results and experiences. All the information then generates a hypothesis about the cause of the problem and a plan of action to resolve it. For example, an Ethernet with an abnormally high rate of collisions would infer further tests of the backbone cable and terminators, and eventually arrive at a conclusion.

Hewlett-Packard's LAN Analyzers meet the criteria of an expert system. Network General has an expert system known as the Expert Sniffer, which automatically identifies problems in real-time and suggests solutions based upon a combination of expert technologies. Other LAN vendors with plans for expert systems include Bytex and Wandel & Goltermann.

H-P's expert is named the Fault Finder. The user or the analyzer furnishes Fault Finder with a fault symptom and the analyzer develops a hypothesis based upon current network conditions and/or analyzer-generated tests. This process continues until the analyzer reaches a conclusion. If the process is inconclusive, the analyzer gives the user a list of potential problems and network symptoms to use in further troubleshooting. Because the expert system automates the hypothesis/testing cycle, it should minimize network downtime.

Because of the complex nature of WAN protocols, such as ISDN and Signaling System 7-SS7, third-generation WAN analyzers offer very powerful analysis features. For example, third-generation analyzers perform statistical analyses of the incoming datastream. A summary of these statistics at either the frame (OSI Layer 2) or packet (OSI Layer 3) level offers a quick diagnosis of the health of the WAN link; a low number of frames with CRC errors or few reject packets indicates a healthy link. Should errors occur, WAN protocol analyzers can help identify the cause by selectively examining the information on that high-speed link through a process known as *filtering*. For example, if only one workstation was experiencing a problem, the analyst could set a filter to capture only the data from that workstation.

PC-Based Analyzers

Intel Pentium microprocessors have brought the minicomputer power of the 1980s to the modern desktop. With their heavy-duty processing power, these lightweight units are ideal platforms upon which to build test equipment. The portability of laptop computers allows you to carry the analyzer to a remote site. The standardized bus (ISA, EISA, Micro Channel, or PCI) also allows you to easily add other devices, such as modems, for remote access. As a result, many of the analyzer manufacturers have chosen the PC as their hardware platform. The LAN analyzer manufacturers have traditionally supported PC-based systems because of their similarity to a network workstation. WAN analyzers are now basing their products on PCs as well.

When examining analyzers built on the PC platform, you need to ask two questions: How does the manufacturer define "PC-compatible," and how do you implement those capabilities? First, there's a difference between using a PC as the analyzer platform, and having PC capabilities built in to the analyzer itself. A number of vendors, including CXR/Digilog and ProTools, based their instrument on a laptop, luggable, or desktop computer. Cabletron Systems has an analyzer based on the Apple Macintosh. As a result, you can use these devices for other applications, such as word processing or spreadsheets, when you're not using them for network analysis. Other vendors, such as Wandel & Goltermann, use multiple processors: one for PC applications and another for network analysis. A third alternative, software supported by GN Navtel, allows any PC to analyze data captured by the analyzer. Other products allow you to use standard DOS disk drives for data storage, or an external output to a CRT or printer. Thus, you need to find out what a vendor means when you see the specification "PC-based."

The second issue is implementation: How do you turn your PC into an analyzer? You have three choices here as well. FTP Software's LAN analyzer is a standalone software product that you install on your own PC equipped with a LAN interface card. FTP offers versions of the software for various interface cards, such as 3Com Etherlink, Proteon ProNET, and so on. A second option is to purchase a combination hardware/software package and install it in a PC. WAN analyzers from Frederick Engineering and Progressive Computing use this approach. The third alternative, a complete turnkey system, is available from a number of LAN and WAN analyzer vendors, including CXR/Digilog Inc., Hewlett-Packard Company, Network General Corporation, and TTC/LP COM. Turnkey products provide better support because just one vendor is responsible for the system.

Alternatively, you can obtain protocol analyzers and their source code for free. One such example of a high-quality protocol analyzer that has been ported to Unix and Windows environments is Ethereal. For more information on this free protocol analyzer, consult `www.ethereal.com`.

Network Management Protocol Support

Volumes have been written about the need for network management standards to assist in the centralized management of complex internetworks. Two network management protocols that have been considered for this task are SNMP and CMIP. SNMP, is used widely within the TCP/IP community; and the OSI network management protocol, known as *Common Management Information Protocol* (CMIP). SNMP is the predominant standard. Although there is some support for CMIP—Tekelec supports CMIP for WANs, and AR/Telenex supports IBM's NetView, CMIP implementations are largely extinct these days.

SNMP's ability to decode network management protocols serves several purposes. Developers of SNMP Agents or Managers can test their code for accuracy by capturing the Agent-Manager information. The analyzer can also determine response time delays between an Agent report and an associated Manager response. Because management data consumes network bandwidth, the analyzer can also measure the percentage of network management information versus user traffic on the network.

SNMP can be decoded by Micro Technology, Novell for LANs, Kamputech, Wandel & Goltermann, and Network General for LAN/WANs.

Novell initially incorporated SNMP into a network probe called LANtern. LANtern attached to an Ethernet/IEEE 802.3 network, and uses SNMP to communicate with an SNMP-compliant network management console. The network itself provided the communication path between probe and console, and the probe is the SNMP agent. Because LANtern was an Ethernet network monitor, not a protocol analyzer, it collected network statistics such as collisions, CRC errors, and frame errors, but performs no frame decoding. Experience with LANtern, enabled Novell to contribute to the development of the RMON (Remote Monitoring) MIBs and RMON device standards.

Another LAN analyzer vendor, FTP Software, offers an interesting product, known as SNMP Tools, which is based on FTP's well-known product PC/TCP. SNMP Tools runs on any DOS PC and is supported by a large number of LAN interface cards. It also offers a development kit for custom SNMP applications.

Integration with Network Simulation/Modeling Tools

When networks were host-centric or confined to a single location, it was much easier to calculate delay and response time parameters and forecast network growth. The wide distribution of network resources has made predicting these network performance metrics more difficult. Performing an analysis of the current internetwork can help with these predictions.

Analyzers have always done an amazing job of collecting reams of data. But what do you do with all that information? Early analyzers provided a hardcopy ASCII output of the captured data. Later analyzers could convert the data into a spreadsheet or database file format for further analysis. For example, the spreadsheet could sort traffic on a LAN by source address and bill the appropriate department for network usage.

Most products in the LAN market today integrate the LAN analyzer with a LAN simulation or modeling software tool such as BONeS (ComDisco Systems, Inc., Foster City, CA) or LANSIM (InternetiX, Inc., Upper Marlboro, MD). Quintessential Solutions, Inc. (San Diego, CA), a developer of WAN simulation and modeling tools, offers products with the ability to input data from WAN analyzers. A typical application is modeling the response time of a polled SNA circuit. Given the actual polling or response time delays from the analyzer, the QSI software can predict the changes in these variables resulting from increases in traffic, adding applications, and so on.

Simulation/modeling software is useful for a number of purposes, including initial network design, reconfiguration or redesign, and stress testing. Numerous variables (which exceed 100, depending on the network under study) specifying the number and type of workstations, servers, protocols in use, traffic loads, and so on must be entered into the model. The value of these variables can change the outcome of the simulation significantly. For example, network response time is a function of the number of servers plus the number of users logically attached to each one. If response time degrades, the administrator might consider redistributing the users or adding servers. Rather than making an educated guess about the network's traffic measurements, using actual data from the analyzer allows the simulation to provide a much more accurate representation of the network's characteristics. This facilitates the interactive process of network design, growth, and redesign.

Bytex, Network General, and Spider Systems are among the LAN analyzer vendors that can export their data to one of the simulation/modeling tools mentioned. In the future, simulation/modeling software will be directly incorporated into LAN analyzers.

Setting Up SNMP

SNMP enables network administrators to remotely troubleshoot and monitor hubs, routers, and other devices. Using SNMP, you can find out information about remote devices without having to be physically present at the device itself.

SNMP can be a useful tool if understood and used properly. You can obtain various amounts of information on a wide variety of devices, depending on the type. Some examples of information accessible using SNMP include the following:

- The IP address of a router
- The number of open files
- The amount of hard drive space available
- The version number of the software running on the host

SNMP uses a distributed architecture design to facilitate its properties. This means that various parts of SNMP are spread throughout the network to complete the task of collecting and processing data to provide remote management.

Because SNMP is a distributed system, you can spread out the management of it in different locations so as not to overtax any one system, and for multiple management functionality.

The SNMP provided by Microsoft enables a machine running Windows NT/2000 to transfer its current condition to a computer running an SNMP management system. However, this is only the agent side, not the management tools.

Other management utilities are available that are not included in Windows NT/2000, including the following:

- IBM NetView
- Sun Net Manager
- Hewlett-Packard OpenView

Configuring SNMP on Windows

The SNMP service can be installed for the following reasons:

- You want to monitor TCP/IP with Performance Monitor.
- You want to monitor a Windows NT/2000–based system with a third-party application.

The following steps for installing the SNMP service assume that you already have TCP/IP installed and set up, and that you have administrative privileges to install and use SNMP.

Installing the SNMP Service

To install the SNMP service, follow these steps:

1. Open the Network dialog box and from the Services tab, click Add. The Select Network Service dialog box appears.
2. Choose the SNMP service and click OK.
3. Specify the location of the Microsoft Windows NY distribution files.
4. After the files are copied, the Microsoft SNMP Properties dialog box appears. Enter the Community Name and Trap Destination.
5. Click OK to close the SNMP Properties dialog box, and then click Close to exit the Network dialog box. When prompted, click Yes to restart your computer.

Installing the Protocol

The first step in working with SNMP is to install the protocol. The following is a step-by-step process to walk you through the installation of the protocol:

1. Open the Network dialog box, and click the Services tab.
2. Choose Add, select the SNMP Agent, click OK, and enter the source directory.
3. Choose Close on the Network Setting dialog box and restart your system when prompted.

Using SNMPUTIL to Test SNMP

In order to perform this test, you will need a copy of the SNMPUTIL, which can be found in the Windows NT Resource Kit. If you do not have the Resource Kit, you can also find SNMPUTIL on the Internet (however, the Windows NT/2000 Resource Kit is recommended).

You will want to increase the number of lines in the command prompt to support this test. To do this, click the Control Menu box in the upper-left corner of the window and select Properties. On the Layout tab, change the height value to a higher number, such as 300.

Then, follow these steps:

1. Start a command prompt.
2. Enter the following commands:

```
SNMPUTIL get 127.0.0.1 public
.1.3.6.1.4.1.77.1.2.2.0
SNMPUTIL get 127.0.0.1 public
.1.3.6.1.4.1.77.1.2.24.0
```

3. Verify the numbers that you received. To verify the first number, click the Services icon in the Control Panel and count the number of services that are started. (Or type **NET START** from the prompt and count the services listed.)
4. To verify the second number, open the User Manager for Domains and count the number of users.
5. In User Manager for Domains, add a test user. Switch to the command prompt, and enter the second SNMPUTIL command again (use the up arrow to repeat the command).
6. Verify that the user you added increased the number, and then enter the following command:

```
SNMPUTIL walk 127.0.0.1 public
.1.3.6.1.4.1.77.1.2.25
```

   This should list the names of all users.
7. Click the Services icon from the Control Panel again. Stop the Server service. It will warn you that this will also stop the Computer Browser service; this is fine.
8. Re-enter the command:

```
SNMPUTIL get 127.0.0.1 public
.1.3.6.1.4.1.77.1.2.2
```

9. Verify that the services are not running, and then enter the following command:

```
SNMPUTIL walk 127.0.0.1 public
.1.3.6.1.4.1.77.1.2.3.1.1
```

   The services that are running will be listed. Server and Computer Browser should not be included on the list.

Note

You are still able to access this information using the sockets interface even though the server service is stopped. Remember that the server service is a NetBIOS server. Because you are communicating over sockets directly, you are able to use the SNMP agent, which uses UDP port 161 directly.

10. Restart the server service and the Computer Browser service.
11. Enter the following optional command if you want a list of all the information in the LAN Manager MIB:

```
SNMPUTIL walk 127.0.0.1 public
.1.3.6.1.4.1.77
```

Configuring SNMP on Unix

Under Unix, protocol statements enable and disable protocols and set protocol options. There are protocol statements for SNMP, RIP, Hello, ICMP Redirect, EGP, and BGP. The structure of these statements falls into two categories: one structure for interior protocols and one for exterior protocols. SNMP is the only exception to this. The format of the `snmp` statement is

```
snmp yes | no | on | off
```

This command controls whether `gated` registers information with the SNMP daemon. SNMP is not a routing protocol and is not started by this command. You must run SNMP software independently. This statement only controls whether `gated` keeps the management software apprised of its status. Reporting is enabled by specifying `yes` or `on` (it doesn't matter which you use) and it is disabled with `no` or `off`.

SNMP Security Parameters

You can set several options that affect the security of the SNMP agent. By default, the agent will respond to any manager using the community name "public." Because this can be inside or outside your organization, you should at the very least change the community name.

The following sections cover available security options.

Send Authentication Trap

The Send Authentication Trap ends a trap to the configured management station if an attempt is made to access SNMP from a manager that is not from the same community or that is not on the Only Accept SNMP Packets From list.

Accepted Community Names

Accepted community names is a list of community names that the agent will respond to. When a manager sends a query, a community name is included.

Accept SNMP Packets from Any Host

Accept SNMP Packets from Any Host responds to any query from any management system in any community.

Only Accept SNMP Packets from These Hosts

Only Accept SNMP Packets from These Hosts responds to only the hosts listed so that you can only monitor the specified hosts and ignore data from other hosts.

SNMP Agents and Management

The two main parts to SNMP are the management station and the agent:

- The *management station* is the centralized location from which you can manage SNMP.
- The *agent* resides in the piece of equipment from which you are trying to extract data.

Each of these parts is discussed in the following sections.

The SNMP Management System

The management system is the key component for obtaining information from the client; you need at least one to even be able to use the SNMP service. The management system is responsible for asking the questions. As mentioned earlier, there are a certain number of questions it can ask each device, depending upon the type of device. The management system is a computer running one of the various software packages mentioned earlier (see Figure 41.2).

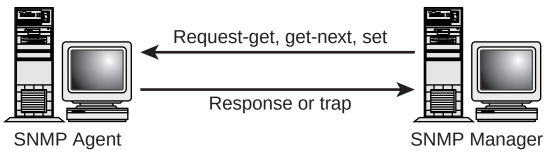


FIGURE 41.2
Most of the communications between an agent and a management station are started from the management station.

There are also certain commands that can be given specifically at the management system. These generic commands are not directly specific to any type of management system:

- `get`—Requires a specific value. For example, it can query how many active sessions are open.

- `get-next`—Requests the next object's value. For example, you can query a client's ARP cache and then ask for each subsequent value.
- `set`—Changes the value on an object that has the properties of read-write. This command is not often used because of security considerations and the fact that the majority of objects have a read-only attribute.

Usually, you have only one management system running the SNMP service per group of hosts. This group is known as a community. Sometimes, however, you may want to have more. Following are some reasons for wanting more than one management station:

- You may want to have multiple management systems monitoring different parts of the same agents.
- There might be different management sites for one community.
- As the network grows and becomes more complex, you may need to help differentiate certain aspects of your community.

SNMP Agents on Windows

You have seen what the SNMP management side is responsible for and can specifically do. For the most part, the management side is the active component for getting information.

The SNMP agent, on the other hand, is responsible for complying with the requests and responding to the SNMP manager accordingly. Generally, the agent is a router, server, or hub. The agent is usually a passive component responding only to a direct query.

In one particular instance, however, the agent is the initiator, acting on its own without a direct query. This special instance involves a *trap*. A trap is set up from the management side on the agent; however, the management system does not need to go to the agent to find out whether the trap information has been tripped. The agent sends an alert to the management system telling it that the event has occurred.

In some cases you will configure other aspects of the SNMP agent. These settings set the type of devices that you will monitor and who is responsible for the system.

The options available are as follows:

- **Contact**—This is the contact name of the person you want alerted about conditions on this station—generally the user of the computer.
- **Location**—This is a descriptive field for the computer to help keep track of the system sending the alert.

- **Service**—The items in this box identify the types of connections and devices this agent will monitor. These include the following:
  - **Physical.** This should be used if this system is managing physical devices such as repeaters or hubs.
  - **Applications.** Set this if the Windows NT/2000 computer uses an application that uses TCP/IP. This should always be selected.
  - **Datalink/Subnetwork.** Selecting this indicates this system is managing a bridge.
  - **Internet.** This should be selected if the Windows NT computer acts as an IP router.
  - **End-to-End.** Set this if the Windows NT/2000 computer uses TCP/IP. Obviously, this should always be selected.

Any errors with SNMP will be recorded in the system log, which records any SNMP activity. Use Event Viewer to look at the errors and to find the problem and possible solutions.

SNMP Tools and Commands

Now that you've learned a little about the management system and agents, you can delve into the different databases that you can query with SNMP commands.

The data that the management system requests from an agent is contained in a *Management Information Base* (MIB). This is a list of values the management system can ask for. (The list of values depends on what type of device it is asking.) The MIB is the database of information that can be queried against.

A variety of MIB databases can be established. The MIB is stored on the SNMP agent and is similar to the Windows Registry in its hierarchical structure. These MIBs are available to both the agents and management system as a reference from which both can pull information.

The SNMP service is an additional component of Windows NT/2000 TCP/IP software. It includes the four supported MIBs; each is a dynamic-link library and can be loaded and unloaded as needed. It provides SNMP agent services to any TCP/IP host running SNMP management software. It also performs the following:

- Reports special happenings, such as traps, to multiple hosts.
- Responds to requests for information from multiple hosts.

- Sets up counters in Performance Monitor that can be used to monitor the TCP/IP performance.
- Uses hostnames and IP addresses to recognize which hosts it receives and requests information.

The SNMP utility does not come with Windows NT/2000, but it is included in Unix and does come with the Windows NT/2000 Resource Kit. Basically, it is a command-line management system utility. It checks that the SNMP service has been set up and is working correctly; you can also use it to make command calls. You cannot do full SNMP management from this utility; but, as you will see, you would not want to because of its complex syntax.

The following is the general syntax structure of the SNMP utility:

```
snmputil command agent community object_identifier_(OID)
```

The following are the commands you can use:

- `WALK`—Moves through the MIB branch identified by what you have placed in the `object_identifier`.
- `GET`—Returns the value of the item specified by the `object_identifier`.
- `GETNEXT`—Returns the value of the next object after the one specified by the `get` command.

To find out the time the WINS server service began, for example, (provided WINS is installed and the SNMP agent is running) query the WINS MIB with the following command:

```
C:\>snmputil getnext localhost public
.1.3.6.1.4.1.311.1.1.1.1
```

In this example, the first part refers to the Microsoft branch: .1.3.6.1.4.1.311 (or `iso.org.dod.internet.private.enterprise.microsoft`). The last part of the example refers to the specific MIB and object you are querying: .1.1.1.1 (or `.software.Wins.Par.ParWinsStartTime`). A returned value may look like the following:

```
Value = OCTET STRING ñ 01:17:22 on 11:23:1997.<0xa>
```

RMON and Related MIB Modules

The objects and events for RMON are contained in five MIB modules (see Table 41.1).

TABLE 41.1 RFCs Relating to RMON

MIB Module	*Description*
RMON-MIB	RFC 1757: Remote Network Monitoring Management Information Base (called RMON1; defines 203 objects and 2 events)
TOKEN-RING-RMON-MIB	RFC 1513: Token Ring Extensions to the Remote Network Monitoring MIB (called Token Ring extensions for RMON1; defines 181 objects)
RMON2-MIB	RFC 2021: Remote Network Monitoring Management Information Base Version 2 (called RMON2, but also includes extensions for RMON1; defines 268 objects)
HC-RMON-MIB	Internet-draft: Remote Network Monitoring Management Information Base for High Capacity Networks (called HC-RMON, and contains extensions for RMON1 and RMON2; defines 184 objects)
SMON-MIB	Internet-draft: Remote Network Monitoring MIB Extensions for Switched Networks (called SMON or SWITCH-RMON; defines 52 objects)

In all, almost 900 objects are defined in the RMON MIB modules. This is a large number. For example, only 56 objects are in the MIB module for transparent bridges, and only 110 objects in the MIB module for Ethernet repeaters. In addition to the RMON MIB modules, the document *Remote Network Monitoring MIB Protocol Identifiers* (RFC 2074) contains the definition of the specification language for protocol identifiers and the first version of a list of protocols. Please note that to apply RMON in your network you do not need to understand all of these objects.

Building Requirements

Following is a list of steps to take to develop a requirement matrix associated with the management of network components and functions.

Develop a Detailed List of Information

First, you'll want to develop a list of information attainable from each managed object. Describe in detail each piece of information, such as what the data element is, average versus actual, counter, raw integer, or a text message.

Present List to Support Organization

Take the list to the support organization responsible for that device function and have them decide what's pertinent to their way of doing business. Focus on information that will enhance their ability to accomplish their job in an easier manner.

Formulate Your Reporting Strategy

Formulate the reporting strategy for the device.

Determine Information Needed for Alarm Reporting (Realtime)

The following elements of information are pertinent to alarm reporting:

- Establish thresholds; for example, three counts in a one-hour time period.
- Establish the priority of the alarm and any thresholds associated with priority escalation of the alarm.
- Establish any diagnostic processes that could be run automatically or that the Help Desk could perform to make their job easier.
- Establish acceptable polling intervals (every five minutes, ten minutes, one hour, and so on).

Determine Information Needed for Monthly Reporting

The following elements of information are pertinent to monthly reporting:

- Availability of devices and services
- Usage and load

Determine Information Needed for Performance Tuning

What elements of information are pertinent to trending and performance tuning of network components and functions?

Look at ways to combine data elements or perform calculations on the data to make it more useful to the support organization.

Interview Management

Interview management to ensure the Network Management System is managing all areas pertinent to the business unit. This interview processes ensures that the solution that you are proposing will meet the organization needs.

As part of interacting with the organization management, you should keep in mind the following:

- Explain the role and objectives of the Network Management System.
- Increase productivity throughout the support organizations.
- Reduce the Mean Time to Repair times on the correction of problems.
- Provide a proactive approach to the detection and isolation of problems.
- Enable collaboration and the flow of information across support departments and sites.

Here is a checklist that will help you gather management requirements:

- Gather the requirements for the management of any function important to the business unit.
- Don't limit these functions to only SNMP-manageable devices.
- If the devices associated with a function have no intelligence whatsoever, go back to management later with a proposal to upgrade the devices.

Implement the Requirements

Implement the requirements. Focus each implementation toward each requirement while integrating the total system. The specific techniques for accomplishing this are discussed in the following sections.

Alert Support Organization to Monitoring

After implementation of each piece, notify the support organization associated with the managed object or system that monitoring has started.

Revisit Requirements

To ensure that the initial requirements are still valid during the life cycle of a network, you should revisit the requirements periodically. The following is a list of things to consider when revisiting requirements:

- At the first reporting period, go back and revisit the requirements with each support organization and management.

- Reestablish requirements if necessary.
- Be advised that the reports and types of data will change as each support organization becomes better informed.

Keep the Help Desk Informed

During implementation, focus the alarm messages toward the Help Desk. Its personnel are the front line of any MIS organization. Keeping them well informed of problems is paramount to the successful deployment of the Network Management System.

Test Alarms

Perform dry runs of alarms and the diagnostic steps associated with getting the problem on the road to resolution in a quick and efficient manner. Have the appropriate support organizations participate so that all diagnostic steps can be identified and included. Don't leave out any management notifications that may be necessary.

Train the Help Desk to Troubleshoot

Train the Help Desk to input troubleshooting procedures pertinent to their function into the diagnostics table. This can include anything from a user calling in with a problem with an application (for example, MS Word), to filling out forms for a specific service to be provided to an end user.

Document Diagnostic Procedures

The skills associated with the support organizations in one Management Functional Domain (MFD) may be different from another MFD. The gathering of diagnostic procedures allows a sharing of the wealth of knowledge across the enterprise. The diagnostics procedures are a knowledge base of information, by symptom, of problems and tasking and what needs to be accomplished to correct the problem. Having the skills of Desktop Support, Unix System Support, Network Support, and so on at the fingertips of Help Desk personnel increases their ability to logically react to problems as they occur. The Network Management System, as a total integrated system, must be modular and easy to expand and contract as the needs of the business change.

Simplify Element Management Systems (EMSs)

Element Management Systems, whether they are third-party products such as SunNet Manager, HP OpenView, NetView 6000, NetView, NetMaster, 3M TOPAZ, Larsecom's Integra-T, or in-house developed pollers, need to be easy to integrate into the whole system. Recognize that in the architecture, no EMS is really aware of another. Awareness across EMS's needs to be accomplished at a higher layer so that the EMS's can focus on their area of management within their MFD.

Relying on Artificial Intelligence

Functions such as Alarm Correlation, Diagnostics across EMS's, and so on can be accomplished using artificial intelligence principles within a relational database. Almost all manner of Manager products employ risk assessment of how likely a component is to break. The risk assessment is often done by an expert systems component. The inclusion of the expert system component drives up the cost because of the complexity of software. These types of decisions need to be accomplished through the support organizations within the MFD because these folks know the local environment better than any machine or personnel at another site. Doesn't the overall application serve its purpose better if it is more tightly integrated into the business units?

Expert systems still need to be applied, but at a much different level. Network General Distributed Sniffer Servers are an excellent application of expert systems technology. By analyzing the relationships of protocols, traffic, connections, and LAN control mechanisms, the DSS uses expert systems to sort out problems at a very low level before they become user-identifiable problems and cause degradation or downtime.

Additionally, artificial intelligence can be used to capture the heuristics of network behavior and help with the diagnostics. The information available from past alarms of similar problems associated with what was accomplished to isolate and correct the problem needs to be incorporated into the overall system.

Summary

This chapter has covered Simple Network Management Protocol as it relates to Network Management. As you have seen, SNMP is a very simple protocol that can be used to look at the information stored in a Management Information B2zase. This allows management software (such as HP's OpenView) to read information from a Windows NT/2000 or Unix system.

If you intend to use SNMP, you must purchase SNMP management software. SNMP can be installed whether you are using it directly or not; this is done to allow the Performance Monitor counters to function correctly when using Windows NT/2000.

The following list summarizes the key points in this chapter:

- You need to understand that the SNMP agent is only an agent, and only an SNMP Manager API (no software) is provided.
- You need to know the three commands that a manager can send an agent: `set`, `get`, and `get-next`.
- You need to know what a trap (event notification) is, and that this is sent from the agent.
- You need to know the five areas the agent can monitor and where each is used: physical, applications, datalink/subnetwork, Internet, and end-to-end.
- You need to know how to install the agent.
- You need to know how to configure an authentication trap.
- You need to know how to configure the community names and the addresses of the stations that will be acting as managers.
- You need to understand the structure of an MIB and which four MIBs come with Windows NT/2000: LAN Manager MIB II, Internet MIB II, DHCP MIB, and WINS MIB.
- You need to know that the SNMP agent must be installed to enable the Performance Monitor counters.

Many excellent products are available today that provide capabilities to manage not just hardware, but services and applications. The ways that these systems are implemented are also critical in that each management capability installed must match a business need for such a system. Additionally, these diverse systems must be integrated together and into the support organizations to achieve maximum effectiveness.

CHAPTER 42

SNMP: The Network Management Protocol

by Tim Parker

In This Chapter

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The previous chapter discusses network management issues and the network management tools. This chapter presents a more detailed look at the *Simple Network Management Protocol* (SNMP), which is used to administer network devices and obtain information about peripherals. SNMP is used on many TCP/IP networks, especially larger ones, because it makes administration much easier. SNMP was also designed to enable intelligent peripherals to send messages about their own states to special SNMP server software, relaying details about error conditions or other problems that may occur. A network administrator can use SNMP to reconfigure and obtain statistics about any node on the network that is capable of dealing with SNMP, all from one location.

What Is SNMP?

The Simple Network Management Protocol was originally designed to provide a means of handling routers on a network. SNMP, although it is part of the TCP/IP family of protocols, is not dependent on IP. SNMP was designed to be protocol-independent (so it could run under IPX from Novell's SPX/IPX just as easily, for example), although the majority of SNMP installations use IP.

SNMP actually has three components, which are

- **Management Information Base (MIB):** A database containing status information
- **Structure and Identification of Management Information (SMI):** A specification that defines the entries in an MIB
- **Simple Network Management Protocol (SNMP):** The method of communicating between managed devices and servers

Peripherals that have SNMP capabilities built-in run a management agent, either loaded as part of a boot cycle or embedded in firmware in the device. These devices with SNMP agents are called by a variety of terms depending on the vendor, but they are known as SNMP-manageable or SNMP-managed devices. SNMP-compliant devices also have the code for SNMP incorporated into their software or firmware. When SNMP exists on a device, it is called a *managed device*.

SNMP-managed devices communicate with SNMP server software located somewhere on the network. The two ways the device talks to the server are *polling* and *interruption*. A polled device has the server communicate with the device, asking for its current condition or statistics. The polling is often done at regular intervals, with the server connecting to all the managed devices on the network. The problem with polling is that information is not always current, and network traffic rises with the number of managed devices and frequency of polling.

An interrupt-based SNMP system has the managed device send messages to the server when some conditions warrant it. This way, the server knows of any problems immediately—unless the device crashes, in which case notification must be from another device that tried to connect to the crashed device. Interrupt-based devices have their own problems, too. Primary among the problems is the need to assemble a message to the server, which can require a lot of CPU cycles, all of which are taken away from the device's normal task. This can cause bottlenecks and other problems on that device. If the message to be sent is large, as it would be if it contains a lot of statistics, the network can suffer a noticeable degradation while the message is assembled and transmitted.

If a major failure occurs somewhere on the network, such as a power grid going down and uninterruptible power supplies kicking in, each SNMP-managed device may try to send interrupt-driven messages to the server at the same time to report the problem. This can swamp the network and result in incorrect information at the server.

A combination of polling and interruption is often used to get by all these problems. The combination, called *trap-directed polling*, involves the server polling for statistics at intervals or when directed by the system administrator or on receiving an SNMP trap message. In addition, each SNMP-managed device can generate an interrupt message when certain conditions occur, but these tend to be more rigorously defined than in a pure interrupt-driven system. For example, if you use interrupt-only SNMP, a router may report load increases every 10 percent. If you use trap-directed polling, you will know the load from the regular polling and can instruct the router to send an interrupt only when a significant increase in load is experienced. After receiving an interrupt message with trap-directed polling, the server can further query the device for more details, if necessary.

An SNMP server software package can communicate with the SNMP agents and transfer or request a number of different types of information. Usually, the server will request statistics from the agent, including number of packets handled, status of the device, special conditions associated with the device type (such as out-of-paper indications or loss of connection from a modem), and processor load.

The server can send instructions to the agent to modify entries in its database (the Management Information Base). The server can also send thresholds or conditions under which the SNMP agent should generate an interrupt message to the server, such as when CPU load reaches 90 percent.

Communications between the server and agent are accomplished in a fairly straightforward manner, although they use the ASN.1 (Abstract Syntax Notation Rev 1) for message contents. For example, the server might send a "What is your current load" message and receive back a "75%" message. The agent never sends data to the server unless an interrupt is generated or a poll request is made. This means that some long-standing problems can exist without the SNMP server knowing about them, simply because a poll wasn't conducted or an interrupt generated.

Management Information Base

Every SNMP-managed device maintains a database that contains statistics and other data. This database is called a Management Information Base, or MIB. The MIB entries have four pieces of information in them: an object type, a syntax, an Access field, and a Status field. MIB entries are usually standardized by the protocols and follow strict formatting rules defined by *Abstract Syntax Notation One* (ASN.1).

The object type is the name of the particular entry, usually as a simple name. The syntax is the value type, such as a string or integer. Not all entries in an MIB will have a value. The Access field is used to define the level of access to the entry, normally defined by the values read-only, read/write, write-only, and not accessible. The Status field contains an indication of whether the entry in the MIB is mandatory (which means the managed device must implement the entry), optional (the managed device may implement the entry), deprecated (on its way out to being obsolete), or obsolete (not used).

Two types of MIB are in use, called MIB-1 and MIB-2. The structures are different. MIB-1 was used starting in 1988 and has 114 entries in the table, divided into groups. For a managed device to claim to be MIB-1–compatible, it must handle all the groups that are applicable to it. For example, a managed printer doesn't have to implement all the entries that deal with the *Exterior Gateway Protocol* (EGP), which is usually implemented only by routers and similar devices. Instead, to be MIB-1–compatible, it needs to address only those issues a printer has to deal with.

MIB-2 is a 1990 enhancement of MIB-1, made up of 171 entries in 10 groups. The additions expand on some of the basic group entries in MIB-1 and add three new groups. As with MIB-1, an SNMP device that claims to be MIB-2–compliant must implement all those groups applicable to that type of device. You will find many devices that are MIB-1–compliant but not MIB-2–compliant.

In addition to MIB-1 and MIB-2, several experimental MIBs are in use that add different groups and entries to the database. None of these have been widely adopted, although some show promise. Some MIBs have also been developed by individual corporations for their own use, and some vendors offer compatibility with these MIBs. For example, Hewlett-Packard developed an MIB for its own use that some SNMP-managed devices and software server packages support.

Using SNMP

The Simple Network Management Protocol itself has been through several iterations. Usually SNMP is used as an asynchronous client/server application, meaning that either the managed device or the SNMP server software can generate a message to the other and wait for a reply, if one is expected. These are packaged and handled by the network software (such as IP) as would be any other packet. SNMP uses UDP as a message transport protocol. UDP port 161 is used for all messages except traps, which arrive on UDP port 162. Agents receive their messages from the manager through the agent's UDP port 161.

The first major release of SNMP, SNMP v1, was designed for relatively simple operation, relatively easy implementation by device manufacturers, and good portability to operating systems. SNMP v1 supports only five kinds of operations between server and agent:

- `get`—Used to retrieve a single entry in the MIB
- `get-next`—Used to move through the MIB entries
- `get-response`—The response to a `get`
- `set`—Used to change MIB entries
- `trap`—Used to report interrupt conditions

When a request is sent, some of the fields in the SNMP entry will be left blank. These are filled in by the client and returned. This is an efficient method of transferring the question and answer in one block, eliminating complex look-up algorithms to find out what query a received answer applies to.

The `get` command, for example, is sent with the Type and Value fields in the message set to `NULL`. The client sends back a similar message with these two fields filled in (unless they don't apply, in which case a different error message is returned).

SNMPs v2 added new capabilities to the older SNMP version. One such capability that is useful for servers was the new `get-bulk` operation, with which a large number of MIB entries can be sent in one message. (SNMP v1 required multiple `get-next` queries.) In addition, SNMP v2 has much better security than SNMP v1, keeping unwanted intruders from monitoring the state or condition of managed devices. Both encryption and authentication are supported by SNMPv2. Of course, SNMPv2 was a more complex protocol and is not as widely used as SNMP v1. Because of political problems in the development of SNMP v2, SNMP v2 was never widely implemented. The current version of SNMP is version 3, and it includes support for IP version 6, as well as improved security and administration.

SNMP allows proxy management, which means that a device with an SNMP agent and MIB can communicate with other devices that do not have the full SNMP agent software. This proxy management makes it possible to control other devices through a connected machine by placing the device's MIB in the agent's memory. For example, a printer can be controlled through proxy management from a workstation acting as an SNMP agent, which also runs the proxy agent and MIB for the printer. Proxy management can be useful to offload some devices that are under heavy load.

Despite its widespread use, SNMP has a few disadvantages. The most important is its reliance on UDP. Because UDP is connectionless, there is no reliability inherent in messaging between server and agent. Another problem is that SNMP provides only a simple messaging protocol, so filtering messages cannot be performed. This increases the load on the receiving software. Finally, SNMP almost always uses polling to some degree, which consumes a considerable amount of bandwidth.

The SNMP manager handles the overall software and communications between the devices using the SNMP communications protocol. Support software provides a user interface, enabling a network manager to observe the condition of the overall system and individual components and monitor any specific network device.

Unix and SNMP

When dealing with a very large network, SNMP is often the only way for an administrator to know what's going on with the devices on the network, as well as to get warnings about problems. SNMP is bundled with every Unix version available, is quite simple to set up, and after a quite steep learning curve, can be effectively used to manage networks with thousands of devices on them. For those running Linux, the approach is exactly the same as that for Unix.

This section looks at how to set up SNMP on a typical Unix system. As you can probably imagine, a GUI-based SNMP management software package is a lot friendlier than a character-based system, so many Unix vendors have special add-in SNMP administration applications.

Setting Up SNMP Under Unix and Linux

Most Unix versions include both the client and server software as part of the operating system. The client software is executed through the `snmpd` daemon, which usually runs all the time when SNMP is used on the network. Normally, the `snmpd` daemon is started automatically when the system boots, controlled through the `rc` startup files. When

SNMP starts, the daemon reads a number of configuration files. On most SNMP agents, the files `snmpd` reads are

```
/etc/inet/snmpd.conf
/etc/inet/snmpd.comm
/etc/inet/snmpd.trap
```

The directories these files are under may be different for each Unix version, so you should check the filesystem for the proper location.

The `snmpd.conf` file contains four system MIB objects. Most of the time these objects are set during installation, but you may want to verify their contents. Here is a sample `snmpd.conf` file:

```
descr=SCO TCP/IP Runtime Release 2.0.0
objid=SCO.1.2.0.0
contact=Tim Parker  tparker@tpci.com
location=TPCI Int'l HQ, Richmond
```

In many `snmpd.conf` files, you will have to fill out the contact and location fields yourself (which define the contact user and physical location of the system), but the `descr` and `objid` fields should be left as they are. The variables defined in the `snmpd.conf` file correspond to MIB variables in this manner:

```
descr        sysDescr
objid        sysObjectID
contact      sysContact
location     sysLocation
```

The `snmpd.comm` (community) file is used to provide authentication information and a list of hosts that have access to the local database. Access by a remote machine to the local SNMP data is provided by including the remote machine's name in the `snmpd.comm` file. A sample `snmpd.comm` file looks like this:

```
accnting    0.0.0.0        READ
r_n_d    147.120.0.1      WRITE
public   0.0.0.0        read
interop  0.0.0.0        read
```

Each line in the `snmpd.comm` file has three fields: the community name, the IP address of the remote machine, and the privileges the community has. If the IP address is set to 0.0.0.0, any machine may communicate with that community name. The privileges can be `READ` for read-only, `WRITE` for read and write, and `NONE` to prevent access by that community. Read and write access are references to capabilities to change MIB data, not filesystems.

The snmpd.trap file specifies the name of hosts to whom a trap message must be sent when a critical event is noticed. A sample snmpd.trap file looks like this:

```
superduck 147.120.0.23   162
```

Each line in the snmpd.trap file has three fields: the name of the community, its IP address, and the UDP port to use to send traps.

SNMP Commands

Unix offers a number of SNMP-based commands for network administrators to obtain information from an MIB or an SNMP-compliant device. The exact commands vary a little depending on the implementation, but most SNMP systems support the commands shown in Table 42.1.

TABLE 42.1 SNMP Commands

Command	*Description*
getone	Uses the SNMP get command to retrieve a variable value
getnext	Uses the SNMP getnext command to retrieve the next variable value
getid	Retrieves the values for sysDescr, sysObjectID, and sysUpTime
getmany	Retrieves an entire group of MIB variables
snmpstat	Retrieves the contents of SNMP data structures
getroute	Retrieves routing information
setany	Uses the SNMP set command to set a variable value

Most of the SNMP commands require an argument that specifies the information to be set or retrieved. The output from some of the commands given in Table 42.1 is shown in the following extract from an SNMP machine on a small local area network:

```
$ getone merlin udpInDatagrams.0
Name: udpInDatagrams.0
Value: 6
$ getid merlin public
Name: sysDescr.0
Value: UNIX System V Release 4.3
Name: sysObjectID.0
Value: Lachman.1.4.1
Name: sysUpTime.0
Value: 62521
```

None of the SNMP commands can be called user-friendly because their responses are terse and sometimes difficult to analyze. For this reason, many GUI-based SNMP network management systems have become popular. The use of a graphical interface offers a more effective environment for the operation of SNMP functions and the presentation of the resulting management data.

The use of a GUI-based SNMP tool enables the presentation of full-color graphical displays that can be used to relay network operational statistics in real-time. These tools are often complex and expensive to implement; however, once established they can provide an essential source for network monitoring and device management.

One of the most useful features of SNMP is that it provides network devices with the capability to signal error conditions and performance problems. The use of a GUI management station makes it possible to graphically represent this information within topological network maps.

Windows and SNMP

Windows NT/2000/XP, Windows 9x/ME, and Windows 98 can all participate to some extent in SNMP. There are drivers available for each operating system that let you act as an agent on an SNMP reporting network, and some operating systems such as Windows NT/2000/XP and Windows 9x/ME support administration agents. The following sections take a quick look at each operating system to see how SNMP is used on them.

Windows NT/2000

Windows NT/2000 provides a set of SNMP monitoring services that can be installed as a standard service. Begin by launching the Network applet from the Control Panel, and choose the Services page tab. If SNMP Services does not appear on the list, click the Add button, then scroll down the list of services to SNMP Services and add it to your system. After reading a set of drivers from the distribution list, a window with three page tabs will appear in which you can add configuration information.

The first SNMP page, shown in Figure 42.1, is for the SNMP Administrator's contact information. The two fields at the top of the page are for the administrator's name and location. These fields are optional and don't have to be filled in, but doing so makes it easier for someone to find out who the SNMP administrator is across a network. The lower part of the window shows the services on which SNMP is to be used. The default values are the best set for most networks.

FIGURE 42.1
The SNMP Agent page tab.

The Traps page tab, shown in Figure 42.2, is used to enter the name of SNMP communities that are to be watched. Any community listed will be monitored for error traps. Usually, all machines on a network are members of the public community. If you do enter information into this page, it lets you specify an IP address for each community's SNMP monitoring device. This lets you route SNMP traps from a community called "research" to the research SNMP manager, for example.

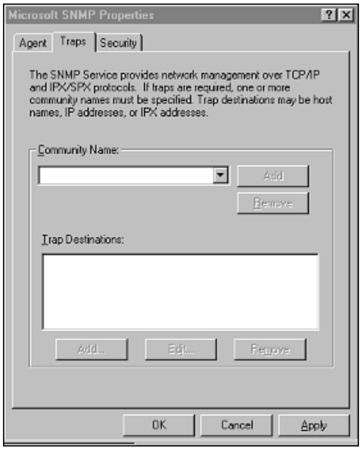
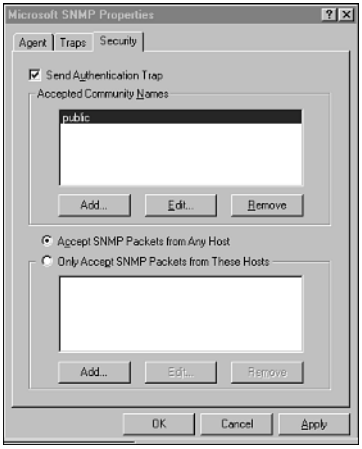


FIGURE 42.2
The SNMP Traps page tab.

The last page tab in the SNMP Services window is the Security tab, shown in Figure 42.3. This window can be used to restrict access to the SNMP service based on community and console. The lower screen has two buttons that let you force SNMP to accept requests only from certain devices.

FIGURE 42.3
The SNMP Security page tab.



After this process is completed, Windows NT will reboot and the SNMP Services will be active.

Windows 9x/ME

A number of Windows 9x/ME SNMP agents are becoming available, mostly public domain or shareware, readily found using Web search engines. Windows SNMP agents tend to allow you to monitor networks, some report SNMP problems, and a few allow you to manage a network from a Windows platform.

One of the most popular Windows 9x/ME tools is NetGuardian, developed at the University of Lisbon. NetGuardian requires a TCP/IP stack or Trumpet WinSock. Usually distributed as a .ZIP file, NetGuardian unpacks into a directory and does not need linking into the Windows kernel or special loading of drivers. This makes it very easy to use (and ignore when you don't need it). One of the best features of NetGuardian is its interface, which is about as simple as you can get with a complex subject like SNMP.

The main window for NetGuardian is shown in Figure 42.4. The figure shows a network map with all the machines that NetGuardian knows about on the diagram. A big X through the machine means NetGuardian can't connect to it (which isn't surprising, because this is the default setup sent with the NetGuardian package and represents machines in Europe!). To have NetGuardian search your own network, you need to select the Discover option from the Net menu. This will display a window that asks for a range of IP addresses to search, as shown in Figure 42.5.

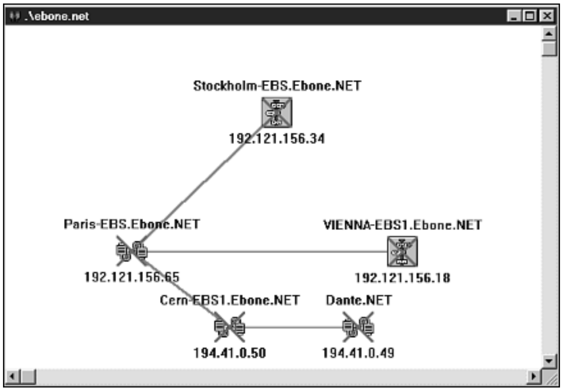


FIGURE 42.4
The NetGuardian window showing a network map.

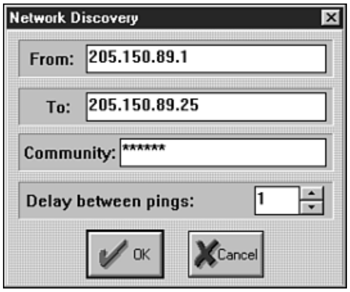


FIGURE 42.5
When discovering a network, NetGuardian asks for a range of IP addresses.

After a check of each machine in the range you specify, NetGuardian shows the results in a new map. Figure 42.6 shows a simple network with only three machines reporting their presence. NetGuardian discovers machines on the network by pinging each address in the range you specify.

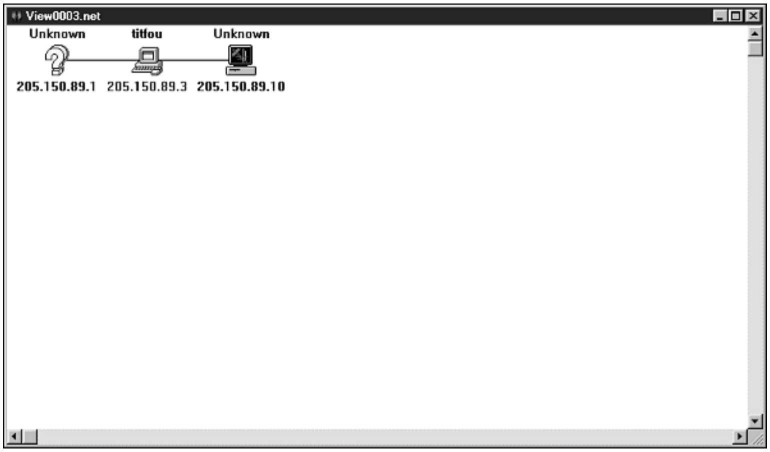
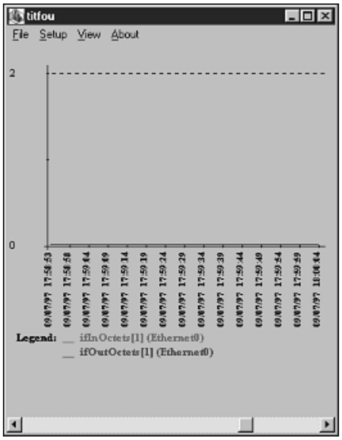


FIGURE 42.6
The NetGuardian network map with three machines reporting active on a network.

Using the simple NetGuardian interface, an administrator (or a curious user) can check on machines that are active on the network, add or remove items from the network map, and rearrange network maps so they look different. The NetGuardian package is very easy to learn and use, and has a number of special features that many SNMP packages lack (such as the graphing of net performance, shown in Figure 42.7).

FIGURE 42.7
A graph of network performance from NetGuardian.



Note

You can get a copy of NetGuardian from a number of places on the Web, or from anonymous FTP through `ftp.fc.ul.pt` in the directory `/pub/networking/snmp/netgXXX.zip`, where *XXX* is the version number.

Summary

SNMP is a simple, effective method of managing network devices. It has grown in complexity and popularity since its inception in 1988 and is the management system of choice. The simple nature of SNMP is one of its major advantages because vendors of peripherals can incorporate SNMP capabilities into their devices with minimal effort. For the network administrator, though, SNMP is nothing short of a wonderful tool.

CHAPTER 43

Securing TCP/IP Transmissions

by Anne Carasik

IN THIS CHAPTER

- **Defining Required Network Security** *980*
- **Enforcing Network Security** *985*
- **Configuring Applications** *990*
- **Using Ports and Trusted Ports** *994*
- **Firewalls** *995*

As much as networking is about having access, in today's world it's just as important to have security. You need to determine whether applications should be allowed access to network services based on the TCP port they use. Also, you can secure TCP/IP through *Virtual Private Networks* (VPNs) to create a secure tunnel without having to secure the application itself.

Defining Required Network Security

When you define a network security policy, you need to define what network traffic and what network applications you allow outbound and inbound (if any). Unless you have an absolute need (and it should be well-defined if you do), do not allow inbound network packets if you can avoid it. Too many "script kiddies" are out there who can download a script from a hacking site and easily access your network if you're not careful.

If you do allow inbound traffic, make sure you're extremely careful in monitoring the software running on the inbound port and make sure you make patches to the software as soon as it becomes available.

Another option you have is cryptographic applications such as Secure Shell, Secure Sockets Layer (SSL), and VPN products that allow you to have better authentication and encryption with public key ciphers. It's also a good solution for outbound traffic—you don't want people sending out unencrypted information like passwords to your business partner's site.

What Is Network Security?

Network security, in its simplest sense, can be defined as what network traffic is allowed in and out of a network. A network can be a subnet in a *Local Area Network* (LAN) or it can cover an entire region, such as a *Wide Area Network* (WAN).

One way to define network security is to segment a network to include *chokepoints*, such as a firewall or router. On a firewall or router, you can define what types of network traffic and network applications are allowed through the chokepoint.

A chokepoint works like a filter. It allows only certain network traffic through (inbound, outbound, or both). For example, e-mail is crucial for business. In a very simple network security policy, e-mail should be allowed inbound and outbound on port 25 for *Simple Mail Transfer Protocol* (SMTP). All other traffic should be blocked and not allowed through.

Figure 43.1 shows examples of various chokepoints.

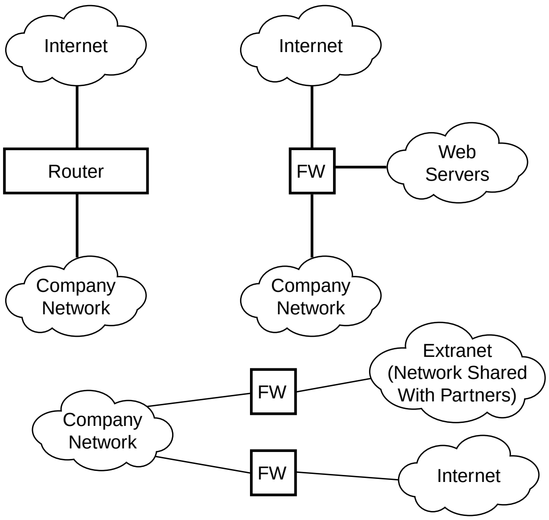


FIGURE 43.1
How chokepoints separate various networks.

Why Is Network Security Important?

As the number of users on the Internet continues to grow, so does the need for security. Many more people and businesses are susceptible to an attack. The following are some of the reasons attacks occur:

- Someone wants to obtain sensitive information about you or your company.
- Someone is testing his penetration testing skills and decides to use you as a guinea pig.
- Because it's a fun thing to do.

Security Levels

Network security is also defined by access—who has it and who doesn't. With network security, certain users can have administrative privileges, whereas others have a general level of privileges that all users have.

There are also many levels of security between the administrators and the users. Some administrators have limited access to one system, whereas others may have access to several systems. For example, there may be an administrator for the development system, while someone else administers the firewalls.

Many operating systems, such as Unix and Windows NT/2000, have administrator accounts (on Unix, this is the root account) and general user accounts. These represent the two extremes of network security. Other levels of access include users with some administrator privileges but not others, and a general account such as guest.

Note

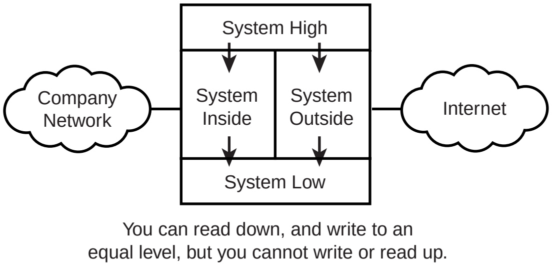
Be very careful adding accounts like "guest," which come by default with some Unix systems and Windows NT/2000. You'll want to disable them before you connect your system to the network, especially if you have critical information on it.

Some operating systems, such as HP-UX CMW (Compartmented Mode Workstation), which is used in the HP-UX Virtual Vault, use a compartmentalized version of HP-UX. Access is defined by four different levels, and there is no one administrator account. The administrator privileges are divided among several accounts. The four different levels are *system high*, *system low*, *system outside*, and *system inside*, as illustrated in Figure 43.2.

Note

Certain operating systems, like Windows NT/2000, automatically assign the "Everyone" group full control (read, write, delete, and execute) of items. Users should want to go in and redefine their permissions appropriately (such as removing "everyone" access). Also, administrators should do the same on critical system and network files.

FIGURE 43.2
The compartmentalized access for HP-UX CMW.



Within the four different levels, a user cannot write up but can read down. Reading and writing on the same level are permitted. For example, someone who is using his administrator account in the system low compartment cannot write to system high.

Note

For more information on the Virtual Vault, go to `http://www.hp.com/security/products/virtualvault`.

Passwords and Password Files

Passwords are the most common way to verify a user's access to an account. There are other means, including biometrics (which authenticates on physical attributes) and public key cryptography. However, most network authentication protocols and applications still use passwords.

The problem with passwords is that they are easy to bypass. Some password schemes do not have strong encryption mechanisms, and others allow ways to bypass the password mechanisms altogether. However, even if the password mechanisms are implemented properly, there are other problems.

Unfortunately, most passwords are easy to crack because users want something easy to remember. Many people will pick a password found in the dictionary or use their birthdate, phone number, dog's name, or something equally as easy to discover about them.

As a result, many administrators are requiring users to pick strong passwords. There is software available that will pick strong passwords or force people to use them.

A strong password includes the following:

- Alphanumeric characters (numbers and letters)
- Mixed cases (upper- and lowercase)
- Special characters (!@#$%^&*_-=+\|?/>)—adding <.,”’:~`)

These decrease the likelihood that a password will be cracked in a relatively short time.

An example of a strong password is

```
%Ji928a*jpeijAjdkljW
```

The problem with this password, however, is that you couldn't remember it. You would have to write it down, which is a security risk in itself. Instead, you'll want to use a phrase that you remember and write it in a license plate fashion:

```
iLuv2c0mputePrimez!
```

This would not be easy for someone to crack with a dictionary attack.

Tip

Adding a space to your password also helps make it more secure.

Also, the time to change the password should be enforced. Many secure sites usually require a password change every 90 days. They also require that you do not reuse a password because that is a security risk as well.

If you want to see the value of strong passwords, run a test machine (without any critical information on it and remove it from the network) and create dummy user accounts. Make some passwords easy to crack, and others with different levels of strength. Software is available to allow you to test how long it will take to break a password. Table 43.1 shows you a list of some freeware password crackers you can use to test the value of your passwords.

TABLE 43.1 Password Crackers

Program	*Location*
Crack	`http://www.cs.purdue.edu/COAST`
L0phtcrack	`http://www.l0pht.com`
John the Ripper	`http://www.openwall.com/john/`

Controlling Access to Passwords

Passwords should be stored in an encrypted file or database to prevent users from reading others' passwords and logging in to those accounts.

Passwords are stored in various locations depending on the operating system. Table 43.2 shows you the location of some password files.

TABLE 43.2 Location of Local Password Files on Different Operating Systems

Operating System	*Password File Location*
Windows NT	Registry
Unix	`/etc/passwd` or `/etc/shadow`

The permissions and ownership to the password files need to be set properly. For example, the password file on Unix should only be accessible by root, and if the passwords are shadowed, the shadow file should only be readable by root and not other users.

On more secure versions of Unix, such as the HP-UX CMW and the B1 Solaris, passwords are stored in a database or multiple files. This prevents someone from accessing one file and trying to crack all the passwords at one time.

Enforcing Network Security

Enforcing network security is always the biggest challenge because it involves getting users to agree to policies and follow them. Many people will not follow security policies if they do not benefit from them. However, ways exist to help you enforce and even improve your network security.

Types of Attacks

In the world of network security, there are several types of attacks, which are explained in the following sections.

Trojan Horses

Trojan horses are programs that are disguised as another program, but really get information for a hacker. For example, someone can substitute a fake network login program and obtain your username and password, and it just sends you error messages. After the fake program gets the information, it mails it to the attacker.

Trojan horses do not just gather information. They are really destructive programs that masquerade as benign ones. Trojan horses do not replicate themselves and are therefore not technically viruses. For example, a Trojan horse can masquerade as a Unix login where you try to log in and it prints out error messages. Each time you type your password, it is stored on the system for later access.

Backdoors

Backdoors are hidden in a program or operating system and are not known by the public, so someone can obtain access by overriding any security measures in place.

Denial of Service/Quality of Service

Denial of Service and Quality of Service attacks either bring down a network service completely (for example, a Web server) or slow it down considerably, affecting its performance and making users very unhappy.

Network Attacks

Network attacks include scanning ports for an opening. For example, port 5641 on Windows NT/2000 and Windows 9x is the PCAnywhere port. This port will prompt you for a username and password. As a result, someone can use brute force to get a password or username or obtain backdoor information from PCAnywhere.

Spoofing

Spoofing is pretending to be a user or host that you're not. One of the biggest problems that the Berkeley r-utilities have is that they can be easily tricked. The only thing that the r-utilities trust is the hostname, so they do not check to make sure the hostname is coming from the right place and the right machine.

The r-utilities can be tricked because hostname and username authentication can be easily faked. For example, you can change the hostname on a system on the outside to the same as a trusted system on the inside. Unfortunately, there is nothing that will check to make sure the system you connect from is the actual trusted system. You can spoof the hostname and trick the r-utilities that way.

Note

Today's routers have anti-spoofing mechanisms for IP addresses to help prevent this type of thing, but they do not affect the hostname. You can also define rules that do not allow the r-utilities to have traffic inbound as well.

Password Cracking

If someone is able to get hold of the password file or the NT/2000 registry, he can download freeware off the Internet and get password crackers. Provided the person has the time, he can eventually crack at least one of the passwords and obtain access to a computer.

Software Exploits and Buffer Overflows

A common method of attack today is to check a software program for an exploit, or a hole in the program, that allows someone to get root or administrator access from a program that does not panic when too much information is entered. This makes the program choke, and produces a memory dump. This type of exploit is known as a *buffer overflow*.

Many network applications, such as sendmail and NFS, have many exploits and are considered insecure network applications.

Note

There are other options for STMP in addition to sendmail, such as qmail, which is a secure mail server package. You can find out more about it at `http://www.qmail.org/`.

Even though NFS is insecure and a necessity, there is an alternative known as Andrew File System (AFS). For more information on AFS, take a look at `http://www.faqs.org/faqs/afs-faq/`.

Improper Permissions

If a file on Unix or Windows NT/2000 has improper permissions, someone may have the ability to run a program as root (or Administrator) and either crash the system or open an application exploit. When an application is opened with improper permissions, someone can exploit the system and gain root or Administrator privileges.

If root or Administrator owns a file which others can write to, someone can change the contents of the file or application to give a local or remote user root or Administrator privileges without the root or administrator knowing.

Virus

A virus is a program that attaches itself to another program without anyone knowing. The sole purpose of a virus is to cause damage to a computer, including remapping the keyboard, destroying the contents to a hard drive, or wiping out only a particular type of file.

Many companies make antivirus software. The key to making the antvirus software work effectively is to make sure the virus profiles, or databases, are updated at least monthly.

However, the latest and greatest craze in the Internet is to declare every problem a virus. Many programs (such as Netbus and Back Orifice) that are Trojan horses and backdoors are considered viruses by the virus companies. Even though these programs technically are not viruses, virus companies do help detect and prevent a world of problems that would otherwise bring a system to its knees. Some organizations run more than one virus detection software in the hope that if one virus detection software cannot detect a virus, the others can.

Social Engineering

Social engineering, which is obtaining access by feigning you need access, is the hardest form of network security exploit to fight. Someone can con a system support person into giving him or her a password over the phone, thereby giving him or her access.

Social engineering also includes such methods as bribing or tricking employees into giving you their access information or leaving you alone with access to their computer. Another method involves pretending to be a delivery person to try to gain access to computers. The movies *Sneakers* and *Mission: Impossible* are both very good examples of social engineering to get access to a network.

Enforcing Network Security

This section shows you some of the things you can do to enforce your network security. Keep in mind that resources like time, people, and how much sleep you want play into how much enforcement you can actually do with your network security.

User Education and Re-Education

Believe it or not, education is the most important thing you can do to enforce your network security. You need to make sure that employees, both new and old, are familiar with your network security policy and that they believe in it. Provided they do and it becomes part of the corporate culture, then you can enforce things like securing passwords, keeping smart cards and private keys in secure locations, and making sure people don't share critical files.

Intrusion Detection Systems

Intrusion detection systems detect unusual network traffic including Denial of Service attacks and using uncommon packets like Windows OOB (Out of Bound packet) that can cause a system to crash. This can help you track down someone trying to attack your system. Table 43.3 shows some intrusion-detection systems available.

TABLE 43.3 Intrusion-Detection Systems

System	*Location*
Network Flight Recorder	`http://www.nfr.com`
RealSecure	`http://www.iss.net`
NetProwler	`http://www.symantec.com`

Penetration Testing

Penetration testing is breaking into your own network through known security holes. This is the most effective way to make sure your network is secure; however, it is also the most controversial because many hackers have become highly sought after by consulting firms that offer penetration testing services. Even if you don't use the consulting services, you should run penetration tests against your own system for a minimal check to make sure that no obvious holes exist in your network.

Plenty of software is available to help you with penetration testing. Many Web sites have hacker's code available for you to download and compile to test on your own system.

Many commercial and freeware programs are available from the security community as well. Table 43.4 lists some penetration testing software that is available.

TABLE 43.4 Penetration Testing Software

Software	*Location*
Internet Security Scanner	`http://www.iss.net`
SATAN	`http://www.fish.com/satan/`
Nessus	`http://www.nessus.org`
Cybercop	`http://www.nai.com`

File Integrity

One of the most fundamental ways to determine whether someone has gained access to your system is to check whether files have changed. Programs are available that can check whether the file system has changed or whether a file has been altered. This technique can help find what has been altered and whether a system administrator is changing the files or whether someone is really attacking the system. Table 43.5 shows some file integrity software that is available.

TABLE 43.5 File Integrity Software

Software	*Location*
Tripwire	`http://www.tripwiresecurity.com`
COPS	`http://www.cerias.purdue.edu/coast/`
Tiger	`http://www.cerias.purdue.edu/coast/`
System Scanner	`http://www.iss.net`

Log Monitoring

Log monitoring is the simplest and cheapest way to check for attacks. You look at your logs for strange activity. This, unfortunately, is also one of the most time-consuming and tedious things you can ever do. Another problem with checking your logs is that you cannot prove they have not been altered. If someone has gained administrator or root access to your computer, he or she has the ability to change the logs and cover his or her own tracks.

Configuring Applications

To ensure a secure network, you need to configure your applications properly and, if you can, securely. Properly configuring network applications is key to network security. Some important things to remember include the following:

- Only use applications you absolutely need.
- Turn off everything you don't need.
- Secure the applications you run as best as you can.
- Networks are designed for access. Anytime you allow network access, you create an opening to your network and thus risk allowing someone not meant to have access a way in.

The Internet Daemon and /etc/inetd.conf

Most of the applications on Unix can be turned off in `/etc/inetd.conf`. The `/etc/inetd.conf` file controls what network application daemons are run by the Internet super daemon, `inetd`.

> **Note**
>
> There is more information on `inetd` and `/etc/inetd.conf` in Chapter 39, "Protocol Configuration and Tuning."

A new system where the `/etc/inetd.conf` file has not been edited and configured may look like this:

```
#
# Authors:      Original taken from BSD Unix 4.3/TAHOE.
#            Fred N. van Kempen, <waltje@uwalt.nl.mugnet.org>
#
echo      stream      tcp      nowait      root      internal
echo      dgram      udp      wait      root      internal
discard      stream      tcp      nowait      root      internal
discard      dgram      udp      wait      root      internal
daytime      stream      tcp      nowait      root      internal
daytime      dgram      udp      wait      root      internal
chargen      stream      tcp      nowait      root      internal
chargen      dgram      udp      wait      root      internal
time      stream      tcp      nowait      root      internal
time      dgram      udp      wait      root      internal
```

```
# These are standard services.
#
ftp    stream   tcp   nowait root  /usr/sbin/tcpd   in.ftpd -l -a
telnet stream   tcp   nowait root  /usr/sbin/tcpd   in.telnetd
#
# Shell, login, exec, comsat and talk are BSD protocols.
#
shell  stream   tcp   nowait   root   /usr/sbin/tcpd   in.rshd
login  stream   tcp   nowait   root   /usr/sbin/tcpd   in.rlogind
#exec   stream   tcp   nowait   root   /usr/sbin/tcpd   in.rexecd
#comsat dgram   udp   wait   root   /usr/sbin/tcpd   in.comsat
talk    dgram   udp   wait   root   /usr/sbin/tcpd      in.talkd
ntalk   dgram   udp   wait   root   /usr/sbin/tcpd      in.ntalkd
#dtalk   stream  tcp   waut   nobody   /usr/sbin/tcpd      in.dtalkd
#
# Pop and imap mail services et al
#
#pop-2   stream  tcp     nowait  root    /usr/sbin/tcpd      ipop2d
pop-3   stream  tcp     nowait  root    /usr/sbin/tcpd      ipop3d
imap    stream  tcp     nowait  root    /usr/sbin/tcpd      imapd
#
```

In this case, any service that does not have a comment (#) in front of it is an active network application that `inetd` runs. If you want to keep this system so that the only network application daemons running are FTP and Telnet, the new `/etc/inetd.conf` file looks like this:

```
#
# Authors:      Original taken from BSD Unix 4.3/TAHOE.
#         Fred N. van Kempen, <waltje@uwalt.nl.mugnet.org>
#
#echo          streamtcp   nowait   root   internal
#echo          dgramudp   wait          root   internal
#discard   streamtcp   nowait   root   internal
#discard   dgramudp   wait           root   internal
#daytime   streamtcp   nowait   root   internal
#daytime   dgramudp   wait           root   internal
#chargen   streamtcp   nowait   root   internal
#chargen   dgramudp   wait          root   internal
#time          streamtcp   nowait   root   internal
#time          dgramudp   wait          root   internal

# These are standard services.
#
ftp   stream   tcp   nowait   root   /usr/sbin/tcpd   in.ftpd -l -a
telnet   stream  tcp    nowait  root    /usr/sbin/tcpd   in.telnetd
#
# Shell, login, exec, comsat and talk are BSD protocols.
#
```

```
#shell   stream   tcp   nowait   root   /usr/sbin/tcpd   in.rshd
#login   stream   tcp   nowait   root   /usr/sbin/tcpd   in.rlogind
#exec   stream   tcp   nowait   root   /usr/sbin/tcpd   in.rexecd
#comsat   dgram   udp   wait   root   /usr/sbin/tcpd   in.comsat
#talk   dgram   udp   wait   root   /usr/sbin/tcpd   in.talkd
#ntalk   dgram   udp   wait   root   /usr/sbin/tcpd   in.ntalkd
#dtalk   stream   tcp   waut   nobody   /usr/sbin/tcpd   in.dtalkd
#
# Pop and imap mail services et al
#
#pop-2   stream  tcp     nowait  root    /usr/sbin/tcpd   ipop2d
#pop-3   stream  tcp     nowait  root    /usr/sbin/tcpd   ipop3d
#imap    stream  tcp     nowait  root    /usr/sbin/tcpd   imapd
#
```

Now, with everything commented out, the only network application daemons running are FTP and Telnet. This means that known insecure applications like `echo`, `login`, `shell`, and `finger` are disabled and no one can connect to your computer using those services.

Note

Note that Telnet and FTP are not secure applications themselves. They send passwords in plain text, and they can be read by a packet sniffer.

Encryption Network Software

One of the best ways you can secure your TCP/IP transmissions is with encryption software. This includes Secure Sockets Layer (SSL), which is used to encrypt http traffic; Secure Shell (SSH), which is usually used to encrypt terminal and X traffic; and Virtual Private Network (VPN), which is used to create tunnels usually between two remote sites through the Internet or a client connecting to a main site through the Internet.

SSL and SSH can be used to create secure tunnels for other applications including POP3, IMAP, and FTP. When you use SSL or SSH, you use public keys (RSA or DSA, for example) for authenticating and usually symmetric ciphers for encryption (DES, triple DES, or IDEA).

VPNs are usually used to allow all insecure network traffic from one end to another. For example, file sharing, which is very insecure, can be secured by using VPNs without having to re-create the network application from the ground up.

Note

More information on SSH can be found at `http://www.employees.org/~satch/ssh/faq`. You can find more information on SSL at `http://psych.psy.uq.oz.au/~ftp/Crypto/`. For more information on VPNS, take a look at `http://www.vpnc.org`.

TCP Wrappers

Many network applications can be secured with TCP Wrappers. These Wrappers enable a way to track and limit access to network applications that are run by `inetd`. They also enable an audit trail and a way to control who has access to certain network applications like `finger`, `rsh`, and `ftp`.

In order to get a network application daemon to work with TCP Wrappers, you need to make sure that TCP Wrappers is installed and configured properly on your system. When you run a TCP application through TCP Wrappers, it is considered wrapped.

To install TCP Wrappers, just uncompress the tar archive and run `make`:

```
# gzip -dc tcp_wrappers-7.6.tar.gz | tar -xvf -
# cd tcp_wrappers-7.6
# make
```

Next, you'll need to follow the instructions for installing TCP Wrappers for your environment.

After that, you'll need to configure `/etc/inetd.conf`, `/etc/hosts.deny`, and `/etc/hosts.allow`. The two configuration files that TCP Wrappers used for access control are `/etc/hosts.allow` and `/etc/hosts.deny`. In order to use TCP Wrappers, you need to have the network application daemons run by the TCP Wrapper program, `tcpd`.

To add an entry for wrapped network application through `/etc/inetd.conf`, the basic format looks like this:

```
netappd     stream  tcp     nowait  root    /usr/sbin/tcpd  netappd
```

This will fork a new process for `netappd` from `/etc/inetd.conf` on each request to Secure Shell (SSH).

Assume with the previous example that you still only want to run FTP and Telnet. To start an FTP wrapped daemon, the entry will change from

```
ftp   stream   tcp   nowait   root   /usr/sbin/in.ftpd   in.ftpd -l -a
```

to the following:

```
ftp   stream   tcp   nowait   root   /usr/sbin/tcpd   in.ftpd -l -a
```

You'll want to make sure your `/etc/hosts.deny` is set so no one can access your system through TCP Wrappers applications. This prevents any host not defined in `/etc/hosts.allow` from being allowed in. To keep everyone out except for those you specify, you'll want to put this entry in `/etc/hosts.deny`:

```
ALL : ALL
```

After creating your `/etc/hosts.deny`, you need to add entries for `ftpd` to `/etc/hosts.allow`. A simple `/etc/hosts.allow` file for a wrapped FTP and Telnet daemon looks something like this:

```
in.ftpd: example.com: allow
in.telnetd: example.com : allow
```

This will allow in only clients from the `example.com`. The basic format for the `/etc/hosts.allow` and `/etc/hosts.deny` looks like this:

```
deamons: clients: allow/deny
```

In the following example, you don't trust any clients from the `evil.org` domain. In this case, you would define your `/etc/hosts.deny` to look like this:

```
in.fingerd: evil.org: deny
```

Note

You can find more information about TCP Wrappers at `ftp://ftp.porcupine.org/pub/security`.

Using Ports and Trusted Ports

Ports are used by Unix and Windows NT/2000 services.

If someone runs a port scan and checks to see whether the port is open, usually he or she will check what type of application runs on that port. This port may be a backdoor or it may be a way to flood packets to the machine, thus bringing it to its knees in a Denial of Service attack.

Firewalls

A firewall is a chokepoint on a network that determines what types of network applications are allowed through. Most firewall products only work on TCP/IP networks, although other firewall products may work on other networks such as IPX.

Firewalls do provide logging functionality, so you can see which applications are being run and which ones are being dropped or blocked from going out or coming in to your network. Many firewalls have built-in definitions of what applications are allowed through.

Note

Just because a firewall allows insecure connections like NFS and Berkeley "r" commands through does not mean you should configure your firewall to do so.

A firewall is only as secure as you make it. You need to make sure you do not enable unsecure applications because they defeat the purpose of having a firewall.

Packet Filters

Packet filters check the packet to make sure it's going through an allowed port. The contents of the packet are not checked. For example, a router can be a packet filter that just lets packets go in and out through certain ports but does not check the content. Despite the fact that packet filters do not check the content of the packet, they are very quick and provide very fast performance.

Application Gateway

In addition to the port being checked, the packet itself is checked to make sure that the contents of the packet match the application it is trying to connect to. An application gateway checks everything on the packet, including the type of application it connects to. Because the application gateway has so much information on each packet to check, performance takes a considerable hit compared to a packet filter. This also prevents an application gateway from being very scalable.

Many application gateways provide additional functionality such as VPN support, work in conjunction with intrusion detection systems, and provide router management.

Application gateways have a difficult time detecting what application an encrypted packet for Secure Shell (SSH) or *Secure Sockets Layer* (SSL) connects to. In this case, the application gateway acts more like a packet filter.

Other Application Filters

Checkpoint, Novell's BorderManager, and Cisco PIX use *stateful inspection*, which is a hybrid of an application gateway and a packet filter. The inspection checks the contents of the packet, but not to the extent that an application gateway does.

Note

For more information on firewalls, see Chapter 20, "Firewalls."

Summary

When securing TCP/IP transmissions, it's important to define what TCP/IP traffic you need. It's also important to define a chokepoint, which is what will be a gatekeeper for allowing certain types of traffic in and out of your network.

You can also define which network services you want running. When you do this, you define which network applications need to be configured properly to make sure you secure your transmissions.

Even though most network applications are considered insecure, you can run network encryption applications such as Secure Shell, Secure Sockets Layer, and Virtual Private Networks. These applications will help protect you from someone eavesdropping or hijacking your session.

CHAPTER 44

Troubleshooting Tools and Issues

by Bernard McCargo

In This Chapter

- **Monitoring Network Behavior** *998*
- **Standard Utilities** *998*
- **Troubleshooting the Network Interface** *1012*
- **Troubleshooting the Network (IP) Layer** *1013*
- **Troubleshooting TCP and UDP** *1019*
- **Troubleshooting the Application Layer** *1021*

Because most problems have a simple cause, developing a clear understanding of the problem often provides the solution. Unfortunately this is not always true, so this section begins to discuss the tools that can help you attack the most intractable problems. Many diagnostic tools are available, ranging from commercial systems with specialized hardware and software that may cost thousands of dollars, to free software available from the Internet. This chapter emphasizes free or "built-in" diagnostic tools.

There are a few reasons for this emphasis. First, a commercial system that costs thousands of dollars should be fully documented. Second, many administrators can't buy commercial diagnostic tools, but everyone has access to the free tools. Finally, most network problems can be solved using the free diagnostic software. Large networks probably need a commercial *time domain reflectometer* (TDR), but many smaller networks can make do with the publicly available diagnostic software.

The tools used in this chapter, and many more, are described in RFC 1147.

Monitoring Network Behavior

To approach a problem properly, you need a basic understanding of how to monitor the network. Without some type of third-party or built-in network monitoring system, troubleshooting network problems would be very time consuming.

Monitoring the network behavior allows you to perform preventative maintenance before a problem occurs. If a problem does occur, it provides you the ability to gather detailed information about exactly what's happening. When the problem is reported, review what was recorded on the network monitoring system. Find out which application failed. What is the remote host's name and IP address? What is the user's hostname and address? What error message was displayed? Try to verify the problem by having the user run the application while you talk him through it. If possible, duplicate the problem on your test system.

Standard Utilities

The standard utilities discussed in this chapter and throughout this book are

- `ifconfig`—Provides information about the basic configuration of the interface. It is useful for detecting bad IP addresses, incorrect subnet masks, and improper broadcast addresses. This tool is provided with Unix operating systems. The same tool is called `ipconfig` on Windows NT/2000 operating systems and `winipcfg` on Windows 9x operating systems.

- `arp`—Provides information about Ethernet/IP address translation. It can be used to detect systems on the local network that are configured with the wrong IP address. This tool exists on Windows and Unix systems.
- `netstat`—Provides a variety of information. It is commonly used to display detailed statistics about each network interface, network sockets, and the network routing table. This tool exists on Windows and Unix systems.
- `ping`—Indicates whether a remote host can be reached. `ping` also displays statistics about packet loss and delivery time.
- `nslookup`—Provides information about DNS name service.
- `dig`—Also provides information about name service, and is similar to `nslookup`. `dig` is available via anonymous `ftp` from `venera.isi.edu` in the file `pub/dig.2.0.tar.Z`.
- `ripquery`—Provides information about the contents of the RIP update packets being sent or received by your system. It is provided as part of the `gated` software package, but it does not require that you run `gated`. It will work with any system running RIP.
- `traceroute`—Tells you which route packets take going from your system to a remote system. Information about each hop is printed. It is available via anonymous `ftp` from `ftp.ee.lbl.gov` in the file `traceroute.tar.Z`. On Windows NT/2000, this is called tracert.
- `etherfind`—Analyzes the individual packets exchanged between hosts on a network. `etherfind` is a TCP/IP protocol analyzer that can examine the contents of packets, including their headers. It is most useful for analyzing protocol problems. It is the SunOS version of a program called `tcpdump`. `tcpdump` is available via anonymous `ftp` from `ftp.ee.lbl.gov`.
- `ethereal`—Analyzes the individual packets exchanged between hosts on a network. `ethereal` is a high-quality TCP/IP protocol analyzer that can examine the contents of packets, including their headers. This program has been ported to Windows and most Unix operating systems. For more information consult `www.ethereal.com`.

Each of these tools, even those covered earlier in the text, is used in this chapter. We start with `ping`, which is used in more troubleshooting situations than any other diagnostic tool.

Testing Basic Connectivity

The `ping` command tests whether a remote host can be reached from your computer. This simple function is extremely useful for testing the network connection, independent of the application in which the original problem was detected. `ping` allows you to determine whether further testing should be directed toward the network connection (the lower layers) or the application (the upper layers). If `ping` shows that packets can travel to the remote system and back, the user's problem is probably in the upper layers. If the packet can't make the round trip, lower protocol layers are probably at fault.

Frequently, a user reports a network problem by stating that he can't `telnet` (or `ftp`, or send e-mail, or whatever) to some remote host. He then immediately qualifies this statement with the announcement that it worked before. In cases like this, where the ability to connect to the remote host is in question, `ping` is a very useful tool.

Using the hostname provided by the user, `ping` the remote host. If your `ping` is successful, have the user `ping` the host. If the user's `ping` is also successful, concentrate your further analysis on the specific application with which the user is having trouble. Perhaps the user is attempting to `telnet` to a host that only provides anonymous `ftp`. Perhaps the host was down when the user tried his application. Have the user try it again, while you watch or listen to every detail of what he is doing. If he is doing everything right and the application still fails, detailed analysis of the application with `etherfind` and coordination with the remote system administrator may be needed.

If your `ping` is successful and the user's `ping` fails, concentrate testing on the user's system configuration, and on those things that are different about the user's path to the remote host, when compared to your path to the remote host.

If your `ping` fails, or the user's `ping` fails, pay close attention to any error messages. The error messages displayed by `ping` are helpful guides for planning further testing. The details of the messages may vary from implementation to implementation, but there are only a few basic types of errors:

- `unknown host`—The remote host's name cannot be resolved by name service into an IP address. The name servers could be at fault (either your local server or the remote system's server), the name could be incorrect, or something could be wrong with the network between your system and the remote server. If you know the remote host's IP address, try to `ping` that. If you can reach the host using its IP address, the problem is with name service. Use `nslookup` or `dig` to test the local and remote servers, and to check the accuracy of the hostname the user gave you.
- `network unreachable`—The local system does not have a route to the remote system. If the numeric IP address was used on the `ping` command line, re-enter the `ping` command using the local hostname. This eliminates the possibility that the IP address was entered incorrectly, or that you were given the wrong address. If a routing protocol is being used, make sure it is running and use `netstat` to check the routing table. If RIP is being used, use `ripquery` to check the contents of the RIP updates being received. If a static default route is being used, reinstall it. If everything seems fine on the host, check its default gateway for routing problems.

- `no answer`—The remote system did not respond. Most network utilities have some version of this message. Some `ping` implementations print the message `100% packet loss`. `telnet` prints the message `Connection timed out`, and `sendmail` returns the error `cannot connect`. All of these errors mean the same thing. The local system has a route to the remote system, but it receives no response from the remote system to any of the packets it sends.

  There are many possible causes of this problem. The remote host may be down. Either the local or remote host may be configured incorrectly. A gateway or circuit between the local host and the remote host may be down. The remote host may have routing problems. Only additional testing can isolate the cause of the problem. Carefully check the local configuration using `netstat` and `ifconfig`. Check the route to the remote system with `traceroute`. Contact the administrator of the remote system and report the problem.

The tools mentioned in this section are discussed later in this chapter. However, before leaving `ping`, let's look more closely at the command and the statistics it displays.

The `ping` Command

The basic format of the `ping` command is

ping *host* [*packetsize*] [*count*]

host is the hostname or IP address of the remote host being tested. Use the hostname or address provided by the user in the trouble report.

packetsize defines the size in bytes of the test packets. This field is only required if the *count* field is going to be used. Use the default *packetsize* of 56 bytes.

count is the number of packets to be sent in the test. Use the *count* field, and set the value low. Otherwise, the `ping` command continues to send test packets until you interrupt it, usually by pressing Control+C (^C). Sending excessive numbers of test packets is not a good use of network bandwidth and system resources. Usually five packets are sufficient for a test.

To check that `uunet.uu.net` can be reached from workstation `bernard`, we send five 56-byte packets with the following command:

```
% ping -s uunet.uu.net 56 5
PING uunet.uu.net: 56 data bytes
64 bytes from uunet.UU.NET (137.39.1.2): icmp_seq=0. Time=14. ms
64 bytes from uunet.UU.NET (137.39.1.2): icmp_seq=0. Time=14. ms
64 bytes from uunet.UU.NET (137.39.1.2): icmp_seq=0. Time=14. ms
64 bytes from uunet.UU.NET (137.39.1.2): icmp_seq=0. Time=14. ms
64 bytes from uunet.UU.NET (137.39.1.2): icmp_seq=0. Time=14. ms
```

```
----uunet.UU.NET PING Statistics----
5 packets transmitted, 5 packets received, 0% packet loss
round-trip (ms) min/avg/max = 12/13/15
```

The -s option is included because bernard is a Sun workstation, and we want packet-by-packet statistics. Without the -s option, Sun's ping command would only print a summary line saying uunet.uu.net is alive. Other ping implementations do not require the -s option; they display the statistics by default.

This test shows an extremely good wide area network link to uunet.uu.net with no packet loss and fast response. The round trip between bernard and uunet.uu.net is taking an average of only 13 milliseconds. A small packet loss, and the round-trip times an order of magnitude higher, would be more normal for a connection made across a wide area network. The statistics displayed by the ping command can indicate low-level network problems. The key statistics are

- The sequence in which the packets are arriving, as shown by the ICMP sequence number (icmp_seq) displayed for each packet
- How long it takes a packet to make the round trip, which is displayed in milliseconds after the string time=
- The percentage of packets lost, which is displayed in a summary line at the end of the ping output

If the packet loss is high, the response time is very slow, or packets are arriving out of order, there could be a network hardware problem. If you see these conditions when communicating great distances on a wide area network, there is nothing to worry about. TCP/IP was designed to deal with unreliable networks, and some wide area networks suffer a lot of packet loss. But if you see these problems on a local area network, they indicate trouble.

On a local network cable segment the round-trip time should be near zero, there should be little or no packet loss, and the packets should arrive in order. If these things are not true, there is a problem with the network hardware. On an Ethernet the problem could be improper cable termination, a bad cable segment, or a bad piece of "active" hardware, such as a repeater or transceiver. Check the cable terminations first. They're easy to check; either there is a terminating resistor or there isn't, and it's a common problem, particularly if the cable ends in a work area where users have access to it.

A helpful tool for checking cable hardware problems is a *time domain reflectometer* (TDR). A TDR sends a signal down the cable and listens for the echoes the signal produces. These echoes are displayed on a small screen on the front of the tester. If the cable is not terminated, the signal display jumps to the top of the screen. A normal display shows only small spikes where the transceivers tap into the network. With a TDR, detecting a cable problem is easy.

The results of a simple ping test, even if the test is successful, can help you direct further testing toward the most likely causes of the problem. But other diagnostic tools are needed to examine the problem more closely and find the underlying cause.

Note

Under some systems such as Linux, the ping command does a reverse lookup of the target IP address. If DNS is not running, the ping command takes a long time because it waits for DNS to time out. The results of ping, in this case, are misleading because of the long delays reported due to DNS timeout. To eliminate this possibility, do a ping with the -n option, which suppresses name resolution.

Troubleshooting Network Access

The no answer and cannot connect errors indicate a problem in the lower layers of the network protocols. If the preliminary tests point to this type of problem, concentrate your testing on routing and on the network interface. Use the ifconfig, netstat, and arp commands to test the Network Access Layer.

Using the ifconfig Command

ifconfig checks the network interface configuration. Use this command to verify the user's configuration if the user's system has been recently configured, or if the user's system cannot reach the remote host while other systems on the same network can.

When ifconfig is entered with an interface name and no other arguments, it displays the current values assigned to that interface. For example, checking interface le0 on bernard gives this report:

```
% ifconfig le0
le0: flags=63<UP,BROADCAST,NOTRAILERS,RUNNING>
inet 128.66.12.2 netmask ffff0000  broadcast 128.66.0.0
```

The ifconfig command displays two lines of output. The first line of the display shows the interface's name and its characteristics. Check for the following characteristics:

- UP—The interface is enabled for use. If the interface is down, have the system's superuser bring up the interface with the ifconfig command (ifconfig le0 up). If the interface won't come up, replace the interface cable and try again. If it still fails, have the interface hardware checked.
- RUNNING—This interface is operational. If the interface is not running, the driver for this interface may not be properly installed. The system administrator should review all the steps necessary to install this interface, looking for errors or missed steps.

The second line of `ifconfig` output shows the IP address, the subnet mask (written in hexadecimal), and the broadcast address. Check these three fields to make sure the network interface is properly configured.

Using the `arp` Command

The `arp` command is used to analyze problems with IP-to-Ethernet address translation. The `arp` command has three useful options for troubleshooting:

`-a`—Displays all ARP entries in the table.

`-d` *`hostname`*—Deletes an entry from the ARP table.

`-s` *`hostname ether-address`*—Adds a new entry to the table.

With these three options you can view the contents of the ARP table, delete a problem entry, and install a correct entry. The ability to install a corrected entry is useful in buying time while you look for a permanent fix.

Use `arp` if you suspect that incorrect entries are getting into the address resolution table. One clear indication of problems with the ARP table is a report that the wrong host responded to some command, such as `ftp` or `telnet`. Intermittent problems that affect only certain hosts can also indicate that the ARP table has been corrupted. ARP table problems are usually caused by two systems using the same IP address. The problems appear intermittent because the entry that appears in the table is the address of the host that responded quickest to the last ARP request. Sometimes the correct host responds first.

If you suspect that two systems are using the same IP address, display the address resolution table with the `arp -a` command. Here's an example:

```
% arp -a
bernard (128.66.12.2) at 8:0:20:b:4a:71
annette (128.66.12.1) at 8:0:20:e:aa:40
bernadette (128.66.12.3) at 0:0:93:e0:80:b1
```

Verifying that the IP and Ethernet address pairs are correct is easiest if you have a record of each host's correct Ethernet address. For this reason, you should record each host's Ethernet and IP address when it is added to your network. If you have such a record, you'll quickly see whether anything is wrong with the table.

If you don't have this type of record, the first three bytes of the Ethernet address can help you to detect a problem. The first three bytes of the address identify the equipment manufacturer. A list of these identifying prefixes is found in the Assigned Numbers RFC, in the section titled "Ethernet Vendor Address Components."

Table 44.1 lists several equipment manufacturers and their assigned prefixes. Using this information, we see that the first two ARP entries displayed in our example are Sun systems (8:0:20). If `bernadette` is also supposed to be a Sun, the 0:0:93 Proteon prefix indicates that a Proteon router has been mistakenly configured with `bernadette`'s IP address.

TABLE 44.1 Vendor Ethernet Prefixes

Prefix	*Manufacturer*	*Prefix*	*Manufacturer*
00:00:0C	Cisco	08:00:0B	Unisys
00:00:0F	NeXT	08:00:10	AT&T
00:00:10	Sytek	08:00:11	Tektronix
00:00:1D	Cabletron	08:00:14	Excelan
00:00:65	Network General	08:00:1A	Data General
00:00:6B	MIPS	08:00:1B	Data General
00:00:77	MIPS	08:00:1E	Apollo
00:00:89	Cayman Systems	08:00:20	Sun
00:00:93	Proteon	08:00:25	CDC
00:00:A2	Wellfleet	08:00:2B	DEC
00:00:A7	NCD	08:00:38	Bull
00:00:A9	Network Systems	08:00:39	Spider Systems
00:00:C0	Western Digital	08:00:46	Sony
00:00:C9	Emulex	08:04:47	Sequent
00:80:2D	Xylogics Annex	08:00:5A	IBM
00:AA:00	Intel	08:00:69	Silicon Graphics
00:DD:00	Ungermann-Bass	08:00:6E	Excelan
00:DD:01	Ungermann-Bass	08:00:86	Imagen/QMS
02:07:01	MICOM/Interlan	08: 00:87	Xyplex terminal servers
02:60:8C	3Com	08:00:89	Kinetics
08:00:02	3Com (Bridge)	08:00:8B	Pyramid
08:00:03	ACC	08:00:90	Retix
08:00:05	Symbolics	AA:00:03	DEC
08:00:08	BBN	AA:00:04	DEC
08:00:09	Hewlett-Packard		

If neither checking a record of correct assignments nor checking the manufacturers' prefixes helps you identify the source of the errant ARP, try using `telnet` to connect to the IP address shown in the ARP entry. If the device supports `telnet`, the login banner might help you identify the incorrectly configured host.

Checking the Interface with `netstat`

If the primary tests lead you to suspect that the connection to the local area network is unreliable, the `netstat -i` command can provide useful information. The following example shows the output from the `netstat -i` command:

```
% netstat -i
Name Mtu   Net/Dest Address     Ipkts Ierrs Opkts Oerrs Collis Queue
le0 1500 family.com annette   442697  2   633524  2    50679   0
lo0 1536 loopback localhost  53040  0   53040    0    0        0
```

The line for the loopback interface, `lo0`, can be ignored. Only the line for the real network interface is significant, and only the last five fields on that line provide significant troubleshooting information.

Let's look at the last field first. There should be no packets queued (`Queue`) that cannot be transmitted. If the interface is up and running and the system cannot deliver packets to the network, suspect a bad drop cable or a bad interface. Replace the cable and see whether the problem goes away. If it doesn't, call the vendor for interface hardware repairs.

The input errors (`Ierrs`) and the output errors (`Oeers`) should be close to zero. Regardless of how much traffic has passed through this interface, 100 errors in either of these fields is high. High output errors could indicate a saturated local network or a bad physical connection between the host and the network. High input errors could indicate that the network is saturated, the local host is overloaded, or there is a physical network problem. Tools, such as `ping` statistics or a TDR, can help you determine whether it is a physical network problem. Evaluating the collision rate can help you determine whether the local Ethernet is saturated.

A high value in the collision field (`Collis`) is normal, but if the percentage of output packets that result in a collision is too high, it indicates that the network is saturated. Collision rates greater than 5 percent bear watching. If you consistently see high collision rates, and you see them among a broad sampling of systems on the network, you may need to subdivide the network to reduce traffic load.

Collision rates are a percentage of output packets. Don't use the total number of packets sent and received; just use `Opkts` and `Collis` when determining the collision rate. For example, the output in the earlier `netstat` example shows 50,679 collisions out of

633,424 outgoing packets. That's a collision rate of 8 percent. This sample network could be overworked; check the statistics on the other hosts on this network. If the other systems also show a high collision rate, consider subdividing this network.

Checking Routing

The `network unreachable` error message clearly indicates a routing problem. If the problem is in the local host's routing table, it is easy to detect and resolve. First, use `netstat -nr` and `grep` to see whether a valid route to your destination is installed in the routing table. This example checks for a specific route to network 128.8.0.0:

```
% netstat -nr | grep '128\.8\.0\.0'
128.8.0.0       26.20.0.16    UG     0     37     std0
```

This same test, run on a system that did not have this route in its routing table, would return no response at all. For example, a user reports that the network is down because he cannot `telnet` to `nic.ddn.mil`, and a `ping` test returns the following results:

```
% ping -s nic.ddn.mil 56 2
PING nic.ddn.mil: 56 data bytes
sendto: Network is unreachable
ping: wrote nic.ddn.mil 64 chars, ret=-1
sendto: Network is unreachable
ping: wrote nic.ddn.mil 64 chars, ret=-1

----nic.ddn.mil PING Statistics----
2 packets transmitted, 0 packets received, 100% packet loss
```

Based on the `network unreachable` error message, check the user's routing table. In our example, we're looking for a route to `nic.ddn.mil`. The IP address of `nic.ddn.mil` is 192.112.36.5, which is a Class C address. Remember that routes are network oriented. So we check for a route to network 192.112.36.0:

```
% netstat -nr | grep '192\.112\.36\.0'
%
```

This test shows that there is no specific route to 192.112.36.0. If a route was found, `grep` would display it. Because there's no specific route to the destination, remember to look for a default route. This example shows a successful check for a default route:

```
% netstat -nr | grep def
default     128.66.12.1     UG     0     101277       le0
```

If `netstat` shows the correct specific route, or a valid default route, the problem is not in the routing table. In that case, use `traceroute`, as described later in this chapter, to trace the route all the way to its destination.

If `netstat` doesn't return the expected route, it's a local routing problem. There are two ways to approach local routing problems, depending on whether the system uses static or dynamic routing. If you're using static routing, install the missing route using the `route add` command. Remember that most systems that use static routing rely on a default route, so the missing route could be the default route. Make sure that the startup files add the needed route to the table whenever the system reboots.

If you're using dynamic routing, make sure that the routing program is running. For example, the following command makes sure that `gated` is running:

```
% ps `cat /etc/gated.pid`
PID TT STAT  TIME COMMAND
27711 ?  S   304:59 gated ñtep /etc/log/gated.log
```

If the correct routing daemon is not running, restart it and specify tracing. Tracing allows you to check for problems that might be causing the daemon to terminate abnormally. The next two sections discuss RIP updates and tracing routes.

Checking RIP Updates

If the routing daemon is running and the local system receives routing updates via Routing Information Protocol (RIP), use `ripquery` to check the updates received from your RIP suppliers. For example, to check the RIP updates being received from `annette` and `bernadette`, the `bernard` administrator enters the following command:

```
% ripquery -n -r annette bernadette
44 bytes from annette.family.com(128.66.12.1):
0.0.0.0, metric 3
26.0.0.0, metric 0
   264 bytes from bernadette.family.com(128.66.12.3):
128.66.5.0, metric 2
128.66.3.0, metric 2
    .
    .
    .
128.66.12.0, metric 2
128.66.13.0, metric 2
```

After an initial line identifying the gateway, `ripquery` shows the contents of the incoming RIP packets, one line per route. The first line of the preceding report indicates that `ripquery` received a response from `annette`. That line is followed by two lines for the two routes advertised by `annette`. `annette` advertises the default route (destination 0.0.0.0) with a metric of 3, and its direct route to Milnet (destination 26.0.0.0) with a metric of 0. Next, `ripquery` shows the routes advertised by `bernadette`. These are the routes to the other family-net subnets.

The two `ripquery` options used in this example are

- `-n`—Causes `ripquery` to display all output in numeric form. `ripquery` attempts to resolve all IP addresses to names if the `-n` option is not specified. Using the `-n` option is a good idea; it produces a cleaner display, and you don't waste time resolving names.
- `-r`—Directs `ripquery` to use the `RIP REQUEST` command, instead of the `RIP POLL` command, to query the RIP supplier. `RIP POLL` is not universally supported. You are more likely to get a successful response if you specify `-r` on the `ripquery` command line.

The routes returned in these updates should be the routes that you'd expect. If they are not, or if no routes are returned, check the configuration of the RIP suppliers. Routing configuration problems cause RIP suppliers to advertise routes that they shouldn't, or to fail to advertise the routes that they should. You can detect these problems only by applying your knowledge of your network configuration. You must know what is correct to detect what is wrong. Don't expect to see error messages or strange garbled routes.

Tracing Routes

If the local routing table and RIP suppliers are correct, the problem may be occurring some distance away from the local host. Remote routing problems can cause the `no answer` error message, as well as the `network unreachable` error message. But the `network unreachable` error message does not always mean a routing problem. It can literally mean that the remote network cannot be reached because something is down between the local host and the remote host destination. `traceroute` is the program that can help you locate these problems.

`traceroute` traces the route of UDP packets from the local host to a remote host. It prints the name (if it can be determined) and IP address of each gateway along the route to the remote host.

`traceroute` uses two techniques, small *time-to-live* (ttl) values and an invalid port number, to trace packets to their destination. `traceroute` sends out UDP packets with small ttl values to detect the intermediate gateways. The ttl values start at one and increase in increments of one for each group of three UDP packets sent. When a gateway receives a packet, it decrements the ttl. If the ttl is then zero, the packet is not forwarded and an ICMP `Time Exceeded` message is returned to the source of the packet. `traceroute` displays one line of output for each gateway from which it receives a `Time Exceeded` message.

When the destination host receives a packet from `traceroute`, it returns an ICMP `Unreachable Port` message. This happens because `traceroute` intentionally uses an invalid port number (33434) to force this error. When `traceroute` receives the `Unreachable Port` message, it knows that it has reached the destination host, and it terminates the trace. In this way, `traceroute` is able to develop a list of the gateways, starting at one hop away and increasing one hop at a time, until the remote host is reached.

The following example shows a `traceroute` to `nic.ddn.mil` from a system hanging SURAnet. `traceroute` sends out three packets at each ttl value. If no response is received to a packet, `traceroute` prints an (*). If a response is received, `traceroute` displays the name and address of the gateway that responded, and the packet's round-trip time in milliseconds.

```
% traceroute nic.ddn.mil
traceroute to nic.ddn.mil (192.112.36.5), 30 hops max, 40 byte packets
1  * pgw (129.6.80.254)  4 ms  3 ms
2  129.6.1.242 (129.6.1.242)  4 ms  4 ms  3 ms
3  129.6.2.252 (129.6.2.252)  5 ms  5 ms  4 ms
4  128.167.122.1 (128.167.122.1)  50 ms  6 ms  6 ms
5  * 192.80.214.247 (192.80.214.247)  96 ms  18 ms
6  129.140.9.10 (129.140.9.10)  18 ms  25 ms  15 ms
7  nsn.sura.net (192.80.214.253)  21 ms  18 ms  23 ms
8  GSI.NSN.NASA.GOV (128.161.252.2)  22 ms  34 ms  27 ms
9  NIC.DDN.MIL (192.112.36.5)  37 ms  29 ms  34 ms
```

This trace shows that eight intermediate gateways are involved, that packets are reliably making the trip, and that round-trip travel time for packets from this host to `nic.ddn.mil` is about 33 ms.

Variations and bugs in the implementation of ICMP on different types of gateways, and the unpredictable nature of the path a datagram can take through a network, can cause some odd displays. For this reason, you shouldn't examine the output of `traceroute` too closely. The most important things in the `traceroute` output are

- Did the packet get to its destination?
- If not, where did it stop?

The following shows another trace of the path to `nic.ddn.mil`. This time the trace does not go all the way through to the NIC.

```
% traceroute nic.ddn.mil
traceroute to nic.ddn.mil (192.112.36.5), 30 hops max, 40 byte packets
1  * pgw (129.6.80.254)  3 ms  3 ms
2  129.6.1.242 (129.6.1.242)  4 ms  4 ms  4 ms
3  129.6.2.252 (129.6.2.252)  5 ms  5 ms  4 ms
4  128.167.122.1 (128.167.122.1)  6 ms  6 ms  10 ms
5  enss.sura.net (192.80.214.248)  9 ms  6 ms  8 ms
6  t3-1.cnss58.t3.nsf.net (140.222.58.2)  10 ms  15 ms  13 ms
7  t3-0.enss142.t3.nsf.net (140.222.142.1)  13 ms  12 ms  12 ms
```

```
8  GSI.NSN.NASA.GOV (128.161.252.2)  22 ms  26 ms  21 ms
9  * * *
10* * *
       .
       .
       .
29* * *
30* * *
```

When `traceroute` fails to get packets through to the remote endsystem, the trace trails off, displaying a series of three asterisks at each hop count until the count reaches 30. If this happens, contact the administrator of the remote host you're trying to reach, and the administrator of the last gateway displayed in the trace. Describe the problem to them; they may be able to help. In our example, the last gateway that responded to our packets was `GSI.NSN.NASA.GOV`. We would contact this system administrator, and the administrator of `nic.ddn.mil`.

Checking Name Service

The server problems are indicated when the `unknown host` error message is returned by the user's application. Name server problems can usually be diagnosed with `nslookup` or `dig`. `dig` is an alternative tool with similar functionality to that of `nslookup`. Before looking at `dig`, let's take another look at `nslookup` and see how it is used to troubleshoot name service.

The three features of `nslookup` that we will cover are particularly important for troubleshooting remote name server problems. These features are its ability to

- Locate the authoritative servers for the remote domain using the `NS` query
- Obtain all records about the remote host using the `ANY` query
- Browse all entries in the remote zone using `nslookup`'s `ls` and `view` commands

When troubleshooting a remote server problem, directly query the authoritative servers returned by the `NS` query. Don't rely on information returned by non-authoritative servers. If the problems that have been reported are intermittent, query all the authoritative servers in turn and compare their answers. The remote servers returning different answers to the same query sometimes cause intermittent name server problems.

The `ANY` query returns all records about a host, thus giving the broadcast range of troubleshooting information. Simply knowing what information is (and isn't) available can solve a lot of problems. For example, if the query returns an MX record but no A record, it is easy to understand why the user couldn't `telnet` to that host! Many hosts are accessible to mail that are not accessible by other network services. In this case, the user is confused and is trying to use the remote host in an inappropriate manner.

If you are unable to locate any information about the hostname that the user gave you, perhaps the hostname is incorrect. Given that the hostname you gave is wrong, looking for the correct name is like trying to find a needle in a haystack. However, `nslookup` can help. Use `nslookup`'s `ls` command to dump the remote zone file, and redirect the listing to a file. Then use `nslookup`'s `view` command to browse through the file, looking for names similar to the one the user supplied. Many problems are caused by a mistaken hostname.

An alternative to `nslookup` for making a name service query is `dig`. `dig` queries are usually entered as single-line commands, whereas `nslookup` is usually run as an interactive session. But the `dig` command performs essentially the same function as `nslookup`. Which you use is mostly a matter of personal choice. They both work well.

As an example, we'll use `dig` to ask the root server `aggie.nca&t.edu` for the NS records for the `jhu.edu` domain. To do this, enter the following command:

```
% dig @aggie.nca&t.edu jhu.edu ns
```

In this example, `@aggie.nca&t.edu` is the server that is being queried. Name or IP address can identify the server. If you're troubleshooting a problem in a remote domain, specify an authoritative server for that domain. In this example we're asking for the names of servers for a top-level domain (`jhu.edu`), so we ask a root server.

Troubleshooting the Network Interface

Although there doesn't seem to be much at this layer, it is possible for things to go wrong at the bottom of the stack. There are basically four problems you might run into at this level:

- **Physical connectivity.** As with all networking, TCP/IP works better if it is plugged in. All networks require that the system be connected to the network, so always check the cable.
- **No IP address was assigned to the DHCP client.** This should be obvious to the user because a large message appears. There are two ways you can receive an IP address. You can statically configure an IP address, or you can dynamically obtain an IP address from a DHCP (Dynamic Host Configuration Protocol) server. However, you should always verify that an IP address is assigned by using the `IFCONFIG` utility in Unix, the `WINIPCFG` utility in Windows 9x, or the `IPCONFIG` utility in Windows NT/2000.

- **ARP problem.** If the address resolution protocol is not functioning properly, you will not be able to resolve an IP address to a MAC address. The `ARP` utility, described earlier in this chapter, allows you to verify the ability to resolve addresses.
- **Duplicate IP addresses are on the network.** Another problem you can run into occurs when two systems on the network share the same IP address. This is not supposed to happen; but if it does, your system may resolve the MAC address to one system at first and to the other the next time.

The only case in which you should have a problem with the ARP is if a static resolution is added to the ARP cache, which might be done for performance purposes. However, if the network adapter is changed in the system for which the IP address was entered, the mapping will cause problems. You can check for this problem using `ARP`.

Troubleshooting the Network (IP) Layer

As you should recall, the Internet Layer is responsible for the routing of packets. This is where you will need to carefully check the IP address, subnet mask, and default gateway. In addition to the configuration, there may be problems with the routing table or with a router somewhere between your system and the system you are attempting to communicate with.

TCP/IP Configuration Parameters

Three main parameters specify how TCP/IP is configured: the IP address, the subnet mask, and the default gateway, which is usually the router's interface to your particular segment. These parameters are configured in a Windows environment through the Protocols tab of the Network dialog box, as opposed to the command-line entry using `ifconfig` in a Unix environment. Although receiving an IP address from a DHCP server is possible, for the moment this discussion focuses on parameters that are manually configured.

The three TCP/IP parameters must be configured correctly or you will not be able to connect with TCP/IP. An incorrect configuration can result from typographical errors; if you type the wrong IP address, subnet mask, or default gateway, you may not connect properly or at all.

Whether the TCP/IP configuration parameters are wrong due to a typo or due to a mistaken number, the incorrect parameters affect communications. Different types of problems occur when the different parameters have a configuration error. Identifying and fixing the errors are covered in the following sections.

IP Address Configuration Problems

An incorrect TCP/IP address might not cause any problems. If you configure an IP address that is on the correct subnet and is not a duplicate, but it uses the wrong host ID, the client may be able to communicate just fine. If, however, the correct IP address has been entered in a static file or database that resolves hostnames to IP addresses, such as an `LMHOSTS` file or a DNS database file, there are going to be some communication problems. Typically, therefore, an incorrect IP address causes some problems.

Incorrect configuration of the TCP/IP parameters can cause different symptoms for each type of parameter. The following sections examine the effects that each TCP/IP parameter can have on IP communications.

IP Address

A TCP/IP address has two or possibly three components that uniquely identify the computer the address is assigned to. At the very least, the IP address specifies the network address and host address of the computer. Also, if you are subnetting, the third part of the address specifies the subnet address of the host.

Figure 44.1 shows the effect of an incorrect network address. In this example, the TCP/IP address assigned to a client is typed incorrectly. The address assigned to the client is 143.168.2.9, whereas the correct address was supposed to be 133.168.3.9. The network ID for the incorrect address is 143.168.x.x, whereas the network ID for the correct address should be 133.168.x.x.

With this incorrect address (143.168.3.9), the client is not able to communicate with any other TCP/IP hosts. Because the network address is incorrect, any packets this client sends will be routed to the wrong location.

If the incorrect host (143.168.3.9) sends a message to a local client (133.168.3.20), the TCP/IP configuration of the sending host indicates this is a remote address because it doesn't match the network address of the host initiating the communication. The packet won't ever reach the local client because the address 133.168.3.20 is interpreted as a remote address.

If a local client (133.168.3.6) sends a message to the incorrect host (143.168.3.9), the message never reaches its intended destination. The message is either routed (if the local client sends the message to the IP address as written) or it stays on the local subnet (if the local client sends it to what should have been the address, 133.168.3.9). If the message is routed, the incorrect client does not receive the message because it is on the same segment of the network as the local client. If the message is not routed, the message still does not reach the incorrect client because the IP address of the destination host (133.168.3.9) does not match the address as configured on the incorrect client (143.168.3.9).

FIGURE 44.1
An example of the effect of an incorrect IP address.

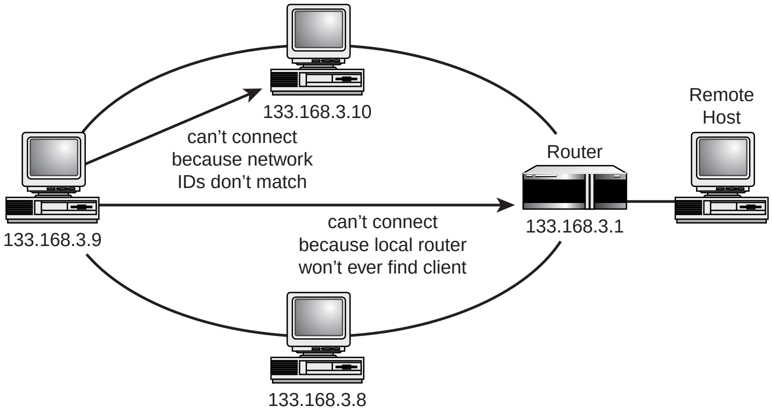
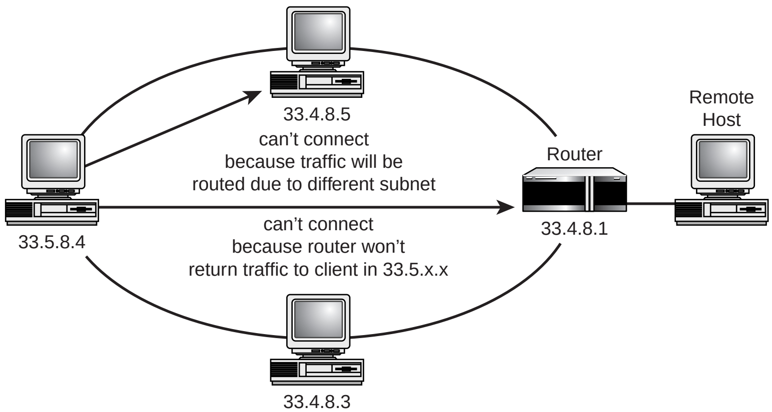


Figure 44.2 gives another example of an incorrect IP address. In this case, a Class A address is used (33.x.x.x). The subnet mask (255.255.0.0) indicates the second octet is being used to create subnets. In this case, even though the client has the same network address as the other clients on the same subnet, the client has a different subnet number because the address was typed incorrectly.

This time the incorrect address specifies the wrong subnet ID. The client 33.5.8.4 is on subnet 5 while the other clients on the subnet have the address 33.4.x.x. In this case, if the client 33.5.8.4 tries to contact other clients on the same subnet, the message is routed because the subnet ID doesn't match the subnet number of the source host. If the client 33.5.8.4 tries to send a message to a remote host, the message is routed; however, the message isn't returned to the client because the router doesn't handle subnet 5—it only handles subnet 4.

FIGURE 44.2
An example of the IP address returning an incorrect subnet ID.



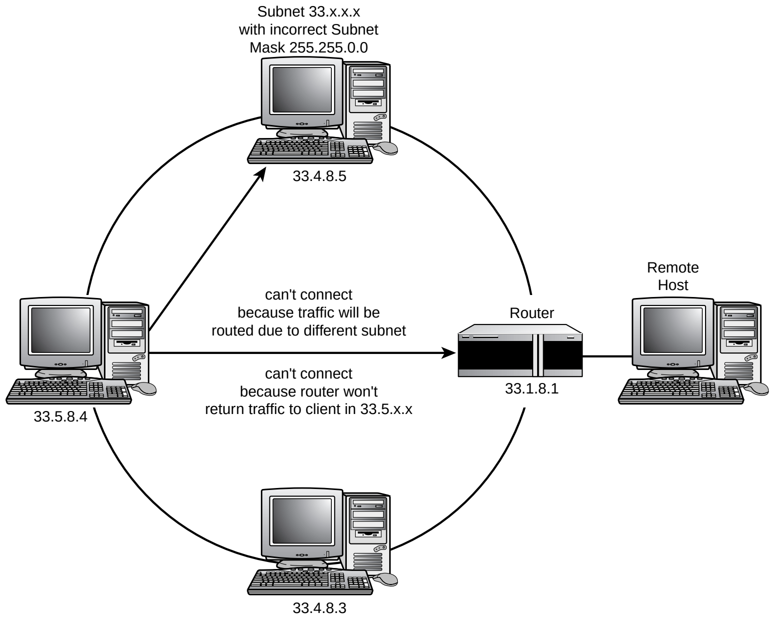
If a local client tries to send a message to 33.5.8.4, the message doesn't reach the client. If the local client uses the address as configured, the message is routed, which isn't the correct solution because the intended destination host is local. If the local client sends the message to what should have been the IP address, 33.5.8.4 doesn't receive the message because the IP address isn't configured correctly.

The last component of an IP address that can cause communication problems is the host address. An incorrect host address may not always cause a problem, however. In Figure 44.3, a local client has the wrong IP address, but only the host address portion of the address is wrong. The network address and subnet match the rest of the clients on the subnet.

In this case, if a client sends a message to the client with the incorrect address, the message still reaches the client. However, if someone tries to contact the client with what should have been the address, he cannot. In fact, he could contact another host that ended up with the address that was supposed to have been given to the original host.

If the original host ends up with the same IP address as another host through the configuration error, the first client to start up works, but the second client to start up may note the address conflict and not load the TCP/IP stack at all. In this case, the second client to start up isn't able to make any TCP/IP communications.

FIGURE 44.3
An example of the effect of an incorrect IP address giving the wrong host ID.



Another problem arises when the correct address is registered in static files, such as an LMHOSTS file or a DNS database. In this case, no one can communicate with this client by name because the name resolution for this host always returns the correct address, which can't be used to contact the host because the address has been typed incorrectly.

Basically, the problems you encounter with an incorrect host address are intermittent. However, if the host was configured to be a WINS client (using a Windows operating system, not Unix), the hostname is registered along with the incorrect address. Another WINS client trying to connect with this computer receives an accurate mapping for the hostname.

Subnet Mask

The subnet mask indicates which portion of the IP address specifies the network address and the host address. Also, the subnet mask can be used to divide part of what would have been the host address into subnets. If the subnet mask is not configured correctly, your clients may not be able to communicate at all, or you may see partial communication problems.

Figure 44.4 shows a subnet on a TCP/IP network that uses a Class B network address of 138.13.x.x. However, the third octet is used in this case for subnetting, so all the clients in the figure should be on subnet 4, as indicated by the common addresses 138.13.4.x.

Unfortunately, the subnet mask entered for one client is 255.255.0.0. When this client tries to communicate with other hosts on the same subnet, he should be able to contact them because the subnet mask indicates they are on the same subnet, which is correct. However, if the client tries to contact a host on another subnet, such as 138.13.3.x, the client fails.

In this case, the subnet mask still interprets the destination host to be on the same subnet, and the message is never routed. Because the destination host is on another subnet, the message never reaches the intended destination. The subnet mask is used to determine routing for outgoing communications, so the client with the incorrect subnet mask can receive incoming messages. However, when the client tries to return communications, the message isn't routed if the source host is on the same network but on a different subnet.

So, in actuality, the client really can establish communications with only one side of the conversation. Contacts with hosts outside the local network still work because they are routed.

FIGURE 44.4
Even if the IP address is right, the wrong subnet ID can be used because of the subnet mask.

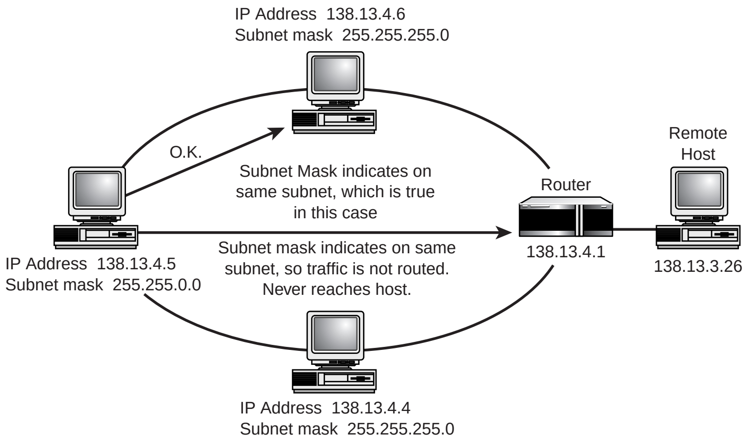


Figure 44.5 shows a subnet mask that masks too many bits. In this case, the subnet mask is 255.255.255.0. However, the network designers had intended the subnet mask to be 255.255.240.0, with four bits of the third octet used for the subnet and four bits as part of the host address.

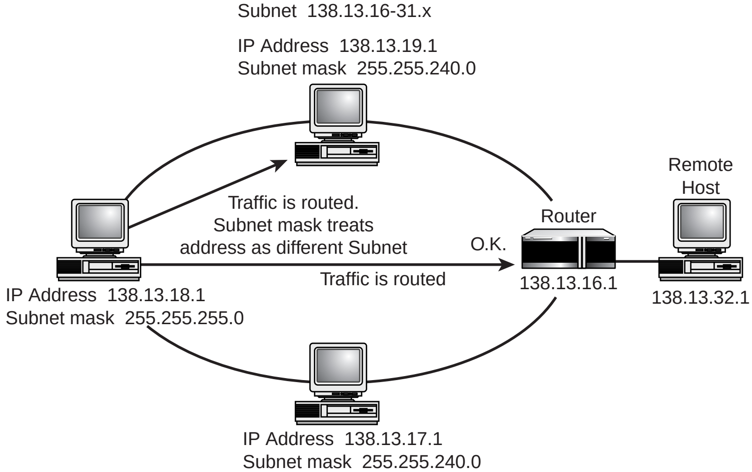
If the correctly configured client tries to send a message to a local host and the third octet is the same, the message is not routed and, thus, reaches the local client. However, if the local client has an address that differs in the last four bits of the third octet, the message is routed and never reaches its destination. If the incorrectly configured client tries to send a message to another client on another subnet, the message is routed because the third octet is different.

Problems with the subnet mask also lead to intermittent connections: Sometimes the connection works, sometimes it doesn't. The problems show up when the IP address of the destination host causes a packet to be routed when it shouldn't, or to remain local when it should be routed.

Default Gateway

The default gateway address is the address of the router—the gateway to the world beyond the local subnet. If a client's default gateway address is wrong, it can contact local hosts but is not able to communicate at all beyond the local subnet. It is possible for the incorrect client to receive a message because the default gateway is used only to send packets to other hosts. However, as soon as the incorrect client attempts to respond to the incoming message, the default gateway address doesn't work and the message doesn't reach the host that sent the original message.

FIGURE 44.5
Communication problems will occur if the subnet mask uses too many bits.



Troubleshooting TCP and UDP

There is little to worry about at the Transport Layer. If you can `ping`, your Transport Layer should be functioning properly. The only problem that you will normally have at this layer concerns the `TCPWindowSize` discussed in Chapter 9, "Overview of the IP Family of Protocols."

This problem will typically result in slow communication speed (similar to the 110-baud terminals used in the 1970s and '80s). However, if you have verified everything up to this point, a quick way to check `TCPWindowSize` (in Windows NT/2000, for example) is to open the Registry and see whether a Window Size entry exists. If you see an entry, make a note of the setting and then delete the value. This will reset the window size to its default.

Sockets Problems

Assuming that you have the correct IP address and protocol, and that you are able to find a route to the remote computer, it will need to be running the service you are looking for on the correct socket. If you are providing services to the network or trying to connect to a service on the network, you need to know which port number to use.

The *Internet Assigned Numbers Authority* (IANA) assigns the common port (socket) numbers; however, in some cases the service might use a different port. There is a file (described in the following section) that you will want to check to verify that the correct port is used. After you verify this, you can use the `NETSTAT` command to verify that the port is ready to receive data.

The Services File

Located in the `system32\drivers\etc` directory of Windows NT/2000 is a services file, which is used by most of the services that initialize the socket numbers they use when they initialize. The following is a small portion of a services file:

```
#

#   This file contains port numbers for well-known services as
# defined by RFC 1060 (Assigned Numbers).

#


#   Format:

#


#   <service name>   <port number>/<protocol>   [aliasesÖ]   [#<comment>]
#
echo          7/tcp

echo          7/udp

discard          9/tcp        sink null
discard          9/udp        sink null
systat        11/tcp

systat        11/udp        users

daytime        13/tcp

daytime        13/udp

netstat        15/tcp

qotd        17/tcp        quote

qotd        17/udp        quote

chargen        19/tcp        ttytst source

chargen        19/udp        ttytst source
ftp-data        20/tcp

ftp        21/tcp

telnet        23/tcp
```

```
smtp        25/tcp        mail

time        37/tcp        timeserver

time        37/udp        timeserver

rlp        39/udp        resource           #  resource location
name        42/tcp        nameserver
name        42/udp                  nameserver
whois        43/tcp        nicname           #  usually to sri-nic
domain        53/tcp        nameserver        #  name-domain server
domain        53/udp        nameserver
nameserver    53/tcp        domain            #  name-domain server
nameserver    53/udp        domain
mtp        57/tcp                   #  deprecated         bootp
67/udp                    # boot program server        tftp       69/udp
```

If you are having problems with particular services, you should check this file if they are listed to make sure the correct port is used. If a service is not listed, you may need to add it so that the system knows which port to initialize the service on. (This is a normal text file that can be viewed and edited using either Edit or Notepad.)

Troubleshooting the Application Layer

Finally you come to the Application Layer, where you will want to verify communications. There are two main problems you may encounter at this layer: NetBIOS problems and name resolution problems. By far the most common problem will be name resolution problems, which affect both socket applications and NetBIOS applications. In the next sections, these name resolution problems will be reviewed.

Name Resolution Problems

If you have configured TCP/IP correctly and the protocol is installed and working, the problem with connectivity is probably due to errors in resolving hostnames. When you test connectivity with TCP/IP addresses, you are testing a lower level of connectivity than users generally use.

When users want to connect to a network resource—to map a drive to a server to connect to a Web site, for example—they usually refer to that server or Web site by its name rather than its TCP/IP address. In fact, users do not usually know the IP address of a particular server. The name used to establish a connection, however, must be resolved down to an IP address so that the networking software can make a connection.

After you've tested the IP connectivity, the next logical step is to check the resolution of a name down to its IP address. If a name cannot be resolved to its IP address, or if it is resolved to the wrong address, users will not be able to connect to the network resource with that name, even if they can connect to it using an IP address.

As you know, two types of computer names are used when communicating on a network: A NetBIOS name is assigned to a NetBIOS computer, such as a Windows NT/2000 server or a Windows 9x system; and a hostname is assigned to non-NetBIOS computers, such as a Unix server. In general, when using Microsoft networking to connect to a server for file sharing, print sharing, or applications, for example, you refer to that computer by its NetBIOS name. But when you execute a TCP/IP-specific command as you do when using FTP or a Web browser, you refer to that computer by its hostname.

Summary

Problems caused by bad TCP/IP configurations are much more common than problems caused by bad TCP/IP protocol implementations. Most of the problems you encounter will succumb to analysis using the simple tools we have already discussed. But on occasion, you may need to analyze the protocol interaction between two systems. In the worst case, you may need to analyze the packets in the data stream bit by bit.

Appendixes

Part X

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B Abbreviations and Acronyms *1039*

APPENDIX A

RFCs and Standards

by Tim Parker

IN THIS APPENDIX

- **Accessing RFCs** *1026*
- **Useful RFCs Sorted by General Category** *1027*
- **List of RFCs by Number** *1037*

Most of the information about the TCP/IP protocol family is published as *Requests for Comments* (RFCs). RFCs define the various aspects of the protocol, the protocol's use, and the management of the protocol as a set of loosely coordinated notes.

There is a lot of useless information (mostly because it is system-specific or considerably outdated) in the RFCs, but there is also a wealth of detail. Unexpectedly, there is quite a bit of interesting and humorous reading in the RFCs, including several classic works such as "'Twas the Night Before Start-up" (RFC 968), "ARPAWOCKY" (RFC 527), and "TELNET Randomly-Lose Option" (RFC 748).

This appendix lists the important or interesting RFCs which readers may want to refer to. Instructions for accessing the RFCs are also included. This list is not complete; old and outdated RFCs have been dropped from the list.

Accessing RFCs

RFCs can be obtained in several ways, the easiest of which is electronically. Paper copies are available, upon request. Electronic copies are usually in ASCII format, although some are in PostScript format and require a PostScript interpreter to print them. Most RFCs obtained electronically don't have diagrams, figures, or pictures.

Accessing RFCs Through the Web

Many sites catalog RFCs on the World Wide Web. The easiest way to find them is to use a search engine with the search string "RFC". Most sites present simple lists of the RFCs in numerical order, but some do provide a breakdown of interesting subjects (although the lists tend not to be complete). For the official RFC index, visit the site
`http://www.rfc-editor.org`

Accessing RFCs Through FTP

RFCs can be obtained using FTP through the Internet *Network Information Center* (NIC) or one of several other FTP sites. Use FTP to access the NIC archive `NIC.DDN.MIL`. Use the user name `guest` and the password `anonymous`. RFCs can then be retrieved by using the FTP `get` command with the following format:

```
<RFC>RFC527.txt
```

Replace the `RFC527` portion with the number of the RFC required. You can only FTP into the NIC archive if you have access to a machine with Internet access.

Accessing RFCs Through Email

RFCs can be requested through electronic mail. Both the NIC and the NFSNET Network Service Center provide automated responses, returning the requested RFC. Both services read incoming electronic mail for keywords that indicate which RFC is required, as well as the sender's e-mail address, and then send back the RFC requested.

To obtain an RFC from the NIC, send a message with the subject field set to the RFC that you want. Mail it to `service@nic.ddn.mil`. If you want more information on obtaining information through the NIC e-mail system, send mail with the word `help` as the subject.

To obtain RFCs from the NFSNET Network Service Center, send a message with the first two lines like this:

```
REQUEST: RFC
TOPIC: 527
```

The first line specifies that you want an RFC and the second line gives the RFC number. Send the mail to `info-server@sh.cs.net`. For more information, set the topic to `help`.

Accessing Printed Copies of RFCs

You might not have access to electronic communications, so a preprinted copy of an RFC must be requested. To obtain a printed copy of any RFC, call the Network Information Center at 1-800-235-3155.

It is considered bad manners to make the NIC staff wait while you find which RFCs you want. Make a list first so your telephone conversation is short and succinct. The staff must answer many calls a day and are usually quite busy.

Useful RFCs Sorted by General Category

The list that follows includes most of the RFCs that provide either details of the protocols and their usage, or more general information about a particular subject to do with TCP/IP. There are many RFCs not included in this list, both because they have been superseded and are obsolete, or because they have nothing of interest to TCP/IP. The list is, admittedly, one chosen by the author of this book based on my own preferences. With that in mind, you might want to check the entire list of RFCs if you don't find what you are looking for.

General Information

RFC1340	"Assigned Numbers," Reynolds, J.K.; Postel, J.B.; 1992
RFC1360	"IAB Official Protocol Standards," Postel, J.B.; 1992
RFC1208	"Glossary of Networking Terms," Jacobsen, O.J.; Lynch, D.C.; 1991
RFC1180	"TCP/IP Tutorial," Socolofsky, T.J.; Kale, C.J.; 1991
RFC1178	"Choosing a Name For Your Computer," Libes, D.; 1990
RFC1175	"FYI on Where to Start: A Bibliography of Internetworking Information," Bowers, K.L.; LaQuey, T.L.; Reynolds, J.K.4 Reubicek, K.; Stahl, M.K.; Yuan, A; 1990
RFC1173	"Responsibilities of Host and Network Managers: A Summary of the 'Oral Tradition' of the Internet," vanBokkelen, J.; 1990
RFC1166	"Internet Numbers," Kirkpatrick, S.; Stahl, M.K.; Recker, M.; 1990
RFC1127	"Perspective on the Host Requirements RFCs," Braden, R.T.; 1989
RFC1123	"Requirements for Internet Hosts—Application and Support," Braden, R.T., ed; 1989
RFC1122	"Requirements for Internet Hosts—Communication Layers," Braden, R.T., ed; 1989
RFC1118	"Hitchhiker's Guide to the Internet," Krol, E.; 1989
RFC1011	"Official Internet Protocol," Reynolds, J.R.; Postel, J.B.; 1987
RFC1009	"Requirements for Internet Gateways," Braden, R.T.; Postel, J.B.; 1987
RFC980	"Protocol Document Order Information," Jacobsen, O.J.; Postel, J.B.; 1986

TCP and UDP

RFC1072	"TCP Extensions for Long-Delay Paths," Jacobson, V.; Braden, R.T.; 1988
RFC896	"Congestion Control in IP/TCP Internetworks," Nagle, J.; 1984
RFC879	"TCP Maximum Segment Size and Related Topics," Postel, J.B.; 1983

RFC813	"Window and Acknowledgment Strategy in TCP," Clark, D.D.; 1982
RFC793	"Transmission Control Protocol," Postel, J.B.; 1981
RFC768	"User Datagram Protocol," Postel, J.B.; 1980

IP and ICMP

RFC1219	"On the Assignment of Subnet Numbers," Tsuchiya, P.F.; 1991
RFC1112	"Host Extensions for IP Multicasting," Deering, S.E.; 1989
RFC1088	"Standard for the Transmission of IP Datagrams over NetBIOS Networks," McLaughlin, L.J.; 1989
RFC950	"Internet Standard Subnetting Procedure," Mogul, J.C.; Postel, J.B.; 1985
RFC932	"Subnetwork Addressing Schema," Clark, D.D.; 1985
RFC922	"Broadcasting Internet Datagrams in the Presence of Subnets," Mogul, J.C.; 1984
RFC9l9	"Broadcasting Internet Datagrams," Mogul, J.C.; 1984
RFC886	"Proposed Standard for Message Header Munging," Rose, M.T.; 1983
RFC815	"IP Datagram Reassembly Algorithms," Clark, D.D.; 1982
RFC814	"Name, Addresses, Ports, and Routes," Clark, D.D.; 1982
RFC792	"Internet Control Message Protocol," Postel, J.B.; 1981
RFC791	"Internet Protocol," Postel, J.B.; 1981
RFC781	"Specification of the Internet Protocol (IP) Timestamp Option," Su, Z.; 1981

Lower Layers

RFC1236	"IP to X.121 Address Mapping for DDN IP to X.121 Address Mapping for DDN," Morales, L.F. Jr.; 1991
RFC1220	"Point-to-Point Protocol Extensions for Bridging," Baker, F., ed.; 1991
RFC1209	"Transmission of IP Datagrams over the SMDS Service," Piscitello, D.M.; Lawrence, J.; 1991
RFC1201	"Transmitting IP Traffic over ARCNET Networks," Provan, D.; 1991

RFC1188	"Proposed Standard for the Transmission of IP Datagrams over FDDI Networks," Katz, D.; 1990
RFC1172	"Point-to-Point Protocol Initial Configuration Options," Perkins, D.; Hobby, R.; 1990
RFC1171	"Point-to-Point Protocol for the Transmission of Multi-Protocol Datagrams over Point-to-Point Links," Perkins, D.; 1990
RFC1149	"Standard for the Transmission of IP Datagrams on Avian Carriers," Waitzman, D.; 1990 (April 1 release!)
RFC1055	"Nonstandard for Transmission of IP Datagrams over Serial Lines: SLIP," Romkey, J.L.; 1988
RFC1044	"Internet Protocol on Network System's HYPERchannel: Protocol Specification," Hardwick, K.; Lekashman, J.; 1988
RFC1042	"Standard for the Transmission of IP Datagrams over IEEE 802 Networks," Postel, J.B.; Reynolds, J.K.; 1988
RFC1027	"Using ARP to Implement Transparent Subnet Gateways," Carl-Mitchell, S.; Quarterman, J.S.; 1987
RFC903	"Reverse Address Resolution Protocol," Finlayson, R.; Mann, T.; Mogul, J.C.; Theimer, M.; 1984
RFC895	"Standard for the Transmission of IP Datagrams over Experimental Ethernet Networks," Postel, J.B.; 1984
RFC894	"Standard for the Transmission of IP Datagrams over Ethernet Networks," Hornig, C.; 1984
RFC893	"Trailer Encapsulations," Leffler, S.; Karels, M.J.; 1984
RFC877	"Standard for the Transmission of IP Datagrams over Public Data Networks," Korb, J.T.; 1983

Bootstrapping

RFC1084	"BOOTP Vendor Information Extensions," Reynolds, J.K.; 1988
RFC951	"Bootstrap Protocol," Croft, W.J.; Gilmore, J.; 1985
RFC906	"Bootstrap Loading Using TFTP," Finlayson, R.; 1984

Domain Name System

RFC1035	"Domain Names—Implementation and Specification," Mockapetris, P.V.; 1987

RFC1034	"Domain Names—Concepts and Facilities," Mockapetris, P.V.; 1987
RFC1033	"Domain Administrators Operations Guide," Lottor, M.; 1987
RFC1032	"Domain Administrators Guide," Stahl, M.K.; 1987
RFC1101	"DNS Encoding of Network Names and Other Types," Mockapetris, P.V.; 1989
RFC974	"Mail Routing and the Domain System," Partridge, C.; 1986
RFC920	"Domain Requirements," Postel, J.B.; Reynolds, J.K.; 1984
RFC799	"Internet Name Domains," Mills, D.L.; 1981

File Transfer and File Access

RFC1094	"NFS: Network File System Protocol Specification," Sun; 1989
RFC1068	"Background File Transfer Program (BFTP)," DeSchon, A.L.; Braden, R. T.; 1988
RFC959	"File Transfer Protocol," Postel, J.B.; Reynolds, J.K.; 1985
RFC949	"FTP Unique-Named Store Command," Padlipsky, M.A.; 1985
RFC783	"TFTP Protocol (Revision 2)," Sollins, K.R.; 1981
RFC775	"Directory-Oriented FTP Commands," Mankins, D.; Franklin, D.; Owen, A.D.; 1980

Mail

RFC1341	"MIME (Multipurpose Internet Mail Extensions) Mechanisms for Specifying and Describing the Format of Internet Message Bodies," Borenstein, N.; Freed, N.; 1992
RFC1143	"Q Method of Implementing Telnet Option Negotiation," Bernstein, D.J.; 1990
RFC1090	"SMTP on X.25," Ullmann, R.; 1989
RFC1056	"PCMAIL: A Distributed Mail System for Personal Computers," Lambert, M.L.; 1988
RFC974	"Mail Routing and the Domain System," Partridge, C.; 1986
RFC822	"Standard for the Format of ARPA Internet Text Messages," Crocker, D.; 1982
RFC821	"Simple Mail Transfer Protocol," Postel, J.B.; 1982

Routing Protocols

RFC1267	"A Border Gateway Protocol 3 (BGP-3)," Lougheed, K.; Rekhter, Y.; 1991
RFC1247	"OSPF Version 2," Moy, J.; 1991
RFC1222	"Advancing the NSFNET Routing Architecture," Braun, H.W.; Rekhter, Y. 1991
RFC1195	"Use of OSI IS-IS for Routing in TCP/IP and Dual Environments," Callon, R.W.; 1990
RFC1164	"Application of the Border Gateway Protocol in the Internet," Honig, J.C.; Katz, D.; Mathis, M.; Rekhter, Y.; Yu, J.Y.; 1990
RFC1163	"Border Gateway Protocol (BGP)," Lougheed, K.; Rekhter, Y.; 1990
RFC1074	"NSFNET Backbone SPF-based Interior Gateway Protocol," Rekhter, J.; 1988
RFC1058	"Routing Information Protocol," Hedrick, C.L.; 1988
RFC904	"Exterior Gateway Protocol Formal Specification," Mills, D.L.; 1984
RFC827	"Exterior Gateway Protocol (EGP)," Rosen, E.C.; 1982
RFC823	"DARPA Internet Gateway," Hinden, R.M.; Sheltzer, A.; 1982
RFC1136	"Administrative Domains and Routing Domains: A Model for Routing in the Internet," Hares, S.; Katz, D.; 1989
RFC911	"EGP Gateway under Berkeley Unix 4.2," Kirton, P.; 1984
RFC888	"STUB Exterior Gateway Protocol," Seamonson, L.; Rosen, E.C.; 1984

Routing Performance and Policy

RFC1254	"Gateway Congestion Control Survey," Mankin, A.; Ramakrishnan, K.K., eds.; 1991
RFC1246	"Experience with the OSPF Protocol," Moy, J., ed.; 1991
RFC1245	"OSPF Protocol Analysis," Moy, J., ed; 1991
RFC1125	"Policy Requirements for Inter-Administrative Domain Routing," Estrin, D.; 1989
RFC1124	"Policy Issues in Interconnecting Networks," Leiner, B.M.; 1989

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List of RFCs by Number

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APPENDIX B

Abbreviations and Acronyms

by Tim Parker

ABI Application Binary Interface

ACB Access Control Block

ACIA Asynchronous Communications Interface Adapter

ACK Acknowledgment

AD Active Directory

AF Address Family

AFP AppleTalk Filing Protocol

AFS Andrew File System

AIX Advanced Interactive Executive (IBM Unix)

ANSI American National Standards Institute

AOCE Apple Open Collaborative Environment

API Application Programming Interface

APPC Advanced Program-to-Program Communications

APPN Advanced Peer-to-Peer Networking

ARA AppleTalk Remote Access

ARP Address Resolution Protocol

ARPA Advanced Research Projects Agency

AS Autonomous System

ASA American Standards Association

ASCII American National Standard Code for Information Interchange

ASN.1 Abstract Syntax Notation One

ASPI Advanced SCSI Programming Interface

ATM Adobe Type Manager

ATM Asynchronous Transfer Mode

AUI Attachment Unit Interface

A/UX Apple Unix

BBLT Bus Block Transfer

BBN Bolt, Beranek, and Newman, Incorporated

BER Basic Encoding Rules

BER Bit Error Rate

BGP Border Gateway Protocol

BIOS Basic Input/Output System

BISDN Broadband ISDN (Integrated Services Digital Network)

BITBLT Bit Block Transfer

BITNET Because It's Time Network

BSD Berkeley Software Distribution

CAMMU Cache/Memory Management Unit

CBLT Character Block Transfer

CCITT Consultative Committee on International Telegraphy and Telephony (translated from French)

CDE Common Desktop Environment

CDMA Code Division Multiple Access

CLI Call-Level Interface

CLI Command-Line Interpreter

CMC Common Messaging Calls

CMIP Common Management Information Protocol

CMIS Common Management Information Services

CMOT Common Management Information Services and Protocol over TCP/IP

CORBA Common Object Request Broker Architecture

COSE Common Open Software Environment

CPU Central Processing Unit

CRC Cyclic Redundancy Check

CREN Consortium for Research and Education Network

CSMA/CD Carrier Sense Multiple Access with Collision Detection

CSNET Computer Science Network

CUA Common User Access

DARPA Defense Advanced Research Projects Agency

DARPANET Defense Advanced Research Projects Agency Network

DAT Digital Audio Tape

DBMS Database Management System

DCA Defense Communications Agency

DCE Data Circuit-terminating Equipment (also called Data Communications Equipment)

DCE Distributed Computing Environment

DDBMS Distributed DBMS (Database Management System)

DDE Dynamic Data Exchange

DDN Defense Data Network

DES Data Encryption Standard

DFS Distributed File Service

DHCP Dynamic Host Configuration Protocol

DIF Data Interchange Format

DIME Dual Independent Map Encoding

DISA Defense Information Systems Agency

DIX Digital, Intel, and Xerox Ethernet Protocol

DLL Dynamic Link Library

DLP Data Link Protocol

DME Distributed Management Environment

DNS Domain Name System

DOE Distributed Objects Everywhere

DSA Directory System Agent

DSAP Destination Service Access Point

DTE Data Terminal Equipment

DTMF Dual-Tone Multifrequency

DUA Directory User Agent

DVI Digital Video Interactive

EBCDIC Extended Binary Coded Decimal Interchange Code

ECC Error Correction Code

ECM Error Correction Mode

EGP Exterior Gateway Protocol

ENS Enterprise Network Services

EOF End of File

EOR End of Record

ERLL Enhanced Run Length Limited

ESDI Enhanced Small Device Interface

FAT File Allocation Table

FCS Frame Check Sequence

FDDI Fiber Distributed Data Interface

FIN Final Segment

FTAM File Transfer, Access, and Management

FTAM File Transfer Access Method

FTP File Transfer Protocol

GGP Gateway-to-Gateway Protocol

GIF Graphics Interchange Format

GOSIP Government Open Systems Interconnection Profile

GPF General Protection Fault

GPI Graphics Programming Interface

GTF Generalized Trace Facility

GUI Graphical User Interface

HAL Hardware Abstraction Layer

HDLC High-level Data Link Control Protocol

HDX Half Duplex

HFS Hierarchical File System

HIPPI High Performance Parallel Interface (also called HPPI)

HOB High Order Byte

HPFS High Performance File System

HPPI High Performance Parallel Interface (also called HIPPI)

HTTP Hypertext Transport Protocol

IAB Internet Activities Board

IAB Internet Architecture Board

IAC Interapplication Communication

IAC Interpret as Command

IANA Internet Assigned Numbers Authority

ICMP Internet Control Message Protocol

ID Identifier

IDE Integrated Drive Electronics

IEEE Institute of Electrical and Electronic Engineers

IEN Internet Engineering Notes

IESG Internet Engineering Steering Group

IETF Internet Engineering Task Force

IFF Interchange File Format

IGMP Internet Group Management Protocol

IGP Interior Gateway Protocol

IMAP Interactive Mail Access Protocol

INT Interrupt

IP Internet Protocol

IPC Interprocess Communications

IPX/SPX Internet Packet Exchange/Sequenced Packet Exchange

IRC Interrupt Request Controller

IRQ Interrupt Request

IRTF Internet Research Task Force

ISDN Integrated Services Digital Network

IS-IS Intermediate System to Intermediate System Protocol

ISN Initial Sequence Number

ISO International Organization for Standardization

ISODE ISO Development Environment

JPEG Joint Photographic Experts Group

KB Kilobyte (1024 bytes)

LAN Local Area Network

LAPB Link Access Procedures Balanced

LAPD Link Access Procedures on the D-channel

LLC Logical Link Control

LOB Low Order Byte

LSB Least Significant Bit (or Byte)

LSD Least Significant Digit

MAC Media Access Control

MAN Metropolitan Area Network

MAPI Messaging API (Application Programming Interface)

MAU Medium Access Unit

MFC Microsoft Foundation Classes

MFS Macintosh File System

MHS Message Handling Service

MIB Management Information Base

MILNET Military Network

MIME Multipurpose Internet Mail Extensions

MNP Microcom Networking Protocol

MSB Most Significant Bit (or Byte)

MSS Maximum Segment Size

MTA Message Transfer Agent

MTU Maximum Transmission Unit

MTU Message Transfer Unit

MX Mail Exchanger

NAU Network Access Unit

NDIS Network Driver Interface Specification

NDS NetWare (or Novell) Directory Service

NETBIOS Network Basic Input/Output System

NETBEUI NetBIOS Extended User Interface

NFS Network File System

NIC Network Information Center

NIC Network Interface Card

NIS Network Information Service

NIST National Institute of Standards and Technology

NIU Network Interface Unit

NLM NetWare Loadable Module

NMI Nonmaskable Interrupt

NNTP Network News Transport Protocol

NOS Network Operating System

NREN National Research and Education Network

NSAP Network Service Access Point

NSFNET National Science Foundation Network

NVT Network Virtual Terminal

ODAPI Open Database API (Application Programming Interface)

ODI Open Datalink Interface

ONC Open Network Computing

OSF Open Software Foundation

OSI Open Systems Interconnect

OSPF Open Shortest Path First

PAD Packet Assembly/Disassembly

PCMCIA Personal Computer Memory Card International Association

PDU Protocol Data Unit

PI Protocol Interpreter

PING Packet Internet Groper

POP Post Office Protocol

POTS Plain Old Telephone Service

PPP Point-to-Point Protocol

QIC Quarter-Inch Cartridge

RARP Reverse Address Resolution Protocol

RFC Request For Comment

RFS Remote File System

RIP Routing Information Protocol

RMON Remote Network Monitor

RPC Remote Procedure Call

RST Reset

RTT Round Trip Time

SAP Service Access Point

SDLC Synchronous Data Link Communication

SLIP Serial Line Interface Protocol

SMDS Switched Multimegabit Data Service

SMTP Simple Mail Transfer Protocol

SNA Systems Network Architecture

SNMP Simple Network Management Protocol

SONET Synchronous Optical Network

SPF Shortest Path First

SSAP Source Service Access Point

SSCP System Services Control Point

SYN Synchronizing Segment

TCB Transmission Control Block

TCP Transmission Control Protocol

TCP/IP Transmission Control Protocol/Internet Protocol

TCU Trunk Coupling Unit

TELNET Terminal Networking

TFTP Trivial File Transfer Protocol

TLI Transport Layer Interface

TP4 OSI Transport Class 4

TSAP Transport Service Access Point

TTL Time-to-Live

UA User Agent

UART Universal Asynchronous Receiver/Transmitter

UDP User Datagram Protocol

ULP Upper Layer Protocol

URL Uniform Resource Locator

UUCP Unix-to-Unix Copy

WAN Wide Area Network

WWW World Wide Web

XDR External Data Representation

XNS Xerox Network Systems

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