

# Approach to binary exploitation

Rodrigo Castillo

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## 1. Analazyng and exploiting a very very simple authentication program

for this tutorial, i made this simple script that simulates an authentication program:

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

int main(int argc, char *argv[]) {
    if(argc==2) {
        printf("Autenticando...: %s\n", argv[1]);
        if(strcmp(argv[1], "Hola a todos")==0) {
            printf("Acceso Concedido");
        } else {
            printf("Acceso Denegado");
        }
    } else {
        printf("El programa recibe 2 parametros");
    }
    return 0;
}
```

Figura 1: Very simple crackme

and i compile it with *gcc* compiler. the result is a binary file that simulates a very very simple authentication program... as an atacker, i want to bypass authentication without knowing the password for this prupose, i previusly know many ways for bypass this security:

```
rer-Octopus:~$ ./very_simple_authentication "Hola a todos"
Autenticando...: Hola a todos
Acceso Denegado
```

Figura 2: Acceso Denegado

1. Bruteforcing the password
2. Debugging the binary file
3. Disassembly the binary

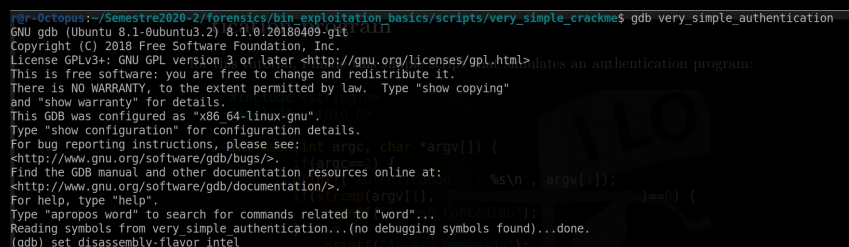
## 1.1. bruteforcing

Actually, we know that if the password is secure, trying to brute force it is going to take millions of years, so this is not an intelligent option, sometimes it works but just use it when is the only option that you have.

The second option goes for understanding the binary file and modifying the flood of execution of the program, for this, we will use the GDB debugger, but any debugger is ok .

## 1.2. The first step is running the binary in the machine

(dont use it with a malware because the debugger is going to execute de binary file)



```

Ter-Octopus:~/Semestre2020-2/forensics/bin_exploitation_basics/scripts/very_simple_crackme$ gdb very_simple_authentication
GNU gdb (Ubuntu 8.1-0ubuntu3.2) 8.1.0.20180409-git
Copyright (C) 2018 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>.
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law. Type "show copying"
and "show warranty" for details.
This GDB was configured as "x86_64-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from very_simple_authentication...done.
(gdb) set disassembly-flavor intel

```

Figura 3: Runnig and setting GDB

disassebly flavor intel is just because there are many assembly syntaxes, the most common is intel syntaxes and im used to it

first, we are going to use a disassembler for checking the functions that the binary file is importing as we know, the "main"function is the function where the program is really

0x00000000	5 292	-> 293	sym.imp._libc_start_main
0x00000560	3 23		sym.init
0x00000590	1 6		sym.imp.puts
0x000005a0	1 6		sym.imp.printf
0x000005b0	1 6		sym.imp.strcmp
0x000005c0	1 6		sub._cxa_finalize_248_5c0
0x000005d0	1 43		entry0
0x00000600	4 50	-> 40	sym.deregister_tm_clones
0x00000640	4 66	-> 57	sym.register_tm_clones
0x00000690	4 49		sym._do_global_dtors_aux
0x000006d0	1 10		entry1.init
0x000006da	6 134		main
0x00000760	4 101		sym._libc_csu_init
0x000007d0	1 2		sym._libc_csu_fini
0x000007d4	1 9		sym.fini

Figura 4: Functions

running, the other functions like *sym.init* are functions that the *gcc* debugger is calling for compiling the *c* code into a binary file.

so what we are going to do is to check the disassembly code of the *main* function. in GDB, the command is *disassemble main* , the content of this file is... understanding assembly code

```

0x00000000000006da <+0>: push    %rbp
0x00000000000006db <+1>: mov     %rsp,%rbp
0x00000000000006de <+4>: sub     $0x10,%rsp
0x00000000000006e2 <+8>: mov     %edi,-0x4(%rbp)
0x00000000000006e5 <+11>: mov     %rsi,-0x10(%rbp)
0x00000000000006e9 <+15>: cmpl    $0x2,-0x4(%rbp)
0x00000000000006ed <+19>: jne     0x74d<main+115>
0x00000000000006ef <+21>: mov     -0x10(%rbp),%rax
0x00000000000006f3 <+25>: add     $0x8,%rax
0x00000000000006f7 <+29>: mov     (%rax),%rax
0x00000000000006fa <+32>: mov     %rax,%rsi
0x00000000000006fd <+35>: lea     0xe4(%rip),%rdi    # 0x7e8
0x0000000000000704 <+42>: mov     $0x0,%eax
0x0000000000000709 <+47>: callq   0x5a0<printf@plt>
0x000000000000070e <+52>: mov     -0x10(%rbp),%rax
0x0000000000000712 <+56>: add     $0x8,%rax
0x0000000000000716 <+60>: mov     (%rax),%rax
0x0000000000000719 <+63>: lea     0xdd(%rip),%rsi    # 0x7fd
0x0000000000000720 <+70>: mov     %rax,%rdi
0x0000000000000723 <+73>: callq   0x5b0<strcmp@plt>
0x0000000000000728 <+78>: test    %eax,%eax
0x000000000000072a <+80>: jne     0x73f<main+101>
0x000000000000072c <+82>: lea     0xe2(%rip),%rdi    # 0x815
0x0000000000000733 <+89>: mov     $0x0,%eax
0x0000000000000738 <+94>: callq   0x5a0<printf@plt>
0x000000000000073d <+99>: jmp     0x759<main+127>
0x000000000000073f <+101>: lea     0xe3(%rip),%rdi    # 0x829
0x0000000000000746 <+108>: callq   0x590<puts@plt>
0x000000000000074b <+113>: jmp     0x759<main+127>
0x000000000000074d <+115>: lea     0xec(%rip),%rdi    # 0x840
0x0000000000000754 <+122>: callq   0x590<puts@plt>

```

Figure 5: Main

is, as programming, about technique and experience, noone reads all the disassebly code, just take a look at the important parts of the code... on the space `0x0000000000000709` the program is calling the function *printf* , then , there is a *strcmp* on space `0x0000000000000723` and there is a *test* on the space `0x0000000000000728` , that means that the *printf* function is the part of the program where he is invoking the string *.^utenticando....^*and the compa-  
risson between our input and real password is in the function *strcmp@plt* in memory space `0x0000000000000723`.

How does *strcmp* works ? its easy as assembly is working with processors that store numbers in hex , one easy way for comparing to strings is substracting the hex values that are stored in the processors ... if the result is 0 it means that the strings are the same, if the result is different to 0 , it means the strigins are different...

ones we understand previus concepts , its hacking time ...

we know that the *strcmp* function is running in memory space `0x0000000000000723` and then the *test* function is called, that means that this function is checking if the value is equal to 0 , if the test funccion returns false, the next instrucion *jne* is going to redirect us to `0x73f` space of memory, that means that we introduced a non-valid password , but if the comparisson is true, the *jne* instruction is going to let us bypass password authentication, for this, what we are going to do, is inserting the value 0 on the comparisson of the processor *eax* .

first , we are going to set a breakpoint on memory space of main and run the program with the input that we want nl, in GDB the instruction goes with *break main*

```

(gdb) break main
Breakpoint 1 at 0x6de
(gdb) run escribologoquiera
Starting program: /home/r/Semestre2020-2/forensics/bin_exq
bologoquiera
Breakpoint 1, 0x00005555555546de in main ()
(gdb) █

```

with *ni* we can run next intruccion, so what we are going to do is walk till the intruccion is the memory space of *test* function . we can also set a breakpoint in the corresponding space of memory with *break \*0x0000555555554728* ... running the program we can see that the

way that we interpreted the assembly code was right ... now, we are going to keep walking

```
0x0000555555554704 in main ()
(gdb)
0x0000555555554709 in main ()
(gdb)
Autenticando...: escribiloquequiera
0x000055555555470e in main ()
(gdb)
0x0000555555554712 in main ()
(gdb)
0x0000555555554716 in main ()
(gdb)
0x0000555555554719 in main ()
(gdb) █
```

Figura 6: Pasopaso

till we are in the value of test function and finally...

```
0x0000555555554716 in main ()
(gdb)
0x0000555555554719 in main ()
(gdb)
0x0000555555554720 in main ()
(gdb)
0x0000555555554723 in main ()
(gdb)
0x0000555555554728 in main ()
(gdb) █
```

We are in *test* function! here, we can check the actual values of processors, and we can see that *eax* is storing the *little endian* corresponding to our input .

```
0x0000555555554728 in main ()
(gdb) info registers
rax      0x15      21
rbx      0x0       0
rcx      0x0       0
rdx      0x50      80
rsi      0x555555547fd 93824992233469
rdi      0x7fffffff23f 140737488347711
rbp      0x7fffffffdd70 0x7fffffffdd70
rsp      0x7fffffffdd60 0x7fffffffdd60
r8       0x0       0
r9       0x12      18
r10      0xffffffff 4294967278
r11      0x246     582
r12      0x555555545d0 93824992232912
r13      0x7fffffffde50 140737488346704
r14      0x0       0
r15      0x0       0
rip      0x555555554728 0x555555554728 <main+78>
eflags   0x202     [ IF ]
cs       0x33      51
ss       0x2b      43
ds       0x0       0
es       0x0       0
fs       0x0       0
gs       0x0       0
(gdb) █
```

Figura 7: info registers

as we mentioned before, we need to force the *test* instruction to return *True* , so what we are going to use is set the value of *eax* to 0, in GDB the command is *set \$eax = 0* , then, we can proceed to next instructions and voila!

```
(gdb) set $eax=0
(gdb) ni
0x000055555555472a in main ()
(gdb) ni
0x000055555555472c in main ()
(gdb) ni
0x0000555555554733 in main ()
(gdb) ni
0x0000555555554738 in main ()
(gdb) ni
Acceso Concedido
0x000055555555473d in main ()
```

Figura 8: Access Granted!

this trick is very powerfull, because it means that we can redirect the flood of execution of any program and bypass its credentials!(or whatever we want) , somethimes , the process of understanding the way that programs works are a little bit more complicated but the spirit is the same, also, this is the most powerfull trick of this section because security companies encode strings and validation keys

### 1.3. disassemble the code

for disassemble the code, we can use any disassembler , personally, i like one that is called radare2, but with in the course of forensics you can do it with idapro. we already know the functions that the program is importing, as we know, the comparisson between the real password and our input, is in *main* function, so we are going to disassamble main function and check it's flood of execution

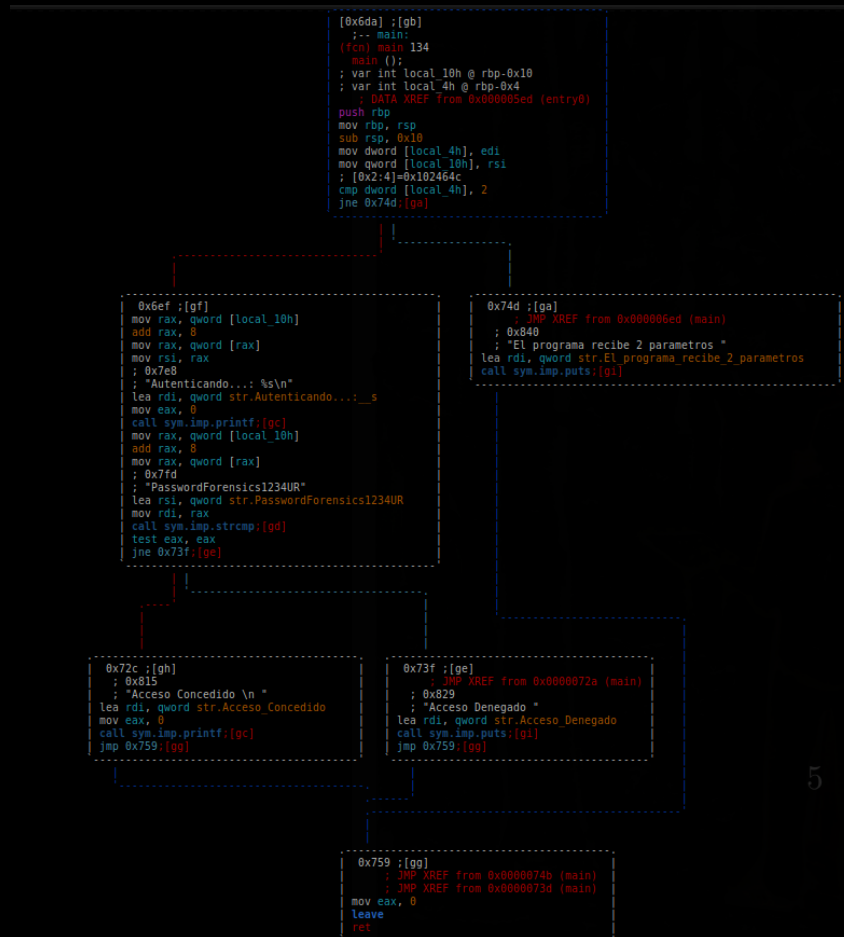


Figura 9: Flood

here, we can see the complete flood of execution of *main* function. this is interesting, when the diagram of flood diffuse in 2 different diagrams, it means that there is a jump , in code, this can represent an *if* (and sometimes a loop). the first if, is when the program checks if we passed 2 parameters



Figura 10: First jump

Then, there are two options...



Figura 11: Options



if we passed correctly 2 parameters , the program send us to authentication, if not, print .El programa recibe 2 parámetros”  
we are interested for the flood of execution of the first option... here, we can see that if the



Figura 12: Flood

input is *PasswordForensics1234UR* is going to return true and print .Acceso concedido.and if the input is different to *PasswordForensics1234UR* is going to print .Acceso Denegado” that means that this is the password. this trick is powerfull somethimes, but normally companies compare hashes instead of plain text passwords, that makes the disassembling process a little bit more complicated, the real challenge of disassembling a binary comes for reversing the algorithm that makes the password return true .

## 2. Buffer Overflows

There are many magic tricks for exploiting binaries such as heap based buffer overflows, format strings attacks , Use After Free attacks , off by one attacks , Logic flaws attacks ...etc , but in this section we are going to exploit a stack based buffer overflow .

Buffer Overflow is one of the most common vulnerability in binaries out there, there are many types of it and it’s exploitation is not intuitive at the beginning, but as a hacker is one of first and more important things that you can learn. this is a vulnerability that was found on 80’s in the golden age of hacking , but today there exists many problems because of this bug .

### 2.1. What is a Buffer Overflow?

a buffer overflow is when the program allows the user to store a custom variable in the stack of the memory .... so the problems comes when a user insert an input bigger than the section of memory where it is supposed to be allowed, what really happens is that the input overwrite the next memory space, and this is very very powerfull i’ll show you why in the next section ...

Stack Looks Like This

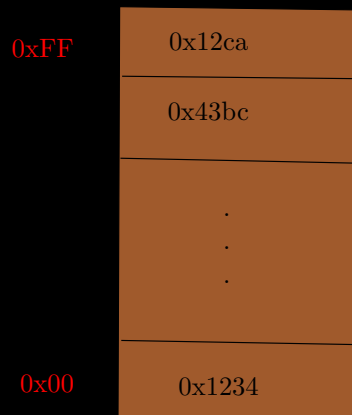


Figura 13: stack

Stack Looks Like This

Input:

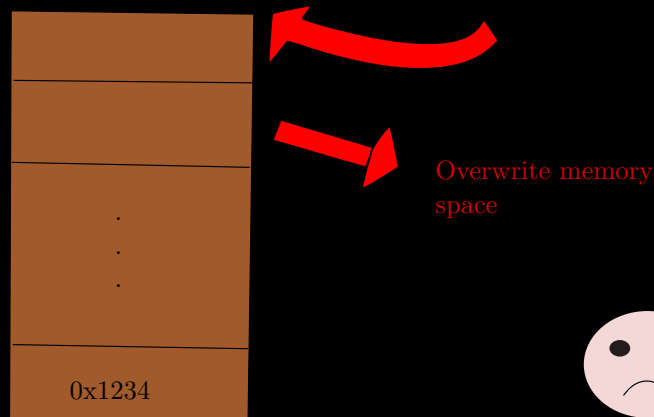


Figura 14: bof

## 2.2. Exploiting a Buffer Overflow

for this section, i took one vulnerable machine from a guy that its callet *protostar* , the link is here ... <https://exploit-exercises.lains.space/download/> its a virtual machine that contains a lot of vulnerable exercises to practice binary exploitation

the first step is to mount the virtual machine and blah blah blah, we all already done that and it's the boring part of the process . inside the protostar's machine, in */opt/protostar/bin* there are those exercises ..

in his page, we can find the source code of the exercise, an skilled hacker actually dont need to check the source code of the binary because he can reverse it using a disassembler

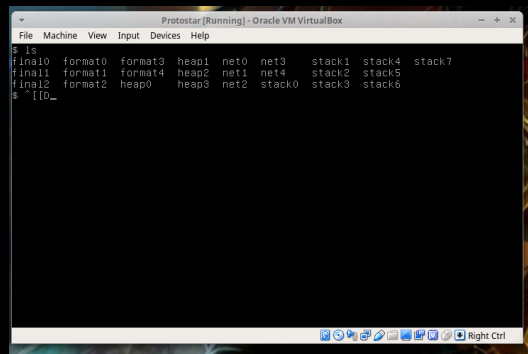


Figura 15: Protostar Exercises

we want to pwn the stack exercises , so we are going to check the *stack0* exercise in this section just as a beginning example in this section just as a beginning example. the source code of the exercise is ... so the first thing we will do is to execute the binary in

```
(stack0.c)
1  #include <stdlib.h>
2  #include <unistd.h>
3  #include <stdio.h>
4
5  int main(int argc, char **argv)
6  {
7      volatile int modified;
8      char buffer[64];
9
10     modified = 0;
11     gets(buffer);
12
13     if(modified != 0) {
14         printf("you have changed the 'modified' variable\n");
15     } else {
16         printf("Try again?\n");
17     }
18 }
```

Figura 16: Source Code

protostar's machine.

```
$ ls
final0 format0 format3 heap1 net0 net3 stack1 stack4 stack7
final1 format1 format4 heap2 net1 net4 stack2 stack5
final2 format2 heap0 heap3 net2 stack0 stack3 stack6
$ ./stack0
hola a todos
Try again?
$
```

Figura 17: stack0

now, we are going to run the binary file with GDB debugger. as we can see in the source code (or in a disassembler), the program is calling for *gets* function, so we are going to check *gets* function . functions ...

---

```
(gdb) info functions
All defined functions:

File stack0/stack0.c:
int main(int, char **);

Non-debugging symbols:
0x080482bc  _init
0x080482fc  __gmon_start__
0x080482fc  __gmon_start__@plt
0x0804830c  gets
0x0804830c  gets@plt
0x0804831c  __libc_start_main
0x0804831c  __libc_start_main@plt
0x0804832c  puts
0x0804832c  puts@plt
0x08048340  _start
0x08048370  __do_global_ctors_aux
0x080483d0  frame_dummy
0x08048440  __libc_csu_fini
0x08048450  __libc_csu_init
0x080484aa  __i686.get_pc_thunk.bx
0x080484b0  __do_global_ctors_aux
0x080484dc  _fini
(gdb) _
```

Figura 18: functions

## gets function info



Figura 19: Gets

in the description of this function we can see the string "Never Use this Function", this is because gets function is vulnerable to buffer overflows attacks that can let the attacker gain control of the machine. if we check the bugs section, it says so we are going to exploit

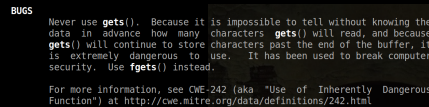


Figura 20: Bug

the buffer overflow in function *gets...*, we are going to search the function in the disassembly of main function

```
(gdb) disassemble main
Dump of assembler code for function main:
0x080483f4 <main+0>:  push    %ebp
0x080483f5 <main+1>:  mov     %esp,%ebp
0x080483f7 <main+3>:  and     $0xffffffff0,%esp
0x080483fa <main+6>:  sub     $0x60,%esp
0x080483fd <main+9>:  movl    $0x0,0x5c(%esp)
0x08048405 <main+17>:  lea     0x1c(%esp),%eax
0x08048409 <main+21>:  mov     %eax,(%esp)
0x0804840c <main+24>:  call    0x804830c <gets@plt>
0x08048411 <main+29>:  mov     0x5c(%esp),%eax
0x08048415 <main+33>:  test    %eax,%eax
0x08048417 <main+35>:  je      0x8048427 <main+51>
0x08048419 <main+37>:  movl    $0x8048500,(%esp)
0x08048420 <main+44>:  call    0x804832c <puts@plt>
0x08048425 <main+49>:  jmp     0x8048433 <main+63>
0x08048427 <main+51>:  movl    $0x8048529,(%esp)
0x0804842e <main+58>:  call    0x804832c <puts@plt>
0x08048433 <main+63>:  leave
0x08048434 <main+64>:  ret
End of assembler dump.
~*~*~
```

Figura 21: Main

and now we know that the program is calling puts function in 0x804840c, we want to know what is happening after this space of memory, so we are going to set a new breakpoint in this space of memory or walk till this point with *ni* command.

now, we know the point where the program is comparing the instruction.

```
in stack0/stack0.c
(gdb) ni
11 in stack0/stack0.c
(gdb) ni
0x08048409 11 in stack0/stack0.c
(gdb) ni
0x0804840c 11 in stack0/stack0.c
(gdb) ni
11 in stack0/stack0.c
(gdb) ni
13 in stack0/stack0.c
0x08048415 13 in stack0/stack0.c
(gdb) ni
0x08048417 13 in stack0/stack0.c
(gdb) ni
16 in stack0/stack0.c
0x0804842e 16 in stack0/stack0.c
(gdb) ni
Try again?
18 in stack0/stack0.c
(gdb) ni
0x08048434 in main (argc=134513652, argv=0x2) at stack0/stack0.c:18
18 in stack0/stack0.c
(gdb)
```

Figura 22: Tryagain

now we execute it again but check the registers after 0x804840c

but now, i'll put an input bigger than 64Bytes to exploit it and Boom! we modified the next variable called *modified* in the source code of the program! too powerfull!

now that we understand the concept, lets make it easy, we are going to make a simple python script that is going to run something bigger than 64 bytes and is going to pipe it into the program

Figura 23: Exploited

Figura 24: Exploit

```

rgr-Octopus:~/Semestre2020-2/forensics/bin_exploitation_basics/scripts/stack0$ python3 exploit.py
you have changed the 'modified' variable
Segmentation fault (core dumped)

```

overflow, but this vulnerability can let an skilled hacker to gain control over the machine , here, in protostar page there are many examples of codes that can let you fall into a buffer overflow . one of the most interestings are...

Figura 26: Redirect functions or get full controll of the victims machine

### **3. conclusion**

Debuggers and Disassemblers are tools for forensics and designed to understand programs, however, they have many uses and one of them is hacking, attackers use those tools to understand programs and exploit.

Sometimes, those attacks require abilities and practice, mostly they are made for making jokes or competitions or by bug bountiers, but sometimes, there are people who have the same abilities and use it for breaking into companies, bypassing security systems and making in general, that's why understanding tools like mentioned before, can take us to perform better security systems.