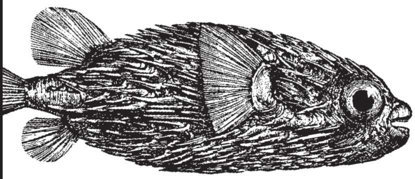
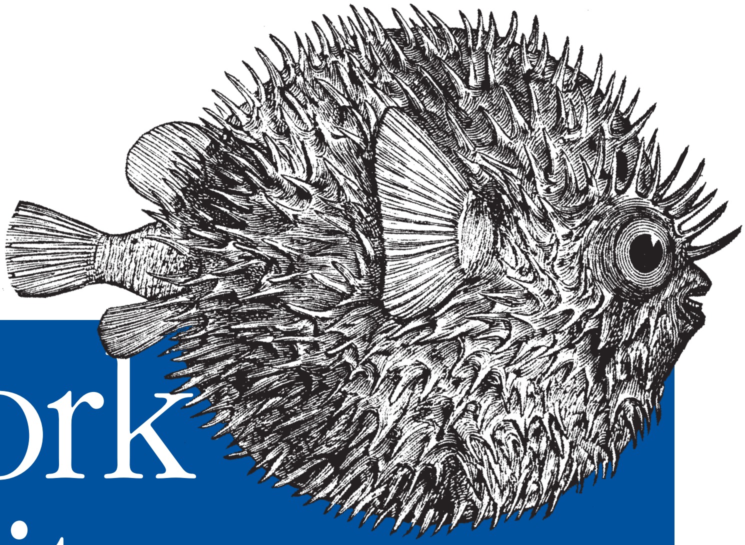
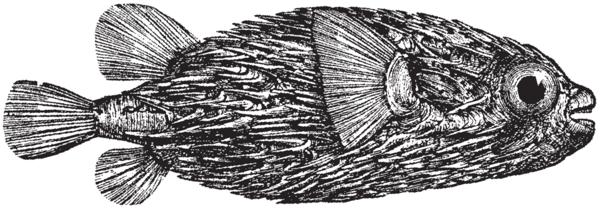
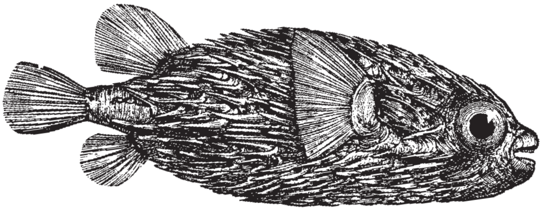
Know Your Network





Network Security Assessment





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CHAPTER 4

IP Network Scanning

This chapter focuses on the technical execution of IP network scanning. After undertaking initial reconnaissance to identify IP address spaces of interest, network scanning builds a clearer picture of accessible hosts and their network services. Network scanning and reconnaissance is the real data gathering exercise of an Internet-based security assessment. The rationale behind IP network scanning is to gain insight into the following elements of a given network:

- ICMP message types that generate responses from target hosts
- Accessible TCP and UDP network services running on the target hosts
- Operating platforms of target hosts and their configuration
- Areas of vulnerability within target host IP stack implementations (including sequence number predictability for TCP spoofing and session hijacking)
- Configuration of filtering and security systems (including firewalls, border routers, switches, and IDS sensors)

Performing both network scanning and reconnaissance tasks paints a clear picture of the network topology and its security mechanisms. Before penetrating the target network, further assessment steps involve gathering specific information about the TCP and UDP network services that are running, including their versions and enabled options.

ICMP Probing

The Internet Control Message Protocol (ICMP) identifies potentially weak and poorly protected networks. ICMP is a short messaging protocol that's used by systems administrators and end users for continuity testing of networks (e.g., using the *ping* or *traceroute* commands). From a network scanning and probing perspective, the following types of ICMP messages are useful:

Type 8 (echo request)

Echo request messages are also known as ping packets. You can use a scanning tool such as *nmap* to perform ping sweeping and easily identify hosts that are accessible.

Type 13 (timestamp request)

A timestamp request message requests system time information from the target host. The response is in a decimal format and is the number of milliseconds elapsed since midnight GMT.

Type 15 (information request)

The ICMP information request message was intended to support self-configuring systems such as diskless workstations at boot time, to allow them to discover their network address. Protocols such as RARP, BOOTP, or DHCP do so more robustly, so type 15 messages are rarely used.

Type 17 (subnet address mask request)

An address mask request message reveals the subnet mask used by the target host. This information is useful when mapping networks and identifying the size of subnets and network spaces used by organizations.

Firewalls of security-conscious organizations often blanket-filter inbound ICMP messages and so ICMP probing isn't effective; however, ICMP isn't filtered in most networks because ICMP messages are often useful for network troubleshooting purposes.

There are a handful of other ICMP message types that have relevant security applications (such as ICMP type 5 redirect messages sent by routers), but they aren't related to network scanning.

Table 4-1 outlines popular operating systems and their responses to certain types of direct ICMP query messages.

Table 4-1. Operating system responses to direct ICMP query messages

Operating system	Direct ICMP message types (non-broadcast)			
	8	13	15	17
Linux	Yes	Yes	No	No
*BSD	Yes	Yes	No	No
Solaris	Yes	Yes	No	Yes
HP-UX	Yes	Yes	Yes	No
AIX	Yes	Yes	Yes	No
Ultrix	Yes	Yes	Yes	Yes
Windows 95, 98, and ME	Yes	Yes	No	Yes
Windows NT 4.0	Yes	No	No	No
Windows 2000	Yes	Yes	No	No
Cisco IOS	Yes	Yes	Yes	No

Indirect ICMP query messages can be sent to the broadcast address of a given subnet (such as `192.168.0.255` in a `192.168.0.0/24` network). Operating systems respond in different ways to indirect queries issued to a broadcast address, as shown in Table 4-2.

Table 4-2. Operating system responses to broadcast ICMP query messages

Operating system	Indirect ICMP message types (broadcast)			
	8	13	15	17
Linux	Yes	Yes	No	No
*BSD	No	No	No	No
Solaris	Yes	Yes	No	No
HP-UX	Yes	Yes	Yes	No
AIX	No	No	No	No
Ultrix	No	No	No	No
Windows 95, 98, and ME	No	No	No	No
Windows NT 4.0	No	No	No	No
Windows 2000	No	No	No	No
Cisco IOS	No	No	Yes	No

Ofir Arkin of the Sys-Security Group (*http://www.sys-security.com*) has undertaken a lot of research into ICMP over recent years, publishing white papers dedicated entirely to the use of ICMP probes for OS fingerprinting. For quality in-depth details of ICMP probing techniques, please consult his research available from his web site.

SING

Send ICMP Nasty Garbage (SING) is a command-line tool that sends fully customizable ICMP packets. The main purpose of the tool is to replace the *ping* command with certain enhancements, including the ability to transmit and receive spoofed packets, send MAC-spoofed packets, and support the transmission of many other message types, including ICMP address mask, timestamp, and information requests, router solicitation, and router advertisement messages.

SING is available from *http://sourceforge.net/projects/sing/*.[*] Examples using the *sing* utility to launch ICMP echo, timestamp, and address mask requests follow. In these examples, I direct probes at broadcast addresses and individual hosts.

Using *sing* to send broadcast ICMP echo request messages:

```
# sing -echo 192.168.0.255
SINGing to 192.168.0.255 (192.168.0.255): 16 data bytes
```

[*] URLs for tools in this book are mirrored at the O'Reilly site, *http://examples.oreilly.com/networksa/tools*.

```
16 bytes from 192.168.0.1: seq=0 ttl=64 TOS=0 time=0.230 ms
16 bytes from 192.168.0.155: seq=0 ttl=64 TOS=0 time=2.267 ms
16 bytes from 192.168.0.126: seq=0 ttl=64 TOS=0 time=2.491 ms
16 bytes from 192.168.0.50: seq=0 ttl=64 TOS=0 time=2.202 ms
16 bytes from 192.168.0.89: seq=0 ttl=64 TOS=0 time=1.572 ms
```

Using *sing* to send ICMP timestamp request messages:

```
# sing -tstamp 192.168.0.50
SINGing to 192.168.0.50 (192.168.0.50): 20 data bytes
20 bytes from 192.168.0.50: seq=0 ttl=128 TOS=0 diff=327372878
20 bytes from 192.168.0.50: seq=1 ttl=128 TOS=0 diff=1938181226*
20 bytes from 192.168.0.50: seq=2 ttl=128 TOS=0 diff=1552566402*
20 bytes from 192.168.0.50: seq=3 ttl=128 TOS=0 diff=1183728794*
```

Using *sing* to send ICMP address mask request messages:

```
# sing -mask 192.168.0.25
SINGing to 192.168.0.25 (192.168.0.25): 12 data bytes
12 bytes from 192.168.0.25: seq=0 ttl=236 mask=255.255.255.0
12 bytes from 192.168.0.25: seq=1 ttl=236 mask=255.255.255.0
12 bytes from 192.168.0.25: seq=2 ttl=236 mask=255.255.255.0
12 bytes from 192.168.0.25: seq=3 ttl=236 mask=255.255.255.0
```

nmap

nmap can perform ICMP ping-sweep scans of target address spaces easily and relatively quickly. Many hardened networks will blanket-filter inbound ICMP messages at border routers or firewalls, so sweeping in this fashion isn't effective in some cases. Example 4-1 demonstrates how *nmap* can be run from a Unix-based or Win32 command prompt to perform an ICMP ping sweep against `192.168.0.0/24`. *nmap* is available from *http://www.insecure.org/nmap/*.

Example 4-1. Performing a ping sweep with nmap

```
# nmap -sP -PI 192.168.0.0/24

Starting nmap 3.45 ( www.insecure.org/nmap/ )
Host   (192.168.0.0) seems to be a subnet broadcast address (2 extra pings).
Host  (192.168.0.1) appears to be up.
Host  (192.168.0.25) appears to be up.
Host  (192.168.0.32) appears to be up.
Host  (192.168.0.50) appears to be up.
Host  (192.168.0.65) appears to be up.
Host  (192.168.0.102) appears to be up.
Host  (192.168.0.110) appears to be up.
Host  (192.168.0.155) appears to be up.
Host   (192.168.0.255) seems to be a subnet broadcast address (2 extra pings).
Nmap run completed -- 256 IP addresses (8 hosts up)
```

Using the `-sP` ping sweep flag within *nmap* doesn't just perform an ICMP echo request to each IP address; it also sends TCP ACK and SYN probe packets to port 80 of each host. In Example 4-1, *nmap* is run with the `-PI` flag, to specify that we're sending only ICMP echo requests. Overall, using the standard `-sP` flag is often more effective because it identifies web servers that may not respond to ICMP probes; however, in some environments it is beneficial to use more specific probe types.

Gleaning Internal IP Addresses

In some cases, it is possible to gather internal IP address information by analyzing all ICMP responses with a stateful inspection system such as a personal firewall on your workstation or a Linux machine on the edge of your network performing stateful inspection of all IP traffic.

After sending an ICMP echo request to a publicly accessible IP address, the target firewall often uses network address translation to forward the packet to the correct internal IP address (within a DMZ or internal network space). If the firewall is configured to permit ICMP echo request messages to go through and fully forwards ICMP echo request messages (as opposed to rewriting the headers as proxies do), sometimes unsolicited ICMP echo reply messages appear from private IP addresses.

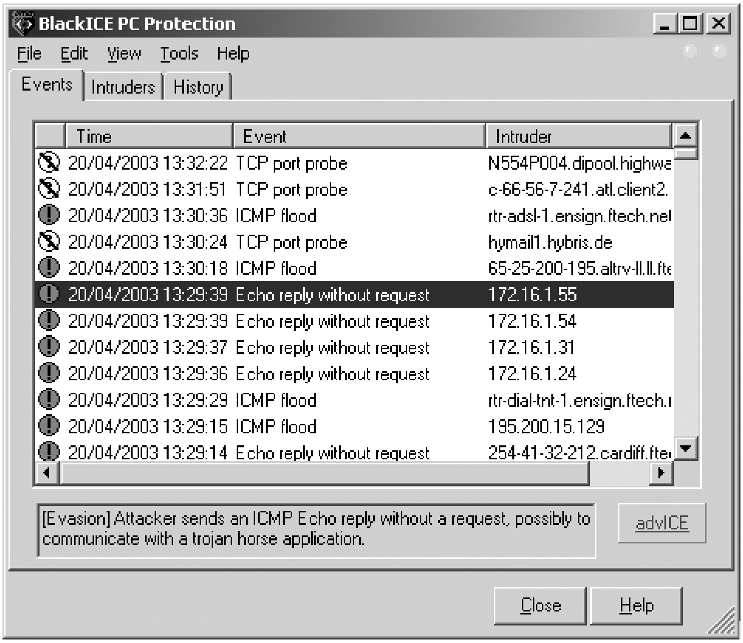
Tools such as *nmap* and *sing* don't identify these responses from private addresses, because doing so requires low-level stateful analysis of the traffic flowing into and out of a network, such as performed by a firewall. A quick and simple example of this behavior is to watch the ISS BlackICE event log in Figure 4-1 as a simple ICMP ping sweep is undertaken using *SuperScan* or a similar tool.

Figure 4-1 shows that ISS BlackICE has identified four unsolicited ICMP echo replies from private addresses (within the `172.16.0.0/16` space in this case, but they are often within `192.168.0.0/16` or `10.0.0.0/8`). By carefully monitoring such a stateful inspection mechanism when performing any kind of probing or network scanning, you can gain useful insight into areas of target network configuration.

A Linux system running *tcpdump* or *ethereal* can be used to great effect on our penetration testing launch network simply by picking up ICMP echo reply messages and filtering out public and nonpublic addresses using simple *awk* scripts.

Identifying Subnet Broadcast Addresses

Subnet broadcast addresses can be easily extracted using functionality within *nmap* that monitors the number of ICMP echo replies when a ping sweep is initiated. Such broadcast addresses will respond with multiple replies if they aren't filtered, which lets you see how to segment the target network space. Example 4-2 shows *nmap* mapping out the broadcast addresses in use for a pool of ADSL routers and systems.



Time	Event	Intruder
20/04/2003 13:32:22	TCP port probe	N554P004.dipool.highwa
20/04/2003 13:31:51	TCP port probe	c-66-56-7-241.atl.client2.
20/04/2003 13:30:36	ICMP flood	rtr-adsl-1.ensign.ftech.net
20/04/2003 13:30:24	TCP port probe	hymail1.hybris.de
20/04/2003 13:30:18	ICMP flood	65-25-200-195.altrv-ll.ll.fte
20/04/2003 13:29:39	Echo reply without request	172.16.1.55
20/04/2003 13:29:39	Echo reply without request	172.16.1.54
20/04/2003 13:29:37	Echo reply without request	172.16.1.31
20/04/2003 13:29:36	Echo reply without request	172.16.1.24
20/04/2003 13:29:29	ICMP flood	rtr-dial-tnt-1.ensign.ftech.ı
20/04/2003 13:29:15	ICMP flood	195.200.15.129
20/04/2003 13:29:14	Echo reply without request	254-41-32-212.cardiff.fte

[Evasion] Attacker sends an ICMP Echo reply without a request, possibly to communicate with a trojan horse application.

Figure 4-1. ISS BlackICE statefully gleans internal IP addresses

Example 4-2. Identifying subnet broadcast addresses with nmap

```
# nmap -sP 62.2.15.0/24

Starting nmap 3.45 ( www.insecure.org/nmap/ )
Host 62.2.15.8 seems to be a subnet broadcast address (returned 1 extra pings).
Host pipex-gw.abcconsulting.co.uk (62.2.15.9) appears to be up.
Host mail.abc.co.uk (62.2.15.10) appears to be up.
Host www-dev.abc.co.uk (62.2.15.13) appears to be up.
Host 62.2.15.15 seems to be a subnet broadcast address (returned 1 extra pings).
Host 62.2.15.16 seems to be a subnet broadcast address (returned 1 extra pings).
Host pipex-gw.smallco.net (62.2.15.17) appears to be up.
Host mail.smallco.net (62.2.15.18) appears to be up.
Host 62.2.15.19 seems to be a subnet broadcast address (returned 1 extra pings).
Host 62.2.15.20 seems to be a subnet broadcast address (returned 1 extra pings).
Host pipex-gw.example.org (62.2.15.21) appears to be up.
Host mail.example.org (62.2.15.22) appears to be up.
Host www.example.org (62.2.15.25) appears to be up.
Host ext-26.example.org (62.2.15.26) appears to be up.
Host ext-27.example.org (62.2.15.27) appears to be up.
Host staging.example.org (62.2.15.28) appears to be up.
Host 62.2.15.35 seems to be a subnet broadcast address (returned 1 extra pings).
```

This scan has identified three separate subnets within the `62.2.15.0` network:

- The *abc.co.uk* subnet from `62.2.15.8` to `62.2.15.15` (8 addresses)
- The *smallco.net* subnet from `62.2.15.16` to `62.2.15.19` (4 addresses)
- The *example.org* subnet from `62.2.15.20` to `62.2.15.35` (16 addresses)

TCP Port Scanning

Accessible TCP ports can be identified by port scanning target IP addresses. The following nine different types of TCP port scanning are used in the wild by both attackers and security consultants:

Standard scanning methods
Vanilla `connect( )` scanning
Half-open SYN flag scanning

Stealth TCP scanning methods
Inverse TCP flag scanning
ACK flag probe scanning
TCP fragmentation scanning

Third-party and spoofed TCP scanning methods
FTP bounce scanning
Proxy bounce scanning
Sniffer-based spoofed scanning
IP ID header scanning

What follows is a technical breakdown for each TCP port scanning type, along with details of Windows and Unix-based tools that can perform scanning.

Standard Scanning Methods

Standard scanning methods, such as vanilla and half-open SYN scanning, are extremely simple direct techniques used to identify accessible TCP ports and services accurately. These scanning methods are reliable but are easily logged and identified.

Vanilla connect( ) scanning

TCP `connect( )` port scanning is the most simple type of probe to launch. There is no stealth whatsoever involved in this form of scanning because a full TCP/IP connection is established with TCP port one of the target host, then incrementally through ports two, three, four, and so on.

TCP/IP's reliability as a protocol, vanilla port scanning is a very accurate way to determine which TCP services are accessible on a given target host. Figures 4-2 and 4-3 show the various TCP packets and their flags, as they are sent and received by the attacker and the host he is scanning.

In Figure 4-2, the attacker first sends a SYN probe packet to the port he wishes to test. Upon receiving a packet from the port with the SYN and ACK flags set, he knows that the port is open. The attacker completes the three-way handshake by sending an ACK packet back.

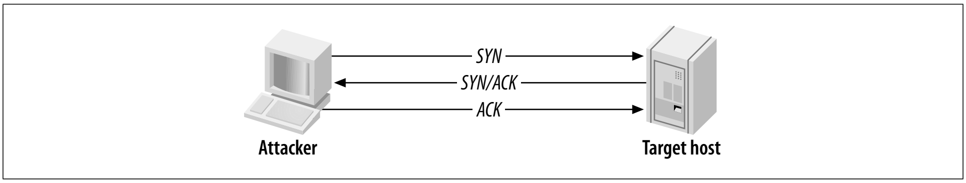


Figure 4-2. A vanilla TCP scan result when a port is open

If, however, the target port is closed, the attacker receives an RST/ACK packet directly back, as shown in Figure 4-3.

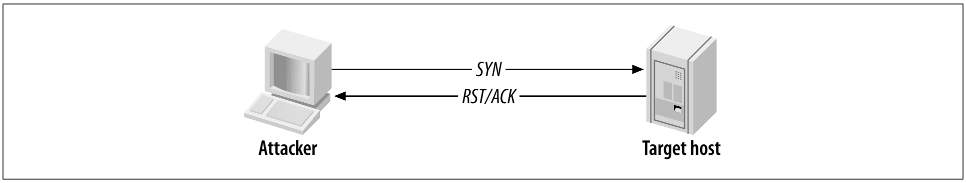


Figure 4-3. A vanilla TCP scan result when a port is closed

As before, the attacker sends a SYN probe packet, but the target server responds with an RST/ACK. Standard `connect( )` scanning in this way is a reliable way to identify accessible TCP network services. The downside is that the scanning type is extremely simple and hence easily identified and logged.

Tools that perform connect( ) TCP scanning. *nmap* can perform a TCP `connect( )` port scan using the `-sT` flag. Other very simple scanners exist; one such as *pscan.c*, which is available as source code from many sites, including Packet Storm (*http://www.packetstormsecurity.org*).

For Windows, Foundstone's *SuperScan* is an excellent port-scanning utility with good functionality. It's available from *http://www.foundstone.com/knowledge/scanning.html*.

> When performing a full assessment exercise, every TCP port from 0 to 65535 should be checked. For speed reasons, tools such as *SuperScan* and *nmap* have internal lists of only some 1,500 common ports to check; thus they often miss all kinds of interesting services that can be found on high ports—for example, Check Point SVN web services on TCP port 18264.

Half-open SYN flag scanning

Usually, a three-way handshake is initiated to synchronize a connection between two hosts; the client sends a SYN packet to the server, which responds with SYN and ACK if the port is open, and the client then sends an ACK to complete the handshake.

In the case of half-open SYN port scanning when a port is found to be listening, an RST packet is sent as the third part of the handshake. Sending an RST packet in this way abruptly resets the TCP connection, and because you have not completed the three-way handshake, the connection attempt often isn't logged on the target host.

Most intrusion detection systems (IDS) and other security programs, such as *portsentry*, can easily detect and prevent half-open SYN port-scanning attempts. In cases where stealth is required, other techniques are recommended, such as FIN or TTL-based scanning, or even using a utility such as *fragroute*, to fragment outbound probe packets.

Figures 4-4 and 4-5 outline the packets sent between the two hosts when launching a SYN port scan and finding either an open and a closed port.

In Figure 4-5, a SYN probe packet is sent to the target port; a SYN/ACK packet is received indicating that the port is open. Normally at this stage, a `connect()` scanner sends an ACK packet to establish the connection, but this is half-open scanning so instead, a RST packet is sent to tear down the connection.

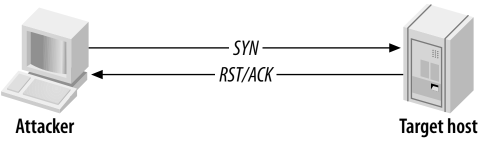


Figure 4-4. A half-open SYN scan result when a port is closed

Figure 4-4 shows that when a closed port is found, a RST/ACK packet is received, and nothing happens (as before in Figure 4-3). The benefit of half-open scanning is that a true three-way TCP handshake is never completed, and the connection doesn't appear to be established.

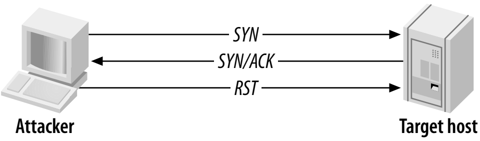


Figure 4-5. A half-open SYN scan result when a port is open

Nowadays, all IDS and personal firewall systems can identify SYN port scans (although they often mislabel them as *SYN flood attacks* due to the number of probe packets). SYN scanning is fast and reliable, although it requires raw access to network sockets and, therefore, privileged access to Unix and Windows hosts.

Tools that perform half-open SYN scanning. *nmap* can perform a SYN port scan under both Unix and Windows environments using the `-sS` flag. Many other Unix half-open port scanners exist, including *strobe*, which is available in source form from many sites including Packet Storm (*http://www.packetstormsecurity.org*).

> The `-T` flag can be used within *nmap* to change the timing policy used when scanning. Networks protected by commercial firewalls (NetScreen, WatchGuard, and Check Point in particular) will sometimes drop SYN probes if *nmap* is sending the packets out too quickly, *nmap*'s actions resemble a SYN flood denial of service attack. I have found that by setting the timing policy to `-T Sneaky`, it's often possible to glean accurate results against hosts protected by firewalls with SYN flood protection enabled.

A second SYN port scanner worth mentioning is the *scanrand* component of the Paketto Keiretsu suite by Dan Kaminsky. Paketto Keiretsu contains a number of useful networking utilities that are available at *http://www.doxpara.com/read.php/code/paketto.html*. The *scanrand* tool is very well designed, with distinct SYN probing and background listening components so that you can launch the quickest possible scans. Inverse SYN cookies (using the HMAC SHA1 hashing algorithm) tag outgoing probe packets, so that false positive results become nonexistent (because the listening component registers only SYN/ACK responses with the correct cryptographic cookies). Example 4-3 shows *scanrand* identifying open ports on a local network in less than one second.

Example 4-3. Using scanrand to quickly scan the local network

```
# scanrand 10.0.1.1-254:quick
  UP:        10.0.1.38:80    [01]   0.003s
  UP:       10.0.1.110:443   [01]   0.017s
  UP:       10.0.1.254:443   [01]   0.021s
  UP:        10.0.1.57:445   [01]   0.024s
  UP:        10.0.1.59:445   [01]   0.024s
  UP:        10.0.1.38:22    [01]   0.047s
  UP:       10.0.1.110:22    [01]   0.058s
  UP:       10.0.1.110:23    [01]   0.058s
  UP:       10.0.1.254:22    [01]   0.077s
  UP:       10.0.1.254:23    [01]   0.077s
  UP:        10.0.1.25:135   [01]   0.088s
  UP:        10.0.1.57:135   [01]   0.089s
  UP:        10.0.1.59:135   [01]   0.090s
  UP:        10.0.1.25:139   [01]   0.097s
  UP:        10.0.1.27:139   [01]   0.098s
  UP:        10.0.1.57:139   [01]   0.099s
  UP:        10.0.1.59:139   [01]   0.099s
```

Example 4-3. Using scanrand to quickly scan the local network (continued)

```
  UP:        10.0.1.38:111   [01]   0.127s
  UP:        10.0.1.57:1025  [01]   0.147s
  UP:        10.0.1.59:1025  [01]   0.147s
  UP:        10.0.1.57:5000  [01]   0.156s
  UP:        10.0.1.59:5000  [01]   0.157s
  UP:        10.0.1.53:111   [01]   0.182s
```

Due to the way *scanrand* sends a deluge of SYN probes and then listens for positive SYN/ACK responses, the order in which the open ports are displayed will look a little odd. On the positive side, *scanrand* is lightning fast; it allows specific ports (e.g., common backdoors) to be identified in seconds even across large networks, as opposed to minutes or hours with a bulkier tool such as *nmap*.

Stealth TCP Scanning Methods

Stealth scanning methods involve idiosyncrasies in the way TCP/IP stacks of target hosts process and respond to packets with strange bits set or other features. Such techniques aren't effective at accurately mapping the open ports of some operating systems but do provide a degree of stealth and are sometimes not logged.

Inverse TCP flag scanning

Security mechanisms such as firewalls and IDS usually detect SYN packets being sent to sensitive ports of target hosts. Programs are also available to log half-open SYN flag scan attempts, including *synlogger* and *courtney*. Probe packets with strange TCP flags set can sometimes pass through filters undetected, depending on the security mechanisms deployed.

Using half-open SYN flags to probe a target is known as an *inverted technique* because responses are sent back only by closed ports. RFC 793 states that if a port is closed on a host, an RST/ACK packet should be sent to reset the connection. To take advantage of this feature, attackers send TCP probe packets with various TCP flags set.

A TCP probe packet is sent to each port of the target host. Three types of probe packet flag configurations are normally used:

- A FIN probe with the FIN TCP flag set
- An XMAS probe with the FIN, URG, and PUSH TCP flags set
- A NULL probe with no TCP flags set

Figures 4-6 and 4-7 depict the probe packets and responses generated by the target host if the target port is found to be open or closed.

The RFC standard states that, if no response is seen from the target port, the port is open, or the server is down. This scanning method isn't necessarily the most accurate, but it is stealthy; it sends garbage to each port that usually won't be picked up.

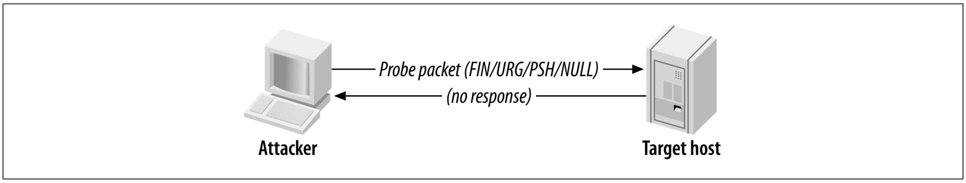


Figure 4-6. An inverse TCP scan result when a port is open

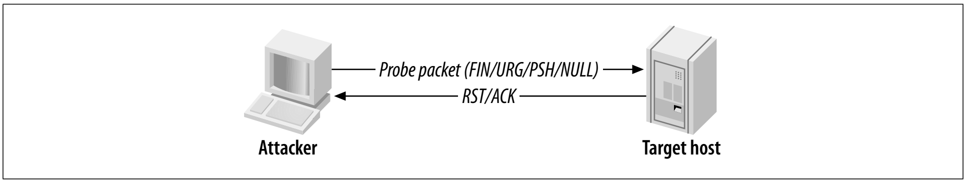


Figure 4-7. An inverse TCP scan result when a port is closed

For all closed ports on the target host, RST/ACK packets are received. However, some operating platforms (such as those in the Microsoft Windows family) disregard the RFC 793 standard, so no RST/ACK response is seen when an attempt is made to connect to a closed port. Hence, this technique is effective against most Unix-based operating systems.

Tools that perform inverse TCP flag scanning. *nmap* can perform an inverse TCP flag port scan under both Unix and Windows environments, using the following flags:

`-sF` For a scan with only the FIN flag set on probe packets

`-sN` For a NULL scan with no TCP flags set on probe packets

`-sX` For an Xmas tree scan with all TCP flags set

vscan is another Windows tool you can use to perform inverse TCP flag scanning. The utility doesn't require installation of WinPcap network drivers; instead it uses raw sockets within Winsock 2 (present in Windows 2000, XP, and 2003). *vscan* is available at *http://host.deluxnetwork.com/~vsniff/vscan.zip*.

ACK flag probe scanning

A stealthy technique documented by Uriel Maimon in *Phrack* Magazine, Issue 49, is that of identifying open TCP ports by sending ACK probe packets and analyzing the header information of the RST packets received from the target host. This technique exploits vulnerabilities within the BSD derived TCP/IP stack and is therefore only effective against certain operating systems and platforms. There are two main ACK scanning techniques that involve:

- Analysis of the time-to-live (TTL) field of received packets
- Analysis of the WINDOW field of received packets

These techniques can also check filtering systems and complicated networks to understand the processes packets go through on the target network. For example, the TTL value can be used as a marker of how many systems the packet has hopped through. The *firewalk* filter assessment tool works in a similar fashion, available from *http://www.packetfactory.net/projects/firewalk/*.

Analysis of the TTL field of received packets. To analyze the TTL field data of received RST packets, an attacker first sends thousands of crafted ACK packets to different TCP ports, as shown in Figure 4-8.

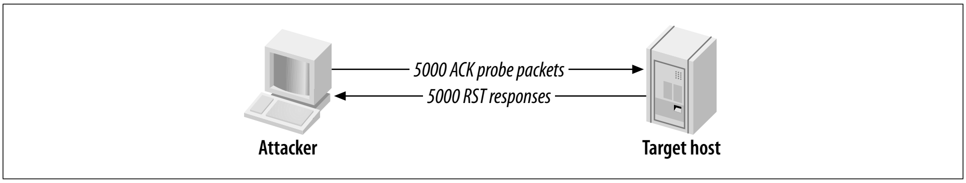


Figure 4-8. ACK probe packets are sent to various ports

Here is a log of the first four RST packets received using the *hping2* utility:

```
1: host 192.168.0.12 port 20: F:RST -> ttl: 70 win: 0
2: host 192.168.0.12 port 21: F:RST -> ttl: 70 win: 0
3: host 192.168.0.12 port 22: F:RST -> ttl: 40 win: 0
4: host 192.168.0.12 port 23: F:RST -> ttl: 70 win: 0
```

By analyzing the TTL value of each packet, an attacker can easily see that the value returned by port 22 is 40, whereas the other ports return a value of 70. This suggests that port 22 is open on the target host because the TTL value returned is smaller than the TTL boundary value of 64.

Analysis of the WINDOW field of received packets. To analyze the WINDOW field data of received RST packets, an attacker sends thousands of the same crafted ACK packets to different TCP ports (as shown in Figure 4-8). Here is a log of the first four RST packets received, again using the *hping2* utility:

```
1: host 192.168.0.20 port 20: F:RST -> ttl: 64 win: 0
2: host 192.168.0.20 port 21: F:RST -> ttl: 64 win: 0
3: host 192.168.0.20 port 22: F:RST -> ttl: 64 win: 512
4: host 192.168.0.20 port 23: F:RST -> ttl: 64 win: 0
```

Notice that the TTL value for each packet is 64, meaning that TTL analysis of the packets isn't effective in identifying open ports on this host. However, by analyzing the WINDOW values, the attacker finds that the third packet has a non-zero value, indicating an open port.

The advantage of using ACK flag probe scanning is that detection is difficult (for both IDS and host-based systems, such as personal firewalls). The disadvantage is that this scanning type relies on TCP/IP stack implementation bugs, which are prominent in BSD-derived systems but not in many other modern platforms.

Tools that perform ACK flag probe scanning. *nmap* supports ACK flag probe scanning, with the `-sA` and `-sW` flags to analyze the TTL and WINDOW values respectively. See the *nmap* manpage for more detailed information.

hping2 can also sample TTL and WINDOW values, but this can prove highly time consuming in most cases. The tool is more useful for analyzing low-level responses, as opposed to port scanning in this fashion. *hping2* is available from *http://www.eaglenet.org/antirez/hping2.html* and *http://www.hping.org*.

Third-Party and Spoofed TCP Scanning Methods

Third-party port scanning methods allow for probes to be effectively bounced through vulnerable servers to hide the true source of the network scanning. An additional benefit of using a third-party technique in this way is that insight into firewall configuration can be gained by potentially bouncing scans through trusted hosts that are vulnerable.

FTP bounce scanning

Hosts running outdated FTP services can relay numerous TCP attacks, including port scanning. There is a flaw in the way many FTP servers handle connections using the `PORT` command (see RFC 959 or technical description of the `PORT` feature) that allows for data to be sent to user-specified hosts and ports. In their default configurations, the FTP services running on the following platforms are affected:

- FreeBSD 2.1.7 and earlier
- HP-UX 10.10 and earlier
- Solaris 2.6/SunOS 5.6 and earlier
- SunOS 4.1.4 and earlier
- SCO OpenServer 5.0.4 and earlier
- SCO UnixWare 2.1 and earlier
- IBM AIX 4.3 and earlier
- Caldera Linux 1.2 and earlier
- Red Hat Linux 4.2 and earlier
- Slackware 3.3 and earlier
- Any Linux distribution running WU-FTP 2.4.2-BETA-16 or earlier

The FTP bounce attack can have a far more devastating effect if a writable directory exists because a series of commands or other data can be entered into a file and then relayed via the `PORT` command to a specified port of a target host. For example, someone can upload a spam email message to a vulnerable FTP server and then send this email message to the SMTP port of a target mail server. Figure 4-9 shows the parties involved in FTP bounce scanning.

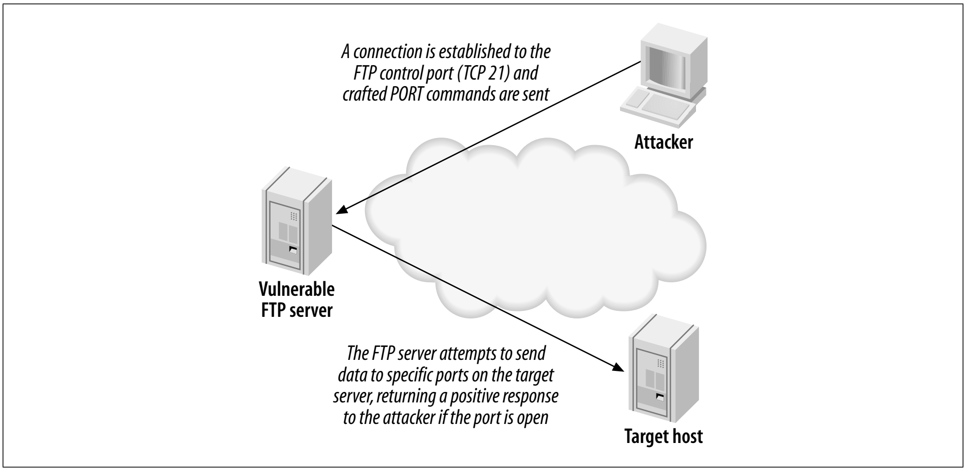

A connection is established to the FTP control port (TCP 21) and crafted PORT commands are sent
Attacker
Vulnerable FTP server
The FTP server attempts to send data to specific ports on the target server, returning a positive response to the attacker if the port is open
Target host

Figure 4-9. FTP bounce port scanning

The following occurs when performing an FTP bounce scan:

1. The attacker connects to the FTP control port (TCP port 21) of the vulnerable FTP server that she is going to bounce her attack through and enters passive mode, forcing the FTP server to send data using DTP (data transfer process) to a specific port of a specific host:

   ```
   QUOTE PASV
   227 Entering Passive Mode (64,12,168,246,56,185).
   ```

2. A `PORT` command is issued, with an argument passed to the FTP service telling it to attempt a connection to a specific TCP port of the target server; for example, TCP port 23 of `144.51.17.230`:

   ```
   PORT 144,51,17,230,0,23
   200 PORT command successful.
   ```

3. After issuing the `PORT` command, a `LIST` command is sent. The FTP server then attempts to create a connection with the target host defined in the `PORT` command issued previously:

   ```
   LIST
   150 Opening ASCII mode data connection for file list
   226 Transfer complete.
   ```

   If a 226 response is seen, then the port on the target host is open. If, however, a 425 response is seen, the connection has been refused:

   ```
   LIST
   425 Can't build data connection: Connection refused
   ```

Tools that perform FTP bounce port scanning. *nmap* for both Unix and Windows can effectively perform an FTP bounce port scan, using the -P0 and -b flags in the following manner:

```
nmap -P0 -b username:password@ftp-server:port <target host>
```

Proxy bounce scanning

Attackers bounce TCP attacks through open proxy servers. Depending on the level of poor configuration, the server will sometimes allow a full-blown TCP port scan to be relayed. Using proxy servers to perform bounce port scanning in this fashion is often time consuming, so many attackers prefer to abuse open proxy servers more efficiently by bouncing actual attacks through to target networks.

ppscan.c, a publicly available Unix-based tool to bounce port scans, can be found in source form at:

> *http://www.dsinet.org/tools/network-scanners/ppscan.c*
> *http://www.phreak.org/archives/exploits/unix/network-scanners/ppscan.c*

Sniffer-based spoofed scanning

An innovative half-open SYN TCP port scanning method was realized when jsbach published his *spoofscan* Unix-based scanner in 1998. The *spoofscan* tool is run as root on a given host to perform a stealthy port scan. The key feature that makes this scanner so innovative is that it places the host network card into promiscuous mode and then sniffs for responses on the local network segment.

The following unique benefits are immediately realized when using a sniffer-based spoofing port scanner:

- If you have superuser access to a machine on the same physical network segment as the target host or a firewall protecting a target host, you can spoof TCP probes from other IP addresses to identify trusted hosts and to gain insight into the firewall policy (by spoofing scans from trusted office hosts, for example). Accurate results will be retrieved because of the background sniffing process, which monitors the local network segment for responses to your spoofed probes.
- If you have access to a large shared network segment, you can spoof scans from hosts you don't have access to or that don't exist (such as unused IP addresses within your local network segment), to effectively port scan remote networks in a distributed and stealthy fashion.

The beauty of this method is that the attacker is abusing his access to the local network segment. Such techniques can even be carried out to good effect in switched network environments using ARP redirect spoofing and other techniques. *spoofscan* is available at *http://examples.oreilly.com/networksa/tools/spoofscan.c*.

IP ID header scanning

IP ID header scanning (also known as *idle* or *dumb* scanning) is an obscure scanning technique that involves abusing implementation peculiarities within the TCP/IP stack of most operating systems. Three hosts are involved:

- The host, from which the scan is launched
- The target host, which will be scanned
- A zombie or idle host, which is an Internet-based server that is queried with spoofed port scanning against the target host to identify open ports from the perspective of the zombie host

IP ID header scanning is extraordinarily stealthy due to its blind nature. Determined attackers will often use this type of scan to map out IP-based trust relationships between machines, such as firewalls and VPN gateways.

The listing returned by the scan shows open ports from the perspective of the zombie host, so you can try scanning a target using various zombies you think might be trusted (such as hosts at remote offices or DMZ machines). Figure 4-10 depicts the process undertaken during an IP ID header scan.

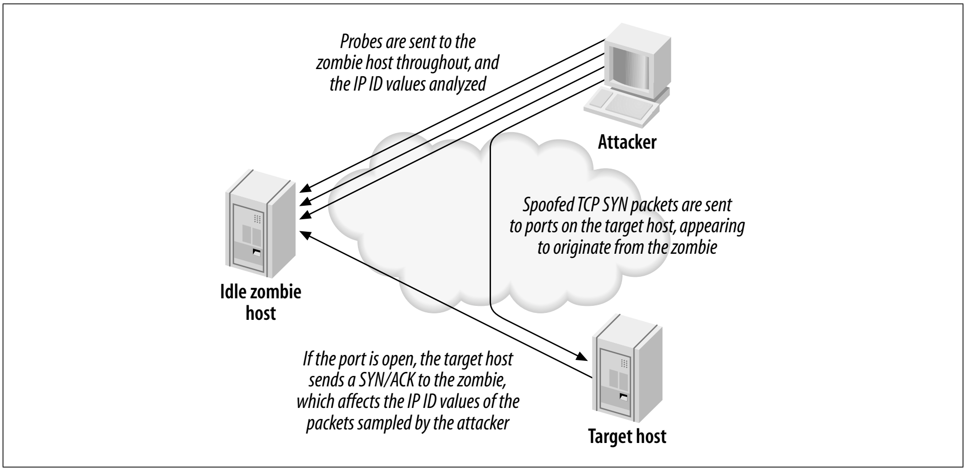

Probes are sent to the zombie host throughout, and the IP ID values analyzed
Attacker
Spoofed TCP SYN packets are sent to ports on the target host, appearing to originate from the zombie
Idle zombie host
If the port is open, the target host sends a SYN/ACK to the zombie, which affects the IP ID values of the packets sampled by the attacker
Target host

Figure 4-10. IP ID header scanning and the parties involved

hping2 was originally used in a manual fashion to perform such low-level TCP scanning, which was time consuming and tricky to undertake against an entire network of hosts. A white paper that fully discusses using the tool to perform IP ID header scanning by hand is available from *http://www.kyuzz.org/antirez/papers/dumbscan.html*.

nmap supports such IP ID header scanning with the option:

```
-sI <zombie host[:probe port]>
```

Example 4-4 shows how *nmap* uses this functionality to scan 192.168.0.50 through 192.168.0.155.

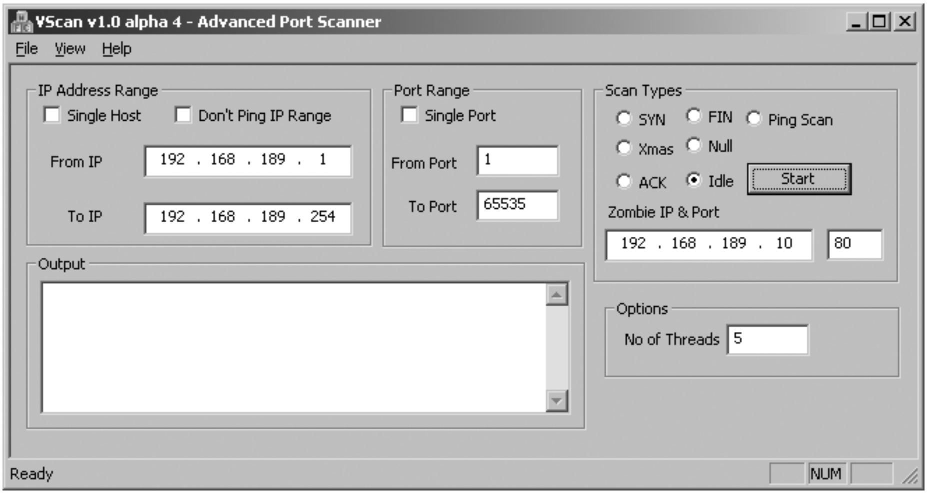
Example 4-4. Using nmap to perform IP ID header scanning

```
# nmap -P0 -sI 192.168.0.155 192.168.0.50

Starting nmap 3.45 ( www.insecure.org/nmap/ )
Idlescan using zombie 192.168.0.155; Class: Incremental
Interesting ports on  (192.168.0.50):
(The 1582 ports scanned but not shown below are in state: closed)
Port       State      Service
25/tcp     open       smtp
53/tcp     open       domain
80/tcp     open       http
88/tcp     open       kerberos-sec
135/tcp    open       loc-srv
139/tcp    open       netbios-ssn
389/tcp    open       ldap
443/tcp    open       https
445/tcp    open       microsoft-ds
464/tcp    open       kpasswd5
593/tcp    open       http-rpc-epmap
636/tcp    open       ldapssl
1026/tcp   open       LSA-or-nterm
1029/tcp   open       ms-lsa
1033/tcp   open       netinfo
3268/tcp   open       globalcatLDAP
3269/tcp   open       globalcatLDAPssl
3372/tcp   open       msdtc
3389/tcp   open       ms-term-serv

Nmap run completed -- 1 IP address (1 host up)
```

If *nmap* is run without the -P0 flag when performing third-party scanning, the source IP address of the attacker's host performs ICMP and TCP pinging of the target hosts before starting to scan; this can appear in firewall and IDS audit logs of security-conscious organizations.

vscan is another Windows tool that can perform the same inverse IP ID scanning. As discussed earlier, the *vscan* utility doesn't require installation of WinPcap network drivers. Instead, it uses raw sockets within Winsock 2 (present in Windows 2000, XP, and 2003). *vscan* is available at *http://host.deluxnetwork.com/~vsniff/vscan.zip*.

Figure 4-11 shows the *vscan* utility in use, along with its options and functionality.



□ Single Host □ Don't Ping IP Range

From IP 192 . 168 . 189 . 1

To IP 192 . 168 . 189 . 254

□ Single Port

From Port 1

To Port 65535

○ SYN ○ FIN ○ Ping Scan

○ Xmas ○ Null

○ ACK ● Idle

Zombie IP & Port 192 . 168 . 189 . 10 80

No of Threads 5

Figure 4-11. vscan used to launch an IP ID header scan

UDP Port Scanning

Because UDP is a connectionless protocol, there are only two ways to effectively enumerate accessible UDP network services across an IP network:

- Send UDP probe packets to all 65535 UDP ports, then wait for "ICMP destination port unreachable" messages to identify UDP ports that aren't accessible.
- Use specific UDP service clients (such as *snmpwalk*, *dig*, or *tftp*) to send UDP datagrams to target UDP network services and await a positive response.

Many security-conscious organizations filter ICMP messages to and from their Internet-based hosts, so it is often difficult to assess which UDP services are accessible via simple port scanning. If "ICMP destination port unreachable" messages can escape the target network, a traditional UDP port scan can be undertaken to deductively identify open UDP ports on target hosts.

Figures 4-12 and 4-13 show the UDP packets and ICMP responses generated by hosts when ports are open and closed.

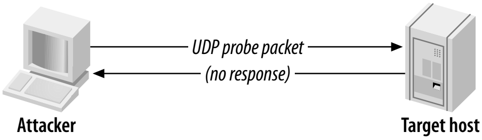


Figure 4-12. An inverse UDP scan result when a port is open

UDP port scanning is an inverted scanning type in which open ports don't respond. What is looked for, in particular, are ICMP destination port unreachable (type 3 code 3) messages from the target host, as shown in Figure 4-13.

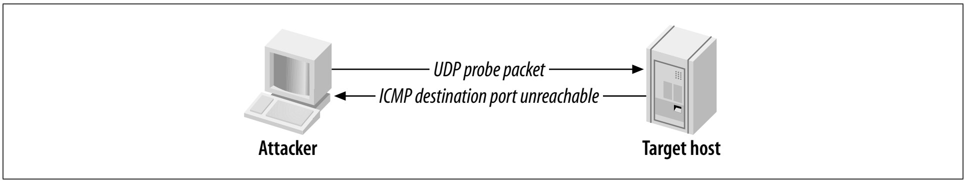


Figure 4-13. An inverse UDP scan result when a port is closed

Tools That Perform UDP Port Scanning

nmap supports UDP port scanning with the `-sU` option. The latest version of Foundstone's *SuperScan* also supports UDP port scanning. However, both tools wait for negative "ICMP destination port unreachable" messages to identify open ports (i.e., those ports that don't respond). If these ICMP messages are filtered by a firewall as they try to travel out of the target network, inaccurate results are gleaned.

During a comprehensive audit of Internet-based network space, you should send crafted UDP client packets to popular services and await a positive response. The *scanudp* utility developed by Fryxar (*http://www.geocities.com/fryxar/*) does this very well.

Example 4-5 shows the *scanudp* utility being downloaded, compiled, and run from my Linux launch system against a Windows 2000 server at `192.168.0.50`.

Example 4-5. Downloading, building, and running scanudp

```
# wget http://www.geocities.com/fryxar/scanudp_v2.tgz
# tar xvfz scanudp_v2.tgz
scanudp/
scanudp/scanudp.c
scanudp/enum.c
scanudp/enum.h
scanudp/makefile
scanudp/enum.o
scanudp/scanudp.o
scanudp/scanudp
# cd scanudp
# make
gcc enum.o scanudp.o -o scanudp
# ./scanudp
./scanudp v2.0 -   by: Fryxar
usage: ./scanudp [options] <host>
```

Example 4-5. Downloading, building, and running scanudp (continued)

```
options:
 -t <timeout>     Set port scanning timeout
 -b <bps>         Set max bandwidth
 -v               Verbose

Supported protocol:
echo daytime chargen dns tftp ntp ns-netbios snmp(ILMI) snmp(public)

# ./scanudp 192.168.0.50
192.168.0.50    53
192.168.0.50    137
192.168.0.50    161
```

IDS Evasion and Filter Circumvention

IDS evasion, when launching any type of IP probe or scan, involves one or both of the following tactics:

- Use of fragmented probe packets, assembled when they reach the target host
- Use of spoofing to emulate multiple fake hosts launching network scanning probes, in which the real IP address of the scanning host is inserted to collect results

Filtering mechanisms can be circumvented at times using malformed or fragmented packets. However, the common techniques used to bypass packet filters at either the network or system-kernel level are as follows:

- Use of source routing
- Use of specific TCP or UDP source ports

First, I'll discuss IDS evasion techniques of fragmenting data and emulating multiple hosts, and then filter circumvention methodologies. These techniques can often be mixed to launch attacks using source routed, fragmented packets to bypass both filters and IDS systems.

Fragmenting Probe Packets

Probe packets can be fragmented easily with *fragroute* to fragment all probe packets flowing from your host or network or with a port scanner that supports simple fragmentation, such as *nmap*. Many IDS sensors can't process large volumes of fragmented packets because doing so creates a large overhead in terms of memory and CPU consumption at the network sensor level.

fragtest

Dug Song's *fragtest* utility (available as part of the *fragroute* package from *http://www.monkey.org/~dugsong/fragroute/*) can determine exactly which types of fragmented ICMP messages are processed and responded to by the remote host. ICMP echo request messages are used by *fragtest* for simplicity and allow for easy analysis; the downside is that the tool can't assess hosts that don't respond to ICMP messages.

After undertaking ICMP probing exercises (such as ping sweeping and hands-on use of the *sing* utility) to ensure that ICMP messages are processed and responded to by the remote host, *fragtest* can perform three particularly useful tests:

- Send an ICMP echo request message in 8-byte fragments (using the `frag` option)
- Send an ICMP echo request message in 8-byte fragments, along with a 16-byte overlapping fragment, favoring newer data in reassembly (using the `frag-new` option)
- Send an ICMP echo request message in 8-byte fragments, along with a 16-byte overlapping fragment, favoring older data in reassembly (using the `frag-old` option)

Here is an example that uses *fragtest* to assess responses to fragmented ICMP echo request messages with the `frag`, `frag-new`, and `frag-old` options:

```
# fragtest frag frag-new frag-old www.bbc.co.uk
frag: 467.695 ms
frag-new: 516.327 ms
frag-old: 471.260 ms
```

After ascertaining that fragmented and overlapped packets are indeed processed correctly by the target host and not dropped by firewalls or security mechanisms, a tool such as *fragroute* can be used to fragment all IP traffic destined for the target host.

fragroute

Dug Song's *fragroute* utility intercepts, modifies, and rewrites egress traffic destined for a specific host, according to a predefined rule set. When built and installed, Version 1.2 comprises the following binary and configuration files:

/usr/local/sbin/fragtest
/usr/local/sbin/fragroute
/usr/local/etc/fragroute.conf

The *fragroute.conf* file defines the way *fragroute* fragments, delays, drops, duplicates, segments, interleaves, and generally mangles outbound IP traffic.

Using the default configuration file, *fragroute* can be run from the command line in the following manner:

```
# cat /usr/local/etc/fragroute.conf
tcp_seg 1 new
```

```
ip_frag 24
ip_chaff dup
order random
print
# fragroute
Usage: fragroute [-f file] dst
# fragroute 192.168.102.251
fragroute: tcp_seg -> ip_frag -> ip_chaff -> order -> print
```

Egress traffic processed by *fragroute* is displayed in *tcpdump* format if the `print` option is used in the configuration file. When running *fragroute* in its default configuration, TCP data is broken down into 1-byte segments and IP data into 24-byte segments, along with IP chaffing and random reordering of the outbound packets.

fragroute.conf. The *fragroute* manpage covers all the variables that can be set within the configuration file. The type of IP fragmentation and reordering used by *fragtest* when using the `frag-new` option can be applied to all outbound IP traffic destined for a specific host by defining the following variables in the *fragroute.conf* file:

```
ip_frag 8 old
order random
print
```

TCP data can be segmented into 4-byte, forward-overlapping chunks (favoring newer data), interleaved with random chaff segments bearing older timestamp options (for PAWS elimination), and reordered randomly using these *fragroute.conf* variables:

```
tcp_seg 4 new
tcp_chaff paws
order random
print
```

I recommend testing the variables used by *fragroute* in a controlled environment before live networks and systems are tested. This ensures that you see decent results when passing probes through *fragroute* and allows you to check for adverse reactions to fragmented traffic being processed. Applications and hardware appliances alike have been known to crash and hang from processing heavily fragmented and mangled data!

nmap

nmap can fragment probe packets when launching half-open SYN or inverse TCP scanning types. The TCP header itself is split over several packets to make it more difficult for packet filters and IDS systems to detect the port scan. While most firewalls in high security environments queue all the IP fragments before processing them, some networks disable this functionality because of the performance hit incurred. Example 4-6 uses *nmap* to perform a half-open SYN TCP scan using fragmented packets.

Example 4-6. Using nmap to perform a fragmented SYN scan

```
# nmap -sS -f 192.168.102.251

Starting nmap 3.45 ( www.insecure.org/nmap/ )
Interesting ports on cartman (192.168.102.251):
(The 1524 ports scanned but not shown below are in state: closed)
Port       State       Service
25/tcp     open        smtp
53/tcp     open        domain
8080/tcp   open        http-proxy

Nmap run completed -- 1 IP address (1 host up) scanned in 0 seconds
```

Emulating Multiple Attacking Hosts

By emulating a large number of attacking hosts all launching probes and port scans against a target network, IDS alert and logging systems will be rendered effectively useless. *nmap* allows for decoy hosts to be defined, so that a target host can be scanned from a plethora of spoofed addresses (thus obscuring your own IP address).

The flag that defines decoy addresses within *nmap* is `-D [decoy1,ME,decoy2,decoy3,...]`. Example 4-7 shows *nmap* being used in this fashion to scan `192.168.102.251`.

Example 4-7. Using nmap to specify decoy addresses

```
# nmap -sS -P0 -D 62.232.12.8,ME,65.213.217.241 192.168.102.251

Starting nmap 3.45 ( www.insecure.org/nmap/ )
Interesting ports on cartman (192.168.102.251):
(The 1524 ports scanned but not shown below are in state: closed)
Port       State       Service
25/tcp     open        smtp
53/tcp     open        domain
8080/tcp   open        http-proxy

Nmap run completed -- 1 IP address (1 host up) scanned in 0 seconds
```

Notice that the `-P0` flag is also specified. When performing any kind of stealth attack, it is important that even initial probing (in the case of *nmap*, an ICMP echo request and attempted connection to TCP port 80) isn't undertaken, because it will reveal the true source of the attack in many cases.

Source Routing

Source routing is a feature traditionally used for network troubleshooting purposes. Tools such as *traceroute* can be provided with details of gateways the packet should be loosely or strictly routed through so that specific routing paths can be tested. Source routing allows you to specify which gateways and routes your packets should take, instead of allowing routers and gateways to query their own routing tables to determine the next hop.

Source routing information is provided as an IP options field in the packet header, as shown in Figure 4-14.

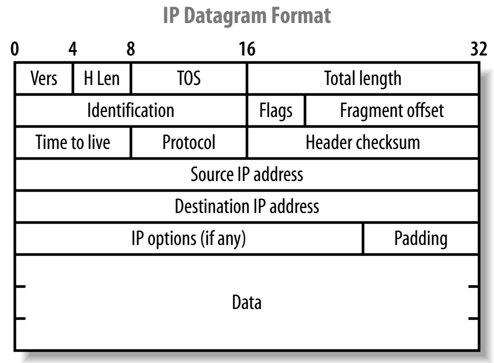


Figure 4-14. IP datagram format

The format of the IP option data within a source-routed packet is quite simple. The first three bytes are reserved for IP option code, length, and pointer. Because IP option data can be used for different functionality (timestamp, strict routing, route, and record), the code field specifies the option type. The length field, oddly enough, states the size of the optional data, which can't be larger than 40. Finally, the offset pointer field points to the current IP address in the remaining data section, which is rewritten as the packet traverses the Internet. Figure 4-15 demonstrates the offset pointer in action.

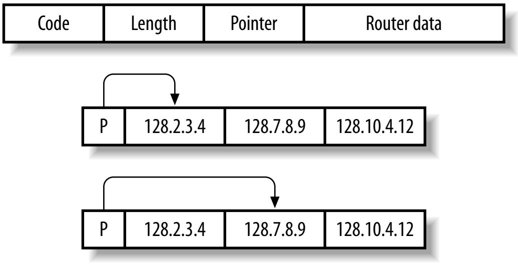


Figure 4-15. The source routing IP option and flags

There are two types of source routing, both defined in RFC 791:

- Strict Source and Route Record (SSRR)
- Loose Source and Route Record (LSRR)

Loose source routing allows the packet to use any number of intermediate gateways to reach the next address in the route. Strict source routing requires the next address in the source route to be on a directly connected network; if not, the delivery of the packet can't be completed.

The source route options have a variable length, containing a series of IP addresses and an offset pointer indicating the next IP address to be processed. A source-routed datagram completes its delivery when the offset pointer points beyond the last field and the address in the destination address has been reached.

There is a limit of 40 characters for the router data within the IP options field. With 3 bytes used for the header information and 4 bytes committed for the final host address, there remain only 33 bytes to define loose hops, so 8 IP addresses can be defined in the list of hops (not counting the final destination host).

Source routing vulnerabilities can be exploited by:

- Reversing the source route
- Circumventing filters and gaining access to internal hosts

If a firewall or gateway reverses the source routing information when sending packets back, you can sniff traffic at one of the hops you defined. In a similar fashion to using sniffer-based spoofed scanning, you can launch scans and probes from potentially trusted hosts (e.g., branch office firewalls) and acquire accurate results.

In the case of Microsoft Windows NT hosts, the circumvention of filters involves manipulating the source routing options information to have an offset pointer set greater than the length of the list of hops and defining an internal host as the last hop (which is then reversed, sending the packet to the internal host). This vulnerability is indexed as SecurityFocus BID 646, accessible at *http://www.securityfocus.com/bid/646*.

Assessing source-routing vulnerabilities

Todd MacDermid of Syn Ack Labs (*http://www.synacklabs.net*) has written two excellent tools that can assess and exploit source routing vulnerabilities found in remote networks:

lsrscan
: *http://www.synacklabs.net/projects/lsrscan/*

lsrtunnel
: *http://www.synacklabs.net/projects/lsrtunnel/*

Both tools require *libpcap* and *libdnet* to build, and they run quite smoothly in Linux and BSD environments. A white paper written by Todd that explains source routing problems in some detail is also available from *http://www.synacklabs.net/OOB/LSR.html*.

lsrscan. The *lsrscan* tool crafts probe packets with specific source routing options to determine exactly how remote hosts deal with source-routed packets. The tool checks for the following two problems:

- Whether the target host reverses the source route when sending packets back
- Whether the target host can forward source-routed packets to an internal host, by setting the offset pointer to be greater than the number of hops defined in the loose hop list

The basic usage of the tool is as follows:

```
# lsrscan
usage: lsrscan [-p dstport] [-s srcport] [-S ip]
               [-t (to|through|both)] [-b host<:host ...>]
               [-a host<:host ...>] <hosts>
```

Some operating systems will reverse source-routed traffic only to ports that are open, so *lsrscan* should be run against an open port. By default, *lsrscan* uses a destination port of 80. The source port and source IP addresses aren't so necessary (*lsrscan* selects a random source port and IP address) but can be useful in some cases.

The -b option inserts IP addresses of hops before the user's host in the source route list. Likewise, the -a option inserts specific IP addresses after the user's host in the list (although those hosts must support source route forwarding for the scan to be effective). For more information about the flags and options that can be parsed, consult the *lsrscan* manpage. Example 4-8 shows *lsrscan* being run against a network block to identify source routing problems.

Example 4-8. Using lsrscan to identify source routing issues

```
# lsrscan 217.53.62.0/24
217.53.62.0 does not reverse LSR traffic to it
217.53.62.0 does not forward LSR traffic through it
217.53.62.1 reverses LSR traffic to it
217.53.62.1 forwards LSR traffic through it
217.53.62.2 reverses LSR traffic to it
217.53.62.2 does not forward LSR traffic through it
```

Because some systems reverse the source route, spoofing attacks using *lsrtunnel* can be performed. Knowing that systems forward source-routed traffic, accurate details of internal IP addresses need to be gained so that port scans can be launched through *fragroute* to internal space.

lsrtunnel. *lsrtunnel* spoofs connections using source-routed packets. For the tool to work, the target host must reverse the source route (otherwise the user will not see the responses and be able to spoof a full TCP connection). *lsrtunnel* requires a spare IP address on the local subnet to use as a proxy for the remote host.

Running *lsrtunnel* with no options shows the usage syntax:

```
# lsrtunnel
usage: ./lsrtunnel -i <proxy IP> -t <target IP> -f <spoofed IP>
```

The proxy IP is an unused network address an attacker uses to proxy connections between her host and the target address. The spoofed IP address is the host that appears as the originator of the connection. For additional detail, consult the *lsrtunnel* manpage.

In this example of *lsrtunnel* in use, `192.168.102.2` is on the same local subnet as the host:

```
# lsrtunnel -i 192.168.102.2 -t 217.53.62.2 -f relay2.ucia.gov
```

At this point, *lsrtunnel* listens for traffic on the proxy IP (`192.168.102.2`). Using another system on the network, any TCP-based scan or attack launched against the proxy IP, is forwarded to the target (`217.53.62.2`) and appears as if it originated from *relay2.ucia.gov*.

Using Specific TCP and UDP Source Ports

When using a tool such as *nmap* to perform either UDP or TCP port scanning of hosts, it is important to assess responses using specific source ports. Here are four source ports you should use along with UDP, half-open SYN, and inverse FIN scan types:

- TCP or UDP port 53 (DNS)
- TCP port 20 (FTP data)
- TCP port 80 (HTTP)
- TCP or UDP port 88 (Kerberos)

Using specific source ports, attackers can take advantage of firewall configuration issues. UDP port 53 (DNS) is a good candidate when circumventing stateless packet filters because machines inside the network need to communicate with external DNS servers, which in turn respond using UDP port 53. Typically, a rule is put in place allowing traffic from UDP port 53 to destination port 53 or anything above 1024 on the internal client machine.

Check Point Firewall-1, Cisco PIX, and other stateful firewalls aren't vulnerable to these issues (unless grossly misconfigured) because they maintain a state table and allow traffic back into the network only if a relative outbound connection or request has been initiated.

An inverse FIN scan should be attempted when scanning the HTTP service port because a Check Point Firewall-1 option known as *fastmode* is sometimes enabled for web traffic in high throughput environments (to limit use of firewall processing resources). For specific information regarding circumvention of Firewall-1 in certain configurations, consult the excellent presentation from Black Hat Briefings 2000 by Thomas Lopatic, John McDonald, and Dug Song, titled "A Stateful Inspection of Firewall-1" (available as a Real media video stream and Powerpoint presentation from *http://www.blackhat.com/html/bh-usa-00/bh-usa-00-speakers.html*).

On Windows 2000 and other Microsoft platforms that can run IPsec, a handful of default exemptions to the IPsec filter exist, including one that allows Kerberos (source TCP or UDP port 88) traffic into the host if the filter is enabled. These default exemptions are removed in Windows Server 2003, but still pose a problem in some environments that rely on filtering at the operating-system kernel level.

With the -g option, *nmap* can launch a half-open TCP SYN port scan that uses the source port of 88 against a Windows 2000 server running IPsec filtering, as shown in Example 4-9.

Example 4-9. Using nmap to specify source ports when scanning

```
# nmap -sS -g 88 192.168.102.250

Starting nmap 3.45 ( www.insecure.org/nmap/ )
Interesting ports on kenny (192.168.102.250):
(The 1528 ports scanned but not shown below are in state: closed)
Port       State       Service
7/tcp      open        echo
9/tcp      open        discard
13/tcp     open        daytime
17/tcp     open        qotd
19/tcp     open        chargen
21/tcp     open        ftp
25/tcp     open        smtp
42/tcp     open        nameserver
53/tcp     open        domain
80/tcp     open        http
88/tcp     open        kerberos-sec
135/tcp    open        loc-srv
139/tcp    open        netbios-ssn
389/tcp    open        ldap
443/tcp    open        https
445/tcp    open        microsoft-ds
464/tcp    open        kpasswd5
515/tcp    open        printer
548/tcp    open        afpovertcp
593/tcp    open        http-rpc-epmap
636/tcp    open        ldapssl
1026/tcp   open        nterm
2105/tcp   open        eklogin
6666/tcp   open        irc-serv

Nmap run completed -- 1 IP address (1 host up) scanned in 1 second
```

Low-Level IP Assessment

Tools such as *nmap*, *hping2*, and *firewalk* perform low-level IP assessment. Sometimes holes exist to allow certain TCP services through the firewall, but the expected service isn't running on the target host. Such low-level network details are useful to know, especially in sensitive environments (e.g., online banking environments), because very small holes in network integrity can sometimes be abused along with larger problems to gain or retain access to target hosts.

Insight into the following areas of a network can be gleaned through low-level IP assessment:

- Uptime of target hosts (by analyzing the TCP timestamp option)
- TCP services that are permitted through the firewall (by analyzing responses to TCP and ICMP probes)
- TCP sequence and IP ID incrementation (by running predictability tests)
- The operating system of the target host (using IP fingerprinting)

nmap automatically attempts to calculate target host uptime information by analyzing the TCP timestamp option values of packets received. The TCP timestamp option is defined in RFC 1323; however, many platforms don't adhere to RFC 1323. This feature often gives accurate results against Linux operating systems and others such as FreeBSD, but your mileage may vary.

Analyzing Responses to TCP Probes

A TCP probe always results in one of four responses. These responses potentially allow an analyst to identify where a connection was accepted, or why and where it was rejected, dropped, or lost:

TCP SYN/ACK
: If a SYN/ACK packet is received, the port is considered open.

TCP RST/ACK
: If a RST/ACK packet is received, the probe packet was either rejected by the target host or an upstream security device (e.g., a firewall with a reject rule in its policy).

ICMP type 3 code 13
: If an ICMP type 3 code 13 message is received, the host (or a device such as a firewall) has administratively prohibited the connection according to an access control list (ACL) rule set.

Nothing
: If no packet is received, an intermediary security device silently dropped it.

nmap returns details of ports that are open, closed, filtered, and unfiltered in line with this list. The unfiltered state is reported by *nmap* from time to time, depending on the number of filtered ports found. If some ports don't respond, but others respond with RST/ACK, the unresponsive ports are considered unfiltered (because the packet is allowed through the filter but the associated service isn't running on the target host).

hping2 can be used on a port-by-port basis to perform low-level analysis of responses to crafted TCP packets that are sent to destination network ports of remote hosts. Another useful tool is *firewalk*, which performs filter analysis by sending UDP or TCP packets with specific TTL values. These unique features of *hping2* and *firewalk* are discussed next.

hping2

hping2 allows you to craft and send TCP packets to remote hosts with specific flags and options set. From analyzing responses at a low level, it is often possible to gain insight into the filter configuration at network level. The tool is complex to use, and it has many possible options. Table 4-3 lists the most useful flags for performing low-level TCP assessment.

Table 4-3. hping2 options

Option	Description
`-c <number>`	Send a specific number of probe packets
`-s <port>`	Source TCP port (random by default)
`-d <port>`	Destination TCP port
`-S`	Set the TCP SYN flag
`-F`	Set the TCP FIN flag
`-A`	Set the TCP ACK flag

Here's a best practice way to use *hping2* to assess a specific TCP port:

```
# hping2 -c 3 -s 53 -p 139 -S 192.168.0.1
HPING 192.168.0.1 (eth0 192.168.0.1): S set, 40 headers + 0 data
ip=192.168.0.1 ttl=128 id=275 sport=139 flags=SAP seq=0 win=64240
ip=192.168.0.1 ttl=128 id=276 sport=139 flags=SAP seq=1 win=64240
ip=192.168.0.1 ttl=128 id=277 sport=139 flags=SAP seq=2 win=64240
```

In this example, a total of three TCP SYN packets are sent to port 139 on `192.168.0.1` using the source port 53 of the host (some firewalls ship with a configuration that allows DNS traffic through the filter with an any-any rule, so it is sometimes fruitful to use a source port of 53).

Following are four examples of *hping2* that generate responses in line with the four states discussed previously (open, closed, blocked, or dropped).

TCP port 80 is open:

```
# hping2 -c 3 -s 53 -p 80 -S google.com
HPING google.com (eth0 216.239.39.99): S set, 40 headers + 0 data
ip=216.239.39.99 ttl=128 id=289 sport=80 flags=SAP seq=0 win=64240
ip=216.239.39.99 ttl=128 id=290 sport=80 flags=SAP seq=1 win=64240
ip=216.239.39.99 ttl=128 id=291 sport=80 flags=SAP seq=2 win=64240
```

TCP port 139 is closed or access to the port is rejected by a firewall:

```
# hping2 -c 3 -s 53 -p 139 -S 192.168.0.1
HPING 192.168.0.1 (eth0 192.168.0.1): S set, 40 headers + 0 data
ip=192.168.0.1 ttl=128 id=283 sport=139 flags=R seq=0 win=64240
ip=192.168.0.1 ttl=128 id=284 sport=139 flags=R seq=1 win=64240
ip=192.168.0.1 ttl=128 id=285 sport=139 flags=R seq=2 win=64240
```

TCP port 23 is blocked by a router ACL:

```
# hping2 -c 3 -s 53 -p 23 -S gw.example.org
HPING gw (eth0 192.168.0.254): S set, 40 headers + 0 data
ICMP unreachable type 13 from 192.168.0.254
ICMP unreachable type 13 from 192.168.0.254
ICMP unreachable type 13 from 192.168.0.254
```

TCP probe packets are dropped in transit:

```
# hping2 -c 3 -s 53 -p 80 -S 192.168.10.10
HPING 192.168.10.10 (eth0 192.168.10.10): S set, 40 headers + 0 data
```

firewalk

Mike Schiffman and Dave Goldsmith's *firewalk* utility (Version 5.0 at the time of writing) allows assessment of firewalls and packet filters by sending IP packets with TTL values set to expire one hop past a given gateway. Three simple states allow you to determine if a packet has passed through the firewall or not:

- If an ICMP type 11 code 0 (*TTL exceeded in transit*) message is received, the packet passed through the filter, and a response was later generated.
- If the packet is dropped without comment, it was probably done at the gateway.
- If an ICMP type 3 code 13 (*communication administratively prohibited*) message is received, a simple filter such as a router ACL is being used.

If the packet is dropped without comment, this doesn't necessarily mean that traffic to the target host and port is filtered. Some firewalls know that the packet is due to expire and send the expired message whether the policy allows the packet or not.

firewalk works effectively against hosts in true IP routed environments, as opposed to hosts behind firewalls using network address translation (NAT). I recommend reading the *firewalk* white paper written by Mike Schiffman and Dave Goldsmith, available from *http://www.packetfactory.net/projects/firewalk/firewalk-final.pdf*.

Example 4-10 shows *firewalk* being run against a host to assess filters in place for a selection of TCP ports (21, 22, 23, 25, 53, and 80). The utility requires two IP addresses: the gateway (*gw.test.org* in this example) and the target (*www.test.org* in this example) that is behind the gateway.

Example 4-10. Using firewalk to assess network filtering

```
# firewalk -n -S21,22,23,25,53,80 -pTCP gw.test.org www.test.org
Firewalk 5.0 [gateway ACL scanner]
Firewalk state initialization completed successfully.
TCP-based scan.
Ramping phase source port: 53, destination port: 33434
Hotfoot through 217.41.132.201 using 217.41.132.161 as a metric.
Ramping Phase:
 1 (TTL  1): expired [192.168.102.254]
 2 (TTL  2): expired [212.38.177.41]
 3 (TTL  3): expired [217.41.132.201]
Binding host reached.
Scan bound at 4 hops.
Scanning Phase:
port  21: A! open (port listen) [217.41.132.161]
port  22: A! open (port not listen) [217.41.132.161]
port  23: A! open (port listen) [217.41.132.161]
port  25: A! open (port not listen) [217.41.132.161]
port  53: A! open (port not listen) [217.41.132.161]
port  80: A! open (port not listen) [217.41.132.161]

Scan completed successfully.
```

The tool first performs an effective *traceroute* to the target host in order to calculate the number of hops involved. Upon completing this initial reconnaissance, crafted TCP packets are sent with specific IP TTL values. By analyzing the responses from the target network and looking for ICMP type 11 code 0 messages, an attacker can reverse-engineer the filter policy of *gw.test.org*.

Passively Monitoring ICMP Responses

As port scans and network probes are launched, you can passively monitor all traffic using *ethereal* or *tcpdump*. Often, you will see ICMP responses from border routers and firewalls, including:

- ICMP TTL exceeded (type 11 code 0) messages, indicating a routing loop
- ICMP administratively prohibited (type 3 code 13) messages, indicating a firewall or router that rejects certain packets in line with an ACL

These ICMP response messages give insight into the target network's setup and configuration. It is also possible to determine IP alias relationships in terms of firewalls performing NAT and other functions to forward traffic to other hosts and devices (for example, if you are probing a public Internet address but see responses from a private address in your sniffer logs).

IP Fingerprinting

Various operating platforms have their own interpretations of IP-related standards when receiving certain types of packets and responding to them. By analyzing responses from Internet-based hosts carefully, attackers often can guess the operating platform of the target host via IP fingerprinting, usually by assessing and sampling the following IP responses:

- TCP FIN probes and bogus flag probes
- TCP sequence number sampling
- TCP WINDOW sampling
- TCP ACK value sampling
- ICMP message quoting
- ICMP ECHO integrity
- Responses to IP fragmentation
- IP TOS (type of service) sampling

Originally, tools such as *cheops* and *queso* were developed specifically to guess target system operating platforms; however, the first publicly available tool to perform this was *sirc3*, which simply detected the difference between BSD-derived, Windows, and Linux TCP stacks.

Today, *nmap* performs a large number of IP fingerprinting tests to guess the remote operating platform. To enable IP fingerprinting when running *nmap*, simply use the -O flag in combination with a scan type flag such as -sS, as shown in Example 4-11.

Example 4-11. Using nmap to perform IP fingerprinting

```
# nmap -O -sS 192.168.0.65

Starting nmap 3.45 ( www.insecure.org/nmap/ )
Interesting ports on 192.168.0.65:
(The 1585 ports scanned but not shown below are in state: closed)
Port       State       Service
22/tcp     open        ssh
25/tcp     open        smtp
53/tcp     open        domain
80/tcp     open        http
88/tcp     open        kerberos-sec
110/tcp    open        pop-3
135/tcp    open        loc-srv
139/tcp    open        netbios-ssn
143/tcp    open        imap2
389/tcp    open        ldap
445/tcp    open        microsoft-ds
464/tcp    open        kpasswd5
593/tcp    open        http-rpc-epmap
636/tcp    open        ldapssl
```

Example 4-11. Using nmap to perform IP fingerprinting (continued)

```
1026/tcp   open        LSA-or-nterm
1029/tcp   open        ms-lsa
1352/tcp   open        lotusnotes
3268/tcp   open        globalcatLDAP
3269/tcp   open        globalcatLDAPssl
3372/tcp   open        msdtc

Remote OS guesses: Windows 2000 or WinXP

Nmap run completed -- 1 IP address (1 host up)
```

TCP Sequence and IP ID Incrementation

If TCP sequence numbers are generated in a predictable way by the target host, then blind spoofing and hijacking can occur (although this is usually limited to internal network spaces). Older Windows operating platforms suffer from this because the sequence numbers are simply incremented instead of randomly generated.

If the IP ID value is incremental, the host can be used as a third party to perform IP ID header scanning as discussed in the section "IP ID header scanning." IP ID header scanning requires the ID values returned from the third party to be incremental so that accurate scan results can be gathered.

Example 4-12 shows *nmap* being run in verbose mode (-v) with TCP/IP fingerprinting (-O). Setting both options shows the results of both TCP and IP ID sequence number predictability tests.

Example 4-12. Using nmap to test TCP and IP ID sequences

```
# nmap -v -sS -O 192.168.102.251

Starting nmap 3.45 ( www.insecure.org/nmap/ )
Interesting ports on cartman (192.168.102.251):
(The 1524 ports scanned but not shown below are in state: closed)
Port       State       Service
25/tcp     open        smtp
53/tcp     open        domain
8080/tcp   open        http-proxy

Remote OS guesses: Windows 2000 RC1 through final release
TCP Sequence Prediction: Class=random positive increments
                         Difficulty=15269 (Worthy challenge)
IPID Sequence Generation: Incremental

Nmap run completed -- 1 IP address (1 host up) scanned in 1 second
```

Network Scanning Recap

Different IP network scanning methods allow you to test and effectively identify vulnerable network components. Here is a list of effective network scanning techniques and their applications:

ICMP scanning and probing
: By launching an ICMP ping sweep, you can effectively identify poorly protected hosts (as security conscious administrators filter inbound ICMP messages) and perform a degree of operating-system fingerprinting and reconnaissance by analyzing responses to the ICMP probes.

Half-open SYN flag TCP port scanning
: A SYN port scan is often the most effective type of port scan to launch directly against a target IP network space. SYN scanning is extremely fast, allowing you to scan large networks quickly.

Inverse TCP port scanning
: Inverse scanning types (particularly FIN, Xmas, and NULL) take advantage of idiosyncrasies in certain TCP/IP stack implementations. This scanning type isn't effective when scanning large network spaces, although it is useful when testing and investigating the security of specific hosts and small network segments.

Third-party TCP port scanning
: Using a combination of vulnerable network components and TCP spoofing, third-party TCP port scans can be effectively launched. Scanning in this fashion has two benefits: hiding the true source of a TCP scan and assessing the filters and levels of trust between hosts. Although time consuming to undertake, third-party scanning is extremely useful when applied correctly.

UDP port scanning
: Identifying accessible UDP services can be undertaken easily only if ICMP type 3 code 3 (destination port unreachable) messages are allowed back through filtering mechanisms that protect target systems. UDP services can sometimes be used to gather useful data or directly compromise hosts (the DNS, SNMP, TFTP, and BOOTP services in particular).

IDS evasion and filter circumvention
: Intrusion detection systems and other security mechanisms can be rendered ineffective by using multiple spoofed decoy hosts when scanning or by fragmenting probe packets using *nmap* or *fragroute*. Filters such as firewalls, routers, and even software (including the Microsoft IPsec filter) can sometimes be bypassed using specific source TCP or UDP ports, source routing, or stateful attacks.

Network Scanning Countermeasures

Here is a checklist of countermeasures to use when considering technical modifications to networks and filtering devices to reduce the effectiveness of network scanning and probing undertaken by attackers:

- Filter inbound ICMP message types at border routers and firewalls. This forces attackers to use full-blown TCP port scans against all of your IP addresses to map your network correctly.
- Filter all outbound ICMP type 3 unreachable messages at border routers and firewalls to prevent UDP port scanning and firewalking from being effective.
- Consider configuring Internet firewalls so that they can identify port scans and throttle the connections accordingly. You can configure commercial firewall appliances (such as those from Check Point, NetScreen, and WatchGuard) to prevent fast port scans and SYN floods being launched against your networks. On the open source side, there are many tools such as *portsentry* that can identify port scans and drop all packets from the source IP address for a given period of time.
- Assess the way that your network firewall and IDS devices handle fragmented IP packets by using *fragtest* and *fragroute* when performing scanning and probing exercises. Some devices crash or fail under conditions in which high volumes of fragmented packets are being processed.
- Ensure that your routing and filtering mechanisms (both firewalls and routers) can't be bypassed using specific source ports or source-routing techniques.
- If you house publicly accessible FTP services, ensure that your firewalls aren't vulnerable to stateful circumvention attacks relating to malformed PORT and PASV commands.
- If a commercial firewall is in use, ensure the following:
  - The latest service pack is installed.
  - Antispoofing rules have been correctly defined, so that the device doesn't accept packets with private spoofed source addresses on its external interfaces.
  - Fastmode services aren't used in Check Point Firewall-1 environments.
- Investigate using inbound proxy servers in your environment if you require a high level of security. A proxy server will not forward fragmented or malformed packets, so it isn't possible to launch FIN scanning or other stealth methods.
- Be aware of your own network configuration and its publicly accessible ports by launching TCP and UDP port scans along with ICMP probes against your own IP address space. It is surprising how many large companies still don't properly undertake even simple port-scanning exercises.