

# Advanced Windows Exploitation

Morten Schenk  
Alexandru Uifalvi



Copyright © 2024 OffSec Services Limited

*All rights reserved. No part of this publication, in whole or in part, may be reproduced, copied, transferred or any other right reserved to its copyright owner, including photocopying and all other copying, any transfer or transmission using any network or other means of communication, any broadcast for distant learning, in any form or by any means such as any information storage, transmission or retrieval system, without prior written permission from the author.*

## Table of Contents

1	Introduction.....	8
2	Microsoft Edge Type Confusion .....	9
2.1	Exploitation Introduction.....	9
2.1.1	64-bit Architecture.....	9
2.1.2	Vulnerability Classes.....	12
2.1.3	Basic Security Mitigations .....	13
2.2	Edge Internals .....	17
2.2.1	JavaScript Engine.....	18
2.2.2	Chakra Internals.....	19
2.2.3	JIT and Type Confusion .....	23
2.3	Type Confusion Case Study.....	24
2.3.1	Triggering the Vulnerability.....	25
2.3.2	Root Cause Analysis .....	26
2.4	Exploiting Type Confusion.....	31
2.4.1	Controlling the auxSlots Pointer .....	31
2.4.2	Abuse AuxSlots Pointer.....	34
2.4.3	Create Read and Write Primitive.....	39
2.5	Going for RIP .....	43
2.5.1	Vanilla Attack.....	44
2.5.2	CFG Internals.....	45
2.6	CFG Bypass.....	49
2.6.1	Return Address Overwrite.....	49
2.6.2	Intel CET .....	53
2.6.3	Out-of-Context Calls.....	54
2.7	Data Only Attack.....	57
2.7.1	Parallel DLL Loading .....	57
2.7.2	Injecting Fake Work.....	58
2.7.3	Faking the Work .....	63
2.7.4	Hot Patching DLLs .....	69
2.8	Arbitrary Code Guard (ACG) .....	72
2.8.1	ACG Theory.....	72
2.8.2	ACG Bypasses.....	74
2.9	Advanced Out-of-Context Calls .....	75
2.9.1	Faking it to Make it .....	75

2.9.2	Fixing the Crash .....	83
2.10	Remote Procedure Calls .....	88
2.10.1	RPC Theory .....	88
2.10.2	Is That My Structure .....	91
2.10.3	Analyzing the Buffers .....	95
2.10.4	Calling an API .....	106
2.10.5	Return of Mitigations .....	111
2.11	Perfecting Out-of-Context Calls .....	116
2.11.1	Come Back to JavaScript .....	116
2.11.2	Return Value Alignment .....	119
2.11.3	Call Me Again .....	125
2.12	Combining the Work .....	129
2.12.1	NOP'ing CFG .....	129
2.12.2	Call Arbitrary API .....	131
2.13	Browser Sandbox .....	133
2.13.1	Sandbox Theory Introduction .....	133
2.13.2	Sandbox Escape Theory .....	135
2.13.3	The Glue That Binds .....	136
2.14	Sandbox Escape Practice .....	139
2.14.1	Insecure Access .....	139
2.14.2	The Problem of Languages .....	142
2.15	The Great Escape .....	143
2.15.1	Activation Factory .....	143
2.15.2	GetTemplateContent .....	150
2.15.3	What Is As? .....	152
2.15.4	Loading the XML .....	155
2.15.5	Allowing Scripts .....	159
2.15.6	Pop That Notepad .....	161
2.15.7	Getting a Shell .....	163
2.16	Upping The Game - Making the Exploit Version Independent .....	165
2.16.1	Locating the Base .....	165
2.16.2	Locating Internal Functions and Imports .....	167
2.16.3	Locating Exported Functions .....	171
2.17	Wrapping Up .....	175
3	Kernel Exploitation and Payloads .....	176

3.1	The Windows Kernel.....	176
3.1.1	Privilege Levels.....	176
3.1.2	Interrupt Request Level (IRQL) .....	177
3.1.3	Windows Kernel Driver Signing.....	179
3.2	Kernel-Mode Debugging on Windows.....	179
3.2.1	Remote Kernel Debugging Over TCP/IP .....	180
3.3	Communicating with the Kernel.....	183
3.3.1	Native System Calls .....	184
3.3.2	Device Drivers.....	193
3.4	Kernel Vulnerability Classes.....	209
3.5	Kernel-Mode Payloads .....	211
3.5.1	Token Stealing.....	212
3.5.2	ALC Editing .....	217
3.5.3	Kernel Mode Rootkits .....	221
3.6	Vulnerability Overview and Exploitation.....	222
3.6.1	Triggering the Vulnerability.....	222
3.6.2	Redirecting Execution to Usermode .....	234
3.7	ROP-Based Attack.....	236
3.7.1	Stack Pivoting.....	236
3.7.2	Kernel Read/Write Primitive .....	242
3.7.3	Restoring the I/O Ring Object.....	254
3.8	Elevate Privileges .....	255
3.8.1	Data Only Attack .....	255
3.9	Developing a Rootkit.....	258
3.9.1	Bypassing DSE .....	258
3.9.2	Elevating Permissions .....	263
3.9.3	Evading Detection.....	272
3.10	Version Independence.....	276
3.10.1	Dynamic Gadget Location .....	276
3.11	Extra Mile Exercise.....	278
3.12	Wrapping Up .....	278
4	Untrusted Pointer Dereference.....	280
4.1	Vulnerability Overview and Exploit Types.....	280
4.1.1	Identifying the Vulnerability through Patch-Diffing .....	281
4.2	Introduction to Memory Paging and Structures.....	291

4.2.2	Memory Descriptor Lists (MDLs) .....	299
4.2.3	The PML4 Self-Reference Entry .....	301
4.2.4	PML4 Self-Reference Entry Randomization .....	306
4.3	Virtualization-Based Security .....	307
4.3.1	Hyper-V - The Windows Hypervisor .....	308
4.3.2	Windows Hypervisor Debugging .....	312
4.4	Interacting With the Device Driver .....	317
4.5	Extra Mile Exercise .....	339
4.6	Reaching the Vulnerable Code Block .....	339
4.6.2	Joy: From Happiness to Insight .....	348
4.6.3	A Wild Blue Screen Appears .....	394
4.6.4	Contentment: Unveiling Inner Peace .....	407
4.6.5	Uncertainty: Navigating the Unknown .....	435
4.6.6	Doubt: Understanding Self-Doubt .....	442
4.6.7	Fear: Facing Our Deepest Anxieties .....	462
4.7	Despair: The Path to Hope .....	474
4.8	Mapping Physical Memory to User-Mode .....	530
4.9	Exploiting the Vulnerability .....	556
4.10	Wrapping Up .....	566
5	Unsanitized User-mode Callback .....	567
5.1	Windows Desktop Applications .....	567
5.1.1	Windows Kernel Pool Memory .....	567
5.1.2	Creating Windows Desktop Applications .....	580
5.1.3	Reversing the TagWND Object .....	591
5.1.4	Kernel User-mode Callbacks .....	598
5.1.5	Leaking pWND User-Mode Objects .....	611
5.2	Triggering the Vulnerability .....	619
5.2.1	Spraying the Desktop Heap .....	620
5.2.2	Hooking the Callback .....	625
5.2.3	Arbitrary WndExtra Overwrite .....	628
5.3	TagWND Write Primitive .....	638
5.3.1	Overwrite pWND[0].cbWndExtra .....	639
5.3.2	Overwrite pWND[1].WndExtra .....	647
5.4	TagWND Leak and Read Primitive .....	653
5.4.1	Changing pWND[1].dwStyle .....	654

5.4.2	Setting The TagWND[1].spmenu .....	657
5.4.3	Creating a fake TagWND[1].spmenu .....	664
5.4.4	GetMenuBarInfo Read Primitive .....	686
5.5	Privilege Escalation.....	688
5.5.1	Low integrity .....	688
5.5.2	Data Only Attack .....	692
5.5.3	Restoring The Execution Flow .....	701
5.6	Executing Code in Kernel-Mode .....	704
5.6.1	Leaking Nt and Win32k Base .....	706
5.6.2	NOP-ing kCFG .....	711
5.6.3	Hijacking a Kernel-Mode Routine .....	716
5.6.4	Wrapping Up.....	721