

## **CONTENTS IN DETAIL**

ABOUT THE AUTHORS	xix
About the Technical Reviewer	xx
About the Contributing Authors	
FOREWORD by Richard Bejtlich	xxi
ACKNOWLEDGMENTS	xxv
Individual Thanks	xxv
INTRODUCTION	xxvii
What Is Malware Analysis?	
Prerequisites Practical, Hands-On Learning What's in the Book?	xxix
0 MALWARE ANALYSIS PRIMER	1
The Goals of Malware Analysis  Malware Analysis Techniques  Basic Static Analysis  Basic Dynamic Analysis  Advanced Static Analysis  Advanced Dynamic Analysis  Types of Malware  General Rules for Malware Analysis  PART 1  BASIC ANALYSIS	
1 BASIC STATIC TECHNIQUES	9
Antivirus Scanning: A Useful First Step	10
Hashing: A Fingerprint for Malware	10
Finding Strings	11
Packed and Obfuscated Malware	
Packing Files  Detecting Packers with PEiD	۱۵ ۱3 ۱ ۱
Portable Executable File Format	
Linked Libraries and Functions	
Static, Runtime, and Dynamic Linking	

Exploring Dynamically Linked Functions with Dependency Walker	
Imported Functions	
Exported Functions	18
Static Analysis in Practice	18
PotentialKeylogger.exe: An Unpacked Executable	
PackedProgram.exe: A Dead End	
The PE File Headers and Sections	
Examining PE Files with PEview	
Viewing the Resource Section with Resource Hacker	25
Using Other PE File Tools	26
PE Header Summary	26
Conclusion	
Labs	
2 MALWARE ANALYSIS IN VIRTUAL MACHINES	29
The Structure of a Virtual Machine	
Creating Your Malware Analysis Machine	
Configuring VMware	
Using Your Malware Analysis Machine	
Connecting Malware to the Internet	
Connecting and Disconnecting Peripheral Devices	
Taking Snapshots	
Transferring Files from a Virtual Machine	
The Risks of Using VMware for Malware Analysis	
Record/Replay: Running Your Computer in Reverse	3/
Conclusion	3/
3 BASIC DYNAMIC ANALYSIS	39
Sandboxes: The Quick-and-Dirty Approach	40
Using a Malware Sandbox	
Sandbox Drawbacks	
Running Malware	42
Monitoring with Process Monitor	43
The Procmon Display	44
Filtering in Procmon	44
Viewing Processes with Process Explorer	47
The Process Explorer Display	47
Using the Verify Option	
Comparing Strings	49
Using Dependency Walker	49
Analyzing Malicious Documents	
Comparing Registry Snapshots with Regshot	50

Faking a Network	
Using ApateDNS	
Monitoring with Netcat	52
Packet Sniffing with Wireshark	53
Using INetSim	55
Basic Dynamic Tools in Practice	56
Conclusion	
Labs	
PART 2	
ADVANCED STATIC ANALYSIS	
4 CDACH COURSE IN YOU DISACCEMBLY	
A CRASH COURSE IN X86 DISASSEMBLY	65
Levels of Abstraction	66
Reverse-Engineering	67
The x86 Architecture	
Main Memory	
Instructions	
Opcodes and Endianness	
Operands	
Registers	71
Simple Instructions	
The Stack	
Conditionals	
Branching	
Rep Instructions	
C Main Method and Offsets	
More Information: Intel x86 Architecture Manuals	03
Conclusion	83
5	
IDA PRO	87
Loading an Executable	88
The IDA Pro Interface	89
Disassembly Window Modes	
Useful Windows for Analysis	
Returning to the Default View	92
Navigating IDA Pro	02
Searching	
Using Cross-References	
Code Cross-References	
Data Cross-References	90

Enhancing Disassembly	100
Renaming Locations	100
Comments	
Formatting Operands	
Using Named Constants	
Redefining Code and Data	
Extending IDA with Plug-ins	
Using IDC Scripts	
Using IDAPython	
Using Commercial Plug-ins	
Conclusion	
Labs	10/
6	
RECOGNIZING C CODE CONSTRUCTS IN ASSEMBLY	
Global vs. Local Variables	110
Disassembling Arithmetic Operations	112
Recognizing if Statements	
Analyzing Functions Graphically with IDA Pro	
Recognizing Nested if Statements	114
Recognizing Loops	
Finding for Loops	
Finding while Loops	
Understanding Function Call Conventions	
cdecl	
stdcall	
fastcall	
Push vs. Move	
Analyzing switch Statements	
Îf Style	122
Jump Table	123
Disassembling Arrays	
Identifying Structs	
Analyzing Linked List Traversal	
Conclusion	
Labs	
Labs	133
7	
ANALYZING MALICIOUS WINDOWS PROGRAMS	135
The Windows API	136
Types and Hungarian Notation	
Handles	
File System Functions	
Special Files	
The Windows Registry	
Registry Root Keys	
Regedit	140
Programs that Run Automatically	
Common Registry Functions	141

Regist	try Scripting with .reg Files	142
Networking AP	'ls	143
Berkel	ley Compatible Sockets	143
The Se	erver and Client Sides of Networking	144
The W	VinINet API	145
Following Runn	ing Malware	145
DLLs .		145
Proces	sses	147
	ds	
	rocess Coordination with Mutexes	
	ces	
The C	Component Object Model	154
	otions: When Things Go Wrong	
	Mode	
	Wode	
Labs		102
	ED DYNAMIC ANALYSIS	
8		
	1G	167
8 DEBUGGIN		
8 DEBUGGIN Source-Level vs.	. Assembly-Level Debuggers	168
8 DEBUGGIN Source-Level vs. Kernel vs. User-	. Assembly-Level Debuggers -Mode Debugging	168
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debugg	. Assembly-Level Debuggers -Mode Debugging ger	
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debug Single	. Assembly-Level Debuggers -Mode Debugging ger -Stepping	
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debug Single Steppi	. Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into	
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debugg Single Steppi Pausir	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints	
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debugg Single Steppi Pausir Exceptions	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints	
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debugg Single Steppi Pausir Exceptions First- o	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions	
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debugg Single Steppi Pausir Exceptions First- c Comm	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions non Exceptions	
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debugg Single Steppi Pausir Exceptions First- c Comm Modifying Exec	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions non Exceptions cution with a Debugger	
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debuge Single Steppi Pausir Exceptions First- c Comm Modifying Exec Modifying Prog	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions non Exceptions cution with a Debugger gram Execution in Practice	
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debuge Single Steppi Pausir Exceptions First- c Comm Modifying Exec Modifying Prog	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions non Exceptions cution with a Debugger	
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debuge Single Steppi Pausir Exceptions First- c Comm Modifying Exec Modifying Prog	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions non Exceptions cution with a Debugger gram Execution in Practice	
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debuge Single Steppi Pausir Exceptions First- c Comm Modifying Exec Modifying Prog	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions non Exceptions cution with a Debugger gram Execution in Practice	
8 DEBUGGIN Source-Level vs. Kernel vs. User-Using a Debugg Single Steppi Pausir Exceptions First- a Comm Modifying Exec Modifying Prog Conclusion	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions non Exceptions cution with a Debugger gram Execution in Practice	
8 DEBUGGIN Source-Level vs. Kernel vs. User-Using a Debugg Single Steppi Pausir Exceptions First- c Comm Modifying Exec Modifying Prog Conclusion  9 OLLYDBG	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ing Execution with Breakpoints and Second-Chance Exceptions inon Exceptions cution with a Debugger gram Execution in Practice	168
8 DEBUGGIN Source-Level vs. Kernel vs. User-Using a Debugg Single Steppi Pausir Exceptions First- c Comm Modifying Exec Modifying Prog Conclusion  9 OLLYDBG Loading Malwo	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ing Execution with Breakpoints and Second-Chance Exceptions inon Exceptions cution with a Debugger gram Execution in Practice	168
8 DEBUGGIN Source-Level vs. Kernel vs. User-Using a Debugg Single Steppi Pausir Exceptions First- a Comm Modifying Exect Modifying Prog Conclusion  9 OLLYDBG Loading Malwa	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ing Execution with Breakpoints and Second-Chance Exceptions inon Exceptions cution with a Debugger gram Execution in Practice	168 169 169 170 171 175 176 176 177 177 178
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debugg Single Steppi Pausir Exceptions First- a Comm Modifying Exec Modifying Prog Conclusion  9 OLLYDBG Loading Malwa	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ing Execution with Breakpoints and Second-Chance Exceptions inon Exceptions cution with a Debugger gram Execution in Practice	168 169 169 170 171 175 175 176 177 177 178
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debugg Single Steppi Pausir Exceptions First- c Comm Modifying Exec Modifying Prog Conclusion  9 OLLYDBG Loading Malwo Openi Attach The OllyDbg In	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions non Exceptions cution with a Debugger gram Execution in Practice	168 169 169 170 171 175 175 176 177 177 178 180 180 181
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debugg Single Steppi Pausir Exceptions First- a Comm Modifying Exec Modifying Prog Conclusion  9 OLLYDBG Loading Malwa Openi Attach The OllyDbg In Memory Map	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions non Exceptions cution with a Debugger gram Execution in Practice	168 169 169 170 171 171 175 176 176 177 177 178 180 180 181 181
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debugg Single Steppi Pausir Exceptions First- a Comm Modifying Exec Modifying Prog Conclusion  9 OLLYDBG Loading Malwa Openi Attach The OllyDbg In Memory Map Rebas	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions non Exceptions cution with a Debugger gram Execution in Practice	168 168 169 169 170 171 175 175 176 177 177 178 180 180 181 181 183
8 DEBUGGIN Source-Level vs. Kernel vs. User- Using a Debugg Single Steppi Pausir Exceptions First- o Comm Modifying Exec Modifying Prog Conclusion  9 OLLYDBG Loading Malwo Openi Attach The OllyDbg In Memory Map Rebas Viewing Thread	Assembly-Level Debuggers -Mode Debugging ger -Stepping ing-Over vs. Stepping-Into ng Execution with Breakpoints and Second-Chance Exceptions non Exceptions cution with a Debugger gram Execution in Practice	168 168 169 169 170 171 175 175 176 177 177 178 180 180 181 181 181 183

Breakpoints	188
Software Breakpoints	188
Conditional Breakpoints	189
Hardware Breakpoints	190
Memory Breakpoints	190
Loading DLLs	191
Tracing	
Standard Back Trace	
Call Stack	
Run Trace	
Tracing Poison Ivy	
Exception Handling	
Patching	
Analyzing Shellcode	
Assistance Features	
Plug-ins	
OllyDump	
Hide Debugger	
Command Line	
Bookmarks	
Scriptable Debugging	
Labs	
10	
KERNEL DEBUGGING WITH WINDBG	205
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	206
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	206
ERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	
ERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code  Setting Up Kernel Debugging  Using WinDbg  Reading from Memory	
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	206 207 210 210 211 211 212 212 212 213
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	206 207 210 210 211 211 212 212 212 213 215
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	206 207 210 210 211 211 212 212 212 213 215
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code	206 207 210 210 211 211 212 212 212 213 215 215
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code  Setting Up Kernel Debugging  Using WinDbg  Reading from Memory  Using Arithmetic Operators  Setting Breakpoints  Listing Modules  Microsoft Symbols  Searching for Symbols  Viewing Structure Information  Configuring Windows Symbols  Kernel Debugging in Practice  Looking at the User-Space Code	206 207 210 210 211 211 212 212 212 213 215 215
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code  Setting Up Kernel Debugging  Using WinDbg  Reading from Memory  Using Arithmetic Operators  Setting Breakpoints  Listing Modules  Microsoft Symbols  Searching for Symbols  Viewing Structure Information  Configuring Windows Symbols  Kernel Debugging in Practice  Looking at the User-Space Code  Looking at the Kernel-Mode Code	206 207 210 210 211 211 212 212 213 215 215 217 220
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code Setting Up Kernel Debugging Using WinDbg Reading from Memory Using Arithmetic Operators Setting Breakpoints Listing Modules  Microsoft Symbols Searching for Symbols Viewing Structure Information Configuring Windows Symbols  Kernel Debugging in Practice Looking at the User-Space Code Looking at the Kernel-Mode Code Finding Driver Objects	206 207 210 210 211 211 212 212 212 213 215 215 217 220 221
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code  Setting Up Kernel Debugging  Using WinDbg  Reading from Memory  Using Arithmetic Operators  Setting Breakpoints  Listing Modules  Microsoft Symbols  Searching for Symbols  Viewing Structure Information  Configuring Windows Symbols  Kernel Debugging in Practice  Looking at the User-Space Code  Looking at the Kernel-Mode Code  Finding Driver Objects  Rootkits  Rootkits In Practice	206 207 210 210 211 211 212 212 212 213 215 215 217 220 221
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code  Setting Up Kernel Debugging  Using WinDbg  Reading from Memory  Using Arithmetic Operators  Setting Breakpoints  Listing Modules  Microsoft Symbols  Searching for Symbols  Viewing Structure Information  Configuring Windows Symbols  Kernel Debugging in Practice  Looking at the User-Space Code  Looking at the Kernel-Mode Code  Finding Driver Objects  Rootkits	206 207 210 210 211 211 212 212 212 213 215 215 217 220 221
RERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code  Setting Up Kernel Debugging  Using WinDbg  Reading from Memory  Using Arithmetic Operators  Setting Breakpoints  Listing Modules  Microsoft Symbols  Searching for Symbols  Viewing Structure Information  Configuring Windows Symbols  Kernel Debugging in Practice  Looking at the User-Space Code  Looking at the Kernel-Mode Code  Finding Driver Objects  Rootkits  Rootkit Analysis in Practice  Interrupts  Loading Drivers	206 207 210 210 211 211 211 212 212 213 215 215 215 217 220 221 222 225
KERNEL DEBUGGING WITH WINDBG  Drivers and Kernel Code  Setting Up Kernel Debugging  Using WinDbg  Reading from Memory  Using Arithmetic Operators  Setting Breakpoints  Listing Modules  Microsoft Symbols  Searching for Symbols  Viewing Structure Information  Configuring Windows Symbols  Kernel Debugging in Practice  Looking at the User-Space Code  Looking at the Kernel-Mode Code  Finding Driver Objects  Rootkits  Rootkit Analysis in Practice  Interrupts	206 207 210 210 211 211 211 212 212 213 215 215 215 217 220 221 222 225 226

## PART 4 **MALWARE FUNCTIONALITY**

11 MALWARE BEHAVIOR	231
Downloaders and Launchers	
Backdoors	
Reverse Shell	
RATs	
Botnets	
RATs and Botnets Compared	
Credential Stealers	
GINA Interception	
Hash Dumping	
Keystroke Logging	
Persistence Mechanisms	
The Windows Registry	
Trojanized System Binaries	
DLL Load-Order Hijacking	
Privilege Escalation	
Using SeDebugPrivilege	
Covering Its Tracks—User-Mode Rootkits	
IAT Hooking	
Inline Hooking	
Conclusion	
12	251
COVERT MALWARE LAUNCHING	253
Launchers	253
Process Injection	
DLL Injection	
Direct Injection	257
Process Replacement	
Hook Injection	
Local and Remote Hooks	
Keyloggers Using Hooks	
Using SetWindowsHookEx	
Thread Targeting	
Detours	
APC Injection	
APC Injection from User Space	
APC Injection from Kernel Space	
Conclusion	
	205 266

13 DATA ENCODING	269
The Goal of Analyzing Encoding Algorithms	270
Simple Ciphers	
Caesar Cipher	270
XOR	271
Other Simple Encoding Schemes	276
Base64	277
Common Cryptographic Algorithms	
Recognizing Strings and Imports	
Searching for Cryptographic Constants	
Searching for High-Entropy Content	
Custom Encoding	
Identifying Custom Encoding	285
Advantages of Custom Encoding to the Attacker	
Decoding	
Self-Decoding	
Manual Programming of Decoding Functions	
Using Instrumentation for Generic Decryption	
Conclusion	
Labs	
MALWARE-FOCUSED NETWORK SIGNATURES	
	<b>297</b>
Network Countermeasures	297
Network Countermeasures	297 298
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity	
Network Countermeasures  Observing the Malware in Its Natural Habitat  Indications of Malicious Activity  OPSEC = Operations Security	
Network Countermeasures  Observing the Malware in Its Natural Habitat  Indications of Malicious Activity  OPSEC = Operations Security  Safely Investigate an Attacker Online	
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity  OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics	
Network Countermeasures  Observing the Malware in Its Natural Habitat  Indications of Malicious Activity  OPSEC = Operations Security  Safely Investigate an Attacker Online  Indirection Tactics  Getting IP Address and Domain Information	
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity  OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics  Getting IP Address and Domain Information  Content-Based Network Countermeasures	
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity  OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics  Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort	
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity  OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics  Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort Taking a Deeper Look	297 298 298 299 300 300 302 303
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity  OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics  Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort  Taking a Deeper Look  Combining Dynamic and Static Analysis Techniques	297 298 298 299 300 300 302 303 303
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort Taking a Deeper Look  Combining Dynamic and Static Analysis Techniques The Danger of Overanalysis	297 298 298 299 300 300 302 303 303 304 307
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort Taking a Deeper Look  Combining Dynamic and Static Analysis Techniques The Danger of Overanalysis Hiding in Plain Sight	297 298 298 299 300 300 302 303 304 307 308
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort Taking a Deeper Look  Combining Dynamic and Static Analysis Techniques The Danger of Overanalysis Hiding in Plain Sight Understanding Surrounding Code	297 298 298 299 300 300 302 303 304 307 308 308
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort Taking a Deeper Look  Combining Dynamic and Static Analysis Techniques The Danger of Overanalysis Hiding in Plain Sight Understanding Surrounding Code Finding the Networking Code	297 298 298 299 300 300 300 303 304 307 308 312
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort Taking a Deeper Look  Combining Dynamic and Static Analysis Techniques The Danger of Overanalysis Hiding in Plain Sight Understanding Surrounding Code Finding the Networking Code Knowing the Sources of Network Content	297 298 298 299 300 300 300 302 303 304 307 308 312 313
Network Countermeasures  Observing the Malware in Its Natural Habitat Indications of Malicious Activity OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort Taking a Deeper Look  Combining Dynamic and Static Analysis Techniques The Danger of Overanalysis Hiding in Plain Sight Understanding Surrounding Code Finding the Networking Code Knowing the Sources of Network Content Hard-Coded Data vs. Ephemeral Data	297 298 298 299 300 300 300 302 303 304 307 308 312 313
Network Countermeasures Observing the Malware in Its Natural Habitat Indications of Malicious Activity OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort Taking a Deeper Look  Combining Dynamic and Static Analysis Techniques The Danger of Overanalysis Hiding in Plain Sight Understanding Surrounding Code Finding the Networking Code Knowing the Sources of Network Content Hard-Coded Data vs. Ephemeral Data Identifying and Leveraging the Encoding Steps	297 298 298 299 300 300 300 302 303 304 312 314 314
Network Countermeasures Observing the Malware in Its Natural Habitat Indications of Malicious Activity OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort Taking a Deeper Look  Combining Dynamic and Static Analysis Techniques The Danger of Overanalysis Hiding in Plain Sight Understanding Surrounding Code Finding the Networking Code Knowing the Sources of Network Content Hard-Coded Data vs. Ephemeral Data Identifying and Leveraging the Encoding Steps Creating a Signature	297 298 298 299 300 300 300 302 303 304 307 308 312 313 314 315
Network Countermeasures Observing the Malware in Its Natural Habitat Indications of Malicious Activity OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort Taking a Deeper Look  Combining Dynamic and Static Analysis Techniques The Danger of Overanalysis Hiding in Plain Sight Understanding Surrounding Code Finding the Networking Code Knowing the Sources of Network Content Hard-Coded Data vs. Ephemeral Data Identifying and Leveraging the Encoding Steps Creating a Signature Analyze the Parsing Routines	297 298 298 299 300 300 300 302 303 304 307 308 312 314 314 315 317
Network Countermeasures Observing the Malware in Its Natural Habitat Indications of Malicious Activity OPSEC = Operations Security  Safely Investigate an Attacker Online Indirection Tactics Getting IP Address and Domain Information  Content-Based Network Countermeasures Intrusion Detection with Snort Taking a Deeper Look  Combining Dynamic and Static Analysis Techniques The Danger of Overanalysis Hiding in Plain Sight Understanding Surrounding Code Finding the Networking Code Knowing the Sources of Network Content Hard-Coded Data vs. Ephemeral Data Identifying and Leveraging the Encoding Steps Creating a Signature	297 298 298 299 300 300 300 302 303 304 307 308 312 313 314 315 317

## PART 5 **ANTI-REVERSE-ENGINEERING**

15 ANTI-DISASSEMBLY	327
Understanding Anti-Disassembly	328
Defeating Disassembly Algorithms	
Linear Disassembly	329
Flow-Oriented Disassembly	331
Anti-Disassembly Techniques	334
Jump Instructions with the Same Target	
A Jump Instruction with a Constant Condition	
Impossible Disassembly	
NOP-ing Out Instructions with IDA Pro	
Obscuring Flow Control	
The Function Pointer Problem	
Adding Missing Code Cross-References in IDA P	
Return Pointer Abuse	
Misusing Structured Exception Handlers	
Thwarting Stack-Frame Analysis	
Conclusion	349
Labs	350
16 Anti-debugging	351
Windows Debugger Detection	
Using the Windows API	
Manually Checking Structures	
Checking for System Residue	
Identifying Debugger Behavior	
INT Scanning	
Performing Code Checksums	
Timing Checks	
Interfering with Debugger Functionality	
Using TLS Callbacks	
Using Exceptions	
Inserting Interrupts	
Debugger Vulnerabilities	
The OutputDebugString Vulnerability	
Conclusion	
Labs	
Labs	30/
1 <i>7</i> ANTI-VIRTUAL MACHINE TECHNIQUES	369
VMware Artifacts	370
Bypassing VMware Artifact Searching	
Checking for Memory Artifacts	3/3

Vulnerable Instructions	
Using the Red Pill Anti-VM Technique	
Using the No Pill Technique	
Querying the I/O Communication Port	
Using the str Instruction	
Anti-VM x86 Instructions	
Highlighting Anti-VM in IDA Pro	
Using ScoopyNG	
Tweaking Settings	
Escaping the Virtual Machine	
Labs	
Lubs	301
18	
PACKERS AND UNPACKING	383
Packer Anatomy	384
The Unpacking Stub	384
Loading the Executable	
Resolving Imports	
The Tail Jump	
Unpacking Illustrated	
Identifying Packed Programs	
Indicators of a Packed Program	
Entropy Calculation	
Unpacking Options	
Automated Unpacking	
Manual Unpacking	
Rebuilding the Import Table with Import Reconstructor	
Finding the OEP	391
Repairing the Import Table Manually	
Tips and Tricks for Common Packers	
UPXPECompact	
ASPack	
Petite	
WinUpack	
Themida	
Analyzing Without Fully Unpacking	
Packed DLLs	
Conclusion	
Labs	
PART 6	
SPECIAL TOPICS	
19	
SHELLCODE ANALYSIS	407
Loading Shellcode for Analysis	408
• • • • • • • • • • • • • • • • • • •	

Position-Independent Code	
Identifying Execution Location	
Using call/pop	
Using fnstenv	
Manual Symbol Resolution	
Finding kernel32.dll in Memory	
Parsing PE Export Data	
Using Hashed Exported Names	
A Full Hello World Example	
Shellcode Encodings	
NOP Sleds	
Finding Shellcode	
Conclusion	
Labs	425
00	
20 C++ ANALYSIS	427
Object-Oriented Programming	
The this Pointer	
Overloading and Mangling	
Inheritance and Function Overriding	
Virtual vs. Nonvirtual Functions	
Use of Vtables	
Recognizing a Vtable	
Creating and Destroying Objects	
Conclusion	
Labs	439
21	
64-BIT MALWARE	441
Why 64-Bit Malware?	4.40
Differences in x64 Architecture	
Differences in the x64 Calling Convention and Stack Usage	
64-Bit Exception Handling	
Windows 32-Bit on Windows 64-Bit	
64-Bit Hints at Malware Functionality	
Conclusion	
Labs	430
A	
IMPORTANT WINDOWS FUNCTIONS	453
В	
TOOLS FOR MALWARE ANALYSIS	465

C SOLUTIONS TO LABS	477
Lab 1-1477	Lab 13-1 607
Lab 1-2479	Lab 13-2612
Lab 1-3480	Lab 13-3617
Lab 1-4481	Lab 14-1 626
Lab 3-1	Lab 14-7
Lab 3-2	Lab 14-3
Lab 3-3	
Lab 3-4	Lab 15-1645
	Lab 15-2
Lab 5-1494	Lab 15-3652
Lab 6-1501	Lab 16-1655
Lab 6-2503	Lab 16-2 660
Lab 6-3507	Lab 16-3 665
Lab 6-4511	Lab 17-1 670
Lab 7-1513	Lab 17-2 673
Lab 7-2517	Lab 17-3 678
Lab 7-3519	Lab 18-1 684
Lab 9-1530	Lab 18-2
Lab 9-2	Lab 18-3
Lab 9-3	Lab 18-4
	Lab 18-5
Lab 10-1548	
Lab 10-2554	Lab 19-1 696
Lab 10-3560	Lab 19-2
Lab 11-1566	Lab 19-3703
Lab 11-2571	Lab 20-1712
Lab 11-3581	Lab 20-2713
	Lab 20-3717
Lab 12-1586	1   01   700
Lab 12-2	Lab 21-1
Lab 12-3	Lab 21-2
Ldb 12-4	
INDEX	733