Lecture 4
Exploiting. Shellcodes
Computer and Network Security
October 21, 2019
Computer Science and Engineering Department

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CNSO Outline
Vulnerabilities and Exploits
Runtime Exploiting
Shellcode
Trigerring and Placing Shellcodes
Conclusion

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Outline

CNSO
Bugs and Vulnerabilities
- bugs: misbehaving sofware
- vulnerability: misbehaviour that can benefit an attacker
- exploiting: turning a vulnerability into an advantage for the attacker
- auditing: analyzing an application to determine its vulnerabilities

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CNSO Why Bugs and Vulnerabilities?
- developer carelessness or ignorance
- poor development process
- poor design
- platform (hardware, OS, libraries) issues
- lack of resources

Why Bugs and Vulnerabilities?

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CNSO Preventing Vulnerabilities
- development process: defensive programming, code review, code audit
- design with security in mind
- audit systems, penetration testing
- security-centered training
- invest resources

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Preventing Vulnerabilities

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CNSO Security Attacks
- eavesdropping, impersonating
- password breaking
- denial of service
- exploiting

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Security Attacks

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CNSO Exploiting
- exploiting vulnerabilities
- focus is controlling the system (root account)
- an intermediary step is gaining shell access to user
- privilege escalation

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Exploiting

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CNSO Why Exploiting?
- money
- fame
- challenge
- fun
- political, ideological
- find security holes and fix them (ethical hacking)

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CNSO CTF crunch Detect/Prevent Exploiting
- monitoring
- update software
- stay connected
- in-depth security
- honeypots
- state of mind: "it will happen"

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CNSO Types of Exploits
- local exploit
- remote exploit
- user space exploit
- kernel space exploit

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Runtime Application Exploiting
- find vulnerability in process runtime: memory, use of resources
- alter normal execution pattern
- aim for: getting a shell, getting access to resources, information leak, crash application, denial of service
- usually tamper with process memory and bad ways of memory management
- special focus on string management functions, input/output, pointers

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CNSO Runtime Exploit Components
- preparatory phase
- shellcode
- triggering phase

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- buffer overflow (on stack or heap)
- integer overflow
- race conditions
- string formatting

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CNSO Buffer Overflow
- write beyond buffer limits
- stack-based overflow: overwrite variable, return address or function pointer
- heap overflow: corrupt dynamically allocated memory

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CNSO Shellcode
- sequence of machine level instructions
- stored in memory at a convenient address
- executed when requested by jumping at the start address

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Shellcode

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- executed when requested by jumping at the start address

CNSO
Shellcode Objectives
- typically the goal is to create a shell (if possible, with root privilege)
- may be any useful binary code execution, such as starting a client socket, or reading or writing a file, or sending a file over the network

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Shellcode Samples
- http://www.shell-storm.org/shellcode/
- hexadecimal form for exec-ing a shell process
- also dubbed payload

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CNSO
Shellcode Types
- spawn shell using `execve` syscall
- use `setresuid` to restore root privileges (for setuid-enabled programs)
- port-binding shellcode: create listener socket, accept connections, duplicate file descriptors and spawn shell
- connect-back shellcode: create client socket and connect to remote listener socket (accesible and controled by attacker), duplicate file descriptors and spawn shell

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Creating a Shellcode

- may be done in C but it is recommended to do it in assembly
  - allows shorter shellcodes
  - complete control over the end result (binary machine code)
- need to use syscalls for `execve`, `setresuid`, `dup2` and others
- need to place the `/bin/sh` string in memory (or other strings) and pass it as argument to syscall

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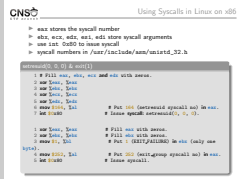


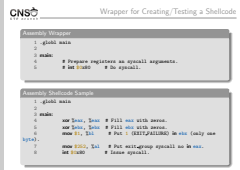
Using Syscalls in Linux on x86

- eax stores the syscall number
- ebx, ecx, edx, esi, edi store syscall arguments
- use int 0x80 to issue syscall
- syscall numbers in /usr/include/asm/unistd_32.h

setresuid(0, 0, 0) & exit(1)

```
    1 # Fill eax, ebx, ecx and edx with zeros.
    2 xor %eax, %eax
    3 xor %ebx, %ebx
    4 xor %ecx, %ecx
    5 xor %edx, %edx
    6 mov $164, %al           # Put 164 (setresuid syscall no) in eax.
    7 int $0x80               # Issue syscall: setresuid(0, 0, 0).
```

```
    1 xor %eax, %eax          # Fill eax with zeros.
    2 xor %ebx, %ebx          # Fill ebx with zeros.
    3 mov $1, %bl             # Put 1 (EXIT_FAILURE) in ebx (only one
byte).
    4 mov $252, %al           # Put 252 (exit_group syscall no) in eax.
    5 int $0x80               # Issue syscall.
```



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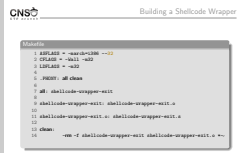
Wrapper for Creating/Testing a Shellcode

Assembly Wrapper

```
1 .globl main
2
3 main:
4         # Prepare registers an syscall arguments.
5         # int $0x80     # Do syscall.
```

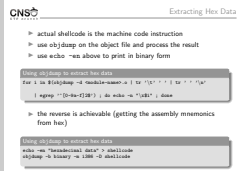
Assembly Shellcode Sample

```
1 .globl main
2
3 main:
4         xor %eax, %eax  # Fill eax with zeros.
5         xor %ebx, %ebx  # Fill ebx with zeros.
6         mov $1, %bl     # Put 1 (EXIT_FAILURE) in ebx (only one
byte).
7         mov $252, %al   # Put exit_group syscall no in eax.
8         int $0x80       # Issue syscall.
```



Makefile

```
1  ASFLAGS = -march=i386 --32
2  CFLAGS = -Wall -m32
3  LDFLAGS = -m32
4
5  .PHONY: all clean
6
7  all: shellcode-wrapper-exit
8
9  shellcode-wrapper-exit: shellcode-wrapper-exit.o
10
11 shellcode-wrapper-exit.o: shellcode-wrapper-exit.s
12
13 clean:
14         -rm -f shellcode-wrapper-exit shellcode-wrapper-exit.o *~
```



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Extracting Hex Data

- actual shellcode is the machine code instruction
- use `objdump` on the object file and process the result
- use `echo -en` above to print in binary form

Using `objdump` to extract hex data

```
for i in $(objdump -d <module-name>.o | tr '\t' ' ' | tr ' ' '\n'

    | egrep '^[0-9a-f]2$') ; do echo -n "\x$i" ; done
```

- the reverse is achievable (getting the assembly mnemonics from hex)

Using `objdump` to extract hex data

```
echo -en "hexadecimal data" > shellcode
objdump -b binary -m i386 -D shellcode
```

CNSO CTF crunch Shellcode Constraints
due to input data filtering
small code
null-free
position-independent
alphanumeric (not always)
more on the next lecture

Shellcode Constraints

- due to input data filtering
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CNSO CTF crunch Null-free

- required when dealing with null-terminated strings
- BAD: mov $1, %eax
  - uses null bytes
  - \xb8\x01\x00\x00\x00
- GOOD: xor %eax, %eax + inc %eax
  - doesn't use null bytes
  - \x31\xc0\x40
- BAD: mov $100, %eax
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  - \xb8\x64\x00\x00\x00
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- place shellcode in local buffer on stack
- rewrite return address to point to beginning of the buffer on the stack
- may need NOPs if exact address is not known
- unable to be done if stack is non-executable

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CNSO
Using an Environment Variable
- initialize an environment variable with the shellcode string
- environment variable is placed on the stack of main
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- more on the next lecture

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- place the shellcode on the heap
- requires a heap buffer overflow
- made difficult by ASLR and non-executable flags

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CNSO Triggering Shellcodes
- stack buffer overflow
  - overwrite return address and point to address on stack or environment variable
  - overwrite local pointer and point to address on stack or environment variable
- heap buffer overflow
  - overwrites metadata pointers for heap allocated data

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Triggering Shellcodes

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CNSO CTF crunch Keywords

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- vulnerabilities
- exploit
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- shellcode triggering
- shellcode placing
- syscall
- null
- stack buffer overflow
- heap buffer overflow
- pwntools

Keywords

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- https://docs.pwntools.com/en/stable/

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  - Chapter 13 & 14
- A Guide to Kernel Exploitation
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